LITORIA SPENCERI

Spotted Tree Frog

Population and Habitat Viability Assessment Workshop

Arthur Rylah Institute
Melbourne, Australia

5 - 8 August 1996

DRAFT REPORT

A Collaborative Workshop

Natural Resources and Environment, Victoria
Australasian regional Association of Zoological Parks and Aquaria
Conservation Breeding Specialist Group (SSC/IUCN)

Credits for photos

Reference for the book (editors, title, date, location, 'press')

Availability statement

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Section I

Executive Summary

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EXECUTIVE SUMMARY

The Spotted Tree Frog (*Litoria spenceri* Dubois 1984) is a medium-sized species of frog in the family Hylidae. Females may attain 61 mm (snout-vent length) while males are smaller, attaining 50 mm (Watson *et al.* 1991).

The Spotted Tree Frog is confined predominantly to the north-west side of the Great Dividing Range between the Central Highlands in Victoria and Mt Kosciusko in New South Wales. It inhabits naturally-vegetated, rocky, swift-flowing upland streams in dissected mountainous country, between 280 and 1110 metres above sea level. Frog populations are generally in areas with limited access and disturbance. Distribution along streams is patchy, most individuals being associated with loose rock substrates, rocky banks and rapids. Adjacent stream-side vegetation is also used for sheltering and basking. Eggs are deposited under large instream boulders, and tadpole development occurs within the stream (Hero *et al,* 1995). The stream environment is used by this species from October to April - it is not known what habitats are used at other times.

Recent extensive surveys reveal only eleven 'populations' extant in Victoria and one in NSW. These occur in the catchments of fifteen streams. Survey results strongly suggest that the species has a limited and fragmented distribution and has suffered a significant decline during the past twenty years. All extant populations appear under threat from various disturbances; many are small, and some have declined. Analysis of disturbance histories at individual sites indicates an association between the contraction in distribution and a number of human-induced disturbances to forest and riparian habitats (Gillespie and Hollis, 1995). Little is known of the genetic variability within and between 'populations' (Watson *et al* 1991, Gillespie and Hollis, 1996), or of the extent of their genetic isolation.

The Spotted Tree Frog is recognised as Endangered in Victoria (CNR 1995) and nationally (Endangered Species Protection Act 1992).

A Population and Habitat Viability Assessment (PHVA) workshop was held in Melbourne, Australia at the Arthur Rylah Institute for Environmental Research facility of the Department of Natural Resources and Environment, from August 5 - 8, 1996. The workshop was opened by the Minister for Conservation and Land Management, the Hon. Mrs. Tehan, and was attended by 58 biologists, managers and stakeholders from within Victoria and interstate. It was conducted by Dr. Ulysses S. Seal, chair of the Conservation Breeding Specialist Group (CBSG) of the Species Survival Commission/World Conservation Union (SSC/IUCN), with assistance from Dr. P. Miller (CBSG). The workshop was hosted by Flora and Fauna Branch of the Department of Natural Resources and Environment, and conducted in collaboration with the Australasian Regional Association of Zoological Parks and Aquaria and CBSG.

The purpose was to collate and review all data pertaining to the biology, threats and management of the Spotted Tree Frog, as a basis for developing population simulation models, assessing extinction risks, and formulating and assessing different management scenarios. Specific research and management recommendation, with indications of their priority for recovery of the species, were formulated during the workshop.

Specific objectives for the workshop were to:

- provide another opportunity for stakeholder's views to be included in planning for this species;
- assess various management scenarios before actual field management is undertaken;
- identify areas requiring further information and/or management planning;
- conduct peer and external review of research and proposals for management; and
- promote best practice in threatened species recovery planning.

The first day comprised a series of presentations summarising our current knowledge of the biology and management requirements of the species, followed by presentations on small population biology and the modelling process using VORTEX. The workshop participants then formed four smaller working groups (life history and modelling; genetics; threats; habitat management) to review in detail the information, to hear all ideas, and to develop management scenarios and recommendations. Stochastic population simulation models were developed and initialised with ranges of values for the key life history variables to estimate the viability of populations and to determine the relative importance of these key variables, using the VORTEX software modelling package. Simultaneously, working groups summarised their deliberations into clear recommendations for research and management that can target the most important variables as identified by the modelling.

RECOMMENDATIONS

Management

Modelling has indicated that management actions should be directed at reducing mortality between egg and metamorphling (the transitional stage between tadpole and frog) stages and of juveniles. Key threats were identified as predation from fish and sedimentation of stream habitat. It is recommended to:

- implement a trial project to evaluate the effects of excluding fish on increasing the production of metamorphlings. This is likely also to immediately benefit treated populations by reversing further declines.

- investigate captive or artificial on-stream management as a means of rapidly stabilising or increasing wild populations

- investigate with fishing groups (both local and state) their willingness to participate in further surveys of fish predation on Spotted Tree Frog and management actions.

- assess the need and feasibility of fish exclusion or control works at all frog populations.

- identify at all frog sites all significant sources of sedimentation that require urgent attention and implement remedial works as a priority action.

- implement an additional auditing program aimed specifically at ensuring that roading and forestry activities (including State Forest and National Parks) are conforming with prescriptions detailed in the draft Action Statement and Central Highlands Forest Management Plan.

- if predator control results in increases in frog population sizes, consider the necessity and potential to increase the carrying capacity of all frog habitats.

Research

It is recommended to:

- immediately conduct further modelling using VORTEX and other models, suited to amphibian life histories, with additional time spent on investigating the impact of catastrophic events on population viability and repeat the modelling of all scenarios when the additional data (listed below) has been collected.

- collect data on factors affecting egg, tadpole and juvenile survival.

- determine the variation in reproductive output between individual frogs, using genetic techniques.

- investigate the spatial heterogeneity of populations (metapopulation dynamics) using mark-recapture, radio tracking and genetic techniques.

- determine if the Spotted Tree Frog is composed of multiple taxonomic groups, using genetic techniques

- determine the genetic population unit, defined as the areas within which there is random mating, and the genetically viable effective population size for all populations.

- continue monitoring of all populations so that population dynamics and environmental variation can be better estimated.

- determine what genetic management options are available to maximise the evolutionary potential of the species through re-introduction, relocation and cryopreservation.

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Section II

Invitation, Minister's Comments, and Participants

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DEPARTMENT OF CONSERVATION AND NATURAL RESOURCES

Your Ref.
Our Ref. 96/1717-1

27 May 1996

Dr Ulysses Seal
Chair
IUCN/SSC Conservation Breeding Specialist Group
12101 Johnny Cake Ridge Road
Apple Valley MN 55124-8151
USA

Dear Dr Seal,

I am delighted to hear that you may be available to assist with a Population and Habitat Viability Analysis workshop on the Spotted Tree Frog, and I would like to take this opportunity to formally invite you to facilitate the workshop. I am keen for Flora and Fauna Branch to host such a workshop, and have tentatively booked a venue at our research institute for 5 - 8 August.

I am sure that this workshop will make a major contribution to our conservation planning for this endangered species. It comes at an ideal time in our research and management planning, as we are in the third year of a research project on the ecology of this species, and are shortly to prepare a detailed recovery plan. Furthermore, I expect the benefits of introducing a number of our wildlife managers to the PHVA process will be far reaching.

The Australasian Regional Association of Zoological Parks and Aquaria has kindly offered assistance with preparation for and conduct of the workshop, and we have begun to compile a list of participants and the necessary briefing materials. Peter Robertson is coordinating the recovery program for the Spotted Tree Frog, and will liaise directly with ARAZPA to organise the workshop. Please feel free to contact him at any time, at Flora and Fauna Branch on (03) 9412 4291 (or email at P.Robertson@dce.vic.gov.au).

I look forward to meeting you in August.

Yours sincerely,

Robert Begg
Acting Manager,
Flora and Fauna Branch

cc. Jonathan Wilcken. ARAZPA

240 Victoria Parade, East Melbourne, Victoria 3002 Telephone: (03) 412 4011 Facsimile: (03) 412 4803

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MINISTER FOR CONSERVATION AND LAND MANAGEMENT

OPENING OF THE POPULATION AND HABITAT VIABILITY WORKSHOP ON THE SPOTTED TREE FROG

CONCERN FOR THE CONSERVATION OF FROGS HAS BECOME A GLOBAL ISSUE OVER THE PAST DECADE THAT HAS ATTRACTED MUCH PUBLIC INTEREST. MANY FROG SPECIES SEEM TO BE IN DECLINE AND OFTEN THE REASONS FOR THIS ARE UNKNOWN. THIS TREND IS SYMPTOMATIC OF MUCH OF OUR BIODIVERSITY WITH INCREASING NUMBERS OF SPECIES GOING ONTO THE THREATENED SPECIES LIST.

MANAGERS OF BIODIVERSITY MUST BRING ALL MEASURES TO BEAR ON CORRECTING THIS SITUATION. AMONGST THESE ACTIONS WE MUST IMPROVE OUR CONCEPTUAL AND APPLIED TOOLS TO GAIN BETTER RETURNS FOR THE RESOURCES INVESTED BY GOVERNMENT.

POPULATION AND HABITAT VIABILITY ASSESSMENT (PHVA) IS AN INVALUABLE TOOL IN PLANNING CONSERVATION MEASURES. IT ALLOWS VARIOUS MANAGEMENT SCENARIOS TO BE ASSESSED FOR COST AND BENEFIT BEFORE ACTUAL FIELD MANAGEMENT IS UNDERTAKEN.

PHVA HAS BEEN USED BY MY DEPARTMENT OVER THE PAST SIX YEARS DURING WHICH THERE HAS BEEN CONTINUOUS IMPROVEMENT IN THE PLANNING AND MANAGEMENT OF THREATENED SPECIES. THE DEPARTMENT IS RECOGNISED BY EXTERNAL PRACTITIONERS AS MAINTAINING BEST PRACTICE IN THIS SPECIALIST FIELD. FOR EXAMPLE, THE ASSESSMENTS DONE ON HELMETED HONEYEATER, ORANGE-BELLIED PARROT AND EASTERN BARRED BANDICOOT HAVE GUIDED FIELD MANAGEMENT TO

MAKE GREATER CONSERVATION GAINS THAN WOULD HAVE OTHERWISE BEEN POSSIBLE.

FLORA AND FAUNA BRANCH INVITED DR SEAL TO CONDUCT A PHVA WORKSHOP ON THE SPOTTED TREE FROG DURING HIS STAY IN AUSTRALIA. DR SEAL HAS BEEN CHAIR OF THE CONSERVATION BREEDING SPECIALIST GROUP OF THE SPECIES SURVIVAL COMMISSION OF INTERNATIONAL UNION FOR THE CONSERVATION OF NATURE SINCE 1979. HE IS AN INTERNATIONALLY RECOGNISED EXPERT ON PHVA SIMULATIONS AND HAS FACILITATED WORKSHOPS ON THIS SUBJECT THROUGHOUT THE WORLD.

THE AUSTRALASIAN REGIONAL ASSOCIATION OF ZOOLOGICAL PARKS AND AQUARIA HAS KINDLY OFFERED TO ASSIST WITH THE WORKSHOP REFLECTING THE ZOO INDUSTRY'S INTEREST IN THE CONSERVATION OF BIODIVERSITY.

THE SPOTTED TREE FROG IS ONE OF AUSTRALIA'S MOST ENDANGERED AMPHIBIANS. IT IS A LISTED TAXON UNDER THE VICTORIAN FLORA & FAUNA GUARANTEE ACT AND IS PROTECTED UNDER THE WILDLIFE ACT. IT IS ALSO LISTED UNDER THE NEW SOUTH WALES AND COMMONWEALTH ENDANGERED SPECIES ACTS.

THE FROG HAS BEEN THE SUBJECT OF THREE YEARS OF INTENSIVE RESEARCH BY THE FLORA & FAUNA BRANCH, JOINTLY FUNDED WITH THE AUSTRALIAN NATURE CONSERVATION AGENCY. NOW WE HAVE SUFFICIENT SCIENTIFIC DATA ON THE ECOLOGY OF THE SPOTTED TREE FROG TO ENABLE THE PHVA SIMULATIONS TO BE RELIABLE.

A DRAFT FLORA & FAUNA ACTION STATEMENT HAS BEEN PREPARED, AND A NATIONAL RECOVERY PLAN IS IN PREPARATION.

MAJOR ISSUES AFFECTING THE SPECIES ARE PREDATION BY INTRODUCED FISH, DETERIORATION OF STREAM QUALITY ASSOCIATED WITH ROADING AND TIMBER HARVESTING, AND (IN THE PAST) EDUCTOR DREDGING.

I WOULD LIKE TO WELCOME DR SEAL AND HIS COLLEAGUE, DR PHILLIP MILLER, EXPERTS IN A VARIETY OF DISCIPLINES FROM VICTORIA AND INTERSTATE, INDUSTRY AND COMMUNITY GROUP REPRESENTATIVES AND A RANGE OF THE OTHER KEY STAKEHOLDERS.

THIS WORKSHOP WILL USE CUTTING-EDGE WILDLIFE MANAGEMENT TECHNOLOGY, AND ILLUSTRATES THE SOPHISTICATED APPROACH USED BY MY DEPARTMENT IN THREATENED SPECIES MANAGEMENT. IT PROVIDES ANOTHER SIGNIFICANT OPPORTUNITY FOR STAKEHOLDER'S VIEWS TO BE INCLUDED IN SETTING FUTURE DIRECTIONS FOR THE CONSERVATION OF THIS SPECIES.

IN PARTICULAR, THE INTENSE WORK THAT WILL BE DONE OVER THE NEXT FOUR DAYS WILL ALLOW COMPLEX MANAGEMENT SCENARIOS TO BE TESTED AND PREFERRED OPTIONS FOR ONGROUND IMPLEMENTATION TO BE SELECTED AND DOCUMENTED IN AN OBJECTIVE REPORT.

I WISH YOU WELL IN YOUR ENDEAVOURS AND THANK YOU FOR YOUR INPUT.

Alphabetical list of Spotted Tree Frog PHVA Workshop participants

GARY BACKHOUSE	Flora and Fauna Branch, NRE	1
CHRIS BANKS	Melbourne Zoo	2
NICK BARLEE	Snowy Mountains Hydro-electric Authority	3
ALAN BAXTER	Fisheries Branch, NRE	4
ROBERT BEGG	Flora and Fauna Branch, NRE	5
PAUL BENNETT	Water Bureau, NRE	6
CARSTEN BERBERICH	Melbourne Water	7
ALISTAIR BROWN	Flora and Fauna Branch, NRE	8
MARK BURGMAN	University of Melbourne	10
TIM DOEG	Flora and Fauna Branch, NRE	12
STEVEN DONNELLAN	South Australian Museum	13
MARTIN DRESCHLER	University of Melbourne	14
GILL EARL	Flora and Fauna Branch, NRE	15
TONY EDGAR	North East Region, NRE	16
FELICITY FARIS	Threatened Species Network WWF	17
GORDON FRIEND	National Parks Service, NRE	19
GAIL GATT	Gippsland Region, NRE	20
GRAEME GILLESPIE	Arthur Rylah Institute, NRE	21
MARC HERO	James Cook University	22
GREG HOLLIS	Gippsland Region, NRE	23
BRONWYN HOULDEN	Taronga Zoo	25
DAVID HUNTER	University of Canberra	27
ANN JELINEK	Australian Nature Conservation Agency	28
KATE KENNEDY	Wilderness Society	30
JOHN KOEHN	Marine and Freshwater Resources Institute, NRE	31
KIM LOWE	Flora and Fauna Branch, NRE	32
RICHARD LOYN	Arthur Rylah Institute, NRE	33
GERRY MARANTELLI	Amphibian Research Centre	35
PETER MENKHORST	Flora and Fauna Branch, NRE	37
PHILLIP MILLER	IUCN/SSC Conservation Breeding Specialist Group	38
PETER MYRONIUK	Melbourne Zoo	39
SIMON NICOL	Marine and Freshwater Resources Institute, NRE	40
BILL O'CONNOR	Flora and Fauna Branch, NRE	41
DIANA PATTERSON	Flora and Fauna Branch, NRE	42
GEOFF PIKE	Gippsland Region, NRE	43

GRAHAM PYKE	Australian Museum	44
PETER ROBERTSON	Flora and Fauna Branch, NRE	45
NATASHA SCHEDVIN	Flora and Fauna Branch, NRE	46
STEVE SADDLIER	Marine and Freshwater Resources Institute, NRE	47
MICHAEL SCROGGIE	University of Melbourne	48
ULYSSES SEAL	IUCN/SSC Conservation Breeding Specialist Group	49
WILLIAM SHERWIN	University of New South Wales	50
STEVE SMITH	North East Region, NRE	51
BRIAN THOMPSON	Forests Service, NRE	53
ERNA WALRAVEN	Taronga Zoo	54
GRAEME WATSON	University of Melbourne	56
NIGEL WATTS	National Parks Service, NRE	57
KYLIE WHITE	Gippsland Region, NRE	58
NATALIE WHITE	Amphibian Research Centre	59
JONATHAN WILCKEN	ARAZPA	60
MARK WOODMAN	North East Region, NRE	61
GRAEME CREED	Victorian Recreational Fisheries Peak Body	62
KATE CAMPBELL	Wilderness Society	63
MARIALICE SEAL	CBSG	67
LLOYD VAN DER WALLEN	NSW National Parrks & Wildlife Service	68
JUDE DUNN	Wilderness society	71
MEGAN OSHEA	Victorian University of Technology	72
ROSS POTTER	Forests Service, NRE	-

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Section III

Amphibian Decline and Workshop Overview

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Declining Frog Overview.

One of the greatest challenges currently facing biologists is unravelling the unexplained disappearance of frogs around the world. In Australia seven species have disappeared entirely despite rigorous attempts to find them. Many species have gone missing from relatively pristine rainforest at high altitudes, have low fecundity, and are habitat specialists, suggesting that they are more susceptible to extinction (J-M. Hero and S. Williams, unpublished). These data support the hypothesis that the cause of the amphibian declines is a global phenomenon and not a series of isolated events. Several hypotheses have been proposed to explain the declines but they are either impossible to test or have not been investigated throughly investigated. Whatever the cause, it appears that amphibians at high altitudes are under stress throughout the world.

In Victoria, Australia, *Litoria spenceri* has declined in distribution and in population density it is found at high altitudes, has relatively low fecundity and is a habitat specialist, suggesting that it is more susceptible to extinction. Furthermore, there is strong evidence to suggest that this species is under additional stress due to predation on the larval stage by introduced fish, habitat modification and mining activities (see Gillespie and Hollis,1995, attached). These additional stresses may be responsible for the observed declines and all action should be taken to investigate the population dynamics of extant populations and reduce the influences of these anthropogenic influences. This workshop is an ideal forum to collate the current knowledge on the biology *of L. spenceri*, determine the vulnerable life stages of this species and provide guidelines on the research and the appropriate management actions that are urgently required to ensure the integrity of this species in Australia. In addition it will assist biologists throughout the world by providing a basis for the assessment and management of vulnerable amphibians.

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CBSG Population and Habitat Viability Assessment (PHVA) Processes

The objectives of the CBSG Workshop process and training are to assist local managers and policy makers to: 1) formulate priorities for a practical management program for survival and recovery of the species in wild habitat, 2) develop a risk characterization and simulation population model for the species which can be used to guide and evaluate management and research activities, 3) identify useful new technology and training, 4) facilitate inclusion of a wide range of stake holders in an agreed program, and 5) utilize principles of group dynamics in their work with small groups.

A briefing book is prepared for participants. A draft report is prepared during the course with all recommendations reviewed and agreed by the participants. The final report is usually reviewed, completed, and distributed within eight weeks after the PHVA Workshop.

The PHVA Workshop process provides range country managers, biologists and decision makers with practical applications of conservation biology techniques which are effective in improving management of species and habitats at risk. The workshop process assists in development by the participants of population viability assessments for each population of a species or subspecies. The assessment for each species undertakes an in depth analysis of information on the life history, population dynamics, ecology, and population history of the individual populations. Information on the demography, genetics, and environmental factors pertinent to assessing the status of each population and its risk of extinction under current management scenarios and perceived threats are assembled in preparation for the PHVA and for the individual populations before the workshop begins and during the sessions.

Simultaneously with addressing the species and habitat problems, the training emphasis, using a real problem case in the range country, is to provide information and technology transfer that will directly improve the functional capability of managers and assist in decision and policy making on the basis of the best available scientific information. Ten to twenty local managers as well as intermediate supervisors and higher level officials participate.

An important feature of the courses is the elicitation of information from experts that is not readily available in published form yet which may of decisive importance in understanding the behavior of the species in the wild. This information provides a basis for constructing simulation models of each population which will in a single model evaluate deterministic and stochastic effects and interactions of genetic, demographic, environmental, and catastrophic factors on the population dynamics and extinction risks. The process of formulating information to put into the models requires that assumptions and the data available to support the assumptions be made explicit. This process intends lead to consensus building on the biology of the species, as currently known, and usually leads to a basic simulation model for the species that can serve as a basis for continuing discussion of management alternatives and adaptive management of the species as new information is obtained. Means are provided for conducting future management programs as scientific exercises with continuing evaluation of new information in a sufficiently timely manner to be of benefit to adjusting management practices.

Relevant information includes data on: 1) age of first reproduction for males and females, 2) inter-birth interval in the wild population, 3) first year mortality, 4) sex ratio at birth, 5) juvenile survival, 6) adult sex ratio, 7) breeding strategy - monogamous or polygynous in a season, (8) adult mortality (by sex if available), 9) population size, 10) habitat carrying capacity and possible changes through time, 11) environmental variables influencing either reproduction or mortality, 12) potential catastrophic events and their effects upon reproduction or mortality in the year of occurrence, 13) dispersal and movement of animals between breeding groups, 14) mapping of geographic distribution, and 15) patterns of current and projected land use.

These training exercises are able assist the formulation of management scenarios for the respective species and evaluate the possible effects of these scenarios on reducing the risks of extinction. It is also possible through sensitivity analyses to search for factors whose manipulation may have the greatest effect on the survival and growth of the population. One can in effect rapidly explore a wide range of values for the parameters in the model to gain a picture of how the species might respond to changes in management. This approach may also be used to assist in evaluating the information contribution of proposed and ongoing research studies to the conservation management of the species.

Short reviews and summaries of new information on topics of importance for conservation management and recovery of the individual populations are prepared during each training course. Of particular interest are topics addressing:

(1) factors likely to have operated in the decline of the species or its failure to recover with management and whether they are still important,
(2) techniques for monitoring the status of the population during the management manipulations to allow their evaluation and modification as new information is developed,
(3) the role of disease in the dynamics of the wild population, in potential reintroductions or translocations, and in the location and management of captive populations,
(4) formulation of quantitative genetic and demographic population goals for recovery of the species and what level of management will be needed to achieve and maintain those goals,
(5) the potential uses of reproductive technology for the conservation of the species whether through assisted reproduction or genome banking,

(6) the need for molecular taxonomic, genetic heterozygosity, and parentage studies,
(7) the possible need for metapopulation management for long term survival of the species,
(8) the possible role of inbreeding in the dynamics and management of the captive and wild population(s),
(9) cost estimates for each of the activities suggested for furthering conservation management of the species,
(10) need for specific policy decisions,
(11) local training needs and means of accomplishment,
(12) consider principles of small group dynamics for problem solving.

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Section III

Habitat and Threats

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SPOTTED TREE FROG - ASSESSMENT OF THREATS PVA WORKSHOP.

Group members: **Jude Dunn, Nick Barlee, Alan Baxter, Paul Bennett, Steve Saddlier, Steve Smith and Natalie White.**

A brainstorming session was held to identify the known and perceived threats to the survival of the Spotted Tree Frog (STF) and these are listed in Table 1.

Table 1. Known and perceived threats to the survival of the Spotted Tree Frog

PERCEIVED AND KNOWN THREATS

FLOW RATES
- DIVERSIONS
- MODIFICATIONS TO NATURAL FLOWS

SEDIMENTATION
- EDUCTOR DREDGING
- FORESTRY
- ROADING
- AGRICULTURE
- FIRE

PREDATION
- INTRODUCED SPECIES
- NATIVE SPECIES.

HUMAN DISTURBANCE
- REMOVAL OF RIPARIAN VEGETATION
- FORESTRY
- POLLUTION
- COLLECTION

HERBICIDES AND PESTICIDES

DOMESTIC STOCK IMPACTS
- WATERING POINTS
- RIPARIAN VEGETATION REMOVAL/MODIFICATION
- TRAMPLING

FIRE
- WILDFIRE
- CONTROL BURNING

RANKING OF SITES

Why rank sites? Efficient use of limited resources. It is interesting to note that feedback on a draft of the Action Statement included criticism of ranking sites and applying varying levels/standards of remedial works. The rationale was that for such a rare and threatened species, all known populations should be addressed in the same way. Given not only the possibility of limited resources but also the probability that remedial works will be required over a long time period it is worth ranking sites based on the importance of threat amelioration.

Sites can be ranked using the Paired Method where each site is given a ranking in relation to all the other sites.

METHOD

Streams known to contain populations, or in which populations are presumed extinct, were listed and then ranked by members of the group using the Paired Ranking Method according to the question; "Which stream is more important for the long term viability of the species?

Results are presented in Table 2.

Table 2. Ranking results for Spotted Tree Frog streams based on the question; "Which stream is more important for the long term viability of the species."

Site	**Group Members**						
	G.G	S.S	M.W	P.R	N.W	A.B	Average Score
Taponga River	11	13	14	10	13	11	12
Big River (Eildon)	4	4	9	1	4	11	6
Goulburn River	12	13	13	10	14	15	13
Thomson River	0	1	2	0	0	8	2
Jamieson River	5	6	5	2	6	9	6
Howqua River	7	6	7	5	9	2	6
Buffalo Creek.	3	2	2	6	4	7	4
Buckland River	1	0	0	0	0	1	1
Wongungara River	14	9	10	11	13	10	11
Snowy Creek	8	8	6	6	7	5	7
Big River (Mitta)	11	6	4	8	7	4	7
King River	2	3	0	2	1	0	1
Wheeler Creek	8	11	9	8	9	2	8
Bundarra River	7	10	5	6	9	3	7
Bogong Creek	14	13	13	12	13	13	13
West Kiewa River							

RANKING OF THREATS

A range of known and perceived threats were identified, (see Table 1). The relative importance of threats were discussed and a list of the four most important compiled.

These were:

- PREDATION;
- ROADING;
- RIPARIAN DISTURBANCE; and
- MINING.

Each threat was evaluated for each stream using a Weighted Paired Method.

Weightings, assigned as a proportion of one, were:

PREDATION	0.5;
ROADING	0.3;
RIPARIAN DISTURBANCE	0.1; and
MINING	0.1

Results are presented in Table 3 and presented graphically in Figures 1 and 2.

DISCUSSION

PREDATION

Outcomes of the Threat Group discussion session:

What work is required to further elucidate the interactions between tadpoles and fish. (native and exotic species) and what is the extent of those threats to the Spotted Tree Frog?

What range of methods could be conceived for reducing these threats and the feasibility of implementing those measures?

Assess the palatability of those measures to the community and ways of gaining community support for these measures.

Further work on fish/frog interactions.

1. Determine the lifecycles/movement patterns of predatory fish species and overlay on STF life cycle to determine possible implications

2. Which fish occur at Spotted Tree Frog sites and at what densities?

   This can be determined by electrofishing at each site to determine species composition and relative densities. Likely species to be encountered are brown trout, *Salmo trutta*, rainbow trout, *Oncorhynchus mykiss*, River blackfish, *Gadopsis marmoratus*, and Two-spinned blackfish, *G. bispinosus* (*G. bispinosus* is likely to occur in higher reaches).

3. Which fish species, apart from brown trout, are likely to predate on STF?
   Conduct palatability trials on the range of potential predators

4. Which additional fish species have the potential to reach STF Sites?
   Check NRE fish database and distributional records.

5. Undertake comparisons with East Gippsland sites where riverine frogs are not in decline and trout are absent or in small numbers.

6. Determine past and present distribution of fish in King and Buckland Rivers where STF have disappeared.

Range of methods which could be utilised for reducing these threats and the practicality of implemeting those measures

1. Construction of instream barriers to restrict the access of predatory fish species and the application of rotenone to remove all fish species.
These may only be feasible at the smaller sites (width, depth, flows) where barriers can be constructed.

2. Construction of 'refuges' which will provide spawning sites for STF frogs and nursery areas for the ewly hatched tadpoles.

3. Electrofish sections of stream to remove potential predators and reduce the risk of predation, particularly during the critical spawning period.
Monitor the population of frogs/tadpoles and compare with untreated sites. (This may also give a relative idea of movement of predator species back into these sections and a good predator population assessment).

4. Place fish traps downstream of STF sites to capture migrating predatory species during their upstream spawning run, thereby reducing recruitment of predators at or above STF sites.

FEASIBILITY AT SPECIFIC SITES

CATCHMENT	In-stream Barrier	Isolate Small Pools from the Main Stream	Reduce Number of Trout Prior to Tadpole Hatching
Taponga	X	X	X(Experimental)
Goulburn/Black			X(Experimental)
Howqua			
Bogong	X		
Wongungarra	X		
Snowy	X		
Big (Mitta)			
Wheeler			
Big(Eildon)			
West Kiewa			
Jamieson			
Bundarra			

RECOMMENDATIONS

Strategy

Implemented measures to ameliorate the threats of predation and sedimentation.

Recommendation 1

Determine the level of predator fish removal/reduction necessary to increase metamorph production. The prefered biological option is to remove, or reduce, the impact of exotic predators. This will ensure that natural selection/fitness/ evolutionary practices continue to operate on the Spotted Tree Frog population.

Research has indicated that trout are the primary predator on the tadpoles (Gillesie and Robertson 1996).

An option was put forward that these experiments could be carried out at sites where STF is considered extinct. This would involve introduction of frogs (re-introduction/ translocation). However, if experiments are conducted within known populations any benefits for frog conservation would be immediate.

Any experiment should include four replicates (different streams) combining the following componenets; exclusion of all predators, reduction of trout, and no exclusion of predators.

Recommendation 2

Assess the fish composition and abundance at each of the STF sites.

Recommendation 3

Conduct palatability trials on all predatory fish species identified at sites and also those likely to move into STF habitat.

Dietary analysis of collected predators was suggested but is unlikely to be conclusive as tadpoles are believed to be quickly digested and therefor unidentifiable (G. Gillespie pers comm.)

It was suggested that funding for this component could be sought from the recreational fishing Peak Body.

Recommendation 4

Assess feasibility of the various trout exclusion or control measures proposed (e.g. barriers, fish traps, refuges).

Recommendation 5

Identify sedimentation sources which require urgent action.

Recommendation 6

Implement sediment control measures at identified sites.

Recommendation 7

Begin upgrade of all roading to specified standards.

Recommendation 8

Implement an auditing process on roading and forestry activities in STF catchments.

References

Gillespie, G. and Robertson, P. 1996 Recovery Plan (Research Phase) for the Spotted Tree Frog: Annual Report to April 1996, ANCA Endangered Species Program Department of Conservation and Natural Resources Victoria

LITORIA SPENCERI

Spotted Tree Frog

Population and Habitat Viability Assessment Workshop

Melbourne

4 - 8 August 1996

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Section IV

Genetics Assessment and Guidelines

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Goal: Maximise the evolutionary potential of *L. spenceri*, through maintenance of 90% of genetic variation over 200 years.

Rationale and current knowledge relating to genetic issues.

1. Management and vortex modelling would benefit by defining the boundaries of a randomly mating population (the management unit). Currently there is a limited body of knowledge which has been derived from observation of the behaviour of the species, including:

    a. Distribution in patches along riffle/rapid habitat, 50m to 300m apart, separated by deep water not utilised by frogs.

    b. Migration of frogs/tadpoles from patches not recorded and unknown. Site fidelity of approximately 60m. Ability to recolonise unoccupied habitat may be low.

    c. Morphological differences between populations of "southern" and "northern" frogs, which includes, adults body size (needs confirmation) and colour, and difference in tadpole body shape and mouth size. These morphological differences correlate well with geographical barriers. This indicates the possibility of large genetic differences within the species, or that more than one species exists.

2. Outbreeding depression may be an issue in reintroduction/relocation programs where individuals from different gene pools are put into a single breeding population. This is potentially a greater problem if *L. spenceri* comprises multiple, different evolutionary significant units (ESUs). Within the genus *Litoria*, there are taxa (eg. *L. ewingi* and *L. paraewingi*) which are indistinguishable to any morphometric analyses and the frogs themselves do not appear to be able to discriminate. However, in crosses between these two taxa, there is severe reproductive incompatibility leading to 67% mortality of hybrid offspring before metamorphosis, compared to a control level of a few percent. Something like this could potentially occur even between morphologically identical *L. spenceri* populations.

3. We do not have a base line of current genetic variation from which to evaluate the success of our genetic management. We will determine this empirically.

4. We do not know how the census size (number of adults) relates to effective population size. Low estimates of Ne are cause for concern because they indicate high rates of loss of genetic diversity. Ne can be estimated if the population is analysed over multiple years, and/or from linkage disequilibrium data gained from allozymes. These can be compared with estimates obtained from demographic data using vortex.

5. There has been sampling for genetics from 7 catchments to date, as tabulated below.

	Catchment	size	distribution		sample* number and extent
1.	Taponga	800	20		30; 2 clusters, 10 apart
2.	Goulburn/Black		1155	33	26; 1 cluster, 3 km
3.	Howqua		400	8	25; 2 clusters, 4 km apart
4.	Wongungarra	180	9		30; 2 km
5.	W. Kiewa	<25	<1		6; from one clutch 50m of stream,
6.	Big R./Mitta	175	7		30; 2 clusters, 8 km apart
7.	Snowy	500	25		30; 3 clusters, 5 km apart
8.	Bogong		600	1.6	27; 1.6 km stretch of stream

* combination of juveniles/metamorphs/adults, where a cluster includes multiple patches along a single stream.

The need for further sampling is indicated in sections in the text below.

Strategy:

1. Analyse the level of genetic variation and differentiation of the species throughout its range.

2. Determine what management options are feasible to maximise the evolutionary potential of the species.

Strategy 1. Analysis of the level of genetic variation and differentiation of the species throughout its range.

Qualification: With all sampling for genetic analysis effort should be made to determine that individuals sampled represent the variation present within the population and as a guide should be collected as follows.

a) Eggs if collected should be from different egg masses.
b) Tadpoles should be collected from different pools.
c) Precise information on the collection site and life stage of specimens collected should be recorded.
d) If required numbers are not accessible through a) and b) above, specimens may be taken at different times within and between years as further eggs or different tadpoles enter the system.
e) Adult or juvenile frogs can be considered to be representative of their population but should be collected as broadly as possible within the unit being assessed.
f) Husbandry technology should be used where appropriate to minimise harvest costs to the population. (raising of eggs or tadpoles to produce frogs for genetic analysis)

Objectives:

1. Determine if *L. spenceri* as it is currently recognised is composed of multiple taxonomic groups.

Action: Sample at least 5 individuals per river system from all known populations, throughout the range of species, for allozyme variation at 30-40 loci.

Outcome: Would be considered to be distinct species. If fixed differences are found, they should be confirmed with an evolutionary analysis of mitochondrial DNA sequences.

2. Determine the management unit(s), (genetic unit) defined as areas within which there is random mating. A management unit may be a patch/reach, stream or catchment(s).

Action: Sample at least 30 individuals per river system, and analyse them for >4 polymorphic allozyme loci and/or mt DNA allele frequencies.

Outcome: Determine if there is significant genetic substructure. If no substructure is detected, this will represent the randomly mixing population (management unit).

Action: If substructure is evident, it will be detected at finer levels of geographic distance until we have defined the level of the management unit. This is likely to involve a large panel of allozyme loci, or possibly microsatellites if allozymes are not sufficiently variable. Further sampling may need to identified from individuals at the patch level, which would be the finest level that could be analysed. These intensively studied populations may be Taponga, Goulburn and Bogong Ck. In these populations, all of the adults in the patches along a stream could be analysed from toe clippings from adults or juveniles. Because there may be only 2 or 3 individuals per patch, sample at least 30 individuals along the stream, and test for heterozygote deficits.

Outcome: Define the management unit.

3. Determine the likely maximum and minimum level of inbreeding in populations.

Action: Sample at least 30 individuals (if possible) from 2 large populations and 2 small populations, and compare the levels of inbreeding (heterozygous deficits) at each. If the population is defined as a patch, this analysis will not be possible.

Outcome: Minimum level of inbreeding (found in the large population), and maximum level of inbreeding (found in the small population) determined and used in modelling.

4. Determine variation in reproductive output to refine input for Vortex.

Action:. Analyse reproductive output in intensively sampled patches, where the genotypes of the parents were established, and a cohort could be identified, and sampled before metamorphosis, over multiple years (preferably).

Outcome: Values for variation in reproductive output can be applied to Vortex modelling.

5. Determine genetically viable Ne for each current population.

Action:. Use genetic data from intensively sampled populations to estimate Ne, and use estimates of genetic change from Vortex to calculate genetically viable Ne based on demographic data.

Outcome: Estimates of genetically viable Ne can be used to develop management protocols.

Strategy 2. Determine what genetic management options are available to maximise the evolutionary potential of the species.

I. *In-situ* management: Translocation. (movement of animals within or among sites, with or without a husbandry component)

At the recipient location, this may be appropriate when:
a. the populations has gone extinct
b. and habitat is not recolonised due to barriers to dispersal

In situ management: Reintroductions. (release of animals after a period of holding/rearing)
At the recipient location, this may be appropriate when:
a. the recipient populations is currently not viable (Vortex)

Translocation/reintroductions can occur when:

a. threats abatement has occurred, and/or is being tested
b. and the population can be monitored for success of this process
c. genetic issues are resolved. For sites where the species is extinct, eg., Buffalo Ck, the genetic affinities of frogs needs to be determined from museum specimens before selecting source populations, because these site occurs at the boundary of the two morphotypes (which may be separate species).

This may be appropriate when the source location:
a. can sustain harvesting (as determined by Vortex mortality).
b. is determined to be suitable by genetic analysis (within ESUs and/or MUs)
c. is not viable and animals may be removed, reared in the absence of threats, and reintroduced.

Actions: Conduct Reintroduction/translocation programs if appropriate considering:

a. life stage at which animals are harvested (egg mass/tadpole/juvenile/adult).
b. life stage at which animals are released (egg mass/tadpole/juvenile/adult).

c. the number of individuals to be sourced at each life stage, so that a recipient population can achieve sustainable size (currently unknown),as estimated using Vortex modelling,
d. the use of husbandry technology to minimise costs (financial and biological) of harvesting/release
e. the timing of collection and release
f. develop experimental protocols for re-release/decline hypothesis testing

Outcome: Develop a plan for re-establishment of extinct populations which achieves a 90% retention of source population genetic variation and ultimately a self-sustaining population.

II. *Ex-situ* management

1. Captive management

In any population which is determined to have an effective population size of less than 50, (which will definitely include the W. Kiewa), threat abatement should be immediately implemented. If this is not possible, the recommendation is to translocate tadpoles or egg masses into captivity, hold them in captivity until metamorphosis. At this point the majority should be released back to the site. A small number should be kept for rearing experimentation to investigate husbandry protocols which have been largely unsuccessful to date post-metamorphosis (see appendix 1). This process would allow us to bolster such small populations by avoiding mortality at the tadpole stage with the use of proven technology and without the risks associated with long-term holding. It also provides animals for experimental holding at little cost to the founder population and may enable animals from genetically distinct localities to be represented in captivity in case of catastrophe, and for possible subsequent cryo-preservation of genetic variation. Further thoughts on this process are outlined in appendix 2.

2. Cryo-preservation

The goal must be to maintain these populations in the wild. Cryo-preservation can preserve high levels of founder representation. Frogs are believed to be a relatively easy group to use this technology on, but it requires recently fertilised eggs, which may be difficult to obtain. Advice from experts in the field should be sought on this issue (John Clulow, Biological Science at Newcastle University, Alan Trounson, Animal Gene Storage and Resource Centre of Australia, Monash Medical Centre, and Graeme Watson, Zoology Department at Melbourne University).

Appendix 1. Husbandry experiences with *L. spenceri.*

Purpose of holding/ animals held.	Achievements	% success/ sample size	organisation
Adults held to obtain spawn for determination of clutch size andoviposition site	Spawning was achieved but eggs failed to develop due to technical problems with refrigeration. Both adults released.	N/A	ARC
Adults held for over-wintering to attempt captive spawning	held 5-6 months - continuing	100% (n=4)	ARC
metamorphs held awaiting genetic analysis	held (0-3 months)	>70% (n>50)	ARC
metamorphs kept for raising	attained reproductive maturity but showed deformities and considerably reduced adult size.	100% (n=2)	ZBV
tadpoles held for trials on food preference	tadpoles held 1-2 months	>90% (n=36)	ARC
tadpoles held for raising for genetic analysis	raised to 0-weeks post metamorphosis	>90% (n>30)	ARC
tadpoles held for raising	tadpoles raised to metamorphosis (#? / n=?) metamorphs raised to ?? one animal remaining after ?? months post metamorphosis.??	% (n=?) % (n=?) %(n=?)	ZBV

ARC: Amphibian ResearchCentre, ZBV: Melbourne Zoo

Further problems with husbandry of *L. spenceri*

Small size of adults raised in captivity (clutch size ?)
Calcareous deposits along bones in captive raised animals (calcium balance problems?)
Evidence that bone density is reduced in wild animals held for as little as two months.
Uncontrollable disease outbreaks?

Problems with holding, raising, and breeding frogs for translocation or reintroduction.

- Alteration of phenotype
- Alteration to fitness through:
  - loss of imprinting processes ?
    - alteration of "birthplace" fidelity?
    - seasonal breeding recognition?
  - absence of normal inoculation processes (exposure to juvenile diseases?)
  - growth inconsistent with field performance (wrong size animals for cohort)

Appendix 2. Some thoughts on the translocation/reintroduction process.

Collection for translocation.

Translocating from tadpoles probably has the minimal impact on the source population. Tadpoles or metamorphs would allow for a large genetically representative sample, but the effect of harvesting each life stage on the source needs to be modelled using Vortex to ensure the minimal impact. A broad representation of available genetic material should be sought, so that single egg masses or tadpoles from a single pool would not be appropriate.

Captive husbandry has been established to a stage that tadpole mortality is much lower than in the wild. It cannot be assumed that mortality in captivity is non-selective and does not change genetic representation. This should be checked by allozyme or microsatellite work unless mortality is zero.

The number of individuals required to establish a sustainable population could be modelled using Vortex, as a single translocation, or as a single translocation with supplementation. As a guide, from a genetic perspective releases could consist of the release equivalent of at least 20 breeding individuals (a figure estimated to retain >95% of the heterozygosity, with an 87% chance of sampling (at least once) an allele present at >5% in the sampled population).

There are still numerous questions that are unanswered with respect to translocations and reintroductions for frogs. Any actions need to be designed to maximise the opportunities of not only achieving the goal of sustainable populations but to investigate the economics of this process. The following parameters could be considered for testing at the release site.

Mortality: is mortality at various life stages influenced by the translocation/reintroduction process.

Fitness: is fitness of various life stages altered by the translocation/reintroduction process.

Dispersal: how do released animals disperse.

Flow Diagram of Options for translocation and captive breeding

Needs to be drawn

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Spotted Tree Frog

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Section V

Populations and Modeling

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POPULATION BIOLOGY AND MODELLING OF THE SPOTTED TREE FROG *Litoria spenceri*

Working Group Participants

Greg Hollis (Natural Resources & Environment, Gippsland Region), Graham Pyke (Australian Museum), Jean-Marc Hero (James Cook University), Simon Nicol (Natural Resources & Environment, Marine & Freshwater Ecology), Graeme Gillespie (Natural Resources & Environment, Arthur Rylah Institute), Martin Drechsler (University of Melbourne), Jonathan Wilcken (Australasian Regional Association of Zoological Parks & Aquaria), Phil Miller (Conservation Breeding Specialist Group).

Introduction

The need for and consequences of intensive management strategies can be modelled to suggest which practices may be the most effective in conserving the stf. VORTEX, a simulation software package written for population viability analysis, was used as a tool to study the interaction of a number of life history and population parameters treated stochastically, to explore which demographic parameters may be the most sensitive to alternative management practices.

The VORTEX package is a Monte Carlo simulation of the effects of deterministic forces as well as demographic, environmental, and genetic stochastic events on wild populations. VORTEX models population dynamics as discrete sequential events (e.g., births, deaths, sex ratios among offspring, catastrophes, etc.) that occur according to defined probabilities. The probabilities of events are modelled as constants or as random variables that follow specified distributions. The package simulates a population by stepping through the series of events that describe the typical life cycles of sexually reproducing, diploid organisms.

VORTEX is not intended to give absolute answers, since it is projecting stochastically the interactions of the many parameters which enter into the model and because of the random processes involved in nature. Interpretation of the output depends upon our knowledge of the biology of the spotted tree frog, the conditions affecting the population as well as possible changes in the future. Data on the population biology of the Spotted Tree Frog collected by Gillespie (*unpub. data*) over the previous three years were utilized for this analysis.

Some aspects of the life history of high-fecundity species are not immediately transferable to VORTEX modelling. Modelling populations which include the egg-tadpole stage for some of the sites involves tracking the individual 'fate' of large numbers of individuals (ie: >60,000), which is beyond the capability of the VORTEX model. To circumvent this problem, 'reproduction' has been defined for the purpose of these simulations as the successful production of metamorphs. This reduces, by an order of magnitude, the number of individuals in the population VORTEX is required to keep account of.

Separate estimates of mean clutch size and tadpole survivorship were available (Gillespie *unpublished data*). It was possible, therefore, to subsequently model variations in survivorship in *L. spenceri* tadpoles by adjusting reproductive output to reflect changes solely in this parameter.

Input Parameters for Simulation

Initial simuation was based on data for life history parameters from the Bogong Creek population, the Taponga Creek population and a population designed to reflect the Jamieson River population using Bogong Creek parameters with a smaller population size (Gillespie *unpublished data*). The parameter estimates are subject to uncertainty. Below the best parameter estimates are listed ("base line scenarios"), separately for the Bogong, the Taponga, and the Jamieson population. Deviations from these best estimates and their effects on the population were discussed in the sensitivity analysis (see below). The following parameter list

Bogong Population

Mating System: Polygynous. No specific data on the breeding system are currently available. Polygyny has been assumed on the basis of known mating systems of frogs (Gillespie, Robertson, Hero *pers. com.*). This breeding system was applied to all scenarios.

Age of First Reproduction: VORTEX precisely defines breeding as the time at which offspring (in this case, metamorphs) are born, not simply the age of sexual maturity. In addition, the program uses the mean (or median) age rather than the earliest recorded age of young production.

The population has been modelled over one year units, to encompass the annual breeding cycle of the species. Age one is defined as the age at the first spring subsequent to metamorphosis.

Ages of reproductively active females and males in the Bogong Creek population have been determined by Gillespie (*unpublished data*) using skeletal chronology. The youngest reproductively active females detected were 5 years of age, the youngest reproductively active males three years (Gillespie *unpublished data*). These have been assumed to represent reasonable estimates of age at first reproduction.

Age of Reproductive Senescence: VORTEX assumes that animals can breed (at the normal rate) throughout their adult life. This has been assumed to be the case for *L. spenceri*, allowing for age of reproductive senescence in this species to be determined through estimates of longevity.

Skeletal chronology analysis of specimens captured from the Bogong Creek population recorded a maximum age at 10 yrs (Gillespie *unpublished data*), and this has been assumed to represent a reasonable estimate of longevity in this species. One individual, recorded as 13 years old, was considered an outlier, and not a reliable indicator of longevity in the species.

This parameter was varied in subsequent sensitivity analysis to eight years.

The Taponga Creek population was modeled with a maximum age of reproductive senescence at 6years (Gillespie unpublished data)

Offspring Production: for the purposes of modelling all population dynamics, 'reproduction' for a given female was defined as the successful production of metamorphs. Therefore, mean reproductive output was calculated by imposing mean tadpole mortality rates on mean egg production, resulting in a value for the average number of metamorphs expected from one egg mass.

Mean clutch size for 25 egg masses collected was 531 (range: 300 - 700), three outliers (56, 850,

943) were excluded (Figure 1 *egg mass histogram*). 90% tadpole mortality was recorded in surveys of the Bogong and Taponga populations (Gillespie *unpublished data*) (Figure 2. *graph of % survival at Bogong Creek*). Mean production of metamorphs is therefore estimated 53 per clutch.

The distribution of reproductive output around the mean was set to reflect the distribution of egg production. A range between 25 - 75 was entered, determined from the variation observed from the egg masses collected and the structure of this distribution was set to reflect the structure of the egg mass distribution.

Tadpole survivorship is suspected to vary considerably in the wild (with records between 0 - 40%) and subsequent sensitivity analysis tested the impact on population viability.

Annual variation in female reproduction is modelled in VORTEX by entering a standard deviation (SD) for the proportion of females that do not reproduce in a given year. VORTEX then determines the proportion of females breeding each year of the simulation by sampling from a binomial distribution with the specified mean (e.g., 20%) and standard deviation (e.g., 5%). It is assumed that 100% of females breed in most years (Gillespie *unpublished data*) and the proportion of females breeding each year was initially set at 100%, with an annual variation of 25% (although the effect of reduced variation was later tested).

Sex Ratio at Birth: assumed to be 1:1 on the basis of adult sex ratio. There is no empirical evidence from other frog spp. that sex ratios differ at metamorphosis.

Male Breeding Pool: No data are available for this parameter and all males of reproductive size/age (ie. older than two years) have been assumed to be available for breeding in each year. The intial model was set at 100%. Evidence that only 10% of adults may raise offspring in a given year exists for other frog species (Hero pers. com.), therefore in subsequent models the effect of reducing the male breeding pool to 10% of the adult males was tested, to assess the impact on mean levels of heterozygosity retained in populations after 100 years.

Mortality: Estimates of tadpole mortality, and population age structures determined through skeletal chronology by Gillespie (*unpub. data*) (Figure 3. *Age structure at Bogong Creek*) allow for estimates of age specific survivorship (Lx) (Figure 2. *graph of % survival at Bogong Creek*). These data were used to construct the following schedule of age-specific mortalities.

Metamorph - 1 yrs	90%
1-2 yrs	90%
2-3	40%
3-4	5%
adult:	5%

As with the environmental variation set for female reproduction, we set the annual variation in mortality to be approximately 25% of the mean rates. Subsequent models were developed with juvenile mortality set at either 85 or 80 % and adult mortality set at 10% for the purposes of sensitivity analysis

Catastrophes: Catastrophes are singular environmental events that are outside the bounds of normal environmental variation affecting reproduction and/or survival. Natural catastrophes can be tornadoes, floods, droughts, disease, or similar events. These events are modelled in VORTEX by assigning a probability of occurrence and a severity factor ranging from 0.0 (maximum or absolute effect) to 1.0 (no effect).

No catastrophes were included in any models.

Initial Population Size: The Bogong Creek population was inferred from adult census data which suggests that approximately 600 individuals are present at the site (Gillespie, unpub. data) (Figure 4 *Pop. size estimates*). With juvenile mortality estimated at 90%, adult population size was assumed to represent approximately 10% of total population of juveniles and adults. Initial population size at Bogong Creek was therefore set at 6000 individuals.

Carrying Capacity: The carrying capacity, K, for a given habitat patch defines an upper limit for the population size, above which additional mortality is imposed across all age classes in order to return the population to the value set for K. VORTEX, therefore, uses K to impose density-dependence on survival rates. The program also has the capability of imposing density-dependent effects on reproduction that change as a function of K, but since no such data are available for stf populations, we chose not to include density-dependent reproduction in our models.

In absence of clear indication, initial models assumed carrying capacity incorporated a carrying capacity of greater than the current population size. In the case of the baseline scenario for Bogong, K was set at 8000 which represented the upper limit of computer capacity.

Iterations and Years of Projection: All scenarios were simulated 100 times, with population projections extending for 100 years. Output results were summarized at 10-year intervals for use in some of the figures that follow. All simulations were conducted using VORTEX version 7.2 (June 1996).

Taponga Population

The parameters are the same as in the Bologon Population, except for the following differences. In the Bogong population females and males reach reproductive age at year 4 and 2, respectively Gillespie (unpublished data). The Taponga population size is estimated at 8000 juveniles and adults, as inferred from adult census data (Figure 4: Gillespie, unpublshed data)..

Jamieson Population

The parameters are the same as in the Bogong population, but the population size is estimated to be substantially smaller, with an adult population size of 50 individuals (Figure 4: Gillespie, unpublished data) resulting in total population estimates of approximately 500 juveniles and adults. Carying capacity has been assumed to be twice the current population (K = 1000), thus allowing the population to grow if stochastic growth rates were positive. The effect of increasing K was tested in later analyses.

Subsequent development of model

The sensitivity of the model to change across a range of parameters effect was tested, as a method of determining the most vulnerable characteristics of Spotted Tree Frog populations. The following parameters were varied, using a range of values for each parameter.:

- number of young produced per female per year
  range of values tested: 25, 53, 75, 100

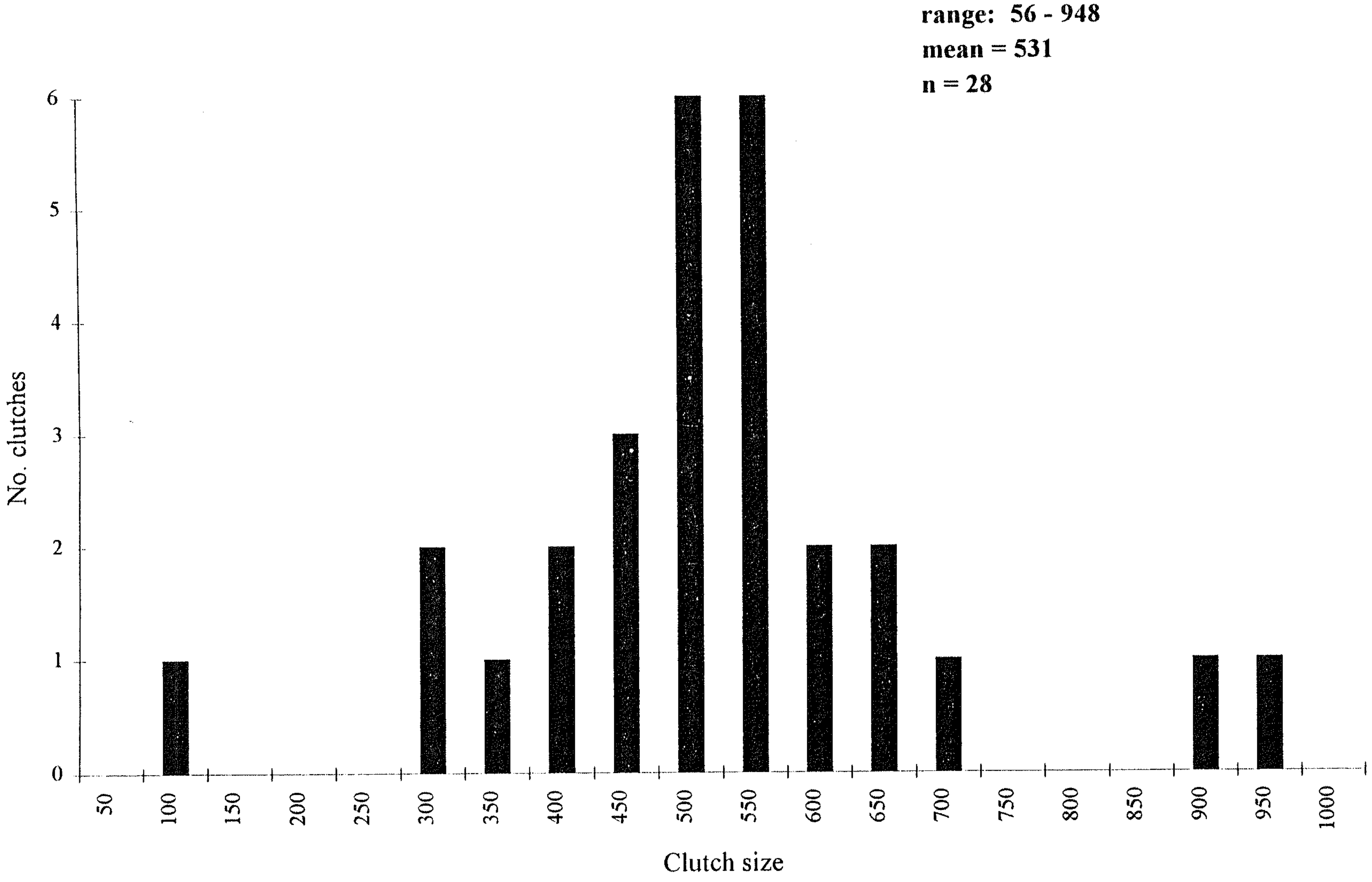


Figure 1. Frequency distribution of clutch sizes

Figure 2. **Percentage survival of offspring of Spotted Tree Frogs from egg-deposition at Bogong Creek**

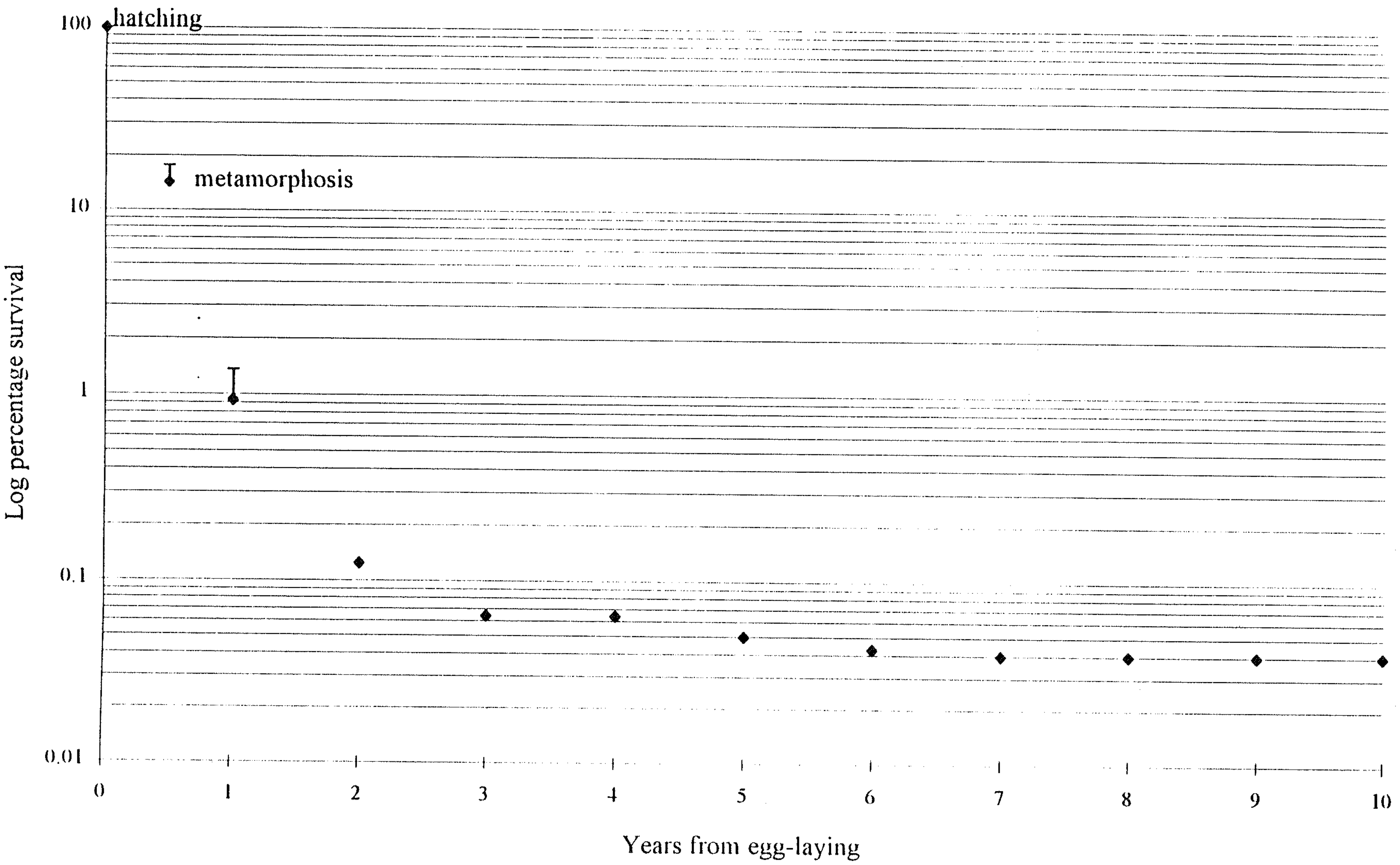
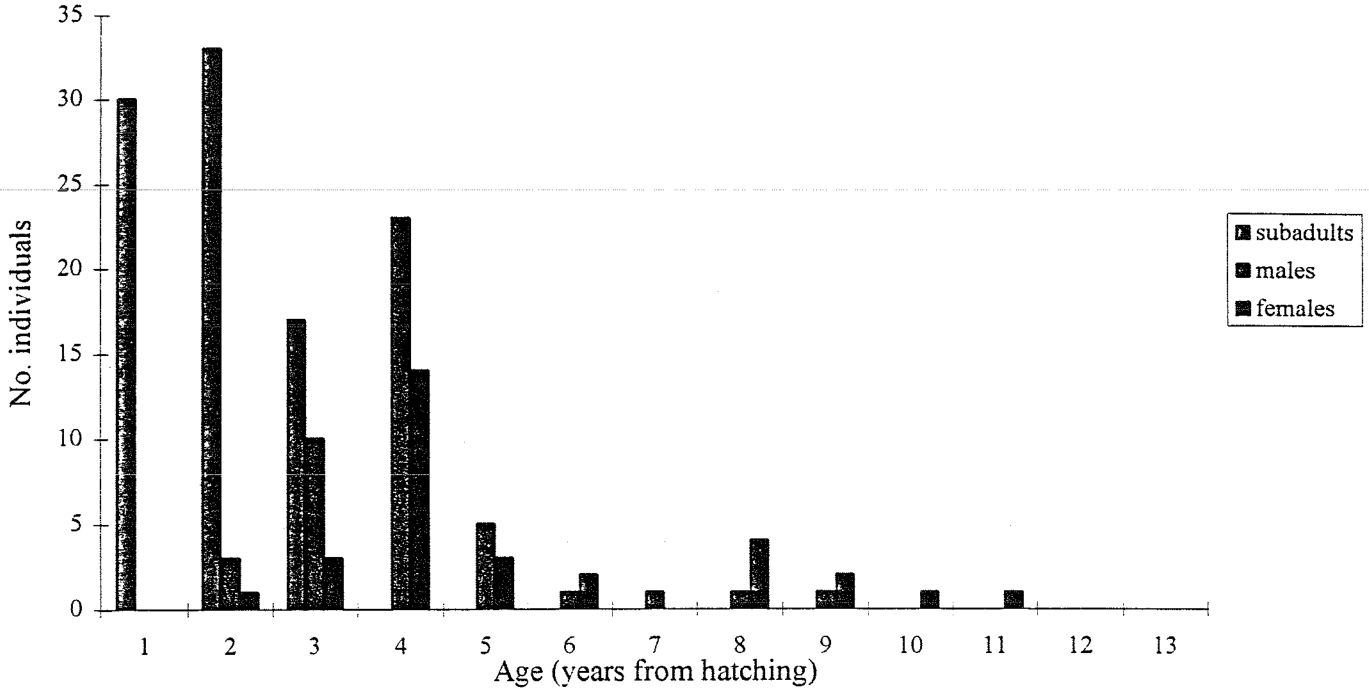


Figure 3a

Proportion of each age class present at Bogong Creek in the 1994/95 summer season.



Proportion of each age class present at Bogong Creek in the 1995/96 summer season.

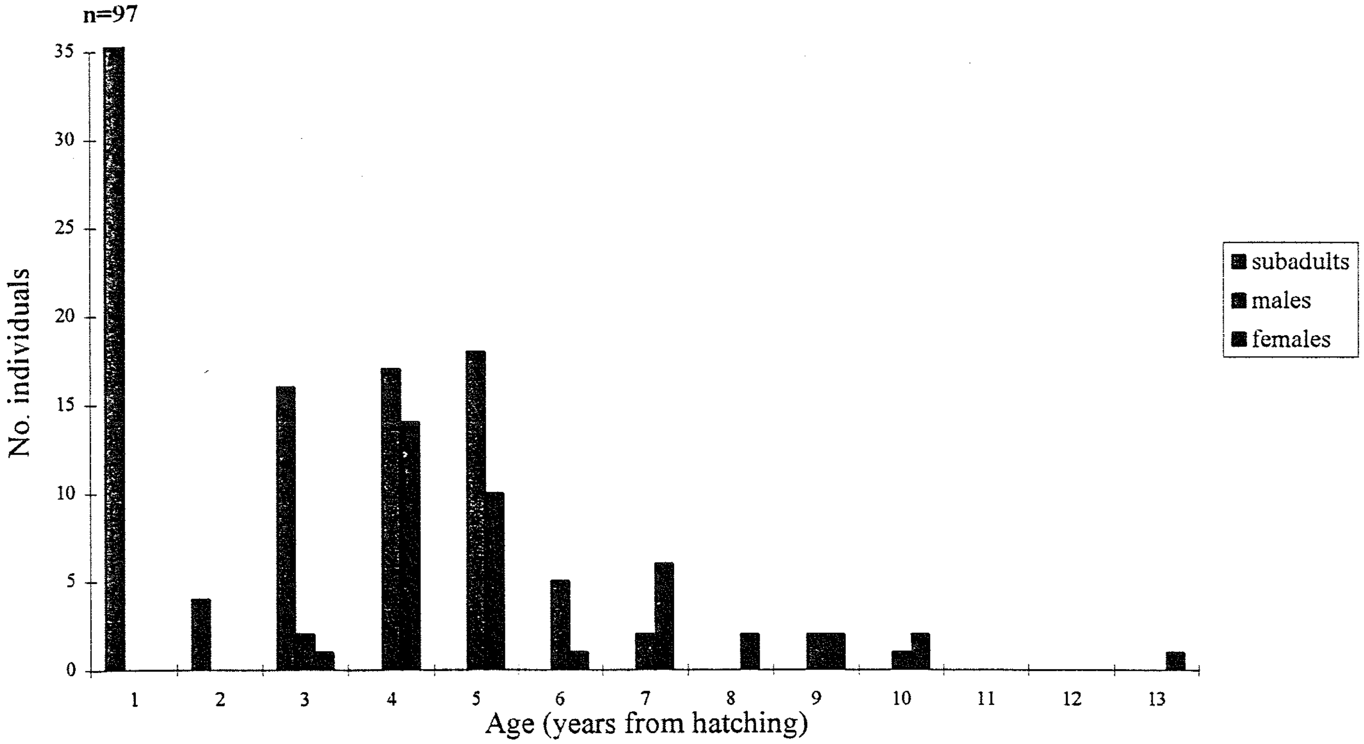
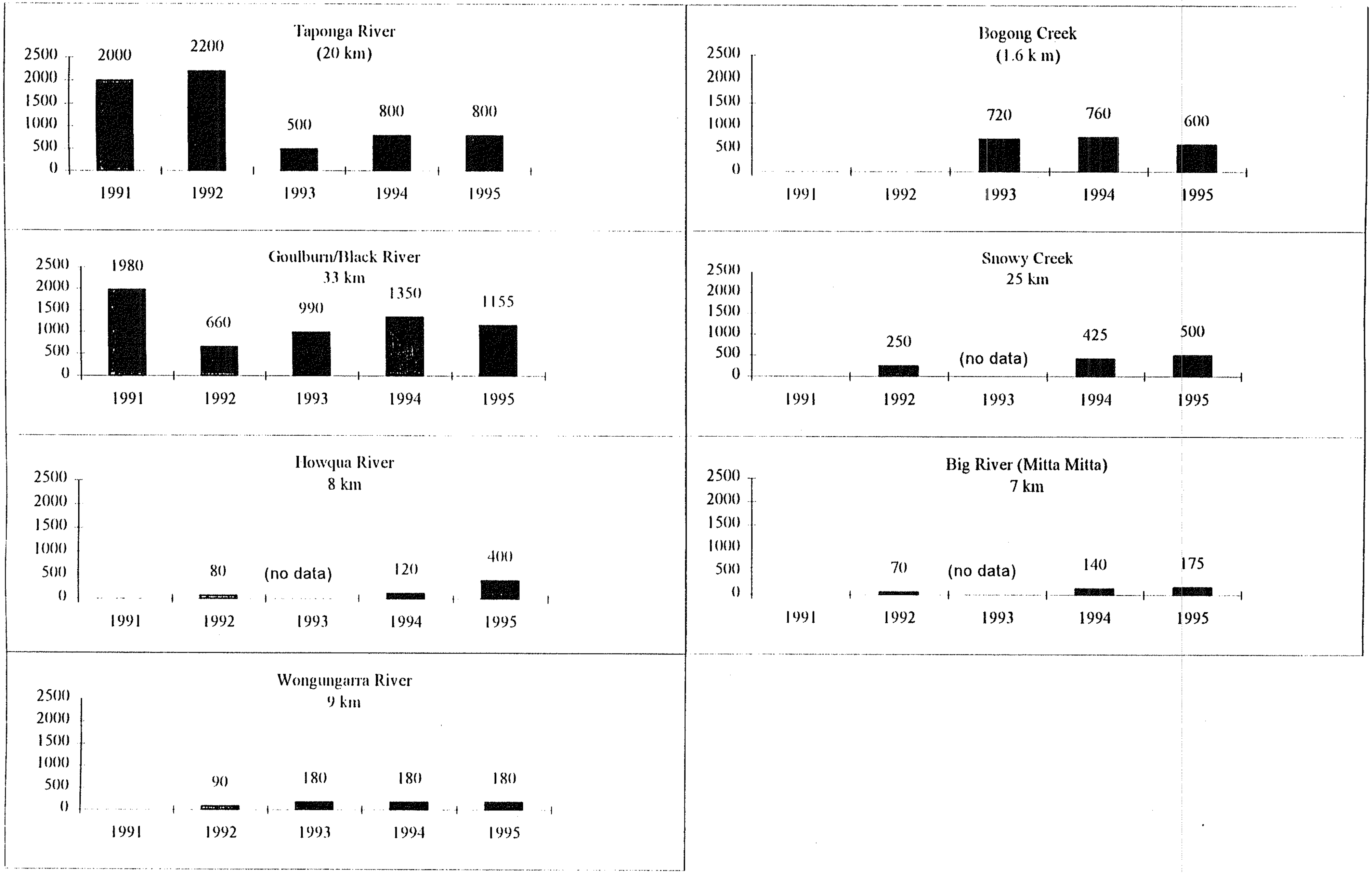


Figure 4. **Population size estimates of Spotted Tree Frogs in catchments which have been monitored**
Length of potential stream habitat in parenthesis



- SD in reproductive output
  range of values tested: 10, 20

- juvenile mortality
  range of values tested: 90%, 85%, 80%

- adult mortality
  range of values tested: 5%, 10%

- maximum age of reproduction
  range of values tested:

Bogong	8,10
Jamieson	8,10
Taponga	6

- percent males breeding
  range of values tested: 100%, 10%

- Environmental variation in % females breeding each year.
  range of values tested: 5, 25

- carrying capacity in Jamieson population
  range of K values: 1000, 3000, 6000

Each value was tested against combinations of the other variables. All other parameters remained as baseline values.

Data analyses:

Stepwise multiple regression was used to determine the primary life history traits that influenced the probability of extinction and associated population parameters predicted by the Vortex simulations. In the results section we present the coefficients of each variable (life history traits) retained in the final stepwise equation (C) that represents the unit change in that variable. To compare the influence of each life history trait with the other life history traits these coefficients were then standardised (Standardised Coefficients) to represent the effect of changing each variable by 10% of the benchmark value of that variable (SC = C x 10 % of the benchmark value).

T-tests were used to examine the influence of manipulating the variance in annual reproductive output per female.

With so many varying parameter values the array of outputs from the simulations is potentially very complex. To help resolve this complexity a backwards stepwise linear regression approach was taken to analyse the results of the simulations.

Note that because of time limitations it was not possible to consider the possibilities of interactions between the variables or non-linear effects.

RESULTS

General modelling results are presented in Table 1-14.

Synthesis of results to identify the most important life history traits that influence the probability of extinction and associated population parameters predicted by the Vortex simulations (Marc Tables 1-3).

Simulating Bogong Population Characteristics

Using Bogong life history characteristics, regression analyses (Marc Table 1 and 2) clearly identified the influence of juvenile survival in the year following metamorphosis (= juvenile survival), changes in longevity of adult frogs (maximum age), and egg and tadpole survival (= no. metamorphs produced). Changes in adult mortality and the % of males reproducing had little influence on the predicted population parameters. Adjusted coefficients suggest that juvenile mortality had the greatest influence on the predicted population parameters followed by longevity and egg and tadpole survival. Reducing the total population size (comparing Marc Table 1 with Marc Table 2) did not alter the relative importance of the life history traits.

Simulating Taponga Population Characteristics

Using Taponga life history characteristics, regression analyses (Marc Table 1 and 2) clearly identified the influence of juvenile survival in the year following metamorphosis (= juvenile survival) and egg and tadpole survival (= no. metamorphs produced). Changes in adult mortality and the % of males reproducing had little influence on the predicted population parameters. Adjusted coefficients suggest that juvenile mortality had the greatest influence on the predicted population parameters followed egg and tadpole survival. Longevity of adult frogs (maximum age) was not analysed for the Taponga population.

Comparison of Bogong and Taponga population charactistics

Comparing the predicted mean population characteristics between the Bogong and Taponga simulations (Tables 1 & 3), the Taponga populations were more prone extinction in all scenarios. The mean stochastic growth rate (r), across all scenarios modelled, for the Taponga populations was -0.199, compared with mean r = -0.088 for the Bogong simulations.

Manipulating the variance in egg and tadpole survival (= no. metamorphs produced) .

T-tests found no significant differences between the predicted population parameters estimated when the standard deviation around the mean egg and tadpole survival (53) was doubled (changing the range of metamorphs from 45 - 61 , 0 - 100).

DISCUSSION

Vortex modelling predicts that juvenile survival in the year following metamorphosis (= juvenile survival), changes in the longevity of adult frogs (maximum age), and egg and tadpole survival (= no. metamorphs produced) are the important life history characteristics that influence Spotted Tree Frog populations. Changes in adult mortality and the % of males reproducing had little influence on the predicted population parameters

Furthermore changes in the variation in the number of eggs produced by individual females had little influence on Spotted Tree Frog populations.

Lower lifetime reproductive output (ie reduced longevity) typical of the Taponga population leads to substantially higher extinction probabilities, indicating a greater risk of extinction for populations sharing these characteristics.

Table 1. Stepwise Multiple Regression results for **BOGONG large.** Life history data: $n = 6000$, $K = 8000$ (*** $p \leq 0.001$; ** $0.001 < P < 0.01$, * $p > 0.01$). The coefficient in the equation (not in bold) represents the unit change in the variable. Standardised coefficients (in bold) represent the effect of changing each variable by 10% of the benchmark value (to compare among life history traits).

Bogong Large		**Manipulated Life History Trait**				
Population Characteristic (range)	**MEAN** n=30	**No. Metamorphs** (25-53)	**Juvenile Mortality** (80-85-90)	**Adult Mortality** (5-10)	**Maximum Age** (8-10)	**% Male** (10-100)
Benchmark Values		**53**	**90 %**	**5%**	**10**	**100**
P (E)	**0.543**	*** - 0.022 **- 0.112**	*** 0.047 **0.423**		** - 0.12 **- 0.12**	
Population Size	**1414**	*** 76 **403**	*** - 295 **- 2,655**		* 622 **622**	
SD Pop. Size	688	*** 40 212	** - 104 - 936			
Stochastic r	**-0.088**	*** 0.005 **0.0265**	*** - 0.012 **- 0.108**	*** - 0.004 **- 0.002**	*** 0.033 **0.033**	
SD stochastic r	0.446		*** 0.02 0.18		** - 0.029 - 0.029	
Time to Extinction	**48**					

Table 2. Stepwise Multiple Regression results for **BOGONG small.** Life history data: $n = 500$, $K = 1000$ (*** $p \leq 0.001$; ** $0.001 < P < 0.01$, * $p > 0.01$).). The coefficient in the equation (not in bold) represents the unit change in the variable. Standardised coefficients (in bold) represent the effect of changing each variable by 10% of the benchmark value (to compare among life history traits).

Bogong Small		**Manipulated Life History Trait**				
Population Characteristic (range)	**MEAN n=42**	**No. Metamorphs** (25-53-75-100)	**Juvenile Mortality** (80-85-90)	**Adult Mortality** (5-10)	**Maximum Age** (8-10)	**% Male** (10-100)
Benchmark Values		**53**	**90 %**	**5 %**	**10**	**100**
P (E)	**0.498**	*** - 0.012 **- 0.064**	*** 0.041 **0.369**		** - 0.115 **- 0.115**	
Population Size	**315**	*** 9 **47.7**	*** -39 **- 351**		*** 81 **81**	
SD Pop. Size	128	*** 3.2 16.96				
Stochastic r	**-0.055**	*** 0.003 **0.0159**	*** -0.012 **- 0.108**	* -0.004 **- 0.002**	*** 0.034 **0.034**	* < (- 0.000)
SD stochastic r	0.484		*** 0.021 0.189		*** -0.037 - 0.037	
Time to Extinction	**38**					* -0.272 **-2.72**

Table 3. Stepwise Multiple Regression results for **TAPONGA.** Life history data: $n = 8000$, $K = 8000$ (*** $p \leq 0.001$; ** $0.001 < P < 0.01$, * $p > 0.01$)). The coefficient in the equation (not in bold) represents the unit change in the variable. Standardised coefficients (in bold) represent the effect of changing each variable by 10% of the benchmark value (to compare among life history traits). Note: maximum age not manipulated in these simulations.

Taponga		**Manipulated Life History Trait**			
Population Characteristic (range)	**MEAN n=18**	**No. Metamorphs** (25-53)	**Juvenile Mortality** (80-85-90)	**Adult Mortality** (5-10)	**% Male** (10-100)
Benchmark Values		**53**	**90 %**	**5 %**	**100**
P (E)	**0.879**	* -0.006 **- 0.0318**	** 0.035 **0.315**		
Population Size	**71**		** -20 **- 180**		
SD Pop. Size	137		* - 41 - 369		
Stochastic r	**-0.199**	*** 0.006 **0.0318**	*** - 0.016 **- 0.054**	* -0.002 **- 0.001**	
SD stochastic r	0.541	** 0.002 0.0106	*** 0.015 0.135		
Time to Extinction	47	*** 1.064 **5.639**	*** -3.283 **- 29.547**		

Summary and Recommendations

Most significant variables with respect stochastic growth rate (ranked):

Juvenile mortality
Max age of reproduction (production of metamorphs)
No. metamorphs produced (egg and tadpole survival)

Varying mortality schedules causes variation between 5% annual growth to 13% annual decline. Under conditions of low metamorph production, even the most optimistic schedules of juvenile and adult mortality tested led to negative growth rates, and a high probability of extinction.

Degree of polygyny has virtually no effect on the demographic characteristics of the population, but leads to additional loss of genetic variability due to reduction in effective population size.

A reduction in initial population size to levels equivalent to that at the Jamieson River site leads to lower stochastic growth rates, and substantially higher probability of extinction and a more substantial loss of heterozygosity.

Doubling the variance in metamorph production per female, while keeping the mean no. of metamorphs constant, resulted in no significant difference in stochastic growth rate, or the probability of extinction. [This may suggest small variation in the total reproductivity of the population which may be explained by the Central Limit Theorem. This theorem states that the sum of a large number of random variables (reproductivity of all females) has a smaller coefficient of variation that each of the variables (reproduction of each single female) themselves; only if you like it.]

Taponga population:
Lower lifetime reproductive output (ie reduced longevity) typical of the lower altitude populations leads to substantially higher extinction probabilities. These lower altitude populations are likely to be most at risk.

Recommendations:

Management Actions:

1. Immediate management actions should be aimed primarily at reducing mortality between egg and metamorph stage

2. Once causes of juvenile mortality are better determined, and if managament actions to reduce these causes are possible, these management actions should be pursued

Future Research :

3. Further investigate egg and tadpole mortality, their site specificity and the factors influencing them. In particular, the different trade-offs in egg and tadpole mortality between the Taponga and the Bogong population should be investigated more closely.

4. Investigate factors affecting juvenile mortality, including site specificity.

5. Monitoring of populations should continue to further investigate annual variations in survivorship.

6. Investigate the spatial heterogeneity of populations (meta-population dynamics) and its impact on the genetic stochasticity and the viability of the population.

7. Investigate the potential impact of catastrophic events on population viability.

Table 1. The Effect of Varying Mortality Schedules in the baseline Bogong population

Conditions	File name	Stochastic Growth Rate (r)	SD(r)	P(e)	Mean final pop. size	SD(N)	Het. retain.	Mean Time to Extinct
Mortality: 90% juv., 5% adult	STF101.OUT	-0.061	0.564	0.290	110.65	172.26	81.74	81.6
Mortality: 85% juv., 5% adult	STF102.OUT	0.007	0.390	0.000	4180.63	2353.17	98.68	0.0
Mortality: 80% juv., 5% adult	STF103.OUT	0.048	0.311	0.000	6402.91	1520.57	99.22	0.0
Mortality: 90% juv., 10% adult	STF104.OUT	-0.082	0.569	0.630	43.00	43.58	74.66	77.5
Mortality: 85% juv., 10% adult	STF105.OUT	-0.012	0.401	0.010	2010.78	1907.77	96.40	95.0
Mortality: 80% juv., 10% adult	STF106.OUT	0.031	0.312	0.000	5627.59	1981.44	99.09	0.0

Table 2. The Impact of Varying Mortality Schedules in the Bogong population; Max. age of reproduction reduced to 8 yrs

Conditions	File name	Stochastic Growth Rate (r)	SD(r)	P(e)	Mean final pop. size	SD(N)	Het. ret.	Mean Time to Extinct
Mortality: 90% juv., 5% adult	STF107.OUT	-0.134	0.622	1.000	0.00	0.00	0.00	59.0
Mortality: 85% juv., 5% adult	STF108.OUT	-0.057	0.472	0.320	260.35	491.66	83.74	80.8
Mortality: 80% juv., 5% adult	STF109.OUT	0.001	0.339	0.010	3377.02	2353.97	97.62	14.0
Mortality: 90% juv., 10% adult	STF110.OUT	-0.152	0.638	1.000	0.00	0.00	0.00	52.5
Mortality: 85% juv., 10% adult	STF111.OUT	-0.081	0.503	0.650	86.14	116.18	75.66	75.6
Mortality: 80% juv., 10% adult	STF112.OUT	-0.014	0.348	0.010	1732.18	1762.24	95.74	100.0

Table 3. The Impact of Varying Mortality Schedules in the Bogong population; mean annual reproductive output reduced to 25 metamorphs per female per year

Conditions	Max. Age of Repro.	File name	Stochastic Growth Rate (r)	SD(r)	P(e)	Mean final pop. size	SD(N)	Het. ret.	Mean Time to Extinct
Mortality: 90% juv., 5% adult	10 years	113	-0.176	0.466	1.000	0.00	0.00	0.00	45.6
Mortality: 85% juv., 5% adult		114	-0.119	0.420	0.950	18.80	12.11	52.25	64.6
Mortality: 80% juv., 5% adult		115	-0.069	0.345	0.440	68.11	109.35	77.48	82.7
Mortality: 90% juv., 10% adult		116	-0.203	0.486	1.000	0.00	0.00	0.00	39.6
Mortality: 85% juv., 10% adult		117	-0.142	0.423	1.000	0.00	0.00	0.00	56.1
Mortality: 80% juv., 10% adult		118	-0.099	0.369	0.870	21.85	19.15	68.85	72.6
Mortality: 90% juv., 5% adult	8 years	119	-0.261	0.513	1.000	0.00	0.00	0.00	31.2
Mortality: 85% juv., 5% adult		120	-0.195	0.477	1.000	0.00	0.00	0.00	40.9
Mortality: 80% juv., 5% adult		121	-0.149	0.439	1.000	0.00	0.00	0.00	53.0
Mortality: 90% juv., 10% adult		122	-0.277	0.521	1.000	0.00	0.00	0.00	29.1
Mortality: 85% juv., 10% adult		123	-0.209	0.455	1.000	0.00	0.00	0.00	38.0
Mortality: 80% juv., 10% adult		124	-0.162	0.450	1.000	0.00	0.00	0.00	49.2

Table 4. The Impact of Varying Mortality Schedules in the Bogong population; no. males in the breeding pool reduced to 10%

Conditions	File name	Stochastic Growth Rate (r)	SD(r)	P(e)	Mean final pop. size	SD(N)	Het. ret.	Mean Time to Extinct
Mortality: 90% juv., 5% adult	STF125.OUT	-0.063	0.563	0.390	146.54	338.08	79.78	83.0
Mortality: 85% juv., 5% adult	STF126.OUT	0.005	0.397	0.010	3724.64	2343.76	97.86	59.0
Mortality: 80% juv., 5% adult	STF127.OUT	0.050	0.311	0.000	6684.84	1380.41	98.86	0.0
Mortality: 90% juv., 10% adult	STF128.OUT	-0.086	0.577	0.710	41.62	43.15	69.20	76.7
Mortality: 85% juv., 10% adult	STF129.OUT	-0.009	0.397	0.000	2005.40	1804.06	95.27	0.0
Mortality: 80% juv., 10% adult	STF130.OUT	0.030	0.310	0.000	5888.07	1883.94	98.56	0.0

Table 5. The Impact of Varying Mortality Schedules in the baseline Taponga population (N = 8,000; K = 8,000)

Conditions	File name	Stochastic Growth Rate (r)	SD(r)	P(e)	Mean final pop. size	SD(N)	Het. ret.	Mean Time to Extinct
Mortality: 90% juv., 5% adult	STF201.OUT	-0.227	0.652	1.000	0.00	0.00	0.00	36.2
Mortality: 85% juv., 5% adult	STF202.OUT	-0.128	0.561	0.980	46.00	8.49	74.80	61.0
Mortality: 80% juv., 5% adult	STF203.OUT	-0.058	0.446	0.390	546.64	1255.02	79.43	80.9
Mortality: 90% juv., 10% adult	STF204.OUT	-0.235	0.665	1.000	0.00	0.00	0.00	34.7
Mortality: 85% juv., 10% adult	STF205.OUT	-0.152	0.571	1.000	0.00	0.00	0.00	53.2
Mortality: 80% juv., 10% adult	STF206.OUT	-0.072	0.477	0.550	232.24	523.49	73.44	76.0

Table 6. The Impact of Varying Mortality Schedules in the Taponga population (N = 8,000; K = 8,000); mean annual reproductive output reduced to 25 metamorphs per female per year

Conditions	File name	Stochastic Growth Rate (r)	SD(r)	P(e)	Mean final pop. size	SD(N)	Het. ret.	Mean Time to Extinct
Mortality: 90% juv., 5% adult	STF207.OUT	-0.379	0.539	1.000	0.00	0.00	0.00	21.9
Mortality: 85% juv., 5% adult	STF208.OUT	-0.293	0.495	1.000	0.00	0.00	0.00	28.1
Mortality: 80% juv., 5% adult	STF209.OUT	-0.241	0.474	1.000	0.00	0.00	0.00	34.1
Mortality: 90% juv., 10% adult	STF210.OUT	-0.387	0.545	1.000	0.00	0.00	0.00	21.2
Mortality: 85% juv., 10% adult	STF211.OUT	-0.302	0.483	1.000	0.00	0.00	0.00	27.3
Mortality: 80% juv., 10% adult	STF212.OUT	-0.247	0.486	1.000	0.00	0.00	0.00	32.8

Table 7. The Impact of Varying Mortality Schedules in the Taponga population (N = 8,000; K = 8,000); no. males in the breeding pool reduced to 10%

Conditions	File name	Stochastic Growth Rate (r)	SD(r)	P(e)	Mean final pop. size	SD(N)	Het. ret.	Mean Time to Extinct
Mortality: 90% juv., 5% adult	STF213.OUT	-0.224	0.654	1.000	0.00	0.00	0.00	35.6
Mortality: 85% juv., 5% adult	STF214.OUT	-0.128	0.554	0.970	20.33	14.01	51.38	61.2
Mortality: 80% juv., 5% adult	STF215.OUT	-0.059	0.455	0.380	325.24	568.45	69.67	77.5
Mortality: 90% juv., 10% adult	STF216.OUT	-0.228	0.647	1.000	0.00	0.00	0.00	35.6
Mortality: 85% juv., 10% adult	STF217.OUT	-0.147	0.560	1.000	0.00	0.00	0.00	55.4
Mortality: 80% juv., 10% adult	STF218.OUT	-0.071	0.479	0.560	108.02	112.61	65.88	80.9

Table 8. The Effect of Varying Mortality Schedules in the baseline Jamieson population

Conditions	File name	Stochastic Growth Rate (r)	SD(r)	P(e)	Mean final pop. size	SD(N)	Het. ret.	Mean Time to Extinct
Mortality: 90% juv., 5% adult	STF131.OUT	-0.071	0.598	0.840	38.44	28.89	61.50	64.5
Mortality: 85% juv., 5% adult	STF132.OUT	0.006	0.411	0.030	435.45	298.35	89.42	58.3
Mortality: 80% juv., 5% adult	STF133.OUT	0.047	0.320	0.000	765.95	218.55	93.40	0.0
Mortality: 90% juv., 10% adult	STF134.OUT	-0.096	0.616	0.970	38.33	54.42	44.68	55.8
Mortality: 85% juv., 10% adult	STF135.OUT	-0.018	0.434	0.180	241.82	257.91	80.37	67.5
Mortality: 80% juv., 10% adult	STF136.OUT	0.027	0.329	0.000	695.87	250.85	91.12	0.0

Table 9. The Impact of Varying Mortality Schedules in the Jamieson population; Max. age of reproduction reduced to 8 yrs

Conditions	File name	Stochastic Growth Rate (r)	SD(r)	P(e)	Mean final pop. size	SD(N)	Het. ret.	Mean Time to Extinct
Mortality: 90% juv., 5% adult	STF137.OUT	-0.158	0.650	1.000	0.00	0.00	0.00	34.8
Mortality: 85% juv., 5% adult	STF138.OUT	-0.072	0.544	0.830	55.65	48.68	66.78	63.0
Mortality: 80% juv., 5% adult	STF139.OUT	-0.010	0.406	0.140	307.94	250.19	78.96	67.0
Mortality: 90% juv., 10% adult	STF140.OUT	-0.178	0.694	1.000	0.00	0.00	0.00	31.7
Mortality: 85% juv., 10% adult	STF141.OUT	-0.091	0.564	0.960	53.50	27.87	72.52	56.4
Mortality: 80% juv., 10% adult	STF142.OUT	-0.025	0.438	0.370	280.40	268.33	77.84	73.6

Table 10. The Impact of Varying Mortality Schedules in the Jamieson population; mean annual reproductive output reduced to 25 metamorphs per female per year

Conditions	Max. Age of Repro.	File name	Stochastic Growth Rate (r)	SD(r)	P(e)	Mean final pop. size	SD(N)	Het. ret.	Mean Time to Extinct
Mortality: 90% juv., 5% adult	10 Years	143	-0.196	0.512	1.000	0.00	0.00	0.00	28.6
Mortality: 85% juv., 5% adult		144	-0.127	0.453	1.000	0.00	0.00	0.00	43.4
Mortality: 80% juv., 5% adult		145	-0.086	0.414	0.940	27.17	19.90	51.03	59.8
Mortality: 90% juv., 10% adult		146	-0.207	0.516	1.000	0.00	0.00	0.00	26.6
Mortality: 85% juv., 10% adult		147	-0.154	0.479	1.000	0.00	0.00	0.00	36.3
Mortality: 80% juv., 10% adult		148	-0.105	0.444	1.000	0.00	0.00	0.00	51.5
Mortality: 90% juv., 5% adult	8 Years	149	-0.266	0.542	1.000	0.00	0.00	0.00	20.9
Mortality: 85% juv., 5% adult		150	-0.213	0.524	1.000	0.00	0.00	0.00	26.6
Mortality: 80% juv., 5% adult		151	-0.162	0.490	1.000	0.00	0.00	0.00	33.7
Mortality: 90% juv., 10% adult		152	-0.295	0.547	1.000	0.00	0.00	0.00	18.6
Mortality: 85% juv., 10% adult		153	-0.223	0.517	1.000	0.00	0.00	0.00	24.8
Mortality: 80% juv., 10% adult		154	-0.179	0.520	1.000	0.00	0.00	0.00	30.3

Table 11. The Impact of Varying Mortality Schedules in the Jamieson population; no. males in the breeding pool reduced to 10%

Conditions	File name	Stochastic Growth Rate (r)	SD(r)	P(e)	Mean final pop. size	SD(N)	Het. ret.	Mean Time to Extinct
Mortality: 85% juv., 5% adult	STF156.OUT	0.003	0.414	0.060	442.72	273.88	84.21	71.2
Mortality: 80% juv., 5% adult	STF157.OUT	0.049	0.314	0.000	838.47	183.58	90.10	0.0
Mortality: 90% juv., 10% adult	STF158.OUT	-0.092	0.613	0.920	30.00	29.01	53.03	54.6
Mortality: 85% juv., 10% adult	STF159.OUT	-0.022	0.439	0.200	225.40	244.61	68.13	74.2
Mortality: 80% juv., 10% adult	STF160.OUT	0.029	0.327	0.020	719.40	223.84	87.49	88.5

Table 13. The impact of varying reproductive output (no. of metamorphs/female) against variable levels of juvenile mortality in the Jamieson population; adult mortality = 10%

Conditions			File name	Output						
Repro. output	SD (repro. output)	Juv. Mort.		Stochastic Growth Rate (r)	SD(r)	P(e)	Mean final pop. size	SD(N)	Het. ret.	Mean Time to Extinct
53	10	90	301	-0.071	0.589	0.820	41.33	46.31	64.65	63.7
75	10	90	302	-0.008	0.625	0.170	339.40	277.68	82.20	68.8
100	10	90	303	0.022	0.624	0.010	512.13	291.29	89.77	46.0
53	20	90	304	-0.072	0.589	0.880	98.67	158.32	63.00	66.3
53	10	85	305	0.004	0.410	0.040	418.74	276.18	88.33	73.8
75	10	85	306	0.059	0.425	0.000	777.32	225.19	93.19	0.0
100	10	85	307	0.082	0.448	0.000	822.05	206.59	92.83	0.0
53	20	85	308	0.004	0.405	0.030	442.60	311.10	86.49	84.7
53	10	80	309	0.045	0.324	0.000	770.30	234.34	92.79	0.0
75	10	80	310	0.100	0.339	0.000	891.69	156.66	92.85	0.0
100	10	80	311	0.124	0.350	0.000	874.58	149.85	92.13	0.0
53	20	80	312	0.044	0.315	0.000	767.21	218.67	92.92	0.0

Table 14. The Impact of Varying Reproductive output (no. of metamorphs/female) against variable levels of juvenile mortality in the Jamieson population; adult mortality = 10%

Conditions			File name	Output						
Repro. output	SD (repro. output)	Juv. Mort.		Stochastic Growth Rate (r)	SD(r)	P(e)	Mean final pop. size	SD(N)	Het. ret.	Mean Time to Extinct
53	10	90	313	-0.098	0.609	0.990	3.00	0.00	61.11	56.3
75	10	90	314	-0.029	0.632	0.390	235.56	247.10	79.92	72.6
100	10	90	315	0.003	0.633	0.070	379.47	297.07	83.96	65.6
53	20	90	316	-0.099	0.617	0.980	28.50	21.92	51.19	53.9
53	10	85	317	-0.018	0.431	0.210	273.44	259.21	81.11	72.9

75	10	85	318	0.045	0.440	0.000	691.00	251.71	91.60	0.0
100	10	85	319	0.066	0.444	0.000	785.97	241.22	91.37	0.0
53	20	85	320	-0.016	0.434	0.150	226.66	238.00	79.18	80.0
53	10	80	321	0.029	0.325	0.010	680.91	238.68	91.70	53.0
75	10	80	322	0.086	0.345	0.000	856.68	170.00	92.39	0.0
100	10	80	323	0.109	0.357	0.000	873.09	164.76	92.09	0.0
53	20	80	324	0.030	0.323	0.000	744.84	248.43	91.67	0.0

Sample VORTEX Input File

```
STF105.OUT     ***Output Filename***
Y     ***Graphing Files?***
N     ***Each Iteration?***
Y      ***Screen display of graphs?***
100     ***Simulations***
100     ***Years***
10     ***Reporting Interval***
1     ***Populations***
N     ***Inbreeding Depression?***
Y     ***EV correlation?***
0     ***Types Of Catastrophes***
P     ***Monogamous, Polygynous, or Hermaphroditic***
5     ***Female Breeding Age***
3     ***Male Breeding Age***
10     ***Maximum Age***
0.500000     ***Sex Ratio***
80     ***Maximum Litter Size***
N     ***Density Dependent Breeding?***
0.000000     ***Population 1: Percent Litter Size 0***
0.000000     ***Population 1: Percent Litter Size 1***
0.000000     ***Population 1: Percent Litter Size 2***
0.000000     ***Population 1: Percent Litter Size 3***
0.000000     ***Population 1: Percent Litter Size 4***
0.000000     ***Population 1: Percent Litter Size 5***
0.000000     ***Population 1: Percent Litter Size 6***
0.000000     ***Population 1: Percent Litter Size 7***
0.000000     ***Population 1: Percent Litter Size 8***
0.000000     ***Population 1: Percent Litter Size 9***
0.000000     ***Population 1: Percent Litter Size 10***
0.000000     ***Population 1: Percent Litter Size 11***
0.000000     ***Population 1: Percent Litter Size 12***
0.000000     ***Population 1: Percent Litter Size 13***
0.000000     ***Population 1: Percent Litter Size 14***
0.000000     ***Population 1: Percent Litter Size 15***
0.000000     ***Population 1: Percent Litter Size 16***
0.000000     ***Population 1: Percent Litter Size 17***
0.000000     ***Population 1: Percent Litter Size 18***
0.000000     ***Population 1: Percent Litter Size 19***
0.000000     ***Population 1: Percent Litter Size 20***
0.000000     ***Population 1: Percent Litter Size 21***
0.000000     ***Population 1: Percent Litter Size 22***
0.000000     ***Population 1: Percent Litter Size 23***
0.000000     ***Population 1: Percent Litter Size 24***
0.000000     ***Population 1: Percent Litter Size 25***
0.000000     ***Population 1: Percent Litter Size 26***
0.000000     ***Population 1: Percent Litter Size 27***
0.000000     ***Population 1: Percent Litter Size 28***
0.000000     ***Population 1: Percent Litter Size 29***
1.600000     ***Population 1: Percent Litter Size 30***
1.600000     ***Population 1: Percent Litter Size 31***
1.600000     ***Population 1: Percent Litter Size 32***
1.600000     ***Population 1: Percent Litter Size 33***
1.600000     ***Population 1: Percent Litter Size 34***
0.800000     ***Population 1: Percent Litter Size 35***
0.800000     ***Population 1: Percent Litter Size 36***
0.800000     ***Population 1: Percent Litter Size 37***
0.800000     ***Population 1: Percent Litter Size 38***
0.800000     ***Population 1: Percent Litter Size 39***
1.600000     ***Population 1: Percent Litter Size 40***
1.600000     ***Population 1: Percent Litter Size 41***
1.600000     ***Population 1: Percent Litter Size 42***
1.600000     ***Population 1: Percent Litter Size 43***
1.600000     ***Population 1: Percent Litter Size 44***
2.400000     ***Population 1: Percent Litter Size 45***
2.400000     ***Population 1: Percent Litter Size 46***
2.400000     ***Population 1: Percent Litter Size 47***
2.400000     ***Population 1: Percent Litter Size 48***
2.400000     ***Population 1: Percent Litter Size 49***
3.000000     ***Population 1: Percent Litter Size 50***
4.000000     ***Population 1: Percent Litter Size 51***
5.000000     ***Population 1: Percent Litter Size 52***
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5.000000     ***Population 1: Percent Litter Size 53***
5.000000     ***Population 1: Percent Litter Size 54***
5.000000     ***Population 1: Percent Litter Size 55***
5.000000     ***Population 1: Percent Litter Size 56***
5.000000     ***Population 1: Percent Litter Size 57***
5.000000     ***Population 1: Percent Litter Size 58***
3.000000     ***Population 1: Percent Litter Size 59***
3.000000     ***Population 1: Percent Litter Size 60***
1.600000     ***Population 1: Percent Litter Size 61***
1.600000     ***Population 1: Percent Litter Size 62***
1.600000     ***Population 1: Percent Litter Size 63***
1.600000     ***Population 1: Percent Litter Size 64***
1.600000     ***Population 1: Percent Litter Size 65***
1.600000     ***Population 1: Percent Litter Size 66***
1.600000     ***Population 1: Percent Litter Size 67***
1.600000     ***Population 1: Percent Litter Size 68***
1.600000     ***Population 1: Percent Litter Size 69***
1.600000     ***Population 1: Percent Litter Size 70***
0.800000     ***Population 1: Percent Litter Size 71***
0.800000     ***Population 1: Percent Litter Size 72***
0.800000     ***Population 1: Percent Litter Size 73***
0.800000     ***Population 1: Percent Litter Size 74***
0.800000     ***Population 1: Percent Litter Size 75***
0.000000     ***Population 1: Percent Litter Size 76***
0.000000     ***Population 1: Percent Litter Size 77***
0.000000     ***Population 1: Percent Litter Size 78***
0.000000     ***Population 1: Percent Litter Size 79***
0.000000     ***Population 1: Percent Litter Size 80***
25.000000     ***EV--Reproduction***
85.000000     ***Female Mortality At Age 0***
5.000000     ***EV--FemaleMortality***
90.000000     ***Female Mortality At Age 1***
5.000000     ***EV--FemaleMortality***
40.000000     ***Female Mortality At Age 2***
8.000000     ***EV--FemaleMortality***
5.000000     ***Female Mortality At Age 3***
2.000000     ***EV--FemaleMortality***
5.000000     ***Female Mortality At Age 4***
2.000000     ***EV--FemaleMortality***
10.000000     ***Adult Female Mortality***
3.000000     ***EV--AdultFemaleMortality***
85.000000     ***Male Mortality At Age 0***
5.000000     ***EV--MaleMortality***
90.000000     ***Male Mortality At Age 1***
8.000000     ***EV--MaleMortality***
40.000000     ***Male Mortality At Age 2***
8.000000     ***EV--MaleMortality***
10.000000     ***Adult Male Mortality***
3.000000     ***EV--AdultMaleMortality***
Y     ***All Males Breeders?***
Y     ***Start At Stable Age Distribution?***
6000     ***Initial Population Size***
8000     ***K***
0.000000     ***EV--K***
N     ***Trend In K?***
N      ***Harvest?***
N     ***Supplement?***
Y     ***AnotherSimulation?***
```

Sample VORTEX Output File

```
VORTEX -- simulation of genetic and demographic stochasticity

STF105.OUT
Tue Aug  6 08:08:44 1996

  1 population(s) simulated for 100 years, 100 iterations

  No inbreeding depression

  First age of reproduction for females: 5   for males: 3
  Age of senescence (death): 10
  Sex ratio at birth (proportion males): 0.50000


Population 1:

  Polygynous mating; all adult males in the breeding pool.

  Reproduction is assumed to be density independent.

     0.00 (EV = 25.00 SD) percent of adult females produce litters of size 0
     0.00 percent of adult females produce litters of size 1
     0.00 percent of adult females produce litters of size 2
     0.00 percent of adult females produce litters of size 3
     0.00 percent of adult females produce litters of size 4
     0.00 percent of adult females produce litters of size 5
     0.00 percent of adult females produce litters of size 6
     0.00 percent of adult females produce litters of size 7
     0.00 percent of adult females produce litters of size 8
     0.00 percent of adult females produce litters of size 9
     0.00 percent of adult females produce litters of size 10
     0.00 percent of adult females produce litters of size 11
     0.00 percent of adult females produce litters of size 12
     0.00 percent of adult females produce litters of size 13
     0.00 percent of adult females produce litters of size 14
     0.00 percent of adult females produce litters of size 15
     0.00 percent of adult females produce litters of size 16
     0.00 percent of adult females produce litters of size 17
     0.00 percent of adult females produce litters of size 18
     0.00 percent of adult females produce litters of size 19
     0.00 percent of adult females produce litters of size 20
     0.00 percent of adult females produce litters of size 21
     0.00 percent of adult females produce litters of size 22
     0.00 percent of adult females produce litters of size 23
     0.00 percent of adult females produce litters of size 24
     0.00 percent of adult females produce litters of size 25
     0.00 percent of adult females produce litters of size 26
     0.00 percent of adult females produce litters of size 27
     0.00 percent of adult females produce litters of size 28
     0.00 percent of adult females produce litters of size 29
     1.60 percent of adult females produce litters of size 30
     1.60 percent of adult females produce litters of size 31
     1.60 percent of adult females produce litters of size 32
     1.60 percent of adult females produce litters of size 33
     1.60 percent of adult females produce litters of size 34
     0.80 percent of adult females produce litters of size 35
     0.80 percent of adult females produce litters of size 36
     0.80 percent of adult females produce litters of size 37
     0.80 percent of adult females produce litters of size 38
     0.80 percent of adult females produce litters of size 39
     1.60 percent of adult females produce litters of size 40
     1.60 percent of adult females produce litters of size 41
     1.60 percent of adult females produce litters of size 42
     1.60 percent of adult females produce litters of size 43
     1.60 percent of adult females produce litters of size 44
     2.40 percent of adult females produce litters of size 45
     2.40 percent of adult females produce litters of size 46
     2.40 percent of adult females produce litters of size 47
     2.40 percent of adult females produce litters of size 48
     2.40 percent of adult females produce litters of size 49
```

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   3.00 percent of adult females produce litters of size 50
   4.00 percent of adult females produce litters of size 51
   5.00 percent of adult females produce litters of size 52
   5.00 percent of adult females produce litters of size 53
   5.00 percent of adult females produce litters of size 54
   5.00 percent of adult females produce litters of size 55
   5.00 percent of adult females produce litters of size 56
   5.00 percent of adult females produce litters of size 57
   5.00 percent of adult females produce litters of size 58
   3.00 percent of adult females produce litters of size 59
   3.00 percent of adult females produce litters of size 60
   1.60 percent of adult females produce litters of size 61
   1.60 percent of adult females produce litters of size 62
   1.60 percent of adult females produce litters of size 63
   1.60 percent of adult females produce litters of size 64
   1.60 percent of adult females produce litters of size 65
   1.60 percent of adult females produce litters of size 66
   1.60 percent of adult females produce litters of size 67
   1.60 percent of adult females produce litters of size 68
   1.60 percent of adult females produce litters of size 69
   1.60 percent of adult females produce litters of size 70
   0.80 percent of adult females produce litters of size 71
   0.80 percent of adult females produce litters of size 72
   0.80 percent of adult females produce litters of size 73
   0.80 percent of adult females produce litters of size 74
   0.80 percent of adult females produce litters of size 75
   0.00 percent of adult females produce litters of size 76
   0.00 percent of adult females produce litters of size 77
   0.00 percent of adult females produce litters of size 78
   0.00 percent of adult females produce litters of size 79
   0.00 percent of adult females produce litters of size 80

  85.00 (EV = 5.00 SD) percent mortality of females between ages 0 and 1
  90.00 (EV = 5.00 SD) percent mortality of females between ages 1 and 2
  40.00 (EV = 8.00 SD) percent mortality of females between ages 2 and 3
   5.00 (EV = 2.00 SD) percent mortality of females between ages 3 and 4
   5.00 (EV = 2.00 SD) percent mortality of females between ages 4 and 5
  10.00 (EV = 3.00 SD) percent annual mortality of adult females (5<=age<=10)
  85.00 (EV = 5.00 SD) percent mortality of males between ages 0 and 1
  90.00 (EV = 8.02 SD) percent mortality of males between ages 1 and 2
  40.00 (EV = 8.00 SD) percent mortality of males between ages 2 and 3
  10.00 (EV = 3.00 SD) percent annual mortality of adult males (3<=age<=10)
   EVs may have been adjusted to closest values
       possible for binomial distribution.
   EV in reproduction and mortality will be correlated.

  Initial size of Population 1:
    (set to reflect stable age distribution)
 Age 1      2      3      4      5      6      7      8      9     10     Total
  2062    206    123    112    100     89     81     73     65     59     2970  Males
  2062    206    123    118    111    100     90     81     73     66     3030  Females

  Carrying capacity = 8000 (EV = 0.00 SD)

Deterministic population growth rate (based on females, with assumptions of
  no limitation of mates, no density dependence, and no inbreeding depression):

     r =  0.001     lambda = 1.001     R0 =     1.005
   Generation time for:  females = 7.19    males = 5.95

Stable age distribution:  Age class     females     males
                              0         0.410       0.410
                              1         0.062       0.062
                              2         0.006       0.006
                              3         0.004       0.004
                              4         0.004       0.003
                              5         0.003       0.003
                              6         0.003       0.003
                              7         0.003       0.002
                              8         0.002       0.002
                              9         0.002       0.002
                             10         0.002       0.002

Ratio of adult (>= 3) males to adult (>= 5) females: 1.348
```

```
Population 1

Year 10
     N[Extinct] =        0, P[E] = 0.000
     N[Surviving] =    100, P[S] = 1.000
     Population size =         4939.32 ( 193.64 SE, 1936.38 SD)
     Expected heterozygosity =    0.999 (  0.000 SE,    0.000 SD)
     Observed heterozygosity =    1.000 (  0.000 SE,    0.000 SD)
     Number of extant alleles = 1517.73 (  35.54 SE,  355.41 SD)

Year 20
     N[Extinct] =        0, P[E] = 0.000
     N[Surviving] =    100, P[S] = 1.000
     Population size =         4443.83 ( 210.78 SE, 2107.77 SD)
     Expected heterozygosity =    0.998 (  0.000 SE,    0.001 SD)
     Observed heterozygosity =    0.999 (  0.000 SE,    0.001 SD)
     Number of extant alleles =  827.35 (  25.13 SE,  251.31 SD)

Year 30
     N[Extinct] =        0, P[E] = 0.000
     N[Surviving] =    100, P[S] = 1.000
     Population size =         3532.99 ( 186.53 SE, 1865.26 SD)
     Expected heterozygosity =    0.996 (  0.000 SE,    0.002 SD)
     Observed heterozygosity =    0.998 (  0.000 SE,    0.002 SD)
     Number of extant alleles =  544.01 (  19.17 SE,  191.75 SD)

Year 40
     N[Extinct] =        0, P[E] = 0.000
     N[Surviving] =    100, P[S] = 1.000
     Population size =         3517.80 ( 230.25 SE, 2302.48 SD)
     Expected heterozygosity =    0.994 (  0.000 SE,    0.005 SD)
     Observed heterozygosity =    0.996 (  0.001 SE,    0.005 SD)
     Number of extant alleles =  381.52 (  15.32 SE,  153.24 SD)

Year 50
     N[Extinct] =        0, P[E] = 0.000
     N[Surviving] =    100, P[S] = 1.000
     Population size =         3016.69 ( 226.85 SE, 2268.54 SD)
     Expected heterozygosity =    0.991 (  0.001 SE,    0.010 SD)
     Observed heterozygosity =    0.994 (  0.001 SE,    0.008 SD)
     Number of extant alleles =  287.16 (  12.44 SE,  124.45 SD)

Year 60
     N[Extinct] =        0, P[E] = 0.000
     N[Surviving] =    100, P[S] = 1.000
     Population size =         2782.11 ( 218.07 SE, 2180.67 SD)
     Expected heterozygosity =    0.988 (  0.001 SE,    0.011 SD)
     Observed heterozygosity =    0.991 (  0.001 SE,    0.010 SD)
     Number of extant alleles =  223.47 (  10.68 SE,  106.78 SD)

Year 70
     N[Extinct] =        0, P[E] = 0.000
     N[Surviving] =    100, P[S] = 1.000
     Population size =         2418.09 ( 213.02 SE, 2130.17 SD)
     Expected heterozygosity =    0.983 (  0.002 SE,    0.020 SD)
     Observed heterozygosity =    0.989 (  0.001 SE,    0.011 SD)
     Number of extant alleles =  178.96 (   9.64 SE,   96.36 SD)

Year 80
     N[Extinct] =        0, P[E] = 0.000
     N[Surviving] =    100, P[S] = 1.000
     Population size =         2247.83 ( 207.73 SE, 2077.30 SD)
     Expected heterozygosity =    0.977 (  0.003 SE,    0.029 SD)
     Observed heterozygosity =    0.985 (  0.002 SE,    0.021 SD)
     Number of extant alleles =  146.19 (   8.51 SE,   85.12 SD)

Year 90
     N[Extinct] =        0, P[E] = 0.000
     N[Surviving] =    100, P[S] = 1.000
     Population size =         2022.86 ( 186.31 SE, 1863.06 SD)
     Expected heterozygosity =    0.969 (  0.004 SE,    0.039 SD)
     Observed heterozygosity =    0.979 (  0.003 SE,    0.029 SD)
     Number of extant alleles =  122.41 (   7.66 SE,   76.65 SD)
```

```
Year 100
     N[Extinct] =        1, P[E] = 0.010
     N[Surviving] =     99, P[S] = 0.990
     Population size =          2010.78 ( 191.74 SE, 1907.77 SD)
     Expected heterozygosity =    0.964 (  0.004 SE,    0.040 SD)
     Observed heterozygosity =    0.971 (  0.004 SE,    0.035 SD)
     Number of extant alleles =  104.00 (   6.86 SE,    68.26 SD)

In 100 simulations of Population 1 for 100 years:
  1 went extinct and 99 survived.

This gives a probability of extinction of 0.0100 (0.0099 SE),
  or a probability of success of         0.9900 (0.0099 SE).

1 simulations went extinct at least once.
Of those going extinct,
    mean time to first extinction was 95.00 years (0.00 SE, 0.00 SD).

No recolonizations.

Mean final population for successful cases was 2010.78 (191.74 SE, 1907.77 SD)

   Age 1       2       3       4   Adults    Total
  688.56   78.30                   232.93    999.79  Males
  691.83   67.86   37.30   38.89  175.11   1010.99  Females

Without harvest/supplementation, prior to carrying capacity truncation,
  mean growth rate (r) was -0.0125 (0.0040 SE, 0.4010 SD)

Final expected heterozygosity was      0.9640 ( 0.0040 SE,  0.0403 SD)
Final observed heterozygosity was      0.9712 ( 0.0035 SE,  0.0350 SD)
Final number of alleles was           104.00 (   6.86 SE,   68.26 SD)
************************************************************************
```

Model Results Figure Legends

Figure 1. Probability of extinction (A) and population size (B) for alternative scenarios of juvenile mortality in the Bogong population of the spotted tree frog. Specific values of juvenile (metamorph to one year) mortality are indicated in the figures.

Figure 2. Probability of extinction (A) and population size (B) for alternative scenarios of juvenile mortality in the "Jamieson" population of the spotted tree frog. Specific values of juvenile (metamorph to one year) mortality are indicated in the figures.

Figure 3. Loss of population heterozygosity for alternative scenarios of juvenile mortality for the Bogong and "Jamieson" populations of the spotted tree frog. Specific values of juvenile (metamorph to one year) mortality are indicated in the figures. The dashed line delineates the retention of 90% of the original population heterozygosity.

Figure 4. Stochastic growth rates (r_s) under alternative scenarios of juvenile mortality for the Bogong and Taponga populations of the spotted tree frog.

Figure 1.
Spotted Tree Frog Population Viability:
Juvenile Mortality in the Bogong Population

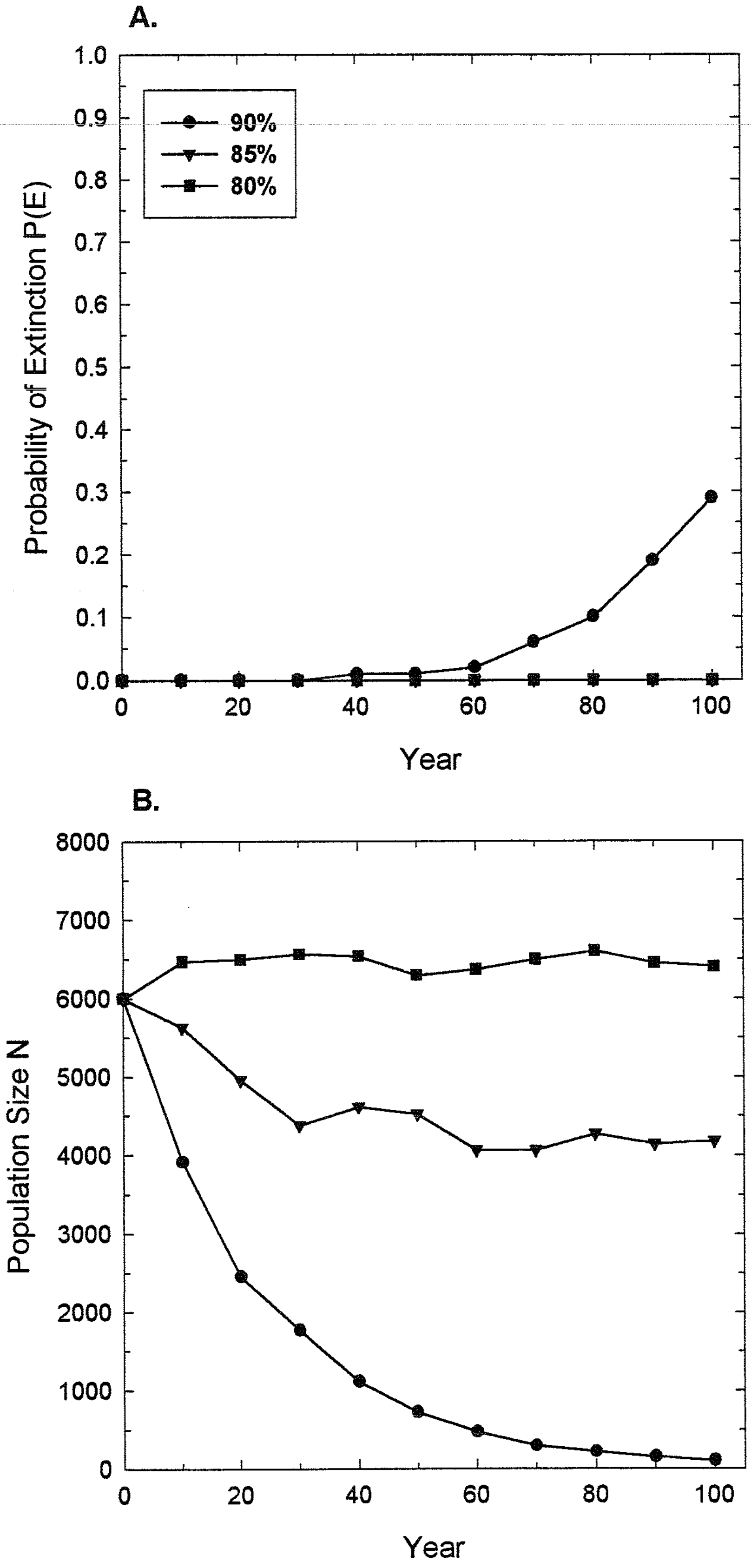


Figure 2.
Spotted Tree Frog Population Viability:
Juvenile Mortality and the "Jamieson" Population

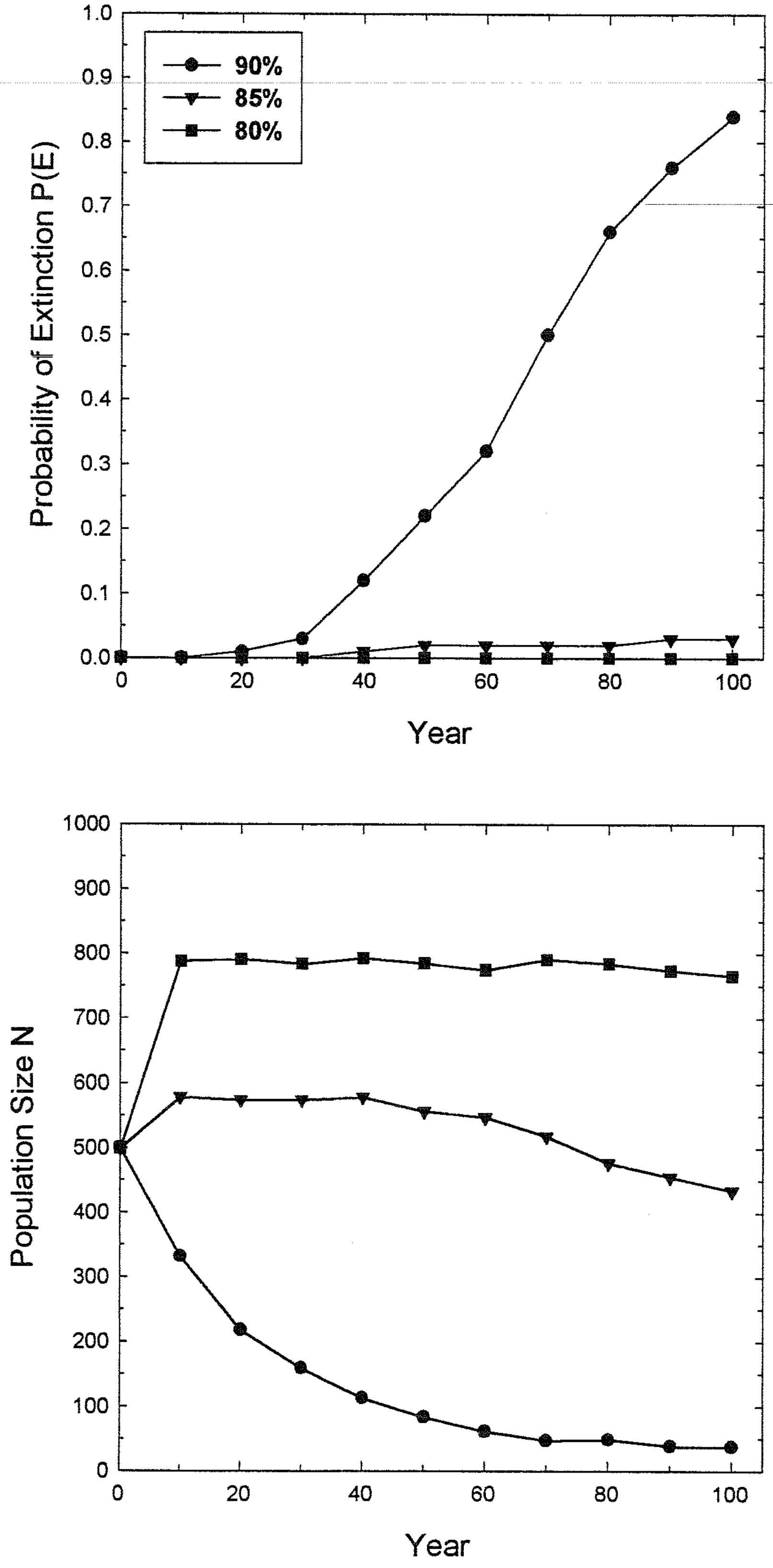
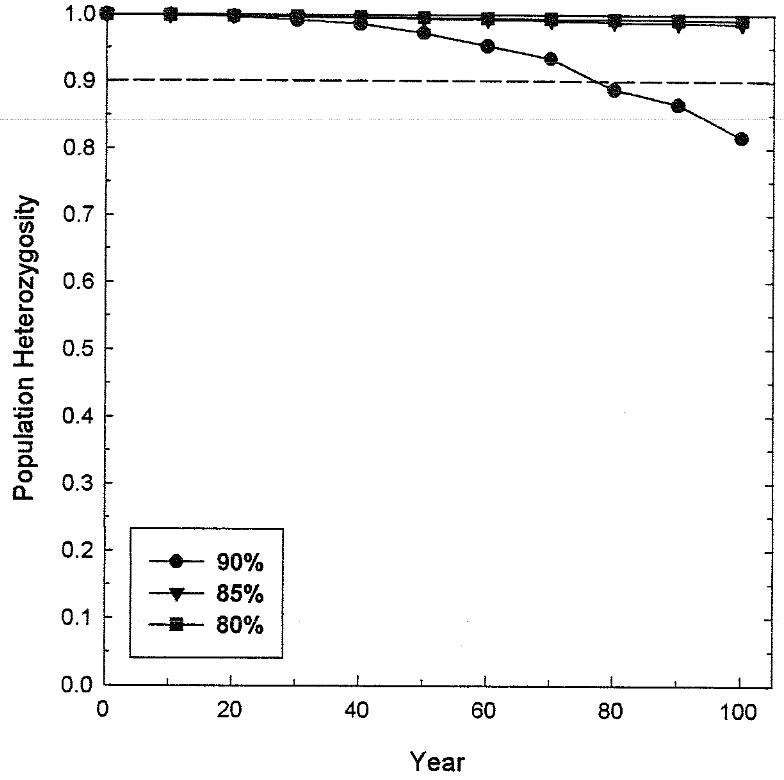


Figure 3.
Spotted Tree Frog Population Viability:
Population Size and Retention of Heterozygosity

A. Bogong (N_0 = 6000; K = 8000)



B. Jamieson (N_0 = 500; K = 1000)

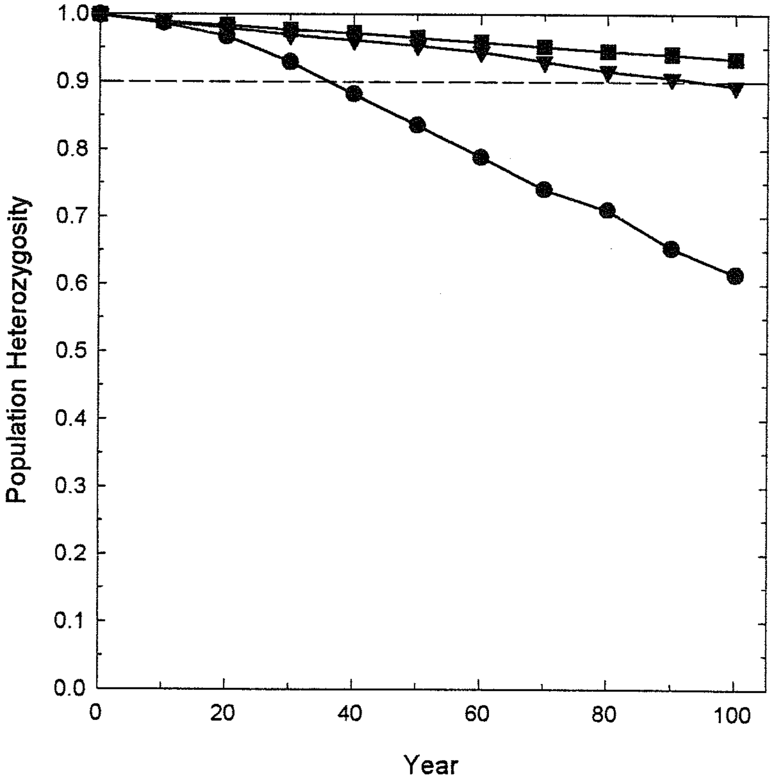
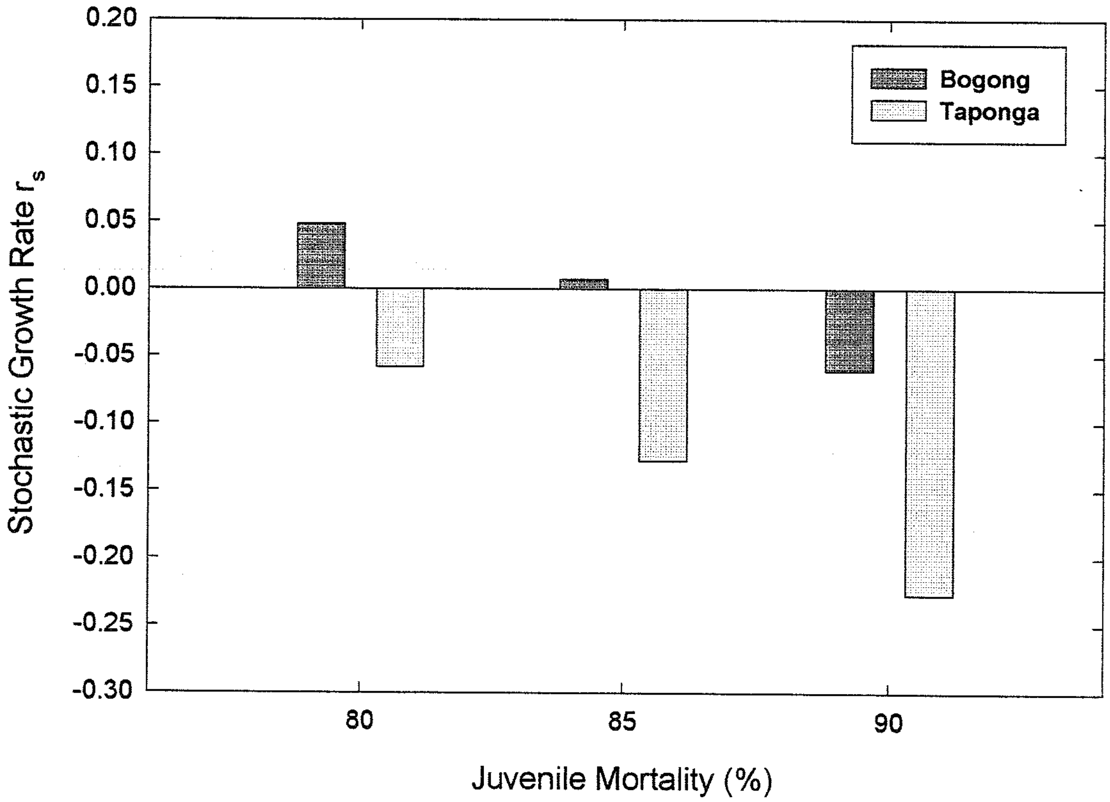


Figure 4.
Spotted Tree Frog Population Viability:
Comparison of Bogong and Taponga Characteritics



LITORIA SPENCERI

Spotted Tree Frog

Population and Habitat Viability Assessment Workshop

Melbourne

4 - 8 August 1996

DRAFT REPORT

Section VI

Selected Papers

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LITORIA SPENCERI

Spotted Tree Frog

Population and Habitat Viability Assessment Workshop

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Section VII

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LITORIA SPENCERI

Spotted Tree Frog

Population and Habitat Viability Assessment Workshop

Melbourne

4 - 8 August 1996

DRAFT REPORT

Section VII

IUCN Guidelines

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GUIDELINES FOR RE-INTRODUCTIONS

Introduction

These policy guidelines have been drafted by the Re-introduction Specialist Group of the IUCN's Species Survival Commission (Guidelines for determining procedures for disposal of species confiscated in trade are being developed separately by IUCN for CITES.) in response to the increasing occurrence of reintroduction projects world-wide, and consequently, to the growing need for specific policy guidelines to help ensure that the re-introductions achieve their intended conservation benefit, and do not cause adverse side-effects of greater impact. Although the IUCN developed a Position Statement on the Translocation of Living Organisms in 1987, more detailed guidelines were felt to be essential in providing more comprehensive coverage of the various factors involved in re-introduction exercises.

These guidelines are intended to act as a guide for procedures useful to re-introduction programmes and do not represent an inflexible code of conduct. Many of the points are more relevant to re-introductions using captive-bred individuals than to translocation of wild species. Others are especially relevant to globally endangered species with limited numbers of founders. Each re-introduction proposal should be rigorously reviewed on its individual merits. On the whole, it should be noted that re-introduction is a very lengthy and complex process.

This document is very general, and worded so that it covers the full range of plant and animal taxa. It will be regularly revised. Handbooks for re-introducing individual groups of animals and plants will be developed in future.

1. Definition of Terms

a. "Re-introduction ":

An attempt to establish a species (The taxonomic unit referred to throughout the document is species: it may be a lower taxonomic unit [e.g. sub-species or race] as long as it can be unambiguously defined.) in an area which was once part of its historical range, but from which it has become extinct (CITES criterion of "extinct": species not definitely located in the wild during the past 50 years of conspecifics.). ("Re-establishment" is a synonym, but implies that the re-introduction has been successful) .

b. "Translocation ":

Deliberate and mediated movement of wild individuals or populations from one part of their range to another. IUCN/SSC Draft Reintroduction Guidelines 2 *c. "Reinforcement/Supplementation":*

Addition of individuals to an existing population.

d. "Conservation/Benign Introductions":

An attempt to establish a species, for the purpose of conservation, outside its recorded distribution but within an appropriate habitat and eco-geographical area.

2. Aims and Objectives of the Re-Introduction

a. Aims:

A re-introduction should aim to establish a viable, free-ranging population in the wild, of a species or subspecies which was formerly globally or locally extinct (extirpated). In some circumstances, a re-introduction may have to be made into an area which is fenced or otherwise delimited, but it should be within the species' former natural habitat and range, and require minimal long-term management.

b. Objectives:

The objectives of a re-introduction will include: to enhance the long-term survival of a species; to re-establish a keystone species (in the ecological or cultural sense) in an ecosystem; to maintain natural biodiversity; to provide long-term economic benefits to the local and/or national economy; to promote conservation awareness; or a combination of these.

Re-introductions or translocation of species for short-term, sporting or commercial purposes - where there is no intention to establish a viable population - are a different issue, beyond the scope of these guidelines. These include fishing an(I hunting activities.

3. Multi disciplinary Approach

A re-introduction requires a Multi disciplinary approach involving a team of persons drawn from a variety of backgrounds. They may include persons from: governmental natural resource management agencies; non-governmental organizations; funding bodies; universities; veterinary institutions; zoos (and private animal breeders) and/or botanic gardens, with a full range of suitable expertise. Team leaders should be responsible for coordination between the various bodies and provision should be made for publicity and public education about the project.

4. Pre-Project Activities

a. Biological:

(I) Feasibility study and background research

- An assessment should be made of the taxonomic status of individuals to be re-introduced. They must be of the same subspecies as those which were extirpated, unless adequate numbers are not available. An investigation of historical information about the loss and fate of individuals from the re-introduction area, as well as molecular genetic studies, should be undertaken in case of doubt. A study of genetic variation within and between populations of this and related taxa can also be helpful. Special care is needed when the population has long been extinct.

- Detailed studies should be made of the status and biology of wild populations (if they exist) to determine the species' critical needs; for animals, this would include descriptions of habitat preferences, intra specific variation and adaptations to local ecological conditions, social behavior, group composition, home range size, shelter and food requirements, foraging and feeding behavior, predators and diseases. For plants it would include biotic and abiotic habitat requirements, dispersal mechanisms, reproductive biology, symbiotic relationships (e.g. with mycorrhizae, pollinators), insect pests and diseases. Overall, a firm knowledge of the natural history of the species in question is crucial to the entire re-introduction scheme.

- The build-up of the released population should be modeled under various sets of conditions, in order to specify the optimal number and composition of individuals to be released per year and the numbers of years necessary to promote establishment of a viable population.

- A Population and Habitat Viability Analysis will aid in identifying significant environmental and population variables and assessing their potential interactions, which would guide long-term population management.

(ii) Previous Re-introductions

- Thorough research into previous re-introductions of the same or similar species and wide-ranging contacts with persons having relevant expertise should be conducted prior to and while developing re-introduction protocol.

(iii) Choice of release site

- Site should be within the historic range of species and for an initial reinforcement or re-introduction have very few, or no, remnant wild individuals (to prevent disease spread, social disruption and introduction of alien genes). A conservation/ benign introduction should be undertaken only as a last resort when no opportunities for re-introduction into the original site or range exist.

- The re-introduction area should have assured, long-term protection (whether formal or otherwise).

(iv) Evaluation of re-introduction site

- Availability of suitable habitat: re-introductions should only take place where the habitat and landscape requirements of the species are satisfied, and likely to be sustained for the for-seeable future. The possibility of natural habitat change since extirpation must be considered. The area should have sufficient carrying capacity to sustain growth of the re-introduced population and support a viable (self-sustaining) population in the long run.

- Identification and elimination of previous causes of decline: could include disease; over-hunting; over-collection; pollution; poisoning; competition with or predation by introduced species; habitat loss; adverse effects of earlier research or management programmes; competition with domestic livestock, which may be seasonal.

- Where the release site has undergone substantial degradation caused by human activity, a habitat restoration programme should be initiated before the reintroduction is carried out.

(v) Availability of suitable release stock

- Release stock should be ideally closely-related genetically to the original native stock.

- If captive or artificially propagated stock is to be used, it must be from a population which has been soundly managed both demographically and genetically, according to the principles of contemporary conservation biology.

- Re-introductions should not be carried out merely because captive stocks exist, nor should they be a means of disposing of surplus stock.

- Removal of individuals for re-introduction must not endanger the captive stock population or the wild source population. Stock must be guaranteed available on a regular and predictable basis, meeting specifications of the project protocol.

- Prospective release stock must be subjected to a thorough veterinary screening process before shipment from original source. Any animals found to be infected or which test positive for selected pathogens must be removed from the consignment, and the uninfected, negative remainder must be placed in strict quarantine for a suitable period before retest. If clear after retesting, the animals may be placed for shipment.

- Since infection with serious disease can be acquired during shipment, especially if this is intercontinental, great care must be taken to minimize this risk.

- Stock must meet all health regulations prescribed by the veterinary authorities of the recipient country and adequate provisions must be made for quarantine if necessary.

- Individuals should only be removed from a wild population after the effects of translocation on the donor population have been assessed, and after it is guaranteed that these effects will not be negative.

b. Socio-Economic and Legal Activities

- Re-introductions are generally long-term projects that require the commitment of long-term financial and political support.

- Socio-economic studies should be made to assess costs and benefits of the e-introduction programme to local human populations.

- A thorough assessment of attitudes of local people to the proposed project is necessary to ensure long term protection of the re-introduced population, especially if the cause of species' decline was due to human factors (e.g. over-hunting, over-collection, loss of habitat). The programme should be fully understood, accepted and supported by local communities.

- Where the security of the re-introduced population is at risk from human activities, measures should be taken to minimize these in the re-introduction area. If these measures are inadequate, the re-introduction should be abandoned or alternative release areas sought.

- The policy of the country to re-introductions and to the species concerned should be assessed. This might include checking existing national and international legislation and regulations, and provision of new measures as necessary. Re-introduction must take place with the full permission and involvement of all relevant government agencies of the recipient or host country. This is particularly important in re-introductions in border areas, or involving more than one state.

- If the species poses potential risk to life or property, these risks should be minimized and adequate provision made for compensation where necessary; where all other solutions fail, removal or destruction of the released individual should be considered.

In the case of migratory/mobile species, provisions should be made for crossing of international/state boundaries.

5. Planning. Preparation and Release Stages

- Construction of a Multi disciplinary team with access to expert technical advice for all phases of the programme. IUCN/SSC Draft Reintroduction Guidelines 6

- Approval of all relevant government agencies and land owners, and coordination with national and international conservation organizations.

- Development of transport plans for delivery of stock to the country and site of re-introduction, with special emphasis on ways to minimize stress on the individuals during transport.

- Identification of short-and long-term success indicators and prediction of programme duration, in context of agreed aims and objectives.

- Securing adequate funding for all programme phases.

- Design of pre- and post- release monitoring programme so that each re-introduction is a carefully designed experiment, with the capability to test methodology with scientifically collected data.

- Appropriate health and genetic screening of release stock. Health screening of closely related species in re-introduction area.

- If release stock is wild-caught, care must be taken to ensure that: a) the stock is free from infectious or contagious pathogens and parasites before shipment and b) the stock will not be exposed to vectors of disease agents which may be present at the release site (and absent at the source site) and to which it may have no acquired immunity.

- If vaccination prior to release, against local endemic or epidemic diseases of wild stock or domestic livestock at the release site, is deemed appropriate, this must be carried out during the "Preparation Stage" so as to allow sufficient time for the development of the required immunity.

- Appropriate veterinary or horticultural measures to ensure health of released stock throughout programme. This is to include adequate quarantine arrangements, especially where founder stock travels far or crosses international boundaries to release site.

- Determination of release strategy (acclimatization of release stock to release area; behavioral training - including hunting and feeding; group composition, number, release patterns and techniques; timing).

- Establishment of policies on interventions (see below).

- Development of conservation education for long-term support; professional training of individuals involved in long-term programme; public relations through the mass media and in local community; involvement where possible of local people in the programme.

- The welfare of animals for release is of paramount concern through all these stages.

6. Post-Release Activities

- Post release monitoring of all (or sample of) individuals. This most vital aspect may be by direct (e.g. tagging, telemetry) or indirect (e.g. spoor, informants) methods as suitable.

- Demographic, ecological and behavioral studies of released stock.

- Study of processes of long-term adaptation by individuals and the population.

- Collection and investigation of mortalities.

- Interventions (e.g. supplemental feeding; veterinary aid; horticultural aid) when necessary.
- Decisions for revision rescheduling, or discontinuation of programme where necessary.
- Habitat protection or restoration to continue where necessary.
- Continuing public relations activities, including education and mass media coverage.
- Evaluation of cost-effectiveness and success of re- introduction techniques.
- Regular publications in scientific and popular literature.

Description and distribution

Description

Adults The Spotted Tree Frog (*Litoria spenceri* Dubois 1984) is a medium-sized species in the Family Hylidae. Females may attain 61 mm (snout-vent length) while males are smaller, attaining 50 mm (Watson *et al.* 1991). The dorsum is highly variable; it may be pale brown, bright green to olive-grey, with or without darker blotches, usually with numerous small raised `warts'. The ventral surface is pale and granular, often becoming flushed with pale orange towards the rear and on the underside of the hind limbs. Toes and fingers are distinctly flattened, with the discs moderately expanded; the fingers have distinct basal webbing and the toes are fully webbed. The head is broad and a distinct fold is present above the indistinct tympanum.

Larvae The tadpole is free swimming. The body is elongated and flattened, and individuals reach a total length of 40 mm prior to metamorphosis. The tail is moderately thick and has a rounded tip. The eyes are dorso-lateral and the mouth is ventral. The oral disc is large relative to other closely-related species, and the oral papillae have a wide anterior gap. There are two rows of anterior labial teeth and three posterior rows. The body is dark brown to black above, with fine silver chromatophores extending onto the flanks. Darker spots may be present on the dorsal surface. Ventral surface is darkly pigmented. Tail fin and muscle are covered with fine melanophores (Hero *et al.* 1995).

Distribution

The Spotted Tree Frog is confined predominantly to the north-west side of the Great Dividing Range between the Central Highlands in Victoria and Mt Kosciusko in New South Wales. Within this area, extensive searches have now been completed (Watson *et al* 1991, Gillespie and Hollis, 1996) - every major stream (approx. 99) within the broad distribution of the species within Victoria has been examined. streams. The results of this work reveal only eleven populations extant in Victoria. These occur in the catchments of fifteen streams (several populations occurring around the confluences of streams). One further population is known from Kosciusko National Park in NSW. Survey results strongly suggest that the species has a limited and fragmented distribution and has suffered a significant decline during the past twenty years.

Habitat

Spotted Tree Frogs inhabit naturally-vegetated, rocky, swift-flowing upland streams in dissected mountainous country, between 280 and 1110 metres above sea level. Frog populations are generally in areas with limited access and disturbance. Distribution along streams is patchy, most individuals being associated with loose rock substrates, rocky banks and rapids. Adjacent stream-side vegetation is also used for sheltering and basking. Eggs are deposited under large instream boulders, and tadpole development occurs within the stream (Hero *et al,* 1995).

The full range of habitats used by the species is unknown - other species of riparian tree frogs range widely from streams during the non-breeding period. Spotted Tree Frogs may utilise similar off-stream habitats. The stream environment is used by this species from October to April - it is not known what habitats are used at other times.

Conservation status

Current status

CNR (1995)	Endangered
SAC (1991a)	Threatened
Endangered Species Protection Act (1992)	Endangered

The Spotted Tree Frog has been listed as a threatened taxon on Schedule 2 of the *Flora and Fauna Guarantee Act* 1988.

Reasons for conservation status

Distribution and Abundance

Surveys of the distribution and abundance of the Spotted Tree Frog revealed the species at only 12 sites (11 in Victoria, one in NSW). It was found along six streams in which it had not been recorded before, but could not be found along four streams in which it had previously been recorded. The surveys failed to detect Spotted Tree Frogs at historical sites on a further four streams, but located the species elsewhere along those streams. As a result of these surveys we now have a good understanding of the status and distribution of this species.

The Spotted Tree Frog appears to have suffered a general decline in distribution and abundance. All extant populations appear under threat from various disturbances; many are small, and some have declined. Analysis of disturbance histories at individual sites indicates an association between the contraction in distribution and a number of human-induced disturbances to forest and riparian habitats (Gillespie and Hollis, 1995). Little is known of the genetic variability between isolated populations.

Table 1. Streams in which Spotted Tree Frogs have been recorded, and the current status of their populations. Population size estimates are extrapolated from known actual densities of adults at two sites, repeated monitoring over the past five years, and known distribution of potentially suitable habitat. (SF - State Forest; SP - State Park; NP - National Park)

Population/Stream	**Pop. Size (adults)**	**Population Record Status**	**Catchment Status**	**Year of First**	**Last**
Thompson River	0	Presumed Extinct	SF	1971	1971
Buffalo Creek	0	Presumed Extinct	NP	1979	1983
King River	0	Presumed Extinct	SF/NP	1977	1977
Buckland River	0	Presumed Extinct	SF/NP	1961	1961
Howqua River	400	Declined	SF/NP	1972	1996
Big River (Eildon)	< 25	Declined	SF	1979	1993
Snowy/Lightning Crks.	500	Possibly declined	SF	1958	1996
Goulburn/Black Rivers	1150	Declined	SF	1961	1996
Jamieson River	250	Possibly declined	SF/NP	1992	1992
Wongungarra River	180	No apparent decline	SF	1985	1996
Big River (Mitta Mitta)	180	Unknown	SF/NP	1983	1996
Taponga/Still/Whites Crks.	800	Declined	SF/SP	1989	1996
Bundarra River	300	Unknown	SF/NP	1994	1994
Wheeler Creek	600	Unknown	SF	1993	1994
West Keiwa River	< 25	Unknown	SF/NP	1993	1996
Bogong Creek (NSW)	600	Possibly declined	NP/SMA	1975	1996

Threats

Disturbance which may result in changes to the physical or biotic habitat in, and adjacent to, streams include: roading, timber harvesting, eductor dredging, human disturbance (e.g. angling), weed invasion, predation by exotic animals (including trout), impoundments, herbicides, inappropriate fire regimes and possibly grazing.

Important concerns include: changes in flow rates, which may effect the viability of eggs or the survivorship of tadpoles; increases in sediment levels, which may effect the availability of egg-deposition sites or the survivorship of tadpoles; and predation of tadpoles by trout, which may reduce or preclude recruitment to the adult population.

Protection
Only one of the known Victorian localities is completely within a permanent conservation reserve (the population is thought to be extinct at this locality); all other Victorian localities are within State Forest, although part of the catchments of some may be within conservation reserves. The Code of Forest Practice provides some protection of the stream environment. The limited protection of Spotted Tree Frog habitat currently in place may afford little long-term protection for the populations.

Ecological issues specific to the taxon

Very little is known about the biology or micro-habitat requirements of this species (and of Australian riverine frogs in general). It is extremely difficult to undertake research because of the isolation of sites and the secretive nature of the species. Frog populations are isolated, possibly indicating a much wider distribution in the past with a decline to present levels. The small size and isolation of these populations exposes all populations to extinction from stochastic events with little chance of natural recolonization.

Potentially threatening processes implicated in the decline of this species (Gillespie and Hollis, 1996) include disturbance in and adjacent to streams and in catchments of streams, which may result in changes to water flow, quality, sedimentation or other changes to the physical or biotic habitat. These include roading, timber harvesting, eductor dredging, human disturbance (e.g. angling and illegal use of frogs as bait), weed invasion, predation by exotic animals (including trout), impoundments, herbicides, pesticides, inappropriate fire regimes, and possibly grazing. Sheltering and/or foraging sites away from streams may also be affected by such disturbances.

Timber harvesting proposed in some catchments may change various stream parameters (e.g. increase sedimentation, flow rates, turbidity, etc.). Such in-stream changes may particularly affect egg and larval viability - a major factor in frog population dynamics.

The mechanisms of natural fluctuations in population numbers occurring as a result of yearly variations in weather patterns, stream flow rates, levels of predation and subsequent recruitment are yet to be investigated. However, populations do appear to experience extremely variable recruitment, and thus may be particularly vulnerable to further disturbances.

The collection of baseline data on factors possibly affecting frog populations, or on stream quality parameters, is extremely time consuming, and unlikely to provide information for management prescriptions in the short-term. However, the interim prescriptions for roading and timber harvesting contained herein, as recommended by O'Shaughnessy and Associates (1995), are proposed as adequate to prevent any detectable change in stream sediment parameters.

Some catchments still supporting Spotted Tree Frogs have experienced various disturbances in the past, and may be able to tolerate low levels of these disturbances. However, populations have become extinct in the past, and may do so in the future (with little or no possibility of recolonisation from other populations) if inappropriate levels of disturbance are allowed.

Research Program

In 1993 research plan was implemented for the Spotted Tree Frog with the following objectives:

Examine the ecology and population dynamics of the Spotted Tree Frog and sympatric riverine anurans, including:

habitiat requirements of adults
reproductive biology
activity an movement patterns
recruitment, growth and population turnover

Examine factors which might limit growth and survival of larvae, including:

competition with other riverine anuran species
food availability an the effects of increased deposited sediments.
impact of introduced fish

Methods

Study sites

Study transects, 200 m in length, were established on three river systems supporting populations of Spotted Tree Frogs. Transects were established on the Taponga and Still Creeks in 1992, Bogong Creek in 1993, and the Goulburn River in 1995. Sites were chosen to encompass the range of habitats used by the species at sites which supported population densities suitable for study.

Habitat use, Activity patterns and Poulation Dynamics

At each site diurnal and nocturnal censuses were conducted within 24 hours of each other at two to three week intervals from October through to April. Prior to commencing each census, weather conditions were recorded, including wet/dry temperature, water temperature, cloud cover, precipitation, moon phase and wind level. All temperatures were also taken at the completion of each census. Censuses were conducted with two people moving slowly along the transect searching for active frogs and lifting rocks and other loose material for sheltering frogs. All frogs captured were weighed (+/- 0.1 gm) and measured (+/- 0.1 mm), sexed and reproductive condition assessed if possible, individually marked by toe-clipping (after Hero 1989) and then released at site of capture. Clipped toes were stored in 10% neutral buffered formalin for skeletal chronology. Details of the position and activity of each frog on the transect were recorded; distance along transect and from side bank (+/- 0.5 m), height above water and distance to nearest pool, riffle and run (+/- 5 cm), and substrate or shelter type.

Two approaches have been taken to assess habitat use of frogs along transects: Firstly; with the exception of the Goulburn River site, random samples of points were selected along each transect. One hundred points were generated for each site except Bogong Creek at Bourke's Gorge where 200 points were taken. This was done because of the perceived greater habitat variability and much greater number of frog records at the Bourke's Gorge site. At each point a random height was generated and the nearest substrate to that point recorded. At this point the same set of site variables recorded for each frog located (above) was recorded. Each random set of habitat variables will be compared to respective observed sets, using multivariate analyses of variance (MANOVA). Secondly; for each 10 m section of Still Creek, Taponga River and Bogong Creek/ Alpine Way, and each 5 m section of Bogong Creek/ Bourke's Gorge, various habitat characteristics were measured, including areas of each major substrate and water body type, average stream width and depth, gradient, vegetation structure along banks and canopy cover. Habitat variables will be reduced using principal components analysis and the relationship between frog abundance and habitat components will be examined by descriminant function and regression analyses.

The program Jolly (U. S. Fisheries and Wildlife Service 1988) was used to model population size and turnover from mark-recapture data.

Skeletalchronology was used to determine ages to sexual maturity, longevity and age-specific mortality of frogs

Radio tracking was conducted at Bogong Creek/Bourke's Gorge. Transmitters used were single stage, fully-sealed with magnetic reed switches, weighing 0.85 - 1.0 gm (Holohil Systems Ltd, Ontario, Canada). These transmitters have battery lives of five and nine weeks respectively. In an attempt to reduce abrasion problems experienced during the previous season, a new harnessing system was developed. This used 1.5 mm diameter silicon surgical tubing which was secured to the transmitter body by fine cotton threaded through the tubing. Transmitter and harness weights were generally no more than 10% of frog weight, all these being on females; however, 15 % body weight was used on several occasions for males and small females. Each frog was tracked for up to 35 days. Fixes were made three times each day for five days, approximately every two weeks. This was reduced to once per day from January onwards due to the low movements of frogs. Transmitters were removed when abrasion occurred.

Distribution, habitat use, activity patterns, and development of tadpoles.

Active searches were conducted over a broad area of each stream for oviposition sites of each species. Emphasis was placed on locating *L. spenceri* sites. All submerged and semi emergent rocks not embedded in the stream bed which could be moved were examined for the presence of eggs over 1 km stretches of Bogong Creek, Taponga/Still Creek and the Goulburn River. Aquatic vegetation, sticks and logs were also examined. Searches were conducted twice at Taponga/ Still Creek and Goulburn River in November and December, and four times at Bogong Creek from November 1995 to January 1996. For each egg clutch located the following characteristics were recorded; dimensions of the clutch, number of eggs (mean of three counts), development stage, depth, substrate, water body type, rock diameter (three measurements) and circumference (three measurements), distance from bank and canopy cover. Clutches were left in place and their development monitored on subsequent visits to the site.

Due to the low success rate of locating oviposition sites in the stream, to collect data on clutch size variation, several gravid females were collected away from the transects in November and December, and housed either in containers in the stream or in tanks in Melbourne. Clutches deposited by these frogs were counted and reared, and the adult frogs measured, toe-clipped and released. Clutches were also dissected from five dead frogs found along Bogong Creek in March 1996 which were preserved. This will provide information on age and/or size-specific fecundity. Voucher specimens of eggs were preserved from different developmental stages through to hatching from one *L. spenceri* clutch so that the early developmental biology of the species can be described and compared to related taxa. All hatched tadpoles were either returned to the stream near where the clutch was located, or used in tadpole experiments described below.

Tadpole censuses were conducted along transects from December to March. Habitat use of *L. spenceri*, *L. phyllochroa* and *L. lesueuri* tadpoles was determined by timed dip netting of various stream microhabitats. Census data were also used to estimate relative abundance, development and survival rates.

Within each 10 m section of transects on Still Creek, Taponga River and Bogong Creek/Bourke's Gorge, two 2 minute dip-net searches of all pool and slow-moving water habitats were conducted. Visual searching was also conducted, especially at Taponga River and Still Creek where tadpole numbers were exceedingly low. All tadpoles caught in the first dip-net sample were retained while the second was conducted, then both counts were released. Tadpole counts were recorded for each species for each 10 m section, thus providing estimates of relative abundance of each species along the transect and population size estimates. A random sample of 20 tadpoles (where available) of each species was measured and staged (Gozner 1960) after each census. These censuses were conducted approximately every 2 weeks to March at Taponga River and Still Creek and until late March at Bourke's Gorge. The relationship between stream habitat characteristics and relative abundance of tadpoles along the Bogong Creek transect will be analysed in a similar procedure to that described above for frogs.

Activity patterns and micro-habitat use of *L. spenceri* tadpoles were examined at Bourke's Gorge in February and March 1996. Three sites at which tadpoles were present were randomly chosen along the stream. A square grid of 64 cells, each 15 x15 cm, constructed from a timber frame with string cross lines, was over-layed on the water in a still or slow-flowing section, abutting the water's edge. Within each grid cell the average depth and percentage cover of litter, rock, gravel, algae and detritus were recorded. The number of tadpoles was counted in each grid cell at each site during the day in full sun and at night. After each count the water temperature of each grid cell was also taken. Three sets of counts were made. The relative abundance of tadpoles in relation to substrate type, water temperature and depth will be examined by MANOVA.

Palatability of tadpoles of *L. spenceri* and other riverine species to native fish and introduced trout.

The palatability of *L. spenceri*, *L. lesueuri* and *L. phyllochroa* tadpoles to Two-spined Blackfish and trout was examined using a standard palatability experimental design. Tadpoles of *L. spenceri* were collected from Bogong Creek; *L. lesueuri* tadpoles were collected from the Gibbo River; and *L. phyllochroa* tadpoles were collected from the Aberfeldy River in January 1996. Banjo Frog (*Limnodynastes dumerilii*) tadpoles were used as a known palatable control, supplied by the Amphibian Research Centre (Coburg, Victoria). Brown trout and Two-spined Blackfish were collected from Taponga River using a backpack electrofishing unit and immediately transferred to an in-stream storage cage. Sixteen blackfish and 16 trout were randomly assigned to 50 lt buckets. Each bucket contained 50 lt of stream water and an aeration stone. These fish were allowed to acclimatise for 12 hours, then ten tadpoles from one of the four species were also placed in each bucket. Each tadpole species was randomly assigned to four of each fish species. The number of live and dead tadpoles remaining in each bucket was counted every 12 hours and the experiment was terminated after 36 hours. All buckets were washed out and the experiment repeated with new fish from the in-stream enclosure and new tadpoles. All tadpoles were measured and staged prior to experimentation and all fish were measured after experimentation. This randomised block design was analysed by two factor ANOVA.

The potential of trout to have a significant predatory impact upon *L. spenceri* tadpoles was further assessed in an in-stream experiment. This was set up in an isolated rock pool at Bogong Creek, whereby tadpoles had access to natural substrata and refugia, and trout had some access to alternative food sources. This pool contained approximately 5 m^3 of water. A gravity feed system was established with 8 m of 50 mm polypropylene pipe, with approximately 1.5 m of head. This delivered at least 60 lt of stream water per minute to the pool. The two exit points from the pool were fenced off with fly wire mesh, secured with rocks and sealed with gravel and sand to prevent tadpoles escaping. The pool was partitioned into two compartments using fly wire in a similar fashion. Chicken wire was placed around the pool and along the partitioning fence to stop trout from escaping or changing sides by jumping. Tadpoles of *L. spenceri* and *L. phyllochroa* were collected from the stream and fifty of each species were placed in each side of the pool. Rainbow Trout were caught from Bogong Creek above the aqueduct pondage. The fish were caught using barbless fly-fishing hooks, rather than electrofishing, to minimise stress. One fish was placed on one side of the pool; the other side was used as the control. Each trial was left for between two and seven days, after which the fish was removed and tadpoles of each species were counted on each side of the enclosure. Tadpoles were counted and removed using repeated dip-net searches. Dip net searches were repeated until no more tadpoles could be located. After each trial the stomach contents of the fish were examined to assess availability of alternative food items. This procedure was repeated four times with different fish, using alternative sides of the pool for the treatment and control to eliminate compartment effects. Differences in survival of the tadpole species were analysed by two way ANOVA.

Competitive interactions between tadpoles of *L. spenceri* and *L. lesueuri* in limiting abundance and distribution of *L. spenceri*

Density-dependent competition between *L. spenceri* tadpoles and those of *L. lesueuri* and *L. phyllochroa* were both examined in in-stream enclosures at Bogong Creek. Plastic 20 lt containers with fly wire mesh sides and fly wire mesh lids established up on a timber frame in a still pool along the stream in early December 1995. A gravity feed system was set up to augment stream water flow through each container. This comprised a length of 50 mm polypropylene pipe running 80 m up-stream to a waterfall, with a fly wire mesh filter intake. This provided approximately 3.5 m of head. This pipe flowed into a length of 90 mm PVC pipe which ran the length of the container grid. Branches 12 mm in diameter ran off the PVC pipe at regular intervals. Each branch had seven or eight 4 mm pipes running off to experimental containers. Flow in the 12 mm branches could be regulated by taps. Flow rates for each 4 mm tube averaged 1.6 lt per minute. Due to the high main water pressure, flow rate reduction along the branches was negligible.

Details of tadpole diets are poorly known and difficult to examine. Observations of lotic hylids in south eastern Australia strongly suggests that they are benthic browsers, feeding on algae or detritus or both (Duellman and Trueb 1986). Consequently, an attempt was made to provide this combination of food to the experimental enclosures. Fine detritus was collected from the stream bed at several locations, mixed in a bucket, and each container had 300 ml placed on the bottom. The experimental containers were set up one month prior to introduction of tadpoles, after which time the container sides were colonised with dense filamentous algae.

Table 1. Tadpole densities and species combinations used in competition experiment.

		3 *L.spenceri*	6 *L.spenceri*	9 *L.spenceri*
		3	6	9
3 *L. lesueuri*	3	3:3	3:6	-
6 *L. lesueuri*	6	6:3	-	-
9 *L. lesueuri*	9	-	-	-
3 *L. phyllochroa*	3	3:3	3:6	-
6 *L. phyllochroa*	6	6:3	-	-
9 *L. phyllochroa*	9	-	-	-

Three replicates of each treatment were randomly assigned to experimental enclosures. *Litoria spenceri* and *L. phyllochroa* tadpoles were collected from Bogong Creek. *Litoria lesueuri* tadpoles were only available at the time from Nariel Creek near Corryong. Tadpoles were chosen to minimise variation in size and development within a species. *Litoria spenceri* tadpoles ranged from 5.6 - 7.1 mm body length and Gozner stage 26 - 28; Leaf - green Tree Frogs were 4.5 - 5.2 mm and stage 25 - 26; *L. lesueuri* tadpoles were 4.4 - 6.3 mm and stage 25 - 26. Tadpoles were randomly assigned to each enclosure. Enclosures were stocked with tadpoles on January 2, 1996. Tadpoles were subsequently measured and staged on March 3, 1996. Density dependent effects on growth and development rates will be examined by 2 way ANOVA.

<u>Effects of sedimentation and food availability on the growth and survival of *L. spenceri* tadpoles.</u>

The effects of sedimentation on the growth and survival of *L. spenceri* tadpoles was examined in conjunction with the competition experiments in similar enclosures in the same pool with the same gravity feed system. The six following experimental treatments were used on three densities of tadpoles (3, 6 and 9) in a fully orthogonal random block design: No sediment, single sediment and multiple sediment treatments by algae-only and algae plus detritus treatments.

Table 2. Tadpole densities and substrate treatments used in food availability and sedimentation experiment.

	Tadpole Numbers of *L. spenceri* tadpoles								
	No sediment			Sediment			Repeated Sediment		
Algae	3	6	9	3	6	9	3	6	9
Alga and Detritus	3	6	9	3	6	9	3	6	9

Half the containers had 300 ml of detritus added in early December and all were allowed to be colonised by algae for one month. On January 1, 1996, two thirds of each of these treatments had 150 ml of fine clay sediment added. This was adequate to create a thin layer of sediment across the bottom of the enclosures. The sediment was collected from silt traps established on Bourke's Gorge Road at the Bogong Creek Crossing. Two additional similar deposits of sediment were placed in half of these enclosures from each treatment at subsequent fortnightly intervals. Treatments and tadpole densities were randomly assigned to enclosures. Enclosures were stocked with tadpoles on January 2, 1996. Tadpoles were measured and staged on March 2, 1996. Tadpole growth and development was analysed by 3 way ANOVA.

Algal samples were also collected from each enclosure before and after the experiment, and detritus samples were collected after the experiment. This was so that if variation in growth rates within treatments was significantly large, an analysis of food availability, growth rate and treatment type could be conducted, using organic content and chlorophyll a assays. This will only be conducted if time is available.

Statistical analyses have been conducted with SYSTAT version 5 (1992), SYSTAT Inc. Illinois, USA.

Results to Date

Breeding Activity

Breeding activity of *L. spenceri* commenced in late October at Still Creek and in early November at Bogong Creek. Searches for egg clutches were conducted along transects on Still Creek, Taponga and Goulburn Rivers, and over a 1 km section of Bogong Creek in late November, mid - December and the end of December. No clutches were located at Still Creek or Taponga and Goulburn Rivers, However one clutch was located on the Howqua River in late November 1995 while conducting a census of long-term monitoring transects. Egg clutches were first located in Bogong Creek at the end of November and most females located at this time appeared to have layed their eggs. However, in 1995 sever cold weather and high stream flows occured in December, which may have delayed the breeding season. One pair of *L. spenceri* was located in amplexus on 24 December - these subsequently layed eggs on Christmas day in an aquarium. In contrast, tadpoles had hatched at Bogong Creek by this time last year. Five clutches were located in November, two of which were collected and raised in the laboratory to characterise developmental stages. Two of the remaining three were washed away during subsequent flooding in December. A further six clutches were located in late December and early January. The developmental stages of these indicated that most were layed prior to the flooding. Immature tadpoles (Gosner stage 27) were located at one locality in late March, indicated that at least one clutch was layed as late as February.

Examination of clutches from known individuals in the field and from museum specimens indicates that clutch size can vary from 56 to 943 eggs, with a mean of 531 (Fig. 1). While there is a weak correlation between clutch size and female age, there is a much stronger correlation with female size (Fig. 2). Clutches were all located in tight crevices under rocks, in still or near still connected pools. Rock sizes varied from 12 cm average diameter upwards to greater than 100 cm. Most sites located were under rocks of approximately 30 cm diameter, where the stream depth ranged from 8 to 21 cm, where the substrate was either gravel or rock, and always in an area of zero to 5 % canopy cover. Clutch sizes in the field are similar to those dissected from gravid females, indicating that all eggs are probably layed in the one location. A single egg mass was also layed by the captive pair. Only a small number of clutches were detected in relation to the female population size on Bogong Creek (ie. 3 clutches vs 43 females per 200m of stream). Many more clutches are likely to have been layed under larger rocks in inaccessible locations. This is supported by the appearance of clusters of newly-hatched tadpoles in early January in the vicinity of large boulders. This choice of secluded oviposition sites may be for predator avoidance or to avoid flooding effects from high stream levels during November - December.

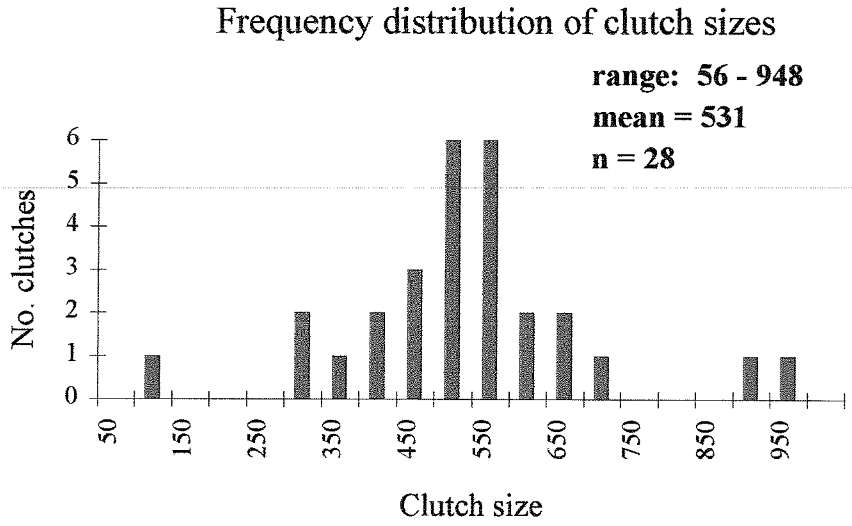


Figure 1. Size distribution and frquency of clutch size for the Spotted Tree Frog

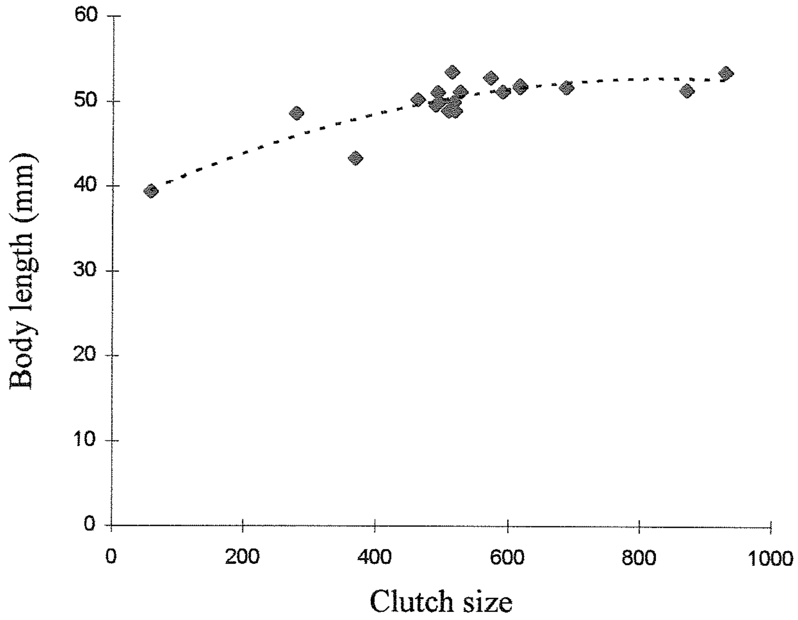
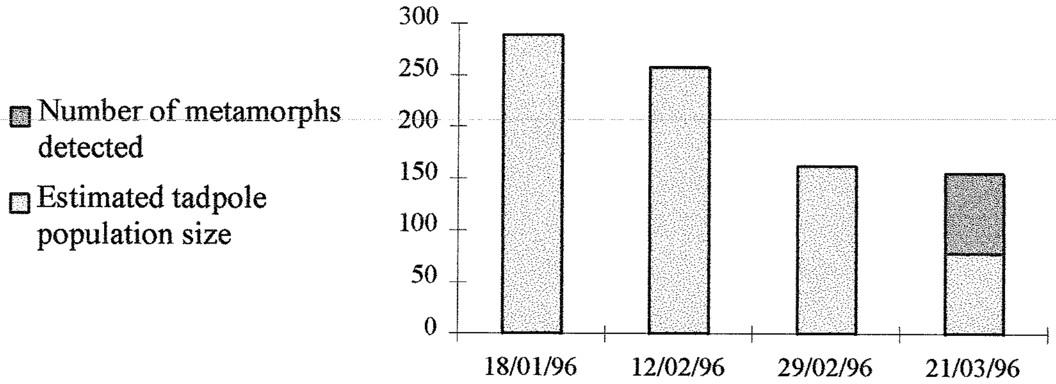


Figure 2. Relationships between female size and clutch size

Known clutches began hatching in late December and early January. In 1995/96, despite surviving the flood events, hatching appeared to have been delayed by as much as three weeks compared with the previous year. This is probably a consequence of colder water temperatures in December (Appendix I). The number of surviving eggs is variable but several clutches produced less than 50 tadpoles and two known clutches had 100 % mortality in the 1995/96 season. Data are not available for the previous season on clutch mortality for comparison; however, tadpole censuses indicate that the relative abundance of tadpoles this year is substantially lower than the previous year.

Of those tadpoles which hatched on the Bogong Creek transect in 1995/96, survival to metamorphosis was remarkably high, despite the delayed season. Four depletion-sampling population estimates were conducted along the transect from January 18 to March 21, 1996. Tadpole survival to metamorphosis was estimated at over 50% (Fig. 5).

Figure 3. Relative population size estimates for *L. spenceri* tadpoles along the Bogong Creek transect.



Only one tadpole was detected along Still Creek in mid-December 1995 and 10-15 tadpoles have been detected along each of the Taponga and Goulburn River transects. While indicating the presence of at least one clutch on each transect, in view of the ease of detection of *L. spenceri* tadpoles, this also suggests that egg or early-tadpole mortality has been high at these sites.

Litoria phyllochroa calling and egg laying activity coincided with that for *L. spenceri*. Twelve egg clusters were located in late November at Bourke's Gorge. Numbers of eggs ranged from 35 to 436 with a mean of 143. Three pairs were collected in amplexus on the 28th November - these subsequently layed eggs overnight in aquaria. Unlike *L. spenceri*, the eggs were in several clusters, with total clutch sizes ranging from 148 to 534.

Oviposition sites for *L. phyllochroa* were also highly consistent in habitat. All were attached to submerged sticks or carex leaves in still, deep, in-stream pools. Depths ranged from 2 - 66 cm. In contrast to *L. spenceri*, none of the clutches detected at this time appeared to have survived the flood events in December. Some subsequent egg laying took place as tadpoles were located in a deep pool along the transect and in three other deep pools along the stream in mid-January.

Egg clutches of *L. lesueuri* have been located in an isolated rock pool on lower Bogong Creek and in a connected stream side pool on the Goulburn River transect. Clutches have been located elsewhere in Victoria in similar situations. Based on developmental stages of egg clusters in the connected pool on the Goulburn River, two clutches appeared to have been layed there with sizes of 1010 and 1200; substantially larger clutches than the other two species examined. The laying of eggs in isolated pools may be a predator or flood avoidance strategy. Clutches were found as early as late October, and gravid females were found on the Goulburn River in early January. This suggests that the egg-laying season of *L. lesueuri* is much longer than that of both other species. This may also increase flexibility of the population in stream environments with unpredictable October - December stream flows.

Population Dynamics

The numbers of adult and sub-adult frogs detected along Still Creek in 1995/96 remains similar to those observed in the previous season (Figs. 4 & 5). Recapture rates of adults and subadults along both the Still Creek and Taponga River transects are over 90%. Thirty one males have now been marked on Still Creek since 1992, with no new males being recorded this season. Only eight females have been marked; two of which were recruited this season; previously marked as subadults. The population numbers at Still Creek and Taponga River are too low for generating Jolly Seber estimates of population size and turnover; however the high recapture rate and low numbers mean that absolute population sizes of adults are known. Adult populations on Still Creek and Taponga River are very similar, suggesting that the population crash observed on Still Creek after the 1992/93 season probably affected the Taponga system as a whole. Along Still Creek there are currently four males and four females, and along Taponga River there are seven males and three females. The mean sex ratio is not significantly skewed; the difference in sex ratio on the Taponga transect is probably an artefact of low population numbers and the difference in age to sexual maturity between males and females. The adult population size on the Still Creek transect remains very similar in size to the previous two seasons. Annual recruitment at Still Creek is 14 % for males and 50% for females. Annual survival estimates are 50 % for males and 30% for females.

Only three male *L. spenceri* have been detected on the Goulburn River transect during the one season of censusing. No females have been found; however, the presence of tadpoles at two locations along the transect suggests the presence of at least two females during the breeding season. The adult population size of *L. lesueuri* at this site is similar to that of *L. spenceri*.

Numbers of adults detected along Bogong Creek in 1995/96 are also similar to those observed in the previous season; however, numbers of subadults are lower. This reflects the low recruitment of juveniles in the previous season (Figs. 6 & 7). The low numbers of frogs observed at Bogong Creek in early December, 1995 probably reflects the cold weather patterns at that time (Appendix I). Jolly Seber estimates of population size for 1995/96 and the previous two seasons are presented in table 1. The adult population size appears to be stable over the study period, with 1:1 sex ratio. Mean population size of males ranges from 46 to 58 per 200 m, and females from 40 to 54 per 200 m. The estimated annual survival rate for females is fairly stable; ranging from 41 to 47 %. Male survival rates are much more variable (12 - 64 %). This is due to the apparently low survival rate estimate for this spring season, which may be due to the suppressed detection levels during cold conditions in December (Appendix I).

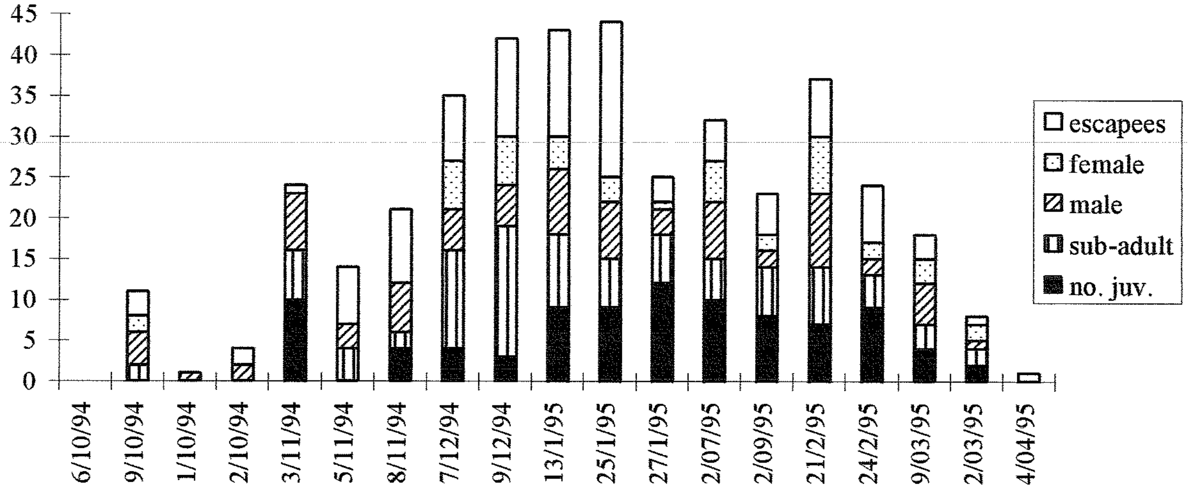


Figure 4. Numbers of each age class of *L. spencer*i detected during diurnal censuses on the Bogong Creek transect in the 1994/95 season. Metamorphs are not shown.

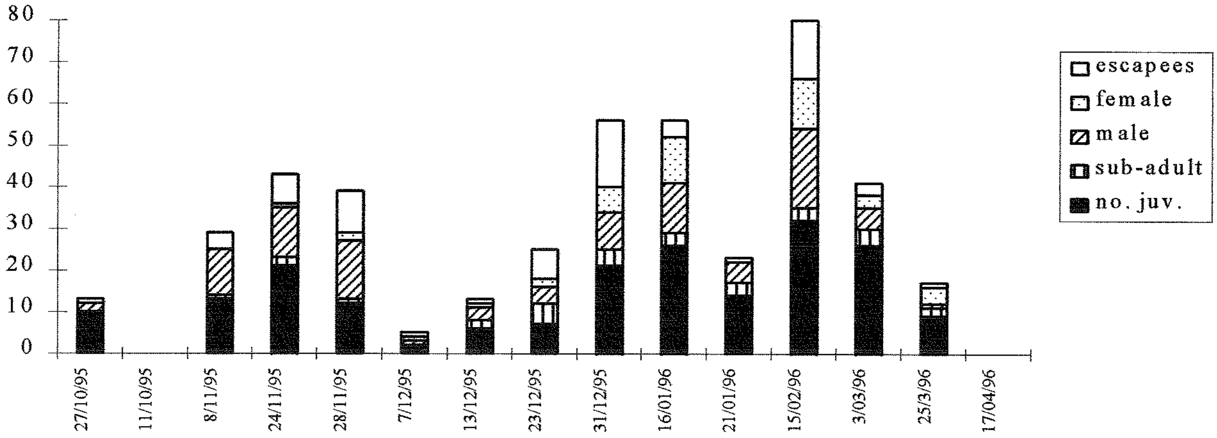


Figure 5. Numbers of each age class of *L. spenceri* detected during diurnal censuses at Bogong Creek in the 1995/96 season. Metamorphs are not shown.

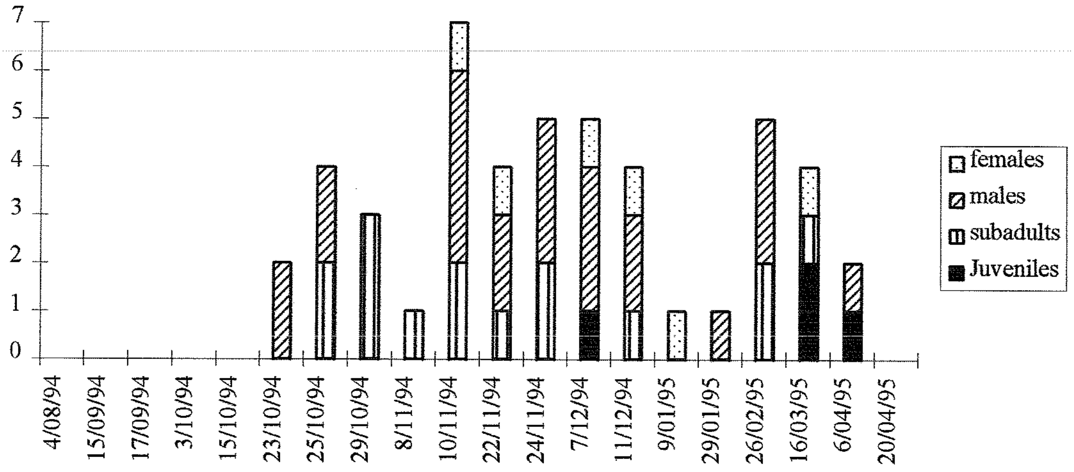


Figure 6. Numbers of each age class of *L. spenceri* detected along the Still Creek transect in the 1994/95 season (diurnal and nocturnal censuses combined). Metamorphs are not shown.

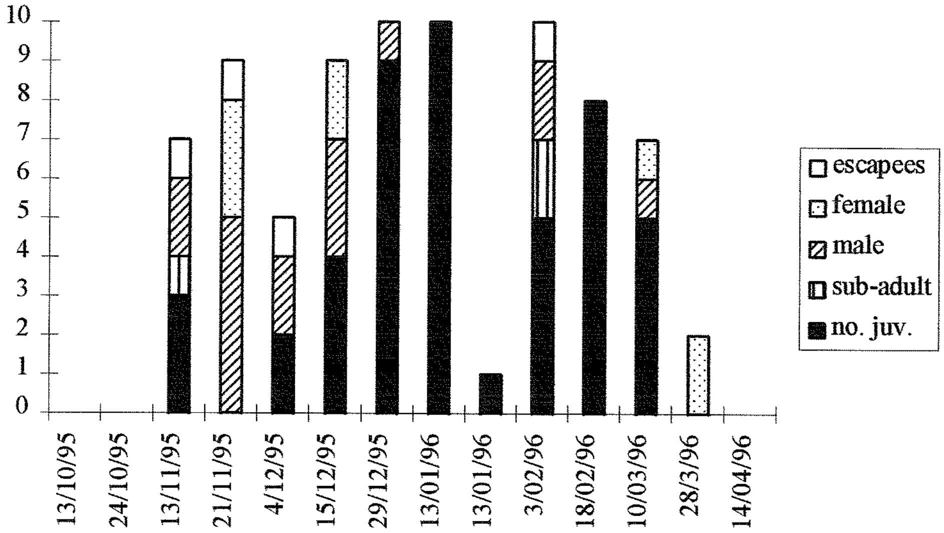


Figure 7. Numbers of each age class of *L. spenceri* detected along the Still Creek transect in the 1995/96 season (diurnal and nocturnal censuses combined). Metamorphs are not shown.

Table 3. Jolly Seber population size estimates, survival and recruitment rates for male and female *L. spenceri* at Bogong Creek for the three years of sampling to date.

	Females	Males

Sampling Season	1993/94	1994/95	Nov-Dec 1995	1993/94	1994/95	Nov-Dec 1995
Mean Population Size	40	54	43	46	58	49
Mean Survival per Sampling Interval	0.9	0.95	0.92	0.92	0.9	0.68
Survival rate per Season	0.47	0.41	0.42	0.64	0.36	0.12
Recruitment per Season	9.83	6.26	11.87	13.93	0	5.2

Population Age Structure

Age estimates have been made of 47 adult male and 55 adult female Spotted Tree Frogs from Bogong Creek, 30 adults male and 10 adult females from Taponga River/Still Creek population, using toes removed from frogs since 1994. Population age profiles have also been augmented by individuals of known age from mark-recapture data for both populations (Fig.8,9,10,11). Several museum specimens have also been aged. The maximum age recorded was 13 years for a female at Bogong Creek. Several 10 year old males and females were recorded at this site. In contrast the maximum age detected in the Taponga population was six years. Age to sexual maturity at Bogong Creek is 3-4 years for males and 5-6 years for females. In contrast, age to sexual maturity in the Taponga population is 2-3 years for males and 4 years for females.

Figure 8. Proportion of each age class on the Bogong Creek transect in 1994/95

Figure 9 Proportion of each age class on the Bogong creek transect in 1995/96

Figure 10 Proportion of each age class on the Still creek transect in 1995/96

Figure 11 Proportion of each age class detected in the Tapnga catchment (including Still Creek) in 1995/96.

Based upon a minimum age to reproductive maturity of five years, the number of reproductively mature females present in the Bogong Creek population varies from 14 to 25 recorded for the 1994/95 and 1995/96 seasons (44 - 62 % of females respectively). This gives an estimate of between 7434 and 13275 eggs, produced on the 200 m transect each year.

Numbers of juveniles (one year old frogs) observed varied substantially between seasons at both Still and Bogong Creeks. On Bogong Creek, 97 juveniles were recorded in the 1995/96 season, compared with a total of 35 in the previous season (Figs. 8 & 9). On Still Creek, 31 juveniles were recorded this season compared with two juveniles in the previous season (Figs. 10 & 11). Furthermore, recapture rates of juveniles at both sites only reached about 75% by March. Estimates of juvenile population size, assuming no mortality or migration during the sampling season for Still and Bogong Creeks, are approximately 55 and 190. This is consistent with the high recruitment of metamorphs observed in March 1995 on the Bogong Creek transect and at most of the long-term monitoring transects throughout north eastern

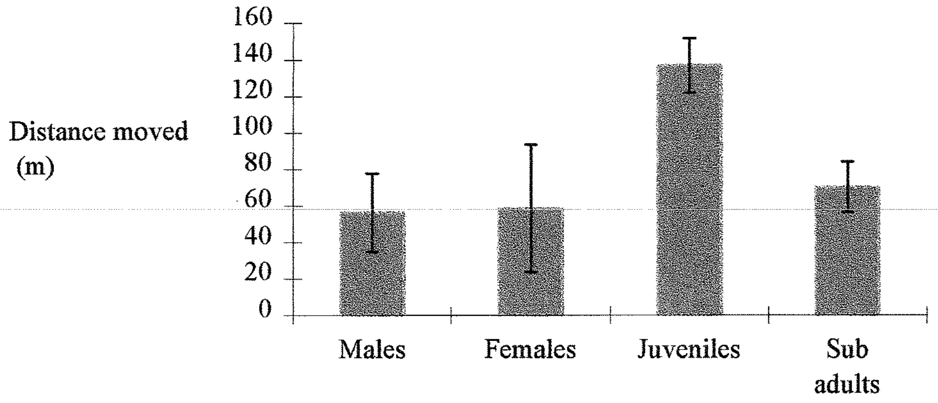
Victoria. The number of juveniles which metamorphosed in 1995 was estimated to be approximately 200 - 3500 on Bogong Creek. Therefore, despite the relatively successful breeding season in 1994/95, juvenile mortality appears to be very high. By contrast, comparison of the relative proportions of adults persisting in each cohort from 1994/95 to 1995/96 indicates a very high annual survival rate of all adults Annual estimates in eggs produced, numbers of metamorphs, juveniles and subadults detected, and survival estimates for adult cohorts provide estimates for expected age-specific mortality of Spotted Tree Frogs at Bogong Creek (Fig. 12). Percentage mortality is approximately 99% in the first year, 88% for the second year, reducing to undetectible level by four years. Based upon these estimates, approximately 0.2 % of eggs survive to sexual maturity.

Limited data are available from Still Creek because the numbers of juveniles detected in previous years has been very low (1-6 per year). However most of the subadults detected last season have persisted in the population and adult survival below six years appears high. This suggests that juvenile mortality is similarly very high in this population also.

Movement and Activity Patterns

Mark-recapture data for both Bogong and Still creek shows very high site fidelity for *L. spenceri*, with many individuals remaining on the transect after two years. The average net movements of individuals caught in the 1993/94 season and still known to be on the Bogong Creek transect in 1995/96 are presented in Fig. 13. The numbers of adult males and females are similar and the average distance moved is the same. Juveniles clearly move the greatest distances. This examination is biased towards the movement patterns of individuals remaining on the transect; however, searches above and below the transect for several hundred metres have located few marked individuals (<10). The maximum movement of any individual detected so far is 325m. Preliminary examination of short-term movement patterns of individuals indicates that more movement along streams may be occurring at the beginning and end of the active season.

Figure 13. Mean and standard errors of net movements of *L. spenceri* along Bogong Creek since December 1993. (males; n=13, females; n=12, juveniles; n=12, subadults; n=21)



Preliminary examination of activity patterns indicates that, apart from the clear seasonal restrictions on activity, day-time temperature strongly influences frog activity. More frogs are detected on warm days and mild nights than under cool conditions. Females make up a larger proportion of active individuals on cool nights, which may be related to their larger body weights. Calling activity during the breeding season is also correlated with temperature, not rain. Detection rates of frogs are generally lower after rain. This may be due to a combination of lower activity levels and movement away from the immediate stream environment. There does not appear to be any sesonal differences in detection rates of males and females through the season, wich contrasts with many other anuran species. These data are yet to be analysed in detail.

Frog Habitat Use

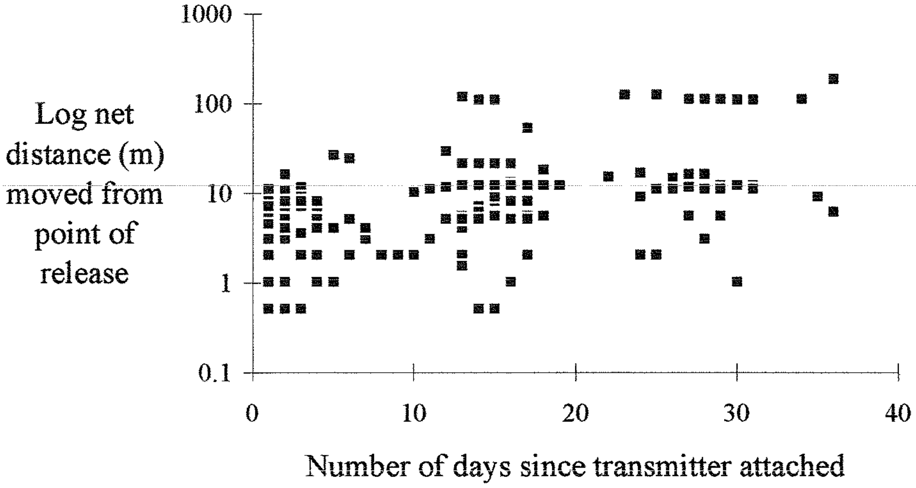
Preliminary examination indicates marked differences in microhabitat use between *L. spenceri* and *L. phyllochroa* at Bogong Creek. *Litoria spenceri* show a preference for rapids or water falls and areas of exposed rocks and boulders. *Litoria phyllochroa* show a preference for deep pools or slow-flowing stream sections and are largely restricted to stream side vegetation, particularly ferns and sedges. Interestingly, *L. spenceri* at Still Creek also show a preference for stream side ferns and sedges, but they are still largely associated with rapids. Preliminary examination of the low numbers of *L. lesueuri* detected at study sites suggests a preference for open rocky areas of watercourses.

Mark-recapture data for March indicate that actual numbers of frogs present on the stream transect is reduced at this time, suggesting that most frogs are leaving the stream during or immediately prior to this period.

Radio tracking was attempted on 28 female and 3 male *L. spenceri* at Bogong Creek between November and March 1996. The results of radio tracking were consistent with the sedentary patterns observed during the breeding season as indicated by mark-recapture data. Net movements along the stream for radio-tracked frogs are presented in Fig 14. Most frogs moved less than 10 m in 4 - 5 weeks, and few frogs moved more than 100 m in this time.

A number of attempts was made to develop a transmitter attachment system which did not cause excessive abrasion. However, despite extensive trials with several different harness materials and designs, it was not possible to avoid significant levels of abrasion occurring on most individuals after 2 - 3 weeks. In several instances transmitters had to be removed after only one week. Consequently it was not possible to track frogs through the autumn to their over wintering refugia. Nevertheless, radio tracking has provided important data on movement patterns and habitat use of *L. spenceri* over short time periods (1 - 4 weeks), which indicate that the frogs remain in the vicinity of the stream environment and are unlikely to venture great distances away from the stream during the season.

Figure 14. Net distance moved along stream from release point by *L. spenceri* over time radio tracked



Tadpole Habitat Use

Habitat use by tadpoles of *L. spenceri* and *L. phyllochroa* at Bogong Creek is presented in Figure 15. Substantial differences are apparent in the stream habitats used by these species. *L. spenceri* show a strong preference for shallow pools and to some extent riffles; *L. phyllochroa* tadpoles are largely restricted to large deep pools.

The numbers of *L. lesueuri* and *L. spenceri* tadpoles detected on the Goulburn River transect were too low to provide any statistical comparison of habitat use (Fig. 16). However, a qualitative assessment, based on this data and observations of *L. lesueuri* tadpoles in other streams, indicates greater overlap in habitat use by these two species than with *L. phyllochroa*.

Microhabitat use by *L. spenceri* was examined as described in the methods section. Preliminary examination of these data indicates that tadpoles cluster in the shallow margins of pools during the day and dissipate into deeper water at night. This may be a thermoregulatory response.

Figure 15. Average numbers of tadpoles of *L. spenceri* and *L. phyllochroa* recorded in different stream microhabitats along Bogong Creek. (n = per habitat type).

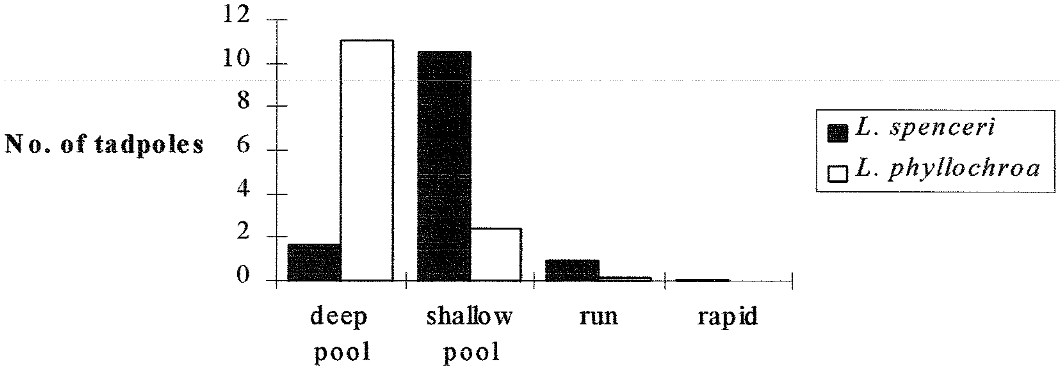
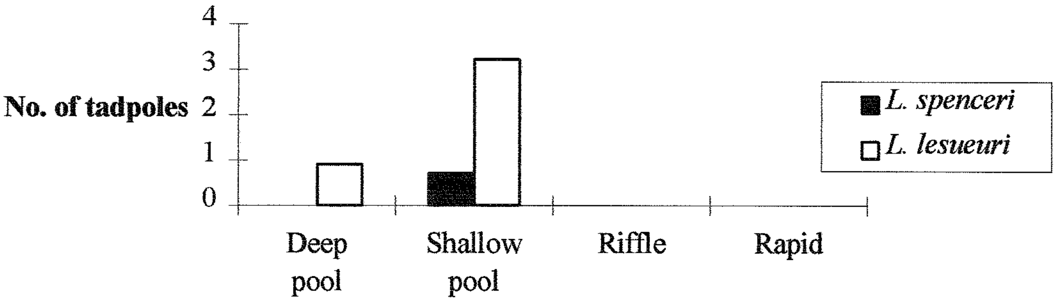


Figure 16. Average numbers of tadpoles of *L. spenceri* and *L. lesueuri* recorded in different stream microhabitats along the Goulburn River. (n = 20 per habitat type)



<u>Palatability of tadpoles of *L. spenceri* and other riverine species to native fish and introduced trout.</u>

Two trials of four replicates of each fish/tadpole species treatment were conducted. However, very few tadpoles of any species were eaten by either fish species in the second trial, including the known palatable control, *L. dumerilii.* This contrasted markedly with the first trial. Consequently these data are not included in analyses. The fish used in the second trial may have been in poorer condition than those used first, as they had been housed within in-stream enclosures for 40 hours while the first trial was conducted.

With the exception of two *L. phyllochroa* tadpoles, Blackfish ate only the known palatable control, *L. dumerilii* (Fig. 17). This difference in palatability between the palatable control and all riverine tadpole species is significant (F = 19.109; P<0.001). In contrast, trout preyed upon all species (Fig. 18). While the numbers of *L. lesueuri* and *L. dumerilii* tadpoles eaten are less than those of *L. spenceri* and *L. phyllochroa,* the difference is not significant (F = 0.516; P = 0.68). These results are consistent with the preliminary trials conducted on trout last year. Riverine tadpoles of these species are unpalatable to native fish but this defence does not extend to introduced trout.

Figure 17. Box plots of numbers of each tadpole species eaten by Two-Spined Blackfish.

Figure 18. Box plots of numbers of each tadpole species eaten by Brown Trout

In addition to the palatability experiments, stream enclosure experiments were conducted with *L. spenceri* and *L. phyllochroa* tadpoles and Rainbow Trout at Bogong Creek from January to March, 1996. Four replicates were conducted, each with different trout and alternating treatments between sides of the enclosure (Fig. 19). The presence of trout had a significant impact on survival of both species of tadpoles ($F = 32.85$; $P < 0.001$), and there was no significant difference between tadpole species ($F = 1.55$; $P = 0.237$). The stomach contents of the fish were examined at the completion of each trial and were all found to contain food items other than tadpoles. These included ditiscid beetles and other unidentifiable arthropod carapace material and a Mountain Galaxid. This result indicates that, despite the availability of alternative food sources for the trout and sheltering sites amongst rocks and detritus for tadpoles, predation from trout has the potential to significantly impact on tadpole populations of these species.

Figure 19. Box plots comparing survival of *L. spenceri* and *L.* phyllochroa tadpoles in a stream pool with the presence and absence of trout.

Competitive interactions between tadpoles of *L. spenceri* and *L. lesueuri* to determine the importance of other sympatric species in limiting abundance and distribution of *L. spenceri*.

Density-dependent competition experiments were conducted between *L. spenceri* and *L. lesueuri* and *L. spenceri* and *L. phyllochroa* tadpoles from January to March, 1996.

Tadpole mortality or loss was very low and spread between species and treatments, with the exception of one 9-*L. phyllochroa* experimental unit which was damaged, resulting in all the tadpoles escaping. This has been excluded from analyses. The results for growth rate of *L. spenceri* tadpoles are presented in Fig. 20. Preliminary examination of growth rates of *L. spenceri* at different densities with different species combinations indicates a significant intra-specific density effect on growth rate (F = 21.04, P = 0.002). Inter-specific density effects are also significant; however they are much less severe than intra-specific effects (F = 3.66, P = 0.044); i.e. *L. spenceri* performed better in the presence of *L. phyllochroa* and *L. lesueuri* tadpoles than other *L. spenceri* tadpoles at the same density. In contrast, *L. phyllochroa* did not grow as well in the presence of *L. spenceri* compared to similar conspecific densities (Figs. 21 & 22). Significant differences in growth rates exist between the different 9-tadpole density treatments (F = 41.09, P = 0.001). This is evidence of asymetrical density dependent competition between these species, in favour of *L. spenceri.* Growth rates of *L. lesueuri* were similarly lower but not significantly different (F = 0.89, P = 0.46). Developmental stage data have not yet been examined for this experiment.

Figure 20. Box plots of mean body lengths of *L. spenceri* tadpoles grown at different intraspecific and interspecific densities. sp = *L. spenceri*; phyl = *L. phyllochroa*; les = *L. lesueuri*.

Figure 21. Box plots of mean body lengths of *L. phyllochroa* tadpoles grown at different intraspecific and interspecific densities.

Figure 22. Box plots of mean body lengths of *L. lesueuri* tadpoles grown at different intraspecific and interspecific densities.

It was not possible to find *L. lesueuri* tadpoles at any high altitude sites similar to that at Bogong Creek in early January this season due, presumably, to the cold spring delaying reproduction. Consequently, animals from Nariel Creek were used. This site is at 300 m which is substantially lower than that at Bogong Creek where the experiment was conducted (1100 m). Temperature is a major factor determining tadpole growth rates and it is plausible that local climatic adaptations exist within species to accommodate climatic differences across their geographic ranges. The comparative low growth of *L. lesueuri* tadpoles at low densities, compared with that of the other two species, suggests that the *L. lesueuri* tadpoles may have been disadvantaged by this. In addition the slow growth rate of *L. lesueuri* tadpoles may have produced less competition, reducing the sensitivity of the experiment. It is therefore possible that these results do not adequately assess competition between tadpoles of *L. spenceri* and *L. lesueuri*.

Effects of sedimentation and food availability on the growth and survival of *L. spenceri* tadpoles.

Sedimentation and food availability were examined experimentally in parallel with the in-stream competition experiments. Preliminary analyses indicate tadpole density to be highly significant for both body length and Gosner stage of *L. spenceri* tadpoles across all treatments (Gosner stage; F = 24.42, $P < 0.001$; Fig. 23). No significant difference was found in mean body size between treatments for any one tadpole density; however, tadpoles at high density in the multiple siltation treatment were slightly smaller on average than those in non-siltation treatments. In contrast, a significant effect of treatment was found on mean Gosner stage (F = 2.7, P = 0.036). Tadpoles at high densities with multiple siltation treatments had significantly lower mean development than those with no siltation (Fig. 24). This contributed much less to the observed differences in tadpole development than density. However, no significant interaction was detected between treatment and density (F = 0.32, P = 0.97), suggesting that siltation affected tadpole development across all densities examined. Tadpole mortality has not been analysed yet but was very low and spread across all treatments and is not expected to be significant. These preliminary results indicate that siliceous deposited sediment in streams has the potential to adversely effect tadpole survival by reducing developmental rate.

Table 23. Box plots of mean Gozner stages of *L. spenceri* tadpoles across different densities.

Figure 24. Box plots of mean Gozner stages of *L. spenceri* tadpoles across different experimental substrate treatments.
1 - algae only; 2 - algae/detritus; 3 - algae/single silt;
4 - algae/detritus/single silt; 5 - algae/multiple silt;
6 - algae/detritus/multiple silt.

Long-term Population Monitoring

long- term monitoring has been conducted on a bi-annual basis along 1 km transects across 16 sites in nine stream systems for up to 4 years now. This has included historic sites at which the species formerly occurred. The species has not re-appeared at any of these historic sites during the monitoring period. Comparison of mark-recapture population size estimates from Bogong and Still Creeks, it is estimated that single censuses under suitable conditions detected a minimum of 10% of adults present on a transect. Based upon this estimate, and the extent of potential habitat present in each population, total population size estimates have been generated for those extant populations being monitored (fig. 25). These estimates are believed to be optimistic because they assume a uniform distribution of frogs and suitable habitat along the length of stream mapped with potential habitat, and detection rates may be much higher than 10%.

Figure 25. Annual adult population size estimates and extent of potential habitat for for populations of Spotted Tree Frogs which have been monitored. Solid bars indicate estimates based upon mark-recapture data; open bars ae one-off estimates

A survey for *L. spenceri* was conducted in Kosciusko National Park in January and February. New South Wales National Parks and Wildlife Service, Kosciusko National Park, provided operating costs and a vehicle for this work. Thirty two sites were intensively sampled across 21 streams spread out along the western fall of the Kosciusko National Park (Hunter 1996). No additional populations of *L. spenceri* were detected, despite the presence of extensive potentially suitable habitat. The down-stream distribution of *L. spenceri* was investigated and found to be much more limited in extent than previously thought. The population is largely restricted to a stretch of stream less than 1.5 km long. This extends down-stream from below the aqueduct pondage wall to the top of a large waterfall. In contrast to the high density of frogs observed above the falls, only three frogs and one pool containing tadpoles were observed below, despite searches over several kilometres. This abrupt change in status coincided with the down-stream limit of Mountain Galaxids, which are also abundant in Bogong Creek above the falls. The falls also marked the up-stream limit of trout (apart from above the aqueduct) which were abundant in stretches of Bogong Creek below these falls. This juxtaposition of trout distribution and frog abundance is consistent with trout exerting significant predation pressure on *L. spenceri* tadpole populations.

Conclusions

The Spotted Tree Frog is a specialised lotic anuran which has specific habitat requirements at all life stages.

Individuals within populations are sedentary and appear to have limited dispersal capability.

Juvenile mortality is high in populations with both low and high adult densities and may vary substantially between years depending upon environmnetal variation.

Age to sexual maturity is long; up to 6 years for females and 4 years for males

Individuls may live for over ten years at high altitudes with reduced longevity at low altitudes.

Predation of the larval stage by introduced trout is strongly implicated as a magor cause of population decline

Increased seiment loads in streams are also implicated through direct reduction in suitable oviposition sites and limiting food avalability of tadpoles

Riparian habitat degradation has also been implicated in earlier studies by correlation with relative abunce and decline of the species. This may operate in siniginstically with impacts from sediment and trout.

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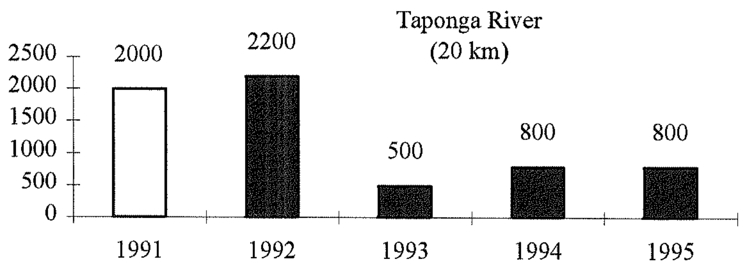
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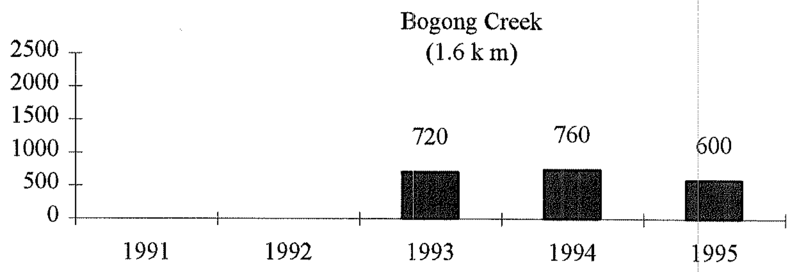
(20 km)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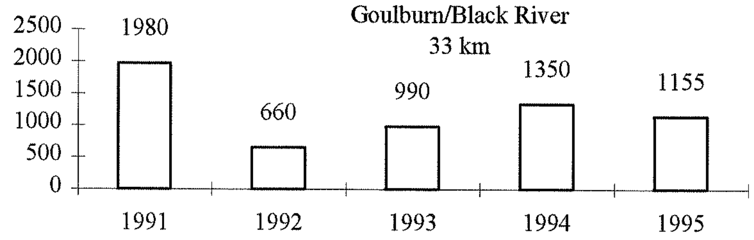
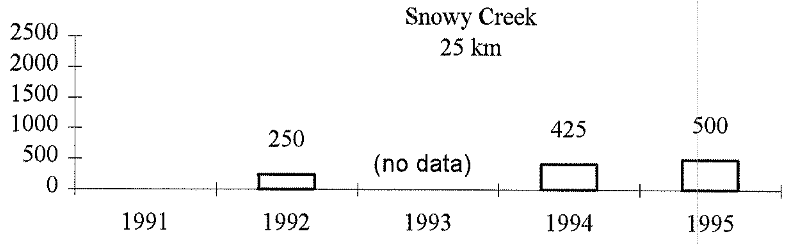
(1.6 k m)


Goulburn/Black River
33 km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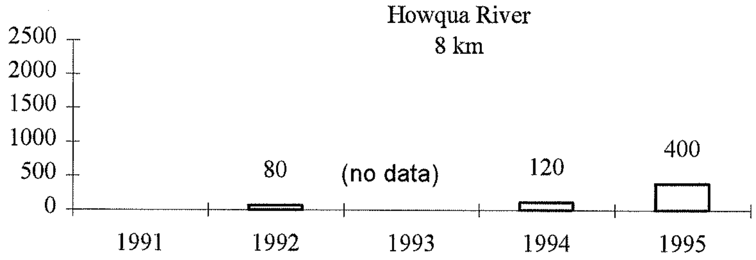
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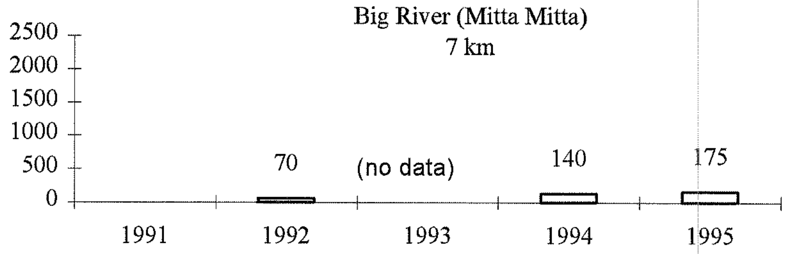
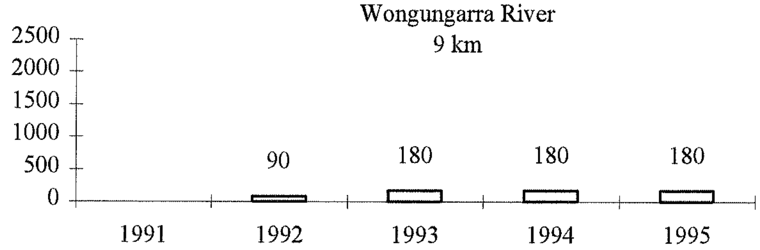
8 km


Big River (Mitta Mitta)
7 km


Wongungarra River
9 km