

APPENDIX 4

CAPTIVE BREEDING OF TUATARA

A total of 149 Cook Strait tuatara (all from Stephens Island) are held in captivity in New Zealand and could potentially be used to establish successful captive breeding procedures. A further seven adults and 18 juveniles from the same population are held overseas. However, success with captive breeding has not been high (Cree and Daugherty, 1990). Most of the New Zealand animals (82) are juveniles that were hatched from wild-collected eggs during incubation studies at VUW by Thompson (1990). The remaining Stephens Island tuatara in captivity in New Zealand include 27 adults held in mixed pairs or groups in which breeding could potentially occur, two adults in isolation, 30 juveniles hatched from eggs laid in captivity and 9 juveniles hatched in captivity by zoos from wild-collected eggs (Table 2). In addition, one aged female, 130 juveniles and hatchlings and c20 incubating eggs from the Brothers tuatara, and 35 adults and 14 juvenile Northern tuatara are held.

No institution has yet raised juvenile tuatara to maturity (the oldest is nine years), and thus, no self-maintaining captive population exists. Probable reasons for the lack of success in captive breeding include high adult mortality, inappropriate cues for reproduction, lack of social interactions, improper nutrition, high densities, poor egg quality, inappropriate incubation conditions and high juvenile mortality (Cree and Daugherty, 1990 and unpubl.). Recent research on reproductive biology (Appendix 1) means that several of these contributing factors should now be overcome.

Areas in which further research is urgently needed include nutrition (including that leading to high egg quality), and the reasons for high juvenile mortality. To illustrate the latter, 87 juveniles have been distributed during the last 2-4 years from incubation experiments at VUW to a total of seven husbandry institutions, but only 47 (54.0%) survive. Deaths have occurred at all institutions, but because autopsies have not been required, detailed information on the likely causes of death is often not available. Circumstantial evidence from curators suggests that acute overheating (>25°C?) has been involved in many cases. Many surviving juveniles in captivity have chronic calcium deficiency resulting from improper nutrition and lack of natural sunlight (A. Cree, unpubl. obs.). This deficiency can be overcome by appropriate design of enclosures to allow exposure to natural sunlight without risking overheating, by provision of artificial light sources that produce wavelengths mimicking natural sunlight, and by providing dietary supplements containing vitamin D₃ and a high calcium: phosphorus ratio.

A further area of captive breeding in which improvements are required is in the institutional structure of captive breeding programmes (Cree and Daugherty, 1990). Until 1990, institutions holding tuatara in New Zealand had no formal procedures for sharing information among themselves or for providing detailed, regular reports to DoC. Improved communication and record-keeping, preferably supervised by DoC, is essential to ensure that: (i) experience in husbandry techniques is shared; (ii) inbreeding is avoided; (iii) reasons for mortality are known; and (iv) adults are kept in sufficiently large colonies to provide a reasonable chance of successful breeding (some institutions may have admirable facilities for raising juveniles but not for maintaining adults, and some currently rearing juveniles may end up with a small number of related adults of only one sex). To assist in these matters, a workshop was held in 1990 for all institutions maintaining tuatara in captivity in New Zealand and a national co-ordinator to liaise between these institutions and DoC was appointed (Blanchard, 1991).

Further information to assist the captive breeding of tuatara can be found in Newman *et al.* (1979), Thompson *et al.* (1988) and in the DoC pamphlet "A guide to the keeping of tuatara in captivity".

APPENDIX 5

SURVEY DATA SHEETS

PROCEDURE

Surveys should be carried out in warm, moist weather (17°C or higher) during October-March inclusive. On very small islands, one night of searching in suitable weather may suffice, but on larger islands 3-7 nights should be allowed for.

Mark area surveyed on a photocopy of a map of this island and enclose with this report.

On completion of survey, please lodge copies of data sheets with:

- (1) Conservation Advisory Scientist, Regional Conservancy Office, Department of Conservation

- and (2) Science and Research Directorate
Department of Conservation
Box 10-420
WELLINGTON

If blood samples are to be collected, please contact the following for details of sampling procedure and additional morphological details to be recorded:

Dr C.H. Daugherty
School of Biological Sciences
Victoria University of Wellington
Box 600
Wellington

GENERAL INFORMATION

Island surveyed:

Dates:
Team Leader:
Other members:
.....
.....
.....
.....

DATA TO RECORD EACH NIGHT

Parameters to record	Date	Date	Date	Date	Date	Date
No. previously toe-clipped animals caught						
No. animals not toe-clipped caught						
No. animals toe-clipped tonight						
Total no. caught						
Total no. person-hours searched						
Capture rate (no./person/hour)						
Air temperature at 10pm (°C)						
Relative humidity at 10pm (%)						
Rain or mist?						
Mark area searched on map						

Notes to explain table on next page

1. AC number = number assigned to animal during 1988/1989 VUW/DoC survey (leave blank)
2. If not absolutely sure of the sex, insert a question mark.
3. Snout-vent length (to nearest millimetre).
4. Vent-tail length (to nearest millimetre).
5. Length of tail regeneration (to nearest millimetre).
6. Weight (to nearest 10 grams).
7. Looking down on back of animal:
LF = left front; RF = right front; LR = left rear; RR = right rear.
Number the toes from inside to outside of limb, i.e., thumb (innermost) = 1, outermost toe = 5.
8. Any comments on unusual appearance (aged/wounded/scarred etc.) or behaviour.

APPENDIX 6

PEOPLE WITH EXPERIENCE IN LEADING FIELD TRIPS TO SURVEY AND/OR COLLECT BLOOD SAMPLES FROM TUATARA

Surveying and blood-sampling:

Dr Alison Cree
Department of Zoology
University of Otago
Box 56
Dunedin
Ph: (03) 479-7482

Dr Charles Daugherty
School of Biological Sciences
Victoria University of Wellington
Box 600
Wellington
Ph: (04) 472-1000

Mr Ian McFadden
DoC Science and Research
62 Tatariki St
Pipakura
Ph: (09) 298-5888

Dr Mary McIntyre
School of Biological Sciences
Victoria University of Wellington
Box 600
Wellington
Ph: (04) 472-1000

Dr Michael B. Thompson
School of Biological Sciences
Zoology A08
University of Sydney
NS W 2006
AUSTRALIA
Ph: (61-2) 692-3989

Mr Tony Whitaker
Ngatimoti
RD 1
Motueka
Ph: (052-468) 703

Surveying only:

Mr Derek Brown
Havelock Field Centre
Department of Conservation
13 Mahakipawa Road
Havelock
Ph: (03) 574-2019

Mr Donald Newman
Conservation Sciences Centre
Department of Conservation
Box 10-420
Wellington
Ph: (04) 710-726

Mr Phil Thomson
Waikato Conservancy
Department of Conservation
Private Bag 3072
Hamilton
Ph: (07) 838-3363

Dr David Towns
Conservation Sciences Centre
Department of Conservation
Box 10-420
Wellington
Ph: (04) 710-726

APPENDIX 7

SOME FACTORS TO CONSIDER WHEN CHOOSING NEW ISLANDS FOR TUATARA

Tables 5a and 5b illustrate some factors to consider when investigating new islands as possible sites for tuatara populations. The examples given are islands that have been suggested as possible sites for the first two new populations of the Brothers tuatara (Table 5a) and for a further population of Cook Strait tuatara. Further information on factors or questions to consider in transfer attempts should be sought from Atkinson (1990), Towns et al. (1990) and the Transfer Guidelines For Indigenous Terrestrial Fauna and Flora (DOC Policy 17 September 1990).

TABLE 5a: Comparison of five islands suggested as possible sites for a new population of the Brothers tuatara.

Factor considered	Island ¹				
	Titi	Outer Chetwode	Motuara	South Brother	Mama
Area (ha)	31	80	58	8	217
Evidence for past presence of tuatara?	No	Possible (Buller, 1894)	No	No	Possible (bones in midden)
Approximate distance from North Brother Island (km)	30	35	15	<1	27
Approximate no. of tuatara that could be supported ²	1500	4000	2600	200	5000+
Presence of potential tuatara predators?	Norway rats eradicated 1970s	Weka	Kiore (eradication carried out in 1990 - apparently successful)	None	Harriers, takahe, black backed gulls
Is the island beyond the swimming distance of rodents or mustelids from any nearby sources?	Yes	Yes	Yes	Yes	Yes
Forest with soil suitable for burrowing?	Yes	Yes	Yes	Very small area of windswept scrub	Small area (but could be increased)
Insects suitable for food?	Tree wetas and spiders abundant; Tree wetas and <i>Mimopeus</i>	Tree wetas and <i>Mimopeus</i>	?	Tree wetas, giant wetas, <i>Mimopeus</i>	
Small nesting seabirds?	Few, if any	Few fluttering shearwaters	Few diving petrels on cliffs	Fairy prions	None

Factor considered	Titi	Island ¹			
		Outer Chetwode	Motunara	South Brother	Mana
Suitable nearby source island for re-stocking with insects and petrels?	Stephens	Stephens	North Brother?	North Brother	Cook Strait Islands
Open areas of soil for nesting?	Yes	Yes	Probably, but may be limited	?	Yes
Species present that could be endangered by tuatara?	No	? Unconfirmed and probably low numbers of Duvaucel's gecko	No	Duvaucel's gecko present, but probably would not be endangered	giant weta; goldstripe gecko; McGregor's skink
Reserve status	Nature Reserve	Nature Reserve	Scenic and Historic Reserve (with public access, Jetty and track)	Nature Reserve	Scientific reserve (with restricted public access and tracks)
Boat access?	Yes	Yes	Yes	Very difficult	Yes
Possible conflicts with other goals for the island?	Possible release of saddlebacks? (Roberts, 1990)	Possible release of saddlebacks? (Roberts, 1990)	To be determined as part of restoration/recovery plan for island.	Conflict with "minimum impact" status of island	Presence or possible release of incompatible species
Permanently staffed	No	No	No	No	Yes

¹ Details from Brian Bell, D. Brown, I. Miller, D. Towns (pers. comm.) or from reference given in body of table, except for number of tuatara supported.

² Approximate number of tuatara supported calculated by assuming a density of 100 tuatara/ha over half of each island, except for South Brother which probably has only about 25% of its land area suitable for tuatara.

Conclusions from table 5a:

Both Titi Island and Outer Chetwode Island appear to have considerable potential for tuatara and should be investigated further. The fauna on Titi Island has been degraded by the past presence of Norway rats, which have now been eradicated. Wekas would need to be removed from both Inner and Outer Chetwode Island, should Outer Chetwode be chosen for tuatara. Both Titi and Outer Chetwode would probably benefit from re-stocking with small petrels to enhance their suitability for tuatara. Duvaucel's gecko may be present on Outer Chetwode, but would not necessarily be harmed by tuatara as this species co-exists with tuatara on many other islands. The release of tuatara on Titi or Outer Chetwode need not be in conflict with the possible release of other threatened species such as the saddleback there (Roberts, 1990), provided all desired uses of the island are considered from the outset and releases are timed and

located accordingly. Motuara Island also appears to have similar biological potential for tuatara once kiore are eradicated, but is probably not appropriate as a sanctuary for the rare Brother Island species in the short-term because of its unrestricted public access.

South Brother Island is in more-or-less pristine condition and the release of tuatara here would conflict with recommended transfer policy (Atkinson, 1990; Towns et al., 1990); its very small size of (suboptimal) habitat and its extreme difficulty of access also make it unsuitable (it should, however, be searched to determine whether tuatara already exist there). Mana Island has the potential to support a very large population of tuatara, but appears unsuitable in the short-term until a restoration/recovery plan is prepared for the island.

Somes Island in Wellington Harbour once supported a tuatara population and has the potential to do so again. It was not considered as a desirable site for either of the first two releases of Brothers tuatara because the high level of human activity on this island make; it potentially more vulnerable to rodent re-introduction, but may be appropriate as a site for Cook Strait tuatara (see below).

TABLE 5b: Comparison of three islands suggested as possible sites for a new population of the Cook Strait tuatara.

Factor considered	Island ¹		
	Mana	Somes	Tinui
Area (ha)	217	25	89
Evidence for past presence of tuatara?	Possible (bones in midden)	Yes	No
Approx. distance from nearest island with Cook St. tuatara (km)	70km	95km	10km
Approximate no. of tuatara that could be supported ²	5000+	1250	4450
Presence of potential tuatara predators?	Harriers; takahe	Black-backed gull, harrier	Black-backed gull, harrier, Norway rat
Is the island beyond the swimming distance of rodents or mustelids from any nearby sources?	Yes	Yes	Yes (rodents) No (stoats)
Forest with soil suitable for burrowing?	Small area (but could be increased)	Small area	Small areas

Insects suitable for food?	Tree wetas, giant wetas, <i>Mimopeus</i>	<i>Mimopeus</i>, ?tree weta	Not known
Small nesting seabirds?	None (experiment commenced to attract fairy terns to breed)	None	? None
Suitable nearby source island for re-stocking with insects and petrels?	Cook Strait Islands	Cook Strait Islands	Cook Strait Islands
Open areas of soil for nesting?	Yes	Yes	Yes
Species present that could be endangered by tuatara?	Giant weta; goldstripe gecko; McGregor's skink	None	? None
Reserve status	Scientific reserve (with restricted public access and tracks)	(High security quarantine station, MAF)	No (Maori owned)
Boat access	Yes	Yes	Yes
Possible conflicts with other goals for the island?	Presence or possible release of incompatible species	Possible release of endangered invertebrates	None known
Permanently staffed	Yes	Yes	No

Conclusions from Table 5b:

Of the three islands listed here, Maria is considered as a possible site for Brothers Island tuatara in the longer term, so it might be decided that this species should be given priority there over Cook Strait tuatara. Tinui Island has Norway rats, but a feasibility study to assess the potential to remove these and restore habitats on the island has been developed so it may be suitable for tuatara in the future. A re-introduction of Cook Strait tuatara to Somes Island is the subject of a current proposal (see Objective 13). The primary purpose of establishing a further population of Cook Strait tuatara is to allow the public to see the animals in the wild under controlled conditions (Objective 13), so questions of control of access and impacts of visitation on other island values will need careful consideration.

APPENDIX 8: IMPACT ASSESSMENT

Introduction

The major actions proposed in this recovery plan for the next five years are the eradication of kiore from seven islands, and the (re)establishment of tuatara populations on eight islands (three reintroductions to supplement or re-establish nearly extinct populations; three reintroductions to islands where tuatara have been extinct for about 100-200 years; and two introductions to islands where tuatara are not known to have definitely been present). These actions have implications for the existing endemic fauna of these islands, for endemic species that might be introduced in the future to these islands, and for two introduced mammals (kiore, rabbits) currently present on some tuatara islands. Possible impacts from these proposals are discussed below.

Implications of proposed mammal eradications

Both kiore and rabbits were introduced to New Zealand by humans and are thus not part of our native fauna. More are widely distributed throughout South-East Asia, Indo-Malaya, the Pacific Islands and some islands in the Indian Ocean (Atkinson and Moller 1990). They were brought to New Zealand by the Polynesians, who arrived about 1000 AD, and kiore have since spread either accidentally or deliberately to many offshore islands. The dates that kiore first appeared on islands inhabited by tuatara are not known and may for at least some islands have been as recent as 100-200 years ago. Kiore apparently had both positive and negative outcomes for the Maori: they were eaten, but also probably contributed to food spoilage; the extent of a possible role in the spread of disease is unknown (Atkinson and Moller 1990).

Kiore became almost extinct on the New Zealand mainland following the introduction and spread of European rodents. However, they still survive in Fiordland and on many offshore islands, most uninhabited by tuatara. Research is currently being carried out to establish whether there is significant genetic variation among these kiore populations. Excluding Fiordland, kiore were present in 1984 on 55 offshore islands totalling 240,928 ha in area. Between 1984 and 1991 they were eradicated from four of these islands totalling 124 ha. This recovery plan advocates their eradication on a further seven (854 ha) by 1995; this represents 13.7% of the 1991 total of 51 populations and only 0.4% of the 1991 total of 240,804 ha occupied. Thus, the magnitude of the eradications proposed is small and will have no significant effect on the survival of kiore in New Zealand.

Rabbits are present on one island (Stanley) occupied by tuatara. Rabbits were introduced to New Zealand by Europeans in 1777 (Gibb and Williams 1990), and to Stanley about the turn of this century (Towns et al., 1990). There is no evidence that the population on Stanley is genetically distinct from any other population in New Zealand. Rabbits remain widespread throughout much of the North and South Islands and their eradication from Stanley has no implications for the survival of the species in New Zealand.

Both circumstantial and experimental evidence indicates that kiore and rabbit eradication will have many significant benefits for the flora and fauna of these islands, independent of benefits to tuatara. These include increased forest regeneration, and increased abundance of invertebrates, lizards and small seabirds (Towns, 1991 and pers. comm.).

Impact of tuatara (re)introductions on existing and potential endemic island fauna

(Re)introduced populations of tuatara are unlikely to have significant undesirable impacts on the physical environment of their islands. The only major physical modification carried out by tuatara is burrow construction, but the extent of this will probably be insignificant compared with the burrowing activities of co-existing healthy seabird populations. The impact of tuatara on the flora will also probably be small. Tuatara are primarily insectivorous carnivores, and although fragments of plant material (stems, etc.) have been found in their faeces (Walls, 1981) this probably represents material accidentally ingested when catching animal prey. The movements of tuatara about the forest floor could reduce seedling establishment to a small extent, but again the effect is likely to be negligible compared with that caused by healthy seabird populations.

The primary impact of (re)introduced tuatara is likely to arise from predation on prey species. Total daily intake of prey species by tuatara has never been measured and thus it is difficult to predict quantitatively what the overall impact of (re)introduced tuatara might be. Qualitatively, their effect is likely to be much smaller than for an introduced mammal or bird species reaching similar body size and density. This is because reptiles, which are cold-blooded, require only about 10% the level of energy intake required by mammals or birds of the same size (Pough, 1980). Furthermore, tuatara are likely to have even lower food requirements than most other reptiles, because their metabolic rates are extremely low as a consequence of adaptation to cool temperatures (Wilson and Lee, 1970; Wells et al., 1990). Captive tuatara are, for instance, known to survive months without food (Buller, 1877, 1879).

Dietary studies on Stephens Island indicate that the impacts of introduced tuatara are likely to be greatest on ground-dwelling invertebrate prey (see Appendix 1). The major prey item is likely to be beetles such as *Mimopeus* species, although further information on the diets of genetic stocks of tuatara other than the Cook Strait form would be helpful. Provided that healthy populations of invertebrates are present, the impact of (re)introduced tuatara on lizard and bird populations is likely to be small. Diurnal *Leiopisma* skinks are too fast to be frequently caught by tuatara, and nocturnal geckos (*Hoplodactylus* spp.) are probably too arboreal and fast to be frequently caught. Nocturnal *Cyclodina* skinks are probably also too fast to be predated in significant numbers. Seabird chicks are probably taken only by adult tuatara and only those species breeding during late spring-autumn would be vulnerable, as tuatara have low activity over winter. Strong evidence of the ability of rare species of lizards and invertebrates to co-exist with safely with tuatara comes from Middle Island in the Mercury Group and from Stephens Island. On Middle, tuatara co-exist with the endangered tusked weta as well as 10 species of lizards, including two endangered species of *Cyclodina*. On Stephens, rare giant weta and seven lizard species, including the rare striped gecko *Hoplodactylus stephensi*, co-exist with a high density of tuatara.

Tuatara (re)introductions will only take place following an approved DoC Transfer Proposal, which will include assessment of the impact of tuatara on any sensitive species. Where necessary, tuatara could be released on a distant part of the island from that where sensitive species are present or to be introduced, or even penned where necessary until potential prey populations have reached a pre-determined target population size. This may be particularly relevant for islands recently inhabited by rats, on which prey abundance is likely to be depleted and may take several years following rat eradication to recover. Overall, however,

the small number of individual tuatara likely to be available for reintroduction, plus their low energy intake, sedentary behaviour, low growth rate, prolonged time till sexual maturity and low reproductive rate, mean that the impact of tuatara (re)introductions will probably be small for many decades. Prey species are smaller, faster to mature and reproduce more quickly than tuatara, and are thus likely to recover more rapidly following rat eradication than are tuatara, which will probably take decades to even double in numbers. For instance, based on estimates for nesting frequency, clutch size, incubation success, juvenile survivorship and age till maturity on Stephens Island, an introduced population of 20 adult tuatara (five males, 15 females) would require about 15-20 years to reach double the number of adults (40).

Finally, because of the lack of information on potential success and impacts of (re)introductions of tuatara, it is important that well-monitored trials with releases of both juvenile and adult tuatara are carried out in the near future. Efforts under discussion to re-establish non-endangered genetic stocks of tuatara on islands such as Whale and Somes useful in this regard. Research to monitor the effects of introduced tuatara on invertebrate populations and the extent of tuatara dispersal from the release site would be valuable.

Conclusions

The tuatara (re)introductions proposed here have implications for both introduced mammals and for endemic species potentially or currently present on islands proposed for (re)introduction attempts. More eradication will be required on seven islands representing 0.4% of the area inhabited as of 1991 on offshore and outlying islands in New Zealand by kiore. Eradication will thus have no significant effect on the total area occupied by this introduced species in New Zealand, but will have highly significant positive effects for tuatara. The re-establishment of healthy populations of tuatara on seven islands previously occupied by kiore represents 23% of the current number of tuatara populations. More eradication on these seven islands and rabbit eradication on Stanley will benefit many other aspects of the biota of these islands in addition to tuatara.

The impact of (re)introduced tuatara will probably be greatest on ground-dwelling invertebrate prey. To help predict the effects of tuatara (re)introductions on endemic faunas, research on diets of the different types of tuatara would be useful. DoC Transfer Proposals are required before the release of tuatara on any island, and these will highlight the presence of species sensitive to introduction of tuatara. Where necessary, restocking of invertebrate food supplies and/or temporary penning of released tuatara could be considered. However, (re)introduction of tuatara need not prevent the introduction or survival of rare prey species on the same island, provided the introductions are spaced appropriately in both space and time. Finally, the low metabolic rate, long time till sexual maturity, and low reproductive rate of tuatara, and the low numbers proposed for release, suggest that the impact of (re)introduced tuatara will probably be small for many decades, and much less than the effect that kiore had prior to eradication.

REFERENCES

- Atkinson, I.A.E. 1968. An ecological reconnaissance of Coppermine Island, Hen and Chickens group. *N.Z. J. Bot.* 6: 285-294.
- Atkinson, I.A.E. 1973. Protection and use of the islands in Hauraki Gulf Maritime Park. *Proc. N.Z. Geol. Soc.* 20: 103-114.
- Atkinson, I A E 1986. Rodents on New Zealand's northern offshore islands: distribution, effects and precautions against further spread. In: *The offshore islands of northern New Zealand*. Wright, A.E. and Beever, R.E. (Eds). New Zealand Department of Lands and Survey Information Series 16: 13-40.
- Atkinson, I A E 1990. Ecological restoration on islands: prerequisites for success. In: *Ecological restoration of New Zealand islands*. Towns, D.R., Daugherty, C.H. and Atkinson, I.A.E. (Eds). *Conserv. Sci. Publ. No. 2*. Pp. 73-90.
- Atkinson, I.A.E. and Moller, H. 1990. Kiore. In: *The handbook of New Zealand mammals*. King, C.M. (Ed). Oxford University Press, Melbourne.
- Bell, B.D. 1986. The conservation status of New Zealand Wildlife. *NZ Wildl. Serv. Occ. Publ. No. 12*.
- Blanchard, B. 1991. Future plans for the captive breeding of tuatara. *N.Z. J. Zool.* 18: 343 (Abstract)
- Brown, M.A., Cree, A., Chambers, G.K. and Newton, J.F. 1989. Techniques for detecting vitellogenesis in the tuatara *Sphenodon punctatus*. *N.Z. J. Zool.* 16: 25-35.
- Buller, W.L. 1877. Notes on the tuatara lizard (*Sphenodon punctatus*), with a description of a supposed new species. *Trans. Proc. N.Z. Inst.* 9: 317-325.
- Buller, W.L. 1878. Notice of a new variety of tuatara lizard (*Sphenodon*) from East Cape Island. *Trans. Proc. N.Z. Inst.* 10: 220-221.
- Buller, W.L. 1879. Further notes on the habitats of the tuatara lizard. *Trans. Proc. N.Z. Inst.* 11:349-351.
- Buller, W.L. 1894. Illustration of Darwinism. *Trans. Proc. N.Z. Inst.* 11: 349-351.
- Carmichael, C.K., Gillingham, J.C. and Keall, S.N. 1989. Feeding ecology of the tuatara (*Sphenodon punctatus*) on Stephens Island based on niche diversification. *N.Z. J. Zool.* 16: 269 (abstract).
- Castanet, J., Newman, D.G. and Saint-Girons, H. 1988. Skeletochronological data on the growth, age, and population structure of the tuatara, *Sphenodon punctatus*, on Stephens and Lady Alice Islands, New Zealand. *Herpetologica* 44: 25-37.

- Colenso, W. 1886. Notes on the bones of a species of *Sphenodon*, (*S. diversum*, Col.) apparently distinct from the species already known. Trans. Proc. N.Z. Inst. 18: 118-123.
- Craig, J.L. 1986. The effects of kiore on other fauna. In: The offshore islands of northern New Zealand. Wright, A.E. and Beever, R.E. (Eds). New Zealand Department of Lands and Survey Information Series 16: 75-83.
- Cree, A. 1990. Draft Tuatara Recovery Plan. Unpubl. report to Threatened Species Unit, Department of Conservation, Wellington. 74pp.
- Cree, A. and Daugherty, C.H. 1990. Captive breeding of the New Zealand tuatara: past results and future directions. In: Proceedings of the Fifth World Conference on Breeding Endangered Species in Captivity, Cincinnati, Ohio. Dresser, B.L., Reece, R.W. and Maruska, E.J. (Eds). Pp. 477-491.
- Cree, A. and Thompson, M.B. 1988. Unravelling the mysteries of tuatara reproduction. Forest and Bird No. 250: 14-16.
- Cree, A., Thompson, M.B., Guillette, L.J. Jr., Hay, J.M. and McIntyre, M.E. 1989. Embryonic development of tuatara in forested and open habitats on Stephens Island, New Zealand. N.Z. J. Zool. 16: 270 (abstract).
- Cree, A., Guillette, L.J. Jr., Cockrem, J.F., Brown, M.A. and Chambers, G.K. 1990a. Absence of daily cycles in plasma sex steroids in male and female tuatara (*Sphenodon punctatus*), and the effects of acute capture stress on females. Gen. Comp. Endocrinol. 79: 103-113.
- Cree, A., Guillette, L.J. Jr., Cockrem, J.F. and Joss, J.M.P. 1990b. Effects of capture and temperature stresses on plasma steroid concentrations in male tuatara (*Sphenodon punctatus*). J. Exp. Zool. 253: 38-46.
- Cree, A. and Daugherty, C.H. 1991. Sex hormone concentrations in plasma of captive adult tuatara from northern islands and captive juvenile tuatara from Stephens Island. Unpubl. report to Threatened Species Unit, Department of Conservation, Wellington. 13pp.
- Cree, A., Daugherty, C.H. and Hay, J.M. 1991a. Reproduction and conservation of rare populations of tuatara (*Sphenodon punctatus*) on offshore islands of New Zealand. Proceedings of the 60th ANZAAS Congress, University of Adelaide, October 1991. Held on microfiche at the University of New South Wales, Sydney.
- Cree, A., Daugherty, C.H., Schafer, S.F. and Brown, D. 1991b. Nesting of tuatara (*Sphenodon guntheri*) on North Brother Island, Cook Strait. Tuatara 31: 9-16.
- Cree, A., Cockrem, J.F., Brown, M.A., Watson, P.R., Guillette, L.J. Jr, Newman, D.G. and Chambers, G.K. 1991c. Laparoscopy, radiography, and blood analyses as techniques for identifying the reproductive condition of female tuatara. Herpetologica 47: 238-249.
- Cree, A., Guillette, L.J. Jr. and Cockrem, J.F. 1991d. Identification of female tuatara in ovulatory condition using plasma sex steroid concentrations. NZ. J. Zool. 18: 421-426.

- Cree, A., Cockrem, J.F. and Guillette, L J Jr 1992. Reproductive cycles of male and female tuatara (*Sphenodon punctatus*) on Stephens Island, New Zealand. *J. Zool. Lond.* 226: 199-217.
- Crook, I G 1970. Tuatara. *Wildlife - A Review* No. 2: 16-19.
- Crook, I.G. 1973. The tuatara, *Sphenodon punctatus* Gray, on islands with and without populations of the Polynesian rat, *Rattus exulans* (Peale). *Proc. N.Z. Ecol. Soc.* 20: 115-120.
- Crook, I.G. 1975. The tuatara. In: *Biogeography and ecology in New Zealand*. Kuschel, G. (ed.). Junk, The Hague. Pp. 331-352.
- Daugherty, C.H., Cree, A., Hay, J.M. and Thompson, M.B. 1990. Neglected taxonomy and continuing extinctions of tuatara (*Sphenodon*). *Nature*. 347(6289): 177-179.
- Daugherty, C.H., Thompson, M.B. and Cree, A. In press. Conservation of the New Zealand tuatara: past, present and future. In: *Proceedings of the International Workshop on Herpetology of the Galapagos*. Snell, H. and Fritts, T. (Eds). University of New Mexico Press, Albuquerque.
- Department of Internal Affairs. Unpublished files 46/14/17, 46/14/20, 46/18/4 and 46/18/61. National Archive, Wellington.
- Falla, R.A. 1960. The fauna of New Zealand. In: *A descriptive atlas of New Zealand*. McClintock, A.H. (Ed.). Government Printer, Wellington. Pp. 25-27.
- Fraser, N.C. 1988. The osteology and relationships of Clevosaurus (Reptilia: Sphenodontida). *Phil Trans R Soc Lond B* 321: 125-178.
- Gibb, J.A. and Williams, J.M. 1990. European rabbit. In: *The handbook of New Zealand mammals*. King, C.M. (Ed). Oxford University Press, Melbourne. Pp. 138-160.
- Hamilton, H. 1913. Unpublished letter. Department of Internal Affairs unpublished file IA 46/18/4 (Part 1), National Archive, Wellington.
- Hislop, J. 1920. Annual report of the Department of Internal Affairs for the year ended 31st March, 1920. App. J. House Repr. 1920 H-22: 1-5.
- Holdaway, R.N. 1989. New Zealand's pre-human avifauna and its vulnerability. *N.Z. J. Ecol.* 12: 11-25.
- Hunt, D. (Ed.). 1991. Moutohora (Whale) Island Draft Management Plan. Bay of Plenty Conservancy, DoC, PO Box 1146, Rotorua.
- Hutton, M. 1990. Mana: island of hope and glory. *Forest and Bird* 21 (2):13-17.
- IUCN. 1988. 1988 IUCN red list of threatened animals. IUCN, Gland, Switzerland.

- Knox, F.J. 1869. On the tuatara (*Hatteria punctata*, Gray); or great fringed lizard of New Zealand. Trans. Proc. N.Z. Inst. 2: 17-20.
- Mair, W.G. 1873. Notes on Rurima Rocks. Trans. Proc. N.Z. Inst. 5: 151-153.
- McCallum, J. 1980. Reptiles of the northern Mokohinau Group. Tane 26: 53-59.
- McCallum, J. 1981. Reptiles of Tawhiti Rahi Island, Poor Knights Islands, New Zealand. Tane 27: 55-58.
- Moller, H. 1985. Tree wetas (*Hemideina crassicuris*) (Orthoptera: Stenopelmatidae) of Stephens Island, Cook Strait. N.Z.J.Zool. 12:55-69.
- Molloy, J. and A. Davis. 1992. Setting priorities for the conservation of New Zealand's threatened plants and animals. Department of Conservation, Wellington.
- Moors, P.J. 1980. East Island. Wildlife - A Review. No. 11: 48-52.
- Moors, P.J., Atkinson, I.A.E. and Sherley, G.H. 1989. Prohibited immigrants: the rat threat to island conservation. World Wide Fund for Nature, Wellington.
- Newman, A.K. 1878. Notes on the physiology and anatomy of the tuatara (*Sphenodon guntheri*). Trans. Proc. N.Z. Inst. 10: 222-239.
- Newman, D.G. 1980. An ecological reconnaissance of islands in the Hen and Chickens Group. Unpubl. report to the New Zealand, Wildlife Service, Wellington.
- Newman, D.G. 1982a. Tuatara, *Sphenodon punctatus*, and burrows, Stephens Island. In: New Zealand Herpetology. Newman, D.G. (Ed.). N.Z. Wildl. Serv. Occ. Publ. No. 2: 213-221.
- Newman, D.G. 1982b. Current distribution of the tuatara. In: New Zealand Herpetology. Newman, D.G. (Ed.). N.Z. Wildl. Serv. Occ. Publ. No. 2: 145-147.
- Newman, D.G. 1986. Can tuatara and mice co-exist? The status of tuatara, *Sphenodon punctatus* (Reptilia: Rhynchocephalia), on the Whangamata Islands. In: The offshore islands of northern New Zealand. Wright, A.E. and Beever, R.E. (Eds). New Zealand Department of Lands and Survey Information Series No. 16: 179-195.
- Newman, D G 1987a. Tuatara. John McIndoe, Dunedin.
- Newman, D.G. 1987b. Burrow use and population densities of tuatara (*Sphenodon punctatus*) and how they are influenced by fairy prions (*Pachyptila turtur*) on Stephens Island, New Zealand. Herpetologica 43: 336-344.
- Newman, D.G. 1988. Evidence of predation on a young tuatara, *Sphenodon punctatus*, by kiore, *Rattus exulans*, on Lady Alice Island. N.Z. J. Zool. 15: 443-446.

- Newman, D.G. and McFadden, I. 1990a. Seasonal fluctuations of numbers, breeding, and food of kiore (*Rattus exulans*) on Lady Alice Island (Hen and Chickens Group), with a consideration of kiore:tuatara (*Sphenodon punctatus*) relationships in New Zealand. N.Z. J. Zool. 17: 55-63.
- Newman, D.G. and McFadden, I. 1990b. Status of the tuatara, *Sphenodon punctatus*, on Hongiora and Ruamahua-iti Islands, Aldermen Group, New Zealand. N.Z. J. Zool. 17: 153-156.
- Newman, D.G. and Watson, P.R. 1985. The contribution of radiography to the study of the reproductive ecology of the tuatara, *Sphenodon punctatus*. In: Biology of Australasian Frogs and Reptiles. Grigg, G., Shine, R. and Ehmann, H. (Eds). Surrey Beatty, Sydney. Pp. 7-10.
- Pough, F.H. 1980. The advantages of ectothermy for tetrapods. Am. Nat. 180:92-112.
- Reischek, A. 1886. Observations on *Sphenodon punctatum* [sic], fringe-back lizard (tuatara). Trans. Proc. N.Z. Inst. 18: 108-110.
- Roberts, A. 1990. South Island saddleback recovery plan (Draft III). Unpublished Report to the Threatened Species Unit, Department of Conservation.
- Saint Girons, H. and Newman, D.G. 1987. The reproductive cycle of the male tuatara, *Sphenodon punctatus*, on Stephens Island, New Zealand. N.Z. J. Zool. 14: 231-237.
- Sandager, F. 1890. Observations on the Mokohinau Islands and the birds which visit them. Trans. Proc. N.Z. Inst. 22: 286-294.
- Schauinsland, H. 1898. Beitrage zur Biologie der *Hatteria*. Sitzber. Preuss. Akad. Wiss. 1898: 701-704.
- Smale, S. and Owen, K. 1990. Motuhora: a whale of an island. In: Ecological restoration of New Zealand islands. Towns, D.R., Daugherty, C.H. and Atkinson, I.A.E. (eds.). Conserv. Sci. Publ. No. 2. In press.
- Taylor, G.A.S. 1989. A register of northern offshore islands and a management strategy for island resources. New Zealand Department of Conservation Northern Region Technical Report Series No. 13.
- Thilenius, G. 1899. Vorlaufiger Bericht uber die Eiablage and erste Entwicklung der *Hatteria punctata*. Sitzber. Preuss. Akad. Wiss. 1: 247-256.
- Thomas, B. and Taylor, R. 1988. Rat eradication in Breaksea Sound. Forest and Bird 19 (1):30-33.
- Thompson, M.B. 1990. Incubation of eggs of tuatara, *Sphenodon punctatus*. J. Zool. (Lond.) 222: 303-318.

- Thompson, M.B., Cree, A. and Daugherty, C.H. 1988. Guidelines for maintenance and breeding of tuatara in captivity. Unpublished draft available from the authors.
- Thompson, M.B., Daugherty, C.H., Cree, A., French, D.C., Gillingham, J.C. and Barwick, R.E. In press. Status and longevity of the tuatara, *Sphenodon punctatus*, and Duvaucel's gecko, *Hoplodactylus duvaucelii*, on North Brother Island, New Zealand. J. Roy. Soc. N.Z.: in press.
- Thompson, M.B., Newman, D.G. and Watson, P.R. 1991. Use of oxytocin in obtaining eggs from tuatara, (*Sphenodon punctatus*). J. Herpetol. 25:101-104.
- Thompson, P. 1990. Interim recovery plan for tussock wetlands (draft). Unpublished report to the Threatened Species Unit, Department of Conservation.
- Towns, D.R. 1990. Recovery plan for Whitaker's skink and the robust skink (First Draft). Unpublished report to the Threatened Species Unit, Department of Conservation.
- Towns, D.R., Daugherty, C.H. and Cromarty, P.L. 1990. Protocols for translocation of organisms to islands. In: Ecological restoration of New Zealand islands. Towns, D.R., Daugherty, C.H. and Atkinson, I.A.E. (eds.). Conserv. Sci. Publ. No. 2.: 240-254.
- Towns, D.R. 1991. Response of lizard assemblages in the Mercury Islands, New Zealand, to the removal of an introduced rodent: the kiore (*Rattus exulans*). J. Roy. Soc. N.Z. 21: 19-36.
- Walls, G.Y. 1978. The influence of the tuatara on fairy prion breeding on Stephens Island, Cook Strait. N.Z. J. Ecol. 1: 91-98.
- Walls, G.Y. 1981. Feeding ecology of the tuatara (*Sphenodon punctatus*) on Stephens Island, Cook Strait. N.Z. J. Ecol. 4:89-97.
- Walls, G.Y. 1983. Activity of the tuatara and its relationships to weather conditions on Stephens Island, Cook Strait, with observations on geckos and invertebrates. N.Z. J. Zool. 10: 309-318.
- Ward, W.T. 1961. Soils of Stephens Island. N.Z. J. Sci. 4: 493-505.
- Wells, R.M.G., Tietens, V., Houseley, G.D., Young, A.A., Dawson, N.J. and Johansen, K. 1990. Effect of temperature on control of breathing in the cryophilic rhynchocephalian reptile, *Sphenodon punctatus*. Comp. Biochem. Physiol. 96A:333-340.
- Wermuth, H. and Mertens, R. 1977. Liste der rezenten Amphibien and Reptilien. Testudines, Crocodylia, Rhynchocephalia. Das Tierreich, Berlin 100: 1-174.
- Wettstein, O. von. 1931. Rhynchocephalia. In: Handbuch der Zoologie Vol. 7. Kuekenhal, W. and Krumbach, T. (eds.). de Gruyter, Berlin and Leipzig. Pp. 1-235.
- Wettstein, O. von. 1943. *Sphenodon punctatus reischeki* nov. subsp. Zoologisches Anzeiger 143: 45-47.

- Whitaker, A.H. 1974. Report on a visit to the Mokohinau Islands, Hauraki Gulf, 20 November to 4 December 1973. Unpublished report to DSIR Ecology Division 7/2/74.
- Whitaker, A.H. and C H Daugherty. 1991. Research on the tuatara (*Sphenodon punctatus*) of Little Barrier Island, 5-12 February 1991. Unpubl. report to Threatened Species Unit, Department of Conservation, Wellington. 54pp
- Wilson, K.J. and Lee, A.K. 1970. Changes in oxygen consumption and heart-rate with activity and body temperature in the tuatara, *Sphenodon punctatus*. Comp. Biochem. Physiol. 33:311-322.