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APPENDIX 1. BIOLOGY OF TUATARA

Evolutionary Relationships

Tuatara are of exceptional significance to the evolutionary history of the reptiles. They are the sole living representative of the Order Sphenodontida (Fraser, 1988), one of four orders of living reptiles. Fossil sphenodontidans were small to medium-sized reptiles that lived about 120-225 million years ago at about the same time as the dinosaurs. They have been found in Europe, Africa, England and North America, suggesting that they were once widespread across the Pangaca supercontinent.

The lineage from which tuatara evolved was probably isolated in New Zealand when New Zealand broke away from Gondwanaland about 80 million years ago. This lineage was probably anatomically, ecologically and physiologically different from the species we know today as tuatara. The reason why the tuatara lineage survived and all other sphenodontidans became extinct is unknown, but the absence of endemic land mammals in New Zealand may have been significant.

Tuatara look like lizards, but they are not. For instance, tuatara and other sphenodontidans have a unique dentition, in which a single row of teeth in the lower jaw fits in a groove between two rows of teeth in the upper jaw. A highly specialised jaw movement is also present in tuatara, allowing the lower jaw to move forwards between the two upper rows when the mouth is closed. Thus, tuatara are very efficient at shearing apart hard, chitinous insects such as wetas, and at decapitating small seabirds.
Some of the other features that distinguish tuatara from lizards include: (i) the presence of small bony extensions *(uncinate processes)* on the ribs; (ii) a complete lower temporal bar in the skull (a condition known as *diapsid);* and (iii) the absence of a copulatory organ in males.

TABLE 2: Types of tuatara recognised in this recovery plan [1]

Northern tuatara: *S. p. punctatus* (Gray, 1843)	Identified by blood-sample analysis from 22 islands in the Hauraki Gulf and Bay of Plenty. Three other populations in this area not yet blood-sampled (Half, North Stack and Middle Chain Stack in the Aldermen Group) are presumed to fall within this subspecies.
Brothers tuatara: *S. guntheri Butler*, 1877	Known only from North Brother Island in Cook Strait. Originally described as a separate species by Buller (1877) but reduced to subspecific status by Wettstein (1931). Recent blood-sample analysis supports its classification as a separate species. A population on East Island, which is thought to have belonged to the same species (Buller, 1878), became extinct in the early 1900s (Moors, 1980).
Cook Strait tuatara: *S. punctatus*	Known from Stephens, North Trio, Middle Trio and South "Trio Islands. Wermuth and Mertens (1977) implied that these populations belonged to the subspecies *S. p. guntheri*, but blood-sample analysis indicates that they are distinct from both *S.*

guntheri and *S. p. punctatus*, and they probably warrant recognition as a separate subspecies of *S. punctatus*.

[1] An extinct subspecies (*S. p. diversum)* is described from bones around Hawkes Bay in the North Island (Colenso, 1886; Wettstein, 1931).
[2] Reference to analysis of blood-samples (for allozyme variation) is from Daugherty et al. (1990) and Whitaker and Daugherty (1991).

Taxonomy

Current taxonomy (Wermuth and Mertens, 1977) and recent studies of variation in blood proteins (Daugherty et al., 1990; Whitaker and Daugherty, 1991) indicate that three different types of tuatara must be recognised for management purposes (Table 2).

Habitats and Habits

Tuatara are now restricted to cool, often cliff-bound and windswept islands off the New Zealand coast. Most tuatara islands have been extensively affected in the past by fires, introduced animals and human occupation (Appendix 3). On most islands, tuatara live in burrows in coastal forest or scrub. They are most active at night, but also bask close to their burrow entrances by day. Activity is greatest in warm, wet weather (Walls, 1983).

Existing information (Crook, 1973; Newman, 1987a; Carmichael et al., 1989; Appendix 3) suggests that the following features provide ideal habitat for the long-term survival and reproduction of a population of about 1000 tuatara. This list is based primarily on knowledge of Cook Strait tuatara from Stephens Island, and to a lesser extent Northern tuatara and the Brothers tuatara.

- an area of land approximately 10 ha or greater (assumes an average density of 100 tuatara/ha or more; see below);

- coastal forest or scrub (preferably mahoe, pohutukawa, ngaio or taupata). A relatively open understorey without extensive groundcover is required for successful courtship;

- friable soil in which burrows can be dug;

- ambient air temperatures varying seasonally between about 5° and 28°C;

- generally high relative humidities with heavy rain at least every few weeks (standing water need not be present);

- a habitat free of introduced mammals;

- a diverse fauna of insects (preferably including tree wetas and *Mimopeus* beetles), other invertebrates, small lizards, and small nesting seabirds (particularly fairy prions or diving petrels) on which to feed;

- areas of open, sunny soil on northward-facing slopes in which to nest (preferably at least 0.5 m deep, with moist soil at temperatures fluctuating seasonally between about 8° and 27°C).

Some of these features can be compromised to some extent without necessarily preventing tuatara survival. For instance, several tuatara populations currently survive on islands <10 ha in area and presumably have done so since the last ice age ended about 10,000 years ago. However, because of the very small numbers of tuatara present, the security of these populations is not great. Tuatara also survive in sheep pasture on Stephens Island, showing that forest cover is not essential on some islands. However, tuatara densities are lower in such habitats, and activity and the range of food available is reduced (Carmichael et al., 1989; J.C. Gillingham, pers. comm.).

Density

Tuatara densities vary enormously (see Table 3 below) but densities in good habitat on rat-free islands are usually at least 100 tuatara/ha and often much higher. The enormously high density in remnant forest on Stephens Island probably results from two factors: (i) the extremely dense seabird fauna; and (ii) the presence of sheep pasture nearby, in which a large amount of tuatara nesting occurs. Densities are generally lower on kiore-inhabited islands than on islands without rats.

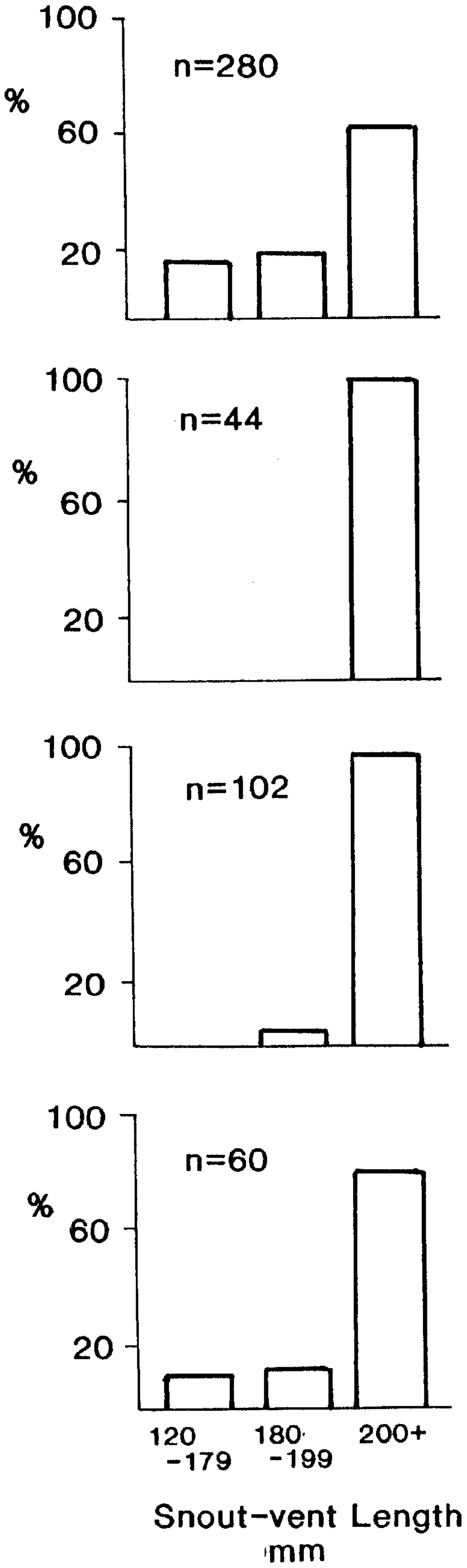
Table 3. Densities of tuatara in areas of suitable habitat on a range of islands.

ISLAND	HABITAT	INTRODUCED MAMMALS	TUATARA PER HECTARE	REFERENCE
Stanley	forest	kiore, rabbits	< 1	Daugherty et al. unpubl. obs.
Lady Alice	forest	kiore	approx. 100	D.G. Newman pers. comm.
			< 10	Daugherty et al. unpubl. obs.
Whenuakura	forest	house mice*	99	Newman, 1986
North Brother	windswept scrub		132	Thompson et al., 1992
Stephens	pasture	sheep	415-480	Crook, 1975; Carmichael et al., 1989
	forest	-	1420-2015	Newman, 1975b; Carmichael et al., 1989

* Norway rats subsequently appeared, and the tuatara population is probably extinct.

Feeding relationships

The only significant dietary studies on tuatara have been carried out on Stephens Island. These indicate that tuatara feed almost exclusively on small, moving prey items, including insects, spiders, isopods, earthworms, lizards and seabird eggs and chicks. Faecal samples showed that over 100 different prey items were taken and more than 54% of these were



1. No kiore

Density high except on Poor Knights (Mean density, where surveyed, > 400/ha)
Juveniles, small adults & large adults present

2. Endangered

Extremely low density (< < 1/ha)
No juveniles or small adults present

3. Threatened

Very low density (< 1/ha)
No juveniles, few or no small adults

4. Uncertain, depleted

Low density (< 10/ha)
Juveniles, small adults & large adults present

Figure 5. Percentage of Northern tuatara in three size-classes found during surveys in 1989-91 (Daugherty, Cree & Hay, unpubl.). Surveys were carried out in forested and open habitats known to be suitable for adult and large juvenile tuatara. The size-classes shown correspond roughly to large juveniles (120-179 mm SVL), small adults (180-199 mm SVL) and large adults (200+ mm SVL). Islands sampled in each group were: (a) Tawhiti Rahi, Aorangi, Aorangaia and Stack B (Poor Knights Group), Middle and Green (Mercury Group), Hongiora, Nga Hora, Ruamahua-nui and Ruamahua-iti (Aldermen Group), Karewa, Plate and Moutoki; (b) Stanley, Red Mercury, Cuvier and Little Barrier; (c) Coppermine, Whatupuke and Hen; (d) Lady Alice. Statistical tests (G-test, chi-square test) show that the size-class frequency distributions differ between (a) and (b) and between (a) and (c) with a probability of $P < 0.001$. (d) does not differ significantly from (a) but the difference is close to statistical significance ($0.1 > P > 0.05$).

insects (Walls, 1981). Large beetles (especially the darkling beetle *(Mimopeus opaculus))* were the most frequent and were probably preferentially selected. The remaining items identified by Walls (1981) were other invertebrates (20%), reptiles (4%), birds (4%), plant material (14%) and inorganic material (2%). Moller (1985) reported that in January, bird material made up 45-49% and insect material 23-45% by volume of faecal remains, with variation existing between forested and pasture habitats. However, figures derived from faecal samples do not provide any indication of how frequently any one prey item is consumed by an individual tuatara. Nor do they indicate the extent of size- and sex-related differences in diet. Juvenile tuatara for instance probably do not consume seabird chicks. On the basis of stomach pumping, Carmichael et al. (1989) observed that tuatara in forest on Stephens Island fed mainly on darkling beetles and tree weta, whereas those in pasture fed largely on isopods (slaters), craneflies and coleopterans. Geographic variation in diet of tuatara is also likely. For instance, some tuatara islands with low coastal scrub rather than forest (e.g. North Brother) appear to have no tree weta.

Adult tuatara have few if any natural predators. Large nesting seabirds such as Buller's shearwater *(Puffinus bulleri)* are aggressive toward tuatara (Newman, 1987a) but are unlikely to kill them. Australasian harriers *(Circus approximans)* take small adult tuatara from open habitats on Stephens Island. Extinct predatory birds such as the adzebill and the New Zealand raven may once have fed on tuatara (Holdaway, 1989). Predators of juvenile tuatara include kingfishers, and perhaps moreporks and gulls. Cannibalism occurs but is rare (Walls, 1981).

Relationships with seabirds

High densities of tuatara on offshore islands are dependent on the continued productivity of surrounding marine ecosystems. The petrels with which tuatara co-exist feed at sea and subsequently benefit tuatara in several ways (Ward, 1961; Crook, 1975). (1) They provide eggs and chicks on which tuatara feed. (2) They deposit nutrient-rich droppings and regurgitated stomach contents. These provide a food source for some invertebrates on which tuatara feed, and also favour plant growth that can then be utilised by other invertebrates on which tuatara teed. (3) They dig burrows, which helps aerate and distribute nutrients through the soil. Tuatara often live in unused petrel burrows (although they also dig their own).

Relationship with kiore

Kiore (Polynesian rats) were introduced to New Zealand by the Polynesians, who are thought to have arrived here about 1200-1300 AD (Anderson, 1992). Kiore have subsequently become established on many offshore islands. Crook (1973) was the first to provide evidence that kiorc had negative effects on tuatara. He observed that juvenile (<180 mm SVL) and small adult (180-199 mm SVL) tuatara were readily found on rat-free islands, whereas small adults were present at low frequency and juveniles were absent on the kiore-inhabited islands surveyed (Table 4). Crook suggested that kiore inhibit recruitment of juvenile tuatara.

Additional surveys during the 1960s-1980s have supported Crook's observations. Juvenile and small adult tuatara have been found on all rat-free islands where more than ten tuatara were found, collectively accounting for 22-79% of the sampled population. In contrast, on four kiore-inhabited islands (all in the Hen and Chickens Group), juveniles and small adults have rarely been seen, accounting for 0-15% of the sample (Table 4).

The most recent surveys (1988-91) visited all eight kiore-inhabited islands and obtained further compelling evidence for reduced densities and inhibition or failure of tuatara recruitment in the presence of kiore (Daugherty, Cree and Hay, unpubl.; Fig. 5). On kiore-free islands inhabited by northern tuatara, juvenile and small adult tuatara were readily seen, accounting for 38% of the sample (Fig. 5.1). On four kiore-inhabited islands, tuatara populations were relictual and in danger of extinction. Densities were extremely low (<<1/ha), juveniles and small adults were never seen, and several of the remaining large adults appeared lean and aged (Fig. 5.2). Three kiore-inhabited islands, (Whatupuke, Coppermine and Hen) had slightly higher though still reduced densities, and juveniles and small adults were seen only occasionally (Fig. 5.3). The eighth kiore-inhabited island, Lady Alice, had a low density of tuatara, although juveniles and small adults were present (Fig. 5.4).

Statistical tests (chi-square test, G test) show that the size-class frequency distributions in Fig. 5.2 and 5.3 differ greatly from that on the kiore-free islands in Fig. 5.1 (probability $P<0.001$). Although the difference in size-class frequency distribution between Lady Alice (Fig. 5.4) and kiore-free islands does not quite reach statistical significance ($0.1>P>0.05$), concern must also be felt for this population.

The surveys reported in Fig. 5 used the same search techniques and search habitats on all islands. The results for kiore-free islands and for Lady Alice show that juveniles and small adults can readily be sighted using these procedures. The results from Lady Alice are particularly instructive because they also demonstrate that juveniles and small adults show no convincing evidence of behavioural avoidance (e.g. increased secretiveness) in the presence of' kiore. Thus, the total inability to find juvenile and small adult tuatara on other kiore-inhabited islands almost certainly reflects a real absence of these size-classes.

In addition to the evidence from densities and size-class frequency distributions noted above, there is other evidence linking kiore with tuatara extinction:

- tuatara have already become extinct on at least three islands in the presence of kiore (Appendix 2).

- tuatara are absent from at least six other kiore-inhabited islands on which on biogeographic grounds they would be expected to be present (Crook, 1973; Whitaker, 1978; Cree, Daugherty and Hay, unpubl.).

Although direct observation of the interaction between kiore and tuatara is lacking (Craig, 1986), the circumstantial evidence indicating that kiore are detrimental to tuatara and can lead to their extinction is compelling (Crook, 1973; Whitaker, 1978; Cree and Thompson, 1988; Atkinson and Moller, 1990; Newman and McFadden, 1990a). Kiore probably prey on tuatara eggs (Cree and Thompson, 1988) and juveniles (Newman, 1988). Kiore also lead to depauperate faunas of the insects, lizards and small petrels on which tuatara feed. Direct experimental evidence of the interactions between kiore and tuatara would be difficult to obtain in any meaningful time-frame and has never seriously been sought. The most constructive and economical way of testing the hypothesis that kiore inhibit recruitment in tuatara is to remove kiore from several tuatara-inhabited islands, as proposed in this recovery plan (Hen and Chickens Group), and monitor the results. Recent removal of kiore from islands without tuatara in the Mercury Group led to rapid enhancement of lizard populations (Towns, 1991), and similar, though slower, recovery of moderately depleted tuatara populations could be anticipated under similar conditions.

The effect of kiore on different populations of tuatara is probably influenced by the time that kiore have been present, by the extent of habitat modification, by the size of the island and by the presence of other predators or competitors of tuatara (Newman and McFadden, 1990x). Variation in these factors could explain why juvenile and small adult tuatara are present on Lady Alice Island at higher frequencies than on other kiore-inhabited islands. It is conceivable that some tuatara islands received kiore as recently as 100 years ago (Whitaker, 1978) and that some of the remaining tuatara were alive at the time kiore first appeared.

For information on the impacts of kiore and rabbit eradication proposed in this recovery plan, see Appendix 8.

Reproduction

1. Cook Strait tuatara

Nothing is known about tuatara reproduction on the three Trios islands. However, intensive studies of reproduction have been made on Stephens Island, and the following summarises these observations (Schauinsland, 1898; Thilenius, 1899, Newman and Watson, 1985; Saint Girons and Newman, 1987; Castanet et al., 1988; Cree and Daugherty, 1988; Cree and Thompson, 1988; Cree et al., 1989, 1990 a,b, 1991c,d, 1992; Brown et al., 1989; Daugherty et al., in press b; Thompson, 1990; J.C. Gillingham, M.E. McIntyre and T. Miller, pers. comm.).

Female Reproductive Cycle. Females on Stephens Island take about 13 years to reach the size of sexual maturity (about 170-180 mm SVL). Nesting of the population occurs regularly each year between late October and mid-December, with the peak occurring during November. However, individual females lay eggs only once every 4 years on average. A few females have been recorded nesting two years apart, but none is known to have nested in consecutive years. Age and nutritional condition are probably important influences on how frequently a female reproduces.

The low frequency of nesting in female tuatara is a result of both a slow rate of egg yolk production (vitellogenesis) and a slow rate of egg-shelling. Females incorporate yolk gradually into their ovarian follicles over several years. In the year that nesting occurs, each female mates in late summer (January-March), ovulates within 1-2 months, and carries eggs in her oviducts until nesting the following spring. Egg-shelling occurs gradually throughout winter. The duration of vitellogenesis of a single clutch (about 3 years) and of egg-shelling (6-8 months) are longer than known in any other reptile.

In spring, gravid females (those containing eggs in their oviducts) migrate up to 200 m, perhaps further, to preferred nesting areas. When Stephens Island was still forested late last century, females moved out of the forest to nest on open cliff tops, but following lighthouse construction females quickly took advantage of vegetable gardens and tracks in which to nest. Today, large numbers of females nest in a few highly popular areas of sheep pasture.

Each female may spend several weeks at the nesting area. Females often begin digging in one site and then abandon it for another, sometimes taking over diggings abandoned by other females. Females also dig up nest sites containing eggs laid by other females. Completed nest diggings are 10-50 cm deep and are separate from residence burrows. Oviposition of about 11 eggs occurs on a single night and the female then returns to the nest each night for up to a week to fill it with soil and grass and defend it from other females. Females sometimes also remain with their nests by day, sheltering in long grass alongside.

The choice of unforested sites for nesting seems to be related to warmer soil temperatures. Females do not nest in forest on Stephens Island, and eggs placed in experimental nests in the forest, where soil temperatures are cooler than in the pasture, do not hatch. In natural nests in the pasture, eggs take about 11-16 months to hatch, and about 42% hatch successfully. Higher incubation success has been achieved during artificial incubation in the laboratory but is highly dependent on temperature; in moist laboratory substrates (-100 to -400 kiloPascals), eggs hatch successfully at 18-22°C with up to 79% hatching success, but do not hatch successfully at 15° or 25°C. The eggs are soft-shelled (leathery) and absorb water during development. In natural nests, eggs are about 4 g at laying and about 10 g or more at hatching. Research is underway to establish whether sex is determined by incubation temperature, although preliminary results suggest that this is unlikely (M.B. Thompson, pers. comm.).

The eggs hatch during spring-summer and hatchlings are extremely vulnerable to desiccation and overheating. During the first few months they are diurnal, sheltering among clumps of grass and under logs. They gradually move to long grass at the forest margins, and at about 1 y of age they begin burrowing and become nocturnal. By about 120 mm SVL the juveniles are readily seen in the same habitat and at the same time as adults.

Male Reproductive Cycle. Males become mature at about 180 mm SVL on Stephens Island but probably obtain little opportunity to mate until reaching about 240 mm SVL or more. Mating occurs during January-March, and males are territorial during this time. In general, large adult males occupy larger territories than smaller adult males and thus have greater access to females, which are resident within a male's territory. During territorial disputes, males engage in "face-off" displays, chases and fighting. Males often receive bites to the face or neck during fights, but these are probably rarely if ever fatal.

During territorial displays and courtship, male tuatara inflate their crest and throat skin. Visual signals arc probably highly important in both displays and courtship. During courtship, the male slowly circles the female in a slow, stiff-legged walk. If the female is receptive, the male eventually mounts her, and copulation lasts about an hour. Unreceptive females disappear down burrows.

Males show a pronounced annual cycle in sperm production and in the concentration of male sex hormone (testosterone) in the blood. Mature sperm are produced during about November-March, and testosterone is elevated during the same period. Testosterone probably stimulates production of mature sperm, as well as aggressive and mating behaviour. Males that appear old and lean may fail to show high testosterone levels or sperm production during summer and are probably reproductively inactive. Male tuatara are unlike other temperate-zone reptiles in that the testes do not become fully regressed during winter; instead the early stages of sperm production are present year-round.

2. Northern Tuatara

Less is known about reproduction of Northern tuatara than for tuatara on Stephens Island. Females on islands in the Mercury, Hen and Chickens and Poor Knights Groups probably do not nest each year (Newman and Watson, 1985; Cree et al., unpubl. obs.). On several rat-inhabited islands (Lady Alice, Whatupuke, Coppermine, Hen), measurements of blood sex hormone levels suggest that the proportion of females nesting is similar to that on rat-free islands close by. However, no evidence of nesting has been found on Stanley Island (Cree et al., unpubl. obs.) . This may simply reflect the low number of females examined (eight in 1989, seven in 1990). An alternative explanation is that age and/or lack of food have inhibited reproduction. On Stanley Island the recent presence of rats and rabbits has been associated with a depauperate fauna of insects, lizards and nesting sea-birds.

Measurements of blood testosterone levels in males on several islands (Tawhiti Rahi, Aorangi, Stack B, Lady Alice, Whatupukc, Coppermine, Hen, Middle, Green, Red Mercury, Ruamahua-iti, Ruamahua-nui, Hongiora and Nga Hora) showed that males were in breeding condition during February-early April and that most males appeared reproductively active (Cree et al., unpubl. obs.). On Stanley Island, there was a trend towards lower testosterone levels in March 1989 than on other islands in the Mercury and Hen and Chickens groups. This trend was not statistically significant, but suggests that reproductive activity in the males then remaining on Stanley Island may have been declining and should be monitored closely in the future. Measurements of blood testosterone levels on Karewa, Moutoki and Plate Island during January suggest that most males are reproductively active (Cree et al., unpubl. obs.). The two males caught on Little Barrier in February 1991 also had elevated testosterone levels typical of other islands at this time (Cree et al., unpubl.).

3. Brothers Tuatara

Female tuatara on North Brother Island nest in unvegetated, northward-facing areas during November, the average clutch size is 6.5 eggs, and probably only about 20% of females nest each year (Cree et al., 1991b). Measurements of blood testosterone levels in January suggest that most males are reproductively active (Cree et al., unpubl. obs.).

Table 4 Frequencies with which tuatara in three size classes were found in surveys of islands where > 10 tuatara were found during 1960-1986. The size class < 180 mm SVL corresponds approximately to juveniles, 180-199 mm SVL approximately to small adults and >200 mm SVL approximately to large adults.

Status	Island or island group	Year of survey	Total sample size	< 180 mm	180-199mm	> 200 mm	Reference
Kiore-free	Stephens	1970-71	237	26	19	55	Crook (1973)
	Trios and North Brother	1970-71	103	23	27	50	Crook (1973)
	Green and Middle	1970-71	93	7	23	70	Crook (1973)
	Karewa, Plate, & Moutoki	1970-71	154	27	43	30	Crook (1973)
	Aldermen Group (except Hongiora)	1970-71	129	37	32	69	Crook (1973)
	Stephens	1960	1224	60		40	Dawbin (1982)[1]
		1980	1105	44		56	Dawbin (1982)[1]
	Stephens	1975	415	21.2	11.8	67.0	Newman (1980)
	Whenuakura (mice present)	1980	110	14	19	67	Newman (1986)
	Ruamahua-iti	1986	60	57	22	21	Newman and McFadden (1990b)
	Hongiora	1986	43	7	15	78	
Kiore-inhabited	Coppermine	1968	43	0	2.3	97.7	A.H. Whitaker (pers, comm.)
	Chickens Islands	1970-71	127	0	3	97	Crook (1973)
	Lady Alice	1979	106	2.8	0	97.2	Newman (1980)
	Whatupuke	1979	20	5.0	0	95.0	Newman (1980)
	Coppermine	1979	41	0	14.6	85.4	Newman (1980)
	Hen	1984	17	0	0	100	I. McFadden (pers, comm)[2]

Notes:

[1] Percentages read from graphs in original publication, so are approximate.

[2] Two small animals that were probably juvenile were seen but not caught.

APPENDIX 2

OFFSHORE ISLANDS ON WHICH TUATARA ARE REPORTED TO HAVE BECOME EXTINCT WITHIN HISTORIC TIMES[1]

ISLAND	AREA[2] (ha)	COMMENTS[3]
Mokohinau Group (3 islands)	75 (Fanal) 56 (Burgess) plus one smaller	Said by Sandager (1890) to be present on two islands in the group. Reported on Burgess Island by Hamilton (1913), on Fanal Island in 1922 (Crook, 1970) and in the Knights Group in the 1930s (Ray Walters, pers. comm. in McCallum, 1980). Kiore are present on Fanal, Burgess and most other islands in group.
Slipper	247	Reported 1935 (Crook, 1970). Date of extinction unknown. Norway rats are present.
Shoe	53	Reported 1935 (Crook, 1970). Date of extinction unknown. Rabbits and Norway rats are present.
Whenuakura	2	Still surviving in 1981 in presence of house mice, but became extinct between 1981 and 1984 when Norway rats appeared (Newman, 1986).
Motiti (Flat)	691	Apparently still present in 1800s (Buller, 1877). An unknown species of rat is present.
Whale	170	Mair (1873) implied that tuatara were already extinct here, whereas Buller (1894) stated that they were abundant. Sheep present 1800s-1940s; cats once present (date of eradication not stated); goats eradicated by 1977; rabbits and Norway rats eradicated in 1980s (Smale and Owen, 1990).
East (Whangaokino)	13	Still present in 1870s (Buller, 1877, 1878). Many "sent away" (collected?) during building associated with lighthouse operations (Hamilton, 1913). Became extinct in presence of kiore and cats, probably in early 1900s (Moors, 1980).
Somes	25	Present in 1842 when rabbits were present (Knox, 1869). Extinct prior to 1968 when ship rats appeared (ship rats were eradicated in 1989).

1 Tuatara are also reported or implied to have been present on the following islands, but less information is available about the causes of extinction: Great Barrier Island and the Chetwodes (Buller, 1894); the Moturoa Islands off the Karekare Peninsula in Northland; small islands off Mayor Island (Hamilton, 1913; Falla, 1960); and Hauturu in the Whangamata Group (Newman, 1986). Tuatara bones have recently been found in a midden on Mana Island (Michelle Horwood, pers. comm.), but it is not certain whether they were resident here or taken here by the Maori from elsewhere for food.

2 Island areas from Taylor (1989), or New Zealand Geographic Board (Somes Island).

3 Presence of rats from Atkinson (1986).

APPENDIX 3

STATUS OF CURRENT TUATARA POPULATIONS

ISLAND	AREA[1] (ha)	RESERVE STATUS AND LAND TENURE[2]	MANAGEMENT AUTHORITY[3]	HUMAN ACTIVITIES AND INTRODUCED ANIMALS[4]	NO. TOE-CLIPPED TUATARA[5]	LIKELY POPULATION SIZE[6]	DATE OF LAST SURVEY	PRESENCE OF TUATARA ≤180 mm SVL[7]
POOR KNIGHTS:								
Tawhiti Rahi	163.0	Nature Reserve	DoC Northland, MOT	Maori occupation till early 1800s. Lighthouse beacon	63	Hundreds or low thousands	1989 (VUW/DoC)	Yes
Stack B	0.8	Nature Reserve	DoC Northland	None	2	Few tens	1989 (VUW/DoC)	Yes
Aorangi	110.0	Nature Reserve	DoC Northland	Maori occupation till early 1800s. Pigs 1700s-1936	26	Hundreds or low thousands	1989 (VUW/DoC)	Yes
Aorangaia	6.3	Nature Reserve	DoC Northland	None	1	Few tens	1989 (VUW/DoC)	None found
Motu Kapiti	1.25	Nature Reserve	DoC Northland	None	2	Few tens	1991 (DoC)	None found
HEN AND CHICKENS:								
Lady Alice (Marotiri)	155.0	Nature Reserve	DoC Northland	Once Maori-occupied. Kiore. Saddlebacks introduced 1971	about 250	Up to about 1000	1989 (VUW/Doc)	Yes
Whatupuke	101.9	Nature Reserve	DoC Northland	Once Maori-occupied. Kiore. Saddlebacks introduced 1964	33	Low hundreds	1989 (VUW/DoC)	One found 1979. None found in 1989.
Coppermine	79.5	Nature Reserve	DoC Northland, MOT	Once Maori-occupied. Copper mining 1800s; prospecting 1960s. Lighthouse beacon. Kiore. Saddlebacks self-introduced from Whatupuke	81	Low hundreds	1989 (VUW/DoC)	"Small animals" seen in 1965, but no juveniles seen in surveys in 1968, 1979 or 1989.
Hen (Taranga)	500.0	Nature Reserve	DoC Northland, MOT	Once Maori-occupied. Lighthouse beacon. Stitchbirds introduced 1980-1981. Little-spotted kiwi introduced 1988-1989	29	Low hundreds	1989 (VUW/DoC)	Two nests and two possible juveniles seen in 1984. No juveniles seen in 1989.
Little Barrier	3083.0	Nature Reserve	DoC Auckland	Once Maori-occupied. Logging in 1800s. Kiore. Four species of birds introduced and established 1900-1989 (North Island brown kiwi, kakapo, saddleback, kokako). Wildlife Officer 1897-present. Pigs, dogs and cats eradicated	-	Few tens? (4 removed to captivity)	February 1991 (Whitaker & Daugherty, 1991)	None found during 1991 survey.
Cuvier	170.0	Nature Reserve and Lighthouse Reserve	DoC Waikato, MoT	Lighthouse-keepers 1889-1981. Sheep and cattle till 1960s. Goats eradicated 1961. Cats eradicated 1964. Saddlebacks	introduced 1968. Stitchbirds introduced	1982. Parakeets re- introduced 1974	-	Less than 10? (6 removed to captivity)

ISLAND	AREA[1] (ha)	RESERVE STATUS AND LAND TENURE[2]	MANAGEMENT AUTHORITY[3]	HUMAN ACTIVITIES AND INTRODUCED ANIMALS[4]	NO. TOE-CLIPPED TUATARA[5]	LIKELY POPULATION SIZE[6]	DATE OF LAST SURVEY	PRESENCE OF TUATARA ≤180 mm SVL[7]
MERCURY GROUP:								
Middle	13.1	Scenic Reserve (but managed as if Nature Reserve)	DoC Waikato	Probably visited by Maori	34	Low thousands	1989 (VUW/DoC)	Yes
Green	2.3	Scenic Reserve (but managed as if Nature Reserve)	DoC Waikato	Probably visited by Maori	41	Hundreds	1989 (VUW/DoC)	Yes
Stanley (Kawhitihu)	99.5	Nature Reserve	DoC Waikato	Once Maori-occupied. Kiore, Rabbits. Saddlebacks introduced 1968	17	Few tens (15 removed to captivity, at least 6 may be alive on island).	1989 (VUW/DoC)	None found in surveys in 1989 or 1990
Red Mercury	225.0	Scenic Reserve (but managed as if Nature Reserve)	DoC Waikato	Once Maori-occupied. Kiore. Saddlebacks introduced 1966, little spotted kiwi 1983	3	Few tens (11 removed to captivity, at least 2 may be alive on island.)	1989 (VUW/DoC)	None found in surveys in 1989, 1990 or 1991
ALDERMEN GROUP:								
Ruamahua-nui	32.5	Nature Reserve	DoC Waikato	Once occupied or visited by Maori	10	Hundreds	1989 (VUW/DoC)	Yes
Ruamahua-iti	25.0	Nature Reserve	DoC Waikato	Once occupied or visited by Maori	17	Hundreds	1989 (VUW/DoC)	Yes
Hongiora	16.3	Nature Reserve	DoC (Waikato)	Once occupied or visited by Maori	5	Low hundreds	1989 (VUW/DoC)	Yes
Nga Horo (previously known as Hernia)	3.4	Nature Reserve	DoC Waikato	Probably visited by Maori	3	Tens-low hundreds	1989 (VUW/DoC)	None found in survey in 1989
Half	1.5	Nature Reserve	DoC Waikato	Probably visited by Maori	-	Tens-low hundreds?	1971 (Crook, 1973)	Yes
North Stack	0.7	Nature Reserve	DoC Waikato	Probably visited by Maori	-	Tens	1971 (Crook, 1973)	Yes
Middle Chain Stack	0.4	Nature Reserve	DoC Waikato	Probably visited by Maori	-	Tens? (presence of tuatara based on faeces only)	1971 (Crook, 1973)	?
Karewa	5.0	Wildlife Sanctuary	DoC Bay of Plenty	Probably visited by Maori in past	31	Hundreds	1989 (VUW/DoC)	Yes
Smaller northern part of Plate Island (Motunau)	0.8	Wildlife Sanctuary	DoC Bay of Plenty plus Maori owners	Visited by Maori in past. Muttonbirding by owners still allowed with DoC permit	-	Hundreds	1988 (DoC Bay of Plenty)	Yes

ISLAND	AREA[1] (ha)	RESERVE STATUS AND LAND TENURE[2]	MANAGEMENT AUTHORITY[3]	HUMAN ACTIVITIES AND INTRODUCED ANIMALS[4]	NO. TOE-CLIPPED TUATARA[5]	LIKELY POPULATION SIZE[6]	DATE OF LAST SURVEY	PRESENCE OF TUATARA ≤180 mm SVL[7]
Larger southern part of Plate Island (Motunau)	2.8	Wildlife Sanctuary	Doc Bay of Plenty plus Maori owners	Visited by Maori in past. Muttonbirding by owners still allowed with DoC permit	18	Hundreds	1989 (VUW/Doc)	Yes
Moutoki (Rurima Rocks)	0.8	Wildlife Refuge	DoC Bay of Plenty plus Maori owners	Landing is legal without DoC permit, but requires permission of Maori owners. Owners can visit without permit	30	About 300-400	1989 (VUW/DoC)	Yes
North Brother Island	4	Wildlife Sanctuary and Lighthouse Reserve	DoC Nelson-Marlborough, MoT	Lighthouse keepers 1877-1990	112	300+	1991 (VUW/DoC)	Yes
TRIOS:								
Middle Trio	20	Wildlife Sanctuary (Maori-owned)	DoC Nelson-Marlborough plus Maori owners	Visited by Maori in past	59	Low thousands	1988 (VUW/DoC)	Yes
North Trio	1	Wildlife Sanctuary (Maori- owned)	DoC Nelson-Marlborough plus Maori owners	None	3	Few tens	1988 (VUW/DoC)	Yes
South Trio	2	Wildlife Sanctuary (Maori- owned)	DoC Nelson-Marlborough plus Maori owners	None	3	Few tens	1988 (VUW/DoC)	Yes
Stephens	150	Wildlife Sanctuary, Lighthouse Reserve	DoC Nelson-Marlborough, MOT (subject to Maori land claim)	Lighthouse keepers 1894-1989. DoC officer 1989-present. Cats 1890s-1910. Yellow-crowned parakeet introduced 1970 (no longer present). Guinea fowl removed 1975; Antipodes I. parakeet introduced 1986 (removed 1988). Stock grazed entire island 1890s-1951. One or more pigs once briefly present. Cattle removed 1988; dog removed 1989. Sheep still graze about 30% of the area above cliffs.	About 2000	At least 30,000 (Newman, 1982a)	Density estimated in 1988 (Carmichael *et al.*, 1989)	Yes

(see next page for notes)

Notes to Appendix 3:

1 Source: Taylor (1989) or where no data available in Taylor (1989), from Newman (1982b). Note that data are given separately for the two parts of Plate Island, which are separated by a gap about 2 m wide.

2 Source: Taylor (1989).

3 DoC = Department of Conservation
MoT = Ministry of Transport

4 Sources: Atkinson (1973, 1990)
McCallum (1981)
Moore (1973)
A. Cree (unpubl. obs.).

Many tuatara islands appear to have had fires in the past, and some have had extensive collections of tuatara, but because of incomplete information for all islands these have not been separately listed.

5 Toe-clip records held by D.G. Newman (DoC S&R) for some animals on Lady Alice Island and Stephens Island, and by A.H. Whitaker for some animals on Coppermine Island. Remaining records held by A. Cree, C.H. Daugherty and M.E. McIntyre (VUW).

6 Estimated from data provided by the following sources:

Crook (1973) and A.H. Whitaker (pers. comm.): Half, North Stack and Middle Chain Stack

Daugherty *et al.* (unpubl. obs.): rough estimates based on capture frequency and apparent density during surveys in 1988-1989 for all islands except Little Barrier, Cuvier, Half, North Stack, Middle Chain Stack and the northern part of Plate.

Newman (1982b and pers. comm.): Estimates for Stephens Island and Lady Alice Island.

Newman and McFadden (1990b): Hongiora, Ruamahua-iti.

Thompson *et al.* (1992): North Brother Island

7 Sources: Atkinson (1968): Coppermine Island, surveyed 1965.

Crook (1973): all islands except North Stack, Middle Chain Stack, Red Mercury, Stanley, Little Barrier and Poor Knights Islands.

Daugherty *et al.* (unpubl. obs.): all islands except Half, North Stack, Middle Chain Stack and the northern part of Plate.

P. Jansen (pers. comm.): northern part of Plate

I. McFadden (pers. comm.): nests and possible juveniles seen on Hen Island 1984.

Newman (1980): Lady Alice, Whatupuke and Coppermine, surveyed 1979.

Newman and McFadden (1990b): Hongiora and Ruamahua-iti, surveyed 1986.

A.H. Whitaker (pers. comm.): Coppermine, surveyed 1968; North Stack, surveyed 1971.

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