Brown Teal (Pateke) diet and its consequences for releases

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Abstract

This thesis addresses three research needs central to the conservation of the Brown Teal (*Anas chlorotis*): diet, release and post-release techniques for captive-bred teal, and identifying cause of death.

The diet of wild Brown Teal was studied using gut and faecal analysis, and feeding observations. Teal had a very diverse diet for a dabbling duck: 78 taxa were recorded, including terrestrial, freshwater and marine invertebrates, fungi, and terrestrial and freshwater vegetation. Despite having the bill morphology of a typical dabbling duck, wild Brown Teal were observed prising open the shells of cockles to extract the flesh. Oystercatchers (*Haematopus* spp.) are the only other birds known to use this feeding method.

Wild Brown Teal had a more varied and higher fibre diet than captive teal. The digestive tract is morphologically flexible, and differences between captive and wild diets can cause differences in birds' gut morphology. The size and mass of the digestive organs (proventriculus, gizzard, small intestine, caeca, rectum and liver) of 57 wild, 7 captive and 4 captive-bred released teal were compared. Captive Brown Teal had much shorter and lighter small intestines and caeca than wild teal. These differences could reduce the ability of captive-bred teal to efficiently digest a wild diet. Increased fibre and diversity in the captive diet, plus supplementary feeding post-release, are recommended.

Little is known of the causes of mortality in captive-bred Brown Teal released to the wild. A method to detect starvation using the wing fat content of Brown Teal was developed. Lipids were extracted from four outer wing components of 17 intact teal carcasses. The lipid content of each component reflected the birds' nutritional condition (based on body mass and size, and visible fat). Lipids were also extracted from the outer wing components of seven partial Brown Teal carcasses, six of which were from captive-bred released birds. All of the released teal were found to have been in very poor nutritional condition, identifying starvation as the cause of death. Starvation was also identified as the cause of death for six wild juvenile teal from Great Barrier Island. Human-induced changes to the landscape may limit food availability for wild teal, particularly during droughts.

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Ngati Rehua gave consent for me to work on Pateke from Aotea. Kevin Evans facilitated access to the captive birds for wing fat analysis and gut morphology chapters. The following captive institutions supplied birds: Otorohanga Kiwi House, Willowbank Wildlife Park, Wellington Zoo and Ron Munroe (via Kevin Evans). Kevin Evans and Neil Hayes were prompt to answer any questions I might have about captive management. Alan Tennyson and Noel Hyde of Te Papa, and Brian Gill of Auckland Museum, made the Pateke in their care available to me. Thanks also to Raewyn Empson who provided access to the Karori Wildlife Sanctuary birds. Colin Webb's expertise in seed identification and willingness to assist were greatly appreciated.

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Preface

Each of the research chapters in this thesis has been written as a paper, two of which are in press. This preface gives references for the two chapters soon to be published and explains the roles of the contributing authors to each of the research chapters and Appendix 2. For each chapter I did the majority of the work, planned and carried out the research, and analysed and wrote up the results. My supervisors were Ed Minot and Ian Henderson of Massey University, and John Innes of Landcare Research.

Chapter 2 The diet of North Island Brown Teal

Co-authors:
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Phil F Battley, Department of Mathematics and Statistics, Otago University.

Ian Henderson assisted with invertebrate identification for gut and faecal samples, as well providing editorial and statistical advice. Colin Webb identified the seeds found in the gut samples. Phil Battley accompanied me during some field work on Great Barrier, assisted with initial dissections, helped identify bivalves and estimate shell length from hinges, and provided editorial advice.

Chapter 3 Cockle-opening by a dabbling duck, the Brown Teal

Co-author: Phil F Battley, Department of Mathematics and Statistics, Otago University.

Phil and I both observed teal feeding on cockles. Phil helped measure bivalve densities at Akapoua Bay, and gave editorial advice. This chapter is in press:

Moore, S.J. and P.F. Battley. 2003. Cockle-opening by a dabbling duck, the Brown Teal. Waterbirds 26(3): 331-334.

Chapter 4 Digestive organ morphology of wild and captive Brown Teal and implications for releases

Co-author: Phil F Battley, Department of Mathematics and Statistics, Otago University.

Phil Battley assisted with the initial carcass dissections, and later provided statistical and editorial advice.

Chapter 5 The use of wing remains to determine condition before death in Brown Teal

Co-author: Phil F Battley, Department of Mathematics and Statistics, Otago University.

Phil Battley assisted with initial dissections. He demonstrated how to use the Soxhlet apparatus, and helped set it up for the first batch of wing components, later Phil provided statistical and editorial advice. This chapter is in press:

Moore, S.J. and P.F. Battley. 2003. The use of wing remains to determine condition before death in Brown Teal (*Anas chlorotis*). Notornis 50: 133-140.

Appendix 2. Pateke/Brown Teal Monitoring, Okiwi Basin, Great Barrier Island, August – November 2001.

Co-author: Phil F Battley, Department of Mathematics and Statistics, Otago University.

This appendix was originally written as a report to the Department of Conservation, as part of a contract position we shared on Great Barrier Island.

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Introduction

"Brown Teal are New Zealand's least known endangered bird, forgotten outside Northland and Auckland. They are rarer than any kiwi, with more threats than kaka, no safe populations such as those of yellow-eyed penguins on southern islands, and still declining rapidly."

Innes, Jansen and Baucke, 2000

For more than 130 years, biologists have observed the decline of a New Zealand endemic dabbling duck, once widespread throughout the North, South, Stewart and Chatham Islands (Hayes and Williams 1982), the Pateke or Brown Teal (*Anas chlorotis*). In addition to lakes and rivers, Brown Teal formerly occupied a wide range of habitats including "coastal dunes, lagoons, and swamps, inland forests as diverse as wet rimu forests and seasonally dry matai forests in low rainfall areas, to montane silver beech and dry mountain beech forests up to 800 m altitude" (Worthy 2000).

Their gradual disappearance from the Canterbury region of the South Island was first noted in the 1860s, when Brown Teal were described as "very much scarcer of late years than we can remember it" (Potts 1869). Soon, the decline was also noticeable in the North Island and Kirk (1895) noted that "where large numbers were formerly seen only a comparatively few individuals can be found to-day". Brown Teal became extinct on the Chatham Islands early in the 20th century (Fleming 1939). Although Brown Teal gained legal protection from recreational hunters in 1921 (Marchant and Higgins 1990), the decline continued and subsequent publications track the disappearance of local populations in the North Island (Balham 1952; McKenzie 1971; McKenzie 1979; Parrish and Williams 2001; Williams 2001). Now, based on flock counts, around 300 Brown Teal remain in Northland (Neill 2003) and 620 on Great Barrier Island (Howard and Jamieson 2003); a 1999 survey using trained dogs located eight teal in Fiordland (Willans 2001).

The Brown Teal was not formally recognised as an endangered species until 2000 (BirdLife International 2000), but management had been initiated some 40 years earlier. In the 1960s the New Zealand Wildlife Service established a captive population at Mt Bruce Native Bird Reserve from wild Brown Teal caught on Great Barrier Island (Roderick 1969; Hayes and Williams 1982). In 1968, following two trial releases into existing teal populations in Northland (for which no published data are available), nine captive-bred and one wild-bred Brown Teal were released onto Kapiti Island, near Wellington (Williams 1974). This was the first, and one of the very few, successful releases of Brown Teal, as it resulted in the establishment of a small self-sustaining population (Williams 1974; Howell 1985). Members of Ducks Unlimited New Zealand began captive-rearing Brown Teal for release to the wild in the 1970s (Hayes and Williams 1982), both to re-establish teal in areas where they had become locally extinct and to reinforce dwindling wild populations. Captive management techniques were fine tuned, and by 1994 more than 1,500 Brown Teal had been reared in captivity (Hayes 1994).

The vast majority of releases of captive-bred Brown Teal were not successful at establishing new populations (Table 1.1). Furthermore, few releases were adequately monitored, so little information was gained on the fate of released teal. Suspected cause of death was recorded for only 57 of the 1,818 Brown Teal released between 1967 and 1999; of these 38 (67%) were killed by predators, and 15 (26%) shot by recreational hunters (Table 1.2). The reliability of the predation data is questionable, as differentiating scavenging from predation and determining which of multiple potential predators was responsible based on feeding sign alone are notoriously difficult (Larivière 1999). The proportion of hunters that sent bands recovered from illegally shot birds to the New Zealand National Banding Office is also unknown. Around half of the released birds reported shot had moved 18 - 93 km from their release sites, suggesting that dispersal contributed to the failure of releases to establish local populations (Table 1.2).

Attempts to reinforce existing Brown Teal populations and establish new ones by releasing captive-bred birds continued in 2000, 2001 and 2002. Teal were released on Kapiti and Mana Islands and Karori Wildlife Sanctary in the Wellington Region, and on Tiritiri Matangi Island in the Hauraki Gulf. All four sites are free of introduced predators (apart from mice, *Mus musculus*, in Karori; Empson 2001), and are closed to recreational hunters. All birds were pinioned or wingclipped prior to release to limit dispersal. The carcasses of fourteen released teal were recovered within two months of release (Tiritiri Matangi Island, 3; Kapiti Island, 6; Mana Island, 2; Karori Wildlife Sanctuary, 3; Stamp 2000; R. Stamp pers. comm.; Empson 2001; Appendix 2.1).

TABLE 1.1. Summary of Brown Teal (*Anas chlorotis*) releases 1967 - 2000.

Release site	No. releases	Years	No. teal	Result	Refs
Hokianga Harbour, Northland	2	1993 - 1994	110	Declined, disappeared	1, 2
Kaeo River, Northland	1	1986	21	Declined, disappeared	3
Kaihoka Lakes, Nelson	1	1978	20	Declined, disappeared	4
Kaikokapu, Manawatu	1	1983	60	Declined, disappeared	5
Kapiti Is., Wellington	3	1968 - 2000	23	Still present	6, 7
Karori, Wellington	1	2000	8	Still present	8
Kerikeri Farm Park, Northland	1	1986	4	Declined, disappeared	9
Lake Koputara, Manawatu	6	1974 – 1982	130	Declined, disappeared	4, 10, 11
Lake Omanuka, Manawatu	11	1968 – 1974	28	Declined, disappeared	12
Mana Is., Wellington	1	2000	10	Still present	6
Matakana Is., Bay of Plenty	3	1980 – 1981	69	Declined, disappeared	13
Matapouri, Northland	2	1984 – 1985	86	Declined, disappeared	14, 15
Mimiwhangata, Northland	8	1984 – 1991	321	Wild popn. present	16-18
Moturoa Is., Northland	3	1985 - 1994	22	Still present in 1999	19, 20
Nga Manu, Wellington	5	1983 – 1985	65	Declined, disappeared	21
Parorerahi, Northland	3	1997 – 1999	51	Declined, disappeared	22
Pukepuke Lagoon, Manawatu	9	1973 - 1982	216	Declined, disappeared	4, 5, 10
Puketi, Northland	5	1995 – 1999	48	Declined, disappeared	23-25
Purerua, Northland	7	1989 – 1992	328	Declined, disappeared	20, 26-29
Takou Bay, Northland	1	1985	45	Declined, disappeared	30
Tawharanui, Auckland	1	1995	8	Declined, disappeared	31
Te Anau, Fiordland	4	1984 – 1989	45	Declined, disappeared	12, 32
Tiritiri Matangi Is., Auckland	4	1987 – 1990	12	Maintained by releases	33
Trounson, Northland	2	1996 – 1997	17	Declined, disappeared	34
Urupukapuka Is., Northland	4	1988 – 1994	25	Declined, still present	20, 29, 35
Waikino, Northland	1	1994	30	Declined, disappeared	2, 20
Warkworth	1	1967	10	Declined, disappeared	12
Whangaruru	1	1995	?	Declined, disappeared	36
Whau Dam, Whangarei	2	1971-1972	6	Declined, disappeared	12
TOTAL	94		1818		

[1]Wilks 1994a;[2]Wilks 1994b;[3]Hayes 1987;[4]Hayes 1981;[5]Anon. 1983;[6]Stamp 2000;[7]Williams 1969; [8]Empson 2001;[9]Munn 1986;[10]Anon. 1982;[11]Williams 1976;[12]N. Z. National Banding Scheme;[13]Garrick & Gill 1982; [14]Anon 1985a; [15]Anon 1985b; [16]Anon 1986; [17]Anon 1989a; [18]Wilks 1992; [19]Asquith 1999, [20]Dumbell 2000; [21]P. McKenzie pers. comm.; [22]Miller, 1999; [23]Miller 1996; [24]Miller & McManus 1997; [25]Evans 2000; [26]Anon 1989b;[27]Anon 1991;[28]Anon 1992;[29]Wilks 1993; [30]Anon 1985c; [31]Greene 1996; [32]Rasch 1992; [33]Veitch 1994; [34]Anon 1997b; [35]Anon 1988; [36]Beachman 1996.

TABLE 1.2. Causes of death attributed to captive-bred released Brown Teal (*Anas chlorotis*), 1966 - 1999. Comments for shot birds refer to distances between release and recovery sites.

Cause of death	Release Site	Year	No. of birds	Comment	Ref.
Predation	Hokianga	1993	3	1 by harrier	1, 2
	Mimiwhangata	1986	1		3
	Mimiwhangata	1991	4	Mustelid	4
	Parorerahi	1998	3	2 by stoat	5
	Parorerahi	1999	4	Dog	6
	Pukepuke	1979	2	Cat	3
	Pukepuke	1981	1		3
	Pukepuke	1982	9	Mustelid	3
	Puketi	1995	2	Rat and cat or dog	7
	Takou Bay	1985	1	Cat	3
	Tawharanui	1995	6	Mustelid or cat	8
	Trounson	1996	1	Cat?	9
	Trounson	1997	1	Mammalian predator	10
Shot	Hokianga	1993	1		2
	Kaikokapu	1983	1	93 km	3
	Lake Koputara	1977	2	0 km	3
	Mimiwhangata	1986	1	8 km	3
	Pukepuke	1980	1	93 km	3
	Pukepuke	1981	2	18, 0 km	3
	Pukepuke	1982	4	0, 0, 0, 0 km	3
	Pukepuke	1983	1	23 km	3
	Purerua	1989	1	40 km	3
	Te Anau	1989	1	74 km	3
Motor vehicle	Matakana Island	1981	1		3
Trapped	Nga Mana	1983	1		11
Starvation	Puketi	1995	1	Very thin 4 days prior to death	12
Poisoned	Tiritiri Matangi	1993	1	Kiore eradication	13

[1]Dumbell 1994; [2]Wilks 1994b; [3]N. Z. National Banding Scheme; [4]Fitzgerald 1991; [5]Hoskins 1998; [6]Miller 1997; [7]Fitzgerald 1996; [8]Greene 1996; [9]Anon. 1997a; [10]Anon. 1997b; [11]P. McKenzie pers. comm,; [12]Wilson 1996; [13]Veitch 1994.

Necropsies determined that two teal had starved, one had suffered a broken leg prior to death, and a fourth had become entangled in vegetation on release (Empson 2001; Appendix 1). Causes of death for the other ten birds were unknown, as only partial carcasses, or for two birds piles of feathers with a transmitter nearby, were recovered.

Although captive breeding may result in a self-sustaining captive population, the biological fitness of captive animals for reintroduction is often poor (Cade and Temple 1994), and reintroductions of captive-bred animals are more likely to fail than those using exclusively wild-caught animals (Griffith *et al.* 1989). As captive populations become increasingly domesticated, their genetic and phenotypic makeup becomes progressively more different from that of wild animals, and culturally-transmitted behaviours may be lost (Snyder *et al.* 1996). Hessler *et al.* (1970) noted behavioural deficiencies in captive-reared released Ring-necked Pheasants (*Phasianus colchicus*), which were very unwary and could be seen standing and walking on roads for prolonged periods of time, and readily showed themselves rather than hiding in available cover. Similar observations have been made of captive-bred released Brown Teal (Wilson 1996; S. Moore unpubl. data), although this may have been due to the birds' poor nutritional condition.

Captive breeding can sometimes preempt other potentially better techniques for species recovery; productive captive breeding programmes can give a false impression of species security, and are often more politically expedient than addressing the problems facing wild populations (Snyder *et al.* 1996). Although Brown Teal flourished in captivity, other aspects of management received less attention, and critical information such as the cause of the continuing decline in wild populations, and feeding ecology in the wild remained largely unknown more than 30 years after captive breeding had been achieved (Innes *et al.* 2000). Detailed ecological studies of species' requirements are the foundation for sound conservation science and the key to accurately identifying cause(s) of decline (Simberloff 1988; Caughley and Gunn 1996). Ensuring that there is enough food to support and conserve an endangered species is an important component of this (Caughley and Sinclair 1994), and requires knowledge of the species' diet and methods of assessing nutritional condition.

This thesis has three aims: (1) to describe the diet of wild North Island Brown Teal; (2) to evaluate whether dietary differences between captive and wild birds result in morphological differences in the digestive system of the captive birds that could affect their ability to digest effectively in the wild; (3) to test a method of assessing body condition from partial carcasses. Chapter 2 combines feeding observations, gut content analysis and faecal analysis to identify the diet of Brown Teal in Northland, Hauraki Gulf Islands and the Wellington Region. Chapter 3 describes how teal feeding on intertidal flats on Great Barrier Island open cockles (*Austrovenus stutchburyi*). This unusual behaviour may be culturally transmitted and therefore unknown to captive-bred birds. Chapter 4 compares the gut morphology of captive-bred and wild Brown Teal and shows that captive teal have significantly shorter small intestines and caeca than wild birds. These differences are likely due to low-fibre diets Brown Teal are fed in captivity and would cause nutritional stress in captive-bred released birds. Chapter 5 demonstrates that the fat content of outer wing components (often all that is left in depredated/scavenged carcasses) can be used to estimate body condition at death. This technique holds great promise for determining whether poor nutrition is a factor in deaths often otherwise attributed to predation. Chapter 6 discusses the outcomes of this thesis, and makes suggestions for improved management of captive and released Brown Teal.

Although it is disappointing that Brown Teal have reached such a precarious status and are perilously close to extinction, there are still grounds for hope that the species will survive in the North Island. The New Zealand Department of Conservation has greatly intensified efforts to determine causes of and arrest the decline in two of the remaining wild North Island populations (Anon. 2001). A second aim of the Department is to establish new populations via releases of birds (Anon. 2001), and, with careful management, the previous successes in captive breeding Brown Teal may contribute to this. Greater knowledge of Brown Teal ecology and identifying the factors limiting the survival of released captive-bred teal can only increase the likelihood of the recovery programme succeeding.

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2

The diet of North Island Brown Teal

S.J. Moore, I.M. Henderson, C.J. Webb & P.F. Battley

Abstract

The diet of wild North Island Brown Teal (*Anas chlorotis*) was studied using feeding observations, gut and faecal analysis. Teal had a very diverse diet for a dabbling duck: 78 taxa were recorded, including terrestrial, freshwater and marine invertebrates, fungi, and terrestrial and freshwater vegetation. The most frequently occurring foods were Cyperaceae seeds, White Clover leaves, cased caddisfly larvae, beetles, earthworms, gastropods and bivalves. Although contemporary Brown Teal include introduced species in their diet, human-induced changes to the New Zealand landscape may limit the availability of suitable foods, particularly during droughts.

Introduction

Effective conservation management requires knowledge of species' ecology, including diet. Without this basic information, cause of decline may be incorrectly diagnosed, delaying successful management of the species (Caughley and Gunn 1996). The Brown Teal or Pateke (*Anas chlorotis*) is an endangered dabbling duck, endemic to New Zealand (BirdLife International 2000). There have been no definitive studies on Brown Teal diet (Marchant and Higgins 1990), and much of the existing dietary information is speculative and poorly documented (Innes *et al.* 2000), hampering management efforts.

Brown Teal are generally shy, crepuscular or nocturnal birds which, in prehistoric times, occupied a very wide range of habitats, including areas of dense podocarp and beech forest far from open water (Worthy 2002). Most of the existing Brown Teal diet information has arisen from observations of foraging birds, but their secretive nature tends to bias feeding observations towards open habitats where they can be watched undisturbed, such as tidal flats and agricultural pastures, without necessarily enabling the observer to identify food items taken (Table 2.1).

TABLE 2.1. Available information on Pateke or Brown Teal (*Anas chlorotis*) diet.

Habitat	Behaviour and food items
Pasture	Teal feed on paddocks at night, especially in the winter months or in damp conditions[1, 2, 3, 4, 5]. Most food items not identified, but believed to include ostracods, mosquito larvae and *Chironomus* sp. from puddles[1]; slugs, snails, worms[5]; insects [2, 5, 6]; and seeds[1, 6]. Observed diurnally feeding on caterpillars in February[7].
Coastal flats & tidal creeks	Teal feed in tidal areas nocturnally and/or at low tides, especially during dry summer months[1, 2, 7, 8, 9, 10, 11]. Food items not identified but believed to include foraminifera, ostracods, polyzoans, and nematodes[1]; amphipods, isopods, caddis-like larvae in cases[7]; and crabs[6, 7].
Rocky coast	Teal seen feeding on small black mussels, *Xenostrobus pulex*, on rocks at low tide on Great Barrier Island.[9] Droppings containing mussel shells found at a reported teal roost site, Takou River mouth, Northland (R. Parrish, Department of Conservation, pers. comm.)
Freshwater	On Great Barrier teal observed upending, dabbling and diving (up to 2 feet deep), food items not identified but animals present included fairy shrimp, snails, isopods, water boatmen and fish.[7] Observed feeding diurnally on spire snails and *Lemna* sp. in a Northland river[12].

[1] Gravatt 1966; [2] McKenzie 1971; [3] Cometti 1975; [4] Dumbell 1987; [5] Barker 1998; [6] Sanderson 1945; [7] Weller 1974; [8] D. Barker 1999; [9] Heather 1980; [10] Oliver 1930; [11] Weller 1975; [12] Edgar 1971.

Two methods commonly used to determine waterfowl diets are analysing droppings or contents of the digestive tract. The advantages of faecal analysis are that it is non-invasive and samples are often readily available, but it is biased towards hard, indigestible items (Hartman 1985). Similarly, gizzard content analysis is biased towards harder to digest items such as seeds. Analysis of oesophageal contents from birds that have recently fed is recommended as the most accurate way to obtain dietary information (Swanson and Bartonek 1970; Briggs *et al.* 1985), although it usually involves sacrificing the study animals.

In this study we describe North Island Brown Teal diet using gut contents analysis, faecal analysis and our observations of foraging birds. As all the birds used in our gut content analysis were accidental casualties, many of which had been hit by motor vehicles in agricultural or residential areas of Great Barrier Island, basing our study on gut contents alone would have biased the study towards teal that had recently fed near roads at night. By including foraging observations and faecal analysis we could gather information on Brown Teal in coastal and forested areas, and reduce the bias towards developed areas of Great Barrier Island.

Methods

Foraging observations

From August 2001 - January 2002, we sporadically observed Brown Teal feeding in the wild on Great Barrier (36°18'S, 175°34'E), Kapiti (40°50.5'S, 174°56'E) and Mana (41°05'S, 174°47'E) islands using a 20-45x spotting scope, binoculars and the naked eye. Night vision equipment (ITT Night Mariner with infra-red filtered Petzl headlamp) was also trialed but found to be unsuitable, as it did not provide clear vision at a close enough range. All of the birds observed on Great Barrier were wild-bred birds, and those on Kapiti and Mana were captive-bred birds that had been released.

Gut content analyses

Brown Teal are a protected species and this research was carried out under permit from the New Zealand Department of Conservation. All carcasses used were from birds found dead by members of the public or staff from the Department of Conservation and Karori Wildlife Sanctuary between 1991 and 2003. Wild Brown Teal were sourced from Great Barrier Island, Little Barrier Island (36°20'S, 175°11'E), Mimiwhangata and Helena Bay in Northland (35°43'S, 174°40'E), and Parekura Bay in Northland (35°15'S, 174°14'E). Captive-bred birds that had been released to the wild were sourced from Kapiti Island and Karori Wildlife Sanctuary (41°18'S, 174°44'E). In our analysis, we only include birds that died in the wild.

Most carcasses had been stored frozen, apart from three captive-bred released birds which had been necropsied and stored in formalin, and the sole Parekura Bay bird's gizzard contents which were sent to us stored in ethanol. Ducklings were distinguished from juveniles and adults by the presence of down, small body size and incomplete flight feathers. A small number of birds was aged by the presence (juvenile) or absence (adult) of the bursa or because they were banded as known-age juveniles, but otherwise adult-sized juveniles and adults could not be reliably discriminated throughout the year so are pooled in this study. Most carcasses were sexed by plumage, inspection of the gonads, or the presence (male) or absence (female) of the bulla, a bony enlargement at the base of the trachea. Some carcasses were badly damaged or decomposed and could not be sexed, or had only a partial digestive tract remaining.

The entire (or remaining) digestive tract was removed from each carcass and tied around the top of the oesophagus and lower end of the rectum to prevent the loss of gut contents. The oesophagus, proventriculus, and gizzard were cut open and the contents scraped out and retained in pre-weighed labeled containers (oesophageal and proventricular contents were combined). The fresh contents were weighed (±0.01 g) and refrozen.

Gut contents were thawed, placed in a petri dish with 70% ethanol and examined under a binocular microscope against a white background (to facilitate detection of dark objects) and then a black one (to facilitate detection of pale objects such as slug shell). Seeds and fruits were separated from other food items for identification by C.J.W. Reference specimens of animal remains were stored in 70% ethanol. Identifications were based on the following: pasture plants, Healy 1976; molluscs, Winterbourn 1973, Child 1974, Powell 1979, G.M. Barker 1999, Parkinson 1999; crabs, Dell 1963, Melrose 1975; aquatic insects, Winterbourn *et al.* 2000; terrestrial insects, CSIRO 1991, Crowe 2002; other invertebrates, Barth and Broshears 1982.

Our priority was to analyse the contents of the oesophagus and proventriculus combined, where items were more intact, to enable identification of soft foods such as oligochaetes. Accordingly, we analysed the oesophagus and proventriculus contents of all wild Brown Teal available to us. We also analysed a subsample of the gizzards (all ducklings, all Northland and Little Barrier Brown Teal, and some Great Barrier Island adult birds). Any digestive tracts that did not contain a minimum of four small identifiable items (such as seeds, or a recognisable part of an invertebrate) or one large item (such as an earthworm) were excluded from analysis. Under this criterion one Northland and twelve Great Barrier Island teal were excluded.

Our analysis included 45 Brown Teal from Great Barrier Island (oesophagus and proventriculus, 40; gizzard, 8); 2 from Little Barrier Island (oesophagus and proventriculus, 2; gizzard, 2), 9 from Northland (oesophagus and proventriculus, 6;

gizzard, 9), 2 from Kapiti Island (oesophagus and proventriculus, 2), and 3 from Karori Wildlife Sanctuary (oesophagus and proventriculus, 2; gizzard, 1). All of the ducklings (3) and juveniles (6) included in our gut analysis were from Great Barrier Island. We had slightly more male (31) than female (24) Brown Teal; six birds were too damaged or immature to sex. We assigned teal to one of four seasons based on their recovery date (summer Dec – Feb; autumn Mar – May; winter June – Aug; spring Sep - Nov), apart from three Great Barrier birds whose recovery dates had not been recorded.

Percentages of terrestrial, marine, and freshwater plants and animals were visually estimated to the nearest 5%. The frequency of occurrence (percentage occurrence; Swanson *et al.* 1974) of each food item was obtained by dividing the number of birds that consumed that particular food item by the number of birds in the sample. Food items were grouped into 22 broad categories for analyses (Appendix 2.1), which were performed in PC-Ord version 4.0 (McCune and Mefford 1999). We used Multi-Response Permutation Procedures (MRPP) to test for differences in the composition of gut contents by age (ducklings plus known juveniles compared with other birds), sex, season and site (comparing three categories: Great Barrier, Northland, and the forested sites of Little Barrier Island, Karori Wildlife Sanctuary, and Kapiti Island). When a significant difference was detected we used Indicator Species Analysis to identify the diet items that differed between the groups of birds, and carried out Detrended Correspondence Analysis (DCA) to compare the groups visually.

Faecal analysis

Brown Teal were observed feeding or roosting in coastal habitats at four sites on Great Barrier Island (Akapoua Bay, Awana Estuary, Karaka Bay, and Burrill's Drain near Okiwi Estuary) and one site in Northland (Owai River near Helena Bay). Immediately after the birds had moved away, the area was searched for droppings which were scraped off the sediment surface and stored frozen. Great Barrier Island droppings were collected between 18 September 2001 and 12 January 2002. Northland droppings were collected on 4 January 2002. Droppings were also collected from Brown Teal on Little Barrier Island in February 2002 and from the roost site of a single female at Karori Wildlife Sanctuary in June 2001.

Droppings were thawed and mixed with water in a petri dish and sorted under a binocular microscope. Intact bivalve hinges and other identifiable fragments such as seeds, insect larvae, and gastropod shell fragments were separated from the rest of the sample. The polychaete *Pectinaria australis* was identified by its characteristic golden paleae (bristles surrounding the mouth). Hinge lengths of Pipi (*Paphies australis)* and Common Cockles (*Austrovenus stutchburyi*) were measured under a binocular microscope with an eye-piece micrometer.

We collected reference samples of 21 Pipi from Awana Estuary and 8 Common Cockles from Akapoua Bay and Karaka Bay, sites on Great Barrier where teal had been observed foraging minutes earlier. Shell lengths of the larger bivalves were measured with calipers; other shell and hinge lengths were measured under a binocular microscope with an eye-piece micrometer. These measurements were used to make predictive equations to estimate total shell length from hinge remains (Dekinga and Piersma 1993). For Pipi, the strongest relationship was a log-transformed linear regression: log length = 2.208 + log hinge x 1.133 (R^2 = 0.980, $F_{1,19}$ = 951.775, $P <$ 0.001). For cockles, untransformed hinge length gave the best fit: length = 0.044 + 11.607 x hinge (R^2 = 0.994, $F_{1,6}$ = 1026.466, $P < 0.001$). We used these predictive equations to calculate the shell length of Pipi and cockles ingested by Brown Teal.

Results

Feeding observations

Although we observed wild Brown Teal feeding on 41 occasions on Great Barrier Island between 22 August 2001 and 12 January 2002, we could confidently identify their food items on only eight occasions, all during daylight hours (Table 2.2). All of these observations were of Brown Teal that had apparently become used to humans and were unusually confiding. Although most observations were of single pairs or a pair with juveniles, groups of adults were seen feeding on clover (Karaka Bay, 18 birds; Awana, 5 birds) or dabbling in shallow estuarine (Owai River near Helena Bay, 19 birds; Awana Estuary, 23 birds) and coastal waters (Karaka Bay, 10 birds). Feeding was observed seven times on Kapiti Island, but no food items were identified; of 19 feeding observations on Mana Island, food items were only identified on five occasions (Table 2.2).

Great Barrier Island residents reported three additional dietary items to us; strawberries from an Okiwi garden (G. Burke pers. comm.), grapes from an Okiwi orchard (H. Mabey pers. comm.) and earthworms eaten by a mother duck and three fluffy ducklings in a Port FitzRoy garden (A. Cox pers. comm.).

TABLE 2.2. Food items identified during observations of foraging wild Brown Teal. GBI refers to Great Barrier Island. Asterisks denote that both ducklings and adults were observed feeding; all other observations are of adults only.

Food item	Location	Date	Time
Common Cockle *Austrovenus stutchburyi*	Akapoua Bay, GBI.	4 Nov 2001	1545
	Karaka Bay, GBI.	5 Nov 2001	1700
	Akapoua Bay, GBI.	18 Nov 2001	1645*
	Akapoua Bay, GBI.	28 Nov 2001	1350*
Potamopyrgus pupoides & probable *P. estuarinus*	Akapoua Bay, GBI.	7 Nov 2001	1740*
	Akapoua Bay, GBI.	20 Nov 2001	1708*
White Clover leaves *Trifolium repens*	Karaka Bay, GBI.	12 Jan 2002	1350
	Awana Estuary, GBI.	12 Jan 2002	1730
Cocksfoot *Dactylis glomerata*	Mana Is.	9 Sep 2001	1645
Pond weeds *Lemna minor* & *Azolla filiculoides*	Mana Is.	8 Oct 2001	1528
	Mana Is.	9 Oct 2001	1730
	Mana Is.	15 Nov 2001	1410
Sea Aster leaves *Aster subulatus*	Mana Is.	15 Dec 2001	1615

Gut content analyses

More than 65 taxa were identified from gut contents; most Brown Teal had eaten both animal (87% of all individuals) and plant material (89% of individuals; Table 2.3). On average, teal diet comprised 58% terrestrial plant (including Cyperaceae nuts), 18% terrestrial animal, 2% freshwater plant, 9% freshwater animal, 11% marine animal and 2% fungi. A large number of Cyperaceae nuts were found (up to eight species per gut), but only two genera (*Uncinia* and *Carex*) were identified. Some birds had eaten large quantities of a single item. The oesophagus and proventriculus of an adult male Brown Teal from Great Barrier Island contained a large amount (13.45 g) of yellow fungal fruiting bodies (identified by P. Novis, Landcare Research). The oesophagus of another Great Barrier teal, run over in late November, contained only White Clover (*Trifolium repens*; 525 leaves, 5.81 g). A third Great Barrier Island bird had 99 *Potamopyrgus antipodarum* in its oesophagus and proventriculus, and a further 722 in its gizzard. The gizzard of one Northland teal contained 866 seeds.

Like adults, ducklings and juveniles had consumed a wide range of foods (Table 2.3). One tiny piece of spider cuticle was found in the oesophagus of a medium-sized fluffy duckling (111 g), but was not included in frequency analysis due to the small amount of food the duckling contained.

Bivalve remains were found in 11% of guts analysed (six birds from Great Barrier Island and one from Kapiti Island). Three teal, including the Kapiti Island bird, had fed on tiny freshwater bivalves (< 4 mm long). The other four, including one juvenile, had consumed marine bivalves, Pipi and Common Cockles . The predicted shell length of these bivalves, based on hinge measurements, ranged from 2.8 - 16.2 mm for Pipi, and 5.1 - 12.0 mm for Common Cockles (Table 2.4).

Using MRPP, we did not detect any differences in diet in relation to age (P = 0.336), sex (P = 0.606) or season (P = 0.289), but there appeared to be a difference between sites (P = 0.040). Indicator Species Analysis identified differences in the number of terrestrial arthropods (P = 0.032) and unidentified seeds (P = 0.035), both of which were more common in Brown Teal from Northland.

The first two components of the DCA ordination explained little of the variance between sites (using relative Euclidean distance Axis 1 R^2 = 0.250, Axis 2 R^2 = 0.076; Fig. 2.1). The first axis reflects the gradient from terrestrial (far left), to freshwater and then marine food items. Given that many individual teal had fed in several of these habitats, and that the habitat of some items, such as very small bivalves, could not be determined, it is not surprising that so much variance remains unexplained. Brown Teal from Great Barrier Island had the greatest variety in their diet (wider spread on both axes).

Faecal analysis

Twenty nine Brown Teal faecal samples from seven sites were examined (Table 2.5). At all sites only adult teal were present, apart from Akapoua Bay where a single dropping each was collected from two 7-week old ducklings. One of the duckling droppings contained only *Potamopyrgus* sp. shell fragments; the other contained approximately 90% animal remains (amphipod and other unidentified arthropod cuticle) and 10% plant matter (seed fragments). Although most items in faecal samples were damaged, several small snails, seeds, the Foraminifera, and three chironomid larvae had stayed relatively intact during their passage through the teals' digestive tracts. Most samples from the four coastal Great Barrier sites and Helena Bay contained gastropod and bivalve shell fragments.

TABLE 2.3. Percentage occurrence of food items from the upper digestive tracts of Brown Teal (*Anas chlorotis*). Where known, habitat is either: freshwater, F; marine or estuarine, M; or terrestrial, T. Nthld refers to the Northland region, and includes birds from Mimiwhangata, Helena Bay, and Parekura Bay in the Bay of Islands. Kapiti+Karori refers to 2 captive-bred teal released on Kapiti Island and 3 captive-bred teal released in Karori Wildlife Sanctuary; all other birds were wild-bred. Subtotals for higher classification levels are in bold. A single asterisk denotes a food item found in the digestive tract of a juvenile teal, double asterisks a food item found in a duckling, triple asterisks both juvenile and duckling (see Methods for definitions).

Food item		Habitat	Great Barrier *n* = 45	Nthld *n* = 9	Little Barrier *n* = 2	Kapiti+ Karori *n* = 5	Total n = *61*
ANIMAL			**82*** **	**89**	**100**	**100**	**87**
Oligochaeta			**16**	**11**			**13**
Gastropoda			**36*** **	**44**		**80**	**39**
	Unidentified gastropod		20***	33		40	23
	Whelk	M	4				3
	Zeacumantus lutulentus	M	2				2
	Nodolittorina antipodum	M	2**				2
	Potamopyrgus spp.	M/F	2				2
	Potamopyrgus antipodarum	F	4*			40	7
	Potamopyrgus pupoides	M	7*				5
	Cantareus aspersus	T	2	11			3
	Slug (*Milax gagates*?)	T	9**				7
Bivalvia		M/F	**13***			**20**	**11**
Unidentified arthropod			**24** **	**44**	**50**	**20**	**28**
Arachinidae			**13** **				**10**
	Acarina (mites)	F/T	13**				10
	Opiliones (harvestmen)	T	2				2
Crustacea			**13** **				**10**
	Ostracod	M/F	4				3
	Isopod		7**				5
	Amphipod		4**				3
	Halicarcinus varius (crab)	M	2				2
Diplopoda	Millipede	T	**4** **				**3**
Insecta			**33*** **	**89**	**100**	**60**	**46**
	Unidentified insect		11***	33		60	18
Lepidoptera	Caterpillar	T	4**		50		5
	Unidentified moth	T			50		2
	Unidentified chrysalis	T				20	2
	Psychidae (bag moth)	T	2				2
Plecoptera			2				2
Trichoptera	*Oxyethira albiceps* larva	F	7*				5
	Oeconesus maori larva	F				20	2
	Olinga sp. larva	F	4*	22			7
	Pycnocentrodes sp. larva	F	2*	11			3
	Hudsonema sp. larva	F		11		20	3
	Helicopsyche sp. larva	F		11			2
Phasmidae	Stick insect	T		11			2
Hemiptera	Hemiptera (bug)	T	2				2

TABLE 2.3. Continued

Food item		Habitat	Great Barrier $n = 45$	Nthld $n = 9$	Little Barrier $n = 2$	Kapiti Karori $n = 5$	Total $n = 61$
Coleoptera	Unidentified adult	T	7**	67	50		16
	Unidentified larva	T/F	2				2
	Scirtidae larva (marsh beetle)	F	2				2
	Hydrophilidae larva	F	2				2
	Staphylinidae adult	T/F	2				2
	Weevil larva	T	2**				2
	Weevil adult	T		11			2
Diptera	Unidentified larva		2				2
	Unidentified pupa		2				2
	Unidentified adult	T	2				2
	Ephydridae larva (shore fly)	M/F	2*				2
	Empididae larva (dance fly)	T/F	2	11			3
	Simuliidae larva (sand fly)	F			50		2
	Unidentified tipulid larva	F/T	4				3
	Paralimnophila sp. larva	F	2				2
	Zelandotipula sp. larva	F	2	11		20	5
	Chironomus sp. larva	F	2				2
	Culicidae larva (mosquito)	F	4				3
FUNGI			**2**				**2**
PLANT			**84*****	**100**	**100**	**100**	**89**
	Algae	M/F	4				3
	Moss	T/F	7*	11	50		8
	Trifolium repens leaves	T	20***				15
	Grass blade	T	4				3
	Unidentified vegetation		13	22	50	20	16
	Potato peeling	T	2				2
	Seeds + fruits	T	73***	100	50	100	79
Seeds + fruits:							
Cyperaceae	*Uncinia* sp.	T	4				3
	Carex sp.	T/F	2				2
	Other Cyperaceae spp.	T/F	42**	56		40	43
Graminae	Grass	T	4				3
Restionaceae	*Apodasmia similis*	T	2				2
Sparganiaceae	*Spargamium subglobosum*	T	2				2
Rubiaceae	*Coprosma* spp.	T	4		50		5
Rutaceae	*Melicope simplex*	T	2				2
Epacridaceae	*Leucopogon fascicularis*	T	4				3
Ranunculaceae	*Ranunculus* sp.	T	4				3
Oxalidaceae	*Oxalis corniculata*	T	2				2
Rosaceae	*Rubus* sp.	T				20	2
Polygonaceae	*Persicaria decipiens?*	T	2**				2
	Naturalised spp. endocarps	T	7		50		7
	Naturalised legumes	T	9	22			10
	Unidentified		44***	44	50	100	49

TABLE 2.4. Estimated shell lengths of Pipi (*Paphies australis*) and Common Cockles (*Austrovenus stutchburyi*) consumed by Brown Teal (*Anas chlorotis*). Shell lengths (mm) were estimated from lengths of hinges found in Brown Teal droppings and digestive tracts. Dates shown are when droppings were collected or carcasses found. **Mean** (range, *n*) shown for all samples that contained > 3 measurable hinges, for other samples all values shown.

Site	No. of samples	Date	Pipi	Cockle
Akapoua Bay	4 faecal	Nov 2001	**5.0** (2.6 - 6.7, 7)	**4.5** (2.4 – 7.4, 11)
Awana Estuary	6 faecal	Jan 2002	**4.7** (1.1 – 10.8, 128)	-
Burrill's Drain	2 faecal	Nov 2001	**4.4** (1.7 – 8.4, 19)	**3.6** (2.8 – 4.4, 5)
Karaka Bay	2 faecal	Nov 2001	**4.4** (1.2 – 8.8, 25)	-
Karaka Bay	1 gut	Mar 2003	14.4	-
Port FitzRoy	1 gut	May 2000	**6.7** (3.2 – 16.2, 26)	**8.1** (5.1 – 12.0, 10)
Tryphena	1 gut	Nov 2000	**4.7** (2.8 – 7.8, 30)	-
Tryphena	1 gut	Mar 2003	4.2, 4.2, 4.6	-
Helena Bay	3 faecal	Jan 2002	**2.9** (1.1 – 5.1, 28)	**4.0** (1.8 – 14.7, 41)
Total			**4.7** (1.1 – 16.2, 267)	**4.6** (1.8 – 14.7, 67)

The Pipi was the most common bivalve found in faecal samples (17 of 29 samples) and intact hinges indicated shell lengths from 1.1 – 10.4 mm had been consumed (Table 2.5). Remains of Common Cockles were found in 12 samples; hinge lengths indicated shells from 1.8 – 14.7 mm in length had been consumed (Table 2.5).

Discussion

North Island Brown Teal fed on a wide range of plants and animals in terrestrial, freshwater, estuarine and coastal environments. As well as dabbling for small food items, Great Barrier Island teal have developed ingenious methods for feeding on bivalves (Heather 1980; Chapter 3) and have expanded their diet to include introduced White Clover, a relatively high protein, low fibre food (Thomson 1984). Statistically, there was little difference in the diets between the sites included in our study (Great Barrier Island, Little Barrier Island, Northland, Kapiti Island, Mana Island and Karori Wildlife Sanctuary). However our sample sizes for all sites, except Great Barrier, were

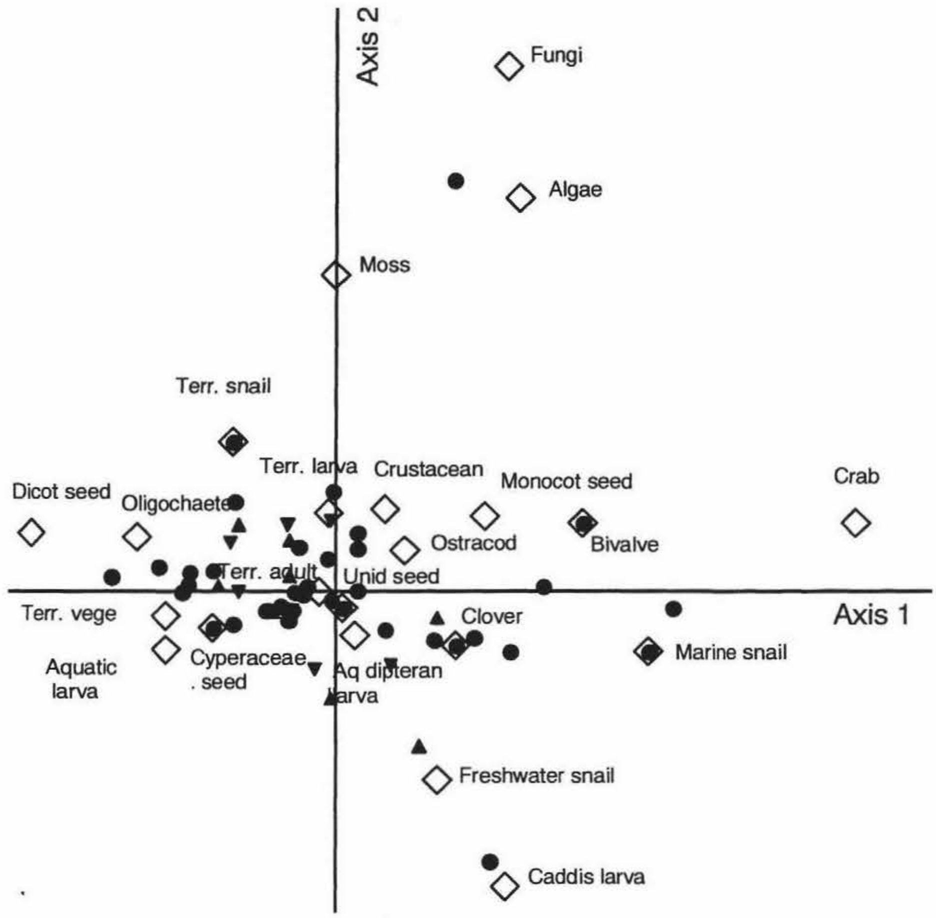

FIGURE 2.1. Relative positions of diet items and individual teal on the first two axes of Detrended Correspondence Analysis ordination for site and diet. Hollow diamonds, food items; circles, Great Barrier Island birds; upwards pointing triangle, Northland birds; downwards pointing triangles Little Barrier Island, Kapiti Island, and Karori Wildlife Sanctuary birds.

small, and it is likely that differences exist due to local food availability and perhaps cultural transmission of specialised feeding behaviour. Similarly, differences between sexes, seasons, and age classes were not found, but subtle differences are likely, due to seasonal food availability, and requirements for nutritionally demanding events such as structural growth, egg production, and moult.

Each of the methods used in this study (recording foraging behaviour, and analysing gut contents and droppings) detected food items missed by the others. Gut content analysis was the most productive method, allowing the identification of large numbers of small fruits, seeds and invertebrates (65 of the 78 taxa recorded).

TABLE 2.5. Number of Brown Teal (*Anas chlorotis*) faecal samples containing identifiable food items in each category. Great Barrier Island sites are: a, Akapoua Bay; b, Awana Estuary; c, Burrill's Drain, Okiwi Estuary; d, Karaka Bay; all of which are marine localities. Asterisks denote items found in duckling faeces.

	Site	Great Barrier				Helena Bay,	Little	Karori
		a	b	c	d	Northland	Barrier	
	No. of samples	6	6	2	5	8	1	1
ANIMAL								
Gastropoda	Unidentified gastropod		1	1	2	2		
	Whelk	2						
	Zeacumantus sp.				1			
	Potamopyrgus spp.	1*	1		2	4		1
	Cats eye, Turban shell				1			
	Amalda sp.				1			
Bivalvia	Unidentified bivalve					1		
	Austrovenus stutchburyi	4	2	2	1	3		
	Nucula sp.	4			2			
	Paphies australis	4	6	2	4	3		
Polychaeta	*Pectinaria australis*	1						
Unidentified arthropod		1*	1		1	1	1	
Crustacea	Unidentified crustacean	3			2			
	Amphipod	1*			1			
	Ostracod					1		
Insecta	Chironomid larva					1		
	Mosquito larva					1		
	Zephlebia sp. (mayfly)							1
	Aoteapsyche sp. (caddis)							1
Foraminifera			5			1		
PLANT	Seeds	2*			2	4		
	Leafy green vegetation		1		1	4	1	
	Flower sepals + stalk					1		

Foraging observations identified plant foods on Mana Island (a site for which no gut samples were available), which would have been very difficult to recognise in droppings. Foraging observations also alerted us to Brown Teal's propensity to feed on bivalves (Chapter 3). Faecal analysis confirmed the importance of small bivalves and other marine molluscs in the diet, and was the only method that detected Ephemeroptera (mayflies), a polychaete and Foraminifera. While it is unlikely that Foraminifera contribute to the teal's energetic requirements, they, like mollusc shell, may provide nutrients needed for egg production.

Each method also had its own shortfalls. Although on numerous occasions, we observed teal dabbling in shallow coastal water where small bivalves were abundant, and also observed teal foraging amongst short grasses and forbs where isopods and slugs were present, without gut and faecal analysis, we could not have confirmed that these items were being consumed. Faecal analysis identified a limited number of foods, partly because of the small number of samples analysed, but also because the remains of many foods (such as oligochaetes) would have been unrecognisable under a 40x binocular microscope. Much of our gut content information was derived from the contents of the oesophagus and proventriculus (52 analysed), rather than the gizzard (20 analysed). The exceptions to this are the nine Northland birds, all of which had their gizzards analysed, but only six of which had an oesophagus or proventriculus suitable for inclusion in our study. Although we did find some soft, easily digestible foods such as tipulid larvae and oligochaetes in the gizzards, we also recorded many seeds, which may account for the diet of Northland birds having a higher proportion of unidentified seeds than that of birds from any other site. Briggs *et al.* (1985) noted that gizzard analysis can lead to an overestimation of the importance of seeds in waterfowl diets. However, all of the Northland oesophagi and proventriculi examined contained seeds (some also contained fleshy fruits), so these gizzard samples may in fact provide an accurate indication of the importance of seeds in their diet.

Cyperaceae seeds were found in the digestive tracts of Brown Teal from all sites apart from Little Barrier Island, and are eaten by many other species of dabbling duck including Grey Teal (*A. gibberifrons*), Mallard (*A. platyrhynchos*), Grey Duck (*A. superciliosa*) and Pink-eared Duck (*Malacorhynchus membranaceus*; Balham 1952; Goodrick 1979; Briggs *et al.* 1985). Similarly, Polygonaceae and Ranunculaceae seeds are also recognised as important food sources for other waterfowl, which help spread the seed (Balham 1952; Coffey and Clayton 1988). Brown Teal also ate foods atypical of dabbling ducks; marine bivalves are more commonly eaten by sea ducks such as steamerducks, eiders and scaup, than dabbling ducks (del Hoyo *et al.* 1992). While aquatic invertebrate larvae such as *Oxyethira albiceps*, *Pycnocentrodes* sp., *Olinga* sp., *Helicopsyche* sp., *Chironomus* sp., *Zephlebia* sp. and *Aoteapsyche* sp. are important components of the diet of Blue Duck (*Hymenolaimus malacorhynchos*: Wakelin 1993; Veltman *et al.* 1995). The Brown Teal's ability to remove flesh from large cockles is shared only with oystercatchers (Chapter 3). Brown Teal forage on a wide range of terrestrial foods, causing Weller (1974) to suggest that they fill the ground-feeding niche normally occupied by quail or pheasants, as well as that of dabbling ducks.

The Brown Teal's broad diet reflects the variety of foraging techniques used. On Great Barrier Island, we observed teal dabbling in shallow coastal or estuarine water, then flying to short pasture where they resumed foraging, either plucking clover leaves or delving around the bases of the plants, presumably for invertebrates. Teal feeding on *Potamopyrgus* spp. appeared to vacuum the small snails off the substrate. Heather (1980) observed Brown Teal rapidly vibrating their mandibles to loosen groups of mussels *Xenostrobus pulex*, then macerate the mussels in the bill, before swallowing them. Weller (1974) observed teal diving 0.6 m deep for food in a stream pool, and also observed them jumping up with an outstretched neck to eat caterpillars from the tops of plants.

Although we identified a wide range of food items, Brown Teal diet would once have been much broader. The distribution of subfossil remains and information published over the last 130 years reveal a marked decline in the abundance and distribution of Brown Teal (Potts 1869; Williams 2001; Worthy 2002). We were unable to gather information on the diet of Brown Teal in the South Island, although it is likely a tiny population remains in Fiordland (8 wild adult Brown Teal were found during a survey using trained dogs in 1999; Willans 2001). Our study examined the diet of remnant wild populations on Great Barrier Island, Northland and Little Barrier Island, and three populations established by the introduction of captive-bred birds. None of these sites include large lakes, dense podocarp or beech forest, yet these were once inhabited by Brown Teal (Worthy 2002). Worthy (in Anon. 2000) suggests that Brown Teal may have foraged for beech nuts. They could equally well have fed on other seeds and fruits, terrestrial invertebrates, and fungi.

Although Brown Teal diet now includes introduced species such as White Clover, Brown Garden Snails (*Cantareus aspersus*) and Jet Slugs (*Milax gagates*), it is likely that introduced species and changes in land use over the last 130 years have caused an overall reduction in year-round food availability for Brown Teal. The Brown Teal diet of seeds and invertebrates overlaps substantially with that of rats (Atkinson and Moller 1990; Innes 1990; Moors 1990), House Mice (*Mus musculus*: Murphy and Pickard 1990), European hedgehogs (*Erinaceus europaeus*; Brockie 1990), Blackbirds (*Turdus merula*; Heather and Robertson 1996) and Mallards (Balham 1952). Rabbits (*Oryctolagus cuniculus*) graze palatable low-growing plants such as White Clover and indirectly reduce the abundance of terrestrial molluscs (Diaz 2002). The overall availability of White Clover may be limited on Great Barrier Island, as the soil there is deficient in essential elements such as molybdenum, cobalt and selenium, and clover can only grow in areas that have been artificially fertilised (Clough 2001).

On Great Barrier Island, almost all of the alluvial flats that were once swamps have been burned and drained for agriculture, as have most of the freshwater wetlands (Ogden 2001). It is probable that Brown Teal ducklings, like the young of other dabbling ducks, feed on invertebrates early in life before switching to a more herbivorous adult diet (Sugden 1973; Cox *et al.* 1998). Invertebrate feeders are often adversely affected by land drainage, which dries the topsoil, making surface-dwelling invertebrates less active and soil dwelling ones less available, especially in dry periods (Newton 1998). Although marine invertebrates would still be available to some teal ducklings, frequent feeding in coastal areas may slow the growth of very young ducklings unable to process the high salt intake (even Eider *Somateria mollissima* ducklings require fresh water in the first few weeks of life; Swennen 1989).

Newton (1998) noted that in the short term, birds respond to food shortages in two ways, by moving to areas were food is more plentiful, and through changes in local survival and reproductive success. Reports of adult Brown Teal feeding in coastal areas more often during dry summers than in other seasons (Table 2.1) may reflect food shortages inland at these times. There is also recent evidence that some wild Brown Teal on Great Barrier Island starve during dry periods. In the summer of 2002-2003, six of the eleven juvenile teal being monitored by the Department of Conservation, and four adult teal, were found to have been in extremely poor nutritional condition prior to death (Howard and Jamieson 2003; Chapter 5; Moore 2003). Barker and Williams (2002) suggested that drought-induced reproductive failure was at least partly to blame for the low brood survival they observed at Okiwi on Great Barrier Island. Food shortages during droughts may also have affected Northland Brown Teal. Williams

(2001) noted that the catastrophic decline of two Northland populations coincided with a drought caused by the most protracted El Niño event recorded in the twentieth century. While the main cause of Brown Teal decline is probably predation, food shortages during droughts are likely to decrease recruitment and adult survival, something Brown Teal as a species can ill afford.

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APPENDIX 2.1. Diet items found in gut contents as grouped for analysis in PC-Ord.

Category	Food items
Oligochaete	Oligochaetes
Terrestrial snail	Unidentified gastropod, *Cantareus aspersus*, slug (*Milax gagates*?)
Marine snail	Whelk, *Zeacumantus lutulentus*, *Nodolittorina antipodum*, *Potamopyrgus pupoides*
Freshwater snail	*Potamopyrgus* spp., *Potamopyrgus antipodarum*
Bivalve	Bivalves
Ostracod	Ostracods
Crustacean	Isopods, amphipods
Crab	*Halicarcinus varius*
Terrestrial adult	Acarina, Opiliones, Phasmidae, Staphylinidae, Hemiptera, unidentified arthropod, unidentified insect, unidentified moth, unidentified beetle adult, weevil adult, unidentified dipteran adult
Terrestrial larva	Psychidae, caterpillar, unidentified chrysalis, unidentified beetle larva, weevil larva, unidentified dipteran larva, unidentified dipteran pupa, unidentified tipulid larva
Aquatic larva	Plecoptera, Scirtidae, Hydrophilidae
Caddis larva	*Oxyethira albiceps*, *Oeconesus maori*, *Olinga* sp., *Pycnocentrodes* sp., *Hudsonema* sp., *Helicopsyche* sp.
Aquatic diptera larva	Ephydridae, Empididae, Simuliidae, Culicidae, Paralimnophila sp., *Zelandotipula* sp., *Chironomus* sp.
Fungi	Fungi
Algae	Algae
Moss	Moss
Clover	*Trifolium repens* leaves
Terrestrial vegetation	Grass blade, potato peeling, unidentified vegetation
Cyperaceae seed	*Uncinia* sp., *Carex* sp., other Cyperaceace spp.
Monocot seed	Grass seed, *Apodasmia similis*, *Spargamium subglobosum*
Dicot seed	*Coprosma* spp., *Melicope simplex*, *Leucopogon fascicularis*, *Ranunculus* sp., *Oxalis corniculata*, *Rubus* sp., *Persicaria decipiens?*, legume seed
Unknown seed	Naturalised spp. endocarps, unidentified seeds

3

Cockle-opening by a dabbling duck, the Brown Teal

S.J. Moore & P.F. Battley

Abstract

Many birds feed on bivalves, but only oystercatchers (*Haematopus* spp.) are known to prise open the shells. Brown Teal (*Anas chlorotis*), a dabbling duck endemic to New Zealand, were observed opening Common Cockles (*Austrovenus stutchburyi*) on Great Barrier Island. The teal jackhammered into the open shells of feeding cockles and quickly scooped out the flesh. Despite having the bill morphology of a typical dabbling duck, they were adept at this feeding method.

While many birds, especially waterfowl and waders, feed on bivalve shellfish (del Hoyo *et al.* 1992, 1996; Stott and Olsen 1973), only oystercatchers are known to prise them open (Baker 1974; Norton-Griffiths 1967; Tuckwell and Nol 1997; Ward 1991). Large gulls (such as Herring Gulls *Larus argentatus* and Southern Black-backed Gull *L. dominicanus*) also feed on bivalve flesh, but they drop the bivalves onto a hard surface to crack them (Ward 1991; del Hoyo *et al.* 1996). Ducks that feed predominantly on bivalves usually swallow them whole, crushing the shell in the gizzard (Barnes and Thomas 1987; Klasing 1998). This note describes how Brown Teal (*Anas chlorotis*), a dabbling duck endemic to New Zealand, prise open Common Cockles (*Austrovenus stutchburyi*), an unexpected finding given their bill morphology.

Brown Teal are shy, largely nocturnal ducks, and relatively little is known of their feeding ecology. Most reports of these teal feeding are of birds in grazed pasture at night (Dumbell 1987; Gravatt 1966; McKenzie 1971; Weller 1974; Williams and

Dumbell 1996), or in coastal areas, especially at low tide (Dumbell 1987; Gravatt 1966; McKenzie 1971; Oliver 1930; Weller 1974) where they were believed to feed on marine invertebrates including small mussels that were macerated and swallowed whole (Heather 1980).

Among the Anatidae, bill and tongue morphology usually relate to specific foraging behavior (Kehoe and Thomas 1987; Lagerquist and Ankney 1989). Brown Teal have very well developed lamellae and a reduced nail on the bill tip, characteristics that are strongly associated with dabbling and suggest that the bill is not used for grasping (Delacour and Mayr 1945; Gravatt 1966). Indeed, Brown Teal are adept at dabbling, sucking water in through the bill tip, then pushing the water out through their lamellae, thus straining out any food particles in the water or substrate.

On several occasions in November 2001, Brown Teal on Great Barrier Island (36°18'S, 175°34'E), New Zealand, were observed opening cockles. Observations were made with a 20-45x spotting scope, binoculars, and the naked eye at distances of 3 -100 m (the ducks were unusually confiding as they had become used to humans).

On 4 November at Akapoua Bay, two teal were swimming in shallow water in the mid-afternoon, near low tide. They appeared to be probing in sediment to feed, before bringing their heads up to swallow. When one was observed bringing a cockle up out of the sediment, we approached the pair more closely.

The female began walking along the waters' edge, dabbling in the sand then, presumably upon encountering a slightly open cockle, she would quickly move her bill up and down like a jackhammer into the open cockle (Fig. 3.1, upper), and neatly disembody it. (This action should not be confused with the 'hammering' action of oystercatchers as they break through bivalve shells; Baker 1974). Occasionally the cockle flesh could be seen (Fig. 3.1 lower), but usually it was quickly swallowed. She took around five seconds to remove and swallow the flesh per cockle. She also dabbled in open cockle shells, and sometimes around floating seaweed, where she appeared to be eating small crabs.

Like the female, the male sometimes 'jackhammered' cockles open while wading in shallow water, but he also moved slowly with his head immersed in water, digging with his bill and pushing his head back and forth, then raising his head back up to the surface. Three of his droppings were collected, all of which contained small pieces of white bivalve shell, although there were no shell fragments present in the surrounding sediment. It appears that the male was feeding both on the flesh of larger cockles and on whole, small bivalves, probably cockles, Pipi (*Amphidesma australis*) and Wedgeshells (*Macomona lilliana*).

The following day, 5 November, teal were observed at Karaka Bay, shortly before low tide. Ten Brown Teal were feeding in sediment in the water or at the water's

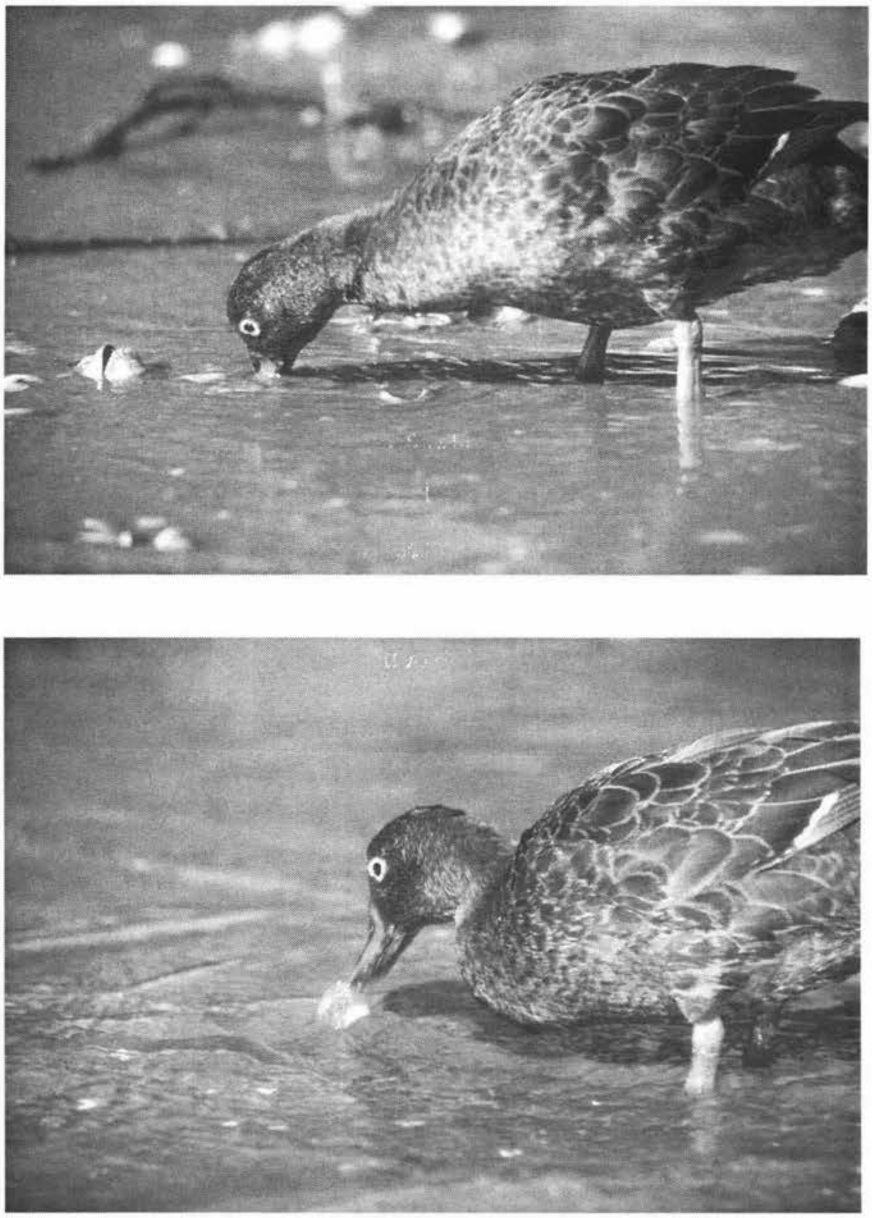

FIGURE 3.1. (Upper) Brown Teal with its head positioned vertically in order to 'jackhammer' open a cockle. (Lower) Brown Teal removing the flesh from a cockle. Photos by P.F.B.

edge. Several of these teal were extracting the flesh from cockles using the same technique as the Akapoua Bay birds. Some of the faecal samples collected from these birds contained small white shell fragments. Again, it appears that the teal were swallowing small bivalves whole, and opening the larger cockles.

On 18 November and 28 November, a female and her two ducklings (near fledging but still with down on the back, *ca* 9 weeks old) were observed feeding at Akapoua Bay. Both the female and ducklings were opening cockles, although the ducklings appeared less successful than their mother and one of the ducklings was seen pulling a cockle out of the water by its siphon. The three teal mostly fed in the sediment, but also dabbled briefly around seaweed and small rocks.

Twenty core samples (diameter 7.5 cm) taken on 28 November over an area of 70 x 30 m where the ducks had been feeding indicated a mean density of 376 cockles per m^2, with an average length of 16.5 mm (range 4 –27 mm).

Teal were never seen carrying cockles to harder sediment to open (which oystercatchers commonly do), probably reflecting the relatively small sizes of cockle present (which are presumably easier to open than larger individuals) and the shape of the teal's bill, which may not be well suited to jamming into cockles that are only slightly open.

Although many other duck species, including other *Anas* ducks (Grandy 1972; Kålås and Roalkvam 1983), have been observed eating bivalves, this is the first report of ducks opening bivalves to extract their flesh. Extracting bivalve flesh is usually regarded as a specialty of oystercatchers, who use their strong stout beaks to 'stab' into or 'hammer' their way through the shells (Baker 1974; Goss-Custard 1987; Goss-Custard and Durell 1987). Oystercatchers selectively prey on cockles which are feeding and have their shells open, stabbing their bills into the gap to sever the adductor muscle (Baker 1974; Hulscher 1976). Brown Teal use a stabbing method similar to this, which is rather unexpected given their bill shape. Despite having the bill morphology of a typical dabbling duck, their bills are excellent for scooping out bivalve flesh. Our observations caution against making ecological inferences solely on the basis of bill morphology.

Brown Teal were once widespread throughout New Zealand and found in a wide variety of habitats (Worthy 2002). They are now an endangered species (BirdLife International 2000), restricted to a few sites in New Zealand, and not all of the remaining birds feed in intertidal sites. However, eating small bivalves is still common for Brown Teal from Great Barrier Island and is also known from at least one site in Northland (Chapter 2). Although cockle opening by teal was only observed in two areas, it may have been more widespread in the past. Alternatively it may be that, like young oystercatchers (Norton-Griffiths 1967; Safriel 1985), young teal learn specialized feeding techniques from their parents and that cockle-opening is a culturally transmitted technique unique to Brown Teal in a few areas.

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4

Digestive organ morphology of wild and captive Brown Teal

S.J. Moore & P.F. Battley

Abstract

The digestive tract of many animals is morphologically flexible and can adjust to make the most efficient use of the foods available. Differences between captive and wild diets often cause large differences in gut morphology of captive and wild birds. We compared the size and mass of the digestive organs (proventriculus, gizzard, small intestine, caeca, rectum and liver) of 57 wild, 7 captive and 4 captive-bred released Brown Teal (*Anas chlorotis*). Captive Brown Teal had much shorter and lighter small intestines and caeca than wild Brown Teal. These differences could reduce the ability of captive-bred teal to efficiently digest a wild diet in the weeks following release, and are likely to contribute to the number of released teal found dead in extremely poor nutritional condition. Increased fibre and diversity in the captive diet, plus supplementary feeding post-release, are suggested to improve the survival of captive-bred Brown Teal released to the wild.

Introduction

An efficient and appropriate digestive system is vital for an individual's survival. Eider Ducks (*Somateria mollisma*) and Black Scoters (*Melanitta nigra*) that feed predominantly on intact hard-shelled molluscs have large muscular gizzards to crush the shells of their prey (Goudie and Ryan 1991), while herbivorous waterfowl such as Gadwall (*Anas strepera*) and Brent Geese (*Branta bernicla*) have large caeca to break down the large amounts of fibrous plant material they consume (Barnes and Thomas 1987). Having a large gut is energetically expensive (Moss 1972), so birds such as

Oldsquaw (*Clangula hyemalis*), which eat easily digestible soft-bodied invertebrates, tend to have relatively small gizzards and caeca (Barnes and Thomas 1987).

Over the course of the year an animal's diet may change dramatically due to changing food availability, or differing requirements for energetically demanding reproduction or moult (Krapu 1974; Hartman 1985). The digestive system needs to be morphologically flexible to cope with these changes. Unlike structural components such as bones that essentially do not change in size once an animal is mature, digestive organs can change in size and mass to more efficiently digest different foods (Starck 1999a, b).

The effects of diet on digestive organ size and efficiency may have important consequences for wildlife management and conservation. Many game bird and threatened species are bred in captivity for release to the wild in attempts to augment existing populations or establish new ones (for example, Black *et al.* 1997; Brittas *et al.* 1992), but may be released with digestive organs little suited to their diet in the wild. By experimentally simulating the abrupt change from a captive to a wild diet for hand-reared Grey Partridges (*Perdix perdix)*, Liukkonen-Antilla *et al.* (1999) found that the birds lost weight dramatically after the diet change and that a period of six weeks could be inadequate for the partridges to adjust to the new diet.

Moss (1972) found that caecum and small intestine lengths in captive Red Grouse (*Lagopus lagopus scoticus*) on an artificial diet decreased in length, and that decreases continued over several generations in captivity. These decreases were ascribed to the change in diet, particularly the decreased fibre compared with a wild diet, and were thought to become more extreme over the generations as the captive situation actively selected for birds with short caeca. The small intestine and caeca were also smaller in captive-reared than in wild Rock Partridges (*Alectoris graeca)*, and this was thought to affect the survival of the captive-reared birds on release (Paganin and Meneguz 1992).

In New Zealand, a captive breeding programme is part of the recovery effort for the endangered Brown Teal or Pateke (*Anas chlorotis)* (Birdlife International 2000). Between 1968 and 1999 more than 1,700 captive-bred Brown Teal were released into the wild (Dumbell 2000), but few new self-sustaining populations have been established as a result. Monitoring of recent releases has indicated that some released teal were in very poor nutritional condition prior to death (Chapter 5). Although the diet of wild Brown Teal is not particularly well known (Marchant and Higgins 1990), it includes both hard shelled molluscs (Heather, 1980; Chapter 1) and large quantities of terrestrial vegetation (Chapter 1). In contrast, the diet of captive Brown Teal is often based on commercially prepared poultry mash (Hayes 1981). It is likely that such large differences between the wild and captive diets will be reflected in the gut morphology of captive and wild teal, potentially affecting the survival of captive-bred teal released to the wild. This study compares the gut morphology of wild and captive Brown Teal, and discusses the implications of this for the release programme.

Methods

Brown Teal are a protected species and this research was carried out under permit from the New Zealand Department of Conservation. All carcasses used were from birds found dead by members of the public, captive breeders or Department of Conservation staff.

Wild Brown Teal were sourced from Great Barrier Island (36°18'S, 175°34'E; 44 birds), Little Barrier Island (36° 20'S, 175° 11'E; 2 birds), Kapiti Island (40°50.5'S, 174°56'E; 2 birds) and Northland (35° 43'S, 174° 40'E; 9 birds; Table 4.1). Three of the Great Barrier Island teal and both of the Kapiti Island teal had died after a short period (6-7 days) in captivity; the majority of the other Great Barrier Island birds had been killed on roads. Although the Kapiti Island teal are believed to be descendents of a 1968 release, and some teal released in Northland between 1984 and 1995 were recruited into the local wild population (Williams and Dumbell 1996), there have been no releases of captive-bred birds to either Great Barrier or Little Barrier, and all of the wild Brown Teal in this study were wild-bred. The seven captive teal were from four different breeders; one female was wild-bred and had lived in captivity for 8 years, while the remaining six birds had been bred in captivity. Four captive-bred birds that had died after release to the wild (after 1, 2, 3 and 24 weeks) were also analysed. Ducklings, which were distinguished from juveniles and adults by the presence of down, small body size and incomplete flight feathers, were not included in our analysis. Adult-sized juveniles and adults could not be reliably discriminated throughout the year, so are pooled in this study.

TABLE 4.1. Sources of Brown Teal (*Anas chlorotis*) carcasses used in analysis. The number in brackets indicates the number of birds in that category that were emaciated (note that the captive emaciated bird died of age-related emaciation, not neglect). See text for more information.

	Male	Female	Unknown
Great Barrier Island	20 (5)	22 (4)	2
Little Barrier Island	1	1	
Northland	2	6 (2)	1
Kapiti Island		1	1
Captive population	2	5 (1)	
Released captive-bred	3 (3)	1	

Carcasses were stored frozen and thawed prior to external measurements being taken. Bill length and tarsus were measured with calipers (± 0.1 mm), wing length of the straightened flattened wing with a steel rule (± 1 mm), and body mass with a Pesola balance (± 1 g). Wing lengths of birds with broken wing tips or moulting primaries were excluded from the analysis.

Most carcasses were sexed by plumage and inspection of the gonads. If this was not possible, the presence (male) or absence (female) of the bulla, a bony enlargement at the base of the trachea, was recorded. Some carcasses were badly damaged or decomposed and could not be sexed. One wild female and one captive female were gravid; a second wild female had a brood patch.

We visually assessed the condition of most carcasses, noting the amount of subcutaneous and abdominal fat, and size and shape of the pectoral muscle. We assigned teal into three condition categories: good (visible subcutaneous fat, ranging from little to very much), poor (no visible fat) and emaciated (no visible fat, shrunken breast muscles with a protruding keel). Teal were also classified as emaciated if a post-mortem examination by a veterinary pathologist had determined that starvation was the primary cause of death, or if wingfat analysis (Chapter 5) had found less than 10% ulnar lipid. We noted during the dissections that most of the birds we had classified as emaciated had a bloodied or blackened gizzard lining, which has also been observed in European waterfowl and seabirds that have starved (K. Camphuysen, Netherlands Institute for Sea Research, pers. comm. February 2003). Teal assigned to either the good or poor condition categories are described hereafter as healthy.

As this study was on an endangered species, sample sizes were limited by the available carcasses which were often recovered in poor condition, and many of which were desired for other purposes (including post-mortem pathology, taxidermy, museum collections, and cultural uses). This has resulted in variable sample sizes between organs and in small samples of captive and captive-bred released teal. Many carcasses were partial, so the complete set of digestive organs could not always be collected.

Digestive organ morphology

The entire digestive tract plus liver was removed, tied around the top of the oesophagus and lower end of the rectum to prevent the loss of gut contents, weighed, labeled and stored frozen in plastic bags.

Before analysis, the digestive organs were thawed, and the liver removed. Fat and mesenteries were removed from the digestive tract, which was laid out, straightened but not stretched, on a wet surface. Proventriculus length and gizzard length, width and depth were measured with calipers (± 0.1 mm). Lengths of: the small intestine from the gizzard to the anterior junction with caeca; each caecum to the junction with the small intestine; and the rectum from the anterior caecal junction, were measured using a steel rule (± 1 mm).

The remaining tract was separated into six sections, oesophagus, proventriculus, gizzard, small intestine (gizzard to anterior junction of caeca), rectum (anterior junction of caeca to cloaca) and caeca (which were removed separately). The oesophagus, proventriculus, gizzard, rectum and caeca were cut open and the contents scraped out and retained in pre-weighed labeled containers. The small intestine was cut into lengths and squeezed three times to remove any contents. If the contents were very gritty or fibrous and could not be removed by squeezing, the small intestine was cut open and scraped out. The contents were weighed (±0.01 g) and frozen, and any intestinal parasites found were stored in 70% ethanol for later analysis. Body weight for intact birds was calculated as the fresh carcass weight minus the mass of the gut contents (no weight could be recorded for partial carcasses).

All organs were weighed fresh (± 0.01 g) in labeled, pre-weighed aluminium foil dishes, then dried in 60°C ovens. After cooling in a dessicator, samples were reweighed, and the process was repeated until each achieved a constant mass.

Data were analysed using Systat 10 (SPSS Inc.).

Results

On average (± SD), wild, non-emaciated female teal in our study weighed 482 ± 76 g (*n* = 20), and males weighed 564 ± 58 g (*n* = 17). Digestive organs made up less than 10% of the total mass, with an average fresh weight of 43 g. Wild Brown Teal had muscular gizzards containing grit, long small intestines, and well-developed caeca. For non-emaciated Brown Teal, captive birds tended to have a larger mass than wild birds ($F_{1,40} = 4.455$, $P = 0.041$, when sex and source are included as factors in ANOVA; first order interactions between sex and source were not significant in any analyses, and consequently are not reported). The average mass of captive, non-emaciated females was 565 ± 96 g (*n* = 4); the two captive males weighed 531 and 668 g.

For wild, non-emaciated birds, we investigated whether lengths or dry masses of different digestive organs were correlated with each other, with body mass or with structural size variables (Table 4.2). The lengths and the dry masses of the small intestine, caeca and rectum were highly correlated, likely due to their similar roles in the digestive process, absorption of nutrients and water. The liver was the only organ whose dry mass was correlated to body mass, while gizzard volume and dry mass were strongly correlated to structural size (bill, wing and tarsus lengths). The lengths (and volume for the gizzard) of each part of the digestive tract were highly correlated to their dry masses, with Pearson's correlation coefficients from 0.462 for rectum to 0.965 for gizzard (in all cases $P > 0.001$).

We tested for differences in gut morphology of healthy wild and captive teal, using ANCOVA, taking source (whether the bird was captive or wild; the wild-bred female which had lived in captivity for 8 years was included as captive) and sex as factors, with body mass, (and for the gizzard, structural size), as a covariate. We did not test for differences in proventriculus due to our small sample size for captive birds (n = 2), but the values we did have for captive birds were within 1 SD of the mean of wild birds (Table 4.3). Cumulative probability plots were used to test for normality; only dry liver mass required a log transformation. There was no difference in gizzard mass or volume between captive and wild teal. Average lengths and dry masses of the small intestine and caeca were significantly larger in wild than in captive birds. Caecum lengths, but not caecum dry masses, were greater in male than in female teal. Heavy teal had the largest liver dry mass, but there was no difference in liver size between captive and wild birds when body mass was included as a covariate.

TABLE 4.2. Relationships between digestive organs, body mass and body size in wild Brown Teal (*Anas chlorotis*), not including emaciated birds or ducklings. Values are Pearson correlation coefficients; significance levels are from Bonferroni probabilities. Data used were lengths (most organ size measurements), volume (gizzard size), dry masses (all organ masses) and fresh mass (body mass). Caeca values were for both caeca combined.

	Proventriculus	Gizzard	Small intestine	Caeca	Rectum	Liver
Organ size						
Proventriculus	1.000					
Gizzard	0.249	1.000				
Small intestine	0.462**	0.371*	1.000			
Caeca	0.356*	0.377*	0.600***	1.000		
Rectum	0.319*	0.186	0.538***	0.396*	1.000	
Body mass	0.391*	0.285	0.397*	0.200	0.341*	
Bill length	0.281	0.378*	0.228	0.351*	-0.019	
Wing length	0.439**	0.422**	0.308	0.267	0.301	
Tarsus length	0.325*	0.356*	0.428**	0.395*	0.042	
Organ mass						
Proventriculus	1.000					
Gizzard	0.236	1.000				
Small intestine	0.169	0.004	1.000			
Caeca	0.180	0.179	0.576***	1.000		
Rectum	0.110	0.181	0.716***	0.607***	1.000	
Liver	0.476**	0.218	0.275	0.482**	0.263	1.000
Body mass	0.306	0.311	-0.000	0.140	0.011	0.586**
Bill length	0.084	0.389**	-0.054	0.266	-0.003	0.081
Wing length	0.140	0.352*	-0.021	0.227	0.154	0.291
Tarsus length	0.120	0.325*	0.085	0.065	0.017	0.428*

* = $P < 0.05$; ** = $P < 0.01$; *** = $P < 0.001$.

Gut parasites (cestodes, trematodes and nematodes) were found in wild birds from Great Barrier Island (6) and Northland (4), and in one of the captive birds. There was no significant difference in lengths or dry masses of the small intestine and caeca between wild teal with and without gut parasites either using Student's *t* test ($t_{48} = 0.187$, $P = 0.852$) or using ANCOVA with body mass as a covariate ($F_{1,41} = 0.030$, $P = 0.863$).

We also assessed the digestive organs of two additional groups of teal, emaciated wild birds, and captive-bred birds that were released or emaciated. Of the latter group, one died in captivity of age-related emaciation (at 18 years of age), and another had become trapped in vegetation shortly after release and was found dead within a week of release, leaving only three birds believed to have fed in the wild. Of these three, two had starved after less than four weeks in the wild, and the third had lived in the wild for 24 weeks before being killed by a predator (J. Hoskins, Patuone Hoskins Whanau Trust, pers. comm.). In general, the emaciated wild, and released or emaciated captive birds had lighter gizzards than most healthy wild and captive teal (Fig. 4.1). They also had lighter small intestines and caeca than the majority of the healthy wild teal, similar in mass to those of the healthy captive teal. The exception to this was the captive-bred teal that had lived in the wild for 24 weeks; its digestive organs were similar to those of healthy wild teal.

Discussion

Compared to healthy wild Brown Teal, captive teal were heavier and fatter, and had correspondingly larger livers. Increased liver weight is associated with increased feeding in several waterfowl species (Ankney 1977; DuBowy 1985) and is likely due to the liver's role in protein metabolism and lipid storage (Kehoe *et al.* 1988; Ankney and Scott 1988).

There was no difference in mean gizzard size between captive and wild Brown Teal, but the small intestine and caeca of the captives were smaller than those of healthy wild teal, and were comparable in length and mass to those of emaciated wild birds (Fig. 4.1). The small intestine and caeca have similar functions; the enzymatic digestion and absorption of the digestive end products (Klasing 1998). Although gut parasites can cause an increase in the host's intestine mass (Kristan and Hammond 2000), no effect of gut parasites on intestine length was apparent in wild Brown Teal.

If the captive environment favoured teal with short caeca and small intestines, selection for these attributes could cause the captive population to differ genetically from wild birds. The captive population was apparently descended from 76 wild Brown Teal collected from Great Barrier Island between 1960 – 1987, but no records of the age or parentage of breeding birds were kept (Dumbell 2000). The captive-bred birds in our study are an unknown number of generations removed from the wild and could have

TABLE 4.3. Gut morphology of Brown Teal (*Anas chlorotis*), not including emaciated birds or ducklings. Lengths are in mm, volumes in cm^3, and masses are in g. Only significant results ($P < 0.05$) are shown for the covariate (mass) and the factors (source = whether a bird was captive or wild, and sex). Liver dry mass was log transformed for analysis of variance, but untransformed descriptive statistics are shown.

		Wild				Captive				Difference?			
Organ		Mean	SD	Range	*n*	Mean	SD	Range	*n*	Factor	F-ratio	P	R^2
Proventriculus	Length	35.3	4.7	21.4 – 45.6	41	32.1	1.3	31.1 – 33.0	2	-	-	-	-
	Fresh	1.58	0.37	0.72 – 2.36	41	1.48	0.35	1.23 – 1.73	2				
	Dry	0.39	0.11	0.16 – 0.82	41	0.32	0.09	0.25 – 0.38	2	-	-	-	-
Gizzard	Volume	32.4	12.3	13.7 – 64.0	45	30.6	3.2	27.9 – 35.9	6	-	-	-	-
	Fresh	17.04	5.92	8.19 – 32.80	45	14.74	2.47	11.19 – 18.73	6				
	Dry	4.68	1.58	2.35 – 9.20	45	4.44	0.49	3.54 – 4.96	6	-	-	-	-
Small intestine	Length	1556	216	1015 – 1925	41	1229	116	1074 – 1402	6	Source	$F_{1,36} = 14.423$	0.001	0.329
	Fresh	10.15	3.49	5.23 – 19.86	41	6.39	0.86	5.52 – 7.57	6				
	Dry	2.23	0.74	1.01 – 4.57	41	1.52	0.15	1.24 – 1.66	6	Source	$F_{1,36} = 5.207$	0.029	0.175
Caeca	Length	236	34	179 – 332	42	199	27	153 – 227	6	Source	$F_{1,35} = 4.260$	0.046	0.256
										Sex	$F_{1,35} = 4.237$	0.047	
	Fresh	1.44	0.42	0.74 – 2.58	42	0.89	0.18	0.63 – 1.17	6				
	Dry	0.31	0.10	0.15 – 0.58	42	0.21	0.04	0.17 – 0.27	6	Source	$F_{1,35} = 5.817$	0.021	0.150
Rectum	Length	65	14	42 – 90	42	58	13	45 – 74	6	-	-	-	-
	Fresh	0.96	0.38	0.51 – 2.58	42	0.75	0.27	0.44 – 1.17	6				
	Dry	0.20	0.09	0.09 – 0.55	42	0.17	0.04	0.12 – 0.22	6	-	-	-	-
Liver	Fresh	11.58	4.58	3.10 – 24.02	30	15.27	4.97	11.53 – 22.82	5				
	Dry	3.67	1.62	0.81 – 8.73	30	5.83	1.93	4.46 – 9.11	5	Mass	$F_{1,27} = 17.624$	<0.001	0.527

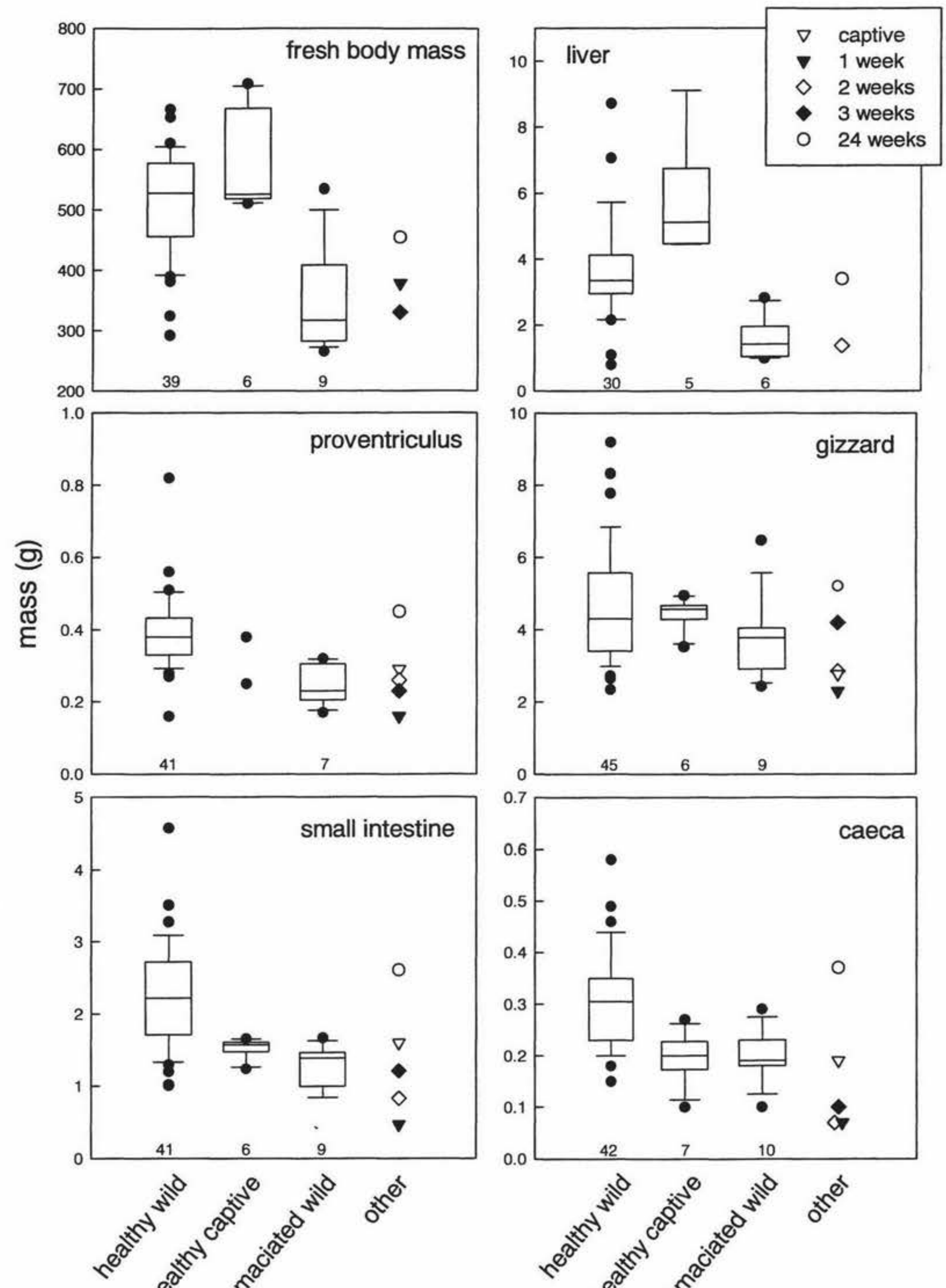

FIGURE 4.1. Fresh body mass and digestive organ dry mass of healthy wild, healthy captive, emaciated wild, and 'other' Brown Teal (*Anas chlorotis*). Healthy birds were those assigned to either the good or poor condition categories. The 'other' category includes one emaciated captive Brown Teal, and four captive-bred released teal that died after 1, 2, 3 and 24 weeks in the wild respectively (see legend). Boxes enclose the median, with 25 to 75 percentiles, and whiskers show the 10th and 90th percentiles. Sample size is shown below each box.

been subject to selective pressure favouring small guts and caeca. It is possible that genetic factors contributed to the differences we observed between captive and wild Brown Teal. A small number of wild Great Barrier teal were recently added to the captive population (Davis and O'Connor 2002). Combined with well planned pairings, this should help decrease any genetic differences between wild and captive birds.

Dietary factors such as food intake and diet type (fibre content and degree of softness/hardness) affect digestive organ sizes across a wide range of bird species (Battley and Piersma in press). The captive diet for adult teal is usually based on either commercially prepared poultry mash (K. Evans, Brown Teal captive breeding co-ordinator, pers. comm. 2 May 2003; N. Hayes, Brown Teal captive breeder, pers. comm. 2 May 2003) or Massey University Teal pellets, both low in fibre (maximum of 6% fibre in Sharpes Stockfeed Ltd, Carterton, New Zealand hi-lay mash), although some breeders use commercially prepared trout or calf pellets (K. Evans, pers. comm. 2 May 2003). In contrast, the diet of wild Brown Teal includes hard shelled molluscs, hard seeds and terrestrial vegetation (Heather 1980; Chapter 2).

Compared to the captive diet, the 'wild' diet requires higher intake rates and more digestive processing to provide the necessary energy and nutrients, due to its higher proportion of difficult or impossible to digest constituents such as cellulose and shell. These dietary differences are likely to have resulted in the larger small intestine and caeca we observed in wild Brown Teal relative to captive birds. Increases in small intestine and caecal length and mass often follow a decrease in food quality (Miller 1975; Moss and Trenholm 1987; Kehoe *et al.* 1988) and/or increasing food intake (Drobney 1984; Heitmeyer 1988), and may be observed within five days of a diet change (Kehoe *et al.* 1988). Although more metabolically expensive, long guts improve an animal's ability to survive on poor food (Moss 1983). A large small intestinal volume may also permit the passage of mollusc shell fragments through the gut (Barnes and Thomas 1987).

The unnatural diet of captive teal and the resulting reduction in small intestines and caeca place newly released captive-bred teal at a disadvantage. Released Brown Teal may be unfamiliar with the wild food available, and initially unwilling to try new foods, either because they are suspicious of them (Liukkonen-Anttila *et al.* 1999), because they are reluctant to eat foods unsuited to their digestive organs (Piersma *et al.* 1993), or, for some foods, because they have had no training in how to access it (Chapter 3). When they do start feeding on wild foods, their guts may be inefficient at digesting them. Although digestive organs can rapidly change in size to accommodate a new diet, it may take more than six weeks on the new diet for them to fully adapt (Liukkonen-Anttila *et al.* 1999). When captive Mallards (*A. platyrhynchos*) were put on a high fibre diet, their small intestine and caeca increased in mass and length, more closely approximating that of wild Mallards (Miller 1975; Kehoe *et al.* 1988). The captive Mallards achieved their maximum gizzard, intestine and caeca mass after ten days on the high fibre diet, but caecum and intestine lengths were still increasing at 25 days when the experiment finished (Kehoe *et al.* 1988).

When birds change from a high to low quality diet, they need to consume more food to compensate for the reduced digestibility (Miller 1975). In spite of a higher intake rate and the constant temperature regimes of their captive situation, captive Grey Partridges decreased in body mass in the first week of a high fibre diet, and stabilised at a lower level than that of control (low fibre diet) birds (Liukkonen-Anttila *et al.* 1999). Captive-bred released Brown Teal face higher energy demands than the birds typically used in captive dietary studies. Released teal are likely to need more energy for thermoregulation due to lower ambient temperatures. They may disperse over quite large distances; three captive-bred released teal were shot more than 70 km from their release site within four months of release (New Zealand bird banding office database). Reacting to predators or aggressive competitors may also be energy demanding.

At least initially, captive-bred released teal are likely to be poorly suited for digesting a wild diet, unfamiliar with what food there is available, and subject to higher metabolic costs than most captive birds used in diet experiments. If so, this should manifest as teal in poor nutritional condition. Monitoring of Brown Teal releases at four sites in 2001 and 2002 found that at least eight captive-bred birds (23 % of those released) starved within six weeks of release (Chapter 5).

A simple test of whether the observed differences in digestive organ size are caused by dietary differences would be to increase the fibre content of one group of captive teal but not another, then after two months sacrifice the birds and compare their caecal and gut lengths. Alternatively, a more appropriate test for an endangered species such as the Brown Teal could be to release the two groups of birds to the same site in the wild and closely monitor for any feeding difficulties (re-capturing birds and weighing them regularly) within the first two months in the wild. Even if increased fibre in the diet allows captive-bred teal to be released with digestive organs suitable for a diet in the wild, behavioural deficiencies (such as in recognition of wild foods) may still limit survival. Providing accessible and familiar supplementary food to birds post-release could also help ease the transition from the captive to a wild diet and should also be trialled to see if post-release survival of captive-bred Brown Teal can be improved.

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5

The use of wing remains to determine condition before death in Brown Teal

S.J. Moore & P.F. Battley

Abstract

Little is known of the causes of mortality in captive-bred Brown Teal (*Anas chlorotis*) released to the wild. To test whether feeding difficulties have contributed to the poor survival of released birds, we developed a method to detect starvation using the wing fat content of Brown Teal. We extracted the lipids from four outer wing components of 17 intact Brown Teal carcasses. The lipid content of each component reflected the birds' nutritional condition (based on body mass and size, and visible fat). Lipids were also extracted from the outer wing components of seven partial Brown Teal carcasses, six of which were from captive-bred released birds whose cause of death could not be determined. All of the released teal were found to have been in very poor nutritional condition immediately prior to death, implicating starvation as a factor in their deaths. Improving the feeding regime of captive-bred Brown Teal (pre- and post-release) is likely to increase their survival.

Introduction

New Zealand's Brown Teal (*Anas chlorotis)* has recently been recognised as an endangered species (Birdlife International 2000). Efforts to save the species include releases of captive-bred birds to establish new populations. Between 1968 and 1999 more than 1,700 captive-bred Brown Teal were released into the wild (Dumbell 2000), but few self-sustaining populations were established (Chapter 1). The failure of the releases has been variously ascribed to predation by introduced mammals (Greene 1996; Hayes 1994), dispersal (Hayes and Williams 1982; Dumbell 1987; Dumbell 1996), shooting (Hayes and Williams 1982; Dumbell 1987; Hayes 1994) and poor habitat at release sites (Hayes 1994).

In 2000, 2001, and 2002, 66 captive-bred Brown Teal were released at four sites that are free of introduced mammalian predators and where shooting is prohibited: Karori Wildlife Sanctuary (41°18'S, 174°44'E), Kapiti Island (40°50.5'S, 174°56'E), Mana Island (41°05'S, 174°47'E) and Tiritiri Matangi Island (36°60'S, 174°90'E). All birds released on Kapiti and Mana Islands and in Karori Wildlife Sanctuary were wing-clipped or pinioned to reduce dispersal. Between six and ten of the 20 teal released on Kapiti died within the first two months post-release, as did either two or three of the 17 birds released on Mana (Moore 2002), and at least three of the 11 teal released on Tiritiri Matangi. Most of the recovered carcasses were partial due to predation or scavenging prior to recovery and the cause of death could not be established. The Institute of Veterinary Animal and Biomedical Sciences, Massey University, performed necropsies on the two intact carcasses recovered. One bird had become trapped in *Muehlenbeckia* spp. and starved; the other bird had not been entangled but had also died of starvation. Three carcasses were recovered from the Karori Wildlife Sanctuary; one carcass was intact and a necropsy found that this bird had also starved (Empson 2001).

Poor nutritional condition could also have been a factor in the deaths of other released teal, for which only partial carcasses were recovered. Poor condition may lead to death directly via starvation, or indirectly via increased risks of predation and exposure as birds with depleted fat reserves become lethargic (Ringelman *et al.* 1992) and eventually immobile (Cherel *et al.* 1988).

Newton (1993) defined condition as the current status of an animal's metabolic reserves relative to likely demands. Birds store nutritional fuel as fat, protein and carbohydrate, but fat forms the largest body fuel reservoir by far (Cherel *et al.* 1988) and thus is often used as an indicator of condition (Woodall 1978; Owen 1981; Gauthier and Bédard 1985; Ringelman and Szymczak 1985). As a bird fasts it increases its use of fat, sparing its protein stores, but in the final stages of a fast, when most fat stores are exhausted, protein is increasingly used (Thouzeau *et al.* 1997). It is this final loss of protein (which is needed for body structure, muscle function, and enzymes) that limits survival in starvation (Cherel *et al.* 1998).

Strong relationships between the fat content of the wing and overall body condition have been demonstrated in waterfowl (Hutchinson 1984; Jeske *et al.* 1994; Ringelman *et al.* 1992) and waders (Guglielmo and Burns 2001). This study investigates the use of wing remains as indicators of condition in Brown Teal, and uses these indicators to estimate the condition of captive-bred released teal recovered as partial carcasses from Tiritiri Matangi, Kapiti, and Mana Islands and Karori Wildlife Sanctuary. Determining whether poor condition was implicated in the deaths of these released teal could help identify the relative importance of starvation in the failure of previous releases, allowing managers to refine release techniques and improve teal survival at future releases.

Methods

The Brown Teal is a protected species and this research was carried out under permit from the New Zealand Department of Conservation. All carcasses used were from birds found dead by members of the public or by Department of Conservation staff.

Morphology

Morphometric data were collected from the carcasses of 56 wild-bred adult Brown Teal from Great Barrier Island (44), Little Barrier Island (2) and Northland (10). Morphometric data were also gathered from 24 captive-bred adult birds, both from live birds before release (12), which were measured by Mt Bruce National Wildlife Centre staff, and from the intact carcasses of birds that had died in captivity (5) or after release (7). As some carcasses were not intact, a complete set of measurements could not be collected for all birds, so sample sizes vary in different analyses.

We sexed the carcasses by plumage and inspection of the gonads. National Wildlife Centre staff sexed the live captive birds by cloacal examination. Two females were gravid and were excluded from the analysis, as was a female with a brood patch. Bill length and tarsus were measured with calipers (± 0.1 mm), wing length of the straightened and flattened wing was measured with a steel rule (± 1 mm), and body mass with a Pesola balance (± 1 g). Wing lengths of birds with broken wing tips or moulting primaries were excluded from the analysis.

As well as using single morphometric measures in analyses, we also calculated an index of body size (the size PC) using the first factor from a principal component analysis of the correlation matrix of bill length and tarsus (an accurate wing length could not be obtained for one of the intact carcass birds used in wing fat analyses). This first factor explained 74.3% of the size variance (component loadings; 0.862 bill length, 0.862 tarsus).

We visually assessed the condition of the carcasses, noting the amount of subcutaneous and abdominal fat, and size and shape of the pectoral muscle. We assigned teal to one of three condition categories: good (visible subcutaneous fat, ranging from little to very much), poor (no visible fat), and starved (no visible fat, shrunken breast muscles with a protruding keel).

Wing fat analysis

Seventeen intact adult Brown Teal carcasses and seven partial carcasses were used for wing fat analysis (Appendix 5.1, pp. 70-71). All of the intact carcasses were obtained from Department of Conservation freezers, except the two captive birds which were supplied by Brown Teal breeders. The amount of information about the carcasses varied, so we did not know the date found or cause of death for some birds. We selected the carcasses to include equal numbers of males and females. There were few intact carcasses of birds with no visible fat deposits, so all found were included for analysis to ensure that the indicators developed would be applicable to birds with little carcass fat. Carcasses and wings were stored frozen. Although all of the wild birds included in the analysis were fresh carcasses, two of the released birds (individuals 19 and 22) were recovered in a state of partial decomposition.

For each bird, we plucked the contour feathers and the alula from both wings, and separated the outer wings from the carcass at the junction of the metacarpals with the radius and ulna (including the carpals with the outer wing). We dissected out both ulnae and removed any adhering tissue. Each ulna was then broken into three sections using wire-cutting pliers to gain access to the bone marrow. The outer wings were prepared in two ways:

1. Plucked wing. The primary flight feathers were plucked.
2. Cut wing. The flight feathers were trimmed away where they met the wing flesh using scissors, and the embedded shafts were removed by cutting along the line of their bases in the tissue with a scalpel. The cut shafts were kept separately for weighing and fat extraction, and are referred to as shafts in the analysis.

We alternated whether the left or right wing was cut or plucked for each bird, using a list of specimens ordered by the source location of the birds, ensuring an even spread of left and right wings across the plucked and cut wing samples.

This provided us with five samples (left ulna, right ulna, plucked outer wing, cut outer wing, and cut feather shafts) for 22 of the birds. Two of the released birds had been pinioned (individuals 21 and 22) so only three samples could be obtained for these birds (left and right ulnae, plucked outer wing).

Samples were weighed fresh (± 0.0001 g) in labeled, pre-weighed aluminium foil dishes, then dried in 60°C ovens. After cooling in a desiccator, samples were reweighed, and the process was repeated until all had achieved a constant mass (10-18 days, mean 13).

During the final reweighing we noted which ulnar samples had left greasy marks on their paper labels, making the paper appear transparent (similar to Ringelman *et al.*'s 1992 blot test). An ulnar paper-fat score of 0 was given if there was no visible fat on the label, 0.5 for one bird with a tiny fat spot, and 1 for birds that had extensive spotting or pooling on the label. The ulnar paper-fat score was recorded for 21 individuals.

Samples were then packaged into individual filter-paper 'envelopes' and the fat was extracted using a Soxhlet apparatus, with petroleum ether as the solvent. The Soxhlet apparatus was run during the day, and samples were left soaking in ether overnight, before flushing at least four times the following morning. The fat extractions ran for 20 hours or longer. After extraction, samples were redried for 18-24 hours at 60°C, cooled in a desiccator, and weighed. Tray weights were subtracted from the fresh and dry weights, and fat mass was calculated as the difference between the dry mass and the fat-free dry mass. Percentage fat was calculated as fat mass/dry mass x 100, and was arcsine transformed before analysis. Data were analysed using Systat 10 (SPSS Inc.).

Four birds (from road accidents) had one ulna broken before analysis. For these birds only the fat values from the unbroken ulnae were included. One bird had both ulnae broken, and was not included in the ulnar fat analyses. For the remaining 19 birds, percentage fat values for right and left ulnae were highly correlated (Pearson's r = 0.98), so we used the average value for the left and right ulnae.

Results

Body mass and size

Across all the complete carcasses, body size had a significant influence on body mass (regressions of body mass against size measurements; vs. tarsus $P < 0.001$, $R^2 = 0.221$, n

= 57; vs. wing $P = 0.003$, $R^2 = 0.170$, $n = 51$; vs. size PC, $P < 0.001$, $R^2 = 0.221$, $n = 54$; vs. bill $P = 0.019$, $R^2 = 0.102$, $n = 54$). Log transforming the mass and size measurements did not improve the relationships. It was not surprising that relatively little of the variation in body mass was explained by body size, as the samples included captive-bred and wild individuals, from throughout the year and with a wide range of nutritional condition. There was also some evidence that captive-bred birds may grow differently from wild birds. While female teal are generally smaller than male teal (Dumbell 1987), we found that the tarsus lengths of captive-bred female teal were as large as those of male captive teal (means 40.9 and 41.0 mm for female and male captive birds respectively, compared with 39.7 and 41.5 mm for wild birds; ANOVA, sex*source status interaction, $F_{1,69} = 5.632$, $P = 0.020$), suggesting that tarsus length is not a good size measure for captive teal. The other size measures were not affected by the source of the birds. Nevertheless, in wing fat analyses (below) we repeated analyses with all four body size measures (bill length, tarsus, wing length and size PC), as not all measurements were available for all birds.

Wing fat

To determine whether the fat content of the four wing components reflected the relative body mass of the complete carcass birds, we performed multiple linear regressions of wing fat against body mass plus each of the size measurements (Table 5.1). All four wing fat measures were positively related to body mass, and the best model for each component explained between 47% and 71% of the total variation in wing fat content. Bill length and mass explained the highest proportion of variation for three of the four wing fat components (and came a very close second for the fourth component).

Even when size is accounted for, body mass is only a coarse indicator of nutritional condition (Gauthier and Bédard 1985). There is substantial mass variation for a given body size among teal, and individuals in poor condition may not always be detectable from a simple analysis of body mass and body size. Accordingly, we used ANOVA and Bonferroni post-hoc tests to determine whether wing fat reflected the apparent condition of Brown Teal based on our visual assessments of carcass condition (as either good, poor, or starved). Visual fat assessments, based on subcutaneous fat, are frequently used in studies of small to medium sized birds (see Rogers 1991). These 'condition' categories alone explained between 37% and 91% of the variation in wing fat content (Table 5.2), confirming that wing fat content is a good indicator of the

TABLE 5.1. Significance values from multiple linear regressions of percent wing fat against body mass and various size measurements for Brown Teal (*Anas chlorotis*). Size PC is the first factor from a principal component analysis on the correlation matrix of bill length and tarsus. The strongest relationship for each wing fat measure is in bold.

Dependent variable	Independent variables	*P*	R^2	*n*
Ulnar fat	Mass + Bill length	0.004	0.571	16
	Mass + Tarsus	0.008	0.526	16
	Mass + Wing	0.078	0.371	14
	Mass + size PC	**0.004**	**0.577**	**16**
Plucked wing fat	**Mass + Bill length**	**0.012**	**0.467**	**17**
	Mass + Tarsus	0.033	0.385	17
	Mass + Wing	0.154	0.268	15
	Mass + size PC	0.029	0.398	17
Cut wing fat	**Mass + Bill length**	**<0.001**	**0.714**	**17**
	Mass + Tarsus	0.003	0.567	17
	Mass + Wing	0.018	0.486	15
	Mass + size PC	0.001	0.647	17
Shafts fat	**Mass + Bill length**	**0.004**	**0.545**	**17**
	Mass + Tarsus	0.009	0.491	17
	Mass + Wing	0.033	0.434	15
	Mass + size PC	0.010	0.482	17

nutritional status in Brown Teal (although the three categories could not be distinguished using the fat content of the plucked wing component). Ulnar fat content varied between all three categories. For cut wings, the poor and starved categories did not differ in wing fat, whereas shaft wing fat content differed only between the good and starved categories.

Finally, we plotted the wing fat content for the six released birds whose partial remains were retrieved from the field (nos. 19-24, Appendix 5.1, pp. 70-71), alongside the individuals in the three condition categories (Fig. 5.1). The fat content of these released birds corresponded unequivocally with birds in starving or poor condition.

TABLE 5.2. Results of analyses of variance testing whether wing fat content differed between the visually assessed condition categories for Brown Teal (*Anas chlorotis*). Bonferroni post-hoc tests were used to determine which categories differed in wing fat content (final column; categories within brackets do not differ from each other).

Wing component	d.f.	F-ratio	*P*-value	R^2	Different categories
Ulna	2,14	68.351	< 0.001	0.907	good + poor + starved
Plucked	2,15	4.382	0.032	0.369	none
Cut	2,15	19.582	< 0.001	0.723	good + (poor + starved)
Shafts	2,15	7.381	0.006	0.496	good + starved

An incomplete carcass (a road-kill) from Great Barrier Island (individual 7) grouped with birds in good condition.

Given the strength of the relationship between ulnar fat and body condition based on visual fat, we also tested whether the presence of fat spots on the paper labels used when drying the ulnae related to the actual fat content in the bones. This basic assessment proved to be highly related to the true fat content of the ulna ($F_{2,18} = 191.5$, $P < 0.001$, $R^2 = 0.955$; Fig. 5.2).

Discussion

Bone marrow fat has been used or suggested as an indicator of whether birds are under severe nutritional stress (Hutchinson 1984; Ringelman *et al.* 1992; Thouzeau *et al.* 1997). Bone marrow fat, however, is one of the body's last fat reserves to be used during a fast or starvation, so reasonable marrow fat levels do not necessarily prove that a bird was in good condition (Mech and DelGiudice 1985). Hutchinson (1984) found that waterfowl that were not dying of starvation had 20 – 40% marrow fat, but that once total body fat dropped below 20% ulnar fat was rapidly used and that levels of 1% ulnar fat or less indicated starvation. Our results (Fig. 5.1) fit with Hutchinson's findings with birds we classified as in good condition having 24 – 41% ulnar lipid, while poor and starved birds had 16% or 0%, respectively. This suggests that the birds we visually classified as in "poor condition" (including a captive-bred bird released in Northland), were in the early stages of starvation.

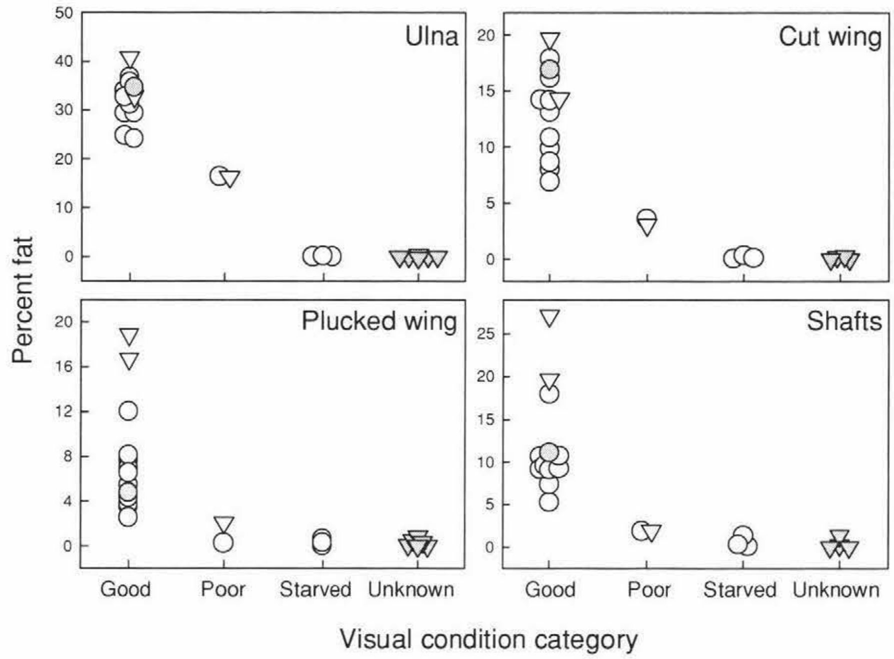

FIGURE 5.1. Wing fat content of Brown Teal (*Anas chlorotis*) in relation to visually assessed body condition. Hollow circles, complete carcass wild birds; filled circle, partial carcass wild bird; hollow triangles, complete carcass captive-bred birds; filled triangles, partial carcass captive-bred birds. The unknown category refers to the partial carcasses of captive-bred Brown Teal released into the wild whose condition could not be assessed visually. As two captive-bred released birds had been pinioned, sample sizes are smaller for cut wing and shafts lipids.

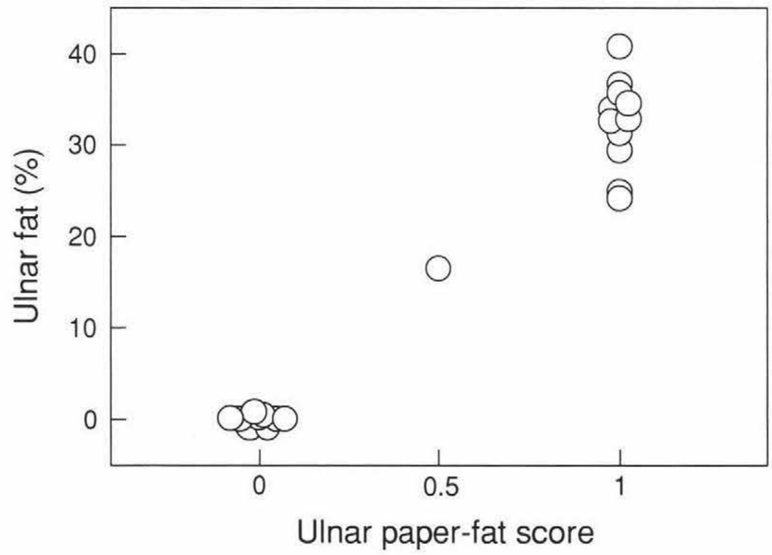

FIGURE 5.2. The relationship between Brown Teal (*Anas chlorotis*) ulnar fat and ulnar paper-fat score (n = 21). See methods for details.

We also analysed the fat content of the other outer wing components to see whether they would provide additional information (Guglielmo and Burns 2001). While fat content of the cut wing had the best relationship with body mass (Table 5.1), all three outer wing fat measures showed the same pattern of change with relative condition as ulnar lipid (Fig. 5.1). The two birds with by far the largest visual fat deposits (individuals 16 and 17, two captive-bred birds that died in captivity) had the highest plucked wing and shaft fat content. Individual 17 also had the highest ulnar and cut wing fat content (Fig.5.1, hollow triangles, good condition). The results of all of the wing fat components indicate that the six "unknown" released birds were in very poor nutritional condition at the point of death.

Starvation is not the only cause of extremely low lipid levels in waterfowl as lead poisoning can cause chronic weight loss and death within weeks (Sanderson and Bellrose 1986). However, waterfowl shooting is not permitted on Great Barrier Island (one of the teal used in our wing fat analysis had been illegally shot by a visiting high school student, but this was an isolated incident) and no recreational shooting is permitted on Tiritiri Matangi, Kapiti and Mana Islands or in the Karori Wildlife Sanctuary, so it is very unlikely that the low lipid levels we observed were caused by lead poisoning.

The results of the wing fat analysis on the partial remains of the released birds are consistent with starvation. However, two of the partial carcasses (individuals 19 and 22) were partially decomposed, which could have affected their lipid levels. Individual 19 was seen alive on 6 August 2001; when next checked on 26 August the desiccated scavenged remains were found lying out in the open, so the carcass may have been up to 20 days old. Individual 22 was found lying in a stream, and although the flesh was intact and feathers were still attached to the body, feathers slipped off when the carcass was handled and it had a strong unpleasant smell. Ringelman *et al.* (1992) found that percent ulnar lipid was not related to the apparent freshness of wings in mallards (*A. platyrhynchos*), in winter in the cold dry San Luis Valley, Colorado. These conditions are not likely to be applicable to individual 22. When we cracked individual 22's ulnae open, they contained a watery reddish substance, as did the ulnae of the "starved" condition birds (also observed by Hutchinson 1984 in starved waterfowl). The apparent similarity in ulnar contents suggested to us that individual 22's ulnae were suitable for analysis and should be included. However we cannot rule out the possibility that this was a result of decomposition.

Other evidence that individual 22 was in poor nutritional condition prior to death came from the carcass itself. When the bird was released it weighed 556 g; when the carcass was retrieved (minus its head) it weighed 408 g. We weighed the only Brown Teal head available to us at the time, that of a large male (40 g), and even if individual 21 had an equivalently large head, its total carcass weight at death would have been 448 g, a loss of 19% of its body weight in the 24 days since release.

All seven of the captive-bred released teal used in the wing-fat analysis (six incomplete carcasses, and one complete carcass) were in poor nutritional condition immediately before death. Autopsies on the carcasses of two other captive-bred released teal indicated that they had starved to death (Empson 2001; Moore 2002). It is most likely that some sort of feeding difficulties caused the deaths of these birds. Although female waterfowl may become extremely emaciated or even starve during incubation (Ankney 1977) none of the teal was believed to be breeding. Eight of the nine were recovered dead within 6 weeks of release (the date of recovery for individual 18 was not recorded).

For five of the seven captive-bred released teal used in the wing fat analysis, it is not known if starvation or predation was the immediate cause of death. The carcass of individual 24 was still warm when it was recovered from a feeding harrier (*Circus approximans*) (R. Thorogood, pers. comm.), while the bird released in Northland had neck wounds likely to have been caused by a predator. Nevertheless, poor condition is implicated in the deaths of all seven birds. Wing fat analysis on the partial carcasses of five wild juvenile Brown Teal, recovered during a drought on Great Barrier Island in late 2002, indicated that the wild juveniles were also in extremely poor condition (S.J.M. unpubl. data).

Captive-bred animals released to the wild may have feeding difficulties as a result of behavioral deficiencies (Snyder *et al.* 1996), or may be unable to adequately absorb the nutrients available from wild foods. Several studies have found differences in gut morphology of birds fed predominantly soft foods in captivity, compared with the same species (or even the same birds) when on a higher fibre or wild diet (Miller 1975; Piersma *et al.* 1993). Liukkonen-Anttila *et al.* (1999) suggested that because of the physiological and morphological differences between captive-reared and wild grey partridges (*Perdix perdix*), an abrupt change from a commercial to a natural diet affected the captive-reared partridges' survival, and a previous study (Putaala and Hissa 1993) found that captive-reared partridges were vulnerable to starvation after release to the wild. Whether released captive-bred teal are more likely to die of starvation than wild teal could be tested by capturing wild birds and releasing them plus captive-bred birds at a new site, and comparing the survival of the two groups. If feeding difficulties cause higher mortality in captive-bred teal, providing captive teal with a diet that more closely resembles that of wild teal, trialing soft release methods, and providing released teal with suitable supplementary food could all help increase their survival.

We found a very strong relationship between ulnar paper-fat score and percentage ulnar fat (Fig. 5.2). For future recoveries of Brown Teal carcasses, retrieving the ulnae and using them to obtain an ulnar paper-fat score is likely to provide the information required for management purposes in an easy and inexpensive manner. For fuller analyses of the type carried out here, weighing wing samples to 0.001 g or 0.01 g would be sufficient. Shafts were the smallest component used in our analysis; the minimum dry weight of the smallest shaft was 0.2817 g, of which 0.0001 g was fat. Thus using 0.01 g would have affected only a small number of values and not changed the overall conclusions.

Finally, although ulnar lipid levels have proven a useful tool for assessing Brown Teal nutritional condition, they cannot be used for all bird species. In some bird species, the marrow of various bones has been replaced by air sacs (Hutchinson 1984). However, fat levels in other outer wing or leg components could still prove useful as condition indicators for these species.

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APPENDIX 5.1 Source details and morphometrics of Brown Teal (*Anas chlorotis*) used in wing fat analyses. Birds from Great Barrier Island are wild-bred; all others were captive-bred. See methods for definitions.

Bird	Carcass	Location	Date	Sex	Body mass (g)	Bill length (mm)	Tarsus (mm)	Wing length (mm)	Visual score	Comments
1	Whole	Great Barrier Is.	3 Dec 95	Female	615	41.5	42.0	191	Good	Shot
2	Whole	Great Barrier Is.	2 May 99	Female	455	42.1	40.8	190	Good	Road fatality
3	Whole	Great Barrier Is.	6 Jun 00	Female	595	42.4	40.3	206	Good	Throat wound
4	Partial	Great Barrier Is.	14 Dec 00	Female		40.9	38.9	205	Good	Road fatality, abdomen missing
5	Whole	Great Barrier Is.	5 Oct 01	Female	468	39.1	39.7	198	Good	Road fatality
6	Whole	Great Barrier Is.		Female	285	42.2	40.9	201	Starved	No visible fat, keel protruding, extremely thin
7	Whole	Great Barrier Is.		Female	395	39.4	39.6	206	Poor	Road fatality
8	Whole	Great Barrier Is.	21 Dec 96	Male	415	46.5	43.1	173	Starved	Road fatality. No visible fat, keel protruding, very small breast muscles
9	Whole	Great Barrier Is.	24 Jan 97	Male	490	38.2	39.2	215	Good	Road fatality
10	Whole	Great Barrier Is.	17 May 00	Male	600	42.2	41.8	207	Good	Road fatality
11	Whole	Great Barrier Is.	19 May 00	Male	590	45.6	42.2	211	Good	Road fatality
12	Whole	Great Barrier Is.	7 Nov 00	Male	612	41.6	41.2	208	Good	Road fatality

APPENDIX 5.1. Continued

Bird	Carcass	Location	Date	Sex	Body mass (g)	Bill length (mm)	Tarsus (mm)	Wing length (mm)	Visual score	Comments
13	Whole	Great Barrier Is.	12 Jan 01	Male	630	42.4	42.9	197	Good	Road fatality
14	Whole	Great Barrier Is.	25 Jul 01	Male	575	43.1	39.6	210	Good	
15	Whole	Great Barrier Is.		Male	540	42.9	40.8	216	Starved	Deformed leg (badly broken), no visible fat, keel very prominent
16	Whole	Captive		Female	525	38.6	41.3	198	Good	Died in transit between breeders
17	Whole	Captive		Male	679	42.8	43.4		Good	Sudden death in captivity
18	Whole	Released Northland	21 Sep 98	Female	469	42.9	41.7		Poor	Neck injury, released 1 Apr 98
19	Partial	Released Mana Is.	26 Aug 01	Female		41.4	40.9	202		Released 25 July 01
20	Partial	Released Kapiti Is.	10 Aug 01	Female		43.2	41.2	199		Released 24 July 01
21	Partial	Released Kapiti Is.	10 Aug 01	Male		41.6	40.4	201		Released 24 July 01
22	Partial	Released Karori	8 May 01	Male			41.0	206		Released 14 Apr 01
23	Partial	Released Tiritiri Is.	1 Aug 02	Female		43.1	40.8	192		Released 25 July 02
24	Partial	Released Tiritiri Is.	27 July 02	Male						Released 18 June 02

6

Discussion and recommendations

Introduction

Caughley and Gunn (1996) stressed the need for ecologists to become familiar with their study species in the wild, prior to assessing species management requirements. Consistent with that philosophy, this study commenced on 24 July 2001, with the release and monitoring of captive-bred Brown Teal or Pateke (*Anas chlorotis*) on Mana and Kapiti Islands near Wellington. On 9-10 August 2001, the partial carcasses of three of the four Brown Teal released at Okupe Lagoon on Kapiti Island were recovered. It seemed unlikely that predation by harriers (*Circus approximans*), which had been blamed for deaths of released teal on Kapiti the previous year (Stamp 2000), was the only problem. Within a week of release, two of the teal had been observed sitting in the open during the day, and were slow to take cover when approached. This behaviour made the birds more vulnerable to harriers. What had caused it? On 19 August 2001, the intact carcass of a released teal was recovered from Rangatira on Kapiti; necropsy determined that this bird had starved. Unfortunately, there was no technique available to assess the other birds' nutritional condition from the partial carcasses recovered.

From September 2001, the remaining captive-bred released Brown Teal were monitored monthly, and my focus shifted to the feeding behaviour of wild-living Brown Teal on Great Barrier Island. Observations of foraging wild teal on Great Barrier, Kapiti and Mana Islands in 2001, were combined with analyses of teal droppings, and oesophagus, proventriculus and gizzard contents of Brown Teal from Great Barrier, Little Barrier and Kapiti Islands, Northland, and Karori Wildlife Sanctuary. Those results are presented in Chapter 2, and comprise the first comprehensive study of Brown Teal diet in the wild. Brown Teal had a very diverse diet for a dabbling duck: 78 taxa were identified, including terrestrial and freshwater vegetation (mostly seeds, fruits, and clover leaves), terrestrial, freshwater and marine invertebrates, and fungi. The novel way Brown Teal on Great Barrier prise open cockles to extract the flesh, as described in

Chapter 3, was very unexpected, and is a skill only Brown Teal and oystercatchers (*Haematopus* spp.) possess.

Wild Brown Teal fed on relatively high-fibre foods compared with the low-fibre diets of teal fed in captivity. For captive-reared teal, apparent post-release feeding difficulties may be linked to this low-fibre diet. Measurements of digestive organ size and dry mass of wild and captive Brown Teal revealed substantial differences in the gross morphology of the small intestine and caeca between the two groups (Chapter 4). Captive-living teal had significantly shorter and lighter small intestines and caeca than wild birds, probably resulting from the artificial diet of captive birds. These differences would place nutritional stress on released birds as they adjusted to wild foods.

In January 2002, I obtained 41 Brown Teal carcasses from the Department of Conservation wildlife freezer on Great Barrier. In the subsequent 18 months a further 36 carcasses were collected on Great Barrier. The need to determine the condition of teal from partial remains, and the presence of a large collection of intact carcasses of wild teal in various nutritional states, led to the testing of wing fat content as a condition indicator (Chapter 5). This technique for assessing nutritional condition of Brown Teal from wing remains confirmed that teal recovered as partial carcasses on Kapiti in 2001, and captive-bred teal released to Mana Island, Karori Wildlife Sanctuary and Tiritiri Matangi Island, were in very poor condition prior to death. It has since proven useful in determining the condition of wild juvenile and adult teal recovered on Great Barrier Island as partial carcasses.

The work undertaken in this thesis has addressed three key research needs identified by the Brown Teal Recovery Programme audit (Innes *et al.* 2000):

- Research on teal diet.
- Refine/investigate release and post-release techniques for captive-raised teal.
- Research on the cause of death by necropsy of wild teal.

Much of the information gained from this study is already being applied to Brown Teal recovery. Areas where further improvements could be achieved and where future research needs have been identified are discussed below.

Captive management

The audit of the Brown Teal Recovery Programme (Innes *et al.* 2000) states that "research is not required to support captive rearing itself, since this is already very successful". Nevertheless, it is likely that the quality of the progeny currently being reared could be improved. One area of captive management that requires attention is how the ducklings are raised. Research on other bird species suggests that parent-reared birds adjust better to life in the wild than those reared by surrogates, which in turn fare better than those raised in incubators. Ring-necked Pheasants (*Phasianus colchicus*) hatched in incubators and fostered by domestic chickens had higher clutch and brood survival in the wild than incubator-hatched pheasants reared under lamps (Brittas *et al.* 1992). Parent-reared Nene Geese (*Branta sandvicensis*) were dominant to, more vigilant than, and integrated into the adult flock sooner than goslings reared without parents or goslings reared in the sight of adults (Marshall and Black 1992). Only parent-reared goslings avoided rather than approached a predator, a behaviour which is believed to account for the disproportionately high number of Nene, all reared without parents, that were killed when a fox (*Vulpes vulpes*) got through the perimeter fence at the Wildfowl and Wetlands Trust, Slimbridge (Marshall and Black 1992). While gathering data for Table 1 of the Introduction, I found evidence of similarly inappropriate predator responses in captive-bred released Brown Teal. In 1983, the day after 34 Brown Teal were released at Pukepuke Lagoon in coastal Manawatu, 8 were found dead by the release site, presumably killed by a mustelid (Anon. 1983). Ducks Unlimited then changed their release site to Nga Manu Sanctuary in the Wellington Region. Later that year at Nga Manu, a recently released captive-bred Brown Teal was observed leading a mob of waterfowl in pursuit of a stoat (*Mustela erminea*; P. McKenzie, Nga Manu, pers. comm.).

Key references and manuals for Brown Teal captive breeders recommend that eggs be removed and reared either in incubators, by bantam hens, or by other *Anas* species, to increase the number of ducklings produced (Hayes and Williams 1982; Hayes and Dumbell 1990; Hayes 2002). Although this increases the number of birds available for release, it may compromise their ability to cope in the wild. Until the importance of parent-rearing for Brown Teal has been properly assessed, it is prudent to assume that Brown Teal are similar to other species studied. Breeders should be encouraged to take a quality over quantity approach and parent-rear Brown Teal.

Research into the post-release survival and breeding of captive-bred teal reared under different regimes would clarify the values of this approach.

Release practices

The Brown Teal Recovery Programme had been criticised for its poor track record in monitoring the fates of released captive-bred teal (Innes *et al.* 2000; Pierce *et al.* 2002) and data shown in Table 1.1 of the Introduction were collected with difficulty. Although hardly comprehensive, Table 1.1 is the most complete and up-to-date summary of Brown Teal releases. Searches of Department of Conservation and Wildlife Service files, New Zealand National Banding Office records, Ducks Unlimited New Zealand publications, and contact with personnel involved in various releases, revealed that few of the 94 permitted releases were adequately reported. In addition to the releases listed in Table 1.1, unpermitted releases by captive breeders direct from the breeding facilities have also occurred (K. Evans, Pateke Captive Breeding Co-ordinator, pers. comm.).

Unfortunately, the failure to adequately monitor and report Brown Teal releases has continued. During this study, I was provided with carcasses of captive-bred teal released on Tiritiri Matangi Island in 2002 for wing fat analysis, but had difficulty determining how long the birds had survived post-release, as release and recovery dates had not been recorded. Brown Teal releases in 2002 were intended to be run as experimental trials, with the Tiritiri Matangi releases testing whether habitat improvements can achieve higher numbers of birds, and whether harness design can be improved (Pierce *et al.* 2002). Given that there is no intention within the Department to write a report on the outcomes of the Tiritiri Matangi releases (R. Stamp, DoC, pers. comm.) and the difficulties in finding basic information such as release dates, these releases have failed to meet their objectives.

More encouragingly, recommendations regarding release practices resulting from the research in Chapter 4 (gut morphology) are already being instigated. It was recommended that released captive-bred birds be provided with adequate supplementary food, and that fibre be increased in the captive diet in an attempt to prepare the guts of captive teal for wild foods. In June 2003, 38 captive-bred Brown Teal were released at Port Charles, Coromandel Peninsula. The teal were supplied with accessible and familiar supplementary foods for more than the first month post-release (J. Roxburgh, Department of Conservation, pers. comm.).

At the request of the Pateke Recovery Group, the Poultry Nutrition Unit, Massey University, is preparing an alternative teal pellet with a higher fibre content, that can be fed to captive birds in the months prior to release. A further refinement would be to determine the nutritional content of the wild Brown Teal diet (by analysing gizzard contents of wild Brown Teal or collecting foods eaten by teal and analysing these). The captive diet could then be made much more similar to that in the wild, removing much of the guesswork currently involved in captive diet preparation.

Measuring gut morphology could be a useful means of assessing the effects of changing the captive diet or, if the existing captive diets continue to be used, determining how long it takes captive birds to adjust to wild foods. As gut morphology can only be reliably studied on fresh or frozen tissues, not those stored in formalin, the guts of necropsied captive or released Brown Teal could be frozen and returned to the Department of Conservation to reduce any future need to sacrifice healthy birds.

Assessing nutritional condition

The use of wing fat analysis to assess nutritional condition (Chapter 5) has been readily adopted by the Pateke Recovery Group. In the few months since Chapter 5 was completed, the ulnar paper-fat of 12 carcasses has been assessed at the Recovery Group's request. This has shown that some wild Brown Teal starved during the summer of 2002-2003 on Great Barrier Island, and that two teal found dead after release in Warrenheip, a site secure from introduced predators in the Waikato Region, did not starve, but died of unknown causes.

I have demonstrated ulnar paper-fat methodology to members of the Pateke Recovery Group and pathology staff at the Institute of Veterinary, Animal and Biomedical Sciences, Massey University, and have supplied them with a simple one-page instruction sheet (Appendix 3). Although nutritional condition should always be noted during necropsy, it will not usually require ulnar paper-fat assessment. A bird's nutritional condition can often be determined by visual assessment of the carcass's subcutaneous and abdominal fat and pectoral muscles. Only if the carcass is too decomposed or damaged for visual assessment, will an ulnar paper-fat score be needed.

It should be noted that ulnar paper-fat scores can only be determined for birds that are fresh or frozen (not those that have been stored in formalin).

Endangered species managers have expressed interest in applying the ulnar paper-fat technique to other species. Although ulnar lipid levels have proven a useful tool for assessing Brown Teal nutritional condition, they may not be suitable for all bird species. In some bird species, the marrow of various bones has been replaced by air sacs (Hutchinson 1984); in others, such as kiwi (*Apteryx* spp.), the wing bones are greatly reduced. It is likely that fat levels in other outer wing or leg components could prove useful as condition indicators for these species. Marrow lipid levels, however, must be calibrated against those from birds of known nutritional condition (including both starved and healthy birds) for each new species, to ensure that the indicator used is applicable to the species in question.

Ageing and sexing Brown Teal

Collecting age and sex data during necropsy would enable Brown Teal managers to determine whether some parts of the population are more vulnerable to certain mortality agents than others. As well as providing basic information on unbanded birds, it could be used to confirm the age and sex of banded Brown Teal (inspections of the gonads have shown that teal are sometimes sexed wrongly during banding; Dumbell 1987; pers. obs.). Although there are standard ornithological techniques available for this, they are currently seldom applied to Brown Teal (pers. obs.).

For much of the year, Brown Teal cannot be reliably sexed by plumage. Only if a male is in breeding plumage or the female has a brood patch can their sex be determined, and even in breeding plumage the most colourful females may be more brightly coloured than the dullest males (Dumbell 1987). However, like other members of the Anatidae, Brown Teal can be sexed by the presence (male) or absence (female) of a large syringeal bulla (Pettingill 1985; pers. obs.). This technique is particularly helpful when a carcass is too decomposed or damaged to be sexed by visual inspection of the gonads.

Brown Teal can be aged by the appearance of the gonads and bursa of fabricius (bursa). The bursa is clearly visible to the naked eye in young teal, but becomes smaller as birds approach maturity (Pettingill 1985; pers. obs.). Inspection during necropsy of a five to six-month old banded Brown Teal from Great Barrier showed this bird's bursa was no longer visible (S.J.M unpubl. data). Recording the bursa size in known-age banded wild teal will allow unbanded birds to be more accurately aged during necropsy. Inspection of the ovaries and oviduct provides additional aging information on females which may be old enough to no longer have a visible bursa, but have never bred and thus still have a straight rather than convoluted oviduct.

Recording moult, particularly of flight feathers, will also help age Brown Teal, and could easily be done by teal managers prior to dispatching carcasses for necropsy. Currently, the moult of juvenile Brown Teal is undescribed (Marchant and Higgins 1990) and validated age-moult data are required for captive and wild birds. Preliminary observations suggest juveniles undergo at least a partial moult involving flight and some contour feathers in the winter following fledging (S.J.M. and P.F. Battley unpubl. data). This differs from adult teal which usually undergo a complete body moult, the pre-basic moult, at the end of the breeding season in early summer (Marchant and Higgins 1990).

The pre-basic moult is a vulnerable time for Brown Teal. Like other waterfowl, all tail and flight feathers are shed simultaneously making the birds temporarily flightless, hindering predator avoidance and reducing foraging ranges. It is unknown how long the flightless period lasts in Brown Teal, but it may be similar to that of Mallards (*Anas platyrhyncos*) which lasts 33 to 36 days and may be prolonged if birds are under nutritional stress (Owen and King 1979). Recording teal moult would reveal whether moulting teal have lower survival than non-moulting birds and may shed some light on the function of flock sites. Brown Teal flock sites may be chosen for their qualities as safe moult sites; prior to pre-basic moult males, and to a lesser extent females, of many species of dabbling duck migrate to secluded places safe from predators with suitable feeding areas and water nearby (Salomonsen 1968).

Food shortages as a cause of decline

Recent wing fat analysis and the diet information contained in Chapter 2 suggest that wild Brown Teal are periodically food limited; a problem likely to be intensified by land use changes, such as the draining of wetlands for residential and agricultural use. During this study, 13 wild Brown Teal from Great Barrier Island were identified as having died in extremely poor nutritional condition, defined here as having less than 1% ulnar lipid (Table 6.1). Only one of these birds, an adult male from Okiwi with a badly broken leg, had any obvious predisposition to feeding difficulties, although two other

TABLE 6.1. Wild Brown Teal found to have died in extremely poor nutritional condition (ulnar marrow fat <1%) on Great Barrier Island. Asterisk denotes that these birds were too damaged to sex during dissection, so the sex assigned during banding is given. Wing fat means that the percentage fat in the outer wing components was determined by fat extraction, ulnar paper means only the ulnar paper score was determined (see Chapter 5).

Band	Date	Location	Age	Sex	Evidence
-	21 Dec 96	Okiwi	Adult (moult)	M	Wing fat
-	Pre 2002	-	-	F	Wing fat
-	Pre 2002	-	Adult (plumage)	M	Wing fat
L-33777	16 Apr 02	Okiwi	Adult (banded in 1990s)	F	Ulnar paper
S-70431	18 Nov 02	Okiwi	Juv 4 mth (band)		Wing fat
S-70401	20 Nov 02	Okiwi	Juv 4 mth (band)	M*	Wing fat
S-70430	20 Nov 02	Okiwi	Juv 4 mth (band)	F*	Wing fat
S-70435	21 Nov 02	Okiwi	Juv 4 mth (band)	M	Wing fat
S-70432	28 Nov 02	Okiwi	Juv 4 mth (band)	M	Wing fat
-	16 Dec 02	Okiwi	Adult (moult)		Ulnar paper (likely)
S-61031	3 Jan 03	Okiwi	Adult (banded in 1990s)	F	Ulnar paper (likely)
S-70418	13 Jan 03	Okiwi	Juv 6 mth (band)		Ulnar paper
-	25 Feb 03	Medlands	Juv (bursa visible)	F	Ulnar paper

teal which had been banded in the late 1990s may have been affected by old age.

In 2002-2003, Department of Conservation staff aimed to monitor 20 juveniles in the Okiwi Basin, Great Barrier Island using mortality transmitters, however very few could be located and only 11 juveniles were monitored from October 2002 to January 2003 (Howard and Jamieson 2003). Six of these 11 juveniles died between November 2002 and January 2003; wing fat analysis did not detect any ulnar lipid remaining in five of the birds, and ulnar-paper fat suggested a similar result for the sixth. Four of these six carcasses were too damaged to determine whether predation or starvation was the immediate cause of death; a fifth had been scavenged by a harrier (there was no obvious bruising on the back as would be expected if it had been killed by the harrier) and the sixth showed no sign of any teeth marks or stripping, but had been severely scavenged by maggots. Hutchinson (1984) found that levels of 1% ulnar fat or less indicated starvation. By this criterion, all known juvenile deaths at Okiwi in the spring-summer of 2002-2003 were due to starvation. This suggests that food shortages were a key cause of the poor recruitment observed at Okiwi in 2002-2003.

Ten of the thirteen starved Brown Teal recovered so far on Great Barrier Island were found in the Okiwi Basin (no location was recorded for two), but as Brown Teal monitoring efforts are concentrated at Okiwi, it is not possible to know whether similar feeding problems have occurred elsewhere on the island. Howard and Jamieson (2003) noted that Great Barrier Island experienced an unusually dry spring and summer in 2002-2003. However, rainfall data supplied by NIWA for this period; October 57 mm, November 63 mm, December 52 mm, January 211 mm, February 143 mm (S. Burgess, NIWA, pers. comm.), do not seem markedly different from that recorded by Barker (1999) at Okiwi Station from 1997-1999. There are currently inadequate data to determine whether this pattern of juvenile mortality is an annual occurrence on Great Barrier, as this is the first year that wing fat and ulnar-paper fat analysis have been used to determine nutritional condition in dead wild Brown Teal.

Wing fat analysis enables Brown Teal managers to determine whether adult and juvenile teal are starving. However, food shortages can also affect populations by reducing reproductive success through non-laying, small clutches, egg-desertion, poor chick growth and survival, and reduced numbers of nesting attempts per season (Newton 1998). Non-laying has been recorded at Mimiwhangata in Northland (12 of 30 monitored females did not attempt to nest in 2002; Neill 2003) and at Okiwi on Great Barrier (6 of 18 monitored females in 2002; Howard and Jamieson 2003). Two nests at Okiwi were abandoned for unknown reasons in 2002, and while chick survival was certainly poor at Okiwi in 2002 (only 5 of 35 chicks hatched in monitored nests survived to fledging; Howard and Jamieson 2003), the cause of chick mortality remains unknown. If teal chicks were affected by food shortages they would have been more vulnerable to predation. Hungry chicks are more visible to predators as they move around more in search of food (Newton 1998) and are slower to respond to parent alarm calls (Swennen 1989). Finally, although renesting has been observed at Mimiwhangata (3 females in 2002; Neill 2003) and on Mana Island (including one female that renested three times in 2001; Appendix 1), it was not recorded at Okiwi in 2001 or 2002 (Appendix 2; Howard and Jamieson 2003). The effects of food supply on reproductive success of Brown Teal could be tested by the provision of extra food to monitored pairs at a managed site.

More information on the relationships between Brown Teal food availability, abundance of competitors (such as rats and rabbits), climate, and habitat type is urgently needed. There is currently so little known of the interactions between Brown Teal and the species that may compete with Brown Teal for food, that it seems unwise to recommend their control in case it leads to increased predation on Brown Teal by harriers, cats, and morepork (*Ninox novaeseelandiae*). Rats, mice and rabbits were monitored by Barker (1998, 1999) from 1997-1999. This monitoring urgently needs to be reinstated (especially as the wild cat control instigated since then may have caused rat, mouse and rabbit abundances to increase). To better assess whether prolonged dry spells are affecting Brown Teal feeding, it would be useful to monitor rainfall, relative humidity and temperature at key management sites. This information could then be compared to nutritional condition of local teal as assessed at banding and during necropsy, and also to the key breeding parameters already being monitored.

The only productivity and survival data available for wild Brown Teal are from four predominantly pastoral sites: Okiwi on Great Barrier Island, and Mimiwhangata, Clendon Cove, and Tutaematai in Northland (Barker 1998; Barker 1999; Williams 2001; Appendix 2; Howard and Jamieson 2003). Management of wild Brown Teal management is currently focused on two of these pastoral sites, Okiwi and Mimiwhangata. Nothing is known of Brown Teal population demographics in lowland forest or large intact wetland areas. Little lowland forest remains on Great Barrier as most of the alluvial flats were cleared for farmland and are now in grass or regenerating scrub, but a large freshwater wetland remains at Kaitoke. Twelve of the Brown Teal carcasses used in the diet analysis were from teal hit by cars near the Kaitoke Swamp, three of which were found on the road near the Claris Police Station in the last six months (the police station is directly across the road from the one of the few areas of permanently open water in Kaitoke Swamp; Ogden 2001). The number of teal carcasses found adjacent to Kaitoke (which included a duckling and two juveniles) suggests there is a Brown Teal population resident in Kaitoke Swamp. Surveying the area with a trained dog, would reveal whether the population is large enough to yield useful information if it was monitored intensively. Two juveniles were killed by motor vehicles adjacent to Kaitoke Swamp in the summer 2002-2003, both were in good nutritional condition (unlike all the juveniles recovered from Okiwi). Monitoring the nutritional condition of birds caught or carcasses found, plus the survival and productivity at a non-pastoral site on Great Barrier, such as the Kaitoke Swamp, could reveal whether the food shortages that have affected Brown Teal at Okiwi station are related to land use and vegetation, rather than simply being climate or competitor driven.

Like captive-bred released Brown Teal, the survival of wild Brown Teal may be limited by both food supplies and predators. The provision of additional food has aided the recovery of other endangered waterbirds in the wild, such as the Trumpeter Swan (*Cygnus buccinator*) and several crane species (*Grus* spp.) in Japan (Cade and Temple 1994). It may be that for the Brown Teal, predator control around populations in a very modified environment is not enough to save the species, and food shortages need to be addressed.

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Appendix 1

Pateke/Brown Teal Monitoring

Kapiti and Mana Islands, 2001

Report for Department of Conservation,
Waikanae Area Office

Suzanne J Moore

February 2002

Table of contents

Summary

In August 2000, thirteen captive-bred brown teal (*Anas chlorotis*) were released on Kapiti Island and ten captive-bred brown teal were released on Mana Island. In July 2001, a further seven captive-bred teal were released on both Kapiti and Mana Islands. Kapiti and Mana Islands are free of introduced mammals, but Kapiti has more avian predators (weka, black-backed gulls, morepork, pukeko) than Mana. Mana Island has a large wetland area, Waikoko Wetland, which was constructed to provide brown teal habitat (a network of ponds and waterways with good cover). All of the teal released in 2001 and some of the teal released in 2000 were radio-tagged. I monitored the survival and breeding attempts of teal from these releases between late July and mid December 2001.

Between six and ten of the twenty teal released on Kapiti, and two or three of the seventeen birds released on Mana, died within the first two months post-release. Most of the carcasses were predated/scavenged prior to being recovered and the cause of death could not be established. However, two carcasses were intact. One had become trapped in *Muehlenbeckia* at the release site and died of starvation/dehydration (Mana Island); the other was not entangled but had also died of starvation/dehydration (Kapiti Island). Captive-bred released teal are known to have died of starvation at Karori Wildlife Sanctuary. Supplementary feed was provided at three sites on Kapiti Island, but was essentially unavailable to most teal. Survival in the first month after release was higher on Mana than on Kapiti Island, which may have been due to Mana's lower predator numbers and better food availability.

There were seven known breeding attempts on Mana Island. The first three (within 12 months of release) did not fledge any chicks. The fourth attempt fledged four ducklings. At the end of monitoring a further three ducklings were near fledging and four ducklings were half adult size. None of the teal released in 2001 attempted breeding. No breeding has been recorded on Kapiti Island in 2000 or 2001. This may be due to Kapiti's small numbers of teal present/monitored, food shortages, and/or higher numbers of predators.

Recommendations for future teal releases are provided.

Introduction

The pateke or brown teal (*Anas chlorotis*) is a small endemic duck that was once widely distributed throughout New Zealand (Heather and Robertson 1996). Brown teal should be considered critically endangered and are likely to be extinct in the wild within ten years without management intervention (Innes et al. 2000). Predation, habitat loss, hunting and disease have all been implicated as possible causes of their decline (Williams and Dumbell 1996).

The establishment of new viable teal populations on "predator safe" islands is acknowledged as a high conservation priority (Williams and Dumbell 1996; Innes et al. 2000).

The Wildlife Service released ten brown teal onto Kapiti Island in 1968 (Williams 1974). Williams noted that within four months of release at least one female had bred, and ducklings had fledged. Observations logged in Kapiti Island field books note sporadic sightings of small numbers of wild brown teal through the 1990s.

In July 1996, six brown teal (an adult pair from Okupe Lagoon, an immature male from the upper Wharekohu catchment, an adult female from Maraetakaroro catchment, and an adult pair from the Taepiro catchment) were caught using a trained dog, and held in captivity at Rangatira. They were held to safeguard the teal against accidental poisoning during the September 1996 rat eradication (aerial application of Brodifacoum). However, within two weeks of capture, aggression between the six teal resulted in the deaths of four of them. The two surviving teal were released in 1997 (Kapiti Island Wildlife Observation Book May 96 - 98).

In July 2000, a female brown teal was heard calling at Rangatira Swamp (D. Eason, Kapiti Island Wildlife Observation Book Nov 98 - present). In early August 2000, a pair of brown teal and a brown teal-mallard hybrid were seen on Okupe Lagoon (R. Stamp, Kapiti Island Brown Teal Book 2/8/00 - present).

On 14 August 2000, thirteen captive-bred brown teal were released on Kapiti Island. Two of the birds died within the first month post release and no breeding was recorded in 2000 (Stamp 2000).

There are no known records of brown teal on Mana Island prior to 2000. Ten captive-bred brown teal were released on Mana in 2000 (Stamp 2000). In late October 2000, one duckling hatched (Mana Bird Book brown teal section).

Study Sites

Kapiti Island lies approximately 5 km off the west coast of the southern North Island. The island is around 10 km by 2 km, with a total area of 1,965 ha and a maximum height above sea level of 520 m (DoC website, www.doc.govt.nz). Much of the island was farmed in the 1800s, and farming continued at the northern end of the island well into the mid 1900s. The island is now covered in regenerating native bush; small clearings remain around the inhabited areas (Rangatira and Waiorua). A poison operation in 1996 eradicated rats, leaving Kapiti free of introduced mammals. Teal have been released into three areas on Kapiti (Okupe Lagoon, Rangatira Swamp and Wharekohu Stream) and released teal have subsequently moved to the Waiorua Stream.

Okupe Lagoon, at the north-eastern tip of Kapiti Island, is approximately 750 m^2, and up to 1.2 m deep (Stamp 2000). The vegetation around the lagoon is mostly dense small-leaved shrubs, with manuka/kanuka (*Leptospermum scoparium/Kunzea ericoides*) west of the lagoon. The lagoon has no major inlet streams or surface outlet to the sea.

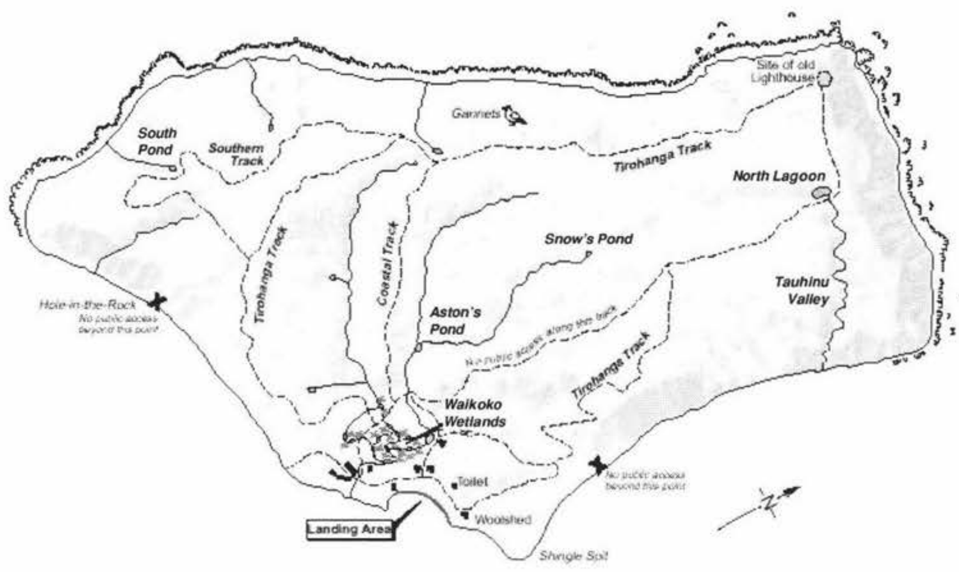
The closest area of fresh water to Okupe Lagoon is Waiorua Stream, 750 m south, but the two are not connected by surface water. Waiorua Stream is around 1 m wide and 20 cm deep. In the lower part of the Waiorua Valley, the stream flows through rank grassland, past the Waiorua houses. In the mid-reaches, the stream edges are surrounded by a narrow margin of regenerating bush.

Rangatira Swamp, mid-way down the east coast, is a series of waterways 20-50 cm deep, and damp mud. Plant cover is predominantly flax (*Phormium tenax*), sedges and grasses.

Wharekohu Stream, near the southern end of Kapiti Island, has been shaped into a narrow (1-2 m wide), stone-walled waterway in the lower reaches, which have narrow margins of regenerating bush. Directly upstream are several large sedge (*Cyperus* sp.) wetlands, with a large area of regenerating native bush further upstream.

Mana Island (Fig. 1) lies 2.5 km off the west coast of the southern North Island in Cook Strait. The island has a total area of 217 ha. Mana is free of introduced mammals. Pukeko (*Porphyrio porphyrio*) and black-backed gulls (*Larus dominicanus*) have been controlled on the island. Much of the island is in the early stages of regenerating to native bush (the last farm stock were removed in 1986), and is currently rank grassland.

Figure 1. Map of Mana Island, showing major tracks and placenames.



A series of ponds were created in 1998 to form Waikoko Wetland. The ponds are smallish (c. 20 m^2 surface area) and are surrounded by *Carex*, poroporo (*Solanum laciniatum*), ngaio (*Myoporum laetum*), flax and sedges. Sea aster (*Aster subulatus*) provides year round cover in shallow water. Manuka branches have been placed on the water's edge to provide cover. Waikoko Wetland Ponds mentioned in this report include: the House Pond, Jason's Pond, Ducks Unlimited Pond, the Sewage Pond, the Spillway, Ephemeral Pond, Lower Weta Pond, the Diversion, and the Silt Trap.

There are nine ponds outside of Waikoko Wetland. Only one, Aston's Dam, has manuka brush provided for cover. Teal were released into three of these ponds: South Pond, Snow's Pond and the North Lagoon (see Fig. 1).

South Pond was approximately 15 m x 6 m in September 2001. About 1/5 of the water's edge is covered by overhanging flax. A dense area of flax and cabbage trees (*Cordyline australis*) extends for approximately 60 m up from the pond. The pond has a very small catchment and no discrete inflows or outflows. Below the pond are cliffs on the steep south-west side of the island. GPS E2658881, N6011004.

Snow's Pond was approximately 6 m x 14 m in September 2001. There was little overhanging vegetation and little cover around the water's edge. No surface water ran into or out of the pond, but there were damp gullies down the valley. The pond is in the head of the Waikoko Wetland catchment. GPS (5m accuracy) E2659677, N6011954.

North Lagoon was approximately 12 m x 20 m in September 2001, with a shallow creek up to 5 m wide extending a further 30 m upstream. A low branched macrocarpa (*Cupressus macrocarpa*) provided a tiny amount of cover at the water's edge, but there was no cover around most of the pond. GPS (6m accuracy) E2659870, N6012478.

Methods

All brown teal released on Kapiti and Mana in 2001 were captive-bred. Teal were provided by Neil Hayes, Paul (Galatea), Ron Munroe, Russell Langdon, Queenstown Wildlife Park and Wellington Zoo (Tables 1 and 2).

Quarantine

Eighteen teal were supplied for the 2001 release and taken to Mt Bruce Wildlife Centre in early May 2001 for quarantine. The teal were tested for a number of diseases including Newcastles Disease, other Parmyxoviruses, fowl plague (Avian Influenza), avian pox, *Salmonella* spp., *Yersinia pseudotuberculosis*, fowl cholera (*Pasteurella multocida*), avian TB (*Mycobacterium avium*), Mycoplasma spp., Chlamydiosis, intestinal nematodes, cestodes (tapeworms), trematodes (flukes), fleas, nasal mites, and ticks (Reed 2001).

A pooled sample from two of the teal tested positive for *Chlamydophila* and a pooled sample from two other teal tested positive for Newcastles Disease. Tests for *Chlamydophila* and Newcastles Disease were repeated on all eighteen birds and the teal were moved to Matiu (Somes Island) on 14 June pending results from these tests. No further positive results were obtained (Reed 2001). The four birds involved in the positive disease tests were withheld from release.

Banding and transmitters

The remaining fourteen teal were wing-clipped, banded with metal bands and individually colour-banded. Mt Bruce staff measured the wing (1 mm), bill (0.1 mm), and tarsus (0.1 mm) of ten of the fourteen teal. Teal were weighed a day or two prior to release.

The first six of the females released, plus one of the males, were wearing mortality transmitters (Sirtrack, 20/40 ppm, 12 hours latching, 16 months life) on brown teal weak-link harnesses (linen thread weak-link). The other six males were wearing non-mortality transmitters on brown teal weak-link harnesses.

An underweight female (S-73248), who weighed 430g on 18 July, was held back from the July release and received veterinary treatment for a kidney infection. She was released on Mana Island, weighing 450g, on 28 August 2001. A transmitter was not attached prior to release due to her low body weight.

Details of teal released on Kapiti and Mana in 2000 and 2001 are shown in Tables 1 and 2.

Efforts were made to supplementary feed any broods of ducklings near fledging, to make them easier to catch. No juvenile teal were colour-banded or radio-tagged due to the limited availability of experienced staff and periods of bad weather that prevented boat access to Mana. Jason Christensen and Richard Gill metal banded one brown teal brood (bands on the right leg) on 29 November 2001. Ducklings were weighed to the nearest gram, and tarsus, head + bill, bill width and culmen were measured to the nearest 0.1 mm.

Table 1. Brown teal released on Kapiti Island 2000 - 2001, grouped by release site (2000 data from Stamp 2000 and DoC files).

Metal Band	Colour Bands	Tx frequency	Sex	Source	Pre-release weight (g)[1]	Wing (mm)	Bill (mm)	Tarsus (mm)	Release date	Release site	Pre- release comments
L-28716	WY-M	N/A	Male	Otorohanga	558				14 Aug 00	Okupe	
L-35160	GR-M	N/A	Male	Otorohanga	528				14 Aug 00	Okupe	
L-28692	M-OG	34	Female	Queenstown	412				14 Aug 00	Okupe	
L-28732	M-YB	24	Female	Hamilton Zoo	437				14 Aug 00	Okupe	
L-28735	M-YR	16	Female	Hamilton Zoo	456				14 Aug 00	Okupe	
L-28738	M-RB	12	Female	Kevin Evans	504				14 Aug 00	Okupe	Feather condition poor
L-28740	M-OW	32	Female	Kevin Evans	424				14 Aug 00	Okupe	Feather condition poor
S-73242	M-OB	86*	Female	Ron Munroe	519	189	41.2	39.3	24 July 01	Okupe	
S-73244	M-WW	82*	Female	Ron Munroe	584	199	43.2	41.2	24 July 01	Okupe	
S-73246	M-RY	26*	Female	R. Langdon	485				24 July 01	Okupe	
S-73249	OB-M	80*	Male	R. Langdon	540				24 July 01	Okupe	Sore leg
L-28691	YG-M	N/A	Male	Queenstown	482				14 Aug 00	Rangatira	
L-28711	M-RG	8	Female	Otorohanga	498				14 Aug 00	Rangatira	
L-35159	M-WG	36	Female	Otorohanga	489				14 Aug 00	Rangatira	
L-35350	OY-M	10	Male	Paul (Galatea)	617	204	43.7	40.2	24 July 01	Rangatira	Exposed wing joints 18/6/01
S-73245	YL-M	6	Male	Paul (Galatea)	541	202	43.9	41.5	24 July 01	Rangatira	
L-28736	RY-M	N/A	Male	Hamilton Zoo	526				14 Aug 00	Wharekohu	
L-35157	M-WB	14	Female	Otorohanga	435				14 Aug 00	Wharekohu	
L-35158	M-BO	22	Female	Otorohanga	461				14 Aug 00	Wharekohu	
L-35308	YR-M	14	Male	Neil Hayes	598	212	42.5	43.1	24 July 01	Wharekohu	

* Mortality transmitter

[1] Birds released in 2000 had 9 g subtracted from all female weights to allow for transmitter weights. It is not known if transmitter weights were subtracted from the 2001 weights.

Table 2. Brown teal released on Mana Island 2000 - 2001, grouped by release site (2000 data from Stamp 2000).

Metal Band	Colour Bands	Tx frequency*	Sex	Source	Pre-release weight (g)[1]	Wing (mm)	Bill (mm)	Tarsus (mm)	Release date	Release site	Pre-release comments
L-28714	WO-M	N/A	Male	Otorohanga	567				14 Aug 00	Waikoko	
L-28731	YO-M	N/A	Male	Hamilton Zoo	490				14 Aug 00	Waikoko	
L-28741	RW-M	N/A	Male	Kevin Evans	499				14 Aug 00	Waikoko	
L-28715	M-GW	2	Female	Otorohanga	467				14 Aug 00	Waikoko	
L-28717	M-GO	28	Female	Otorohanga	441				14 Aug 00	Waikoko	
L-28718	M-WR	38	Female	Otorohanga	446				14 Aug 00	Waikoko	
L-28733	M-OY	26	Female	Hamilton Zoo	470				14 Aug 00	Waikoko	
L-28734	M-GY	18	Female	Hamilton Zoo	412				14 Aug 00	Waikoko	
L-28739	M-BY	6	Female	Kevin Evans	485				14 Aug 00	Waikoko	Feather condition poor
L-32981	M-OR	32	Male						3 Nov 00	Waikoko	
S-73238	YW-M	12	Male	Neil Hayes	541	207	42.9	39.3	25 July 01	South Pond	
S-73240	BY-M	8	Male	Paul (Galatea)	572	209	41.0	41.2	25 July 01	South Pond	
S-73248	B-M	N/A	Female	R. Langdon	450				28 Aug 01	South Pond	Kidney infection treated (weight 489 g May 01)
S-73239	LO-M	16	Male	Neil Hayes	571	212	44.2	39.6	25 July 01	Snow's Pond	
S-73241	M-GG	96*	Female	Ron Munroe	542	190	42.0	39.6	25 July 01	Snow's Pond	
S-73243	M-YW	20*	Female	Ron Munroe	613	202	41.4	40.9	25 July 01	North Lagoon	
S-73247	OW-M	30	Male	Wellington Zoo / Queenstown	554				25 July 01	North Lagoon	

* Mortality transmitter

[1] Birds released in 2000 had 9 g subtracted from all female weights to allow for transmitter weights. It is not known if transmitter weights were subtracted from the 2001 weights.

Monitoring

Teal were monitored for the first three weeks after the release, and then during monthly visits from September to December 2001. Periods of monitoring on Kapiti Island were: 25–30 July, 1–3 August, 7–11 August, 13–16 September, 12–15 October, 10–12 November, and 12–15 December 2001. Periods of monitoring on Mana Island were: 31 July, 4–7 August, 9–13 September, 8–12 October, 15–16 November, and 15–16 December 2001.

Radio-tagged teal were tracked using a Telonics TR4 receiver and Yagi hand-held aerial. Most tracking was done during the day, or at dawn or dusk. Night-time checks were made periodically using night vision equipment (ITT Night Mariner with infra-red filtered Petzl headlamp). Co-ordinates of release sites and subsequent teal locations were determined with an Etrex hand held GPS.

Transmitters giving mortality signals were pinpointed and retrieved immediately. Any intact carcasses found were sent to the Institute of Veterinary, Animal and Biomedical Sciences (IVABS) at Massey University for post-mortem examination. Birds with non-mortality transmitters were checked on consecutive days where possible to determine whether the signal had moved. If it had not, males were tracked closely and seen, to confirm that they were still alive. No attempts were made to flush females out of hiding places (even if the signal had not moved), to avoid the risk of nest abandonment. They were simply rechecked the following month. If a female was seen with ducklings, her hiding place was checked for a nest, and any nest contents examined. Any remaining eggs were sent to IVABS.

On each visit to Kapiti, Okupe Lagoon, the Rangatira feeder pond and Wharekohu Stream were checked for the presence of teal, using Nikon 10 x 21 binoculars or, occasionally, a spotting scope.

Supplementary Feeding

There was some confusion prior to the release about whether the teal were to be supplementary fed or not. Wellington conservancy office staff informed me that they would not be, however Waikanae area office staff had obtained barley to feed the teal, and there were three "Gimpex Grain Dispensers" available for use on Kapiti Island (two were set up on 24 July 2001).

The Gimpex Grain Dispensers used were 20 L white plastic buckets with tightly fitting lids, with a hole in the bottom where a perspex tube was inserted. The tubes had small holes around the bottom edge, so that when the tube was bumped small amounts of grain would fall out (see Fig. 2).

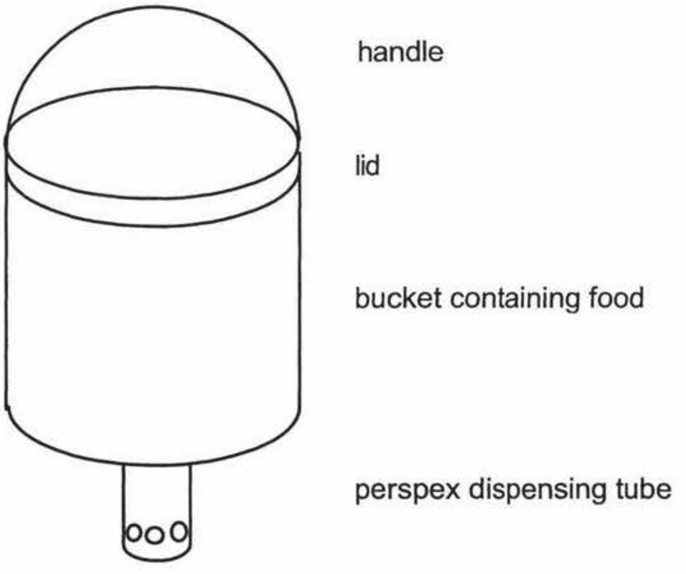
Three feeders were filled with barley and installed at the following sites:

- Wharekohu Stream, under the small bridge near the hut,
- Rangatira Swamp, under a tripod made of three warratahs over a small open pond,
- Okupe Lagoon, under a tripod made of three warratahs over very shallow water approximately 2 m from the western shore, near the release site.

The Wharekohu and Rangatira feeders were set up on the day of the release (24 July). The Okupe feeder was not set up until 5 days after the release (29 July), although food pellets were left on ground beside release site on 24 July. The Rangatira and Okupe Lagoon feeders were removed during the study period.

On Mana Island, barley was sprinkled beside all three release sites for the first few nights post-release. The South Pond teal continued to be fed whenever the site was visited (approximately once a fortnight), until mid December. The teal family at Jason's Pond was fed from late September till December.

Figure 2. Gimpex grain dispenser - birds tap on the dispensing tube, and grain falls out of the holes.



Results

Kapiti Island

Monthly relocations of Kapiti Island teal are given in Table 3, after the case studies.

Case studies of teal seen in 2001

Okupe and Waiorua

M-OG female tx 34

- Released at Okupe 14 August 2000. Last found near Okupe in August 2001. Whether she had a mate and attempted breeding is unknown.

Stamp (2000) found this bird with a male (WY-M) in September 2000 on the western side of Okupe Lagoon, near the old wharf. In November and December 2000, Stamp tracked her to the southeastern side of the lagoon.

Her transmitter was still active on 24 July 2001, and she was tracked in late July and early August. Her changing locations suggested that she was not nesting. On 25 July 2001 she was located alone near the top of the ridge on the southeast side of the lagoon, under dense divaricating *Coprosma*. There was no evidence of a nest. On 28 July 2001 she had moved south to the eastern arm of the lagoon and was tracked to a dense area of divaricating shrubs, approximately 10 m from the water's edge. She was in a similar area on 29 July 2001 and 3 August 2001. On 10 August 2001 she was slightly northeast – 30 m inland from the lagoon, south of where eastern arm joins the main lagoon.

No signal was detected in September, October, November and December 2001. It is not known if this was due to transmitter failure (13 months after release) or if she had left the site.

M-YB female tx 24

- Released at Okupe 14 August 2000. Last seen in Waiorua Stream in August, with mate. Breeding attempts unknown.

Moved to Waiorua Stream within 6 days of release, and remained in the Waiorua valley for the duration of Stamp's monitoring (i.e. until December 2000).

Her transmitter was still active on 28 July 2001, and she was tracked in late July and early August. Her changing locations suggested that she was not nesting, and she was seen on several occasions with a mate but no ducklings. On 28 July 2001, she and another teal were seen running from an area of *Carex* beside Waiorua Stream, downstream of the old takahe pen. It is not known if the other bird was banded. On 29 July 2001, her signal was upstream of the takahe pens. On 3 August 2001, she and another teal were seen swimming upstream of the takahe pens. On 10 August 2001, she was tracked to a large patch of sedge inside the takahe pen (potential nesting habitat so she was not disturbed). The following day she had left the sedge and was back in nearby Waiorua Stream.

No signal was detected in September, October, November and December 2001, which may have been due to transmitter failure (13 months after release) or she may have left the site. A two-person survey of Waiorua Stream upstream of the houses (one person walking upstream, one walking downstream) on 15 September 2001 failed to locate any teal. At dusk on 10 November 2001, a teal was seen in Waiorua Stream near the houses (J. Barrett, pers. comm.).

M-OB female tx 86

- The sole survivor of the four teal released at Okupe on 24 July 2001. Never seen (she moved through dense divaricating shrubs each time and was difficult to track), and it is not known if she had a mate or attempted to breed.

On 25 and 26 July she was found north of the release site. By 28 July she had moved to the south side of the lagoon. She was tracked to different locations on the south and south east shores of the Lagoon on 29 July, 3 August, 10 August, 15 September, 13 October, 11 November and 13 December 2001.

On 3 August 2001, her signal and the signal for a male (tx 80 OB-M) were nearby. The two may have been together and she was still near tx 80 when he was found dead on 10 August.

M-WW female tx 82

- Released at Okupe on 24 July 2001. Died between 3 and 10 August (10–17 days post-release), body heavily scavenged/predated, cause of death unknown.

Heard dabbling in the lagoon just north of the release site, after dark on 25 July. She was seen on 26 and 28 July near the release site. On 29 July her signal was still close to the release site. On 3 August her signal was faint west/north west of the release site, but she was not located (no signal from Kiwi Hut or from boulder ridge north of the lagoon). On 10 August found dead (transmitter in mortality mode) on boulders on the northern coast, c. 3 m north of bait station 50 (over the boulder ridge from the lagoon) near the black-backed gull colony. The carcass had been heavily scavenged/predated - all that remained were wings, feet, head, backbone and ribs. She was lying in a shallow pool of water under a dense mass of divaricating shrubs, not visible from above, presumably dragged there by a weka (*Gallirallus australis*). The transmitter was about 5 m away (weak link broken) and lots of teal feathers were scattered over a 1 m radius on open ground a further metre away.

M-RY female tx 26

- Released at Okupe on 24 July 2001. Tx and feathers found on 9 August (10–16 days post-release). Probably died between 3 and 9 August, but carcass not located.

Signal coming from south of the release site on 25 and 26 July. On 28 July signal coming from the southern end of lagoon. On 29 July she was seen in Waiorua Stream behind houses. On 3 August signal in/near Waiorua Stream downstream of Boysie's windmill, upstream of houses. On 9 August, the transmitter was found (weak link broken) lying on grass near the creek, approximately 20 m east of John Barrett's lodge. Two big piles of teal contour and flight feathers were near the transmitter. There were takahe (*Porphyrio mantelli*) droppings on both piles of feathers (droppings large and grassy, identification confirmed by R. Empson). The carcass could not be located, despite a thorough search of the immediate area.

OB-M male tx 80

- Released at Okupe on 24 July 2001. Died between 3 and 10 August (10–17 days post-release), carcass heavily scavenged/predated.

Seen on 25 July near release site. Signal heard near release site on 26 July signal. He was seen again, mid-afternoon on 28 July, running down the track beside the release site. On 29 July his signal was north of the release site. On 3 August his signal (along with that of a female, tx 86 M-OB) was on southern shore of the lagoon. The two birds may have been together. On 10 August his carcass was found under dense divaricating shrubs (5 m crawl from grass edge), 8 m from water's edge on the south side of the lagoon. A weka was scavenging the carcass when found. The transmitter was still attached to the body, which had been reduced to wings, feet, vertebrae and the top half of the skull and bill. The carcass was very smelly.

Rangatira

YG-M male

- Released at Rangatira on 14 August 2000. Still there in December 2001.

Within a few days of release he had paired up with a wild female in Rangatira Swamp, and was seen with her until December 2000 (Stamp 2000). In 2001, YG-M was repeatedly seen at Rangatira. Pukeko dominated the feeder pond while there was grain in the feeder (and were seen chasing YG-M), but once the feeder was empty, teal regained use of feeder pond. On 1 September 2001, YG-M was seen copulating with M-RG in the feeder pond (J. Newell, Kapiti Island teal book.). They were seen there again on 16 September 2001. On 8 October and 15 December 2001 he was seen alone in the feeder pond (G. Moorcroft, pers. comm.).

M-RG female tx 8

- Released at Rangatira on 14 August 2000. Still there in December 2001.

In 2000, she was often with another female (M-WG) and found in Rangatira Swamp below the whare, or further north, in the swamp near the visitor shelter (Stamp 2000).

On 1 September 2001, she was seen copulating with YG-M in the Rangatira feeder pond, and both were seen there again on 16 September 2001. On 13 and 14 December 2001 she was seen back on the feeder pond and, on the evening of 14 December, was seen fighting with an unknown teal.

M-WG female tx 36

- Released at Rangatira on 14 August 2000. Still there in December 2001.

In 2000, she was often with another female (M-RG) and found in Rangatira Swamp below the whare, or further north, in the swamp near the visitor shelter (Stamp 2000).

On 6 June 2001 (2000 hrs) she was seen near track below the Field Centre Manager's house (P. Griffen, in litt.). On 14 December 2001 (2027 hrs) a teal was seen walking along the track near the old teal aviary. The bird had a pale band above a dark band on her right leg, and a transmitter aerial - this was likely to be M-WG.

OY-M male tx 10

- Released at Rangatira, near feeder pond on 24 July 2001. Died of starvation between 9 and 19 August 2001.

Signals changing strength, or in slightly different locations to previous signals, were recorded nine times between 25 July and 8 August 2001. All were from the south part of Rangatira Swamp (near feeder pond and generator shed). He was seen swimming in the feeder pond on 9 August 2001. Found dead on 19 August 2001 near the old teal aviary, with no obvious signs of injury, but he was very thin, and weighed 337 g (cf. 617 g pre-release). IVABS pathology report stated that he had died of starvation/dehydration.

YL-M male tx 6

- Released at Rangatira, in the wetland area below the Field Centre Manager's house on 24 July 2001. Signal last picked up on 25 July. Fate of bird unknown.

On the day after release (25 July 2001), the bird had moved south into the wetland area below the Whare. All surveys from 27 July onwards failed to pick up a signal for tx 6.

Areas surveyed included Rangatira (day and night surveys), the eastern coast by boat, the Coastal track, the track from Rangatira to Okupe and around Okupe Lagoon, Wharekohu catchment, Te Mingi catchment, the upper Taepiro catchment, Trig and Wilkinson Tracks.

Wharekohu

RY-M male

- Released at Wharekohu on 14 August 2000. Still there with mate M-WB in December 2001, no breeding attempts known.

RY-M was repeatedly seen near the Wharekohu bridge with mate M-WB in 2000 (Stamp 2000) and in 2001. On one occasion in 2000, and in late July 2001 he was seen with the other released female M-BO. In 2001, he usually roosted near the bridge, and would swim out to the bridge when called (the feeder was refilled at the same time).

M-WB female tx 14

- Released at Wharekohu 14 August 2000. Still there with mate RY-M in December 2001. No breeding attempts known.

M-WB was repeatedly seen near the Wharekohu bridge with mate RY-M in 2000 and 2001. As she was seen in August, September, October, November, December 2000 and July, September, October, November, December 2001 without ducklings, she is not thought to have fledged ducklings during these months.

M-BO female tx 22

- Released at Wharekohu in August 2000. Last seen in July 2001 at Wharekohu. No breeding attempts known.

Stamp (2000) usually found her a short distance upstream of the Wharekohu feeder. In mid-September 2000 she was seen with the released male RY-M near the Wharekohu bridge (Stamp, Kapiti Island teal book). In October 2000 her signal was detected halfway up Wharekohu valley (Stamp, 2000). By July 2001, she had dropped her transmitter. She was seen with the male RY-M several times on 27 July 2001, but was not seen again.

YR-M male tx 14

- Released at Wharekohu on 24 July 2001. Last found on 14 September 2001 in Wharekohu catchment.

YR-M was released at Wharekohu in July 2001, unfortunately with the same tx frequency as a bird released at Wharekohu in 2000 that still had a working transmitter (M-WB). Only after 14 September, when it was confirmed that M-WB's transmitter had failed, could YR-M be detected from transmitter signals with certainty.

On 26 July 2001, one of the tx 14 birds was tracked to a group of flax bushes, at the eastern edge of Wharekohu Bay, near Bait Station 9. On 27 July 2001, a tx 14 bird with a yellow band (presumably YR-M) was flushed from low scrub on the beach end of the track to the hut. Later that morning, a strong signal was heard downstream of the Wharekohu Stream bridge, near were teal were heard fighting minutes earlier. YR-M was never seen using the feeder at the bridge, although the other three Wharekohu teal used it in July 2001.

On 7 August 2001, tx 14 signal was tracked to two locations, in the morning to the valley between T93 and T90 in the Wharekohu catchment, and later in the day to a stream up the valley behind the Wharekohu hut. On 8 August the signal was back in the T93/T90 valley, and the bird was approached closely, but could not be seen through the thick sedge cover.

In September, when M-WB's transmitter was no longer working, YR-M was tracked to the T93/T90 valley, and glimpsed running through the bush (due to disturbance from my approach). Later in the day, his signal was back in the sedge wetland area.

He was not seen or heard again. Areas surveyed included T29, partway down T9, along T81 and T75 to the junction with T41, up T93 to grassy clearing at top, a boat survey of the east coast, up T86 to the junction with T20, along the Coast track from Rangatira, up T60, down 19p to Taepiro, up T60 to the Trig and down the Wilkinson track, and around Okupe Lagoon.

Table 3. Relocations of brown teal on Kapiti Island, August 2000 - December 2001.

Colour Bands	Tx	Release Site	Aug 00	Sept 00	Oct 00	Nov 00	Dec 00	Jan 01	Feb 01	Mar 01	Apr 01	May 01	June 01	July 01	Aug 01	Sept 01	Oct 01	Nov 01	Dec 01
WY-M	-	Okupe		S															
GR-M	-	Okupe	S																
M-OG	34	Okupe	U	U	Tx	Tx	Tx							S	Tx				
M-YB	24	Okupe	U	Tx	Tx	S	Tx							S	S				
M-YR	16	Okupe	Dead 29/8																
M-RB	12	Okupe																	
M-OW	32	Okupe	Dead 25/8																
M-OB	86*	Okupe												Tx	Tx	Tx	Tx	Tx	Tx
M-WW	82*	Okupe												S	Dead 10/8				
M-RY	26*	Okupe												S	Dead 9/8				
OB-M	80*	Okupe												S	Dead 10/8				
YG-M	-	Rangatira	S	S	S		S								S	S	S		S
M-RG	8	Rangatira	S	U	Tx	Tx	Tx			Tx			S			S			S
M-WG	36	Rangatira	Tx	U	Tx	Tx	Tx						S						S
OY-M	10	Rangatira												Tx	Dead 19/8				
YL-M	6	Rangatira												Tx					
RY-M	-	Wharekohu	S	S	S	S	S							S		S	S	S	S
M-WB	14	Wharekohu	S	Tx	S	S	S							S	Tx?	S	S	S	S

Table 3 continued.

Colour Bands	Tx	Release Site	Aug 00	Sept 00	Oct 00	Nov 00	Dec 00	Jan 01	Feb 01	Mar 01	Apr 01	May 01	June 01	July 01	Aug 01	Sept 01	Oct 01	Nov 01	Dec 01
M-WB	14	Wharekohu	S	Tx	S	S	S							S	Tx?	S	S	S	S
M-BO	22	Wharekohu	S	S	Tx	Tx								S					
YR-M	14	Wharekohu												S	Tx?	Tx			

S = Seen, Tx = Tx signal moving or in non-mortality mode but bird not seen, U = Not known whether seen or tx. * = Mortality transmitter

Mana Island

Monthly relocations of Mana Island teal are given in Table 4, after the case studies. Breeding attempts are summarised in Table 5.

Case studies of teal seen in 2001

M-GW female tx 2

- Released at Waikoko Wetland on 14 August 2000. Had four ducklings in December 2001.

Stamp (2000) found M-GW with the male YO-M in the Ephemeral and Lower Weta ponds (September and November). No breeding attempts were known.

In October 2001, she was seen with WO-M and was incubating six eggs, in flax beside the Diversion. By mid-November she had six young ducklings, four of which remained in mid-December (see Table 5).

M-GO female tx 28

- Released at Waikoko Wetland on 14 August 2000. Two breeding attempts in 2001; by December 2001 she had 3 ducklings near fledging.

Stamp (2000) found M-GO in or near the Sewage Pond. No mate or breeding attempts were noted.

In early March 2001, M-GO was seen with 4 ducklings, which were 3/4 adult size when last seen on 30 March (Mana Island Wildlife Book). It is unlikely that the ducklings survived to fledging. No unbanded teal were seen on the wetlands, and a pair without ducklings was seen in their territory on 8 April 2001, before the ducklings would have fledged.

During this study, she was often seen with male WO-M (31/8, 11/9,12/9, 15/11, 15/12). In October 2001, M-GO re-nested beside the Sewage Pond and by 15 December 2001 had 3 ducklings near fledging (see Table 5).

M-WR female tx 38

- Released at Waikoko Wetland 14 August 2000. Always seen alone in 2000 and 2001. No breeding attempts known.

Stamp (2000) usually found M-WR alone in the Spillway Pond. In July-September, M-WR was seen or tracked to flax by the Silt Trap, on or by the Spillway, and on the Ducks Unlimited Pond (where she was attacked by M-OW on 10 September). There was no tx signal by mid-October, and she was not seen again until 16 December (alone on the Ducks Unlimited Pond, tx still attached).

M-OY female tx 26

- Released at Waikoko Wetland on 14 August 2000. Nested in August/September 2001 but her eggs were infertile.

Stamp (2000) found M-OY on the House Pond, with no mate or breeding attempts noted. Seen in 2001 with male YO-M (11/9, 8/10, 15/11) on the House Pond. Nested unsuccessfully on the House Pond in August/September (see Table 5).

M-GY female tx 18

- Released at Waikoko Wetland 14 August 2000. Seen in August, October and December 2001. No known breeding attempts.

In September 2000, she was found with the male WO-M in the Ducks Unlimited Pond. Later seen alone, but her signal was not picked up after mid November 2000 (Stamp, Mana Island Wildlife Book). In 2001, she was seen with male M-OR on Aston's Pond on 6/8, 9/10 and 15/12 (tx failed but still on). No known breeding attempts.

M-BY female tx 6

- Released at Waikoko Wetland on 14 August 2000. Three breeding attempts, four chicks fledged.

Stamp (2000) noted that M-BY had paired with male RW-M. In November 2000, one duckling hatched from her clutch of five eggs – the other 4 eggs were sent to IVABS (two eggs were infertile, one embryo had died early, the other had died late in development and had an external yolk sac). The duckling was last seen when it was around 15 days old.

M-BY renested and hatched 3 chicks in March 2001. It is not known if the chicks survived but this seems unlikely as only one chick remained after 14 April (5 weeks old and half adult size), and the remains of an unbanded teal were found on 21 June.

She was regularly seen with male RW-M on Jason's Pond during this study and nested in August 2001. Four chicks fledged and were banded on 29 November (see table 6). IVABS reported that the two unhatched eggs remaining in the August 2001 nest were fertile, but that the embryos had died at 13–16 days old (see Appendix 1).

M-OR male tx 32

- Released at Waikoko Wetland on 3 November 2000. No breeding attempts known.

This male was released to help balance the sex ratio (3 males: 6 females). He was found between the Spillway and Ducks Unlimited Ponds in mid-November and mid-December 2000 (Mana Island Wildlife Book).

During this study, he was seen on several occasions with female M-GY in or near Aston's Pond. M-GY's transmitter has failed, and no breeding attempts are known.

WO-M male

- Released at Waikoko Wetland on 14 August 2000. Bred with two females at the same time in late 2001.

Seen with M-GW on 28 September 2000 on the Ephemeral Pond, there were no other sightings in 2000 (Mana Island Wildlife Book).

During this study he was seen regularly with two females and their broods, M-GO (had three ducklings near fledging in December) and M-GW (four half-adult sized ducklings in December) (see Table 5).

YO-M male

- Released at Waikoko Wetland on 14 August 2000. Unsuccessful breeding with M-OY in 2001.

He was found with the female M-GW in September and November 2000 (Mana Island Wildlife Book), with no breeding attempts noted (Stamp 2000). Seen in 2001 with female M-OY, who nested unsuccessfully (nest abandoned - all four eggs were infertile) (Table 5, Appendix 1).

RW-M male

- Released at Waikoko Wetland on 14 August 2000. Bred with M-BY in 2001 (4 chicks fledged).

Only reported once in 2000, on 6 September (with female M-BY, who hatched a duckling in early November 2000). Regularly seen with M-BY during this study, they raised four ducklings to fledging (Table 5).

YW-M male tx 12

- Released at South Pond on 25 July 2001. Did not breed.

Seen on the South Pond every month until December (moulting flight feathers in November). In December, he and the other male released at the South Pond (BY-M) were found in the pond at the junction of the Coastal and Tirohanga tracks (near the concrete gannets).

BY-M male tx 8

- Released at South Pond on 25 July 2001. Did not breed.

Seen on the South Pond every month until December (moulting flight feathers in November). In December, he and the other male released at the South Pond (YW-M) were found in the pond at the junction of the Coastal and Tirohanga tracks (near the concrete gannets). By December BY-M had dropped his transmitter by the small pond at the head of the Weta Valley, several hundred metres from where he was found in December.

B-M female

- Released at South Pond on 28 August 2001. Not seen post-release.

LO-M male tx 16

- Released at Snow's Pond on 25 July 2001. No breeding attempts known.

By 31 July he had moved to the top of the Kaikomako Valley (head of the Waikoko catchment), and was found in Waikoko Wetland from 4 August onwards. Often seen with female M-GG (who also traveled from Snow's Pond to Waikoko).

M-GG female tx 96

- Released at Snow's Pond 25 July 2001. No breeding attempts known.

Transmitter faulty and no signal picked up post-release. Seen regularly with male LO-M in Waikoko Wetland from 12 September onwards.

OW-M male tx 30

- Released at North Lagoon on 25 July 2001. Died within 10 days of release.

On 4 August he was found dead tangled in *Muehlenbeckia* at the release site (pathology report in Appendix 1).

M-YW female tx 20

- Released at North Lagoon on 25 July 2001. Died within a month of release.

Moved between North Lagoon and Tauhinu Valley several times in early August. Her scavenged dried remains were found in Tauhinu Valley on 26 August.

Breeding Summary

There were no known breeding attempts on Kapiti Island during this study or the previous year (Stamp 2000, Kapiti Island teal book).

On Mana Island, four females released in 2000 are known to have nested, with a total of seven nests (Table 5). The first breeding attempt was within 6 weeks of the 2000 release. In March 2001 two pairs attempted breeding (the second attempt for one pair), although no ducklings are thought to have fledged. The peak of breeding occurred in October 2001, when four of the six females released in 2000 were known to be breeding. No breeding is known from the 2001 released birds, but only one true pair remain from this release.

Nest contents were known for five nests, which contained 28 eggs (5, 5, 7, 5, 6). Of the 28 eggs, 15 hatched (1, 3, 5, 0, 6), a hatching rate of 53.6%. Ten unhatched eggs were sent to IVABS; six of the eggs were infertile and the embryos had died in the other four. Four of the fifteen ducklings had fledged by the end of this study, with another three near fledging and four half adult size.

Four teal ducklings were confirmed to have fledged during this study period. They were banded at 80 days out of the nest. Their band numbers and morphometric data are given in Table 6.

Table 4. Relocations of brown teal on Mana Island, August 2000 - December 2001.

Colour Bands	Tx	Release Site	Aug 00	Sept 00	Oct 00	Nov 00	Dec 00	Jan 01	Feb 01	Mar 01	Apr 01	May 01	June 01	July 01	Aug 01	Sept 01	Oct 01	Nov 01	Dec 01
WO-M	-	Waikoko		S											S	S	S	S	S
YO-M	-	Waikoko	U	S		U										S	S	S	1
RW-M	-	Waikoko		S												S	S	S	S
M-GW	2	Waikoko	U	S	U	U			Tx	Tx				U	Tx	S	S	S	S
M-GO	28	Waikoko	U	S	U	U	U		Tx	S	U			U	S	S	Tx	S	S
M-WR	38	Waikoko	U	U	Tx	U	U	S	S	U	U			U	Tx	S			S
M-OY	26	Waikoko	U	S	Tx	S			S	U	U			U	S	Tx	S	S	
M-GY	18	Waikoko	U	S	Tx	U		S							S		S		2
M-BY	6	Waikoko	U	S	U	S	U		S	Tx				S	S	S	S	S	S
M-OR	32	Waikoko				U	S		Tx	S	U			Tx	S	Tx	S	Tx	S
YW-M	12	South Pond												S	S	S	S	S	S
BY-M	8	South Pond												S	S	S	S	S	S
B-M	-	South Pond																	

S = Seen, Tx = Tx signal moving or in non-mortality mode but bird not seen, U = Not known whether seen or tx. * = Mortality transmitter.

[1] One teal (no tx aerial) seen in this pair's territory on 16/12/01 and male call heard, but bands not seen.

[2] Female wearing failed tx seen with M-OR at Aston's Pond on the night of 15 December 2001. On two previous occasions when a female was seen with M-OR it was M-GY (who has a failed tx). Female's bands were not seen on this occasion.

Table 4. Continued

Colour Bands	Tx	Release Site	Aug 00	Sept 00	Oct 00	Nov 00	Dec 00	Jan 01	Feb 01	Mar 01	Apr 01	May 01	June 01	July 01	Aug 01	Sept 01	Oct 01	Nov 01	Dec 01
LO-M	16	Snow's Pond												S	S	S	S	S	S
M-GG	96*	Snow's Pond														S	S	S	S
M-YW	20*	North Lagoon												S	Dead 26/8				
OW-M	30	North Lagoon												Tx	Dead 4/8				

S = Seen, Tx = Tx signal moving or in non-mortality mode but bird not seen, U = Not known whether seen or tx. * = Mortality transmitter.

Table 5. Brown teal breeding attempts on Mana Island.

Pair	Territory	Date nest found	# eggs	# chicks hatched	Hatching date	# chicks fledged	Comments
M-BY + RW-M (?)	Jason's Pond	28 Sept 00	5	1	1 Nov 00	0	4 unhatched eggs sent to IVABS; two were infertile, one embryo had died early in development, the other embryo had died late in development due to an external yolk sac. Chick last seen on 5 Nov 00. M-BY + mate repeatedly seen without duckling from 17 Nov 00 onwards.
M-BY + ?	Jason's Pond	25 Mar 01	5	3	pre 29 Mar 01	?	2 chicks 3 April to 12 April. 1 chick 14 April to 11 June. Remains of one unbanded teal found in DU pond on 21 June.
M-BY + RW-M	Jason's Pond	31 Aug 01	7	5	10 Sept 01	4	5 chicks 11 to 21 Sept. 4 chicks 25 Sept. Chicks downy 1/3-adult size on 8 Oct. Chicks flat-tailed with no long primaries (2 with down remaining on rump) on 15 Nov. Fledglings caught and banded on 15 Nov. Pair with 3 fledglings seen on 15 Dec.
M-GO + ?	Sewage Pond	Not found	?	At least 4	pre 6 Mar 01	?	Female + 4 ducklings seen 6 Mar & 7 Mar. By 30 Mar female + 4 _-size ducklings. On 8 April 2001 pair seen on Sewage Pond without ducklings.
M-GO + WO-M	Sewage Pond	Suspected nesting by 8 Oct 01	?	At least 4	pre 15 Nov 01	3 likely	Pair + 4 ducklings first seen 15 Nov, ducklings downy with first tail feathers (estimate c. 3-4 weeks old). Pair with 3 ducklings, near fledging (near adult size, but some down on back of neck and above tail) seen 15 December.
M-OY + YO-M	House Pond	31 Aug 01	5	0	N/A	0	Female on nest 9 to 21 Sept. Female off nest 8 Oct - nest contained 4 cold eggs covered with grass. Female still off nest 9 Oct – nest damp, eggs still cold and covered. No sign of 5th egg. Eggs removed and sent to IVABS - all 4 eggs were infertile. Pair repeatedly seen on pond without duckling. If 5th egg had hatched, it is unlikely the duckling survived.
M-GW + WO-M	Lower Weta Diversion Ephemeral	9 Oct 01	6	6	pre 15 Nov 01	4 possible	Female + 6 ducklings first seen 15 Nov, ducklings small and fluffy (estimate c. 2 weeks old). Pair + 4 ducklings (fluffy and half adult size) seen on 15 December 01.

Table 6. Mana Island fledglings banded on 29 November 2001, aged c. 80 days. Measurements taken by Jason Christensen and Richard Gill.

Band number	Weight (g)	Tarsus (mm)	Head + Bill (mm)	Bill width (mm)	Culmen (mm)
L-37522	493	37.1	82.7	16.3	40.8
L-37523	543	38.6	85.7	16.8	37.6
L-37524	433	38.5	83.2	16.6	39.5
L-37525	433	39.6	85.1	11.4 (?)	38.6

Supplementary Feeding

Wharekohu

All three of the teal released in 2000 were seen using the feeder in 2001. The male released in 2001 was never seen using the feeder. A few days after the 2001 release, teal were heard calling and splashing just downstream of the feeder. One of the tx 14 birds appeared to be in a fight with other teal released in 2000. The Wharekohu feeder was an invaluable tool for monitoring the pair at Wharekohu; after calling, then shaking or refilling the feeder, within a few minutes the two resident birds would appear at the feeder. As neither of these teal had working transmitters, it would have been very difficult to monitor them without it. The Wharekohu feeder was usually found waterlogged and jammed with damp and mouldy food on each visit, due to changing water levels in the stream.

Rangatira

This feeder was predominantly used by a group of three pukeko, who monopolised the feeder pool, and in early August were seen five times chasing away teal that ventured into the pool. The bottom of the feeder was broken, which was thought to have been caused by pukeko's vigorous tugging and pecking. A weka was seen once swimming out to the feeder and using it (2/8/01). After these observations, the feeder was not refilled. A male teal was seen subsequently chasing the pukeko out of the pond. Teal then resumed periodic use of the pond.

Okupe Lagoon

Teal did not use the supplementary food provided in 2001. The pellets scattered on the ground by the release site on 24 July were still there on 26 July 2001. By the time the Okupe feeder was installed (29 July), no teal were known near the release site. Okupe Lagoon water levels changed between visits, leaving the feeder waterlogged and jammed with mouldy food. No birds were ever observed using the feeder.

Mana Island

Feeding the two males at the South Pond was a useful monitoring tool. Both of these birds had non-mortality transmitters and during the day they were often in very dense flax near the pond, where they would have been very difficult to track. Within a few minutes of calling and sprinkling barley on the edge of the pond, the two males would come out to feed.

Feeding also helped Richard and Jason catch the four fledglings for banding. The fledglings had become accustomed to walking into the small pen where feed was scattered and were easily caught.

Discussion

Kapiti Island survival

Thirteen teal were released on Kapiti Island in August 2000; two were found dead within a month of release at Okupe, three were not sighted after the first month post-release, and eight of them were seen during this study. Seven teal were released in July 2001; four were found dead within a month of release, and one has not been located since the day after the release. Between 6 and 10 of the 20 birds died within the first two months post-release.

In two cases, M-OW and M-RY, (both at Waiorua) a transmitter was found lying on open ground in a large pile of feathers (Stamp 2000, this study). This is consistent with sign left by harriers (*Circus approximans*) after a bird has been predated or scavenged. In three other cases, M-YR, M-WW and OB-M, (all at Okupe), heavily scavenged/predated bodies were found under dense vegetation, with a weka feeding on one. It is likely that all three of these carcasses were moved by weka, although their case of death remains unknown.

On Kapiti, morepork (*Ninox novaeseelandiae*), harrier, weka, and black-backed gulls are common, while pukeko and takahe are present in small numbers. An adult teal is bigger than the average morepork meal (see Higgins 1999), so morepork predation on released adult birds seems unlikely (morepork have been seen attacking teal ducklings on Great Barrier Island, P. Battley, pers. comm.).

Takahe may appear an unlikely predator of teal, but Stamp (2000) observed two takahe cornering a female teal (and chased the takahe away from the teal). Also, there are anecdotal reports of takahe killing teal ducklings on Tiritiri Matangi Island. Takahe may have been involved in demise of M-RY – takahe droppings were found on both piles of feathers. There are small family groups of takahe and Waiorua and Rangatira, yet at Waikoko Wetland, where there are more takahe present, there has no been no evidence that takahe were attacking teal.

There is a large black-backed gull colony at Okupe, and the gulls may be predating or scavenging on brown teal. During this study a black-backed gull was observed swooping down to the lagoon and carrying off a small paradise shelduck (*Tadorna variegata*) duckling and eating it. Black-backed gulls have been observed killing teal ducklings on Great Barrier Island (T. Bouzaid, pers. comm.).

Harriers appear to have been involved in scavenging or predating the two dead Waiorua birds. Weka were implicated in at least scavenging the remains of the three Okupe birds. Nevertheless, the causes of death for these five birds remain unknown. The other carcass found (at Rangatira) was intact, and post-mortem examination determined that the bird had died of starvation/dehydration. A captive-reared teal released at the Karori Wildlife Sanctuary also died of starvation/dehydration (post-mortem in May 2001).

Mana Island survival

The ten teal released on Mana Island in August 2000 were all seen in the latter half of 2001, and had survived at least 12 months post-release. Of the seven birds released in 2001, there have been two confirmed deaths, and one fate unknown (this bird was released in poor condition and not seen again). Two or three of the 17 birds released died within the first two months after release. Survival was higher on Mana Island than on Kapiti Island.

The two known Mana Island deaths both occurred within a month of release. One bird ran into nearby *Muehlenbeckia* on release and was found dead at that site. This death could have been avoided by not releasing the bird immediately beside *Muehlenbeckia*. The second carcass was found heavily scavenged/predated and cause of death is unknown. Her death could have been due to predation, starvation, disease, or a combination of these factors.

Survival summary

On Kapiti Island a total of 20 teal were released. Six were found dead, all within a month of release (30% known mortality). The cause of death was unknown for 5; the other bird starved to death. Another 4 birds were not seen again after the first month post release. Ten of the 20 birds (50%) are known to have survived the first few months.

On Mana Island a total of 17 teal were released. Two were found dead, both within a month of release (12% known mortality). The cause of death was entanglement in *Muehlenbeckia* for one bird, but was unknown for the second. A third bird was not seen after release. 14 of the 17 birds (82%) are known to have survived the first few months.

Survival was higher on Mana than on Kapiti Island, which may have been due to:

- lower numbers of predators
- better food availability.

Supplementary feeding

Starvation caused the death of at least one teal on Kapiti and at Karori Wildlife Sanctuary, and possibly one teal on Mana Island. Feeders were installed at the Kapiti release sites but were inadequate for the following reasons;

- pukeko excluded teal from using the feeder (seen at Rangatira),
- teal excluded other teal from using the feeder (Wharekohu),
- feeders became waterlogged making food mouldy (all three feeders),
- the feeder was installed after teal had dispersed from the area (Okupe Lagoon).

The feeder design was impractical:

- The lids were extremely tight-fitting and difficult to remove and replace.
- Teal were seen nibbling at the holes for food and tapping at feeders to dislodge food, but were not seen feeding on the grain/pellets that fell out of the feeder – much of the food sunk and was wasted.

There may have been additional problems with teal not recognising the feeders and the barley/pellets provided as a food source.

Pukeko were first seen using the Rangatira Gimpex feeder in late December and January 2001 (J. Newell, Kapiti Island Wildlife and Vegetation Observations 1998 - present). If feeders are installed to enhance teal survival, and pukeko are excluding teal from using feeders, then the pukeko should be removed from the site.

It is not adequate to install one feeder for a group of teal to share. It would be best to trial one feeder per pair, with feeders spaced so that they are not within view of the other feeders.

Teal should be trained to use feeders prior to release. The feeder could be placed higher, if a board is provided below it for teal to stand on. This would reduce the potential for waterlogging, could reduce food spillage into water, and would also provide the opportunity to more easily read teal bands. Different types of feeders should be trialed. A simple bait station attached to a warratah in the water would have reduced food spillage and been easier to refill than the Gimpex feeder.

Breeding

There have been seven known breeding attempts on Mana Island, and by the end of this study, four chicks had fledged, three chicks were near fledging and four were half-adult size. There have been no known breeding attempts on Kapiti since October 1996, when ducklings were seen on Okupe Lagoon (C. Miskelly, Kapiti Island Wildlife Observations May 96–98).

The lack of known recent breeding attempts on Kapiti may be due to:

- the small numbers of teal present
- the paucity of teal with working transmitters
- low food availability
- higher numbers of potential predators.

There have been some misleading reports on post-release breeding on Kapiti and Mana. Jakob-Hoff et al. (2001) stated that within eight months of the 2000 release breeding had occurred on both islands. Stamp (2000) stated that on Mana a "pair successfully fledged one duckling", and goes on to state that this duckling was last seen at 15 days old. This is not a fledged teal. Heather and Robertson (1996) define fledging as fully feathered; able to fly. Marchant & Higgins (1990) stated that captive young are able to fly 50-55 days after hatching. The four ducklings that left their nest near Jason's Pond on 10 September 2001 still had no long primaries (two had down remaining on rump) on 15 November (66 days after leaving the nest).

Dispersal

It is likely that wild brown teal move between Okupe Lagoon and Waikanae estuary. On 2 May 1999, four brown teal (two male, two female) and a male brown teal-mallard hybrid were seen on Waikanae Estuary (A. Tennyson, DoC files). On 17 August 1999, three teal (one male, two female) and a male hybrid were seen on Okupe Lagoon (J. Newell, Kapiti Island Wildlife and Vegetation Observations notebook). It appears likely that this was the same group of birds. Unbanded brown teal have also been seen at Nga Manu Bird Reserve in Waikanae (P. McKenzie in litt.).

A brown teal was reportedly seen flying onto Mana from the mainland on 31 October 2001 (Nio, Mana Island Bird Book). Brown teal certainly dispersed around Mana Island after the 2001 release. All of the teal released in 2000 were released into Waikoko Wetland, where there is a network of waterways and ponds with both natural and artificial cover available. These teal remained in Waikoko, apart from one pair which used nearby Aston's Pond (where artificial cover had been provided).

In 2001, the seven teal were released into isolated dams on the island, where available cover around water varied from 1/5 of pond surface (South Pond), to being practically non-existent (North Lagoon). Five of these seven teal are known to have moved away from the release site (one died at its release site shortly after release; the seventh has not been seen since release). The pair released at Snow's Pond in the head of the Waikoko catchment walked down through paddocks of rank grass to the Waikoko wetland (the male was found at Waikoko ten days after release). After moulting, the two males released at the South Pond moved overland and explored two other ponds on the west coast of the island. Both ponds are in the head of the Waikoko catchment, so it will be interesting to see if they too make their way down to Waikoko. Both birds released at the North Lagoon died. The female had traveled up and down the Tauhinu Valley, which had small damp areas but did not provide areas of open water with cover.

It is unwise to release wing-clipped brown teal into isolated waterways that do not provide good cover. Artificial cover (such as manuka brush) should be provided at all ponds on Mana Island, to increase the roosting and breeding habitat available to teal on Mana Island, and to encourage any fledglings to remain on the island, rather than dispersing to the mainland with its many introduced predators.

Transmitters

Of the seven teal transmitters that DOC provided for the 2001 release, five were double-ups on frequencies used in the previous year's release (6, 8, 12, 14, 16). At Wharekohu the only two birds with working transmitters had the same frequency. A register of Wellington Conservancy (including Karori) teal transmitter frequencies should be kept to prevent any more double-ups when transmitters are ordered.

Recommendations

- Condition the birds pre-release so that they are familiar with the feeders and with the food available both in the feeder and naturally (natural foods depend on the release site).
- Supplementary feed captive-bred teal post release.
- Install feeders prior to releasing teal.
- Trial alternatives to Gimpex feeders, such as bait stations.
- Place a plank below the feeder for teal to stand on, allowing the feeder to be raised higher above the water and bird bands to be read.
- Allow one feeder per pair of birds and place feeders near cover.
- Monitor feeder use to ensure that feeders are not being monopolized by the wrong species (time-lapse video recording would allow easy monitoring).
- Keep a register of teal transmitter frequencies used in Wellington Conservancy.
- Use mortality transmitters on all released birds. Have latching times of less than 12 hours, and a time of death function on transmitters.
- Monitor released birds daily for the first month post release (highest mortality was recorded during this period).
- Provide artificial cover at all ponds on Mana Island.

Acknowledgements

Peter Griffen, Julie Newell, Jason Christensen and Grant provided transport to and around Kapiti and Mana Islands and teal observations. Colin Miskelly, Selena Brown, Denise Fastier, Maryanne Rossiter, Greg Moorcroft and Sally Chesterfield contributed teal observations. Dick Gill and the Waikanae Area Office staff helped with logistics. Paul Jansen provided the night vision equipment. Emma Neill sent down the mortality transmitters for the release at very short notice. Phil Battley assisted with December fieldwork and provided much help with this report, including preparing the figures. Ray Pierce kindly provided helpful criticism that improved this report.

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Appendix 1

IVABS Pathology Reports

Four eggs from M-BY's November 2000 nest

Gross findings –

Egg A – 45 g, 55 x 40 mm. Addled and infertile.

Egg B – 48 g, 55 x 40 mm. Addled and infertile.

Egg C – 55 g, 60 x 40 mm. Contained a severely autolysed small embryo.

Egg D – 44 g, 58 x 39 mm. Contained a normal near term embryo CRL = 90 mm. It had a 20 x 30 x 30 mm external yolk sac. It was malpositioned with its head under the left wing.

Histopathology – Embryo D's bone marrow appears depleted and contains mainly granulocytic elements. Liver, gizzard, intestine, muscle, brain, cord and the internal yolk sac show no significant changes.

Diagnosis -

A - infertile egg

B - infertile egg

C- early embryonic death

D - late embryonic death due to external yolk sac.

Comments – Failure of closure of the umbilicus and externalization of the yolk sac are thought to be due to high incubation temperatures, poor gas exchange (high humidity) and egg infections.

Date: 22 March 2001 Pathologist: M R Alley

Two eggs from M-BY's September 2001 nest

Both eggs reported as embryonic death – records for one egg below.

Gross findings – Egg weight 49.5 g. Egg length 60.3 mm. Egg diameter 42.7 mm. Crown rump length of embryo 7.5 cm. Headlength – not measured. Yolk occupying most of egg, with membranes strongly adherent to shell in equator.

Histopathology – Colonies of similar coccal bacteria scattered through skeletal muscle, kidney, chambers of heart and other tissues, and without any reaction associated. Autolysis present but not advanced.

Microbiology – Culture results: Heavy growth of mixed organisms including *Pseudomonas stutzeri.* Heavy growth of another oxidase positive, gram negative bacillus. This organism has been stored if further identification is required. No Salmonella isolated.

Diagnosis – embryonic death at approximately 16-19 days of incubation, possibly as a result of infection of the egg with a soil bacteria.

Comments – HANZAB records eggs of *Anas chlorotis* as 60.3 (56.7-66.4) by 42.9 (39.8-45.2) mm. And fresh (newly laid?) weight 60.8 (55.9-66.9) g or in captivity mean 61.4 (n=20) g. Incubation period of 29-30 days recorded in wild and 27-30 days in captivity.

Using Hamburger and Hamilton's standardized Gallus chick staging criteria, this embryo is judged to approximate to Stage 39. In this classification there are 45 stages in the egg, with Stage 46 being the newly hatched chick. Stage 39 occurs at about 13 days of the 21-day Gallus chick incubation period. Precisely which day this stage corresponds to in the longer duck incubation period is not described in the literature available.

Date: 17 October 2001 Pathologist: R J Norman

Four eggs from M-OY's nest

Eggs opened - no evidence of any embryogenesis at all. No blood spot or further sign of an embryo. No further examination thought likely to be productive.

Date: 16 October 2001 Pathologist: P H G Stockdale.

Male OW-M, S-73247

Gross findings - the carcass was in poor condition and showed dehydration of subcutaneous tissues. The crop, proventriculus and gizzard were empty and the intestine contained minimal contents. The cloaca contained gritty semi-fluid green/grey material. Both kidneys were pale and slightly swollen and contained numerous pinpoint white foci.

Histopathology - the heart contains occasional small foci of acute inflammatory necrosis centred on large colonies of bacteria. The crop contains proliferating bacterial colonies within the submucosal glands (post mortem invaders). The lung also shows numerous small disseminated foci of recent inflammatory necrosis centred on colonies of bacteria (large Gram-positive cocci resembling staphylococci). The kidney shows recent focal necrosis of cortical tubular epithelial cells. The testes show severe generalised tubular degeneration. The brain, liver, thymus and adrenal gland show no significant changes.

Diagnosis - 1. Starvation/dehydration due to vine entanglement. 2. Acute bacterial septicaemia (terminal).

Comments - The bacterial invasion is extensive and recent but not extremely severe. It is likely to have been a terminal event occurring in a bird which was immuno-suppressed.

Date: 30 August 2001 Pathologist: M R Alley.

Male OY-M, L-35350

Gross findings – weight 337 g. The carcass was in poor condition with no body fat reserves and a prominent keel. The eyes were sunken (not missing) and there was severe dehydration of subcutaneous tissues. Little food was present in the gastrointestinal tract and the colon contained grey/green semifluid contents. No other gross abnormalities were seen.

Diagnosis – starvation/dehydration

Date: 21 August 2001 Pathologist: M R Alley

Appendix 2

Pateke/Brown Teal Monitoring
Okiwi Basin, Great Barrier Island
August-November 2001

Report to Department of Conservation,
Port FitzRoy, Great Barrier Island

January 2002

Suzanne J. Moore and Phil F. Battley

Table of Contents

Summary

The Department of Conservation (DoC) is controlling cats and pukeko on Okiwi Station in an attempt to boost brown teal (*Anas chlorotis*) survival and productivity. Seventeen female teal were radio-tagged at Okiwi, Great Barrier Island, during the 2001 breeding season and monitored intensively from late August until the end of November 2001. The monitoring objectives were to determine adult survival during the breeding season, to detect nesting attempts and establish their outcomes, and, if possible, to follow the fate of chicks.

Three radio-tagged teal died during this study. Two died before intensive monitoring began (approximately 34 and 40 days after radio-tagging). The third nested, hatched chicks, and was then killed shortly after she took her chicks from the bush nest site into pasture (54 days after radio-tagging). She was killed during the day, almost certainly by a harrier. If the mortality rate was constant over the year, predicted annual survival would be 50.9%.

Nine of the radio-tagged teal were known to have attempted breeding (though some early nesting attempts may have been missed before radio-tagging). No nesting details are known for one bird (who was gravid when caught but died in July, before intensive monitoring). Of the eight known nests, only three are known to have hatched eggs. Three nests were wholly or partly predated, probably by rats and harrier. One nest was abandoned. The final nest was lost to unknown causes. Video monitoring at two nests that subsequently failed showed frequent rat visits to the nest sites. Low nesting success was an important component of the low overall productivity.

Only one brood of chicks survived the first few days after hatching; of the five hatchlings in this brood, two were seen with the parents five and a half weeks after hatching. One brood disappeared when the female was killed, and the other was not seen after hatching (the female was seen feeding alone soon afterwards). It is not known whether the apparently low productivity of the radio-tagged teal is characteristic of teal throughout the Okiwi Basin, or is peculiar to teal living in predominantly pastoral areas.

Regular counts were made at several flock sites in northern Great Barrier Island, primarily in Okiwi Basin. Individual flock counts sometimes varied greatly within a week. It appears that the majority of teal using the Okiwi flock sites in 2001 was adult.

Introduction

The brown teal or pateke (*Anas chlorotis*) is an endemic duck. Once common throughout New Zealand, substantial wild populations remain only on Great Barrier Island (Aotea) and in parts of Northland. An audit of the Department of Conservation (DoC) Brown Teal Recovery Programme (Innes et al. 2000) recommended that the threat category for teal (currently Category B) be reconsidered. If the audit team is correct, brown teal could become extinct in the wild within ten years unless management is undertaken, and should be considered highly endangered.

Brown teal populations are declining rapidly in Northland (Parrish & Williams 2001; Williams 2001). The audit noted that the key actual means of teal death is probably predation at all life stages. In Northland, brown teal are vulnerable to a wide range of predators both introduced (mustelids, rats, cats, possums, hedgehogs, pigs, dogs) and native (such as pukeko, morepork, harrier and eels). At Mimiwhangata, trapping of mustelids and feral cats in pastoral areas, and 1080 and brodifacoum poisoning targeting possums in adjacent bush, was undertaken from April 1996 to April 1998 (Innes et al. 2000). Adult survival increased significantly over that period (Fraser 2000), though results may have been confounded by the lack of a control site. From 1997-1999 flock counts increased substantially at Mimiwhangata, but similar increases were also recorded at Teal Bay and the main Whananaki River flock site (where no pest control was undertaken), suggesting that other environmental factors could have played a part in increased survival (Parrish & Williams 2001).

Great Barrier Island lacks many of the predators found on the mainland, being free of mustelids, Norway rats, possums and hedgehogs. The island was believed to provide a safe refuge for brown teal, with a supposedly stable population of around 1,400 – 1,500 birds (Marchant & Higgins 1990). However, in 1999 it was realised that brown teal numbers on Great Barrier Island were declining, and had been for some while (Innes et al. 2000). The Department of Conservation's annual counts at eighteen traditional teal roost sites on Great Barrier showed an almost 50 percent decline from 1994 to 2000 (Figure 1).

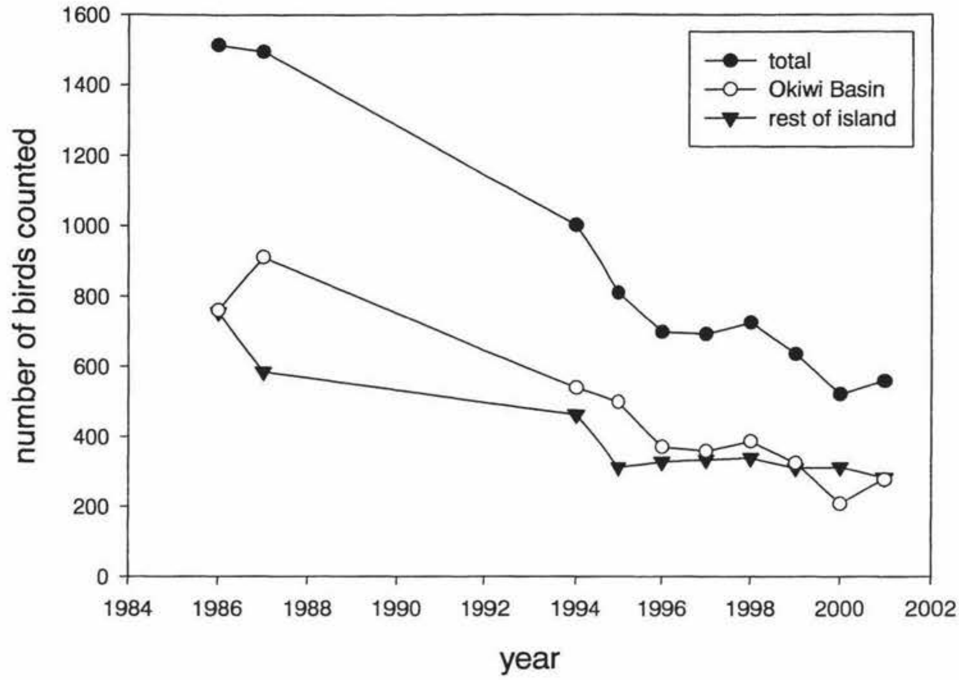

Figure 1. Flock counts of brown teal on Great Barrier Island. Department of Conservation, unpublished data.

Okiwi Basin is home to more teal than any other site, but numbers have declined drastically since counts began in the mid-1980s (Figure 1). Ascertaining why this population has decreased in recent years and increasing the population are critical to the long-term survival of brown teal. Previous teal research in the Okiwi Basin (July 1997 - June 1999) focused on habitat use (Barker, 1998, 1999). To increase the Okiwi teal population, the Department of Conservation started intensive predator control in Okiwi Basin in 2000 (see below). Teal flock counts in 2001 showed an increase in the Okiwi Basin (Figure 1). In August 2001, we commenced monitoring a radio-tagged sample of female brown teal to provide an indication of the effectiveness of the predator control. The aim of the study was to determine adult survival during breeding, and if possible to assess juvenile survival. This report details the results of this monitoring work.

Predator control

In 2000 and 2001 predator control in Okiwi Basin focused on feral cat and pukeko control, and education of dog owners. Agnew (2001) reported on the recent feral cat and pukeko control. Cage traps for cats were set for 2 weeks every 2 months from July 2000 to mid-April 2001. Since then, the network of approximately 65 traps has been serviced each week. Traps are opened on Mondays, baited with fish and checked daily, until they are closed on Fridays. Trapping encompasses the length and breadth of Okiwi Basin. Traps are set predominantly along bush and road edges, though they also extend along sand-dune country near Whangapoua

Beach. Trapping does not extend into bush or into wetlands. Pukeko are shot or trapped after cat traps have been serviced.

Eighty-nine cats were killed in Okiwi Basin between June 2000 and July 2001, and small numbers of cats were killed during this study (4 in August, 3 in September, 2 in October and 4 in November). Six-hundred and eighty pukeko were shot or trapped in the basin from September 2000 to November 2001. Pukeko numbers are being monitored by DoC.

Breeding Biology

Breeding biology of brown teal has been summarised in Marchant and Higgins (1990). Broods have been recorded in all months of the year (see also Moore 2002). There is a distinct breeding season (June to October), which peaks in July and August. In the wild, clutches vary from 4 to 8 eggs, with 5 or 6 eggs being commonest. In captivity, teal lay daily and the incubation period is 27 to 30 days. Captive bred young are able to fly 50 - 55 days after hatching.

Study site

Okiwi Basin (Figure 2) is on the east coast of northern Great Barrier Island (36°9' S, 175°24' E). Roughly 5 km N-S and 3 km W-E, the total area of the basin is about 3,021 ha, of which 339 ha is estuary and associated saltmarsh habitat, 790 ha is developed farmland, and 1,835 ha is scrub or bush (there is also 50 ha of sand and 7 ha of plantation forest). Okiwi Station, a Department of Conservation reserve, occupies most of the southern end and western side of Okiwi Basin.

Major teal flocking sites are known at Mabey's farm, Burrill's Drain, and the River Reserve (also known as the Orchard flock site). Two dams also served as flock sites, Pond 3 (below the ridge opposite Motairehe Road) and Pond 1 on Okiwi Station. Sites mentioned frequently in this report are shown in Figure 2.

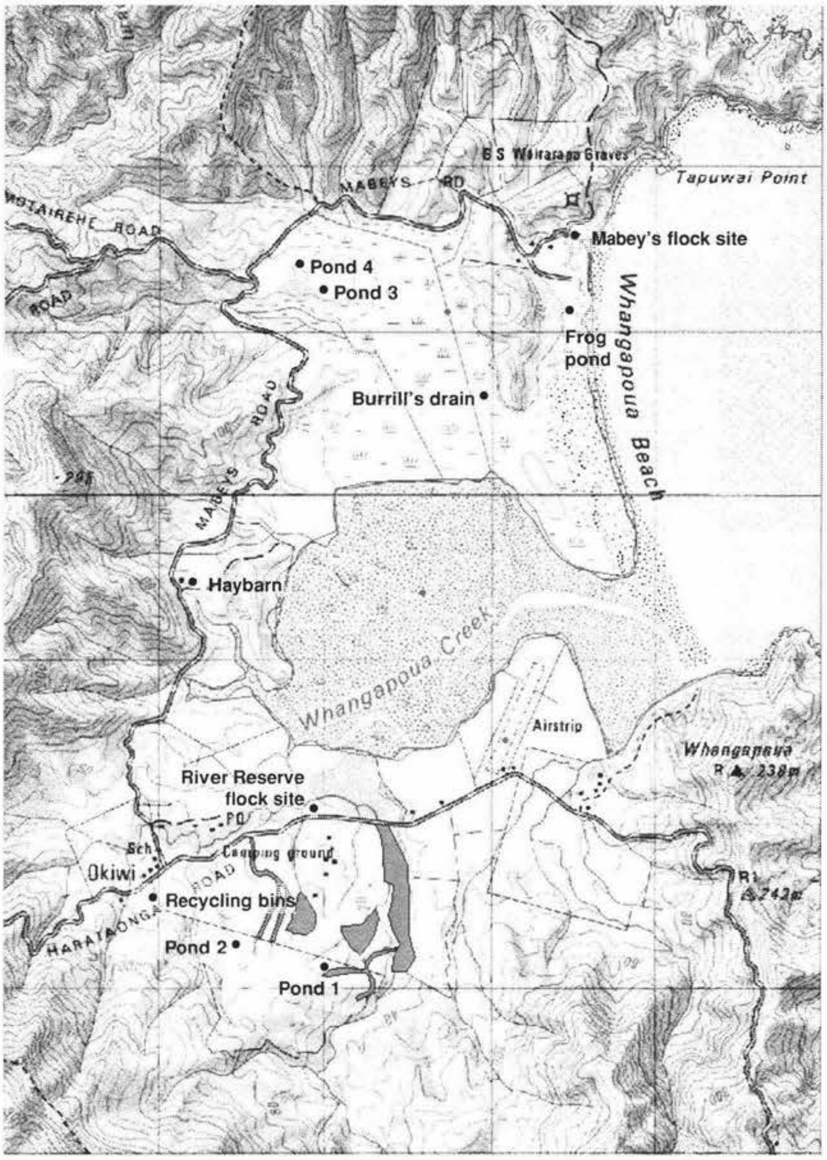

Figure 2. Okiwi Basin, Great Barrier Island. Filled areas south of Harataonga Road are retired areas on Okiwi station.

Methods

Transmitter monitoring of individuals

DoC staff caught female brown teal for transmitter attachment between June and August 2001. Most birds were caught at night by spot-lighting; two were caught in the late morning by mist-netting (Tx 42 and Tx 54, at Burrill's Drain). Teal were sexed by cloacal examination by Ian Hogarth or David Agnew. Seventeen were radio-tagged with Sirtrack long-life mortality transmitters, fitted on a harness system with built-in weak link. Transmitters had pulse rates of 20 per minute in regular mode and 40 per minute in mortality mode (24 hour latching time, i.e. time until mortality signal activited), with an estimated working life of 16 months. Transmitter, metal band and capture details are given in Table 1. Birds were not colour-banded.

Table 1. Transmitter frequencies, bands, capture dates and sites for radio-tagged female brown teal in 2001.

Tx	band	date	weight (g)	grid reference[1]	location[2]
16	S-70522	8/8/01	600	2727742 6558162	paddock 16, by road
18	S-70548	20/6/01	520	270 575	paddock 8, eastern fence
20	S-70540	21/6/01	800	270 575	paddock 8, near Woolshed
22	S-70533	18/7/01	640	2726779 6557933	paddock 8, near road
26	S-70531	19/7/01	710	2726727 6558068	across road from paddock 8
28	S-70535	18/7/01	740	2726531 6557043	paddock 11, southern end
30	S-70534	18/7/01	550	2726830 6557433	paddock 8, west of Woolshed Wetland
36	S-70539	21/6/01	-	269 575	paddock 8, northeast of Woolshed Wetland
38	S-70550	20/6/01	570	271 575	paddock 5, upstream from Dump Wetland
40	S-77601	21/6/01	720	270 575	paddock 8, near Woolshed
42	S-70546	21/6/01	-	278 608	Burrill's Drain
44	S-70529	19/7/01	650	2726113 6557675	paddock 10
46	S-70530	19/7/01	685	2726403 6557536	paddock 9, middle
48	S-75154	18/7/01	795	2726953 6556885	paddock 13, by small pond
50	S-70524	8/8/01	590	2727476 6558197	paddock 29, below ridge
52	S-70528	7/8/01	560	2727170 6557662	paddock 5, north end
54	S-70545	21/6/01	500	278 608	Burrill's Drain

1. 14 digit numbers are GPS references, east and north; 6 digit numbers are New Zealand map grid references.
2. Paddock numbers are those used for Okiwi Station farm management.

Transmitter signals were monitored using a hand-held Telonics TR-4 receiver with a Yagi aerial. David Agnew and Craig Mabey checked signals of all birds weekly or less frequently during July and early August. We checked signals during the daytime on most weekdays and some weekends from 20 August to 27 November 2001.

Any transmitters giving mortality signals were pinpointed and retrieved immediately. Otherwise, birds were tracked to general locations, and if the daytime signal had not moved for around a week, the location was pinned down more accurately. When close, the receiver was used without the aerial to determine what vegetation clump birds were in. Suspected nests were approached quietly to within a metre or two to confirm their location. Thereafter, during regular monitoring we quietly approached the general vicinity of the suspected nest and used the receiver without the aerial to determine whether the female was still nearby. Suspected nests were not interfered with, and no attempts were made to count eggs while females were incubating. Some habitats proved impossible or irresponsible to search in (e.g. dense bracken and swamp where teal or teal nests could have unwittingly been damaged and tracks in could have provided easy access for predators). Night-time checks were made periodically to locate the radio-tagged birds when feeding, mostly using night vision equipment (ITT Night Mariner with infra-red filtered Petzl headlamp), but occasionally using a headlamp or spotlight.

Nest video recording

A single infra-red time-lapse video unit (DoC Electronics Laboratory, Science & Research Unit, model SRU-30) was obtained part-way through the breeding season after the failure of several teal nests. The camera was placed with a view of the entrance of one suspected (Tx 22) and one confirmed (Tx 30) teal nest, with the hope of determining causes of nest failure and ascertaining the length of time females spent off the nest during incubation. The unit recorded at 3 frames per second, giving 24 hour coverage from a 3 hour tape. Unfortunately, the batteries did not last 24 hours, and the video sometimes cut off before dawn. Batteries and tapes were changed daily, and videos were watched on normal speed to record any teal or other animal departures and arrivals at the nest.

Teal counts

Almost daily flock counts were made at Mabey's flock site throughout the season. Pond 1 was counted several times a week, particularly in the latter half of the study. Counts were also made at other known teal sites in Okiwi Basin (see Figure 2):

- Frog Pond, south of the access track to Whangapoua Beach and the M.V. Wairarapa graves (usually a single observer; on foot),
- Ponds 3 and 4, two dams on the old airstrip paddock (usually a single observer; on foot or from vehicle [Pond 4 only]),
- Burrill's Drain (usually two observers; twice by counting birds both directions from the southern hide, three times by pushing the birds past a concealed observer in the hide),

- River Reserve flock site (usually a single observer; once approached by kayak from downstream, other times counted with a telescope from the creek bank downstream, or counted from downstream while the second observer walked downstream from the picnic table clearing),
- Pond 2, a small dam on the south-west corner of Okiwi Station (usually a single observer; counted on foot).

Additional counts were made opportunistically at Karaka Bay (Orama), Port FitzRoy and Akapoua Bay, Harataonga, Awana and Claris. Counts were made with binoculars (Zeiss 10 X 40 or Nikon 10 X 21) or a Nikon 20-45 X 60 spotting scope. Any banded birds were noted, and attempts made to read the metal band number or colour-band combination.

Results

Case histories of radio-tagged females

Tx 16 S-70522

Caught by spot-lighting on 8/8/01 on paddock 16. From 20/8 (when intensive monitoring started), all but two day-time signals were NE from the picnic table[1] (i.e. towards the River Reserve flock site or in adjacent saltmarsh). On the day of 20/9 she was in roadside grass by paddock 18, but had returned to the River Reserve vicinity the following day. At night she was found on paddocks 16 and 18 (23/8, seen with male), and on paddock 25 (13/9, signal heard). Her transmitter was shed in paddock 16 on 14-15/10, giving a harness life of 67 days. Her occasional daytime visits to paddocks 16 and 18 suggests that she was not breeding at that time, and did not appear to have chicks remaining from any earlier breeding.

⇨ unknown whether bred, but no evidence for successful breeding

⇨ survived until at least 15/10, when transmitter shed

Tx 18 S-70548

Caught by spot-lighting on 20/6/01 on paddock 5. All daytime signals were from the saltmarsh adjacent to the River Reserve picnic table or in the direction of the River Reserve flock site. At

[1] The picnic table refers to the Auckland City Council Okiwi River Reserve clearing, immediately upstream of the River Reserve flock site, and across the road from Okiwi Station compound.

night, she was recorded three times S or SSW from the picnic table track, and twice located in paddock 8 on Okiwi station, below Dale Tawa's house. From 21/8 to 6/11 she was recorded in the saltmarsh between the road and the creek (signals SE or E from the picnic table clearing) 53 times, but on 4 days had been recorded towards the River Reserve flock site (signal N or NE from the flock site; 6/9, 14/9, 15/10, 17/10). On 7/11 she shifted location towards the flock site or swamp nearer to the 'truck clearing' opposite the Okiwi Station entrance, and was recorded there until 19/11. No signal could be found anywhere in Okiwi basin, Port FitzRoy, Karaka Bay or Awana from 21/11 to 27/11, when monitoring stopped.

Because the bird was not repeatedly tracked down in the saltmarsh, it is unclear whether she bred or not. Periods when she moved location towards the flock site could indicate that she was not incubating, particularly the records on 15/10 and 17/10. No monitoring was done on 13/10, 14/10 or 16/10, so she could have shifted location for more than two days.

We do not know what happened to this bird when her signal disappeared in late November.

- ⇨ breeding status uncertain
- ⇨ survived from 20/6 to at least 19/11, when signal disappeared

Tx 20 S-70540

Caught (gravid) by spot-lighting on 21/6/01 on paddock 5. Signals were heard from the Woolshed on Okiwi Station by David Agnew on 24/6, 28/6 (both in the direction of the bush between the road and paddock 29) and 13/7 (in the creek downstream from the Woolshed Wetland in paddock 8). On 26/7, she was found by David Agnew, dead, in the open, 20 m from a stream in Paddock 8, which was closely-grazed with occasional rush clumps (GPS location 2726870E 6557704N). The carcass was picked clean with feathers spread around the carcass for approximately 1 m^2. Feathers remained on the wings only, and the skeleton was intact apart from the left leg, with the lower mandible missing. A puncture mark on the sternum was thought to be consistent with that of a cat tooth, though it may just as reasonably have been from a harrier talon (I. McFadden pers. comm. to D. Agnew). The carcass was still fresh. As she was gravid when caught, she could have had a nest near or at the point of hatching when killed.

- ⇨ gravid when caught
- ⇨ DIED approximately 34 days after banding

Tx 22	S-70533

Caught by spot-lighting on 18/7/01 on paddock 8 near the main road. This bird resided around the River Reserve flock site and associated wetlands from 21/8 to 14/9, apart from three days when she was found in dense roadside kikuyu near the track to the picnic table clearing (28/8, 31/8 and 11/9), in different places each time. On 17/9 her signal was recorded from the road 100 m W of the picnic table track. Her location was pin-pointed on 19/9, when her signal was tracked to a small gorse/rush (*Juncus*)/grass clump (suspected nest), 8 m from the roadside fence in paddock 8. She remained there for three and a half weeks until 11/10, when she moved back to the River Reserve area. Thereafter, she was only located in the River Reserve area.

A video unit was set up at the nest site on 10/10 and 11/10, and may have caused her to abandon the nest (see video monitoring section below).

A quick search of the site on the evening of 11/10 did not find any sign of nesting. On 20/10 the site was thoroughly searched and the remains of a nest-bowl containing two small eggshell fragments, some down and dead grass were found at the end of the north-facing tunnel. It is likely that a nest was present but had been predated before 20/10. The bird may have abandoned and the nest contents scavenged subsequently.

- ⇨ probable unsuccessful nesting attempt
- ⇨ survived from 18/7 to at least 27/11

Tx 26	S-70531

Caught by spot-lighting on 19/7/01 across the road from paddock 8, west of the track to the picnic table and River Reserve. Tx 26 stayed around the River Reserve during the day from 21/8 to 7/9, after which she nested in roadside kikuyu 100 m west of the picnic table track. She alternated between the River Reserve and the roadside bank until 14/9, after which she remained in the kikuyu until 18/10. On 20/10, she had left the nest site (signal E of picnic table), and we found the remains of five hatched eggs and one cold but live late-stage egg in the nest. On 23/10 she was seen with four chicks in the bush west of the clearing. After 25/10, all daytime signals were east of the picnic table clearing, though on the night of 26/10 she was located with at least two chicks in a bog in the paddock west of the picnic table track. A bird with transmitter, almost certainly Tx 26, was seen with a male and two half-sized fluffy ducklings near the River Reserve flock site on 27/11 (four other birds with transmitters were present in the area, but none was thought to have chicks).

She was resident at the nest site continuously until hatching (14/9 to 20/10) for five weeks. It is not known if she was still laying at the start of this period.

⇨ successful breeding: laid six eggs, hatched five chicks, two of which survived until at least five and a half weeks

⇨ survived from 19/7 to at least 27/11

Tx 28	**S-70531**

Caught by spot-lighting on 19/7/01 on the south-western side of paddock 11 (blind in the left eye). Her signal was heard towards the River Reserve from the DoC workshop on Okiwi station on 2/8. From 12/8 to 20/10 all daytime signals were towards or in the bush along the south-western edge of Okiwi Station (between cat traps A8 and A9). She was seen with a male a couple of hundred metres up a small bush creek on 17/9. On 28/9 her seven-egg nest was found on a ridge overlooking this stream (near the hakea-native bush boundary). On 20/10, no signal was heard from this female during the day, and when checked her nest was cold and damp, though the eggs were covered. The signal had returned by 21.20 h that evening (south-west from the Woolshed), and on the morning of 21/10 she was present on or near the nest. From 22/10 onwards no signal was heard in Okiwi, Karaka Bay, Rakitu Island, Port FitzRoy, Awana, Harataonga, Kaitoke, Claris, Medlands, Blind Bay or Whangaparapara. Given that her signal disappeared between 18/10 and 20/10 but reappeared on 21/10, it is probable that she left the site rather than had a failed transmitter.

The seven abandoned eggs were sent to IVABS, Massey University, for autopsy (Appendix 1). Eggs were late-term. One egg was infertile, and one had severe fungal infections. Five had external yolk sacs remaining at a stage when the sacs should be internal; this problem can arise from temperature, humidity or incubation problems.

⇨ unsuccessful breeding: seven eggs laid but clutch abandoned late in incubation

⇨ survived from 19/7 to at least 21/10, when signal lost

Tx 30	**S-70534**

Caught by spot-lighting on 18/7/01 at the southern end of paddock 8. In late August she was found in the River Reserve. On 30/8, she was tracked to a clump of sedges (*Cyperus ustulatus*) by a small creek under Manuka in paddock 8, in the first creek west of the retired Woolshed Wetland. She remained there during daily checks, and a nest with at least 4 eggs was confirmed on 24/9.

The female was last recorded at or near the nest on 20/10. The following day she was east of the picnic table, in the swamps around the River Reserve. A video had been set up on the nest from 13-22/10, and recorded multiple rat visits (see video monitoring section below). When the nest was checked on 22/10, no eggshell remains (not even fragments) were present and rat droppings were found in the tunnel leading to the nest.

After leaving the nest site she remained in the wetlands east of the picnic table, particularly between towards the large culvert opposite the junction of paddocks 2 and 3. On 31/10 she was seen feeding at night with a male in a damp area in paddock 4.

- ⇨ unsuccessful breeding: laid at least 4 eggs but nest failed probably due to rat predation
- ⇨ survived from 18/7 to at least 27/11

Tx 36	**S-70539**

Caught by spot-lighting on 21/6/01 in paddock 30. In late August she moved around Okiwi Station (signals NNW, N, SE, S and W-WSW from the Woolshed) and the River Reserve area before settling down in a small clump of grass and *Juncus* in paddock 5, where a nest with at least 2-3 eggs was confirmed on 29/8. She remained on the nest until 27/9. On 28/9, remains of 4 hatched eggs were found in the nest and entrance tunnel, and the female had relocated to a clump of rushes 70 m away. That night she was observed (with night vision equipment) feeding alone near the nest site, and the next day had moved to the River Reserve area (NE of the picnic table). On 3/10 she was observed again feeding alone at night near the nest site. She remained between the picnic table and the 'truck clearing' opposite the Okiwi Station entrance until late November, apart from twice being found on the Pond 1 flock site (21/11 and 26/11). On the final day of fieldwork (27/11) she was not found at Pond 1, the picnic table or Burrill's Drain.

- ⇨ unsuccessful breeding: 4 eggs hatched, adult seen without chicks at night
- ⇨ survived from 21/6 to at least 26/11

Tx 38	**S-70550**

Caught by spot-lighting on 20/6/01 in paddock 5, east of the Woolshed. On 23/8, she was tracked to *Juncus* beside a small creek in paddock 5, upstream of the Dump wetland (a retired wetland area in paddock 5). On 27/8 she was tracked to the Dump wetland. On 28/8 she was back in the creek-side rushes and remained there until 25/9, presumably incubating. On 26/9 she had moved back to the Dump wetland. The rushes around one edge of her nest were flattened, egg remains were scattered on the grass near the nest, and one eggshell was in the creek 4 m away. Eggs were broken, some with damp chick feathers inside. Four to five eggs were estimated to have been present. The sign was thought to be consistent with harrier predation, though pukeko cannot be ruled out. Remains of lambs' tails downstream indicated that harriers frequented the immediate area.

From then on, Tx 38 spent periods in or near the Dump wetland, in the River Reserve wetland area (a flock site), at Pond 1 (a flock site), and in late November in paddock 8 in the creek that Tx 30 nested in.

- ⇨ unsuccessful nesting: probable harrier predation
- ⇨ survived from 20/6 to at least 27/11

Tx 40	**S-77601**

Banded as an adult on 10/10/96 (weight 640 g), and in 1998 was part of Dave Barker's telemetry study of teal on Okiwi station. When caught in 1998 (3 July) she was gravid and weighed 790 g. She was recaptured for this study (by spot-lighting) on 20/6/01 at the southern end of paddock 8, weighing 720 g (the high mass suggests she could have been gravid when caught).

Signals were heard from the Woolshed wetland, the Dump wetland and the River Reserve in June and July. On 2/8 she was found dead by David Agnew near the south-eastern corner of paddock 8 (GPS 2726945E 6557314N). The body was scavenged, with two main pieces of carcass about 3 m apart. The head, legs, wings and one foot were found, but one foot and the bill were missing. There was a small hole in the breast bone and the keel was flattened. She was thought to have died about three days before being found. She was at least five and a half years old when she died.

- ⇨ unknown whether breeding attempted
- ⇨ DIED about 40 days after banding (20/6 to around 30/7)

Tx 42	**S-70546**

Herded into a mist-net at Burrill's Drain during daytime on 21/6/01. On almost every occasion from 12/8 to 26/11, this bird was found at Mabey's flock site. She could often be seen sitting on the creek edge or bank with other teal and did not appear to have a mate. The only exceptions were on 24/8 (signal east of the access ridge to Burrill's Drain), 31/8 (no signal at Mabey's), and 5/9 (when tracked to a small sedge clump a metre or two from the access track to Whangapoua Beach and the M.V. Wairarapa graves).

- ⇨ did not attempt to breed

⇨ survived from 21/6 to at least 26/11

Tx 44	S-70529

Caught by spot-lighting on 19/7/01 in paddock 10. From 21/8, her daytime location was always the retired area between paddock 10 and Okiwi settlement, in dense swamp. She was repeatedly tracked to a very dense stand of umbrella fern (*Gleichenia dicarpa*) and *Juncus* under large tutu (*Coriaria* spp.) towards the south-western corner of paddock 10 (6/9, 18/9, 24/9 and 4/10). On the night of 31/8 she was seen with a male in paddock 10, for at least 1.25 h.

On 9/10 she was seen alone further downstream in the retired area during the daytime, and was seen briefly that night feeding alone in paddock 10. From then until 26/11 she was located throughout the retired area, often downstream from her early location. Given the type of habitat she occurred in (dense umbrella fern), the similarity of behaviour with another bird (Tx 46) and the fact that she was seen without ducklings, we suspect she did not breed. However, the vegetation was too dense to search for a nest and a failed nesting attempt cannot be ruled out.

⇨ no evidence for breeding

⇨ survived from 19/7 to at least 26/11

Tx 46	S-70530

Caught by spot-lighting on 19/7/01 in the middle of paddock 9. Tx 46 was one of the most site-faithful teal monitored. On 21/8 she was located near the roadside end of the retired area in paddock 9, and her signal could easily be heard from the main road just below. She was repeatedly found in an area of bracken approximately 10 m by 8 m until 18/11. Any searching within the bracken was fruitless – the bird could sometimes be heard moving around, and any searching damaged the site. On 9/11 she had moved to the River Reserve area (NE of the picnic table, strong WNW of the truck clearing opposite Okiwi Station entrance), where she remained thereafter.

Her bracken patch was thoroughly searched after she had left it. Feathers were widely spread through open areas under the bracken and at the lower edge of the patch (above the stream that flows through the retired area). There was no evidence for nesting, and she had presumably used the bracken simply as a convenient roosting site next to paddock 9, where she was found feeding at night four times (seen with mate on 27/8).

⇨ no evidence for breeding

⇨ survived from 19/7 to at least 27/11

Tx 48	S-75154

Banded as an adult (630 g) on 5/11/98 at the southern side of Okiwi station. Recaptured for this study (by spot-lighting) on 18/7/01 in paddock 13. She was heavy when recaptured (795 g) and considered to be gravid. In late July and early August her signal was located towards the SE corner of Okiwi Station, and on 21/8 she was tracked to a nest in the bush on the south-eastern fence-line of the retired area below paddock 13. The nest was in a lone pampas clump next to a large creek, in regenerating ti-tree scrub. On 8/9 she was incubating 6 eggs, five of which had hatched by 10/9. At 10.30 h on 10/9 she was tracked to a small *Juncus* clump in paddock 13. At least two chicks were seen with her. At 18.30 h on 10/9 she was found dead by a small pond (40 m away from the *Juncus* clump). The carcass was plucked, with feathers strewn around and intestines exposed and pulled out. The right pectoral muscle was extensively eaten, and the left muscle had a couple of angular gouges taken out (see Figure 3). She was cold at 18.30 h, so had died between 10.45 and around 17.00 h, presumably killed by a harrier (daylight kill, plucked and disembowelled, with beak-like gouges on the breast). There were no signs of the chicks. The chicks had probably hatched prior to 9/9 and been moved overnight from 9-10/9. The female was therefore killed on the day she moved her clutch from the bush to farmland.

The remaining egg was left in the nest overnight on 10/9. On 11/9 the egg had been scavenged, presumably by a rodent, and had a rectangular hole about 10 mm wide and 5 mm high at the upper end. The egg contained only grey, smelly sludge.

⇨ unsuccessful breeding: laid 6 eggs, hatched 5 chicks, adult died and clutch lost

⇨ DIED 54 days after banding (18/7 to 10/9)

Figure 3. Carcass of Tx 48, found on 10/09/01. Above, plucked carcass *in situ*. Below, close-up of carcass. Note the gouges to the left (lower) pectoralis muscle. Intestines have been replaced into the abdominal cavity.

Tx 50	**S-70524**

Caught by spot-lighting on 8/8/01 at in paddock 29 (with male). This female spent the spring in the River Reserve wetlands or in bracken on the ridge near the western fence of paddock 29. In late August and early September her signals were all E or NE from the picnic table. On 8/9 she had moved and the signal was strong N from the main road E of the cattleyards. Signals were similar on 10/9 and 11/9, and on 12/9 she was tracked to bracken at the bush edge on the ridge above paddock 29. She stayed there until 17/9. On 18/9 she was back at the River Reserve area, but returned to the ridge on at least three occasions (11/10, 21/11 and 23/11). From 23/10 radio-checks were made from the clearing opposite the Okiwi Station entrance. Her signal was consistently NNW-NE, indicating that she was in the swampy eastern parts of the wetland rather than the River Reserve flock site. Her regular movements between the ridge above paddock 29 and the River Reserve wetlands suggest she did not breed successfully this season.

⇨ no evidence for breeding

⇨ survived from 8/8 to at least 27/11

Tx 52	S-70528

Caught by spot-lighting on 7/8/01 at the north end of paddock 5. In late August she was usually found in the River Reserve wetlands. She visited the swampy retired area between paddocks 2 and 3 on 29/8 and 1/9, and on 6/9 was tracked to a *Carex virgata* and gorse clump near a grassy creek in the retired area. This site was within metres of an active harrier roost. Daytime checks confirmed that she remained in the area until October. On the week leading up to 1/10 she was confirmed daily in the gorse/sedge clump, but on 2/10 she had left her nest and moved into the wetlands downstream of the retired area, on the north side of the main road. Her nest contained 4 cold eggs, approximately 1 cm^2 broken eggshell, with some egg yolk (and maggots) on the remaining eggs. The nest itself appeared undamaged, and only a teal-sized tunnel led to it. The eggs were removed and later confirmed as being fertile and well developed.

The female moved between the River Reserve flock site area and the wetlands immediately east (across the road from her nest site) until early November. On 5/11 she was in a seepage creek in paddock 5 but back across the road from her nest the next day. On 12/11 her shed transmitter was found (in mortality mode), submerged in a different seepage creek in paddock 5, 95 days after fitting.

⇨ unsuccessful breeding: laid at least five eggs, nest abandoned (one egg predated/scavenged) late in incubation

⇨ survived from 7/8 to at least 10-11/11, when transmitter shed

Tx 54	S-70545

Caught by mist-netting during the day-time on 21/6/01 at Burrill's Drain. Tx 54 travelled the most of any of the teal monitored. In chronological order, she was located:

- around or east of the retired wetland between paddocks 36 and 34, on the western side Okiwi Basin (24/8 to 27/8),

- in bush SW of the haybarn on Mabey's Rd (28/8),
- at Mabey's flock site (29-30/8),
- north of the junction of Mabey's Rd/Motairehe Rd, probably in bush (31/8),
- at Mabey's flock site (1/9, 4-5/9),
- east or south-east from Burrill's ridge (6-9/9),
- near the scrub-saltmarsh edge east of paddock 34 (c. 10/9 to late September),
- near the retired wetland area between paddocks 34 and 36 (1/10 to 5/10),
- in bush SW of the haybarn on Mabey's Rd (8/10 to 16/11),
- east or south-east from Mabey's Road above paddock 36 (19, 21 and 23/11), and
- in bush SW of the haybarn on Mabey's Rd (26/11).

While she was in the bush opposite the haybarn on Mabey's Road (8/10 to 16/11), we tracked her three times but the signal moved in the dense vegetation and could not be pin-pointed. Each time she was in a different general location, so was apparently not nesting.

⇨ probably did not breed

⇨ survived from 21/6 to at least 26/11

Survival summary

Of the seventeen female teal monitored, three died, two before formal monitoring began and one immediately after hatching chicks (Table 2). An average of 131.2 days (0.359 of a year) of monitoring was possible per bird (from the banding date to the end of the study, or, for birds whose fate was unknown, i.e. dropped their transmitter or disappeared, the final day they were recorded). If mortality is constant over the year, 8.35 (3/0.359) of the 17 birds would be expected to die over the year. Annual survival of the radio-tagged sample would therefore be 50.9% [(17-8.35)/17*100].

Table 2. Summary of survival of radio-tagged female brown teal in Okiwi Basin, June to November 2001.

Tx	band	capture date	last record	days monitored	status
16	S-70522	8 August	14-15 October	67	transmitter shed
18	S-70548	20 June	19 November	152	signal lost
20	S-70540	21 June	25 July	34	dead
22	S-70533	18 July	27 November	132	alive at end of study
26	S-70531	19 July	27 November	131	alive at end of study
28	S-70535	19 July	21 October	94	signal lost
30	S-70534	18 July	27 November	132	alive at end of study
36	S-70539	21 June	26 November	158	alive at end of study
38	S-70550	20 June	27 November	160	alive at end of study
40	S-77601	20 June	30 July	40	dead
42	S-70546	21 June	26 November	158	alive at end of study
44	S-70529	19 July	26 November	130	alive at end of study
46	S-70530	19 July	27 November	131	alive at end of study
48	S-75154	18 July	10 September	54	dead
50	S-70524	8 August	27 November	111	alive at end of study
52	S-70528	7 August	10-11 November	95	transmitter shed
54	S-70545	21 July	26 November	128	alive at end of study

Breeding summary

Nine of the seventeen radio-tagged teal were known to have made nesting attempts, but only one raised chicks past the first day out of the nest (Table 3). Five birds probably did not breed. Breeding status of three birds was unknown (two lived in swamps, one died before intensive monitoring began).

Table 3. Summary of breeding attempts by radio-tagged female brown teal in Okiwi Basin, late August to November 2001.

Tx	band	breeding status	# eggs	# hatched	comment
16	S-70522	unknown			probably did not have chicks
18	S-70548	unknown			
20	S-70540	unsuccessful	?	?	gravid when caught, died in July
22	S-70533	unsuccessful	?	0	clutch lost to unknown cause, not incubated long enough to hatch
26	S-70531	successful	6	5	2 chicks remained at 5_ weeks
28	S-70535	unsuccessful	7	0	nest abandoned
30	S-70534	unsuccessful	4 (+)	?	nest predated, probably by rats
36	S-70539	unsuccessful	4	4	chicks never seen
38	S-70550	unsuccessful	4-5	0	nest predated, possibly by harrier
40	S-77601	unknown			died in early August
42	S-70546	did not breed			
44	S-70529	no evidence of breeding			
46	S-70530	no evidence of breeding			
48	S-75154	unsuccessful	6	5	adult killed when moved into farmland
50	S-70524	no evidence of breeding			
52	S-70528	unsuccessful	5 (+)	0	nest abandoned after partial predation
54	S-70545	did not breed			

Video monitoring

Tx 22. On 10/10 a video unit was set up on what was thought to be an entrance tunnel to the suspected nest site. The resulting picture was not very clear. The only teal recorded were individuals that walked past the corner of the view at 21.40 and 01.39 h. Meanwhile, a rat visited the nest for 40 sec at 00.03 h. On the evening of 11/10, the camera was shifted to a different suspected nest entrance at 22.00 h, while the bird was off the nest (signal south in paddock 8). A teal was recorded near the nest at 05.19 h (looking closely at the camera), but the bird did not enter the nest. That day (12/10) bird 22 had relocated to the River Reserve wetlands.

Tx 30. This nest was filmed from 13-22/10 (except for 16-17/10, because of Search and Rescue commitments). The female was seen leaving and re-entering the nest on the nights of 13-17/10, but on 18/10 left the nest earlier than usual (19.55 h, compared with 20.18, 20.20 and 20.29 or three previous occasions), dropped down into the creek directly instead of using her usual tunnel, and was not seen to return to the nest that night. She was not seen again on video, though she returned to the immediate area, as there was a signal from the sedge clump on 20/10. Many rat visits to the nest were recorded on the nights of 14/10 and 17-21/10 during the female's absence. No teal chicks or eggs were seen on the videos. The nest had apparently failed by 18/10, probably as a result of rat predation. In late November, five Victor rat traps were set under black Corflute covers near the failed nest site. A ship rat weighing 190 g was caught. The following night one trap was sprung, with rat droppings on the cover.

Video monitoring transcripts are provided in Appendix 2.

Teal counts – Mabey's flock site

Teal numbers built up from around 40 in late August to a peak of 136 on 17 and 18 October, but were generally lower thereafter (Figure 4). On 12 and 14 November, low counts coincided with sheep shearing in the woolsheds on the north side or cattle grazing on the south side of the creek. It is unknown where the balance of the teal was on those days. On another low count, 23 November, Tx 42 was not present at Mabey's roost and no signal was heard in the northern end of Okiwi basin (she was back at Mabey's by 26 November).

The majority of teal using Mabey's roost at this time of year is apparently adult, although chicks are present periodically and fledged young were confirmed as present from the beginning of October:

- A pair with 2 small ducklings on 20 August had only 1 duckling on 24 August and the chick was not seen thereafter.
- A female with 4 CII ducklings was seen once in mid-September.
- Five large ducklings with only patches of down on their rumps remaining were seen on 25 September but not on the next day,
- On 26 September a half-sized downy chick with some contour feathers was seen.

Ducklings or juveniles with some remaining down were seen throughout October and into November, but distinguishing fledged juveniles from adults was difficult. The peak count of supposed young of the year was 18 of 119 present on 3 October, comprising 1 small duckling with few contour feathers, 4 essentially fledged birds with some down remaining on the backs, and 13 birds thought to be immature (with shorter wings and smarter plumage). An adult female with a brood patch was seen at the flock site on 27 August.

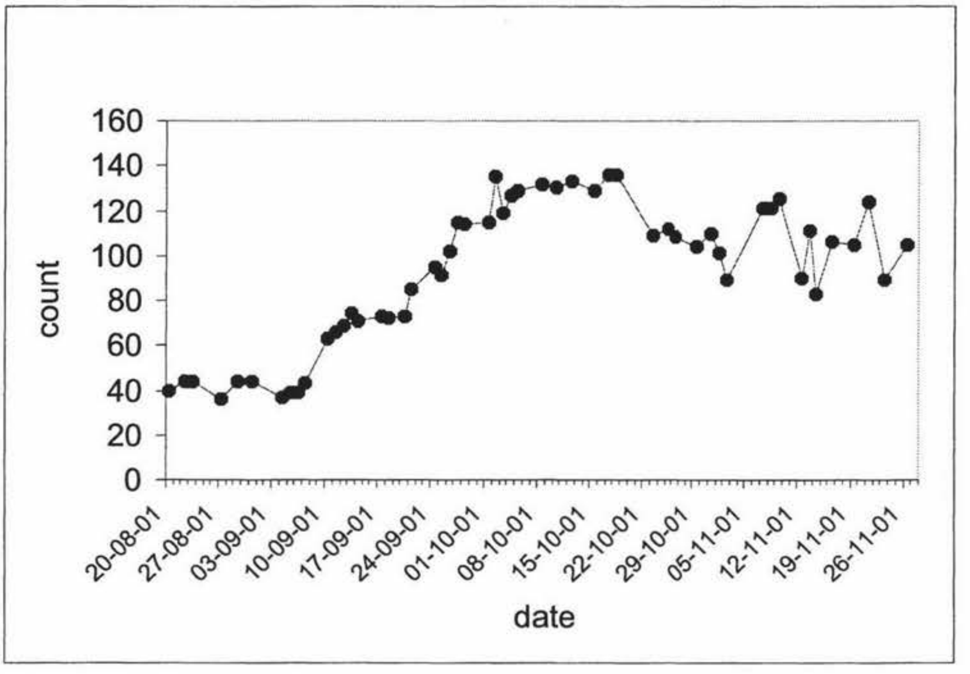

Figure 4. Brown teal counts at Mabey's flock site from August to November 2001.

Teal counts – Pond 1

Only a single pair of teal was visible in late August, which was joined by two males by 8 September (Figure 5). Two pairs, one with three small fluffy chicks, had arrived by 10 September. The three chicks remained at Pond 1 and were identifiable as 'flat-tails' (see section on ageing criteria in the field below) by 10 October. At least one other flat-tail was present from 10 October onwards. A pair with a single large fluffy chick arrived on 9 November, and the chick was still present on 21 November, though it was also absent on some days. The build-up and variation in numbers of teal at this site primarily reflected arrival or movements of adults, with a maximum of five juveniles (from three broods) recorded. Two radio-tagged birds (Tx 36 and Tx 38) periodically visited Pond 1 after their nests failed, though Tx 38 was as often hidden in rushes as out in the open with other teal.

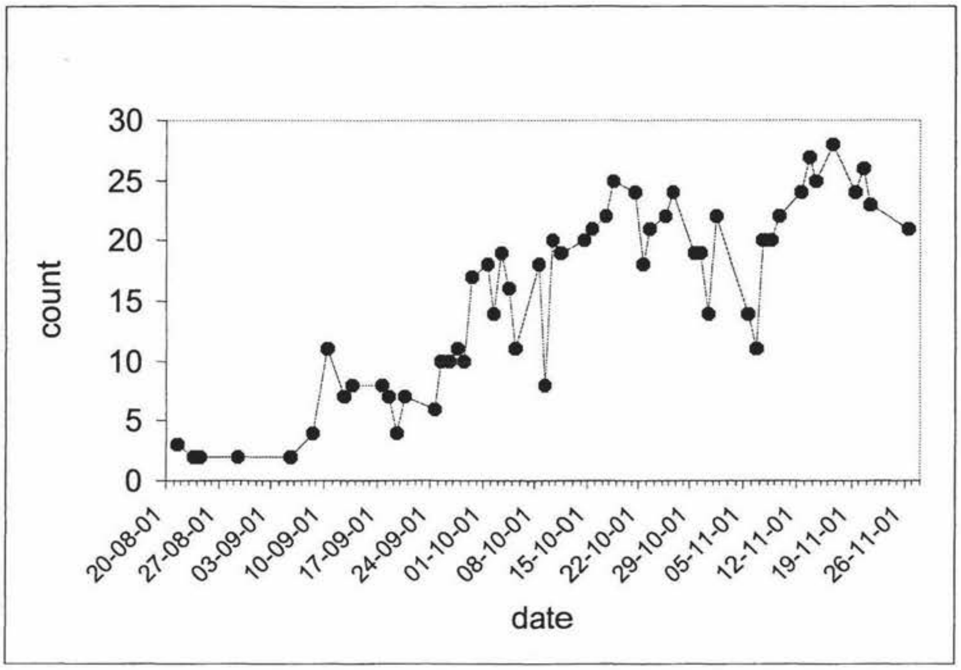

Figure 5. Brown teal counts at Pond 1, Okiwi Station, from August to November 2001.

Teal counts – Pond 3

Regular counts were made from mid-October, when Craig Mabey counted 27 teal on this dam (Figure 6). Numbers varied between 15 and 23, and a probable flat-tailed juvenile was seen on 9 November.

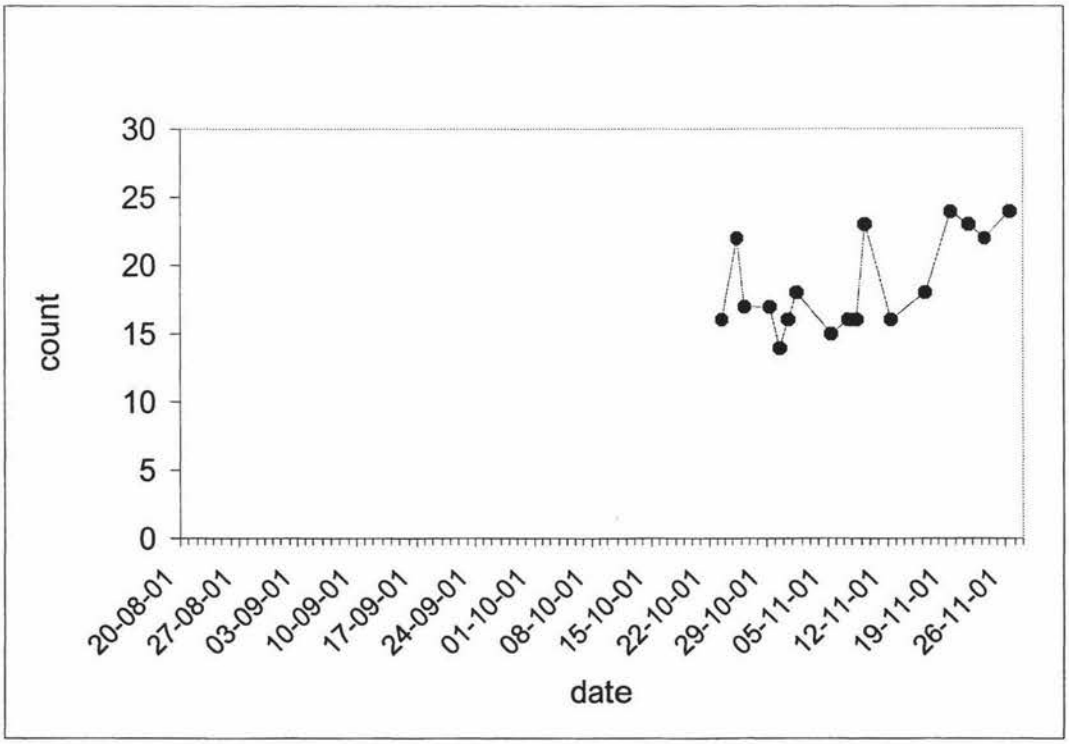

Figure 6. Brown teal counts at Pond 3 in October and November 2001.

Teal counts – River Reserve and Burrill's Drain.

Counts at these sites are given in Table 3. Teal were very skittish at the River Reserve on 3/10, which was thought could be a result of disturbance during previous visits; visits were less frequent thereafter.

Table 4. Brown teal counts at the River Reserve Flock Site and Burrill's Drain, September to November 2001

site	date	observers	time	tide	count	comments
River Reserve	5/9	PFB+SJM	1330	low	30	from downstream, birds on sandbank
	13/9	PFB	0900	low	39	mostly male, three Tx birds in vicinity not seen
	24/9	SJM	0924	mid	57	conservative count
	30/9	SJM	1140	low	70	approximate only
	3/10	SJM	1243.	low	30	poor count; all ducks upstream
	9/11	PFB	1135	low-mid	30	possibly another 20 teal, seen upstream from picnic table
	27/11	PFB+SJM	1120	low	43	good count, including Tx pair + 2 chicks
Burrill's Drain	7/9	PFB	1350	low	36	good count, 18 each way from hide
	20/9	PFB+SJM	1520	low	53	fairly good count
	30/10	SJM+D.Agnew	1533	mid	65	excellent count
	16/11	PFB+Z.Mann	1350	low	117	good count; lots of juveniles
	27/11	PFB+SJM	1015	low	80	poor count; ducks flighty

Other sites were visited less frequently or held smaller numbers of birds. Details of these counts are given in Appendix 3.

Resightings of banded birds

Three banded birds were identified during fieldwork:

L-33755 A banded male (-/M) was regularly seen at Mabey's flock site throughout the study. The band was read on 11/09/01. He was banded on 21/2/1998 at Burrill's Drain, and recorded there on 23, 26 & 27/2/1998 (DoC Great Barrier Island Brown Teal banding database).

S-70547 This banded male (-/M) was seen at Karaka Bay (Orama) on 05/11/01, and again on 12/01/02. He was banded east of the Woolshed Wetland, on 20/6/01, as the mate of Tx 18.

M/YW Seen at River Reserve flock site, 9 November 2001, presumably banded during Dave Barker's studies in the late 1990s.

Discussion

Survival and breeding

This study started part-way through the 2001 breeding season (three birds caught from June to August were gravid[2] and ducklings were present at Mabey's flock site on the first day of the study, 20 August). Some birds included in this study may have made breeding attempts prior to the start of intensive monitoring.

Three radio-tagged birds died during this study, corresponding to an annual survivorship of 50.9%. Survival rates are not well known for Brown Teal, so it is not clear if this is unusually low. If female teal are more vulnerable to predators during breeding, annual survival could be higher than we estimated. Dumbell (1987) calculated annual survival for Brown Teal at Awana in the mid-1980s as 63%, with little seasonal variation. Williams (2001) assessed annual survival by resightings in two declining teal populations in Northland as being 15% and 43%. He found little evidence for mortality during breeding (June-October). Instead, losses occurred in summer (post-breeding), and also in autumn (pre-breeding) in one population. It is not known whether the mortality patterns found in these two populations are typical, or if they were due to specific conditions during the study (farm management practices, predator guild and drought conditions).

Predator identity is unknown for two of the three teal that died during the 2001 field season (Tx 20 and Tx 40). The third bird's carcass (Tx 48), was retrieved within hours of the kill and appeared to have been a harrier predation. Teal are extremely secretive during daytime when incubating, but sometimes move about with chicks in daylight. This may make them more vulnerable to predation. An unbanded teal was found dead 8 m from the fence around Pond 1 on 13/11/01 (P.F.B.). The neck and most of the head were skinned, and the sternum was completely bare of flesh. The skeleton and wings remained, but feathers were spread over an area of approximately 100 x 60 cm on one side of the body. The body was fairly dry, though some maggots were present.

Of the seventeen radio-tagged teal, nine were known to have attempted breeding, two did not breed, three almost certainly did not, two are of uncertain status, and one bird died with no information about breeding status. Barker & Williams (2000) recorded radio-tagged birds that did not attempt to breed, with only 12 of 16 birds in 1999 confirmed as nesting.

Nesting success was extremely low in the radio-tagged sample of teal. Only three of eight known nests made it to hatching, and only one nest resulted in chicks being raised past the first day out of the nest (Table 2). Predators were implicated in the failure of at least four of the eight nests. Harriers are thought to have predated one nest and killed another female with

[2] One bird was not included in the telemetry study.

chicks. Harriers were seen attacking adult chickens and predating Guinea fowl nests on a property neighbouring Okiwi Station during this study (G. Burke, pers. comm.). Rats almost certainly predated one nest (Tx 30) and may well have been involved in the loss of others. The remaining egg in the hatched nest of Tx 48 was scavenged by a rat, the loss of at least one egg from the nest of Tx 52 could been due to rats, and a rat visited Tx 22's nest during video monitoring. Kirk (1895) listed brown teal as a species that suffered severely from the depredations of rats.

Barker & Williams (2000) found eggs hatched in 10 of 15 nests monitored (67%) at Okiwi, with 59% of all eggs hatching. Equivalent values for our study were 3 of 8 nests hatched eggs (37.5%), and 14 of 36 eggs hatched (38.9%). On Mana Island in 2001, 4 of 5 nests found hatched eggs (80%) and 15 of 28 eggs hatched (53.6%) (Moore 2002). Barker & Williams (2000) questioned whether nest success is a sensitive or useful measure of productivity, given that they found no between-year differences in hatching success, instead finding differences in brood persistence. They concluded that factors post-hatching are more likely to affect productivity than events at the nest. In our study, most nests did not hatch successfully, indicating that in 2001, nesting success was an important determinant of the low productivity.

The low rate of breeding attempts and the low success of those that did breed may not be typical for all habitats in Okiwi Basin. Most of the teal monitored were caught feeding on paddocks on Okiwi Station (Table 1), which may not be typical of the population. An unknown proportion of the population feeds in other habitats (estuarine areas, bush, swamps) and may have been excluded from this study.

Good breeding sites may be scarce in pastoral areas, causing some birds to not even attempt breeding (suggested also by Williams & Barker 1995 and Barker & Williams 2000). An uneven sex ratio could also have this effect.

The high rates of nest failure may only occur in pastoral areas. Rat numbers may be higher in these areas (but have not been monitored), and a lack of cover makes teal vulnerable to harriers. Over 100 cats have been removed from Okiwi basin over the past 18 months, which could have increased rat numbers. Cat control may also have boosted rabbit numbers, providing more food for harriers. It is possible that cat control is favourable for some portions of the teal population of Okiwi Basin but not for others. Flock counts will be made in March 2002 and may reveal whether the low productivity of the radio-tagged birds has extended to the rest of the population.

It was good to note that while uncontrolled dogs were occasionally seen in the Okiwi basin, there were no known dog predations on teal. Dog owner education appears successful and should be continued.

Monitoring

Daily monitoring enabled movements and changes of behaviour to be readily detected. We were quickly alerted to potential nesting attempts and could estimate likely hatching dates. Daily monitoring also allowed the detection of movements of several birds over distances that indicated the absence of ducklings.

Our inability to track birds in dense vegetation was a limitation. Two birds could have been tracked more closely in the densely vegetated River Reserve area, but a combination of radio-tracking and using a trained dog may be the best tool for locating teal in such habitats with the minimum of disturbance. Some habitats were, for monitoring purposes, impenetrable. The *Gleichenia* and rush site of Tx 44 and the bracken of Tx 46 could not be searched without damaging the site.

There is a risk that monitoring may disturb breeding females, causing nest desertion. Barker & Williams (2000) suggested that nest success be monitored by counting nest contents after hatching. Barker (1998) reported that visits to hatched nests found only eggshell debris, and suggested that broods returning to the nest and rat activity could have reduced shells to fragments. Video monitoring of the nest of Tx 30, in which no eggshell remains were found, indicates that rat predation and scavenging can remove all traces of eggs. Had we been making only weekly checks, failed or partially hatched nests could have been completely scavenged and incorrect conclusions made.

The weak links on two harnesses broke during the study (67 and 95 days after fitting). Two birds disappeared towards the end of the study – Tx 18 and Tx 28 – but as Tx 28's signal was absent during the day on 21/10 but back that evening, she is thought to have moved out of receiver range rather than having a failed transmitter. These two birds presumably left the catchment. Teal banded in the Okiwi Basin have been recorded at Wairahi Bay (southern Port FitzRoy area), Forestry Bay (Port FitzRoy), Motairehe (Barker 1999), and Karaka Bay (this study). The banded bird seen at Karaka Bay (S-70547) had moved 4.7 km from the banding site between late June and November.

The latching time of 24 h is too long. Whangarei Area Office DoC use 12 h latch on their teal transmitters. We suggest that future transmitters have a latching time of no more than 12 h. Whangarei Area Office has recently started using transmitters that record the time of death (E. Neill, in litt.). This would be useful on Great Barrier Island also.

Video monitoring is potentially a very useful tool for determining nest predators. It is best used in the latter half of incubation to reduce the chance of abandonment. DoC technical staff may be able to provide a video system with a much smaller camera that could be placed inside the nest and give more definitive information. We did not have a video player with a frame advance function available for our use on Great Barrier – there needs to be one for future video reviewing, as many nest visits occurred too quickly to determine identity on normal speed reviewing.

It was suggested to us that incubating female teal were unlikely to spend more than 30-60 minutes off the nest at night. The little information we gathered indicated that this may not be the case. Video monitoring of Tx 30 showed she was off the nest for periods of 43, 55, 85, 91, 94, 119, 326 and 467 minutes (see Appendix 2; we do not know if the nest was intact during these times). A female on Mana, when accidentally flushed off her exposed and already wet nest on a cold and rainy day, remained off the nest for at least 5.5 hours, but successfully hatched all six eggs several weeks later (Moore 2002). Teal eggs can apparently survive long periods without incubation. Any nests found apparently abandoned should be checked but any eggs left in the nest for at least 24 hours, in case the female returns.

Flock site use

Although monthly changes in flock counts around Okiwi Basin have been described (Barker 1998, 1999), more frequent counts have not been published. Barker (1999) found that teal at Mabey's flock site increased from 40 in August 1998 to a peak of 124 in November, before declining to around 80 in February and March 1999. In our study, the increase of teal was slightly earlier, with a plateau of about 130 birds through mid-October, before a small, variable, decrease from late October. Changes of up to 30 birds between counts were recorded, even between consecutive days, such as between 12/11 (90 birds), 13/11 (111 birds) and 14/11 (83 birds).

In our study, the increase of teal at Mabey's did not appear to be from newly fledged young, so must reflect the return of birds from breeding or individual roosting sites. Some of our radio-tagged birds went to flock sites immediately after their breeding attempts failed. Barker (1999) commented that the presence of female teal at Mabey's during the breeding season (July to September) suggested that many female teal did not breed in that season. We were not confident of sexing teal well enough by plumage to attempt to determine the sex ratio of teal in September at Mabey's, especially as male teal have been recorded in body moult in August (Marchant & Higgins 1990).

The increase in teal at Pond 1 was also primarily an increase in adult teal. Pond 3 likewise held almost only adults. Williams & Barker (1995) suggested that as many as two-thirds of adult birds may remain in their breeding areas rather than be at flock sites over summer. This estimate was based on the proportion of banded birds they encountered at breeding sites in September and again in February, and on the low numbers of colour-banded birds they located at nearby flock sites. A converse of this suggestion was that flocks may contain predominantly young birds rather than adults. Our detailed observations at three flock sites in 2001 tend not to support this, though this could simply represent a lack of juveniles produced locally. At Burrill's Drain on 16/11, many juveniles appeared present, though they could not be accurately counted.

Ageing criteria in the field

There is little information on brown teal fledging ages in the wild. Marchant & Higgins (1990) stated that captive young are able to fly 50-55 days after hatching. A six-seven week fledging period seems to be the working estimate circulating amongst teal workers in New Zealand (pers. obs.). In captivity, Campbell Island teal have lost all down by 8 weeks (Gummer 1999).

We made incidental observations of duckling development on Great Barrier Island (this study) and Mana Island (Moore 2002), assessed plumage development, and identified a useful character for identifying recently fledged juveniles.

1. Pond 1, Okiwi Station. Pair plus three downy chicks (hatch date unknown), first seen 10/9. The three ducklings still had down on their backs on 4/10. By mid-October we distinguished the young by their 'flat-tailed' profiles. The tails of the juveniles, instead of pointing upwards as in adults, sloped down from the peak of the back and ended just above or in the water. The side and rear profiles of these teal were distinctive, and birds could still be discriminated this way until mid-November, when the probable juveniles appeared 'short-tailed' and darkish, rather than flat-tailed.
2. Akapoua Bay, Port FitzRoy. Highly approachable pair plus small fluffy chicks seen on 20/9. Chicks were without any contour feathers at c. 31 days old (Figure 7, left), and had down remaining on hind-neck and rump but no flight feathers at c. 60 days old (Figure 7, right). Ducklings were independent for short periods of time by c. 60 days.
3. River Reserve wetlands. Tx 26's ducklings left nest between 18/10 and 20/10. Ducklings sighted on 27/11, aged c. 38 days, half adult size and fluffy.
4. Mana Island. Chicks left nest on 10/9. On 8/10 (28 days), chicks were downy and 1/3 adult size. On 15/11 (66 days), 2 of 4 chicks still had down remaining on rump; all 4 were flat-tailed with no long primaries. The 4 chicks were still with their parents when caught for banding on 29/11 (80 days old), but by 15/12 only 3 remained with parents.

These observations suggest that brown teal fledging times in the wild are longer than those recorded in captivity. It appears that fledglings can be distinguished from adults by their flat-tailed profiles. The technique seems quite robust, although moulting adults may also temporarily have this appearance. Detailed observations of resident or marked young would be worthwhile to confirm the validity of this character.

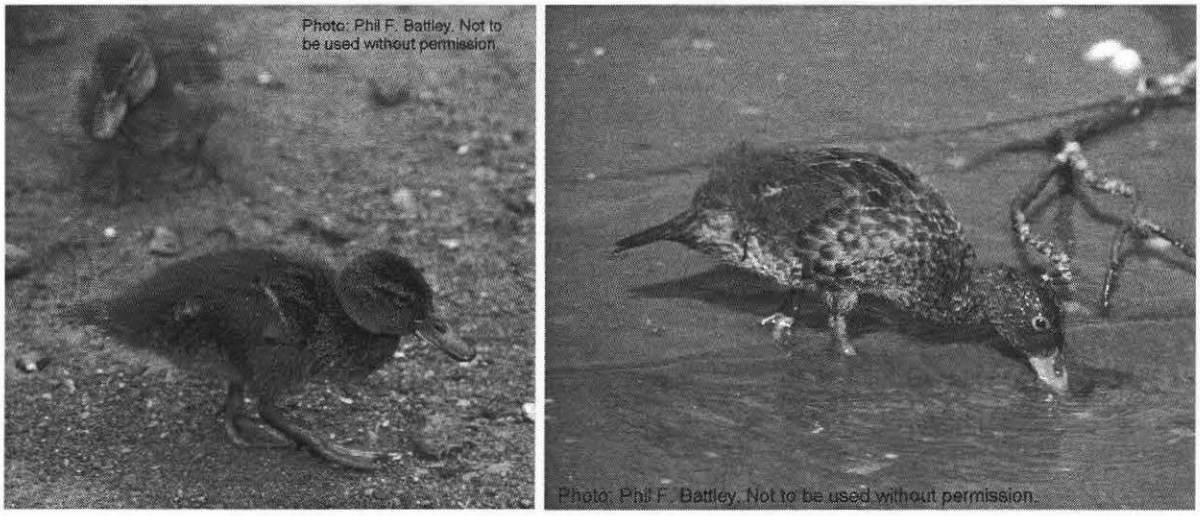

Figure 7. Young brown teal at Akapoua Bay, Port FitzRoy. Left, aged c. 31 days (20/10/01). Right, aged c. 60 days (18/11/01).

Recommendations

1. Harrier and rat numbers appeared high during this study, though there is no hard evidence for this. Rodent monitoring using footprint tracking tunnels should be initiated. Harrier monitoring may be more problematic but would be useful.
2. With pukeko and cat control occurring, harriers and rats appeared to be the main predators in this study. Harrier and rat control may also be required to maximise teal productivity.
3. To reduce the attraction of Okiwi Station to harriers, alternatives to docking lambs tails with rings should be considered. Dropped lambs' tails provide a ready food source for harriers in pasture areas.
4. We knew of two nests in roadside kikuyu during this study period. City council contractors mowed roadside verges during this time. It would be prudent to avoid mowing during the main breeding season (June–October). This should be discussed with council.
5. We had the strong impression that teal were easily disturbed at the River Reserve flock site. Visits to this site, including recreational kayaking, should be minimised.
6. Colour-banding should be restarted on Great Barrier Island teal. At the very least, colour-banding radio-tagged birds would enable individuals to be differentiated on flock sites.
7. Mortality transmitters should have a shorter latching time than was used during this study and have the time of death function.

8. Nest video monitoring should be continued, perhaps using a smaller camera set in the nest. Video systems should only be used in the second half of incubation, to reduce the risk of abandonment. A video-player with frame advance needs to be available for daily reviewing of tapes.
9. Any teal suspected to be nesting should not be disturbed for at least the first two weeks at the site, to reduce the risk of abandonment (it is possible to check potential nest sites while the female is off feeding at night).
10. Any nests found apparently abandoned should be checked but any eggs left in the nest for at least 24 hours, in case the female returns.
11. We agree with Barker (1999) that tracking broods at night is difficult and potentially detrimental to the ducklings. From our data, we expect that ducklings will be near fledging and still with their parents at 6-7 weeks. Checking broods at this age is likely to be easier, and safer for the ducklings.
12. Annual flock counts should be conducted throughout the basin on the same day, and repeated several times to reduce the effects of day to day variation in flock attendance.

Acknowledgments

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Appendix 1. Post mortem pathology report: 7-egg clutch of Tx 28.

Institute of Veterinary, Animal and Biomedical Sciences

Submitter's Ref.: Date Sent: 31/10/2001 Accession No.: 32767

GROSS FINDINGS

Egg 1 - weight 47 grams, width 38.8 mm, length 57 mm. Addled egg.

Egg 2 - weight 42 grams, width 41.6 mm, length 62 mm, yolk size 18 mm width, 4 mm length. External yolk sac. Fully formed chick in normal position.

Egg 3 - weight 41.20 grams, width 41.6mm, length 60 mm, yolk size 21 mm width, 43 mm length.

Egg 4 - weight 39.54 grams, width 43 mm, length 60 mm. External yolk sac.

Egg 5 - weight 39.50 grams, width 42 mm, length 58 mm. External yolk sac.

Egg 6 - weight 39.67 grams, width 43 mm, length 59 mm. External yolk sac.

Egg 7 - weight 38 grams, width 42 mm, length 58 mm. External yolk sac.

HISTOPATHOLOGY

Egg 2 - The yolk sac and visceral organs show no significant changes.

Egg 3 - There is a very severe fungal infection of the abdominal skin, subcutaneous tissue and most of the underlying yolk sac. The hyphae show occasional branches and little evidence of septum formation. Invasion of blood vessels is occurring in some areas. Other visceral organs show no significant changes.

Egg 4 - There is recent moderate haemorrhage in the gizzard mucosa and submucosa. Other visceral organs show no significant changes.

MICROBIOLOGY

Egg No. 3 - Moderate growth of E.coli.

Egg No. 5 - Light growth of Pseudomonas.

DIAGNOSIS

Egg 1 - Infertile egg.

Egg 2 - External yolk sac.

Egg 3 - Mycotic yolk sacculitis and omphalitis.

Eggs 4, 5, 6 and 7 - External yolk sac.

COMMENTS

External yolk sacs often arise from temperature, humidity and incubation problems.

Date: 29 November 2001 Pathologist: M R Alley / M J Gaddam

Appendix 2. Video monitoring transcripts

TAPE ONE

TX 22, 10-11 October 2001, north side of nest

2030	*Tape starts*
2139	Teal walks past bottom right of screen
0002	Rat goes to nest
0003	Rat leaves nest
0138	Teal walks past bottom left of screen
0303	*Tape finishes*

TAPE TWO

TX 22, 11-12 October 2001, north and south sides of nest

0924	*Tape starts*
2145	Phil changes the battery and resets camera till 2200
2240	Car lights
2320	Car lights
0002	Car lights
0519	Duck head close up at bottom right of screen
0823	*Tape finishes*

TAPE THREE

TX 30, 12-13 October 2001, west side of nest

1250	*Tape starts*
1252 -1309	Phil setting up camera gear in background
1522	Pair of pukeko across stream

Stopped reviewing tape as not taping nest entrance used by teal

TAPE FOUR

TX 30, 13-14 October 2001, east side of nest

1110	*Tape starts*
1955	Animal (can't identify) goes up tunnel into nest
2029	Female leaves nest
2124	Female returns to nest
2325	Female leaves nest
2329	Something (duck or rabbit) leaves nest
0056	Female returns to nest
0242	Rat(?) leaves nest - poking around but doesn't appear to spend time around nest
0243	Rat(?) goes to nest
0252	Female(?) leaves nest
0403	*Tape finishes*

TAPE FIVE

TX 30, 14-15 October 2001, east side of nest

1930	*Image poor, with grass waving in front of lens. Watched from 1930 – 2100, then from 2355, after image improved.*

0006	Female leaves nest
0202	Rat leaves nest
0407	Rat goes to nest
0438	Rat leaves nest
0521	Rat leaves nest (check)
0532	Female returns to nest.
0609	*Tape finishes*

TAPE SIX
TX 30 15-16 October 2001, east side of nest

1048	*Tape starts*
1930	Reviewing starts
2020	Female leaves nest
2145	Female returns to nest
0043	Female leaves nest
0217	Female returns to nest
0345	Female leaves nest
0544	Female returns to nest
0632	*Tape finishes*

No recording 16-17 October due to Search and Rescue operation

TAPE SEVEN
TX 30, 17-18 October 2001, east side of nest

1025	*Tape starts*
1930	*Reviewing starts*
2018	Female leaves nest
2101	Female returns to nest
2211	Female leaves nest
2213	Rat goes to nest
0342.	Rat leaves nest
0502	Rat goes to nest
0506	Rat leaves nest
0558	Female returns to nest
0704	*Tape finishes*

TAPE EIGHT
TX 30, 18-19 October 2001, east side of nest

0855	*Tape starts*
1930	*Reviewing starts*
1955	Movement at nest, female jumps straight into creek from nest
2103	Rat leaves nest
2222	Rat goes to nest
2308	Little eel pokes head out of water and swims by
2341	Grass moving in water
2344	Eel in water below nest
2355	Something swims by in creek
0007	Something swims by in creek
0008	Eel in water below nest
0017	Eel in water below nest
0021	Eel in water below nest
0105	Something swims by again

0137	Eel noses up by nest and leaves
0200	Slight movements in water
0213	Eel in water below nest
0238	*Tape finishes*

TAPE NINE
TX 30, 19-20 October 2001, east side of nest

0715	*Tape starts*
1923	Screen very dark - image poor until 1942
2309	Big rabbit leaves nest
2357	Rat leaves nest
0151	*Tape finishes*

TAPE TEN
TX 30, 20-21 October 2001, east side of nest

1055	*Tape starts*
1336	Phil and Sue walk past in background
1627	Rabbit goes up to nest then leaves
1740	*Image very dark hard to see until 1756*
2023	Rat goes to nest
2057	Rat leaves nest
0159	Rat leaves nest
0326	Rat leaves nest
0405	Rat goes to nest
0600	*Nest entrance very dark - hard to see until 0630*
0849	*Tape finishes.*

TAPE ELEVEN
TX 30, 21-22 October 2001, east side of nest

1054	*Tape starts*
1930	*Reviewing starts*
2051.58	Rat goes to nest
2055.10	Rat leaves nest
0403.59	Rat goes to nest
0405.57	Rat leaves nest
0406.02	Rat off screen
0514	*Tape finishes*

Appendix 3. Incidental teal counts

Counts were made by PFB or SJM or passed on to them where credited.

site	date	observer	time	ad	juv	total	comment
Awana	6-Sep-01	PFB+SJM	1526	10		10	Of 7, 4 male 3 female.
Awana	28-Sep-01	PFB+SJM	809	19		19	
Awana	29-Oct-01	PFB+SJM	1438	8		8	
Awana	12-Nov-01	PFB	1550	8		8	Incomplete; 8 under pohutakawa, others under south bank not seen.
Awana	21-Nov-01	S.O'Connor		7		7	Could have been more. By pohutukawa
Awana	26-Nov-01	SJM	1210	23		23	16 pohutukawa on north, 7 under rushes on south.
Awana	12-Jan-02	SJM+PFB	1645	32		32	9 near pohutukawa, rest feeding downstream from campsite.
Claris[3]	12-Nov-01	PFB	1405	14		14	
Claris	21-Nov-01	S.O'Connor		22		22	
Frog Pond [4]	17-Sep-01	C.Mabey		1	5	6	Female + ducklings reported a few days before the 20th.
Frog Pond	24-Sep-01	C.Mabey		2	1	3	Pair + small fluffy duckling.
Frog Pond	25-Sep-01	C.Mabey		2		2	No duckling seen.
Frog Pond	26-Sep-01	C.Mabey		2	3	5	Pair plus 3 tiny ducklings.
Frog Pond	27-Sep-01	C.Mabey		3	3	6	Pair with 3 little fluffy ducklings and another adult seen.
Frog Pond	28-Sep-01	SJM		2	5	7	Pair with 3 little fluffy ducklings, 2 bigger ducklings half adult size.
Frog Pond	8-Oct-01	PFB	1320	2	3	5	Pair with 3 small fluffy ducklings.

[3] Pond by main road south of airport
[4] Near access to Whangapoua Beach and the M.V.Wairarapa graves

site	date	observer	time	ad	juv	total	comment
Frog Pond	10-Oct-01	PFB	1357	2	3	5	Big-headed med-small fluffy juvs, active, diving; adults mated.
Frog Pond	15-Oct-01	PFB	1331	2	3	5	Pair + 3 chicks, still no contour feathers obvious on chicks.
Frog Pond	17-Oct-01	PFB	1310	2	3	5	Ducklings starting to show contour feathers on breast and sides.
Frog Pond	18-Oct-01	PFB	1230	0	0	0	
Frog Pond	26-Oct-01	SJM	1034	0	0	0	
Frog Pond	5-Nov-01	PFB	1126	2	1	3	Pair with 1 half sized duckling, with a lot of down on back and rump and some down on back of head, tail points up.
Frog Pond	7-Nov-01	PFB	1208	2	3	5	Pair + 3 large flat-tailed juveniles.
Frog Pond	8-Nov-01	PFB	1208	2	3	5	Large flat-tailed juveniles.
Frog Pond	9-Nov-01	PFB	1537	4	4	8	adult, + female + 2 large flat-tails, + pair + 1 medium flat-tail with more down.
Frog Pond	12-Nov-01	PFB	1105	3	2	5	Female + 2 fledglings, pair.
Frog Pond	13-Nov-01	PFB	1255	4	4	8	Pair + 3 fledgling, pair + 1 fledgling.
Frog Pond	16-Nov-01	PFB+Z.Mann	1040	4	1	5	Pair + 1 juv, pair.
Frog Pond	21-Nov-01	SJM	1221	3		3	1 smaller, but none had flat tails.
Frog Pond	23-Nov-01	SJM	1012	5		5	No flat-tails.
Frog Pond	26-Nov-01	SJM	1408	5		5	No flat-tails but 4 smaller than the other 2.
Hale's farm	25-Sep-01	PFB+SJM	1500	0		0	Walked down creek from road; no sign of ducks.
Harataonga	25-Oct-01	PFB+SJM	1630	8		8	
Harataonga	12-Nov-01	PFB	1615	13		13	Around island, 6 under pohutukawa.
Harataonga	17-Nov-01	PFB+SJM	1400	11		11	4 under tree, 2 on water, 5 on bank.
Harataonga	21-Nov-01	S.O'Connor	1300	14		14	Near pohutukawa. Pair of mallard present.
Harataonga	12-Jan-02	PFB+SJM	1815	2		2	Males, under pohutukawa.

site	date	observer	time	ad	juv	total	comment
Kaitoke	21-Nov-01	S.O'Connor		10	1	11	Juvenile with a little down on back.
Kaitoke Ck	3-Sep-01	PFB+SJM	1517	1		1	Male with 2 Mallard-farm ducks, preening on ck edge (low tide).
Kaitoke Ck	23-Sep-01	PFB+SJM	1600	1		1	Male on rock with shags; 3 Mallards upstream.
Karaka Bay	18-Sep-01	PFB	1330	6		6	Feeding at low tide at water's edge.
Karaka Bay	16-Oct-01	PFB	1000	8		8	8 disturbed from creek/ditch flew to beach (high tide).
Karaka Bay	5-Nov-01	PFB+SJM	1649	19		19	Most by jetty, feeding at low tide.
Karaka Bay	19-Nov-01	D.Robertson		32		32	Early morning on grass; gravid mate of banded bird under Rose Cottage.
Karaka Bay	26-Nov-01	D.Robertson	1930	18		18	On lawn.
Karaka Bay	27-Nov-01	SJM	1355	31		31	All on rocks by jetty. Lawns being mown.
Karaka Bay	12-Jan-02	PFB+SJM	1440	28		28	21 on grass, 7 at water's edge.
Motairehe	21-Nov-01	S.O'Connor		0		0	Maurice Ngatai reported 12 birds, including 2 pairs each with 4 ducklings.
Pond 2 [5]	7-Sep-01	PFB	1114	1		1	Male teal; pair Mallard and 2 male Paradise Shelduck also on dam.
Pond 2	28-Sep-01	SJM	1116	0	0	0	Single male Paradise Shelduck on dam.
Pond 2	1-Oct-01	SJM	1048	0	0	0	Single male Paradise Shelduck on dam.
Pond 2	3-Oct-01	SJM	1407	0	0	0	Single male Paradise Shelduck on dam.
Pond 2	4-Oct-01	SJM	1150	0	0	0	Pair of Paradise Shelducks.
Pond 2	20-Oct-01	PFB+SJM	1241	0	0	0	2 Paradise Shelduck nearby.
Pond 2	19-Nov-01	SJM+S.O'Connor	1032	4		4	Pair Paradise Shelduck there also.
Pond 2	20-Nov-01	S.O'Connor		4		4	Pair Paradise Shelduck + 1 duckling.
Pond 2	21-Nov-01	SJM	1105	0		0	Paradise duck + duckling; no teal.

[5] Okiwi Station, south-western side of paddock 11, near trap A8

site	date	observer	time	ad	juv	total	comment
Pond 2	26-Nov-01	SJM	1100	0		0	2 Paradise Duck + small duckling.
Pond 4	30-Oct-01	SJM+D.Agnew	1620	3	6	9	Pair with 3 small ducklings, single adult with 3 large ducklings near fledging.
Pond 4	31-Oct-01	SJM	1036	3	6	9	
Pond 4	1-Nov-01	SJM	1537	1	3	4	Female plus 3 ducklings near fledging.
Pond 4	5-Nov-01	PFB	1147	4	4	8	Pair with 2 fledged flat-tails, pair with 2 small downy chicks.
Pond 4	7-Nov-01	PFB	1112	3	5	8	Adult + 3 flat-tails, adult + 2 chicks, adult.
Pond 4	8-Nov-01	PFB	1112	3	5	8	Female + 3 flat-tailed juvs, female + 2 chicks, adult.
Pond 4	9-Nov-01	PFB	1415	3	5	8	Pair + 2 chicks, female + 3 flat-tails.
Pond 4	12-Nov-01	PFB	1047	3	5	8	Pair + 2 chicks, female + 3 flat-tails.
Pond 4	16-Nov-01	PFB+Z.Mann	1120	2	5	7	Female + 2 chicks, 4 ducks on bank probably female + 3 fledglings.
Pond 4	19-Nov-01	SJM+Z.Mann	1202	4		4	At least 2 flat-tails; possibly the female + 3.
Pond 4	21-Nov-01	SJM	1311	4	4	8	Pair + 2 fluffy ducklings, + 4, 2 flat-tails, but possibility of being ad + 3 (hard to age).
Pond 4	23-Nov-01	SJM	1107	6	2	8	Pair + 2 fluffy ducklings, + 4, pair Paradise Duck.
Pond 4	26-Nov-01	SJM	1430	6	2	8	Pair + 2 half-sized ducklings, 4 others, 2 of which were flat-tails.
Rakitu Island	19-Oct-01	PFB+SJM	1200	3		3	See appendix 4.
Rakitu Island	18-Nov-01	D.Agnew	1100	4		4	Pond/creek near beach.
Shoal Bay, Tryphena	29-Nov-01	PFB+SJM	1150	5		5	On mudflats at low tide.

Appendix 4. Rakitu Island bird list.

A short visit to Rakitu Island was made by Great Barrier Island DoC staff on 19/10/01. A bird list was made on the island from 1200-1400 h. Birds at sea were recorded on the boat trip back to the northern end of Great Barrier Island. The weather was fine and warm, and the sea had a moderate swell. Birds are listed in taxonomic order. Phil Battley, Sue Moore, David Agnew, Perry Duggan and Stan McGeady contributed to this list.

Species	**heard/seen**	**habitat**	**comment**
flesh-footed shearwater	seen	at sea	2 seen N of Rakitu.
Buller's shearwater	seen	at sea	10-20 feeding with fluttering shearwaters off Close Island. c. 1000 between Rakitu and the N end Great Barrier Island.
sooty shearwater	seen	at sea	1 seen N of Rakitu.
fluttering shearwater	seen	at sea	300 feeding near Close Island.
black petrel	seen	at sea	2 seen N of Rakitu.
Australasian gannet	seen	at sea	
pied shag	seen	coastal	
paradise shelduck	seen	farmland	
brown teal	seen	wetland	3 seen in creek near the houses. Bryce Rope reported that a pair had recently hatched 8 ducklings by the house but all chicks had disappeared (attributed to eel predation). He also reported that a pair had 5 ducklings in the swamp on the saddle near Rockfall Bay. 23 teal had been counted on Rakitu by Phil Todd some time earlier.
weka	seen /heard	native forest	1+ seen in N, heard in S.
spur-winged plover	seen	farmland	
red-billed gull	seen	coastal	110 off the E coast
kereru	seen	native forest	
shining cuckoo	heard	native forest	
sacred kingfisher	seen	farmland	
skylark	heard	farmland	
welcome swallow	seen	farmland	
grey warbler	seen	native forest	
fantail	seen	native forest	
tui	seen	native forest	
yellowhammer	seen	farmland	
goldfinch	heard	farmland	
house sparrow	seen	farmland	
starling	seen	farmland/coastal	
common myna	seen	farmland	
Australian magpie	seen	farmland	

Appendix 3

Determining ulnar paper-fat scores

For more information see: Moore, S.J. & Battley, P.F. 2003. The use of wing remains to determine condition before death in brown teal (*Anas chlorotis*). Notornis 50: 133-140.

If the carcass is relatively intact, there may be no need to measure wing fat. Instead check abdominal and subcutaneous fat (by slitting the skin and having a look). If there is any fat, the teal did not starve. If there is no fat, but quite a lot of pectoral muscle, it is unlikely the bird starved... if you are unsure you may wish to check the ulnar paper-fat.

- Prepare a tray e.g. a small aluminium pie dish and lay a small square of paper in it.
- Dissect out the ulna.
- Clean any adhering tissue off the ulna.
- Holding the ulna over the paper-lined tray, break it in 2 places. I use bone cutters, but sharp secateurs would probably work. Leave all 3 pieces on the paper.
- Record the appearance of the inside of the ulna. Does it appear dry? Is there pale pink bloody liquid, or fatty orange liquid?
- Leave the bone in the pie dish in a drying oven set at 60°C for several days.
- Check the paper. Note down if there are any marks and their appearance. You can expect either:

1. **No marks**. The bone was probably too dry. Results inconclusive.
2. **Oily marks**, which make the paper almost transparent. There may also be brown blood spots. Oil spots suggest there was still lipid in the ulnar marrow and this bird did not starve to death.
3. **Pale brown marks** from dried blood **only**. If the bone was fresh enough for there to be liquid in the marrow, but no fat, the bird was likely to be in very poor nutritional condition.