SHORT COMMUNICATION

The diet of brown teal (*Anas chlorotis*)

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Abstract: The brown teal or pateke (*Anas chlorotis*) is an endangered endemic duck that has declined greatly throughout its range in the last 120 years but about which there is little dietary information to inform the species' management. We studied the diet of brown teal from six populations (most data were from Great Barrier Island, with additional samples from Northland, Little Barrier Island, Kapiti Island, Mana Island and Karori Wildlife Sanctuary) using feeding observations, gut and faecal analyses. Brown teal had a diverse diet for a dabbling duck: 78 taxa were recorded, including terrestrial, freshwater and marine invertebrates, fungi, and terrestrial and freshwater vegetation. Based on gut content analysis, the most frequently occurring foods were Cyperaceae nuts, white clover leaves, cased caddisfly larvae, beetles, earthworms, gastropods and bivalves. Faecal analysis and visual observations showed marine molluscs to be abundant in the diet in intertidal areas. The use of pastures by much of the present-day population may make teal vulnerable to starvation during dry summers.

Keywords: brown teal; pateke; *Anas chlorotis*; diet

Introduction

Effective conservation management requires knowledge of species' ecology, including diet. Without this basic information the cause of decline may be incorrectly diagnosed, which may compromise successful management of the species. The brown teal or pateke (*Anas chlorotis*) is an endangered, endemic dabbling duck (BirdLife International, 2000) that formerly occupied a wide range of habitats throughout New Zealand including dense podocarp and beech forest far from open water (Worthy, 2002). Nowadays, the bulk of the population lives in pastoral/scrub/swamp areas on Great Barrier Island. While predation is considered to be the main cause of the brown teal's decline (Innes *et al*., 2000), recent research has found that captive-bred and wild brown teal, particularly juvenile birds, are vulnerable to death by starvation in the wild (Moore and Battley, 2003a; S. Stevenson, Department of Conservation, Great Barrier Island, pers. comm.). Poor condition can also predispose birds to predation. However, there have been no definitive studies on brown teal diet in the wild and much of the existing dietary information is speculative and poorly documented (Innes *et al*., 2000).

Most of the existing diet information is derived from observations of foraging birds, but because brown teal are generally shy and crepuscular or nocturnal, feeding observations are biased towards open habitats such as tidal flats and agricultural pastures where birds can be seen but the food items being taken are seldom identifiable. Despite having been observed foraging in pasture, coastal areas, freshwater ponds and creeks, the only prey directly identified have been caterpillars (pasture; Weller, 1974), small black mussels (*Xenostrobus pulex*, rocky shore; Heather, 1980), spire snails (Hydrobiidae, river) and pondweed (*Lemna* sp., farm dam; Edgar, 1971).

Two more quantitative and commonly used methods to determine waterfowl diets are the analysis of droppings or contents of the digestive tract. Faecal analysis is non-invasive and samples are often readily available, but it is biased towards hard, indigestible items, as is gizzard content analysis. 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).

In this study we describe brown teal diet using gut contents analysis, faecal analysis and observations of foraging birds from six sites or regions where brown teal are currently found (three are natural populations; three are introduced). As all of the birds used in gut content analyses were accidental casualties, many of which had been hit by motor vehicles in agricultural or residential areas on Great Barrier Island, basing the study on gut contents alone would have biased results towards teal that had recently fed near roads at night. In an effort to reduce this bias we included diet information obtained from observing teal foraging in coastal and freshwater areas and analyses of faecal samples from coastal and forested areas, although sample sizes for both of these methods are small. The intensity of sampling is therefore not proportional to the intensity of habitat use for the whole populations being studied, but we have attempted to identify food types taken by brown teal in the main habitats used over much of the current range of the species.

Methods

Carcasses, foraging observations and faeces were collected or obtained from Northland (Mimiwhangata and Helena Bay, 35°43'S, 174°40'E, eight carcasses, faeces; Parekura Bay, 35°15'S, 174°14'E, one carcass), Great Barrier Island (hereafter called Great Barrier, 36°18'S, 175°34'E, 45 carcasses, faeces, observations), Little Barrier Island (36°20'S, 175°11'E; two carcasses, faeces), Kapiti Island (40°51'S, 174°55'E, two carcasses, observations), Mana Island (41°05'S, 174°47'E, observations) and Karori Wildlife Sanctuary (41°18'S, 174°44'E; three carcasses, faeces). Carcasses (which were mostly of birds killed on roads on Great Barrier) dated from 1991 to 2003, foraging observations were made between August 2001 and January 2002 and faeces were collected from June 2001 to January 2002. Birds in Northland, Great Barrier and Little Barrier Island were wild; birds on Kapiti Island, Mana Island and Karori Wildlife Sanctuary were captive-bred birds that had been released in 2000 and 2001.

Based on banding data or physical characteristics, three carcasses could be aged as ducklings, six as juveniles and 17 as adults; the remaining full-sized birds could not be aged definitively. Contents of the oesophagus and proventriculus were analysed from all available carcasses, as soft items were more complete in these organs than in the gizzard. Additionally, gizzard contents were analysed from all ducklings, all Northland and Little Barrier Island birds, and some Great Barrier adults. In badly damaged carcasses often only a partial digestive tract remained. Data from the oesophagus, proventriculus and gizzard are presented together as the 'upper digestive tract'. Gut contents were examined in ethanol under a binocular microscope against white and black backgrounds. Seeds and fruits were separated out and subsequently identified by C.J.W. In this paper we discuss only digestive tracts that contained four or more small identifiable items or one or more large items.

Because it was often impossible to establish how many individual food items were involved, we restricted our analysis to the percent occurrence of each item ($n_{\text{birds per food item}}$ / $n_{\text{total birds}}$ × 100; Swanson *et al.*, 1974). As this method weights single and multiple occurrences of dietary items equally, it does not reflect relative abundances in samples. The general contribution of terrestrial, marine, and freshwater plants and animals in the diet was visually estimated to the nearest 5%. Bootstrap confidence intervals for estimates of percentage composition were computed from 1000 bootstrap samples.

Droppings were sorted in water under a binocular microscope, and intact bivalve hinges and other identifiable fragments such as seeds, insect larvae, and gastropod shell fragments separated. Hinge lengths of pipi (*Paphies australis)* and common cockles (*Austrovenus stutchburyi*) were measured under a binocular microscope with an eyepiece micrometer. Hinge and total lengths were also measured for 21 reference pipi and eight cockles from intertidal foraging sites on Great Barrier. Equations to estimate total shell length from hinge remains (Dekinga and Piersma, 1993) were derived from these reference shellfish: pipi, log length = 2.208 + log(hinge) × 1.133 (R^2 = 0.980, $F_{1,19}$ = 951.775, P < 0.001); cockles, length = 0.044 + 11.607 × hinge (R^2 = 0.994, $F_{1,6}$ = 1026.466, P < 0.001). We used these equations to estimate the shell length of pipi and cockles ingested by brown teal.

Results

Feeding observations

From 41 feeding observations on Great Barrier, food items could be identified only eight times, with white clover (*Trifolium repens*) leaves, common cockles, and estuarine mudsnails (*Potamopyrgus pupoides* and probable *P. estuarinus*) being taken. All of these observations were during daytime in coastal areas and of birds that had apparently become habituated to humans. Feeding was observed seven times on Kapiti Island, but no food items were identified. Of 19 feeding observations around ponds on Mana Island, food items were only identified five times; these were cocksfoot (*Dactylis glomerata*), pond weeds (*Lemna minor* and *Azolla filiculoides*) and sea aster (*Aster subulatus*) leaves. Great Barrier residents reported three additional dietary items taken from gardens: strawberries (G.

Burke, pers. comm.), grapes (H. Mabey, pers. comm.) and earthworms (A. Cox, pers. comm.).

Gut content analyses

More than 65 taxa were identified from gut contents; most brown teal had eaten both plant (89% of teal) and animal material (87% of teal; Table 1). Based on visual estimates of the composition of the 61 gut samples, teal diet comprised on average (with 95% bootstrap confidence intervals in brackets) 58% (48-67%) terrestrial plant, 18% (12-25%) terrestrial animal, 2% (0-5%) freshwater plant, 8% (3-13%) freshwater animal, 12% (5-19%) marine animal and 2% (0-5%) fungi. Large numbers of Cyperaceae nuts were found (up to eight species per gut), but only two genera (*Uncinia* and *Carex*) could be identified. The frequency of occurrence masks the predominance of certain items in individual guts. The oesophagus and proventriculus of an adult male brown teal from Great Barrier contained 13.5 g of yellow fungal fruiting bodies (identified by P. Novis, Landcare Research Lincoln). The oesophagus of another Great Barrier teal contained only white clover (*Trifolium repens*; 525 leaves, 5.8 g). A third Great Barrier bird had 99 small gastropods (*Potamopyrgus antipodarum*) in its oesophagus and proventriculus, and a further 722 in its gizzard. The gizzard of one Northland teal contained 866 seeds.

Bivalves were found in 11% of guts analysed (six birds from Great Barrier and one from Kapiti Island; Table 1). Three teal, including the Kapiti Island bird, had fed on Sphaeriidae, tiny freshwater bivalves (< 4 mm long). The other four had consumed marine bivalves (pipi and common cockles).

Faecal analysis

Thirty-three faecal samples were examined. Plant matter was recorded in faeces from Northland, Great Barrier and Little Barrier (seeds in nine droppings; leafy green vegetation in 11 droppings, and flower sepals plus stalk in one dropping). Animals were identified at all sites. Predominant items were gastropods (*Potamopyrgys* spp., 9; unidentified, 6; whelks, 2; *Amalda* sp., 1; cats eye/turban shell, 1; *Zeacumantus* sp., 1), and bivalves (pipi, 19; cockles, 12; nutshell *Nucula* sp., 6). Less frequent items were the polychaete *Pectinaria australis* (1 dropping from Great Barrier), crustaceans (amphipod, 2; ostracod, 1; unidentified, 5), insects (terrestrial spp., 2; Chironomid larva, 1; mosquito larva, 1; mayfly *Zephlebia* sp., 1; caddis *Aoteapsyche* sp., 1) and Foraminifera (6). In keeping with their collection locations, faeces from coastal Great Barrier sites had either marine or marine+terrestrial items, those from a coastal creek in Northland contained terrestrial, freshwater and marine items, Little Barrier faeces contained vegetation and arthropods, and a single dropping from regenerating forest at Karori contained stream invertebrates.

Intact shellfish hinges found in faecal and gut samples indicated pipi 1.1 – 16.2 mm (mean 4.7 ± s.d. 2.2 mm, n = 267) and cockles 1.8 – 14.7 mm (mean 4.6 ± 2.6 mm, n = 67) in length had been consumed whole.

Discussion

In the wild, brown teal feed on a wide range of plants and animals in terrestrial, freshwater, estuarine and coastal environments. In intertidal areas teal dabble in wet sediment and shallow water, feeding on small shellfish, gastropods and presumably any other invertebrates they encounter (e.g. crustaceans, polychaetes). On Great Barrier, they also open larger cockles to extract the flesh (Moore and Battley, 2003b). At high tide, the same individuals may feed in adjacent freshwater streams on gastropods and insect larvae, or in nearby pastures, where vegetation such as white clover (an introduced relatively high protein, low fibre food; Thomson, 1984) is eaten. For birds feeding in pasture/scrub/wetland areas (the general habitat type on Great Barrier where most of the gut content information in our study came from), seeds and fruits were frequently eaten, particularly Cyperaceae (sedge) nuts. Adult and larval terrestrial insects were also recorded in gut contents, while teal have been observed feeding on earthworms and caterpillars. On freshwater ponds, teal were observed eating leaves of various wetland plants. Teal are clearly versatile foragers, combining non-visual dabbling (in wet areas such as creeks and tidal flats) with visual foraging (for example on adult insects and large cockles) to include a wide range of prey in the species' diet. Weller (1974) suggested that teal fill the ground-feeding niche normally occupied by quail or pheasants, as well as that of dabbling ducks.

Although we identified a wide range of food items, brown teal diet would once have been much broader. Teal are known to have occurred on large lakes and in dense podocarp or beech forests (Worthy, 2002), and they currently occur quite deep into regenerating forest on Great Barrier, a habitat from which we have no direct diet data. In such bush settings they are likely to feed on stream invertebrates, berries and seeds, and ground-dwelling invertebrates.

The breadth of the potential brown teal diet means that they are likely to be affected less by specific changes to the composition of the prey community than by all-encompassing factors that impact on the whole community. Although the diet of brown teal 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 have caused an overall reduction in year-round food availability for brown teal. The brown

Table 1. Percent occurrence of food items from the upper digestive tracts of brown teal. Nthld refers to the Northland region. Kapiti+Karori refers to captive-bred teal released on Kapiti Island (2 birds) and Karori Wildlife Sanctuary (3 birds); all other birds were wild-bred. Subtotals for higher classification levels are in bold. 95% binomial confidence intervals are given for Great Barrier and the total dataset.

Food item		Habitat[1]	Great Barrier		Nthld	Little Barrier	Kapiti+Karori	Total	
			n = 45		*n* = 9	*n* = 2	*n* = 5	*n* = 61	
			%	95% C.I.	%	%	%	%	95% C.I.
Plant			**84**	(70-94)	**100**	**100**	**100**	**89**	(78-95)
	Algae	M/F	4	(0-15)				3	(0-11)
	Moss	T/F	7	(1-18)	11	50		8	(3-18)
	Trifolium repens leaves	T	20	(10-35)				15	(7-26)
	Grass blade	T	4	(0-15)				3	(0-11)
	Unidentified vegetation		13	(5-27)	22	50	20	16	(8-28)
	Potato peeling	T	2	(0-12)				2	(0-9)
	Seeds + fruits	T	73	(58-85)	100	50	100	79	(66-88)
Seeds + fruits:									
	Unidentified seed + fruit		42	(28-58)	56	50	100	49	(36-62)
	Naturalised spp.	T	7	(1-18)		50		7	(2-16)
	Naturalised legumes	T	11	(4-24)	22			11	(5-22)
Cyperaceae	*Uncinia* sp.	T	4	(0-15)				3	(0-11)
	Carex sp.	T/F	2	(0-12)				2	(0-9)
	Other Cyperaceae spp.	T/F	44	(30-60)	78		60	49	(36-62)
Poaceae	Grass	T	7	(1-18)	11			7	(2-16)
Restionaceae	*Apodasmia similis*	T	2	(0-12)				2	(0-9)
Sparganiaceae	*Spargamium subglobosum*	T	2	(0-12)				2	(0-9)
Rubiaceae	*Coprosma* spp.	T	4	(0-15)	11	50	20	8	(3-18)
Rutaceae	*Melicope simplex*?	T	2	(0-12)				2	(0-9)
Epacridaceae	*Leucopogon fascicularis*	T	4	(0-15)				3	(0-11)
Ranunculaceae	*Ranunculus* sp.	T	4	(0-15)	11			5	(1-14)
Oxalidaceae	*Oxalis corniculata*	T	2	(0-12)				2	(0-9)
Rosaceae	*Rubus* sp.	T					20	2	(0-9)
Polygonaceae	*Persicaria decipiens*?	T	11	(4-24)	11			10	(4-20)
Griseliniaceae	*Griselinia* sp.?	T			11			2	(0-9)
Fungi			**2**	(0-12)				**2**	(0-9)
Animal			**82**	(68-92)	**89**	**100**	**100**	**87**	(76-94)
Oligochaeta			**16**	(7-80)	**11**			**13**	(6-24)
Gastropoda			**36**	(22-51)	**44**		**80**	**39**	(27-53)
	Unidentified gastropod		20	(10-35)	33		40	23	(13-36)
	Whelk	M	4	(0-15)				3	(0-11)
	Zeacumantus lutulentus	M	2	(0-12)				2	(0-9)
	Nodolittorina antipodum	M	2	(0-12)				2	(0-9)
	Potamopyrgus spp.	M/F	2	(0-12)				2	(0-9)
	P. antipodarum	F	4	(0-15)			40	7	(2-16)
	P. pupoides	M	7	(1-18)				5	(1-14)
	Cantareus aspersus	T	2	(0-12)	11			3	(0-11)
	Slug (*Milax gagates*?)	T	9	(3-21)				7	(2-16)
Bivalvia*		M/F	**13**	(5-27)			**20**	**11**	(5-22)
	Paphies australis	M	9	(3-21)				9	(3-21)
	Austrovenus stutchburyi	M	2	(0-12)				2	(0-12)
	Sphaeriidae	F	2	(0-12)				2	(0-12)
Unidentified arthropod**			24	(13-40)	44	50	20	28	(7-41)
Arachnidae**			**13**	(5-27)				**10**	(4-20)
	Acarina	T/F	13	(5-27)				10	(4-20)
	Opiliones	T	2	(0-12)				2	(0-9)
Crustacea**			**13**	(5-27)				**10**	(4-20)
	Ostracod	M/F	4	(0-15)				3	(0-11)
	Isopod		7	(1-18)				5	(1-14)
	Amphipod		4	(0-15)				3	(0-11)
	Halicarcinus varius	M	2	(0-12)				2	(0-9)
Diplopoda	Millipede	T	**4**	(0-15)				**3**	(0-11)
Insecta			**33**	(20-49)	**89**	**100**	**60**	**46**	(33-59)
	Unidentified insect		11	(4-24)	33		60	18	(9-30)
Lepidoptera	Caterpillar	T	4	(0-15)		50		5	(1-14)

Table 1 contd.

Food item		Habitat[1]	Great Barrier		Nthld	Little Barrier	Kapiti+Karori	Total	
				n = 45	*n* = 9	*n* = 2	*n* = 5		*n* = 61
			%	95% C.I.	%	%	%	%	95% C.I.
	Unidentified moth	T				50		2	(0-9)
	Unidentified chrysalis	T					20	2	(0-9)
	Psychidae	T	2	(0-12)				2	(0-9)
Plecoptera			2	(0-12)				2	(0-9)
Trichoptera	*Oxyethira albiceps* larva	F	7	(1-18)				5	(1-14)
	Oeconesus maori larva	F					20	2	(0-9)
	Olinga sp. larva	F	4	(0-15)	22			7	(2-16)
	Pycnocentrodes sp. larva	F	2	(0-12)	11			3	(0-11)
	Hudsonema sp. larva	F			11		20	3	(0-11)
	Helicopsyche sp. larva	F			11			2	(0-9)
Phasmidae	Stick insect	T			11			2	(0-9)
Hemiptera	Hemiptera	T	2	(0-12)				2	(0-9)
Coleoptera	Unidentified adult	T	7	(1-18)	67	50		16	(8-28)
	Unidentified larva	T/F	2	(0-12)				2	(0-9)
	Scirtidae larva	F	2	(0-12)				2	(0-9)
	Hydrophilidae larva	F	2	(0-12)				2	(0-9)
	Staphylinidae adult	T/F	2	(0-12)				2	(0-9)
	Weevil larva	T	2	(0-12)				2	(0-9)
	Weevil adult	T			11			2	(0-9)
Diptera	Unidentified larva		2	(0-12)				2	(0-9)
	Unidentified pupa		2	(0-12)				2	(0-9)
	Unidentified adult	T	2	(0-12)				2	(0-9)
	Ephydridae larva	M/F	2	(0-12)				2	(0-9)
	Empididae larva	T/F	2	(0-12)	11			3	(0-11)
	Simuliidae larva	F				50		2	(0-9)
	Unidentified tipulid larva	T/F	4	(0-15)				3	(0-11)
	Paralimnophila sp. larva	F	2	(0-12)				2	(0-9)
	Zelandotipula sp. larva	F	2	(0-12)	11		20	5	(1-14)
	Chironomus sp. larva	F	2	(0-12)				2	(0-9)
	Culicidae larva	F	4	(0-15)				3	(0-11)

[1]Where known, habitat is freshwater (F), marine or estuarine (M) or terrestrial (T).

teal diet of seeds and invertebrates overlaps substantially with that of rats (*Rattus* spp.; Atkinson & Towns, 2005; Innes, 2005a,b), house mice (*Mus musculus*; Ruscoe & Murphy, 2005), European hedgehogs (*Erinaceus europaeus*; Jones & Sanders, 2005), 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 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).

The current restriction of most brown teal to pastoral habitats probably makes them more vulnerable to nutritional stress during dry periods than they would have been when a wider range of habitats was available. On Great Barrier almost all of the alluvial flats that were once swamps have been burnt and drained for agriculture, as have most of the freshwater wetlands (Ogden, 2001). 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). While farm dams may provide suitable roosting sites, at night teal disperse to surrounding pastures to feed, and pastures may become too dry for profitable feeding. Barker and Williams (2002) suggested that drought-induced reproductive failure was at least partly to blame for low brood survival at Okiwi on Great Barrier, and Williams (2001) noted that the catastrophic decline of two Northland teal populations coincided with a severe drought. Thus, while predation may be the key agent in the brown teal's decline (Innes *et al.*, 2000), food shortages during dry periods are likely to further decrease recruitment and adult survival.

Our study has shown that brown teal feed on a wide variety of foods, so their current feeding difficulties are unlikely to be due to the lack of a specific food type. Rather, the restricted habitats that teal now occupy may mean that changes in food supply affect a wide range of potential prey simultaneously. Further work on the nutritional values of various foods, the availability of these items under different environmental conditions and the brown teal's requirements at different life stages would allow likely feeding shortfalls to be identified. The provision of adequate food supplies year-round could then be achieved through habitat manipulation, supplementary feeding and well-informed selection of management sites.

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