ILKIW, J.E., SUTER, C.M., FARVER, T.B., McNEAL, D. & STEFFEY, E.P. 1996. The behavior of healthy awake cats following intravenous and intramuscular administration of midazolam. *J. Vet. Pharmacol. Therap.* 19: 205–216.

KRAHWINKEL, D.J. 1970. The use of tiletamine hydrochloride as an incapacitating agent for a lion. *JAVMA*. 157: 622–623.

LIN, H.C. 1996. Dissociative anaesthetics. In J.C. Thurman, W.J.Tranquilli & G.J. Benson (Eds). Lumb & Jones Veterinary Anesthesia 3rd edn. Ch. 10. Williams & Wilkens, Baltimore.

McKENZIE, A.A. & BURROUGHS, R. E. J. 1993. Chemical capture of carnivores. In A.A. McKenzie (Ed.). The capture and care manual. Section B1 Wildlife Decision Support Services, Pretoria.

STEGMANN, G.F. 1998. Observations on the use of midazolam for sedation, and induction of anaesthesia with midazolam in combination with ketamine in the goat. *J. S. Afr. Vet. Ass.* 69:89–92.

STEGMANN, G.F. 1999. Observations on some cardiopulmonary effects of midazolam, xylazine, and a midazolam/ketamine combination in the goat. *J. S. Afr. Vet. Ass.* 70:122–126.

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Winter and spring foods of white-faced whistling ducks in northern KwaZulu-Natal, South Africa

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Foods of white-faced whistling ducks *Dendrocygna viduata* were studied relative to sex, age, time of winter and spring, habitat type, and molt intensity in northern KwaZulu-Natal, South Africa, 1995. Adults and juveniles were collected on a naturally occurring pan (Yengweni Pan) and a large water storage dam (Pongolapoort Dam) during early winter (June), late winter (August) and spring (October). While the proportions of individual foods varied throughout the winter and spring and between the two collection sites, there were no sex or age-related dietary differences at either of the sites ($P > 0.05$). The seeds of moist soil (> 99% aggregate dry mass) and aquatic plants (> 97%) were the principal dietary items of birds using the Pongolapoort Dam and Yengweni Pan, respectively. While extensive submerged plant communities permit birds to consume large quantities of aquatic seeds on the Yengweni Pan, large fluctuations in water level on the Pongolapoort Dam impede aquatic plant establishment, forcing birds to forage elsewhere. The most commonly consumed seeds contained fat and crude protein levels ranging between 0.82–1.60 and 7.00–12.69%, respectively. Invertebrates were minor dietary items (< 1.0%) and although birds tended to consume higher levels of animal matter during the wing-molting period, invertebrate consumption was not correlated with molt intensity. Continued drainage and overgrazing of shallow pans and damming of floodplain systems will adversely affect the aquatic foods used by wintering white-faced whistling ducks, particularly during wing-feather molt. The consequences of large-scale water abstraction schemes and wetland drainage may be even more severe for diving ducks, as they are incapable of foraging in terrestrial habitats.

Keywords: *Dendrocygna viduata*, management, moult, nutrition, white-faced whistling duck, waterfowl, South Africa

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Introduction

Semi-arid conditions prevail throughout much of southern Africa (Alexander 1985) and restricts the availability of waterfowl habitats during characteristically dry winters. This inherent habitat shortage has been exacerbated by the degradation of natural wetlands through drainage, development, siltation, and eutrophication (Begg 1986). White-faced whistling duck (*Dendrocygna viduata*) populations have increased in southern Africa since the 1960s (Clark 1974, 1976; Colahan 1984) which presumably has increased pressures on the few remaining wintering habitats. The decline in naturally occurring wetlands has been partly offset by the construction of water storage dams and reservoirs which are used extensively by wintering waterfowl (Colahan 1984). However, the relative suitability of man-made and naturally occurring wetlands for satisying the nutritional requirements of wintering waterfowl is unknown.

North-temperate occurring waterfowl replace wing feathers on or near the breeding grounds, with the exception of occasional late nesting-females (Hohman, Ankney & Gordon 1992). In contrast, white-faced whistling ducks in northern KwaZulu-Natal, South Africa, undergo wing feather molt in early and late winter and replace contour feathers throughout winter (Petrie 1998a). Molt is an energetically and nutritionally costly event for waterfowl (Payne 1972; King 1981; Heitmeyer 1988) and birds may select food items that are high in protein content or particular amino acids to satisfy demands (Sedinger & Raveling 1984; Murphy & King 1987).

The objective of this study was to compare foods eaten by white-faced whistling ducks using two different habitats (natural *vs* manmade) and to determine if there is a relationship between intensity of molt and the level of invertebrate consumption. I hypothesized that since food availability may be the major factor determining the diet of white-faced whistling ducks (Dallmeir & Rylander 1982; Petrie & Rogers 1996), the proportion of plant/animal matter and the particular foods consumed by birds using natural pans would differ from those using water storage reservoirs. Given the high protein costs of molt (Payne 1972; King 1981; Heitmeyer 1988), I further hypothesized that invertebrate consumption would be positively correlated with molt intensity.

Study area

Northern KwaZulu-Natal, South Africa is arid/semi-arid, receiving approximately 600 mm of annual rainfall, and is characterized by hot, wet summers, and mild, dry winters (Watkeys, Mason & Goodman 1993). Two large river systems flow across the region forming a number of floodplain and swamp systems and there is an abundance of semi-permanent and permanent shallow pans (basins). These coastal plain wetlands support large concentrations of white-faced whistling ducks in winter as natural wetlands in the interior of South Africa are often dry at this time (Colahan 1984).

The Yengweni Pan (27°38′S, 32°26′E) is approximately 120 ha in size and has an extensive aquatic plant community dominated by *Nymphaea* spp., *Ceratophyllum demersum*, *Potamogeton pectinatus*, and *Polygonum lapathifolium*. The Pongolapoort Reservoir (27°30′S, 31°59′E) is a large (15 000–20 000 ha depending on the flood level) reservoir that has frequent and abrupt changes in water levels. Fluctuating water levels inhibit aquatic macrophyte establishment and restrict the littoral zone to sparse stands of *Scirpus* spp., *Panicum* spp., and *Nymphaea* spp. Both of these waterbodies are censused during January (summer) and July (winter) each year as part of the African Coordinated Waterbird Count. Data from 1992–1995 indicate that the Yengweni Pan and Pongolapoort Dam support, on average, 345 and 1526 white-faced whistling ducks in winter and 54 and 689 in summer, respectively (Mkuzi Game Reserve unpublished data).

Methods

Collection and dietary intake

White-faced whistling ducks were collected at random on the Yengweni Pan and the Pongolapoort Dam throughout the day by shotgun during early winter (8–16 June 1995, $n = 35$), late winter (10–18 August 1995, $n = 39$) and spring (1–8 October 1995, $n = 39$). The purpose of the study was to look at the foods of white-faced whistling ducks throughout the non-breeding period. Therefore, timing of collections was based on the fact that white-faced whistling duck breeding (generally between October and April) in semi-arid regions is less defined by season and more by rainfall (Clark 1976).

To ensure an esophageal food sample, waterfowl typically have been observed foraging for a minimum of ten minutes prior to collection (Swanson & Bartonek 1970). White-faced whistling ducks spent very little time foraging on the Pongolapoort Dam and wintering white-faced whistling ducks congregate in large flocks making it difficult to identify and limit collection to feeding birds. Therefore, most individual birds were not observed foraging prior to collection.

Approximately 10 ml of 80% alcohol was injected down the throat of all specimens immediately upon collection to prevent post-mortem digestion. Birds were tagged for identification and placed in a cooler with ice and returned to the laboratory where the esophageal and proventricular contents were removed and stored in 80% ethanol. Diet samples were sorted, dried at 60°C for 24 hours and weighed. Samples with < 5 items or < 0.01g were excluded from subsequent analyses. Seeds and invertebrates were identified by Department of Agriculture personnel in Pretoria and Albany Museum personnel in Grahamstown, respectively. Plant and invertebrate dietary data are expressed as mean aggregate percent dry mass and frequency of occurrence (Swanson, Krapu, Bartonek, Serie & Johnson 1974). Birds were aged and sexed using plummage characteristics and by cloacal examination, respectively.

Within-habitat type and collection period sex and age-related differences in the aggregate percent dry mass of particular food items were determined using Kruskal-Wallis rank sums multiple comparisons tests (Conover 1980). No sex or age differences in food consumption were detected, consequently the data on males, females and age groups were grouped by habitat type for each collection period. Seasonal dietary differences within-habitat type (early winter × late winter × spring) were analyzed using Kruskal-Wallis rank sums multiple comparisons tests. Mann-Whitney U-tests were used to assess difference in the overall diet between the two habitats (pan × dam).

The three seed species most commonly consumed by wintering white-faced whistling ducks (*Scirpus* sp., *Nymphaea* sp., and *Poylgonum lapathifolium*) were analyzed for crude protein (micro Kjedahl method), crude fiber (soxhlet extract), fat (ether extract), ash (oven), phosphorus (vanado molybdate spectrophotometric method), and calcium (atomic absorption). To determine the relative size of food items, 10 subsamples of the three most commonly consumed seeds were counted to determine the mean number of seeds per gram.

Molt intensity

The intensity of feather replacement was determined by scoring the presence of blood quills in several feather regions. Molt intensity was scored as 0, 1, or 2 for no molt, light molt ($<$ 15% of tract molting), and heavy molt ($>$ 15% of tract molting), respectively (Austin & Frederickson 1986), in twenty feather regions (crown, face, chin-throat, neck, upper back, scapulars, lower back, rump, upper tail coverts, retrices, lower tail coverts, belly, centre chest, side chest, side, flank, primaries, secondaries, tertials, and wing coverts). The total molt intensity index was the sum of all twenty feather regions and had a maximum value of 40. To confirm that birds were in a non-reproductive state, the ovary and oviduct of females and one testis of males were excised and weighed to the nearest 0.01 g.

A Spearman's correlation coefficient was used to identify relationships between percent macroinvertebrate consumption by mass and both overall molt intensity score and the intensity of wing-feather molt (primaries and secondaries combined). Adult male and female white-faced whistling ducks replace wing-feathers while on the wintering grounds and continue to replace contour feathers throughout the entire winter, and with the exception of a slightly higher molt intensity in late wintering males, males and females have similar molt patterns in winter (Petrie 1998a). Males and females were grouped by habitat type in order to identify relationships between molt intensity score and percent macroinvertebrate consumption by mass for both study sites. All adults from both habitat types were subsequently grouped and compared using the same method. Due to small sample sizes, juveniles were grouped by sex and habitat type and a Spearman's correlation coefficient used to identify the relationship between molt intensity and invertebrate consumption.

Results

Food use by habitat

White-faced whistling duck diet composition was determined from 60 birds collected on the Pongolapoort Dam (21 adult female, 31 adult male, 8 juvenile) and 55 birds collected on the Yengweni Pan (25 adult female, 19 adult male, 11 juvenile). White-faced whistling ducks were primarily granivorous, as seeds represented 99.9 and 98.1% of the aggregate per cent dry mass of the diet of birds collected on the Pon-

Table 1 Aggregate per cent dry mass (Agg %) and per cent occurrence (% Occ) of foods in the upper digestive tract of white-faced whistling ducks during early winter (*n* = 15), late winter (*n* = 21) and spring (*n* = 24) on the Pongolapoort Dam in KwaZulu-Natal, South Africa, 1995

	Early winter			Late winter			Spring		Composite[a]	
Food item	Agg %	% Occ		Agg %	% Occ		Agg %	% Occ	Agg %	% Occ
Moist soil plants										
Scirpus sp.	93.6	100		99.2	100		97.9	100	97.8	100
Panicum coloratum	5.6	93.3	*[b]	0.5	42.9	*	1.1	91.7	1.6	75.0
Panicum sp.				0.1	42.8		0.4	79.2	0.2	46.7
Ambrosia sp.	Tr	33.3		Tr	14.3		0.2	20.8	Tr	21.7
Hibiscus sp	Tr	20							Tr	5.0
Sesamum triphylum	0.1	6.7							Tr	1.7
Paspalum scorbiculatum							Tr[c]	4.2	Tr	1.7
Unknown seed spp.				0.1	61.9		0.2	54.2	0.1	43.3
Aquatic plants										
Nymphaea sp.	0.4	26.7		Tr	19.0		Tr	4.2	0.1	15.0
Polygonum lapathifolium	0.1	40.0		Tr	23.8		0.1	37.5	0.1	33.3
Total plant matter	**99.8**	**100**		**99.9**	**100**		**99.9**	**100**	**99.9**	**100**
Animal matter										
Diptera	Tr	6.7					Tr	4.2	Tr	3.4
Hemiptera	Tr	6.7		Tr	4.8		Tr	4.2	Tr	11.7
Coleoptera	Tr	33.3					Tr	8.4	Tr	11.7
Gastropoda	Tr	6.7					Tr	4.2	Tr	3.3
Pelecypoda							Tr	4.2	Tr	1.7
Total animal matter	**0.1**	**40.0**		**Tr**	**4.8**	*	**0.1**	**20.8**	**Tr**	**20.0**

[a]early winter, late winter and spring diets combined. [b]denotes a between collection period difference ($P < 0.05$) in the aggregate % dry mass of that food item. [c]Tr < 0.05 g. All plant matter consist of seeds otherwise indicated

golapoort Dam and Yengweni Pan, respectively (Tables 1 and 2). There were no within-habitat type differences in the proportion of individual food items consumed by adult males, adult females or juveniles ($P > 0.05$).

The seeds of native moist soil plants were the principal dietary items (> 99%) of birds collected on the Pongolapoort Dam. *Scirpus* was the most common food during all three collection periods (Table 1) and represented 97.8% of the composite winter diet. With the exception of *Panicum coloratum*, all individual food items were consumed in similar proportions during the three collection periods ($P > 0.05$). Only 12 of 60 birds collected on the Pongolapoort Dam contained invertebrates, which represented < 0.05% of the aggregate percentage dietary dry mass.

Aquatic plant seeds were the principal foods consumed (> 97%) by birds collected on the Yengweni Pan. *Nymphaea* sp. was the most important dietary item during early winter (91.7%) and spring (86.3%) while *Polygonum lapathifolium* dominated the late winter diet (93.7%) (Table 2). *Ceratophyllum demersum*, an aquatic herb, was also a common dietary item during spring (9.5%). Only 12 of 55 birds collected on the Yengweni Pan contained invertebrates, which represented 0.2% of the aggregate percentage dietary dry mass.

There was very little overlap in the composite diets of birds using the Pongolapoort Dam and the Yengweni Pan (Table 1 and 2). Birds collected on the Pongolapoort Dam consumed higher quantities of *Scirpus* sp., *Panicum coloratum*, and *Panicum* sp. seeds, ($P < 0.001$) than birds collected on the Yengweni Pan, all of which are moist soil plants. Birds using the Yengweni Pan contained higher quantities of *Nymphaea* sp., *Ceratophyllum demersum*, *Potagometon pectinitus* seeds ($P < 0.01$), all of which are aquatic plant species. Yengweni Pan birds consumed larger quantities of plant stems ($P < 0.001$), indicating that they gleaned seeds directly from plants. Yengweni Pan birds consumed slightly higher proportions of animal matter (0.2%) than Pongolapoort Dam birds (<0.05%) but the difference was not significant ($P = 0.526$).

Invertebrate consumption and molt intensity

Molt intensity was not correlated ($P > 0.05$) with the % dry mass of invertebrates in the diet of adults collected from the Pongolapoort Dam ($r^2 = 0.198$), the Yengweni Pan ($r^2 = -0.085$) or for adults ($r^2 = 0.001$) or juveniles from both habitats combined ($r^2 = 0.252$). While it was only significant for late wintering birds on the Pongolapoort Dam ($P = 0.03$), birds at both collection sites consumed larger proportions of invertebrates during early winter and spring (Tables 1 and 2), the time of most intense wing-feather molt in white-faced whistling ducks (Table 3). However, when birds from both sites were grouped by collection period, the proportion of invertebrates in the diet (by mass) was higher during early winter ($P = 0.03$) and spring ($P = 0.01$) than during late winter (Table 3). For adults, invertebrate consumption was more strongly correlated with wing-feather molt ($r^2 = 0.166$) than overall molt intensity ($r^2 = 0.001$).

Table 2 Aggregate per cent dry mass (Agg %) and per cent occurrence (% Occ) of foods in the upper digestive tract of white-faced whistling ducks during early winter (n = 25), late winter (n = 14) and spring (n = 16) on the Yengweni Pan in KwaZulu-Natal, South Africa, 1995

	Early winter			Late winter			Spring		Composite[a]	
Food item	Agg %	% Occ		Agg %	% Occ		Agg %	% Occ	Agg %	% Occ
Moist soil and terrestrial plants										
Scirpus sp.	0.1	20.0		0.9	14.2		Tr[c]	12.6	0.5	23.6
Panicum sp.				Tr	7.1				Tr	1.8
Dichrostachys cinerea	2.1	8.0							Tr	1.8
Aquatic plants										
Nymphaea sp.	91.7	88.0	*[b]	2.9	64.3	*	86.3	87.5	49.9	81.9
Nymphaea sp. (rhizomes)				1.9	7.1		86.3	87.5	49.9	81.9
Polygonum lapathifolium	Tr	12.0	*	93.7	57.1	*	Tr	6.3	44.2	21.8
Ceratyphyum demersum	2.2	48.0	*	0.1	21.4	*	9.5	50.0	2.1	41.8
Potamogeton pectinatus	0.3	24.0		0.1	21.4		1.7	12.5	0.4	20.0
Unknown seed spp.	2.1	8.0							0.9	3.6
Unknown stems	1.0	28.0		0.3	21.4		1.1	12.5	0.7	100
Total plant matter	**99.5**	**100**		**99.9**	**100**		**99.2**	**100**	**99.7**	**100**
Animal matter										
Diptera	0.3	20.0							0.1	9.1
Hemiptera	Tr	4.0		Tr	7.1		0.8	6.3	0.1	3.6
Coleoptera	0.1	24.0					Tr	6.3	Tr	10.9
Unidentified parts	Tr	8.0							Tr	3.6
Total animal matter	**0.4**	**40.0**		**Tr**	**7.1**		**0.8**	**6.3**	**Tr**	**21.8**

[a] early winter, late winter and spring diets combined. [b] denotes a between collection period difference ($P < 0.05$) in the aggregate % dry mass of that food item. [c] Tr < 0.05 g. All plant matter consist of seeds unless otherwise indicated

Composition and size of seeds consumed

The three seed species most commonly eaten by wintering white-faced whistling ducks contained crude protein, fat, phosphorus, and calcium levels between 7.00–12.69%, 0.82–1.60%, 0.18–0.39%, and 0.12–0.39%, respectively (Table 4). The three most commonly consumed species of seed are extremely small, with the number of seeds per gram between 389 and 1147 (Table 4).

Discussion

Dynamics of food use

The diets of white-faced whistling ducks wintering on the Yengweni Pan and the Pongolapoort Dam were similar in several respects: (1) they comprised > 99% plant matter; (2) small native seeds were the principal dietary items; (3) dietary diversity was low; (4) dietary composition was independent of sex; and (5) dietary composition was independent of age. However, birds on the Pongolapoort Dam primarily consumed the seeds of moist soil plant species, while Yengweni Pan birds ate aquatic species (Tables 1 and 2).

In winter, the stable water levels in most pans and warm climate in northern KwaZulu-Natal favour aquatic plant growth and seed production at a time when most other wetlands in South Africa are either too cold, or have too little water to encourage such growth (Rogers 1984). High seed production enables wintering white-faced whistling ducks to concentrate most of their foraging efforts on pans (Petrie & Petrie 1998); terrestrial seeds were consumed in small (1.8%) amounts. In contrast, the narrow littoral zone and abrupt changes in water level on the Pongolapoort Dam apparently reduces the availability of aquatic plants, forcing birds to forage elsewhere.

Few birds were observed foraging on the Pongolapoort Dam, and while their destination could not be determined, white-faced whistling ducks were observed making crepuscular flights from the dam, presumably to forage in more suitable or profitable habitats. Waterfowl may increase time\effort spent consuming terrestrial grains if aquatic foods are less readily available (Rave & Baldassarre 1989; Petrie & Rogers 1996). Therefore, low foraging effort and low aquatic seed consumption suggests that the Pongolapoort Dam, and possibly other large water-storage dams, provide limited foraging opportunities for waterfowl. However, whistling ducks, dabbling ducks and geese can compensate for inadequate aquatic food availability by foraging in terrestrial habitats, whereas diving ducks cannot. Therefore, whereas the provision of manmade aquatic habitats may be beneficial to whistling ducks, dabbling ducks and geese, the loss and conversion of natural wetlands has probably had a negative effect on diving ducks.

None of the birds collected in this study had consumed agricultural grains. Native terrestrial and aquatic seeds are presumably more readily available than agricultural grains as cereal grain cultivation is not extensive in northern KwaZulu-Natal. In contrast, the proliferation of intensive agriculture in the north-temperate regions of North America has reduced the

Table 3 Mean moult intensity scores (overall and flight feather) and aggregate percent dry mass of animal matter consumed by adult white-faced whistling ducks during early winter, late winter and spring on the Pongolapoort Dam and Yengweni Pan in northern KwaZulu-Natal, South Africa, 1995.

Time	*n*	Overall moult intensity score	Flight feather intensity score	Animal matter Agg%	Animal matter %Occ
Early winter	31	21.6	0.40	0.18	40.6
Late winter	32	23.5	0.04	Tr[a]	3.6
Spring	31	28.0	1.00	0.17	15.6

[a] < 0.05

availability of small native seeds while increasing the availability and predictability of large agricultural grains to waterfowl (Krapu & Swanson 1977; Quinlan & Baldassarre 1984; Alisauskas & Ankney 1992). The fat content of the three seeds most commonly consumed (Table 4) is below that of corn (2.82%) consumed by white-faced whistling ducks wintering in Northern Province, South Africa (Petrie 1998b) and *Panicum schinzii* (5.42%), a native terrestrial seed consumed by breeding birds on the Nyl River floodplain, South Africa (Petrie & Rogers 1996). Therefore, birds wintering in northern KwaZulu-Natal probably have to ingest large quantities of seeds to meet energetic, as well as future reproductive requirements.

Invertebrate consumption and molt intensity

Molt is an energy and protein costly event for waterfowl (Payne 1972; King 1981; Heitmeyer 1988) and white-faced whistling ducks replace flight as well as contour feathers while on wintering areas (Petrie 1998a). Since the increased protein demands of molt are primarily satisfied through the diet (Young & Boag 1982; Heitmeyer 1985), birds may select food items that are high in protein content or particular amino acids (Sedinger & Raveling 1984; Murphy & King 1987). Invertebrate consumption by white-faced whistling ducks was minor and independent of molt intensity (Tables 1, 2 and 3) and all of the seeds most commonly consumed had a protein content considerably below that reported for invertebrates (Sugden 1973; Driver, Sugden & Kovach 1974). The proportion of invertebrates in the diet was, however, slightly higher during early and late winter when white-faced whistling ducks replace wing-feathers. Dietary diversity was low, therefore, this may be a strategy to satisfy the requirement for a particular amino acid as the extremely low levels of invertebrates in the diet during early and late winter (Table 3) would have little influence on overall dietary protein content. Results support the hypothesis that white-faced whistling ducks are exceptionally efficient at assimilating protein (and particular amino acids) from plant matter (Petrie & Rogers 1996).

Research and management implications

White-faced whistling ducks and a few other species of waterfowl (e.g. Redbilled Teal *Anas erythrorhyncha*, Spur-winged Geese *Plectropterus gambensis*, Egyptian Geese, *Alopochen aegyptiacus*) have responded positively to the post-European settlement provision of municipal and agricultural water-storage dams and reservoirs in South Africa (c.f. Petrie & Rogers 1997, S.A. Petrie & T.D. Nudds, unpublished data). This can be attributed largely to the fact that these species are primarily herbivorous (Halse 1984, Halse 1985, Petrie 1996) and are morphologically capable of feeding terrestrially. Consequently, for some species, the anthropogenic provision of permanent waterbodies has probably partially offset the adverse affects of widespread wetland drainage in South Africa. However, this conversion of natural wetlands to permanent waterbodies is probably having an adverse affect on South Africa's three species of diving ducks. Diving ducks are incapable of foraging terrestrially, and the deep, rapidly fluctuating water levels typical of man-made waterbodies are not generally conducive to aquatic plant growth. Therefore, since water depth is a major determinant of wetland plant growth and distribution (Rogers, Ellery, Winternitz & Dohmeier 1989), and consequently, the availability of aquatic foods to wintering waterfowl, South African municipalities and farmers should be encouraged to construct and manage stock, irrigation and water storage dams and reservoirs in such a way as to encourage aquatic bird use.

The hydrological integrity of northern KwaZulu-Natal pans requires increased protection, as their characteristic large surface area to volume ratio and endorheic hydrological regime make them particularly susceptible to drainage and development. Important waterfowl wintering sites should also be protected from disturbance, as increased human and cattle populations in KwaZulu-Natal will continue to adversely affect submergent and emergent aquatic macrophytes.

The response of waterfowl to spatial and temporal changes in the availability of particular food items, the ecological fac-

Table 4 Composition and relative size of seeds commonly consumed by white-faced whistling ducks during winter and spring on the Pongolapoort Dam and the Yengweni Pan in northern KwaZulu-Natal; South Africa, 1995

Site and Species	Crude protein	Crude fibre	Fat	Ash	Phos-phorus	Calcium	# Seeds/g[a]
Pongolapoort Dam							
Scirpus sp.	7.8	17.5	1.5	3.5	0.18	0.34	2369
Yengweni Pan							
Nymphaea sp.	7.0	12.7	0.8	5.8	0.18	0.12	756
Polygonum lapathifolium	12.7	35.4	1.6	3.3	0.39	0.21	1147

[a]On a dry mass basis

tors that influence aquatic food availability (plant and animal), and the suitability of manmade waterbodies for satisfying the foraging requirements of flightless waterfowl all require further study.

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References

ALEXANDER, W.J.R. 1985. Hydrology of low latitude southern hemisphere land masses. *Hydrobiologia* 125:75–83.

ALISAUSKAS, R.T. & ANKNEY, C.D. 1992. The costs of egg laying and its relationship to nutrient reserves in waterfowl. In B.D.J. Batt, A.D. Afton, M.G. Anderson, C.D. Ankney, D.H. Johnson, J.A. Kadlec & G.L. Krapu (Eds), The ecology and management of breeding waterfowl. Minneapolis: University of Minnesota Press.

AUSTIN, J.E. & FREDRICKSON, L.H. 1986. Moult of female lesser scaup immediately following breeding. *Auk.* 103:293–298.

BEGG, G. 1986. The wetlands of Natal (Part 1.) Natal town and regional planning report Vol. 68. Natal town and regional planning commission. Pietermaritzburg, Natal, South Africa.

CLARK, A. 1974. The status of whistling ducks in South Africa. *Ostrich* 45:1–4.

CLARK, A. 1976. Observations on the breeding of whistling ducks in southern Africa. *Ostrich* 47:59–64.

COLAHAN, B.D. 1984. The ecology and conservation of waterfowl in Natal. M.Sc. Thesis, University of Pietermaritzburg, South Africa.

CONOVER, W.J. 1980. Practical nonparametric statistics, 2nd ed. New York: John Wiley & Sons.

DALLMEIER, F.G. & RYLANDER, M.K. 1982. Observations on the feeding ecology and bioenergetics of the white-faced whistling duck. *Wildfowl* 33:17–21.

DRIVER, E.A., SUGDEN, L.G. & KOVACH, R.J. 1974. Caloric, chemical and physical values of potential duck foods. *Freshwat. Biol.* 4:281–292.

HALSE, S.A. 1984. Diet, body condition, and gut size of Egyptian Geese. *J. Wildl. Manage.* 48:569–573.

HALSE, S.A. 1985. Diet and size of digestive organs of Spur-winged geese. *Wildfowl* 36:129–134.

HEITMEYER, M.E. 1985. Wintering strategies of female Mallards related to dynamics of lowland hardwood wetlands in the Upper Mississippi Delta. Ph.D. dissertation, Columbia. Univ. Missouri.

HEITMEYER, M.E. 1988. Protein costs of the prebasic molt of female Mallards. *Condor* 90:263–266.

HOHMAN, W.L., ANKNEY, C.D. & GORDON, D.H. 1992. Ecology and management of postbreeding waterfowl. In B.D.J. Batt, A.D. Afton, M.G. Anderson, C.D. Ankney, D.H. Johnson, J.A. Kadlec & G.L. Krapu (Eds). The ecology and management of breeding waterfowl. Minneapolis: University of Minnesota Press.

KING, J.R. 1981. Energetics of avian molt. *Proc. XVII Int. Orn. Congr.* 312–317.

KRAPU, G.L. & SWANSON, G.A. 1977. Foods of juvenile, brood hen, and post-breeding pintails in North Dakota. *Condor* 79:504–507.

MURPHY, M.E. & KING, J.R. 1987. Dietary discrimination by molting white-crowned sparrows given diets differing only in sulphur amino acid concentration. *Physiol. Zool.* 60:279–289.

PAYNE, R.B. 1972. Mechanisms and control of molt. In D.S. Farner & J.R. King (Eds), Avian biology, vol. 2 (pp. 104–157). New York: Academic Press.

PETRIE, S.A. 1996. Red-billed teal foods in semiarid South Africa: a north-temperate contrast. *J. Wildl. Manage.* 60:874–881.

PETRIE, S.A. 1998a. Molt patterns of nonbreeding white-faced whistling ducks in South Africa. *Auk.* 115: 774–780.

PETRIE, S.A. 1998b. Nutrient reserve dynamics, foraging strategies, molt patterns and movements of white-faced whistling ducks in South Africa. Dissertation. University of the Witwatersrand, Johannesburg, South Africa.

PETRIE, S.A. & ROGERS, K.H. 1996. Foods consumed by breeding white-faced whistling ducks on the Nyl River floodplain, South Africa. In M. Birkan, J. van Vessem, P. Havet, J. Madsen, B. Trolliet & M. Moser Gibier Faune Sauvage (Eds). Proceedings of the Anatidae 2000 conference, Strasbourg, France, 5–9 December 1994. *Game Wildl.* 13:755–771.

PETRIE, S.A. & ROGERS, K.H. 1997. Satellite tracking of white-faced whistling ducks in semiarid South Africa. *J. Wildl. Manage.* 61:1208–1213.

PETRIE, S.A. & PETRIE, V. 1998. Activity budget of white-faced whistling ducks during winter and spring in northern KwaZulu-Natal, South Africa. *J. Wildl. Manage.* 62:1119–1126.

QUINLAN, E.E. & BALDASSARRE, G.A. 1984. Activity budgets of nonbreeding Green-winged teal on playa lakes in Texas. *J. Wildl. Manage.* 48:838–845.

RAVE, D.P. & BALDASSARRE, G.A. 1989. Activity budget of green-winged teal wintering in coastal wetlands of Louisiana. *J. Wildl. Manage.* 53:752–759.

ROGERS, K.H. 1984. The role of *Potamogeton crispus* L. in the Pongolo River floodplain ecosystem. Ph.D. Dissertation. Univ. Natal, Pietermaritzburg.

ROGERS, K.W., ELLERY, W.N., WINTERNITZ, N.L. & DOHMEIER, R. 1989. Physical, chemical and biotic responses to decreasing water depth in a highveld pan following wet and dry summers. *Sth Afr. J. Aquat. Sci.* 15:67–90.

SEDINGER, J.S. & RAVELING, D.G. 1984. Dietery selectivity in relation to availability and quality of food for goslings of cackling geese. *Auk.* 101:295–306.

SUGDEN, L.G. 1973. Feeding ecology of pintail, gadwall, american wigeon and lesser scaup ducklings in southern Alberta. *Can. Wildl. Serv. Rep.* No.24.

SWANSON, G.A. & BARTONEK, J.C. 1970. Bias associated with food analysis in gizzards of blue-winged teal. *J. Wildl. Manage.* 34:738–746.

SWANSON, G.A., KRAPU, G.L., BARTONEK, J.C., SERIE, J.R. & JOHNSON, D.H. 1974. Advantages in mathematically weighting waterfowl food habits data. *J. Wildl. Manage.* 38:302–307.

WATKEYS, M.K., MASON, T.R. & GOODMAN, P.S. 1993. The role of geology in the development of Maputuland, *South Africa. J. of Afr. Earth Sci.* 16:205–221.

YOUNG, D.A. & BOAG, D.A. 1982. Changes in physical condition of male Mallards (*Anas platyrhynchos*) during moult. *Can. J. Zool.* 60:3220–3226.