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STUDIES OF WATERFOWL (ANATIDAE) IN NORTH QUEENSLAND. 6. FEEDING METHODS AND FOODS

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SUMMARY

The feeding habits of 14 species of waterfowl occurring in north Queensland during 1958-1963 are described.

The principal foods of all waterfowl were the seeds of accessible wetland plant species, which in turn were taken relative to availability.

Waterfowl species utilized different types of foods, particularly during dry seasons, and different areas of supply, particularly during wet seasons, with least seasonal variation in habits by the local breeding species. Because species congregated on the coastal plains during dry seasons, the coastal species generally had the greater ecological advantage in north Queensland.

In the periods between seasons, especially during severe drought and extreme flooding, food was scarce or inaccessible. Because of the relationship between waterfowl and food supply, populations then were liable to severe stress.

I. INTRODUCTION

There are few records of the feeding habits of waterfowl (Anatidae) in tropical Australia.

Qualitative studies were undertaken during 1958-1963, particularly at the adjacent Inland Study Area and Coastal Study Area (see Lavery 1966). All species present, as follows, were examined except the vagrant chestnut teal.

- Magpie goose (*Anseranas semipalmata* (Latham))
- Grass whistling-duck (*Dendrocygna eytoni* (Eyton))
- Water whistling-duck (*Dendrocygna arcuata australis* Reichenbach)
- Black swan (*Cygnus atratus* (Latham))
- Radjah shelduck (*Tadorna radjah rufitergum* Hartert)
- Black duck (*Anas superciliosa rogersi* Mathews)
- Grey teal (*Anas gibberifrons gracilis* Buller)
- Chestnut teal (*Anas castanea* (Eyton))
- Shoveler (*Anas rhynchos rhynchos* Latham)
- Pink-eared duck (*Malacorhynchus membranaceus* (Latham))
- Freckled duck (*Stictonetta naevosa* (Gould))
- White-eyed duck (*Aythya australis* (Eyton))
- Maned wood duck (*Chenonetta jubata* (Latham))
- Green pygmy goose (*Nettapus pulchellus* Gould)
- Australian pygmy goose (*Nettapus coromandelianus albipennis* Gould).

II. MATERIALS AND METHODS

Random collections by shooting were undertaken in late 1958 and thenceforth every month from January 1959 to December 1963 in both study areas. Additional material was obtained at most of the larger, more populated localities in the study areas and elsewhere from shooters' bags submitted for assessment of total harvest.

Crop and gizzard contents were removed in the laboratory. Gizzards containing a few hard seeds as well as inorganic matter, mostly of the same type in all species, were considered to be empty. The numbers of crops and gizzards examined are shown in Table 1.

TABLE 1

NUMBERS OF CROPS AND GIZZARDS OF WATERFOWL EXAMINED IN NORTH QUEENSLAND, 1958-1963

Species	No. of Crops		No. of Gizzards	
	With Food Content	Empty	With Food Content	Empty
Magpie goose .. .	40	11	56	1
Grass whistling-duck .. .	22	130	353	7
Water whistling-duck .. .	109	387	1,095	38
Black swan .. .	46	49	87	8
Radjah shelduck .. .	2	Nil	2	Nil
Black duck .. .	14	343	2,387	117
Grey teal .. .	90	191	338	71
Shoveler .. .	Nil	3	3	Nil
Pink-eared duck .. .	Nil	3	2	1
Freckled duck .. .	Nil	1	1	Nil
White-eyed duck .. .	89	68	226	16
Maned wood duck .. .	46	24	62	8
Green pygmy goose .. .	21	12	32	3
Australian pygmy goose .. .	65	48	95	18

The contents of a crop or gizzard were sorted and identified from reference collections; individual items were counted; and volumes of each food species were measured by displacement. Composition was determined by (a) volume of a food species relative to the total volume of all foods consumed by a waterfowl species, and (b) occurrence of a food species relative to the total number of birds of a species examined.

Checks revealed that crop and gizzard contents of a species were similar in types and proportions of food species in all except two Anatidae; the more comprehensive gizzard samples generally were used in calculations of diets. The types of foods eaten by magpie geese and maned wood ducks usually made recognition and measurement of gizzard contents difficult and the crops of these species were used. For comparison of the diet of some individuals of the latter species with the grass whistling-duck, however, it was possible to utilize gizzard contents. Individuals of either the magpie goose, grass whistling-duck or maned wood duck taken at one locality during one day were grouped as single sample units because of the species' gregarious habits. Congregations of other species usually represented roosting birds that had fed in small flocks over a wide area, and all individuals approximated to random distribution and were given equal status.

III. RESULTS

(a) Magpie Goose

Congregations, infrequently with other waterfowl species, inhabited coastal swamps and salt pans during the months of higher rainfall (December-April) and coastal lagoons and meadows thereafter. Feeding took place at these localities mainly at dawn and dusk and often throughout the night. Food was obtained mostly by digging and scooping, for which the bill is appropriately shaped, and by grazing and dabbling, after the manner described by Davies (1963).

The crop contents of 40 magpie geese collected at 20 localities in the Townsville Study Region are summarized in Table 2.

TABLE 2

CROP CONTENTS OF MAGPIE GEESE COLLECTED IN NORTH QUEENSLAND, 1958-1963

Food		Volume (%)	Frequency of Occurrence (%)
Plant material			
Nymphaeace	11.4	22
Pontederiaceae	9.4	16
Cyperaceae	62.3	72
Gramineae	11.8	34
Others	3.5	22
Total plant material	98.4	100
Total animal material	1.6	6
Number of crops		40
Number of samples		32

Tubers, with some seeds and stems, of bulkuru sedge (*Eleocharis dulcis* (Burm. f.) Trin.) provided the bulk of food eaten (60.3% by volume and in 66% of all crops) throughout a year. Other sedges, from which mostly seeds were eaten, occurred less commonly both in crop contents and in the habitat; species included *Eleocharis equisetina* Presl., *Cyperus pilosus* Vahl and coastal club rush (*Scirpus littoralis* Schrad.), the last from saltpans. The remainder of the foods came mostly from moist-land meadows (as examples, seeds of early spring grass (*Eriochloa* sp.), Australian rice (*Oryza australiensis* Domin), mud grass (*Pseudoraphis spinescens* (R.Br.) Vickery), awnless barnyard grass (*Echinochloa colonum* (L.) Link), Townsville stylo (*Stylosanthes humilis* H.B.K.) and other grasses (*Brachiaria* species)) and occasionally from lagoons (as examples, seeds of waterlilies (*Nymphaea* species) and stems of the submerged aquatic plant hydrilla (*Hydrilla verticillata* (L. f.) Royle)). These habitat types bordered the swamp sedge zone. Animal material was eaten at these habitat types and included, respectively, grasshoppers such as *Bermiella* sp. (Acrididae) and freshwater molluscs such as *Notopala essingtonensis* Frauenfeld (Viviparidae).

This diet, which is predominantly the tuber of the common freshwater sedge of coastal tropical Australia, is the same as that recorded for the species in the Northern Territory (see Frith and Davies 1961).

(b) Grass Whistling-duck

Inland birds fed in small flocks on the shallow waters, notably where these had been provided by impoundment. On the coastal plains, birds fed mostly as large flocks at localities surrounding the deeper-water roosting areas (see Figure 1). Feeding movements then were apparently erratic: as examples, a flock moved 17 miles to a feeding ground in July 1962 and 1 mile to feed in November of that year, with food much more abundant at the former time; some large feeding grounds were unused during some years; and large flocks were attracted to feed for prolonged periods near captive flocks held at otherwise unused feeding grounds. Some feeding occurred at the coastal roosting lagoons at dawn and dusk, with movements 3-4 hours after sunset to outlying meadows where grazing, in compact flocks, finished approximately 2 hours before sunrise. Food was obtained also by dabbling and picking on the surface of shallow waters.

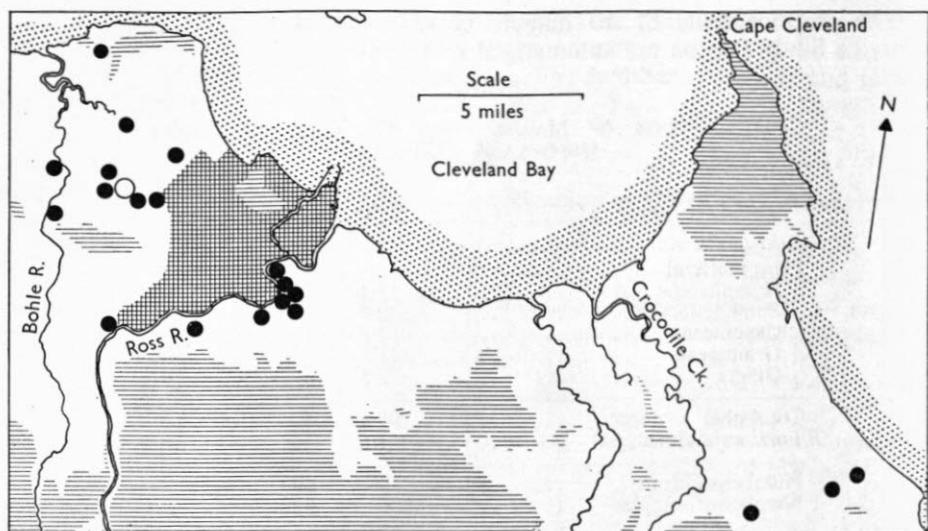


Fig. 1.—Main feeding grounds (●) of flocks of grass whistling-ducks roosting at Mt. St. John, Townsville, Q. (○), 1958-1963.

Gizzard contents of 351 birds collected at 28 localities in both study areas are summarized in Table 3.

TABLE 3

GIZZARD CONTENTS OF GRASS WHISTLING-DUCKS COLLECTED IN NORTH QUEENSLAND, 1958-1963

Food	Inland Study Area			Coastal Study Area	
	Volume (%)	Frequency of Occurrence (%)		Volume (%)	Frequency of Occurrence (%)
Plant material					
Leguminosae	2.0	29		5.7	54
Gentianaceae	15.9	64		1.3	32
Polygonaceae	Nil	Nil		1.8	12
Potamogetonaceae	6.9	29		0.1	4
Cyperaceae	50.9	93		14.1	59
Gramineae	18.6	86		68.4	93
Marsileaceae	0.1	7		1.4	30
Others	3.6	64		5.6	54
Animal material					
Crustacea	1.6	7		0.1	2
Insecta	0.2	7		1.2	9
Others	0.2	7		0.3	2
Total plant material	98.0	100		98.4	100
Total animal material	2.0	21		1.6	11
Numbers of gizzards		72			279
Numbers of samples		14			56

In the Inland Study Area the seeds of sedges, particularly *Fimbristylis* sp. (42.3% by volume), were consumed in greatest quantities. Awnless barnyard grass seeds (18.6% by volume) occurred most frequently (in 85.7% of gizzards). Other grasses and submerged aquatics (e.g. fennel pondweed (*Potamogeton pectinatus* L.)), emergent aquatics (e.g. water snowflake (*Nymphoides indicum* (L.) O.K.)) and herbs (e.g. budda pea (*Aeschynomene indica* L.)), common at adjacent habitat types, comprised most of the remainder of the foods. Some animal matter was consumed, mainly the larvae of aquatic hydrophilid beetles (*Berosus ?australisae* Muls.).

In the Coastal Study Area seeds of awnless barnyard grass (47.1% by volume in 83.9% of gizzards) predominated throughout the dry season over those of other grasses such as mud grass, Australian rice, ditch millet (*Paspalum orbiculare* Forst. f.), green summer grass (*Brachiaria miliiformis* (Presl) Chase), crowsfoot grass (*Eleusine indica* (L.) Gaertn.), summer grass (*Digitaria ciliaris* (Retz.) Koeler), coast button grass (*Dactyloctenium aegyptium* (L.) Beauv.), *Paspalidium flavidum* (Retz.) A. Camus, and *Panicum* sp. In months of higher rainfall grass whistling-ducks sometimes fed out on grasslands, eating seeds of Townsville stylo, budda pea and *Aeschynomene villosa* Poir., while in the dry season birds fed occasionally at shallow waters eating seeds of sedges (*Cyperus* species, *Eleocharis* species, *Scleria* species, *Fimbristylis* sp. and coastal club rush); these habitat types were adjacent to meadows.

Gizzards of 25 flightless young grass whistling-ducks collected throughout the Townsville Study Region contained foods similar to those of adults inhabiting coastal districts (Table 4).

TABLE 4
GIZZARD CONTENTS OF 25 FLIGHTLESS YOUNG GRASS WHISTLING-DUCKS COLLECTED IN NORTH QUEENSLAND, 1958-1963

Food		Volume (%)
Plant material		
Gentianaceae	5.4
Gramineae		
Awnless barnyard grass	..	69.5
Others	6.8
Others	16.7
Total plant material	98.4
Total animal material	1.6

Grass whistling-ducks were primarily grazing birds on those dry lands that supported plants of wetland origin, i.e. flood-prone lands. The principal food plant, awnless barnyard grass, was distributed chiefly in tropical and subtropical coastal regions.

(c) Water Whistling-duck

Birds occurred in coastal districts on grasslands and meadows during the wet season and on lagoons for the remainder of the year. Feeding took place on meadows and on lagoons, including the swamp edges of these, at dawn and dusk. Birds frequently fed throughout the night. The species dived to collect food in waters 2-7 ft deep, often feeding in compact flocks. At other times birds dabbled on the surface of the water and grazed by stripping seed-heads from vegetation emerging from the water.

Table 5 summarizes the gizzard contents of 1,087 water whistling-ducks collected from 34 localities in the four main districts of the Townsville Study Region.

TABLE 5

GIZZARD CONTENTS OF WATER WHISTLING-DUCKS COLLECTED IN NORTH QUEENSLAND, 1958-1963

Food (Percentage Volume)	Inland Study Area	Coastal Study Area		
	Charters Towers	Ingham	Townsville	Bowen
Plant material				
Nymphaeaceae	10·0	5·3	26·1	0·5
Leguminosae	24·1	1·1	2·9	<0·1
Gentianaceae	34·1	32·6	3·5	0·3
Boraginaceae	Nil	5·9	0·1	Nil
Polygonaceae	Nil	20·3	14·0	<0·1
Naiadaceae	Nil	8·0	0·4	2·1
Cyperaceae	23·4	15·0	17·4	84·3
Gramineae	8·1	Nil	26·2	0·6
Characeae	Nil	1·3	0·3	8·4
Others	0·3	10·5	7·0	3·2
Animal material				
Insecta	Nil	Nil	2·0	0·5
Others	Nil	Nil	<0·1	Nil
Total plant material	100·0	100·0	97·9	99·5
Total animal material	Nil	Nil	2·1	0·5
Numbers of gizzards	7	19	774	287

Within the main coastal distribution range there was a marked seasonal change in types of foods consumed, from the seeds of meadow grasses such as awnless barnyard grass, mud grass and para grass (*Brachiaria mutica* (Forsk.) Stapf) during the wet season to those of waterlilies in deep water immediately before and after the wet season, and of sedges, smartweeds (*Polygonum* species) and water snowflake in marginal shallow waters during the dry season, with a wide variety of plant seeds ingested towards the end of this drier period. Species within these seasonal groups of plants varied according to availability (see Table 5). The principal animal foods, of which only small quantities were eaten, were aquatic insects, particularly larvae of *Berosus* sp., dragonfly nymphs (spp. indet.) and *Plea brunni* Kirk. and *Micronecta* sp. (Hemiptera), taken from shallow waters bordering meadows during the wet season. The time of onset and extent of each part of the food cycle varied annually according to rainfall (Figure 2).

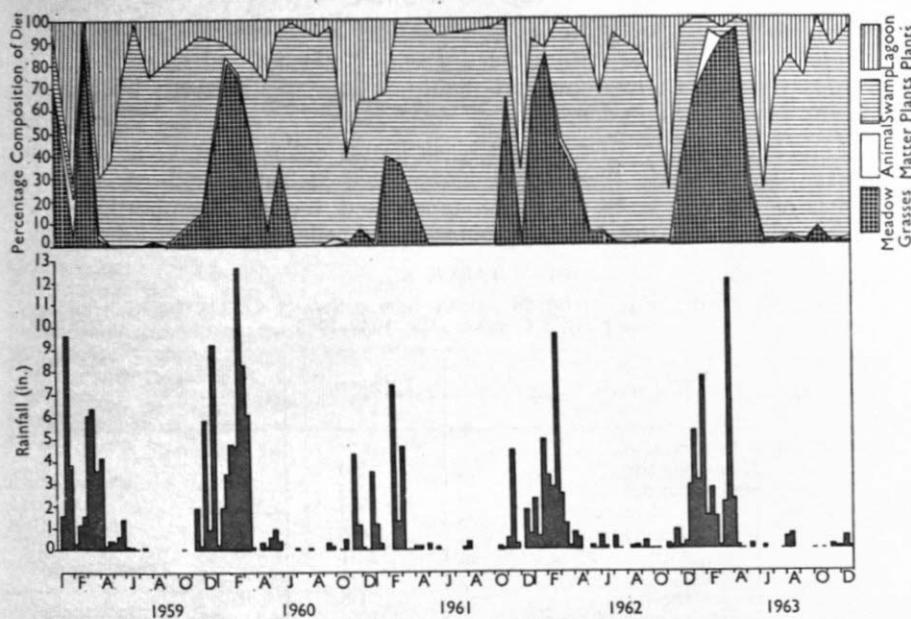


Fig. 2.—Mean monthly composition of the foods of water whistling-ducks collected in the Coastal Study Area of north Queensland, 1959–1963, showing annual and seasonal variations in diet in relation to rainfall at Garbutt.

The foods of young water whistling-ducks, present during and immediately following the wet season, were similar to those of adults under the same conditions (see also Lavery 1970a).

The two whistling-duck species fed mostly at different habitat types, by different methods and on different foods (see also Table 6).

TABLE 6

DIETS OF THE TWO WHISTLING-DUCK SPECIES COLLECTED AT OONOONBA LAGOON, COASTAL STUDY AREA, Q., JUNE 1, 1963

Food (Percentage Volume)	Grass Whistling-duck	Water Whistling-duck
Plant material		
Nymphaeaceae	0·6	72·8
Gentianaceae	0·3	10·5
Polygonaceae	6·2	1·1
Gramineae	83·7	1·2
Others	9·2	14·2
Total plant material	100·0	99·8
Total animal material	Nil	0·2
Numbers of gizzards	32	12

(d) Black Swan

Birds inhabited mainly the shallow saltpans and swamps early in each year and deep-water lakes later during the dry season. Large and small flocks fed at these types throughout the day and night. Food was gathered by probing in water usually over 12 in. in depth.

The gizzard contents of 58 adult black swans collected at 17 areas throughout the Townsville Study Region are summarized in Table 7. Birds were taken at all times of the year from all habitat types used, though disproportionately few birds were collected at the relatively inaccessible saline areas.

TABLE 7
GIZZARD CONTENTS OF 58 ADULT BLACK SWANS COLLECTED IN
NORTH QUEENSLAND, 1958-1963

Food		Volume (%)	Frequency of Occurrence (%)
Plant material			
Nymphaeace	2·0	3
Haloragaceae	1·5	2
Hydrocharitaceae	1·3	3
Potamogetonaceae	56·6	21
Cyperaceae	24·1	56
Gramineae	1·1	7
Characeae	1·6	7
Indet. submerged aquatics	10·6	21
Others	1·1	
Animal material			
Ostracoda	<0·1	2
Insecta	<0·1	5
Total plant material	99·9	100
Total animal material	0·1	6

Seeds, inflorescences and stems of submerged aquatics such as fennel pondweed (55·6% of total volume), floating pondweed (*Potamogeton javanicus* Hassk.) (1·0%), nitella (*Nitella* sp.) (1·5%), water milfoil (*Myriophyllum* sp.) (1·5%) and eelgrass (*Vallisneria* sp.) (1·3%) comprised the majority of foods. There was little detectable regional and seasonal variation in diet except during the months of highest rainfall, when quantities of the seeds of sedges, particularly coastal club rush, were eaten. At this time young birds, unable to probe to the deeply submerged vegetation, had a large intake of the floating seeds from these plants (Lavery 1970c).

Black swans largely fed on submerged aquatic plants otherwise accessible only to diving ducks; most birds fed on vegetated non-tidal saline areas uncommon under normal tropical conditions.

(e) Black Duck

This species inhabited the widest range of waterfowl habitat types, as both large and small flocks. Birds fed at all localities at all times of the day and night, with most activity at dawn and dusk. Food was gathered by dabbling for floating material, by dredging and 'tipping' for submerged matter, and by stripping seeds from emergent vegetation.

The gizzard contents of 2,373 birds collected regularly from 53 localities in the four main districts of the Townsville Study Region are summarized in Table 8.

TABLE 8

GIZZARD CONTENTS OF BLACK DUCKS COLLECTED IN NORTH QUEENSLAND, 1958-1963

Food (Percentage Volume)	Inland Study Area	Coastal Study Area		
	Charters Towers	Ingham	Townsville	Bowen
Plant material				
Nymphaeace ..	2.1	Nil	16.1	0.4
Leguminosae ..	2.7	5.3	5.5	0.5
Gentianaceae ..	8.0	0.2	40.0	0.4
Polygonaceae ..	24.1	52.8	21.8	0.1
Ceratophyllaceae ..	0.3	Nil	0.8	1.0
Potamogetonaceae ..	0.5	38.5	0.2	0.4
Ruppiaeae ..	Nil	Nil	<0.1	1.2
Cyperaceae ..	53.2	2.3	4.5	81.2
Gramineae ..	6.4	Nil	3.1	0.4
Characeae ..	Nil	Nil	0.5	8.0
Others ..	1.0	0.9	3.2	2.6
Animal material				
Mollusca ..	0.1	Nil	0.6	1.5
Arthropoda				
Insecta ..	Nil	Nil	2.2	2.2
Others ..	1.6	Nil	1.4	<0.1
Total plant material ..	98.3	100.0	95.8	96.2
Total animal material ..	1.7	Nil	4.2	3.8
Numbers of gizzards ..	26	7	960	1,379

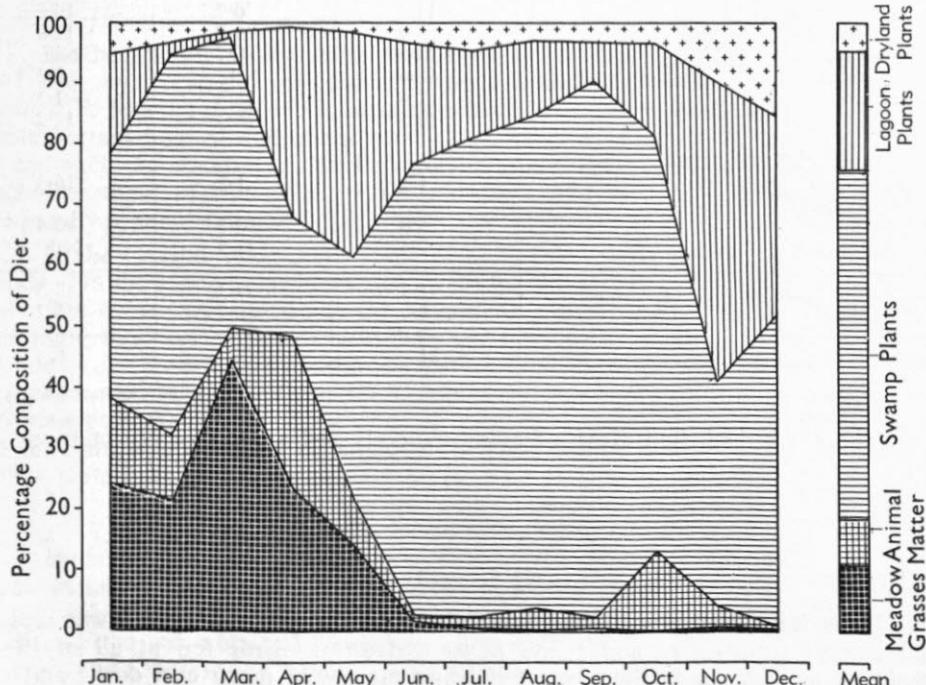


Fig. 3.—Mean monthly composition of the foods of black ducks collected in the Coastal Study Area of north Queensland, 1958-1963, showing seasonal variation in diet.

There were regional and seasonal changes in diet similar to those of the water whistling-duck. Meadow grass seeds were taken in the wet season, followed by animal matter and some deep-water plant material, then seeds of shallow-water swamp plants for most of the year until dryland and deep-water plant materials were consumed at the commencement of the next wet season (Figure 3). Although foods were the same as those of water whistling-ducks and other species, the plants and animals were from different sources: within a district, black ducks obtained foods from isolated localities not often inhabited by other waterfowl, and from the surface of these wetlands (see also Tables 5 and 8). As with other waterfowl, differences in food habits were minimized in the Bowen district because of the effect of an atypical abundance of coastal club rush provided on the 6,000 acre artificial impoundment at Caley Valley.

The foods of flightless young black ducks (Table 9), present during and immediately following wet seasons throughout the Townsville Study Region, were similar to those of adult black ducks but different from those of all ages of water whistling-ducks.

TABLE 9

GIZZARD CONTENTS OF FLIGHTLESS YOUNG BLACK DUCKS COLLECTED IN NORTH QUEENSLAND, 1958-1963

Food (Percentage Volume)	Estimated Age (weeks)		
	0-6	6-10	10-15
Plant material			
Nymphaceae	11.5	0.2	16.6
Gentianaceae	5.0	9.7	12.9
Polygonaceae	10.5	0.7	Nil
Cyperaceae	42.6	Nil	0.3
Gramineae	11.4	12.4	1.3
Others	10.5	14.3	12.2
Animal material			
Mollusca	1.1	1.2	16.3
Arthropoda			
Insecta	5.0	30.3	40.4
Arachnida	2.4	31.2	Nil
Total plant material	91.5	37.3	43.3
Total animal material	8.5	62.7	56.7
Numbers of gizzards	31	12	6

The black duck had diverse feeding methods and a wide variety of foods.

(f) Grey Teal

Birds inhabited a wide range of inland freshwaters during the wet season and coastal freshwaters and saline areas thereafter. Birds fed at all of these localities, activity on freshwater areas being mainly at dawn and dusk, and on saline areas mainly at times of low tide. Food was gathered by dabbling, by dredging and 'tipping', and by stripping emergent vegetation of seeds.

The gizzard contents of 307 birds collected at 39 localities in the two study areas are summarized in Table 10. As with black swans, disproportionately few birds were taken from the relatively inaccessible saline areas.

TABLE 10
GIZZARD CONTENTS OF GREY TEAL COLLECTED IN NORTH QUEENSLAND, 1958-1963

Food	Inland Study Area		Coastal Study Area	
	Volume (%)	Frequency of Occurrence (%)	Volume (%)	Frequency of Occurrence (%)
Plant material				
Nymphaeace ..	11.3	18	4.2	10.5
Leguminosae ..	1.1	10	3.4	15.1
Gentianaceae ..	4.8	47	23.1	29.5
Pontederiaceae ..	14.5	16	1.4	2.3
Cyperaceae ..	53.9	55	22.7	69.4
Gramineae ..	6.5	57	10.6	20.2
Others ..	4.8	22	16.1	55.8
Animal material				
Mollusca ..	0.8	4	12.2	11.2
Arthropoda				
Crustacea ..	0.5	8	0.5	1.6
Insecta ..	1.8	14	5.7	12.8
Pisces ..	Nil	Nil	0.1	0.4
Total plant material ..	96.9	98	81.5	96.5
Total animal material ..	3.1	18	18.5	20.5
Numbers of gizzards ..	49		258	

In the Inland Study Area the seeds of sedges, notably *Fimbristylis* sp. (47.8% by volume) and the recently established monochoria (*Monochoria cyanea* F. Muell.) (14.5%), were consumed in greatest quantities, the latter as an important item of diet of the young, e.g. 69.8% of the total volume of foods in six week-old ducklings from Pajingo, February 1962. Many other plant seeds, including those of waterlilies, water snowflake and meadow grasses, were eaten frequently in small amounts.

In the Coastal Study Area seeds of sedges were also the principal freshwater foods. On the saline areas bordering these, the sedge was coastal club rush. There was then a marked increase in the amount of marine animal material consumed, including molluscs such as *Odostomia* sp. (Pyramidellidae) (2.3% of the total volume of foods), *Pictoneritina oualanensis* Lesson (Neritidae) (1.5%), *Amphidesma angusta* (Reeve) (Amphidesmatidae) (0.5%) and *Modiolus* sp. (Mytilidae) (0.3%). This diet of marine organisms, greatest during times of drought, was the main difference between the food habits of grey teal and of other waterfowl in the Townsville Study Region.

(g) White-eyed Duck

Birds in both study areas inhabited mostly deep freshwater habitat types such as lakes, rivers and lagoons. The species fed mainly at these types and on some widespread shallow-water types such as swamps. Feeding was at dusk and dawn. Food was obtained by diving, although water frequently was too shallow for this and dabbling and 'tipping' was common.

The gizzard contents of 214 birds collected at 20 localities throughout the Townsville Study Region are summarized in Table 11.

TABLE II

GIZZARD CONTENTS OF 214 WHITE-EYED DUCKS COLLECTED IN
NORTH QUEENSLAND, 1958-1963

Food		Volume (%)	Frequency of Occurrence (%)
Plant material			
Nymphaeace	21.8	21.0
Leguminosae	2.1	18.7
Gentianaceae	4.5	22.9
Polygonaceae	25.5	33.2
Ceratophyllaceae	3.8	19.2
Lemnaceae	2.9	0.9
Naiadaceae	11.8	3.3
Cyperaceae	20.5	70.6
Characeae	2.3	5.6
Others	0.6	9.8
Animal material			
Mollusca			
Gastropoda	1.4	3.3
Lamellibranchiata	2.4	1.4
Arthropoda			
Crustacea	<0.1	1.4
Insecta	0.3	5.6
Total plant material	95.8	98.6
Total animal material	4.2	11.2

Seeds of waterlilies (21.8% by volume) and of smartweeds (mostly *Polygonum lapathifolium* L.) (25%) from adjacent vegetation zones provided the bulk of the diet. The remainder of the plant food was deep-water material such as of bushy pondweed (*Najas graminea* Del.) (11.8%), hornwort (*Ceratophyllum demersum* L.) (3.8%) and *Chara* sp. (2.3%). Molluscs (3.8% by volume) were the principal source of animal food; these were mainly the bivalves *Corbiculina* sp. (Corbiculinidae) and *Velesunio wilsonii* (Lea) (Mutelidae) and the gastropods *Gabbia affinis* Smith (Bithyniidae) and *Plotiopsis subornata* Iredale (Thiaridae), obtained by diving in deep freshwaters.

The gizzards of four flightless young white-eyed ducks contained noteworthy quantities (23.8% by volume) of a brachiopod crustacean (*Estheria* sp.).

The majority of white-eyed ducks collected during the study period were from the Coastal Study Area; those few from the Inland Study Area contained mostly seeds of *Polygonum lapathifolium* (74.5% by volume).

White-eyed ducks fed similarly to, and on much the same foods as, water whistling-ducks; the diet differed from those of southern Australian populations of white-eyed ducks (see, for example, Frith, Braithwaite and McKean 1969) in having much less animal matter and a wider range of plant material, consistent with the greater variation in deep-water habitat under tropical conditions.

(h) Maned Wood Duck

Birds occurred as small flocks on habitat types similar to those used by grass whistling-ducks. Feeding also was by grazing on relatively dry areas. Feeding occurred throughout the day and night, with greatest activity at dawn and dusk.

Table 12 summarizes the crop contents of 46 birds collected from 18 localities throughout the Townsville Study Region.

TABLE 12

CROP CONTENTS OF MANED WOOD DUCKS COLLECTED IN NORTH QUEENSLAND, 1958-1963

Food	Inland Study Area		Coastal Study Area	
	Volume (%)	Frequency of Occurrence (%)	Volume (%)	Frequency of Occurrence (%)
Plant material				
Leguminosae ..	0·1	14	0·4	6
Pontederiaceae ..	Nil	Nil	0·5	12
Gramineae ..	77·9	86	39·1	88
Marsileaceae ..	Nil	Nil	1·2	6
Indet. ..	21·9	57	58·4	50
Total plant material ..	99·9	100	99·6	100
Total animal material ..	0·1	14	0·4	6
Numbers of crops ..		17		29
Numbers of samples ..		7		16

Grasses formed the greatest part of the almost vegetarian diet (Table 12), with much leaf and stem material as well as seeds from awnless barnyard grass (seeds 20·6% by volume, leaves and stems 15·6%), para grass (18·8% by volume), and minor quantities of ditch millet, summer grass, mud grass and Townsville stylo. Plants from permanent wetlands comprised 0·9% of the volume of the foods. Animal material was mainly terrestrial beetles (Coleoptera) and bugs (Hemiptera).

The diet of five downy-flapper ducklings collected in the Inland Study Area in March 1962 consisted of 84·2% by volume of awnless barnyard grass seeds, present in all birds.

The foods of maned wood ducks closely resembled those of the grass whistling-duck at all ages except for adults inhabiting the same inland localities during breeding; the grass whistling-ducks involved altered food habits markedly (Table 13).

TABLE 13

DIETS OF ADULT MANED WOOD DUCKS AND GRASS WHISTLING-DUCKS COLLECTED AT LAKE POWLATHANGA, INLAND STUDY AREA, Q., MARCH-MAY, 1963

Food (Percentage Volume)	Maned Wood Duck	Grass Whistling-duck
Plant material		
Gentianaceae ..	0·5	42·3
Cyperaceae ..	0·5	37·8
Gramineae ..	97·9	7·8
Others ..	0·5	7·4
Animal material		
Arthropoda		
Crustacea ..	Nil	4·7
Insecta ..	0·6	Nil
Total plant material ..	99·4	95·3
Total animal material ..	0·6	4·7
Numbers of gizzards ..	25	11

(i) Green Pygmy Goose

Birds were found mainly on swamps during the wet season and on lagoons for the remainder of each year. Feeding was mostly at these localities throughout the day and night, with increased activity at dawn and dusk. Food was obtained on the surface of the water by dabbling, picking and stripping seeds, inflorescences and stems from submerged and emerging aquatic plants.

Foods of birds collected throughout the Townsville Study Region consisted mainly of seeds and some other plant material (Table 14). Waterlilies provided the commonest seeds taken (29.9% by volume), with hydrilla as the commonest leaf and other matter (22.7%). Parts of floating pondweed (11.2%), *Chara* sp. (10.3%), awnless barnyard grass (9.1%) and water snowflake (5.9%) were gathered from marginal habitat types. Animal foods comprised mainly insects, including the waterlily aphid (*Rhopalosiphum nymphaea* (L.)).

TABLE 14

GIZZARD CONTENTS OF 32 GREEN PYGMY GEESE COLLECTED IN
NORTH QUEENSLAND, 1958-1963

Food		Volume (%)	Frequency of Occurrence (%)
Plant material			
Nymphaeace	29.9	28
Gentianaceae	5.9	41
Hydrocharitaceae	22.7	6
Naiadaceae	1.9	3
Potamogetonaceae	11.2	25
Gramineae	12.1	16
Characeae	10.3	13
Others	2.2	34
Animal material			
Insecta	3.7	13
Arachnida	0.1	3
Total plant material	96.2	100
Total animal material	3.8	16

Few sedges and grasses were eaten compared with most other waterfowl in the region.

(j) Australian Pygmy Goose

Birds occurred at the same habitat types as green pygmy geese. Feeding took place throughout the day and night. Food was gathered by dabbling and picking at the surface of the water; birds did not walk to potential food sources.

The gizzard contents of 89 Australian pygmy geese from 23 localities throughout the Townsville Study Region are summarized in Table 15.

TABLE 15

GIZZARD CONTENTS OF 89 AUSTRALIAN PYGMY GEESE COLLECTED
IN NORTH QUEENSLAND, 1958-1963

Food				Volume (%)	Frequency of Occurrence (%)
Plant material					
Nymphaceae	1·4	7
Gentianaceae	1·7	14
Polygonaceae	1·0	7
Ceratophyllaceae	6·2	17
Hydrocharitaceae	19·4	24
Pontederiaceae	0·1	3
Lemnaceae	0·5	9
Naiadaceae	1·4	3
Potamogetonaceae	53·9	37
Cyperaceae	0·9	7
Gramineae	11·8	10
Others	>0·3	8
Animal material					
Insecta					
Coleoptera	1·4	7
Hemiptera	>0·1	1
Others	>0·1	4
Total plant material	98·5	100
Total animal material	1·5	11

In both study areas hydrilla as leaf and other plant parts, and seeds of floating pondweed, were the commonest items consumed (27·6% and 27·7% by volume respectively). Seeds of waterlilies (5·2%), and submerged aquatics such as hornwort (3·1%), were taken from the same habitat, while seeds of bulkuru sedge (12·1%) and awnless barnyard grass (8·8%) were gathered from adjacent habitat types. Animal matter consisted of weevils (*Curculionidae* sp. indet.) (3·7% by volume) and other insects.

Australian pygmy geese fed primarily in a similar surface-picking manner and on the same deep-water types of foods as green pygmy geese; both utilized a food source only partly used by other waterfowl in the area.

(k) Other Species

Radjah shelduck.—The two birds collected were feeding by dabbling amongst other waterfowl on a swamp in the Coastal Study Area in April 1961. Gizzards contained seeds of awnless barnyard grass (52% by volume) and bulkuru sedge (37%); seeds of water snowflake, coastal club rush, para grass and *Sida* sp. comprised the remainder.

Shoveler.—Three birds also collected in the Coastal Study Area at different times had eaten mainly the seeds of fennel pondweed (41%) and sedges (26%); the animal material was a planorbid mollusc (*Pygmanisus* sp.) (7%).

Pink-eared duck.—Two birds from amongst other dabblers in the Coastal Study Area contained 78% by volume of sedge seeds in gizzards. No animal matter was present.

Freckled duck.—The one gizzard examined, from the Inland Study Area, contained 84% by volume of *Cyperus pilosus*; no algae could be detected.

All these species in north Queensland ate foods taken commonly by other waterfowl; diets differed considerably from those elsewhere in Australia (see, for example, Frith 1959).

IV. DISCUSSION

Waterfowl taken in the Townsville Study Region, and elsewhere in north Queensland, derived all foods from wetland habitat. Except for young birds during an early stage of growth (see, for example, Table 9) and for several species during dry seasons (notably the grey teal), waterfowl were principally vegetarian, mostly eating seeds from freshwater plants.

Of 40 spermatophyte families with species occurring in freshwater areas of north Queensland, 29 as follows provided foods: Nymphaeaceae, Caryophyllaceae, Malvaceae, Leguminosae, Haloragaceae, Onagraceae, Cucurbitaceae, Aizoaceae, Gentianaceae, Boraginaceae, Convolvulaceae, Lentibulariaceae, Labiateae, Amaranthaceae, Chenopodiaceae, Polygonaceae, Euphorbiaceae, Ceratophyllaceae, Hydrocharitaceae, Pontederiaceae, Juncaceae, Palmae, Typhaceae, Lemnaceae, Najadaceae, Potamogetonaceae, Restionaceae, Cyperaceae, Gramineae. The remainder were either trees and shrubs with seeding parts inaccessible to feeding waterfowl (Rutaceae, Rhizophoraceae, Myrtaceae, Myrsinaceae, Pandanaceae) or were seldom encountered during field collecting by the author and thus considered relatively uncommon (Cruciferae, Droseraceae, Umbelliferae, Acanthaceae, Liliaceae, Eriocaulaceae).

At one locality—Mt. St. John and adjoining habitat near Townsville—21 of 24 of all plant families present provided waterfowl food. The common species not utilized as foods, i.e. water hyacinth (*Eichhornia crassipes* (Mart.) Solms) and salvinia (*Salvinia auriculata* Aubl.), were comparatively recent introductions to Australia. The relative frequency of the food sources at Mt. St. John, measured at the end of the study period, was: deep-water plants, 39% of vegetated area; shallow-water plants, sedges 20%, grasses 12%, others 29% (Lavery and Blackman 1971). Mean incidences of these as foods in the four local species feeding there (magpie goose, water whistling-duck, black duck, Australian pygmy goose) were respectively 38%, 21%, 13% and 27% (from Tables 2, 5, 8 and 15).

The plant species most widely used as food was bulkuru sedge; all parts of the plant were eaten, including the large tubers of high energy value (78.5% carbohydrates (63.2% starch), 0.5% fat, 5.1% fibre, as well as 5.8% protein). The magpie goose ate mostly this plant (Table 2) and was the most specialized feeder.

Seeding of food plants occurred mainly in winter. Of nine major food species (blue waterlily (*Nymphaea* sp.), water primrose, water snowflake, *Polygonum lapathifolium*, monochoria, bulkuru sedge, coastal club rush, awnless barnyard grass, para grass), numbers seeding each month were: Jan. 2; Feb. 3; Mar. 4; Apr. 8; May 9; June 9; July 9; Aug. 9; Sept. 7; Oct. 7; Nov. 2; Dec. 2. Waterfowl were congregated at single localities mostly in the winter (Lavery 1970b), and, with the occasional exception of the brolga (*Grus rubicundus* (Perry)), always outnumbered all other birds at the feeding habitat, e.g. of 7,400 water-birds of 29 species at Mt. St. John on July 3, 1959, some 6,500 (9 species) were Anatidae.

Although foods of all waterfowl were from the same environment, and although captive birds thrived on a wide variety of food types, species in the wild nevertheless utilized markedly different sources of the total supply. During periods of low rainfall, when birds were chiefly in the coastal regions, foods differed according to groups of waterfowl (Table 16). One species within each of these groups was always more numerous as large flocks at major localities and a second species usually was next most common as numerous widespread flocks at small isolated localities, while the other species were noticeably less common and clearly living out of their more suitable environment. During periods of high rainfall when habitat was widespread and diets of the birds were similar (Table 17), species within these groups were distributed differently, i.e. into breeding ranges (Table 18). Where species of a group occasionally occurred together, during either wet or dry season, the diet of the species breeding in that area was normal and that of the non-resident species abnormal (see, as examples, Tables 3, 12 and 13).

TABLE 16

MAJOR DRY-SEASON FOOD SOURCES OF WATERFOWL SPECIES COMMONLY IN NORTH QUEENSLAND STUDY AREAS, 1958-1963

Species	No. of Gizzards Examined	Food Sources		
		Plant Family	Volume (%)	Frequency of Occurrence (%)
Magpie goose .. .	40	Cyperaceae (tubers) ..	62.3	72
Grass whistling-duck .. .	279	Gramineae	68.4	93
Water whistling-duck .. .	19	Gentianaceae	32.6	74
		Polygonaceae	20.3	42
		Cyperaceae (including saline species) (seeds)	29.3	61
Black duck	2,346	Polygonaceae	24.6	33
		Gentianaceae	23.1	29
Grey teal	258	Cyperaceae (including saline species) (seeds)	22.7	69
		Animal material	18.5	20
White-eyed duck .. .	214	Polygonaceae	25.5	33
Maned wood duck .. .	46	Nymphaceae	21.8	21
Green pygmy goose .. .	32	Gramineae	60.7	88
Australian pygmy goose .. .	77	Nymphaceae	29.9	28
		Potamogetonaceae	11.2	25
		Potamogetonaceae	53.9	43

TABLE 17

MAJOR WET-SEASON FOOD SOURCES OF WATERFOWL SPECIES COMMONLY IN NORTH QUEENSLAND STUDY AREAS, 1958-1963

Species	No. of Gizzards Examined	Food Sources		
		Plant Family	Volume (%)	Frequency of Occurrence (%)
Magpie goose .. .	40	Cyperaceae	62.3	72
Grass whistling-duck .. .	72	Cyperaceae	50.9	93
Water whistling-duck .. .	774	Gramineae	26.2	47
		Cyperaceae	17.4	54
Black duck	26	Cyperaceae	81.2	81
Grey teal	49	Cyperaceae	53.9	55
		Hydrocharitaceae	37.0	8
Australian pygmy goose .. .	12	Cyperaceae	24.1	25

TABLE 18

BREEDING DISTRIBUTIONS OF WATERFOWL SPECIES IN NORTH QUEENSLAND RELATIVE TO DRY-SEASON HABITAT TYPES

Dry-season Food Habitat Type	Species	Main Breeding Distribution Range
Grassland/meadow . . .	Grass whistling-duck . .	Coastal
	Maned wood duck . .	Inland
	Black duck . . .	Widespread
Lake/river/lagoon—sub-surface —surface . .	Water whistling-duck . .	Coastal
	White-eyed duck . .	Inland
	Australian pygmy goose . .	Coastal
	Green pygmy goose . .	Coastal
	Pink-eared duck . .	Inland
	Black duck . . .	Widespread
Tidal flat	Radjah shelduck . .	Coastal
	Grey teal . .	Inland
	Black duck . . .	Widespread
Swamp—sub-surface (only coastal)	Magpie goose . .	Coastal
Saltpan—sub-surface . . .	Black swan . . .	Coastal and Inland (mostly artificial impoundments)

There was one exception to the general pattern: the green pygmy goose and Australian pygmy goose were in turn distributed differently within the coastal region, the former occurring principally in the Gulf of Carpentaria river drainage system and westwards from there and the latter in north-eastern Queensland (see also North 1913; Jones 1946). A similar distribution prevails for the magpie goose and brolga respectively, the latter also feeding predominantly on bulkuru sedge tubers (Lavery and Blackman 1969). Some changes in the general pattern also appeared to be in progress: the radjah shelduck was uncommon at some isolated localities, particularly in north-eastern coastal regions, and extrazonal grey teal and black swans, using similar saline habitat during dry seasons, were relatively abundant. Habitat from water conservation projects concurrently extended the breeding ranges of these two species.

The comprehensive utilization of available food resources, the marked and consistent diversification of habits by species using these, and the clear relationship between these habits and others such as movements and reproduction (see Lavery 1970b, 1970c) indicate that food supply had a fundamental action on all waterfowl populations. Availability of food varies throughout a year: wetland plants seed least during drought at the end of many dry seasons and, while growth and seeding are accelerated during each wet season, flooding makes foods inaccessible. Accordingly, population sizes of resident waterfowl will be most adversely affected during these times.

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