WATERFOWL IN AN INLAND SWAMP IN NEW SOUTH WALES

II. FOOD

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Summary

The food of nine species of waterfowl has been studied in a drought refuge during a period of moderately severe drought. The species involved were the black swan, freckled duck, black duck, grey teal, shoveler, pink-eared duck, hardhead, musk duck, and blue-billed duck. In all, 3697 gizzards were examined.

Although the black swan had certain food plants in common with most other species, particularly during periods of drought, and although the black duck and grey teal had nearly identical food requirements, serious competition between these species was considered unlikely for various reasons. Otherwise, the species were well separated in their feeding places, depths of water utilized, and food collected.

The value of cumbungi swamps as drought refuges is discussed and the adaptations of the waterfowl in utilizing these swamps are examined.

I. INTRODUCTION

A previous study (Frith 1959*b*) also reported on the food of waterfowl in inland New South Wales. In that work the eastern Riverina region was examined and the food of the waterfowl was surveyed over a wide area, particular attention being paid to the lagoons, billabongs, and floodwaters associated with the rivers. In this paper more detailed attention is paid to a cumbungi swamp in the same region.

Cumbungi swamps are the most permanent waterfowl habitat in inland New South Wales. They support populations of musk ducks (*Biziura lobata*), blue-billed ducks (*Oxyura australis*), and black ducks (*Anas superciliosa*), and are visited by black swans (*Cygnus atratus*), freckled ducks (*Stictonetta naevosa*), hardheads (*Aythya australis*), pink-eared ducks (*Malacorhynchus membranaceus*), shovelers (*Anas rhynchotis*), grey teal (*A. gibberifrons*), and wood ducks (*Chenonetta jubata*). During drought, very large numbers of these species survive in cumbungi swamps for long periods. They have been shown to be the most important inland refuges of waterfowl (Frith 1959*c*). In the interests of waterfowl conservation it is important to understand the food niches in the swamp for the different species.

II. METHODS

The study was based on the examination of the gizzard contents of shot samples. The birds were collected by the authors and assistants from the shore shallows during the night and from boats during the day.

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The study extended from September 1962 to April 1967, and throughout this period samples of musk ducks and blue-billed ducks were taken at monthly intervals. Black swans were collected from May 1963 and hardheads from December 1964 to the termination of the study. Each sample consisted of about 20 birds. The other species were collected as opportunity offered during the sampling for the above species, but between April 1966 and April 1967 special efforts were made to ensure that samples of all species in the swamp were secured each month. The regularity and the size of the samples can be taken as an indirect measure of the abundance of the different species in the swamp at the time.

The total numbers of gizzards for each species available for analysis are listed below.

Black swan, *Cygnus atratus* (Latham)	953
Freckled duck, *Stictonetta naevosa* (Gould)	119
Black duck, *Anas superciliosa* (Gmelin)	283
Grey teal, *A. gibberifrons* (Müller)	315
Shoveler, *A. rhynchotis* (Latham)	161
Pink-eared duck, *Malacorhynchus membranaceus* (Latham)	95
Hardhead, *Aythya australis* (Eyton)	303
Blue-billed duck, *Oxyura australis* Gould	593
Musk duck, *Biziura lobata* (Shaw)	875

The gizzards were removed in the field and their contents preserved in 50% alcohol. The difficulties in assessing the contents of gizzards are well known; the principal troubles are that systems based on the volume of different food items tend to overestimate the importance of items retained in the gizzard for relatively long periods, e.g. the chitinous parts of insects remain longer than the soft-bodied larvae and so are more readily found and given undue importance. There are also practical difficulties in assessing the volumes of different kinds of food. On the other hand, methods based on the frequency with which food items appear in different gizzards tend to exaggerate the importance of items eaten in very small quantities by many birds, relative to food items eaten perhaps in large quantities by smaller proportions of the sample (Hartley 1948).

In this study both methods were used. Frequency of occurrence refers to the percentage of gizzards in which at least one example of the food item occurred. Volume percentage refers to the approximate percentage of the different food items on a volumetric basis. Previous work has convinced the senior author that attempts at precision in the measurement of the volume of small quantities of food items of very different compacting properties are misleading and of doubtful value. In this study food items were identified to species and the relative volumes only were estimated. The contents of each gizzard were mixed and then finely spread under a variable (7 to 30 power) stereomicroscope and a visual estimate was made of the relative importance of the different items in the whole.

III. Black Swan

(*a*) *Material*

Swans were abundant throughout the whole period. The first sample was collected in May 1963 and the last in April 1967. A sample of 18 or more birds was collected in almost every month. In all, 906 gizzards of adult birds were available.

(*b*) *Composition of Food*

The average composition of the food by volume in the five-year period is shown in Table 1. The food was almost entirely plant material; 9·7% of the birds included some animal material in their diet but this amounted to only 0·1% of the volume. The few small insect larvae and occasional molluscs were probably collected accidentally as the birds grazed the plants on which they lived.

The plants eaten were collected from the land and all parts of the swamp, but the deep-water flora was the most frequently used; it was found in 62·8% of the birds and comprised 52·3% of the total food. The commonest plants eaten were the algae Chlorophyceae, mainly *Spirogyra*, which were found in 34·9% of the birds and comprised 22·6% of the total volume of food; *Chara* accounted for a further 2·1% of the food. The algae were eaten in considerable quantities each month throughout the study and in some months accounted for as much as 70% of the food found in all the birds.

The cumbungi itself, *Typha* sp., was eaten in large quantities. The young shoots growing from the base of the clump were eaten as well as the leaf bases, roots, and rhizomes. In all, cumbungi accounted for 19·7% of the food and was found in 34·1% of the birds. The sedges, mainly *Scirpus validus*, were not important and contributed only 1·5% of the food.

Whenever the floating plants waterfern (*Azolla*) and duckweed (*Lemna*) were abundant, they were eaten. *Azolla* was a major source of food, particularly every autumn and winter, and overall was found in 30·3% of the birds and made up 4·9% of the diet. In some months, however, it was in 80% of the birds collected and made up as much as 20% of the food in the sample. Other deep-water plants of great importance were the pondweeds Potamogetonaceae, *Potamogeton crispus*, *P. ochreatus*, and *P. pectinatus*, the leaves of which were found in 16·4% of the birds and made up 15·9% of the volume of food. The prickly pondweed (*Najas marina*) and pondweed (*Ruppia*) contributed 4·2% and 3·2% of the volume, having been eaten by 7% and 53% of the birds respectively. Ribbonweed (*Vallisneria gigantea*) contributed 3·8% of the food and was eaten by 15·1% of the birds.

The swans frequently left the swamp to feed in flooded pastures and on the edges of Mirrool Creek. This is reflected in the 7·1% of Gramineae and 2·5% of Leguminosae in the food as well as the significant proportion of "other" plants in Table 1, which include bindweed (*Convolvulus erubescens*), thistle (*Cirsium vulgare*), fat-hen (*Chenopodium pumilio*, *C. nitrariaceum*), peppercress (*Lepidium hyssopifolium*), creeping saltbush (*Atriplex semibaccata*), and Hexham-scent (*Melilotus indica*). The grasses accounted for 7·1% of the food. The commonest were summer grass (*Hordeum marinum* and *H. leporinum*), found in 7·9%, and water couch (*Paspalum*

TABLE 1

FOOD FOUND IN GIZZARDS OF 906 BLACK SWANS COLLECTED AT BARRENBOX SWAMP FROM MAY 1963 TO APRIL 1967

Data expressed as percentage of total volume of gizzard contents for each month

Food	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Mean
Plants													
Chlorophyceae	22·9	6·5	30·7	28·8	12·9	10·9	30·7	24·9	33·6	36·5	11·4	21·6	22·6
Characeae	0	0	1·7	0	0	0	1·4	2·6	2·2	7·5	9·4	0·8	2·1
Azollaceae	1·2	3·6	4·6	10·2	13·4	6·6	4·9	3·9	4·1	3·5	1·8	0·4	4·9
Typhaceae	23·4	39·7	18·0	21·5	23·0	24·5	21·7	16·0	21·0	9·0	11·9	6·5	19·7
Potamogetonaceae	34·3	19·6	13·9	5·9	8·7	6·6	6·6	3·4	9·3	11·1	35·1	37·0	15·9
Najadaceae	4·6	0	10·3	6·1	3·5	14·6	5·4	0	0	0	0	0	3·7
Hydrocharitaceae	10·9	24·8	8·1	10·2	9·8	7·4	23·6	8·6	0	9·2	8·9	13·9	11·3
Gramineae	2·4	0	0·1	2·9	13·2	10·5	0·5	17·1	9·0	10·6	13·6	5·7	7·1
Cyperaceae	0	0	9·9	4·8	0·8	0	0	2·6	0	0	0	0	1·5
Ranunculaceae	0·3	0	0	0	0	0	0	0	8·6	7·1	3·1	0	1·6
Leguminosae	0	0	0	3·2	4·1	8·7	1·9	11·0	0	0·9	0	0	2·5
Haloragaceae	0	1·1	0·9	0·4	5·0	5·4	3·3	2·6	7·7	2·9	3·7	12·1	3·8
Other plants	0	4·7	1·8	5·3	5·5	4·8	0	7·3	4·4	1·7	1·1	2·0	3·2*
Animals													
Insecta	0	0	0	0·7	0·1	0	0	0	0·1	0	0	0	0·1
Total plant food	100·0	100·0	100·0	99·3	99·9	100·0	100·0	100·0	99·9	100·0	100·0	100·0	99·9
Total animal food	0	0	0	0·7	0·1	0	0	0	0·1	0	0	0	0·1
Number of birds	51	37	101	92	99	88	58	88	73	95	65	59	906

* Includes Lemnaceae 0·8%, Juncaceae 0·8%, Polygonaceae 0·9%, Convolvulaceae 0·8%.

distichum), found in 5·7% of the birds. The medics included *Medicago polymorpha*, subterranean clover (*Trifolium subterraneum*), and white clover (*T. repens*), which were found in 10·4% of the birds but only accounted for 2·5% of the total food; all these are cultivated plants or weeds of cultivation.

From time to time swans were collected with appreciable amounts of food in the oesophagus. In all, 81 such birds were available and the food was analysed in order to compare its composition with the more macerated material found in the gizzards. The commonest food was algae, found in 33·3% of the birds (23·6% of the volume). *Typha* was in 28·4% (17·6% volume), *Vallisneria* in 16% (9·7% volume), *Potamogeton* in 18·5% (14·4% volume), *Azolla* in 31·3% (5·8% volume), and *Chara* in 11·1% (5·7% volume). The remainder of the plant food was of similar composition to that in the gizzards. Invertebrates were found in 18·5% of the samples and made up 0·1% of the total volume. It will be seen from this brief summary that the gizzard contents reasonably accurately represented the food taken into the oesophagus.

(*c*) *Seasonal Variation*

The composition of the food varied from year to year and from month to month, according to the water level of the swamp and thus to the rate of discharge of irrigation water, the diversion of drainage water away from the swamp at the weir, and the effects of rainfall. Rain had several effects: it caused local ponding in pasture bays, making pasture plants available to the swans; it might cause sudden changes in water level in the swamp, the reticulation of drains in the irrigation area providing a very large catchment; and it might lead to the release of large quantities of water temporarily not needed for irrigation, resulting in local flooding.

The magnitude of the annual differences in the diet is shown in Table 2. For convenience the years begin in May; in this way all the data can be included.

It can be seen that there were significant annual differences in the overall composition of the food. In 1963/64 the land plants were particularly important, and 41·1% of the birds fed on them and derived 27·8% of their total food from them; in the other years the percentage occurrence ranged from 7·1 to 15·3% and the percentage volume from 3·8 to 8·3%. In 1963/64 on the other hand, the deep-water plants were relatively unimportant, although nearly half the birds (44·8%) fed on them and they made up 29·7% of the food. In the other years, their percentage volume varied from 51·0 to 55·1% and 63·8 to 73·3% of the sample fed on them. Despite these differences, however, the importance of the other classes of plant food varied little during the study; those of the edge ranged from only 2·3 to 6·8% of the volume, floating plants had a range of only 22·9 to 32·4%. It might be inferred that these plants collectively are the most reliable food sources of the black swan.

Figure 1 shows the composition of the food and the water level in the swamp during the period studied. The work began in May 1963, following an extended dry period during 1962 when the swamp had fallen to a low level. Pasture plants had grown and weeds had become established on the edge of the exposed banks of the inlet creek. In late April and early May, discharge of water from the rice farms and, at the same time, unusually heavy rainfall caused a sudden increase in the water level, and this was maintained until mid summer. As the water rose, extensive

areas of pasture plants were flooded and the swans fed almost entirely on them. The only other periods when pasture plants were of appreciable importance were

TABLE 2

COMPOSITION OF FOOD OF BLACK SWANS IN BARRENBOX SWAMP FROM MAY 1963 TO APRIL 1967

Data expressed as percentage of total volume of gizzard contents and as percentage occurrence

Food		1963/64	1964/65	1965/66	1966/67
Plants					
Dry-land	Volume	27·8	3·8	8·3	6·9
	Occurrence	41·1	7·1	15·3	9·9
Edge	Volume	3·0	2·3	6·8	2·9
	Occurrence	21·0	7·2	13·9	7·0
Floating	Volume	29·3	32·2	22·9	32·4
	Occurrence	46·8	48·7	41·3	47·1
Littoral	Volume	10·2	5·6	11·0	5·2
	Occurrence	23·6	15·0	18·8	12·9
Deep-water	Volume	29·7	56·1	51·0	52·6
	Occurrence	44·8	73·3	67·0	63·8
Number of birds		178	225	243	260
Number of samples		8	11	10	12

in the autumn of 1964, the spring of 1965, and the summer of 1966. Each was associated with heavy rainfall that caused ponding in the irrigation bays and sudden availability of pasture plants.

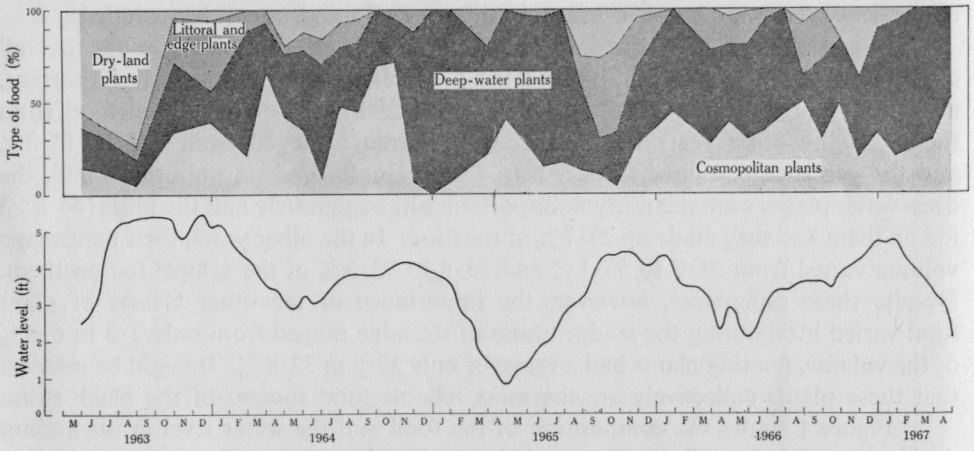

Fig. 1.—Composition of food by volume of the black swan each month from May 1963 to April 1967, showing the effects of variation in water level.

The deep-water flora was eaten throughout the period, but especially at times of low water when the birds remained in the deepest and most permanent parts of the swamp. Thus, in the summer of 1964 and autumn of 1965, when the swamp

declined to an abnormally low level and there was very low rainfall, the diet consisted mainly of the plants, *Typha*, *Najas*, and *Potamogeton*. In 1963 and the first half of 1964, when the swamp retained a high level, very few deep-water plants were eaten. In 1966, when the water was maintained at a moderate level during late summer and early autumn, but was not excessively high in winter, the diet was 40–50% deep-water plants. In early 1967, when the level again fell sharply, the importance of this flora suddenly increased. In the summer of 1964/65 the most important pondweeds were the freshwater species *P. crispus* and *P. ochreatus*. There was a massive bloom of these species throughout the swamp at this time, and in December 1964 they formed 96% of the food. In the years 1965–67 the level of the swamp was lower and apparently the water was more saline; the pondweeds were predominantly the halophytic forms *Najas* and *Ruppia*. In Mirrool Creek, which still flowed, *P. pectinatus* and *P. ochreatus* remained the most important.

TABLE 3

COMPOSITION OF FOOD OF BLACK SWANS OF DIFFERENT AGES AT BARRENBOX SWAMP

Food	Downy Young		Immature		Adult	
	Volume (%)	Occurrence (%)	Volume (%)	Occurrence (%)	Volume (%)	Occurrence (%)
Plants						
Spirogyra	0·1	2·8	19·4	36·4	25·2	34·2
Chara	7·9	16·7	tr.	27·3	5·2	14·4
Azolla	1·7	8·3	20·5	45·0	1·9	17·9
Myriophyllum	0	0	0	0	3·8	9·7
Lemna	0	0	13·9	36·4	0·4	2·3
Typha	2·5	2·8	0·3	18·2	19·2	28·8
Potamogeton	15·4	16·7	23·1	36·4	8·2	7·8
Najas	0	0	0	0	3·8	5·8
Vallisneria	9·4	13·9	2·0	18·2	5·8	9·7
Rumex	10·3	22·2	tr.	27·3	0·7	1·9
Scirpus	tr.	5·6	0·1	27·3	1·8	2·7
Juncus	2·8	2·8	0	0	1·1	1·9
Ranunculus	14·6	22·2	0	0	0	0
Gramineae	17·4	27·8	16·2	27·3	9·8	15·2
Leguminosae	10·4	25·0	4·4	9·1	tr.	1·6
Other plants	7·6	7·8	0·1	5·6	13·1	20·5
Total plant food	99·9	100·0	100·0	100·0	100·0	100·0
Total animal food	0·1	25·0	tr.	54·5	0	0
Number of birds	27		20		257	

The littoral and edge plants, i.e. aquatic plants of shallow water, were most abundant when a high water level had been maintained for some time and dense beds of *Myriophyllum*, *Chara*, and *Nitella* developed in the shallows. Such conditions occurred in the summer of 1963 and the spring of 1965, and *Myriophyllum* and *Chara* were then very important articles of the diet. The cosmopolitan aquatic plants most used by swans were the algae. Algal blooms were frequent but the underlying causes were not understood. When these occurred the algae were eaten in great quantities. During a very extensive bloom in spring 1964 they accounted for 70% of the diet.

TABLE 4

FOOD FOUND IN GIZZARDS OF 119 FRECKLED DUCKS COLLECTED AT BARRENBOX SWAMP FROM MAY 1964 TO FEBRUARY 1967

Data expressed as percentage of total volume of gizzard contents for each month

Food	Jan.	Feb.	Mar.	Apr.	May	June	July*	Aug.	Sept.	Oct.	Nov.	Dec.	Mean
Plants													
Chlorophyceae	0·5	0	7·5	0	1·7	0		5·7	2·3	0·5	1·8	0	1·8
Characeae	10·8	11·8	12·5	2·5	35·8	25·0		12·3	39·3	17·5	27·4	25·0	20·0
Azollaceae	0·1	37·4	0	0	1·7	0		4·4	3·3	0	23·8	15·0	7·8
Typhaceae	6·3	20·9	0	23·2	0	0		21·4	11·3	11·3	1·8	0	8·7
Potamogetonaceae	11·6	0	5·0	0	0	0		3·3	0	0	0	0	1·8
Najadaceae	14·1	13·9	0	11·3	12·5	20·0		9·5	1·6	4·2	2·5	0	8·1
Cyperaceae	3·6	3·0	22·5	0	11·6	10·0		16·3	16·8	23·6	13·0	15·0	12·3
Chenopodiaceae	0	0	0	2·5	0	25·0		0	0	0	0	14·2	3·8
Ceratophyllaceae	49·3	10·2	12·5	40·3	21·7	20·0		19·8	23·3	14·2	22·8	27·5	23·8
Ranunculaceae	0	0	10·0	10·0	0	0		0	0	0	2·5	0	2·0
Leguminosae	0·3	0·3	12·5	0	0	0		2·7	0	0	0	1·7	1·6
Boraginaceae	0·1	1·3	0	0	0	0		0·9	0	8·3	1·4	0	1·0
Other plants	0·1	0·3	7·5	2·5	0	0		0·4	0·5	0	0	0	1·2
Animals													
Insecta													
Coleoptera	3·1	0·9	5·0	5·1	5·0	0		1·0	1·1	7·9	1·8	1·6	3·0
Demispongiae	0	0	2·5	0	10·0	0		0·2	0	12·5	0	0	2·3
Other animals	0·1	0	2·5	2·6	0	0		1·7	0·5	0	1·2	0	0·8
Total plant food	96·8	99·1	90·0	92·3	85·0	100·0		97·1	98·4	79·6	97·0	98·4	93·9
Total animal food	3·2	0·9	10·0	7·7	15·0	0		2·9	1·6	20·4	3·0	1·6	6·1
Number of birds	31	12	2	5	6	1		23	13	8	12	6	119

* No sample.

(*d*) *Food of the Young*

The food found in the gizzards of small samples of downy young and immature birds is compared in Table 3 to that found in adult black swans collected at the same time and in the same place. For this purpose, a downy young is defined as a bird less than 60 days of age and an immature as a bird between 60 and 120 days of age, i.e. fully feathered but with undeveloped primaries and traces of down on the body.

In some waterfowl that feed on vegetable material, the young have a different diet and favour animal food. In black swans, however, this is not the case. Despite the small size of the samples, it is apparent that in all age groups the food was almost entirely plant material, although traces of animal food were found in more young than adults—25·0% of the downy young, 54·5% of the immatures, and 15% of the adults. The composition of the plant food was similar in each age group but the size of the samples does not permit detailed comparison. The plants eaten by the young and the adults associated with them were mainly those of the littoral, indicating the preferred feeding place of the broods. Cumbungi and ribbonweed are normally plants of deep water, but in these birds the only parts of these plants found were the small shoots of young plants that were germinating in shallow water.

IV. Freckled Duck

(*a*) *Material*

Freckled ducks were present in the swamp at all times in small numbers, but only in the period August 1965–February 1966 were they sufficiently numerous for a reasonable sample to be taken. Particular efforts were made to secure freckled ducks throughout the study, so the size of the samples taken is an accurate indication of their relative abundance. The first sample was taken in May 1964 and the last in February 1967. In the intervening period there were 18 samples, comprising 119 birds.

(*b*) *Composition of Food*

The food found in the birds consisted, by volume, of 93·9% plant material and 6·1% animal material. All birds contained some plant material and 38% of the sample contained some animal material. Table 4 shows the composition of the food.

Most of the plant food was derived from plants that are restricted to stable water areas of moderate depth: algae, hornwort, sedges, and bulrushes. This is well in accord with previously published information on the food in other habitats (Frith 1965).

The most important single plant was hornwort (*Ceratophyllum demersum*), of which the leaves, inflorescences, and mainly the fruits, were eaten. This subemergent aquatic plant was most abundant in the deep reaches of the swamp where the water was not entirely stagnant. Hornwort was found in 78·2% of the birds collected and made up 23·8% of the volume of food. In several of the samples every bird contained some seed, and in some it made up half the food of the sample. Some birds, in most samples, had eaten nothing else.

After hornwort, the algae Chlorophyceae and Characeae were the most important food. The Chlorophyceae were found in 14·3% of the birds and provided 1·8% of the diet. Several different genera of algae, including *Microspora* and *Spirogyra*, were involved but these were not individually identified. The Characeae had been eaten by 42·0% of the birds and provided 20·0% of the total food. In most months considerable numbers had fed on *Chara*; in some samples, as many as 70%, and in some it provided up to 55% of the volume of food. The algae were commonest, in dense growths, in the stabilized littoral zone. *Nitella*, characteristic of these areas, was found in 59·0% of the birds and provided 3·0% of the food. The great influx of birds into Barrenbox swamp in mid summer of 1966/67 coincided with an extensive bloom of algae near the edge of the swamp, and each night the freckled ducks flew from the cumbungi to feed there.

The Cyperaceae, also characteristic of stable water, provided 12·3% of the food and were found in 40·0% of the birds. The commonest were *Scirpus validus* (7·8% volume) and *Carex* (3·2%). There were small quantities of *Cyperus* and *Eleocharis*. In each case the seeds were eaten, probably filtered from the water. Of the Typhaceae, cumbungi (*Typha*) provided 8·7% of the volume of the food and was found in 26·1% of the birds. In some samples it was found in all the birds and provided as much as 46·5% of the total food. The seeds readily float, because of tufts of long hairs attached to the pedicel, and were abundant on the water surface at all times. The floating waterfern *Azolla* was also found throughout the swamp and provided 7·8% of the volume of food (12·6% occurrence).

The subemergent plants prickly pondweed (*Najas marina*) and pondweed (*Ruppia*) were commonly used as food. The former provided 8·1% of the volume (40·3% occurrence) and the latter only 0·7% of the volume, but it was found in one-quarter of the birds. Ribbonweed, *Vallisneria gigantea*, although very abundant in most parts of the swamp, was not eaten at all, and water milfoil, *Myriophyllum*, appeared in only three birds; these two plants are very important to some other waterfowl that feed in similar situations.

Occasionally seeds of dry-land plants appeared in the gizzards and had, no doubt, been secured from the flooded edge, or filtered from the surface of deep water, having been carried into the swamp by Mirrool Creek. These included rice (*Oryza sativa*), medic (*Medicago polymorpha*), subterranean clover (*Trifolium subterraneum*), woolly clover (*T. tomentosum*), white clover (*T. repens*), Hexham-scent (*Melilotus indica*), and bindweed (*Convolvulus erubescens*), but none was found in more than a few birds.

The animal food was restricted in variety as well as in quantity. Insects provided the greatest bulk, making up 3·0% of the total volume of 6·1%. The commonest insects were the beetles *Ilybius*, *Noterus*, and *Hydrophilus*, but there were also a few bugs, *Sphaeroderma*, and larvae of Trichoptera. The Crustacea were restricted to a few copepods and ostracods making only 0·2% of the total volume (3·4% occurrence), but they might have been more important than these figures suggest. Owing to their delicate nature these animals probably soon become unrecognizable in the gizzard. The freckled ducks were unusual in having eaten appreciable quantities of the small freshwater sponge *Spongilla*; this made up 2·3% of the total food and was found in 3·4% of the birds.

(*c*) *Seasonal Variation*

The collection was not sufficiently extensive to determine any annual or seasonal variation that might have existed.

(*d*) *Discussion*

Previously published information on the food of freckled ducks refers to 27 birds, most of which were collected in a large lignum swamp 70 miles west of Barrenbox swamp. Lignum swamps are dominated by lignum (*Muehlenbeckia cunninghamii*), and when filled by effluent streams or river flooding can retain water for a couple of years (Frith 1959*a*). They are typically shallow, the bottom initially is bare earth, and there is seldom time for a luxuriant aquatic vegetation to develop before the water disappears.

Under these conditions the food eaten was somewhat different from that of the present sample, but was clearly collected from similar situations, i.e. the most permanent part of the swamp. All the birds had eaten algae which made up 80% of the volume, but the remainder of the plant food consisted of seeds of Polygonaceae, Marsileaceae, Chenopodiaceae, and Cyperaceae, all characteristic of the edges of comparatively stable water, and the seeds of Gramineae and Compositae that were presumably growing on the edge. The grasses, with 10% volume, were the most important land plants, and were mainly barnyard grasses (*Echinochloa crus-galli* and *E. colonum*) and Warrego grass (*Paspalidium jubiflorum*), semi-aquatic species. There is little doubt that the freckled duck is adapted to utilize permanent aquatic environments. The littoral flora, which is dependent on water-level fluctuations, is evidently of basic importance. It is clear that permanent habitats that undergo such fluctuations in water level are uncommon, and also the most vulnerable in the inland.

V. Black Duck

(*a*) *Material*

Black ducks were numerous at all times and regular samples were collected each month between April 1966 and April 1967; 283 gizzards were available. The samples each month were satisfactory, except for July 1967 when only three birds were secured.

(*b*) *Composition of Food*

The composition of the food by percentage of the volume is shown in Table 5. Four-fifths of the diet was plant material and the remainder was mainly insects. Every bird contained both plant and animal material.

The most important group of plants was the grasses, Gramineae, which comprised 19·1% of the total diet. The grasses eaten included a wide variety of dry-land grasses, improved pastures, cultivated cereals, and ditch grasses. The most important grass was barnyard grass (*Echinochloa crus-galli*), which was eaten by 10·6% of the birds and on the average comprised 5·7% of the total food. It was eaten mainly in July and August, when it accounted for 31·6% and 32·6% of the total food

TABLE 5

FOOD FOUND IN GIZZARDS OF 283 BLACK DUCKS COLLECTED AT BARRENBOX SWAMP FROM APRIL 1966 TO APRIL 1967

Data expressed as percentage of total volume of gizzard contents for each month

Food	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Mean
Plants													
Chlorophyceae	6·3	2·6	3·3	0·2	2·7	4·4	0	0·4	0·7	0	5·3	3·0	2·4
Marsileaceae	1·0	1·9	0·7	5·0	0	3·3	0	0	1·7	0·4	5·6	3·9	2·0
Azollaceae	7·3	3·3	0·3	4·5	10·8	12·9	8·3	0·9	3·5	0·4	2·4	1·0	4·6
Typhaceae	7·3	1·0	3·4	12·5	0·4	0	25·0	0·9	0·2	0	5·8	3·9	5·0
Potamogetonaceae	13·9	11·1	4·5	5·3	3·0	14·2	0	0·6	3·0	5·2	4·4	1·1	5·5
Hydrocharitaceae	0	2·4	2·1	2·9	0·4	0·2	0	0	0	0	2·8	0·9	1·0
Gramineae	9·4	30·1	16·0	31·4	13·1	0·5	31·6	36·7	25·6	23·7	2·8	7·9	19·1
Cyperaceae	11·1	10·5	7·0	5·2	10·0	2·1	30·0	3·3	3·2	18·7	18·5	11·9	11·0
Lemnaceae	4·7	0	5·3	0	13·5	5·0	0	0	0	0·4	3·1	3·7	3·0
Polygonaceae	5·5	0·6	11·2	2·5	15·6	7·9	1·7	32·2	17·2	7·1	7·8	19·7	10·8
Ceratophyllaceae	1·2	5·4	16·9	4·4	9·2	7·4	0	6·5	14·2	12·5	0·6	0·5	6·6
Leguminosae	1·0	1·0	0·7	1·2	0·2	0	1·7	2·0	2·4	1·1	3·3	8·1	1·9
Haloragaceae	0·2	4·9	1·5	7·1	2·7	14·2	0	0	0	2·1	0	0	2·7
Compositae	0·4	5·7	0·5	10·8	0	1·9	0	3·3	14·4	0·4	0	0·1	3·1
Other plants	0·9	1·3	7·6	0·5	2·7	6·7	0	1·0	3·3	2·5	1·7	2·5	2·5
Animals													
Insecta													
Odonata	1·3	2·0	0·3	1·3	0	0·5	0	0·7	0·7	0·8	4·2	0·9	1·1
Hemiptera	11·0	10·1	3·1	3·5	8·0	7·2	0	2·3	8·8	17·9	3·3	17·7	7·7
Coleoptera	0·3	1·3	0·2	0·1	0·8	2·2	0	0·9	0·6	0·6	2·8	4·3	1·2
Trichoptera	1·2	2·0	1·5	0·8	6·9	4·5	1·7	1·7	0·2	0·8	0	4·8	2·2
Total insects	13·8	15·4	5·1	5·7	15·7	14·4	1·7	5·6	10·3	20·1	10·3	27·7	12·2
Mollusca	13·0	1·4	8·9	0	0	3·4	0	1·7	0·2	3·9	25·6	3·4	5·1
Other animals	3·0	1·4	5·0	0·8	0	1·5	0	4·9	0·1	1·5	0	0·7	1·5
Total plant food	70·2	81·8	81·0	93·5	84·3	80·7	98·3	87·8	89·4	74·5	64·1	68·2	81·2
Total animal food	29·8	18·2	17·9	6·5	15·7	19·3	1·7	12·2	10·6	25·5	35·9	31·8	18·8
Number of birds	30	42	29	34	13	21	3	23	23	24	18	23	283

respectively; barnyard millet is a serious weed of cultivation. Cultivated rice (*Oryza sativa*) was a prominent food, accounting for 5·7% of the total food and having been eaten by 8·1% of the birds. The greatest quantities were eaten in September and October; in each of these months it comprised 20·8% of the total food and was eaten by 22% and 33% of the birds respectively. In September and October rice is planted and first irrigated with shallow water to germinate and establish the plants, so the seed was readily available. The other grasses eaten in small quantities included cultivated oats (*Avena sativa*) and wheat (*Triticum aestivum*), water couch (*Paspalum distichum*), paspalum (*P. dilatatum*), brome grass (*Bromus unioloides*), summer grass (*Hordeum marinum* and *H. leporinum*), and bearded oats (*Avena barbata*).

The sedges (Cyperaceae) and smartweeds (Polygonaceae) were also prominent, accounting for 11·0% and 10·8% of the volume of food respectively. Among the smartweeds, *Polygonum* was found in 36% of the birds and accounted for 10·5% of the total food; the commonest were wireweed (*P. aviculare*) and small persicaria (*P. minus*), but waterpeppers (*P. hydropiper* and *P. lapathifolium*) were also eaten. The most important sedges were *Scirpus*, which were found in 22·6% of the birds and comprised 7·3% of the total food. The most prominent plant was *Scirpus validus*.

The floating plants, waterfern (*Azolla*), duckweed (*Lemna oligorrhiza* and *L. minor*), and the algae Chlorophyceae, were well represented, being found in 14·1%, 9·2%, and 11·0% of the gizzards respectively, but they did not produce great bulk, accounting for only 4·6%, 3·0%, and 2·4% of the total diet respectively.

The deep-water plants provided 21% of the food and were found in 43% of the birds. Of these, hornwort (*Ceratophyllum demersum*) was the most prominent, being in 26·5% of the birds and accounting for 6·6% of the food. The seeds and leaves of pondweeds (*Potamogeton*, mainly *P. pectinatus*) were in 15·9% of the birds and comprised 5·5% of the food. Smaller amounts of cumbungi seed, the seeds of *Najas marina*, and leaves of ribbonweed (*Vallisneria gigantea*) were also collected in deep water.

The most important animal material was supplied by insects, which were found in 41·3% of the birds and comprised 12·2% of the bulk of the diet. The most commonly found was the large (over 2 cm long) bug *Sphaeroderma rusticum*, which made up 4·3% of the total food eaten and was found in 14·1% of the birds. No other insect was of exceptional importance, but a wide variety was eaten in small numbers. These included the larvae of Trichoptera (2·2% of the volume), larvae of Chironomidae (0·2%), larvae of Odonata (1·1%), the bugs *Naucoris* (2·3%), *Corixa* (1·0%), *Arctocorisa* (0·8%), and *Micronecta* (0·1%), the beetles *Ilybius* (0·1%), *Noterus* (0·1%), *Hydrophilus* (0·7%), and *Berosus* (0·4%), and many others.

The Mollusca were found in 13·4% of the birds and accounted for 5·1% of the food. The most common was the freshwater mussel (*Corbiculina permena*), but the snails *Physastra* and *Glyptanisus* were also commonly eaten. The remaining animal material included the crayfish (*Cherax albidus*), the shrimp (*Caridina mccullochi*), the spider (*Arctosa*), mites, Hydracarina, and ostracods and copepods.

(*c*) *Seasonal Variation*

The importance of the various sources of food varied from time to time during the year. The floating plants were eaten in greatest quantities in the late autumn

and early winter (Fig. 2), when they were most abundant. The shallow-water (edge and littoral) plants retained their importance throughout the year, more or less equal quantities of each group being eaten in most months. The importance of the dry-land plants and insects, however, varied from season to season. The plants were most important in late winter and early spring when water levels were increasing and flooding formerly dry land, the irrigation season was beginning, with the flooding of freshly planted cereals and pastures to secure germination, and the relatively low air temperature was allowing rain pools to persist longer than at other times. Presumably the increased utilization of dry-land plants was due merely to increased opportunities for feeding on them. Similar arguments could explain the importance of insects in the hotter months when they are most abundant and readily available, as the falling water levels cause aquatic animals to concentrate in pools and to become exposed on the receding shoreline of the swamp.

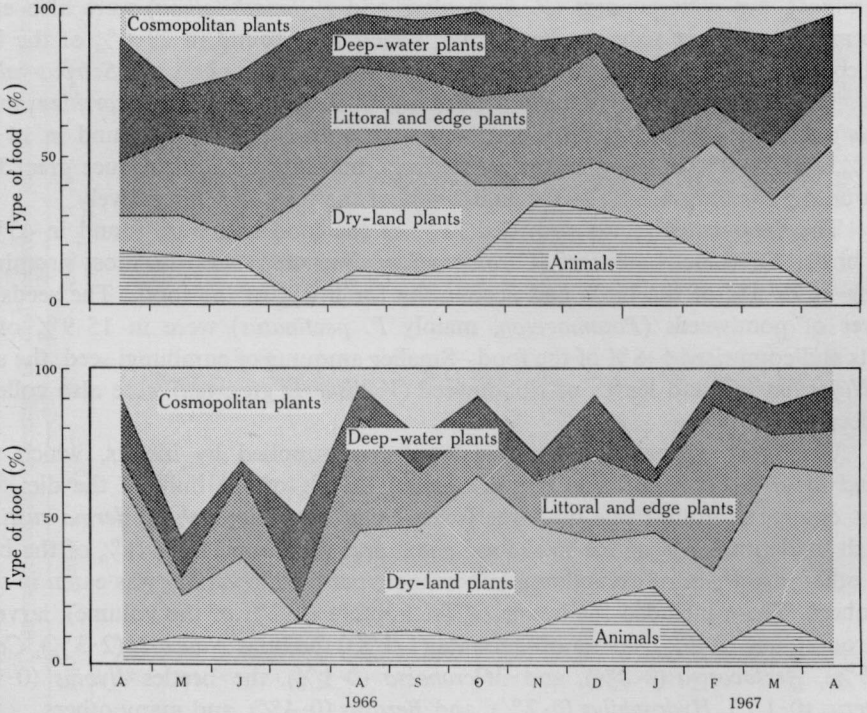

Fig. 2.—Composition of food by volume of the black duck (top) and the grey teal (bottom) each month from April 1966 to April 1967.

(*d*) *Discussion*

The food was similar to that described for the billabongs of the Murrumbidgee River, 20 miles south of Barrenbox swamp, in the previous study (Frith 1959*b*). The main difference was that in the billabongs a greater proportion of animal food was collected, 30·5% as against 18·8% in this study. This result might have been expected as the extensive billabongs and floodwaters give much greater opportunities

TABLE 6

FOOD FOUND IN GIZZARDS OF 315 GREY TEAL COLLECTED AT BARRENBOX SWAMP FROM APRIL 1966 TO APRIL 1967

Data expressed as percentage of total volume of gizzard contents for each month

Food	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Mean
Plants													
Chlorophyceae	26·0	3·0	8·6	0·2	19·0	4·1	0	2·2	4·8	4·0	0·2	2·7	6·2
Marsileaceae	0·2	0	0·4	1·0	1·1	0·5	0	0·8	1·4	1·5	0·5	2·3	0·8
Azollaceae	5·4	1·0	3·4	6·2	21·8	16·2	23·7	3·0	16·5	3·8	17·5	1·1	10·0
Typhaceae	0	0·1	2·8	2·8	4·3	0·5	2·5	1·0	1·2	1·0	0·5	0·3	1·4
Potamogetonaceae	0·8	7·0	2·8	4·1	1·4	0·7	1·0	0	4·3	9·0	1·8	6·7	3·3
Gramineae	3·5	19·6	41·6	44·1	7·8	1·4	0	27·8	19·4	40·1	15·5	4·5	18·8
Cyperaceae	12·0	42·5	2·8	0·7	4·6	14·6	7·8	3·0	10·5	6·0	3·8	14·3	10·2
Lemnaceae	2·3	0·1	0	1·2	16·5	11·1	26·2	0·4	2·0	1·5	11·5	3·9	6·4
Polygonaceae	1·5	13·6	6·4	7·6	0	11·1	0	34·0	6·0	7·3	11·9	12·7	9·3
Chenopodiaceae	0·2	0	0	0·2	0	21·7	0	1·0	0·5	0	0·7	0·7	2·1
Ceratophyllaceae	1·5	1·0	1·8	6·8	7·1	1·3	22·8	7·6	5·5	2·8	0·3	2·0	5·0
Leguminosae	9·9	2·3	6·2	10·7	0·4	3·6	0	5·4	3·2	9·3	13·8	19·7	7·0
Convolvulaceae	2·3	2·0	1·6	1·8	0	0	0	1·6	0·5	1·0	0·5	0	0·9
Boraginaceae	1·9	0	3·0	2·9	4·2	0·9	0	0·8	10·0	2·8	2·1	1·8	2·5
Other plants	6·4	3·3	1·2	3·9	3·2	3·8	1·0	1·6	2·4	2·3	8·1	6·7	3·7
Animals													
Insecta													
Hemiptera	3·9	1·8	3·2	0·5	0·4	1·8	5·0	0	3·8	1·2	4·7	4·0	2·5
Coleoptera	1·2	0·3	1·6	1·6	0	0	0	3·8	0·8	1·9	1·3	2·3	1·2
Trichoptera	3·1	2·4	2·6	3·2	4·7	5·8	10·0	4·8	1·7	2·5	1·1	4·1	3·8
Diptera	0	0	6·0	0·1	3·2	0	0	1·0	5·3	1·1	2·4	2·5	1·8
Other insects	1·8	0	0	0·7	0·3	0·6	0	0·2	0	0·2	0·4	0·3	0·4
Total insects	10·0	4·5	13·4	6·1	8·6	8·2	15·0	9·8	11·6	6·9	9·9	13·2	9·8
Mollusca	9·9	0	4·0	0·6	0	0	0	0	0·2	0·5	1·1	6·4	1·9
Other animals	6·2	0	0	0·1	0	0·3	0	0	0	0·2	0·3	1·0	0·7
Total plant food	73·9	95·5	82·6	93·2	91·4	91·5	85·0	90·2	88·2	92·4	88·7	79·4	87·6
Total animal food	26·1	4·5	17·4	6·8	8·6	8·5	15·0	9·8	11·8	7·6	11·3	20·6	12·4
Number of birds	26	35	25	46	14	22	4	25	32	31	33	22	315

for feeding in shallow water and dredging in sand than does a deep swamp with limited edge. Apart from this difference, the relative proportions of the different plants and animals eaten were quite similar.

The data support the earlier conclusion that the black duck is fairly conservative in its food habits, as it is in its choice of habitat.

VI. Grey Teal

(*a*) *Material*

The numbers of grey teal in the swamp fluctuated greatly, but considerable numbers were present and satisfactory samples were secured in each month except July 1967. In all, 315 gizzards were available for analysis.

(*b*) *Composition of Food*

The composition of the food by volume is shown in Table 6. The diet consisted of 87·6% plant material and 12·4% animal material. All birds contained some animal food and 87·9% of the birds contained some plant food.

As with the black ducks, the most important plant groups were the grasses Gramineae and sedges Cyperaceae, which accounted for 18·8% and 10·2% of the total volume of food.

Of the Gramineae the most prominent grasses were, as for the black duck, barnyard grass and cultivated rice; the barnyard grass was found in 8·8% of the birds and accounted for 5·3% of the volume of food; the rice was found in 13·1% of the birds and comprised 7·6% of the food. Other cultivated cereals included oats (0·6%) and wheat (1·4%), and there were small quantities of seeds of numerous grasses from improved pastures and native grasslands. Associated with the crops and pasture grasses were legumes that comprised 7·0% of the volume; they were mainly *Medicago polymorpha*, *M. sativa*, *Trifolium subterraneum*, *T. tomentosum*, and *T. repens*.

The most important sedges were *Scirpus*, including *S. validus* which was found in 20% of the birds and provided 4·3% of the food, and *Cyperus* spp., which occurred in 6·5% of the birds and accounted for 2·7% of the food.

The Polygonaceae, found in 21% of the birds and providing 9·3% of the diet, were mainly represented by *P. aviculare* and *P. minus* but, as with the black duck, *P. hydropiper* and *P. lapathifolium* were also recorded.

The floating plants were of great importance: algae were found in 11·4% of the birds (6·2% of the volume); waterfern (*Azolla*) provided 10·0% of the total and was found in 31·7% of the birds; and duckweed (*Lemna minor*) occurred in 19·7% and provided 6·4% of the total food. The most important subemergent plant of the deep water was hornwort (*Ceratophyllum demersum*), which occurred in 13·6% of the birds and provided 5·0% of the total food.

The animal food was predominantly insect, these animals comprising 9·8% of the total volume. No one insect or insect family was of overriding importance, but the most frequently eaten were the larvae of Trichoptera which were found in

25% of the birds and provided 3·8% of the diet. As with the black duck, the bugs Corixidae were frequently eaten and provided 2·8% of the food; the genera *Corixa*, *Micronecta*, and *Arctocorisa* were most common. The beetles Coleoptera were represented by *Ilybius*, *Noterus*, *Hydrophilus*, and *Berosus* and provided 1·2% of the volume. Other insect material included dragon-fly (Odonata) larvae (0·6%), and larvae of the Chironomidae (1·7%). As with the black ducks, the molluscs consisted of the freshwater mussel *Corbiculina* and the snails *Gylptanisus* and *Physastra*.

(*c*) *Seasonal Variation*

The seasonal changes in the food eaten were similar to those of the black duck. The main differences were that the floating plants were eaten in greater quantities by, and the dry-land plants were important for the longer period to, the grey teal. These two facts reflect the difference in mobility between the two species: the grey teal is quicker to visit newly flooded areas and rain puddles than the black duck, and its greater flexibility permits it to use these areas for a longer period (Frith 1959*b*). Presumably, grey teal in Barrenbox swamp were quicker to visit irrigated fields than black ducks, and secured food in them longer.

(*d*) *Discussion*

The grey teal in Barrenbox swamp ate relatively less animal food than did birds in the Murrumbidgee billabongs, 12·4% against 23·3% (Frith 1959*b*). In addition, the plants characteristic of permanent water were of relatively greater importance in Barrenbox swamp; these plants include the Azollaceae, Chlorophyceae, Potamogetonaceae, and Ceratophyllaceae.

In Barrenbox swamp the food of the grey teal was very similar to that of the black duck, any differences being explained by different feeding places and how quickly each species utilized new food sources. The black duck depends on practically the same plants in the two environments, but the grey teal is quick to use different groups of plants when confronted with a new situation and little choice of habitat type. The food of the two species is compared in Figure 2.

VII. Shoveler

(*a*) *Material*

Shovelers were present in small numbers throughout the study period and a few were collected in most months between March 1963 and April 1967. In November 1967 there was an influx and groups of up to 100 birds were encountered throughout the remainder of the study, enabling larger samples to be taken. In all, 161 gizzards were examined.

(*b*) *Composition of Food*

The composition of food is shown in Table 7.

Overall, the food consisted of 46·2% plant and 53·8% animal material. Of the whole sample, 86% had eaten some plants and 93·6% some animals.

TABLE 7

FOOD FOUND IN GIZZARDS OF 161 SHOVELERS COLLECTED AT BARRENBOX SWAMP FROM MARCH 1963 TO APRIL 1967

Data expressed as percentage of total volume of gizzard contents for each month

Food	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Mean
Plants													
Marsileaceae	18·3	10·0	3·7	1·0	3·5	5·0	0	1·0	10·0	1·0	3·7	2·0	4·9
Azollaceae	7·0	2·0	1·0	8·0	7·5	28·5	30·0	34·0	40·0	11·5	12·7	7·5	15·8
Typhaceae	3·3	5·5	4·3	6·0	2·5	11·5	10·0	9·0	0	18·5	6·7	5·7	6·9
Potamogetonaceae	2·3	20·0	3·7	26·6	5·0	9·0	23·0	22·0	0	11·5	8·0	5·5	11·4
Najadaceae	0	0·3	0	14·3	0	6·0	0	0	0	0	2·5	0	1·9
Cyperaceae	3·3	1·0	0·3	0	5·0	0	14·0	2·0	0	0	0·3	0·5	2·2
Ceratophyllaceae	0	3·5	7·7	5·0	0	0	0	1·0	0	0	0	0·5	1·5
Leguminosae	0	1·5	0·7	0·7	5·0	0	0	5·0	0	1·0	1·0	3·0	1·5
Haloragaceae	0	2·5	0	0·3	0	0	0	0	20·0	0	0	0	1·9
Other plants	1·3	8·5	9·6	3·8	2·7	1·0	0·7	7·9	10·0	6·0	11·5	6·7	5·8
Animals													
Crustacea	9·0	6·0	1·3	2·7	0	0	0	1·0	0	2·5	3·0	7·5	2·8
Insecta													
Odonata	5·7	1·5	0	0	1·5	5·0	2·5	0	0	2·5	12·0	5·0	3·0
Hemiptera	8·7	18·0	3·3	10·3	0	5·0	2·5	10·0	10·0	25·0	20·3	15·5	10·7
Coleoptera	4·7	1·0	2·7	0	0	0	0	0	0	7·5	3·3	0·5	1·6
Trichoptera	5·0	10·5	8·7	10·2	41·3	27·5	16·5	7·1	10·0	1·5	5·3	0·5	12·1
Other insects	1·7	3·2	0·7	4·8	0	0·5	0·8	0	0	1·5	0	4·1	1·4
Total insects	25·8	34·2	15·4	25·3	42·8	38·0	22·3	17·1	20·0	38·0	40·9	25·6	28·8
Mollusca	29·7	5·0	52·3	6·3	26·0	1·0	0	0	0	10·0	9·7	35·5	14·6
Total plant food	35·5	54·8	31·0	65·7	31·2	61·0	77·7	81·9	80·0	49·5	46·4	31·4	53·8
Total animal food	64·5	45·2	69·0	34·3	68·8	39·0	22·3	18·1	20·0	50·5	53·6	68·6	46·2
Number of birds	28	25	22	21	4	7	4	5	2	3	22	18	161

The plant food was mainly from plants of the permanent water. Of the total volume, 15·8% was from the Azollaceae and 11·4% from the Potamogetonaceae. The Typhaceae provided 6·9% of the volume, but no other family contributed more than 5%. Particularly striking was the almost complete absence of the Gramineae, which, although very valuable to other surface-feeding ducks, contributed only 1·1% of the diet of the shoveler.

The floating plants *Azolla* and *Lemna* were eaten by 49% of the birds and *Azolla* was by far the more important of the two, having been eaten by 41% of the birds and comprising 15·8% of the total food. The seeds of cumbungi were an important source of food. They were eaten by 35·7% of the birds and provided 6·9% of the volume of food. The seeds of *Ruppia* and the leaves of *Vallisneria* were eaten by 17·8% and 3·3% of the birds and provided 6·3% and 3·0% of the volume respectively. One other important plant, nardoo (*Marsilea drummondi*), characteristic of reasonably stable water areas, was frequently eaten; it was found in 17·8% of the birds and made up 4·9% of the diet.

The animal food was largely insects; they comprised 28·8% of the volume or three-quarters of the total animal component. The insect food was predominantly from the Trichoptera and the Hemiptera. By volume, the larvae of Trichoptera were by far the most important insects; they were eaten by 38·2% of the birds and provided 12·1% of the bulk of the food of the whole sample. Other insects frequently eaten were the bugs *Corixa*, mainly *C. eurynome* which was in 26·7% of the birds and provided 4·8% of the food, *Micronecta* with 10·2% occurrence, *Arctocorisa* with 19·1% occurrence, *Sphaeroderma* (4·5%), *Naucoris* (7·6%), and the beetles *Berosus* (10·8%). The larvae of dragon-flies were eaten by 27% of the birds but only provided 3·0% of the food.

The Crustacea were not very important when judged by volume percentage, although 33% of the birds had eaten the minute Cladocera. Probably these soft-bodied creatures would rapidly break down and thus examination of stomach contents would underestimate their importance. Small numbers of copepods were also found but none of the larger crayfish or shrimps.

The Mollusca provided 14·6% of the volume of food and were found in 53% of the birds. The most important by far was the small snail *Physastra*; it was eaten by 24·8% of the birds and constituted 15·4% of the food. Freshwater mussels, mainly *Corbiculina permena*, were found in 13·4% of the birds and, as might be expected, were always small specimens seldom exceeding 3–4 mm in length.

(*c*) *Seasonal Variation*

Although the sample was small, there was a tendency for the amount of animal food to decrease in the cooler months. This coincides with the decreased activity of insects at this season. There was also a decrease in the quantity of the pondweeds eaten in the winter. The relative lack of insects and pondweeds in the diet in the winter was compensated for by an increase in waterfern and the floating seeds of cumbungi.

TABLE 8

FOOD FOUND IN GIZZARDS OF 95 PINK-EARED DUCKS COLLECTED AT BARRENBOX SWAMP FROM MARCH 1965 TO MARCH 1967

Data expressed as percentage of total volume of gizzard contents for each month

Food	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.*	Mean
Plants													
Chlorophyceae	0	8·6	1·2	0	0	0	0	0	0	10·0	0		1·8
Characeae	0·4	2·3	0·3	0	0	0	0	0	0·6	0	0		0·3
Marsileaceae	0·5	0	0	0	0	0	10·0	0	0	0	0		1·0
Azollaceae	4·6	5·9	4·6	2·0	39·6	52·5	75·0	37·8	5·0	10·0	2·5		21·8
Typhaceae	0·4	0·3	1·6	15·0	12·5	27·5	0	14·8	5·0	0	3·7		7·3
Potamogetonaceae	0·1	3·6	4·2	20·0	1·1	0	0	2·8	0	0	2·5		3·1
Najadaceae	3·8	8·2	0·6	22·0	0·6	0	0	0·6	0	0	0		3·3
Gramineae	0	0	0	0	0	0	0	0	4·4	20·0	0		2·2
Cyperaceae	0·8	0·3	0·6	0	0·9	0	0	14·4	5·0	0	0		2·0
Lemnaceae	2·3	1·8	0·5	0	2·2	0	0	1·7	0	0	31·3		3·6
Polygonaceae	3·3	0	0·2	0	0	0	0	0	7·3	0	0		1·0
Chenopodiaceae	0	0	0	0	0·1	0	0	0·2	11·1	0	0		1·0
Ceratophyllaceae	7·1	1·0	26·1	29·0	4·5	0	10·0	0	0	0	0		7·1
Leguminosae	1·1	0	15·5	0	0·2	0	0	0	7·0	20·0	0		4·0
Other plants	1·7	11·0	14·8	1·0	0·5	5·0	5·0	8·3	18·0	0	5·0		6·4
Animals													
Crustacea	63·1	35·6	14·5	0	14·7	0	0	2·2	3·6	40·0	27·5		18·4
Arachnida	0·2	0·5	3·4	1·0	6·2	5·0	0	7·2	2·8	0	3·7		2·7
Insecta													
Diptera	0·8	0	0·1	0	0	0	0	0	4·4	0	3·7		0·8
Trichoptera	4·1	0·9	0·8	5·0	11·8	10·0	0	2·2	18·3	0	0		4·8
Odonata	1·8	5·9	2·5	0	0·9	0	0	1·1	1·1	0	11·3		2·2
Hemiptera	3·9	14·1	8·5	5·0	4·2	0	0	6·7	6·4	0	8·8		5·2
Total insects	10·6	20·9	11·9	10·0	16·9	10·0	0	10·0	30·2	0	23·8		13·0
Total plant food	26·1	43·0	70·2	89·0	62·2	85·0	100·0	80·6	63·4	60·0	45·0		65·9
Total animal food	73·9	57·0	29·8	11·0	37·8	15·0	0	19·4	36·6	40·0	55·0		34·1
Number of birds	24	12	17	5	11	2	1	9	9	1	4		95

* No sample.

(*d*) *Discussion*

The food in this sample was precisely what would be expected of a bird that divides its feeding time between filtering water and dredging in the shallows. Exposed to a permanent swamp, the birds chose mainly to filter feed in the deepest, most permanent parts. This is shown in the heavy preponderance of deep-water products in the diet. At dusk and during the night the birds moved to feed in the shallows near the edge of the swamp, particularly when the littoral flora that harboured an abundant invertebrate fauna was present. The abundance of this fauna is reflected by a preponderance of invertebrates in the food in late spring and summer. Although, as shown by Frith (1967), the shoveler is basically a bird of permanent swamps, water-level fluctuations that determine the availability of littoral flora and its associated fauna are essential for a swamp to provide favourable habitat throughout the year. The shoveler is not well adapted to survive in the more temporary habitats of the inland river systems, although it does have enough flexibility to live in the floodwaters in some numbers when these are extensive.

The food eaten in Barrenbox swamp included less animal matter than a sample collected in floodwaters of the Murrumbidgee River in an earlier study (Frith 1959*b*). Receding floodwaters are dense with copepods, ostracods, and other microscopic life. Under these conditions they were a far more important source of food to the shovelers than they were in the deep cumbungi swamp. In the floodwaters, deep-water plants and those characteristic of stable water areas were not present; their place in the shoveler's diet was taken by a wide variety of Polygonaceae, Chenopodiaceae, and flooded Gramineae, Leguminosae, Cucurbitaceae, Boraginaceae, and Compositae.

VIII. Pink-eared Duck

(*a*) *Material*

The pink-eared duck was not a regular inhabitant of the swamp. During 1965 these ducks were present in small numbers and a few were collected each month. Towards the end of the year, however, they dispersed and were very rare until a few returned at the end of 1967. Ninety-five gizzards were collected.

(*b*) *Composition of Food*

Both plant and animal food were represented: 34·1% of the volume consisted of animals and 65·9% of plants; 88% of the birds had eaten some plant material and 95% had eaten some animal material. The composition of the food is shown in Table 8.

The most important group of animals was the Crustacea, which were found in 57% of the birds and provided 18·4% of the food. Dominant in this group were the Cladocera, found in 51% of the birds. This might have been expected, for pink-eared ducks were often seen in the centre of the swamp feeding near clumps of rotting cumbungi floating in water teeming with Cladocera and other minute animals. Copepods and ostracods together provided 5% of the food, but, because of their abundance and delicate nature, they may have been more important than this figure suggests.

Insects were found in 56% of the birds and provided 13·0% of the volume. The insects eaten were all small species. The most common were the larvae of Trichoptera, which were in 21% of the birds and provided 4·8% of the food. Other insects eaten in numbers included the nymphs of the bugs *Corixa eurynome* (4·3%), *Arctocorisa* (1·7%), *Micronecta batilla* (1·7%), and one *Naucoris congrex*. The commonest beetle was *Berosus australasiae*, but a few *Noterus* and *Hydrophilus latipalpus* and *H. ruficornis* were also eaten.

The water mites Hydracarina were very prominent, being in 38% of the birds but providing only 2·7% of the volume. Water mites were not considered particularly abundant in the swamp, in comparison with copepods and Cladocera, and the hard characteristic carapace of these mites is responsible for their identification in a large number of birds. The Mollusca were restricted to the small snail *Physastra*, which was found in 50% of the birds.

The plant food consisted very largely of the floating plants *Azolla* and *Lemna*, which together accounted for 25·4% of the total food, or three-quarters of the total plant food; the plants were found in 55% of the birds. The other important group comprised plants characteristic of deep water: the seeds of cumbungi appeared in 40% of the birds (7·3% by volume), the leaves of *Ceratophyllum demersum* in 21% (7·1% of the volume), and *Najas marina* and *Potamogeton* were well represented with 11% and 9% occurrence.

The remainder of the plant food was made up of a wide variety of the seeds of both aquatic and dry-land plants, presumably filtered from the water; the genera included *Carex*, *Scirpus*, *Juncus*, *Rumex*, *Marsilea*, *Ranunculus*, *Myriophyllum*, *Avena*, *Bromus*, *Echinochloa*, *Hordeum*, *Paspalum*, *Oryza*, *Medicago*, *Heliotropium*, and *Chenopodium*.

(*c*) *Seasonal Variation*

In general, the amount of plant material increased in the cooler months. In January it was 25% of the total food but it increased during March, and throughout the winter made up 70–80% in most months. The amount declined in September. The most likely reason for this variation is that in winter the small insects and other animals were less abundant in the surface water and the birds were forced to seek alternative food. When plant food increased the main plant was *Azolla*, which becomes very abundant in autumn and winter and forms thick red carpets in protected bays of cumbungi swamps. In some months more than half the food of the pink-eared duck came from this source.

(*d*) *Discussion*

The food eaten by this sample differs significantly from that eaten by birds collected in extensive floodwater, the favoured habitat of the species when they are numerous (Frith 1959*b*). In the earlier sample the food consisted of 94·4% animal items and plant material in the gizzards was thought to be accidental. Conditions also differed considerably for the two studies. In the present work, the swamp was the only water available because of a drought period; in the former, there were immense areas of floodwater and full billabongs and lagoons. Presumably there the pink-eared ducks were free to choose a feeding place, whereas in the present

study no choice was available. In temporary floodwater on the inland plains there is usually little herbage to flood, and the water seldom persists long enough for aquatic plants to grow. Thus, even if the ducks prefer plant food, it is not available in quantity. The evidence suggests that in the cumbungi swamp the pink-eared ducks were obliged to eat other food than that preferred, a fact that could explain the rarity of the birds in the swamp.

IX. Hardhead

(*a*) *Material*

Hardheads were present in the swamp at all times but the numbers increased each summer. The collection was begun in December 1964 and terminated in April 1967. Some birds were secured each month and in all 303 were available.

(*b*) *Composition of Food*

The food consisted of 43·5% animal material and 56·8% plant material. Of the whole sample, 85·3% of the birds had eaten some animals and 91·1% some plants. Its composition is shown in Table 9.

The plants eaten were predominantly those that grow in deep permanent water. The most important single plants were pondweeds (*Potamogeton*, mainly *P. ochreatus* but also some *P. pectinatus*), which comprised 14·5% of the volume and occurred in 47·1% of the birds, and prickly pondweed (*Najas marina*), which made up 13·1% of the volume and 25·3% occurrence. The seeds of cumbungi were found in 24·5% of the birds but contributed only 2·5% of the volume. Among the deep-water plants, *Ruppia*, which provided 0·6% of the volume, ribbonweed (*Vallisneria*) (1·2%), and hornwort (*Ceratophyllum demersum*) (5·1%) were also commonly eaten. Other plants that were collected mainly in deep water, though from or near the surface, were waterfern (*Azolla*), which made up 2·6% of the diet and was found in 23·5% of the birds, and algae, which made up 2·9% of the volume but were identified in 12·2% of the birds. The only other plants with significant percentage occurrence were sedge (*Scirpus validus*), found in 26·5% of the birds, and *Polygonum*, various species of which occurred in 11·6% of the birds. The remainder of the plant food was made up of a wide variety of aquatic and dry-land plants, none of which was of great importance individually.

The animal food consisted very largely of molluscs; 24·0% of the total food or nearly half of the animal food was in this group. They were found in 52·3% of the birds. The freshwater mussel *Corbiculina permena* was in 32·1% of the birds (14·1% of the volume of food); some remarkably large specimens were found, including one 2 in. long by 1 in. wide. The freshwater snail *Physastra* was a common source of food, being in 32·1% of the birds and comprising 14·1% of the food. The snail *Glyptanisus* was less commonly eaten.

The composition of the insect food, which accounted for 19·3% of the diet, was similar to that of the surface-feeding ducks. The greatest volumes were secured from the larvae of caddis flies (Trichoptera) (5·1%), the larvae of midges (Chironomidae) (2·8%), and the larvae of dragon-flies (Odonata) (1·1%). These larvae were

TABLE 9

FOOD FOUND IN GIZZARDS OF 303 HARDHEADS COLLECTED AT BARRENBOX SWAMP FROM DECEMBER 1964 TO APRIL 1967

Data expressed as percentage of total volume of gizzard contents for each month

Food	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Mean
Plants													
Chlorophyceae	2·0	6·0	5·7	4·7	3·0	1·0	0	0	3·0	4·0	4·0	1·0	2·9
Characeae	1·7	0	2·7	0	0	3·5	0	0	1·0	0	8·5	1·5	1·6
Azollaceae	1·7	1·7	1·7	0	1·5	0·5	3·5	2·0	8·0	1·5	6·5	2·0	2·6
Typhaceae	1·0	0·5	3·0	2·0	1·0	1·5	2·0	8·5	4·5	2·0	1·5	2·0	2·5
Potamogetonaceae	19·3	37·0	12·7	13·3	35·5	11·5	25·5	12·0	12·5	4·5	5·0	7·5	16·4
Najadaceae	11·3	2·0	13·0	8·0	2·0	51·0	21·0	14·5	5·0	2·5	15·0	12·5	13·1
Gramineae	1·3	0	0	0	0	0	0	7·0	0	8·0	3·0	0	1·6
Cyperaceae	0·5	11·0	2·7	0·7	10·3	2·5	0·5	1·5	4·5	2·0	2·0	0·5	3·2
Polygonaceae	1·3	2·0	2·0	2·0	7·0	2·0	1·0	2·5	3·5	2·0	1·5	3·0	2·5
Ceratophyllaceae	7·3	8·0	6·0	11·0	7·0	1·5	1·0	6·0	5·0	2·5	3·5	2·5	5·1
Other plants	1·7	0	5·3	12·0	9·2	4·5	4·0	8·5	4·5	3·5	4·0	6·0	5·3
Animals													
Insecta													
Odonata	1·0	0	0·7	0·7	1·5	0·5	0	1·5	2·5	2·5	0·5	1·5	1·1
Hemiptera	5·0	16·0	2·3	9·7	1·0	2·5	3·5	0	2·5	4·0	1·0	17·0	5·4
Coleoptera	0	0	0	0	0	0	0·5	0·5	2·0	3·5	2·5	1·5	0·9
Trichoptera	5·8	8·0	1·0	3·0	1·0	3·5	2·5	9·5	7·5	10·5	5·0	3·5	5·1
Diptera	1·7	0	0·3	1·7	0·5	2·5	0·5	21·0	8·5	3·5	2·5	0·5	3·6
Other insects	2·4	0·8	2·9	3·2	1·5	0	0·5	0·5	6·5	11·5	7·0	1·0	3·2
Total insects	15·9	24·8	7·2	18·3	5·5	9·0	7·5	33·0	29·5	35·5	18·5	25·0	19·3
Mollusca	35·0	7·0	38·0	28·0	18·0	11·0	34·0	4·0	19·0	31·5	27·0	36·0	24·0
Other animals	0	0	0	0	0	0·5	0	0·5	0	0·5	0	0·5	0·2
Total plant food	49·1	68·2	54·8	53·7	76·5	79·5	58·5	62·5	51·5	32·5	54·5	38·5	56·8
Total animal food	50·9	31·8	45·2	46·3	23·5	20·5	41·5	37·5	48·5	67·5	45·5	61·5	43·5
Number of birds	52	6	43	25	12	12	8	28	30	29	28	30	303

identified in 20·6%, 35·9%, and 17·1% of the birds respectively and there seems little doubt that when their fragility is considered in relation to the chitinous parts of bugs (Hemiptera) and beetles (Coleoptera) the volume percentage gives an underestimation of the quantities actually eaten.

The beetles were less important to the hardheads than to some other ducks and comprised only 0·9% of the diet. They included the usual *Ilybius*, *Noterus*, *Hydrophilus*, and *Hydroporus*. The Hemiptera provided 5·4% of the volume and were found in 32% of the birds. By far the most common was *Corixa eurynome* with 15·3% occurrence, but *Sphaeroderma*, *Naucoris*, and *Arctocorisa* also occurred.

The Crustacea were represented by a few crayfish (*Cherax albidus*), shrimps (*Caridina mccullochi*), and the microscopic copepods and ostracods, and clearly were not an important food source.

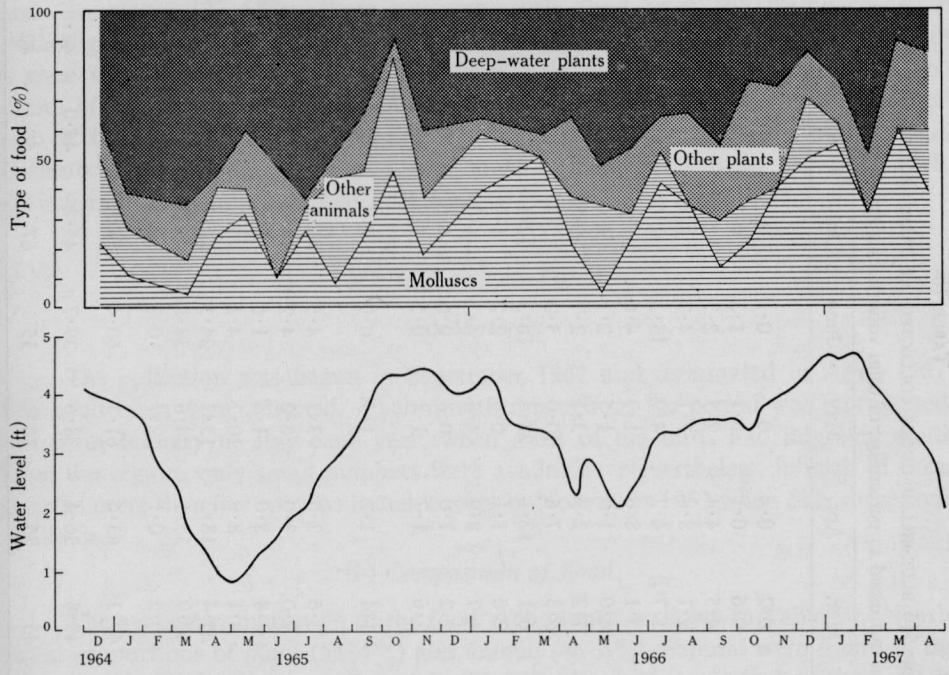

Fig. 3.—Composition of food by volume of the hardhead each month and variation in water level from December 1964 to April 1967.

(*c*) *Seasonal Variation*

Throughout the two-year period, there was a trend towards an increase in the proportion of animal food. At the beginning of the sampling the animal food comprised about 50% of the total; at the end it comprised about 80%. There were irregular fluctuations from month to month. This corresponds with the collection on Mirrool Creek of a greater proportion of birds in each sample towards the end of the study. The majority of birds collected on Mirrool Creek had consumed nothing but molluscs, both *Physastra* and *Corbiculina*. Evidently the continual flow of water in Mirrool Creek permitted large mollusc populations, particularly *Corbiculina*.

TABLE 10

FOOD FOUND IN GIZZARDS OF 546 BLUE-BILLED DUCKS COLLECTED AT BARRENBOX SWAMP FROM SEPTEMBER 1962 TO APRIL 1967

Data expressed as percentage of total volume of gizzard contents for each month

Food	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Mean
Plants													
Chlorophyceae	0·4	0·2	0·2	0·4	0	0·1	0	0·3	3·8	2·3	2·3	1·3	0·9
Characeae	2·0	0·9	0·6	0·1	0·1	1·3	0·2	0·6	0·4	1·7	0·9	3·3	1·0
Azollaceae	1·7	11·6	4·5	4·4	2·5	2·7	2·0	4·0	6·7	8·7	6·2	6·3	5·1
Typhaceae	3·4	10·8	9·1	8·8	7·1	4·7	8·4	11·8	9·4	8·3	6·1	4·9	7·7
Potamogetonaceae	0·6	0·1	1·7	4·2	4·9	13·3	1·0	1·0	1·5	2·4	0·9	2·0	2·8
Najadaceae	2·0	0	5·1	8·6	1·7	4·6	9·7	6·1	4·2	1·4	3·0	0	3·9
Hydrocharitaceae	1·3	1·5	4·0	1·8	1·5	2·1	4·0	2·8	3·4	2·8	1·6	1·1	2·3
Cyperaceae	1·0	0·5	1·2	2·9	3·1	2·7	0·8	1·7	2·3	2·5	2·4	1·4	1·9
Polygonaceae	6·2	2·1	5·3	7·6	10·0	5·0	7·4	10·5	3·0	6·6	3·7	3·4	5·9
Ceratophyllaceae	5·2	3·3	6·1	12·1	22·4	16·3	12·1	8·1	14·1	2·9	7·4	3·5	9·5
Leguminosae	1·0	2·9	2·0	1·1	0·6	2·2	1·9	2·3	1·7	1·3	1·3	1·6	1·7
Haloragaceae	24·5	8·6	4·7	8·9	4·8	4·3	4·0	2·9	3·7	7·2	1·4	7·6	6·9
Compositae	0·8	2·6	2·2	1·0	0·8	0·6	1·6	0·2	0·8	1·2	1·7	3·3	1·4
Other plants	2·6	4·1	2·6	1·7	1·8	0·5	1·7	3·7	1·2	2·1	1·3	5·0	2·4
Animals													
Crustacea	2·1	0·6	1·4	1·2	1·3	0·9	0·4	0·6	2·6	1·9	0·6	1·2	1·2
Insecta													
Odonata	3·6	2·4	3·6	2·0	3·3	4·5	3·5	2·2	2·7	3·4	1·1	2·3	2·9
Hemiptera	5·5	8·8	7·0	3·0	6·0	4·2	4·0	2·1	2·4	6·8	5·9	8·3	5·3
Coleoptera	4·4	1·4	3·8	3·0	1·4	1·5	0·8	0·4	2·9	0·9	2·6	1·2	2·0
Trichoptera	9·6	12·7	8·1	8·9	10·2	4·1	5·9	5·2	10·5	10·4	18·7	12·2	9·7
Diptera	19·3	22·6	25·4	18·2	13·7	24·5	28·1	32·6	21·8	23·4	28·2	28·5	23·9
Total insects	42·4	47·9	47·9	35·1	34·6	38·8	42·3	42·5	40·3	44·9	56·5	52·5	43·8
Other animals	2·8	2·2	0·5	0·1	2·7	0	2·5	0·9	0·9	1·8	2·7	1·6	1·5
Total plant food	52·7	49·2	49·3	63·6	61·3	60·4	54·8	56·0	56·2	51·4	40·2	44·7	53·4
Total animal food	47·3	50·7	49·8	36·4	38·6	39·7	45·2	44·0	43·8	48·6	59·8	55·3	46·5
Number of birds	40	24	45	25	36	35	67	56	42	69	61	46	546

Each year there was an annual cycle of food intake; relatively more animals were eaten in spring than at other times. The various plants were important when they were most available, e.g. dry-land plants were eaten in the greatest quantities in spring when irrigated fields, ditches, and drains were flooded; edge plants were most commonly eaten in spring as the water levels increased and flooded the edge of the swamp. The composition of the food throughout the period is shown in Figure 3.

(*d*) *Discussion*

The hardheads from the Murrumbidgee billabongs (Frith 1959*b*) ate similar proportions of plant and animal food to those in this study, although the plants were more prominent, 74% of the volume against 57%. The composition of the plant food, however, was quite different, being derived mainly from the Cyperaceae (26·5%) and Gramineae (22·5%); there was very little food from the Najadaceae and Potamogetonaceae. It is suggested that the hardheads from the billabongs spent a great deal of their time feeding elsewhere, particularly in the flooded fields and drains of the irrigation system; cultivated rice and water couch, which are characteristic of these areas, were prominent in the diet. On the other hand, the hardheads in Barrenbox swamp were able to secure most of their food from Mirrool Creek, drains, and the swamp, and had little need to forage in the fields.

X. Blue-billed Duck

(*a*) *Material*

The collection was begun in September 1962 and terminated in April 1967; 546 adult birds were collected. Each month throughout the period was represented, but from January to July each year, when most of the birds had migrated south from the region, only small numbers were available. Nevertheless, in each of these months more than five were collected, except in November 1962 when only three were available.

(*b*) *Composition of Food*

The average composition of the food each month is shown in Table 10. Nearly equal proportions of plant (53·4%) and animal (46·6%) material were found in the gizzards. Animal items were found in 96·7% of the birds and plant material in 100%.

The plant material comprised the seeds and leaves of a wide variety of plants but no single plant or family was of overriding importance. The plants characteristic of deep water were the most common and provided the greatest bulk. They were in 94·9% of the birds and contributed 18·0% of the total volume. Half of this quantity was made up of *Ceratophyllum demersum* and this was found in 49·7% of the sample. The seeds of cumbungi had been collected from the water by 69·7% of the birds and made up 7·7% of the volume. Lesser quantities of other plants from the deep permanent areas of the swamp were also found, e.g. *Najas marina* (27·8% occurrence), *Potamogeton*, mainly *P. pectinatus* (19·0% occurrence), and *Vallisneria gigantea* (34·1% occurrence).

The other groups of plants characteristic of the most permanent waters, the Chlorophyceae, Azollaceae, and Haloragaceae, were also eaten in considerable quantities each month, but because of their delicate nature some were probably underestimated on the basis of volume percentage. The green alga *Spirogyra* was found in 13% of the birds (0·9% volume) and *Chara* in 14·9% (1·0% volume);

TABLE 11

COMPOSITION OF FOOD OF BLUE-BILLED DUCKS FROM SEPTEMBER 1962 TO SEPTEMBER 1966

Data expressed as percentage of total volume of gizzard contents and as percentage occurrence

Food		1962/63	1963/64	1964/65	1965/66
Plants					
Dry-land	Volume	5·0	7·5	4·3	5·2
	Occurrence	60·1	72·1	65·9	28·6
Edge	Volume	3·1	8·7	7·4	9·1
	Occurrence	47·3	58·4	69·5	67·1
Floating	Volume	14·0	19·4	11·0	12·5
	Occurrence	74·0	70·4	60·1	52·7
Littoral	Volume	16·2	9·6	6·4	4·7
	Occurrence	75·5	66·8	61·3	27·1
Deep-water	Volume	6·6	11·3	25·7	22·7
	Occurrence	86·4	96·1	98·6	96·5
Animals					
Crustacea	Volume	0·7	0·8	1·5	1·3
	Occurrence	17·5	17·7	29·6	33·0
Insecta	Volume	52·6	41·3	41·8	43·6
	Occurrence	100·0	99·3	100·0	92·9
Mollusca	Volume	1·2	0·7	0·3	0·1
	Occurrence	23·6	2·9	7·0	3·8
Other animals	Volume	0·6	0·7	1·6	0·8
	Occurrence	4·4	9·2	30·9	19·8
Total plant food	Volume	44·9	56·5	54·8	54·2
	Occurrence	100·0	99·3	100·0	100·0
Total animal food	Volume	55·1	43·5	45·2	45·8
	Occurrence	100·0	99·3	100·0	93·6
Number of birds		58	101	169	135
Number of samples		8	9	11	10

Azolla was found in 58% of the birds (5·1% volume). The subemergent *Myriophyllum propinquum* was consistently eaten each month and in some samples was found in as many as 92% of the birds and made up 22% of the food. Overall, it was found in 43% and provided 6·9% of the total food.

The plants mentioned would have been collected from the surface of the water or immediately below it and to these must be added the floating seeds of several

dry-land plants, probably swept into the swamp from irrigation channels. These included *Echinochloa crus-galli* (5·1% occurrence), *Medicago polymorpha* (21·6% occurrence), *Trifolium subterraneum*, *T. repens*, and *T. tomentosum* (7·1% occurrence), *Atriplex* (1·8% occurrence), and *Chenopodium pumilio* and *C. nitrariaceum* (10·1% occurrence). None provided more than 2% of the volume of food.

The edge and littoral plants of which the seeds were eaten included *Carex* (11·7% occurrence), *Scirpus validus* (13·1% occurrence), *Polygonum* (54·0% occurrence) which provided 5·9% of the food and included *P. aviculare*, *P. hydropiper*, *P. lapathifolium*, *P. minus*, and *P. plebeium*, and small quantities of *Marsilea*, *Rumex*, and *Cyperus*.

The animal food was almost entirely of insect material. Of the total 46·5% of the volume, 43·8% was made up of these animals, which were found in 96·6% of the birds. Half the total insect food consisted of the larvae of Chironomidae; they were in 79·1% of the birds and comprised 23·9% of the total food. They were found in large numbers in every sample, and in some cases occurred in every bird and made up as much as 46% of the volume of food. Other larvae were important and included those of Trichoptera (64·9% occurrence), Zygoptera (26·8% occurrence), and Anisoptera (16·6% occurrence). There were also a few larvae of Ephemeroptera. Insect larvae made up 37·3% of the total volume of food or 85% of the total insects.

The remainder of the insect component of the diet was of Hemiptera (5·3% of the volume) and Coleoptera (2·0%). Among the bugs were *Sphaeroderma rusticum*, *Naucoris congrex*, *Corixa eurynome*, *Micronecta batilla*, and *Arctocorisa*, and among the beetles were *Ilybius fenestratus*, *Noterus*, *Hydrophilus latipalpus*, and *Berosus australasiae*. These were eaten by all the other ducks studied.

The minute Cladocera (21% occurrence), Copepoda (3·7% occurrence), and the mites Hydracarina (6·5% occurrence) contributed little to the total volume of food. The Mollusca included the same items as most other ducks, the mussel *Corbiculina permena* (5·8% occurrence) and the snails *Physastra* and *Glyptanisus* (2·6% and 1·4% respectively). Freshwater sponges (*Spongilla*) were found in 1·7% of the birds but contributed little to the volume of food.

(*c*) *Seasonal Variation*

Table 11 summarizes the composition of the food in each year and Figure 4 illustrates the composition for the whole period.

The relative proportions of plant and animal food were very constant in the different years. The mean annual percentage of animals in the diet varied only from 43·5% to 55·1%. Despite this, however, there were significant variations in the amount consumed in different months during each year (Fig. 4). In some months very little animal food was eaten but in others all birds ate some insects, and they comprised 80% of the total food. There were obvious peaks in the consumption of midge larvae, which formed a major part of the diet in autumn and winter 1963, in late spring and summer 1963/64, and in late winter through to summer 1964. Throughout 1965 and 1966, midge larvae were moderately important in the diet. Not enough is known of the biology of the Chironomidae to explore usefully the

reasons for their varying importance in the diet of the ducks; however, it could feasibly be related to a variation in abundance.

There were similar variations in the groups of plants eaten from time to time, and many of the differences could be explained by changes in the water level. In 1963, the year of very high water, greater quantities of land plants (29·0%) and smaller quantities of deep-water plants (6·3%) were eaten than in any other year. In 1965, the year of lowest water, the plant food was characterized by the greatest quantities of deep-water plants (29·0%) and the smallest quantities of land plants (3·3%). As might be expected, the littoral and edge plants were eaten in quantity only at the times of highest water level, the summers of 1963 and 1966; in 1964 when the water level was low throughout the summer, they were hardly ever eaten. These differences were also obvious during each year; in the winter when the water was low, the amount of deep-water flora eaten increased significantly, and in spring and summer, as the water rose and later stabilized, there was a sharp increase in consumption first of edge and littoral plants and later of land plants.

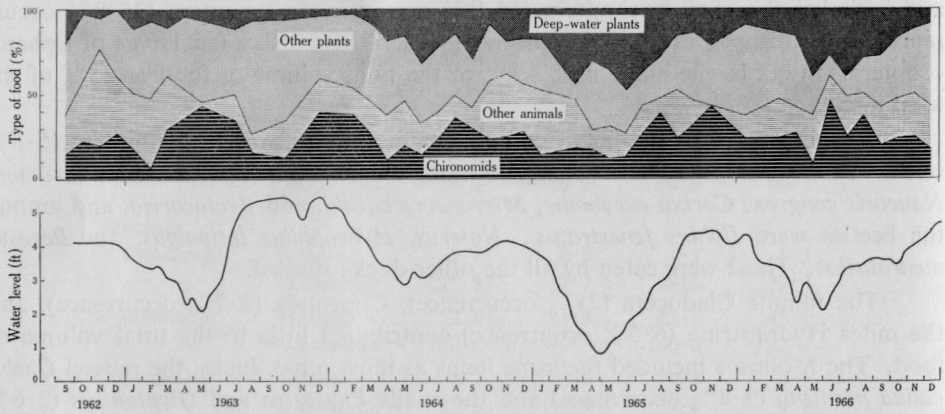

Fig. 4.—Composition of food by volume of the blue-billed duck each month and variation in water level from September 1962 to December 1966.

There seems little doubt that variations in the diet of the blue-billed duck from time to time resulted from the availability or the scarcity of different classes of food, ultimately caused by fluctuations in water level.

(*d*) *Food of the Young*

The food of downy young, immature birds, and adults collected at the same time and in the same places is shown in Table 12. Immature birds were those which were fledged except for the primaries and which retained some down on the body. The data are restricted to those items that were found in 10% or more of any one age group.

The diet was similar in each age group but there was a tendency for the young birds to eat more animal material than the adults.

The composition of the plant and animal food was similar in each age group. Among the plants, none was outstandingly important, but a wide variety characteristic of deep water and the stabilized littoral was eaten in similar quantities by each age group. Among the animals, the larvae of Chironomidae and Trichoptera retained their outstanding importance in the diet.

TABLE 12

COMPOSITION OF FOOD OF BLUE-BILLED DUCKS OF DIFFERENT AGES AT BARRENBOX SWAMP

Food	Downy Young		Immature		Adult	
	Volume (%)	Occurrence (%)	Volume (%)	Occurrence (%)	Volume (%)	Occurrence (%)
Plants						
Carex	0·3	7·4	0·5	10·0	0·3	9·9
Scirpus	0·3	14·8	0·4	5·0	1·1	12·8
Polygonum	4·7	48·1	4·1	40·0	5·7	57·3
Azolla	8·0	59·2	3·0	55·0	5·9	65·8
Spirogyra	0·4	18·6	0	0	0·7	12·4
Chara	0·8	14·8	0	0	1·3	14·9
Myriophyllum	2·7	22·2	2·1	25·0	6·7	43·5
Medicago	1·2	18·6	1·0	15·0	1·3	21·2
Chenopodium	0·4	7·4	0·3	10·0	0·5	14·1
Heliotropium	2·5	11·1	0·5	5·0	0·1	1·7
Cirsium	0·8	11·1	1·4	30·0	2·5	38·3
Typha	8·8	55·6	6·7	60·0	8·5	74·7
Najas	1·7	7·4	0·5	5·0	3·3	18·5
Potamogeton	0·8	11·1	1·0	20·0	1·4	16·4
Vallisneria	0·6	7·4	2·1	30·0	3·2	38·5
Ceratophyllum	6·0	55·6	10·5	50·0	8·2	43·7
Animals						
Cladocera	2·0	29·6	1·5	35·0	1·2	24·6
Hydracarina	0	0	0·5	10·0	0·6	11·7
Chironomidae	30·5	92·6	30·3	95·0	26·7	78·8
Trichoptera	14·9	63·0	6·2	60·0	8·6	62·3
Zygoptera	1·4	33·3	3·5	65·0	1·9	38·8
Hemiptera	6·9	69·2	11·0	80·0	5·1	56·6
Coleoptera	11·1	0·9	3·2	35·0	1·6	26·1
Spongilla	1·6	29·6	1·0	10·0	0·8	15·5
Total plant food	40·3	100·0	39·7	100·0	52·4	100·0
Total animal food	59·7	100·0	60·3	100·0	47·6	100·0
Number of birds	27		20		130	

XI. MUSK DUCK

(*a*) *Material*

Collection of the samples began in September 1962 and continued until April 1967. Until November 1964, however, the gizzards were not analysed on a volumetric basis and the data were restricted to the percentage occurrence of the various food items. The full analysis is confined to the period between November 1964 and April 1967, and includes 399 birds. In the discussion based only on frequency of occurrence the full sample of 813 gizzards of adult birds is used.

TABLE 13

FOOD FOUND IN GIZZARDS OF 399 MUSK DUCKS COLLECTED AT BARRENBOX SWAMP FROM NOVEMBER 1964 TO APRIL 1967

Data expressed as percentage of total volume of gizzard contents for each month

Food	Jan.	Feb.*	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Mean
Plants													
Chlorophyceae	0·5		1·0	0·5	0·5	0	0	1·0	1·0	1·5	1·3	0·5	0·7
Characeae	2·0		0·5	0·5	0	1·0	3·0	0	1·5	1·5	0·7	0	1·0
Marsileaceae	2·0		1·5	0·5	1·5	1·0	1·5	3·5	3·0	2·0	1·7	2·0	1·8
Azollaceae	1·0		1·5	1·0	2·0	0·5	1·0	0·5	5·5	2·5	1·3	1·0	1·6
Typhaceae	1·5		1·5	1·5	9·5	14·5	20·0	9·0	8·0	6·0	5·0	1·5	7·1
Potamogetonaceae	4·5		5·0	12·5	4·0	4·5	9·5	5·0	9·0	3·0	1·7	6·5	5·9
Najadaceae	3·5		1·0	0·5	1·0	5·0	0·5	7·5	1·0	0·5	0·3	0	1·9
Ceratophyllaceae	1·0		4·0	5·0	10·0	5·0	1·0	2·0	1·0	0·5	0·3	0·5	2·8
Other plants	5·0		4·0	5·5	6·0	7·5	3·0	6·0	8·0	3·0	1·5	0·7	4·6
Animals													
Crustacea	12·0		3·0	29·0	12·0	8·0	10·5	6·0	8·0	16·0	6·7	7·5	10·8
Insecta													
Odonata	6·0		11·0	4·5	10·0	12·5	13·0	7·0	13·0	15·5	12·7	8·0	10·3
Hemiptera	36·0		36·0	16·5	22·5	28·5	17·5	10·0	12·5	24·5	30·2	36·5	24·6
Coleoptera	5·5		1·5	2·5	4·5	3·0	6·0	3·0	5·5	3·0	6·3	0	3·7
Trichoptera	3·5		4·5	3·5	1·0	1·5	1·5	5·5	7·0	1·5	6·0	3·0	3·5
Diptera	0·5		0	0	0·5	0	0	8·0	1·5	0·5	0·7	0	1·1
Other insects	0·5		1·5	0·5	0·5	0	1·0	0	0	0	0	0	0·3
Total insects	52·0		54·5	27·5	39·0	45·5	39·0	33·5	39·5	45·0	55·9	47·5	43·5
Mollusca	14·5		16·5	14·0	13·5	4·5	10·5	25·5	12·5	17·5	20·3	28·5	16·2
Other animals	0·5		6·0	2·0	1·0	3·0	0·5	0·5	2·0	1·0	3·3	3·8	2·1
Total plant food	21·0		20·0	27·5	34·5	39·0	39·5	34·5	38·0	20·5	13·8	12·7	27·4
Total animal food	79·0		80·0	72·5	65·5	61·0	61·0	65·5	62·0	79·5	86·2	87·3	72·6
Number of birds	34		22	22	31	46	37	41	36	46	56	28	399

* No sample.

(b) Composition of Food

The composition of the food is shown in Table 13.

The food eaten in the period November 1964 to April 1967 consisted of 72·6% animal material and 27·4% plant material. Animals were found in 98% of the birds and plants in 80%.

Of the animal food, about 60% was derived from the insects which provided 43·5% of the total food. Of the insects, the Hemiptera were the most important group; they were found in 64·2% of the birds and made up 24·6% of the food. The Corixidae provided 11·1% of the total food and were found in 52% of the birds. The insects involved were those eaten by most other ducks, *Corixa eurynome* (4·9% volume), *Micronecta batilla* (2·9%), and *Arctocorisa* (3·9%). The large bugs of the family Belostomatidae were prominent; *Sphaeroderma rusticum* accounted for 11·5% of the volume (36·0% occurrence) and in some months made up as much as one-quarter of the total food; *Naucoris congrex* made up a further 1·5% of the volume.

Unlike the blue-billed duck, the musk duck did not secure many larvae of Chironomidae which accounted only for 1·1% of the volume of food. They did, however, secure considerable numbers of larvae of dragon-flies; the Zygoptera provided 5·4% of the volume and were found in 28% of the birds; the Anisoptera were found in 4·8% (25% occurrence). The larvae of Trichoptera provided 3·5% of the volume (24% occurrence).

The microscopic Crustacea—Copepoda, Cladocera, and Ostracoda—were rarely found, but the large crayfish, *Cherax albidus*, was an important food source and provided 4·9% of the food (19% occurrence). The shrimp, *Caridina mccullochi*, was equally important, making up 4·4% of the volume (19% occurrence). In some months the shrimps and crayfish together provided 30% of the food of the sample.

The most important molluscs were the snails, *Physastra*, which provided 9·7% of the food (25% occurrence). With the other ducks, mussels were the main mollusc eaten. However, freshwater mussels were also eaten by musk ducks and occurred in 19% of the birds, making up 5·3% of the volume. Some of the mussels were very large and measured up to 3 in. long and 1½ in. wide.

Musk ducks also ate several kinds of animal material not found in other birds. Included were fish, found in 3% of the birds and including western carp gudgeon (*Carassiops klunzingeri*), catfish (*Tandanus tandanus*), mosquito fish (*Gambusia affinis*), and smelt (*Retropinna semoni*); some specimens were 4 in. in length. Frogs (Anura) were eaten both as adults and tadpoles, and were found in 3% of the birds. One musk duck was found to contain three downy ducklings of the hardhead (*Aythya australis*).

Most of the plant food was from plants characteristic of deep water. The most important single plant was cumbungi, which provided 7·1% of the total food and was found in 45·2% of the birds. Both the seeds collected from the water and leaf bases stripped from the growing plants were eaten. The seeds and leaves of *Potamogeton* were found in 25% of the birds and provided 5·9% of the food. Other deep-water plants eaten included *Najas marina* (1·9% volume), *Ruppia* (0·5%), *Vallisneria* (0·4%), and *Ceratophyllum demersum* (2·8%). Most of the remaining plant food was made up of plants of the littoral and of floating plants; the most important were *Polygonum* (0·9%), *Marsilea* (1·8%), *Azolla* (1·6%), Chlorophyceae,

TABLE 14

PERCENTAGE OF MUSK DUCKS IN BARRENBOX SWAMP THAT FED ON DIFFERENT FOOD SOURCES FROM 1963 TO 1966

Food	1963	1964	1965	1966
Plants				
Dry-land	37·3	36·5	26·8	17·1
Edge	41·0	38·6	35·5	37·6
Floating*	—	—	42·8	22·4
Littoral*	—	—	30·9	8·9
Deep-water	46·9	49·8	81·4	75·5
Animals				
Crustacea	58·2	44·9	36·5	42·9
Insecta	86·6	92·7	85·8	80·9
Mollusca	40·8	40·0	35·4	41·6
Other animals				
Total plant food	72·2	80·0	93·3	82·8
Total animal food	98·0	96·0	100·0	99·0

* As some of these plants were not adequately identified in the musk ducks in 1963 and 1964, they have been excluded.

mainly *Spirogyra* (0·7%), *Chara* (0·9%), and *Myriophyllum* (0·8%). Dry-land plants were rarely found except for an occasional seed of a grass or legume that had presumably been swept into the swamp.

(*c*) *Seasonal Variation*

Table 14 shows the percentage of the birds that fed on different groups of food items in each year, and Table 15 shows the composition of the food in 1965 and 1966. It is apparent that the composition varied little from year to year. In

TABLE 15

COMPOSITION OF THE FOOD OF MUSK DUCKS IN BARRENBOX SWAMP IN 1965 AND 1966

Food	1965		1966	
	Volume (%)	Occurrence (%)	Volume (%)	Occurrence (%)
Plants				
Dry-land	1·2	26·8	1·8	17·1
Edge	3·7	35·5	3·6	37·6
Floating	3·7	42·8	1·6	22·4
Littoral	3·4	30·9	0·7	8·9
Deep-water	15·6	83·9	13·7	92·9
Animals				
Crustacea	8·2	36·5	10·4	42·9
Insecta	44·4	85·8	40·1	80·9
Mollusca	10·1	35·4	19·0	41·6
Other animals	9·7	2·7	9·1	2·0
Total plant food	27·6	93·3	21·4	82·8
Total animal food	72·4	100·0	78·6	99·0

1965 and 1966, the years for which percentage volume is available, the proportion of animal food varied only from 72·4% to 78·6%, and throughout the study the percentage of birds that included animals in their diet varied only from 96% to 100% in the individual years.

The use of plant material, however, was more variable. In 1963 and 1964, 46·9% and 49·8% of the birds fed on deep-water plants, but in 1965 and 1966 the figures were 81·4% and 75·8% respectively. It is reasonable to suppose that this difference was related to the differences in the level of the swamp in those years. In 1963 and much of 1964 it was high, the edges and littoral were deeply flooded

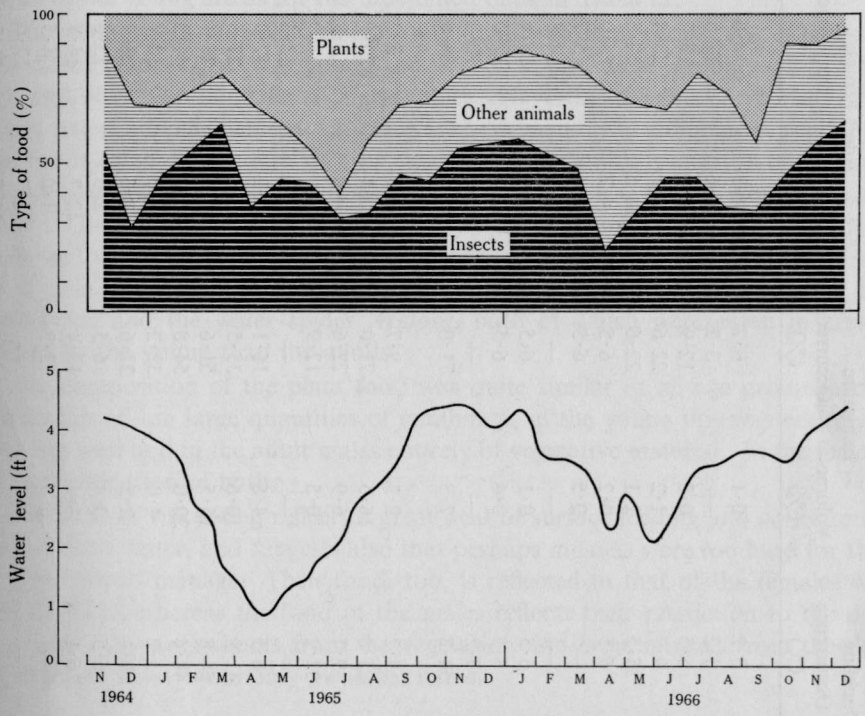

Fig. 5.—Composition of food by volume of the musk duck each month and variation in water level from November 1964 to December 1966.

and luxuriant growth grew in the less permanent parts as well as in the deeper centre. In 1965, however, the swamp fell to an unusually low level and the shallower parts were replaced by extensive mud flats. These were covered again for part of 1966 but little permanent vegetation developed. At times of low water the birds remained in the most permanent parts of the swamp where the only plants available were cumbungi and other deep-water flora; at times of high water level they fed over a greater area and secured a wider variety of plant food. For example, in 1963 at high water level, 37·3% of the birds had eaten plants that normally grow on dry land but in 1966 only 17·1% had secured these items. It can be seen in Figure 5 that there was a tendency for more plants to be eaten in the winter when the water level was low.

	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)
Plants								
Chlorophyceae	—	3·2	0·1	9·7	1·3	13·6	1·2	16·7
Chara	0·2	3·2	—	3·2	1·6	12·5	1·4	10·0
Marsilea	0·6	6·5	0·3	12·9	1·0	18·2	3·6	30·0
Azolla	0·9	9·7	1·2	22·6	2·5	28·4	2·5	20·0
Typha	10·9	35·5	2·1	22·6	14·6	52·3	11·4	43·3
Potamogeton	0·7	6·5	0·2	6·5	4·7	25·0	4·8	26·7
Ruppia	—	—	0·5	6·5	0·4	5·7	1·3	10·0
Vallisneria	—	—	—	—	0·3	4·5	0·9	13·3
Polygonum	0·5	6·5	0·1	6·5	0·9	13·6	0·4	8·3
Ceratophyllum	0·5	6·5	0·4	6·5	1·2	17·0	1·9	16·7
Medicago	0·3	3·2	—	—	0·5	10·2	0·4	13·3
Total plant food	14·8	54·8	7·3	71·0	30·9	89·8	33·8	86·7
Animals								
Anura	0·6	3·2	2·3	9·7	0·5	2·2	1·7	5·0
Cherax	8·1	25·8	16·5	71·0	7·1	23·9	0·8	10·0
Caridina	1·5	9·7	6·9	22·6	4·0	15·9	0·3	3·3
Arctosa	7·6	32·2	0·5	12·9	—	—	—	—
Chironomidae	—	—	—	—	1·1	13·6	0·6	6·7
Trichoptera	1·6	6·5	4·6	16·1	2·2	17·0	3·1	25·0
Odonata—Zygoptera	17·3	41·9	10·6	35·5	6·6	27·3	3·2	20·0
Odonata—Anisoptera	18·8	54·8	15·5	51·6	6·8	26·1	5·7	20·0
Sphaeroderma	20·1	48·4	20·0	54·8	16·2	44·3	1·6	13·3
Corixa	1·0	3·2	4·0	32·2	4·5	30·7	7·1	20·0
Arctocorisa	3·2	19·4	2·5	22·6	3·6	23·9	3·8	25·0
Micronecta	0·3	6·5	0·4	6·5	2·5	13·6	0·2	6·7
Hydrophilus	3·5	16·1	4·4	19·4	2·7	14·8	0·9	5·0
Berosus	—	—	0·6	3·2	1·0	4·5	1·1	10·0
Corbiculina	—	—	—	—	3·7	17·0	10·3	31·7
Physastra	—	—	—	—	10·5	31·8	20·3	40·0
Glyptanisus	—	—	—	—	1·6	9·1	4·1	15·0
Total animal food	85·2	96·8	92·7	100·0	69·1	100·0	66·2	96·7

(*d*) *Food of the Young*

The young of musk ducks are, to a large extent, fed by the female (Frith 1967). After hatching, the brood is led to the edge of the cumbungi and then much of their food is brought up from deep water by the female. The young remove it from her bill. At this time the males remain in their territories in the deepest parts of the swamp. Under these conditions, it would be expected that the males and females would have different foods available to them.

The food of the young and of the adult females collected with them, or in the same place, and of the adult males collected in the same period is shown in Table 16. The ages of the young are as for the blue-billed duck in Table 12.

The young were more dependent on animal food than the adults; it made up 85·2% of the volume in downy young and 92·7% in part downy young compared to 69·1% and 66·2% in adult females and males. Nevertheless, almost all birds of all ages had eaten animal material. There were very significant differences among the animal foods eaten. The adults of both sexes ate considerable quantities of molluscs, 15·8% of the volume in females and 34·7% in the males, but no young ate this material. The young ate many more dragon-fly larvae than the adults, 36·1% of the volume for downy young and 26·1% in part downy young, compared to 13·4% and 8·9% in adult females and males. There was a similar pattern with the bug *Sphaeroderma* and the water spider *Arctosa*, both of which were eaten in greater quantities by the young than the adults.

The composition of the plant food was quite similar in all age groups except that although all ate large quantities of cumbungi, in the young this was entirely of the floating seed and in the adult males entirely of vegetative material. In the females it was a combination of both.

The food of the young reflects a great deal of surface feeding and collection of food in shallow water, and suggests also that perhaps mussels were too hard for their small soft bills to manage. Their food, too, is reflected in that of the females who were with them, whereas the food of the males reflects their restriction to the deep water where cumbungi shoots from the vegetation and large mussels from the deep water were the most commonly available items.

XII. Comparisons among Species

The number of plant and animal species in a single swamp is limited and, as has been shown in the preceding discussion, the number of species that are important food items is even more limited. Where several species of waterfowl, including closely related species, coexist in the same swamp, the possibility of competition between them for food must be seriously considered. Cumbungi swamps are the major drought refuge areas of the inland, and their ability to support large mixed populations of waterfowl for long periods is crucial to the survival of these populations.

When food is superabundant there is no competition and a number of waterfowl may utilize a common abundant food. At other times there may be competition between waterfowl species for the same food plants, when large numbers of different species feed together, often in mixed flocks within the one swamp.

Some species can avoid competition because of characteristics of their general ecology, such as differences in mobility, and this has been illustrated by the grey teal and the black duck (Frith 1963). Competition may be reduced through utilization of different food items, selection being determined to some extent by the bird's behaviour when searching for food and its structure, particularly its bill, both of which determine its ability to collect and utilize different foods. The birds can also select different feeding areas, different habitats in the swamp, different parts of the swamp, or depths of water. Some of these factors can be examined as they applied in Barrenbox swamp in the present study.

(*a*) *Feeding Methods*

The methods used by each species to collect food have been described (Frith 1959*b*, 1967) but it is useful to compare some of the details briefly.

The black swan feeds in water by grazing emergent and subemergent plants or by filtering food from the water's surface. It occasionally stands in shallow water but prefers greater depth in order to float. Its strength enables it to uproot plants too tough for other waterfowl and its size allows it to reach food farther above the surface; it also has sufficient power to strip the leaves from the tough cumbungi. By upending it can reach the bottom or subemergent plants 3 ft from the surface and thus can compete in its food search with all waterfowl except the hardhead, musk duck, and blue-billed duck.

The hardhead, musk duck, and blue-billed duck are adept at diving to the bottom of deep water, and so have food resources that are not available to the surface-feeding waterfowl. There are no data on the ultimate depths the three species can reach but it is known that the greatest depths in Barrenbox swamp are not sufficient to separate them. There are obvious differences in the mobility of the three species and also in their structure, and it will be shown that these are important in the ecological separation of the three diving ducks.

The four surface-feeding ducks, i.e. the black duck, grey teal, shoveler, and pink-eared duck differ greatly in their feeding methods. All can dabble in mud or shallow water, upend, strip seeds from plants, or filter material from the surface of the water. However, the black duck secures whole inflorescences more commonly than the grey teal, which specializes in picking up fallen seed (Frith 1959*b*). The shoveler and pink-eared duck specialize in filter feeding from the surface or just below it. However, the pink-eared duck virtually restricts its feeding to filtering, whereas the shoveler uses the other methods just as frequently as it filters. The lamellae on the bill of the pink-eared duck are finer and more numerous than those of the shoveler, so it can collect much smaller items in quantity (Frith 1959*b*, 1967).

(*b*) *Feeding Habits*

Table 17 summarizes the authors' impressions of the frequency with which the various waterfowl used the different parts of the swamp as feeding places. These impressions are fully confirmed by the composition of the food reported for each species in the previous sections of this paper.

It can be seen that the major divisions of the swamp and its surroundings provided the first separation of the species by their food. The grey teal was the only duck to make extensive use of the irrigated fields, although the black duck was also a frequent visitor. Thus, these two species used a food source not easily available to any other species. Within the swamp there were small differences in the habitat of the two; whereas black ducks were very commonly found feeding in permanent cumbungi areas and among rushes and sedges, grey teal were less commonly found there, and then were usually resting, not feeding.

TABLE 17

FEEDING HABITATS OF WATERFOWL AT BARRENBOX SWAMP, N.S.W.

(E, extensive; F, frequent; O, occasional; R, rare; N, not used)

Species	Swamp Habitats			Watercourses	Fields	
	Permanent Cumbungi	Rush and Sedge	Littoral		Irrigated	Dry
Black swan	E	E	E	F	R	R
Freckled duck	E	F	E	R	R	N
Black duck	E	E	F	E	F	R
Grey teal	F	O	F	F	E	R
Shoveler	F	E	E	O	O	R
Pink-eared duck	E	R	R	R	O	N
Hardhead	E	R	R	E	O	N
Musk duck	E	R	O	F	N	N
Blue-billed duck	E	R	F	O	N	N

The black duck and hardhead were able to use the relatively swiftly flowing Mirrool Creek more than any other species, although the black swan, grey teal, and musk duck were frequently found there. Within the swamp, however, although the black duck and the hardhead were equally abundant in the permanent cumbungi areas, the hardhead was seldom found on the edge or in the littoral, which were extensively used by the black duck.

The differences between the feeding places of the black swan and the freckled duck were not great. However, there was considerable separation in the time the different habitats were used. The black swan, for example, preferred to feed on the new growth in the littoral zone as the water level rose and stabilized in spring and summer. In late summer, however, as the water level fell and the vegetation began to die, it became unattractive to swans but highly attractive to freckled ducks, which fed on the fruits. Similarly, the two stiff-tailed ducks, the musk duck and the blue-billed duck, were found in very much the same situation, except that the latter was much more commonly encountered feeding in relatively shallow water.

The two shovel-billed ducks, the pink-eared duck and the shoveler, chose very different feeding locations. The pink-eared ducks were nearly always found in deep water and were closely associated with places where there was much rotting cumbungi floating on the surface. They seldom came inshore to feed at night. On the other hand, the shovelers were usually found between the edge of the cumbungi and the shoreline, and mostly on the edge of the swamp or in the flooded littoral.

TABLE 18

UTILIZATION OF DIFFERENT FOOD GROUPS BY WATERFOWL COLLECTED AT BARRENBOX SWAMP FROM APRIL 1966 TO MARCH 1967

Data expressed as percentage of total volume of gizzard contents and as percentage occurrence

Food		Black Swan	Freckled Duck	Black Duck	Grey Teal	Shoveler	Pink-eared Duck	Hardhead	Musk Duck	Blue-billed Duck
Plants										
Dry-land	Volume	7·3	3·9	23·1	32·4	4·3	5·9	6·3	2·1	4·5
	Occurrence	9·9	17·2	40·2	54·0	28·0	21·8	29·1	18·1	39·1
Edge	Volume	4·0	12·3	24·3	20·6	5·7	4·1	10·2	3·9	13·6
	Occurrence	8·1	50·0	50·3	52·5	27·4	23·9	47·8	36·3	68·3
Floating	Volume	31·3	5·9	10·5	22·7	14·7	18·0	9·1	1·4	9·6
	Occurrence	44·8	24·6	32·9	45·8	49·0	54·2	44·1	18·3	42·4
Littoral	Volume	5·1	20·6	3·5	0·7	1·9	0·6	1·3	0·5	2·7
	Occurrence	12·5	50·4	10·4	7·8	8·3	6·3	8·4	5·0	17·2
Deep-water	Volume	52·3	53·4	20·1	10·7	18·6	17·6	32·7	16·1	23·8
	Occurrence	62·8	90·0	43·1	31·0	54·8	59·9	76·9	67·3	91·7
Animals										
Crustacea	Volume	0	0·2	0·4	0·7	6·6	31·4	0·2	14·0	2·2
	Occurrence	0	3·0	2·0	5·3	22·3	56·2	4·8	41·9	28·8
Insecta	Volume	0	2·7	12·6	10·3	27·2	18·5	12·8	39·8	42·6
	Occurrence	8·1	33·3	42·9	46·3	73·9	58·3	53·9	86·9	88·2
Mollusca	Volume	0	0	5·1	1·8	20·5	0·5	27·2	18·8	0·5
	Occurrence	1·6	0	13·3	5·4	38·9	4·0	54·8	39·4	5·1
Other animals	Volume	0	1·0	0·4	0·1	0·5	3·4	0·2	3·4	0·5
	Occurrence	0·9	4·1	2·8	2·0	8·3	93·7	8·6	10·6	10·2
Total animal food	Volume	0	3·9	18·5	12·9	54·8	53·8	40·4	76·0	45·8
	Occurrence	9·7	38·4	46·9	50·8	93·6	88·0	83·0	98·5	88·2
Total plant food	Volume	100·0	96·1	81·5	87·1	45·2	46·2	59·6	24·0	54·2
	Occurrence	100·0	100·0	97·8	99·7	86·0	95·0	90·8	81·0	100·0

(c) *Food and Feeding*

Table 18 compares the different floras used by the various waterfowl. Table 19 compares the plant food of the waterfowl on the basis of the families of plants used as sources of food.

In order to increase the validity of the comparisons, where the data are adequate, only the period April 1966 to March 1967 inclusive is considered. Species are the black swan, black duck, grey teal, hardhead, musk duck, and blue-billed duck. Where the samples in the period were not adequate, the whole sample is used in the comparison. Species are the freckled duck, shoveler, and pink-eared duck.

It is apparent from Table 18 that each species, at times, fed over the whole area and secured food from each ecological grouping of food items. Most individuals of each species collected some plant food, the shoveler and musk duck showing the lowest values, where only 86·0% and 81·0% of the birds sampled had used this material. There were greater differences in the species' consumption of animal food. Although 15% of adult black swans consumed some animal material, this was considered accidental, whereas almost all musk ducks, shovelers, and pink-eared ducks, 98·5%, 93·6%, and 88·0% respectively, ate some animals. Those species which did so least frequently were the grey teal (50·8% occurrence), the black duck (46·9%), and the freckled duck (38·4%).

Table 19 shows that all the waterfowl fed on the same groups of plants and animals but each group was of different value to each species. For example, only black swans and freckled ducks fed to any great extent on algae, and then the former favoured the Chlorophyceae and the latter the Characeae; the grasses were of much greater importance to the black duck and grey teal than to any other duck, as were the sedges and smartweeds; the three diving ducks were the only waterfowl that obtained considerable quantities of food from the Mollusca; and the small Crustacea were largely the province of the pink-eared duck.

(i) *Black Swan.*—Black swans fed throughout the swamp, in all the associated habitats, and were also prepared to graze out from the water's edge. Table 18 shows that food was taken by significant numbers of swans from each flora. Table 19 shows that the plants eaten were essentially the same for both the black swans and the various ducks. Despite this overlap of food habits, however, there were broad areas of separation where the swans and the ducks differed in their food requirements.

The most obvious difference was that the black swan ate entirely vegetative material, particularly shoots, whereas the ducks ate mainly fruits and seeds. The swans ate no animal food intentionally and, in this respect, were different from all except the freckled ducks; the similarity of these two species will be examined more closely below. The black swan is unable to dive and, although it can reach down from the surface to a depth of at least 3 ft, it cannot secure many items that are available to the diving ducks and the hardhead; hence it cannot compete for a large part of the food of these species. Swans can feed from the surface but cannot filter-feed in the manner of the shoveler and pink-eared duck, hence many small items are available to these birds but not to the swan. Similarly, food more than 12 in. below the surface is available to the swans but not to the shovel-billed ducks.

TABLE 19

COMPARISON OF THE AMOUNTS OF EACH PLANT FAMILY EATEN BY WATERFOWL AT BARRENBOX SWAMP FROM APRIL 1966 TO MARCH 1967

Data expressed as percentage of total volume of gizzard contents and as percentage occurrence

Plant Family	Utilization by Waterfowl																	
	Black Swan		Freckled Duck		Black Duck		Grey Teal		Shoveler		Pink-eared Duck		Hardhead		Musk Duck		Blue-billed Duck	
	Vol.	Occ.	Vol.	Occ.	Vol.	Occ.	Vol.	Occ.	Vol.	Occ.	Vol.	Occ.	Vol.	Occ.	Vol.	Occ.	Vol.	Occ.
Chlorophyceae	26·1	37·1	1·7	12·8	2·4	10·8	6·2	12·3	2·7	10·2	1·5	9·5	5·3	19·8	0·2	3·9	0·7	11·5
Characeae	0·3	1·6	19·0	45·2	0·7	1·4	0·9	1·7	0·7	4·4	0·5	3·3	0·8	4·9	0·3	3·9	0·7	6·1
Marsileaceae			0·1	0·7	1·6	4·9	0·9	5·2	3·5	17·8	0·4	10·9	1·0	11·0	2·1	21·0	3·5	4·3
Azollaceae	4·5	23·5	8·6	20·1	4·8	15·8	10·0	31·4	11·1	41·0	13·9	54·2	3·3	27·5	1·2	16·5	3·3	30·2
Typhaceae	19·4	28·8	10·7	27·6	4·0	10·4	1·3	10·5	5·5	35·7	5·5	3·9	1·9	21·8	6·8	41·8	5·3	56·2
Potamogetonaceae	17·0	22·8	1·9	6·7	5·7	15·4	3·2	12·7	9·3	26·8	3·5	11·3	22·4	53·1	4·4	23·3	4·4	36·8
Najadaceae	2·6	4·3	8·1	25·1	0·8	1·8	0·5	1·1	0·9	4·5	2·9	10·5	3·4	13·8	0·7	10·4	7·0	34·5
Hydrocharitaceae	12·6	15·6			0·7	3·2	0·3	1·1	0·2	2·5		0·8	0·6	5·1	0·2	3·4	0·2	4·9
Gramineae	6·5	8·3	0·4	8·3	16·8	24·5	16·7	29·6	1·1	6·9		8·5	3·0	8·8	0·1	2·3	0·3	3·1
Cyperaceae	2·5	4·8	12·1	47·1	11·1	28·3	10·2	32·4	0·8	5·6	2·6	10·3	4·4	48·8	0·6	4·8	4·4	31·0
Lemnaceae	0·7	1·7			3·2	10·5	6·1	21·3	0·9	10·2	2·6	15·6	0·4	2·8			0·9	12·0
Juncaceae							0·2	0·3							0·1	1·1		
Polygonaceae	1·5	2·3	0·2	3·2	11·4	32·2	9·2	22·5	1·4	8·6	1·1	9·0	4·1	8·4	1·0	16·3	11·2	79·4
Chenopodiaceae			5·0	12·1	0·4	1·0	2·1	4·8	0·2	1·9	1·1	5·8	0·1	1·3		0·5	0·6	6·1
Ceratophyllaceae	0·7	1·3	24·5	68·3	8·7	25·1	5·4	13·8	2·7	8·2	5·7	21·9	4·3	19·6	2·9	26·5	13·4	62·4
Ranunculaceae	1·6	3·9	1·9	11·1	0·7	4·6	0·2	1·3	0·1	1·9	0·1	1·5	0·3	2·3	0·2	1·5	0·6	7·0
Cruciferae					0·1	0·2		0·3		0·6	0·2	1·7						
Leguminosae	0·8	2·7	1·0	6·8	2·0	13·8	7·0	27·8	1·5	13·5	1·8	22·2	0·8	9·0	0·9	9·2	0·8	14·6
Rutaceae							0·1	0·3					0·6	4·3				
Onagraceae					0·1	0·4	0·1	0·4					0·8	2·1				
Haloragaceae	2·7	8·3	0·2	3·2	2·1	4·7	0·5	2·8	1·1	2·5		0·8	0·2	1·6		1·1	1·3	10·1
Convolvulaceae					0·5	5·1	0·8	4·1	1·1	8·9			0·3	2·2	0·1	2·8		
Boraginaceae			1·4	4·2	0·2	0·6	2·5	7·6	0·3	3·8	1·9	11·3	0·1	2·4			0·2	4·5
Cucurbitaceae						0·3	0·4	2·0		0·6			0·2	0·8				
Compositae					2·5	7·8	0·3	1·0		1·9	0·1	0·8	0·3	2·1		1·8	0·8	16·6
Other plants	0·4	0·6			0·4	2·4	1·1	5·7	0·1	3·1	0·2	0·5	1·0	8·6	0·4	4·4	0·2	1·7
Total	100·0		96·8		80·9		86·2		45·2		45·6		59·6		22·2		59·8	

Possible competition by swans seems limited to the freckled duck, the black duck, and the grey teal. The diets of the freckled duck and the black swan were similar. The common characteristics were that neither ate significant numbers of animals, both found a considerable part of their diet in the deep-water flora (52·3% of the volume in the swan and 53·4% in the freckled duck), and neither paid much attention to the dry-land or the edge plants. There were, however, considerable differences in diet. The black swans secured a large part of their food (31·3%) from the floating plants but the freckled duck secured very little (5·9%). Similarly, the freckled duck fed extensively (20·6%) on the littoral but this was less important to the black swan (5·1%). In each species about half the food was secured from the deep-water flora, but within this group there were significant differences in the plants chosen. The algae were eaten by 37·1% of the swans and provided 26·4% of the food; 56·3% of the freckled ducks fed on the algae which provided 20·7% of the food. However, the freckled duck secured mainly *Chara* and the black swan mainly *Spirogyra*. The subemergent *Ceratophyllum demersum* was collected in large amounts (24·5% of the volume) by the freckled ducks but was ignored by the swans. There can be little real competition between the two birds.

The most obvious difference between the black swan and the black duck and grey teal is that the last two birds utilized significant amounts of animal food and the first did not. There were also considerable differences in the plants used. Although the swans did feed on the edge flora, the 4·0% of food they secured there was insignificant compared to the 24·3% and 20·6% secured by the black duck and grey teal. The swan was also more dependent on cosmopolitan plants than the black duck, 31·3% against 10·5%, but the difference between the swan and the grey teal was less, 31·3% against 22·7%. In this case, however, the grey teal collected mainly *Azolla* and *Lemna* (75% of the total); the swan collected mainly algae (81% of the total). Nevertheless, it does seem that there is some utilization of the same food plants by the three species, and that, in time of real stress, this could become competition.

(ii) *Black Duck, Grey Teal, Freckled Duck, and Hardhead.*—The closely related black duck and grey teal selected their food from essentially the same places and utilized the same plants. The frequency of occurrence of food items from the different ecological groupings was quite similar. The black duck did, however, tend to feed in deep water more often than the grey teal. This is shown by the presence of deep-water plants in 43·1% of the black ducks and in only 31·0% of the grey teal, Mollusca in 13·3% of the black ducks and in only 5·4% of the grey teal, and slightly fewer dry-land plants in the black duck (40·2%) than in the grey teal (50·4%). These general differences, however, are not great, and certainly are not sufficient to demonstrate that the two species had significantly different diets in Barrenbox swamp. Consideration of the different plants included in the floras and the animal families utilized also failed to show any striking differences. Table 20 lists those plants that were eaten by more than 8% of the sample of black ducks or grey teal. The value of 8% was chosen arbitrarily to indicate an important food item. It can be seen that the differences in the overall composition of the food of the two species were merely the result of small differences among the separate food items.

There seems little doubt that in the cumbungi swamp the two species were feeding in much the same places, and the differences in the diet recorded reflected slight differences in the feeding niche rather than in the birds' food preferences. It is interesting to note that in the previous study (Frith 1959*b*) over a much larger area, where the two species were able to exercise any preference for habitat and food to the full, considerable differences were shown to exist between the two species. It must be concluded that in drought, when grey teal are forced to remain in the favoured habitat of black ducks, the two species utilize the same foods, and this could feasibly lead to competition.

TABLE 20

RELATIVE AMOUNTS OF IMPORTANT FOODS EATEN BY BLACK DUCKS AND GREY TEAL AT BARRENBOX SWAMP FROM APRIL 1966 TO MARCH 1967

Food	Grey Teal		Black Duck	
	Volume (%)	Occurrence (%)	Volume (%)	Occurrence (%)
Plants				
Carex	2·5	9·5	0·4	2·9
Scirpus	4·3	20·0	9·4	26·5
Azolla	9·7	31·7	4·5	15·8
Lemna	6·0	19·7	2·9	9·7
Spirogyra	5·8	11·8	2·3	10·0
Echinochloa	5·3	8·8	7·3	10·9
Oryza	7·6	13·1	5·2	7·9
Medicago	4·5	20·2	1·2	10·8
Trifolium	2·7	10·5	0·5	6·2
Typha	1·5	10·7	3·8	9·6
Potamogeton	2·2	6·7	3·7	14·3
Polygonum	20·9	9·3	35·6	10·5
Ceratophyllum	5·3	13·6	8·9	2·5
Insects				
Chironomidae	1·7	9·5	0·2	1·5
Trichoptera	3·8	25·0	2·1	3·8
Sphaeroderma	0·1	1·1	3·2	13·0
Naucoris	0·5	3·3	2·0	9·1

The freckled duck is similar in size to the black duck and has similar methods of feeding, except that it more commonly uses filter feeding. The two species were usually found together, but the food they preferred was quite different. The most striking difference was that very few freckled ducks used dry-land plants, 17·2% compared to 40·2% for the black duck and 54·0% for the grey teal. They also fed in the littoral more frequently than the black duck and grey teal, 50·4% compared to 10·4% and 7·8% respectively; and they fed more extensively in deep water than the other two species, 90·0% compared to 43·1% and 31·0%.

In association with this different feeding niche, the food consumed was quite different. Although the proportion of plant and animal food consumed was not strikingly different between the two species, its composition was very varied. Among

the plants, deep-water flora provided 53·4% of the diet of the freckled duck but only 20·1% of that of the black duck. The freckled duck secured 20·6% of the volume of its food from the littoral and the black duck secured only 3·5%. In these situations the freckled duck fed mainly on *Chara* (17·1%), *Typha* (10·7%), and *Najas* (8·1%). These plants were largely avoided by the black duck, providing nil, 4·0%, and 0·8% respectively. However, they both ate quantities of *Ceratophyllum*, 24·5% of the volume for freckled duck and 8·7% for black duck. Algae were of prime importance to the freckled duck but not to the black duck.

The black ducks also ate considerable quantities of animal food, 18·5% of the volume being from this source; animals were not important to freckled ducks and comprised only 3·9% of the diet.

The hardhead feeds in similar situations to the black duck and grey teal, and the percentage of the populations using the plants of the shallower habitats were similar for the three species. However, the hardhead differed sharply from the others in that a greater number also included deep-water plants in their diet; 76·9% compared to 43·1% and 31·0% for the black duck and grey teal respectively. The prevalence of deep-water feeding is also reflected in the numbers of birds eating molluscs, mainly the freshwater mussel: 54·8% for the hardhead against 13·3% and 5·4% for the black duck and grey teal.

(iii) *Hardhead, Musk Duck, and Blue-billed Duck.*—Despite its diving ability the hardhead fed more commonly on dry-land plants and on cosmopolitan aquatic plants than the musk duck and blue-billed duck. Nevertheless, the proportions of the total volume of food provided by the different floras were similar in the three species. The greatest differences in the diet were in the animal food items. The hardheads ate many molluscs (27·2% of the volume), mainly *Corbiculina* and *Physastra*, but fewer insects (12·8% of the volume). The musk duck ate fewer molluscs but made greater use of the insects from deep water, nearly half the total food being from this source. The musk duck was also able to utilize the crayfish, shrimps, and frogs which were not eaten by the hardhead.

The musk duck and the blue-billed duck are similar in respect to where they are found feeding—always in deep water and usually in the densest part of the swamp. Nevertheless, from Table 17 it can be seen that definite differences exist in the feeding place; relatively few musk ducks fed on dry-land plants, edge plants, the cosmopolitan plants, or on the littoral, when compared to the number of blue-billed ducks. The percentages of the population of musk ducks and blue-billed ducks respectively feeding on these groups of plants were dry-land 18·1%, 39·1%; edge 36·3%, 68·3%; cosmopolitan 18·3%, 42·4%; littoral 5·0%, 17·2%. On the other hand, both species fed together in large numbers in the deepest water.

There were distinct differences in the animal food selected. The musk ducks ate many mussels, 18·8% of the total volume of food, but these were very rarely found in blue-billed ducks and only accounted for 0·5% of the food. The musk duck ate many Crustacea, mainly the large crayfish *Cherax*, 4·9%, and the shrimp *Caridina*, 4·4%, but the few Crustacea (2·2%) found in the blue-billed ducks were the microscopic Cladocera and Ostracoda. Even among the insects, which provided 40% of the food of both species, there were striking differences. The blue-billed

ducks apparently specialized on the larvae of Chironomidae; these provided 23·5% of the total food but were rarely eaten by the musk ducks (1·1%). The larvae of Trichoptera were also favoured by the blue-billed duck; 9·7% against 3·5% in the musk duck. Among the insects, the musk duck favoured the larger beetles and bugs but these were less important to the blue-billed duck, shoveler, and pink-eared duck.

(iv) *Shoveler and Pink-eared Duck.*—The shoveler and pink-eared duck are very similar in their selection of feeding place, except that pink-eared ducks rarely dabble in the mud at the edge of a swamp and shovelers habitually do so. In keeping with these feeding habits it follows that the plant food eaten would be similar for both species; similar percentages of each species did feed on each group of plants. Among the animal foods, however, there were considerable differences. Of the pink-eared ducks, 56·2% had fed on crustaceans, mainly microscopic forms, and 40·2% on other microscopic animals; the corresponding figures for the shoveler were 22·3% and 8·3%. The amount of edge feeding done by shovelers compared to pink-eared ducks is illustrated by the frequency of insects and molluscs in the food. The values for the shoveler are 73·9% and 38·9%, for the pink-eared duck 58·3% and 4·0%. The composition of the food eaten differed greatly between the species; in general the pink-eared duck secured smaller items.

XIII. Discussion

The extent of waterfowl habitat in inland Australia varies from year to year. When there is good rainfall on the catchments, hundreds of miles to the east, the lagoons and billabongs remain full, providing adequate breeding and feeding areas for considerable populations. In times of heavy rainfall on the catchments, there are great floods and extensive areas of temporary habitat are created. Here, immense numbers of some waterfowl, e.g. grey teal, black duck, pink-eared duck, and hardhead are bred, but it has been shown that as the temporary waters decline these birds disperse and are unable to survive (Frith 1962, 1963). Other waterfowl, e.g. musk duck, blue-billed duck, and freckled duck, are restricted to the more permanent types of habitat, and their numbers do not fluctuate greatly from year to year as these habitats are largely invulnerable to failures of river flooding. The birds generally do not utilize the large areas of temporary water following floods, and so do not suffer the great fluctuations in numbers that follow the subsequent disappearance of this water.

Waterfowl are, in general, flexible in their habitat, food requirements, and movement patterns, as they must be to cope with the erratic environment. Most are nomadic, but the degree of nomadism varies greatly from species to species. The grey teal and pink-eared duck, for instance, are highly mobile at all times and are able to move over the whole continent, whereas the black duck and hardhead usually undertake only limited movements, and the musk duck is mainly sedentary. In times of drought, however, the movements of all become exaggerated and even the most sedentary species undertake wide and multidirectional movements in search of more reliable refuge.

The different species move at different times in the progress of the drought, the timing being determined largely by their feeding requirements. The movements,

however, although extensive, are no greater than is really necessary to avoid the effects of the drought, and most waterfowl congregate first in the local permanent refuges while these are available and the food in them remains suitable. In some cases, this concentration is sufficient to avoid the effects of the dry weather; in more extreme conditions, however, the birds disperse again to more distant, usually coastal, refuges.

It is apparent that those species usually restricted to the permanent inland refuges, the cumbungi swamps, must suffer periodic invasion of their habitat by very large numbers of other birds of several species, most of which are able to use much the same food. Many of the invaders are highly nomadic species, able to move very widely whenever necessary, and the permanent residents are basically sedentary and less able to travel great distances *en masse* when their food supply is exhausted. Clearly, the permanent residents are potentially at a disadvantage in a crowded swamp.

The work described in this paper was completed during a period of moderately severe drought in the south-east of the continent, and very large numbers of birds congregated in the swamp. However, the data suggest that there was little direct competition for food by the various species. The highly nomadic species in general did not depend on the deep-water flora for food to any great extent. This source of food remained the province of the species normally resident in the swamp, and they were separated from one another by distinct food habits.

The more nomadic waterfowl, which constitute the important game birds of Australia, were to a large extent dependent on the littoral and edge flora for their food. They utilized the deep-water flora significantly only when the littoral zone remained dry, due to a decrease in the level of the swamp, or was not flooded long enough to enable the flora to establish itself. At these times, however, large numbers of birds left the swamp and presumably sought refuge elsewhere, probably on the coast (Frith 1959*c*).

The coastal refuges have been decreased in number and extent by drainage for agriculture and flood mitigation purposes and are now inadequate to support many of the birds from the inland, and in times of big movements of waterfowl from the inland there is a heavy mortality. There is little doubt that the overall mortality of waterfowl in dry weather could be reduced and the size of waterfowl populations more stabilized if more birds could be induced to remain inland at these times, thus lessening the pressure on the coastal refuges.

The data in this paper demonstrate the versatility of cumbungi swamps as waterfowl refuges. They suggest that a practical step towards waterfowl conservation would be quite simple engineering works designed to increase the numbers of cumbungi swamps in the inland by damming some of the larger billabongs to retain water permanently after flooding, the level subsequently being maintained by pumping. Existing cumbungi swamps, the products of irrigation drainage and water conservation works, could be made much more valuable to waterfowl by works to ensure that the littoral zone, the source of most of the food of the nomadic species, was stabilized in periods of dry weather. One possibility might be a simple system of levee banks around the swamp in which an appropriate water level could be maintained by pumping from the deeper parts during critical periods.

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