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THE ECOLOGY OF WILD DUCKS IN INLAND NEW SOUTH WALES

III. FOOD HABITS

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Summary

The food habits of the wood-duck (*Chenonetta jubata* (Latham)), black duck (*Anas superciliosa* Gmelin), grey teal (*A. gibberifrons* Müller), blue-winged shoveler (*A. rhynchotis* Latham), pink-eared duck (*Malacorhynchus membranaceus* (Latham)), and white-eyed duck (*Aythya australis* (Eyton)), are discussed and compared. These six species are the most common, and economically the most important, wild ducks occurring in inland Australia.

It is shown that the numbers of different food items are relatively small, and that all the species studied eat the same materials but in varying proportions.

I. INTRODUCTION

In order to understand the movements, habitat preferences, economic position, and conservation of any species it is essential to know its food habits and preferences.

Cleland (1918), Kinghorn (1932), Lea and Gray (1935), and Frith (1957*a*, 1957*b*) have published fragmentary data concerning the food of some species of wild ducks, but there is no comprehensive study available on the food of even the commonest species.

This paper presents the results of a study of the food habits of six species of wild ducks in inland New South Wales. The study extended over four years, and 3819 gizzards were examined.

II. METHODS

The study was based on the examination of the contents of gizzards collected in the Murrumbidgee, Lachlan, and central Murray regions. In each region a number of regular sampling sites were visited regularly throughout the whole period, and birds were collected at each. Samples were also collected at other places as opportunity offered.

Ideally, for a study of food habits, each gizzard should be collected by the author of the work and relevant data recorded at the time. In a study of this magnitude that ideal was not practicable, but the quality of the collection, for its purpose, is believed to be satisfactory. In the Lachlan region all the birds were collected by the author or his assistants. In the Murrumbidgee region, where the author was resident, all the samples from the regular sites—Tubbo, Kooba, and Toganmain—were collected by the author and his assistants; most of the remainder were secured from the bags of shooting parties met by appointment in the field or on their return. In the Wakool region the great majority of gizzards were collected, under licence, by Mr. E. Ferguson of Deniliquin, who proved himself a very capable

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and reliable collaborator. The author also collected some material there both alone and in Mr. Ferguson's company, and was able to visit and inspect most of Mr. Ferguson's collecting areas later. The author usually collected at dawn, when most of the gizzards were full; the collaborators sometimes collected at dawn but often did not, and frequently the gizzards taken by them were less than half full.

The gizzards were removed from the birds in the field and preserved in 10 per cent. formalin or 50 per cent. alcohol. In the case of all pink-eared ducks and of small numbers of the other species, each gizzard was first injected with 10 per cent. formalin by means of a hypodermic needle.

The treatment of the gizzards in the laboratory and the compilation of the results were, in general, as already described (Frith 1957*a*, 1957*b*). Variations from that procedure were necessary for some species and will be described when discussing the species concerned. Any gizzard judged to be less than one-quarter full was rejected. The final number of gizzards selected as sufficiently full to be examined was 3819, distributed by species as follows:

Wood-duck	*Chenonetta jubata* (Latham)	572
Black duck	*Anas superciliosa* Gmelin	832
Grey teal	*Anas gibberifrons* Müller	2037
Blue-winged shoveler	*Anas rhynchotis* Latham	47
Pink-eared duck	*Malacorhynchus membranaceus* (Latham)	138
White-eyed duck	*Aythya australis* (Eyton)	193

III. Food of the Black Duck and the Grey Teal

(*a*) *Material*

Of 2107 collected gizzards of grey teal and 892 of black ducks, 2037 and 832 respectively were sufficiently full to be used. The distribution was good geographically, and represented each month of the year. The collecting sites are shown in Figure 1.

(*b*) *Feeding Habits*

Black ducks and grey teal are typical river or dabbling ducks. They are the commonest species in inland New South Wales and are usually found in association; accordingly they are considered together. Food is secured by "tipping", by dredging mud on the water's edge or in the shallows, or by stripping the seeds and inflorescences from plants growing in or near water. They are normally nocturnal feeders, but if not disturbed may feed throughout the day, particularly in dull weather.

In addition to its great nomadic movements, the teal makes smaller local feeding movements, the distance travelled depending on the richness of the habitat at the time (Frith 1957*b*). In general, however, nightly movements from the swamp are not so regular or so extensive as those of the black duck. Normally the grey teal prefers to locate itself at the source of food, rather than to visit the spot only for feeding. In a feeding area the days are usually spent roosting in flocks, on mud-banks or on dead trees, and at dusk the birds move to the edge of the billabong to feed in small groups or pairs. The black duck prefers to remain in a heavily vegetated swamp by day and, if necessary, to fly out at night to feed.

The water level in the billabongs in the area studied fluctuates widely. Normally the banks are rather steep and bare of plant growth; at the top of the bank is a narrow fringe of *Eucalyptus* forest, beneath which there may be some herbage; beyond the forest fringe, which may vary from a few yards to several hundred yards in width, the grassy or saltbush-covered plains begin. At times of rising water level all the teal in the area concentrate on the water-line, moving with it through the forest. When the water line passes the timber the birds, reinforced by great numbers of nomads, virtually vacate the billabong and feed entirely on the shallow flooded plain; at the peak of such a rise in water level the billabongs are very deep,

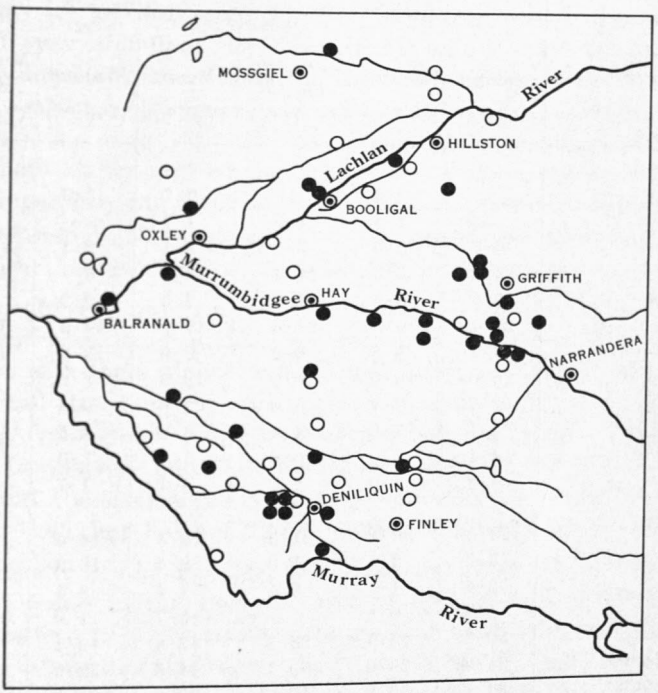

Fig. 1.—Collecting sites for black ducks and grey teal. ○, Grey teal; ●, both species.

swiftly flowing streams, and their aquatic plants are deeply submerged. As the water levels fall the residual waters on the plains become favourite feeding areas for teal and the heaviest concentrations of that species are always found there. The waters continue to be important to the birds until they have almost entirely dried up. The food eaten varies according to the depth and age of the water, and will be discussed in Section III(*c*).

Black ducks are more conservative in their reaction to rising water level than grey teal. They are usually found in the deeper, more permanent swamps farther from the river, and therefore are not so quickly affected by changes in water level. When the level does alter, however, they tend to follow the water-line as do the

teal. As the water falls the black ducks mostly return to their swamps and from there make nightly foraging flights. Whereas the large numbers of teal bred in the floodwaters remain there until their final departure from the district, the black ducks bred there tend to move to and concentrate in the permanent swamps.

TABLE 1

GIZZARD CONTENTS OF 2037 GREY TEAL AND 832 BLACK DUCKS COLLECTED IN SOUTH-WESTERN NEW SOUTH WALES IN 1952–55, SHOWING REGIONAL DIFFERENCES

Food Items	Grey Teal				Black Duck		
	Wakool (Vol.%)	Lachlan (Vol.%)	Murrum-bidgee (Vol. %)	Mean (Vol.%)	Wakool (Vol.%)	Murrum-bidgee (Vol. %)	Mean (Vol.%)
Vegetable food							
Haloragidaceae	—	0·5	—	0·2	2·0	5·6	3·8
Chlorophyceae	—	2·0	1·6	1·2	—	—	—
Marsileaceae	0·7	5·0	3·5	3·1	2·2	6·6	4·4
Polygonaceae	5·8	5·0	28·4	13·1	5·7	17·7	11·7
Chenopodiaceae	2·4	0·5	3·9	2·3	5·2	5·2	5·2
Cyperaceae	22·7	9·5	21·5	17·9	14·2	17·8	16·0
Gramineae—aquatic	3·3	5·5	0·2	3·0	12·6	15·2	13·9
Gramineae—land	20·0	10·0	6·9	12·3	8·2	2·8	5·5
Leguminosae	2·7	2·1	3·0	2·6	0·5	0·6	0·6
Cucurbitaceae	3·1	7·2	4·4	4·9	4·6	4·2	4·4
Compositae	4·4	—	0·6	1·7	3·0	2·0	2·5
Other plants	4·9	7·6	2·7	5·1	1·7	1·4	1·5
Animal food							
Insecta	23·2	39·8	21·9	28·3	14·5	6·5	10·5
Mollusca	3·1	3·1	1·0	2·4	16·2	10·2	13·2
Crustacea	2·4	1·4	0·4	1·4	8·4	4·2	6·3
Other animal	1·3	0·8	—	0·7	1·0	0·0	0·5
Total animal food	30·0	45·1	23·3	32·8	40·1	20·9	30·5
Total swamp plants	35·9	29·0	59·1	41·3	39·9	68·1	54·0
Total land plants	34·1	25·9	17·6	25·9	20·0	11·0	15·5
Number of gizzards	671	278	1088	2037	592	240	832

Other deliberate movements on to the plains occur at times of heavy rain. If the rain is heavy enough to form pools of rain-water these prove a great attraction to the birds, particularly to the teal, which fly there nightly to feed and return to the billabong to roost during the day.

(c) *Food*

(i) *Grey Teal.*—Table 1 summarizes the food found in the gizzards of both species. It can be seen that 41 per cent. of the food of grey teal consisted of marsh

plants,* 33 per cent. of aquatic animals, and the remaining 26 per cent. of a wide variety of plants that normally grow on dry land. Among the marsh plants the most important to the birds were the Cyperaceae (sedges). Four genera were found in the gizzards, *Cyperus* (2·7 per cent.), *Scirpus* (0·9 per cent.), *Eleocharis* (1·9 per cent.), and *Carex* (12·1 per cent.). The last was the most widely eaten single genus, and within it *Carex rhytidocarpa* (11·6 per cent.) was the most commonly eaten food item in the whole collection.

Polygonaceae (smartweeds) were an important source of food. Smartweed (*Polygonum*) (11·7 per cent.) was represented by five species, and dock (*Rumex*) (1·3 per cent.) and lignum (*Muehlenbeckia*) (0·1 per cent.) were eaten to a lesser extent. As many of the birds were collected in swamps where lignum was the sole vegetation and very abundant, it is surprising that it was not more commonly utilized. As the dominant land vegetation throughout much of the district was bluebush (*Kochia*), saltbush (*Atriplex* and *Rhagodia*), and goosefoot (*Chenopodium*) (Chenopodiaceae), one might also have expected the Chenopodiaceae (2·3 per cent.) to have been more highly utilized than they were. *Chenopodium atriplicinum* (2·0 per cent.) was apparently the only member of the family eaten to any extent. Nardoo (*Marsilea drummondii*) (Marsileaceae) (3·1 per cent.) was abundant in the field, particularly in the Lachlan Region, and was frequently eaten.

The Chlorophyceae (green algae) (1·2 per cent.) were commonly found in the gizzards, sometimes in large quantities. At times the drying floodwaters became green and dense with these plants and the teal readily availed themselves of them, despite their small size. Several other aquatic families were found in small quantities, including Ophioglossaceae, Salviniaceae, Selaginellaceae, Typhaceae, Potamogetonaceae, Lemnaceae, and Haloragidaceae. Some of these, particularly Potamogetonaceae and Haloragidaceae, were very abundant in the field, and it is, perhaps, surprising that they did not take a more prominent place in the diet.

Of the normally dry-land plants, the Gramineae (grasses) (15·3 per cent.) were most frequently found in the gizzards, and 18 species were positively identified. Leguminosae (medics) (2·6 per cent.) included at least four species of clover (*Trifolium*) and four of medic (*Medicago*). The Compositae (1·7 per cent.) contributed three thistles (*Cirsium lanceolatum*, *Carthamus lanatus*, and *Sonchus oleraceus*), all common weeds of the area. The Cucurbitaceae (4·9 per cent.) were surprisingly abundant and included the seeds of one plant (3·0 per cent.) that was widely eaten, and apparently was plentiful in the field; however, the plant could not be identified from its seed and could not be found flowering in the field, so that the species remained undetermined. The remainder of the food produced by dry-land plants came from a wide variety of herbs of the following families: Liliaceae, Amaranthaceae, Caryophyllaceae, Ranunculaceae, Geraniaceae, Malvaceae, Convolvulaceae, Boraginaceae, Labiatae, and Solanaceae, each usually represented by a single species.

* "Marsh plants" comprise those normally living in water or wet ground and here includes Chlorophyceae, Ophioglossaceae, Marsileaceae, Salviniaceae, Azollaceae, Selaginellaceae, Typhaceae, Potamogetonaceae, *Echinochloa crus-galli*, *Paspalidium jubiflorum*, *Paspalum distichum*, and *Oryza sativa* (Gramineae), Cyperaceae, Lemnaceae, Juncaceae, Polygonaceae, and *Chenopodium atriplicinum* (Chenopodiaceae).

The principal source of animal food was insects (28·3 per cent.), among which Coleoptera (beetles) (21·0 per cent.) were most commonly eaten, especially the family Dytiscidae (11·6 per cent.); *Berosus* sp. (5·0 per cent.) was the single animal most frequently eaten. After the beetles *Corixa eurynome* (Corixidae) (4·0 per cent.) was the most abundant insect. The aquatic larvae of Trichoptera (0·2 per cent.) and Diptera (0·9 per cent.) were eaten, giving some little support for the often-voiced opinion that wild ducks are important predators of the larvae of Trichoptera (caddis flies).

The Mollusca (2·4 per cent.) comprised a limited range of small species of both Gasteropoda and Lamellibranchia. The Crustacea ranged in size from the minute ostracod *Cyprinotus* sp. to the freshwater yabbie (*Cherax albidus*), and accounted for 1·4 per cent. of the total food; of this the yabbie contributed 1·0 per cent. The fish *Gambusia affinis* was very rarely eaten, although it was usually abundant in the feeding areas.

(ii) *Black Duck.*—The food of the black ducks comprised 54 per cent. marsh plants, 31 per cent. aquatic animals, and 15 per cent. dry-land plants. Their diet therefore contained more products of the swamps and a correspondingly smaller amount of products of dry land than the diet of the grey teal.

Within the aquatic plant group the black duck ate more *Myriophyllum* (3·8 per cent.), *Marsilea* (4·4 per cent.), *Chenopodium* (5·0 per cent.), and *Carex* (12·9 per cent.) than the grey teal, but less *Eleocharis* (0·8 per cent.) and no *Scirpus* or *Typha*. It will be noticed that the black duck tended to concentrate on the larger-seeded and the grey teal on the smaller-seeded species.

Contrary to expectation, the black duck ate greater quantities of Gramineae than the teal. Whereas the bulk of the grasses eaten by the teal were of dry-land origin (*Lolium*, *Danthonia*, *Phalaris*, *Eragrostis*, *Agrostis*), the grasses eaten by the black duck were predominantly aquatic. The most important species to the black duck were barnyard millet (*Echinochloa crus-galli*) (6·6 per cent.), watercouch (*Paspalum distichum*) (3·5 per cent.), rice* (*Oryza sativa*) (2·2 per cent.), and summer grass (*Paspalidium jubiflorum*) (2·0 per cent.). In addition to these differences in species eaten it was noticed that when grass seed was found in the gizzards of grey teal there were often several species, and the seeds were usually mixed with very little vegetative material. In black duck gizzards, however, whenever grass seed occurred it was always mixed with large quantities of husk, seed head, and leaves, which often exceeded the seed in volume. Moreover, the black duck gizzard usually contained only one species of grass. These observations strongly suggest that the black ducks had fed on growing grasses, and that the teal had gathered fallen grass seed.

Among the Cucurbitaceae the black duck ate mainly the seeds and $\frac{1}{4}$-in.-diameter fruits of paddy melon (*Cucumis myriocarpus*) (4·0 per cent.), whereas the teal ate mostly (3·0 per cent.) the seeds of the smaller unidentified plant mentioned

* In the present context rice is considered merely as another aquatic grass. Its presence in the gizzards shows that the birds had been feeding in cultivated rice fields. The effects of such depredations have been discussed in an earlier paper (Frith 1957*b*).

above. The principal species of the Compositae eaten by the black duck was the large-seeded saffron thistle (*Carthamus lanatus*) (4·6 per cent.) but the grey teal ate the smaller-seeded thistles (*Cirsium*, *Sonchus*, and *Leontodon*) in equal amounts.

The black duck ate about the same quantities of animal food as the teal, but the composition of that food was quite different. Insects were not so important to the black duck as to the teal, but the actual species of insects eaten by the two birds were very similar.

Although molluscs were not often eaten by the teal, they amounted to 13·2 per cent. of the diet of the black duck. The freshwater mussels Mutelidae and Corbiculidae were the molluscs most favoured by the black duck, but these groups were eaten only to a very small extent by the teal. The largest mussel found was one $1\frac{1}{4}$ in. long by 1 in. wide but all the remainder were between $\frac{1}{4}$ in. and $\frac{3}{4}$ in. in diameter. Crustacea also were more important to the black duck than the teal. The species most widely eaten by the black duck were a crayfish (*Cherax albidus*) (4·7 per cent.) and the fairy shrimp (*Triops* sp.) (1·5 per cent.), but these were seldom found in teal gizzards.

(*d*) *Seasonal Variation in Diet*

(i) *Grey Teal.*—The mean monthly composition of the food of both species is shown in Figure 2. Marsh plants were eaten by grey teal in considerable quantities in each season, but consumption of them was greatest during the winter months. The majority of the marsh plants listed set seed during the summer months, and therefore the increased usage in winter was not due to greater abundance of the plants but rather to some factor making them more readily available. The dry-land plants were most extensively used in summer, and small quantities only were eaten in winter. The majority of the dry-land plants were summer-flowering grasses, and the increased consumption thus could be explained by greater abundance of those plants.

Large quantities of insects were eaten throughout the year, but especially in the spring. Mollusca and Crustacea were important articles of diet only in the autumn and the spring.

(ii) *Black Duck.*—Figure 2 shows that, unlike the teal, the black duck ate greater quantities of the seed of swamp plants during their summer growing season. The greatest quantities of dry-land plants were eaten in the winter and the spring. Animal food was important to the birds in each season of the year.

It has been pointed out above that vegetable food eaten by the grey teal consisted mainly of individual seeds, whereas that eaten by the black duck usually consisted of the whole seed head. The present observation that more swamp plants are eaten by black ducks during their actual growing season and by teal after the growing season again points to a difference in feeding habits, the grey teal tending more to dredge the mud for fallen seeds and the black duck to strip the growing plant.

(e) *Regional Variation in Diet*

(i) *Grey Teal.*—Table 1 indicates that the diet of the grey teal varied considerably in the three regions. The principal class of food eaten in the Lachlan region was animal food and in the Murrumbidgee region marsh plants, whereas in the Wakool region animal food, marsh plants, and dry-land plants occupied almost equal places in the diet.

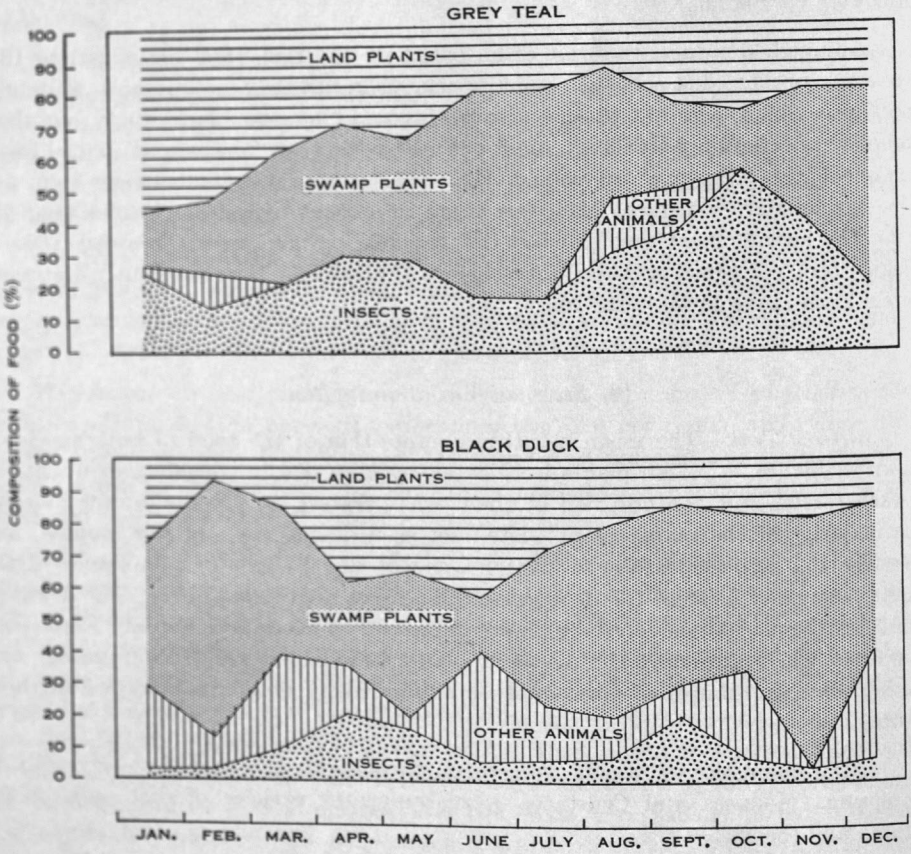

Fig. 2.—Composition of the food of the grey teal and the black duck.

Insect food is most available at times of rising water level (Frith 1957*a*) and in shallow, drying surface water. Dry-land plants are most available after flooding or heavy rain. These facts help to explain the variations in composition of the diet in the different regions.

In the Lachlan region inundation of the shallow claypans and the lignum swamps, in which floodwaters are never deep and are always temporary, leads to great abundance and availability of insect foods. Grass is almost entirely absent, and only comparatively small amounts of dry-land plants are made available by the flooding of the claypans.

In the Wakool region, on the other hand, the frequent irrigation of pastures makes large quantities of flooded dry-land plants available. Birds collected in that region usually had large quantities of seeds of dry-land plants, as well as insects, in their gizzards.

Section III(*f*), below, discusses food supplies available to grey teal in the Murrumbidgee region. It shows that there were very great seasonal variations, but that on the whole marsh plants provided the bulk of food for the birds—sometimes almost the whole of their diet for extended periods.

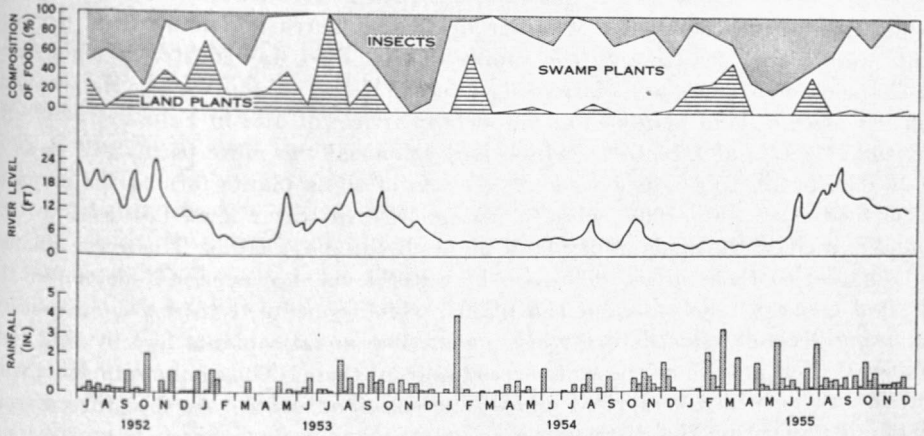

Fig. 3.—Composition of the food of the grey teal on the Murrumbidgee River frontage near Darlington Point, N.S.W., each month in the period 1952–55, showing the effects of rainfall and alteration in water level.

(ii) *Black Duck.*—Similar differences between the diets of the black duck in the Wakool region and in the Murrumbidgee region were observed, but the tendency to eat a higher proportion of dry-land plants in the Wakool region was less marked in the black duck than in the teal. This difference in the amount of regional variation was no doubt due to the difference in feeding habitat of the species, the teal tending to feed in temporary water and the black duck in permanent water. Regional differences in the extent of flooding and irrigation would therefore be less likely to affect the black duck than the teal.

(*f*) *Effect of Environment on Food*

Figure 3 shows the sources of food eaten by grey teal, the river level, and the rainfall on the Murrumbidgee frontage during the period July 1952–December 1955. From Figure 3 it can be seen that the relative amounts of animals, dry-land plants, and marsh plants eaten varied widely from year to year and from season to season, but that there was no regular annual cycle of food.

When observations began in July 1952 the river was in full flood and shallow water extended far across the plain. Very large numbers of grey teal were present on the edges and in the shallower parts of the flood. Surveys by air and boat

showed that the main streams and the billabongs, then seen merely as very deep, swiftly flowing portions of the flood, were quite deserted by the teal. It was found that the birds collected at that period from the floodwaters were feeding almost entirely on the seeds of submerged dry-land plants and insects.

As the flood receded during the summer, the waters separated into large, steadily decreasing areas. Particularly large areas of such residual waters were located on Gum Creek, Kerraberry, and Tubbo Stations. The teal concentrated there in large numbers, but in the billabongs and lagoons, which were still very full, there were very few birds. That situation is reflected in the data showing their feeding habits: as the sheets of water dried up, increasing amounts of dry-land plants were eaten. Presumably the supply of that food was constantly renewed by the changing shore-lines and decreasing average depth of the water. Marsh plants took the place of land plants as an important article of diet in February 1953. By that time *Carex* and *Eleocharis*, which had colonized the more permanent areas of floodwater, began to produce seed. The seeds of these plants formed the majority of the food until July 1953, when a sudden rise in water level flooded low-lying ground and again the seeds of dry-land plants became available. There was a movement of teal to those areas. The rise in water level, however, did not affect the principal areas of floodwater on the plains, which continued to recede and during the spring became reduced to muddy pools. The aquatic plants had by that time completed their growth as the water receded from them. The pools were dense with aquatic insects, which comprised almost the sole food eaten. At that time a great exodus of birds from the district began.

By December 1953 the great concentrations of birds on the floodwaters had entirely dispersed, and the only teal remaining were the resident birds on the few billabongs containing water. These birds were feeding almost entirely on marsh plants. The sudden change illustrated in Figure 3, from a diet entirely composed of insect food to one almost entirely composed of vegetable food, was due to the disappearance of the floodwater habitat and its ducks and to a consequent concentration of the sampling on the small resident population in the billabongs.

In February 1954 very heavy rain fell, causing pools to form on the plains. These pools were immediately utilized by teal that came every night to feed on the submerged seed of dry-land plants. For a time their food was almost entirely from that source. A further result of the rain was germination of the seeds of herbs and grasses in many of the exposed billabong bottoms, but these plants were not then available to the birds.

Throughout 1954, except for a period in December when heavy rain again allowed the birds to forage for grass seed in the rainwater pools, the birds were confined to the billabongs and fed almost entirely on marsh plants. Rises in water level in January and February 1955 flooded some of the dry parts of the lagoons and made available the seeds of dry-land plants growing there, and also increased the availability of insects. That relief was, however, temporary, and by April the resident teal were again reduced to a diet mainly consisting of insects, the water having receded even from the fringe of marsh plants.

When the river flooded again in July 1955 the plants growing on the dry lagoon bottoms, and the marsh plants that had been left by the previously receding water level, became available and were utilized for food. In addition nomadic grey teal moved into the district, into small areas of local flooding, and were found to be feeding predominantly on the submerged seeds of dry-land plants.

It was not possible to secure enough regular samples of black ducks from any one district to trace the climatic effects on their diet in the same detail as for the grey teal.

(*g*) *Summary of Results*

The contents of the gizzards of 2037 grey teal, *Anas gibberifrons*, and 832 black ducks, *A. superciliosa*, collected in south-western New South Wales in the period 1952–1955, were examined.

It was found that the average diet of the grey teal consists of 26 per cent. dry-land plants, 41 per cent. swamp plants, and 33 per cent. aquatic animals. The composition of the diet varied greatly from district to district according to geographical conditions, and from time to time according to the weather. There is no regular annual food cycle. It is shown that the water level of the streams and the intensity of the local rainfall strongly affect the types of food eaten.

The diet of the black duck consisted of 15 per cent. dry-land plants, 54 per cent. swamp plants, and 31 per cent. aquatic animals. The detailed composition of the diet varies greatly from that of the teal. The black duck feeds to a great extent on products of the more permanent water areas, whereas the grey teal tends to feed largely in temporary waters.

IV. Food of the Blue-winged Shoveler

(*a*) *Material and Methods*

Forty-seven gizzards of blue-winged shovelers were collected in the Murrumbidgee and Lachlan regions at the sites shown in Figure 4 (p. 146); a few were taken in each month of the year. No special effort was made to secure them, collection being incidental to the shooting of the more common species. The gizzards were preserved in 70 per cent. alcohol until examined, when they were opened and the contents covered with 50 per cent. alcohol until examination. As much of the food consisted of finely divided animal material and accurate assessment of the volume of individual items was difficult, it was thought that the percentage frequency of occurrence of each item was a more significant and accurate way of expressing the findings. In this paper both methods of presentation are used.

(*b*) *Feeding Habits*

Of the 47 shovelers, 39 were taken in areas of residual floodwater and the remaining eight in permanent lagoons; none was collected, or seen, in the irrigation area drainage swamps or on the main streams of the rivers.

The birds feed by dabbling in mud and shallow water and also by swimming slowly, often in echelon, with bills immersed in the water.

(c) *Food*

Table 2 summarizes the contents of the gizzards examined. It can be seen that the food of the shovelers consisted of 76 per cent. animal food and 24 per cent. vegetable food, by volume. Although all gizzards contained at least 50 per cent. animal food, only 44 per cent. of them contained any vegetable food, and then usually only in small amounts.

TABLE 2

THE CONTENTS OF THE GIZZARDS OF 47 BLUE-WINGED SHOVELERS COLLECTED IN INLAND NEW SOUTH WALES IN THE PERIOD 1952–57

Food Items	Volume (%)	Frequency of Occurrence (%)
Vegetable food		
Marsileaceae	2·6	8·4
Polygonaceae	5·0	8·4
Chenopodiaceae	3·1	4·2
Cyperaceae	2·2	2·1
Gramineae	2·3	2·1
Leguminosae	1·1	2·1
Boraginaceae	2·3	2·1
Cucurbitaceae	0·2	6·3
Compositae	0·4	2·1
Other plants	4·6	6·3
Animal food		
Crustacea	5·8	17·0
Mollusca	21·7	32·0
Insecta		
Coleoptera	30·9	100·0
Hemiptera	10·2	76·7
Other insects	7·6	95·8
Total plant food	23·8	44·1
Total animal food	76·2	100·0

(i) *Animal Food.*—The greater part of the animal food (48·7 per cent. by volume) consisted of insects. Of these the Coleoptera (beetles) were the most important (30·9 per cent.) with a frequency occurrence of 100 per cent.; the commonest beetle was *Berosus* sp. (Hydrophyllidae) (16·9 per cent. by volume), with a frequency occurrence of 73 per cent. *Lancettes lanceolata* (Dytiscidae) (7·7 per cent. by volume) and *Rhantus pulverosus* (Dytiscidae) (6·3 per cent.) came next, and a large number of beetle fragments which could be referred to Aphodiidae, Carabidae, Hydrophyllidae, and Dytiscidae were also found. The only other order of insects found in quantity was the Hemiptera (12·2 per cent. by volume), of which *Corixa eurynome* (Corixidae) (8·6 per cent.) occurred in 63 per cent. of the gizzards. The remainder of the animal material was finely divided, and although individual insects could not be separated a certain amount could be referred to Corixidae, Notonectidae, and Belastomidae. Unidentified insects occurred in 42 per cent. of the gizzards and

consisted of very finely divided fragments and chitin, which it was impossible to ascribe to any order.

Shells were found in 32 per cent. of the gizzards and comprised 21·7 per cent. of the total volume of food. Both Gasteropoda and Lamellibranchia occurred, but in no case was the specimen more than $\frac{1}{2}$ in. in diameter. The most common species were *Lenameria* sp. (Bulinidae) (10·6 per cent.), *Isidorella* sp. (Bulinidae) (7·4 per cent.), and *Corbiculina* sp. (Corbiculidae) (2·9 per cent. by volume). The sole crustacean identified was the ostracod *Cyprinotus leana* (5·8 per cent.). It was found in 17 per cent. of the gizzards and in one case a gizzard contained 1·4 ml of that animal.

(ii) *Vegetable Food.*—The vegetable food consisted of seeds; in no case was anything found that could be identified as leaf or vegetative material. Of the vegetable food 11·9 per cent. by volume was derived from swamp plants and the remainder, 21·9 per cent., from dry-land plants. This finding is consistent with the shovelers' observed preference for feeding in temporary residual floodwater.

Nardoo (*Marsilea drummondii*) (Marsileaceae) (2·6 per cent.) was the most common single plant on a volumetric basis, but that was due to the fact that seven birds collected in one place had eaten relatively large quantities. It was not found in the gizzards of any other birds. The Polygonaceae (6·0 per cent.) occurred in 74 per cent. of the gizzards. The remainder of the vegetable food consisted of a large number of different seeds, none occurring in more than one of the gizzards examined.

(*d*) *Summary of Results*

Examination of gizzards of 47 blue-winged shovelers showed that 76 per cent. by volume of their food consisted of animal material. The diet of the shoveler is somewhat similar to that of the grey teal in the same habitat.

V. Food of the Pink-eared Duck

(*a*) *Material and Methods*

Ten pink-eared ducks were collected each month from August 1952 to June 1953 in an area of residual floodwater on Gum Creek Station near Darlington Point, N.S.W. Smaller numbers were collected in the same area in 1956. The gizzards were removed on collection, injected with 10 per cent. formalin from a hypodermic needle, and preserved in 10 per cent. formalin.

In the laboratory each gizzard was opened, and the contents were suspended in formalin in a flat-bottomed glass dish and examined under a low-power binocular microscope. The presence or absence of each plant or animal class was recorded. The liquid was then poured off and the gizzard contents were air-dried. When dry the contents were sorted and the relative volumes of the larger items were determined.

Large numbers of gizzards were also collected from shooters' bags throughout the period, but as these were not injected with formalin on collection they were examined qualitatively only.

examined. Cladocera were represented in 63 per cent. of the gizzards, and *Daphnia pulex* (Daphnidae) was found in each of these. Copepoda (Deaptomidae) occurred in 22 per cent. of the gizzards and Nematoda in 18 per cent. None of these items was revealed by the volumetric analysis of food. Similarly Ostracoda amounted to only 7 per cent. of the food by volume, but were found in 21 per cent. of the gizzards examined; and Algae were found in 86 per cent. of the gizzards but did not appear in the volumetric measurement.

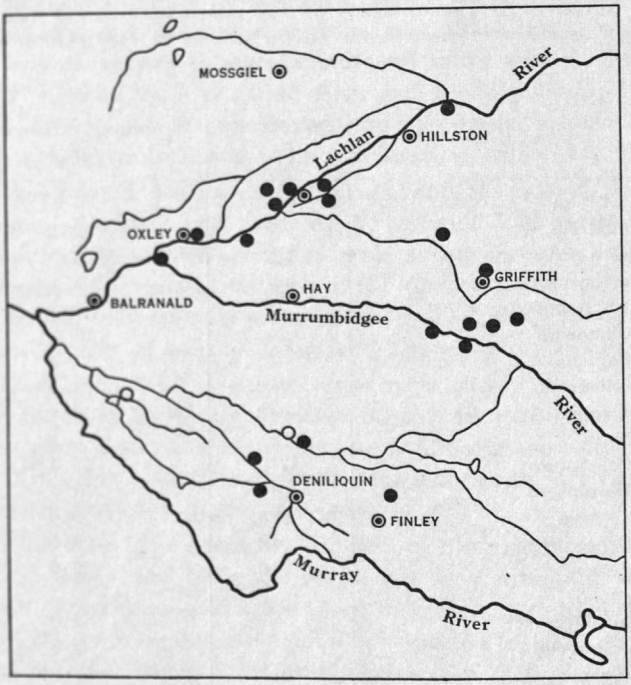

Fig. 4.—Collecting sites for white-eyed ducks.

(*d*) *Summary of Results*

Of the food of the pink-eared duck, 94 per cent. was found to consist of aquatic animals, and included important quantities of microscopic forms. The food was largely derived from the filtration of surface water, and not from the edge or bottom mud as with other species of ducks.

VI. Food of the White-eyed Duck

(*a*) *Material and Methods*

Of 207 gizzards of white-eyed ducks collected, 193 were sufficiently full to be used. The methods of preservation and examination and the compilation of results were as described for the grey teal. The majority of the gizzards were collected from July 1952 to July 1953, and were representative of each month of the year. The collecting sites are shown in Figure 4.

(*b*) *Feeding Habits*

Although the white-eyed duck is, on occasion, found in all habitats, it is most commonly found and most numerous in the deeper, more permanent swamps, e.g. Tuckerbil Swamp, Kooba Lagoon, and Lake Waljeers. Within these swamps it shows a marked preference for the areas of open water and, unlike the black duck, tends to avoid the dense reed beds and the lignum.

TABLE 4

THE CONTENTS OF THE GIZZARDS OF 193 WHITE-EYED DUCKS COLLECTED IN INLAND NEW SOUTH WALES IN THE PERIOD 1952–57

Food Items	Volume (%)
Plant food	
Haloragidaceae	9·4
Polygonaceae	1·4
Chenopodiaceae	0·8
Cyperaceae	26·5
Gramineae	22·4
Leguminosae	1·4
Cucurbitaceae	8·3
Other plants	4·1
Animal food	
Crustacea	1·0
Mollusca	9·6
Insecta	
Coleoptera	8·4
Hemiptera	3·6
Other insects	3·1
Total plant food	74·3
Total animal food	25·7

Feeding is usually achieved by diving from the surface, but dabbling and "tipping" are common. Birds have been seen to dive in water ranging from 3 to 10 ft deep—presumably they also dive in greater depths, but such depths are uncommon in the area except in the main streams of the rivers. White-eyed ducks have not been seen on the main streams, no doubt because of their muddy sterile bottoms. Moving water is no deterrent to the birds, and they have been seen diving in swiftly flowing lagoons and streams in full flood. The time spent under water varies from a few seconds to at least 70 seconds; dives of 20–30 seconds seem most common.

(*c*) *Food*

Table 4 summarizes the food found in the gizzards.

(i) *Plant Food.*—Vegetable products comprised 74·3 per cent. by volume of the total food. The most common plant food was Cyperaceae (26·5 per cent.), and of them the stems, inflorescences, and seeds of sedges (*Carex*) (18·3 per cent.) con-

stituted the most abundant single item of food. *Scirpus* sp. (5·2 per cent.) was commonly eaten, and *Eleocharis plana*, prominent in the diet of other species of wild duck, accounted for 3·0 per cent.

The Gramineae (22·4 per cent.) that were eaten were mainly aquatic forms; watercouch (*Paspalum distichum*) (6·2 per cent.), oat-grass (*Agrostis avenacea*) (9·3 per cent.), rice (*Oryza sativa*) (2·5 per cent.), and barnyard millet (*Echinochloa crus-galli*) (2·9 per cent.). The dry-land grasses rye-grass (*Lolium perenne*) (7·3 per cent.) and *Phalaris paradoxa* (1·6 per cent.) were also found.

As might be expected, water-milfoil (*Myriophyllum*) (Haloragidaceae) (9·4 per cent.) was a useful food but the Polygonaceae (1·4 per cent.), important to other species of ducks, were not eaten to a great extent; wireweed (*Polygonum aviculare*) (1·2 per cent.) and dock (*Rumex brownii*) (0·2 per cent.) were the only representatives of the family found. Paddy melon (*Cucumis myriocarpus*) (Cucurbitaceae) (8·3 per cent.) was surprisingly abundant.

The Leguminosae (1·4 per cent.) accounted for a very small part of the total food, represented by small amounts of *Medicago denticulata*, *Trifolium tomentosum*, and *Medicago minima*.

(ii) *Animal Food.*—The Insecta (15·1 per cent.) were the principal source of animal food. Of the insects, Coleoptera comprised 8·4 per cent.; Dytiscidae (6·2 per cent.), represented by *Berosus* sp. (3·1 per cent.) and *Dytiscus* (2·4 per cent.) were the family most frequently encountered. The remainder of the Coleoptera were too finely divided for identification.

Hemiptera (3·6 per cent.) were the only other important insect food, being represented by *Corixa eurynome* (Corixidae) (1·6 per cent.), unidentified *Corixa* sp. (0·8 per cent.), and Belastomatidae (1·2 per cent.). The larvae of Zygoptera (0·8 per cent.) and of Trichoptera (0·4 per cent.) were also eaten.

The Crustacea (1·0 per cent.) were comparatively rare, and were represented by Ostracoda (0·2 per cent.) and *Cherax albidus* (Parastacidae) (0·8 per cent.)

The Mollusca (9·6 per cent.) consisted almost entirely of Bulinidae: *Lenameria* sp. (4·9 per cent.) and *Isidorella* sp. The only other mollusc found was *Alathyria* sp. (Mutelidae) (1·4 per cent.).

(*d*) *Summary of Results*

The white-eyed duck secures its food largely by diving, but partly also by dredging the mud like other species of ducks.

Gizzard contents comprised 74 per cent. animal food and 26 per cent. vegetable food. The vegetable food consisted largely of seeds of sedges and grasses, and the animal food of insects.

VII. Food of the Wood-Duck

(*a*) *Methods*

Selection of sites for collection of gizzards of wood-ducks was somewhat biased, as special attention was paid to rice-growing districts and, particularly in the Central Murray Region, to the vicinity of rice farms (Frith 1957*b*). The collecting sites are shown in Figure 5.

Special difficulties apply to the study of the food of wood-ducks. The species feeds extensively on the vegetative parts of plants, often immature, and a typical gizzard contains a small amount of very finely divided vegetation. Under these circumstances identification of food items is rather difficult. Accordingly special efforts were made to collect the birds while actually feeding, so that the plants could be examined *in situ* and so that relatively unchanged portions could be recovered from the proventriculus. In this manner it was possible to identify the majority of food items, at least to generic level, with reasonable certainty.

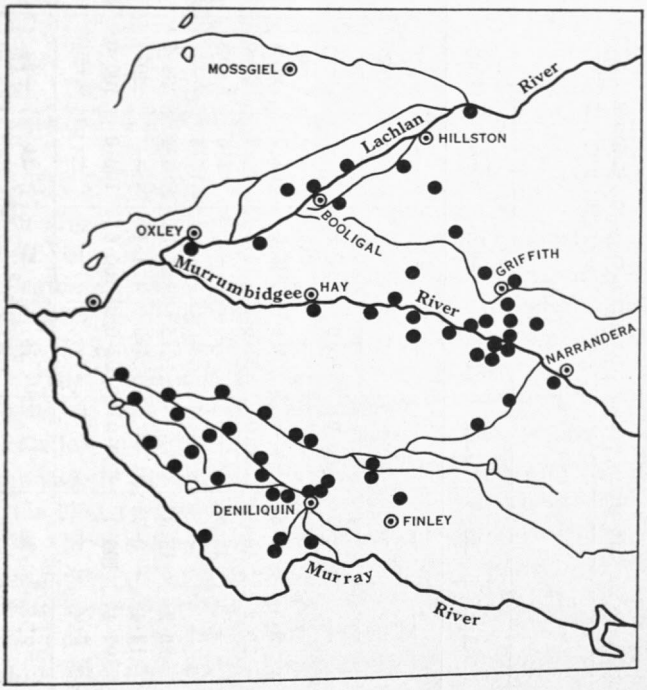

Fig. 5.—Collecting sites for wood-ducks.

To make the results obtained still more significant and accurate, any gizzard containing more than 30 per cent. of unidentified material was rejected. Of 681 gizzards available 572 were sufficiently full of recognizable material to be used in the calculations.

(*b*) *Feeding Habits*

The feeding habits of the wood-duck have been previously discussed in sufficient detail for the present purpose (Frith 1957*a*, 1957*b*).

(*c*) *Food*

Table 5 summarizes the food found in the gizzards during each month of the year.

From Table 5 it can be seen that the wood-duck is almost entirely vegetarian, 99·3 per cent. of the total food being composed of plant materials. Of these only

TABLE 5

THE CONTENTS OF GIZZARDS OF 572 WOOD-DUCKS COLLECTED IN THE PERIOD 1952–57

Food Items	Volume (%)												
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Mean
Haloragidaceae	0·3	—	—	—	—	—	—	—	—	2·6	—	—	0·2
Chlorophyceae	—	—	—	—	—	—	—	—	—	—	—	—	—
Marsileaceae	0·8	—	—	—	—	—	—	10·0	—	—	—	—	0·9
Polygonaceae	—	—	13·2	—	12·5	50·0	50·0	25·0	—	—	—	—	12·5
Chenopodiaceae	—	—	—	—	0·8	—	—	0·9	6·5	—	—	—	0·7
Cyperaceae	5·6	33·3	17·0	8·5	12·8	—	5·6	25·0	41·7	12·8	18·3	24·2	17·1
Gramineae	62·3	60·2	46·6	50·2	40·4	50·0	25·0	0·5	24·7	29·6	43·3	53·1	40·5
Leguminosae	25·9	—	5·8	—	16·9	—	—	—	5·5	0·3	12·4	5·8	6·1
Cucurbitaceae	—	—	11·8	—	—	—	—	—	17·5	—	—	—	2·4
Compositae	0·9	—	—	25·3	13·3	—	12·5	37·5	4·1	34·0	7·3	5·8	11·7
Other plants	4·2	1·6	5·6	13·4	0·7	—	6·9	1·1	—	20·7	18·7	11·1	7·0
Total plant food	100·0	95·1	100·0	97·4	100·0	100·0	100·0	100·0	100·0	100·0	100·0	100·0	99·1
Total animal food	—	4·9	—	2·6	—	—	—	—	—	—	—	—	0·7
Number of gizzards	90	40	51	35	42	11	18	25	24	28	62	146	

41·7 per cent. were derived from plants normally growing in or near water* and the remaining 57·6 per cent. from dry-land plants. These results illustrate the grazing habits of the wood-duck.

The most important single source of food was the Gramineae (grasses), and of these the aquatic species rice (*Oryza sativa*) (3·7 per cent.), barnyard millet (*Echinochloa crus-galli*), (4·4 per cent.), and summer grass (*Paspalidium jubiflorum*) (1·0 per cent.) accounted for 9·1 per cent. The remainder of the grasses eaten consisted of dry-land species, including the pasture plants rye grass (*Lolium perenne*) (2·9 per cent.) and *Phalaris paradoxa* (4·5 per cent.). The most common native species were wallaby grass (*Danthonia caespitosa*) (5·1 per cent.) and Arabian grass (*Schismus barbatus*) (1·1 per cent.). Unidentified grass amounted to 7·4 per cent. of the total food. The occurrence of seed heads of Gramineae was comparatively rare; in most cases grass blades were the predominant parts of those plants found in the gizzards.

The Compositae (thistles) included milk thistle (*Sonchus oleraceus*) (9·6 per cent.) and saffron thistle (*Carthamus lanatus*) (1·0 per cent.). The remainder of the Compositae (1·1 per cent.) could not be identified beyond family level. The Leguminosae (legumes) eaten included *Medicago minima* (0·5 per cent.) and *Trifolium tomentosum* (0·9 per cent.), but the majority of the legumes could not be identified beyond genus; these comprised *Medicago* (4·1 per cent.) and *Trifolium* (0·6 per cent.). The remainder of the dry-land plants consisted of paddy melon (*Cucumis myriocarpus*) (2·4 per cent.) and numerous small herbs, usually represented only as traces in a few gizzards.

Among the swamp plants eaten, Cyperaceae (sedges) were the most abundant and accounted for 17·1 per cent. of the food. The plants eaten were much the same as those eaten by the other species of ducks and included *Eleocharis plana* (8·1 per cent.), *Cyperus difformis* (1·5 per cent.), and *Carex* (5·1 per cent.). The Polygonaceae (smartweeds) were represented by wireweed (*Polygonum aviculare*) (5·1 per cent.), creeping knotweed (*P. prostratum*) (5·3 per cent.), and waterpepper (*P. hydropiper*) (2·0 per cent.). Dock (*Rumex*) was not recorded. Smaller quantities of bulrush (*Typha angustifolia*) (Typhaceae) (2·0 per cent.), the Algae Chlorophyceae (0·4 per cent.), nardoo (*Marsilea drummondii*) (0·9 per cent.), *Myriophyllum* sp. (0·6 per cent.), and *Juncus* sp. (0·4 per cent.) completed the aquatic group.

The sole animal food eaten consisted of occasional *Corixa urynome* (Corixidae), unidentified insects, and, in one case, *Corbiculena australis* (Corbiculidae).

(*d*) *Seasonal Variations in Food*

Figure 6 shows seasonal variations in the food of the wood-duck.

Grasses and legumes were eaten in considerable quantities throughout the year but their consumption declined sharply during the winter and spring. Swamp plants also were important throughout the year, but their consumption increased

* These comprise Chlorophyceae, Marsileaceae, Typhaceae, Scheuchzeriaceae, Cyperaceae, Juncaceae, Polygonaceae, Haloragidaceae, and *Echinochloa crus-galli*, *Oryza sativa*, and *Paspalidium jubiflorum* of the Gramineae.

during the winter when they became the predominant food item. The miscellaneous group of small herbs was eaten in greatest quantities in autumn and spring. That is what might be expected in the area studied, where these seasons are marked by quick flushes of growth of small herbs. The small plants do not survive in the summer.

(e) *Summary of Results*

The wood-duck feeds practically entirely on plant materials. Of those materials 58 per cent. is derived from dry-land plants, and only 42 per cent. from plants that normally grow in or near water.

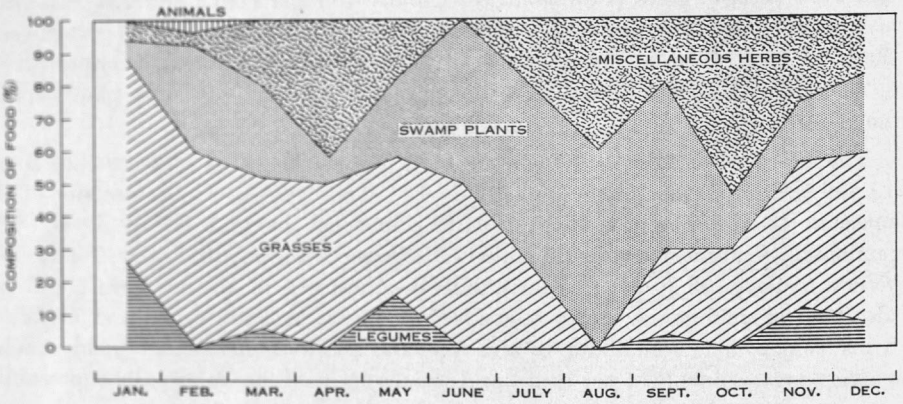

Fig. 6.—Seasonal variation in the food of the wood-duck.

VIII. Food Preference of Three Species

Black ducks, white-eyed ducks, and grey teal may at times occupy the same habitat in great numbers. By comparing the food eaten by the birds at such times a valid comparison of their food preferences can be made. Such a comparison is possible from Tuckerbil Swamp; there very large numbers of the three species congregate each summer, and are regularly heavily shot by sportsmen. In the summer of 1952–53 the swamp was visited periodically and the bags of shooters selected at random were examined. All birds had been shot at dawn, and all their gizzards were full.

The analysis of the gizzard contents of those birds is shown in Table 6.

It can be seen that among the vegetable items each species fed largely on the medium-sized seeds, especially barnyard millet (*Echinochloa crus-galli*), which accounted for one-third to one-half of the diet of the various species. The black duck and white-eyed duck, however, ate much greater quantities of the larger seeds, rice (*Oryza sativa*) and oats (*Avena sativa*), than did the teal. The white-eyed duck ate less smartweed (*Polygonum*) than did the teal.

The consumption of animal food varied greatly among the species. When vegetable food was abundant the black duck and the grey teal ignored animal food and ate almost nothing but plant products. The white-eyed duck, however, selected feeding spots and methods so that 20 per cent. of the total food eaten was of animal origin.

IX. Discussion

It is generally agreed that if two species compete for the same food the chances of them being equally well adapted to collecting that food are negligible, and one species is likely to be eliminated by natural selection (Gause 1934). In the case of wild ducks large numbers of individuals of several species habitually congregate in the same relatively small areas and, as has been shown, eat essentially the same plants and animals, although in different proportions. It is of interest to examine the adaptations whereby those birds avoid serious interspecific competition.

Table 6

THE CONTENTS OF THE GIZZARDS OF 202 BLACK DUCKS, 160 GREY TEAL, AND 61 WHITE-EYED DUCKS COLLECTED IN TUCKERBIL SWAMP, N.S.W., IN THE PERIOD JANUARY–MAY 1953

Food Items	Volume (%)		
	Black Duck	Grey Teal	White-eyed Duck
Plant food			
Gramineae			
Oryza sativa	13·2	1·2	12·7
Avena sativa	19·0	8·0	5·0
Echinochloa crus-galli	34·1	51·0	45·7
Other Gramineae	8·9	9·4	8·5
Leguminosae		2·0	0·1
Polygonaceae	17·3	12·3	6·8
Other plants	5·7	11·3	1·1
Animal food			
Mollusca	0·1		2·2
Insecta	1·7	3·4	17·8
Other animals		1·3	0·1
Total plant food	98·2	95·3	79·9
Total animal food	1·8	4·7	20·1

The wood-duck, totally dependent on vegetable food, eats large quantities of grasses, legumes, and sedges. These plants, however, are eaten as young green growth, whereas the other species of ducks use mainly the seeds and seed heads. Moreover, the wood-duck is adapted to feed on dry land and secures much of its food far from water. In this way it is able to eat plants not available to the other species, which are dependent on water in order to reach their food.

The pink-eared duck, at the other extreme, lives almost entirely on animal food and is completely dependent on the collection of food suspended in water. It is distinguished by its ability to collect and use considerable quantities of plankton that is not generally available to the other duck species. In addition to plankton, the pink-eared duck requires large quantities of the same types of aquatic insects

that are eaten by the other ducks, but it is not in direct competition for those insects because it obtains them mainly by filtration of surface water that the others are not adapted to utilize.

Differences in food utilization also exist among the omnivorous black duck, the grey teal, the blue-winged shoveler, and the white-eyed duck. The white-eyed duck has a diet approximating in composition to that of the black duck, but it is distinguished from the latter species by its ability to utilize food obtainable only by diving to the bottom of deep waters. Such food is not available to the black duck. In addition, animal food is not so important to the teal and the black duck as to the white-eyed duck.

The black duck and the grey teal are very closely related species, and the habitat and feeding places of the teal completely overlap those of the black duck. It has been shown, however, that the two species have very different food habits. The black duck eats mainly the larger seeds of growing plants and the larger invertebrates, whereas the teal is more adapted to living on fallen seed collected from the mud and on the smaller insects.

The habitat and feeding-places of the shoveler also are completely overlapped by those of the grey teal, and it eats essentially the same food; however, it is able to collect and use very much greater quantities of Mollusca than the teal and the other species of ducks.

In inland Australia, where the water areas fluctuate rapidly both in extent and depth, it is apparent that for a water-bird to exist permanently in great numbers it must be sufficiently adaptable in its food habits to deal with a food supply that may alter rapidly in both composition and abundance. The seeding swamp plants being used as food one day may be covered by several feet of clear water the next day, whereas dry grass seed far from the river may equally suddenly become available on account of flooding.

The grey teal has evolved great adaptability with regard to the food eaten by it, its method of collecting food, and its feeding habitat. There is no doubt that that adaptability, which enables it to exploit most types of water and food as soon as they occur, accounts at least in part for the grey teal being the commonest, most widespread, and most mobile species of wild duck in Australia.

The movements of the other highly nomadic species, the pink-eared duck, may also be explained on the basis of its food requirements. Pink-eared ducks are entirely dependent on plants and insects that are common only in stagnant water. In order to secure that food regularly the birds must be prepared to move very rapidly and sometimes very far as water conditions alter.

The black duck and the white-eyed duck are adapted to utilize the foods produced by more permanent water than that whose products provide food for the other species. Their distribution and movements are controlled by the availability of such water, and as changes in its extent cannot be widespread or rapid those species are comparatively local in distribution and low in numbers in the inland.

X. Acknowledgments

Without the cooperation of the owners or managers of a number of pastoral properties, who allowed ready access and collection of samples on all parts of their properties at all times, the present study would not have been possible. The properties visited most frequently included Kooba, Tubbo, Gum Creek, Toganmain, Eurugabar, Ulonga, Angora, Gunbar, and Merungle.

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The figures in this paper were drawn from the author's originals by Mr. W. Goodwin, Division of Plant Industry, C.S.I.R.O.

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