CONSERVATION OF THE MALLEE FOWL, *LEIPOA OCELLATA* GOULD (MEGAPODIIDAE)

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Summary

The ecology of the mallee fowl, *Leipoa ocellata* Gould, is discussed with reference to its conservation.

It is shown that the birds are still widespread in New South Wales, and in some places are reasonably common. In virgin mallee their density probably has not declined, although such areas are few.

It is concluded that the fox is not the main cause of the decline of mallee fowl in uncleared areas. It is more probable that sheep, and perhaps rabbits, enter into direct competition with the birds for food.

I. Introduction

The mallee fowl, *Leipoa ocellata* Gould, was formerly abundant throughout the inland, and in some cases coastal, scrubs of southern Australia. With advancing civilization much of the scrubland has been cleared and much of the uncleared scrub has been stocked with sheep. The mallee fowl, in the eastern states at least, has declined greatly in range and abundance.

Postwar prosperity, population increase, and technical advances in development of marginal lands for agriculture have led to accelerated decrease in the remaining areas of scrub, and it is certain that in the eastern states the position of the species will be critical in the not too distant future. In Western Australia it is thought (Serventy, personal communication) that the species may be holding its own or, in some districts, even increasing in abundance.

In 1951 the New South Wales Fauna Protection Panel undertook a survey of the distribution and abundance of the mallee fowl in that State (Griffiths 1954). That survey was conducted entirely by correspondence, the only method available to the Panel, and was on very general lines. It concluded " . . . the mallee fowl is not by any means extinct in New South Wales. It is not uncommon in the mallee country between the Murrumbidgee and Lachlan Rivers and north of the latter river to the Nyngan–Cobar railway. . . . The species has declined during the past fifty years owing to shrinkage of natural habitat, shooting for food, and the depredations of foxes. At present the principal enemy of the Lowan is the fox."

Since 1951 the author has been engaged in studies of the mallee fowl in New South Wales. Some of the results of these studies have been published (Frith 1956,

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1957, 1959). This paper discusses the general ecology and conservation of the species and examines Griffiths's statements in the light of more adequate data.

II. Methods

(*a*) *Study Area*

The more detailed studies were carried out in mallee scrub near Griffith, New South Wales. That area has been described (Frith 1959). In addition surveys were conducted in all other areas of scrub in the Griffith district, and it was also possible to visit most places suitable for mallee fowl in the eastern states. In each of those places representative areas of scrub were thoroughly searched for mallee fowl mounds.

(*b*) *Surveys*

Two methods were used to show minimum numbers of birds present in the areas surveyed.

(i) *Ground Survey.*—This was the most laborious but the most efficient. The area was systematically searched, using prismatic compass and pedometer. Where possible measured blocks of country were searched, but where that was not possible the distance walked was measured and the area searched was computed from the width of the strip covered. As many observers as possible were used; the number available was never more than five and usually only one. In open mallee three men in line could search a strip 200 yd wide; in dense broom bush, *Melaleuca*, or scrub pine, *Callitris*, the distance was reduced to 20–30 yd. In open mallee three men could search 300 acres in 10 hours, but in dense broom bush they could cover only about 50 acres in that time.

(ii) *Air Survey.*—From low-flying aircraft mallee fowl mounds are clearly visible. Aircraft flying at 60 m.p.h. at 200 ft altitude were used. From 200 ft each observer could search a strip 150 yd wide. By recording flying time and air speed quantitative results were thus obtained. With an observer on each side of the aircraft it was possible to survey about 2000 acres per hour.

A disadvantage of air survey was that, although the mounds could be counted, in the absence of landmarks they could not be relocated. In 1955, in an attempt to overcome this, parts of the main study area were photographed, using an aerial reconnaissance camera. Photographs were made from 2000, 1000, 500, and 300 ft altitude and 5 by 4 in. glossy prints were prepared. The pattern of sunlight and shadow from the mallee, however, provided effective camouflage for the mounds, and only from 300 ft could mounds whose location was known be detected on the prints. This altitude gives a coverage of only 100 yd by 100 yd on the ground and is therefore uneconomical.

The main use of air survey is to make rapid reconnaissance of large trackless areas feasible. It was possible to survey from the air much of the mallee close to Griffith; and during 1959 and 1960, during air surveys for another purpose between Griffith and Hillston, and between Hillston and Wilcannia, representative areas in these districts were traversed. The majority of the New South Wales mallee survey, however, was done on foot.

(c) *Food*

It was not possible to examine the contents of stomachs; accordingly indirect methods were used to assess the food eaten by the birds. From 1955 onwards the birds in the main study area were increasingly accustomed to the author's presence and became remarkably tame. Two birds in particular allowed observation at all times of the day from a distance of a few yards (Frith 1957), and under these circumstances it was possible to observe the food actually eaten. Where the nature of the food item could not be established thus the ground at the feeding spot was inspected and the seeds there (usually only one species being present) were identified. The data collected in this manner are not of great accuracy, but they do serve to indicate the type of food eaten.

III. Results

(a) *Distribution in Australia*

The mallee fowl is distributed throughout inland southern Australia and is found far beyond the mallee. It has been recorded in many habitats, including in coastal heath, wandoo scrub, dryandra scrub, pine scrub, gidgee, and occasionally mulga. In all habitats that the author has been able to examine (including representatives of all the above associations) the actual sites of the mallee fowl record have had three elements in common. These are: a relatively light soil, a dense shrub undergrowth or complete canopy, and one or more abundant *Acacia* shrubs.

(b) *Distribution in New South Wales*

In New South Wales, with the exception of a former occurrence in the Pilliga scrub, the species does seem to be confined to mallee. In every district that the author has visited, except west of the Darling River, it has been possible to locate mallee fowl where suitable habitat exists. West of the Darling there are some suitable areas but the author has not found the birds there. N. Favaloro (personal communication) has had similar experience in this region. It seems inconceivable, however, that the birds should not exist in, at least, the large area of scrub on the South Australian border. That area the author has not surveyed.

It was not possible to determine the actual number of birds in the State as a whole or in any one district. The density in different types of mallee scrub, however, could be determined with some accuracy, and these data are discussed in the following section. It was not possible to determine either the acreage of these types of scrub or the gross acreage of scrub remaining in the State. Accordingly discussion of the distribution of the species must be in rather general terms.

(c) *Habitat*

Mallee scrub in New South Wales is formed of dwarf eucalypt species on sandy soils in the southern part of the State, west of the 17-in. isohyet. The distribution of mallee in New South Wales is shown in Figure 1 (from Beadle 1948). All of the areas shown, except that mentioned above, have been visited since 1951. Although the mallee areas appear compact in Figure 1, in fact most of them are very much dissected by clearing or admixture with other vegetation types.

The mallee scrub in New South Wales is briefly described below; for the purposes of this discussion the following geographic areas have been named after a prominent county in each region:

Cooper.—The mallee areas north of Griffith, lying between the Murrumbidgee and Lachlan rivers.

Blaxland.—The mallee areas north of the line Hilston–Broken Hill.

Taila.—The mallee areas north of the Murray River and west of Balranald.

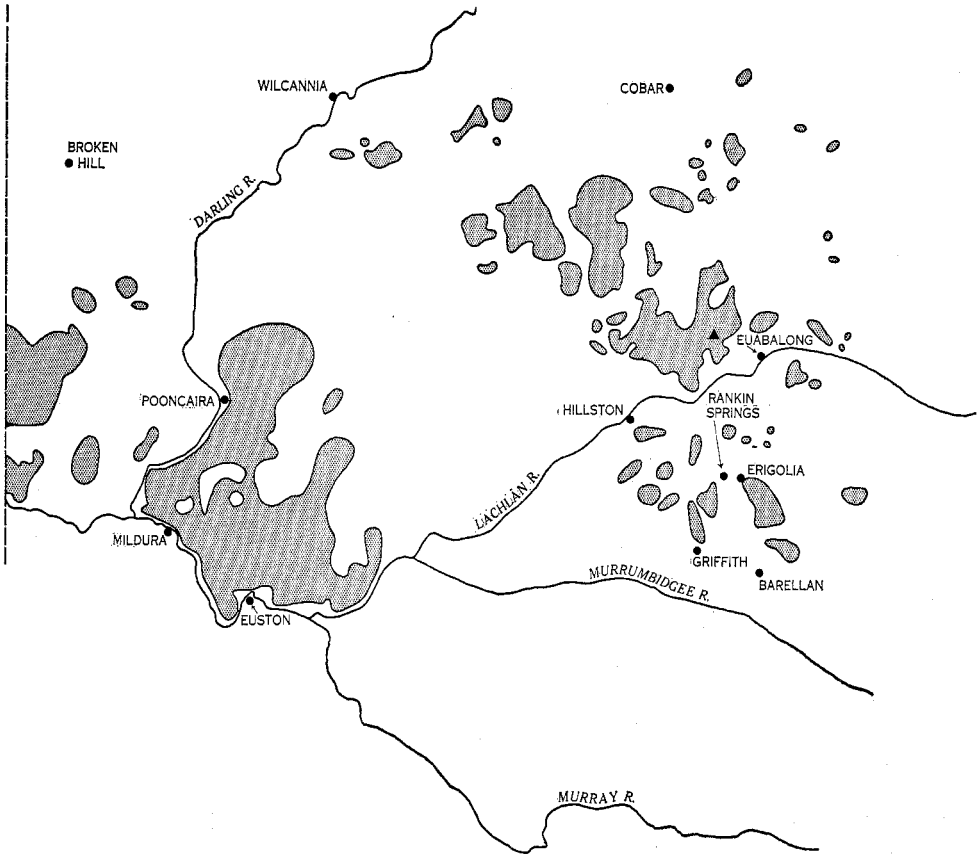


Fig. 1.—The distribution of mallee scrub in New South Wales (after Prescott 1944). The small triangle near Euabalong shows Round Hill Faunal Reserve No. 11.

The distribution of mallee is controlled by the soil type (Prescott 1944). The actual soil profile varies greatly from place to place, and while there is always a high percentage of sand in the upper layers there are large variations in the depth and texture of the sandy layers. As will be seen below, the depth and texture of the surface layers of the soil affect the distribution and abundance of various plants directly and of the mallee fowl indirectly.

The composition of the scrub varies greatly in the different districts. The species of eucalypts comprising the dominant vegetation include *Eucalyptus oleosa*–

E. dumosa association, *E. gracilis*, *E. viridis*, and *E. fruticetorum*. Of these, however, only the first association occurs extensively over the whole area, and the others are of minor or local importance. In places scrub pine, *Callitris verrucosa*, and broom bush, *Melaleuca uncinata*, may form extensive and impenetrable pure communities. According to Beadle (1948), mallee scrub over most of its range is the climatic climax, but between the 14- and 17-in. isohyets, i.e. the areas between the Lachlan and Murrumbidgee Rivers, there is an infiltration of woodland species and the mallee here is not the climatic climax but is a relic of a more arid climatic cycle.

The shrub layer is of greatest importance to mallee fowl because it includes their food plants; the eucalypt bushes provide nothing edible. The composition of the shrub layer varies greatly between the different parts, being richest in the better-watered and better-soil areas in the East; 53 shrub species have been recorded in the mallee areas south of the Lachlan, 35 north of the Lachlan, and only 25 north of the Murray. Of the legumes, most important as food plants, the numbers of species are 16, 12, and 9 respectively (Beadle 1948). East of the Lachlan the scrubs are relatively rich and west of it they become progressively poorer.

The mallee scrub formation in New South Wales can be conveniently divided into five classes according to its density and richness. They are illustrated in Plates 1–3.

Class I.—The characteristics are the presence of "green mallee", *E. viridis*, and a varied and dense, in places impenetrable, shrub layer. At Griffith the sole occurrence was on a rather heavy soil in a depression that retained moisture longer than elsewhere. At Kiata, Vic., on the other hand, the association is found on very deep coarse sands, but there the annual rainfall is much higher than at Griffith.

Class II.—The mallee is tall and dense, forming a complete canopy. There is a rich shrub layer, but the floor of the scrub is very open and in winter and spring supports numerous herbs. The food plants *Cassia eremophila, Bossiaea walkeri, Acacia brachybotrya, A. colletioides, A. hakeoides, A. buxifolia, A. rigens*, and *Beyeria opaca* are abundant. Although over large areas the scrub is remarkably uniform, its detailed composition varies in small areas. In general the deep sands are characterized by scrub pine, *Callitris verrucosa*, sometimes forming impenetrable thickets; where ferruginous or calcareous nodules occur close to the surface of the soil broom bush, *Melaleuca uncinata*, is often dominant. The shrub layer is most highly developed on the areas of heavier soil, and the heaviest soils often carry small areas of woodland and pure stands of *Acacia*.

Class III.—Known as whipstick mallee. The stems are thin and short, seldom exceeding 6 ft in height. The growth is dense. Shrubs are prominent but not so common as in Class II, and very few herbs grow at any time.

Class IV.—Frequently known as bull mallee. The trees are tall, up to 25 ft in height, and the stems thick. The scrub is relatively open although the canopy is complete. Shrubs occur but are not prominent. Much of the ground is invaded by various grasses, both native and introduced. The formation is characteristic of the heavier soils where the sand layer is shallow.

Class V.—The soils are excessively sandy. The mallee formation is very open and sparse and is much invaded by spinifex, *Triodia irritans*, which often forms continuous ground cover. *A. brachybotrya* and *A. colletioides* are present in reasonable density but *Cassia eremophila and Bossiaea walkeri* are usually the dominant leguminous shrubs. Towards the west the mallee merges with the Belah and Rosewood and Mulga associations and becomes intimately mixed. The area between Euabalong and Roto, however, is compact and almost pure mallee. The formation is more uniform than most other classes and extends over vast areas.

West of the Darling River what mallee scrub exists is very open, and the eucalypts are widely separated by areas of bare sand or spinifex, blue bush, and saltbush. It is here considered an extreme example of Class V. The whole area is heavily grazed by sheep.

TABLE 1

THE DENSITY OF MALLEE FOWL IN DIFFERENT CLASSES OF MALLEE SCRUB

Mallee Type	Land Use	Area Surveyed (sq. miles)	Breeding Pairs (per sq. mile)
I	virgin	no record	no record
II	virgin	25	13·7
	grazed	18	2·2
III	virgin	7	7·0
IV	virgin	10	5·8
	grazed	4	0·5
V	virgin	4	4·0
	grazed	17	0·4

The general distribution of these mallee classes in New South Wales may be summarized as follows:

Cooper.—There was one area of 100 acres of Class I, 6 miles from Griffith, but it was cleared in 1957. Class II is dominant and is most widespread between Griffith and Rankin Springs. East towards West Wyalong Class III becomes more common and is the commonest type in many parts. Class IV is found throughout the district but becomes more common west of Griffith, through Goolgowi and Melbergen. There is no Class V mallee in Cooper.

Blaxland.—The most widespread formation is Class V, but there are small areas of Class III, and a few isolated areas of Class IV towards Roto and also near Euabalong. Moving west towards the Darling one finds the Class V formation becoming mixed with the other scrubs and saltbush and merging into shrub steppe, with an occasional mallee bush. North of Hillston are a few small areas of Class II.

Taila.—Close to the Murray River Class II is dominant in the valleys and Class III occupies the ridges. There are extensive areas of Class IV north of the Sturt Highway. North of these the scrub merges into Class V, which in turn merges

into the shrub steppe and mulga scrubs. Class IV mallee continues intermittently along the course of the Darling River to about the Menindee Lakes.

Table 1 shows the density of mallee fowl in the main mallee classes in New South Wales. It can be seen that the density is greater in the florally richer types of scrub than in the poorer, and that grazing of the scrub by sheep is associated with a great decline in the number of birds present.

In a later section it will be shown that the mallee fowl depend for food on herbage and the fallen seeds of shrubs, largely *Acacia*. The only grazing available to sheep in mallee scrub comprises these same plants. Continued grazing leads to the rapid destruction of the herbs and fallen seeds and ultimately results in prevention of regeneration of the shrubs themselves. There seems to be little doubt that the differences in density of mallee fowl noted between grazed and ungrazed scrub are due to the destruction of the birds' food supply.

The mallee fowl is a large and sedentary bird living in what is, at the best of times, an arid and harsh habitat. The densities shown in Table 1, ranging from one breeding pair to about 50 acres in the richest classes of virgin scrub to one pair to 160 acres in the poorest class of virgin scrub, appear reasonably high. The presence of a number of "old" mounds in an area is not necessarily evidence that the area formerly supported a greater number of mallee fowl. It has been shown (Frith 1959) that the birds may move from mound to mound in successive years and that each territory may contain several temporarily disused mounds. It is difficult to imagine much greater densities in a natural population, and it is suggested that there has been little, if any, decline in mallee fowl numbers in virgin areas of scrub. A disadvantage, so far as New South Wales is concerned, is that very few areas of virgin scrub remain and these are, almost without exception, alienated as either freehold or lease. Their permanence is insecure and beyond the immediate control of the State authorities.

(*d*) *Destruction of Habitat*

The mallee areas in Cooper are all located in districts devoted to wheat and sheep farming. Many of the small areas shown in Figure 1 have been cleared for wheat or pasture and all of the large ones are very much dissected. Clearing is continuing in the district, and there is reason to believe it will continue until no mallee remains there.

With the exception of parts of the river frontage, Taila is devoted to grazing. It is to be expected that in the future irrigation development close to the river will destroy much of the better-class mallee in this district. The more arid scrub inland, such as the scrub in Blaxland, is not likely to suffer much clearing. It is, however, partly thinned in places to provide access for sheep and it is probable that such thinning will increase as time goes on. Where the scrub is sufficiently thin to provide sheep grazing without clearing it is used for that purpose.

There is little doubt that the clearing of the scrub and its invasion by sheep have been the chief causes of mallee fowl decline in the past and will continue to be so in the future. There are insufficient data as yet to determine the minimum area

required to ensure a self-perpetuating population of mallee fowl, but the reactions of the birds during clearing operations in one area near Griffith may be related.

Figure 2 shows the area in 1951, the number of pairs of birds in each block, and the years in which the various blocks were destroyed. From numerous observations it is possible to arrive at the following general conclusions.

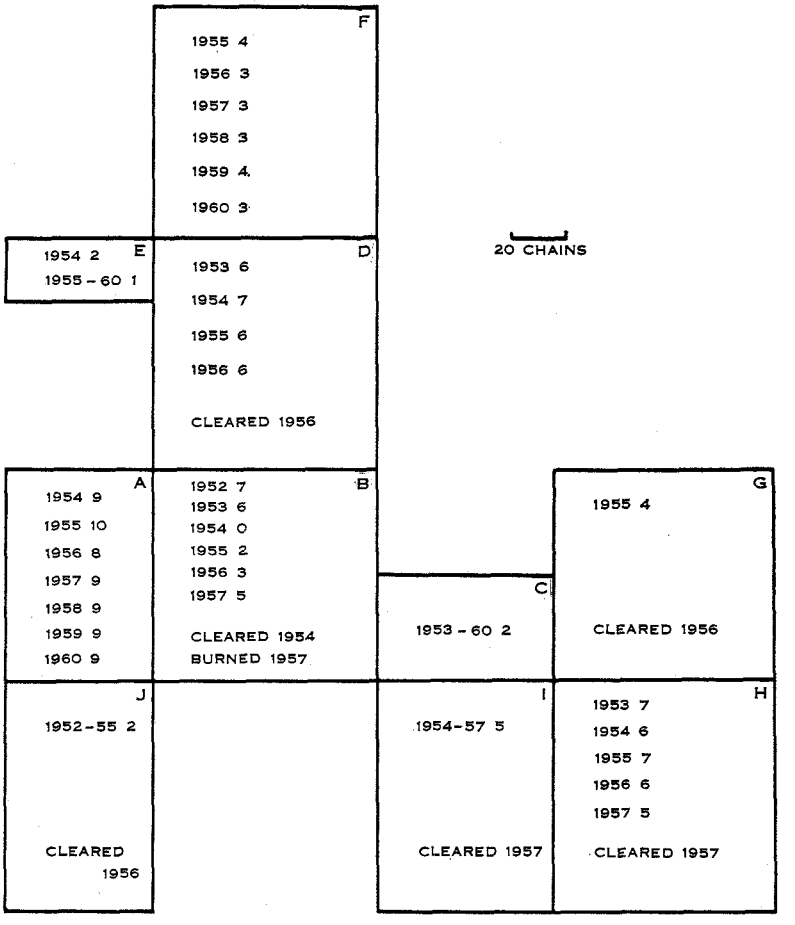


Fig. 2.—Map of the main study area and surroundings showing numbers of breeding pairs of mallee fowl and dates of destruction of habitat.

(1) *When clearing takes place the birds cannot find living space in adjoining areas but are destroyed with the scrub.* Since 1954 block A has supported nine or ten pairs of birds each year, block F three or four pairs, block C two pairs and block E one pair. The clearing of the blocks B, D, G, H, I, and J caused no increase in the numbers of birds in the adjacent undisturbed blocks except in one instance when a known colour-banded bird was able to establish itself in block A when block B was destroyed. The failure of the birds, many of which were colour-banded, to colonize adjoining areas suggests that the neighbouring areas of scrub already supported

the maximum numbers possible under the existing management, and provides general support for the argument advanced in a later section that predators are not the prime cause of low mallee fowl numbers.

(2) *Regrowth areas are quickly recolonized.* Many areas of mallee were cleared in the 1930's but were later allowed to revert to scrub. Today many of these areas are indistinguishable from virgin scrub. The western part of block B was such an area. In all cases examined, where there was adjacent scrub, the regrowth area was fully occupied by mallee fowl.

The speed of re-invasion was seen in block B. This block was rolled (for the second time) in 1954 but it was not burned until 1957. The rolling was carried out in the winter of 1954; by the spring of 1955 the regrowth was 2 ft high and at least two of the old mounds had been reoccupied. In the spring of 1957 there were five occupied mounds, the scrub growth being 4–5 ft tall. The burning in 1957 was final.

(3) *The area needed for maintenance of mallee fowl is probably quite small.* Block A (about 500 acres) has been under observation continuously since 1953, and seven of its 18–20 breeding birds are colour-banded. In this time there has been one known immigrant from block B, but none of the banded birds have moved from block A (Frith 1959). There is no reason to believe that there has been appreciable interchange of birds between it and adjoining blocks. Since 1956 the block has been completely isolated from other mallee, and if allowed to remain undisturbed will ultimately give direct data on the minimum area needed to support a population of mallee fowl.

(4) *Restocking of mallee areas should be possible.* It would be, of course, essential for the original cause of decline in the area to be determined and removed before restocking. It has been the author's practice to remove the eggs from mounds threatened with rolling. These eggs are easily hatched in a laboratory oven at 95°F. The chicks are raised on a diet of minced liver, seeds of Hungarian millet, and *Cassia eremophila* (a "natural" food), until 3–6 weeks old and then released. It has not been possible to secure complete control of a depleted area of mallee for the final test of actually establishing a population; there is, however, no reason to believe that the artificially hatched chicks would not survive as well as chicks from mounds.

(*e*) *Food*

The mallee fowl feeds on invertebrates and seeds, fruits, and flowers of herbs and shrubs obtained from the ground surface or from vegetation up to 2 ft from the ground. It turns over leaf litter freely in search for food but has not been observed to scratch deeply in the soil for this purpose.

Although a large bird it is able to utilize very small objects as food. Individuals have been watched catching ants 2 mm long, and picking up seeds of *A. hakeoides* about 1 mm in diameter. The largest plant items found to be regularly eaten are the berries of *Beyeria opaca,* about 5 mm in diameter. In captivity when presented with a mixture of seeds, including wheat, Hungarian millet, Japanese millet, and canary seed, mallee fowl have invariably selected the smaller seeds and required "training" to the larger.

Table 2 shows the frequency with which the birds were observed feeding on the identified food items. The food consists of a sequence of plants and animals, following their seasonal abundance.

The most commonly eaten seeds were those of the legumes. These are eaten in quantities throughout the year except for a short period in spring. At that time the seeds could not be found under the shrubs, the supply having been exhausted. The legumes flower in early spring and the birds eat some of the blossoms and buds during September and October. The seeds of the commonest species fall successively

TABLE 2

FOOD HABITS OF THE MALLEE FOWL

Showing the frequency with which birds were observed feeding on the different items; based on 436 observation periods

Food	Frequency (%)
Plant Food	
Shrubs	
Cassia eremophila	14
Acacia brachybotrya	14
A. hakeoides	7
A. buxifolia	7
A. rigens	6
Eriostemon difformis	6
Beyeria opaca	10
Pittosporum sp.	4
Other shrubs	5
Herbs	
Total herbs	10
Animal Food	
Formicidae	5
Blattidae	2
Other animals	10

from January until March and there is an increasing amount of leguminous seed on the ground from early January onwards. The amount of seed of these plants eaten begins to increase in January and by March forms almost the whole of the birds' food. The decline in utilization in late autumn is due largely to a decline in the abundance of the seed.

The herbs are eaten in large quantities throughout the autumn, winter, and spring, the only time that these are available; in the hot weather the soil is dry and bare. The herbs provide almost the only plant food available during the colder months, when shrubs are not flowering or setting seed.

Apart from the legumes and herbs, *Beyeria opaca* is the most commonly eaten shrub. It flowers in spring and the berries ripen in early summer. The buds and berries are an important source of food to the birds.

The amount of insect food eaten parallels the availability of the ground insects. The larger forms, i.e. beetles and cockroaches, although perhaps no more abundant in the spring, are certainly very much more obvious then than at other seasons and they may be encountered moving freely over the ground surface. At other times they are rarely seen, presumably because the arid atmosphere causes them to seek a moister microclimate than that of the soil surface.

The birds' water requirements are slight. During the greater part of the summer there is no surface water, no dew, and few succulent fruits. The birds are strictly confined to their territories and do not visit earth tanks or other available water. When rain falls, however, the birds drink freely at any temporary pools formed.

(*f*) *Predation*

Mallee fowl are sometimes shot, or their mounds robbed, for human food. Of the 85 mounds studied in detail, however, only one was robbed, and no birds were shot in the study area. In all 206 occupied mounds have been inspected. In mallee soil human footprints remain visible literally for years, but of these 206 occupied mounds inspected only two showed signs of having been visited by humans. Both were close to and visible from public roads. Experience gained and enquiries made in other districts suggest that human predation is not usually a serious cause of loss of mallee fowl.

On one occasion a shingle-back lizard, *Trachysaurus rugosus,* was found in an open mound eating an egg. That this was an unusual event is suggested by the fact that despite the great abundance of these lizards it has been observed only once and, furthermore, on that occasion the lizard was unable to climb the loose sand of the excavation to escape. The goanna, *Varanus gouldii*, occurs in the study area but has not been observed near the mounds. K. Hateley reports that the goanna has destroyed eggs at Kiata.

Although several birds of prey have been seen in the study area their effect on the mallee fowl is not known. As the mallee fowl have been seen to show a very swift reaction and escape into the scrub when birds of prey fly over, it is probable that they do have something to fear from them on some occasions.

The chief predator of mallee fowl is the introduced fox. Although it has long been thought that foxes were responsible for much of the decline in mallee fowl, opinion has differed as to how they operate. During the course of this study foxes were numerous in the area and their scats were collected wherever found. The 320 scats collected were soaked and washed in water and the residue examined qualitatively. The result of these examinations is given in Table 3. The scat normally consisted almost entirely of remains of insects, including beetles, cockroaches, grasshoppers, and ants. If insects are eaten it is only to be expected that the hard chitinous parts would be highly represented in the scat; but such consistent large quantities indicated that insects were a very important food. The bird feathers were not identified, beyond the fact that they were not mallee fowl or mallee fowl chick. Apart from one occurrence of white feathers of a domestic fowl the remainder

were small indeterminate down feathers, presumably from the nestlings of ground-nesting birds. It was easy to determine whether the egg-shell was of mallee fowl egg or not by its colour, texture, and thickness. Although the sample is rather small Table 3 indicates that foxes do not feed to any extent on mallee fowl, but do prey on their eggs.

There is other circumstantial evidence that foxes destroy very few mature mallee fowl. Of 85 mounds that have been studied throughout a full breeding season, i.e. a period of 9–10 months, only two were abandoned during the season because of the disappearance of one of the birds. In one case the male was found dead from an unknown cause, but certainly not killed by a fox as it was not mutilated; in the other the male disappeared and could have been killed by a fox. Furthermore, 206 active mounds and several hundred disused ones have been examined. None had been abandoned during a breeding season; all the active mounds had signs of fresh

TABLE 3

OCCURRENCE OF REMAINS OF FOOD ITEMS IN 320 FOX SCATS COLLECTED NEAR GRIFFITH IN THE PERIOD 1953–57

Food Item	Occurrence	Occurrence (%)
Insects	320	100·0
Lizards	72	22·5
Seeds and fruits	161	50·3
Birds	17	5·3
Rabbits	6	1·9
Mallee fowl egg	5	1·6

activity, all the disused ones had been dug out at the end of a breeding season. If foxes kill many birds their activities must be confined to the non-breeding season, a period of 3 months. This is, of course, extremely unlikely. Another observation is that none of 11 colour-banded birds has disappeared unless the area has been cleared.

The effect of foxes on chicks is not known, beyond the observation that chicks' feathers were not found in the fox scats. It is probable that some chicks are killed by foxes, but as will be seen during the discussion of fox predation on eggs, predation on chicks can have little effect on the ultimate numbers of mature mallee fowl unless it is extremely heavy.

Table 4 (adapted from Frith 1959) shows that of 85 mounds studied 48% were attacked by foxes, and of the 1094 eggs whose history is known 37% were destroyed.

In each year except 1955–56 more than half the mounds under observation were attacked at least once by a fox. In 1955–56 only one mound was attacked; the fox began visiting in October and continued throughout the season until all the eggs were destroyed. In 1955–56 fox sightings, droppings, and tracks were apparently just as common as in the other years, and there was no reason to believe that the

animals were any less abundant than in years in which attacks were much more severe. That year was one in which the summer was exceptionally mild and there was very frequent light rain (Frith 1959). Herbage and ground insects, particularly ants and cockroaches, were very much more obvious than in the other years. It seems probable that the diminution of fox attack in 1955–56 was due to that fact, alternative food being sufficiently abundant for the animals.

Fox predation was not uniform over the whole area, some nests being attacked each year whereas others were never attacked. Some were attacked in one year but not in others. Numerous observations were made on the foxes in the area and from these the following inferences are drawn.

TABLE 4

FOX PREDATION ON THE MOUNDS AND EGGS OF MALLEE FOWL

Year	Number of Mounds		Number of Eggs	
	Total	Attacked by Foxes	Total	Eaten by Foxes
1952–53	4	2	—	—
1953–54	14	10	231	91
1954–55	10	6	189	96
1955–56	12	1	333	26
1956–57	12	6	192	100
1957–58	14	6	149	94
1958–59	9	5	—	—
1959–60	10	5	—	—
Total	85	41	1094	407

(1) *Not all foxes attack mallee fowl mounds.* In fact the number of actual predators of the mounds may be quite small. This conclusion is supported by the fact that during spotlight traverses through the study area numerous foxes were sighted, as many as 17 on one occasion. Such density of foxes, when one considers that a single animal may visit several mounds, is evidently quite sufficient to enable them to destroy every egg in every mound, but a considerable proportion of mounds and eggs were not attacked.

A further observation is that in 1953–54 and in 1956–57 a vixen occupied a burrow and raised a litter within 30 yd of one mound and within 150 yd of another, yet these two mounds were not attacked.

(2) *Each predator may attack several mounds.* On several occasions foxes were destroyed by shooting or by inserting poison into an egg in a mound subject to predation. Shooting usually had no effect on predation but the poisoning, if the bait was taken, was invariably followed by cessation of fox attack on several mounds, often widely separated.

Figure 3 shows the result of one such poisoning experiment. Ten mounds were suffering constant predation, Nos. 1, 3, 5, 9, 19, 30, 31, 42, 44, and 45. On the afternoon of October 29, 1953, a poisoned egg was placed in each of mounds 3, 30, and 42. The following morning the egg from mound 3 had been removed. Predation immediately ceased on mounds 1, 3, 5, 9, 30, and 42, but continued on the other affected mounds. This observation suggested that at least two foxes had been involved in the predation and that one of them had been visiting six mounds.

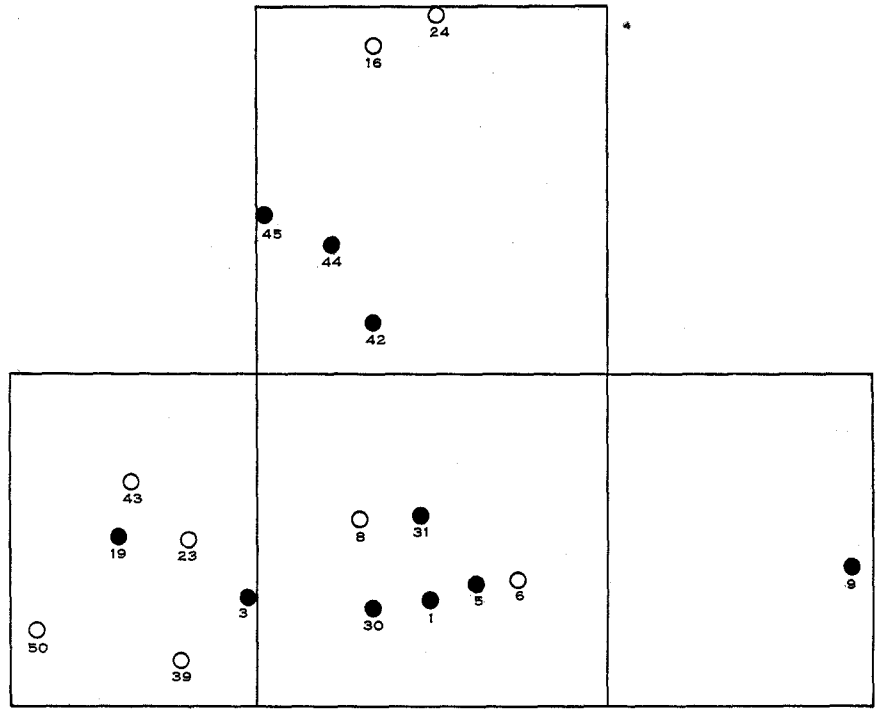


Fig. 3.—Map of main study area showing mallee fowl mounds studied in 1953–54. Those shown as black spots were under fox predation.

(3) *The mound itself does not provoke the response to dig for eggs.* Mallee fowl mounds are very large, characteristic, and conspicuous objects, and it is improbable that the fox does not, sooner or later, discover every mound within its territory, yet not all are attacked; e.g. in Figure 3, although mounds 1, 5, 30, and 31 were attacked, mounds 8 and 6 nearby were not. Fox tracks were frequently found on these and on other mounds that were not attacked during that season.

It seems probable that the individual fox must learn of the presence of eggs in a specific mound before it attacks. Perhaps the animal discovers the mound open with an egg exposed, as frequently occurs during temperature control (Frith 1956), or disturbs the birds during egg-laying.

(4) *The severity of fox attack varies seasonally.* Figure 4 shows the relative frequency of attack by foxes on mounds each month during the breeding season. It can be seen that attacks are most common in spring and autumn but the frequency declines in summer. This variability of attack was apparently correlated with the sequence of mound maintenance by the birds (Frith 1956).

In the spring, when the mounds were low and composed mainly of organic matter with a rather thin covering of sand, they were easily dug out and each egg could be eaten within a day or two of laying. Similarly in late summer and autumn, when the mounds were open almost daily and the eggs were covered only by a few inches of sand, they were removed almost as soon as laid. In midsummer, however, when the eggs were covered by up to 3 ft of loose dry sand, the foxes were apparently incapable of moving back the shoulders of the mound and digging a broad excavation

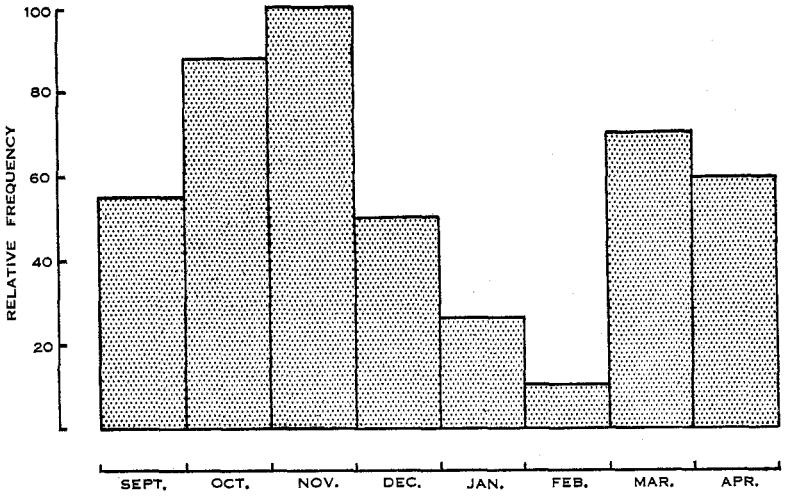


Fig. 4.—Seasonal variation in incidence of fox attack on mounds under predation.

similar to that of the birds. They attempted to dig straight in and were defeated by the running sand. At that time of the year a few eggs accumulated in the attacked mounds, and if the hot weather lasted sufficiently long sometimes one or two were able to hatch; but as soon as the foxes were able to surprise the birds with the mound open for egg-laying, or at the first opening for warming in the autumn, all eggs were eaten (see Plate 4).

IV. Discussion

The major cause of decline of mallee fowl in New South Wales undoubtedly has been the wholesale destruction of habitat for agricultural purposes. Despite this, however, vast areas of scrub remain and the mallee fowl has declined or disappeared in many, but not all, of these.

It is usual to assume that the depredations of foxes have caused the decline, but that is probably not so. The mallee fowl is sedentary, and it is known from observations on banded birds that individuals breed for at least 8 years and

perhaps much more. The mean clutch size over a number of years was 18·6. On an average, then, each pair of birds produced a minimum of 149 eggs in its lifetime; foxes destroyed 37% (55) of these, leaving 94 eggs, of which 74 resulted in living chicks (Frith 1959). Only two of these need survive to replace their parents for the population to remain static. There is nothing in the data to suggest that fox predation on the chicks reaches anything like the level necessary to be a significant factor in decline of the population.

In addition to the above consideration it has been seen that in many areas abounding with foxes mallee fowl are very abundant, probably as abundant as they ever were. There seems to be little doubt that foxes are not the prime cause of decline in mallee fowl numbers in uncleared areas.

On the other hand it has been shown that areas heavily grazed by sheep are characterized by very low densities of mallee fowl. It has been postulated (Frith 1959) that the breeding rate and behaviour of mallee fowl are greatly influenced by the availability of food. It has now been shown in this paper that the density of the birds in different types of scrub is also largely dependent on the abundance of the shrubs providing their food. Sheep, by utilizing the same food, decrease the amount available to the birds and so lead to decline in their numbers. Probably the chicks do not survive.

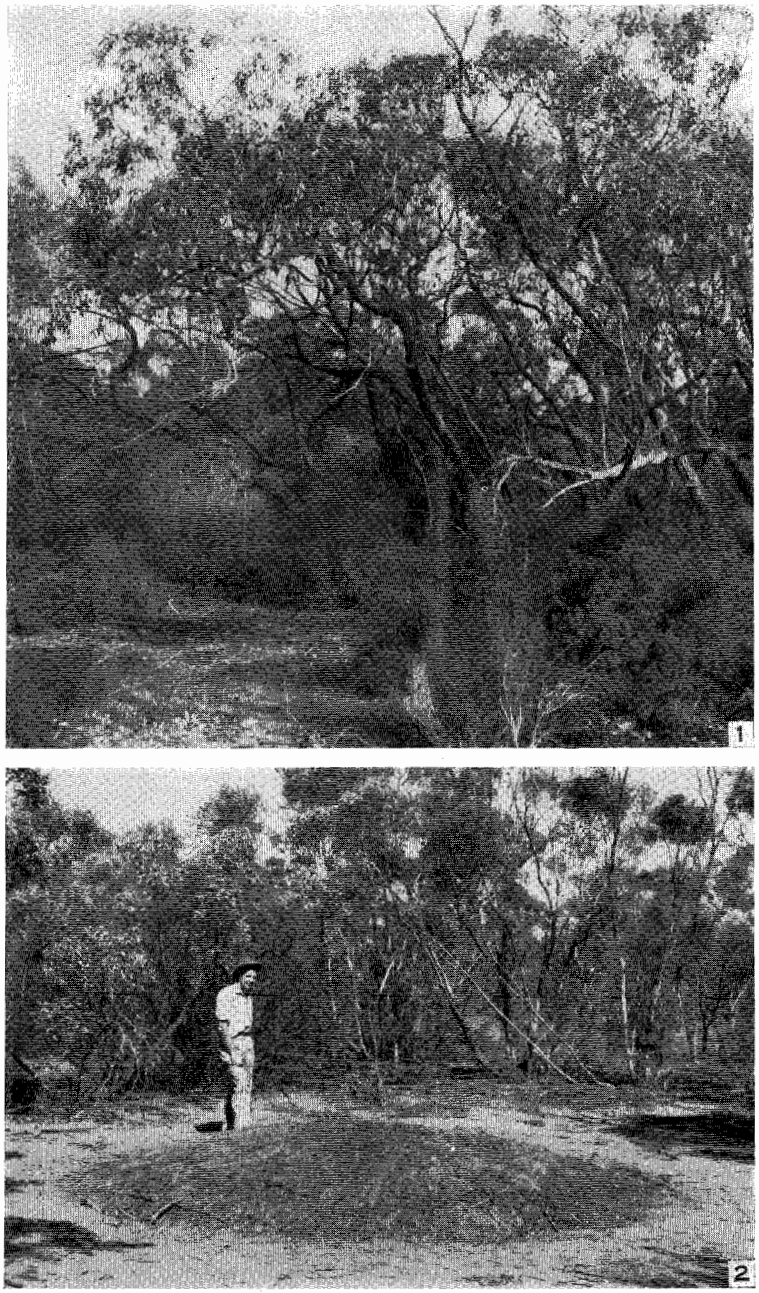
The conservation of mallee fowl demands the creation of mallee reserves. It is essential that these reserves should be protected from grazing by sheep, and, if possible, by rabbits. It is fortunate that rabbits are not generally numerous in the New South Wales mallee. A promising start has been made by the New South Wales Chief Secretary's Department with the acquisition of 12,800 acres of scrub at Round Hill, west of Euabalong (Round Hill Mallee Fowl Faunal Reserve No. 11; Plate 3). It is unfortunate, but unavoidable, that this area consists of rather poor mallee and that the density of mallee fowl in it is low. Its remoteness, harsh surroundings, and dense prickly spinifex virtually deny the sight of mallee fowl in it to any but the most enthusiastic of the public.

The Round Hill Reserve is valuable in preventing the extinction of the species, but it is pointed out that no conservation scheme can be effective if public interest is not aroused. Some of the densest populations of mallee fowl in Australia exist within 40 minutes' drive, on good roads, from Griffith, N.S.W. Some of these birds have become so accustomed to the presence of the author that they carry out their complete complex temperature-regulatory work undisturbed by any number of nearby observers.

If some of that land were acquired by the State or otherwise preserved, there is little doubt that the general public could see and quickly learn to appreciate this unique bird.* What can be done in this regard has been shown by the community at Kiata, Vic., where under the leadership of K. Hateley landholders have donated and placed in trust an area of mallee for the preservation of the species.

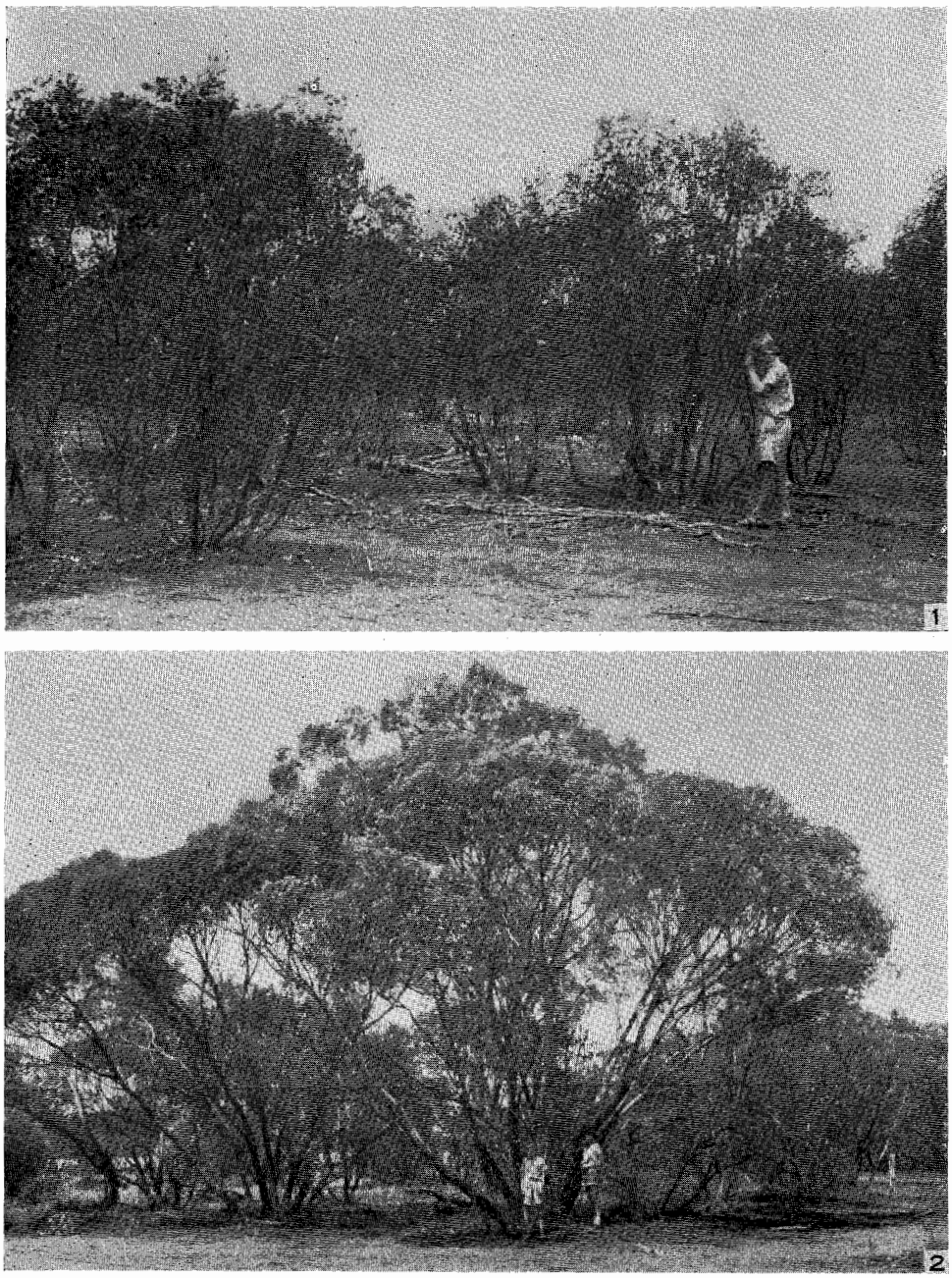
* *Note added in proof.*—As a direct result of the work described here and in preceding papers, the New South Wales Chief Secretary's Department has now been able to secure control of the study area. The land will be devoted to the preservation of mallee fowl and other fauna.

CONSERVATION OF THE MALLEE FOWL



Types of mallee scrub. Fig. 1.—Class I. Kiata, Vic. Fig. 2.—Class II. Rankin Springs, N.S.W.

CONSERVATION OF THE MALLEE FOWL



Types of mallee scrub. Fig. 1.—Class III. Barellan, N.S.W. Fig. 2.—Class IV. Mt. Hope, N.S.W.

CONSERVATION OF THE MALLEE FOWL

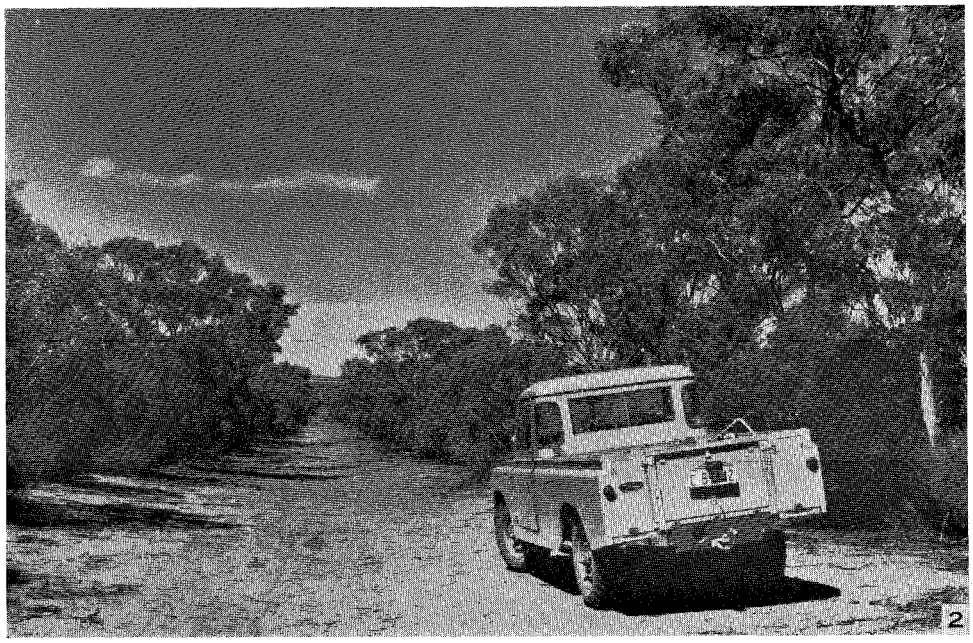


Fig. 1.—Types of mallee scrub. Class V. Round Hill Mallee Fowl Faunal Reserve No. 11.
Fig. 2.—Virgin, mainly ungrazed mallee, class II, near Griffith, N.S.W. The main study area.

CONSERVATION OF THE MALLEE FOWL

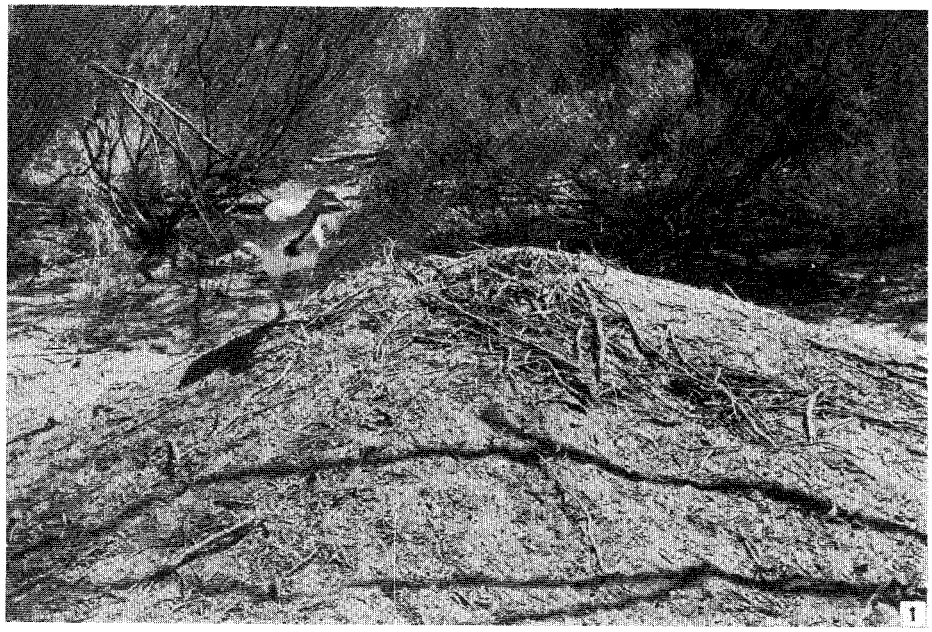


Fig. 1.—In midsummer, when the mounds are heaped high, few eggs are destroyed by foxes.
Fig. 2.—The eggs are most vulnerable when the mound is opened for egg laying.

C.S.I.R.O. Wildl. Res., Vol. 7, *No.* 1

V. Acknowledgments

In 1951 the late Mr. F. J. Griffiths, Chairman of the New South Wales Fauna Protection Panel, requested the author to take part in the survey of mallee fowl abundance. Mr. Griffiths's request and the surveys undertaken to satisfy it, and his interest in the work, stimulated the author to begin a series of studies of mallee fowl of which this is the latest. The whole series can thus be looked upon as a direct outcome of the original request by the Fauna Protection Panel.

The author gratefully acknowledges the field assistance given in this study, as in preceding studies, by Messrs. B. K. Brown, G. Booth, R. A. Tilt, and G. M. Storr—all of them members of the Wildlife Survey Section at the time of their participation.

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