ECOLOGY OF THE MAGPIE GOOSE, *ANSERANAS SEMIPALMATA* LATHAM (ANATIDAE)

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CONTENTS

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Summary

The ecology of the magpie goose, *Anseranas semipalmata* Latham, in the Northern Territory has been studied with a view to determining its relationship to the developing rice industry on the subcoastal plains.

The distribution of the geese since European settlement of Australia is discussed, and it is shown that the species was rapidly exterminated in the southern part of the continent, although irruptions to these regions still occur.

In the Northern Territory geese confine most of their activities to the sub-coastal plain but occasionally use the other habitats available to them.

The birds are to some extent nomadic. In the dry season most of them concentrate on the Mary and South Alligator Rivers, and during the wet season they spread over the other rivers to breed. Movements are mainly controlled by the availability of food, water, and breeding habitat.

The main foods are the seeds of swamp grasses, the blades of dry-land grasses, and the underground bulbs of spike-rush. Changes in the availability of these foods occur both seasonally and annually, and are discussed.

Breeding occurs at the end of the wet season. The breeding season and the location of the colony are determined by the depth of water and the density and height of the swamp vegetation.

It is concluded that the birds will not be a continuing pest of rice, but rather will be eradicated by the industry.

I. Introduction

In 1953 the Northern Territory Administration began experiments on the cultivation of rice on the river plains of the Northern Territory. An experimental farm was established on Humpty Doo Station on the Adelaide River, about 40 miles south-east of Darwin.

The subcoastal plains of the Northern Territory were in an almost virgin state and were the traditional breeding and feeding grounds of large numbers of magpie geese (also known as pied geese), *Anseranas semipalmata* Latham. These birds attacked the early crops of rice and it was feared that they would be a serious hindrance, or even a limiting factor, in the establishment of the rice-growing industry in the region.

In 1955 the C.S.I.R.O. Wildlife Survey Section was invited to report on the possibility of control of the species, and its probable relationship to the industry. The area was visited, and it was decided that any short cut to a practical solution, either for control of the birds or for protection of the crop, would be a waste of time, and that the first need was for a detailed study of the birds' ecology and behaviour.

Apart from taxonomical studies little previous work had been done on the magpie goose and no comprehensive account of the species existed. The ecological study was begun in August 1955 and the behaviour study of the species in January 1957. This paper discusses the birds' ecology, and it is expected that their behaviour will be discussed in separate papers.

II. Methods

(a) *Distribution*

The distribution of the birds was determined by a series of ground and air surveys in the Northern Territory and elsewhere, by correspondence with mission stations and others in isolated localities, and by the examination of published records and of the data accompanying specimens held in Australian and overseas Museums.

(b) *Habitat*

In the Adelaide River Valley it was possible to visit every part of the plain in both the wet season and the dry season. The East Alligator and the Mary Rivers were visited on the ground in both seasons, and the South Alligator in the dry season.

Table 1

DENSITY CLASSES USED IN ESTIMATING DENSITY OF SWAMP VEGETATION

Class	Number of Stems per m^2
I	0–399
II	400–699
III	700–999
IV	1000–1299
V	1300–1599
VI	1600+

Having obtained detailed knowledge of the distribution of the habitats on the ground, the present authors could easily recognize the various plants from the air, and thus it was possible to survey the vegetation accurately and rapidly over very large areas, many of which could not be visited from the ground. As each plant tended to have specific water-depth requirements it was also possible to estimate the depth of the swamps from the air, this work being aided and checked by various other indications, such as wading buffaloes.

The distribution of the plants in the breeding swamps was determined along series of line transects across each swamp. At 50-yd intervals the water depth and the height, density, and composition of the vegetation were determined. The water depth was recorded as the general depth in order to allow for irregularities on the bottom. The maximum height of the vegetation was recorded, as well as the general height in the vicinity. The density was assessed by eye into one of six classes. These density classes were calibrated by comparison with 126 samples of vegetation cut from square-yard quadrats, the plants from which were counted and in some cases weighed. The density classes adopted are shown in Table 1 and are illustrated in Plate 1.

In addition to these surveys, in 1959 a more detailed vegetation survey was carried out in one swamp, Tommy Policeman Plain. The water depth was measured and the vegetation assessed on a 50 by 50 yd grid over 62 acres. Quadrats were cut at each point on a 50 by 100 yd grid.

(c) *Movements*

The movements and numbers of the geese were studied from low-flying aircraft. Two transects were established and flown on the following dates:

Route 1	1955	April 17; September 22, 30; November 18
	1956	February 21; April 3; November 12
	1957	February 7, 21; March 8, 22; April 7, 20; May 4; June 2; September 17; October 23; November 25; December 23
	1958	January 20; February 22; March 26; April 24; May 28
Route 2	1955	October 4
	1956	April 7; November 17
	1957	June 1–3; September 17
	1958	April 24; August 29

Figures 1 and 2 show the region studied. Route 1 (see Fig. 1) was designed to cover the whole of the Adelaide River valley and to obtain a count of the total goose population in it, and to traverse the Mary River plains to check on gross movements to or from that area.

Route 2 (see Fig. 2) was designed to reconnoitre all the river valleys between Darwin and Western Arnhem Land—the East Plains. The object was to record the changes in distribution of the geese among the various rivers in the wet and dry seasons. In addition to noting the changes in distribution, which were very evident, the numbers of geese on each river were estimated, allowing a wide margin of error as many flocks were immense and assessment of numbers difficult.

Geese were banded throughout the study. In 1957, in addition to the numbered aluminium bands of the Australian Bird-Banding Scheme, coloured bands were placed on the birds from each flock to indicate their banding place. In all 2177 geese were banded.

The birds were trapped by means of a cannon net. The net was 40 yd long and 20 yd wide, and was fired by six cannons. A few were also caught in wire-netting traps. In both cases rice was used as bait.

(d) *Food*

A total of 370 crops and 245 gizzards of adult geese were collected during the four seasons of field work from April 1955 to May 1958 in the Adelaide River valley. In addition 22 crops were collected from the Mary River and 10 gizzards from the South Alligator River. Twelve downy goslings, less than 1 week old, and six 7-week old goslings were also collected. The crops, or (if these were empty) the gizzards, were removed as soon as possible after the birds were shot and their contents were spread out on a sheet of paper at air temperature (about 90°F) until they had dried.

The contents of the crops were measured volumetrically after sorting, but with gizzards only the presence or absence of specific foods was recorded,

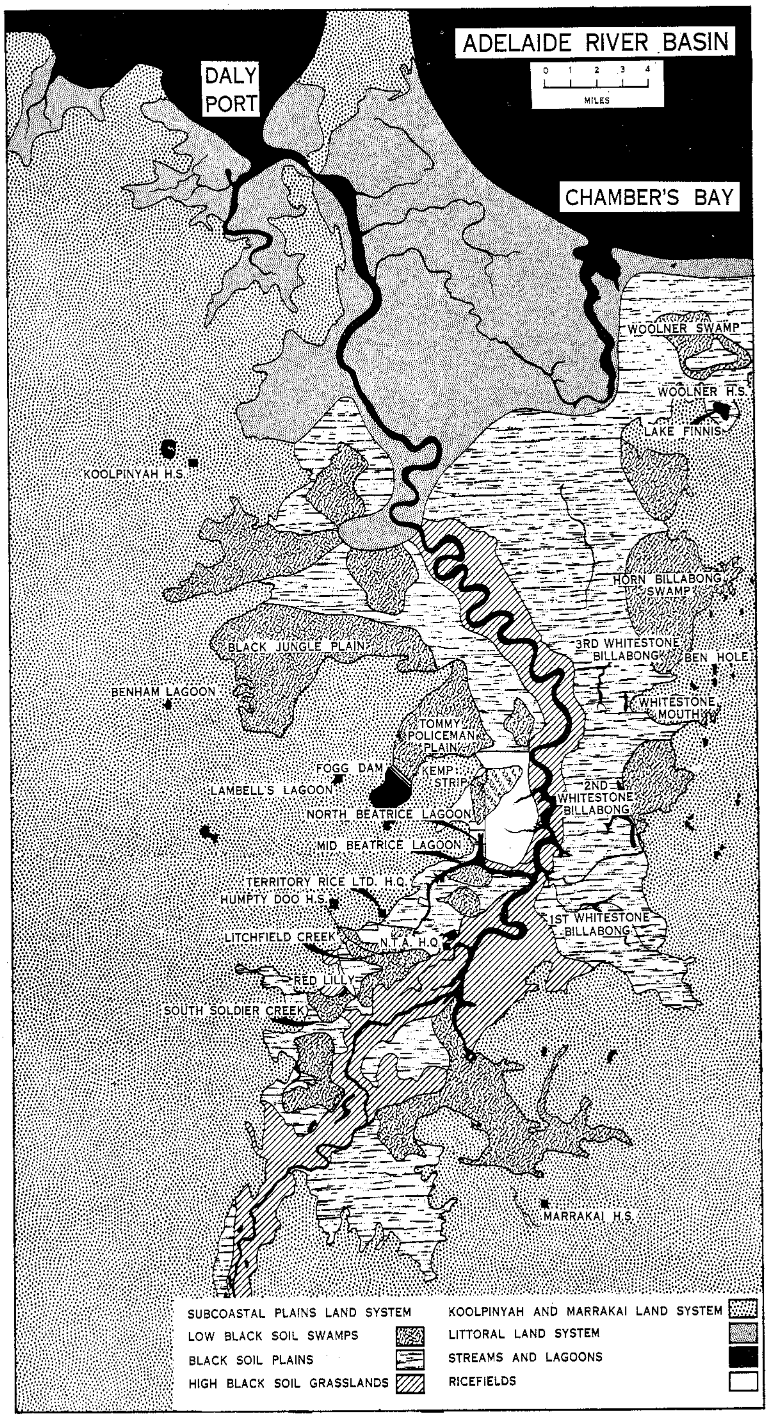

Fig. 1.—Locality map of the Adelaide River Valley.

because much of the material was ground beyond recognition and the volumes obtained could not be compared with those from the crop analyses. Since the number of birds in the various samples taken at different times and places varied greatly, it was considered desirable to take the whole sample (not the individual crop) as the unit. Otherwise undue weight would be given to items in crops of, say, half a dozen geese taken in a locality where they were easy to shoot, as compared with items in the crop of a single goose shot out of an equally large flock in a place more difficult to approach.

In addition to the volumetric method for crops the percentage frequency of occurrence of items contained in both crops and gizzards was considered. Again samples (not individuals) were taken as units. This method gives equal weight

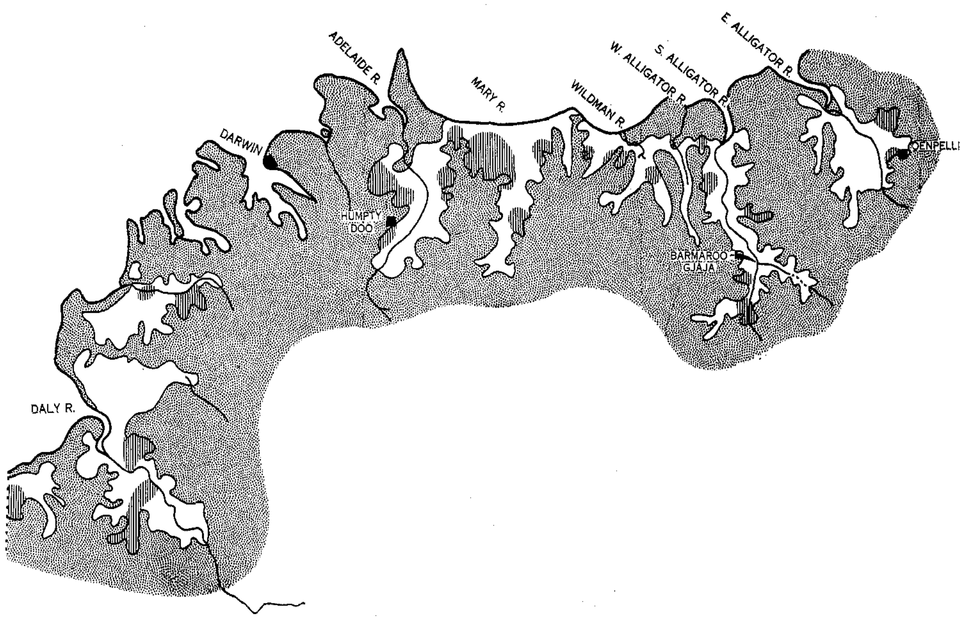

Fig. 2.—Northern and Western coastal rivers of the Darwin Area. The rivers are shown as black lines. The positions of all breeding colonies of the magpie goose are shown by the vertical hatched areas and these, together with the unshaded parts of the map, represent the subcoastal plains of each river.

to an item found in large quantity in one bird in a sample and to another item found in small quantities in all birds in a sample, and therefore is not nearly so precise as the volumetric method. It was used, however, in order to make as much use as possible of the available data and to support the broad conclusions obtained from study of the crops alone.

(*e*) *Breeding*

To study the sexual cycle of the birds, gonads were collected and measurements were taken. The lengths, breadths, and volumes of the testes, and the diameters of the three largest oocytes in each ovary, were recorded.

The testes were preserved for histological examination. In all 208 testes preserved in Bouin's fixative were sectioned, stained with Ehrlich's haematoxylin, and counterstained with eosin for examination of cell structure. Samples of 50 of these testes were preserved in formol calcium fixative, sectioned on a freezing microtome, stained with Ehrlich's haematoxylin, and counterstained with Sharlack R for demonstration of the lipoids.

Breeding data were collected during air surveys, where it was found quite possible to determine the stages of nest-building and egg-laying over large areas very rapidly. Where feasible the colonies located were then visited on foot or by helicopter.

In the 1955–56 season it was possible to make regular ground observations on the colonies on Tommy Policeman Plain and Litchfield Creek until the eggs were laid. In 1956–57 and 1957–58 regular observations were continued and intensified on these colonies, and were extended to more distant colonies.

In each colony and at each nest it was found desirable to record the depth of the water and the composition, density, and height of the vegetation, as well as the usual data on the state of the nest and clutch. Many of the nests were found during egg-laying and many during incubation. Incomplete clutches were visited again, wherever possible. The approximate stage of incubation of complete clutches found was determined by flotation of the eggs in water or by examination of the embryo.

III. Environment

(a) *Climate*

The climate of the north coast of the Northern Territory is monsoonal and is characterized by a wet season extending from September or October until March or April, and a dry season, during which rain rarely falls, covering the remainder of the year. Rainfall has been recorded at Humpty Doo since 1941, but other climatic data have been collected only since 1954, so no generalization can be made. For reference the climatic data for Darwin, 40 miles to the north-west, are shown in Table 2.

The annual average rainfall at Humpty Doo is lower than that at Darwin and in the period studied averaged 58 in., ranging from 36 to 77 in. The distribution of rain in the seasons studied is shown in Table 3, where it can be seen that the wet seasons of 1955–56 and 1956–57 were normal, but in 1957–58 and 1958–59 very much less than average rain fell. The year 1959 was further characterized by an unusual late cyclone in April, during which 12 in. of rain fell and the plains flooded for a second time.

(b) *Land Systems*

The region studied is shown in Figure 2, and Figure 1 shows a more detailed map of the Adelaide River. Christian and Stewart (1953) have described several land systems within the region, which are used as a basis for discussion of the habitats available for the geese. The more important land systems are briefly described below.

(i) *Koolpinyah Land System.*—This system consists of gently undulating land with lateritic soils carrying tall, open eucalypt forests with rather dense undergrowth. The land forms ridges separating the river plains. Lagoons and spring-fed streams occur throughout, and in some places small swamps are formed. In general the Koolpinyah system is not used by geese, although some of the lagoons are minor dry-season concentration places, and the streams are important as sources of water to fill the swamps on other land systems.

TABLE 2

CLIMATIC DATA FOR DARWIN

Average annual rainfall	60 in.
Average number of rainy days	100
Average rainfall per rainy day	0·6 in.
Mean maximum temperature	90·9°F
Mean minimum temperature	74·3°F
Mean temperature hottest month (Nov.)	85·9°F
Mean temperature coolest month (July)	77·4°F
Mean relative humidity (Feb.)	80%
Mean relative humidity (July)	59%

TABLE 3

MONTHLY DISTRIBUTION OF RAINFALL (IN.) AT HUMPTY DOO

Month	1955–56	1956–57	1957–58	1958–59	Mean 1955–59	Mean 1941–59
July	0·91	0·23	0	0	0·28	0·04
August	0	0	0·09	0	0·02	0·02
September	0	0·59	0	0	0·15	0·31
October	2·27	4·42	0·50	2·73	2·48	2·06
November	5·78	2·84	3·27	7·03	4·73	5·70
December	1·35	12·99	10·00	7·35	7·92	7·80
January	8·63	15·68	7·39	11·71	10·85	9·69
February	27·06	18·63	4·84	3·05	13·39	11·27
March	7·28	18·94	6·88	6·30	9·85	7·86
April	8·03	2·92	2·99	15·44	7·35	3·63
May	2·70	0·12	0·50	0·06	0·84	1·06
June	0	0	0	0	0	0·06
Total	64·01	77·36	36·46	53·67	57·88	51·50

(ii) *Buldiva Land System.*—This system comprises the elevated, deeply dissected quartzite table lands and rocky hills of Arnhem Land. Natural water is confined to springs and small permanent streams, and wet-season flooding is confined to some of the small sandy deltas of the creeks. The Buldiva Land System is of no importance to geese.

(iii) *Marrakai Land System*.—This system consists of extensive level alluvial plains in the southern parts of the floodplains of the rivers. It carries low open forests on the gravelly ridges and *Themeda–Eriachne* grasslands on the major plains. Permanent billabongs occur behind the river levees, and lagoons are formed at the base of the surrounding hills. In the wet season the whole plains are flooded to a shallow depth.

The lagoons of the Marrakai land system, though usually devoid of aquatic vegetation, form concentration places for the geese in the dry season, but in the wet season the flooding is neither deep enough nor prolonged enough to provide feeding or breeding habitat for the geese.

(iv) *Littoral Land System*.—This is a narrow strip of country along the coast and the estuaries. It consists of mangrove swamps and saltpans inundated by the tide, sandy beaches, and dunes. Saltwater stringers from this land system penetrate the subcoastal plain, often for some distance, but except for the Howard Swamp, where a large *Melaleuca* swamp is formed by the discharge of the Howard River on to the Littoral land system and constitutes an important dry-season refuge, the Littoral is avoided by geese.

(v) *Subcoastal Plains*.—The lower parts of the floodplains of the rivers consist of low-lying flat, or nearly flat, black-soil plains, traversed by meandering streams. The plains are flooded annually, often to a depth of several feet, for periods of several months; in the dry season, however, the permanent water is reduced to the streams, effluents, and a few scattered lagoons. The economy of the magpie goose is centred on the subcoastal plains land system, and for practical purposes the geese are almost confined to those plains.

(*c*) *Hydrology*

The rivers in their lower courses are typical senile streams, which meander across their own floodplains. In most cases they are bordered by well-defined levees, beyond which the floodplains fall slightly to the foot of the higher land dividing the river plains. Kutena (1957) arbitrarily divided the floodplain of the Adelaide River into two zones, which he called "high black soil" and "low black soil" respectively. For convenience that division is retained in this discussion.

High black soil refers to those parts of the floodplain that are subject only to transitory flooding from the river itself. Low black soil refers to more low-lying areas, typically farther from the river, which receive water from springs as run-off from the higher land, as well as from the river itself; they are flooded in varying degree (usually for several months) almost every year. It appears that failure of flooding in those areas is rare, although it did occur in 1951. The relative extent of the two zones (high black soil and low black soil) fluctuates from year to year, depending on the depth and duration of flooding of the latter zone.

Although the rivers are similar hydrologically some very important differences exist. The Adelaide and the East Alligator have well-defined streams and well-developed floodplains. The South and West Alligators enter their plains through several channels and flow through a maze of lagoons and streams before becoming well-defined again near the coast. On the West Alligator there are extensive plains of high black soil, but little low black soil. The South Alligator, at its confluence in its upper reaches with its tributaries Naurlangie and Jim Jim creeks, forms a series of very large swamps of varying depth, many of which are permanent. These swamps are known locally as Bamaroo-gjaja, Kin-chala, or Goose Camp. As will be shown later, they are of major importance to the geese in the dry season.

The Mary and the Wildman Rivers debouch directly onto the plains. The Wildman forms large swamps in the southern parts of its plain and has a well-defined bed for the lower 10 miles of its course. The Mary, on the other hand, has no definite course and flows through numerous poorly defined channels until it reaches the sea through several mouths. The plain of the Wildman is relatively small, but the plain of the Mary is probably greater than that of any other northern river, except the Daly. In the wet season there are very extensive swamps, and in the dry season many of the numerous streams and effluents form deep and permanent lagoons. The plains of the Mary River are of great importance to the geese at all seasons.

(*d*) *Habitats*

Since the vegetation of each area on the subcoastal plain reflects the water conditions to which that area is subject in that particular season, it is convenient in the first instance to describe the vegetation in terms of depth of water. Where water lies almost permanently on the plain, and exceeds 4–5 ft in depth in the wet season, a "deep-water vegetation" occurs, dominated by *Nelumbo nucifera*, *Scleria oryzoides*, *Eleocharis sphacelata*, *Phragmites karka*, and *Nymphaea stellata*, each usually growing in pure stands. Where the water is deep (3–4 ft) but less permanent, drying back to damp soil in the dry season, *Melaleuca leucodendron* forest develops, particularly close to the edge of the sclerophyll woodland. The *Melaleuca* may or may not have an understory of *Eleocharis brassi*, *E. dulcis*, *E. sphacelata*, and *E. spiralis* together with *Nymphaea stellata* and other aquatic herbs. Mangroves, *Bauhavia* spp., often form a narrow belt between the *Melaleuca* and the open plain. Away from the fringe of the timber, extending into water depths of less than a foot and onto areas that dry out completely in the dry season, the "low-black-soil swamp" occurs. It is dominated by *Eleocharis* spp. and *Oryza fatua*, but contains numerous aquatics, the most frequent of which are *Caldesia oligococca*, *Jussea repens*, *Monochoria cyanea*, *Nymphoides* spp., *Paspalum longifolium*, *Polygonum* spp., *Sesbania* spp., and *Urticularia flexuosa*. Where the plain is subject either to no flooding at all, or to flooding to depths not above 6 in., a typical "high-black-soil grassland" develops containing *Cynodon dactylon*, *Echinochloa colonum*, *E. crus-galli*, *E. sagnina*, *Ischaemum arandaceum*, *Panicum* spp., *Paspalum distichum*, *P. orbiculare*, and numerous other grasses, as well as a great variety of sedges, particularly *Cyperus* spp., *Fimbristylis* spp., *Fuirena umbellata*, and *Scirpus* spp. There are relatively few conspicuous herbs.

Although the boundaries of some of these floras vary considerably from season to season, in correspondence with the extent of flooding, the sequence of habitats between the Koolpinyah woodland and the river channel remains the same. The plains are lowest where they intrude as bays into the high country at the effluence of the small creeks and it is here that the *Melaleuca* forests and permanent lagoons are usually found. The latter often run some distance across the plain as deep channels, sometimes broken into several discrete lagoons, all carrying the deep-water flora. The rest of each bay supports a low-black-soil swamp extending, as far as the flood waters permit, towards the rising ground of the river levees. Both the levees and the inner edges of the low-black-soil swamps, where these do not directly abut on the woodland, are covered with high-black-soil grassland. Transient lagoons form on the grasslands after heavy storms, but the high black soil is wholly flooded only if the river bursts its banks after heavy rain on the headwaters.

Each of the habitats has particular significance for the geese. The *Melaleuca* forests are used as roosts, and breeding may occur in those with an understorey of *Eleocharis*. The permanent lagoons are refuges for the birds and, where they are very extensive, great concentrations of geese occur on them in the dry season. As well as being breeding habitat for the geese, the areas of low-black-soil swamp produce a crop of wild rice (*Oryza*) at the end of the wet season, much of which is stripped by feeding geese. The high-black-soil grasslands are important feeding grounds when the grasses are seeding in the middle of the wet season, but are rarely used at other times.

The habitats described here have been worked out from detailed studies on the Adelaide River. The general observations made on the other rivers showed, however, that very little variation existed over the whole subcoastal plain from Wyndham to Arnhem Land. Such differences as were noticed appeared as changes in the frequency of occurrence of certain plants, so that species rare on one river were dominant on another. For example, on the Mary River some 45 square miles of low black soil near the mouth of the river are covered with *Melaleuca* forest, a type of habitat relatively uncommon on the Adelaide. Again, on the Daly and to a lesser extent on the other western rivers, the areas of deep-water flora are much greater than are ever found on the East Plains. On the Finnis River *Oryza* is relatively rare, its place being taken by *Paspalum* spp.

(e) *Low-Black-Soil Swamps*

In later sections of this paper it will be shown that the rate of growth of the spike-rush (*Eleocharis* spp.) and of the bulk of the emergent vegetation in the low-black-soil swamps is of great importance to the geese. The growth of the spike-rush is strongly affected by the rainfall regime, by the rate of filling of the swamps in the early wet season, and by the depth to which the swamp finally fills.

Rainfall.—The underground bulbs of the spike-rush begin to grow when there has been sufficient rain to saturate the top few inches of the soil. If, following germination, there is not sufficient rain to provide free water, many small shoots arise from the underground parts and the young plants grow thickly. If the swamps then fill slowly the emergent growth is very dense.

If, on the other hand, the early storms are followed by a good rain and the swamps fill rapidly the young shoots are covered by water and many cease growing.

In these cases the emergent growth may be less dense. The differences that can exist are shown in Figure 3 which is derived from five quadrats counted regularly during two wet seasons.

Water Depth.—Figure 4 shows the relationship that existed between the depth of water in the swamp when conditions were stable, in March, and the height and density of the spike-rush. The data were collected in several swamps, but mainly on Tommy Policeman Plain.

It can be seen that both the density and the height of the spike-rush were related to the water depth. In shallow water up to 8 in. deep the density of the spike-rush increased with the water depth, but thereafter the density declined as the water depth increased further.

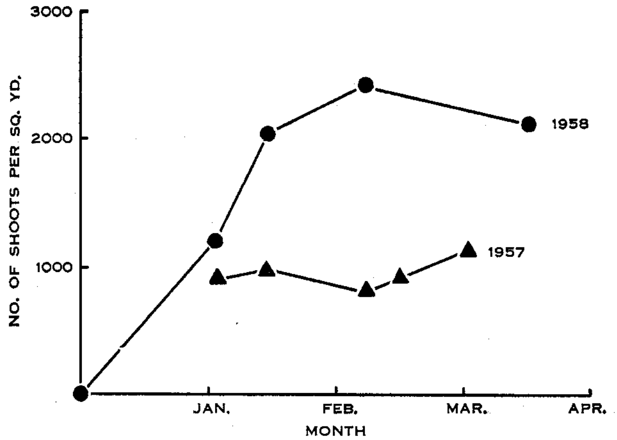

Fig. 3.—Density of sedge growth in the same quadrats in two wet seasons.

In the deeper water the limiting effect of water depth on the spike-rush density was much greater than in the shallower areas.

The height of the spike-rush also increased with the water depth. There is a suggestion that in very deep water the height of the spike-rush tended to decrease, but it was not possible to establish this.

Although Figure 4 shows water depths of up to 72 in., no stand of spike-rush was encountered in naturally occurring swamps of greater depth than 47 in. Normally greater depths than these were occupied by water-lilies. The higher values shown in Figure 4 were collected in the recently built Fogg Dam, where conditions were artificial and the vegetation had not had time to reach its equilibrium with the altered water level.

IV. Description of the Species

The magpie goose is a large, black and white, goose-like bird. It is illustrated in Plate 3. It has osteological and anatomical characters that resemble those of the true Anatidae, but in other features it contrasts with that family and resembles the Anhimidae. It is now generally agreed that it is the sole member of a separate subfamily, the Anseranatinae of the family Anatidae (Boetticher 1943; Delacour 1954). It is expected that this study and that of its behaviour (Davies, unpublished data) will assist further classification of its taxonomic position by those familiar with the world's Anatidae and Anhimidae. In the authors' opinion, based on the behavioural and ecological works, its similarity to the true geese is very great.

In the Northern Territory the magpie goose is characteristic of the subcoastal plains, where it is equally at home on the dry ground or in water. The vicinity of

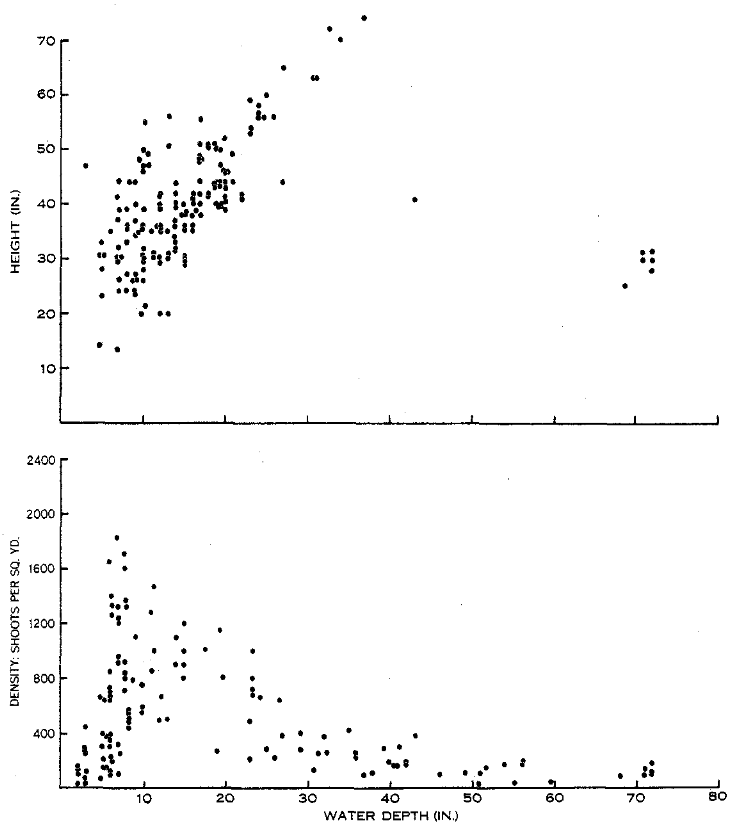

Fig. 4.—The relationships between water depth and the height and density of swamp vegetation.

water is, however, apparently essential for its presence. It walks strongly and flies well. It perches freely in trees and commonly roosts in them, a process simplified by its semi-palmated feet and strong claws.

The sexes are identical in colour, but mature males may be distinguished by examination of the trachea, four loops of which lie outside the pectoral muscle, extending almost to the cloaca. In a 1-year old male the trachea is shorter, extending part way to the end of the sternum, and in a 2-year old male it is similar in length to that in a fully mature bird. It can be readily felt through the skin.

In the females the trachea is not elongated, and usually does not extend outside the pectoral muscles. Of 206 females examined the trachea could be detected externally in 24, then being felt as a single loop one inch in diameter. These were considered to be very old birds.

Table 4

MEAN MEASUREMENTS (AND STANDARD DEVIATION) OF MAGPIE GEESE

Sex	Weight (g)	Body Length (cm)	Wing-Spread (cm)	Wing Length (Olecranon Process to Tip) (cm)	Tarsus Length (cm)	Height of Cranial Knob* (cm)
Male	2766	86·4	154·9	41·9	10·6	4·1
S.D.	283	3·55	6·1	1·27	0·49	0·21
No. examined	402	249	238	165	42	230
Female	2071	77·5	143·0	38·9	9·3	2·6
S.D.	237	3·00	5·1	1·78	0·43	0·28
No. examined	359	220	217	177	43	200

* The cranial knob measurement is a straight line from the top of the cranial process to the front corner of the eye.

The sexes also differ in size. Table 4 shows the measurements recorded. It can be seen that on an average the males were larger than females in all measurements made, although there was much overlap and no measurement could be used as a criterion in the field.

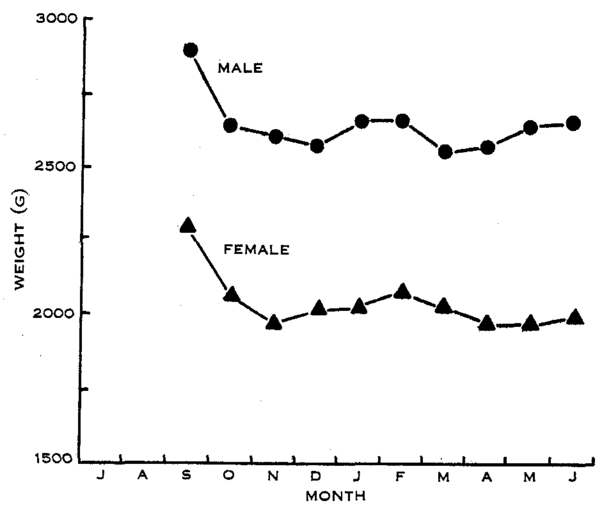

Fig. 5.—Seasonal variation in weights of magpie geese.

Figure 5 shows the weights of the birds in 1955–56 and 1957–58. It can be seen that each sex tended to decrease in weight at the end of the dry season and in the early wet season, and to increase slightly during the late wet season and early dry season. These weight changes will be seen to be related to changes in the abundance of food during the year.

V. Distribution

The discussion of distribution may be conveniently divided into two sections, breeding distribution and nomadic distribution. The nomadic distribution would then include all areas within which single birds or small parties are seen at irregular intervals. In order to study the change in status of the birds, distribution is considered in two periods, before and after 1900. The range of the species is shown in Figure 6.

Fig. 6.—The ranges of the magpie goose. The present breeding areas are shown stippled. The area enclosed in the broken line is beyond the nomadic range of the bird; elsewhere in Australia and Tasmania odd birds have been reported. Black triangles indicate areas in which the geese used to breed but no longer do so.

(a) *Breeding Distribution*

Before 1900.—There are breeding records from the Herbert River, Queensland, between 1888 and 1891 (North 1914) and from Darwin in 1891 (Condon, in litt.). There is a record of a clutch probably taken at Derby, Western Australia, in 1898 (Mees, in litt.), and breeding is unlikely to have extended south of the Fitzroy River in Western Australia. Suitable habitat does not exist between the Fitzroy River and the south-west of Western Australia, where there is no record of the birds ever breeding.

On the east coast breeding is recorded from the Clarence River near Grafton, New South Wales, (North 1914) but not farther south. It occurred at Corinella, Western Port, Victoria (according to the British Museum Catalogue of eggs of 1902), and in south-eastern South Australia (Hood, personal communication). The geese also bred on the lower Lachlan and Murrumbidgee Rivers and on the Murray near its junction with the Murrumbidgee (MacGillivray 1897; Campbell 1901; Stone 1913; North 1914; Condon, in litt.; McEvey, in litt.) in large numbers. Breeding, not described until after 1900, occurred near Moree (D'Ombrain 1921; Morse 1922) and nests were found in 1911 at Darlington, Victoria (mentioned by Mann in Australian Museum Collections), so both these localities may be included. The New Guinea breeding grounds were almost certainly in use.

In summary, the breeding range prior to 1900 was from the Fitzroy River in Western Australia, around the north coast, including the Merauke region of southern New Guinea, at least as far south as Grafton, wherever suitable habitat occurred; in south-western Victoria and south-eastern South Australia; on the lower Lachlan and Murrumbidgee and around the junction of the Murray and the Murrumbidgee, with small colonies at Moree in New South Wales and Western Port in Victoria.

There is no information from the Darling west of Moree, or from south-west Queensland. It is possible that during wet years some geese did breed in these areas.

From 1900 to 1958.—The breeding range in northern Australia appears to be unchanged. The birds still breed on the Fitzroy River (Shilling 1948) and around the coast as far as Townsville (Hopkins 1948). One interesting breeding ground, on the Cloncurry River, 250 miles inland, has not been recorded since 1910 (MacGillivray 1914). Geese were heard in a swamp near Cloncurry in 1956, so that the colony may still exist. There have been no breeding records from Rockhampton since 1913 (Barnard 1913) and the birds were said to be rare there in 1937; and there have been no breeding records from Grafton since 1901 (McEvey, in litt.). The last eggs from Mackay were taken in 1915 (Condon, in litt.) so that the coastal range may be considered to end now at Townsville. Breeding still occurs in the Merauke district of New Guinea and on the coasts of Fredrik Hendrik Island (Hoogerwerf 1959).

The last breeding record from western Victoria was from Darlington in 1911, and the last from the Murray system about 1900 (North 1914). At Moree, some birds bred in 1921 (Morse 1922); some non-breeders were seen in 1930, but no geese at all were seen recently by Elliot (1938) and McGill (1944), so that regular breeding has apparently ceased there too.

The present breeding range is therefore restricted to the north, between the Fitzroy River in Western Australia and Townsville in Queensland, including the Merauke district of New Guinea.

(b) *Nomadic Range*

Before 1900.—In addition to records of magpie geese within the breeding range of the pre-1900 period, odd birds were encountered as far west as Point Cloates (North 1914), and as far south as Tasmania (Petterd 1889). There are several records from Victoria outside the breeding areas (Hill 1898, 1903; Boldrewood 1908; North 1914; Brown 1950) so that the birds may have wandered regularly all over the state. The birds were found on the Hawkesbury River near Windsor, New South Wales, in the early days of settlement, but had disappeared by 1848 (Gould, quoted in Matthews (1914–1915)). There is no information about their distribution on the New South Wales and Victorian coasts between Botany Bay and Western Port, north of the Lachlan, or west of the mouth of the Murray.

From 1900 to 1958.—Magpie geese have almost certainly been recorded once from Tasmania this century (Legge 1905) and possibly twice (Hall 1924). Since the disappearance of the Victorian breeding colonies the chance of the birds visiting Tasmania has probably decreased. Magpie geese are still occasionally seen in inland Australia, the extreme records being Lake Frome, South Australia (McGilp 1919); Lake Goyder (Reese 1924); Murray Mouth, South Australia (Osborne 1940); Gilgandra, New South Wales (McCutcheon 1946); and Newcastle Waters, Northern Territory (White 1923). Serventy (1953) gives an account of the abnormal occurrences of the bird in Western Australia in 1952, a drought year in the north. In that year the birds were seen at Broome, Sherlock River, Lowendal Island near Barrow Island, Carnarvon, Mullewa, Perth, and Madura in the middle of the Nullarbor Plain, and at Meningie, South Australia (Glover 1952).

There is thus no appreciable change in the nomadic range of the birds, although the regularity of their occurrence south of the tropics has greatly decreased. The nomadic range may be considered as the coast of the continent extending up to 400 miles inland. Although no records are available, it is possible that the birds may stray even farther inland, but geese penetrating into the arid interior would be unlikely to survive long.

(c) *Distribution within the Northern Territory*

The distribution of the geese in the Northern Territory can be seen in Figures 2 and 6. It was found that breeding was confined to the floodplains of the coastal rivers. The coast at Ord River, Western Australia, and from Port Keats to Cobourg Peninsula has been visited by the authors. Elsewhere information has been obtained from local inhabitants, generally missionaries. Breeding occurs wherever suitable habitat is found. Since, however, the most extensive area of floodplain lies between Darwin and Oenpelli, most of the population probably breeds there. On the basis of information obtained from 28 aerial surveys between 1955 and 1958 the population of the plains between Darwin and Oenpelli is estimated as 350,000.

In addition Thompson (1949) reports a very large breeding colony on the Glyde River in Arnhem Land, known as Arafura Swamp. The birds breed regularly on Melville Island (present authors' observations) but not on Croker Island or Goulburn Island, or apparently on Groote Eylandt (Mercer, in litt.). Goslings have only once been seen on the Rose River (Hughes, in litt.), so that breeding must be at best sporadic there; but breeding occurs regularly on the Roper River (Gilchrist, in litt.).

In the dry (non-breeding) season, the birds occur inland as far as Coolibah Station on the Victoria River, and have been heard flying over Batchelor and

Katherine. In some years they reach Dunmarra in numbers, but on the other hand they are not known at Goodparla on the South Alligator River. The inland distribution seems to be largely determined by the presence of surface water. The main dry-season concentration points are Lake Finnis on the Adelaide River, many channels on the Mary River, Bamaroo-gjaja on the South Alligator River, and the King River in Arnhem Land (White 1917). Of these Bamaroo-gjaja is by far the largest, containing 50,000–100,000 birds at the height of the dry season. The birds leave the drying coastal swamps at the end of the wet and, moving largely at night, become distributed over the inland lagoons with decreasing regularity as the distance from the coast increases. The limit of the dry-season distribution cannot be defined, but it is only rarely that birds stray more than 200 miles inland.

Table 5

THE EXTRALIMITAL OCCURRENCE OF MAGPIE GEESE*

Authority	Year	Locality	Tropical Weather Conditions
Morton†	1888	Launceston, Tas.	Drought in Qld.
North (1914)	1892	Point Cloates, W.A.	Wet season failed in N.T.
North (1914)	1900	Point Cloates, W.A.	Drought in N.T.
Carter‡	1905	Broome Hill, W.A.	Drought in N.T., Qld.
Jackson (1911)	1911	Moonie River, N.S.W.	Drought in Qld.
Barnard (1913)	1913	Brunette Downs, N.T.	Normal seasons
McGilp (1919)	1918	Lake Frome, S.A.	Drought in N.T.
White (1923)	1923	Newcastle Waters, N.T.	Normal in N.T. Drought in Qld.
Reese (1927)	1927	Lake Goyder, S.A.	Drought in N.T.
Lansell (1940)	1940	Swan Hill, N.S.W.	Drought in Qld. Heavy rains in south
Osborne (1940)	1940	Lake Albert, S.A.	Drought in Qld. Heavy rains in south
Anon.	1948	Sandgate, Qld.	Drought in Qld.
Glover (1952)	1952	Meningie, S.A.	Drought in N.T. Floods in south
Serventy (1953)	1952	Hay, N.S.W.; south W.A.	Drought in N.T. Floods in south
Present Authors	1958	Dareton, N.S.W.	Poor wet season in N.T.

* Other extralimital records without precise date have been made at Talbragar River near Dubbo (Austin 1907), and Gilgandra (McCutcheon 1946).

† Referred to by Petterd (1889).

‡ Quoted by North (1914, Vol. 4, pp. 55–8).

(d) *Discussion*

This review of the distribution of the magpie goose raises two problems. First, why do the birds occasionally wander so far from known breeding areas? Secondly, what caused the sudden and complete disappearance of the species from its southern breeding area?

A study of records of the birds inland or beyond their breeding range shows that these occurrences are associated with dry conditions in the breeding areas. Table 5 presents all the records that can be precisely dated and located. The climatic data are from Foley (1957).

It can be seen that 10 of the 12 records are in the years when drought existed in the northern breeding areas. The 200–300 birds that spent at least February to April on Brunette Downs in 1913 did so in a period during which the northern region of the Northern Territory had a slight rainfall deficiency (1912–1915). This may have caused an inland movement of some birds. It is clear that nomadic birds may be expected to occur far beyond the breeding range when northern areas are suffering from drought, perhaps especially if the south has received good rains, e.g. in 1940 and 1952.

The second point, the disappearance of the birds in southern Australia, has been attributed by several authors to the advance of settlement (Mathews 1914–1915; North 1914; Delacour 1954). The decline was both rapid and complete. In the Murray region at least the birds were still plentiful and bred between 1880 and 1890 (MacGillivray 1897; Hill 1898; Stone 1913; and others) but by 1900 very few birds remained (Hall 1909; Stone 1912, 1913). There is no doubt

TABLE 6
DROUGHTS IN NEW SOUTH WALES AND VICTORIA, 1860–1940

Period	Number of Drought Years
1860–1880	5
1880–1900	12
1900–1920	13
1920–1940	2

that, where the magpie goose population was small, shooting and the disturbance caused by even the most primitive land use would soon eliminate birds so easily approached and with such specific breeding requirements. Probably these factors played a large part in the disappearance of the birds from Western Port, Darlington, Bool Lagoon, and Moree. For example, at Bool Lagoon there are accounts of the birds being shot on the water before the goslings could fly (Hood, personal communication). Despite extensive drainage and grazing of reed beds, however, there are still large areas of *Muehlenbeckia* and *Typha* in the Murrumbidgee–Lachlan region, in which the birds could breed and feed undisturbed. The climatic data for that area from 1860 to 1940 show that over the period in which the crash occurred there were very serious droughts. Table 6 shows the number of drought years in each 20-year period from 1860 to 1940 (data from Foley 1957). From 1880 to 1920, 25 of the 40 years were recorded as drought years. Apart from resulting in long periods in which the geese would have been unable to breed because of lack of suitable habitat, these droughts probably caused food shortages, killing numbers of birds and making others very easy to poison. Large-scale poisoning took place in 1902 on the Murray River (Hall 1909), and probably at other times when the birds invaded the crops. It is therefore not surprising that the species, deprived of breeding opportunities, persecuted, and unable to adapt to a changing environment, was soon exterminated.

The two known liberations of free-winged birds in southern Australia are worth recording. Both occurred in 1958, one at Canberra (10 birds) and the other at Joanna, South Australia (four birds).

VI. Food and Movements

(a) *Food*

The magpie goose manipulates its food almost entirely with its bill, the feet being used only to bend over tall grass heads so that the seeds can be stripped from them.

Digging on dry land is the most striking if not the most characteristic method of feeding employed by the geese. Geese turn over the soil with their hooked bills until they find a bulb, which they then scoop out and swallow. Although geese often remain on one spot and dig on dry land, as in water, flocks moving and digging have been seen. Apparently the geese continue digging for bulbs at the edges of the swamps in May and June while the water recedes and the feeding area is gradually converted from shallow water into dry land, so that dry-land digging, striking as it is, is better regarded as a modification of digging in water than as a completely different pattern.

It is convenient to consider first the major foods of adult geese, that is, the foods that account for more than 70% of the volumetric crop analyses each month. These are grass blades, *Eleocharis* bulbs, and the seeds of *Oryza*, *Echinochloa*, *Paspalum*, and *Cynodon*. The distribution of the intake of each of these food items over the months from September to May inclusive, when adequate crop samples were obtained, is set out in Table 7 and Figure 7, and the distribution of intake over the whole year from the examination of all crops and gizzards is shown in Table 8. The data from crops are shown in Figure 7.

It must be borne in mind that the presence of a developing rice industry in the study area has modified both the feeding habits of the geese and the availability of food. Although the wild rice season lasts only 5 or 6 weeks, the seasons of wild and cultivated rice taken together extend over 2 months. A dry-season rice crop maturing in September and October, as well as extensive rice-baiting associated with cannon-netting between then and December, provided additional easy sources of food used by the geese.

The food cycle under present conditions begins with grass blades, *Eleocharis* bulbs, and *Echinochloa* seeds in January. The latter become even more important in February, when little grass and no bulbs are taken. *Paspalum* seeds, *Echinochloa* seeds, and grass blades are eaten in March, giving place in April to *Oryza* seeds alone. The small samples from June to August (five groups) suggest a considerable variety of food, but observations indicated that much of the food at that time was either grass taken around waterholes or *Eleocharis* bulbs dug from the dry plain. By September bulbs have become an important item and remain so until December. *Oryza* seeds in September, grass blades in October and December, and *Paspalum* seeds in November constitute the rest of the food cycle. The shifts of population associated with these changes in food habits will be discussed in Section VI(*b*).

TABLE 7

MONTHLY DISTRIBUTION OF FOOD EATEN BY MAGPIE GOOSE: PERCENTAGE OF CROP VOLUME

Food	Month									Size of Food Item		
	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Number of Items	Volume (ml)	Dry Weight (g)
Cyperaceae												
Bulbs												
Eleocharis dulcis	16·3	12·5	0·4	—	5·9	—	—	—	5·9	100	85·0	35·9
Eleocharis spp.	43·0	38·1	70·5	45·4	8·0	—	1·9	—	0·4	100	170·0	46·1
Gramineae												
Grass blades	4·4	38·3	8·9	34·9	68·3	2·7	12·7	—	17·2	—	50·0	2·1
Seeds												
Oryza sativa	10·0	—	3·5	4·3	—	23·4	3·7	—	73·2	100	4·0	1·68
O. fatua	24·1	3·1	0·3	—	—	—	1·2	95·3	—	100	4·0	1·13
Echinochloa colonum	1·0	—	0·9	8·1	12·2	59·5	31·8	—	—	100	0·2	0·08
E. sagnina	—	—	—	0·3	3·7	2·8	4·4	0·9	—	100	0·6	0·24
Cynodon dactylon	—	—	2·0	2·7	0·2	6·0	—	—	—	100	0·2	0·10
Paspalum spp.	—	—	11·9	2·4	—	3·1	38·3	0·9	—	100	0·3	0·15
Other	1·2	8·0	1·6	1·9	1·7	2·5	6·0	2·9	3·3			
Number of geese	30	27	85	50	46	45	55	25	27			

TABLE 8

THE MONTHLY DISTRIBUTION OF FOOD EATEN BY THE MAGPIE GOOSE: PERCENTAGE OF OCCURRENCE

Food	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Cyperaceae												
Bulbs												
Eleocharis dulcis	2·0	—	—	—	10·4	26·5	10·5	10·0	28·3	3·7	45·2	34·6
Eleocharis spp.	13·5	3·7	4·3	—	7·0	8·0	5·3	24·9	14·9	14·8	2·0	—
Other	—	1·5	1·7	6·3	3·4	0·7	15·8	—	—	3·5	3·5	0
Gramineae												
Grass blades	28·1	7·3	3·5	5·3	9·0	4·7	—	5·2	22·3	25·3	17·7	28·3
Seeds												
Oryza sativa	0·7	10·1	4·4	—	34·8	8·9	—	24·9	8·8	7·0	11·9	2·1
O. fatua	—	—	2·3	38·0	4·0	2·1	10·5	—	2·0	7·3	2·5	2·1
Echinochloa colonum	22·8	32·5	17·8	9·7	7·4	5·3	5·3	—	4·0	7·0	2·4	13·6
E. sagnina	11·7	8·1	9·0	3·9	—	—	10·5	—	—	—	—	0·8
Cynodon dactylon	4·6	11·7	1·7	—	—	—	—	—	2·0	—	3·9	9·4
Paspalum spp.	2·0	9·9	26·0	7·8	—	1·6	10·5	—	—	—	6·6	2·7
Other	—	5·2	2·9	3·6	4·9	1·0	—	—	—	3·5	—	—
Other plants												
Seeds												
Nymphaea	—	—	3·1	1·0	4·9	—	—	9·9	2·7	15·7	1·4	—
Caldesia	—	—	4·0	8·2	10·2	21·8	10·5	—	—	3·3	—	—
Sesbania	8·2	3·6	2·0	2·4	—	2·2	—	5·3	—	0·4	—	—
Other	6·3	2·0	10·9	11·7	4·1	13·1	21·0	19·8	14·9	8·5	2·9	6·4
Animal food	—	3·1	6·8	2·2	—	4·1	—	—	—	—	—	—
Number of geese	51	38	87	50	49	138	63	67	41	27	6	8

The magpie goose is almost entirely herbivorous and exploits much of the available plant food, but there are a few plants whose seeds are not common in the samples, although they are abundant on the plains. *Panicum* spp., *Fimbristylis* spp., and *Cyperus* spp. are three genera that might be mentioned in this regard, and there seems to be no explanation for their small representation in the samples. Perhaps they are unpalatable to the geese, which learn to avoid them.

Foods of minor importance—that is, those that were found regularly in at least two of the four sample years and in more than two samples—included *Blyxa aubertii*, *Brachiaria*, *Caldesia oligococca*, *Centrolepis*, *Coldenia procumbens*, *Cyperus compressus*, *C. exaltatus*, *C. iria*, *Digitaria*, *Eriochloa*, *Nymphaea*, *Nymphoides indica*, *Panicum*, *Pennisetum typhoideum*, *Scirpus lateriflorus*, and *Sesbania*.

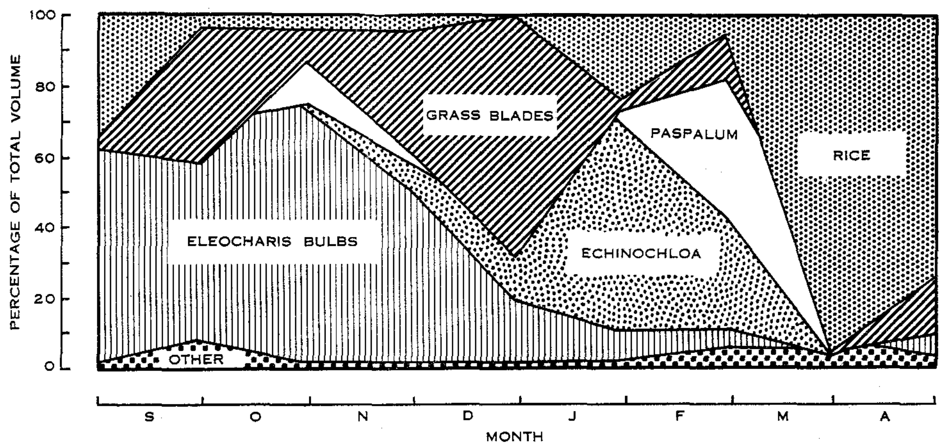

Fig. 7.—Food of the magpie goose.

Of the minor foods *Caldesia oligococca*, the water plantain, and *Sesbania*, a water pea, are the only two plants whose seeds occur at all commonly. Both are swamp plants, fruiting in the late wet season. They have moderately large, resistant seeds, which may tend to be filtered out of the swamps by geese. These seeds are rarely found crushed, even in the gizzard, and it is unlikely that either of the plants provides much nourishment to the geese.

The analysis of 10 gizzards from Bamaroo-gjaja and of 22 crops from the Mary River corresponds with the general food cycle on the Adelaide River outlined above. Thus at Bamaroo-gjaja in October *Eleocharis* bulbs, grass, and the seeds of swamp plants still fruiting in the permanent lagoons were being eaten, while at the same time on the Mary, where the permanent lagoons are smaller and more barren, the bulk of the food was grass tussock and *Eleocharis* bulbs.

The crops from the Mary in January show an emphasis on grass seed, particularly *Echinochloa*, and blades similar to those on the Adelaide. In addition a number of crops contained blue blade, an unidentified floating aquatic, common on the Mary but known from only one locality on the Adelaide.

The results presented above indicate that the geese have three main sources of food supply: grass blades, which can be obtained throughout the year; sedge bulbs, available in the dry season; and seeds of grasses fruiting in the wet season. Despite the apparent abundance of food for most of the year, there are indications that during the latter part of the dry season the geese have some difficulty in obtaining food. From September to October the occurrence of *Eleocharis* bulbs drops from 43·2% to 18·5% (by volume from 59·3% to 50·6%), and the average weight of males drops by 9 oz and that of females by 8 oz. It has not been possible to determine to what extent the food shortage may act as a factor regulating population size, but it seems reasonable to assume that selection, operating against the weaker geese, may take place at that time.

(*b*) *Movements*

The seasonal changes in distribution of the magpie goose in the area between Darwin and Western Arnhem Land—the East Plains—were studied from low-flying aircraft as described in Section II.

In addition the more local movements around Humpty Doo have been recorded by ground observations, supported by banding some 2177 geese in two seasons. The recovery of bands has been slow, but confirms conclusions based on observational methods.

Some observations on the movements of geese in other parts of their range have been recorded, and are briefly discussed at the end of this account.

Feeding Movements

Geese normally feed twice a day, flying from their roosts to the feeding-grounds at dawn and returning to the lagoon edges after a couple of hours. There they spend the day, flying out to feed in the late afternoon and returning to roost at dusk. This pattern may be modified by several factors. Disturbance during the day will cause the geese to feed at night. During the wild rice season birds may spend all day in the swamps, feeding intermittently throughout the day and roosting there also at night.

In the dry season, when birds are digging bulbs or grazing on the short grass around waterholes, their morning feeding is often more prolonged than during the wet season, when grass is longer and thicker and seed-heads are abundant. Dull weather, and particularly rain, appear to stimulate the birds to move to the feeding-grounds much earlier in the afternoon than usual, and they also tend to remain there much longer in the morning on a dull day. In the dry season a few geese spend all day on the small lagoons in the timbered country, feeding irregularly throughout the day. Although geese do not always return to the same spot to feed each day it is possible, at any particular time of the year, to define an area within which feeding geese will always be found. This area has been termed the "flock range". For instance, early in the wet season the flock ranges of geese are almost confined to low-black-soil areas that will ultimately be breeding colonies. Later, although the breeding birds spend much of the day in the colonies, they may (at least until the beginning of egg-laying) fly out to feed with the non-breeding birds on the flock ranges along the river. Still later, when the wild rice crop matures, the flock ranges are again almost confined to the breeding colonies.

Although the flock ranges are relatively constant for a month or 6 weeks, banding from September 1957 to January 1958 indicated that individual geese moved rather freely between them. Thus of 1644 geese banded during that period at four different points, 361 were subsequently retrapped, 42 (12%) of them at places other than the banding site. It appears that roosts may assist the exchange of birds between the flock ranges. Birds from one feeding area have often been seen coming from and going to widely separated roosts, so that the roost to which a goose retires may not be constantly the same, but may depend on which group it follows from the flock range. Similarly the flock range in which it feeds probably depends on which group of geese it follows out of the roost.

TABLE 9
TOTAL GOOSE POPULATION OF THE SUBCOASTAL PLAIN OF THE ADELAIDE RIVER, SEPTEMBER 1957 TO MAY 1958

1957		1958	
September	8,400	January	50,000
October	15,800	February	55,200
November	10,250	March	10,500
December	56,400	April	6,300
		May	4,200

Movements within the Adelaide Valley

Air surveys over the whole subcoastal plain of the Adelaide River (Route 1) were made on 24 occasions. From these surveys it was possible to estimate goose numbers on a representative sample of the plain, and from September 1957 to May 1958 an estimate of the numbers on the whole plain was obtained. The total numbers for each month from September 1957 to May 1958 are shown in Table 9.

The subcoastal plain can be divided into the following major habitats:

(1) The low-black-soil breeding colonies;

(2) The high black soil;

(3) The transitory lagoons;

(4) The permanent lagoons.

All areas where geese were found have been classified according to this scheme, and the classification is given in Table 10. They are shown in Figure 1.

From the numerical estimates of the population described above, the percentage of the total population occupying each of the habitats each month was calculated. These percentages are shown graphically in Figure 8.

The shift from the permanent lagoons inhabited in the dry season to the low-black-soil breeding colonies in the wet is clear. This shift is greatly accentuated by the influx of birds during the wet, as described in the preceding section, all of which resort to the breeding colonies. The transitory lagoons—shallow pools of rain-water—are most used at the beginning of the wet season, at the time of the storms.

TABLE 10

CLASSIFICATION OF THE LOCALITIES ON THE ADELAIDE RIVER PLAIN BY HABITATS

Habitats	Localities
Low black soil breeding colonies	Woolner Swamps; Horn Billabong Swamps; Whitestone Mouth; Bald Hill Mouth; Mosquito Mouth; South Soldier Creek; Litchfield Creek; Tommy Policeman Plain; Black Jungle Plain
High black soil	Kutena's (1957) Zone (a)
Transitory lagoons	First, Second, and Third Whitestone Billabongs; North Beatrice Lagoon; numerous unnamed rain puddles
Permanent lagoons	Lake Finnis; Marraki Creek; Beatrice Creek; Donald's Lagoon; Little Red Lily Lagoon; Beatrice Hill Creek; South Beatrice Lagoon; Lambell's Lagoon

The high black soil has a population peak in January and February each year. The apparent second peak in September 1957 is the result not of an increase in the number of birds on the high black soil but rather of a decrease elsewhere, especially in the breeding colonies. In both September and October 1957 there were only about 600 geese on the high black soil, compared with about 9650 in January 1958.

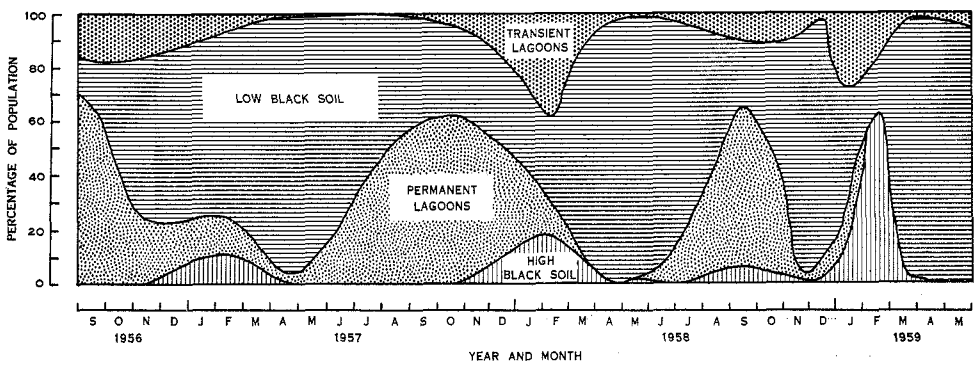

Fig. 8.—Percentage of the goose population occupying the different habitats in the Adelaide River.

These movements can best be interpreted year by year. In 1955–56 the changes correlated with the distribution of both food and water. When the wet season began, the transitory lagoons formed on the plains were used by geese feeding first on *Eleocharis* bulbs in the plain far from permanent water, and later by geese feeding on the seeds of the grasses that fruited on the high black soil in January and February. The fruiting of these grasses also accounted for the peak population on the high black soil at that time. At the start of the wet season many other geese dug for bulbs in the breeding colonies, where surface water was also available.

The grasses of the high black soil finished fruiting and the *Eleocharis* bulbs sprouted, thus preventing the birds from digging them, at the same time that the grasses in the breeding colonies ripened and all the birds concentrated there. After that crop was finished the swamps began to dry and many geese left the valley.

In 1956–57 the pattern was repeated except that the February condition was accentuated. Some birds were in the breeding colonies, but many left to feed on the high-black-soil grasslands, being found either on these or on the transient lagoons in, or adjacent to, them. It is possible that a definite split in the population occurs, with the breeding geese remaining in the colony and the non-breeding geese leaving to feed on the grasses and later returning as the wild rice ripens.

TABLE 11

RELATIVE NUMBERS OF GEESE OBSERVED ON EACH RIVER DURING AIR SURVEYS ALONG ROUTE 2

River	Survey Date						
	Oct. 1955	Apr. 1956	Nov. 1956	June 1957	Sept. 1957	Apr. 1958	Aug. 1958
Adelaide	Few	Very many	Some	Very many	Some	Very many	Few
Mary	Very many	Very many	Many	Many	Very many	Very many	Very many
S. Alligator	Very many	Few	Very many	Few	Very many	Few	Very many
Wildman	Few	Few	Some	Some	Few	Few	Some
W. Alligator	Some	Few	Few	Few	Few	Few	None
E. Alligator	Few	Some	Few	Few	Few	Some	Few

The suggestion that the two populations behave differently is well supported by the 1957–58 data. The season was dry and few geese bred. The influx of birds to the breeding colonies early in the wet season was normal, but the January–February peak on the high black soil was greatly accentuated, and thereafter the total population of the valley declined rapidly. An observed increase in April and May on the Mary River suggests a shift of the population to that river. The population of the breeding colonies remained between 10,000 and 4000 from February to May, whereas it had reached 54,000 in December, suggesting that the geese remaining in the breeding colonies in February stayed there for the rest of the wet season. The wild rice began to flower a week earlier than in the previous two years, but few, if any, of the birds that were on the high black soil in February remained to feed upon it.

Inter-River Movements

The records of air surveys made along Route 2 (see Section II) have been summarized in Table 11. The numbers of geese were so large that usually no attempt was made to count them, but rather the rivers were classified as holding none, few, some, many, or very many geese. It is not necessary to attempt a more precise quantification to demonstrate the gross population shifts that took place every season. The actual numbers of geese in the Adelaide River Valley in the period September 1957 to May 1958 are shown in Figure 9.

From Table 11 it is clear that the Adelaide River holds many more geese in the wet season than in the dry, while the reverse is true of the South Alligator River. The population of the Mary is large throughout the year. A goose banded in the early wet season of 1955 on the Adelaide River was recovered in the dry

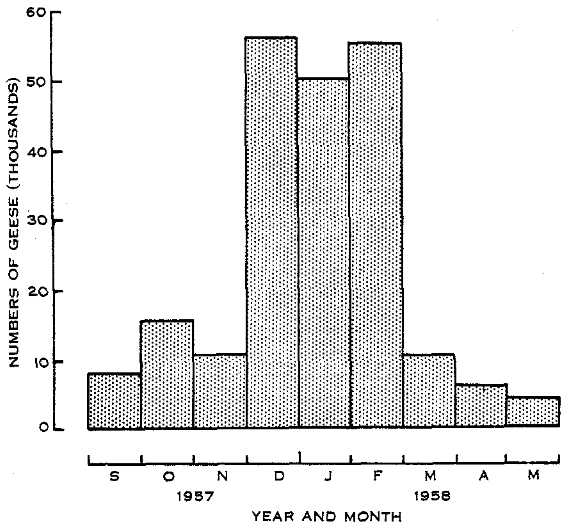

Fig. 9.—The numbers of magpie geese in the Adelaide River valley in the period September 1957 to May 1958 as assessed by air survey.

season of 1956 at Bamaroo-gjaja on the South Alligator River, suggesting a real shift of the population from one river to another. Five other bands have been recovered away from Humpty Doo, three on the Howard River and two on the Daly River. All five geese were banded at Humpty Doo early in the wet season and later shot farther west; possibly they were moving through the Adelaide River towards the wet-season breeding grounds on the western coastal rivers.

The plains of the Adelaide and Mary Rivers have large areas of low black soil providing extensive breeding swamps in the wet, but while the Mary plain has many permanent lagoons that hold water throughout the dry season, there are only one or two such lagoons on the Adelaide River. There is much low black soil on the South Alligator River, but a large part of it is permanently flooded, and the *Eleocharis* swamp that develops is too thick for geese to breed (see Section

VII). On the other hand, since these areas are fed by almost permanent streams, water remains in them for much of the dry season. The geese are found mostly on the Adelaide and Mary Rivers in the wet and the South Alligator and Mary Rivers in the dry season. That is to say, in the wet season they concentrate on the rivers that hold most breeding habitat, whereas in the dry they concentrate where water is most plentiful.

The populations of the Wildman and East and West Alligator Rivers are small but bear out these conclusions. The East Alligator River has a few large low-black-soil swamps, which disappear early in the dry season since the creeks feeding them are small. The survey in June 1957 recorded few geese on this river, but the swamps had by then begun to dry. In April 1958, however, at the height of the breeding season, the survey showed an increased population compared with the dry-season surveys of 1957 and 1958.

The Wildman River lagoons are large, but they dry fairly quickly since they are not fed by permanent creeks. There is much low black soil, largely covered with paperbark forest. The survey in June 1957 showed geese on the lagoons, but later (September 1957) the lagoons had dried out and there were few geese in the valley. During the April survey in 1958 some geese were again on the drying lagoons.

The West Alligator River has a small plain with some low black soil, mostly paperbark forest, and few lagoons, so that it never has a large goose population.

Movements in Other Parts of Australasia

Nothing is known of the movements of the birds that used to breed in Southern Australia. In the north, however, a few movements are recorded. From the coast of northern Australia geese move to some outlying islands each wet season and breed there, and return to the mainland for the dry. This occurs on Melville Island (Mathews 1914–1915) and Croker Island (Blyth, personal communication). They apparently do not breed at Millingimbi (Wells, in litt.), although that area is close to the Arafura Swamp, where Thompson (1949) has reported a large colony; on Goulburn Island (Methodist Mission, in litt.); or on Groote Eylandt (Mercer, in litt.), but they are occasionally seen at the last two localities.

The birds are recorded as leaving Liveringa Swamps on the Fitzroy (Shilling 1948) and Eleamurda Swamp near Wyndham (Mathews 1914–1915) at the end of the breeding season as the plains dry, but those authors give no indication of where they might go. Mackenzie (in litt.) reports more geese on the Archer River in Queensland in the wet than in the dry.

From these reports it appears that the geese often desert their breeding grounds in the dry season, presumably for the more permanent lagoons.

A movement may occur between Cape York and New Guinea. Gwynn (personal communication) and Bishop S. H. Davies (personal communication) both note that birds may be heard passing over the Torres Strait Islands at night. Furthermore Bishop Davies reports that the natives of Saibai Island, a few miles off the New Guinea coast, regularly spear the birds in passage. Banding in New Guinea would certainly provide interesting information on that point.

Observations on Movements

Nearly all observations recording movement refer to geese passing at night (Mathews 1914–1915; Sedgwick 1946; Mackenzie, in litt.; and personal observations). Two personal observations were made during daylight. One was at Humpty Doo between 10 and 11 a.m. on March 19, 1957, when two flocks each of about 100 geese were watched out of sight, flying south-west over the timber. The second was at Cape Don on Cobourg Peninsula, when two geese passed over heading south-east at 4 p.m. on June 5, 1958, probably coming from Melville Island. On the other hand geese were frequently heard passing over Humpty Doo at night, and it seems certain that much movement takes place then.

It was a common observation that when rain began, or on a dull day, geese rose and flew to their feeding areas much earlier than they would do on a fine day. It was also noted that after a storm at the end of the dry season the transitory rain puddles on the plain were quickly occupied by flocks of geese, whereas before the rain there had been no geese at all in the area. Possibly geese are stimulated to move by rain.

Movements in Abnormal Years

It has been suggested (see Section V) that long-distance movements of magpie geese can be correlated with dry conditions in the breeding areas. While the appearance of the birds in Perth or Tasmania is striking, a no less striking movement occurred in the North during the drought in 1951–52. The wet season failed in the Darwin area and local residents there reported that geese invaded the town in large numbers, feeding on lawns and gardens. It is very doubtful whether any breeding occurred on the river plains.

In the same year a much larger number of geese than usual were found on Groote Eylandt, where the wet season was more normal than on the mainland (Mercer, in litt.). There are no other documented records of this type of movement, though it is very probable that it would occur whenever there was a severe drought in the breeding area. The movement can reasonably be considered to result from the fact that most, if not all, geese on the East Plains became non-breeders when the swamps did not flood. The normal wet-season grass and rice crops of the plains did not appear, and the birds left the area.

(c) *Discussion of the Movement Pattern*

The term "migration" has not been used in this account. Lack (1954) limits it to unidirectional movements of animals, and in common usage a movement of a whole population is implied. The movements of geese within the Northern Territory are, at one time, clearly multidirectional. Thus the air surveys indicate that at the beginning of the wet season the geese from Bamaroo-gjaja move north-east to the West Alligator River, north to the neighbouring islands, north-west to the Adelaide River, and probably south-west to the Daly and other western rivers. While the movements of any one goose may be unidirectional in each season, the movements of the population of Bamaroo-gjaja are better considered aside from the somewhat restrictive implications contained in the term "migration".

Bird movements may be usefully considered under two headings: the urge to move and the orientation of movement. The ultimate factors underlying the urge to move in the magpie goose can be discussed only in general terms. Thomson (1953), Svärdson (1953), and Lack (1954) believe that movements are to a very large extent adapted to the food supply, and Thomson (1953) also holds that nesting requirements, implying food for the young, are important.

The movement patterns of the geese bring the birds to their nesting grounds in the wet season and spread them over almost all available water in the dry. During the wet season grass blades and seeds are present in large quantities near the nesting areas, whereas in the dry season the geese feed largely on the bulbs of *Eleocharis*, which are dug from the dry plain as well as from the lagoon fringes. Digging in the plain in September and October indicates that the bulbs occur far from available water as well as near it, yet the geese tend to feed on areas within a mile or so of water rather than on those farther away from it. These circumstances suggest that the dry-season distribution is more closely linked with the availability of water than with that of food, the wet-season distribution being linked with nesting requirements.

The stimuli that control bird movements have been studied by Svärdson (1953), who suggested that the irruptive birds of Northern Europe began to move in response to the same stimuli as migrants, but that movement was inhibited by abundant food. The movements of the magpie goose can be interpreted in the same way if the availability of water and breeding sites is considered as well as that of food.

It has already been mentioned that rain appears to stimulate geese to fly. Observations show that at the end of the dry season movement begins as a spread over the plains when the first storms take place. Such movement, inhibited by surface water but stimulated by rain, would gradually concentrate the birds on the breeding colonies, where the largest areas of water are to be found. There is considerable movement between colonies early in the wet season. Banding in 1957–58 showed that birds move freely from colony to colony with the Adelaide Valley at that period. These movements could be stimulated by rain, but the total population of the colonies remains static since their water areas provide the maximum inhibitory stimuli. Once the sedges begin to grow in the swamps, nest-site selection also might act to inhibit movement.

The balance between the inhibition and the stimulus to movement apparently acts differently on different individuals, some remaining in the breeding colony to breed, others continuing to wander until they concentrate first on the grass crop of the high black soil and later on the wild rice in the breeding colonies. By the time that the wandering is over successful breeders have broods of flightless goslings, with which they remain, while other geese continue to move, stopping at first on lagoons on the plain and ultimately concentrating on the large dry-season refuges as the smaller lagoons dry out.

The observed difference in the departure dates of the main bulk of geese from the Adelaide Valley in 1957 and 1958 supports the suggestion that water is important as an inhibitor of movement at the end of the wet season. In 1957 the plains were deeply flooded in early March and water was abundant for some time thereafter. The main mass of geese left in May and June. In 1958, a dry year, on the other hand, there was never much water on the plains and the main population left in February and March. The difference even suggests that water is more important as an inhibitor than food, since in 1958 the birds abandoned the wild rice crop on the Adelaide River, where there was little water, but concentrated on the wild rice on the Mary River, which was still well flooded.

The following hypothesis is presented concerning the initiation and inhibition of movements: rain and lack of water stimulate movement; abundant food, surface water, and reproductive activities inhibit it.

Hochbaum (1956) discusses at length the role of tradition in the orientation of wildfowl movements, and concludes that there is some evidence that it plays an important part in directing the movements of North American waterfowl. Since the young magpie geese probably stay with their parents until the following wet season, and have been observed with them at the breeding colonies in March, it is unlikely that they would ever make the journey to or from the breeding colonies unaccompanied by experienced geese. The movements are only over short distances but are made in a variety of directions, so that it is simpler to suggest that the young geese learn the direction of movement in company with older birds than to assume that each navigates in an inherited direction, as has been suggested for some birds. The population shifts therefore may be looked on not as a random scatter but rather as a movement directed by the experience of adult birds moving between breeding colonies and the lagoons on which they have wintered.

VII. Breeding

Magpie geese apparently mate for life, since mated groups and family parties can be seen throughout the year. Both pairs and triangular matings occur, the latter situation probably being the commoner. The gander of the trio leads both his females and all three apparently share in nest-building, incubation, and care of the young. Both females of a trio lay in the same nest, one bird usually starting a day before the other.

Nest-building activities begin as soon as the spike-rush growth starts in the breeding swamps, about 2 months before the first eggs are laid. The early nests are merely clumps of spike-rush, bent over to provide the geese with a platform in the swamp on which they can stand to preen and court. As the swamps grow the platforms become more elaborate: several clumps of spike-rush are involved and are woven into quite a substantial stage. Each stage is used once by the geese, immediately after is it built, and then deserted. A new stage is built wherever the group stops next in the swamp.

In experimental situations with hand-reared geese it has been shown that the birds at first react similarly to swamps of various densities and heights, but that after some experience at building they come to build more actively in dense, high swamps than in thin, low ones, and also that there is a highly significant increase in building-frequency on wet days in all densities (Davies, unpublished data).

Shortly before the birds are ready to lay stage-building becomes more elaborate. When the stage has been built, more spike-rush, broken off at water level or wholly uprooted, is dragged on to it. At first only a few loose shoots are added, but later very many may be dragged up to form a substantial pile. Even so, each stage is used only once, until one day, early in the morning, a stage is built heaped with a large quantity of loose spike-rush, and one of the geese lays an egg on it. The geese return there to complete the clutch, laying daily, and continually drag more spike-rush on to the nest, to form a thick, deep cup.

(a) *The Breeding Colony*

Location.—The location of swamps in which magpie geese bred on the plains east of Darwin is shown in Figure 2. It can be seen that the swamps were most numerous and extensive on the Mary River and least extensive on the South and West Alligator Rivers. The extent of the breeding swamps and of the goose colonies was intermediate on the Adelaide and East Alligator Rivers. These differences were correlated with the differences in the hydrology of the rivers (see Section III(*c*)).

There is no doubt that all the colonies on the plains east of Darwin were recorded, but west of Darwin there was only one air survey and probably not all colonies were discovered. It was seen, however, that there were only a few small colonies on the Finnis, Moyle, Fitzmaurice, and Ord Rivers. On the Daly River one very large colony was located near the river mouth. It covered about 16 square miles and was the largest colony observed in the Northern Territory.

The size of the colonies varied from a few acres to the several square miles of the Mary River and Daly River colonies. The extent of each colony varied from year to year, and in addition the density of nests varied greatly among colonies, in the same colony in successive years, and in different parts of the same colony.

It was not possible to determine an average density of nests or to estimate the numbers in a given part. In 1959, however, the density of nests in a portion of one colony, Tommy Policeman Plain, was determined accurately by counting all the nests in a measured area (62 acres). There were 135 nests per 100 acres.

Distribution of Nests.—The colonies were located only in low-black-soil swamps. Of 293 nests at which a quantitative assessment of the vegetation was made 77% were found in places where spike-rush was the dominant plant and 19% where wild rice was dominant. The remaining 4% were found in knife grass (*Scleria*), *Paspalum*, and rush (*Scirpus*). Nests were not found among water-lilies (*Nymphaea*) or cane grass (*Phragmites*). These figures were supported by aerial observations of several thousand other nests. These were invariably in low-black-soil swamps, which were easily recognizable from the air by their vivid green colour.

Although the nests were, for practical purposes, confined to the spike-rush–wild rice association, differences in the density of nests existed within that association. These differences could be related to the depth of the water and the bulk of the spike-rush above the water.

Table 12 shows the distribution of the nests found on the Adelaide River plains in 1956–58, classified according to the depth of the water and the height

TABLE 12

DISTRIBUTION OF NESTS OF MAGPIE GEESE IN THE ADELAIDE RIVER VALLEY IN THE PERIOD 1956–59, ACCORDING TO THE WATER DEPTH AND VEGETATION DENSITY AND HEIGHT

Serial No.	Water Depth			Vegetation Height			Vegetation Density		
	Depth (in.)	Number of Nests	Relative Density of Nests	Height (in.)	Number of Nests	Relative Density of Nests	Density	Number of Nests	Relative Density of Nests
1	0–6	6	0·19	0–6	0	0	I	0	0
2	7–12	115	0·87	7–12	4	0·66	II	4	0·10
3	13–18	76	1·58	13–18	17	0·58	III	21	0·60
4	19–24	41	1·41	19–24	43	0·52	IV	126	1·37
5	25–30	40	4·44	25–30	33	0·50	V	87	2·17
6	31–36	20	1·00	31–36	24	0·69	VI	6	0·30
7	37–42	0	0	37–42	13	0·81			
8				43–48	3	1·0			
9				49–54	1	1·0			
10				55–61	1	1·0			
11				61–67	1	1·0			
Total		298			140			244	

TABLE 13

DISTRIBUTION OF NESTS OF MAGPIE GEESE IN 62 ACRES OF TOMMY POLICEMAN PLAIN IN 1959, ACCORDING TO WATER DEPTH AND VEGETATION HEIGHT AND DENSITY

Serial No.	Water Depth			Vegetation Height			Vegetation Density		
	Depth (in.)	Number of Nests	Relative Density of Nests	Height (in.)	Number of Nests	Relative Density of Nests	Density	Number of Nests	Relative Density of Nests
1	1–3	0	0	0–6	0	0	I	11	0·41
2	4–6	0	0	7–12	0	0	II	9	1·81
3	7–9	1	0·21	13–18	0	0	III	15	2·14
4	10–13	18	0·81	19–24	1	0·48	IV	43	2·72
5	13–16	66	1·96	25–30	32	0·93	V	16	2·57
6	16–19	9	1·65	31–36	50	1·85			
7				37–42	11	3·08			

and density of the vegetation. Table 13 shows these features on Tommy Policeman Plain in 1959. The data are illustrated in Figure 10.

Water Depth.—It can be seen from Table 12 that nests were built in depths of water varying from a few inches to 3 ft. Very few were built in water less than 7 in. or more than 30 in. in depth, and none were built in water deeper than 36 in. The most favoured depth was 25–30 in., nests being three times as dense there as in the next most popular depth, 19–24 in. Of the 205 nests examined 88% were located in water between 13 and 36 in. deep.

In 1959 the optimum depth of water was not available on Tommy Policeman Plain owing to the dry season. Some birds did breed in that colony, and the distribution of their nests according to water depth is shown in Table 13. It can be seen that under these conditions the birds preferred the deepest water available, although some did breed in shallower water than usual.

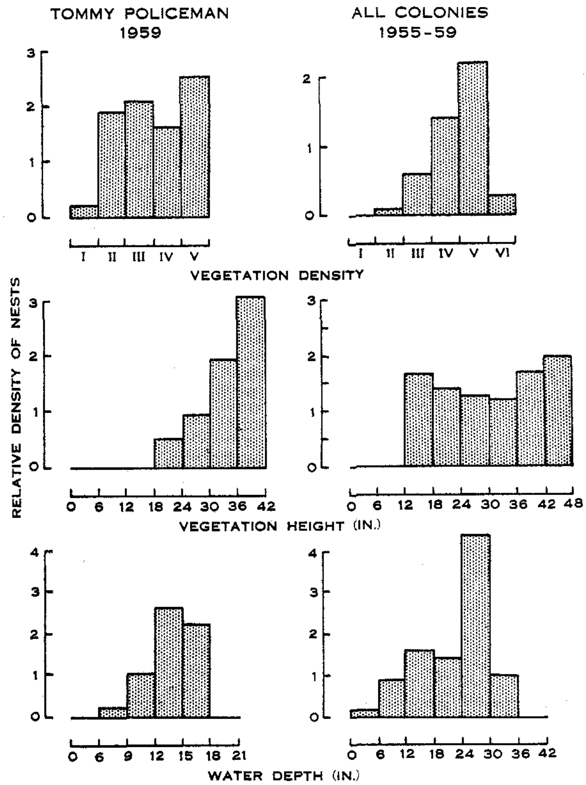

Fig. 10.—The distribution of nests of the magpie goose in all colonies studied in all years and in the Tommy Policeman Plain colony in 1959, classified according to vegetation density, vegetation height, and water depth.

Density of Vegetation.—Although Table 12 shows that some nests were built in all the density classes except the very thin (class I), the greatest number of nests (87%) was found in the moderately thick stands (classes IV and V), nests being on the average three times as common in equal areas of those classes as in class III. The very thick stands of spike-rush were avoided, although apparently providing abundant nesting material. On Tommy Policeman Plain in 1959 (see Table 13) the density requirement for nesting was not so obvious, and although the very thin stands were avoided nests were equally common in all other density classes.

Height of Vegetation.—Very short growth was avoided for nest-building. Apart from this restriction the height of vegetation had no effect on nest distribution except on Tommy Policeman Plain in 1959, when a linear relationship existed between the height of the spike-rush and the density of the nests. It is possible that a similar relationship did exist in the other years but was masked by the difficulty of accurately measuring the height of the spike-rush (Section II(*b*)).

It is clear that magpie goose nests are seldom found elsewhere than in moderately dense (classes IV and V) stands of spike-rush–wild rice associations up to 48 in. in height growing in water between 13 and 31 in. deep. The depth of water has been shown (see Section III(*e*)) to determine the type of vegetation growing in it and also its height and density, and these last are, to some extent, dependent on each other. There are insufficient data to separate the effects of all these factors, or of possible interactions among them, on the distribution of nests.

(*b*) *Sexual Cycle*

It has been shown (see Section VI(*b*)) that with the first storms of the wet season the birds become more active and, reinforced by an influx from elsewhere, move more freely and widely over the plains. This period is also one of increasing sexual activity.

Analysis of data from the gonad samples collected was complicated by the presence of an unknown proportion of non-breeding birds in the population. Accordingly it is necessary to consider these data on the basis of the percentage of birds in each sample showing the change discussed. It is not possible to construct graphs or tables to show the seasonal changes in gonads in a sample of uniform maturity.

The results of the histological examinations of the testes are summarized in Table 14. The data for the 1957–58 breeding season, being the more complete, are discussed below.

In September the testes of two birds were examined. In both the tunica albuginea was thick (up to 100 μ), and the seminiferous tubules were clear and measured up to 40 μ in diameter. They were lined with a single layer of spermatogonia and no mitotic figures were detected in the nuclei. These were typical of sexually inactive testes.

Seven birds were examined in October and seven in November. In these, with one exception, the interstitium was slightly lipoidal and the dimensions of the tubules and the tunica albuginea similar to those of the September sample. The lumina of the tubules were occluded with lipoidal material. In the one exception, collected on November 22, mitotic figures were numerous in the spermatogonia, and primary spermatocytes were present in some tubules. Clearly sexual activity was beginning in this one specimen, but the remainder of the October and November samples were sexually inactive.

In December 10 out of 15 testes examined were inactive, with thick tunics, narrow tubules, and inactive germinal epithelia. In the remaining five both primary and secondary spermatocytes were numerous; the tunics were then averaging 60 μ and the tubules had increased to 100 μ.

The first spermatozoa were seen in January, when out of 30 testes collected seven were inactive, 21 contained numerous spermatocytes, and two contained bunched spermatozoa. The tubules measured 150–170 μ in diameter. The situation was similar in February.

TABLE 14

SUMMARY OF HISTOLOGICAL EXAMINATION OF TESTES OF 205 MAGPIE GEESE, 1957–58

Month and Year	Sexual State of Testis								Total
	Inactive		Spermatocytes		Spermatozoa		Collapsed		
	No.	Percentage of Annual Total	No.	Percentage of Annual Total	No.	Percentage of Annual Total	No.	Percentage of Annual Total	
1957									
Jan.	0	0	4	14·8	0	0	0	0	4
Feb.	3	4·9	5	18·5	4	14·8	0	0	12
Mar.	2	3·3	2	7·4	6	22·2	0	0	10
Apr.	12	19·7	10	37·0	15	55·5	2	18·2	39
May	16	26·2	0	0	2	7·4	5	45·5	23
June	3	4·9	0	0	0	0	4	36·3	7
Sept.	2	3·3	0	0	0	0	0	0	2
Oct.	7	11·5	0	0	0	0	0	0	7
Nov.	6	9·8	1	3·7	0	0	0	0	7
Dec.	10	16·4	5	18·5	0	0	0	0	15
Total	61	100·0	27	99·9	27	99·9	11	100·0	126
1958									
Jan.	7	26·9	21	56·8	2	33·3	1	10·0	31
Feb.	1	3·8	7	18·9	3	50·0	0	0	11
Mar.	5	19·2	4	10·8	0	16·7	3	30·0	12
Apr.	2	7·7	3	8·1	1	0	2	20·0	8
May	3	11·5	1	2·7	0	0	4	40·0	8
June	7	26·9	0	0	0	0	0	0	7
Nov.	1	3·8	1	2·7	0	0	0	0	2
Total	26	99·8	37	100·0	6	100·0	10	100·0	79

In March two of 12 testes examined had collapsed. In these cases the tunic was buckled and the lumina were occluded by lipoidal debris. Five of the remainder were typically inactive, and in the other five the spermatozoa had been shed but the cells had not collapsed. In April and May the situation was similar, with the exception that a new tunica albuginea was being laid down in several cases.

While sexually immature the testis averages about 0·2 ml in volume, but during the breeding season it increases greatly in size until at spermatogenesis it may measure up to 7·0 ml.

TABLE 15

ENLARGEMENT OF MAGPIE GOOSE GONADS: MALES

Month	1955–56			1956–57			1957–58		
	No. in Sample	Birds with Enlarged Testes		No. in Sample	Birds with Enlarged Testes		No. in Sample	Birds with Enlarged Testes	
		No.	Percentage		No.	Percentage		No.	Percentage
Sept.	13	0	0·0	—	—	—	17	0	0·0
Oct.	50	4	8·0	—	—	—	41	1	2·4
Nov.	20	2	10·0	3	0	0·0	9	0	0·0
Dec.	15	2	13·3	—	—	—	30	3	10·0
Jan.	—	—	—	10	4	40·0	37	7	18·9
Feb.	72	25	34·7	19	10	52·6	19	13	68·4
Mar.	45	28	62·2	22	18	81·8	16	4	25·0
Apr.	12	4	33·3	60	25	41·7	13	4	30·8
May	10	0	0	43	7	16·3	12	0	0·0
June	—	—	—	8	1	12·5	—	—	—
Total	237	65	—	165	65	—	194	32	—

TABLE 16

ENLARGEMENT OF MAGPIE GOOSE GONADS: FEMALES

Month	1955–56			1956–57			1957–58		
	No. in Sample	Birds with Enlarged Oocytes		No. in Sample	Birds with Enlarged Oocytes		No. in Sample	Birds with Enlarged Oocytes	
		No.	Percentage		No.	Percentage		No.	Percentage
Sept.	24	0	0·0	—	—	—	22	0	0·0
Oct.	22	0	0·0	—	—	—	23	0	0·0
Nov.	29	2	6·9	—	—	—	8	0	0·0
Dec.	11	1	9·1	—	—	—	10	2	20·0
Jan.	—	—	—	8	1	12·5	23	9	39·1
Feb.	39	19	48·7	21	13	61·9	11	10	90·0
Mar.	22	14	63·6	8	6	75·0	6	4	66·7
Apr.	20	4	20·0	19	12	63·2	3	2	66·7
May	7	1	14·3	29	0	0·0	7	0	0·0
June	—	—	—	15	0	0·0	—	—	—
Total	174	41	—	100	32	—	113	27	—

In 1955 the first increase in testis size was noted on November 11, when one male out of 20 examined had testes averaging 1·1 ml in volume. In 1957 enlarged testes were not seen until December, but this is not considered significant, as the number of birds examined was small.

In the females the first enlarged oocytes were found on November 18, when out of 29 females two had oocytes measuring 6·2 and 5·3 mm in diameter respectively. The immature oocyte measures less than 1 mm in diameter. In 1957 enlarged oocytes were not seen until December but, as in the case of males, the sample was small.

In each year the rate of increase in size of testes and oocytes accelerated sharply in January. The greatest sizes were achieved in March in 1956 and 1957, but in February in 1958.

Tables 15 and 16 show, for each month from September to June in 1955–56, 1956–57, and 1957–58, the percentage of birds with gonads showing significant increase in size from the inactive condition.

It can be seen that the increase in the percentage of birds sexually active was parallel to the increase in size of the gonads of sexually mature birds discussed above. The peak numbers of birds with enlarged gonads were found in March in 1956 and 1957 but in February in 1958.

It is of interest to note from the data in Table 15 that 154 (35·4%) of 435 males examined from December to May (the main sexual period in all years) had enlarged testes. Of 244 females examined during the same period, 100 (41·0%) had enlarged oocytes. These figures can be considered as an estimate of the average proportion of breeding birds in the population over 3 years. As the samples were possibly biased towards breeding birds it is probably an overestimate.

(c) *Breeding Seasons*

The date of the beginning of the breeding season varied in the different swamps in each year and in the same swamp in different years. The date on which the first eggs were laid, the rainfall, and the water level in the two most intensively studied swamps—Litchfield Creek and Tommy Policeman Plain—are shown in Figure 11.

The Litchfield Creek swamp is close to the river and is fed by a large catchment area; it is accordingly rather sensitive to rainfall and subject to flooding. During the course of the study construction of levee banks and drains in and near the swamp led to great differences in its level in different years, quite apart from natural factors. The Tommy Policeman Plain swamp is farther from the river and less subject to sudden severe flooding.

(i) *Annual Differences*

Litchfield Creek.—In 1958 the breeding season began 25 days earlier than in 1956 and 44 days earlier than in 1957. In the 1955–56 wet season there was little rain and the swamp filled very slowly. The spike-rush grew very dense and tall. In December and January the geese, which had occupied the swamp in October, were constructing numerous stages in those parts of the swamp where there were a few inches of water, particularly along the edge of the creek itself. In one of these areas a completed nest was found on February 1 and it seems certain, from later experience, that it had contained an egg that had been removed by a predator. The geese were apparently on the point of beginning to lay. On February 4, 9 in. of rain fell and the swamp was covered by 6 ft of water. The geese dispersed.

When the water had subsided in mid February the swamp was reoccupied and construction of stages and nests began again. The first egg was laid on March 15 in one of the densest areas of spike-rush, and the main breeding season began on April 5.

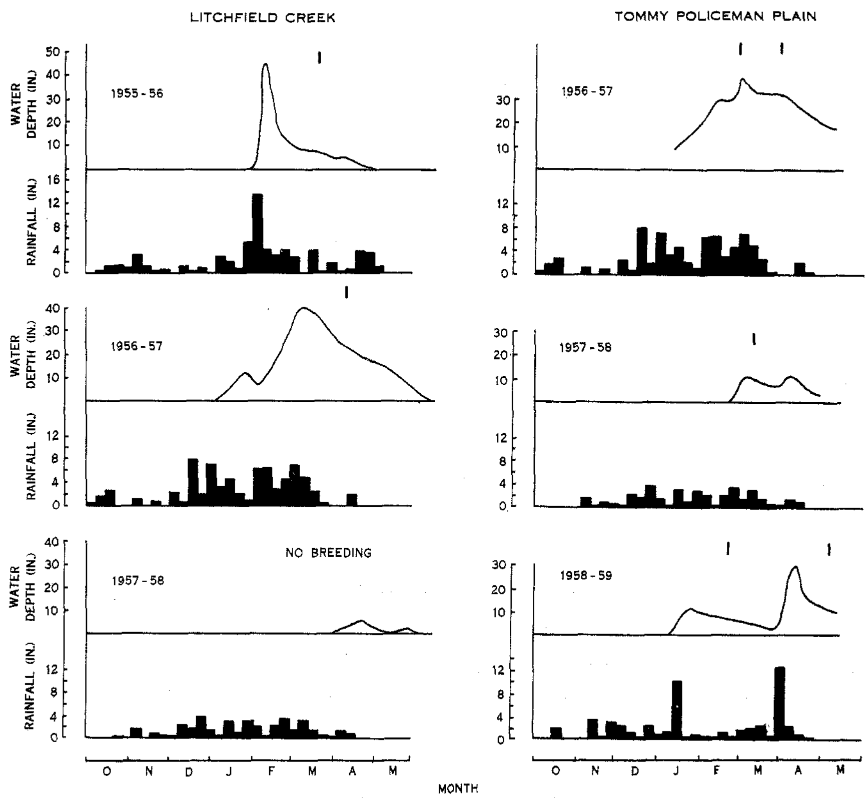

Fig. 11.—The dates of the first eggs of the magpie goose found in two colonies.

In 1956–57 also there was severe flooding of the swamp, caused by a cyclone on March 5. Conditions differed from those of 1955–56 in that there had been heavy early rain and the swamp had been well filled before the flooding. The sedge was not so dense as in the previous year nor did it emerge above water so far. At the end of February, although no eggs or completed nests were found, the activity of the geese suggested that nesting was imminent when the cyclone dispersed the birds. The birds returned in mid March and constructed new nests. The first eggs were laid on April 1.

The 1957–58 wet season produced very little rain, and owing to the construction of a drain the swamp failed to fill completely. By February 24 the water was only 1–2 in. deep, except in a few depressions. These conditions resulted in a very dense growth of sedge. Two thousand geese had occupied the swamp in November but the majority left in January when the swamp failed to fill. The few that remained bred in the deeper parts of the swamp; the first eggs were laid on February 22.

From the records maintained at Humpty Doo by officers of the Division of Plant Industry, Northern Territory Administration, and of Territory Rice Ltd. it is possible to describe briefly the two breeding seasons on Litchfield Creek prior to the beginning of this study. The senior author was in the area at the end of one of those seasons, 1954–55, and was able to confirm the substance of the officers' report for that year.

1953–54.—In 1954 eggs were found in the colony in the third week of March. In the period April 4–8, 10 in. of rain fell and the water level rose by 48 in., flooding all the nests. The majority of the geese left the area, but a few remained and some eggs were laid at the beginning of May. Natives were catching goslings in the first week of June.

1954–55.—In October 1954 there were 9·85 in. of rain, an abnormally high total for the month, and on November 10 the swamp contained 30 in. of water. Breeding began in the first week of January, and the eggs hatched in mid February. Another cyclone on February 14 caused a 60-in. rise in water level and the last few clutches were destroyed.

Tommy Policeman Plain Swamp.—There were similar annual differences in the breeding season. In 1957, following a good wet season, the swamp was well filled, and a few birds had begun to lay in the most favourable parts of the swamp by March 1. The subsequent flooding of the colony destroyed all the nests and breeding was not resumed until March 22.

In 1957–58 the swamp failed to fill satisfactorily, and although there was ample spike-rush there was practically no water in the swamp until early March. Nesting began on March 12.

The rainfall in the 1958–59 wet season was very irregularly distributed and fell mainly in two periods, January 13–19 and April 1–6. The spike-rush was well grown but the swamp contained little water prior to the first period of heavy rain. After that rain and the filling of the swamp nesting activity began; the main breeding season began on February 21, although few birds participated. After the heavy rain in April the water level in the swamp again increased and there was another breeding season. D. Tulloch, who observed it, reported: "The geese laid again or are in the process of laying. There are hundreds of stages of all kinds on Tommy Policeman below the dam, and off Kemp strip we found six nests with eggs in an area of about 1 acre. We did not find any eggs outside this area." Subsequently the volume of breeding increased.

(ii) *Local Differences*

The preceding section has shown that differences existed between the dates on which breeding began in the Litchfield Creek and Tommy Policeman Plain swamps. Other and greater differences existed among other swamps. These differences were most accentuated in 1957–58, a year of poor rainfall. In that year it was seen that in swamps that were fed by large catchment areas and filled early breeding was early. In swamps with small catchment areas breeding was relatively late.

Thus in two swamps of the former class, Bald Hill and Mosquito Creek, there was adequate water in January and breeding began on February 10 and 12 respectively. In Tommy Policeman Plain, where there was little water, breeding was delayed until March 12; and in Litchfield Creek, where there was even less water, breeding virtually failed.

In all of the swamps there was an adequate growth of spike-rush for nest-building throughout the season. Apparently the only factor differing was water depth.

(iii) *Regional Differences*

Thanks to the courtesy of the Rev. R. V. Ash and Mr. D. Viney of Oenpelli Mission near the East Alligator River, 100 miles east of Humpty Doo, it is possible to compare the breeding seasons on the East Alligator with those on the Adelaide. At Oenpelli goose eggs form an important source of food and consequently the nesting chronology is closely watched.

1956.—In 1956 breeding in the various swamps near Humpty Doo began between March 8 and March 29. At Oenpelli the first eggs were laid on March 10 and most birds had laid by March 24. On March 27 a cyclone flooded the Oenpelli swamps and destroyed the nests. New clutches were begun in early April. Paddy Bull collected 50 clutches in the period April 14 and 16; of these 37 were incomplete and fresh.

1957.—The flood history was similar on both rivers, and the nesting chronology was also similar. On the Adelaide breeding began in the various swamps in the period March 1 to April 9. At Oenpelli the first clutches were laid about February 22; they were destroyed by flooding on March 4, and fresh nests were built and clutches begun by April 1.

1958.—The East Alligator River received heavier rainfall than the Adelaide and the swamp filled during January and February. Eggs were laid in the second week of April. This may be compared with laying dates in late February and early March in the Adelaide River Swamp.

(*d*) *Clutch Size*

There are difficulties in the determination of clutch size in the magpie goose. Either one or two females lay in each nest, and in most cases it was not possible to determine how many were laying. In some cases it was established that two females were actually laying, but even then the eggs of each individual were not necessarily different enough in size and shape to enable them to be distinguished. The possibility also exists of one female laying eggs of variable size and shape that could be grouped, by chance, into two series.

A further difficulty is that the nests are subject to very heavy predation, which may take several forms. Sometimes the whole or part of the clutch is removed at one attack; but at other times each egg is removed as it is laid over a period of a few days and then predation ceases, allowing an incomplete clutch to accumulate in the nest. The true clutch size could be determined only by very close observation of a population of marked birds, and under the conditions of this study that ideal was not realizable.

Table 17 shows the numbers of eggs found in nests in which laying had ceased when found, or in which daily visits had been made during the laying period. While they cannot be considered to show the true clutch size they do illustrate the numbers of eggs that are commonly found in nests in the field. The numbers varied from 1 to 14, with a mean of 7·3. The commonest numbers were 6–10.

TABLE 17

SIZES OF CLUTCHES FOUND IN MAGPIE GOOSE NESTS IN WHICH LAYING HAD CEASED

Size of Clutch	No. of Nests Containing Clutch
1	3
2	2
3	10
4	10
5	15
6	28
7	15
8	25
9	15
10	20
11	16
12	8
14	1
Total	168

In 39 nests it was possible to determine with reasonable certainty the number of females laying and the amount of predation that occurred. In 17 nests in which one female laid the number of eggs varied from 5 to 12, and averaged 8·6. In the 22 nests in which two females laid the number of eggs varied from 7 to 12, with an average of 9·4. The data suggest that where two females lay in one nest each produces fewer eggs than when only one female uses the nest.

(e) *Hatching Success*

The hatching success was low. Of 41 nests closely observed 31 (77%) suffered complete or partial predation. Of the 304 eggs in these nests 220 (72%) were eaten by predators. The only predator actually seen attempting to eat eggs was the black snake (unidentified), but there were grounds for suspecting the little eagle, *Hieraaëtus morphnoides*, the crow, *Corvus cecilae*, the dingo, *Canis familiaris* *dingo*, the water rat, *Hydromys* sp., and the goanna, *Varanus gouldii*. In some places the aboriginals also eat large numbers of eggs.

The goslings hatch after 24–25 days of incubation, and spend a day in the nest before they are led through the swamp by their parents. They fledge in 10 weeks but remain with the parents until the following breeding season.

(*f*) *Discussion*

There is much evidence that the breeding seasons of birds are strongly influenced by environmental factors (Marshall 1949; Lack 1950; Moreau 1950; Wagner 1959). Commonly the factors involved are found to be rather specific habitat requirements.

In inland Australia, where the rainfall is erratic, it has been clearly shown that rainfall and its effects on the environment are of very great importance (e.g. McGillivray 1923; Keast and Marshall 1954; Frith 1957), and Serventy and Marshall (1957) were able to generalize for a large part of the continent that the critical stimuli to reproduction were environmental conditions arising after rain. Frith (1959), in a study of several species of wild ducks in inland Australia, showed that the environmental condition required for reproduction was the provision of adequate water areas in which the animal communities were at a suitable stage in their development to provide the appropriate food for the ducklings of the various species. It was shown that the required synchrony was achieved by the stimulation of the sexual cycle of all species studied by increases in the water levels of the lagoons; ovulation in some species, however, was delayed until the water had receded to an appropriate level. Breeding could occur at any time of the year when the habitat requirements were met. The timing of the breeding season of one species, *Malacorhynchus membranaceus*, to occur in rapidly declining water frequently led to the death of later broods owing to drying up of the water.

In the present study it has been shown that the magpie goose breeding season is also controlled by rainfall and its effects on the environment. The sexual cycle is stimulated by rainfall, the nest-building activities are affected by wet days, and the nests are located only in specific habitats, the distribution of which is determined by flooding of the swamps. Although the sexual cycle begins with the first storms of the wet season, ovulation is delayed until the end of the season, when the appropriate habitat is available.

The factors in the habitat influencing nest-building are water depth and the height and density of the vegetation; these are closely related and it is not possible to separate their individual effects.

It is probable, however, that the importance of the various factors varies from place to place and from time to time, and the following examples are cited.

In 1956 the main nesting colony on Tommy Policeman Plain was located on its western edge in water 18–36 in. deep. During 1956 Fogg Dam was constructed across the plain, so that in 1957 the water in that region was up to 72 in. deep. The spike-rush grew through, and although reduced in density was still well within the range of both height and density acceptable to geese. No geese bred in the area, however, in 1957 or in 1958. In the 1958–59 wet season there was insufficient rain to fill the dam and its level fell to 24 in., and the geese reoccupied their former colony. As the vegetation was quite dense in each year, it is suggested that the changes in water level were the important factors affecting the breeding of the geese, the water being too deep in 1957 and 1958 but suitable in 1959.

In 1959 also there was little water below the dam. It has been shown that the geese concentrated their nests in the deepest parts available. The density of the spike-rush was high and apparently adequate everywhere. Under these conditions the height of the spike-rush became a limiting factor and strongly affected the nest distribution in this region.

It is easy to imagine that a species that builds a large nest of swamp vegetation would require dense growth before breeding, merely because of the mechanical needs of construction; accordingly it would be expected that thin growths of spike-rush, associated with shallow water, would be avoided. It has been shown, however, that very dense growths of spike-rush, often associated with water of an apparently suitable depth, are avoided, although there is abundant nesting material. Clearly other factors also operate.

The timing of the breeding season to occur at the end of the wet season, and the location of the nests in the deeper parts of the swamps, ensure that the goslings are hatched at a time and place when seeding grasses are abundant. From what little information is available, it appears that the New Guinea geese also breed at the end of the wet season, February–April (Hoogerwerf 1959).

Table 18 presents the gizzard analysis of 12 downy goslings and six 7-week old goslings. The downy goslings fed primarily on wild rice and the seeds of swamp grasses and sedges, also taking some *Caldesia*. Although arthropods were found in seven of the gizzards they formed a very small portion of the total volume, and it was clear that even at that early stage the geese were herbivorous, feeding on the seeds of plants then fruiting in the swamp. The correlation between the fruiting of the wild rice—the most abundant species of grass in the swamps—and the hatching of the goslings was not consistent. Thus in 1957 the wild rice crop reached a peak about March 26, but the goslings did not hatch in numbers until about April 26. In 1958 the main wild rice crop matured about April 1; some goslings had already hatched, and most were out within a week or so of that date.

The few gizzards of older goslings collected indicate that at the time of collection the young geese were still feeding on the seeds of swamp plants, while the adults were already digging *Eleocharis* bulbs at the edge of the drying swamp.

The wide divergence of plant genera found in crops of the two age groups probably indicates that the young birds are not selective as to the seeds on which they feed, the samples having been taken on opposite sides of the river from entirely different swamp types. There is no doubt that suitable food for the goslings was abundant at the time of hatching in each year.

The water level in the swamps changes throughout the wet season, rising rather rapidly until the end of the monsoonal rains and then falling more slowly. In addition to the fairly regular water-level change, cyclones may occur at any time and several examples have been cited where the resultant flooding has destroyed early nests and eggs. Re-nesting is common after these disasters, provided that suitable water and vegetation conditions return; the cyclones, however, must have a great effect on overall breeding success.

The timing of the breeding season at the end of the wet, in addition to helping to ensure that steadily rising water does not flood nests, results in the goslings being hatched in a swamp in which the water level is rapidly declining. There were frequent observations of goslings moving from drying parts of the swamps to

Table 18

FOOD OF GOSLINGS

Food	Occurrence (%)	
	12 Downy Goslings, May 1957	Six 7-Week Goslings, May 1958
Oryza (cultivated)	12·2	—
Oryza (wild)	6·5	—
Paspalum spp.	5·9	—
Fimbristylis sp.	16·4	—
Cyperus sp.	4·6	—
Panicum sp.	4·6	—
Caldesia sp.	14·8	—
Characeae	4·6	—
Blyxa aubertii	2·7	—
Arthropods	12·6	7·4
Grass blades	—	7·5
Aquatics	—	11·1
Eleocharis dulcis	—	18·4
Ceratophyllum demersum	—	18·4
Nymphaea sp.	—	18·6
Xyridaceae	—	14·8
Monochoria cyanea	—	3·8
Unidentified	15·1	—

deeper water. In the year of inadequate rainfall, 1957–58, many swamps dried before the goslings were on the wing and most of them perished. It would obviously be an advantage for the geese to breed in water of as great a depth as possible, consistent with other requirements.

Examples have been quoted where the density of the vegetation was adequate for nesting (see also Section VII(*d*)) but eggs were not laid until the water depth altered, either increasing or decreasing. These examples lead the authors to believe that water depth is of major importance to the geese in determining the breeding season.

It would appear that a breeding season timed to occur when the water level in the swamps had reached its maximum and was declining would, on the average, be more successful than one timed to occur at a certain density of swamp vegetation.

VIII. Magpie Geese and Rice Cultivation

(a) *Effects of Geese on Rice Crops*

The original aim of the study of the magpie goose was to determine the probable future effect of the geese on the expanding rice industry, and, if possible, to provide methods of controlling damage done by them to the crops or of removing the geese from the cultivated areas.

The effects of geese on rice crops must be considered under two heads, viz.: the relation of feeding to wet-season and dry-season rice crops respectively.

The wet-season crop, which is and probably will remain the principal crop, was at the time of the study usually sown before the ground was made unworkable by the rains. In the past it had been sown some time from September to January, either by drilling or by broadcasting from the air. The crop grows throughout the wet season and is harvested in April or May. Its growth cycle thus closely follows the influx of geese to the Adelaide Valley and the birds' breeding season in the area. Rice and geese have very similar habitat requirements in the wet season.

At sowing time geese become very numerous in the fields, but there is considerable evidence that they do not dig up drilled rice. Although flocks of geese are regularly seen on the rice fields immediately after sowing, samples shot in two separate years have revealed that at that time the birds are feeding on *Eleocharis* bulbs disturbed by the drill. Broadcast rice presents the geese with a ready harvest. Goose-netting operations have shown how speedily geese consume rice on dry ground from September to January, and large-scale air-sowing in January and February 1957 allowed the authors to investigate the reaction of geese to rice sown on wet ground or in shallow water. The geese preferred rice seed scattered in shallow water, but ate some seed on the mud, and they have elsewhere been found to be taking seed in about a foot of water. The period from September to January is one in which the range of food available to the geese is increasing as the wet-season grasses grow and fruit, but it is also one of rising goose population in the Adelaide Valley, so that any exposed rice seed would be likely to be taken. The results of baiting indicated that broadcast seed was still attractive on dry ground at the end of December, but by mid January geese were more interested in the fruiting grasses. Clearly then broadcast rice seed is vulnerable to geese within the sowing period, whereas drilled seed is not.

The germinating rice is grazed by the geese when it is between 2 and 8 in. high, but not after. If the seedling is strongly rooted, i.e. has been drilled, such grazing does not appear to affect the plant at all; indeed, it may encourage tillering. Seedlings that have poor root systems, on the other hand, such as those that have germinated under a considerable depth of water, are often uprooted by grazing.

The geese do not again visit clean crops of rice until late April and May, when the plant comes to head. They are often found, however, in crops that contain weeds such as *Echinochloa*, and collecting showed that they were feeding on the seeds of those weeds. At harvest time the geese treat cultivated rice as they do wild rice, knocking it down and stripping the heads. The ease with which they can be driven off the crop by gunfire at that time depends upon the relative time of maturation of the wild and cultivated crops. If between the end of the grass-seed crop on the high black soil and the maturation of the wild rice crop there is a hiatus during which the cultivated crop comes to seed, the geese are very persistent in their attacks; but once the wild rice crop ripens, the birds concentrate upon it. If the cultivated crop ripens after the wild rice, the attacks are not so persistent, partly because there is still much wild rice in the swamps, partly because the *Eleocharis* bulbs are beginning to be available at the swamp margins, and partly because many geese are leaving the valley as the water level on the plain falls. Perhaps, therefore, a late-maturing wet-season variety of rice would be safer from goose attack than an early-maturing one.

All the above features apply also to dry-season crops, only more acutely. Once the rice is sown in May and June it must be irrigated, and the flooding of the fields comes at a time when the rest of the plain is drying up. There is some evidence that water is an inhibitor of goose movement (see Section VIII(*d*)), so that the sudden appearance of sheets of shallow water attracts geese from the drying plain to filter the seeds (unless they are deeply drilled), to dig the exposed *Eleocharis* bulbs, and to graze on the young seedlings. If undisturbed, or even despite a considerable amount of gunfire, geese will continue to live among the growing crop throughout the dry season since the water remains there in abundance. As harvest approaches in September and October there is some evidence that the main dry-season food—*Eleocharis* bulbs—becomes less available or less attractive to geese. The geese, provided with an alternative source of food in the ripening rice, are very persistent indeed in their attacks on it.

It appears therefore that while a drilled, late-maturing wet-season rice crop is relatively unlikely to be affected by geese in the Darwin region, other types of rice crop, particularly dry-season ones, are likely to suffer in greater or lesser degree from their attention.

(*b*) *Control of Geese*

Attempts at goose control could take three forms, viz.: scaring of geese from the crops, mass destruction, and habitat alteration.

(i) *Scaring*.—The work will not be described in detail. Standard devices using flashing lights, searchlights, revolving metal strips, pyrotechnics, and gunfire were tested, but none were successful.

(ii) *Removal of Geese by Mass Destruction*.—It was shown that geese could be very easily poisoned in the dry season and early wet season, provided that the bait was placed in the usual feeding place for each flock and free-feeding was practised. Later in the wet season, when the swamp vegetation had developed and the geese had more abundant food available, they would not accept bait.

It was considered that mass destruction by poison could have little, if any, effect on the goose population of the rice-growing areas. The principal reason for this conclusion was that it has been shown that the main goose population of the valley is nomadic and is not present in the area at the time when poisoning could be effectively and economically undertaken. Poisoning in the dry season, while it would reduce the damage to dry-season crops, could have no effect on the numbers of geese visiting the area from elsewhere during the wet season.

(iii) *Habitat Alteration.*—It has been seen (see Section V(*d*)) that the populations of geese in Southern Australia rapidly succumbed to changes in the environment following the advance of settlement and also, probably, to drought. In the present study it has been shown that the goose is a slow-breeding species with very specific breeding and food requirements. It is considered that these requirements could be quite easily upset in the Adelaide River Valley, at least in the vicinity of the rice fields, so making the area unattractive to geese.

The life cycle of the geese in the Adelaide Valley centres around the moderately deep water in the low-black-soil swamps, which provides the bulk of their food for the whole year and their breeding habitats; these areas are really very small. It has been shown that when the water level in the Tommy Policeman Plain colony was raised by the construction of a dam the colony was destroyed, and when the water level in the Litchfield Creek colony was lowered by a drainage channel the colony there was similarly destroyed. There are other examples also where a gross alteration in water level destroyed a colony, or where the provision of suitable water created one, and these are sufficient to demonstrate the practicability of preventing the breeding of geese and making the area unattractive to them by effective water control in the swamps.

Up to the present the cultivation of rice has not greatly inconvenienced the geese. The rice fields have been located in areas of shallow water because cultivation is easier there, and the deeper areas have been avoided. These deeper areas provide the breeding places for geese, and the development has resulted in geese and rice crops being maintained in close proximity. The feeding ranges of the flocks are limited, and it is considered that goose damage to crops could be eliminated by a planned development that ensured that all water areas in the vicinity of the fields were subjected to water control, so that suitable conditions for goose breeding were eliminated. This could be achieved by either drainage or flooding.

In any case it is not considered that geese will be a continuing problem to the industry as settlement develops; rather the advance of settlement could virtually eliminate the magpie goose from the Northern Territory.

IX. Acknowledgments

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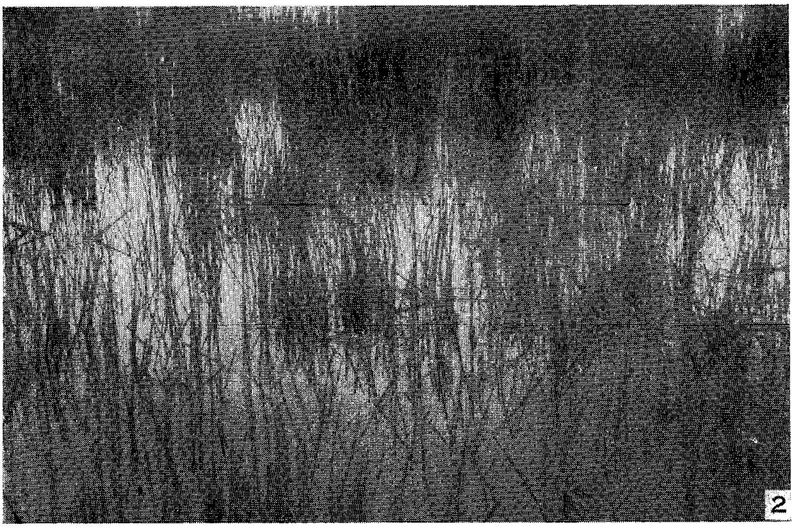
ECOLOGY OF THE MAGPIE GOOSE



Density classes of swamp vegetation. Fig. 1.—Class VI. Fig. 2.—Class I.

ECOLOGY OF THE MAGPIE GOOSE

Fig. 1.—Nest of magpie goose in vegetation of density class IV.
Fig. 2.—Predation of magpie goose nest by the black snake (unidentified).

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