The impact and management of birds on the Ord river development in Western Australia.

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Thesis submitted for the
Master of Natural Resources
Degree of the University of
New England, Armidale, N.S.W.
February, 1977.

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ACKNOWLEDGEMENTS

No man is an island; no thesis is the work of one man. This thesis drew on many of my colleagues and friends, but none more than my original supervisor, the late John Le Gay Brereton, to whom my debt is as absolute as mortality will allow.

The Ord agronomics consortium (Hooker Pastoral Co., Mitsui (Australia) Ltd., and Hawaiian Agronomics), together with the Rural Credits Development fund of the Reserve Bank of Australia, funded the project.

My colleagues in the university team at Kununurra helped me with the collection of farm data; John Miller and Chris Sullivan with some of the field work in 1972 and 1973 respectively.

Ron Darke, Dick Kelley and the staff of Hooker farm were of considerable help, as were the staff of the Kimberley Research Station and the Western Australian Departments of Agriculture and Public Works.

A particular debt is owed to the people who lived in the settlements and on the stations of the Ord-Victoria area. The information they supplied and the general assistance they gave will always be remembered.

Lastly, the debt which I owe to those immediately involved in the preparation of this thesis is considerable. Peter Jarman stepped in and, although already overworked, filled John Brereton's role as supervisor. My wife, Ros, drew the figures while tolerating my thesis madness. Marion Atkinson did yeoman service above and beyond the call of duty at the typewriter.

To all I express my sincere thanks.

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SUMMARY

In 1970 it was thought that birds posed a serious threat to the economic viability of grain sorghum cropping in the Ord valley of Western Australia. In 1970 the major pest species was the little corella; subsequently the magpie goose increased in pest status until it shared equal prominence with the little corella. No other bird species approached the pest status of these two species.

This study reports the steps by which the Ord valley bird pest problems were put in an economic perspective and the management strategies which were developed.

The study shows that in the context of 1972 economic conditions, neither little corella nor magpie geese were of major economic significance to a normally profitable grain sorghum/cattle feed lot enterprise. Further, it shows that the total losses in terms of expected grain withdrawal by birds would approach 600 tonnes for the whole Ord development irrespective of the total area of grain grown.

Notwithstanding the above, management strategies were developed which, if implemented, would minimise the impact of little corella and possibly magpie geese on the grain sorghum growing enterprise. These strategies should, with modification, work for any grain growing enterprise in the valley.

In addition to the agricultural problems, this study briefly considered the other two problems in which birds were involved, namely human health and civil aviation. In the latter, definite strategies could be recommended for minimising the risk posed by birds to scheduled air services. In the case of the former, any definite recommendations must await a better definition of the problem by research currently under way.

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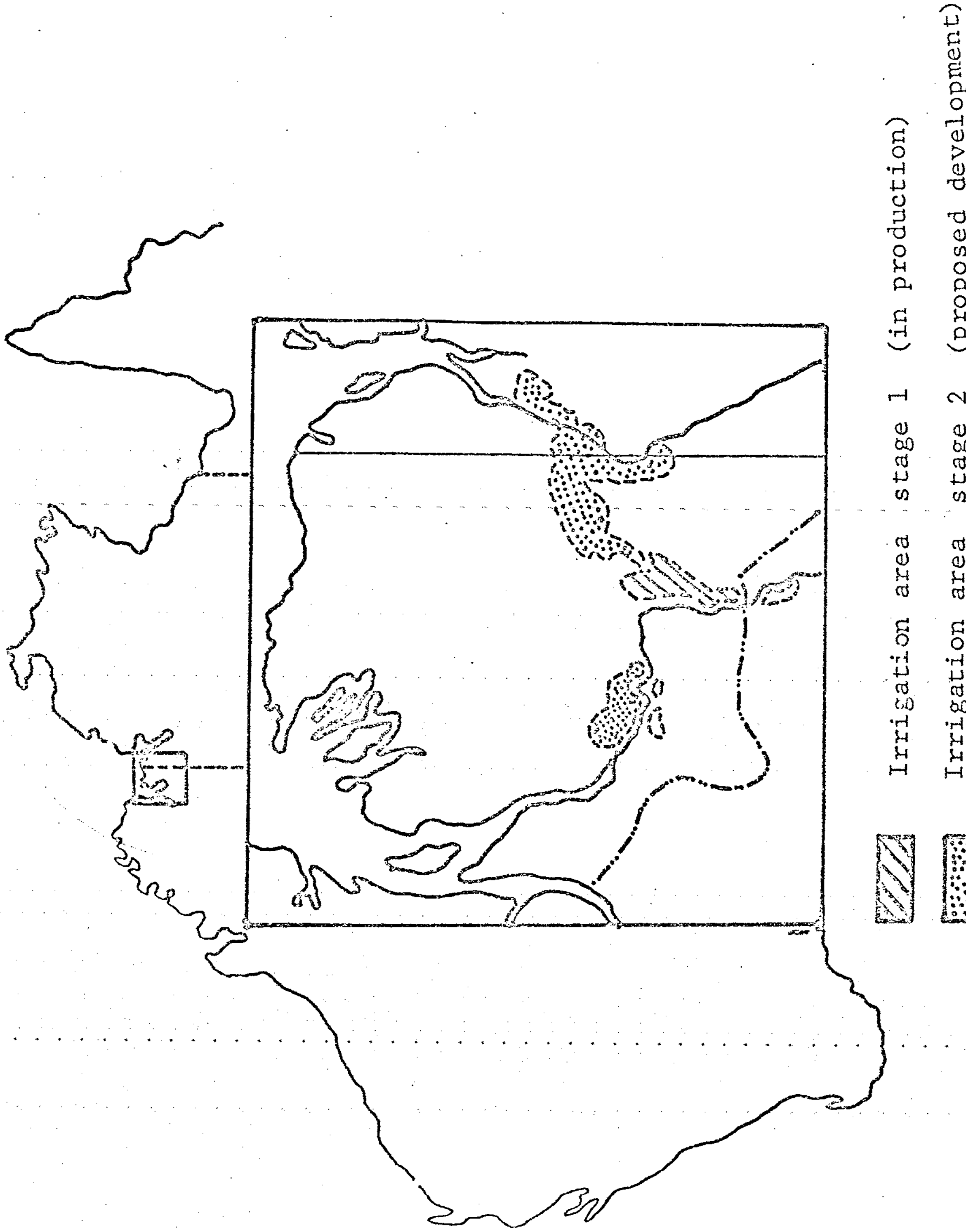

1.0 Introduction and Methods

1.1 The avian problems of the Ord river development

1.1.1 General

This study deals with the impact and management of birds on a new agricultural development in the remote north-east of the state of Western Australia (figure 1.1). A range of problems occurred which could be attributed to a number of species of bird, however no problem was exclusive to any one species.

The major problems could be broadly grouped as involving agriculture, health and civil aviation; the primary pest species in all cases were the little corella (*Cacatua sanguinea* Gould 1842: Psittacidae) and magpie goose (*Anseranas semipalmata* Latham 1798 : Anatidae). Secondary pest species were the galah (*Eolophus roseicapilla* Vieillot 1817 : Psittacidae), the brolga (*Grus rubicunda* Perry 1810 : Gruidae) and various species of duck, the most prominent being the grass whistle duck (*Dendrocygna eytoni* Eyton 1838 : Anatidae). Sixteen species were regarded as having a tertiary pest status; these are listed in Appendix 5.

The major agricultural problem involved the removal of grain from growing cereal crops. At the time of this study grain sorghum was the actual crop involved but others such as rice and wheat had encountered problems in the past.

The major human health concern took the form of problems which were likely to develop from the major changes in bird and insect populations which followed the building of the two Ord river dams. Diseases which could be potentially involved included various arbovirus-caused encephalitic conditions, malaria, schistosomiasis and filariasis (Alpers *et. al.*, 1972 and Stanley, 1972).

The major problem encountered by civil aviation was that common to all areas of high bird density, namely air-strike and bird ingestion. This was a particularly significant problem as the development had a twice-daily jet service which used an unmanned airport (i.e. no fire fighting or control facilities) located at right angles to a major flight path used by all the more numerous bird species.

1.1.2 A short history of bird pests and the Ord river development

This historical review illustrates that the bird pest problems encountered by agriculture in the late 1960's had been recognised as potentially significant since the commencement of agricultural experimentation in the late 1940's. The other problems involving human health and civil aviation have only become apparent in recent years.

In the 1947-48 wet season the first moderate scale grain growing was commenced on the newly founded Kimberley Research Station (K.R.S.) - these crops suffered losses of grain to birds. An analysis of K.R.S. records for the period 1947 to 1951 shows that 70 percent of all experimental grain crops on K.R.S. were written off due to pest damage. Birds were recorded as being significant in 90 percent of damage reports for this period. The significance of birds was recognised by the agronomists working at K.R.S.; Langfield (1948) summarised the situation for little corella as follows:

".. the only pests to do any noticeable damage were finches and white cockatoos. The latter were particularly troublesome and could only be combatted by placing a man on guard during the early morning and late evening. After the experimental section was harvested and the guard removed the cockatoos cleaned up the remainder of the rows in a remarkably short time. I feel that they are going to prove the most serious pest to the growing of grain sorghum in the Kimberlies."

Subsequent reports and letters from K.R.S. contain numerous references to the bird problem and often request assistance. Two visits by professional wildlife biologists were made to K.R.S. in 1955. The first, by Frith, was in April, and the second, by Carrick, in July. In both cases reports were written (Frith, 1955 and Carrick, 1956); Frith in particular recommended that research on the basic biology of the little corella was necessary.

Over the next five years nothing was done. In 1960 the first irrigation land in the Ord irrigation development was brought into commercial production (Anon, 1971). This consisted of a pilot farm [1] of 1,000 ha on which rice was grown. No published reports of bird damage on this enterprise are available and no unpublished records are on file with the W.A. Department of Agriculture (Nelson pers. comm.). Other reports from citizens of Kununurra indicate that considerable brolga damage and some little corella damage occurred. The brolga damage was judged to be sufficiently severe for the company involved to employ three full time brolga shooters (Black pers. comm.).

Rice growing on the pilot farm was found to be not economically viable and production ceased by the mid 1960's. Research on K.R.S. continued, with grain sorghum as the major cereal under test. The following extracts from K.R.S. internal reports clearly indicate that a serious bird pest problem still existed on the experimental area and that the agronomists understood the potential danger of birds to commercial cropping.

"Large numbers of the little corella are doing considerable damage to grain plots on the Research Station and efforts to disperse them have been largely unsuccessful. No detailed study has been made of the bird's habits and any control measures not devised around a knowledge of the bird's

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1 This farm later became Hooker farm.

habits would appear to be in vain. It is suggested that there exists a strong case for a detailed study of this bird to be made." (Mackenzie, 1967)

"In correspondence with Dr. H. J. Frith, Chief of the Division of Wild Life Research, I have put the question to him concerning the little corella and the possible damage that it could cause to commercial crops of grain sorghum in the area. He can see no real reason why these birds could not be a major pest to commercial grain growing concerns in this valley. He pointed out that had an ecological study embracing the fauna of the area been carried out in the Coastal Plains Land Survey (Humpty Doo area), ornithologists would have been in a better position to have done something more positive about the Magpie Goose which caused so much damage to rice in the Humpty Doo scheme. By inference a similar situation exists here." (Mackenzie, 1967)

"Looking through our scientific records which are seriously depleted at present it is amazing to find the number of experiments which have actually been affected or wiped out by birds. The problem of the little corella has been present in sorghum since the early days but has been extremely destructive in this particular crop in the past 2 or 3 years. You will note that most data sent down by David has as one of its provisos the subject of bird damage. I begin to wonder how effective our data is when destruction is continual and difficult to measure. We are all aware of how important sorghum is to the area and how important it is that experimental yields are both insect damage free and bird damage free.

Within our limited resources we have made every effort to control the little corella by experimentation with types of equipment and poisons but all to no avail with the result experiments costing thousands of dollars are being seriously affected. It is important to realise that the problem of the little corella is not only confined to Research Station crops but also to the commercial area.

I know Paul Madge made an approach to the Division and to the Division of Wild Life concerning this problem but as usual no funds were available to invite an officer to the Station for a preliminary investigation. Surely we have had enough experience in other areas to realise the potential danger of not carrying out an investigation. Even now, lost time may not be regained.

I am afraid that I equate this problem with insects and weeds in cotton, both of which had specialist investigation. It is without a doubt that the problem of birds which is at present concerning sorghum will also concern maize and rice and other crops of this nature in the future.

You must agree this is an immediate problem with long term implications. It is one which experts should be called in as soon as possible to undertake at least a preliminary investigation to determine the seriousness of the problem.

I ask for your comments on this matter and also your support in obtaining some assistance."

(Selway, 1968)

These statements were not acted on and commercial development of grain sorghum growing went ahead with no apparent reference to the potential bird pest problem.

In 1969 a consortium known as Ord Agronomics took over the old pilot farm at Kununurra and commenced growing commercial grain sorghum for cattle feed-lotting and possibly export[1]. The University of New England was engaged to carry out research into the practicability of commercial grain sorghum growing and cattle feed-lotting (see section 1.1.3); actual sorghum growing commenced in 1970.

Birds, especially little corella, were an immediate problem. From the onset of grain production a flock of up to 30,000 birds was apparently consuming large amounts of

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1 This was the only significant grain growing in the valley.

grain (up to 2 tonnes per day). This thesis will show that the 1970 little corella problem was in its intensity the product of unusual climatic circumstances. That the problem should have been predicted is however undeniable.

1.1.3 The U.N.E. research programme

The general background and organisation of the University's Ord river research programme has been published elsewhere (Anderson *et al*, 1973). Three brief quotes set the general picture.

"Late in 1969, a contract was negotiated between a consortium comprising the Hooker Pastoral Company Pty. Ltd., Mitsui (Australia) Ltd., and Hawaiian Agronomics and the University of New England, as contractors, to investigate the agro-economic feasibility of grain sorghum production in the Ord Valley of Western Australia. Field research began on the Hooker Farm at Kununurra in January, 1970, and, initially, a two-year contract was negotiated. This period was later extended to the end of April, 1973.

A broad agreement was reached involving the employment of two agronomists, on-farm research costs, research land areas, and machinery usage. The contract was accepted by the University under the responsibility of Professor A. Lazenby (Agronomy) and Professor J. L. Dillon (Farm Management). On the suggestion of Professor Dillon, an economist was added to the team; this member was funded by a grant from the Rural Credits Development Fund of the Reserve Bank of Australia. During 1970 avian pests caused considerable losses of grain and this led to the addition of an ecologist to the research team late in that year.

Although expensive and difficult to administer, the reasons for agri-business corporations wishing to precede large-scale new land development by a serious programme of applied research are quite apparent. Few large-scale

Fig. 1.2 Detailed map of stage one of the Ord river development showing various localities referred to in the text.

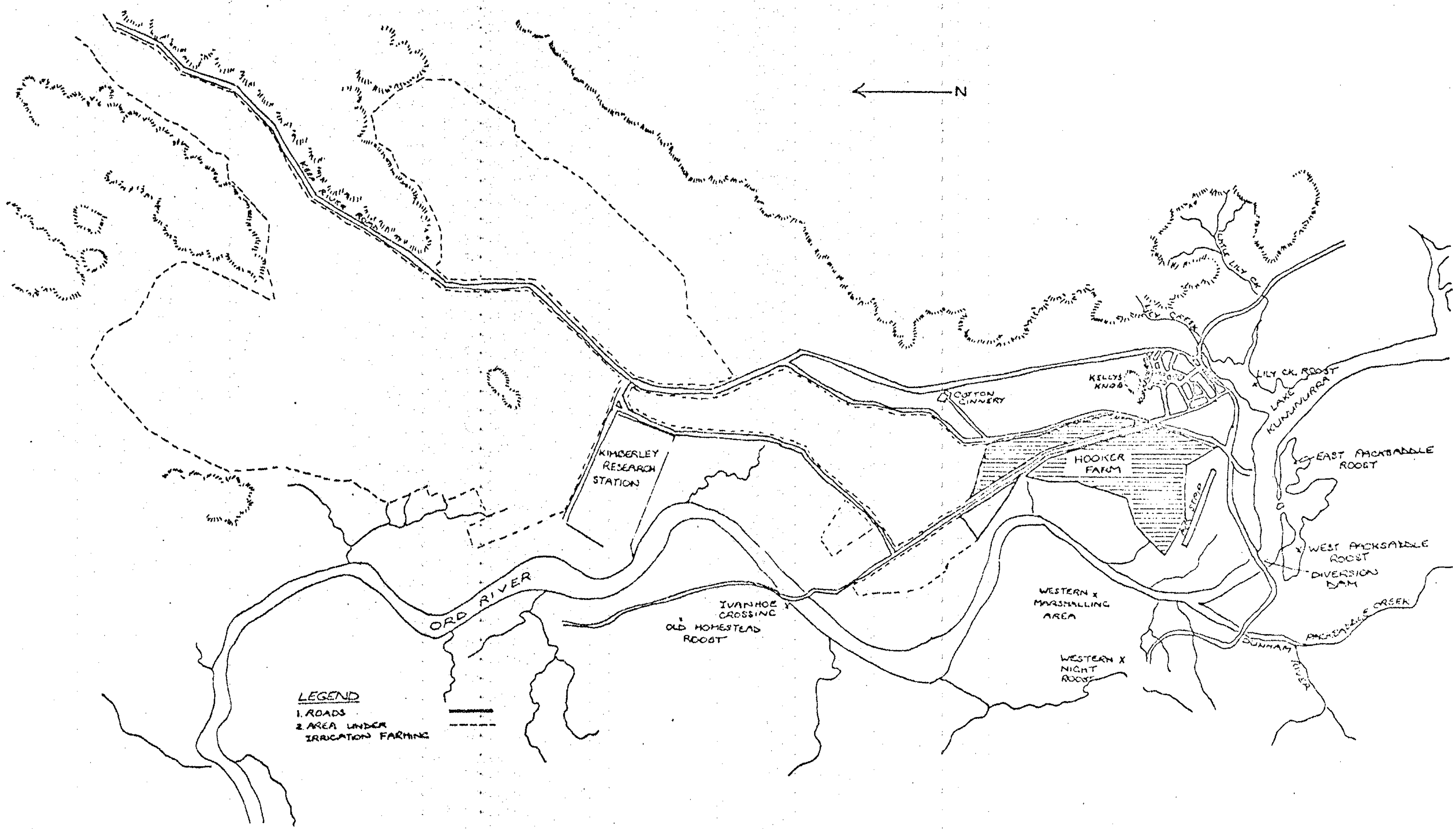
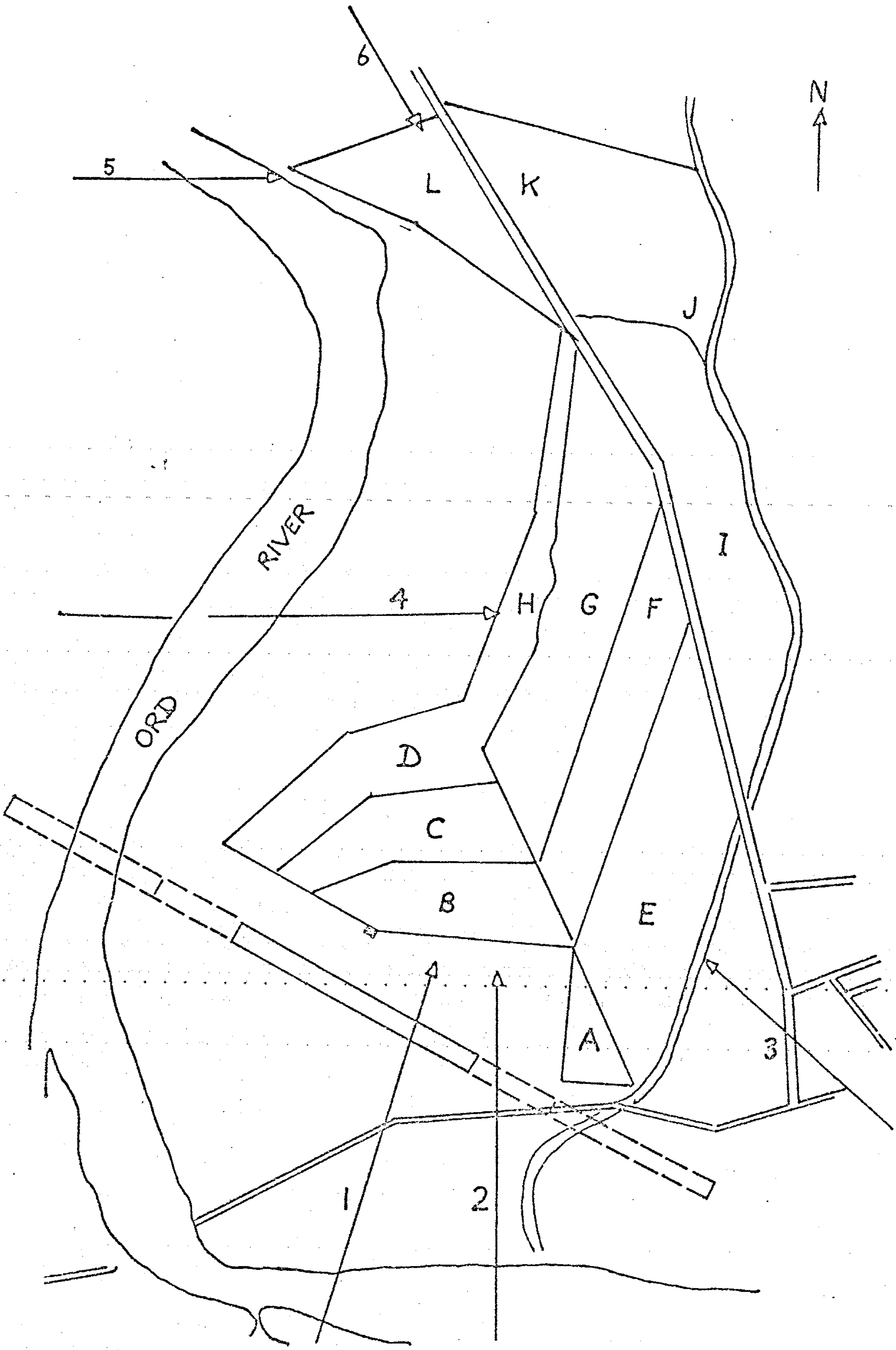


Fig. 1.3 Hooker farm showing irrigation bays and little corella flight paths. Irrigation bays are alphabetically designated and flight paths numerically identified.



agricultural undertakings in Australia north of the tropics have succeeded. It is safe to say that most of these failures have been due to the absence of adequate prior definition of the technical and economic circumstances faced by northern cropping ventures. Had there been a better prior understanding, the cropping ventures so far attempted may either have been more successful or, alternatively, not undertaken. It is thought to be this kind of thinking that prompted the consortium to look for a research agent that could provide an objective assessment of the likelihood of economic success with sorghum cropping on the Ord."

"The research work was carried out by a group of Research Fellows covering the fields of agronomy, farm management, economics and avian pests."

"A co-operative team approach was adopted for all field work but each team member accepted responsibility for specified areas of research according to his qualifications and interests."

(Lazenby and Dillon in Anderson *et al*, 1973)

The author was the research fellow with a primary responsibility for avian pest ecology and management.

As mentioned above the research programme was based on Hooker farm. The farm occupied 1,000 ha of irrigable land adjacent to the town of Kununurra and about 2 km north of the diversion dam (Lake Kununurra) (figure 1.2). Sorghum was grown in large bays defined by irrigation head and tail ditches; these bays were given an alphabetic designation (figure 1.3) for ease of identification. The University's experimental crops were located in bays E, F and I and the rest of the farm was used for commercial grain and forage sorghum production.

The major university programme was completed in early 1973; however, the avian pest research was continued until October 1973. Anderson *et al* (1973) is the major report of the programme; it deals with the aspects of the agronomy, farm management and economics of growing and utilising multiple cropped grain sorghum in the Ord river valley. This report has been extensively drawn on to provide the agronomic, farm management and economic basis for this thesis.

1.1.4 The aims and limitations of this study

In 1970 the stated aims of the avian pest component of the university programme were:-

(i) To develop short term control techniques to be used on the existing little corella problem (i.e. attacks on experimental crops).

(ii) To predict the likely future trends of the little corella and other pest problems in the area.

(iii) From (i) and (ii) to develop long-term control strategies, or failing this to develop means of assessing the likely impact of the pests through time.

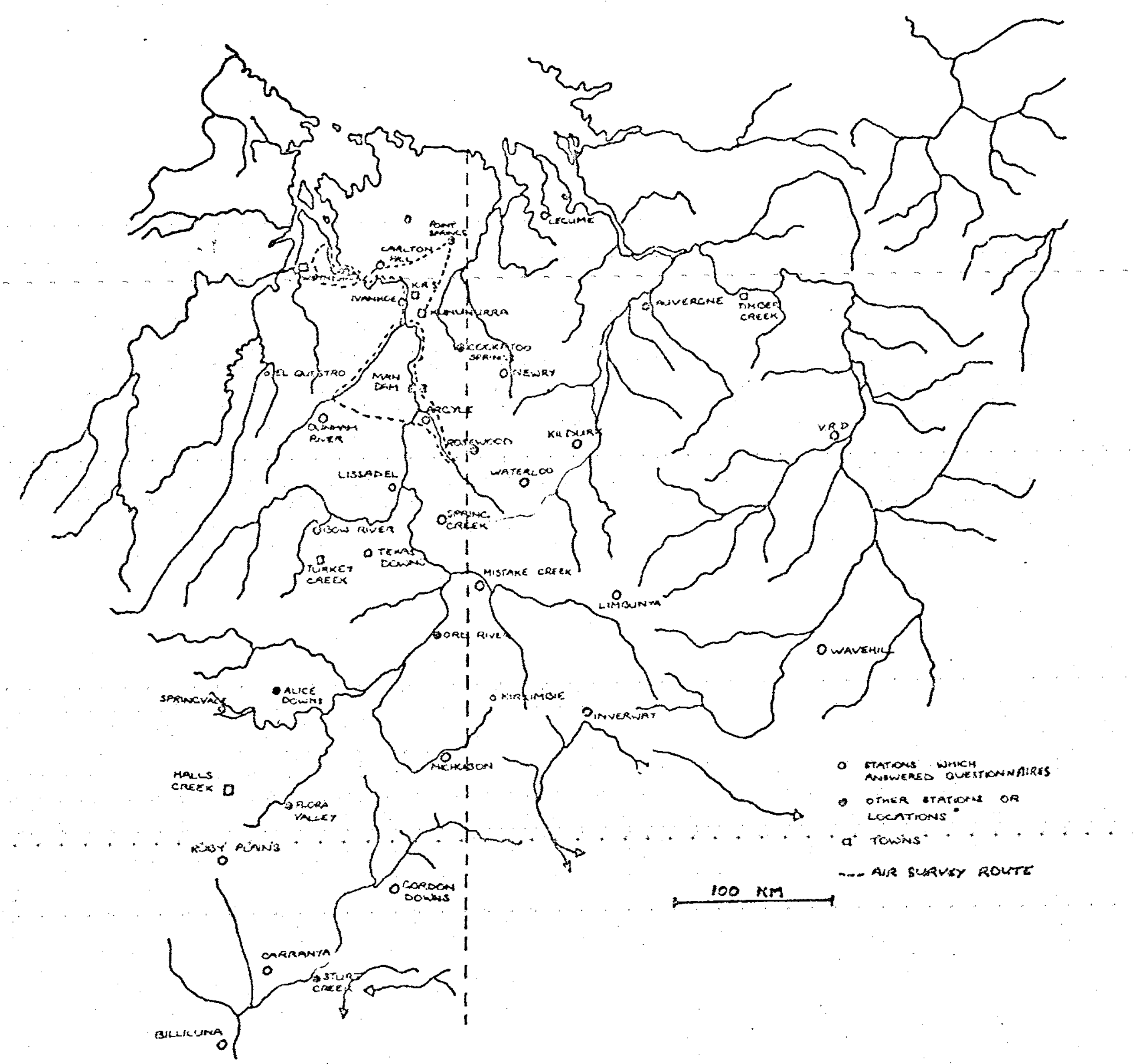
After the study had commenced it became apparent that a number of subsiduary aims were necessary. These were:-

(i) To assess the actual impact of avian pests on Hooker farm and by inference the whole Ord development, should grain growing be expanded. This assessment had to ultimately be in economic terms.

(ii) To attempt an examination of the problem of birds with respect to civil aviation with the ultimate aim of making management recommendations.

(iii) To provide background information on the biology of local avian species which could be of potential value in understanding various aspects of potential human health problems.

Fig. 1.4 The Ord-Victoria region showing drainage patterns together with stations and settlements. Stations which were subjected to regular questionnaires are indicated.



This thesis deals substantially with material relevant to the above six aims; it does not report some aspects of the behavioural ecology of the little corella which will be the subject of a future thesis.

1.2 A geographical outline of the Ord river development

There are many outlines of the physical and economic geography of the Ord river development. The most recent by the Department of National Resources (Anon, 1976) give an up to date picture of the economic geography of the area. Stewart *et al* (1970) provides the best over-view of the region's physical geography.

The purpose of this section is to provide an outline of the physical and floristic geography of the area together with a skeletal outline of the development as it has unfolded to date. Readers are referred to Davidson (1966), Stewart *et al* (1970) and Anon (1976) for more detailed information.

1.2.1 Location and human settlement

The Ord river development and its hinterland (figure 1.1) lies between 127° and 129° east longitude, and 14° and 16° south latitude, and is part of the geographic unit known as the East Kimberley of Western Australia and the Victoria district of the Northern Territory.[1] The region covers approximately 200,000 km^2 and has a population of about 5,000, over three quarters of which is concentrated in the major centres of Kununurra, Wyndham and Halls Creek (figure 1.4). The remainder of the population is concentrated on cattle stations which range in size from 250,000 ha to 2,000,000 ha with a mean of about 400,000 ha.

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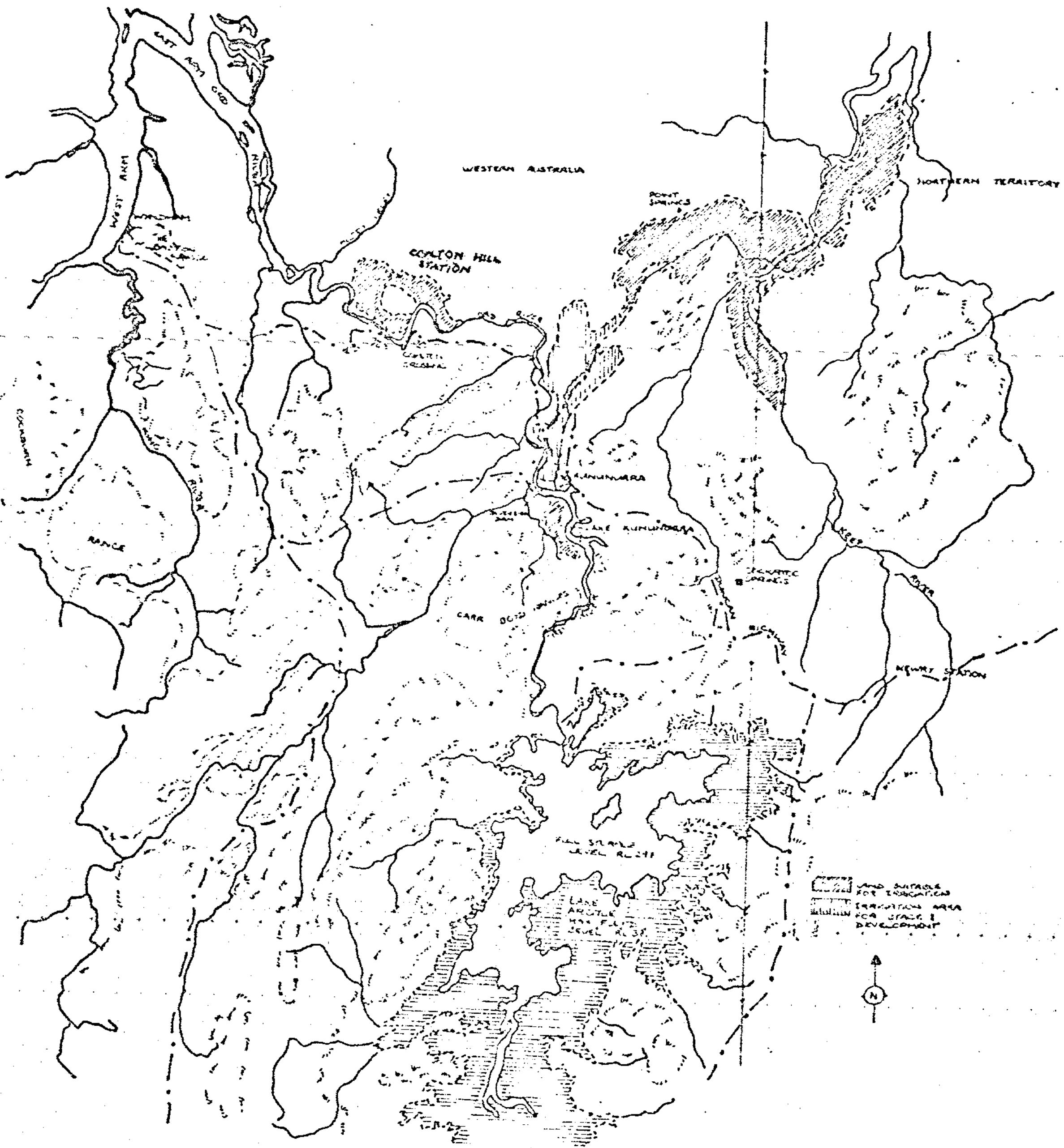
1 The region is also known as the Ord-Victoria area (Stewart *et al*, 1970).

Fig. 1.5 The Ord river development showing irrigation land and dams of stages one and two together with various study sites referred to in the text.



The Ord development (figure 1.5) currently consists of a diversion dam (completed in 1963), 5,540 ha of irrigation land, and the main dam (completed in 1971). The diversion dam empoundment (lake Kununurra) has a capacity of 97.4 million cubic metres and is confined within the natural levies of the Ord river. The main dam empoundment (lake Argyle) has a maximum surface area of approximately 220,000 ha and a maximum capacity of over 28,300,000 million cubic metres (Anon, 1976).

1.2.2 Geology, geomorphology and soils

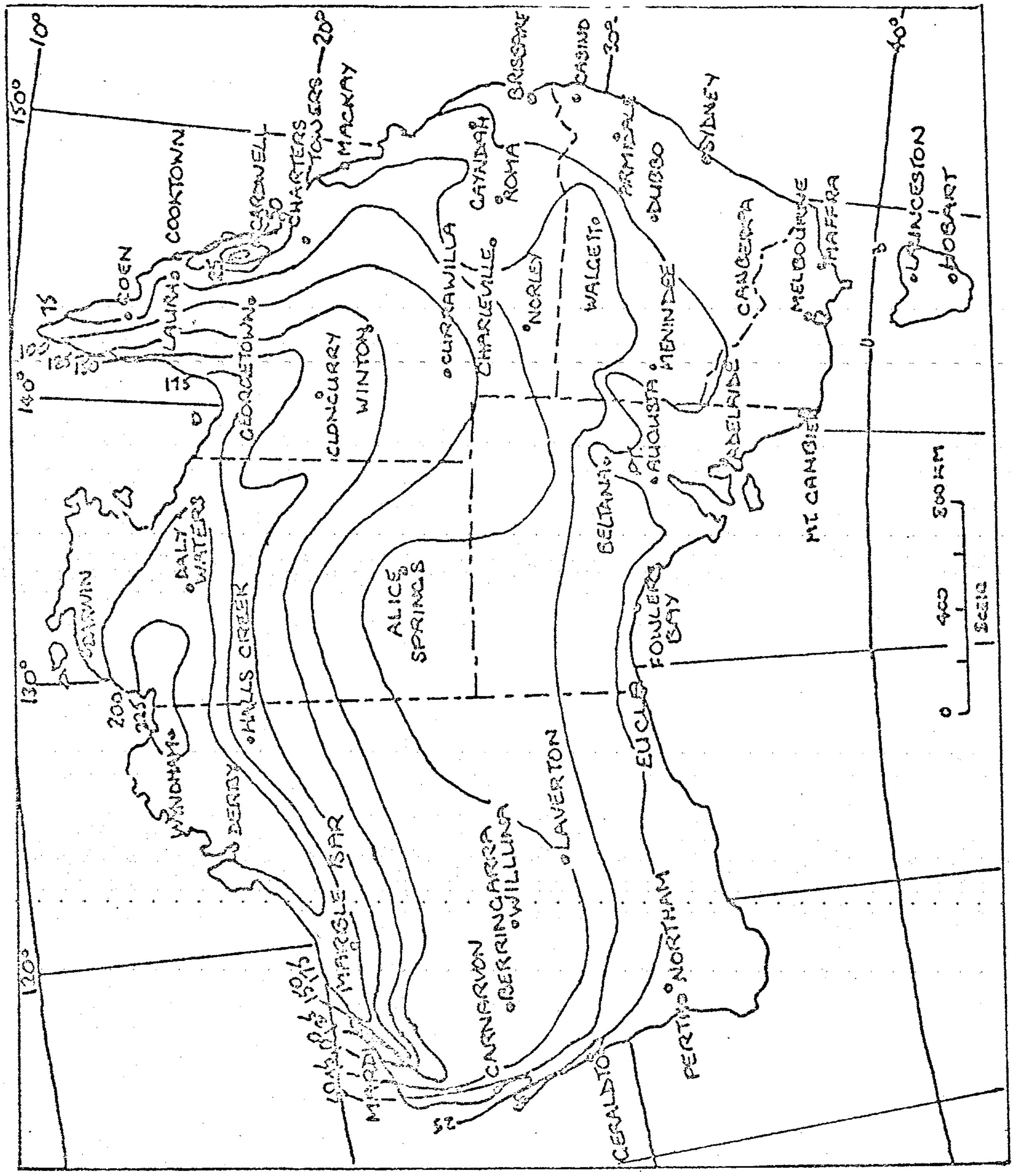
The geology of the Ord development and its hinterland is characterised by rocks of predominantly pre-cambrian and lower paleozoic age. In the north and east marine, sediments which have undergone varying degrees of metamorphosis predominate. In the south these sediments are interspersed by cambrian and pre-cambrian limestones, while in the west extensive areas of pre-cambrian volcanics are found associated with the Kimberley plateau.

The area has undergone periods of inundation, uplift and deep erosion. These processes have continued through to the tertiary; however, the existing drainage patterns are probably of considerable antiquity.

The current landscape is typical of an arid zone area in the post-mature stage of a geographical cycle. Structures such as cuestas, mesas, buttes, benches and lateritic, erosional and deltaic plains predominate. The only structures of quaternary age are the coastal alluvial plain and alluvium associated with riverine flood plains.

The soils are highly variable in both structural and functional characteristics. Water holding capacity is particularly variable and together with fertility, profile depth and degree of slope, has a major effect on vegetation. This makes for a high degree of mosaic patterning of the sub-units of land systems which are themselves markedly patterned.

Fig. 1.6 Average number of days per year when relative strain index equals or exceeds 0.3 at 1500 Hours local standard time, i.e. physiological stress in humans is likely to occur. Base years are 1957 to 1966 inclusive and the index is based on Hounam (1970).



1.2.3 Vegetation

In gross terms the vegetation is similar to that found throughout monsoonal Australia (Perry, in Stewart *et al*, 1970). This is characteristically a woodland of varying tree density with a grass-dominated understory.

In the East Kimberley the major variation occurs in a north-south axis which generally follows a decrease in mean annual rainfall. In the northern woodlands tree densities are high on the lighter soil with a good range of species of *Eucalyptus*. Grass ground cover is also considerable. In the south tree height, density and range of *Eucalyptus* species decreases and grass ground cover decreases. Throughout the area the heavy soils are dominated by grasslands of moderate to zero tree density and good grass ground cover; skeletal soils, especially those on slopes, are covered by sparse to non-existant woodland with a spinifex (*Triodia* sp) understory.

1.2.4 Climate (after Bentley, in Anderson *et al*, 1973)

The region has one of the most severe climates in the world. In terms of a relative strain index developed by Hounam (1970) (figure 1.6) it scores greater than 225 physiologically stressful days per year; this compares with less than 200 days for Darwin and less than 25 for all major Australian cities.

The climate is characterised by a hot wet season between late October and early April, a cool dry season from mid-April to late August and a hot dry season from late August to late October.

Day lengths range from 11 hours 15 minutes in June to 13 hours in December. Radiation levels range from 450 cal/cm^2/day in June to 620 cal/cm^2/day in October, December and March.

Fig. 1.7 Mean monthly evaporation from a standard Australian tank at K.R.S. 1947-70 (Bentley, in Anderson *et. al.*, 1973)

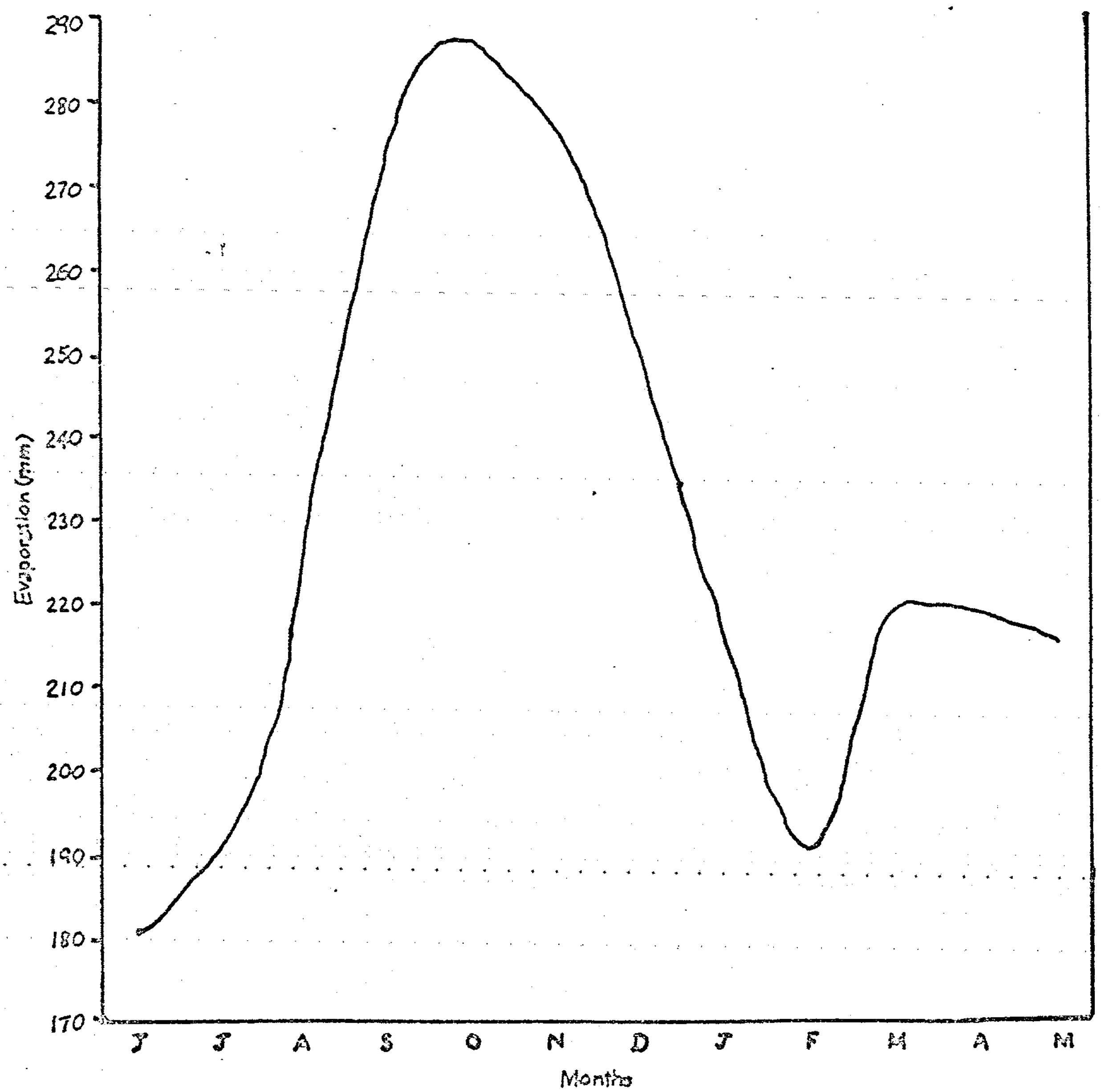


Fig. 1.8 Weekly mean maximum and minimum temperature data for K.R.S. 1947-70 and Hooker farm 1970-73 (Bentley, in Anderson *et. al.*, 1973)

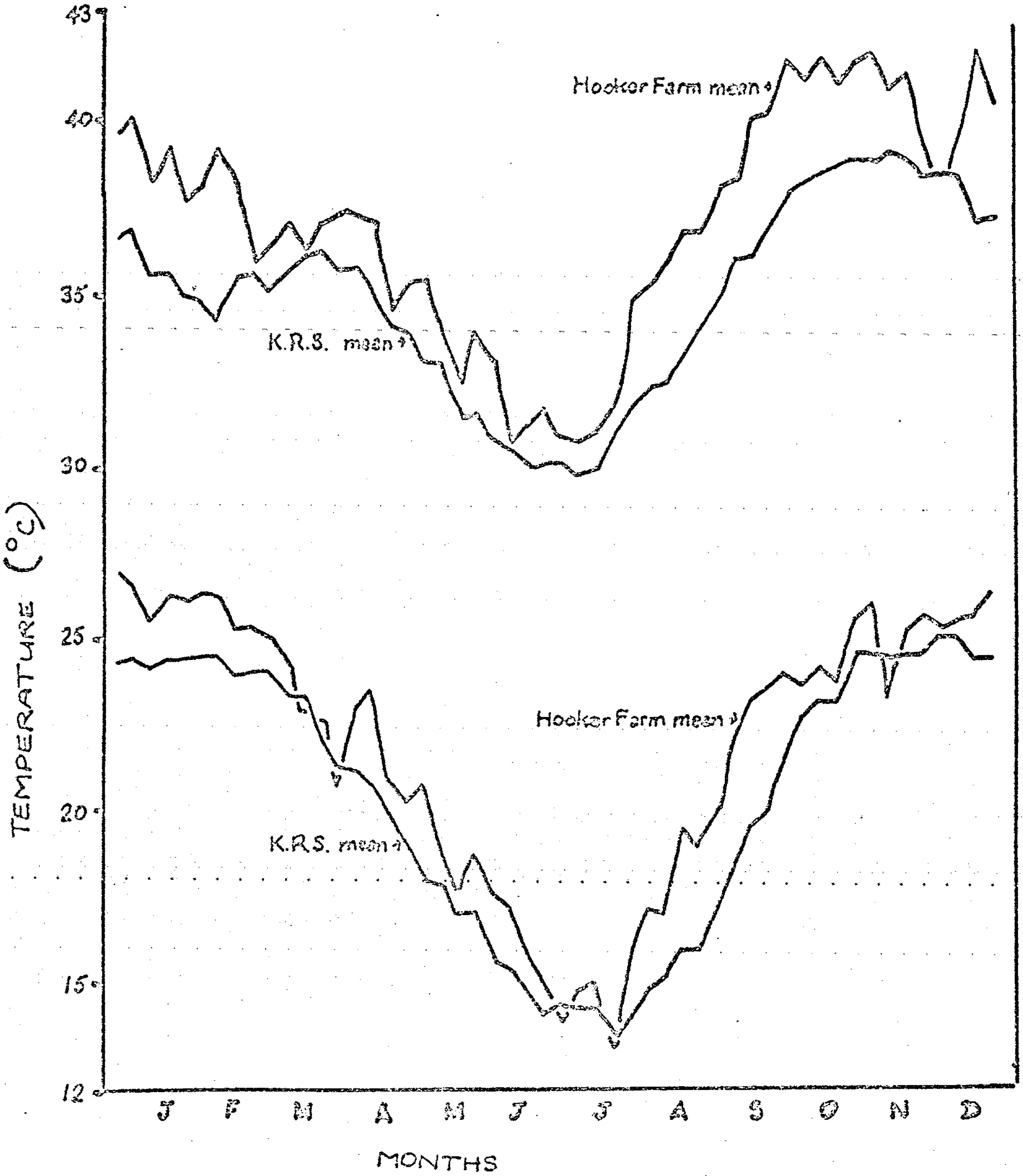
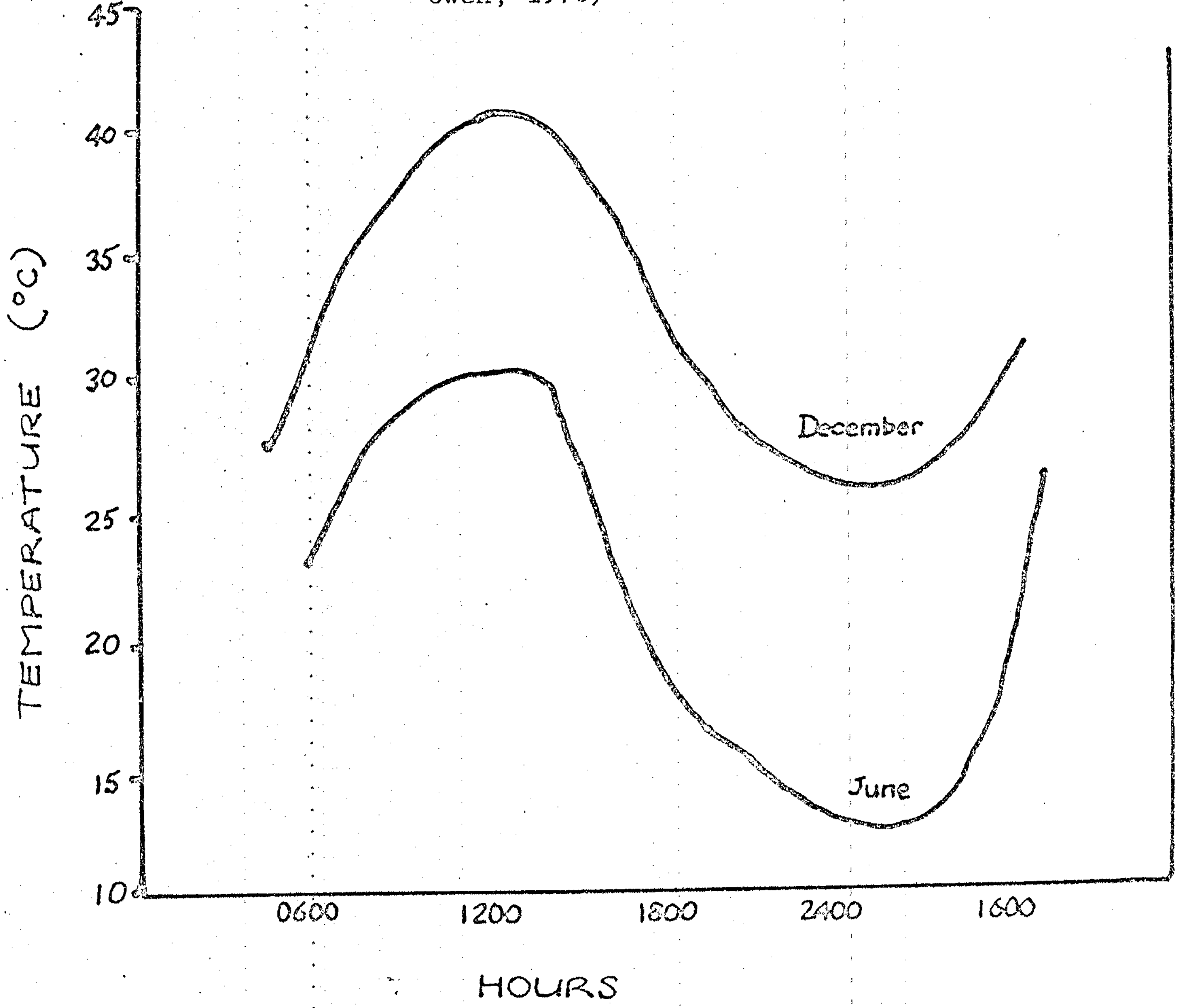


Table 1.1 Rainfall data for Hooker farm in seven-day periods from July 1970 to June 1973 and K.R.S. 24 year mean 1947 to 1970

Period No.	Commencement Date		Rainfall (mm) 1970/71	1971/72	1972/73	K.R.S.1947-70
1	July	2	-	-	-	-
2		9	-	-	-	4
3		16	-	-	-	10
4		23	-	-	-	-
5		31	-	-	-	-
6	August	7	-	-	-	-
7		14	-	-	-	-
8		21	-	-	-	-
9		28	-	-	-	-
10	September	4	-	-	-	1
11		11	-	-	-	-
12		18	-	-	-	2
13		25	-	-	-	1
14	October	2	-	24	-	5
15		9	-	-	-	4
16		16	-	-	-	6
17		23	-	27	45	5
18		30	-	7	-	15
19	November	6	6	12	5	9
20		13	13	-	12	12
21		20	1	-	28	14
22		27	16	10	15	24
23	December	4	24	24	16	19
24		11	2	80	-	28
25		18	4	31	12	33
26		25	46	12	25	31
27	January	1	21	2	15	45
28		8	20	32	40	29
29		15	32	27	48	57
30		22	14	10	6	47
31		29	58	7	23	69
32	February	5	18	3	-	52
33		12	3	71	-	61
34		19	61	22	51	36
35		26	31	80	10	30
36	March	5	-	151	178	46
37		12	28	7	7	28
38		19	52	-	19	15
39		26	13	2	8	4
40	April	2	10	-	3	24
41		9	-	70	-	6
42		16	-	-	55	10
43		23	-	-	-	9
44		30	-	-	-	5
45	May	7	-	-	-	2
46		14	-	-	-	1
47		21	-	-	-	6
48		28	-	-	-	-
49	June	4	-	-	-	-
50		11	-	-	13	4
51		18	-	-	-	-
52		25	-	-	-	-
Total			473	711	634	809
Total as a % of KRS mean			58.4%	87.6%	78%	

Fig. 1.9 The diurnal course of temperature during typical days in December and June (after Owen, 1970)



Mean 0900 hours atmospheric humidities range from 65% in February to 30% in August. Evaporation rates are very high for all months (figure 1.7), giving an annual total of 2,745 mm for a standard tank. There are very few weeks in any year when rainfall exceeds evaporation.

The annual rainfall (table 1.1) of 809 mm follows a characteristic wet/dry seasonal pattern with periods of transition between the two. Six percent of annual rainfall occurs in the dry season, May to October, while more than 65% falls in the three months from late December to mid-March. The early and late parts of the wet (October to late December, and mid-March to May) are characterised by scattered high intensity storms associated with the shifting of the monsoonal low pressure belt. Occasional cyclones in the period late December to early March can result in general very high intensity rain.

Temperatures (figure 1.8) follow a seasonal pattern similar to that of rainfall. Mean maxima range from 30.1^{o}C in June to 39.2^{o}C in mid-November. Long periods of high maxima occur, with periods of over twenty weeks of daily maxima of over 37.8^{o}C (100^{o}F) not being exceptional. Mean minima range from 13.3^{o}C in late July to 25^{o}C in early December.

The diurnal course of temperatures (figure 1.9) changes between seasons. In December, temperatures of over 35^{o}C (95^{o}F) occur for 9 hours per day.

1.2.5 Patterns of ecosystem productivity

The general pattern of primary productivity is dominated by the wet/dry seasonal pattern. For shallow-rooted perennial plants, this results in major growth occuring from the mid-wet until soil moisture reserves are depleted in the early dry; physiological maturity follows. The pattern for annuals is more compressed, with physiological maturity usually occurring while some soil moisture reserves remain. The pattern in deep-rooted perennials is less well defined; however, as a general rule maximum productivity tends to follow the wet/dry pattern.

These patterns of productivity are important for all consumer and decomposer organisms, and adaptation to pulsing primary productivity is to be expected. The relationship between the Ord pest species and their basic food sources will be further developed in the next chapter.

1.2.6 European man's use of the area

The region was one of the last settled by European man in Australia. From the first settlement in 1880 to the establishment of K.R.S. in 1947, the area was dominated by the extensive pastoral industry based on the large stations mentioned above. The only towns were Wyndham and Halls Creek, each with a few hundred inhabitants.

The pastoral industry was based on free ranging cattle which had a variable impact on the existing habitats. Over most of the area this impact was minimal; however, considerable erosional damage did develop on the shallow limestone-derived soils of Ord river and Turner stations. Less extensive but similar damage occurred round dry season water holes.

In 1960 the actual Ord river development was commenced with the starting of work on the diversion dam and the clearing of potential irrigation land. By 1967 about 5,500 ha were cleared and twenty farms in production.

In 1971 the main dam was completed to provide water for a further 69,000 ha of potential irrigation land. To date only about 1,000 ha of new land has been brought under irrigation.

The original intention of the Ord river scheme was to introduce cash crop agriculture and integrated farm/station cattle fattening into a region which was considered underdeveloped. To date, the scheme has met with a singular lack of success. Attempts to grow rice, sunflower, safflower, cotton and many other crops have failed for both biological and economic reasons. The sorghum growing enterprise which is the focus of this thesis has also been suspended. Currently the farmers who remain in the valley are being paid a direct subsidy by the Western Australian Government while the search for a successful crop continues.

Total capital expenditure on the scheme up to June 30, 1975 totalled $38.35 million, research expenditure by the Australian Government, excluding salaries, totals $3.7 million (Anon, 1976). Recurrent expenditure by the Western Australian Government on management and research is unknown; however, over 200 personnel have been involved for at least 15 years. Private capital investment is considerable but unknown.

Understandably, the scheme has been the centre of a controversy which has continued to date. As things currently stand, the Australian Government holds $23.99 million which the Western Australian Government wants released for further development.

This study was carried out in the atmosphere of controversy which surrounded the scheme. The impact of birds on grain sorghum production was claimed to be great. In fact, they were regarded in some interested quarters as being a major - or the major - cause for the lack of success experienced by the enterprise. It is hoped that this study will add an objective insight to at least one aspect of the Ord controversy.

1.3 Methods

1.3.1 General

As mentioned in section 1.1.4, this study was done in parallel with other studies. These studies involved the agronomy, farm management and economics of grain sorghum growing and the behavioural ecology of the little corella. A result of this close association is that material used in this thesis was often collected in conjunction with other studies which are the subject of other reports. This section will outline all methods which are sources of material for this thesis; where these methods will be the subject of a fuller treatment elsewhere this is indicated.

In all, field work for this study covered the period from 17/9/70 to 24/9/73. In this period, 99 weeks of fieldwork were completed by the author; this represents 67 percent of the time available. In addition, the bird pest situation was monitored continually from February 1970 to February 1973 by other members of the University team who had some training in terms of making relevant observations. In the months of March and April 1973, this role was filled by the farm manager and the local warden of the Department of Fisheries and Fauna; the latter in particular was an experienced observer. Thus, birds feeding on Hooker farm were under observation for the entire period of the study.

The situation in the hinterland was different. Here the author relied on a developed friendship network of station people for the reporting of the situation. The contribution made by these observers was invaluable, as it allowed a general picture to be developed over a wide area in which mobility was often severely limited by seasonal conditions.

The study could be divided into three stages, which will be briefly outlined.

FIG. 1·10. EXAMPLE OF WORK SCHEDULE FOLLOWED FOR FIELD WORK AT KUNUNURRA.

	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY	SUNDAY
SEPT	18)	19) LOOKOUT	20) COUNT DAM COLLECTION	21) NEST CHECKS	22) FARM COLLECTION AM AND PM. FARM CHECK.	23) ORGANIZATION	24)
SEPT - OCT	25) COUNT - GOOSE DAMAGE. PACK SAMPLES	26) PHOTO DATA FARM.	27) SPECIAL COLLECTIONS F.L.S. COLLN CARLTON STATION	28) DAY WATCH COCKATOO SPRINGS	29) COLLN CARLTON CROSSING AND FOLK CREEK.	30) DAM NEST CHECK.	1)
OCT	2) GEESE DAMAGE ASSESSMENT —	3) LOOKOUT WATCH. AIR SURVEY. BUILD HIDE ON FARM.	4) RED CK. COLLN. DAM COLLN.	5) HIDE BUILT COCKATOO SPRINGS AND WATCH.	6) COUNT. FARM. COLLN PT. SPRINGS.	7) HIDE WATCH FARM PHOTO DATA	8) HIDE WATCH DAM ROOST
OCT	9) HIDE DAM. CAR IN DOCK	10) CAR IN DOCK	11) FARM SPECIAL COLLN. CARLTON STATION NEST CHECK.	12) WATCH COCKATOO SPRINGS.	13) FARM SPECIAL COLLN. CARLTON CROSSING COLLN.	14) CARLTON STN. COLLN. P.M. LOOK-OUT WATCH.	15) DAMAGE ASSESSMENT FARM.
OCT	16) DAMAGE DATA ANALYSIS.	17) CANNON NETTING COCKATOO SPRINGS.	18) COUNT PT. SPRINGS COLLN. FARM PM. COLLN.	19) LOOKOUT WATCH. NEST CHECK. PM. FLYOUT CHECK.	20) COLLN. CARLTON STN AND CARLTON CROSSING.	21) NEST CHECK. DAM TRIP BIRD COLLN.	22) CROP DAMAGE CHECK. AFTERNOON COUNT.
OCT	23) PACKSAMPLE CHECK A.M. MAKING PORTABLE HIDE	24) HIDE TO COCKATOO SPRINGS AND USED.	25) CARLTON CROSSING COLLN. "	26) HIDE WATCH COCKATOO.	27) FOUR-MILE CREEK FLY-OUT CHECK.	28) FOLLOWING UP VALLEY FLIERS.	29)
OCT - NOV	30) NEST CHECKS, COCKATOO SPRINGS AND DIVERSION DAM.	31) LOOKOUT WATCH. FARM HIDE WATCH. AIR SURVEY. DAM COLLN.	1) AM / PM COUNT POINT SPRINGS COLLN.	2) HIDE WATCH COCKATOO SPRINGS.	3) AIR SURVEY	4) COLLN DAM. SEMINAR PREPARATION FIX BOAT AND LADDER RAM	5) SEMINAR PREPARATION
NOV.	6) NEST-TREE WATCH. COCKATOO SPRINGS. FARM COLLN	7) BEHAVIOUR WATCH AND PHOTOS.	8) COLLN. FARM AND CARLTON STATION.	9) HIDE WATCH COCKATOO SPRINGS.	10) CARLTON CROSSING. WATCH AND COLLN.	11) BEHAVIOUR AND PHOTO	12)
NOV.	13) ADMINISTRATION.	14) LOOKOUT WATCH AM & PM.	15) COUNT AM & PM. POINT SPRINGS COLLN.	16) HIDE WATCH COCKATOO SPRINGS.	17) COLLN. DAM.	18) MAPPING COCKATOO SPRINGS NEST AREA.	

Stage 1 (17/9/70 to 4/3/71 - 13 field weeks)

This was the period of problem familiarisation and preliminary quantification. The little corella problem was observed on the farm, the hinterland was checked for little corella, locals were questioned, little corella counting methods were developed and used, for dissection little corella were collected by shooting, and the whole region was travelled extensively. In addition, all available literature on bird pest impact, bird pest management, Australian bird ecology, and bird ecology in similar environments was assembled and checked.

The period March to May 1971 was occupied with preparing the stage one review of the problem, out of which grew the major strategy for the study.

Stage 2 (15/6/71 to 22/1/73 - 65 field weeks)

This was the major portion of the study. During this period a systematic programme of data collection was followed within a six week work cycle; this cycle was organised so that weekly, fortnightly and monthly tasks were allocated at the start of the period on a daily basis. Spare days were left to be filled by contingencies as they arose. Figure 1.10 is an example of a work schedule.

Regular activities were: lookout watches; counts at farm and hinterland locations; farm damage checks; collections of specimens and their dissection (four separate locations); nest location searches and checks; behavioural watches at the farm, lake Kununurra, and various hinterland locations.

Sporadic activites included: damage measurement; air surveys of bird distribution; specimen collections at other than regular sites; still and cine photography of behaviour; visits to stations throughout the hinterland;

and the sending of questionnaires to stations. Various management trials were also conducted during this period.

At the end of this period, progress was again reviewed and a report written (Beeton, in Anderson *et al*, 1973). This provided the basis for planning the next stage of the programme.

Stage 3 (2/5/73 to 24/9/73 - 21 field weeks)

This final stage of the study aimed at obtaining data on aspects of the study which the stage two report suggested were important.

The focus of work was changed from Kununurra to Cockatoo Springs (figure 1.5) which had been selected for an intensive breeding population study in August 1971. For this period the author lived in a camp at Cockatoo Springs and, when present, had a small population of little corella under continuous observation. In this period farm counts, specimen collections, behavioural watches, station trips, farm damage checks etc. were continued, but at a lower intensity. The same basic system of work scheduling as used for Stage 2 was employed.

1.3.2 Specific methods

1.3.2.1 Counts

Counts of little corella and later counts of magpie geese were the most numerous single activity throughout the study. Little corella counts were two-weekly or monthly and magpie goose counts or estimates opportunistic. The counting procedure for each species will be presented separately.

(a) Little corella farm counts

Little corella always flew to Hooker farm in streaming flocks along flight paths which were predictable from day to day but which changed seasonally.

When large numbers of little corella were present, two major and one minor flight path could be in use; generally however, one major and one minor path were used.

In September 1970 and again in April 1972 the adherence of birds to a given pathway was checked as part of a check on counting accuracy. It was found that in the short term pathway usage was constant; this was very strongly supported by data from lookout watches (see below).

The counting method used was a method which the author had used for many years to count sheep. When little corella were flying over at a rate of less than about 500 per minute (i.e. a flock size of about 10,000) counting was by visually grouping the birds in two's and counting 2 as 1; when 50 was reached 100 was called into a tape recorder and the count re-started at 1. When the rate of little corella flying over became too great, the block size was increased to 10, 50 and 100 for successively increasing rates of fly-over. These blocks were constantly re-calibrated and adjusted up and down to give the block size most appropriate for the rate of fly-out.

Later in the study, group size was of interest and counting was adjusted where possible to allow groups to be called into a constantly running tape recorder. The counts by both methods did not appear to vary.

The following checks were made on these counting methods.

(i) <u>Sequential check of flight path usage</u>

In September 1970, a major flight path was checked on three mornings. For the first two mornings two observers (John Brereton and the author) stood back to back and counted half the flock each as it flew over. On the third morning the flock was counted from Kelly's Knob, 3.2 km away, by Brereton using binoculars. Numbers were called to the author, who wrote them down. The counts for the three mornings were as follows:-

17/9/70	15,850
20/9/70	16,680
21/9/70	15,210

This represents a variation of 8.8 percent and was taken to indicate a high repeatability for counts of a given flight path over a short time.

(ii) Check for observer effects

On February 11, 1971, two experienced counters (Brereton and the author) were checked against each other. This was done by both counting the same flight path from points about 100 m apart along the axis of the path. The two counts were 4,600 and 4,800 respectively. This represents a variation of 4.2 percent and was taken to indicate a reasonable level of counting repeatability between observers.

(iii) Second check of sequential flight path usage

In April/May 1972 a different flight path from that in (i) above was checked for sequential usage. This was a time of high numbers, only one flight path and the most difficult counting conditions encountered in the study. In all, four counts were made before any totals were available; at each count the author's impression of his success was noted. The results, rounded to the nearest 1000, were:-

24/4/72	19,000	"poor count, first birds in flock of 8000 to 9000"
25/4/72	17,000	"good count"
5/5/72	18,000	"good count"
8/5/72	15,000	"poor count, some missed don't know how many"

It should be noted that the comments are the on-the-spot impressions before totals were available. Here the maximum range of variation is 21 percent for the 24/4/72 and 8/5/72 counts, or less than 6 percent for the two counts considered reliable.

These results were again taken to indicate a high repeatability for the method of counting.

(iv) Relative trends in population

In addition to the above confidence in the counting methods as indicators of relative population, trends can be gained when population trends are considered. In 1972 when counts were most regular the changes in population as indicated by count totals[1] show a marked and consistent trend (figure 2.4).

(v) Birds not flying out

A possible source of variation in farm numbers could be the failure of little corella to fly to the farm on all days. Throughout the study, many checks were made of roost and marshalling areas to see if any birds remained after the fly-out. In all cases, a maximum of about 0 to 100 birds could be found. This strongly suggested that this was not a major source of variation.

As more than one pathway was generally used by little corella, actual counting sequence could occupy several mornings for one observer[2]. To facilitate counting, the

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1 Counts for most of this period were made onto magnetic tape and were not transcribed and totalled until February 1973. The author, however, did have an impression of population trends at the time.

2 For a period in 1972 a second observer was available. He was always allocated the smaller group and counted every group by calling it into a tape recorder.

following procedure was adopted:-

- Morning 1 lookout watch to determine pathways in use, relative numbers in each, and other information (see next section).
- Mornings 2, 3 and occasionally 4, each flight path was counted in turn. If some variation was noted or a particular count was not satisfactory, the count was repeated. For the purpose of this study the poor counts referred to in section (iii) above would not have been used as true counts.

(b) Little corella counts of non-farm birds

Whenever little corella were encountered in the hinterland, an estimate was made of their numbers. The method used was to reduce the flock into the smallest blocks possible and count the number of blocks. Given the constant counting experience from the farm, the author was fairly confident of his estimating ability. Checks of these "counts" were found to be impossible, the only obvious method, flock photography, was tried with a surprising lack of success.

(c) Magpie goose counts

Magpie geese were not counted in a similar fashion to little corella. The main reasons for this were the original bias of the study toward the little corella and a lack of time.

Magpie goose numbers were generally based on estimates made by counting blocks on the farm or elsewhere, through binoculars or a 10 x to 60 x zoom telescope. It was realised that this was not the most satisfactory method and two photographic counts were made on 26/9/72 and 17/1/73. These were not analysed until 1976 and were checked against the trend in field estimates made at the time. The results were consistent with this trend (see figure 2.14) and lend confidence to the estimates.

1.3.2.2 Collections

In all, about 800 little corella were collected for specimens. Collections were made by shooting up to 20 birds at a time using a 12 gauge shotgun with number 3 shot.

The collections were made to determine the following:-

(i) The feed intake of farm feeding birds
(ii) The food cycle of birds in the hinterland
(iii) The reproductive cycle of various components of the population and the proportion of the population which bred
(iv) The moult pattern of the species
(v) Mean body weight changes
(vi) What external parameters, if any, could be used for sexing
(vii) What was the parasitic load of the birds.

In stage one of the study, specimens were collected opportunistically throughout the study area. In stages two and three, a regular collecting routine was adopted. This consisted of fortnightly or monthly visits (depending on track conditions) to four collection sites (Point Springs, Carlton crossing, Carlton station homestead and Hooker farm, see figure 1.4). At each site the current population was estimated and a collection of little corella made.

Immediately after shooting the following external measurements were made:-

(i) body weight
(ii) beak width
(iii) periophthalmic ring, horizontal and vertical dimensions
(iv) wing moult (each feather's state was scored)
(v) tail moult (each feather's state was scored)
(vi) body moult (scored on a scale of 0 to 5 for head, back and rump respectively)
(vii) general plumage and skin condition was noted; if it was unusual notes were taken.

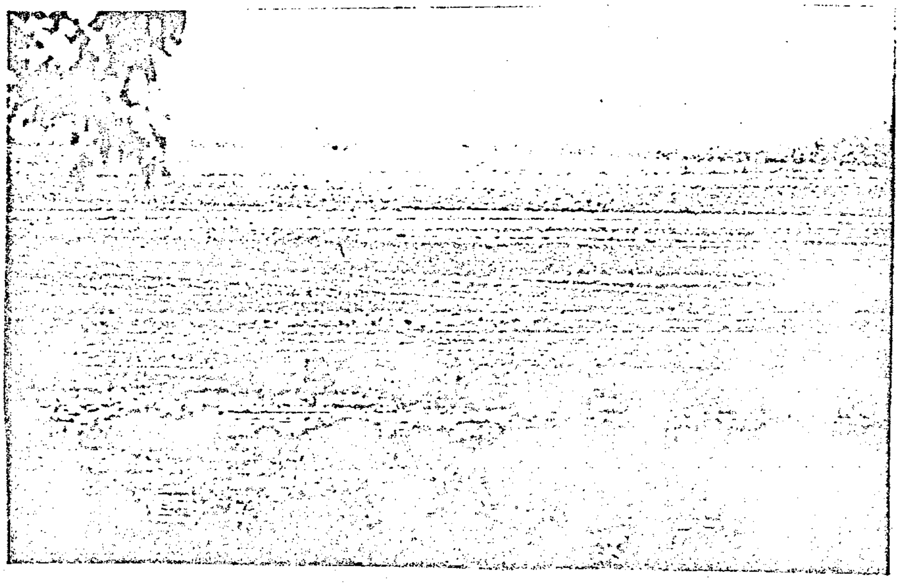


Fig. 1.11 Early morning (0430 Hours W.S.T.) view of Hooker farm from Kelly's Knob lookout. White is a flock of 8,000-plus little corella (approximately 2.6 km from the lookout) feeding on a grain sorghum crop by the edge feeding strategy. The western edge of the farm can be seen in the middle distance.

The birds were then plucked and the sternum removed. The viscera were examined for gross signs of disease or parasites; organs suspected of showing a pathogenic condition were fixed in formal calcium or aqueous Bouin's. The remaining portion of the gastro-intestinal tract (stomach to cloaca) was removed and preserved in 10 percent formalin. The crop contents were noted and preserved in 70 percent alcohol.

The gonads were examined, measured, removed and fixed in aqueous bouins. Particular note was taken of the vas deferens for sperm and the ovary for corpora lutea.

1.3.2.3 Lookout watches

These were observation periods from before first light, for up to 1½ hours or longer. A lookout located on Kelly's Knob (figure 1.2) was used throughout the study. This lookout was about 55 m above the valley floor and commanded a panoramic view of the whole valley (figure 1.11), all night roosts, marshalling areas and flight paths used by all farm birds could be observed with the aid of field glasses or a 10 x to 60 x zoom telescope. The furthest location from the lookout was the western night roost (figure 1.2) 6.5 km to the west. The location of the lookout on the eastern side of the valley greatly facilitated observations.

Lookout watches provided information on the following:-

(i) flight path utilization by little corella and other species
(ii) rough estimates of the number of all species on the farm
(iii) behaviour of the little corella farm flock and other species (especially magpie geese)
(iv) the location of feeding on the farm by all species. This included information on crop, crop stage, bay, numbers, feeding method and feeding time.

(v) The effectiveness of control measures tested
(vi) The general state of the farm; special note was taken of the stage of the crops in each bay.

Throughout each lookout watch, detailed notes were recorded into a tape recorder. These were subsequently transcribed into note books and then summarised on report sheets (see figure 3.3).

1.3.2.4 Farm damage checks

The state of bird damage on Hooker farm was kept under constant review. This was achieved by the amalgamation of information from lookout watches, frequent random checks of susceptible crops (several per week), reports from the four other members of the university team, reports from the farm staff (up to twenty individuals).

When damage to a crop (either vegetative or grain withdrawal) was found, attempts were made to determine the extent of damage. This generally involved deriving an inferred withdrawal figure by means of relating damage per-cent of area to expected yield. If this could not be done, a record was kept of the number of days of crop feeding and the number of birds involved.

1.3.2.5 Aerial surveys

Ten aerial surveys were conducted when prolonged wet weather reduced ground mobility, or when unusual changes in the farm little corella or magpie goose population suggested a quick check of distribution was warranted.

Three aircraft types were used: a Bell two-seater helicopter, a Cessna 182, and a Beechcraft Baron. The surveys were conducted at very low altitude in the middle of the day. When necessary, the aircraft was manoeuvred to "flush" day roosting little corella from the trees for number estimation. The general route flown for the surveys is shown in figure 1.4.

The aim of the surveys was to obtain an idea of the relative distribution of birds, rather than an estimate of absolute numbers.

1.3.2.6 Station questionnaires

Early in the study, one questionnaire was sent to all station properties within a radius of 360 km of Kununurra. A further five questionnaires were sent to those stations willing to answer over the remainder of the study period.

The questionnaires had several aims:-

(i) To initially inform station people of the study and see who would co-operate

(ii) To keep interested observers informed of the study's progress by means of covering letters

(iii) To determine how station people thought seasonality affected little corella and other bird distribution

(iv) To locate areas where little corella flock

(v) To locate areas where little corella breed

(vi) To obtain local ideas on the natural food of little corella

(vii) To determine whether little corella or any other birds were a pest on stations

(viii) To get any information which station people thought should be of interest to the study

1.3.2.7 Other methods

Nest location searches and checks, behavioural watches at Hooker farm, lake Kununurra and various hinterland locations, call recording and context checking, detailed breeding population studies and still and cine photography of behaviour occupied a major portion of the field work. As mentioned in section 1.3.1 these results are the subject of another report and will not be utilised for this thesis. It is, however, impossible to completely separate the two data sets; where reference is made to information obtained from these data sources in subsequent chapters, the methods will be briefly indicated.

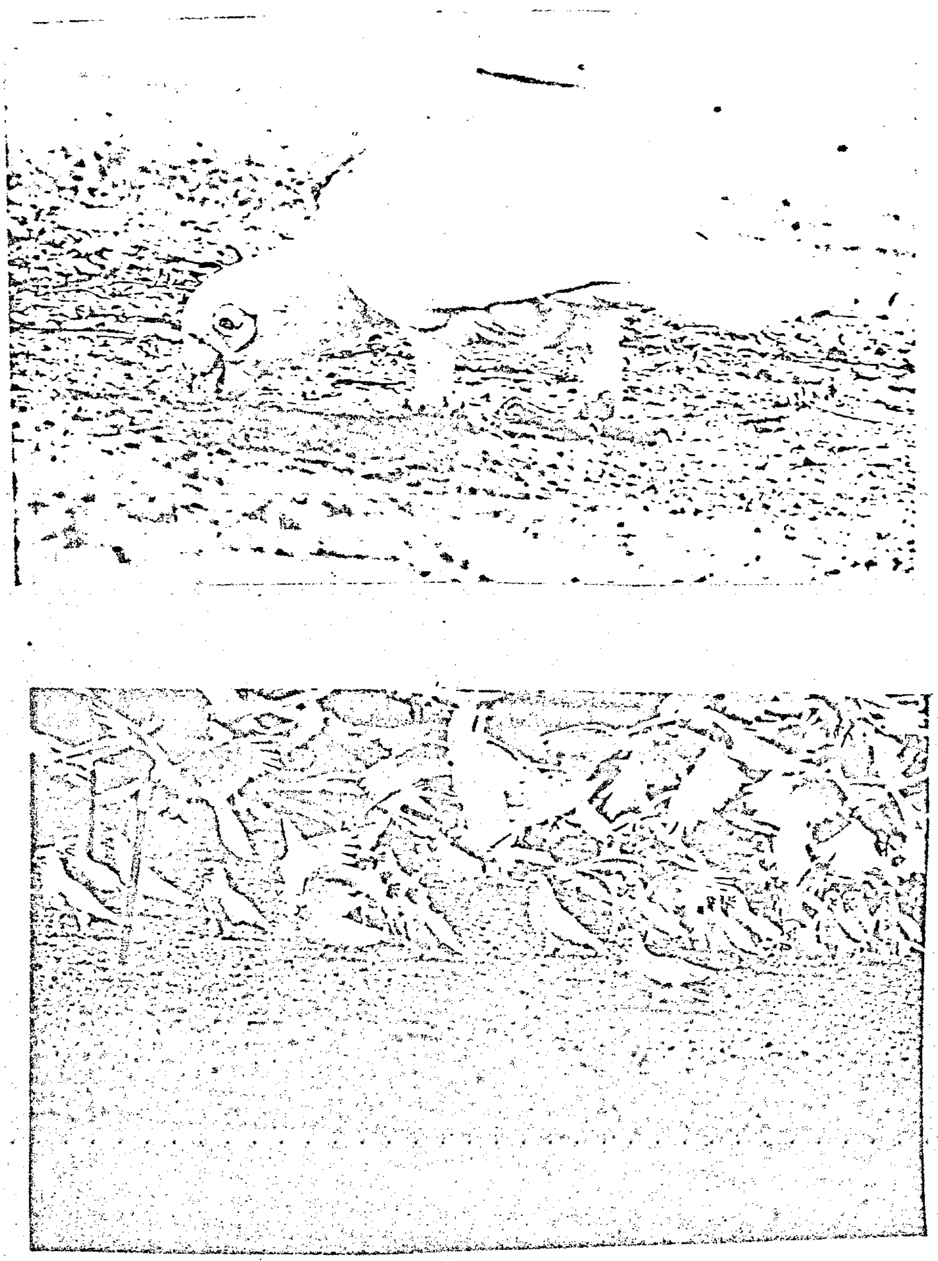


FIG. 2·1. LITTLE CORELLA

2.0 Aspects of the biology of the Ord river bird pests

2.1 Introduction

In 1970 the little corella was apparently the major avian pest of agriculture on the Ord development, thus the initial emphasis in the investigation was on this species. As the study progressed, the magpie goose emerged as a significant agricultural pest, and other species were found to have varying degrees of significance as pests of agriculture and civil aviation, or as threats to public health. Most of these species had been the subject of investigation by other workers. This study, therefore, collected as much local information on their biology as was possible without adversely affecting the study of the little corella.

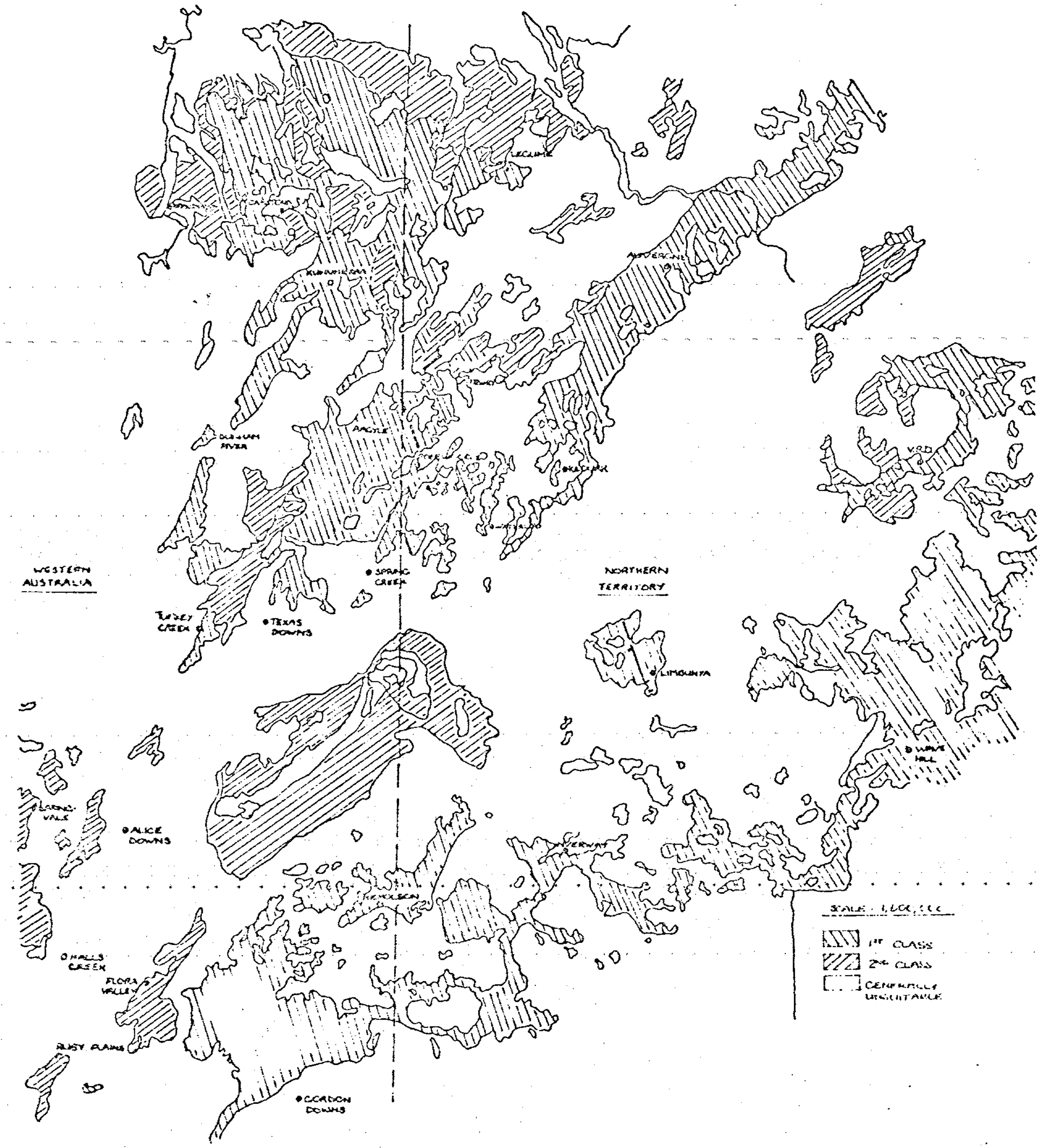
This chapter outlines those aspects of the biology of the little corella which are relevant to the understanding of its impact and the management recommendations made for it. The remainder of the chapter is a synthesis of the findings of the study with published work on three other species, namely, magpie goose, galah, brolga, and duck. Of these, the magpie geese were, with the little corella, considered to be the agricultural bird pests of primary importance. The rest were of secondary importance. A third group of potential problem birds, those of tertiary importance, were noted and will be briefly considered in Chapter 3.

2.2 The little corella

2.2.1 The species and its habitats in the study area

Little corella (*Cacatua sanguinea*, Gould, 1842) (figure 2.1) is a widely distributed cockatoo of the arid zone of Australia. It is said to be extending its range, and it has been suggested that this extension is a response to recent habitat alterations (Forshaw, 1969).

Fig. 2.2   First and second class little corella habitats of the wider study area. First class habitats are those in which little corella could almost always be found and in which their preferred breeding habitat occurred. Second class habitats are those in which flocks of little corella could be found at times of food stress and in which no extensive areas of breeding habitat occurred. The map is based on the land systems of Stewart *et. al*. (1970).



Little corella are typically found in habitats where open grasslands abut onto tree-lined water courses, or in grassy savannah woodlands. They are ground feeders, eating a wide range of seeds of grasses and some other species. They are generally regarded as a hollow tree nesting species; however, other nest sites, such as ant beds, have been reported (Forshaw, 1969).

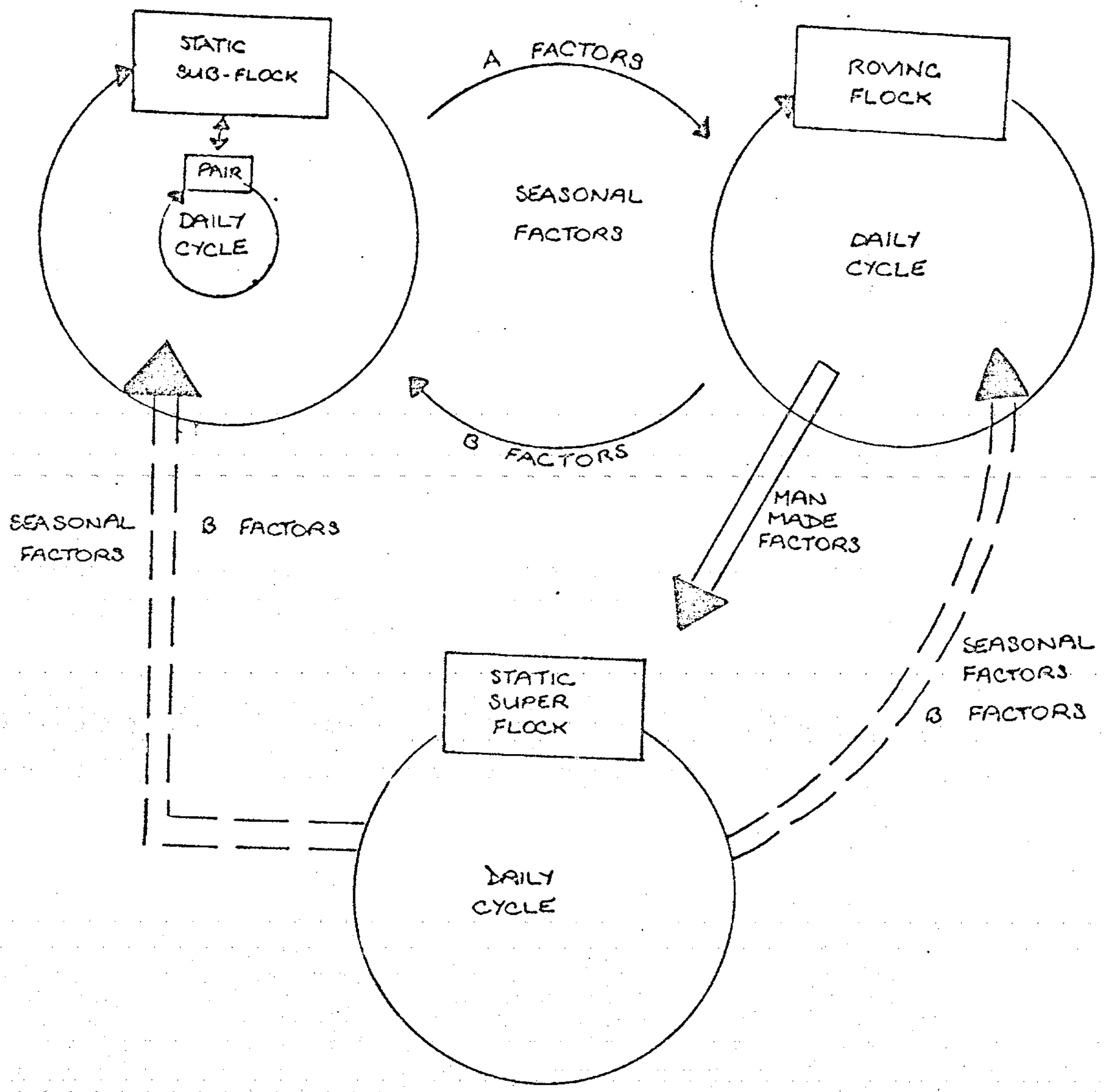
In the study area, little corella showed a distinct preference for certain land systems which came to be recognised, in this study, as first-class little corella habitats. These were habitats in which little corella could almost always be found, and in which their preferred breeding habitat occurred (see section 2.2.3). A second-class habitat category was also recognised. These were habitats in which the little corella were only found in flocks at times of food stress, and in which no extensive areas of breeding habitat occurred. Figure 2.2 indicates the distribution of these two types of habitat for the study area. It is based on the land systems of Stewart *et al* (1970).

2.2.2 Population organisation and seasonal movements

2.2.2.1 The general model and its components

In common with other species of parrot (Brereton, 1971) the little corella population was divided into two fundamental components - the core and the flock. The core, which will be called the static sub-flock, was the unit of birds found in areas of high quality breeding habitats for extended periods of time. These static sub-flocks may range from tens to a few thousand, and are an amalgamation of breeding pairs with non-breeding supernumeraries. The flock component (here called the roving flock) was a larger and more mobile unit of birds than the static sub-flock. At times its members dispersed into the static sub-flock as supernumeraries or possibly breeding birds, and at other times its membership might include all birds from the static

Fig. 2.3 Little corella population organisation. This is the basic model for all little corella in the Ord valley and its hinterland.



A FACTORS FOOD DEPLETION DUE TO SPOILAGE, GERMINATION AND BURIAL [FACILITATED BY TRADITION]

B FACTORS FOOD GENERATION (i) ANNUAL PLANTS, END OF WET.
(ii) PERENNIAL PLANTS, 100 DAYS LATER

[FACILITATED BY TRADITION.]

sub-flock. The roving flock was the component of the population most prominent when food availability was apparently low in the habitat of the static sub-flock. It was the population component found occasionally in second-class little corella habitats.

Roving flocks have the ability to amalgamate to form larger flocks. In the case of the Ord development, roving flocks amalgamated to form what has been called the static super-flock. This was the aggregation of roving flocks which went to make up the Hooker farm pest population. The distinguishing feature of the static-super flock was its static nature and size, brought about by the presence of crops.

Figure 2.3 outlines the relationships between the above population components. It suggests that each component has a characteristic cycle of daily activities; it further suggests that little corella can flow between different components of the population depending upon the availability of natural food.

The remainder of this section will present the evidence on which this general model is based. Some aspects of the daily cycle of the static super-flock will be presented in section 2.2.4.

2.2.2.2 Changes between components of the little corella population

The presence of abundant grain on Hooker farm in all months resulted in the rapid amalgamation of roving flocks into the static super-flock. Roving flocks were only seen in the area of Kununurra (approximately 100 km radius) during periods when the static super-flock numbers were changing rapidly. Further to the south, roving flocks were frequently reported to, and seen by, the author in the wet season. These sightings were often in second-class little corella habitat.

FIG. 2.4. COUNTS OF LITTLE CORELLA VISITING HOOKER FARM. THIS CONSTITUTES THE NUMBER OF LITTLE CORELLA IN THE "STATIC" SUPER-FLOCK.

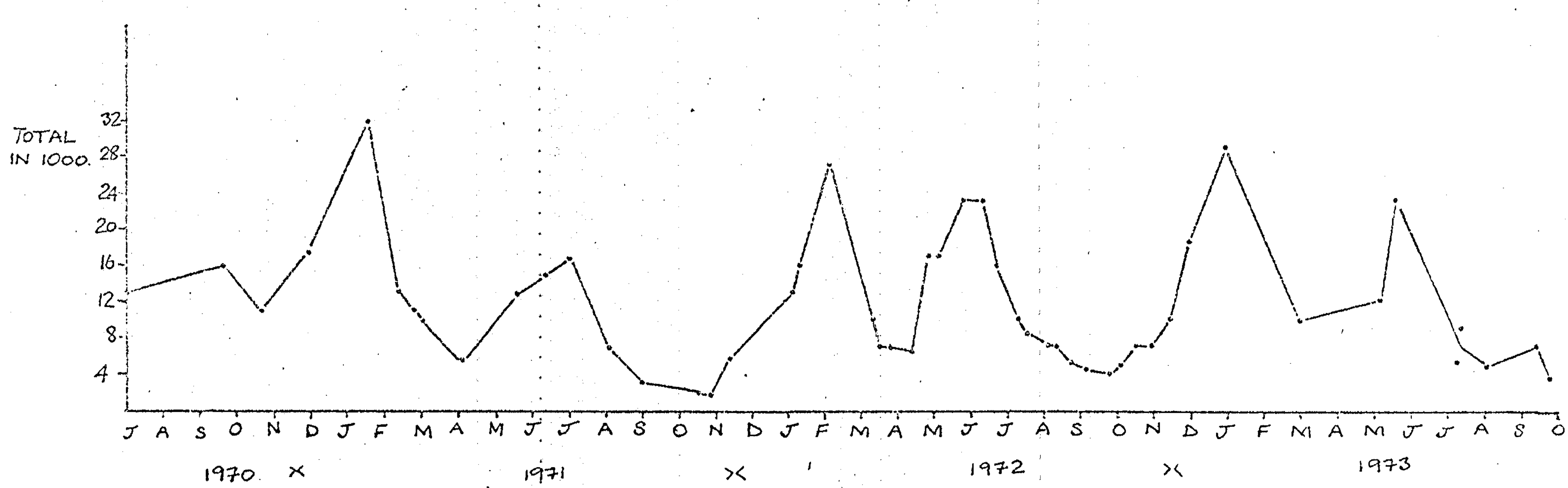


FIG. 2.5 LITTLE CORELLA NUMBERS ESTIMATED AT VARIOUS STATIC SUB-FLOCK AREAS DURING THE STUDY.

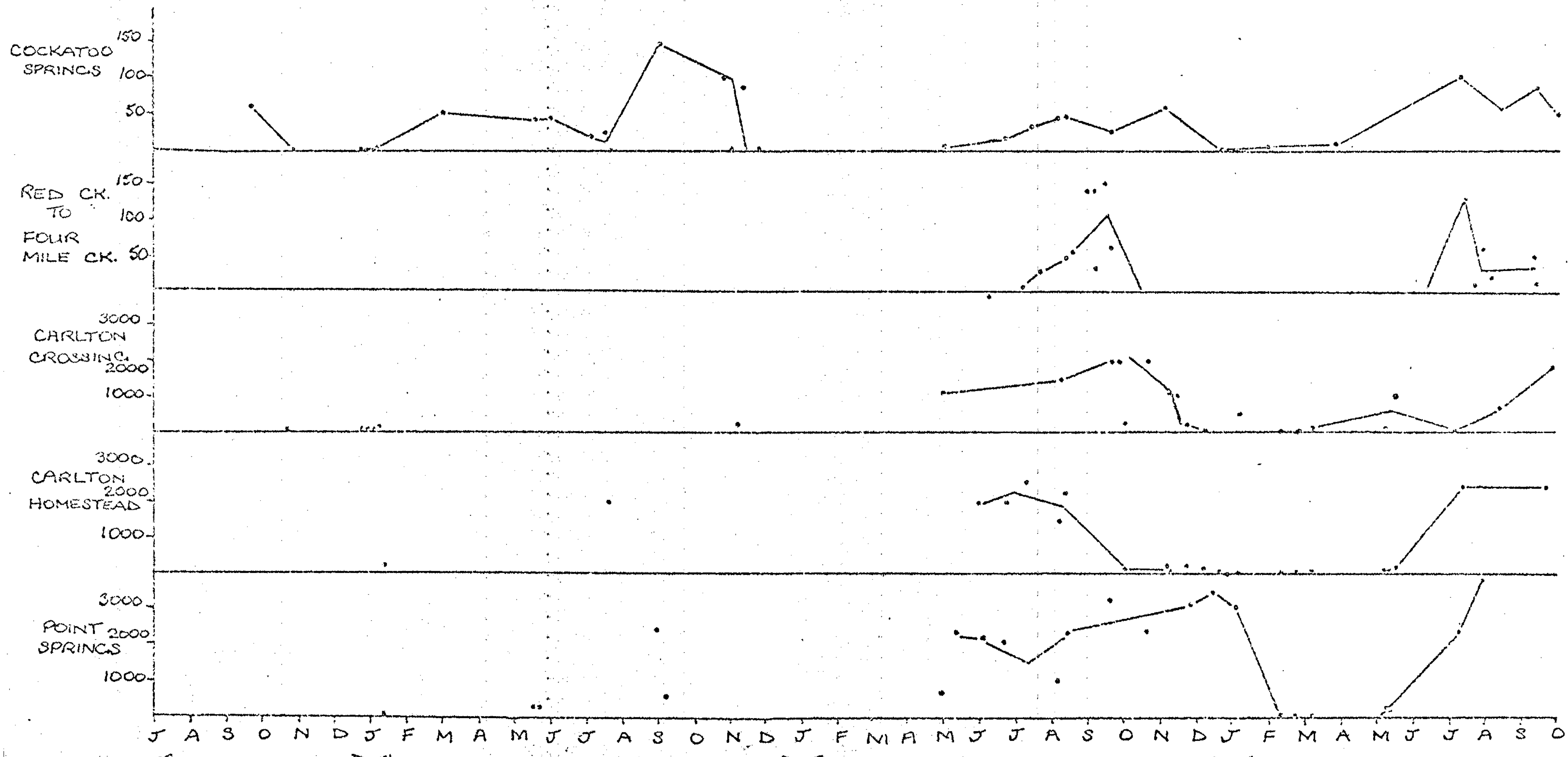


TABLE 2.1 Summary of results, questionnaires and interviews for station properties in 184,000 km^2 wider study area. (Station locations are given on figure 1.4.)

Station	Distance km.	Bearing to grid north	Numbers range	Numbers greatest in wet or dry	Rain gives disappearance	Breeding	Month of egg laying	Aug. last month of wet season
V.R.D.	258	106	0 - 100's	Dry	Yes	No		
Waterloo	118	148	0 - 1000's	Dry	Yes	Young in November	Aug.- Sept.	April - May
Newry	63	119	0 - 1000's	Dry	Yes	Young in November	Aug.- Sept.	April - May
Nicholson	247	176	0 - 100's	Dry	Yes	September onwards	July	April - May
Mistake Ck.	100	166	0 - 1000	Wet	No, concentrate at station	September to November	July - Aug.	April - May
Legune	103	52	0 - 1000's	Dry	Decrease only	-	-	
Kildurk	121	123	0 - 100's	Dry	Yes	Late dry	Aug.- Sept.	April - May
Carranya	360	Approx. 194	0 - 200	Dry	Yes	No	-	
Texas Downs	136	192	0 - 1000's	Dry	Yes	Late dry	Aug.- Sept.	April - May
Wave Hill	305	129	0 - 400	Static	?	No	-	
Ruby Plains	332	200	0 - 850	Bores dry Creeks wet	Movement	No	-	
Spring Ck.	135	173	0 - 300	Flock wet disappear in late dry	Flocking	July on	May - June	April
Limbunya *	208	142	1000's	Flock in wet	Flocking	?	-	
Bow River *	130	205	Less than 100	?	?	May to June	April	April
Inverway *	250	157	200	Dry	?	No?	-	
Auvergne *	140	86	50	?	?	No	-	
Home Valley*			7000 - 12000	Dry	?	No	-	
Ivanhoe 1	9	324	5000 - 10000	Dry	?	Yes	-	
Lissa Dell*	105	190	Everywhere ?	?	?	-	-	
Springvale*	245	210	1000's	?	?	March April	Feb -March	March
Carlton Hill **	38	318	0 - 1000's	Dry	Yes	-	-	
Argyle Downs **	58	177	0 - 1000	Dry	?	-	-	
Billiluna***	450	195	0 - 100's	Dry	?	-	-	
Gordon Downs***	333	182	100's	Permanent?	?	Young in August	April-May	March

Note: Annual v. perennial grasses. More perennials in north than south (Perry in Stewart *et al*).

* One survey only

** One survey plus interview

*** Interview only

1 Ivanhoe is effectively in the Ord river valley. This is one survey plus interview, and represents the historic situation.

AREA COVERED: 350 km East-West; 525 km North-South; 183,750 square km.

The static super-flock and static sub-flock were features of the study area population. Of the two, the static super-flock was monitored throughout the study (as the farm little corella population) and regular counts are available (figure 2.4). Five static sub-flocks were continually monitored for the last 17 months of the study, and regular estimates are available (figure 2.5).

Examination of figures 2.4 and 2.5 strongly suggests that decreases in the static sub-flocks occurred when the static super-flock increased in size in the period October to January, and the reverse in May and June. The February decrease in the static super-flock (farm population) is not accompanied by a change in static sub-flock population. Observations and reports received by the author suggest that roving flocks of little corella were common throughout the area during this period. These roving flocks were particularly noticeable in the area of swamps, where annual grass seed productivity was high. This evidence indicates that the decrease in the static super-flock in February of each year was accompanied by an increase in the total number of birds in the roving flock. The fact that decreases occurred in the number of birds in static super-flock on a regular, and repeatable, basis throughout the study in a situation where the static super-flock's food supply (farm grain) was not changing strongly, suggests that traditional changes in population organisation on an annual basis were a feature of the little corella population.

Further evidence for this is available from the station survey data. An area of 525 km by 350 km was surveyed by means of questionnaires and interviews. Of the 24 stations surveyed (Table 2.1 and figure 1.4), 14 reported greater numbers in the homestead area during the dry season, 4 reported greater numbers in the wet, 2 reported static numbers and 4 were uncertain of the situation. Of the 14 stations which reported greater numbers (hundreds to a few thousands) in the dry season, all were located in first-class little corella habitat (figure 2.2) near to grasslands and permanent water. In addition only 3 of these stations said they did not see breeding, while 7 were positive in identifying breeding. The 4 stations which reported greater numbers in the wet season were all in second-class little corella habitat and all reported groups of birds which resembled roving flocks. The 2 stations where little corella numbers were static were at the extreme edge of the birds' range. These observations strongly support the general picture of the little corella population being organised into components with the number of birds in each component changing in a predictable fashion.

2.2.2.3 Factors causing flows between components of the little corella population

(a) General

Early in the study it became obvious that rainfall had a critical effect on the Hooker farm little corella population. A rapid increase in numbers commenced immediately with the first wide-spread storms in the hinterland. The population continued to increase until a peak was reached in January. An April trough then occurred, followed by a May/June peak and a prolonged dry season trough.

Preliminary post-mortem studies of little corella crop contents and range conditions suggested that the first rains spoilt, buried or germinated the ground seed resources on which the little corella were feeding away from the farm. These studies also suggested that the April drop in the little corella farm population corresponded to the maturation of wild rice *Oryza* sp. in shallow swamps, and of other annual grasses on low water-holding capacity soils. The commencement of the major dry season static super-flock population decline corresponded to the maturation of perennial grass species which constituted the most extensive annual seed crop.

Thus the general picture appeared to be that rain destroyed the food resource of the static sub-flocks causing the formation of, or an increase in, the numbers of birds in roving flocks.[1] These roving flocks normally seek out food in areas where ground seeds have not been destroyed or made unavailable. In the Ord situation, roving flocks amalgamated on the constantly available Hooker farm grain sorghum and formed the static super-flock.

When the first annual grass seeds became available, some of the birds in the static super-flock formed roving flocks which exploited this resource. As it became exhausted or less available, these roving flocks again joined the static super-flock. The major dispersal from the static super-flock then followed as the large perennial grass seed crop matured. By July, most of the population was in the static sub-flock component of the population. It was in this period that breeding occurred.

This general picture was partially confirmed by the results of the station surveys (Table 2.1). Of the 24 stations surveyed, 13 said rain produced immediate little corella movement, while 11 were in a "don't know" category. A further confirmation was the historic pattern of bird damage at K.R.S. This showed the worst little corella damage occurred in April, May and June, and in December, January and February (D. Mackenzie, pers. comm. and unpublished K.R.S. records).

Having arrived at a general picture of corella behaviour, the next step was to attempt to confirm it by means of a prediction model which could be authenticated against known fact.

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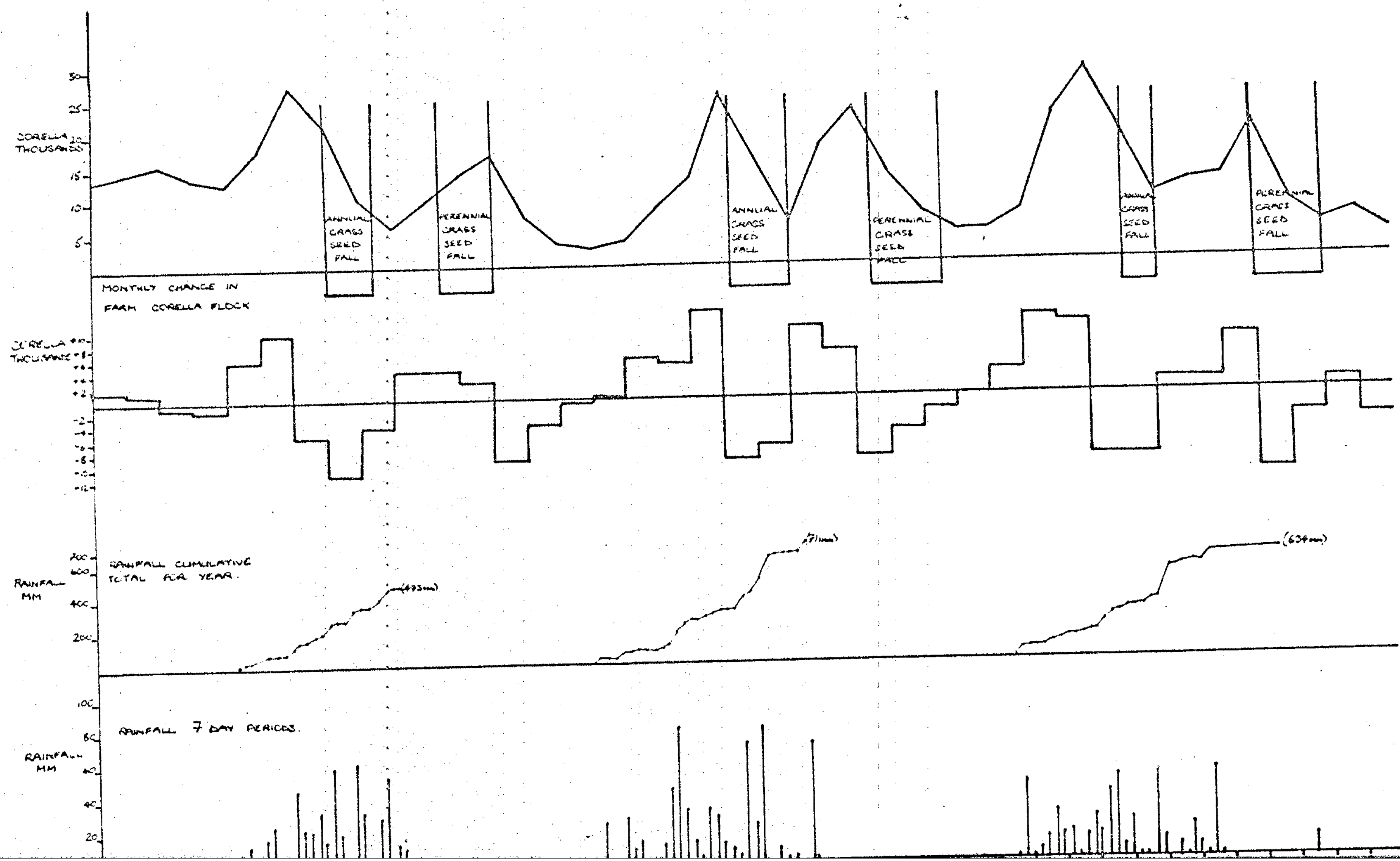
1 The number of birds changing between components almost certainly depends upon rainfall intensity and distribution. In addition, there is almost certainly a status relationship in the static sub-flock which results in the "nest-holding" birds leaving last, if at all.

Fig. 2.6 Numbers of little corella in the static super-flock in relation to grass seed fall (annual and perennial), cumulative rainfall for current wet season and rainfall for seven day periods.



(b) The little corella movement model

The general schematics for this simple model have been given in figure 2.3. The three population components are linked by flows of birds; the major driving functions have been designated as "a" factors and "b" factors which are the natural seasonal factors causing changes in food availability, plus the "man-made" factor of a constantly available food supply on Hooker farm.

The "a" factor of the model was food depletion associated with rainfall. The onset of the wet season resulted in scattered high-intensity storms falling in a patchwork pattern over the hinterland. This would result in the gradual reduction of available seed until about early December, when the whole region had received at least one, and generally several, storms. As no direct studies on seed mortality were done, the general rainfall pattern for the wet season is the only indicator available of seed destruction. In figure 2.6, the Hooker farm pattern of rainfall for the study has been plotted as a cumulative and seven-day total. There is an obvious correlation between the onset of the wet and the numbers of birds arriving in the static super-flock. Further evidence in support of this comes from the crop contents of birds collected from three static sub-flocks. These weekly collections showed a dramatic change after the first heavy storm in the area; the range of seed types increased, cracked and partially germinated seed appeared for the first time in the year, and the degree of crop fullness decreased dramatically. A particularly dramatic case involved 2,000 birds at Carlton station. Within a week of heavy rain, a collection was made in which the quality and quantity of the seed in crops dramatically declined. The entire static sub-flock had disappeared by the next week and did not return to the area for 7 months (see figure 2.5, November).

The "a" factor responsible for the return of birds to the static super-flock in May/June is not clear from this

TABLE 2.2 Pasture growth model authentication. (Output of study model compared with output of Slatyer's (1970) model. The same basic input is used for both models.)

Output	Slatyer (1970)	Study Model
Kununurra mean number of weeks of pasture growth	18.2 $\pm$ 3.4	19
Kununurra mean number of growth weeks with available soil moisture greater than 63.5 mm.	9.5 $\pm$ 2.5	8
Katherine mean number of weeks of pasture growth	22.4 $\pm$ 2.8	23 to 26 [1]
Katherine mean number of weeks with available soil moisture greater than 63.5 mm.	14 $\pm$ 3	7 to 17 [1]

1 Depending on soil available water figure used, see Table A1.1

study. One possibility is that the rapid growth of perennial plants at the end of the wet season makes it very difficult for little corella to locate the fallen annual seed. Another possibility is that the high-intensity storms of the late wet disperse the annual seed crop. Neither of these possibilities has been examined.

The "b" factors, or food generation factors, were more difficult to represent. Apart from the general observation of the state of native pastures made throughout the study, and the range of native grass seeds which formed the little corella's diet, no direct quantification of seed availability for little corella could be made with the resources available. It was therefore determined to adopt an indirect approach of pasture growth modelling, using a simple water balance model together with what was known of the growth patterns of some annual and perennial native grasses.

The pasture growth model of Fitzpatrick and Arnold (1964) was modified for a Hewlett-Packard desk calculator (Appendix 1). The new model was then authenticated by running it with the K.R.S. mean seven-day period rainfall and evaporation data. The results obtained (Table 2.2) suggested that the simplified model approached the original of Fitzpatrick and Arnold (1964).

The new model was then used to re-work the only published information on native pasture growth patterns for land systems similar to those of the study area (Lazarides, Norman and Perry, 1965). This exercise (Appendix II) gave an indication of how some annual and perennial grasses actually performed under known rainfall conditions and pasture growth model output. The exercise also indicated that extremely variable pasture growth conditions would occur on soils of varying water holding capacity.

TABLE 2.3 Input data used in pasture growth model. (Mean standard tank evaporation K.R.S., mean rainfall K.R.S. and actual rainfall Hooker farm.)

Week start		Mean weekly standard tank evaporation	Rainfall KRS mean 1947-70	Actual rainfall Hooker farm for wet seasons			
				1969/70	1970/71	1971/72	1972/73
July	2	47.5	-				
	9	48.8	4				
	16	50.0	10				
	23	51.9	-				
	31	55.0	-				
Aug.	7	58.8	-				
	14	62.0	-				
	21	65.0	-				
	28	67.5	-				
Sept.	4	70.0	1				
	11	70.5	-				
	18	71.3	2	2			
	25	71.9	1				
Oct.	2	71.9	5			24	
	9	71.3	4				
	16	71.0	6	4			
	23	70.3	5	12		27	45
	30	69.5	15			7	
Nov.	6	68.1	9	1	6	12	5
	13	67.5	12	14	13		12
	20	65.5	14		1		28
	27	65.0	24	24	16	10	15
Dec.	4	61.9	19		24	24	16
	11	60.0	28	12	2	80	
	18	58.0	33	30	4	31	12
	25	56.3	31		46	12	25
Jan.	1	54.5	45	2	21	2	15
	8	52.5	29	9	20	32	40
	15	50.0	57	40	32	27	48
	22	48.1	47	11	14	10	6
	29	47.5	69	7	58	7	23
Feb.	5	48.1	52	90	18	3	
	12	50.0	61	70	3	71	
	19	51.0	36	1	61	22	51
	26	52.5	30	0	31	80	10
March	5	54.8	46	17	-	151	178
	12	54.8	28	11	28	7	7
	19	54.8	15		52		19
	26	54.5	4		13	2	8
April	2	54.3	24		10		3
	9	54.0	6			70	0
	16	53.8	10				55
	23	53.8	9				0
	30	53.7	5				0
May	7	53.0	2				0
	14	52.5	1				0
	21	50.5	6	4			0
	28	46.8	-				0
June	4	45.5	-				0
	11	46.3	4				13
	18	46.8	-				
	25	47.0	-				
Totals mm.		2977	809	361	473	711	634
				44%	59%	88%	78%

TABLE 2.4 Pasture growth model output for mean year and years of the study (using soil water-holding capacity of 100 m.m.)

	Mean Year		1969/70		1970/71		1971/72		1972/73	
	Number of growth weeks to date	Soil moisture at end of week	Number of growth weeks to date (N.G.W.)	Soil moisture at end of week (S.M.)	N.G.W.	S.M.	N.G.W.	S.M.	N.G.W.	S.M.
July 2	0	0								
9	0	0								
16	0	0								
23	0	0								
31	0	0								
August 7	0	0								
14	0	0								
21	0	0								
28	0	0								
Sept. 4	0	0								
11	0	0								
18	0	0	0	0						
25	0	0	0	0						
Oct. 2	0	0	0	0			0	0		
9	0	0	0	0			0	0		
16	0	0	0	0			0	0		
23	0	0	0	0			0	0	1	0
30	0	0	0	0			0	0	1	0
Nov. 6	0	0	0	0	0	0	0	0	1	0
13	0	0	0	0	0	0	0	0	1	0
20	0	0	0	0	0	0	0	0	2	0
27	0	0	0	0	0	0	0	0	2	0
Dec. 4	0	0	0	0	0	0	0	0	2	0
11	1	0	0	0	0	0	1	56.0	2	0
18	2	0	1	0	0	0	2	63.8	2	0
25	3	0	1	9	1	1.0	3	53.3	3	0
Jan. 1	4	1.4	1	0	2	0	4	11.7	3	0
8	5	0	1	0	2	0	5	1.7	4	0
15	6	17	2	0	3	0	6	0	5	8.0
22	7	44.8	2	0	3	0	5	0	5	0
29	8	81.0	2	0	4	20.0	6	0	6	0
Feb. 5	9	80.8	3	70.8	5	0	6	0	6	0
12	10	80	4	80	5	0	7	51	6	0
19	11	79.6	5	60.6	6	20.2	8	52.6	7	10.2
26	12	79	6	18.6	7	9.2	9	79	7	0
March 5	13	78.1	7	0	7	0	10.0	78.1	8	78.1
12	14	78.1	7	0	8	0	11.0	63.2	9	63.2
19	15	71.2	7	0	9	8.2	12.0	19.3	10.0	60.2
26	16	53.4			9	0	12.0	0	11.0	46.4
April 2	17	55.6			9	0	12.0	0	12.0	6.0
9	18	18.4			9	0	13.0	48.4	12.0	0
16	19	0					14.0	5.36	13.0	12.0
23	19	0					14.0	0	13.0	0
Number of growth weeks for season	19		7		9		14		13	
Number of weeks when soil moisture exceeded 63.5 m.m.	8		2		0		3		1	
Number of weeks with some plant available soil water at end of week	14		4		5		13		8	

The final step in the process was to use the known Hooker farm rainfall data[1] for the period of the study in the water balance model. This information could then be used together with what was known of the pasture growth/model output relationship to produce a general picture of native grass seed production for the period of the study.

Model input data and model output are given in Tables 2.3 and 2.4. These tables show that the four wet seasons relevant to the study were all below the long-term average in terms of both rainfall and pasture growth period. The interpretation of these results follows.

1969/70 wet season

In this wet season, rainfall was 44 percent of the long-term average. The model output indicates that pasture growth was only possible for 7 weeks; however, when the distribution of these weeks is considered, effective growth would only have been possible from February 5 to March 5, a period of 5 weeks (Table 2.4).

The consequence of such a seasonal pattern would be a failure of the perennial grass seed crop. The non-aquatic annual grass seed crop could have been late but some seed set would have occurred.

1970/71 wet season

Superficially, this was a slightly better season for pasture growth than the previous one. Rainfall was

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1 The validity of using rainfall at one point for simulating pasture growth for a whole region could be questioned. This was checked (Appendix III) by comparing 10 years rainfall for four centres in a 5 million ha triangle. There was a high correlation between centres, suggesting that a good wet season at one point means a good wet season at another and *vice versa*. These results confirmed what was locally held to be fact.

55 percent of the mean, and 9 weeks of effective pasture growth occurred. The distribution of rain and hence pasture growth weeks, was bad, with three periods of water stress occurring during the season.

The perennial grass seed crop would be small and patchy, with the peak of seed fall in about mid-May. Annual grass seed production would be reasonable, with seed fall being extended from February to April.

<u>1971/72 wet season</u>

This was the best season seen in the study. Rainfall was 88 percent of the long-term mean and there were 14 pasture growth weeks, 13 of which had available moisture at the end of the week.

Perennial grass seed production would be high, but the good pasture growth conditions in March would probably have delayed the seed fall to a mid-June start.

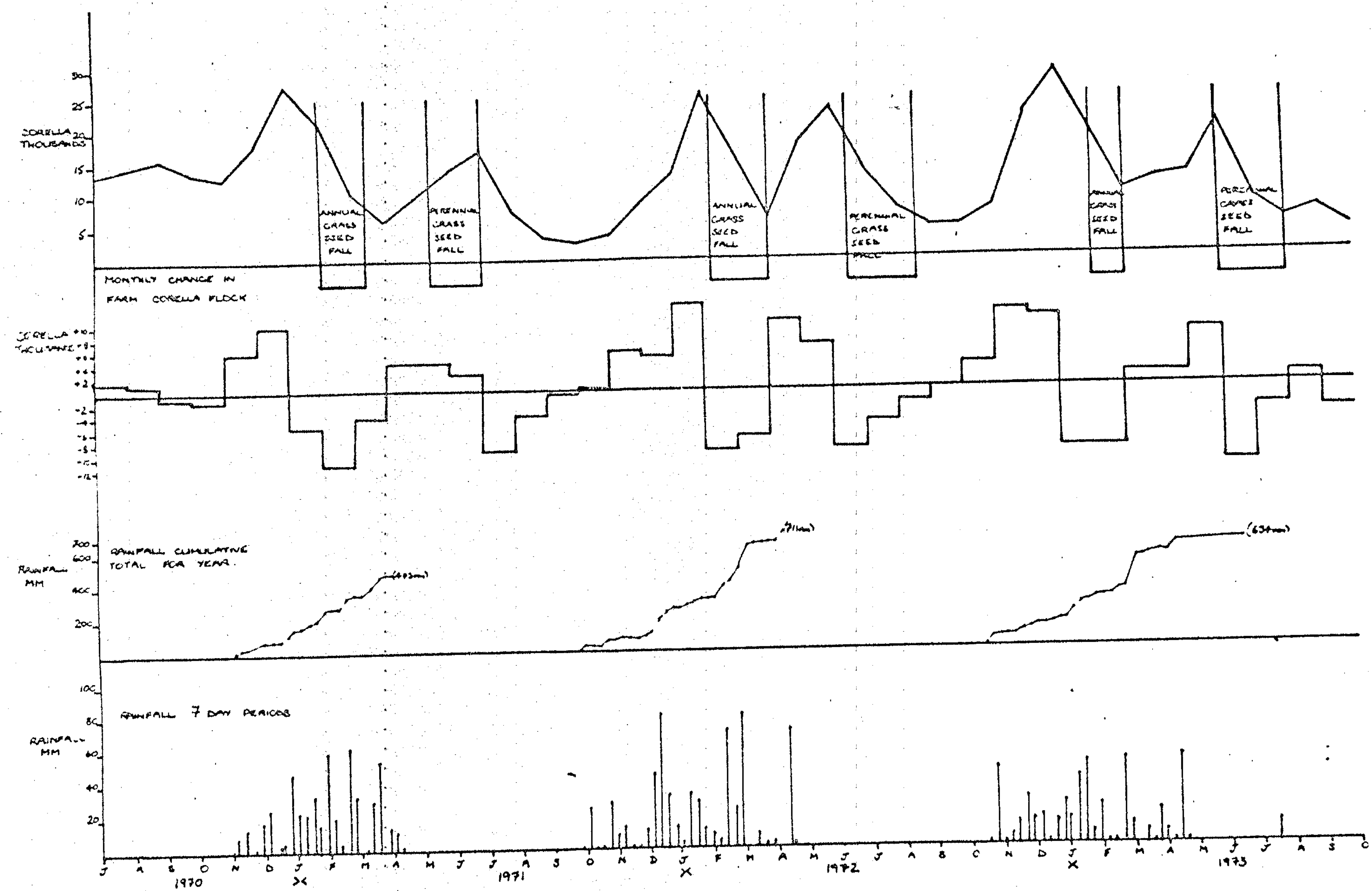
Annual grass seed production would have been high and possibly the seed fall could have been extended.

<u>1972/73 wet season</u>

This was also a good season. Rainfall was 78 percent of the long-term mean, and 13 weeks of pasture growth occurred. There was no sustained pasture growth early in the season, but a good 8 week growth period occurred in February/March.

The perennial seed crop would have been good, with a slightly earlier seed fall than the previous year. The annual seed crop would have also been a good one, but the period of seed fall would probably have been compressed in time by the single late growth period.

Fig. 2.6 Numbers of little corella in the static super-flock in relation to grass seed fall (annual and perennial), cumulative rainfall for current wet season and rainfall for seven day periods.



(c) Fitting the movement model to the farm counts

Figure 2.6 shows on the same time scale the numbers of little corella in the static super-flock at the end of each month, the nett change in numbers for the month, the periods of expected annual and perennial grass seed fall, the cumulative rainfall for the current wet season, and the 7 day rainfall figures. The figure shows the numbers of birds in one component of the model population changing with time; from this the general changes in the whole population mentioned in section (a) above can be inferred.

In 1970 the failure of the perennial seed crop resulted in no significant dry season "b" factor operation. Consequently, a large proportion of the population remained in the static super-flock. The onset of the wet season resulted in those birds which were still in the static sub-flocks and the roving flocks joining the static super-flock. The peak farm little corella count for the study, 32,000 birds, occurred in early January, 1971.

The annual grass seed crop in February and March resulted in a movement of birds out of the static super-flock. This was followed by an increase in April and May possibly as a result of fallen annual seeds becoming unavailable.

The main dry season decrease in the static super-flock followed the perennial grass seed fall. Numbers then remained low until the start of the 1971/72 wet season, and during this period numbers in the static sub-flocks were high.

This pattern was repeated for the next two years, with no great variation from the predicted pattern.

2.2.3 Some aspects of the population dynamics of the little corella

(a) General

The critical question as to whether the little corella population will explode in the face of continually available farm grain in the Ord valley has not been conclusively answered by this study. The results available do, however, indicate that little corella are a species with both low annual recruitment and mortality rates. Most of the evidence for the former involves aspects of the behavioural ecology of the species - a summary of which will be given in this section.

(b) Factors affecting recruitment in little corella

Breeding of the little corella only takes place in the static sub-flock component of the population. It occurs during the dry season, and July to September are the peak months in the immediate area of Kununurra. This peak appears to be earlier in the south, where the wet season ends earlier.

For the first 12 months of this study, no evidence of breeding could be found in the entire region. It was in fact not until November 1971 that one young bird was shot with its parents. Although it was not realised at the time, subsequent findings [1] almost certainly indicate the failure

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1 (i) Apart from the three birds mentioned here, no pre- or post-reproductive gonads, or young birds, were collected for the period June 1970 to September 1972; this contrasts greatly with the later data.
(ii) Possible nest trees checked in 1971 but not used were used in 1972 and 1973
(iii) Behaviour by breeding pairs seen in 1972 and 1973 was not seen in 1970 or 1971
(iv) The grouping of 3 and 4 birds (family groups?) seen in the post breeding static super-flock in 1972 and 1973 were not seen in 1970 or 1971.

of breeding in 1970 and a very low level of breeding in 1971. These results agree with the output of the pasture growth model for 1970 and 1971, which shows these years to be poor ones in terms of the perennial grass seed crop.

In 1972 and 1973, extensive breeding was observed at several sites and reported from many more. Early in 1972, an intensive behavioural study of one static sub-flock was commenced at Cockatoo Springs. This involved 14 hour watches of behaviour once a week from a lookout hide, regular checks of all nests, and detailed watches of behaviour at selected nest trees. This study ran for 18 months and covered both the 1972 and 1973 breeding seasons. In addition, regular (2 weekly) collections of specimens were made at three other static sub-flock areas.

In the Cockatoo Springs area it was found that only 10 pairs, out of a population of about 50 pairs, successfully occupied nest trees and bred. The occupancy of a nest tree by a pair was apparently an attribute not available to the entire population. Nesting sites were always hollows in boab trees (*Adansonia gregorii*) and only a small percentage of available hollows in trees of this species were used. Hollows of other trees were not used, even though apparently suitable. *Eucalyptus* sp. hollows were very numerous in the study area[1].

The occupancy of a nest tree by a pair of little corella involved regular visits to the tree throughout the entire year, the frequent use of duo calling displays on such visits in the non-breeding season, and invariable evening displays in the breeding season. Nest maintenance activites were elaborate and nest fidelity appeared to be absolute.

Each pair of birds laid three eggs, one of which often did not hatch. The hatching was asynchronous. Growth

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1 These hollows were regularly checked and breeding by other species was frequently found.

rates differed between young, and the considerable nest mortality resulted in a fledging rate of 1.2 to 1.5 young per pair.

These results suggest that for the Cockatoo Springs study area, the rate of recruitment of fledging birds into the population was in the order of 15 percent. If the little corella suffered the post-fledging mortality rate of the eastern rosella (*Platycercus eximius*) of 80 percent (Brereton, unpublished data) the rate of recruitment into the year two age class would be about 3 percent.[1]

The results of collections made at the other static sub-flock areas indicated that a similar percentage of the flock was breeding. Collection and checks for nests in the immediate area of lake Kununurra and Hooker farm showed a few pairs of birds successfully breeding in boab trees and following a similar daily pattern of behaviour as that found at Cockatoo springs. Two pairs attempted to nest in dead trees over water in the swamps of lake Kununurra; one pair was unsuccessful and the other fledged one young. In both cases, breeding and fledging were very late, and the likelihood of survival of the young probably low.

This brief outline of breeding in the little corella suggests that the species has, in the Kununurra context at least, a low potential rate of increase. The major factors involved in this are the apparent preference for one species of nest tree, which is of limited distribution (Stewart *et al*, 1970) and the apparently limited proportion of the population which breeds in a breeding year. What would occur in an exceptionally good season following an above-average wet season is unknown at this time.

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1 For the four breeding seasons of this study, the rate of recruitment would have been 0, 0, 3 and 3 percent. This is in fact a mean rate of recruitment of 1.5 percent per annum.

(c) Factors affecting mortality in the little corella

It is impossible in a 40 month study to obtain any measure of mortality for the little corella. The species is known to live for over 70 years in captivity (Forshaw and Cooper, 1973) and for over 11 years in the wild (Purchase[1] pers. comm.). Although it cannot be demonstrated, there is no reason to believe that such longevity is not a characteristic of the little corella population studied.

The only significant disease found in the population studied was a condition called feather-losing syndrome (F.L.S.) which was most prominent in 1972. This condition was characterised by a gradual loss of feathers, which in some cases at least resulted in near-baldness and death. At one time, approximately 10 percent of the static super-flock appeared to have this condition, but it is fairly certain that no mass mortality occurred.

Post-mortem material was collected from birds in an advanced state of F.L.S. This material was examined, and a tentative diagnosis of *Leucocytozoon* spp. or possibly *Plasmodium* spp. was made by Dr. M. E. Nairn (senior veterinary pathologist, W.A. Department of Agriculture). Whether or not F.L.S. could, in the long term, have an effect on the little corella population is not known at this time.

2.2.4 Static super-flock behaviour

2.2.4.1 Introduction

One aspect of little corella behavioural ecology extensively studied was the daily routine of each of the three components of the population. Figure 2.3 indicates that cycles of daily activity are characteristic of all three population components. A general model of daily

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1 This bird was banded by N.J. Favaloro at Merbein, Victoria; it was killed 5 miles north-west of its banding place.

Fig. 2.7 General model of the daily routine of little corella under natural conditions.

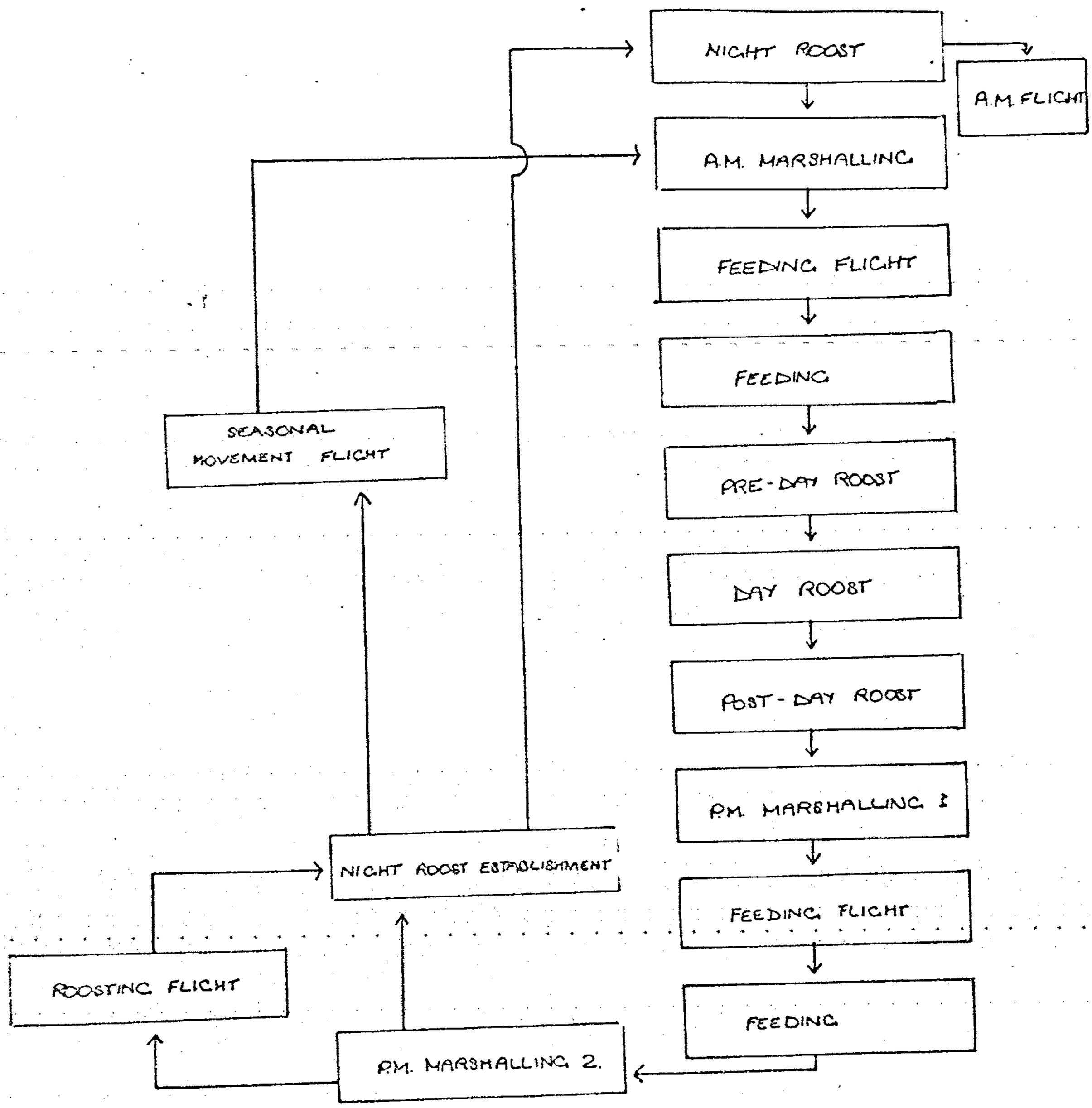
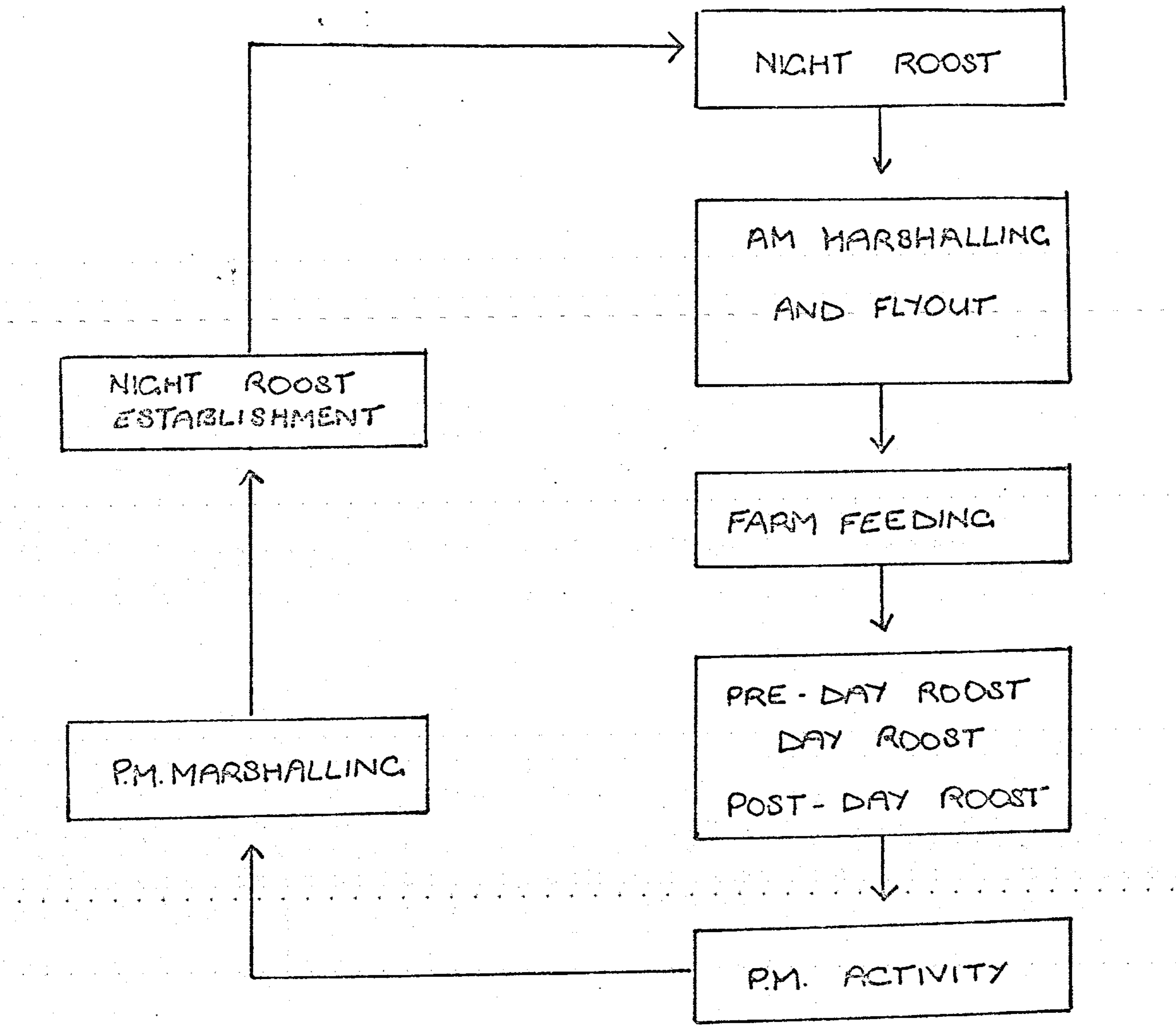


Fig. 2.8 Model of the modified daily routine of little corella in the static super-flock.



routine is followed by all three (figure 2.7). However, between components, the cycles vary in ways which reflect the major activity of the component and the most prominent grouping within the component. Figure 2.8 indicates how the generalised model (Figure 2.7) has been compressed for the static super-flock feeding on Hooker farm. Most of this compression has occurred as a result of the very limited afternoon feeding [1] which occurs in this component. The only black box of the static super-flock model of interest[2] here is the one designated "Farm feeding". This describes how the large little corella flock goes about utilising an unlimited grain sorghum food resource.

2.2.4.2 Understanding the models

In the behavioural model of little corella the black boxes are components of the model which only have limited numbers of entries and exits - usually two. Within each "black box" there occurs a network of "operations" and "branches".

"Operations" are activities such as "adopt a wheeling flight", "few birds drop to crop centre" and so on; these "operations" may involve physical movement of the whole or part of the flock, or a change in the most common behaviour or activity of the flock. If the flock has become fragmented through the operation of a "branch", it is possible for several "operations" to be occurring simultaneously

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1 This is presumably caused by the super-abundance of food on the farm, resulting in one feed per day meeting the little corellas' requirements. If morning feeding was severely disrupted by shooting, extensive afternoon feeding would follow.

2 The models mentioned above constitute a major part of the little corella behavioural ecology project (see Chapter 1).

Fig. 2.9 Detailed model of farm feeding component of little corella daily routine

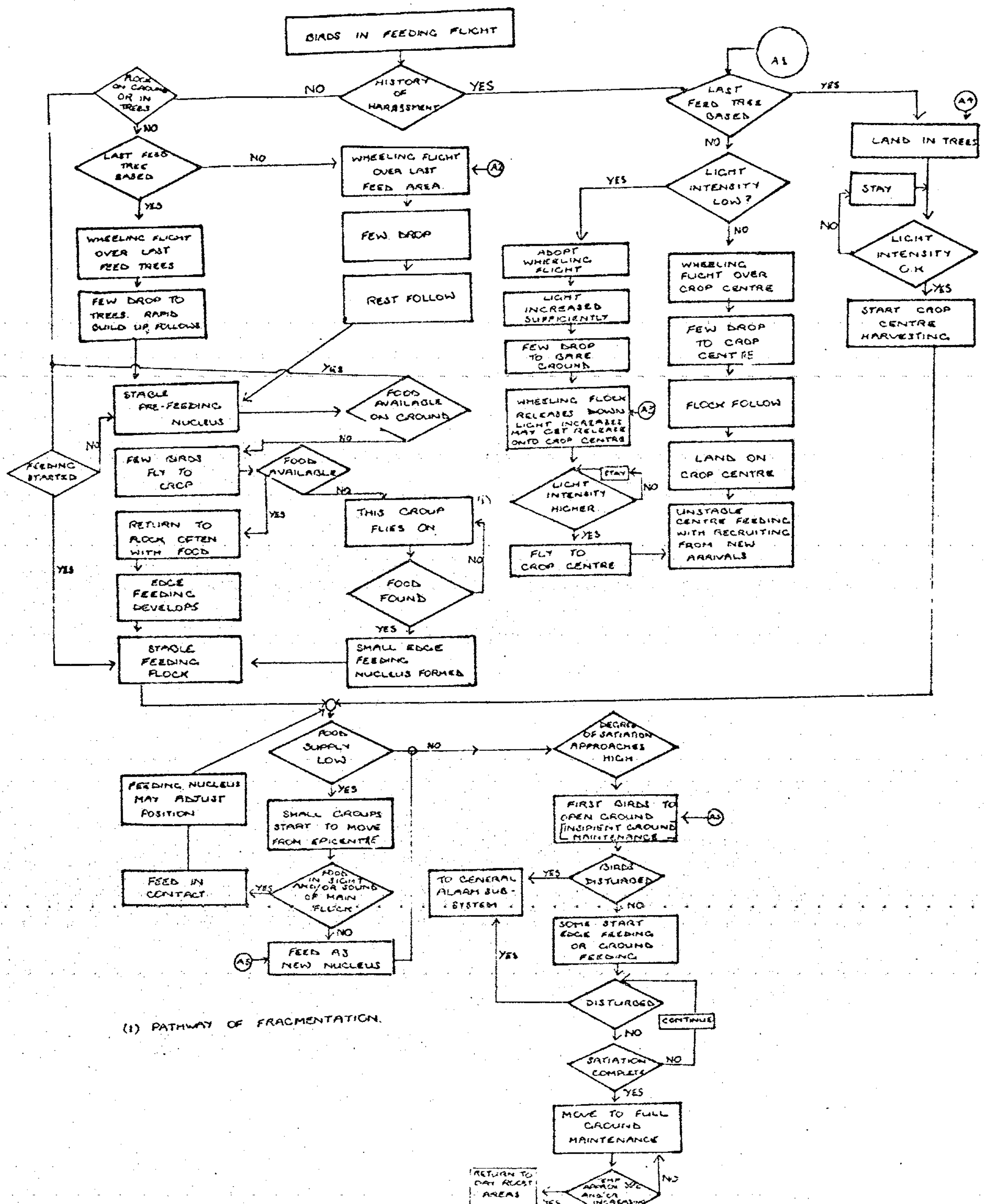
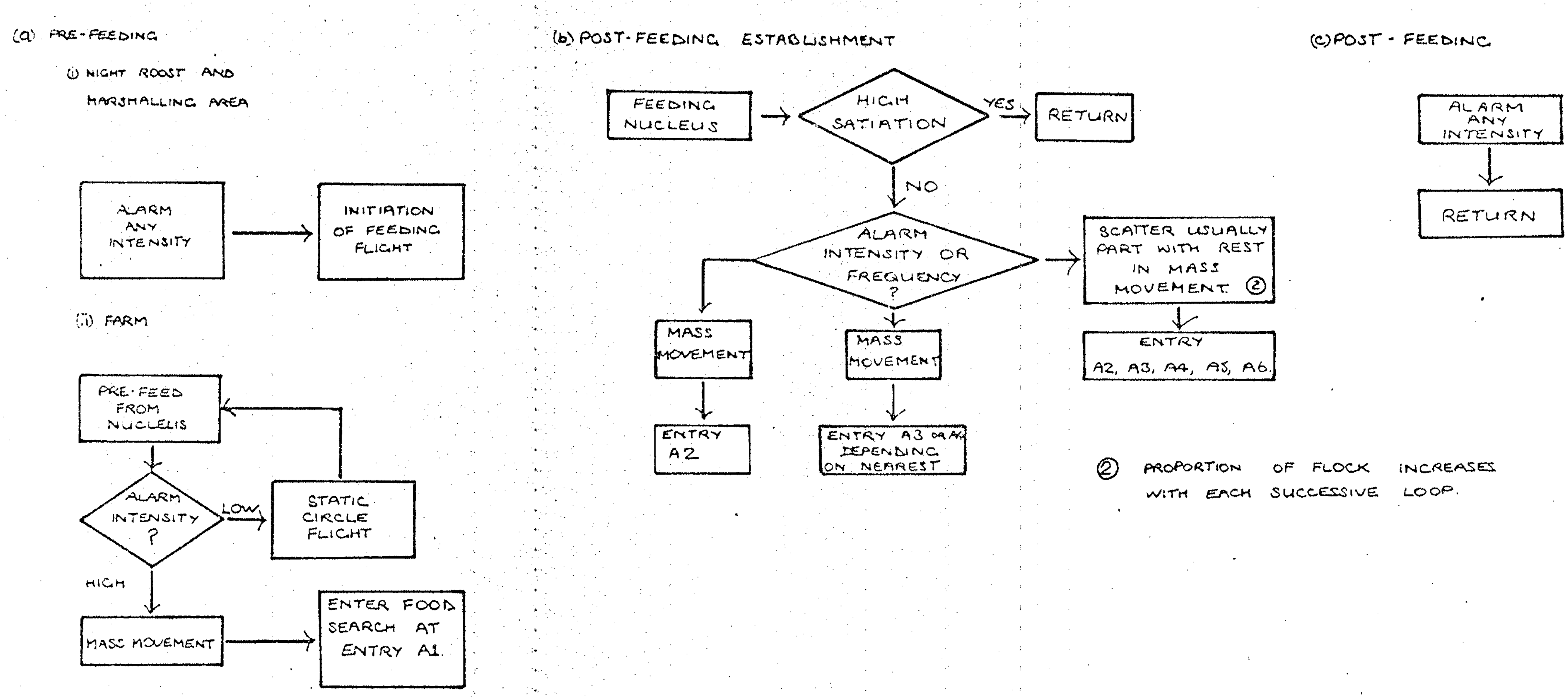


Fig. 2.10 Alarm loops of farm feeding model



in different "mobs"[1] which are located in different areas of the farm. "Operations" only have one exit and usually only one entry. Thus they can, if arranged in a sequence, describe a whole behavioural series as a sequence of discrete entities. "Operations" appear in the model as rectangles.

"Branches" differ from operations in that they have two or more exits. Which exit operates depends upon a question incorporated in the "branch". Examples are "food available on ground?", "food found?" etc. "Branches" are in fact analogous to the "IF" statement in Fortran and similar computer languages. The "branch" density of a particular "black box" is a measure of the plasticity of behaviour shown within the "black box". "Branches" appear as diamonds in the model.

2.2.4.3 The farm feeding model

Figures 2.9 and 2.10 outline the network which describes the behaviour incorporated in figure 2.8 as the "Farm feeding" black box. The model is essentially self-explanatory and shows all the "pathways" which are possible for the static super-flock from the time of its arrival on Hooker farm for feeding to its leaving the farm about one hour later.

The model incorporates man-made aspects of the feeding environment of the static super-flock, such as "history of harassment"[2] and a line of trees abutting onto

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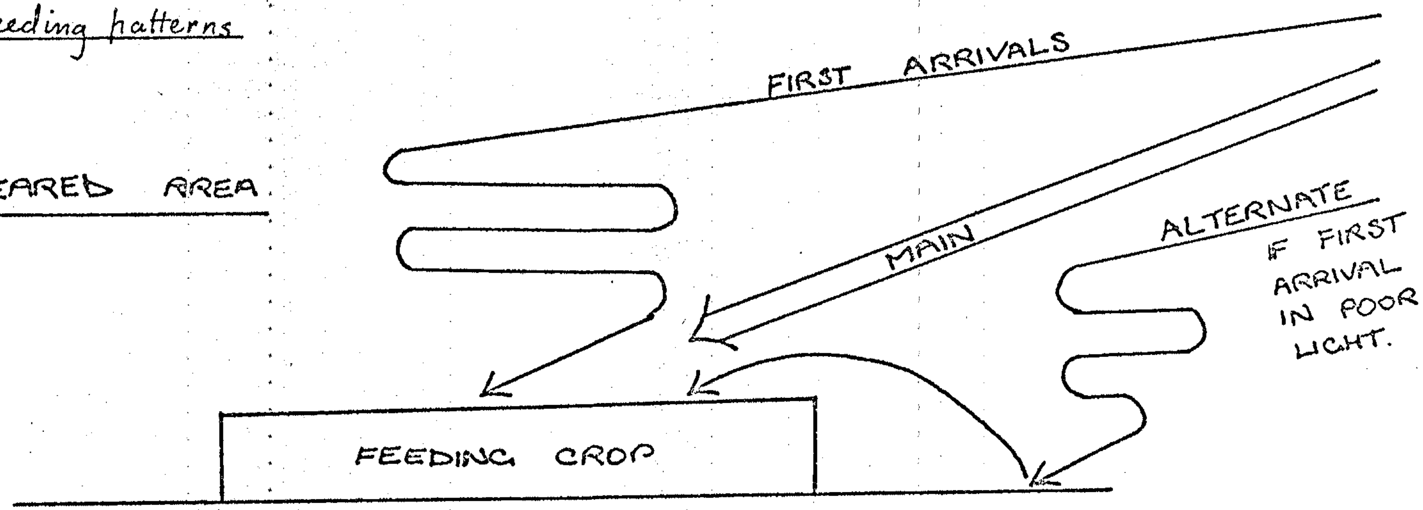
1 "Mobs" is used to describe a large aggregation of birds temporarily operating as an independent unit but which is, in fact, part of a flock.

2 In the Hooker farm context, this means intensive shooting.

Fig. 2.11 Continued

B) Shooting feeding patterns

(I) CLEARED AREA



(II) TREED MARGIN

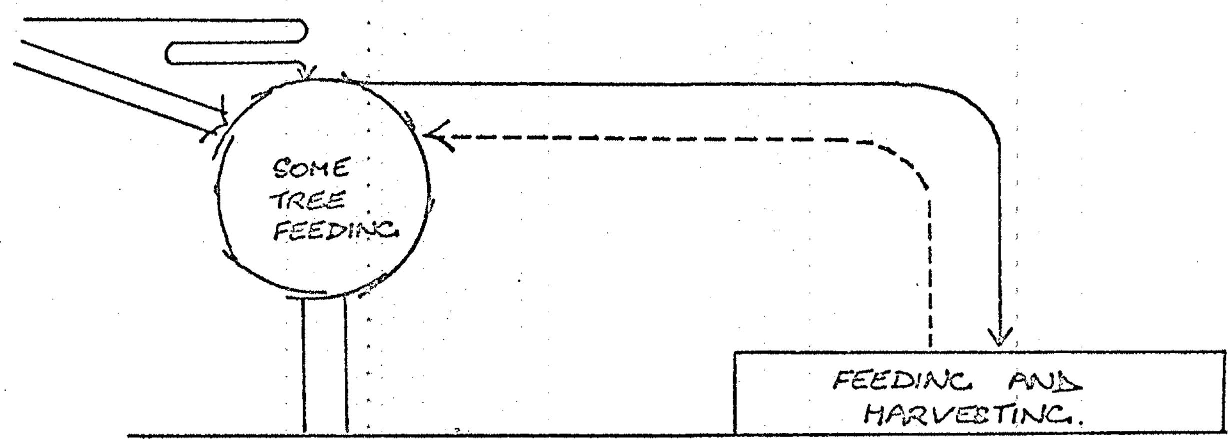
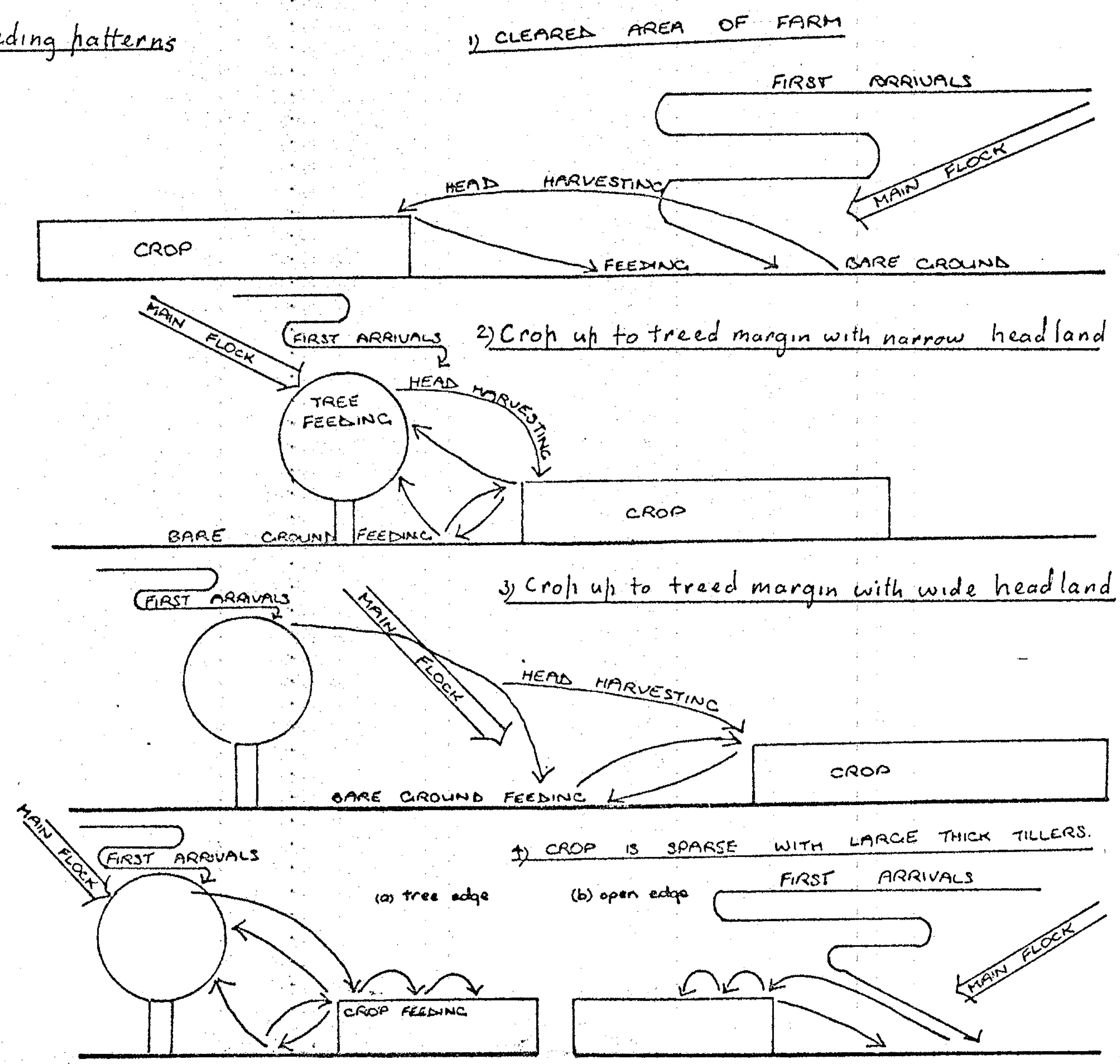


Fig. 2.11 Diagramatic representation of little corella farm feeding strategies.

A) Non-shooting feeding patterns



standing feed; otherwise, it is very similar to the corresponding model for a roving flock.

The value of the model to this study is that it allows prediction to be made about the likely outcome of a particular on-farm management strategy. The general interest of the model is that it shows how plastic the behaviour of a very large aggregation of birds can be without compromising the integrity of the aggregation.

2.2.4.4 Patterns and strategies of farm feeding

Within the framework of the farm feeding model there were four generalised systems of crop feeding utilised by little corella under non-harassed feeding conditions, and two general systems used under harassed feeding conditions (figure 2.11). Within these two divisions, the major determinant of the system used was the presence of trees or bare ground at the edge of the crop.

Under non-harassed conditions little corella removed the entire panicle from the tiller and flew with it to either the bare ground or a nearby tree. The panicle was held in the foot and the grain systematically eaten from it. If birds feeding in this way were alarmed, the panicle was dropped. On the resumption of feeding a new panicle was usually harvested and the original wasted.

In crops of low plant density, tiller diameter was high; in such circumstances little corella would sit on the tiller and remove grain directly from the panicle.

In situations where the birds had been harassed[1]

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1 The major harassment on Hooker farm consisted of shooting accompanied by the chasing of the birds in motor vehicles. Other harassment methods such as noise, chemical repellent baits, poison baits etc. could have a similar effect.

TABLE 2.5 Probability of pasture growing seasons of various durations for Kununurra (based on Slatyer's analysis (in Stewart *et al*, 1970) of historic K.R.S. climatic data

	Length of growing season (weeks)				
	24	20	16	12	8
Probability of occurrence	0.07	0.23	0.47	0.20	0.03
Cumulative probability of figure being exceeded	0.07	0.30	0.77	0.97	1.0

they modified their behaviour (figure 2.9). In terms of feeding this resulted in one of two strategies being used. (figure 2.11). Both strategies involved feeding from the centre of the crop rather than the edge. This resulted in a reduced degree of harassment for the little corella, but it was most unlikely that the amount of grain eaten changed.

2.2.5 Discussion and Conclusion

The little corella population which was the cause for concern at Hooker farm has been shown to be a component of the little corella population of the region. This regional population was broken up into three components between which birds moved depending upon seasonal conditions. The use of a simple water balance model, together with a partial knowledge of the pasture growth pattern and the effect of current rainfall on the seed supply, allowed the fitting of static super-flock fluctuations to measurable seasonal parameters. By inference, the causation of flows between the components of the more general model can be suggested. This provides the basis for realising one of the aims of the study.

The linking of changes in the static super-flock population at Hooker farm with climatic data allows the yearly distribution of severe potential crop damage by little corella to be predicted. Further, it allows the general long-term picture to be seen in perspective.

The seasons over which this study was conducted were exceptional in that two very bad seasons and two below-average seasons followed each other. It is not unreasonable to assume that above-average wet seasons would be followed by a diminution of the little corella problem as the apparently preferred non-farm food resources would be abundant.

Table 2.5 shows the probability of pasture growing seasons of various lengths in the Kununurra area. The probability of pasture growing seasons of greater than 16 weeks is, in the long term, greater than 0.70 (i.e. 70 percent) while the probability of a year like 1969/70 with a growing season of less than 8 weeks is less than 0.03 (3 percent). This suggests that, given a relatively static regional population, the dramatic shifts between the components of the little corella population which was the basis of the Ord development problem in 1970 would be a 3 year in 100 phenomenon. In those years when damage is going to be potentially bad, a knowledge of the previous wet season should give at least two months warning of the situation.

This study has not fully realised its aim of predicting the long-term trend of the problem (i.e. the little corella population). This would require a long-term study of the species' population dynamics. The data available suggest that the little corella recruitment rate is limited by the food availability in the static sub-flock areas and aspects of the behaviour of the species in these areas. Less is known of mortality in the population. It is possible that the presence of farm grain at times of natural grain shortage could reduce mortality to some extent; this could be off-set by the occurrence of *Leucocytozoon* spp. (?) as a debilitating and pathogenic condition in the static super-flock. My judgement is that grain growing in the Ord development area would have little effect on the little corella population in the medium term.

Finally, the study of the behaviour of the static super-flock when feeding has provided a sound basis for predicting, under different conditions, the on-farm behaviour of this flock. The use of the behavioural model in management will be developed in Chapter 4.

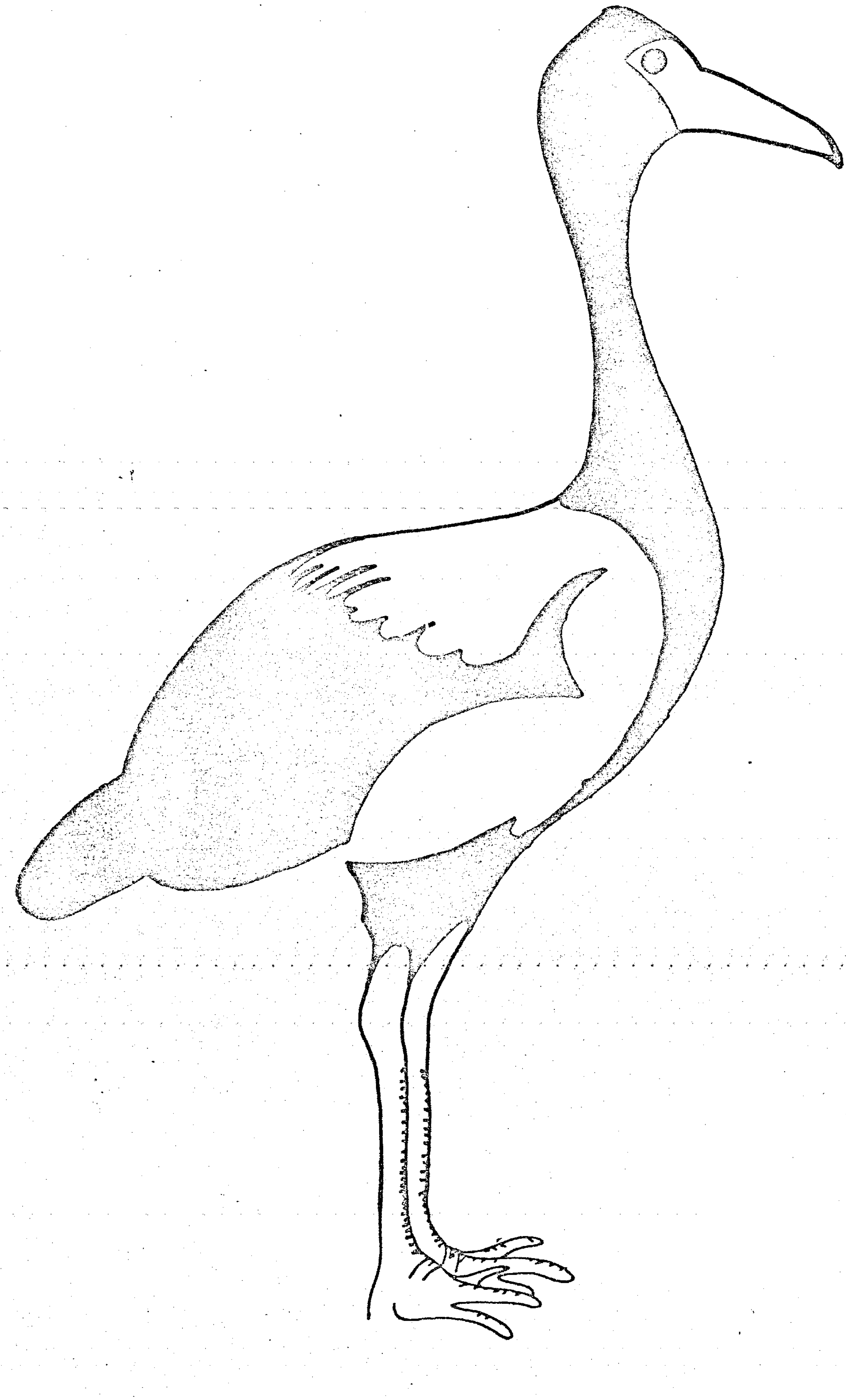


Fig. 2.13 Magpie goose breeding habitats of the Ord - Victoria region (after Frith and Davies (1961) and based on the land systems of Stewart *et. al.*(1970)).

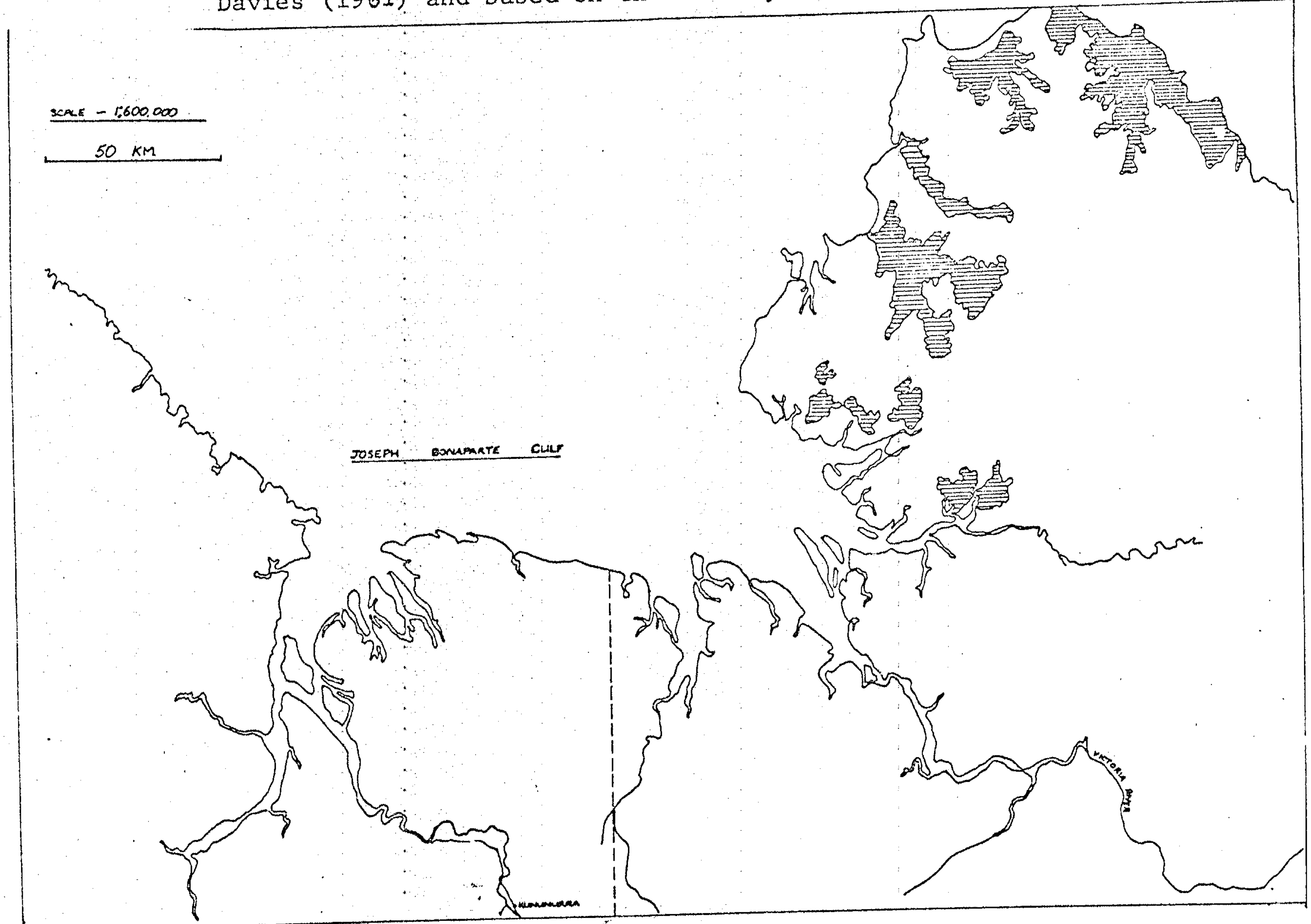
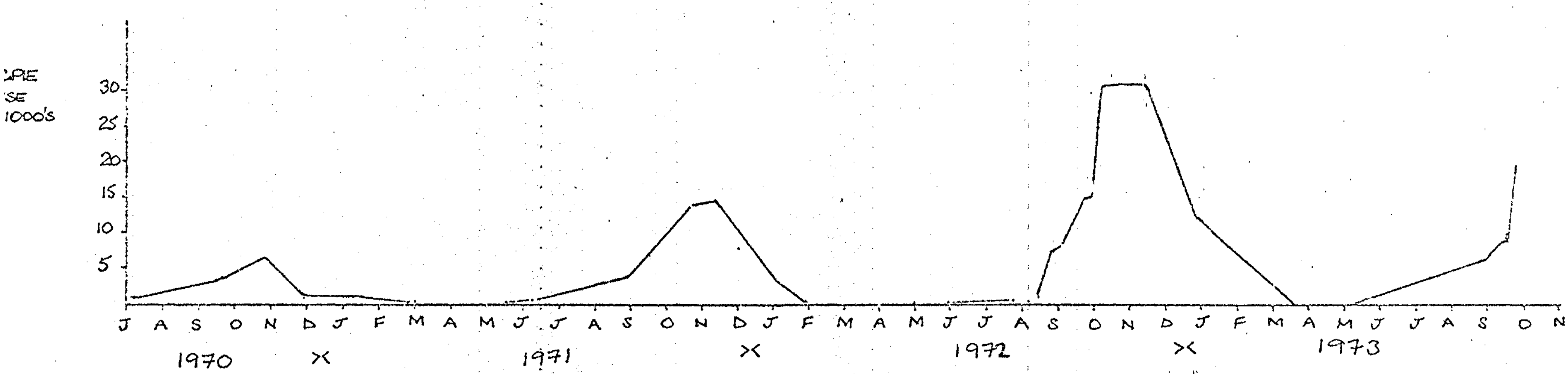


FIG. 2.14. COUNTS AND ESTIMATES OF MAGPIE GEESE VISITING HOOKER FARM.



2.3 Magpie Geese

2.3.1 Introduction

A valuable basis for this study was provided by Frith and Davies' (1961) study of the ecology and behaviour of the magpie goose (figure 2.12) (*Anseranas semipalmata*, Latham, 1798), on the sub-coastal plain of the Northern Territory, approximately 330 km north-east of Kununurra.

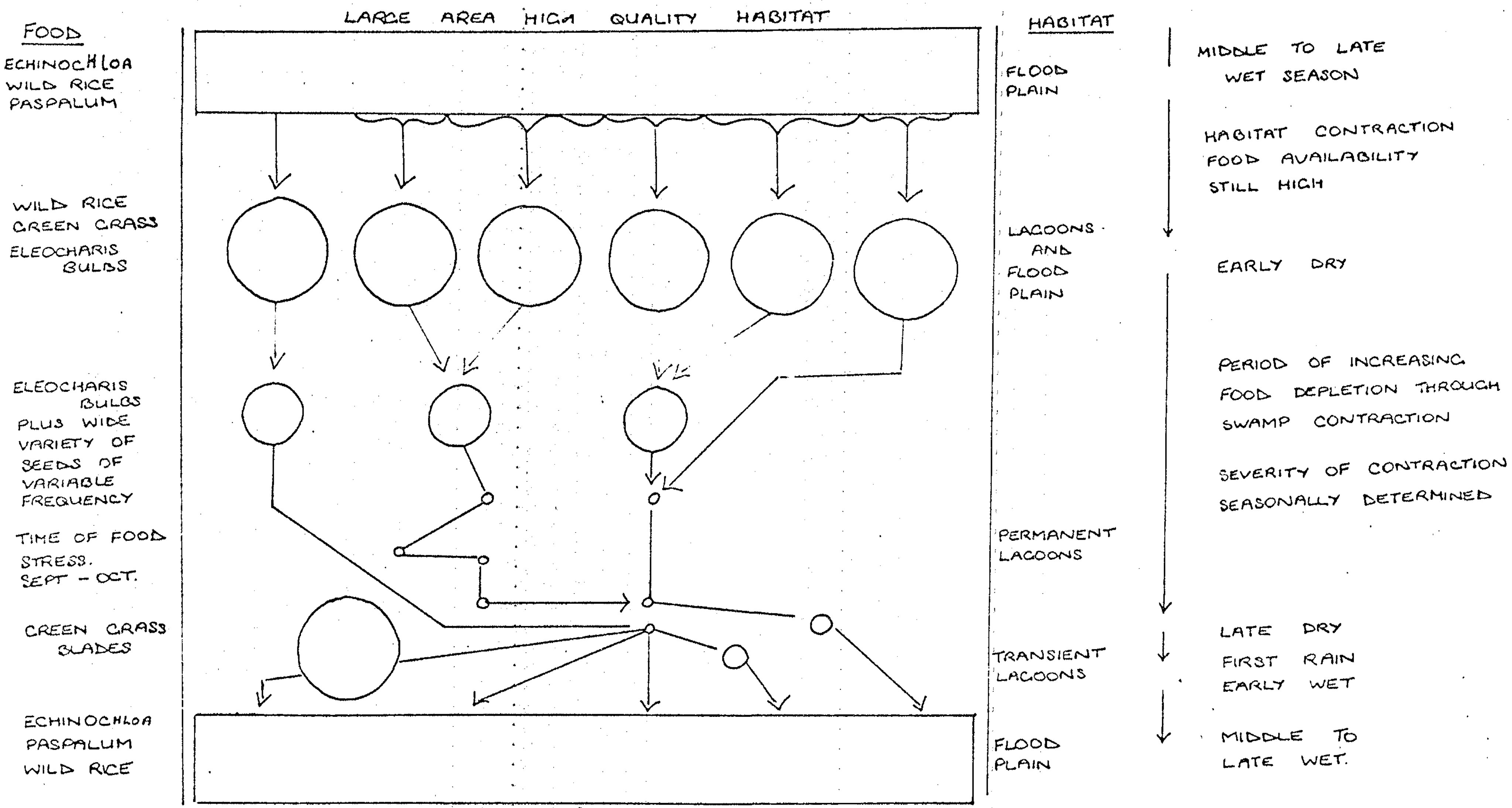
The Kununurra magpie goose population was at the western end of the range of the North Australian population (Frith and Davies, 1961). The available good magpie goose breeding habitat in the area prior to the Ord development was limited to a few restricted areas of swamp associated with the flood plains of the Ord, Forrest, King, Durack and Pentecost rivers. These areas were much less extensive than those on the Fitzmaurice and Daly rivers, 100 to 200 km to the north-east, in the Northern Territory (figure 2.13).

Thus it is almost certain that the population of magpie geese which began annual visits to the Ord farms during this study mainly originated from the breeding swamps of the Northern Territory. Considerable support was given to this contention by an aerial survey in August 1973. This survey was made prior to the major annual increase in magpie goose numbers in the Ord. It covered the flood plains of the Ord and associated rivers, the coastal plains between the Ord and the Victoria rivers, plus sections of the Victoria and Baines rivers and the newly filled main Ord river dam (Lake Argyle). This survey failed to find more than a few hundred magpie geese in the entire area.

2.3.2 The annual pattern of the farm magpie goose population

The magpie goose population in the area of Hooker farm fluctuated seasonally over the course of the study (figure 2.14). The trend in numbers was, however, alarming.

Fig. 2.15 A model showing the relationship between magpie goose habitat utilization, food and seasonality (after Frith and Davies (1963) with modification).



Each year the magpie geese appeared to arrive earlier, stay longer and to be in increased numbers (figure 2.14).

The seasonal pattern of magpie goose invasions was consistent with the findings of Frith and Davies (1961), summarised in figure 2.15. Figure 2.15 shows the late dry season (September to December) to be a period of decreasing food resources and increasing movement by the geese. These are the most plausible explanations for the magpie geese to have a propensity to move onto the development. Other questions are, however, posed by the pattern of increase over the years of the study.

In this study the magpie goose population peak was lowest in the first year following the worst wet season and highest in the last two years following adequate wet seasons. Several explanations can be offered for this superficially anomalous situation.

(i) <u>Breeding</u>

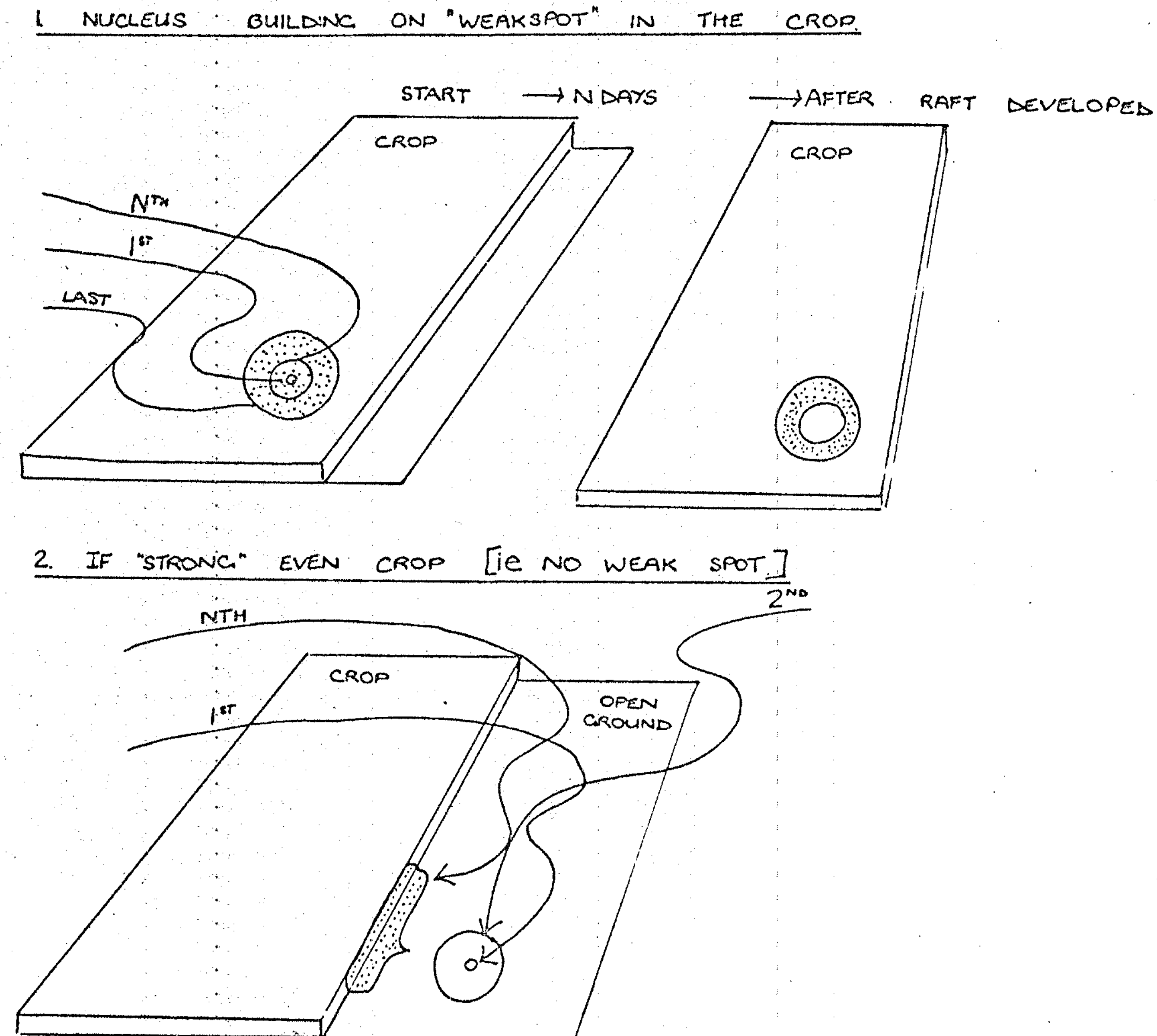
Frith and Davies (1961) showed that breeding success was related to seasonal conditions; thus relatively lower numbers would be in the population after the initially poor year of 1969/70. This does not seem to be a major explanation. 1969/70 was preceded by four exceptionally good years (Table A3.1) over which magpie goose numbers should have increased to give a major problem in the very bad dry season of 1970.

(ii) <u>Increasing use of the new habitats produced by the man-made dams</u>

In the latter part of the study (April-May 1973) some breeding did occur on lake Kununurra. This breeding was limited and no more than a few hundred birds were involved. No breeding was recorded on lake Argyle.

These observations provide a partial explanation for the increasing period over which geese were found in the area; they do not, however, explain the increase in numbers.

Fig. 2.16 Diagramatic representation of magpie goose farm feeding strategies.



(iii) Tradition and learning

Frith and Davies (1961) suggested that tradition had a role in determining the direction of magpie goose movement in their study area. The changes in the farm population over this study strongly suggest that this was the mechanism involved. It could be postulated that a tradition of utilizing the Ord development as a late dry season refuge rapidly became established and spread to the nearest major population of magpie geese in the Northern Territory.

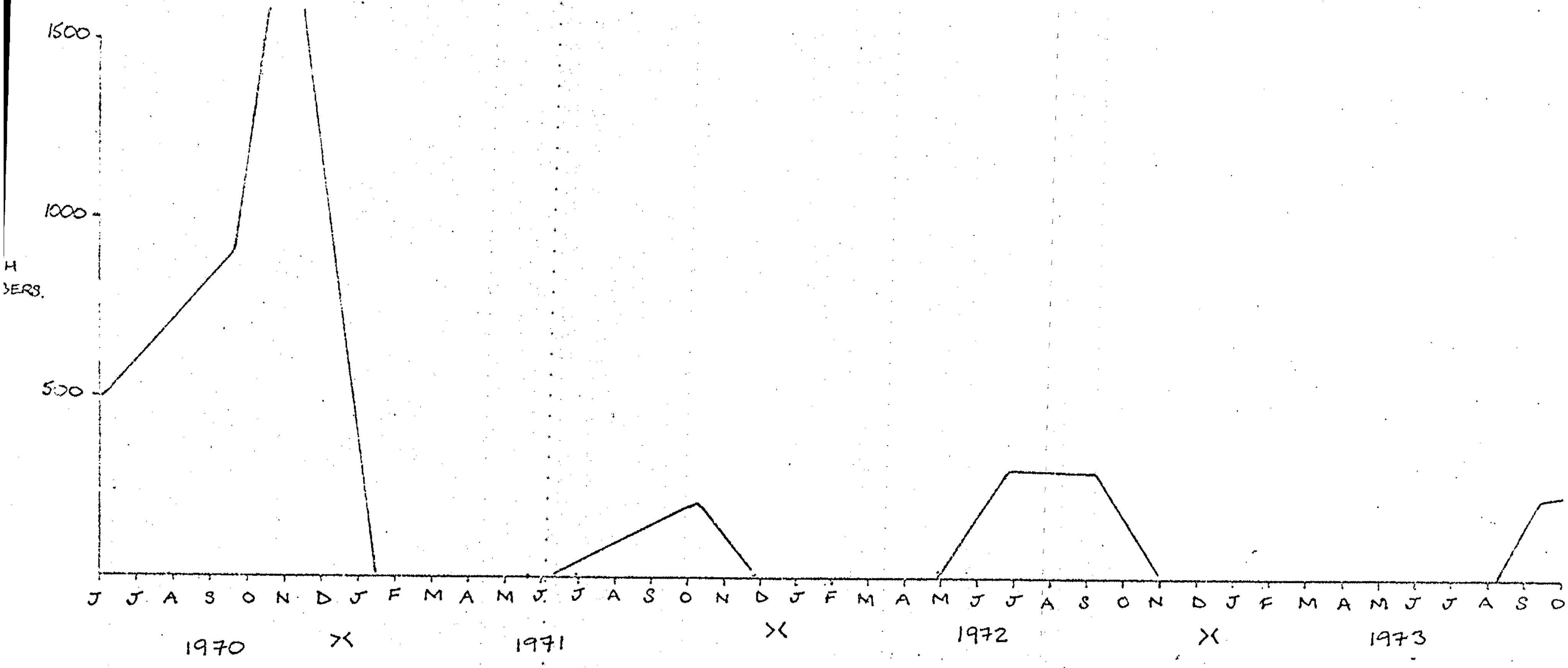
If this line of reasoning is followed then the expectation would be for an increasing late dry season magpie goose invasion of the Ord as the tradition spread. There is, however, probably a finite limit on this increasing trend, as the magpie goose population is probably limited by breeding habitat (Frith and Davies, 1961). If however the area surrounding the 220,000 ha lake Argyle became acceptable magpie goose breeding habitat in the future, a further increase in the absolute population is possible.

The second trend observed, that of the successively earlier arrival of magpie geese at Hooker farm each year, can also be explained by the above hypothesis. Once a tradition of movement direction is established in part of the population, and the area of termination of the movement is a very attractive habitat, it is not unreasonable to expect the movement of magpie geese from a declining habitat to occur earlier each year. This trend would be reinforced by an increasing percentage of a given population being "acquainted" with the Ord visitation tradition.

2.3.3 Patterns and strategies of farm feeding

Magpie geese utilized farm crops both for grazing and for grain (section 3.3). In both cases the same basic strategies were utilized (figure 2.16). Crops were either entered via weak spots (areas of low plant density) which were subsequently enlarged as goose damage increased or entered from the side if no weak spots existed.

FIG. 2·17. COUNTS AND ESTIMATES OF GALAH VISITING HOOKER · FARM.



When green material was eaten, the magpie geese concentrated on young crops or the young tillers of old crops, both of which could be eaten at goose level. When grain was eaten, a strategy of tiller-bending and breaking was developed. This pattern of behaviour appeared to increase during the study as more magpie geese apparently learnt and adopted it. In many ways, the components of this method of feeding resembled the nest-building behaviour of the species (Davies, 1962).

2.3.4 Behaviour

Apart from the adaptations of nest-building behavioural patterns to grain sorghum feeding, no new aspects of magpie goose behaviour were found in this study.

In contrast to the little corella, no useful behavioural basis for on-farm management could be found, a conclusion which fully agrees with that of Davies (1963) who considered a similar problem in the rice fields of Humpty Doo.

2.4 Galah

Galahs were mid to late dry season visitors to Hooker farm (figure 2.17). With the exception of 1970, the numbers involved were only a few hundred. In 1970 about 2,000 galahs were present for a period of at least 4 months and some galahs were present for the whole year. This probably reflects the exceptionally bad dry season of 1970 and the failure of the perennial grass seed crop.

During the course of the study, notes were kept of galah distribution and other relevant matter, such as breeding. These have been combined with the established knowledge of galah ecology and behaviour for eastern and south-western Australia (Pigeon, 1970; Rowley, 1974; Pigeon, pers. comm.; Rowley, pers. comm.; Brereton, pers. comm.) to give

Fig. 2.18 A model showing the relationship between galah population organization and seasonality (after Pigeon (1970), Rowley (1974) with modification)

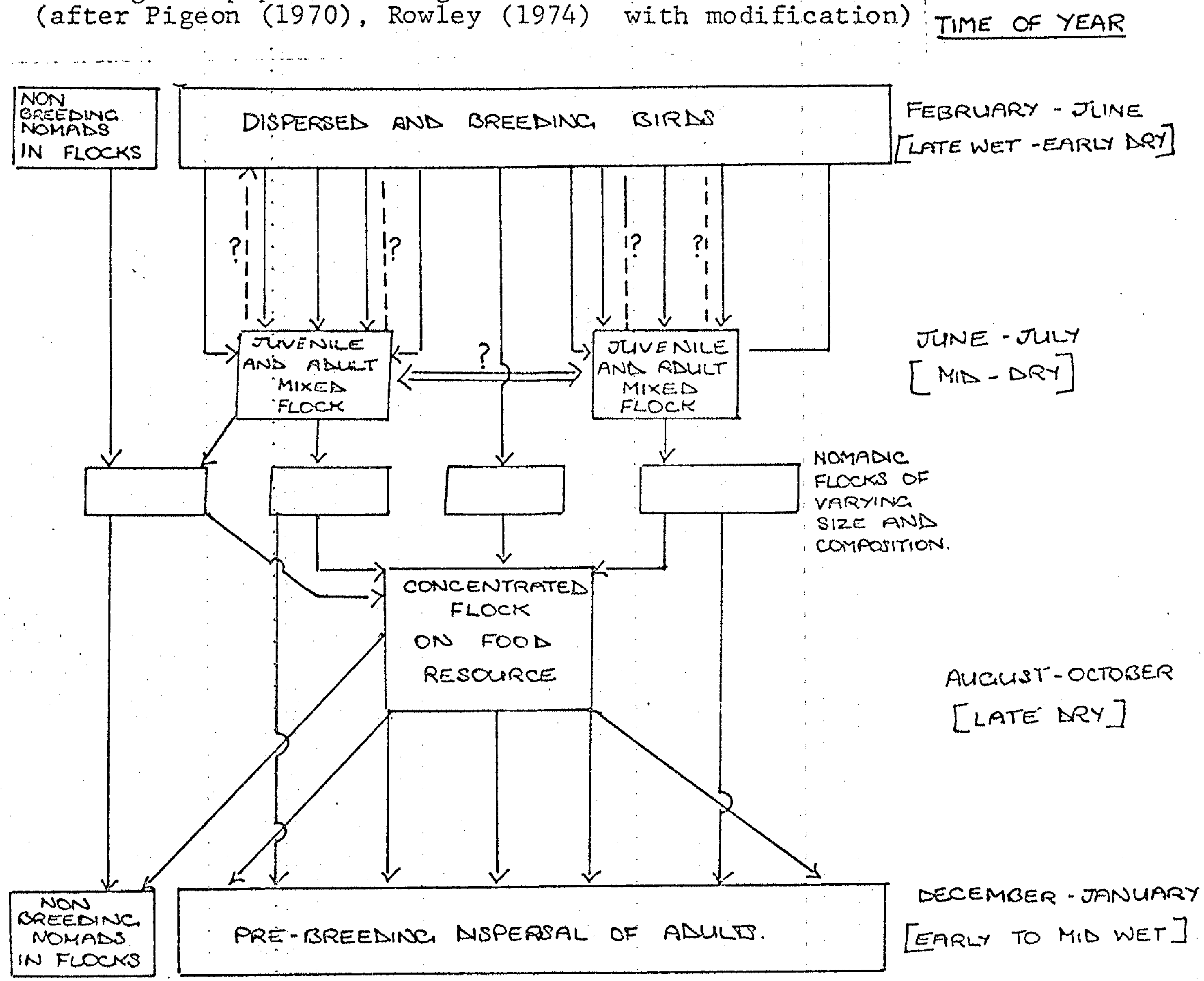


FIG. 2.19. COUNTS AND ESTIMATES OF BROLGA VISITING HOOKER FARM.

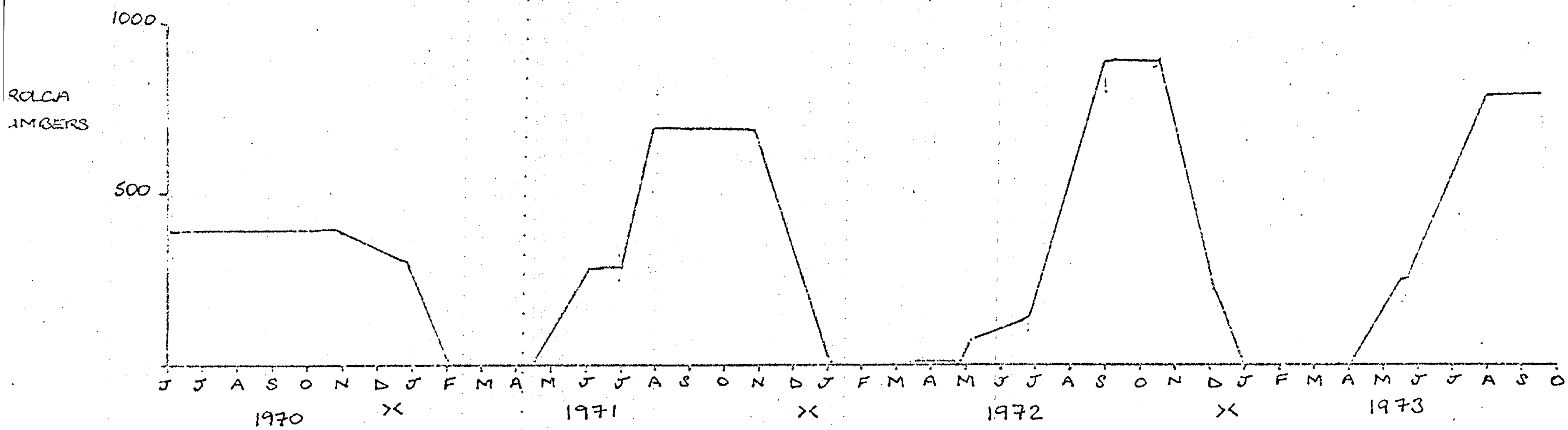
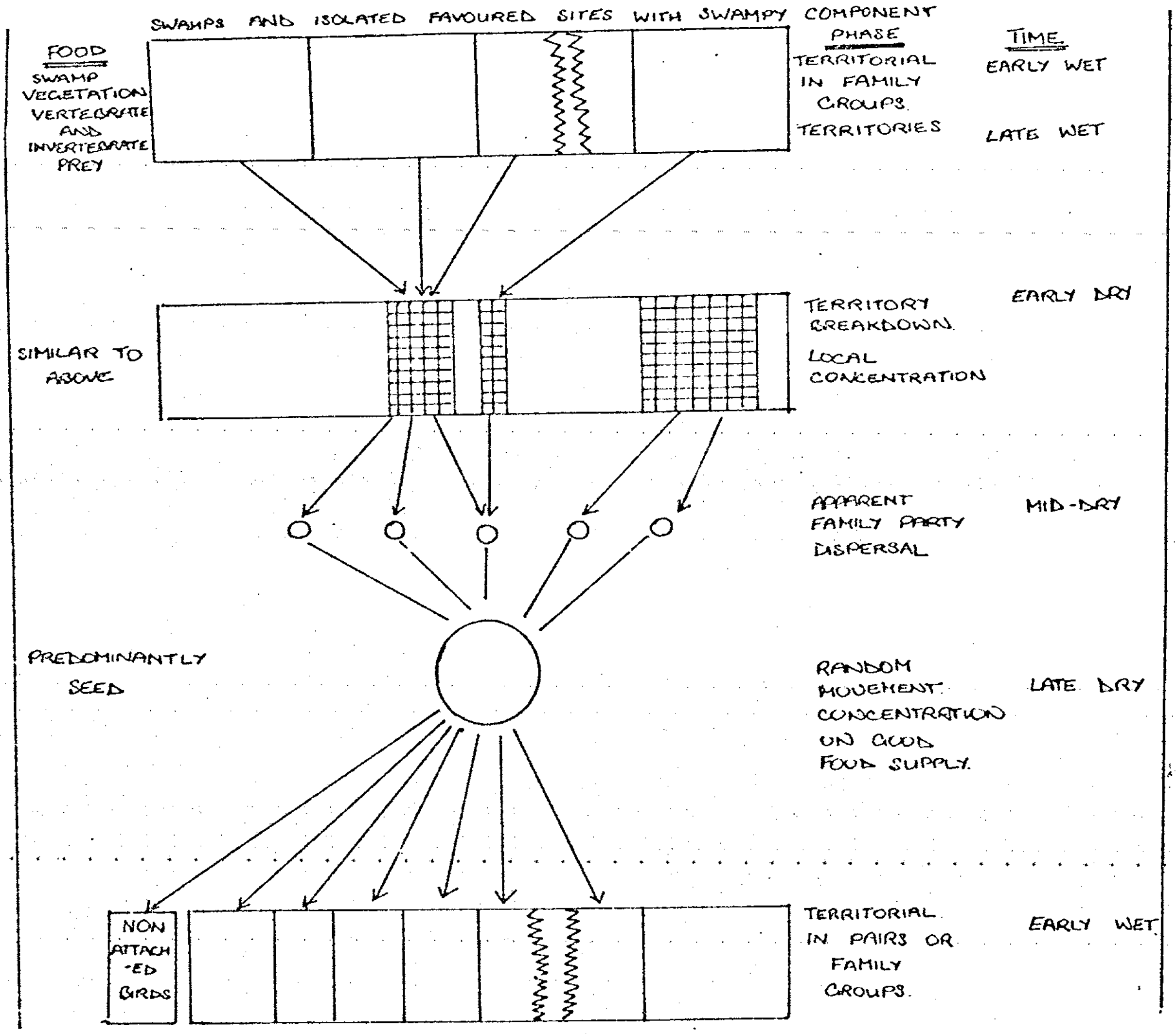


Fig. 2.20 A model showing the relationship between brolga population organization, food and seasonality (from work in collaboration with G. Archibald and after Lavery and Blackman (1969)).



a general picture of the galah population organisation for the East Kimberley (figure 2.18).

The model of population organisation (figure 2.18) suggests a possible reason for the failure of the galah to become an agricultural pest. The observed period of post-breeding flocking corresponded with the time of greatest range feed availability. Thus, although some galahs found their way onto the farm at this time, the population as a whole was not under any pressure to seek out and utilize un-natural food sources. This situation was in contrast to that in the south-west of Australia (Rowley, 1974, and pers. comm.) where wheat maturation, a range food shortage, and galah flocking, all coincide.

The interesting question of why the galah breed on the regular annual grass seed crop and not on the perennial grass seed crop, as the little corella do, remains unanswered by this study. The obvious suggestion of competition for nest sites with the closely related little corella can be eliminated as the two species use different tree species in different locations for nesting.

2.5 Brolga

The only available literature on the ecology and behaviour of brolga (Lavery and Blackman, 1969) originates from the Townsville (Queensland) area. However, during the course of this study the author worked with Dr. G. Archibald of the World Crane Trust, who was collecting both data and live animals for his studies of the cranes of the world. From the work of Lavery and Blackman (1969), Archibald pers. comm., and data collected over the course of this study, a general picture of the biology of the brolga can be presented.

Brolga numbers on Hooker farm and in the valley generally showed a seasonal pattern (figure 2.19). This pattern was consistent with the general model of brolga population organization developed (figure 2.20).

The brolga shows a switching type of social organisation which alternates seasonally between a predominantly territorial phase and a gregarious phase (figure 2.20). In common with most of the world's cranes, this switching is accompanied by a change in diet (Archibauld pers. comm.) in which a grain-based diet can replace an almost exclusively carnivorous one. The brolga problem in the Ord development was related to these changes in the brolga population, in that during the gregarious phase of the population cycle, birds at times attacked grain crops.

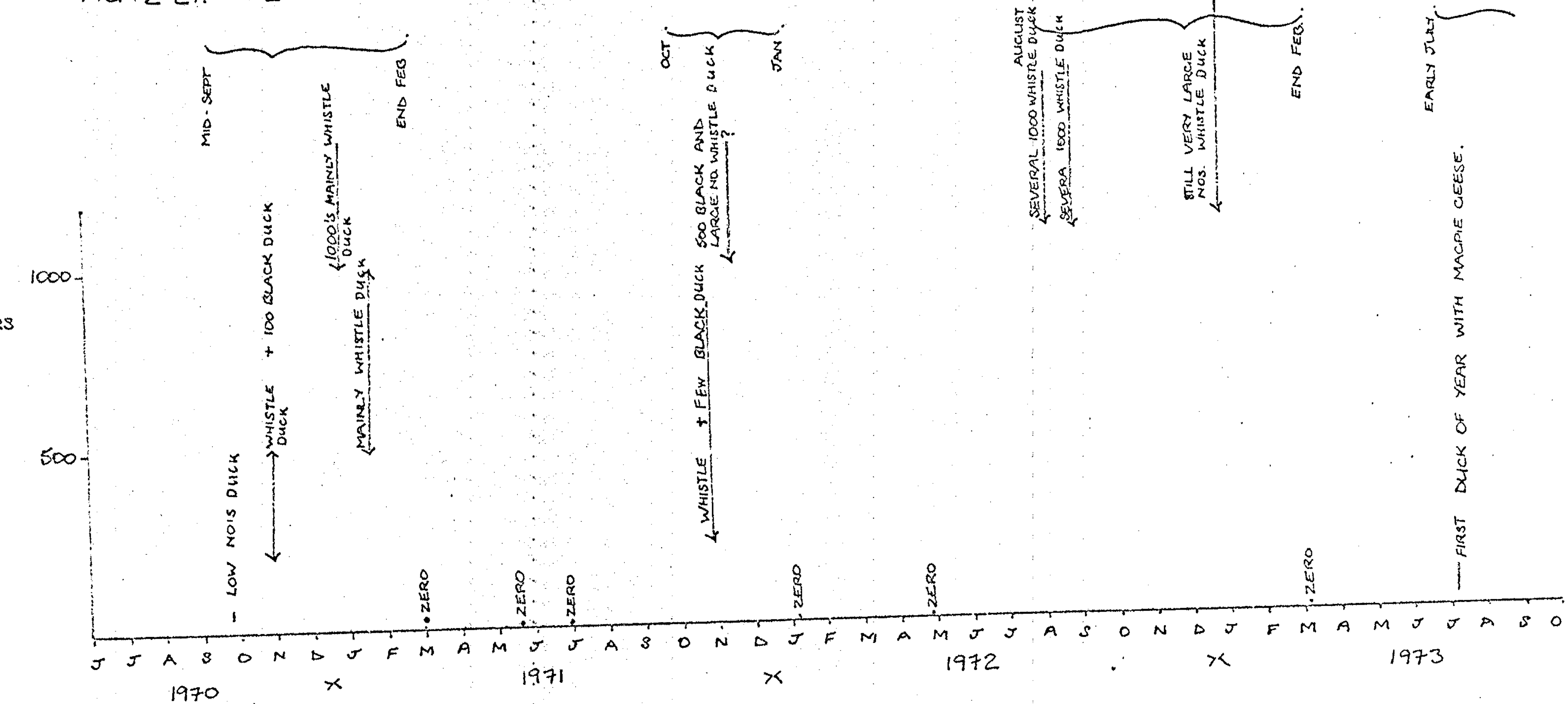
2.6 Duck

The Anatidae have as a group been the subject of a considerable research effort in Australia. This pioneering work in the south-east, summarised by Frith (1967), focused on the general biology and ecological adaptations for breeding in a wide range of species. More recent work by Frith's group has focused on reproduction in assemblages of species in specific habitats (Braithwaite, 1975; Braithwaite, 1976). Much of this work has been south of the Tropic of Capricorn; however, a little is known of the breeding biology of some north Australian ducks (Braithwaite, 1976).

Relative changes in the duck population on Hooker farm occurred on a seasonal basis throughout the study (figure 2.21). The major species involved numerically were the whistle ducks (*Dendrocygna* spp.). Of the two species of whistle duck, the grass whistle duck (*Dendrocygna eytoni*, Eyton, 1838) was by far the more prominant, with the water whistle duck (*Dendrocygna arcuata*, Horsfield, 1837) being an occasional farm visitor.

The changes in the farm population were consistent with what was known of the biology of the species. The increase in numbers in the second half of the dry season was almost certainly refuging occasioned by the contraction of seasonal swamps. The higher incidence of grass whistle duck

FIG 2.21. ESTIMATES OF DUCKS VISITING HOOKER FARM.



at this time was consistent with the species' preference for terrestrial feeding (Frith, 1967). The mid to late wet season decline in numbers corresponded with the expected breeding dispersal of both species onto seasonal swamps (Braithwaite, 1976).

Compared with magpie geese, there was no definite increase in the peak duck population over the course of the study. The future situation, however, cannot be accurately predicted. It will depend to a large extent on whether the species adapt to breeding on the new wet lands produced by lakes Kununurra and Argyle. Of secondary importance is the type of grain crops grown in the valley. Dry season rice growing on a small scale could accentuate what was for grain sorghum a relatively insignificant problem.

2.7 Conclusion

In terms of impact and management, adaptations to seasonality were the most important aspects of the biology of Ord river avian pests. These adaptations, coupled with the practice of dry season grain crop growing, were the major determinants of the Ord valley's bird pest problem in relation to agriculture.

A knowledge of the annual patterns of the agriculturally significant birds, together with a detailed knowledge of their local behaviour, provide a basis for an objective assessment of each species' impact and its management. This will be the subject of the next two chapters.

3.0 The impact of birds on agriculture in the Ord development

3.1 Introduction

(a) General

During the course of this study, Hooker farm was the site of the only significant grain growing in the Ord development. The remainder of the development was almost exclusively used for the growing of cotton. Thus, all the effective bird damage to grain crops was concentrated on Hooker farm. As the total Hooker farm productivity exceeded total bird damage, and there appeared to be no biological factor restraining access by birds to the farm area, it can be assumed that total damage measured on Hooker farm was a measure of the total actual damage which would be experienced by the Ord development irrespective of the total area of grain cropping.

The measurement of agricultural damage by birds has in the past proved difficult[1]. Conditions which existed on Hooker farm throughout this study made it impossible to directly assess bird damage as the difference between expected and actual grain sorghum production. The major contributing factors to this were the uncertainty of commercial yields, the propensity of the birds to feed on low yield areas of crop, the multi-species (birds and invertebrates) nature of most damage, and the distribution of damage over several crops all at different stages of development. This resulted in the adoption of indirect methods of overall impact assessment.

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1 Appendix IV gives a short review of this problem and lists relevant literature. Readers interested in these problems should consult this appendix; however, it is not essential for the remainder of this chapter.

The indirect method used to assess the impact of primary agricultural pests in this study had two estimates as its basis. The first of these was the number of bird-days[1] per month for each species; the second was the estimated grain sorghum intake per day by each species. These two estimates were multiplied to estimate the potential impact (in terms of grain removal) for each species for each month. This was regarded as being the maximum possible damage the species could do for the month.

The actual impact was estimated by considering the maximum possible damage and adjusting the monthly figure in the light of a range of other data sources. These included direct observations of farm feeding and damage, together with reports of current damage as perceived by others. These methods will be fully developed in section 3.4.

Once an estimate of actual damage had been made, it was possible to consider the impact of birds in terms of whole farm production and the economics of the whole farm enterprise. This has been done (section 3.6) using as a basis the agronomic and economic results obtained by other members of the university research team.

(b) Bird pest categories

Early in this study it was possible to divide bird species into four categories of primary, secondary, & tertiary agricultural pests, and others which had no such status. Primary agricultural pests were the little corella and magpie geese, which did measurable damage to grain crops on a regular basis. Secondary agricultural pests were galah, brolga and ducks, which did occasional damage to grain crops or farm equipment but were economically insignificant during this study. They could possibly gain in significance in the future. Tertiary agricultural pests did no damage to Hooker

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1 Bird-days are calaculated as the number of birds present multiplied by the number of days they were present.

farm grain crops. They were, however, regular farm visitors and in some cases had been regarded as pests either in the area or outside it. Data on these species were recorded to give a base line for future reference and a basis for the human health and civil aviation studies which formed part of the project.

3.2 The estimation of the daily grain sorghum intake of little corella and magpie geese

The estimation of the nutritional requirements, and hence grain intake, of a species of granivorous bird living in the wild has not been achieved with any precision to date.[1] The approach adopted in this study was to estimate intake by as many direct and indirect methods as possible. These estimates were made independently and then compared. The degree to which independent estimates were similar was regarded as a basis for establishing confidence in the final figure used for estimated intake. The final intake used was obtained by averaging the various independent estimates.

The various methods used for estimating the daily intake of little corella and magpie geese are given below.

(1) Post-mortem crop weights

Regular collections were made of little corella from the static super-flock. The examination of the crop contents of these birds showed grain sorghum to be the only source of food in over 90 percent of cases. As little

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1 Weins and Dyer (1975) have attempted to do this. Their work, which represents the current state of the art, is based upon extrapolations from basic metabolic energy requirements only.

TABLE 3.1 Weight of grain sorghum recovered from little corella crops post-farm feeding

No. of birds in collection	Total corrected 14 percent moisture contents weight	Percent full[1] rating of crops	Mean corrected full crop weight
4	114 g	100	28.5 g
5	227 g	100	45.4 g
5	170.1 g	100	34 g
5	141.8 g	100	28.4 g
3	113.4 g	100	37.8 g
5	113.4 g	100 (?)	22.7 g
5	198.5 g	100	39.7 g
2	54.9 g	70	39.2 g
6	145.5 g	95	25.5 g
9	140.8 g	66.7	23.5 g
7	109.7 g	51.7	30.3 g
5	99.3 g	62.8	31.6 g
6	130 g	63.3	34.2 g
11	130.5 g	55	21.6 g

Corrected individual full crop mean = 32 g range 24 - 39 g

Assessed intake (mean crop weight + 66 percent of mean crop weight)

= 52 g

1 These are visual assessments of the degree of crop fullness at the time of shooting. This was done to enlarge the sample size, as little corella were almost impossible to shoot at the time when crops were full. The mean crop weight for the 27 full crop birds collected was 34 g.

corella in the static super-flock only fed once a day (see Chapter 2), and early morning collections of birds before feeding showed their crops, proventriculi , gizzards and small intestine to be effectively empty, it was assumed that the crop and gut grain sorghum contents of birds collected after farm feeding would provide a measure of their grain sorghum intake.

During the study, 78 crops were collected from birds shot at the end of a farm feeding period. The mean grain sorghum[1] contents of these crops was determined and corrected to a full crop basis (Table 3.1).

Early in the study the volumetric relationship between crop contents and lower gut contents was visually assessed for 38 post-feeding little corella.[2] As a result of this assessment the total daily intake was set at mean crop contents plus 66 percent of crop contents. Subsequently this semi-quantitative correction was checked. Eleven alimentary tracts (without crops) were removed from little corella after farm feeding and fixed in 10 percent formalin; subsequently they were oven-dried, all tissue was removed, and the contents weighed.[3] The mean 14 percent moisture weight of the alimentary tract contents was 15 g, about 50 percent of the mean crop contents weight (Table 3.1).

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1 14 percent moisture is the harvestable moisture content of grain sorghum. It has been used as a standard figure in Anderson *et al* (1973) and will be used as a standard in this study.

2 This was done by John Le Gay Brereton and the author.

3 The dry matter weight of endogenous secretions has been ignored.

As no allowance could be made for material absorbed from the gut during the one-hour-plus between the start of feeding and the collection of specimens, it was felt that the original 66 percent correction could be retained as a reasonable estimate.

Table 3.1 gives the 14 percent moisture full crop weights for the 78 little corella collected. The mean and range for these have been calculated and adjusted by 66 percent to give estimated intake by this method.

For reasons given in Chapter 1, no routine magpie goose collections were made in the study. One bird with a full crop of grain sorghum was collected to confirm grain sorghum feeding early in the study. This crop contained 121 g of grain which, if the 66 percent correction used for little corella is utilised, gives an intake of 199g.

(2) Grain sorghum intake of magpie geese and little corella estimated from energetic criteria

The energy requirements of a free living bird are composed of the basal or existence metabolism of the bird, plus the energy required for specialised activities such as flight and reproduction, plus the energy stored as lipids. In the case of little corella and magpie geese feeding on Hooker farm, energy requirements were considered necessary for existence and flight only.

There is a considerable literature on the energy need of birds for maintenance. The three expressions selected as most relevant for use in this study were as follows:

$$Hb \text{ (Kcal/day)} = 78.3 \; m^{0.723}$$

where m is mass in kilograms

(Lasiewski and Dawson, 1967)

$$\text{E.M. (Kcal/day)} = 0.5404\ w^{0.7545}$$

where w is weight in grams

(Kendeigh, 1970)

$$Pi_B \text{ (Watts)} = 3.73\ m^{0.723}$$

where m is mass in kilograms
and Pi_B is basal metabolic rate
(Tucker, 1973, modification of
Lasiewski and Dawson, 1967)

As the mean body weights of male and female little corella and magpie geese were known, it was a comparatively simple matter to calculate the daily basal energy needs for the two species.

The energy requirements for flight in birds also has a considerable literature. Kokshaiski (1970) has used a regression technique to calculate the energy requirements for flight in a range of organisms from insects to large birds. He has advanced a basic equation in which weight (w) in grams is the only variable:

$$\text{P cals/hour} = 84.5\ w^{1.015}$$

More recently, Tucker (1973) has developed a detailed set of equations for birds. The Tucker equations outlined below are the result of considerable experimental work by Tucker and they build on a theory of bird flight outlined by Pennycuick (1969). The Tucker (1973) equations are for M.K.S. units:

$$P_i = 1.11 [(2(mg)^2 \cdot ((\pi \rho b^2 R' V) + 1.96\ A_0 V^{5/2})^{-1}) \cdot ((1 + F m^{1/3} c V^c) \cdot (E + Pi_B)^{-1})]$$

where
- m = mass of bird
- ρ = air density
- b = wing span
- R' = correction factor for induced power
- V = flight velocity

A_0 = wing equivalent flat plate area
$C \approx -0.5$
$F \approx 1.8$
g = acceleration due to gravity

and the following approximations can be used:

$$b = 1.1\ m^{1/3}$$
$$Ao = 0.00334\ m^{0.66}$$

passerine $Pi_B = 6.15\ m^{0.729}$

non-passerine $Pi_B = 3.73\ m^{0.724}$

To cover the situation where several of the parameters used in the above are unknown, Tucker (1973) has developed a series of equations which give an approximation of Pi and use only mass or mass and wing span. These are:

(i) If mass only is known:

$$Pi = WV\ (0.927\ w^{-0.20})$$

where $W = mg$
$V = 14.6\ m^{0.20}$

The Pi values estimated from this expression deviated up to 10 percent from measured values.

(ii) If both mass (m) and wing span (b) are known, estimates of Pi with a known range of accuracy of 5 percent can be calculated as follows:

(a) If $b = 1.1\ m^{1/3}$ $\quad Pi = 84.7\ m$
(b) If $b \quad 1.1\ m^{1/3} + 0.2(1.1\ m^{1/3})$ $\quad Pi = 67.3\ m$
(c) If $b \quad 1.1\ m^{1/3} - 0.2(1.1\ m^{1/3})$ $\quad Pi = 113\ m$

Tucker (1973) has also developed equations for estimating the most efficient, least energy used, flight speed for the wing span criteria given above; these are:

(a) $V = 14.6\ m^{0.20}$
(b) $V = 13.1\ m^{0.21}$
(c) $V = 16.7\ m^{0.20}$

TABLE 3.2 Body weights and wing spans for little corella and magpie geese

	Little corella		Magpie goose	
	Male	Female	Male	Female
Wing span	0.864 m[1]	0.787 m[1]	1.549 m[3]	1.430 m[3]
Body weight	0.580 kg[2]	0.508 kg[2]	2.766 kg[3]	2.071 kg[3]

1 Watters, pers. comm.

2 117 and 140 specimens used to give means

3 Frith (1967)

TABLE 3.3 Calculated grain sorghum requirement for little corella and magpie geese engaged in different activites

Authority	Activity as described by authority	Basic equation	Range of grain sorghum required			
			Male corella	Female corella	Male magpie goose	Female magpie goose
Lasiewski and Dawson (1967)	non-flight	$Hb = 78.3\ m^{0.723}$ K cals/day	17.6 - 18.0 g/day	14.6 - 15.5 g/day	49.5 - 52.7 g/day	40.2 - 42.8 g/day
Kendeigh (1970)	existence metabolism	$0.5404\ w^{0.7545}$ K cals/day	19.5 - 21.2 g./day	18.1 - 19.2 g/day	64.7 - 68.9 g/day	52.0 - 55.4 g/day
Lasiewski and Dawson (1967) modified by Tucker (1973)	basal metabolism	$Pi_B = 3.73m^{0.723}$ watts	15.7 - 16.8 g/day	14.3 - 15.3 g/day	48.7 - 51.8 g/day	39.5 - 42.1 g/day
Kok~~s~~haiski (1970)	flight	$P = 84.5\ w^{1.015}$ cals/hour	16.3 - 17.4 g/hour	14.3 - 15.3 g/hour	79.8 - 84.9 g/hour	59.5 - 63.3 g/hour
Tucker (1973)	flight	$Pi = 84.7m$ watts	12.8 - 13.6 g/hour	11.3 - 12 g/hour	61 - 65 g/hour	46 - 49 g/hour

TABLE 3.4 Ranges [1] of grain sorghum requirements for flight and maintenance

		Flight (gm/hr)	Maintenance (gms/hr)
Corella	♂	13 - 17	0.65 - 0.88
	♀	11 - 15	0.58 - 0.79
	Mean	12 - 16	0.62 - 0.84
Magpie geese	♂	61 - 85	2.03 - 2.87
	♀	46 - 63	1.65 - 2.31
	Mean	54 - 74	1.84 - 2.59

1 Derived from calculated ranges all authorities Table 3.3. Maximum and minimum for each activity has been taken.

The body weights and wing spans for male and female little corella and magpie geese are given in Table 3.2. In both cases, the birds are in the (a) category above, so power for flight is given by:

$$Pi = 84.7 \text{ m} \quad \text{watts}$$

and most efficient flight speed by:

$$V = 14.6 \text{ m}^{0.20} \quad \text{m/sec.}$$

The various estimates of energy requirement for flight and rest detailed in the above section were each in turn used to estimate the energy requirements for rest and flight of little corella and magpie geese. These energy values in kilo-calories were converted to grams of grain sorghum using the recognised range of metabolisable energy values for grain sorghum used as bird feed (i.e. 3.1 to 3.3 Kcals/g. National Research Council, 1971). Table 3.3 gives the results of these calculations as grams of grain sorghum per day for non-flight, and grams of grain sorghum per hour for flight. The ranges are given by the upper and lower end of the range of metabolisable energy for grain sorghum being used.

As no criteria existed for distinguishing between the values of the different estimates given in Table 3.3, the range of estimates for each sex category was taken for each species and expressed on an hourly basis (Table 3.4). These values were rounded, as there was no evidence for population sex ratios deviating from one, and an average taken (Table 3.4). Thus for both species daily grain sorghum requirements could be estimated if the day could be divided into hours of flight and non-flight.

From observational data, it was possible to estimate the linear distance flown by the average little corella and magpie goose for the times when they were in the farm feeding flock. Maximum and minimum values were calculated in each case, and these were then doubled to allow for the large amount of extra flying done by both species. The most efficient flight speed equation of Tucker (1973) given above

TABLE 3.5 Little corella and magpie geese flown distance and flying times for wet and dry seasons

	Flown distance (Km)			Time range at most efficient speed (hrs)	Flown Distance (Km)			Time range at most efficient speed (hrs)
	Minimum wet season	Maximum wet season	Range for calculation[1]		Minimum dry season	Maximum dry season	Range for calculation[1]	
Little corella	19.1	38.8	40 - 78	0.86 - 1.68	14.7	38.5	30 - 77	0.64 - 1.65
Magpie geese	4.4	22.0	9 - 44	0.14 - 0.70	Not present	-	-	-

1 Range has been set at twice the estimated linear distance. This allows for the large amount of cycling flying done (especially by little corella). These ranges are probably underestimates for little corella and could be over-estimates for magpie geese. The magpie goose situation is complicated by the species' propensity to fly at night.

TABLE 3.6 Calculated ranges of grain sorghum requirements of little corella and magpie geese based on metabolic criteria only

	Hours of flight [2]	Grain for flight [1] (gms)	Hours other [2]	Grain for maintenance [1] (gms)	Total (gms/day)	Mean
Little corella	0.64 - 1.68	L 7.68 - 20.16 U 10.24 - 26.88	23.36 - 22.32	L 14.48 - 13.84 U 19.62 - 18.75	22.16 - 34.0 29.86 - 45.63	32.9 g/day
Magpie geese	0.14 - 0.70	L 7.56 - 37.8 U 10.36 - 51.8	23.86 - 23.30	L 43.90 - 42.87 U 62.51 - 60.35	51.46 - 80.67 72.87 - 112.15	79.5 g/day

1 Both lower range (L) and upper range (U) are given. These are for the lower and upper ranges of grain sorghum requirements already calculated (figure 3.4).

2 From figure 3.5 range of values.

TABLE 3.7 Summary of some recent literature on body weight, feed intake and conversion efficiency of domestic geese and other poultry

Breed	Age[1]	Period of trial	Body wt.[2]	Daily Intake	Conversion	Nutritional plane 6	Source
Geese domestic	7 M	30 days	3324 g	272 g	8.4	+++	Petrovic (1966)
Geese laying Rhenish	?	2 years	-	186 → 203 g	-	+	Luhmann (1969)
Geese Rhine	0 → 2M	2 months	2320 (3)→ 4341	375 g (3)→ 246	3.58 (3)→ 3.40	+++	Pudsky & Lautner (1972)
Geese Landers	0 → 2M	8 weeks	4263 g	204 g	2.68	+++	Yamani, Marai & Szabo (1973)
Geese Italian	0 → 2M	8 weeks	4354 g	167 g	2.15	+++	Yamani, Marai & Szabo (1973)
Geese laying domestic	old	long period	probably 5000	300 g	-	+	Sloan (1953)
Geese (4) domestic	0 → 4 w	-	2450 g	126 g	1.44	+++	Ewing (no date)
Geese domestic	0 → 4 w	4 weeks	4240 g	144 (3)→ 180 g	-	+++	Nitsan, Nir, Oror & Bruckental (1973)
Hens (4)	adult	-	1800 g	70 g	-	+	National Res. Council (1971)
(4) Broilers	adult	-	2500 g	87 g	-	+	National Res. Council (1971)
Laying(4) domestic duck	adult	-	3200 g	250g → 300g	-	+	Serigar pers. comm.
domestic(4) turkey	9w → 11w	-	2750 g	180g → 200g	-	+++	National Res. Council (1971)

1 M = months; w = weeks
2 If very fast fattening of old geese, start weight is used, otherwise final weight or range is used.
3. Response for range of diets.
4 General figures from standard reference; summary of very large numbers of trials
5 Nutritional plane: +++ very fast fattening, ++ fattening, + maintenance

TABLE 3.8 Estimated daily intake of grain sorghum by little corella and magpie geese using transferred domestic poultry intake data

	Little corella		Magpie goose	
	Adult male	Adult female	Adult male	Adult female
	40 g	36 g	164 g	133 g
Mean	38		149	

was then used to estimate the range hours of flight for each species. The results of these calculations are given in Table 3.5.

The results obtained in Table 3.4 and Table 3.5 were combined to give Table 3.6, which gives the ranges and medians for estimated grain sorghum intake for both species.

(3) Estimated intake of grain sorghum for little corella and magpie goose, based on transformations of data from comparable domestic avian species

With the exception of one paper on North American wild geese (see next section), there is no information available on the daily intake of grain under controlled conditions for species of wild birds similar in size to the two species of concern here. There are however considerable data on the nutritional requirements of domestic poultry (ducks, geese, turkeys and fowls). From an extensive review of this literature, Table 3.7 was drawn up. The criteria for inclusion in this table were one of the following: low growth rates, range conditions, or a review of many references.

The well-established relationship that intake is proportional to body weight raised to the power of 0.723 was used. Constants could be calculated for mean body weights and intakes from Table 3.7 by using the expression

$$\text{Constant (K)} = \frac{\text{mean intake (g)}}{(\text{weight (Kg)})^{0.723}}$$

The constant for all geese in Table 3.7 was 78 and for all non-anserines the constant was 59. The constants were then applied to magpie geese and little corella to give estimates of intake for the two species (Table 3.8).

TABLE 3.9 Estimation of mean body weight of geese used by McFarland and George (1968)

Species	Number in experimental group	Weight of typical female (Lack, 1968)	Total weight
Canada goose	3	5000 g	15,000
Cackling goose	2	1280 g	2,560
Lesser snow goose	5	1700 g	8,500
White fronted goose	2	2180 g	4,360
Total	12		30,420

Mean body weight of "trial goose" 2,535 g

(4) Estimated grain sorghum intake by transforming data from comparable species of wild life

As mentioned above, only one paper - that of McFarland and George (1966) - satisfies these criteria. This paper reported the results of a 49 day cafeteria trial using several species of wild goose. The mean intake for each goose was reported as 182 g per day of grain. As no body weight data were provided in McFarland and George (1966) the mean weight was estimated, using Lack's (1968) data for typical female body weights (Table 3.9).

A similar procedure to that in section (3) was then followed to get an estimate of magpie goose intake corrected for metabolic size. The values for magpie goose males and females were 194 g and 157 g of grain sorghum per day.

(5) Estimated grain sorghum intake by little corella and magpie geese using a direct measurement of grain eaten over a known number of bird-days

Only twice during the course of this study was it possible to measure grain sorghum loss to birds by direct yield reduction. Fortunately, magpie geese were solely involved in the first instance, and little corella were solely involved in the second. In both cases, it was possible to estimate the number of bird days involved in the damage measured, and this allowed the individual daily intake of little corella and magpie geese to be directly estimated.

(a) Estimation of magpie goose daily intake

On 9/10/1971 part of a variety trial was lodged by high winds. Magpie geese fed on the most severely lodged parts of the trial on the 18/10/71 and 19/10/71. On the 20/10/71 the geese were chased from the trial after about one hour's feeding. An armed "goose patrol" was then maintained which ensured that no more grain was lost from the

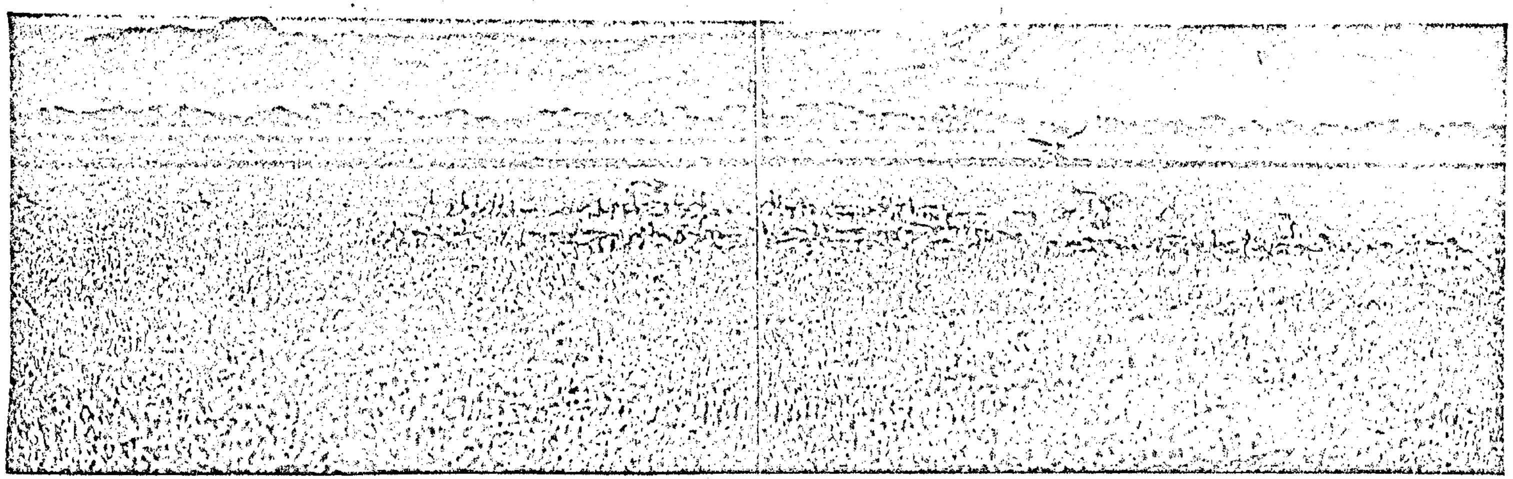

Fig. 3.1 Continued

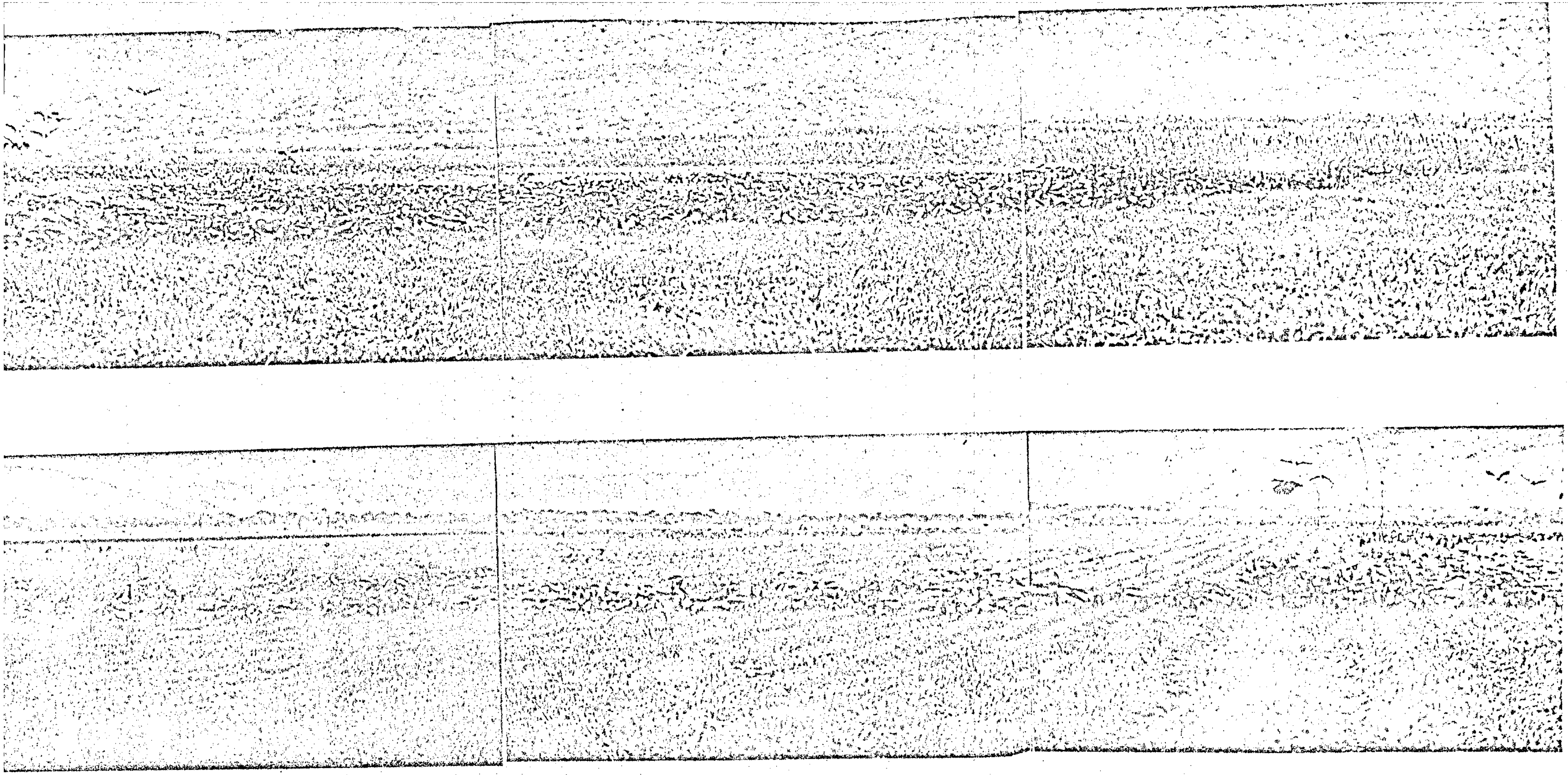

Fig. 3.1 Sequence of photos showing part of a flock of 14,000 magpie geese feeding in a re-cycled sorghum crop on Hooker farm. The tendency of the birds to aggregate in dense groups is evident.

TABLE 3.10 Grain sorghum losses to magpie geese, 18th to 20th October, 1971

Variety	% Plot area where goose damage apparent [1]	Grain losses (kg/ha) inferred from rest of plot yield	Grain withdrawal from experimental plot	Rate of lodging [2]
E55e	9	348	1,002	3
Texas 610	1	36	104	4
NK 212	9	321	812	4
Texas 626	9	294	812	4
E65	55	170	449	4
E57	0	0	0	0
X 241	6	134	429	1

Total loss: 3,608 Kg.

1 Plot sizes 0.59 ha to 0.65 ha.

2 Rate of lodging scale 0 - 5
0 = no lodging
1 = little lodging
2 = moderate lodging
3 = about 50% lodged
4 = greater proportion of crop badly lodged
5 = all crop within 250 mm of ground

trial to birds of any sort.

Overall, the magpie geese had fed on the trial for 6 to 10 hours. From subsequent observations, this represented about 2 to 2½ daily farm feeding periods. Estimates were made by block counting of the number of magpie geese feeding on the farm immediately after the damage occurred, and the population was estimated at 14,000 birds. Figure 3.1 shows part of the magpie goose flock involved on 6/11/71.

The variety trial was harvested on 23/10/71. As the trial was of considerable value to the university team, great care was taken with harvesting; damaged and undamaged heads were harvested and the areas, yields, and grain moisture measured accurately. Table 3.10 was prepared by W. K. Anderson (the university team leader, and senior agronomist); it gives the best possible estimate of total grain loss to magpie geese for the 2 to 2½ days of crop feeding.

The daily intake of grain sorghum can now be estimated by dividing the total loss of grain sorghum, 3608 kg, by the estimated number of bird-days, 28,000 or 35,000, depending on whether 2 or 2½ days of feeding are used. This gives an estimated range of grain sorghum intake of 103 g to 129 g.

(b) Estimation of little corella daily intake

Early in April 1972, the Hooker farm little corella flock was exclusively feeding on a stubble field. On about 8/4/72, this field was flood-irrigated. This resulted in the stubble grain on which the little corella were feeding being destroyed. The flock immediately started to feed on a 124 ha dry land crop in bays J, K and L (figure 1.3). This crop remained the only source of on-farm little corella food until it was harvested on 8/5/72.

Just before harvest, damage to the crop was assessed by the two university agronomists and the author. From walked transects through the crop it was estimated that 15 percent

TABLE 3.11 Estimated individual grain sorghum intake derived by different methods for magpie geese and little corella

(Values in parentheses give range where applicable)

Source	Table 3.1	Table 3.6	Table 3.8	Section 4	Section 5		
Species	Crop weights	Energetic considerations	Transformed poultry data	Transformed wild life data	Crop removal direct measure	Intake used	Range for all calculations[1]
Little corella	53 g/day (40.3 - 64.4)	32.9 g/day (22 - 46)	38 g/day (36 - 40)	-	64 g/day	51 g	22 g - 64g
Magpie geese	199 g/day	79.5 g/day (52 - 113)	149 g/day (133 - 164)	157 g/day	116 g/day (103 - 129)	136 g	52g - 199g

1 This is the extreme range over all estimates made in the study. The author is certain that daily intake is within this range.

of all heads had been eaten by the little corella. The yield of the crop, estimated at approximately 1,430 kg/ha, was crudely checked at harvest by counting the truck loads of grain removed from the field. (This was the only measure possible under the existing farm conditions.) The overall expected harvest of about 150 tonnes was obtained. From these data, the loss of grain sorghum to little corella was approximately 26,600 kg. No shooting was occurring on the farm at the time, and the crop feeding little corella had been the subject of careful observation. The recorded data strongly suggest that almost all of the grain lost was eaten by little corella.

The trend in little corella numbers over the period was:

9/4/72	7,000
16/4/72	7,000
25/4/72	17,000
8/5/72	17,000

If the rapid increase in numbers between 16/4/72 and 25/4/72 is assumed to be a linear increase, the number of bird days of crop feeding would be approximately 417,000. This gives an estimated grain sorghum intake of 64 g per bird day.

(6) Summary

The mean values for the various estimates of grain sorghum intake, together with ranges (where applicable) are given in Table 3.11. The most striking feature of these results is the degree of over-lap between the various independent assessments made for both species. This was surprising, considering the limitations of each estimate. These considerations formed the basis for the estimated intake finally used in the study. This figure was calculated as a weighted average. The intake estimate for little corella based on crop weights, and the estimate of intake based on

TABLE 3.12 Maximum calculated grain sorghum intake for farm feeding little corella (Range and mean, Tonnes per month)

	1970		1971		1972		1973		Study
Month	Average corella numbers	Range and mean in tonnes	Average corella numbers	Range and mean in tonnes	Average corella numbers	Range and mean in tonnes	Average corella numbers	Range and mean in tonnes	Means
January (31 days)	birds present	?	27,000*	19 - 54 44	20,000*	14 - 40 32	24,000	17 - 48 39	16 - 47 38
February (28 days)	birds present	?	14,800*	9 - 27 22	20,600*	13 - 37 30	14,000	9 - 24 20	10 - 29 24
March (31 days)	No birds recorded	-	7,500	5 - 15 12	11,000	8 - 22 18	9,000	6 - 18 15	6 - 18 15
April (30 days)	10,000?	7 - 20 16	7,500	5 - 15 12	10,500	7 - 20 16	11,500	8 - 22 18	7 - 20 16
May (31 days)	12,000	8 - 23 19	12,000	8 - 23 19	20,000	14 - 40 32	18,700	13 - 37 30	11 - 31 25
June (30 days)	13,000	9 - 24 20	15,500	10 - 29 24	21,500	14 - 41 34	14,000	9 - 27 22	11 - 31 25
July (31 days)	14,000	10 - 28 23	12,000	8 - 23 19	9,000	6 - 18 15	8,000	6 - 16 13	8 - 22 18
August (31 days)	15,000	10 - 29 24	5,000	3 - 9 8	6,500	4 - 12 10	6,000	4 - 12 10	6 - 16 13
September (30 days)	16,000	11 - 31 25	2,500	2 - 5 4	4,000	3 - 8 6	5,000	3 - 9 8	5 - 14 11
October (31 days)	12,000	8 - 23 19	2,000	1 - 3 3	6,500	4 - 12 10			5 - 14 11
November (30 days)	15,000	10 - 28 23	6,000	4 - 11 9	10,000	7 - 20 16			7 - 20 16
December (31 days)	23,000	16 - 49 37	11,000	8 - 22 18	24,000	17 - 48 39			13 - 38 31
Year mean Total		206		194		258		175	

Assumptions:

1 Range 22g - 64g/bird day and Mean 51g/bird day from Table 3.11

2 All corella get all food from economic crop.

3 Average numbers of corella are mid-month values (see figure 2.4). In months where numbers fluctuate violently, beginning, mid and end of month figures are averaged. These months are designated by *.

4 Consumption is for the flock rounded to the nearest tonne.

TABLE 3.13 Maximum calculated grain sorghum intake for farm feeding magpie geese (Range and mean, Tonnes per month)

Month	1970		1971		1972		1973		Study
	Average number	Range and mean consumption	Average number	Range and mean consumption	Average number	Range and mean consumption	Average number	Range and mean consumption	Means
January	?		500	1 - 3 2	1000	2 - 6 4	9000	15 - 54 38	
February (28 days)	?		100	-	0	-	4000	6 - 22 15	
March	?		0	-	0	-	0	-	
April (30 days)	?		0	-	0	-	0	-	
May	2500	4 - 15 10	0	-	0	-	0	-	
June (30 days)	100's	-	100	-	0	-	1500	2 - 9 6	
July	?	-	1500	2 - 9 6	700	1 - 4 3	2500	4 - 15 10	
August	?	-	3500	6 - 21 15	3000	5 - 18 13	4500	7 - 27 19	
September (30 days)	3500	5 - 20 14	7000	11 - 41 28	11000	17 - 64 45	10000	16 - 58 41	
October	6000	10 - 36 25	14000	23 - 84 59	31000	50 - 186 130			
November (30 days)	4500	7 - 26 18	12000	19 - 70 49	25000	39 - 146 101			
December	1000	2 - 6 4	6000	10 - 36 25	15000	24 - 90 63			
Year mean total		71		184		359			

Assumptions:
1. Numbers are mid-month estimates (figure 2.14)
2. All magpie geese get all food from economic grain crop
3. Range is based on 52g - 199g per bird day; mean 135g/bird day (see Table 3.11)
4. Consumption is for the flock recorded to the nearest tonne
5. Study means have not been computed as numbers rising year by year

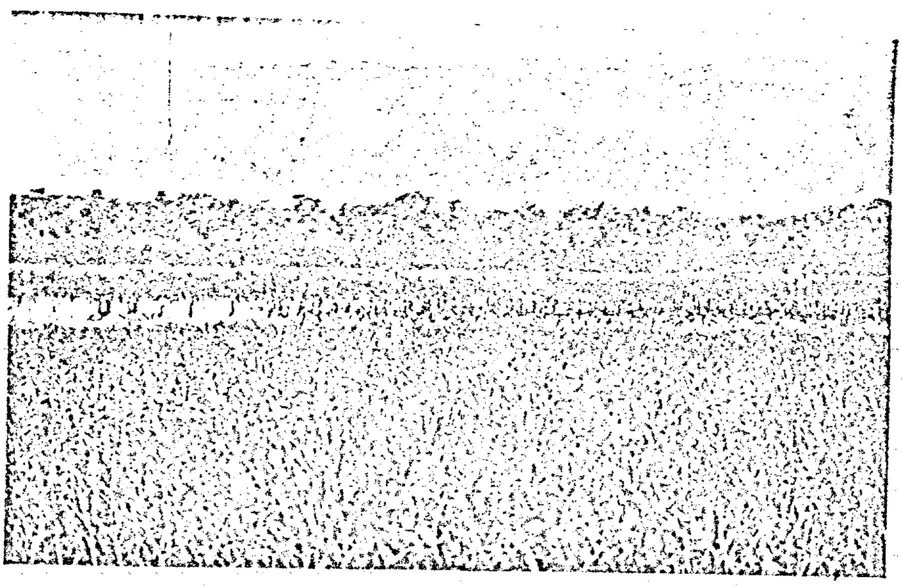

Fig. 3.2 Magpie geese in an area of "goose damaged" forage sorghum. The damaged area, showing as a light zone, will not recover, resulting in a total yield loss.

crop removed, were considered the most accurate. These were weighted by 2, and the remaining estimates by 1. The resultant average was 51 grams per day. For magpie geese, the direct crop removal measure was considered the most accurate and given a weight of 2. The remaining estimates were given a weight of 1, with the resultant average being 136 g per day.

3.3 Estimation of maximum monthly grain sorghum loss to little corella and magpie geese

Using the estimated number of farm feeding little corella (figure 2.4) and magpie geese (figure 2.14), the number of bird-days were calculated for each month for each species. They were then combined with the intake values given in Table 3.11 to give an estimated range and mean for maximum monthly grain removal from Hooker farm for both species (Tables 3.12 and 3.13).

The tables assume that the total loss of grain to both little corella and magpie geese took the form of eaten grain. This was not the absolute case for either species; occasionally, little corella could damage very young seed crops during ground maintenance by chewing off young tillers. This damage was relatively insignificant and easily controlled (see Chapter 4). It was therefore considered insignificant.

In the case of magpie geese, green plant material constituted part of the species' natural diet (Frith and Davies, 1961). Young green shoots of re-cycled grain sorghum crop were often eaten by magpie geese when the crop was being irrigated. Occasionally, severe damage could result in small areas of such crops which remained water-logged for extended periods after irrigation (figure 3.2). Losses in such cases were complete, but the areas were so limited (less than 2 ha for the 40 months of the study) that their inclusion in the overall damage estimation was not warranted.

General losses of tillers to magpie geese in other than water-logged areas would be compensated for by normal plant plasticity, and as a consequence yield would not be affected.

It is worth noting that this problem, though insignificant for grain sorghum, could be of considerable importance to any future small-scale rice growing enterprise. In this case, it is likely that real yield reductions could result from magpie goose damage.

3.4 The estimation of the actual monthly grain sorghum loss to little corella and magpie geese

In the previous section the maximum possible loss to the two species in question has been expressed as a range and mean for each month of the study. The values presented in Tables 3.12 and 3.13 only occasionally reflect the actual monthly loss to either species. Losses were generally much less than maximum, due to the operation of several factors. These were:

(i) Both species often fed on stubble grain which was of no economic value. In fact, such feeding had a positive value as it reduced the choking of irrigation furrows by volunteer sorghum plants.

(ii) Both species at times fed in, or on, forage sorghum which was grown for hay.

(iii) Little corella in particular often fed on weeds and volunteer crop growing on headlands and irrigation ditches.

(iv) Magpie geese at the start and towards the end of their annual visitation often did not feed on Hooker farm but stayed in the swamps of Lake Kununurra.

In order to adjust the estimated maximum monthly loss to an estimated actual monthly loss for each species, a range of data sources were used to provide answers to the following questions for each species:-

Date:

FIG.33 LOOKOUT WATCHES AND FARM WATCHES

Met. Obs. Cloud: Wind:

Sunrise: Workable light:

SPECIES:

FLYOUT PATHS Dam Lily Ck. West North

FEEDING ON BAY/S Crop Stage Type

If stubble: Standing Slashed

Ploughed Burnt

FEEDING STRATEGY Edge Standing edge Centre

Other

IF NOT ON CROP, GIVE DETAILS:

FLYOUT START Temperature FLYOUT END Temperature

FIRST RETURN Temperature LAST RETURN Temperature

IF WATCH TERMINATED, TIME % RETURNED

SHOOTING ON FARM Yes No Indiscriminate
Controlled

% RETURN EACH INCIDENT (Give time)

NUMBERS OF EACH SEQUENCE

MOVE BIRDS TO OTHER CROP AREA 1. Edge feeding

2. Middle feeding

MOVE BIRDS TO STUBBLE

MOVE BIRDS TO BARE GROUND 1. Return to feeding

2. Return to river (dam)

MOVE BIRDS TO TREES 1. Return to feeding

2. Return to river (dam)

VARIATION FROM ABOVE

OTHER CONTROL TRIALS (Details)

ANY OTHER OBSERVATIONS

TABLE 3.14 Number of early morning watches and counts

Year	No. of watches	No. of counts	Total for Year
1970	14	11	25
1971	15	29	44
1972	26	57	83
1973	9	12	21
	64	109	

Total: 173

% of all mornings possible in 99 weeks in field: 25%

% of all mornings for 144 weeks of study: 17%

(i) How many days of crop feeding were seen, reported, or can be estimated for the month?

(ii) What specific observations of damage were available for the month? How much damage was involved in each case? Did observed damage make sense in the light of current bird populations or should some damage be extrapolated back to the previous month or months?

(iii) Did any changes occur in the weather during the month which could affect either farm operations, damage, or both?

(iv) Did the behaviour of the birds change during the month? If so, when and how did it change, and how did this affect damage?

(v) What other factors could affect damage for the month? This category often included farm management practices or the lack of them.

The data sources used to provide answers to these questions were:

(i) Routine data acquisition by the author

Table 3.14 indicates the total number of lookout watches, farm watches and farm counts carried out in this study. It indicates that the on-farm situation in terms of birds present and their source of farm food, was formally recorded on 17 percent of all mornings for the 37 months of the intensive study. Only two such records are available for the first 3 months which preceded the commencement of field work. This data was originally recorded as a written script which was subsequently transcribed to a summary sheet (figure 3.3) designed to facilitate analysis.

(ii) Random farm checks and behavioural watches

These also constituted farm visits by the author. They were as numerous as the watches and counts in (i) above, but were concerned with other aspects of the study. Such a

FIG.3.4 DAMAGE REPORTS FARMS (VALLEYS)

DATE:

LOCATION:

MAJOR SPECIES (or proportion to each)

CROP (Type, Stage, Yield, etc.)

DAMAGE DETAILS:

high farm visitation level kept the author constantly aware of the on-farm situation.

(iii) Specific damage checks

Whenever measurable damage was detected on Hooker farm by the author, other members of the university team or the farm staff, attempts were made to quantify it. This often involved other members of the university team who lent expertise in estimating variables such as expected yield, plant populations, area of crop affected, etc.

Estimates of damage were ultimately recorded on damage report sheets (figure 3.4). The damage was reduced to a quantitative estimate and the damage allocated between the species involved.

(iv) Monthly reports by university agronomists

Throughout the study regular reports were prepared by the U.N.E. team leader (W. K. Anderson) for the consortium partners and the university-based project supervisors. These reports contained the agronomists' independent assessment of the bird pest situation and as such provide an excellent chronology of the problem through other eyes. Below are the four extracts from these reports which were made before this study started.

January/February 1970 (17/3/70)

"Harvest of these experiments was not considered worthwhile. Severe weed competition from flinders grass, awnless barnyard grass (*Chionachne* sp.) and *Sesbania* sp. was in evidence. Damage was also evident from birds (mainly Corellas) and a fairly significant amount of what seemed to be high temperature abortion of the grains. The combination of these factors combined to make the estimated yield very low and uneconomic to harvest."

FIG 3·5. MONTHLY DAMAGE SUMMARY

Month:

Year: 197

CORELLA NUMBERS

ESTIMATED MAXIMUM LOSS

FEEDING SITES CROP TYPE

SPECIFIC OBSERVATIONS OF DAMAGE

WEATHER AND HUMAN FACTORS

OTHER

ESTIMATED REAL LOSS

MAGPIE GEESE NUMBERS

ESTIMATED MAXIMUM LOSS

FEEDING SITES AND CROP TYPES

SPECIFIC OBSERVATIONS OF DAMAGE

WEATHER AND HUMAN FACTORS

OTHER

ESTIMATED REAL LOSS

OTHER SPECIES (Specify with details)

March 1970 (2/4/70)

No bird observations. Rain was 36% of long term average.

April 1970 (4/5/70)

"Whilst minor damage due to aphis, spur-throated locusts and head rot is evident in the plots, the main pest nuisance has undoubtedly been birds. Whilst the numbers of birds (mainly Corellas) are extremely difficult to estimate, they are consuming a great deal of grain and destroying much more by breaking off heads and dropping them to the ground. They have attacked at least 200 Ac. on the farm and destroyed up to 75% of the heads in some parts. The birds began their feeding on about 13/4/1970 and their numbers seem to be still increasing."

May 1970 (3/6/70)

"Bird damage on the plots is not thought to be as serious as on other parts of the crop, but any delays in harvest could drastically alter this. Bird numbers show no sign of decrease, and they are tending to remain in the crop for longer periods each day."

(v) Reports by others on the farm

Reports of any instances of crop feeding or bird damage were solicited from the 15+ farm workers. These reports were used to find areas of damage (section (iii) above) and to maintain a general impression of the on-farm situation.

The various sources of data outlined above were brought together in the monthly damage summary (figure 3.5). This summary contained the numbers of each species and the estimated maximum possible grain loss for the month (from Tables 3.12 and 3.13). Farm watch reports (figure 3.3) were

TABLE 3.15 Little corella and magpie geese estimated, actual and total grain sorghum damage Hooker farm

		1970		1971		1972		1973	
		Corella	Magpie geese	Corella	Magpie geese	Corella	Magpie geese	Corella	Magpie geese
January	E			44	2	32	4	39	38
	A			38	1	20	2	15	10
	T			39		22		25	
February	E			22	0	30	0	20	15
	A			17	0	10	0	10	5
	T			17		10		15	
March	E			12	0	18	0	15	0
	A			7	0	5	0	8	0
	T			7		5		8	
April	E			12	0	16	0	18	0
	A			4	0	16	0	5	0
	T			4		16		5	
May	E			19	0	32	0	30	0
	A			5	0	25	0	7	0
	T			5		25		7	
June	E	20	0	24	1	34	0	22	6
	A	20	0	10	1	3	0	15	2
	T	20		11		3		17	
July	E	23	0	19	6	15	3	13	10
	A	10	0	12	3	3	1	10	2
		10		15		4		12	
August	E	24	0	8	15	10	13	10	19
	A	18	0	3	10	5	3	5	5
	T	18		13		8		10	
September	E	25	14	4	28	6	45	8	41
	A	7	3	2	24	1	30	3	20
	T	10		26		31		23	
October	E	19	25	3	59	10	130		
	A	5	4	2	45	3	90		
	T	9		47		93			
November	E	23	18	9	49	16	101		
	A	18	5	3	15	10	30		
	T	23		18		40			
December	E	37	4	18	25	39	63		
	A	33	1	3	10	30	10		
	T	34		13		40			
Year Total	E	171	61	194	185	258	359	175	129
	A	111	13	106	109	131	166	78	44
	T	124*		215		297		122*	

* Part year only

E Maximum possible estimate or range

A Actual estimate or range

T Total loss both species summed

Fig. 3.6 Little corella, magpie goose and overall, estimated potential and actual grain losses from Hooker farm, June 1970 to September 1973.

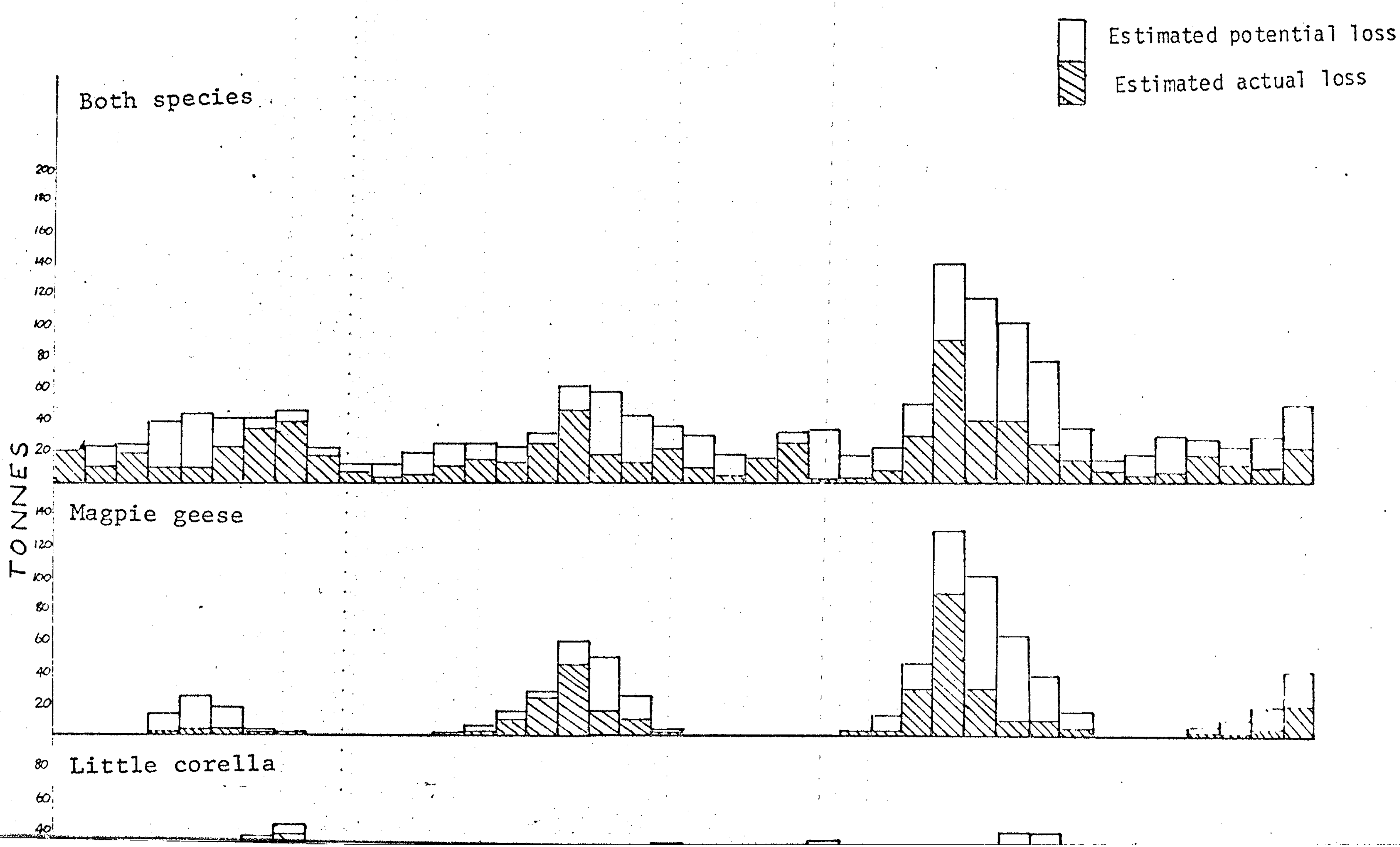

FIG. 3.7. TERTIARY PEST STATUS SUMMARY.

COMMON NAME: NAME:

APPEARANCE REGULAR ON ANNUAL BASIS:

Months present:

Numbers at peak:

Sudden build-up:

Factors involved in build-up:

IF IRREGULAR SPECIFY OBSERVATION

1.

2.

3.

4.

5.

SWAMP-FARM AXIS:

SAVANNA-FARM AXIS:

CROP FEEDING GRAIN:

CROP FEEDING NON-GRAIN (Specify):

FARM FEEDING DRAINS & CHANNELS:

FARM FEEDING OTHER (Specify):

HISTORIC RECORD OF DAMAGE:

CURRENT PEST STATUS (1970-1973) Nil Low Moderate High

POTENTIAL PEST STATUS 1. Nil Low Moderate High

2.

NOTES ON BIOLOGY

used to identify the estimated amount of crop feeding for the month; damage reports (figure 3.4) were considered to see if the ranges were realistic, and the reports of agronomists and others were considered. These variables were then combined with the author's judgement to arrive at a subjective estimate of actual economic crop damage for each species for each month. The results of this exercise are recorded in Table 3.15 and graphed in figure 3.6.[1]

The results show that the total losses to the primary bird pests for the 40 months of the study were 758 tonnes. Little corella accounted for 426 tonnes and magpie geese 332 tonnes. These values compare with estimated potential maximum losses of 1,532 tonnes, 798 tonnes and 734 tonnes for the total, little corella and magpie geese respectively.

3.5 Notes on the impact of other avian species

Throughout the study notes were kept of all birds seen on Hooker farm. Particular note was made of any activities by birds which could have even the most marginal significance either to agricultural or other problems in the valley. This section outlines very briefly the 3 secondary and 18 tertiary species, or groups, which eventually were either the subject of damage reports (figure 3.3) or a tertiary pest; status summary (figure 3.7). These species or groups are listed in order of decreasing significance.

3.5.1 Secondary pests

Two species and one group, all of which do some actual measurable damage to crops, fall into this category. Of the three, the Brolga (*Grus rubicunda*, Perry, 1810) was more damaging to grain sorghum cropping than the Galah (*Eolophus roseicapilla*, Vieillot, 1817) and various duck

1 The basic data used here, lookout watch summaries, damage summaries and monthly reports, are not included in this thesis but have been retained by the author.

species, including water whistle duck (*Dendrocygna arcuata*, Horsfield, 1837), grass whistle duck (*Dendrocygna eytoni*, Eyton, 1838), black duck (*Anas superciliosa*, Gmelin, 1789) and grey teal (*Anas gibberifrons*, Muller, 1842). Of these four species of duck, the grass whistle duck was the numerically most significant; however, mixed flocks were the most common occurrance.

3.5.1.1 Brolga

It was surprising that the brolga, although not appearing as a pest in the K.R.S. records, had the longest history as a commercial grain crop pest in the Ord valley. Interviews revealed that the brolga problem encountered by the first commercial cropping in the valley (rice on N.D.L. farm) was of such significance that two to three full-time shooters were employed to destroy or deter the birds (Black, pers. comm.).

More recently, brolga had done significant damage to a 25 ha soya bean crop (Chergwin, pers. comm.), and rendered useless (50 percent damage) a large commercial trial of grain sorghum on the Agriculture Department's block 36 (Suijendorp, pers. comm.). Brolga damage continued to occur on block 36 during the course of this study, and the most notable case was the loss of 25 percent of an 8 ha grain sorghum crop in the late dry and early wet season of 1970. The only other damage by brolga reported or seen outside Hooker farm was a 20-percent-plus loss of a 14 ha wheat crop in mid-dry season 1972 (Bedbrook, pers. comm.).

On Hooker farm, flocks of up to 1,000 brolga were common during the dry season (see Chapter 2). These birds were occasionally observed to be eating sorghum from the heads of standing crops. The most common feeding sites of brolga were however stubble areas, freshly watered bays, and harvested or rapidly growing forage sorghum crops.

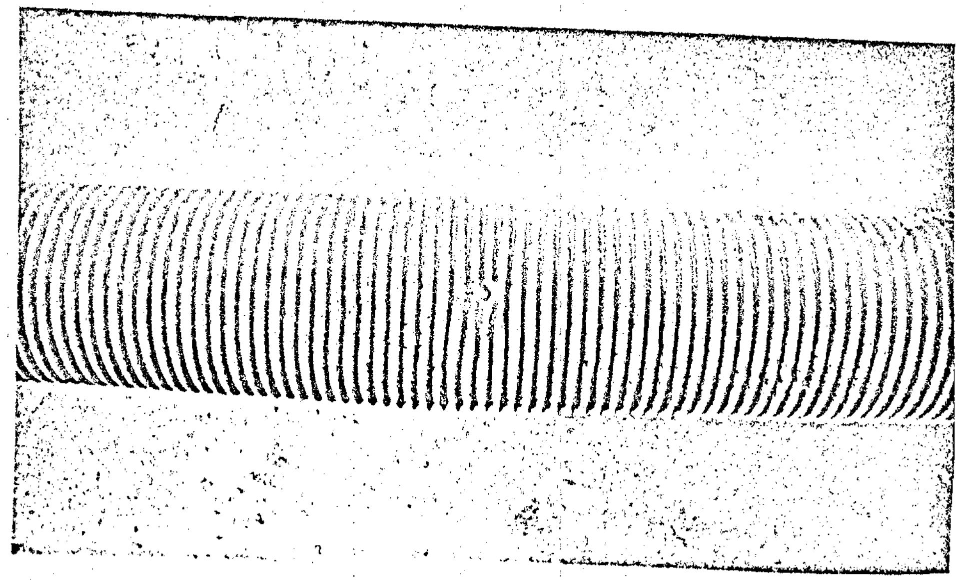

Fig. 3.8 An irrigation syphon damaged by a brolga peck. This damage renders the syphon useless.

It appears that brolga only turned to grain as a food source when animal food was lacking. Grain lying on the ground was preferred to grain in heads.

On the basis of this data, it was concluded that brolga were a relatively insignificant pest of large-scale cropping; they could, however, be significant in isolated instances.

Occasionally, displaying brolga directed ground pecking at irrigation siphons, which became holed (figure 3.8). This mainly caused ill-will between the brolga and irrigators; however, at a siphon cost of $1.50 each, the "custom" could become significant if it spreads throughout the flock.

3.5.1.2 Galah

Galahs are a significant pest of grain growing in some areas of eastern Australia. They are also apparently significant in some areas of the Northern Territory (Tipperary,(Doughton, 1971), Katherine farm (Burnes, pers. comm.)) and in south-western Australia (Rowley, pers. comm.). It was therefore surprising that galahs were at no time a significant pest of standing crops.

The only problem which galahs posed on Hooker farm occurred in the late dry of 1970 when upwards of 2,000 birds were based on the feedlot and grain silos. Most of the grain eaten by these birds was waste; however, their habit of chewing holes in plastic and weldmesh temporary silos, plus the noise they made and their ready accessibility to the office, resulted in a disproportionately large "control" effort being directed at them by the farm staff.

3.5.1.3 Ducks

Flocks of up to several thousand whistling duck, plus hundreds of the other two species, occurred on Hooker farm from time to time. These flocks were typically found on freshly irrigated slashed stubble and cut forage crops. They were frequently in association with magpie geese. There was no doubt that duck contributed to the vegetative damage referred to in the case of magpie geese (section 3.3.3 and figure 3.14). This was not very significant damage and ducks were considered to be non-significant as far as grain sorghum was concerned.

The situation on Hooker farm did not, however, apply to rice growing on the small scale which was attempted in the Ord valley. The one commercial rice crop grown in the valley during this study did suffer some damage and required all-night "duck patrols" by the farmer for protection (Oliver, pers. comm.). Not-withstanding these real problems, it is doubtful whether ducks are as significant a long-term problem as corella and magpie geese.

3.5.2 Tertiary pests

These birds were the subject of status summaries which are presented in Appendix 5 in approximate descending order of significance. It was felt that these historic data were well worth recording, as some species such as the eastern swamphen could be significant in the future. For the present, none of these species is of any direct economic significance to agriculture.

3.6 The economic impact of birds on Hooker farm and agriculture in the Ord development

The impact of birds on agricultural cropping can be measured in various ways. These are:

(i) The total physical loss, or production fore-gone.

(ii) The market value of the physical loss.

(iii) The production cost of the physical loss.

(iv) The percentage loss (physical market value, or production cost - give the same answer).

(v) The change in profitability of the enterprise caused by reduced physical productivity, or the increased variable costs due to necessary control measures.

The estimated physical losses encountered in this study allow each of these calculations to be made for Hooker farm. In addition, these losses provide a basis for calculating the likely impact of birds on any future cereal growing enterprises in the Ord valley.

3.6.1 The losses on Hooker farm

Over the 40 months of this study, the estimated total loss of grain sorghum to birds was 760 tonnes. In terms of the 1972 cost of production ($37 per tonne) this represents a value of $28,120. As no economic export market was available in 1972 (Whan, in Anderson *et al*, 1973), no market value can be put on this loss.

It is not possible to obtain an accurate assessment of total productivity on Hooker farm for the forty months of this study. However, the operation of the UNE-recommended grain sorghum production system (see Chapter 4) over a similar period would give a total grain production of 31,500 tonnes. Thus, the estimated percentage actual loss to birds was 2.41 percent of gross productivity, and the estimated percentage maximum loss for the same period would be 4.86 percent. The maximum and actual percentage losses to the two primary pest species were 2.53 and 1.35 percent for little corella and 2.33 and 1.05 percent for magpie geese.

It is certain that Hooker farm was operating below the level of productivity envisaged in the university grain growing system. Although precise figures cannot be given for actual productivity, it is likely that actual losses to birds at no time exceeded 10 percent of current gross productivity.

The expression of bird damage in the forms above could disguise the real impact which it has on an economic enterprise. A loss of productivity by direct removal, after all the fixed and most of the variable costs of that productivity have been paid, is usually inferred to have a substantial impact on profitability.

In the case of Hooker farm, the only economic use of grain sorghum (given 1972 world export prices) was to use the grain for the lot-feeding of cattle (Whan, in Anderson *et al*, 1973). As the Hooker farm operation was part of a vertically integrated enterprise involving the various subsidiaries of the Hooker Corporation, it was impossible to express bird losses as a percentage of group profits. Whan's budgets for a grain sorghum feed-lotting operation on a stand-alone basis are therfore used and the farm regarded as a single enterprise.

Whan's feed-lot budgets are based upon a cost of production of sorghum of $36.86 per ton [1] of which $15.76 are fixed costs and $21.10 are variable costs. The sensitivity of the variable costs to the decrease in yield if bird damage was present are so small that they can be ignored. Thus, if birds were removing 2.41 percent of the total yield,

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1 Note imperial units are used for this section of the thesis only. This allows these results to be considered with the original budgets on which they are based (Anderson *et. al.*, 1973).

TABLE 3.16 The effect of bird losses on expected profits ($ per beast) over a range of fattening periods and prices for Hooker farm cattle feed lot. (After Whan, in Anderson *et al*, 1973.)

Carcass price Cents per lb. (cents per kg.)	Days in feed lot			
	60	80	100	120
	424 lb. (192 kg.) carcass			
26 (57)	7.44 (7.21)	3.84 (3.49)	0.24 (-0.15)	-3.36 (-3.83)
30 (66)	24.40 (24.17)	20.80 (20.49)	17.20 (16.81)	13.60 (13.13)
35 (77)	45.60 (45.37)	42.00 (41.69)	38.60 (38.21)	35.40 (34.93)
40 (88)	66.80 (66.57)	63.20 (62.89)	59.60 (59.21)	56.00 (55.53)
	530 lb. (240 kg.) carcass			
26 (57)	15.00 (14.77)	11.40 (11.09)	7.80 (7.41)	4.20 (3.73)
30 (66)	36.20 (35.97)	32.60 (32.29)	29.00 (28.61)	25.40 (24.93)
35 (77)	62.70 (62.47)	59.10 (58.79)	55.50 (55.11)	51.90 (51.43)
40 (88)	89.20 (88.97)	85.60 (85.29)	82.00 (81.61)	78.40 (77.93)

the actual internal cost per ton of sorghum grain could be calculated as follows:-

let y = fixed + variable costs
let p = new internal price after bird loss
let x = total productivity in tons

$$\therefore \quad y = 36.86x$$

$$\text{and } y = p(x - \frac{2.41x}{100})$$

$$\therefore \quad 36.86x = px - px(\frac{2.41}{100})$$

$$36.86 = p\ (\ 1 - 0.0241)$$

$$p = \$37.77$$

This implies an increase in ration cost of 78 cents per ton to a new cost of \$38.98 per ton. This changes the cost of feeding one beast for one day to 38.28 cents (old value 37.89 cents).

Table 3.16 was adapted from Whan, in Anderson *et al*, (1973). The Table shows expected profit per beast for a range of feed-lot days, carcass prices and two carcass types. Values in parentheses are the new profit per beast if the bird factor was considered. These values were calculated by subtracting from the original profit the number of days the beast was in the feed-lot, multiplied by the increased feed cost of 0.39 cents per day.

Expected through-put for the feed-lot was in the order of 4,000 cattle per year. Thus, for the two extremes of positive profitability in Table 3.16, the effect of birds on total annual profits for the enterprise were \$1,560 and \$920 for annual profits of -\$600 and +\$356,800 respectively.

TABLE 3.17 Impact of birds as a percent change in profitability of various situations in the Hooker farm cattle feed lot (figures in parentheses are expected profit per beast ($))

Carcass price Cents per lb. (cents per kg.)	Days in feed lot			
	60	80	100	120
	424 lb. (192 kg.) carcass			
26 (57)	3.09 (7.44)	9.11 (3.84)	162.5 (0.24)	- (-3.36)
30 (66)	0.94 (24.4)	1.49 (20.80)	2.27 (17.20)	3.46 (13.60)
35 (77)	0.05 (45.60)	0.74 (42.00)	1.01 (38.60)	1.33 (35.4)
40 (88)	0.34 (66.80)	0.49 (63.20)	0.65 (59.60)	0.84 (56.00)
	530 lb. (240 kg.) carcass			
26 (57)	1.53 (15.00)	2.72 (11.40)	5.0 (7.8)	11.19 (4.2)
30 (66)	0.64 (36.20)	0.95 (32.60)	1.34 (29.00)	1.85 (25.40)
35 (77)	0.37 (62.70)	0.52 (59.10)	0.70 (55.50)	0.91 (51.9)
40 (88)	0.26 (89.20)	0.36 (85.60)	0.48 (82)	0.60 (78.4)

If bird damage was set for the maximum possible (i.e. 4.86 percent), then the effect on the per day feed cost per beast would be 1.2 cents, and the effect on annual profits for the two extremes above would be $4,802 and $2,880 respectively.

Thus, the effect of the bird pests on profit was only significant if the enterprise itself was extremely marginal. Table 3.17 summarises this situation for the data in Table 3.16. An annual turn-off of 4,000 beasts, and university-predicted productivity, have been used as a basis for calculations. It may be seen from this Table that in terms of percentage change in profits, birds are apparently of very low significance on Hooker farm (i.e. less than 1 percent).

3.6.2 The losses in the Ord development

As was mentioned in the introduction to this Chapter, the total physical impact of birds on grain sorghum production on Hooker farm was a measure of their total impact on the Ord development. Thus the results of this study suggest that any grain production enterprise in the Ord valley could expect to lose in the order of 200 to 600 tonnes of grain to birds in some years. In the case of rice, the impact could be at the upper end of the scale, due to the peculiarities of the crop's agronomy.

The likely frequency of such losses on a year-to-year basis will be discussed in the next Chapter.

4.0 The management of the avian pests of the Ord development

4.1 Introduction

At this time, it appears that little corella and magpie geese will remain the primary bird pests of grain cropping on the Ord.[1] Thus the emphasis in this chapter will be on these species.

In Chapter 2, it has been shown that the little corella problem is caused by an annual cycle in the number of birds which attack grain crops in the Ord valley. The intensity of these attacks has been shown to be dependent on seasonal conditions; this suggests that in the long term, a significant problem with little corella will occur in less than 30 percent of years. The evidence available suggests that this situation is unlikely to change in the medium, and possibly long, term.

The magpie geese problem also follows an annual cycle. At this time the likely trend of the farm visiting magpie goose numbers is unclear.[2] The most likely prognosis is that late dry season numbers will increase further until a limit set by available breeding habitat is reached.[3]

In Chapter 3 the impact of little corella and magpie geese on Hooker farm has been shown to be low under 1972 economic conditions. Chapter 3 has also provided a basis which allows the likely impact of bird pests to be considered at the planning stage of any future grain growing enterprise in the development.

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1 In the long term insects (especially *Heliothis armigera*) would be the primary pests of grain cropping.

2 This assumes that the valley remains attractive as a magpie goose dry season refuge.

3 A possible expansion of breeding habitat on the water storages of the Ord development could occur in the future.

This chapter details how the remaining aims of this study (section 1.1.4) were met. Firstly, the results of the search for a workable short-term bird control method are outlined. The chapter then goes on to outline the recommended control methods for each of the two primary species within the framework of the sorghum farming system developed from the wider university study. The individual species control methods are then integrated within the agronomic, farm management and economic constraints of grain sorghum growing on the Ord to give a 'best bet' farming system which will minimise bird damage.

The third section of the chapter considers the non-agricultural problems posed by birds. The two major areas of human health and civil aviation are considered, and management options explored.

The chapter concludes with an examination of the compatibility of the agricultural and non-agricultural problems caused by birds and their management.

4.2 The search for short-term control methods

4.2.1 General

One of the original aims of this study was to find methods which could be used to either minimise bird damage on Hooker farm, or at least to protect agronomic experiments on the farm from bird damage. The exigencies of the 1970 problem were such that this search was commenced and continued from the start of the research programme. The search had two main thrusts.

The first was to obtain as much relevant information on bird management as possible. This involved a literature search the results of which form the basis of Appendix VI. As a result of this review some techniques were thought to have some possible utility under Ord river conditions. These techniques were subjected to experimental testing (see below) which constituted the second aspect of the search for techniques of crop protection.

Overall, the results were negative and no short-term control method was developed for the whole farm. Greater success was had with the secondary aim of protecting agronomic trials. This was achieved by using trained shooters to displace birds (little corella in particular) from the agronomic trials to the commercial crops.

4.2.2 Experimental trials with bird management techniques

During the course of the study, several trials and tests were performed which were directed at testing various available methods of bird manipulation.

Five trials were carried out with chemicals (3 Skat-a-bird*, and 2 Morkit); two trials were performed with a white noise generator; one trial of chemical bombing was performed using a spray aircraft and numerous shooting trials took place.

This section outlines the methods and reports the results of each trial in turn.

4.2.2.1 Skat-a-bird* trials

Skat-a-bird* is a commercially available preparation of sorghum grain impregnated to 0.05% w/w or 0.1% w/w with 4-aminopyridine hydrochloride. The active agent has been used in various preparations overseas where it is known as Avitrol** 200. Overseas experience with this preparation is reviewed in Appendix II.

Three trials using Skat-a-bird* were conducted on Hooker farm. Two took place in October, 1970 (23rd to 29th) and were directed at little corella and galah. The third was 12 months later, in October and November 1971

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* Registered Trade Mark, Wm. Coopers & Nephews Pty. Ltd.

** Registered Trade Mark, Phillips Petroleum Coy. (U.S.A.)

(30/10 to 4/11) and was directed at magpie geese.

For the first trial, Mr. J. H. Ardley (a scientific officer of the manufacturers, Wm. Cooper & Nephews Pty. Ltd.,) worked jointly with the author to ensure familiarity with the product.

Trial 1 with little corella (23 - 29/10/70)

Preliminary Observations

One week was spent in preparation for the trial. In this period intensive watches of the farm's little corella established the current feeding pattern. Most feeding was occurring on a slashed stubble area in the northern end of bay F (see figure 1.3). Towards the end of the period (by 23rd October) some crop attack was originating from the ground nucleus in F onto standing crop in bay C. This indicated that the supply of waste grain in F was low. This was confirmed by an inspection of the area.

Baiting Methods

On 23rd October a total of 18 kg (40 lb.) of bait was prepared using 0.05% active agent skat-a-bird mixed 1 part to 3 parts with grain sorghum.

This preparation was put out with about 450 gms (1 lb.) of bait at each bait station. The station was a bag covering the ground with the grain spread over it. On each bait a small handful of 0.1% w/w skat-a-bird was spread to give an added concentration of active agent.

Bait station layout

Bait stations were laid out on the 23rd October in a pattern designed to give the greatest little corella access to bait. This was based on the assumption that the feeding pattern of previous mornings could be repeated.

Bait stations were about 20 metres apart and located as follows:

(i) 12 in one row along the north-western edge of bay G. This was an area of active edge feeding.

(ii) 2 rows of 6 bait stations at the southern end of the harvested area of bay F. This was grain stubble.

(iii) 2 rows of 6 bait stations at the northern end of bay F. This was forage stubble.

On the 24th October, 12 additional bait stations were put out at the southern area in bay F (site (iii) above).

This situation remained until the 27th October, when 6 of the bait stations from the western side of bay G were transferred to the northern end of bay F. On the 28th the situation was modified by removing the bags and placing the baits directly onto the ground. In addition, a further 2.3 kg (5 lb.) of 0.05% w/w active agent skat-a-bird was placed directly onto the ground along the western edge of the stubble in bay F.

Corella flock manipulation during the trial

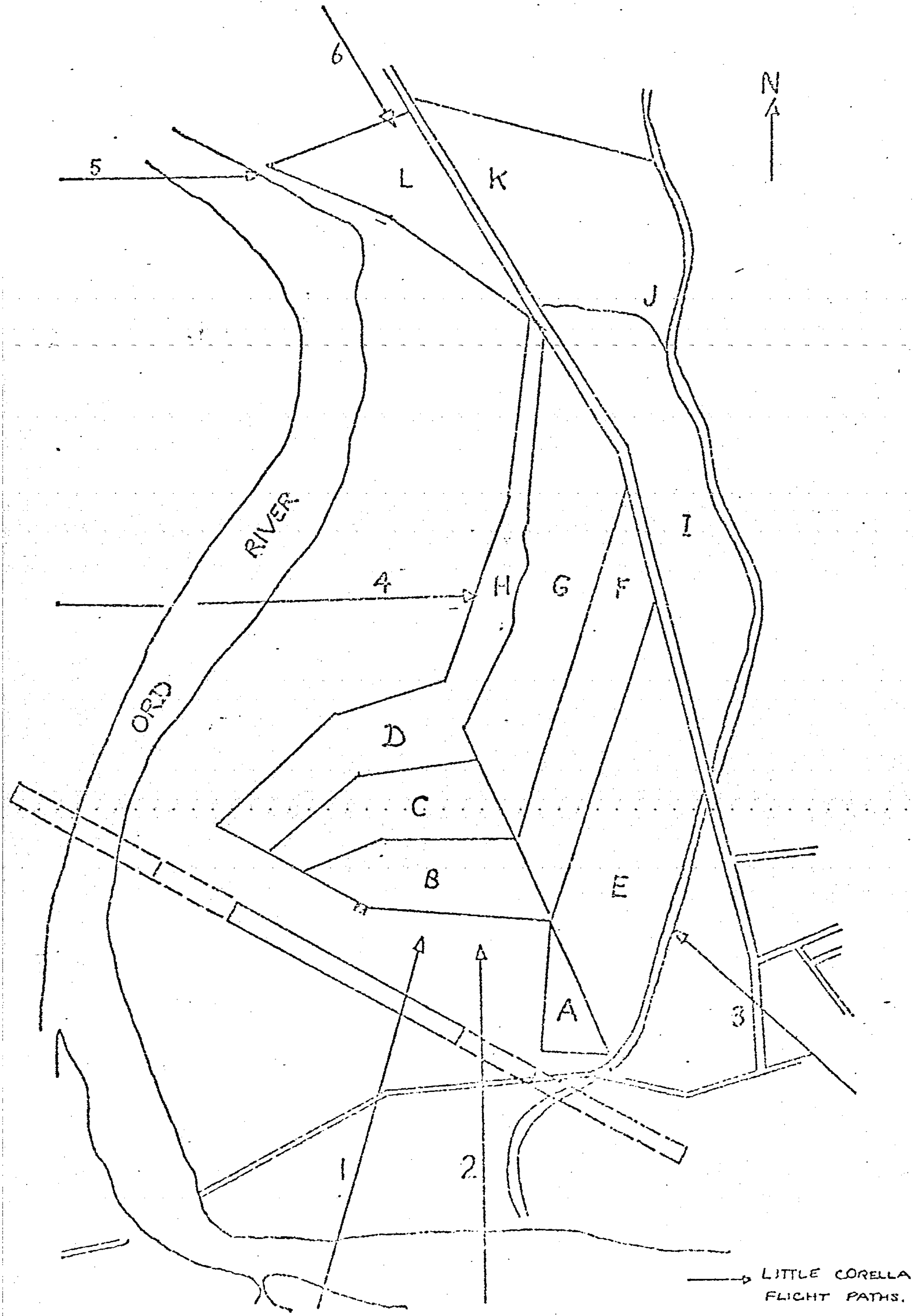
During this trial several sub-trials were conducted. These aimed at increasing the probability of bait ingestion by little corella by attempting to attract the feeding flock to the baited area.

(i) The use of releasers

In Chapter 2 it has been shown that a flock of little corella already on the ground will attract corella in the fly-out phase. A simple experiment was conducted at the baited areas to test whether this behavioural attribute could be used in baiting.

On 24th October patches of white newspaper about 1 metre square were placed in a strip of 6 sites 20 metres apart. This was at right angles to the baits in bay F. On

FIG 1·3. HOOKER FARM SHOWING IRRIGATION BAYS AND LITTLE CORELLA FLIGHT PATHS.



27th October an additional 3 metre square white cloth was placed in the middle of the southern baited area in bay F.

The results of this experiment were inconclusive. The corella landed in the baited bay but not right beside or on the newspaper strips. While on the ground the little corella may have avoided the newspaper strips but this is not a statistically supportable fact.

Generally it may be concluded that the use of landing releasers had no effect on corella distribution for this trial.

(ii) Corella herding

The behavioural basis of herding and its role in management will be discussed elsewhere (section 4.3). What occurred during this trial however, gives an excellent practical demonstration of the method and its limitations.

Herding was commenced on the 27th October following the break-down of stubble feeding the previous morning. The aim of the exercise was to keep the flock of increasingly hungry little corella in the area of the baits for as long as possible, thus increasing the chance of getting sufficient bait taken to give a positive result.

The following account of the methods for, and results of, herding should be interpreted in the framework of a very low grain availability in the target area (the bait area in bay F).

27th October

One vehicle with a driver and a spotter shooter was used. The vehicle was positioned near the area of crop in bay G where feeding had commenced on the previous morning. Corella arrived in the area at 0435 hours and two aimed shotgun blasts resulted in their flying to the road north of bay F.

This group of birds then moved into the stubble in F and the now rapidly arriving flock concentrated in this area. Feeding occurred in the stubble for some time, until this group attempted to pioneer a crop attack on G; shooting again resulted in a re-concentration on F. This process was repeated but as the morning went on control of the birds was lost as they scattered in the face of shooting. This was not a serious problem as the feeding phase was near completion at this time.

The herding was successful with the vast majority of feeding occurring in the baited area. The little corella on-farm feeding period was prolonged by about 40 minutes.

<u>28th October</u>

The same procedure of herding was adopted. But this time two vehicles with guns and two-way radios were used and an observer with a radio was placed on the Kellys knob lookout, from which the whole scene could be observed. The observer directed the herders to any birds which had moved from the desired area.

A period of intense herding followed. Little corella were not allowed to settle on any part of the farm save the baited area. Herding was again successful but by the end of the period it was obvious that the flock was showing signs of "desperation". The little corella on-farm feeding period was prolonged by a further 40 minutes. This 80 minute extension of the normal feeding period suggested that satiation had not occurred and next day the birds would be very hungry.

<u>29th October</u>

The same procedure as for the 28th was adopted.

The results were, however, quite different. The little corella were initially easily concentrated on the stubble area in bay F. The scatter strategy of the birds after this defeated the frantic efforts of the herders, who were swamped by the large number of groups into which the main flock fragmented. It was not until the level of satiation of the flock had increased that it was again possible to herd the birds. This occurred towards the end of the normal feeding time when several thousands of corella were again concentrated in the baited area.

Observations of little corella bait contact, bait ingestion and effects

24th October

Two feeding groups with a total of about 16,000 corella were established in bay F. These groups were close to the baits but at no time did they actually feed over them.

Later inspection showed no bait to have been taken.

25th October

Feeding again occurred in bay F stubble and in adjoining crop. A large number of birds fed in the area of the baits but no bait was taken.

26th October

Feeding again occurred in bay F and at one time the whole flock of about 16,000 corella moved over a strip of baits. A massive crop attack developed from the stubble area. No bait was taken.

27th October

This was the first morning of active herding. The birds were concentrated in the area of the baits for some time. About 1.13 kg (2½lbs.) of bait was eaten from the bait station on the western edge of G. No effect on the flock was observed.

28th October

Herding was successful and the obviously hungry corella were concentrated in the area of the baits for most of the feeding period. An insignificant amount of bait was taken and no effect was observed.

29th October

Herding again was employed but broke down. The bait was placed directly on the ground but no effect on little corella was observed.

Conclusion

The results show that under conditions when apparently hungry birds were in the area of the baits there was a low bait acceptance. The reasons for this are not clear. This situation is further confused by the apparent preference of little corella for stubble feeding (section 4.3) and the ready acceptance of Skat-a-bird by a congeneric species, the galah (see Trial No. 2).

Possible explanations are:

(i) Skat-a-bird is unpalatable to corella. This is highly unlikely.

(ii) The bait station repelled the birds in some way. This is unlikely; subsequent detailed observations of little corella feeding in many situations showed them to be curious of new objects and very willing to eat free grain on the ground.

(iii) The feeding behaviour of little corella militates against successful feeding by one or a few birds at a bait station.

In the feeding flocks of the density existing on Hooker farm at the time of the experiment, (iii) is the most likely explanation. Corella in such a flock are constantly on the move; if grain is encountered it is quickly eaten and the bird moves on. It is likely that a pile of grain encountered by one bird in a flock will have only a small amount of grain removed before the bird moves on. This is only a partial explanation as a flock of 16,000 corella could easily eat 18 kg of sorghum in a few minutes; provided the whole flock was actively feeding.

The second explanation is that flocks operating in an area where the general food density is low are very unstable. Food searching and the pre-disposition to move seem to militate against an individual bird stopping and feeding for a long period of time. This seems to work in two ways. Firstly, feeding birds are easily distracted by a movement elsewhere; i.e. the overall feeding mood of the flock is low. Secondly, the encountering of small amounts of food may initiate conflict which de-stabilises the flock, causing the birds to move away from the food source. This unlikely behaviour has been seen only in very large flocks.

If either of the above explanations is possible, then the strategy of Skat-a-bird baiting would need modification in two ways. Firstly, when flock size is large, Skat-a-bird should always be put out in an area where general food availability is high. Secondly, the concentration of active agent in grain should be much increased. This would result in the drug becoming effective after only a relatively small amount was eaten.

Successful baiting would not however ensure successful control of little corella in the Ord context. The factors against the successful use of Skat-a-bird are:

(i) It would be unlikely to give complete farm area avoidance when the farm is an oasis in the middle of a large area of seasonally depleted food resources.

(ii) If it changed the little corella feeding behaviour on the farm, the effect would be in the wrong direction. This is because the only likely sites of successful Skat-a-bird administration are stubble areas. Even if no little corella management is employed it is desirable that the birds eat as much of the non-economic grain of the stubble as possible. The corollary to this is that Skat-a-bird could result in the corella learning to eat only grain in heads on plants - a thoroughly undesirable result.

(iii) If corella could be repeatedly baited the alarmed birds could scatter. Shooting studies have shown that scattered feeding groups eat no less grain than concentrated groups. The damage is only less obvious.

(iv) The fourth possibility is that the distress of the baited birds would be ignored as was the case for galah (see Trial No. 2).

In summary, the results of this trial were that Skat-a-bird was an unlikely candidate for little corella management on the Ord.

Trial 2 with galah (23 - 29/10/70)

Introduction

When this trial was carried out, there was a resident population of about 2,000 galahs feeding on open field bins of grain sorghum and around the feed-lot area. The limitations of galah to non-crop feeding reduced their pest status to nuisance value only. The reasons for the trial were three-fold:

(i) The galah distribution presented a less difficult situation than that of the little corella. This would allow a good assessment of Skat-a-bird to be made on a species closely related to little corella. Positive results would encourage the search for a workable little corella programme.

(ii) The galah could develop into a serious pest of cropping, as has occurred elsewhere in Australia. Thus, an effective Skat-a-bird control method would be useful information against future developments. (Section 2.4 shows that a galah problem did not in fact eventuate.)

(iii) The galah could develop into a serious feed-lot pest either as disease carriers, feed removers, or generally destructive pests.

Prior to this trial, the galah had been subject to occasional shooting. This generally consisted of a frustrated corella-chaser venting his rage on the congeneric galah. The author witnessed several such incidents. In each case, several shots would be fired, up to 50 or more galah would be killed, the shooter would tire and go away, the galah would go on feeding after the initial alarm. Such was the resistance of the galah to scaring by shooting that they would feed right up to the body of freshly shot birds with no apparent alarm.

Baiting Methods

Baits were from the same mixture as used for little corella.

Two bait stations were established on top of a grain-filled field bin and two were on the ground nearby. All bait stations were bags with about 0.45 kg (1 lb.) of bait on top.

Galah bait contact, bait ingestion and effects

24th October

Galah commenced feeding on the grain bin baits within 16 minutes of their arrival in the area. Up to 12 galah at a time fed on the bait stations and feeding went on for 28 minutes, when the majority of galah flew to their day-roost some miles away.

One galah was flying erratically towards the end of the feeding period; otherwise, no effect was obvious. Post-feeding inspection of the baits showed about 1/8 was eaten (0.3 kg).

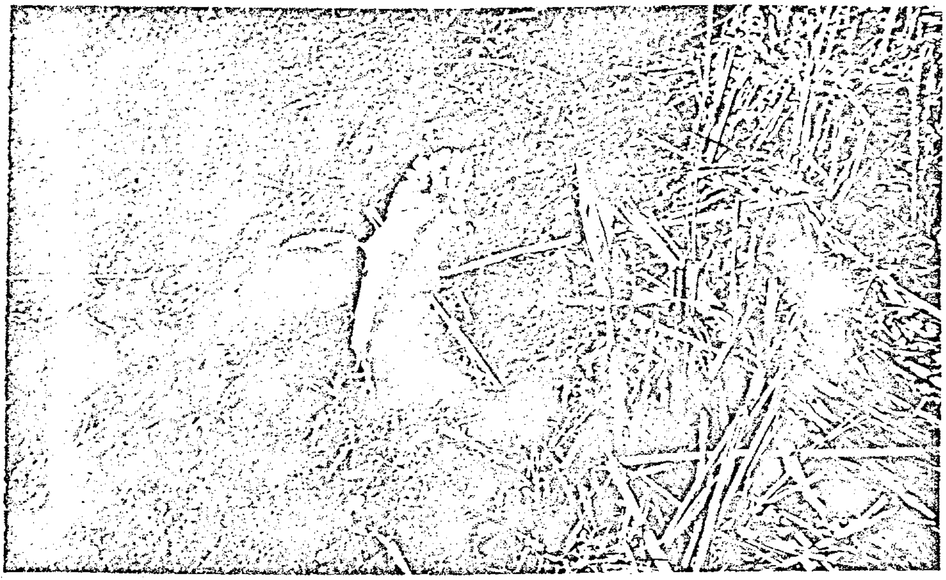
25th October

The galah feeding was not observed; however, by 0540 hours, a large number of severely affected birds was in the area of the baits. The apparent stages of Skat-a-bird intoxication were:

(i) The bird becomes a little erratic in flight and general co-ordination.

(ii) The bird commences to fly in circles and gives a distress call. Objects can still be avoided in flight. Little time is spent on the ground at this stage.

(iii) The flight becomes faster and calling more frantic. The major change from the last stage is that the ability to avoid obstacles is lost. Birds crash into walls, banks, etc. at full speed.



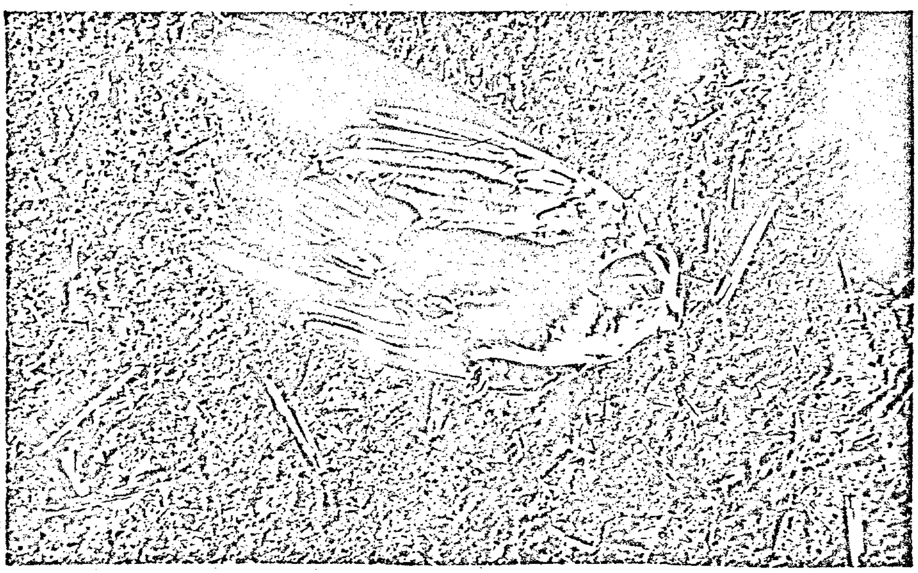


Fig. 4.1 A Skat-a-bird affected galah after loss of flight and immediately before death.

(iv) The ability to fly is lost. This may follow a crash into some obstacle, or alternatively the bird may fly into the ground, or it may literally fall out of the sky.

(v) For a time, the bird can move with an erratic drunken walk. The crest is raised, the pupils dilated, the eyes watering, the wings may be flapped or incorrectly folded, and the bird calls unceasingly (figure 4.1).

(vi) The bird becomes immobile on its side. The eyes water profusely, the pupils are fully dilated, frothing at the mouth occurs, and tetonic spasms commence (figure 4.1). All birds which reached this state died later in the day or were killed by the author.

Although recovery from stage (vi) and possibly stages (v) and (iv) does not occur, the situation for the earlier stages of intoxication is not known. (One of the purported modes of action of the drug is that birds which recover avoid the area where they were intoxicated.)

The most startling observation was that the intoxicated galahs had no obvious effect on other galahs in the area. An intoxicated bird had to literally crash into a silo to disturb the birds feeding there. In one instance, a group of galahs gathered round a stage (vi) bird but then went back to feeding.

26th to 29th October inclusive

Baits were left out for this period. Intoxicated galahs crashed into the feed-lot, occasionally disturbing the cattle, but no effect on the remaining galahs could be detected.

Conclusion

The trial did not achieve any detectable area avoidance by galah. It would seem that the Ord river galahs are truly galahs.

Trial 3 with magpie geese (30/10/71 to 5/11/71)

Introduction

From early September 1971, severe magpie goose damage became apparent on the farm. Following some particularly severe damage in bay I, the crop was harvested and slashed. This stubble became an area of intense magpie goose feeding. About 10,000 to 14,000 geese were feeding in bay I daily.

Preliminary observation (using a 60 x telescope) of the geese feeding on the stubble in I showed that, while a preference seemed to exist for grain in heads, loose grains were being picked up from the ground. These observations suggested that magpie geese could be easily baited with Skat-a-bird .

Baiting Method

29th October

Eleven kg of 25% (0.01% active agent) Skat-a-bird was placed in the area being used by the geese in the morning. The bait was in small piles placed directly onto the ground between the sorghum rows.

31st October

A further 7.3 kg (16 lbs.) of concentrated Skat-a-bird (0.05% w/w active agent) was placed in the feeding area. The bait was run out in long rows 10 sorghum rows apart.

Results

30th and 31st October

The geese fed in the baited area for a long period. Nothing unusual was noticed on both days. At the end of the feeding period on the 31st, an inspection showed no bait was left in the area.

1st to 4th November

The geese fed in the baited area for the whole four-day period. At the end of this period most of the bait was gone. There were no detectable effects on the geese.

On the 5th November, the trial was abandoned. The geese continued to feed in the area until the available grain was exhausted.

Conclusion

This trial was again a failure. It would seem that the source of this failure was either a low responsiveness of the magpie goose to 4-amino-pyridine hydrochloride; or a low ingestion of Skat-a-bird by individual geese. The latter possibility is unlikely. Individual magpie geese, unlike little corella, seem to be relatively static when feeding in a large mob.

Skat-a-bird : Overall assessment

From the three trials, it appeared that Skat-a-bird was an unlikely candidate for bird control in the Ord context. This was surprising in the light of overseas results. A partial explanation may lie in the emphasis of all the United States work on Passeriformes. The chemicals have never been tested on Anseriformes or Psittaci formes.

If further trials were conducted, Skat-a-bird with a much higher concentration of active agent would be desirable. This would overcome the problems of getting sufficient bait ingestion (Trials 1 and 3) and would consequently make baiting a more realistic exercise.

4.2.2.2 Morkit* trials

Morkit is the name for a commercially available range of bird repellant products based on the chemical di-phenylenediketone (anthraquinone). In its various forms, sprays, powders, slurries etc., it has been used for treating mature grain crops, fruit trees, vines and sown seed (see Appendix VI for detailed references). In January 1972, John Brereton heard of the apparently successful use of Morkit to protect a crop of Japanese Millet from budgerygah and quarrions. This second-hand report constituted the first apparently successful instance of a bird repellent chemical working on parrots.

Preliminary investigations of the nature of the chemical were carried out and a trial programme planned for later in the year. Morkit was tested on both little corella and magpie geese under as near to optional conditions as possible.

Morkit* Trial 1 with little corella (24/6 - 2/7/72)

Introduction

This trial was set up after a two-month period of stubble feeding. As the stubble became scarce, it was known that the corella would commence to feed on standing crop. At this time bays G and I had susceptible crop. The rationale was to treat one of these bays (bay I) with Morkit and determine if this treatment in any way affected the subsequent feeding behaviour of the little corella. Fortunately, the location of the two bays was such that under normal food search conditions both would be attacked by little corella. This provided a reasonable assurance that any preferential behaviour shown by the little corella would be attributable to the treatment and not to random effects.

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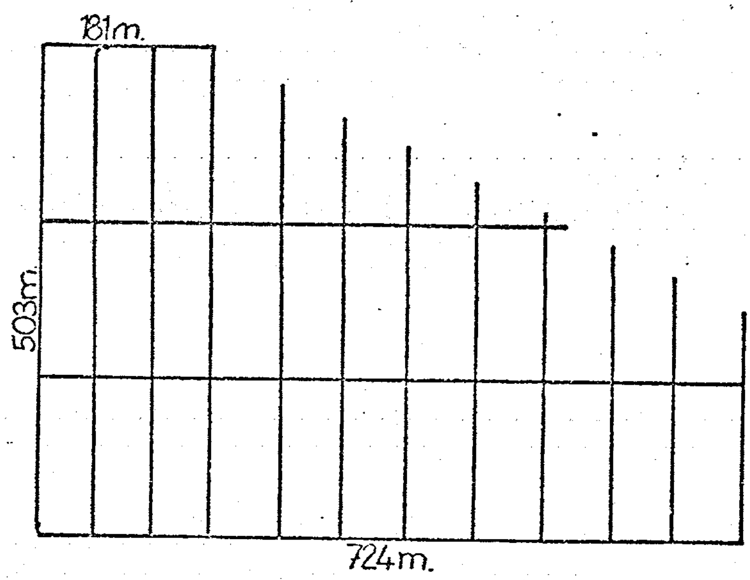
* Trade mark Bayer Australia Ltd.

FIG 4·2. LAYOUT OF SPRAY RUN CENTRES MORKIT TRIAL BAY I. HOOKER FARM.



Morkit Application

The Morkit used was in the form of a water dispersable powder. It was mixed at a rate of 7 gms/litre (7 lb./ 120 U.S. gallons).

The preparation was sprayed onto bay I in the cross-hatched pattern shown in figure 4.2. The sprays on the aircraft were set at an application rate of 56 litres/ha (6 US. gallons/acre). This is equivalent to 392 gms. of Morkit a.i./ha. In areas where the spray runs crossed, the application was twice this. The total area sprayed was 8.1 ha of a total crop area of 25.54 ha; this represents a coverage of about 32% of the crop.

Observations

The continuous monitoring of the farm situation revealed that the little corella started food searching away from the stubble areas mentioned above on the 23rd June.

The Morkit was flown onto the crop on 24th June and observations made in both the mornings and evenings for the next 14 days. In addition, the farm staff and university personnel on the farm were alerted and asked to make observations but not to disturb the birds by shooting or any other action.

To assist observations, 2 metre-long wooden poles were driven into the ground at the start and finish of each spray run (see figure 4.2). These could be observed across the crop with field glasses and allow the Morkit concentration of any portion of the crop to be approximately determined from its co-ordinates.

Results

The results of the trial were negative. No effect could be observed on the feeding behaviour of little corella during the post-spray period. The little corella fed on the crop in bay I (sprayed) and the crop in bay G (unsprayed) with equal partiality. Interchange of birds between the two crops occurred, but no preference for bay G developed.

Additional observations of quarrion and galah crop feeding on the sprayed areas of bay I were made during this period. Neither species showed any response to Morkit .

Conclusion

As was the case for Skat-a-bird no definite explanation can be offered for the lack of effect observed. Morkit* is supposed to be an unpalatable repellent with a reinforcing laxative action. It is obvious from these results that neither of these effects is sufficient to affect the feeding behaviour of the little corella.

Morkit Trial 2 with magpie geese (18/9 - 30/9/72)

Introduction

Like the little corella trial before it, the magpie goose Morkit trial was planned for a time when success was most likely.

The annual increase in magpie geese was expected in September and October (see figure 2.14). In anticipation of this a supply of Morkit was obtained and the available target areas on the farm closely watched.

Early in August 1972 the first magpie geese appeared. By the end of the month, numbers had risen to about 8,000. A rapid increase was obviously under way (see figure 2.14) and crop damage was starting.

For this trial it was determined that the geese would be allowed to establish a feeding pattern. The experiment would then aim at changing the pattern by the use of massive amounts of Morkit .

These test criteria were satisfied by mid-September. Goose numbers were about 10,000 and increasing. A well-developed pattern of crop attack was apparent in a commercial grain crop in bay H. Alternative food sources in the form of grain crops were available in adjacent bays. The trial was commenced on 18th September.

Morkit application

Morkit powder was mixed at a rate of 39gms/litre (49 lb./ 150 U.S. gallons). This preparation was then flown onto bay H at a rate of 56 litres/ha (6 U.S. gallons/acre). This gave an active ingredient application of 2184 gms/ha. The total area sprayed was 10 ha of a 30 ha crop.

The pattern of application was a cross-hatched one similar to the last trial. Marker poles were again used to provide spray path centres.

Observations

Similar observations were made to those in the last trial. Unfortunately, due to a tape failure, five days of detailed records were lost by the author (22 - 27/9/72). This loss does not however invalidate the trial as less detailed written notes were kept, and records before the 22nd and after the 27th are available.

In addition, measurements were made of the sorghum lost from H. This was done at harvest on 22nd October.

Results

(1) Magpie Goose feeding behaviour

No discernible change occurred in the feeding habits of the magpie geese during the 14 days following the application of Morkit . Crop attacks continued in H; however, as numbers further increased other damage centres were developed. It was felt that this latter damage was due solely to the large numbers of magpie geese visiting the farm (30,000-plus by early October).

(2) Damage to H

The sprayed bay (H) was harvested on 22nd October. At the harvest, yield measurements were made for an undamaged section of the crop. The total yield was also measured.

The undamaged area of crop yielded 4.08 tonnes/ha while the overall crop yield was 3.32 tonnes/ha. This represents a loss to magpie geese of about 23 tonnes overall, or 0.76 tonnes/ha. At current prices, this represented a loss of $930 for the crop.

Conclusion

As was the case for little corella, it would appear that the Morkit is of little utility for the control of magpie geese in the Ord context.

Morkit Summary

The results of the two trials were sufficiently disappointing to stop any further testing of the product. After this study ended, the author has seen claims that Morkit is effective if much higher concentrations are used. This would suggest that further trials may be useful.

4.2.2.3 Miscellaneous bird control methods tested

As can be seen in Appendix VI human ingenuity has been fully extended in the area of bird scaring. This section presents some of the methods looked at in a preliminary fashion during the study.

(1) Water baiting

Some success has been had by farmers in the use of water as a baiting medium. A simple test was carried out to determine whether a significant number of corella could be induced to drink while feeding.

The trial was carried out in late October and early November 1972. During this period, over 1,000 little corella were feeding regularly on a pile of waste grain at the southern end of Hooker farm. The grain area had been pegged in a grid for a behavioural study. In this area 10 metal dishes were placed one per 2 metre square. These dishes were filled with fresh water. Observations for two feeding periods , for a total of 6 hours, were made. During this time one dish was turned over by a landing little corella. Apart from this incident the little corella showed no interest in the water.

These observations agreed with the established morning and evening watering behaviour of little corella and no further tests were performed.

(2) Scaring with white noise

For one week in mid-November, an Av-alarm* bird scarer was obtained on loan from Robert Bryce & Co. Ltd. of South Australia. The unit consisted of a box with a volume control and a loud speaker. The whole is battery powered and portable.

When activated, the system emits a loud noise which is designed, in the words of the manufacturer, to "reach the brain and take over the acoustic centres of the brain".

The device was tested on magpie geese, little corella and whistling duck. In all cases the animals moved a couple of hundred metres away and continued their activities.

Judging from the effect on the author, devices such as this would be very effective if placed at 100 m intervals in an environment devoid of human activity. These criteria seem impossible in the Hooker farm situation, and the device was, thankfully, returned.

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* Trade mark Av-Alarm Corporation, California, U.S.A.

(3) Aerial bombing

Methods of bird control for which there are anecdotal reports of African successes and which have probably been carried out in the north of Australia involve aerial spraying and bombing. During the study it was decided to try to mark a large number of little corella on the farm. The main reason for this was to determine the extent of the little corella annual dispersal. A secondary aim was to determine whether the birds could be sprayed on the farm when they were in a single species flock and not near water. The rationale for this was that it could offer a possible means of little corella number reduction with no effect on other species.

The trial was carried out using 100 U.S. gallons of 50% (v/v) Ethanol in which was dissolved methylene blue (2.27 kg). This produced an intense blue solution, very small droplets of which stained feathers on contact.[1] The aircraft used was a Piper Pawnee with full agricultural rig.

The plan of attack devised was for the pilot to approach a concentrated feeding flock of little corella on a 'flat' approach with the aircraft trimmed. At the forward edge of, and about 30 metres above, the flock the emergency release was activated. This dropped the complete load of 100 U.S. gallons (382 litres) in about one second, and at the same time the aircraft was given full power. It was known that the combined effect of the load drop and full power would lift the aircraft well above the birds as they flew up.

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1 Numerous stains and solutions had been tested in the laboratory prior to the choice of the methylene blue and Ethanol combination. The idea of using stains as a marking method came from work with geese in California (Kozlik *et al*, 1959).

The trial was executed at 0540 hours on 9th May 1972. A 16 mm movie film record was made of the drop for subsequent analysis.

The results were disappointing. The actual drop went off without any problems; however, the little corella were remarkably successful in avoiding the descending dye and only very small numbers were dyed. This was despite a dye ground cover of approximately 60 x 30 metres.

The 16 mm film showed that a drop height of less than 15 metres would be needed to get the desired effect. This was simply too dangerous and no further trials were conducted.

(4) Other

During the course of the study various other methods of bird control were considered. These covered a wide range of possibilities. Ultra-sonics, micro waves, smoke generators, electric perches, shot-gun-fired exploding shells, alarm call broadcast systems, "bird resistant" grain sorghums and trained hawks were all considered and not proceeded with on the grounds of impracticability. These methods have been reviewed in Appendix VI.

4.3 Bird management systems for grain sorghum growing on the Ord

4.3.1 General

The previous section has indicated that there was no simple technique for bird management available which could be directly applied to the problem encountered on Hooker farm. This section outlines the agro-economic constraints of grain sorghum growing in the Ord environment, the systems of management developed for each primary bird pest and the economics of the individual systems. The individual systems are then integrated to give the overall system recommended in the context of Hooker farm.

The methods outlined here are generally applicable to grain crops other than sorghum; however, before they are applied, the differences between grain sorghum and the other crop in question should be considered and if necessary some preliminary research carried out.

4.3.2 The growing of multiple cropped grain sorghum in the Ord valley

This has been the subject of two major reports by the university team (Anderson *et al*, (1973), and Anderson, Whan, Bentley and Cross,(1973)). What follows is a brief summary of the sorghum cropping system recommended, together with some of the agronomic, farm management, and economic constraints; the original reports should be consulted for more detailed information.

In the Ord river environment it is possible to grow almost any crop throughout the year. This was the case for grain sorghum; however, several factors reduced the options for economic cropping. In terms of the bird management proposals these were:

(1) Yield potential

It was found that although growth was possible in all months, environmental factors caused a considerable variation[1] in yield potential for different months of growth commencement. This was especially true for the seed crop but also applied to crops re-cycled[2] by slashing, fertilising and watering (see figure 4. 3).

(2) Capital utilisation

Sufficient capital equipment could not be economically employed to perform all farm operations on all bays at the same time. Thus some staggering of operations was essential.

(3) Management practices

A conflict existed between the maintenance of crop cycles to give maximum productivity and the ability of management to keep all operations within the necessary time frames. In addition, there may have been a decrease in expected yield with successive cycles and an increase in the weed problem with successive cycles.

These considerations lead to the university recommending that sorghum be grown on a four cycle basis (one seed crop and three re-cycled crops taking 400 days in all); at the end of the fourth cycle a fallow could be used to place the next seed crop in one of the maximum yield planting dates.

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1 up to 1.5 tonne/ha

2 Crops grown by allowing the harvested plants to re-tiller from their bases. In such crop the cost of land preparation and sowing is saved.

Using 1972 costs for budgeting it was found that 400 ha was the basic area to be worked per unit of capital equipment. If the recommended operating sequence was then followed it would be 4 years before this area of land re-started the cycle of operations again; 10 crops would be harvested in this time.

A second option was that the 400 day system could be reduced to a yearly one if grain drying was employed. The economics of this were attractive, as were the increased flexibility in farm management.

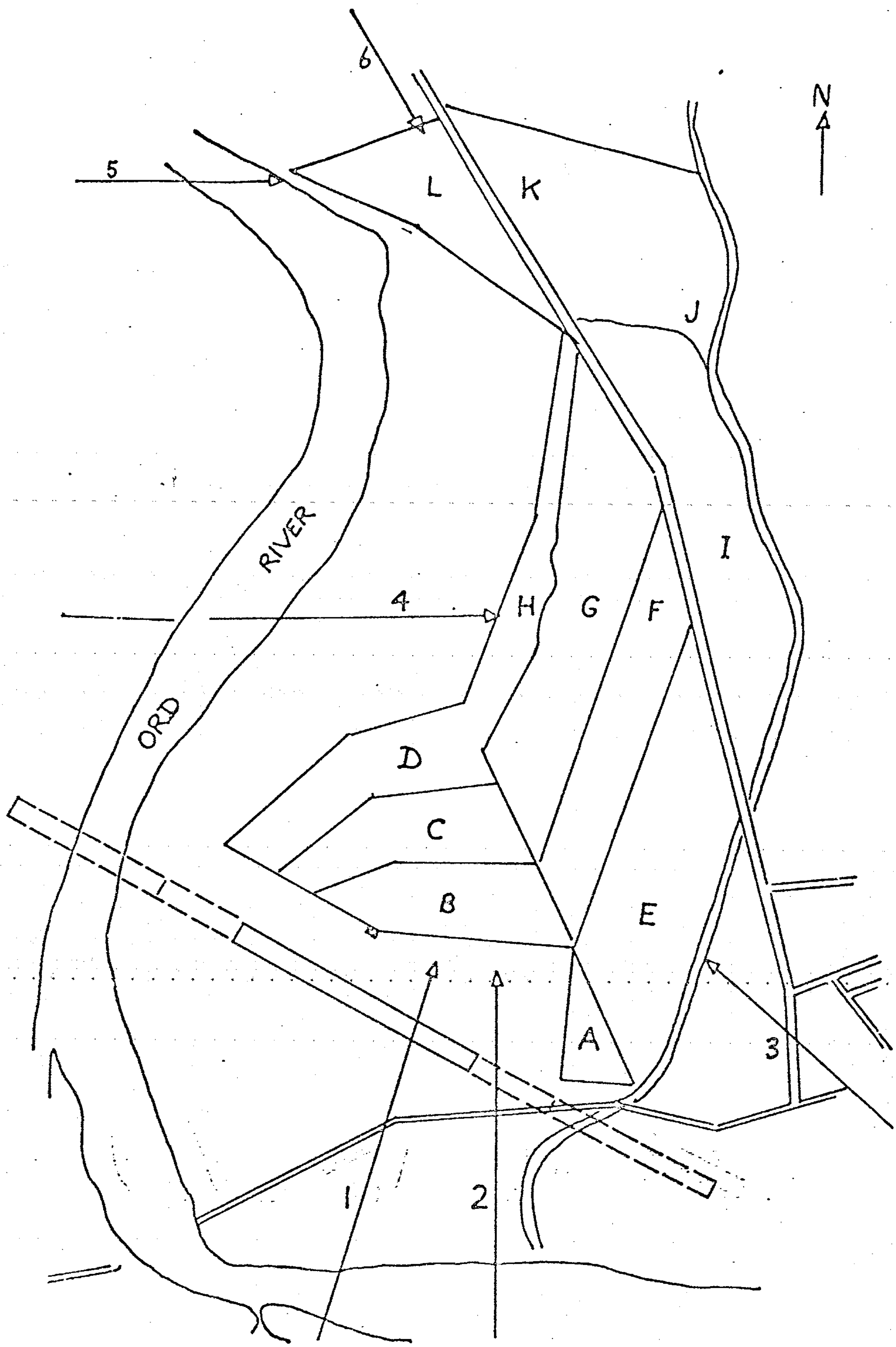
4.3.3 The little corella management system

The system had three components which involved agronomic practices, farm management practices and bird manipulative practices.

The most powerful component of the system involved the planning of the crop year to take account of the annual fluctuation in the static super-flock (Figure 2.4; section 2.2.2.2). The findings of the university team indicated that the timing of the three annual sorghum cycles to give maturity in early April, late August and late November was possible (Anderson *et al*, 1972). Further, given the known climatic regimes, it was possible to predict the period when the crop would be bird-susceptible (soft dough to 14 percent moisture) for each of these periods.

Given the unusually bad years over which this study was conducted (section 2.2.2.3) it could confidently be expected that the above strategy alone would reduce little corella damage to insignificance for at least 70 percent of years (section 2.2.5). As was evidenced by the 1970 and 1971 experience, probabilities can provide a dangerous basis for a farm enterprise on a short term basis. Thus, other strategies were necessary as insurance against the bad year and possible modifications in the birds' temporal patterns of distribution.

Fig. 1.3 Hooker farm showing irrigation bays and little corella flight paths. Irrigation bays are alphabetically designated and flight paths numerically identified.



The second component of the system involved farm management practices. Figure 1.3 shows the fly-out pathway habitually used by little corella for different months of the year. It was already farm management practice to carry out operations sequentially for optimal machinery utilisation. The little corella management recommendation was that these operations be organised so that the first bays to reach soft dough stage in each cycle were the first bays encountered by the major flight paths (i.e. bays B and H in figure 1.3). From this point, a knowledge of the behavioural and feeding models presented (section 2.2.4.3) provided the basis for bird manipulation.

If the corella were allowed to establish feeding on the first crops to become susceptible for the given cycle they were certain to remain feeding on this crop . The management system required that this feeding be maintained. If little corella strayed onto new crop, they were deterred by shooting, which resulted in their returning to the main feeding group (see alarm sub-system, figure 2.10). It was most important that this did not involve disturbing the major feeding group.

The economic crop being consumed by the little corella was considered to be a cost to management. The period of bird depredation was however minimised by harvesting the crop as soon as possible. Harvesting was at 14% moisture. However, if grain drying facilities are introduced in the future the period of economic loss could be considerably reduced. Harvesting was followed by stubble slashing on a same-day basis. The result of this operation was that bare ground with waste grain was now available to the little corella. This was the preferred feeding situation for corella.

The remaining bays were now harvested and slashed in sequence from the start bays. It was most important that the bay being currently utilised by the birds was not watered until slashed stubble was ready in the next bay.

TABLE 4.1 Effect of time of sowing of grain sorghum on yield potential, days to harvest, and number of little corella susceptible days. (Production data from Anderson *et al*, 1973.)

Sowing season	Kg/ha yield potential cycle 1	No. days to harvest	Harvest time	Number of days susceptible to birds at harvest
Early dry	5,000	140	late dry	40
Late dry	3,500	91	early wet	25
Wet	4,000	115 (approx.)	early dry	30

Provided operations were timely, there was always adequate waste (non-economic) grain available on the slashed bays for the birds. There were, however, always occasional birds which would attempt to advance onto economic crop. Careful shooting returned these birds. It was apparent that the little corella were capable of learning to avoid standing crop while stubble grain was available.

During the initial crop feeding period and during periods when a failure of the system resulted in no stubble being available, indiscriminate shooting had to be avoided. The major reason for this was that it established the harassed birds' feeding strategy (figure 2.9) which considerably reduced the flock's amenability to manipulation. A secondary reason was that shooting increased damage. Little corella preferentially harvest a head of sorghum (which contains enough grain for their daily requirements). If they were shot at, the harvested head was abandoned and on resumption of feeding a new head was often harvested. This lead to a potential doubling of damage with every instance of indiscriminate shooting.

The above management system based on the assumption that multiple cropping of grain sorghum was the only grain growing enterprise for the Ord development; other options do exist. One of these is the growing of a single grain sorghum crop. With existing hybrid varieties this would involve an early dry season (say, April/May) sowing and a mid-September harvest (Table 4.1). The little corella-susceptible period for such a crop would be August/September which corresponds to the period of lowest damage potential. In up to 70 percent of years this damage potential could approach zero.

4.3.4 The magpie goose management system

The options available for magpie goose management were not as easily defined as those for little corella. The magpie goose problem grew over the period of the study and future trends in the pest component of the population were not finally resolved by this study (section 2.3). If breeding does not become widespread on lakes Kununurra and Argyle, it is however likely that an absolute upper limit, with the order of magnitude of the 1972 and 1973 populations, exists. Given this assumption, three possible strategies for management can be advanced.

The first is magpie goose destruction. The work of Frith and Davies (1961) indicated that it was relatively easy to bait magpie geese in large numbers. The situation on the Ord would enhance such an activity. Given the great contraction of the range of magpie geese over the last 100 years it is highly probable that a long-term poisoning programme on the Ord could have a significant impact on the breeding population in the western sector of the Northern Territory coastal plains. The unresolved questions would have to be ones of conservation and politics. Can the Western Australian government justify mass killing of a most unusual species, the population of which has already undergone a considerable reduction over the last 100 years? How does the conflict inherent in Western Australia killing what are almost certainly predominantly Northern Territory magpie geese resolve itself?

The second option involves temporal crop placement. Stated simply, the absence of mature grain crops in the Ord valley over the September to January period would eliminate the major portion of the magpie goose problem. Some damage to young cereal crops could occur over this period; however, the actual yield reduction, given normal plant plasticity, would not be great.

The third option would involve the utilising of the pack saddle and Lily creek swamps of lake Kununurra as free feeding areas. The area of shallow water available in these swamps exceeds 200 ha. It would be not unreasonable to expect aerial sowings of rice into these swamps in the early dry, followed by a gradual lowering of water levels to yield one tonne of grain per hectare. This grain, together with the naturally occurring swamp vegetation, would provide sufficient feed for the high visitation rates of 1972 and 1973 (Table 3.15).

The likelihood of a high rate of farm visitation by magpie geese when swamp based food is available is low. The most significant crop attacks by magpie geese which occurred during the course of this study were those which followed a major sudden drop in the water level of lake Kununurra to facilitate maintenance work on the diversion dam.

The adoption of the free feeding strategy could require other management of the lake habitat to limit breeding. The precise requirements will, however, have to await experimental testing of the suggested programme.

4.3.5 The management of secondary species

The results obtained in this study indicated that brolga, galah and duck were only of minor importance to large-scale grain growing.

The only management option available to small-scale grain growing is to either avoid the high damage potential periods (sections 2.4, 2.5 and 2.6) or use armed bird patrols to reduce damage.

4.3.6 The economics of management by the recommended systems

In section 3.4 it has been shown that, for the period of the study, birds had an impact on the cattle feed lotting enterprise only when gross margins were low. Considering that the years of the study were bad ones for granivorous birds and the probability of occurrence of such years was low, the likely long-term impact of birds under 1972 conditions becomes insignificant.

The 1972 situation need not necessarily prevail in the future and the assessment of the economic value of the various management systems is a worth-while exercise. The future use of these budgets will require the adjustment of their assumptions to those prevailing at the time.

4.3.6.1 Major little corella management system

Assumptions: (1) Sorghum is grown continually on a three-cycle basis.

(2) Management is capable of maintaining farm operation schedules and hence crop schedules.

(3) The value of sorghum is \$37 per tonne.

(4) The monthly corella numbers for the year 1972 (rainfall 88% of long-term mean) is typical for all years (see Table 3.12).

Budget

(1) Maximum grain losses for managed system (for susceptible days see Table 6.1)

April	30 days feeding for 10.5 thousand corella =	16.5 tonnes
August	40 days feeding for 6.5 thousand corella =	13.5 tonnes
November	25 days feeding for 10 thousand corella =	13 tonnes
		43.0 tonnes

Value of loss at \$37 /tonne = \$1,591

(2) Labour costs (maximum)

60 days, 2 hours per day, \$2.10 per hour = \$252 p.a.

(3) Vehicle costs (maximum)

60 days, 20 miles per day, 10¢ per mile = \$120 p.a.

∴ Cost of management system for one year = \$1,963

Income forgone if no management applied, based on 1972 potential little corella losses, Table 3.12		250 tonnes at \$37 per tonne
	=	\$9,546
∴ Maximum value of management system for 1972-type year	=	\$7,583
Estimated actual loss to little corella for 1972		131 tonnes @ \$37 per tonne
	=	\$4,847

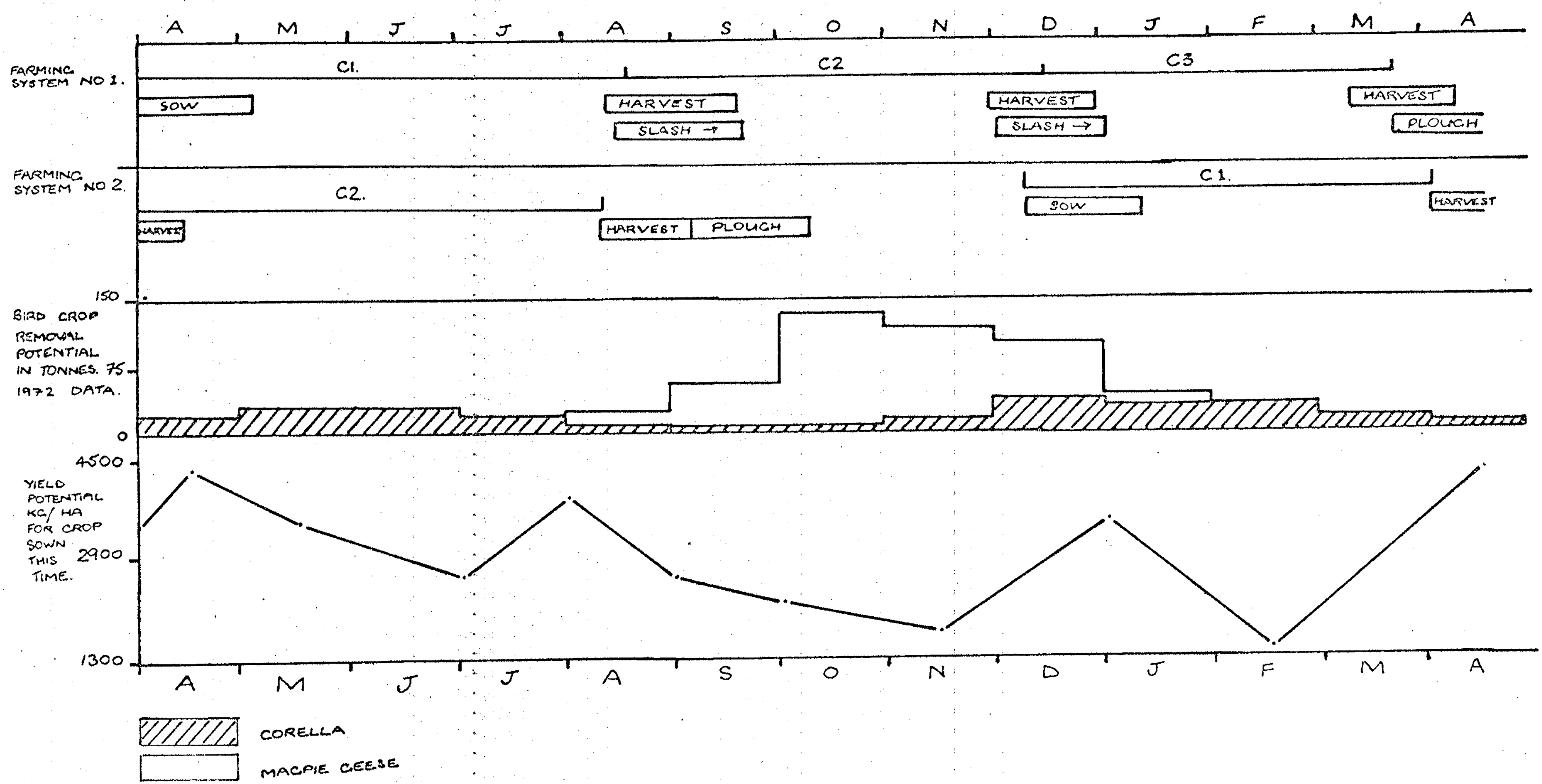
4.3.6.2 Minor corella management system

It was not possible to budget this system accurately. The maximum expected losses for a single crop situation would however be very low. The economic considerations involved in assessing the work of such a system would be the opportunity cost of not growing grain crops year round. These obviously depend on what other agronomic options are open to the farmer.

4.3.6.3 Magpie goose management system

The return to management of a successful magpie goose poisoning system could approach a maximum of \$13,000 per year, less the cost of poison and labour. The non-economic cost of such a programme in terms of reduced survival

Fig. 4.3 Recommended grain sorghum farming systems for Hooker farm in relation to grain sorghum yield potential and bird crop removal potential.



potential for the species cannot be assessed at present.

The return to management of the no-cropping option would be the opportunity cost of fore-going one crop per year.

The return on the third option cannot be accurately assessed. Some approximate budgeting is however possible:

Cost of sowing rice by air	$400 maximum
Cost of seed .... say,	$300
Cost of water level manipulation	negligible
Return could approach	$13,000

Thus, if the system worked, and existing Department of Agriculture personnel could be trained to monitor the situation, the return to free feeding could approach or even exceed that of poisoning.

4.3.7 The management of the primary bird pests of grain sorghum cropping

The previous sections have outlined bird management practices which are possible in a single bird species situation. These programmes will now be integrated with a knowledge of the agro-economic determinants of grain sorghum cropping to give an overall strategy for Hooker farm.

Figure 4.3 (based on Anderson *et al*, 1973) shows the schematic relationship between grain sorghum yield potential, bird damage potential, crop cycle growing periods, and farm operations for Hooker farm. Two possible farming systems are represented in this figure. The first would grow one seed and two cycles of grain sorghum per year and avoid the magpie goose problem at the end of cycle 2 (C2) by using the lake Kununurra swamps as a free feeding area. Some on-farm grain drying facilities, or the use of dessicant chemicals on the first maturing crops, would be necessary to maintain timeliness for this system. The on-farm little corella management for this system would be that outlined in section 4.3.3 above.

The second system would grow one seed and one cycle of grain sorghum with a late dry season fallow. This system would not require grain drying, crop dessication, or magpie goose free-feeding. In addition, it could be implemented with less per hectare capitalisation in terms of equipment. The little corella management component of this system would be the same as in section 4.3.3 above.

The relative economic merits of these two systems or the others which are possible within the framework outlined in figure 4.3 represents an exercise which has to be done using expected fixed and variable costs at the time of a decision being made. Such budgets are therfore outside the scope of this study.

4.4 The non-agricultural problems involving birds in the Ord development

4.4.1 Public health

Stanley (1972) has outlined the possible consequence for public health of the major ecological changes which have accompanied the Ord development. Subsequently, work by Stanley's group, Liehne *et al* (1977a, b, c) has justified Stanley's concern about arbo-viruses: the situation for malaria, filariasis and schistosomiasis has yet to be clarified.

Liehne *et al* (1977c) have shown that over 90 percent of the 31 bird species tested in the Kununurra area are positive for potentially pathogenic arbo-viruses. Both little corella and magpie geese have been shown to have a frequency of positive response to a haemaggputination-inhibition test for Murray Valley encephalitis (M.V.E.) of greater than 50 percent. These results are particularly interesting in that the rate of occurrence of positive individuals seems to be related somehow to lake Kununurra.

The four major implications of the above results when they are considered in the light of the findings of this study are:

(i) The seasonal movement of little corella from the static super-flock to the static sub-flock may concentrate birds with a high infective potential in the immediate area of station homesteads. This concentrating effect could constitute an unrealised hazard to the station population.

(ii) The probable movement of the magpie geese population between the swamps of lake Kununurra and those of the northern territory coastal plains means that the birds are now spending the entire year in environments with high mosquito densities. The resultant increased likelihood of transmission rate between magpie geese which should follow this could accelerate the "critical mass" phenomenon which is thought to be the basis of M.V.E. epidemics in souther-eastern Australia (Burnett, 1962). This has implications for the human populations of the Ord development and of Darwin.

(iii) The Ord has already become, and is likely to increasingly become, a major component of the stable water bird habitat which is available in the uniquely dry Australian continent. The high frequency of arbo-viruses in the local vertebrate populations and the presence of a year-round transmission potential could result in it becoming a major source of the pathogens for the rest of Australia.

(iv) Arbo-viruses previously unknown to Australia could be introduced via the Ord system. The route for this introduction could be via the very large number of inter-continental migratory birds which visit the Ord on a regular basis. The most numerous of these belong to the order charadriiformes and some have migrations which extend well into Eurasia; others, like members of the family cuculidae and the pied heron (*Hydranassa picata*, Gould, 1845) are of south-east Asian origin. All of these species come from areas where pathogenic arbo-viruses foreign to Australia are common. The Ord is the only area in Australia where migrants at a high density mix with native species at a high density in the presence of a high density of many species of mosquito.

The management options open in this situation of uncertainty are very limited. Short of the eradication of birds, the massive use of insecticides, or the abandonment of the Ord development, there are few biological options available for the management of these problems should they become serious. Management must therefore be based upon the normal methods of preventative medicine.

4.4.2 Civil aviation

The problem posed by birds to civil aviation at Kununurra was more immediate than that of human health. The problem was basically that one of the major flight paths used by most of the birds present on the farming area crossed the runway of the local airport (figure 1.3). This resulted in several minor bird strikes and numerous near-misses in the late 1960's. This resulted in an inspection of the problem by G. F. vanTets (Van Tets, 1970). Van Tets recommended the changing of farming practices and the destruction of roost trees as ways of changing the area's attractiveness to birds.

During the course of this study the problems continued and intensified. The most serious incident was a little corella engine ingestion and multiple strike by a Fokker F28 passenger jet. The ingestion, which occurred after V2 [1] had been gained, necessitated the complete shut-down of one of the aircraft's two engines. The aircraft landed safely; however the cost of this ingestion to the operating company (MacRobertson Miller Airlines) would have approached $50,000 (Anderson, pers. comm.). This approaches twice the

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1 This is the safe fly-away speed on one engine.

FIG. 4·4. NUMBERS OF LITTLE CORELLA USING FLIGHT PATHS I AND 2 (ACROSS AIRPORT RUNWAY) APRIL 1971 TO SEPTEMBER 1973 INCLUSIVE.

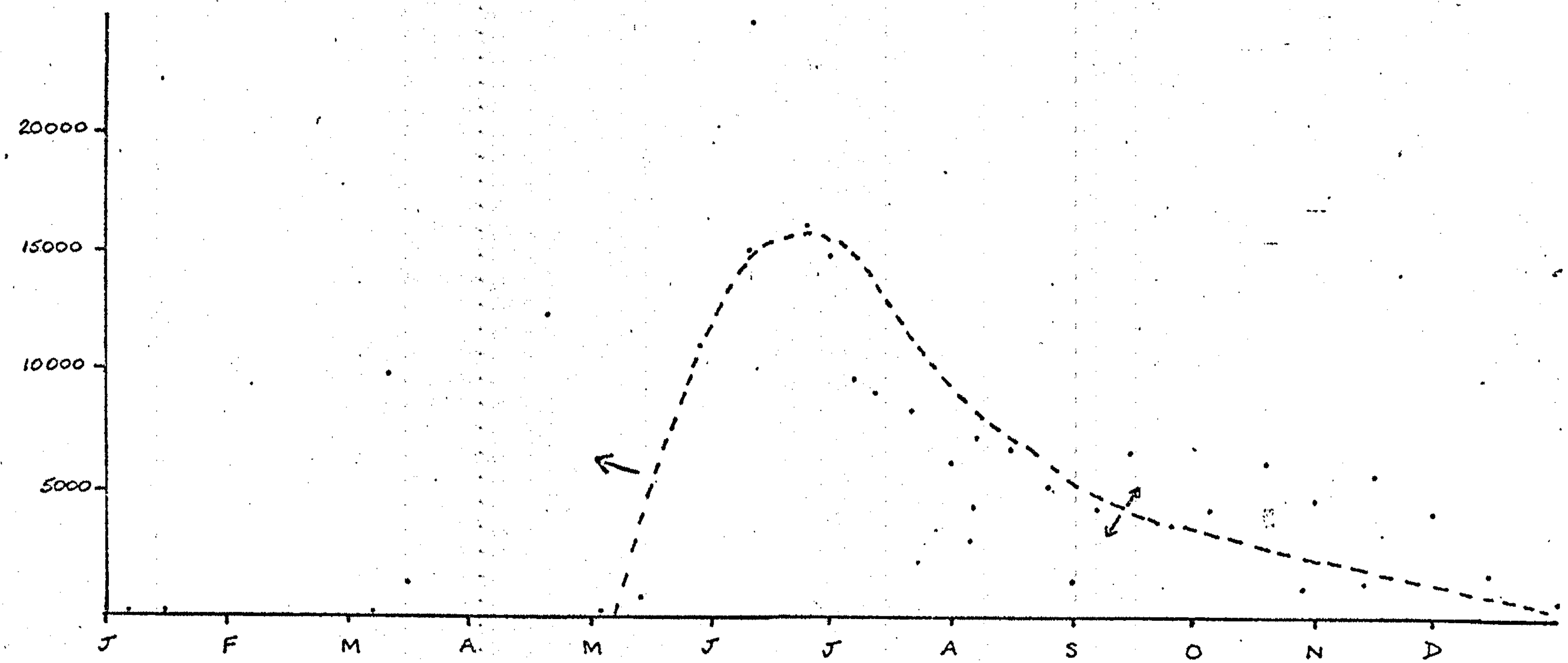


FIG. 4.5. NUMBERS OF MAGPIE GEESE FLYING OVER AIRPORT RUNWAY, (BASED ON 1972 AND 1973 DATA ONLY.)

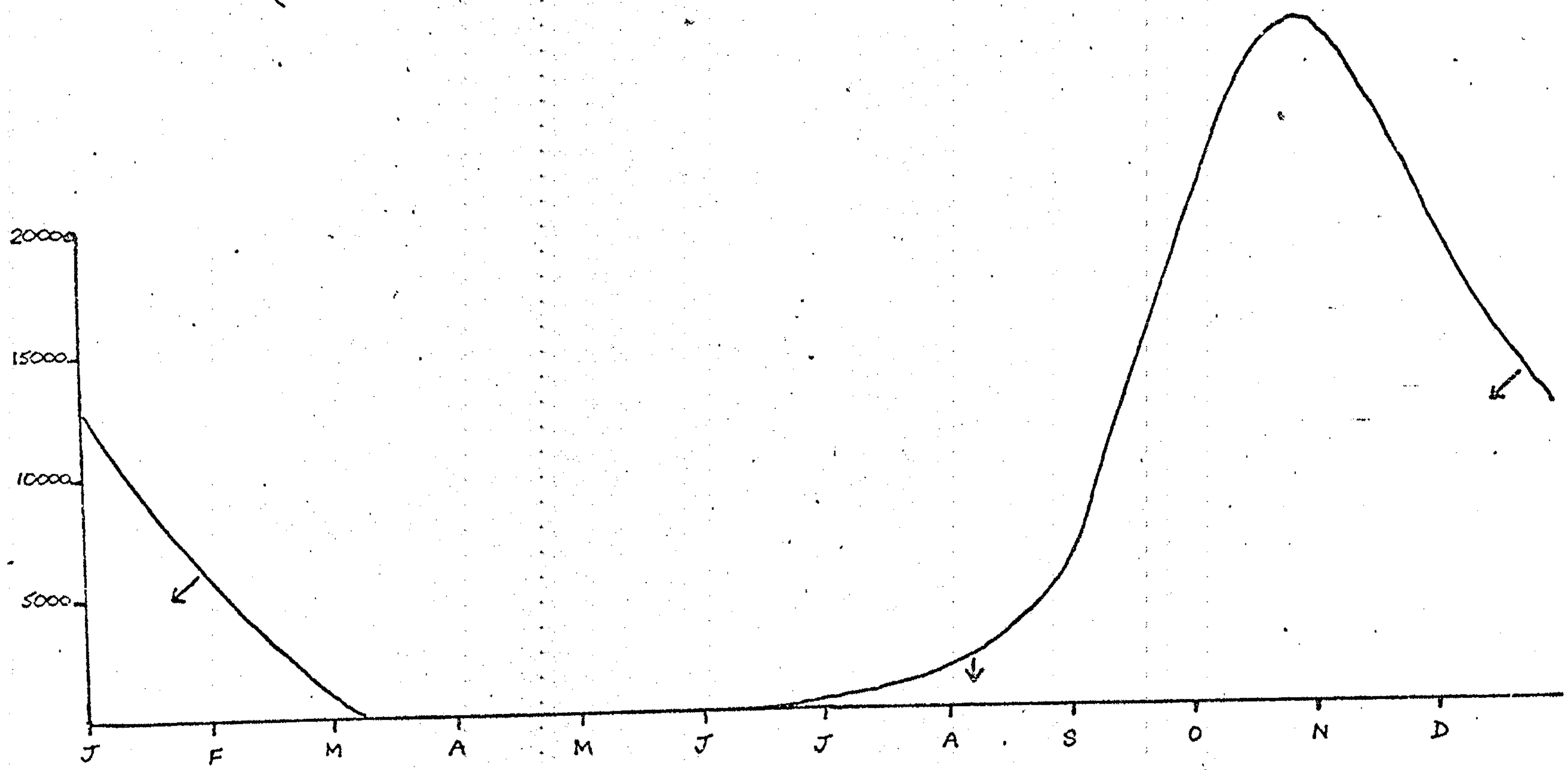


Fig. 4.6 Summary of bird hazard to aviation at Kununurra airport in an average year. (Thickness of bar represents degree of hazard, where degree of hazard $\propto \sqrt[3]{\text{numbers}}$.)

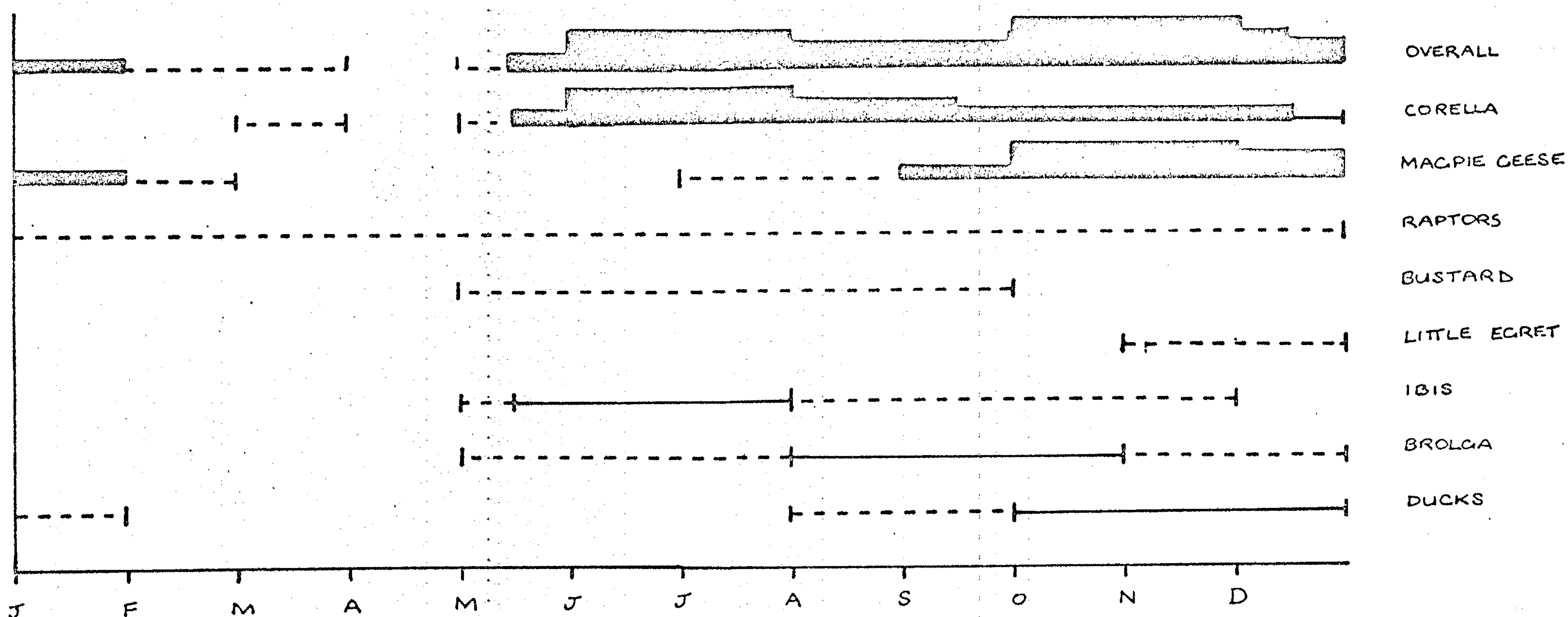
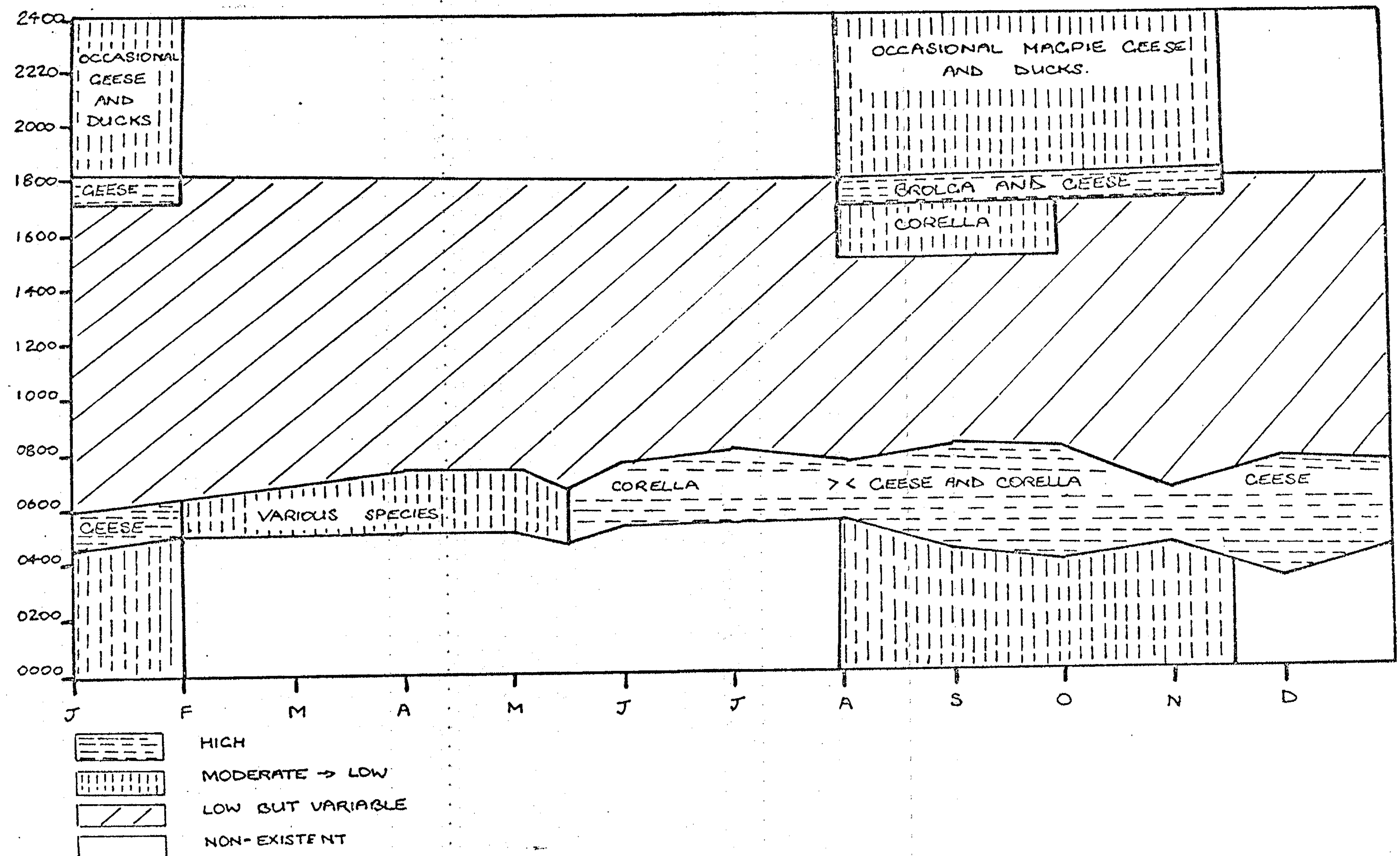


Fig. 4.7 Relationship between hours of the day and degree of bird hazard for Kununurra airport in an average year.



total value of grain lost to birds for the entire study.

The basic determinants of the probability of air-strike in an airport environment are bird numbers, group size, density and behaviour at all times of the day. This information was being routinely gathered as part of the general agricultural study and can be presented here in a form relevant to the air strike problem and its management.

Figures 4.4 and 4.5 give the mean numbers of little corella and magpie geese which utilise the across-airport flight path. The figures show the seasonal pattern which could be expected to prevail if grain cropping was to continue at the same level and in the same location as for 1972. Numerical data for other less significant species are presented in Chapter 3 and Appendix V. Using the numerical degree of hazard index developed by Van Tets (1969) the seasonal hazard presented by the eight most numerically significant species has been calculated (figure 4.6).

Figure 4.6 shows that a substantial bird strike hazard existed at Kununurra from mid-May to late January with a major peak in October to November. The secondary peak which occurred in June and July was particularly interesting as it was caused by the sudden change in night roosting and morning fly-out behaviour of the little corella rather than a change in actual numbers in the valley. This sudden change was particularly hazardous as it typically occurred suddenly over a one or two day period after several months of comparatively low hazard.

Data on the temporal pattern of airport airspace usage by birds were also collected. These data have been combined in figure 4.7, which shows the daily pattern of the bird strike hazard by months. The arbitrary categories used in this figure are:

- (i) High - risk was sufficiently high to warrant closure of the airport
- (ii) Moderate to low - airport usage was possible but a strict operating system should be followed

(iii) Low - airport usage with extra vigilance was possible

(iv) Non-existent - normal usage possible.

From this simple analysis of the problem, the following recommendations are made for the avoidance of bird strike at Kununurra.

(i) In months when the danger is substantial, schedules should be arranged to give Kununurra arrival times which correspond to the minimum hazard (figure 4.7).

(ii) Ground-to-air communications should be available at Kununurra. These should be used to inform the Captain of aircraft of the bird situation on the ground. This should be formalised and a procedure developed for preparing a bird situation report.

(iii) Birds should be considered when planning take-offs and landings. Generally, the greater hazard exists at the eastern end of the runway. This area should be avoided whenever possible, even if its avoidance necessitated a reduction of aircraft take-off weight.

(iv) Bird checks should be formally incorporated into the current landing and take-off procedure used by M.M.A.

(v) Only high performance jets (V_1 close to V_2) should be used on the Kununurra strip. If necessary, their allowable take-off weight should be reduced for operation out of Kununurra to increase the safety margin.

(vi) Flight deck equipment for jets regularly using the Kununurra strip should include gyroscopically stabilised binoculars. This would allow checks of the bird flight paths to be made during the early part of an approach into Kununurra.

These simple precautions do not reduce the risk involved in the operation of jet aircraft in and out of Kununurra to a level comparable with that in other northern centres. If this was desired, a considerable conflict exists with the requirements of both agriculture and conservation.

The world-wide proven method of reducing the bird strike hazard is the management of the airport and its surrounds in a way which reduced their attractiveness to birds. In the case of Kununurra, this would mean the elimination of grain cropping in all areas but the extreme north of the valley. Such a proposal would not find favour with hard-pressed farmers in the area.

An alternative proposition would be to eliminate the birds. This notion has little merit. Firstly, the effectiveness of such a programme would be extremely doubtful. Secondly, wholesale slaughter on the scale required would be unacceptable to the public.

The third alternative would be the most attractive from the absolute reduction of hazard point of view. This would involve moving the airport to a site remote from the diversion dam. The actual siting of the new airport would require a detailed knowledge of the local birds on a daily and seasonal basis as a component in its planning. The cost of such an exercise would, for the time being at least, militate against its implementation.

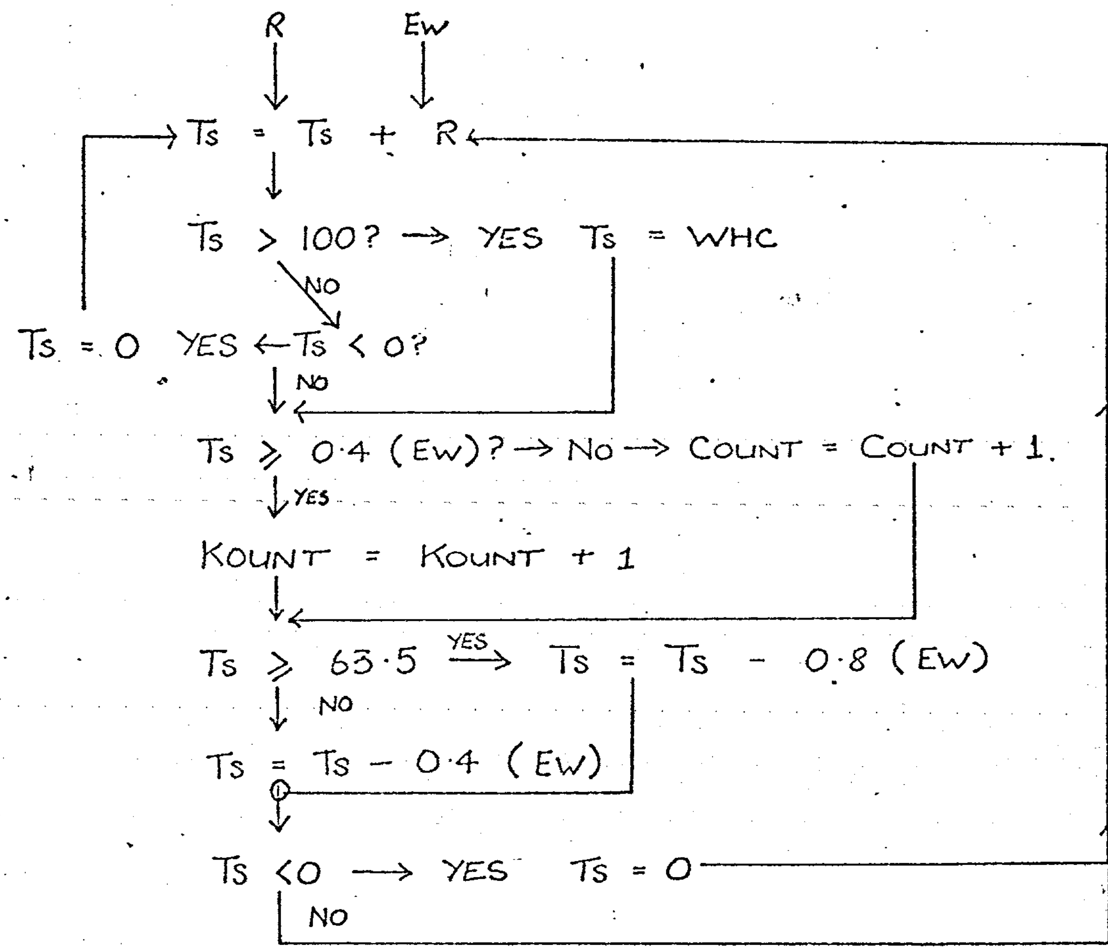
4.5 The compatibility of the agricultural and non-agricultural problems caused by birds

Birds, agriculture, civil aviation and human health are components of a wider system. However, the recommendations pertaining to the management of the civil aviation problem and those relating to the grain sorghum growing problem are highly compatible.

The agricultural management recommendations should reduce the numbers of birds crossing the runway and provide a precise basis for predicting when birds are likely to be flying over the runway. On the other hand, the civil aviation recommendations would have no effect on agriculture in the valley.

The situation for human health and agriculture is less promising. The recommended agricultural management practice of concentrating magpie geese in the swamps of lake Kununurra may effect the rate of cycling of arbo-viruses in the population. In addition, the wide-spread success of agriculture in the valley would, while eliminating the bird pest problem by damage dilution, accentuate the human health problem by increasing the number of humans in the area.

FIG. A.1·1. THE WATER BALANCE MODEL OF PASTURE GROWTH.



KEY

EW = STANDARD EVAPORATION FOR WEEK.
(SET USING K.R.S. DATA 1949 – 1970. FIGURE A 3·1)

WHC = SOIL WATER HOLDING CAPACITY SET AT 100 MM AFTER SLATYER (1960).

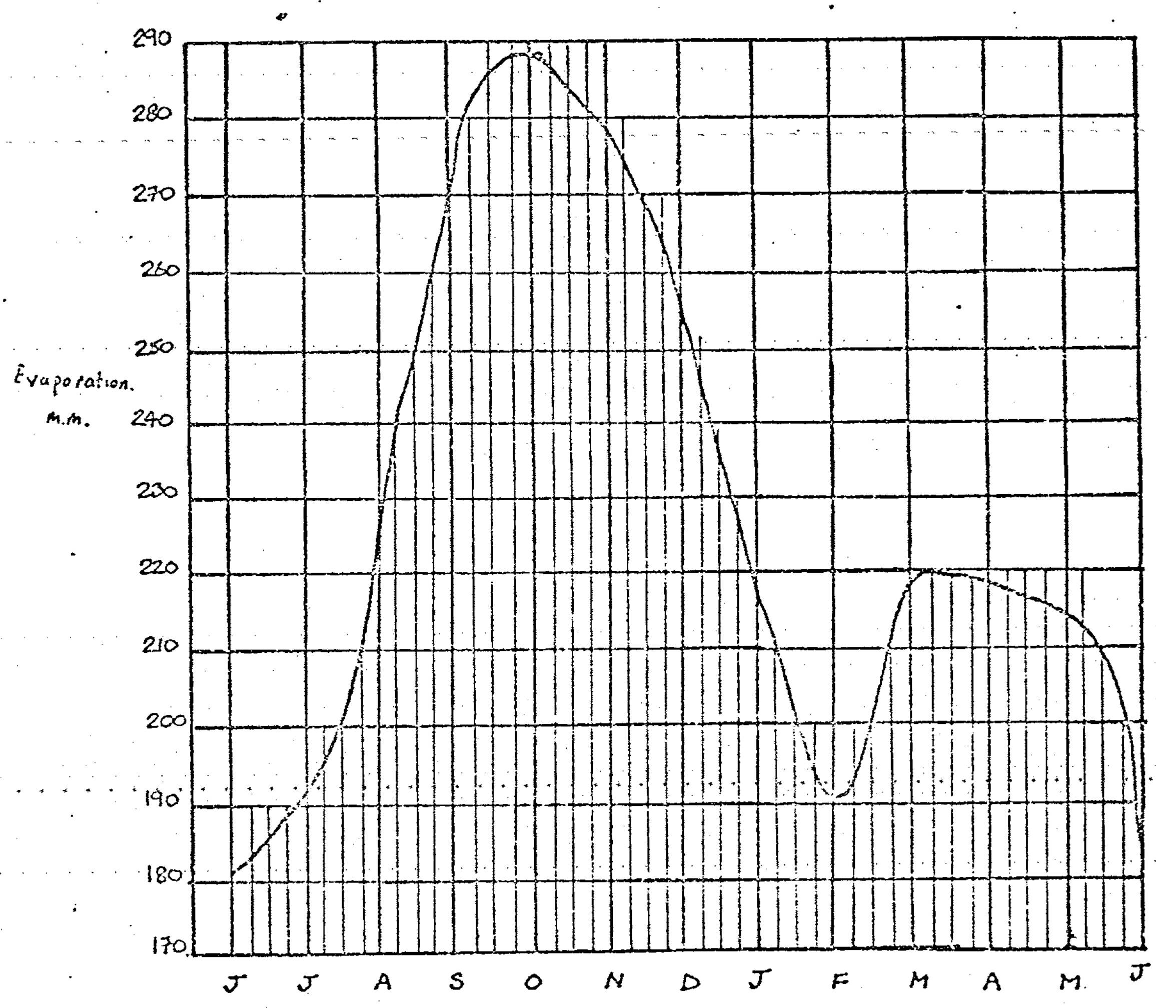
R = RAINFALL FOR WEEK.

TS = TOTAL SOIL WATER.

COUNT = NO. OF NON-GROWTH WEEKS.

KOUNT = NO. OF GROWTH WEEKS.

FIG. A.1.2. MEAN STANDARD OPEN SURFACE EVAPORATION FOR K.R.S.



APPENDIX I

The native pasture growth model

Slatyer (1960) and Fitzpatrick and Arnold (1964) have developed a general model for pasture growth in the study area. These models were originally written for dry land agriculture in the Katherine area by Slatyer (1960). Subsequently, Fitzpatrick and Arnold (1964) modified the model for the native pastures of the west Kimberley. Slatyer (1970) re-applied the Fitzpatrick and Arnold model to the study area.

The models used in the original studies were written for a digital computer and were not available in this original form to the author. The model used in this study (figure A1.1) is a reconstruction of the original model which was written for a Hewlett-Packard - 25 desk calculator and operated manually. It was felt that this reconstructed model is a fair representation of the original models. Model authentication used available data to generate results which were then compared to the results obtained by Slatyer (1970) (Table 2.2, Chapter 2).

The assumptions of the model are detailed by Slatyer (1960) and Fitzpatrick and Arnold (1964). The only deviations from the original are the use of uncorrected open surface evaporation data, and weekly time intervals (fig A1.2). The humidity correction for open water evaporation developed by Slatyer (1960) only gives a change in output of a few percent (Slatyer, 1960). Its use would have required a major re- analysis of Kununurra data; this was not considered necessary for this study. Although daily rainfall and evaporation data are available, weekly sums have been used in this study to simplify calculations.

One assumption of the Slatyer (1960) and Fitzpatrick and Arnold (1964) models was that the top 1.23 metres (4 feet)

TABLE A1.1 Re-analysis of Lazarides, Norman & Perry (1965) using plant growth weeks model of Slatyer (1960) and Fitzpatrick & Arnold (1964).

Week starting	Mean Ew [1] Slatyer (1960)	Mean rainfall Slatyer (1960)	Cumulative growth weeks to date: Tippera soil [3]	Manbullo soil [3]	Blain soil [4]	Growth weeks 1963-64 (Rainfall in parentheses): Tippera soil	Manbullo soil	Blain soil	Week No. in L, N & P
23 Oct.	40.51	7.4	0			(22.9) 1	(45.7) 1 *	(24.1) 1	
30 Oct.	40.5	7.4	0			(3.8) 1	(4.5) 2	(1.3) 1	
6 Nov.	39.2	17.8	1	1	1	(0) 1	(0) 2	(8.9) 1	
13 Nov.	39.2	17.8	2	2	2	(0) 1	(6.4) 2	(0) 1	
20 Nov.	36.6	21.5	3	3	3	(0) 1	(0) 2	(0) 1	
27 Nov.	36.6	21.5	4	4	4	(10.2) 1	(10.2) 2	(10.2) 1	1
4 Dec.	36.5	34.7	5 *	5 *	5 *	(39.4) 2*	(68.6) 3*	(38.1) 2*	2
11 Dec.	36.5	34.7	6 *	6 *	6 *	(30.5) 3*	(2.5) 4*	(15.2) 3	3
18 Dec.	34.9	57.5	7 *	7 *	7 *	(38.1) 4*	(38.1) 5*	(22.9) 4	4
25 Dec.	34.9	57.5	8 **	8 **	8 *	(14) 5*	(10.2) 6*	(6.4) 4	5
1 Jan.	37.6	61.1	9 **	9 **	9 *	(38.1) 6*	(36.8) 7*	(34.3) 5*	6
8 Jan.	37.6	61.1	10 **	10 **	10 *	(24.1) 7*	(27.9) 8**	(38.1) 6*	7
15 Jan.	42	41.5	11 **	11 **	11 *	(7.6) 8	(7.6) 9*	(5.1) 7	8
22 Jan.	42	41.5	12 **	12 **	12 *	(45.7) 9*	(52.1) 10**	(50.8) 8*	9
29 Jan.	41.5	44.1	13 **	13 **	13 *	(10.2) 10	(17.8) 11**	(19.1) 9	10
5 Feb.	41.5	44.1	14 **	14**	14 *	(10.2) 10	(33) 12**	(48.3) 10*	11
12 Feb.	48.1	45.9	15 *	15**	15*	(0) 10	(0) 13 **	(0) 10	12
19 Feb.	48.1	45.9	16 *	16 **	16 *	(15.2) 10	(26.7) 14**	(17.8) 10	13
26 Feb.	55	46.4	17 *	17 **	17	(0) 10	(0) 15**	(0) 10	14
4 March	55	46.4	18 *	18 **	18	(40.6) 11	(53.3) 16**	(41.9) 11	15
11 March	54.4	32.6	19 *	19 **	19	(58.4) 12*	(81.3) 17**	(47.0) 12	16
18 March	54.4	32.6	20 *	20 **	20	(37.6) 13*	(43.2) 18**	(55.9) 13	17
25 March	53.6	20.2	21 *	21 **	20	(7.6) 13	(7.6) 19**	(3.8) 13	18
1 April	53.6	20.2	22 *	22 **	20	(5.1) 13	(12.7) 20**	(2.5) 13	19
8 April	56	1.9	23 *	23 **	20	(2.5) 13	(2.5) 21**	(0) 13	20
15 April	56	1.9	23	24 **	20	13	22*	13	
22 April	56.4	0	23	25 *	20	13	23*	13	
29 April	56.4	0	23	26	20	13	23	13	
6 May	53	2.8	23	26	20	13	23	13	
13 May	53	2.8	23	26	20	13	23	13	
20 May	48.5	1	23	26	20	13	23	13	
27 May	48.5	1	23	26	20	13	23	13	
Total No. of [6] growing weeks			23	26	20	13	23	13	
Total No. of [7] weeks with available water 63.5mm			7	17	0	0	13	0	
Total No. of weeks with available water at end of week			19	21	12	9	22	5	

1. Slatyer (1960) mean for 1948 to 1959. Using fortnightly figure divided by 2.
2. Slatyer (1960) mean for 1911 to 1940. Using fortnightly figure divided by 2.
3. Based on model of Slatyer (1960) and Fitzpatrick & Arnold (1964). Using available soil water storage data of Stewart (1970).
4. Available soil water storage for cockatoo, a similar sandy soil . (Figures used are for 1.23 metres of soil, values are Tippera 81.28mm; Manbullo 132.08 mm; Blain 43.18 mm.)
5. * Soil water in storage $0 < Ts < 63.4$ mm
   ** Soil water in storage $Ts > 63.4$ mm
6. Slatyer (1970) puts this figure at 22.4 ± 2.8 weeks for Katherine generally.
7. Slatyer (1970) puts this figure at 14.5 ± 3 weeks for Katherine generally.

of soil had an available soil storage capacity of 100 mm (i.e. 4 ins.). Subsequently available data (Stewart, 1970) show that soils common in the area show a range of values for this parameter of at least 43 mm to 132 mm. The reworked Lazarides, Norman & Perry (1965) data (Table A1.1) give an indication of the model's sensitivity to this parameter. The implication of this for this study is that any given set of seasonal conditions will give a mosaic of responses in terms of range productivity. Any generalisations made from the output of the model should thus be regarded as indicative and relative rather than absolute.

TABLE A2.1 Growth patterns of some native grasses near Katherine (from data of Lazarides, Norman & Perry (1965)

	Date of commencement of growth stage							
	Vegetative tillers		Reproductive tillers		Seed fall		% seed fall	
Grass species	Burnt	Unburnt	Burnt	Unburnt	Burnt	Unburnt	Burnt	Unburnt
Themeda australis	< 27/11	< 27/11	29/1	15/1	25/3	12/2	35	90
Sorghum plumosum	< 27/11	< 27/11	22/1	15/1	(4)	(4)	-	-
Sehima nervosum	< 27/11	< 27/11	22/1	29/1	19/2	12/2	60	38
Chrysopogon fallax	< 27/11	< 27/11	8/1	25/12	5/2	(5)	85 (6)	
Chrysopogon latifolius 1	< 27/11	< 27/11	19/2	5/2	8/4	26/2	0	100
Heteropogon contortus	< 27/11	< 27/11	29/1	5/2	4/3	18/3	95	40
Sorghum stipoideum 1	–	< 27/11	-	22/1	-	26/2	-	100 (7)
Sorghum stipoideum 2	–	< 27/11	-	29/1	-	19/2	-	100 (8)
Aristida hygrometrica 1	–	< 27/11	-	8/1	-	5/2	-	100 (9)

1. On Manbullo soil (sandy loam)
2. On Blain soil (sand)
3. Seed fall as cumulative % of all reproductive tiller ready for seed fall in week 20.
4. Failed to complete reproduction apparently due to February drought.
5. Very few tillers completed reproduction.
6. These completed by 19/2, rest failed.
7. Complete by 18/4 in 6 weeks for full reproduction cycle.
8. Complete by 4/4 in 4 weeks for full reproduction cycle.
9. Complete by 11/4

APPENDIX II

The development patterns of native pasture species in relation to the pasture growth model output.

A. Development patterns in native grass species at Katherine, N.T.

Lazarides, Norman and Perry (1965) provide the only detailed published account of the development patterns of grasses for land systems similar to those at Kununurra. To provide an accurate extrapolation of these data to Kununurra, the data provided by these authors have been re-worked.

Table A1.2 shows open surface evaporation and average rainfall for Katherine (Slatyer, 1960). These data have been used to generate the average pasture growth characteristics for the three soil types. This exercise utilised the Slatyer (1960) and Fitzpatrick and Arnold (1964) model discussed in Appendix I. Soil water storage characteristics from Stewart (1970) are used in this computation. The mean evaporation figures and the actual rainfall data given by Lazarides, Norman and Perry (1965) are used to generate the pasture growth characteristics for each soil type over the season for which pasture parameters are available.

From Table A1.1 it can be seen that 1963/64 was a poor year, especially for Tippera clay soil. For this site, growing weeks were down to 56.5% of the mean, high growth weeks were down 100% and moderate growth weeks were down 47%. In addition an effective 5 weeks drought occurred in February.

For Manbulloo and sandy loam and Blain sand, the situation is not so severe, but is in both cases below average. Manbulloo soil did not suffer a February drought and the drought in the Blain soil was only of three weeks duration.

Table A2.1 is a summary of the growth patterns of the specified native grasses observed by Lazarides, Norman and Perry (1965). The poor season for Tippera clay soil is reflected in the reproductive failure of both treatments of *Sorghum plumosum*, the partial reproductive failure of the burnt treatment of *Chrysopogon fallax* and the complete reproductive failure of unburnt treatment of *Chrysopogon fallax*. This result agrees with the 1951/52 observations of Arndt and Norman (1959) that, following a rainfall of 42% of the local average, perennial grass seed production failed completely.

The other trends shown in Table A2.1 support field observations by the author at Kununurra that the annual species (*Sorghum stipoideum* and *Aristida hygrometrica*) have a compressed development, with a 100% seed fall by the end of the effective wet season, an observation supported by Frith and Davies (1961), for wild rice at least, on the sub-coastal plains of the N.T. The longer period to maturity on manbullo soil of *Sorghum stipoideum* reflects the better conditions for growth experienced (Table A1.2).

Perennial species have a longer development period and are consequently susceptible to poor seasonal conditions. The results (Table A2.1) suggest that a peak in available ground seed would not occur before mid-May or later. This would be about 9 weeks after the effective finish of the growing season for Tippera soil. The one perennial on manbullo soil (*Chrysopogon latifolius*) shows a delay beyond this for burnt plants and less for unburnt plants. These results suggest that the peaks of perennial fallen seed productivity would occur in May to June for those years when rainfall is adequate. The exact timing of the peak would be dependent on rainfall and the water holding characteristics of the soils involved. In years when rainfall is bad (say, less than 50%) the production of perennial seed would be severely curtailed.

TABLE A2.2 Characteristics of period of useful pasture growth At Kununurra and Katherine (1911-40) (From: Stewart *et al*, 1970)

	Katherine	Kununurra
Start of dominant pasture growth period		
Mean date	Nov. 30	Dec. 14
Standard deviation (wk)	2.7	3.6
Total duration (wk) of useful pasture growth		
Mean	22.4	18.2
Standard deviation	2.8	3.4
Duration (wk) of pasture growth with available water 2.5 in.		
Mean	14.5	9.5
Standard deviation	3.0	2.5
% of years with total duration of pasture growth 8 wk	100	100
12 wk	100	97
16 wk	97	77
20 wk	77	30
24 wk	27	7

B. Native grass seed availability: Ord river area

The pattern of native grass development at Katherine is applicable to the Ord river area. The species of grass, soil types, geomorphology, and general climatic conditions are essentially similar (see Stewart *et al*, 1970). A comparison of the pasture growth data for Kununurra and Katherine (Table A2.2) shows that the mean pasture growth period at Kununurra is about 4 weeks less than Katherine, with slightly fewer weeks of high soil moisture availability. This entire difference is accounted for by an earlier commencement of the growing season at Katherine (early November Katherine, early December at Kununurra). Translated into pasture development, these differences are unlikely to be significant in terms of the timing of seed fall. The general characteristics of a given year are more important than any locational difference.

This general pattern for grass seed availability is supported by field observations in the Kununurra area made during the course of this study.

(d) Monthly rainfall Turkey Creek Post Office, wet seasons 1962/63 to 1969/70 inclusive

	J	A	S	O	N	D	J	F	M	A	M	J	Total
1962/63	2	0	0	13	33	35	325	149	23	7	0	0	587
1963/64	0	0	0	7	5	66	37	72	20	19	29	1	255
1964/65	0	1	10	16	12	55	37	11	150	0	0	1	292
1965/66	0	0	0	21	63	60	263	38	83	0	20	0	548
1966/67	0	9	1	69	48	112	107	322	91	0	0	0	759
1967/68	0	0	0	2	10	32	214	160	180	31	132?	0	761
1968/69	74	0	6	6	20	70	225	401	187	0	0	1	990
1969/70	0	0	18	47	14	106	23	81	82	13	10	0	394

Long-term mean 610 mm.

TABLE A3.1 Monthly rainfall for an 8-year period for four centres in the wider study area

(a) Monthly rainfall Kununurra Post Office, wet seasons 1962/63 to 1969/70 inclusive

	J	A	S	O	N	D	J	F	M	A	M	J	Total
1962/63	12	0	0	61	58	68	199	193	31	18	0	0	640
1963/64	0	0	0	2	30	54	210	63	187	1	13	0	560
1964/65	0	0	0	25	88	22	144	109	216	0	0	0	604
1965/66	0	0	0	2	17	186	277	225	100	5	0	3	815
1966/67	0	0	0	55	114	148	148	323	81	1	0	0	870
1967/68	0	0	0	0	130	46	294	453	246	23	133	0	1325
1968/69	78	0	2	11	59	103	102	397	254	0	0	2	1008
1969/70	0	0	2	21	15	55	63	149	46	7	0	0	358

Mean 772 mm.
Long-term (1949-70) K.R.S.mean 809 mm.

(b) Monthly rainfall Katherine Post Office, wet seasons 1962/63 to 1969/70 inclusive

	J	A	S	O	N	D	J	F	M	A	M	J	Total
1962/63	0	0	0	1	126	61	477	137	68	180	1	0	1,051
1963/64	0	0	0	46	5	128	205	104	197	17	2	0	704
1964/65	0	0	0	99	214	189	98	27	221	15	0	0	861
1965/66	0	0	0	30	4	177	241	226	48	0	2	0	728
1966/67	0	0	29	33	140	132	208	400	217	0	0	0	1,160
1967/68	0	0	0	0	104	155	367	444	176	7	40	0	1,292
1968/69	48	0	2	3	86	109	221	431	158	0	0	2	1,058
1969/70	0	0	2	87	4	266	75	133	12	69	0	0	649

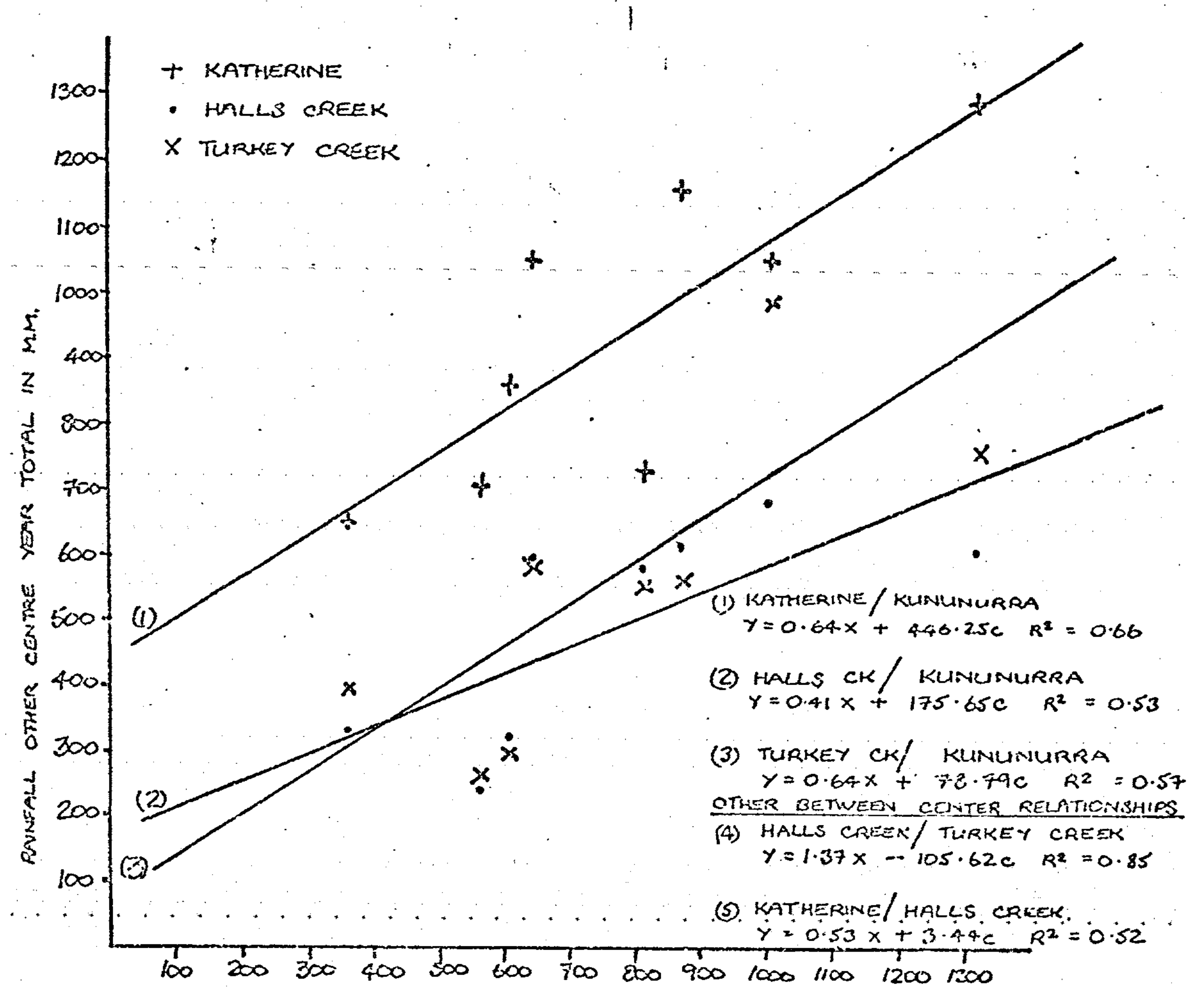
Long-term mean 946 mm.

(c) Monthly rainfall Halls Creek Post Office, wet seasons 1962/63 to 1969/70 inclusive

	J	A	S	O	N	D	J	F	M	A	M	J	Total
1962/63	1	1	0	44	13	47	270	175	43	0	2	0	596
1963/64	0	0	0	2	1	57	62	50	6	19	41	0	238
1964/65	0	3	2	0	3	91	87	39	91	0	0	1	317
1965/66	0	0	0	14	36	25	396	43	37	3	23	6	583
1966/67	0	2	0	14	28	52	147	307	66	0	0	0	616
1967/68	0	0	0	1	8	67	180	163	91	45	52	0	607
1968/69	23	0	1	11	11	11	212	325	88	0	1	1	684
1969/70	3	0	0	20	13	131	36	50	31	27	15	0	326

Long-term mean 504 mm.

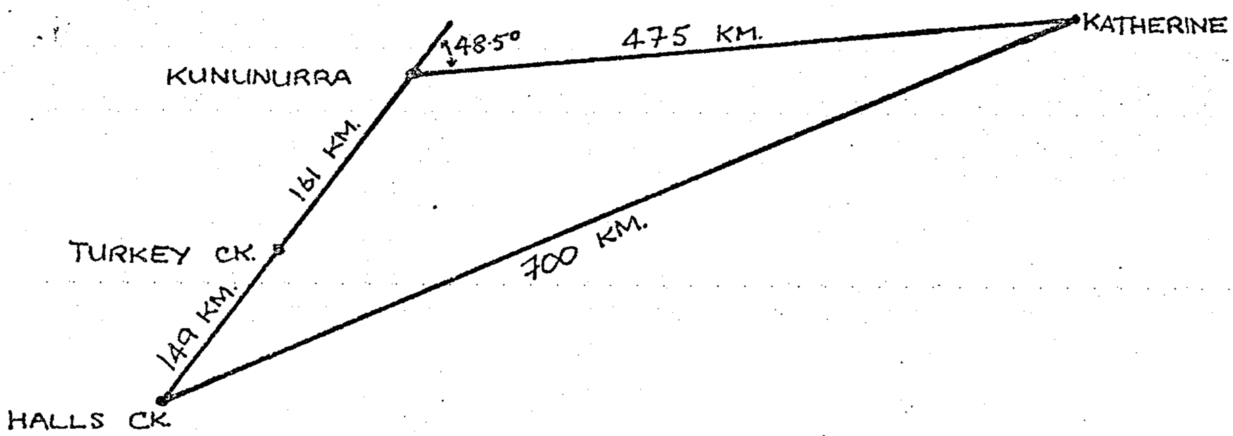
FIG. A. 3·1. RELATIONSHIP BETWEEN, TOTAL ANNUAL RAINFALLS OF SOME ORD, VICTORIA REGION CENTRES FOR THE 1962/63 TO 1969/70 WET SEASONS.



APPENDIX III

The validity of using Hooker farm rainfall as a basis for pasture growth in the whole region

Table A 3.1 gives the monthly and total rainfall figures recorded at Katherine, Kununurra, Turkey Creek and Halls Creek post offices for the wet seasons 1962/63 to 1969/70 inclusive. These four centres lie on the sides of a triangle of 5,069,900 ha.



There is a marked correlation of rainfall between centres. (figure A3.1). This similarity between centres up to 700 km apart allows some confidence to be put in generalisations about seasons based on data recorded at Kununurra during the study.

TABLE A4.1 A brief summary of the assessment of bird damage to grain crops (non-Australian sources)

Author and year	Crop	Country or Continent	Subject matter
Neff (1949)	rice	U.S.A.	General discussion, rice, blackbirds, damage
Ridpath and Murton (1956)	general	U.K.	General discussion, philosophy of approach
Neff and Meanley (1957)	rice	U.S.A.	Blackbirds, damage, control, good overview of local problem
Kear (1963)	cereals	U.K.	General summary, gives perspective especially for wildfowl.
Murton *et al* (1963)	cereals etc.	U.K.	Wood pigeon, feeding ecology, excellent perspective.
Ward (1964)	cereals	Africa	Quelea, general picture
Kear (1965)	cereals	U.K.	Goose damage assessment
Dyer (1966)	corn	Canada/USA	Blackbirds, model of feeding behaviour, damage assessment
Schneider and Jackson (1966)	general	USA/Canada	Edited version of conference gives general picture to date.
Dyer (1967)	maize/sweet corn	Canada	Developed version of Dyer (1966) above
Crook and Ward (1968)	cereals	Africa	Quelea, good general picture of problem to date.
Dunnet and Patterson (1968)	cereals	Scotland	Preliminary report, see Feare (1974), rooks.
De Grazio *et al* (1969)	corn	U.S.A.	Blackbird damage assessment.
Anon (1969)	cereals	Africa	Quelea, report of current research.
Murton (1971)	cereals	U.K.	Good summary of U.K. and African work to date.
Stone *et al* (1972)	corn	U.S.A.	Bird damage for 1970 to corn crop.
Ward (1972)	cereals	Africa	Quelea control.
Anon. (1973)	cereals	Africa	Quelea progress report.
Murton (1973)	cereals etc.	U.K.	View of feedback of agriculture on birds.
Newton & Campbell (1973)	cereals etc.	Scotland	Goose damage, cereal damage negligible, mainly non-grain crops affected.
Ramzan and Toor (1973)	maize	India	Damage to experimental crops by parrots.
Assocn. Appl. Biol. (1974)	general	U.K.	Proceeding of conference, wide range covered, good.
Feare (1974)	cereals	Scotland	Rook damage cereals, control.
Feare *et al* (1974)	cereals	Scotland	Food and feeding behaviour, rooks.
Centre for Overseas Pest Research (1975)	sorghum	Botswana	Dove damage and control.
Dolbeer (1975)	sunflower	U.S.A.	Damage assessment.
Dyer (1975)	corn	Canada/USA	Blackbird damage to corn

APPENDIX IV

Bird damage to grain crops - a short review

Table A4.1 gives a summary of the non-Australian literature which deals with this problem. Although this literature is considerable, it was only in 1975 that Weins and Dyer made the first attempt to put the complex problem of grain removal by birds into a frame-work which could in the future allow accurate damage assessments to be made. Previously, the generally diffuse nature of bird damage, together with the occurrence of severely damaged "local hot spots" had reduced bird damage assessment to a generally subjective exercise when areas greater than a single field or farm were considered.

The Australian situation has in many ways paralleled the overseas experience. Attempts at assessing bird damage have been made by Lavery in Queensland (Lavery, 1965, 1968 and 1971; Lavery and Blackman, 1970), Frith in the Riverina (Frith, 1957) and Frith and Davies in the Northern Territory (Frith and Davies, 1958; 1961). Frith and Frith and Davies' work involved rice growing and duck and magpie geese; Lavery's grain sorghum and parrots. Reference has also been made to little corella and galah damage to crops at Tipperary (Northern Territory) (Daughton, 1971) and occasional references appear in popular books (e.g. Serventy and Whittle, 1967).

Australian work on other aspects of bird pests and agriculture has been carried out mainly by the C.S.I.R.O. Division of Wildlife Research. A good summary of this work may be found in Anon (1976).

APPENDIX V

Tertiary pests, Status summaries

COMMON NAME: Red tailed black cockatoo   NAME: *Calyptorhynchus banksi*

APPEARANCE REGULAR ON ANNUAL BASIS: Yes

Months present: April-September

Numbers at peak: 200 - 1,000 variable

Sudden build-up: Arrive in established mobs

Factors involved in build-up: Dry season nomad

IF IRREGULAR SPECIFY OBSERVATION

1.

2.

3.

4.

5.

SWAMP-FARM AXIS:

SAVANNA-FARM AXIS: ✓

CROP FEEDING GRAIN:

CROP FEEDING NON-GRAIN (Specify):

FARM FEEDING DRAINS & CHANNELS:

FARM FEEDING OTHER (Specify): Feed on forage stubble and waste grain

HISTORIC RECORD OF DAMAGE: Have damaged rice at K.R.S.

CURRENT PEST STATUS (1970-1973)   Nil ✓ Low Moderate High

POTENTIAL PEST STATUS   1.   Nil Low Moderate ✓ High

2.

NOTES ON BIOLOGY   The species flocks in the dry season. These aggregations can be regular and large (e.g. Point Springs, up to 1,000 birds). The two major food items found in collections were *Chionachne hubbardiana* (at Point Springs) and *Eucalyptus* sp. seeds various sites. Forshaw (1973) lists a diet with a preponder nce of native tree species, but also records *Chionachne barbata*. The superficial resemblance of *Chionachne* sp. to rice could be the basis for the establishment of a tradition of rice feeding in a local population.

COMMON NAME: Eastern Swamphen NAME: *Porphyrio porphyrio*

APPEARANCE REGULAR ON ANNUAL BASIS: No

Months present:

Numbers at peak:

Sudden build-up:

Factors involved in build-up:

IF IRREGULAR SPECIFY OBSERVATION

1. Few on farm during 1971 wet season
2.
3.
4.
5.

SWAMP-FARM AXIS: ✓ (?)

SAVANNA-FARM AXIS:

CROP FEEDING GRAIN:

CROP FEEDING NON-GRAIN (Specify):

FARM FEEDING DRAINS & CHANNELS:

FARM FEEDING OTHER (Specify): On-farm activity unknown

HISTORIC RECORD OF DAMAGE: Has been significant rice pest on K.R.S.

CURRENT PEST STATUS (1970-1973) Nil ✓ Low Moderate High

POTENTIAL PEST STATUS 1. Nil Low Moderate High

2. Could be a moderate pest of rice if conditions are correct.

NOTES ON BIOLOGY

This species is apparently nomadic with respect to the East Kimberley. In the 1971 wet season, large numbers appeared in the swamps and a few spent long periods on the farm. For the rest of the study, the bird was absent.

The K.R.S. experience and the situations elsewhere in Australia suggest that this species could be a pest of rice cropping.

COMMON NAME: Budgerygah NAME: *Melopsittacus undulatus*

APPEARANCE REGULAR ON ANNUAL BASIS: No

Months present:

Numbers at peak:

Sudden build-up:

Factors involved in build-up:

IF IRREGULAR SPECIFY OBSERVATION Records 1968-73 are:

1. 1968 - Dry season: large numbers and breeding
2. 1969, 1970 - Dry season: no birds seen
3. 1971 - one bird only seen in July
4. 1972 - large numbers in dry season with breeding June-July.
5. 1973 - Very large numbers in dry season with breeding June-July.

SWAMP-FARM AXIS:

SAVANNA-FARM AXIS:

CROP FEEDING GRAIN:

CROP FEEDING NON-GRAIN (Specify):

FARM FEEDING DRAINS & CHANNELS:

FARM FEEDING OTHER (Specify): Occasionally in trees around farm.

HISTORIC RECORD OF DAMAGE:

CURRENT PEST STATUS (1970-1973) Nil ✓ Low Moderate High

POTENTIAL PEST STATUS 1. Nil Low Moderate High

2. Could be a major dry season pest of small grain crops. Its habit of ground feeding could however militate against this.

NOTES ON BIOLOGY

The species is regarded as an extreme nomad. The visitations to the east Kimberleys correspond to good seasons only. Breeding is apparently opportunistic. The departure of the birds from the area corresponds to the build-up to the wet but pre-dates the annual food destruction.

From station records it appears that in influx and departure could be along a south-east/north-west track.

In the 1972 and 1973 dry seasons, hundreds of thousands of birds were distributed throughout the east Kimberleys. Some concentrations occurred along the water courses.

COMMON NAME: Finches NAME:
10 species occur in the area

APPEARANCE REGULAR ON ANNUAL BASIS: No

Months present:

Numbers at peak:

Sudden build-up:

Factors involved in build-up:

IF IRREGULAR SPECIFY OBSERVATION

1. One or more species could be found on the farm in low numbers at any time.
2.
3.
4.
5.

SWAMP-FARM AXIS:

SAVANNA-FARM AXIS:

CROP FEEDING GRAIN:

CROP FEEDING NON-GRAIN (Specify):

FARM FEEDING DRAINS & CHANNELS:

FARM FEEDING OTHER (Specify): Often feeding in grass on fallow and drains

HISTORIC RECORD OF DAMAGE: A significant pest of small plot agronomy at K.R.S.

CURRENT PEST STATUS (1970-1973) Nil Low Moderate High

POTENTIAL PEST STATUS 1. Nil Low Moderate High

2. Probably Nil for large-scale cropping

NOTES ON BIOLOGY

All are grass seed eating, and with the possible exception of the Crimson (*Neochmia phaeton*), facultatively gregarious.

The species have been a significant pest at K.R.S. but have been swamped into insignificance by large-scale cropping.

COMMON NAME: Weero (Quarrion)   NAME: *Nymphicus hollandicus*

APPEARANCE REGULAR ON ANNUAL BASIS: Yes?

Months present: Dry season

Numbers at peak:

Sudden build-up:

Factors involved in build-up: Apparently dry season flocks of nomadic birds

IF IRREGULAR SPECIFY OBSERVATION

1. September, 1970: 500+ on farm
2. July, 1972: 200+ on farm
3. March, 1973: 200 - 300 on farm
4.
5.

SWAMP-FARM AXIS:

SAVANNA-FARM AXIS: ✓

CROP FEEDING GRAIN: ✓

CROP FEEDING NON-GRAIN (Specify):

FARM FEEDING DRAINS & CHANNELS:

FARM FEEDING OTHER (Specify): Feed on waste around feed lot

HISTORIC RECORD OF DAMAGE: Occasional damage to grain at K.R.S.

CURRENT PEST STATUS (1970-1973)   Nil   Low✓   Moderate   High

POTENTIAL PEST STATUS   1.   Nil   Low✓   Moderate   High

2.

NOTES ON BIOLOGY

This species spends the dry season in groups which are larger than in the wet. Some of these dry season flocks may be apparently sedentary (e.g. Point Springs, up to 1,000, several stations 100's). Other flocks are apparently nomadic. The birds involved in farm visitations are in this latter category.

COMMON NAME: Red-winged Parrot NAME: *Aprosmictus erythropterus*

APPEARANCE REGULAR ON ANNUAL BASIS: No

Months present:

Numbers at peak:

Sudden build-up:

Factors involved in build-up:

IF IRREGULAR SPECIFY OBSERVATION

1. Occasionally groups of this species would feed on the farm.
2.
3.
4.
5.

SWAMP-FARM AXIS:

SAVANNA-FARM AXIS: ✓

CROP FEEDING GRAIN: ✓

CROP FEEDING NON-GRAIN (Specify):

FARM FEEDING DRAINS & CHANNELS:

FARM FEEDING OTHER (Specify):

HISTORIC RECORD OF DAMAGE:

CURRENT PEST STATUS (1970-1973) Nil✓ Low Moderate High

POTENTIAL PEST STATUS 1. Nil✓ Low Moderate High

2.

NOTES ON BIOLOGY

Flocks of 60+ may occur in the dry season. A general lack of flocking behaviour in the species (Forshaw, 1973) suggests that this species has an insignificant pest potential, despite occasional occurrences of sorghum eating.

COMMON NAME: Diamond dove, Bar-shouldered dove, Peaceful dove, Plumed pigeon.

NAME: Order: Columbi formes

APPEARANCE REGULAR ON ANNUAL BASIS:

Months present:

Numbers at peak:

Sudden build-up:

Factors involved in build-up:

IF IRREGULAR SPECIFY OBSERVATION

1.

2.

3.

4.

5.

SWAMP-FARM AXIS:

SAVANNA-FARM AXIS: ✓

CROP FEEDING GRAIN:

CROP FEEDING NON-GRAIN (Specify):

FARM FEEDING DRAINS & CHANNELS:

FARM FEEDING OTHER (Specify): Occasionally feed on headlands and fallow.

HISTORIC RECORD OF DAMAGE:

CURRENT PEST STATUS (1970-1973) Nil✓ Low Moderate High

POTENTIAL PEST STATUS 1. Nil✓ Low Moderate High

2.

NOTES ON BIOLOGY

All these species flock to a greater or lesser extent in the dry season. Bar-shouldered dove flocks may reach 1,000+; at the other end of the spectrum is the Plumed pigeon with flocks of 50+ or less.

The species are not acknowledged or actual pests, but could be significant in isolated and extreme situations.

COMMON NAME: Waders NAME: Order: Charadriiformes

A large number of species is involved.

APPEARANCE REGULAR ON ANNUAL BASIS: Yes

Months present: Wet season

Numbers at peak: 1,000's

Sudden build-up:

Factors involved in build-up:

IF IRREGULAR SPECIFY OBSERVATION

1.

2.

3.

4.

5.

SWAMP-FARM AXIS:

SAVANNA-FARM AXIS:

CROP FEEDING GRAIN:

CROP FEEDING NON-GRAIN (Specify):

FARM FEEDING DRAINS & CHANNELS:

FARM FEEDING OTHER (Specify): Farm is often used as a "rest" area.

HISTORIC RECORD OF DAMAGE:

CURRENT PEST STATUS (1970-1973) Nil Low Moderate High

POTENTIAL PEST STATUS 1. Nil Low Moderate High

2.

NOTES ON BIOLOGY

Waders pass through the east Kimberley in varying numbers each wet season. Birds are often found on the farm in large numbers at this time. These birds have no apparent economic significance to agriculture.

The Oriental pratincole *Glareola pratincola* is the most numerous regular visitor. This species spends most of the wet season in the area.

COMMON NAME: Bustard NAME: *Eupodotis australis*

APPEARANCE REGULAR ON ANNUAL BASIS: Yes

Months present: Dry season

Numbers at peak: 20 to 50

Sudden build-up:

Factors involved in build-up:

IF IRREGULAR SPECIFY OBSERVATION

1.

2.

3.

4.

5.

SWAMP-FARM AXIS: ✓

SAVANNA-FARM AXIS: ✓

CROP FEEDING GRAIN:

CROP FEEDING NON-GRAIN (Specify):

FARM FEEDING DRAINS & CHANNELS:

FARM FEEDING OTHER (Specify): Feeds in dry stubble areas.

HISTORIC RECORD OF DAMAGE: Nil.

CURRENT PEST STATUS (1970-1973) Nil ✓ Low Moderate High

POTENTIAL PEST STATUS 1. Nil ✓ Low Moderate High

2.

NOTES ON BIOLOGY

This is a little known and possibly endangered species.

Observations at Kununurra suggest that bustards are gregarious tolerant birds in the dry season (non-breeding).

In the wet season the birds are found only as pairs and are very aggressive to other large birds, and to humans.

COMMON NAME: Little egret NAME: *Egretta garzetta*

APPEARANCE REGULAR ON ANNUAL BASIS: No

Months present:

Numbers at peak: 100's

Sudden build-up:

Factors involved in build-up:

IF IRREGULAR SPECIFY OBSERVATION

1. 1971 November-December: regular mob of 170 on farm
2. 1973 January: large mob 200 - 300 + on farm.
3.
4.
5.

SWAMP-FARM AXIS: ✓

SAVANNA-FARM AXIS:

CROP FEEDING GRAIN:

CROP FEEDING NON-GRAIN (Specify):

FARM FEEDING DRAINS & CHANNELS: ✓

FARM FEEDING OTHER (Specify): Freshly irrigated areas.

HISTORIC RECORD OF DAMAGE:

CURRENT PEST STATUS (1970-1973) Nil✓ Low Moderate High

POTENTIAL PEST STATUS 1. Nil✓ Low Moderate High

2.

NOTES ON BIOLOGY

COMMON NAME: Egret (White egret) NAME: *Egretta alba*

APPEARANCE REGULAR ON ANNUAL BASIS: Permanent resident

Months present:

Numbers at peak:

Sudden build-up:

Factors involved in build-up:

IF IRREGULAR SPECIFY OBSERVATION

1.

2.

3.

4.

5.

SWAMP-FARM AXIS:

SAVANNA-FARM AXIS: ✓

CROP FEEDING GRAIN:

CROP FEEDING NON-GRAIN (Specify):

FARM FEEDING DRAINS & CHANNELS: ✓

FARM FEEDING OTHER (Specify):

HISTORIC RECORD OF DAMAGE:

CURRENT PEST STATUS (1970-1973) Nil ✓ Low Moderate High

POTENTIAL PEST STATUS 1. Nil ✓ Low Moderate High

2.

NOTES ON BIOLOGY

COMMON NAME: Glossy Ibis NAME: *Plegadis regia*

APPEARANCE REGULAR ON ANNUAL BASIS: No

Months present:

Numbers at peak: Up to 5,000

Sudden build-up:

Factors involved in build-up:

IF IRREGULAR SPECIFY OBSERVATION

1. September 1970 to June 1971 - gradual increase to large numbers up to 5,000 birds
2. August 1972 - sudden arrival; peak in December, 2,000 - 3,000 birds; gone by February 1973.
3. May 1973 - very large mob in area for one month only.
4.
5.

SWAMP-FARM AXIS: ✓

SAVANNA-FARM AXIS:

CROP FEEDING GRAIN:

CROP FEEDING NON-GRAIN (Specify):

FARM FEEDING DRAINS & CHANNELS:

FARM FEEDING OTHER (Specify): Feed on freshly irrigated areas.

HISTORIC RECORD OF DAMAGE: Nil.

CURRENT PEST STATUS (1970-1973) Nil ✓ Low Moderate High

POTENTIAL PEST STATUS 1. Nil ✓ Low Moderate High

2.

NOTES ON BIOLOGY

COMMON NAME: White Ibis NAME: *Threskiornis molucca*

APPEARANCE REGULAR ON ANNUAL BASIS: No

Months present:

Numbers at peak: Up to 1,000

Sudden build-up:

Factors involved in build-up:

IF IRREGULAR SPECIFY OBSERVATION

1. Always few in area.
2. 1970 - several hundred in December, gone by February 1971.
3. 1971 - June/July, large mob of 1,000+
4. 1972 - Nil.
5. 1973 - few in June.

SWAMP-FARM AXIS: ✓

SAVANNA-FARM AXIS:

CROP FEEDING GRAIN:

CROP FEEDING NON-GRAIN (Specify):

FARM FEEDING DRAINS & CHANNELS: ✓

FARM FEEDING OTHER (Specify): On freshly irrigated fields.

HISTORIC RECORD OF DAMAGE: Nil.

CURRENT PEST STATUS (1970-1973) Nil ✓ Low Moderate High

POTENTIAL PEST STATUS 1. Nil ✓ Low Moderate High

2.

NOTES ON BIOLOGY

COMMON NAME: Straw necked Ibis NAME: *Threskiornis spinicollis*

APPEARANCE REGULAR ON ANNUAL BASIS: No

Months present:

Numbers at peak: 1,000's

Sudden build-up:

Factors involved in build-up:

IF IRREGULAR SPECIFY OBSERVATION

1. 1970 - May to October, low numbers, zero by December
2. 1971 - large numbers (2,000 - 3,000) June/July
3. 1972 - Nil on farm, few on swamps in area
4. 1973 - few in May, by July large numbers, then rapid decline.
5.

SWAMP-FARM AXIS: ✓

SAVANNA-FARM AXIS:

CROP FEEDING GRAIN:

CROP FEEDING NON-GRAIN (Specify):

FARM FEEDING DRAINS & CHANNELS: ✓

FARM FEEDING OTHER (Specify): In freshly irrigated crops.

HISTORIC RECORD OF DAMAGE: Nil.

CURRENT PEST STATUS (1970-1973) Nil✓ Low Moderate High

POTENTIAL PEST STATUS 1. Nil ✓ Low Moderate High

2.

NOTES ON BIOLOGY

COMMON NAME: Little Black Cormorant   NAME: *Phalacrocorax sulcirostris*

APPEARANCE REGULAR ON ANNUAL BASIS: Permanent resident

Months present:

Numbers at peak: 100's

Sudden build-up:

Factors involved in build-up:

IF IRREGULAR SPECIFY OBSERVATION

1.

2.

3.

4.

5.

SWAMP-FARM AXIS: ✓

SAVANNA-FARM AXIS:

CROP FEEDING GRAIN:

CROP FEEDING NON-GRAIN (Specify):

FARM FEEDING DRAINS & CHANNELS: ✓ Deep channel feeder

FARM FEEDING OTHER (Specify):

HISTORIC RECORD OF DAMAGE:

CURRENT PEST STATUS (1970-1973)   Nil ✓ Low Moderate High

POTENTIAL PEST STATUS   1.   Nil ✓ Low Moderate High

2. The species has nuisance value by occasionally fouling stock water dams.

NOTES ON BIOLOGY

Mobs of several 100 birds may occasionally concentrate on major channels and farm dams.

Nothing is known of the local biology of the species.

APPENDIX VI

Bird scaring, repelling, displacing and killing - the technical wonderland

Since the advent of agricultural man, human ingenuity has had as one of its concerns the control of the "fowles of the air". For the first five millennia or so, these attempts generally involved labour-intensive methods such as physical scaring by noise, snaring and the use of innovations such as sparrow bottles (Murton, 1971). These methods generally had little impact on both target and non-target species. Since the onset of the technological age and especially over the last thirty years the problems encountered with birds in agriculture, public health and civil aviation have resulted in a proliferation of technological innovations all of which claim some utility in bird management.

In the brief sectionalised review which follows, an attempt is made to cover the full range of potential tools available. Each methodology is illustrated by key references however, this is not an absolute review of the subject area. Where possible, comments are made on the potential value of the technology in the specific context of the Ord development and general context of Australian grain and small crop growing.

Shooting, bombing and trapping

These three methods have been used with one of two aims. Where the aim was to eliminate the population, they have been singularly unsuccessful over a range of species (Murton (1966), Dunnett and Patterson (1968), Newton (1970), Crook and Ward (1968), Murton, Thearle and Thompson (1972), Murton, Westwood and Isaacson (1974), Harris and Brooke (1975)). The most obvious explanation offered, that of populations being buffered against predation at the level at which these techniques can apply it, has come to be widely accepted.

These methods have been more successful where the aim has been to train birds to avoid certain areas or to eliminate a small component of the population in a given area. Bull finch (*Pyrrhula pyrrhula*) trapping has been found to give a measure of protection to fruit buds in years when a partial failure of the bull finch's natural food occurs (Wright (1961), Newton (1968), Newton (1970)). Similarly, Caslick (1966) reported trapping to have an effect on roost selection by red-winged blackbirds (*Agelaius phoeniceus*). A similar roost evacuation effect by blackbird followed the use of dynamite (Neff and Meanley (1957)). Shooting was shown by Neff and Meanley (1957) to be the preferred method of blackbird control on rice crops in Arkansas (U.S.A.). In this case the aim was limited to moving the birds from a particular field.

The applicability of shooting to the Ord situation will be discussed in Chapter 4. The dynamiting of roost for corella was suggested by Frith (1955) as a means of controlling the K.R.S. bird problem.

The use of poison baits and sprays

Considering the wide-spread use of poisons such as 1080 and strychnine for mammalian pest control, it was surprising to find a very limited literature on the subject for birds. The emphasis has rather been on stupifying and physiologically disturbing substances.

What literature is available suggests that poisons can be effective in local situations in the short term, for those species which can be induced to take baits (Anon(1908), Neff and Meanley (1957), Frith and Davies (1961), Snyder (1961), Johnson (1965), Balsar (1966), Caslick (1966)).

Since the advent of organo-phosphates with very low $L.D._{50}$ the use of aircraft delivered sprays has been a possibility. The method has some technical feasibility (Caslick (1966)) but no definitive literature is available.

There are anecdotal reports of the failure of the method against *Quelea* sp. in Africa and the short-term success of the method in Western Australia. In Australia at least some chemical companies are strongly opposed to the use of their insecticides as avicides (Swain, pers. comm.).

Trials were carried out to test both the readiness of the Ord species to take baits and their susceptibility to aircraft spraying (Chapter 4). These methods, however, were not seen as having any long-term utility in the seasonal situation which prevailed. They have however been seriously considered as a means of control in the past.(Carrick (1956) and recently Bladwell (1972)).

The use of sound

Sound has been widely tested as a means of bird scaring for both agriculture and civil aviation. There have been three basic approaches; in the first, alarm sounds are used; in the second white noise is used; and in the third, loud exploding noises are used.

The use of alarm, distress or flight calls as bird dispersants has been of particular interest to civil aviation authorities and to a lesser extent small crop researchers. The general conclusion which may be drawn from the extensive literature is that the methods work for limited areas and some species. A common problem encountered has been that of habituation and the methods have often been integrated with others, such as shooting, to get the desired effect. Key references to this subject include Frings and Frings (1963), Frings (1964), Spear (1966), Balsar (1966), Anon (1968), Boudreau (1968), Busnel and Giban (1968), Brough (1968) and Bremond *et al* (1968). Since 1968, interest in this area appears to have declined.

These methods had little applicability to the extensive cropping situation at Kununurra and its associated airport hazard.

White noise was first mentioned as a possible control agent for limited areas in 1966 (Nelson and Seubert (1966)). The method has, however, only recently become commercially available as a sideline to a U.S. Army crowd control research programme. White noise generators for bird scaring are being marketed by the Av-alarm Corporation of Mountain View, California. There is no literature to date on the relative value of these methods in the U.S.A.; however, Hunter (1974) has found that electronically synthesised sound (i.e. white noise) can give up to three weeks protection from wood pigeon for limited areas of cabbage crops. A white noise generator was tested in this study for Ord river conditions (see Chapter 4).

Explosive and percussive noises have been widely used to startle birds from specific localities. These methods have generally worked best when coupled with shooting which counters the effect of habituation. The range of devices which are available and have been used is almost limitless; it extends from drums in Africa to miniature air-blasting mortar shells, string crackers and carbide guns. (Nelson and Seubert (1966), Giltz (1966), Caslick (1966), Giles (1971).)

Such techniques were of very limited use on the Ord where shooting had the same effect at less cost.

Microwaves and Ultrasonics

These methods have been based on the principle that beams of sound or radiation can be used to "fence" restricted areas such as airports, or clear the path of aircraft. To date there has been no usable techniques developed from this line of research (Nelson & Seubert (1966), Tanner (1966), Tanner *et al* (1969), Romero-Sierra *et al* (1971 a), Romero-Sierra *et al* (1971 b), Hunt (1973), Tanner, pers. comm.).

The use of electric shocks

A device has been developed to give electric shocks to birds which use its special cables as perches. (Pfiefer (1956), Pfiefer (1957), Rosenau and Worstell (1969)). This method may have some use for specialised problems in which limited areas are involved. It has no utility in the Ord situation.

Scare crows, scare models, trained predators and model aircraft

There has been a consdierable range of ingenious devices reported to the author which fall into this category. The literature on the subject is limited, but it seems that such methods may work in local situations for a time at least.

Hunter (1974) reported that metal models of dead wood pigeons deterred other pigeons from entering a cabbage crop for one week.

Solman (1965) and Brough (1968) report that the art of falconry has had some utility in specific airfield situations. The R.A.F. apparently actively encouraged this practice on its airfields in the 1960's with unknown results. Falcons have been seriously suggested as a means of control for experimental crops at K.R.S. (Carrick, 1956) and for extensive cropping on the Ord (Schmitt, 1974).

Detailed observations of the corella and magpie geese interaction with raptors suggested that such methods had little utility in the Ord situation.

The use of stupefying baits

Stupefying baits, developed primarily in England as a means of effectively killing target species of wildlife pests while at the same time having a minimal effect on non-target species, have been successful in some circumstances for a short period of time. Generally their effect has been to temporarily remove the problem. Notwithstanding this, these methods could have a place in control programmes where the biology of the target species is known and the effect of removal of a section of the population can be predicted.

Key references to these methods include Ridpath *et al* (1961), Murton (1963), Murton *et al* (1963), Schafer *et al* (1967), and Thearle *et al* (1971).

Stupefying baits could be useful in the Ord situation if killing was accepted as a management option.

The use of bird repellant chemicals

Attempts to find bird repellant chemicals had met with little success (Thompson, 1953) until, in the early 1960's a range of compounds were patented as bird repellants (see Goodhue and Baumgartner, 1965(a)). The first chemicals for which repellant success was claimed were 4-nitropyridine-N-oxide and 4-aminopyridine (Goodhue and Baumgartner, 1965 (a) and (b)).

Since the original work of Goodhue and his colleagues a range of other compounds has had avian-repallant properties ascribed to it. Examples are: diphenylenediketone, arthroquinone, and the carbamate group of compounds.

A relatively extensive literature has accumulated on the use of these compounds, their effectiveness, residual properties, etc. However, the general picture which emerges is a confusing one. Results range from very considerable success (e.g. West and Dunks (no date)) to no real effect (Dolbeer *et al* (1976)).

In 1970 the effectiveness of these compounds was even less clear than it is now, and trials with the two most promising agents formed part of this study (see Chapter 4).

It now appears that the literature supports the findings of this study that repellant chemicals are of limited utility for large-scale farming when used in the face of strong forces which are directing pest birds onto crops and in the absence of any real knowledge of the behaviour or ecology of the species involved.

References in this subject area include: Goodhue and Baumgartner (1965 (a) and (b)), Balsar (1966), Caslick (1966), Spear (1966), Anon (1968), West (1968), West *et al* (1969), Schafer and Brunton (1971), De Grazio *et al* (1971), De Grazio *et al* (1972), Stickley (1972), Dunning (1974), Rogers (1974), Schafer *et al* (1974), Guarino *et al* (1974), Forbes (1974), Schafer and Marking (1975), Dolbeer *et al* (1976), Stickley *et al* (1976), West and Dunks (no date), De Grazio (no date), Johnson *et al* (1971) and numerous literature available from Bayer Australia Pty. Ltd., and William Cooper and Nephews Pty. Ltd.

The use of bird resistant crops

The ultimate control of any crop pest has to be plant genotypes which possess pest resistant or repelling characteristics while retaining agronomically desirable characteristics. In the late 1960's agronomists in the U.S.A. noticed that some characteristics in available grain sorghum varieties affected the varieties' attractiveness to birds. These characteristics included tannin content of the testa and glumes, and the degree of laxity of the panicle (Harris, 1969 and 1971). Sorghum varieties possessing these apparently resistant characteristics were tested against other varieties in a series of open-access, randomised row trials in high bird damage environments (McMill an *et al*, 1972). One hundred and forty-two varieties and lines were tested in this way. The results of the trial indicated a negative correlation for tannin content, seed colour and plant height with bird damage; however, this result was not absolutely conclusive.

The results above were sufficiently encouraging for high tannin characters to be incorporated into some commercial varieties. To date, no results of rigorous testing of the bird resistance of these varieties under commercial conditions is available.

The major criticism of currently available resistant varieties is that they only offer a partial solution. The early adopters of these varieties can probably expect results as long as other farmers grow non-resistant varieties. If the situation arises where the only food available to pest species is the resistant varieties, resistance as such should break down. For this reason, bird resistant grain sorghum probably has no place on the Ord if the only reason for its choice is bird resistance.

In general, this line of research could be most promising for a wide range of crops and it is worth pursuing with an emphasis both on resistant characters and on characters which give an agronomic performance commensurate with crop maturity at times when the probability of a pest problem is lowest.

The use of reproductive inhibitors

It has been the reproductive potential of a number of avian pest species which has frustrated various attempts at control by killing (see sections "Shooting, bombing and trapping" and "The use of poison baits and sprays"). The rationale behind the use of reproductive inhibitors has been that they reduce the overall annual recruitment rate of the pest population without interfering with the population structure.

The early work using these methods was in the U.S.A. (Spear, 1966; Caslick, 1966; McLean, 1966) and Europe (Brion and Vacher, 1970). In the U.S.A. claims of major reductions in feral pigeon populations have been made (Woulfe, 1970; Schortemeyer and Beckwith, 1970) which have been strongly disputed on grounds which are both methodological and biological by Murton *et al* (1970).

The current situation appears to be that these methods may have limited use for urban bird problems once more of the underlying physiology is understood. They are unlikely to have much applicability for agricultural pests.

<u>The use of bird food preference, habitat preference, and behaviour</u>

In general, two distinct schools of thought on bird pest management can be recognised. The first was the technological school which found its natural base in North America and the U.S.A. in particular. The second, the British school, adopted an essentially ecological approach. In the ten sections preceeding this one, the dominant source of both published work and basic ideas has been North American; in this section the basic sources are overwhelmingly British.

The starting point for the British approach to birds and agriculture is not clear, as it extends back into an aguarian tradition centuries old (see Murton, 1971, for an historical perspective). The most easily identifiable starting point for the post-war British work is, however, Ridpath and Murton (1956). These authors looked at the problem in a broad perspective, considered what had been done prior to 1956, and concluded that most technological methods were palliative at best. Both authors have subsequently developed their ideas of biologically sound management, Murton in the U.K. and Ridpath in the U.K. and then Australia. This section outlines some of the diverse strategies possible. The most critical point is, however, that methods are often not transportable between location, between crops, between species or between continents. The philosophy which sees each problem as an essentially new one in need of a biologically sound solution will generally give a useful result with time.

A. Methods based on food preference

It appears to be a general rule that the elevation of a bird to pest status can be related to the availability of its natural food (Neff and Meanley (1957), Murton *et al* (1963), Newton (1970), Murton (1970, 1972 and 1973)).

Once the basic determinants of such a problem are available the approach has been to look for plasticity in the crop year which would allow the peak of harvest to correspond to the peak of natural foods. If this is not feasible, then it may be possible to predict the likely impact for a given year from a knowledge of expected native food availability (Newton, 1970). This at least allows other control measures to be brought into timely use.

B. Methods based on habitat alteration

These methods have as their rational the notion that habitat preference affects both the way animals use space and the numbers of animals in a specific location.

Habitat alteration has been the most successful method of bird control for the airport environment (Faulkner (1966), Solman (1966), Wright (1968), Solman (1971), Dansereau (1972), Solman (1973)). In Canada where the method was widely used the yield for the national airline alone was a reduction in annual cost of $110,000 (Canadian, 1965). (Solman, 1966).

In agriculture, large-scale habitat alteration cannot be always feasible. However, the emergence of problems can be predicted (Hardman, 1974) and sometimes problems removed (Ridpath, 1968 (a) and (b)). Hopefully in the future habitat management may become the most important component of a bird pest management. The recent work of Weins and Dyer (1975) in Canada provides what may come to be regarded as a major step in this direction.

In the Australian context the above approach could be extended to reduce damage. Examples are ways of reducing the crop susceptible period, planning crop and pasture rotations, and planning crop placements in relationship to local physiography (Beeton, 1976).

Chapter 4 deals with the application of these methods in the Ord context.

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