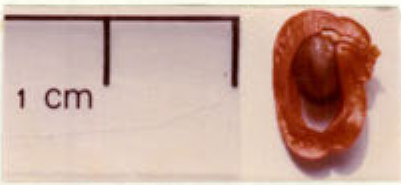
BIRDS AS A DISPERSAL AGENT FOR *ACACIA CYCLOPS*.

John Glyphis
Zoology Honours 1976

F R O N T I S P I E C E

Stages in the growth and development of an *Acacia cyclops* seed. The funicle becomes coloured late in development and only turns red just prior to dehiscence of the pod.



CONTENTS

BIRDS AS A DISPERSAL AGENT FOR *ACACIA CYCLOPS*

1. INTRODUCTION

The Australian Wattle or "Rooikranz" (*Acacia cyclops* A.cunn) is an alien invasive plant in the Southwestern Cape. It was imported during the 1840's to arrest wind-blown sand on the Cape flats (ca 34°S, 19°E) (Roux 1961). Natural dispersal has since ensured the plants' widespread distribution, at present ca 100 000 ha (A.V. Hall *pers. comm.*). Adamson (1938) first drew attention to the threat of *A. cyclops* to the Cape flora, one of the six floral kingdoms of the world (Takhtajian 1969). Control of invasive exotic plants is important if the integrity of this flora is to be conserved, and effective control must rely on some understanding of the biology of these introduced plants.

Acacia cyclops forms dense stands, often in association with another invasive exotic, *A. saligna* (Lindl). These stands of mixed acacias often occur interspersed with indigenous vegetation. However, according to Roux and Middlemiss (1963), *A.cyclops* cannot establish itself in competition with indigenous vegetation in the absence of disturbance by man or, particularly, fire.

Some small mammals and many birds exploit this vegetation mosaic. Of these, at least ten bird species are possible *A.cyclops* seed dispersal agents (Middlemiss 1963, Winterbottom 1970).

Both Janzen (1969) and van der Pijl (1969) list seed and plant attributes which suggest ornithochory - seed dispersal by birds. Amongst these, the colour combination of a vivid red funicle and a shiny black seed testa, as found in *A.cyclops*, has been shown stastistically to be highly preferred (Turcek 1963 in Snow 1971). A second attribute observed by van der Pijl (1969) in *Acacia falcata* (= *A.cyclops*) is the presentation of the seed which hangs by its funicle from the dehisced pod.

The aims of this study were to:

1) estimate the quantity of seeds taken by birds in relation to the seed production of A.cyclops;

2) determine any selective feeding preferences for A.cyclops seeds, using Cape Turtle doves (Streptopelia capicola);

3) estimate the calorific utilization by Cape Turtle doves of A.cyclops seeds; and finally

4) assess any effects on the germination and viability of the A.cyclops seed which might result from its passage through bird gut.

2. STUDY AREA

Two sites were located at Rondevlei Bird Sanctuary and Kuils River (near D.F. Malan airport). Some incidental observations were made at two other areas (Swartklip and Cape of Good Hope Nature Reserve) (Fig. 1). Stands of mixed acacias dominated the sites, with A.cyclops occupying more than 50% of the projected canopy cover (P.C.C.).

3. METHODS

3.1 Estimate of seed production by A.cyclops and consumption by birds

Six medium-sized A.cyclops bushes (approximately 4 m tall and 3 m wide) in Rondevlei Bird Sanctuary were selected during the period of analysis for analysis. All had abundant seed in pods although the flowering and fruiting seed was almost over. (Adamson and Salter 1950). Three of the trees had flowers and some newly developing seed pods for the following season.

Two meter-wide strips of knitted commercial nylon mesh (mesh size = 1 mm^2) were machine sewn together. These very large expanses of net were used to completely enclose three of the trees, two of which bore flowers. The netting was fitted over the trees and gathered tightly with string around the tree trunk. In this way, birds were prevented from feeding on the seed crop and simultaneously all seed which fell during the enclosure period was collected. Where possible the net was kept well clear of the ground with the intention of discouraging rodents.

The other three bushes were half-enclosed with the same nylon netting without excluding any possible foraging birds but trapping any seeds which might fall.

The netting was checked at monthly intervals. Unfortunately, the netting on one completely enclosed tree and one half-enclosed tree was interfered with, evidently by rodents. This rendered their respective seedfalls useless for the purpose of this analysis.

During the last week in August, the litter in the four remaining nets was removed and the seed was siposoted from this litter. The seed and any pieces of funicle were weighted after drying to constant weight over not less than two days. Five individual seeds were weighed in each sample, in order to estimate the number of seeds per sample.

Seed production of A.cyclops

During August, five A.cyclops bushes were selected for this estimation for having similar overall appearance. They were roughly the same size as those mentioned before (4m tall and 4m wide), each had a number of growing pod-bearing branches and branch distribution within the bole of the tree was more or less homogenous. Branches were judged to be growing if numerous paler coloured leaves occurred near the apex and if large numbers of green, almost full-size pods were present. These branches were counted in eight cubic meter volumes, distributed between the five trees. Selection of a specific cubic meter was governed only by accessibility for counting and homogeneity of foliage.

A/........

A visual estimation was made to count the number of green pod clusters found on a growing branch. No branch was found to have more than 10 pod clusters at that stage in the growing season (August). A branch with a series of ten pod clusters was removed from a bush. The number of pods and the number of growing ovules were counted; the latter was done very simply by holding the green pod up to the light and the outline of each ovule was quite clear. From this series of counts and means computed on green pods, it was possible to estimate the seed production per m^3 of canopy. The method is open to wide error range accruing from a lack of homogeneity within each A.cyclops tree and also between trees, differences in growth patterns in trees growing on different soils and error magnification which occurs with extrapolation.

3.2 Seed selectivity in Cape Turtle doves, Streptopelia capicola

Cape turtle doves and laughing doves Streptopelia senegalensis occur in large numbers in Rondevlei Bird Sanctuary (Middlemiss 1975) and in the Acacia spp. stands on the Cape flats (personal observation). For this reason three Cape turtle doves were mistnetted. These were kept in the departmental avairy and fed on a commercial grain mix and ad lib. water.

Three selectivity cages were made, using a wire frame with a mesh floor (mesh size 15 mm) which was surrounded with cardboard (Fig.2). Each bird was placed individually in the cages prior to the actual experimental run, without food but with ad lib. water. After 10 hours they were presented with a mixture of 3,00g A.cyclops seed and 5,00g each of mealies, sunflower and lentil seeds. All these seeds have similar dimensions and a mixture ensured that there was an equal chance for all seeds to be picked. The birds were permitted to feed on this for 8 hours, after which the seed was resorted and weighed to estimate the preferred seed type. A second identical mixture was presented to each bird in order to repeat the test.

3.3/.........

3.3 Calorific utilization of *A.cyclops* seed and funicle by Cape turtle doves.

This fairly crude estimation was conducted on the same three Cape turtle doves used in 3.2. The experiment was sequential following the preference tests.

The birds were starved for 12 hours and presented with 2,0g funicles mixed with 10,0g seed and funicle of *A.cyclops*. After 36 hours had lapsed, the quantities of seed and funicle were re-weighed. The faeces of each bird were collected on aluminium foil sheets placed below the birds for the duration of the *A.cyclops* presentation and an additional 12 hours. These sheets had been dried to constant mass prior to the experiment. The foil sheet and faeces were dried to constant weight at 60°C in an oven and the increased difference in the weight of the foil sheet was the total dry weight of faeces collected during the 48 hour period.

The faeces and seed were pulverized in an electric mill. A sample of known weight was fired in a benzoic acid calibrated bomb calorimeter ("Gallenkamp"). A galvanometer reading, later converted into Joules was obtained for each sample. The manufacturers credit the instrument with a 1% error factor.

3.4 Seed germination and viability experiments.

Seed germination tests were conducted using a controlled environment chamber. The photo-period was set at 12 hr., relative humidity was maintained at 90% during the day and 80% at night and temperature at 30°C during the day and 20°C at night. The germination trays were filled to a depth of 15 mm with sand. This sand was collected from Rondevlei sanctuary. It was sieved and washed to remove excessive litter. The seeds in each batch were laid out on the surface of the sand in grids of 10 x 10 seeds; the seeds were spaced about 1 cm apart. Four grids could be accommodated on a single tray and a "+" shaped furrow was created to separate the grids and to permit irrigation of the tray with 500 ml water every second day without disrupting the grid formation. Such a grid enabled simple daily counting of the total number of germinated seeds in each batch. The daily increase in germination numbers represented the number of new germinations.

Origin of the seeds

Sixteen batches of 100 A.cyclops seeds were randomly picked for germination testing out of larger quantities of seed collected from the following sources: Batches 1 and 2 comprised seeds collected at the end of February from bird faeces which was scattered over the two observation towers on the north side of Rondevlei bird sanctuary. The faeces were considered unlikely to be older than one summer season i.e. six months, since winter rain would easily wash it away. This seed containing faeces was crumbly in texture due to the fibrous digested funicle component. The birds most likely to perch on the towers in large numbers were the European Starlings Sturnus vulgaris, Cape turtle doves and laughing doves (personal observation). It was reasonable to assume that most of the faeces containing some seeds was likely to have been produced by the starlings because, unlike doves, they have less developed koilin pads in their grinding gizzards (Ziswiler and Farner 1972) which would destroy almost no seeds. Seeds for batches 3 and 4 were collected from A.cyclops bushes and trees, surrounding the two observation towers. The seeds were kept for 24 hours before being placed in the germination chambers.

The seeds used in batches 5 to 9 were collected at the end of March on the south side of Rondevlei sanctuary, one month later after the seeds used in the first four batches. All the seeds were collected from a single bush. Some were kept for 24 hours before being treated (see following section) and then placed in the germination chamber. The rest of these seeds were stored deep frozen and 700 more were used one month later (end of April) in batches 10 to 16. These were thawed at room temperature before being treated and immediately after this, as before, they were placed in the germination chamber.

Treatment of seeds.

Batches 1 to 4 - one hundred seeds of batch 1 were cleanly removed from the bird faeces and placed on the germination trays without any further treatment. Batch 2 consisted of 100 seeds onto which seed-sized quantities of faeces adhered to test whether the high nitrogen content of faeces might enhance the germination rate or the condition of the seedlings. Batches 3 and 4 served as controls but the seeds in batch 3 all had funicle removed to check if it had any affect on germination rate.

Batches 5 to 9 - all five batches of 100 seeds without funicles received some form of treatment. This was designed to simulate either some likely chemical or physical action of bird gut on the seed or to simulate some environmental damage. In both cases such treatments would change or damage the outermost protective testa. The testa is the main barrier to rapid water uptake (Roberts 1974) and water uptake is an essential prelude to the initiation of bio-chemical seed processes leading to germination of the embryo (Harper and Benton 1966). Batch 5 was placed in hydrochloric acid pH 1,6 for 2 hours. The type of acid, its pH and the time period were considered to be good approximations to the chemcial conditions the seeds might encounter in digestion in avian gut (Ziswiler and Farner 1972). The seeds in batch 6 were sandpapered to scarify the testas as grit in the bird diet might do manipulated by muscular contraction of the gut wall. This sandpaper scarification was repeated on the seeds in batch 7 and, in addition, the seeds were soaked in 96% ethyl alcohol for 2 hours. Care was taken to avoid exposing endosperm in some places by unequal sanding of the testa. Impermeability of the testa could then be checked by soaking the seed in alcohol. If the outer layer of the testa was the robust protective coat, scarification ought to remove it and a powerful penetrating solvent, alcohol, should render the seed inviable. The seeds in batch 8 were soaked in ethyl alcohol for 2 hours, without scarification of the testa, as a control for batch 7. Treatment of batch 9 by burning was somewhat repetitive of an experiment by Roux and Middlemiss (1963) who instead boiled <u>A. cyclops</u> seeds for varying time periods and monitored subsequent germination rates. The seeds in the present experiment were placed on a damp sand surface and heated to $100 \pm 10^{\circ}C$ with a bunsen flame directed from above and waved across the seeds. Rising steam and one minute heating duration had been found, prior to the experiment, to indicate the above-mentioned temperature range. The seeds in field conditions would encounter a similar temperature range in a veld fire (Sweeney 1969).

Batches 10 to 16 - treatments were intended to repeat, with slight variation, those performed on batches 5 to 9. The 100 seeds in batch 10 were soaked in water for two hours and they served as a control. Batches 11 and 12 were soaked for 2 hr in hydrochloric acid of pH 1,0 and pH 2,0 respectively and, since the pH of avian muscular stomach can vary between 0,2 and 1,2, the lower pH might significantly raise the germination rate. Batch 13 was scarified, but the seed was rotated in a sand and water mixture using a magnetic stirrer instead of rubbing with sand paper. The temperature was maintained at 37±2°C and rotation continued for three hours. Batch 14 was also treated in this way, except that a mammalian enzyme complex, pancreatin, was added to this mixture. Mammalian digestive enzymes closely resemble those found in bird gut (Ziswiler and Farner 1972). The temperature and time period were the same as for batch 13 (37°C for three hours).

Batch 15 was soaked in concentrated formaldehyde to test the permeability of the testa, similarly to the ethyl alcolhol soaking of batch 8. Formaldehyde is acidic as well as being strongly toxic to living tissue. Permeation of the testa would kill the embryo but if the testa was impermeable, formaldehyde may acidically alter it and germination might then be enhanced. Batch 16 was burnt in exactly the same way as batch 9.

All the seeds in batches 10 to 16 were rinsed with a fungicide, "Calomel" 1:1000, to prevent an infection which was noticed on previous batches and which definitely retarded germination.

Viability

At the conclusion of each germination test the batches of seed were removed from the sand tray. All the germinated seed and seedlings were divided into two categories - those likely to survive given natural conditions and those abortive germinations and etiolated seedlings which were non-viable. The assessment was purely subjective from Photographs taken of both categories for each seed batch.

Statistical analysis of results

The 16 seed batches were analysed in three groups (1 to 4, 5 to 9 and 10 to 16) because the seeds used in each group had been treated differently. The seeds in batches 3 to 9 were all planted within 24 hr after field collection. The seeds in batches 10 to 16 were deep frozen for 26 days after collection. Non-parametric Mann-Witney U tests (Zar 1974) were used in comparing germination patterns; and each germination was treated as an observation and observation ranking for the test was performed exactly as outlined by Sokal and Rohlf (1969) χ-squared tests in comparing total numbers of germinated seeds at the conclusion of each experiment; and, average time of germination was calculated for each batch using the formula (mean) $\frac{\sum(gt)}{\sum g}$ where g is the number of seeds germinating and t is the time in days (Jones 1963).

3.5 Three non-vertebrate predators of A.cyclops seeds

Fungi infected some seeds in virtually all 16 batches of A.cyclops seeds. They appeared to affect germination and for this reason identification was considered necessary. Isolation and culturing were done according to a standard method (Webster 1970). The procedure was carried out in such a way as to test whether the fungus originated in the field or the laboratory.

A voracious larva was found in many of the A.cyclops pods which were being routinely emptied of seeds during the course of this study. A few of these larvae were left in pods and the pods sealed in glass sampling bottles to permit pupation and emergence of the moth, which could then be identified.

Some mites were found in the empty, apparently consumed, testas of some A.cyclops seeds. These had previously been collected for the fungus identification mentioned above.

4. RESULTS

4.1 Estimation of seed production by A.cyclops and consumption by birds.

4.1.1 Estimation of seed production

The number of pod-bearing branches per m^3 canopy and the numbers of ovules per pod and pods per cluster are given in Tables 1 and 2. Using the means and ranges of values from these tables, an estimate of seed production was computed (Table 3). Ovules are considered to be the incompletely developed seeds held within the pod prior to dehiscence of the pod. The ovules can be aborted before developing into seed. The number of ovules per m^3 of A.cyclops canopy varied from approx. 88 to approx. 2285. Of all ovules produced about 28% are likely to be aborted (Linder unpubl., see appendix). Thus between 63 and 1645 ovules per m^3 canopy could become available as mature seeds.

A medium size A.cyclops (3m tall, 3m wide, with trunk 1m tall) will have approximately half of the canopy volume bearing pod clusters and seeds (personal observation). The growth form of the tree is such that pod clusters are borne closer to the axis of the plant. The outer shell of the canopy consists of growing and flowering branches. Assuming that the bole of the tree is a sphere, the canopy available to bear seeds can be computed using the formula

$$^{4}/_{3}\,\pi\, r^3$$

where r is the radius of the bole. Using this formula, a medium sized A.cyclops should possess approximately 14, 14 m^3 of canopy, of which 7,07 m^3 is capable of bearing seeds.

Applying values of seed production calculated above a medium sized A.cyclops can bear between 446 and 11630 seeds or between 63 and 1645 seeds / m^3 canopy.

Since the mean weight of an A.cyclops seed without funicle was 0,0452g (S.D. 0,0052, n = 10), a medium sized tree can bear between 20,16g and 525,68g of seeds or between 2,58 and 74,35g/m^3 canopy.

4.1.2/.......

4.1.2 A.cyclops seed consumption by birds.

Seed production in the two trees from which birds were excluded was 266,5/m^3 and 50,0/m^3 (Table 5). These values fall within the range computed above.

Although the results are not statistically testable it seems that up to 50% of the seed produced by an A.cyclops may be removed by birds. Perhaps more importantly, none of the seeds trapped below trees from which birds were excluded showed signs of germination, while 17 and 24 seeds, trapped beneath trees where birds were permitted to feed, had germinated.

4.2 Seed selectivity in Cape turtle doves, Streptopelia capicola.

The results of seed selectivity study are summarised in Table 6. There was no indication of preferential selection of Acacia cyclops seeds. Indeed, A.cyclops seed appears to have been avoided. Replication and a larger number of birds would clarify the situation. Cage size is very important in such testing and any results obtained ought, always, to be treated with caution (Neumann and Klopfer 1969).

During the first eight-hour feeding period each dove consumed a very high percentage of one seed type. During the second eight-hour feeding period this was repeated for only one dove (No. 1) which showed a marked preference for maize, Zea mays. An average of 10,50g of mixed seed was consumed during the entire 16 hour period (Table 7). Any selectivity for A.cyclops seeds which the birds might exhibit in the field is likely to be re-inforced by social facilitation (Murton 1971) since these Turtle doves are social and feed in flocks.

4.3 Calorific utilization of A.cyclops seeds and funicles by Cape Turtle doves.

4.3.1 The estimation of metabolism and possible quantitative consumption of funicles and seeds.

The Existence metabolism of passerine and non-passerine birds can be calculated using the two regression equations

M =/......

$$M = 0{,}5404\ W^{0{,}7545} \quad \text{(Non-passerine)}$$

$$M = 0{,}867\ W^{0{,}724} \quad \text{(Passerine)}$$

where W is the mass of the bird. (Kendeigh 1970).

These equations were used to calculate Existence Metabolism (E.M.) for non-passerine Cape turtle doves and passerine Starlings.

The doves (mean mass 126,3g, n = 3) have an E.M. of 86,9 KJ and the Starlings (mean mass 69,7, n = 6; Middlemiss 1973) have an E.M. of 91,66 KJ.

The requirements for the measurement of E.M. permit only restricted activity and Uramoto (1961) suggests that wild birds have 30 - 50% greater metabolic turnover than caged birds.

The mass and number of seeds with funicle, seeds alone and funicle alone, which each bird species might require, was computed (Table 8). Digestive efficiency was considered to be 80% as suggested by Uramoto (op.cit.).

4.3.2. Correlation of estimation (4.3.1) with the result of a calorific determination.

Two of the three Cape turtle doves consumed sufficient seeds and funicles of A.cyclops to make the determination meaningful, even if somewhat tentative.

The total Kilojoule usage for the 24-hour period was calculated as 75,02 KJ and 63,54 KJ for the two doves (Table 9). This averages about 20% lower than the Existence metabolism calculated above. The digestive efficiency, calculated from the formula

$$\text{Digestive efficiency} = \frac{C - R}{C}$$

where C = mass of consumption

R = mass of rejecta (faeces and urine, urine negligible in birds)

was very low for the two birds (46,8% and 50,6%). This was probably due to the non-ideal conditions where this experiment, unwittingly, was conducted.

However, the results correlate and the quantities of seeds with funicles which the birds could eat in the wild (6,24g) is comparable to those eaten during the experiment (5,84g to 8,45g).

4.4 Seed germination and viability experiments.

Seed germination experiments are summarized in Table 9 . Germination frequencies, the histogram, were compiled from the record of daily totals of germinated seeds (Appendix, Table).

The overall frequency pattern of germination is noticeably bimodal. This made statistical analysis important. However, the results of the Mann-Witney U tests andchi-squared tests are contained in Tables 10 (batches 1 - 4), 11(batches 5 - 9) and 12(batches 10 - 16) and are only referred to where relevant.

4.4.1 The effect of passage through bird gut and simulation of this by treatments.

The bird-defaecated A.cyclops seeds germinate about 9 $\pm$ 1 days sooner than control seeds. In addition, at the conclusion of the experiment (50 days) 50% more seed germinated from the defaecated seed, compared with the control. Adherence of some faeces to the seeds did not significantly affect the germination pattern or the total germination ($p>0,50$). The retention of funicle likewise had no effect on the control batch ($p>0,10$ and $p>0$ 25 respectively). Simulated treatments conclusively support these findings. Scarification of the testa (batches 6 and 13), to simulate the action of bird gut, enhances total germination and is comparable to the findings (above) for defaecated seeds; 25% to 35% germinated. Hydrochloric acid of pH 1,0 (batch 11) enhanced a germinating total to a lesser degree, but nevertheless significantly ($0,05>p>0,025$) improved it. Hydrochloric acid pH 2,0 and concentrated formalin both alter the pattern of germinations. Formalin significantly enhances germination ($p,05>p>0,025$).

The testa is unaffected by 96% ethyl alcohol, only significantly ($p<0,001$), but not completely, reducing total germination. Concentrated formalin, normally lethal to embryonic tissue, is excluded from the seed and appears to enhance germination (as noted above).

4.4.2 The effect of fire on germination and viability.

Batch 9 and 16 were both fire treated. Batch 9 showed an enhanced germination total comparable both to that found in defaecated seed and to those seed batches where the testa was scarified. Batch 16 became infected with a fungus, which was later identified (Section 4.5).

4.5 Three non-vertebrate predators of *Acacia cyclops* seeds.

4.5.1 Fungi

The fungus which was isolated from the laboratory infection of seeds was identified as *Verticillium* sp. A secondary fungal infection occured in two of the petri-dishes and this was due to *Alternaria* sp.

A fungus cultured from seed which had been brought in directly from the field was identified as *Fusarium* sp.

Verticillium sp. and *Fusarium* sp. are both soil-borne fungi (Webster 1970). Their presence is attributable to the unsterilized soil in which the seed was germinated (Miss L. Olivier, *pers.comm.*). *Fusarium* sp. was brought in from the seed collected under sterile conditions in the field and maintained this way in the laboratory. This same fungus was found on the seeds which had been scarified or burnt, and infers that infection can occur by means of a damaged testa.

4.5.2 Moth larva

Unfortunately only a single moth, which pupated from larvae found consuming the funicles and seeds in the pods, could be used for indentification. This moth was tentatively assigned to the family Geleichiidae. The poor condition of the specimen precluded a more definitive identification. A second moth was found with the body contents consumed and its wings broken off. This damage might have been caused by mites (see following section, 4.5.3).

4.5.3 Mites associated with damage to *A.cyclops* seeds.

Mites, identified as *Tyrophagus putrescentiae* (Schrank) were found in the partially consumed remains of some seeds. These seeds had been collected in the field and kept sealed in a petri-dish from the time of collection. They very closely resembled mites found on the remains of a moth, pupated from larvae which were found in *A.cyclops* pods.

5. DISCUSSION

5.1 Seed production

The computed seed production of Acacia cyclops appears comparable with higher values for some central American Leguminosae (Table 14). Janzen (1969) studied bruchid beetle larvae attack on this family of plants and found appreciably higher seed production as a response to seed destruction. High seed production maintained over a long season is a strategy directed towards predator satiation (Janzen 1969, 1971; McKey 1973). Apart from some birds as destructive predators of seed, a gelechiid moth-larvae, a mite and a soil fungus were found in this study to all be potential sources of A.cyclops seed mortality. The litter also contains an abundant rodent population of Rhabdomys pumilio. Mus minutoides, Tatera afra and Otomys irrovatus also occur in these Rhabdomys eats A.cyclops seeds and funicles and the seeds make up between 20% (in winter) and 70% (in summer) of its diet. They appear to consume the seeds which fall on the litter avoiding energy expenditure to dig out those seeds which are in deeper litter layers (Shelton 1975 unpubl.) These seeds could ultimately germinate but the ones falling on the litter surface will be destroyed.

A distinction must be made between a dispersal agent and a predator. Predators will bring about seed mortality, whereas a dispersal agent by epizoochory or endozoochory (van der Pijl 1969) will ensure a chance of survival. Endozoochory involves ingestion of the seed and later deposition (defaecation) in conditions optimal for survival with possible advantage incurred by the seeds from passage through the gut. Epizoochory is mechanical transport involving no ingestion of the seed.

A large seed crop permits all post-dispersal predators to complete their damage and yet leave sufficient seeds over to possibly germinate. Co-evolved ornithochory would ensure that the seeds are ingested by birds before predators could destroy them. Furthermore, the seeds would then be removed to a germination site where competition is much lower. For Acacia cyclops, this would be on the periphery of an A.cyclops stand or amongst the indigenous vegetation.

Associated with this high seed production is the long flowering and seed setting season of A.cyclops (Adamson and Salter 1950, Roux and Middlemiss 1963). The bushes appear to flower and set seed continuously and this might be directed towards spatial and temporal unpredictability, ensuring that seed is always available to dispersal agents during that particular season. The life-cycle of seed destructors however, cannot be selected to rely on abundant food (seeds) at any specific time.

A.cyclops bushes were estimated to lose up to 50% of their seed crops to birds. A number of bird species feed on A.cyclops seeds and funicles, particularly Cape turtle and Laughing doves and European starlings both of which occur in very large flocks amongst the Acacias (Middlemiss 1963, 1974 and Winterbottom 1970).

The doves would destroy most A.cyclops seeds which they might ingest because of their well developed grinding gizzards (Ziswiler and Farner 1972); they must be regarded as seed predators. Starlings, on the other hand, have relatively undeveloped gizzards and would excrete seeds (Ziswiler and Farner op.cit.) intact, having obtained nourishment from the funicle.

The estimate of seed production of A.cyclops is considered to be reliable but the "50%" usage by birds is questionable. The netting used to collect the seed fall would not prevent rodents from entering and feasting on the seed. The strong summer "south wester" wind and the winter noth wind, both of which blew during the period of collection, could gust strongly, agitating the bushes enough to dislodge and blow seeds away. The density of the bush ensures that enough avenues are open for invertebrate colonisation of the plant material trapped in the netting. They very likely consume the nutritious funicle and hence the equally low percentages of this component found in the trapped litter fall (Table 5) in all four A.cyclops trees. These three factors would all inflate the apparent bird removal of A.cyclops seeds. Conversely, the very large populations of doves could account for large amounts of seed removal and destruction. A survey of data from Rondevlei Bird Sanctuary Reports (Appendix Table) (Middlemiss 1960 to 1975), reveals that Laughing and Cape Turtle doves constitute the largest number of birds routinely trapped each year. Ringed recoveries indicate that they do not range far (rarely more than 8 km) compared with the opportunist European starlings which appear to move as much as twice this distance. Particularly during winter, large flocks can be noticed feeding in urban and sub-urban areas.

5.2 The funicle

The selectivity tests on Cape turtle doves did not reveal any preference for A.cyclops seeds. The small sample size (n = 3) used for the test would preclude any definite conclusions, even if all three birds had behaved similarly.

However, there did appear to be some slight avoidance of A.cyclops seeds. Doves are largely predators of the seeds (not completely; occasionally the odd A.cyclops passes intact into the faeces). One might speculate the existence of some secondary substance stored in the seeds which on release in the gut adversly affects the bird. Toxic and semi-toxic substances are highly specific; Janzen (1969) reviews this topic with reference to legumes.

Apart from doves, which are unlikely to be dispersal agents of A.cyclops, other birds will fulfil this role of ornithochory. As mentioned in the introduction, Middlemiss (1963) observed 21 species eating the funicle of the seed. Important dispersal agents are those which will move away from the Acacia stands to roost or feed elsewhere. European and Red-winged Starlings are likely candidates for wide ranging movement and hence dispersal of A.cyclops. Cape bul-buls, Pycnonotus capensis, would ensure marginal dispersal. Some non-quantitative observations were made on Starlings. These birds move about in flocks of between 2 and more than 200 individuals.

An entire flock will arrive and alight on a single A.cyclops bush. The first arrivals began to feed immediately while the last arrivals were inactive and alighted on surrounding trees. It was possible to observe some starlings in the process of removing seed from pods. Each pod cluster was "scrutinized" and the funicle removed from the pod. If the peck action was violent the seed was separated from the funicle, and the bird swallowed the funicle. However, the seed often remained attached. The bird then moved its head in a swift circular movement and the seed might break off the funicle. If the seed still remained attached, both seed and funicle were swallowed. Seed was found on the ground below a bush recently exploited by a starling flock and many of these seeds had a short piece of funicle still attached. This can be duplicated by removing seed from a pod by hand, and then separating seed and funicle; the funicle will tear leaving a short piece attached to the seed. Similar behaviour was briefly described for four species of starling, four smaller granivores and three species of insectivorous birds which were taking the plum-like fruit of Commiphora trothae, a common species in the Serengeti National Park (Lamprey 1967). All would first remove the outer flesh of the fruit with a swift circular motion of the bill, allowing this flesh to drop away. The red pseudo-aril would be eaten, while the "stone" was still attached to the tree. Frequently, the whole fruit would be broken off and the above sequence of removal and eating would occur on the ground. The starlings swallowed the "stone" and pseudo-aril without covering. Later, often before drinking, the cleaned "stones" would be regurgitated. Lamprey (*op.cit.*) had no germination success with such regurgitated seeds.

Before considering the possible calorific utilization of the *Acacia cyclops* funicle by birds, some short consideration should be given to the role of the funicle as a fruit analog, in comparison with the fruits of some other plants. The comparison of *A.cyclops* seed with other Acacia seeds shows little difference on the basis of protein, oils and carbohydrate percentages in the seeds (Table 15). The funicle, however, matches some tree fruits quite remarkably if the protein and fat percentages are compared (Table 14). These particular fruits comprise part of the diet of the Oil bird, *Steatornis caripensis* (Snow 1962). Ornithochory in *A.cyclops* means that, for an attractive fruit function for the funicle, the plant must balance and compromise the energy input to the attractive and nutritious funicle and to the seed. The compromise, then, must entrain the liklihood of dispersal while at the same time ensuring that the seed contains sufficient reserves to allow competitive germination (Snow 1971). The funicle contains about 50% more energy than the seed (31,05 KJ/g in the funicle as compared with 19,83 KJ/g in the seed; Appendix Table 16). Comparison of protein, fat and soluble carbohydrate in both (Table 14) shows that the funicle contains about 44% protein and about 34% soluble carbohydrate of that found in the seed whereas it contains 600% the quantity of fat. This very high value is quite likely to be due to the pigmentation of the funicle (vivid red), which in turn is attributable to carotenoids (Rothschild 1975). The funicle achieves colour at the very end of the development of the seed, just prior to dehiscence of the pod (see frontispiece). This delayed process might ensure that, should the seed be attacked by some invertebrate predator at an earlier stage in development, energetic losses are minimal. It is possible to roughly estimate the number of birds which could be supported by a single medium sized *A.cyclops* bush. Such a tree, as calculated in the results can produce up to 11630 seeds. If up to 50% are taken by birds, this means that roughly 5815 seeds may be consumed by birds. Starlings require 230 funicles per day to continue with normal daily activity. The single tree can support 25.28 starlings for a single day, or a single starling for about 25 days. This last figure can be manipulated so that, incorporating some variety in diet, a single starling will deplete a 3m tall and 3m wide tree in approximately

40/.........

40 days assuming that its diet is only 60% A.cyclops funicle.

A further estimation which can be computed, is the time the starling would need to spend feeding. Assuming it can consume one funicle every ten seconds then it would need to feed unimpeded for 38 minutes per day.

It would be very difficult to estimate the total maximum starling population which could be supported by A.cyclops in the Cape peninsula. For this it would be necessary to know the tree density in a given area and the populations of other birds which might compete for the food source. This figure however would probably be high enough to account for the very large numbers of starlings which occur in and around Cape Town.

The spread of A.cyclops is assured by the large populations of these birds. Invasion into the indigenous vegetation is also aided by enhanced germination resulting from passage through bird gut.

5.3 Germination of A.cyclops seeds.

Both the shape and size of Acacia cyclops seeds infer likely advantages in competitive germination. The compressed elipsoid shape is optimal for maximum contact with a water supplying substrate; the larger the seed "in general the larger the supply of food material provided by the parent plant in the seed ....., the more advanced the phase of succession that the species can normally occupy": Harper and Benton 1966 quoting Salisbury (1942). A comparison of the mass of A.cyclops with five indigenous species indicated that A.cyclops was more than 8 times heavier (Jones 1963).

The experiments conducted using A.cyclops seeds, which had been both defaecated by birds and treated to simulate the possible action of bird gut, indicated that both germination time and viability of seedlings was significantly improved. This is further evidence which infers that A.cyclops has co-evolved with an avian dispersal agent. Janzen (1971) suggests that vertebrate-adapted seeds have, more correctly, retarded germination if they do not pass through a vertebrate gut. The importance of rapid germination is that it may mean a competitive advantage at a favourable growth site (Linhart 1975). Germination of Acacia tortilis seeds was enhanced on excretion in the faeces of some large mammals. Through consumption by antelope and elephant in Serengeti, Tanzania, the A.tortilis seed also escaped possible bruchid beetle damage (Lamprey, Halevy and Makacha 1974). Noble (1975) found that Emus in New South Wales, Australia, apparently facilitate germination of nitre bush seed, Nitraria billardieri by removal in the gut

of/......

of the salt-rich pericarp. This composition of the pericarp appeared to prevent sufficient imbibition of water to initiate germination.

In Acacia cyclops, those treatments which damaged the testa, most significantly enhanced germination. With the fire treatment particularly fine longitudinal cracks were visible on the testa; and germination percentage was relatively high. Thus, A.cyclops seeds have the "double" advantage of enhanced germination when passed through bird gut and also if scorched by fire. Veld fire would also remove competitive plants.

Acacia cyclops seems to have adopted a relatively unexploited dispersal strategy. The only other plant in this area which might utilize ornithochory is Apodytes dimidiata. This forest species occurs in the wetter areas of relict forest patches on Table Mountain B.Mackenzie pers. comm). The seed is characteristically black on a red-aril cushion. Red-winged starlings, Onychognathus morio, were observed to feed on this(W.R. Siegfried pers.comm.). The very large mixed Starling population combined with the vigorous germination and growth properties of Acacia cyclops must account for a good part of this invasive plant's widespread distribution.

6. SUMMARY

1) The alien invasive Acacia cyclops has a high seed productivity per m^3 of canopy (up to 1650). This compares with other leguminosae which are prone to high seed mortality.

2) Birds, mostly European Starlings Sturnus vulgaris, might remove up to 50% of a seed crop.

3) Germination and viability of seeds which survive passage through bird gut, is markedly enhanced.

4) The seed and funicle have characteristics which indicate co-evolution to ornithochory - dispersal by birds.

5) The combinations of seed size, fire and ornithochory would account for a large part of Acacia cyclops success as an invader in the indigenous vegetation.

7. REFERENCES

Adamson, R.S. 1938. The vegetation of South Africa. London. British Empire Vegetation Committee.

Adamson, R.S. and T.M. Salter (eds.) 1950. Flora of the Cape Peninsula. Juta, Cape Town.

Gwynne, M.D. 1969. The nutritive values of *Acacia* pods in relation to *Acacia* seed distribution by ungulates. E. Afr. Wildl. J. 7: 176-178.

Harper, J.L. and R.A. Benton, 1966. The behaviour of seeds in soil. II. The germination of seeds on the surface of a water supplying substrate. J. Ecol., 54(1): 151-166.

Janzen, D.H. 1969. Seed-eaters versus seed size, number, toxicity and dispersal. Evolution 23: 1-27.

Janzen, D.H. 1971. Seed predation by animals. Ann. Rev. Ecol. Syst. 2: 465-492.

Jones, R.M. 1963. Studies in the autecology of the Australian *Acacias* in South Africa. IV. Preliminary studies of the germination of seed of *Acacia cyclops* and *Acacia cyanophylla*. S. Afr. Jour. Sci. 59: 296-298.

Kendeigh, S.C. 1970. Energy requirements for existence in relation to size of bird. Condor 72: 60-65.

Lamprey, H.F. 1967. Notes on the dispersal and germination of some tree seeds through the agency of mammals and birds. E. Afr. Wildl. J. 5: 179-180.

Lamprey, H.F., G. Halevy and S. Makacha. 1974. Interactions between Acacia, bruchid seed beetles and large herbivores. *E. Afr. Wildl. J. 12*: 81-85.

Linhart, Y.B. 1976. Density - dependent seed germination strategies in colonizing versus non-colonizing plant species. *J. Ecol. 64(1)*: 375-380.

McKey, D. 1975. The ecology of coevolved seed dispersal systems. IN: *Coevolution of animals and plants.* (Gilbert, L.E. and Raven, P.H. eds.) University of Texas Press, Austin and London.

Middlemiss, E. 1963. The distribution of *Acacia cyclops* in the Cape Peninsula area by birds and other animals. *S. Afr. Jour. Sci. 59*: 419-420.

Middlemiss, E. 1975. *The Rondevlei Bird Sanctuary 1952-1974.* Published by the Divisional Council of the Cape.

Murton, R.K. 1971. *Man and birds.* Collins, London 364 pp.

Neumann, C.P. and P.H. Kloffer 1969. Cage size and discrimination tests in birds: a methodological caution. *Behaviour 34*: 132-137.

Noble, J.C. 1975. The effects of emus (*Dromaius novaehollandiae* Ratham) on the distribution of the nitre bush (*Nitraria billardieri* DC.). *J. Ecol.* 979-984.

van der Pijl, L. 1969. *Principles of dispersal in higher plants.* Springer-Verlag: New York.

Roberts, E.H. 1974. *The viability of seeds.* Chapman and Hall Ltd., London 448 pp.

Rothschild, M. 1975. Remarks on carotenoids in the evolution of signals. IN: Coevolution of animals and plants. (Eds. Gilbert, L.E. and Raven, P.H.) pp. 20-50. University of Texas Press. Austin and London.

Roux, E.R. 1961. History of the introduction of Australian Acacias on the Cape Flats. S. Afr. Jour. Sci. 57: 99-102.

Roux, E.R. and E. Middlemiss 1963. Studies in the autecology of the Australian Acacias in South Africa. 1. The occurrence and distribution of Acacia cyanophylla and A, cyclops, in the Cape Province. S. Afr. Jour. Sci. 59: 286-294.

Shelton, P. 1975. Unpublished. Analysis of the stomach contents of the striped field mouse, Rhabdomys pumilio Sparrman. Zoology Honours project, University of Cape Town.

Snow, D.W. 1962. The natural history of the Oilbird, Steatornis caripensis, in Trinidad. II Population breeding ecology and food. Zoologica 46: 199-221.

Snow, D.W. 1971. Evolutionary aspects of fruit-eating by birds. Ibis 113: 194-202.

Sokal, R.R. and F.J. Rohlf 1969. Biometry. W.H. Freeman and Co., San Francisco. 776 pp.

Sweeney, J.R. 1969. The effect of wild fire on plant distribution in the southwest. IN: Proceedings of the symposium on fire ecology and the control and use of fire in wild land management (R. Wagle ed.) PP. 23-27. Journal of the Arizona Academy of Science.

Uramoto, M. 1961. Ecological study of the bird community of the broad-leaved deciduous forest of central Japan. Miscellaneous reports of the Y amashina's Institute for Ornithology and Zoology. Vol. 3(1): (No. 16).

Webster, J. 1970. Introduction to Fungi. Cambridge University Press. 424 pp.

Winterbottom, J.M. 1970. The birds of the alien Acacia thickets of the South Western Cape. Zoologica Africana 5(1): 49-57.

Zar, J.H. 1974. Biostatistical analysis. Prentice-Hall, Inc. Englewood Cliffs, N.J. 620 pp.

Ziswiler, V. and D.S. Farner, 1972. Digestion and the digestive system. IN: Farner, D.S. and J.P. King (eds.) Avian biology Vol. II. Academic Press, New York and London.

8. ACKNOWLEDGEMENTS

The project was centred around some ideas of Prof.W.Roy Siegfried, whom I thank for guidance and advice. Dr A.V. Hall, Bolus Herbarium provided many useful bits of information from his wide experience. Dr D. Mitchell, Botany Department, U.C.T. suggested culture of the fungi which were identified by Mrs V. Lomberg and Miss L. Olivier, Microbiology, U.C.T. Dr Vari, Transvaal Museum, Pretoria, identified the moth and Dr M. Meyer, Department of Agricultural Technical Services, Pretoria, identified the mites. Mr C.H. Langley, Rondevlei Bird Sanctuary allowed me to move freely in the reserve. Mr. T. Crowe provided some direction for the manuscript. I am very grateful to all these people. The Botany department kindly allowed me to use their controlled environment germination chambers.

This study was supported by a C.S.I.R. post graduate grant.

9. SUGGESTIONS FOR FURTHER RESEARCH

1) This somewhat basic study was necessarily more qualitative than quantitative; there is almost no published literature on Australian *Acacia* spp.

2) More accurate estimations of *A. cyclops* seed production based on a larger sample size are vital.

3) Careful collection of seeds at the beginning of a dispersal cycle would ensure minimal genotypic variation for use in germination tests.

4) Many aspects of bird foraging behaviour could be quantified.

FIGURE 1 The location of the study sites around the Cape peninsula and on the Cape flats.

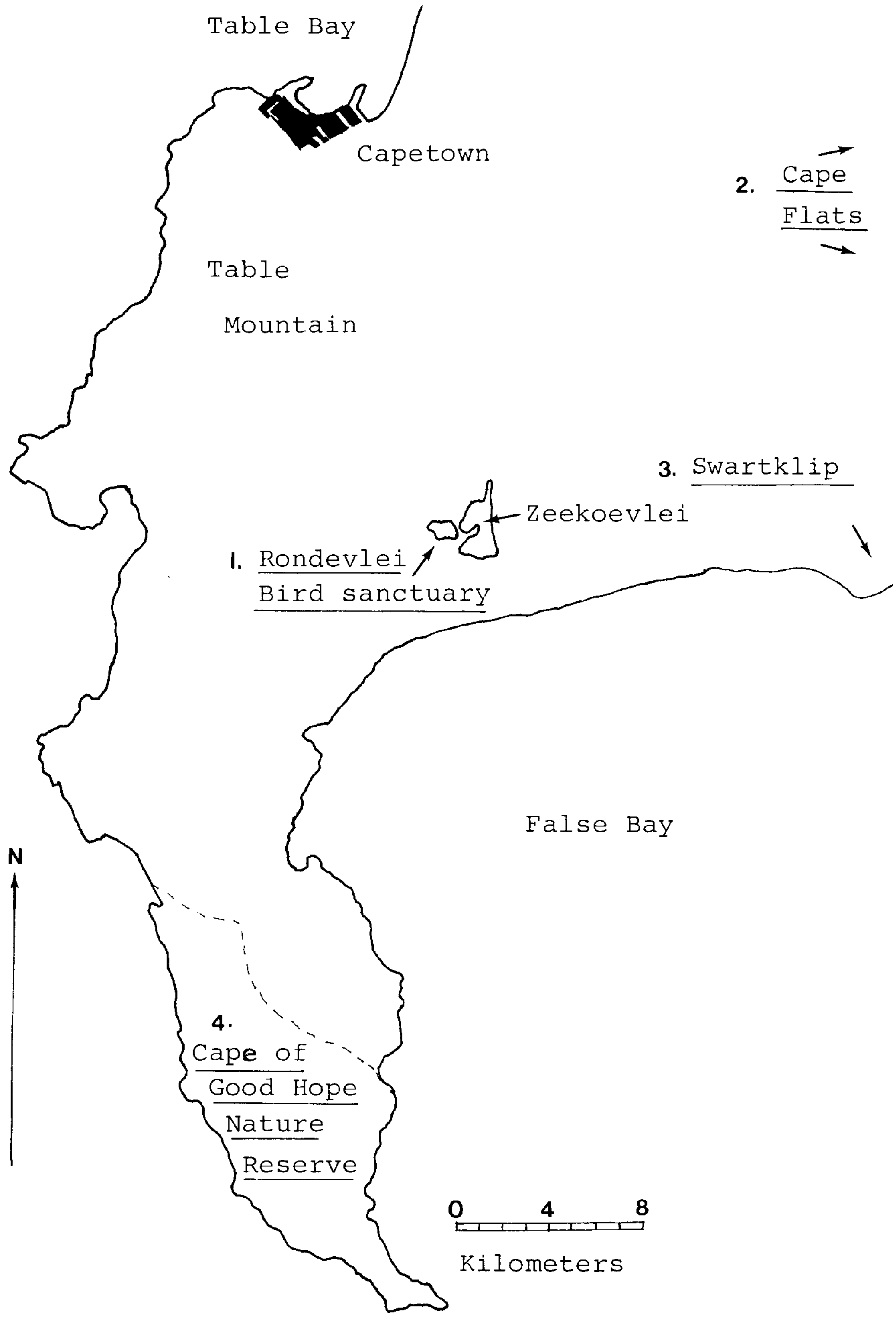


Figure 2 A cut-out view of the cages used in the selectivity trials and the calorific utilization estimates.

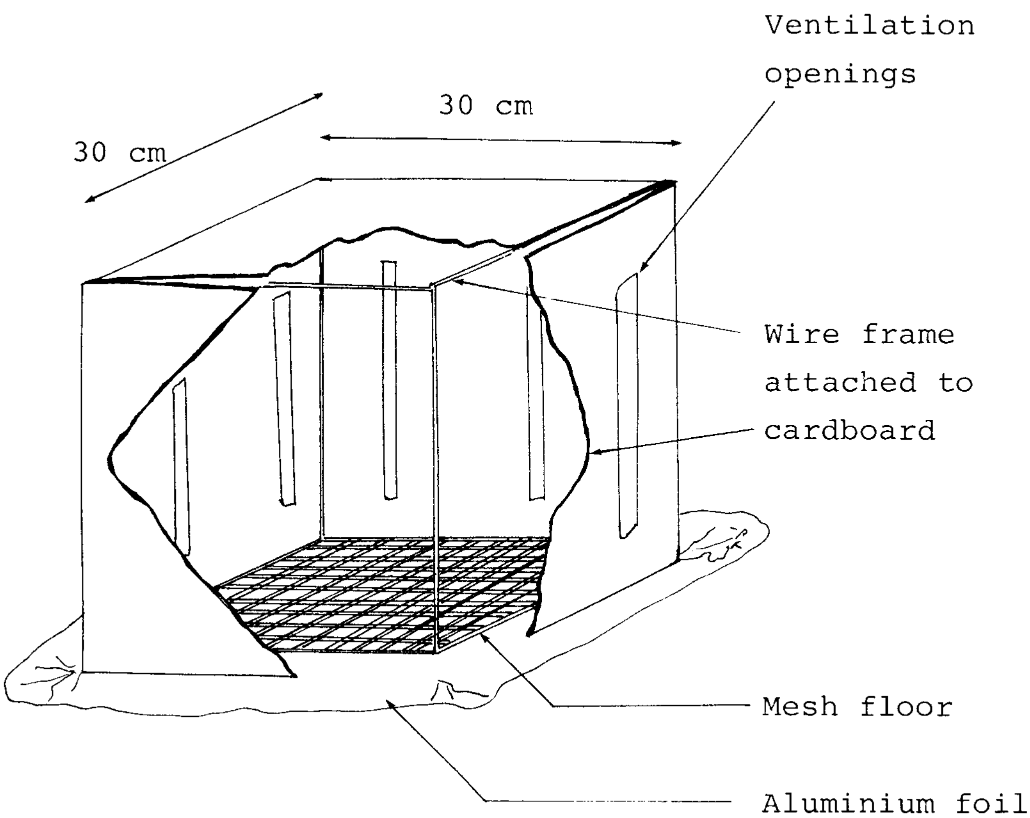


TABLE 1

The number of pod bearing branches counted in 8 x 1 cubic meters of *A. cyclops* bush canopy. The 8 counts were distributed amongst 5 bushes.

5 ; 8 ; 12 ; 20 ; 21 ; 20 ; 14 ; 26	
Mean	15,75
S D	7,19
S E	2,54

TABLE 2

The numbers of ovules per green pod and Pods per cluster found in 10 clusters on a single representative pod-bearing branch of an *A. cyclops* tree.

Ovules/Pod	Pods/cluster
7 7 7	3
10	1
8 10 11 10	4
11 10 8 11	4
9 9 11	3

	Ovules/Pod	Pods/cluster
	11 6 10 12 6 8 9	7
	7 8	2
	9 8 8 11	5
	6 8	2
	9 8 7	3
Total	290	33
Mean	8,79	3.3
SD	1,69	-
SE	0,29	-

TABLE 3

The means, standard deviations and standard errors of 10 Acacia cyclops seeds, and their funicles. This series of 10 was picked randomly from all the seeds used in this study which had been collected at Rondevlei Bird Sanctuary.

Mass of Seeds (g)	Mass of Funicles (g)
.0408	.0175
.0353	.0126
.0455	.0243
.0526	.0277
.0480	.0278
.0465	.0215
.0405	.0213
.0493	.0260
.0442	.0170
.0500	.0305

	Seeds		Funicles
mean	0,0452 g	mean	0,0226 g
SD	0,0052	SD	0,0056
SE	0,0016	SE	0,0017

TABLE 4

A computation of the number of ovules per m^3 of _A. cyclops_ based on the means and ranges in Tables 1 and 2.

A Mean and ranges on number of secondary branches per m^3 (From Table 2)	B Range and Mean of pod clusters per secondary branch (From Table 3)	A x B Pod clusters per m^3.	C Mean no of ovules per pod (From Table 3)	A x B x C Ovules per m^3	A x B x C Less 28% for loss of aborted ovules (Linder unpubl.)
	2	10,0		87,9	63,28
5	3,3	16,5	8,79	145,03	104,42
	10	50,0		439,5	316,44
15,75	2	31,5	8,79	276,88	199.35
	3,3	51,90		456,90	328,97
	10	157,5		1384,42	996.78
26	2	52,0		457,08	329,10
	3,3	85,8	8,79	754,18	543,01
	10	260,0		2285,40	1645,48

T A B L E   5

Differences in number and mass of *A. cyclops* seeds per meter ^{3} between trees where birds were permitted to feed and trees where they were excluded.

	A. cyclops Bush no. and volume	Seeds				Funicles		Germinating seeds	
		g/m^3	mean weight of 5 seeds	no/m^3	%	g/m^3	%	g/m^3	Actual No
Birds Exclu-ded	(m^3) 1 (14,10)	12,34	0,0463	266,5	92,9	0,93	7,1	nil	nil
	2 (4,20)	2,52	0,0504	50,0	89,3	0,30	10,7		
Birds able to feed	3 14,10	5,02	0,0452	111,1	87,9	0,69	12,1	0,63	17
	4 14,10	6,72	0,0490	137,2	92,9	0,51	7,1	0,72	24

T A B L E 6

The relative percentages of maize Zea mays, lentils, dehusked sunflower seeds Helianthus annus and Acacia cyclops eaten by Cape turtle doves during two 8 hour selectivity trials.

Cape Turtle dove	1		2		3	
Trial period length of time	1 8h	2 8h	1 8h	2 8h	1 8h	2 8h
Acacia cyclops seeds with funicles	Og (O%)	Og (O%)	2,72g (90,6%)	Og (O%)	0,25g (8,3%)	Og (O%)
Lentils	0,75g (15%)	0,27g (5,4%)	0,97g (19,4%)	1,07g (21,4%)	1,84g (36,8%)	Og (O%)
Helianthus annus (dehusked)	1,40g (28%)	0,49g (9,8%)	2,35g (47,0%)	0,96g (19,2%)	3,96g (79,2%)	0,08g (1,6%)
Zea Mays Maize	4,6 (92,0%)	4,19g (83,8%)	0,59 (11,8%)	0,74g (14,8%)	4,28g (85,6%)	Og (O%)
Total mass of seed consumed. (g)	11,70		9,40		10,41	

T A B L E 7

A computed estimate of maximum possible intake of Acacia cyclops seeds and funicles by Cape turtle doves and starlings. The existence metabolism was calculated from a regression equation (Kendeigh 1970) in the text.

	Cape turtle Dove	Starling
Existence KJ metabolism (E.M.)	86,90	91,66
Field existence i.e. (140%* x E.M.) KJ	121,66	128,32
Seed with funicle necessary at 80% digestive efficiency (Mean=(0,0452 + 0,0226)g)	6,24g seeds with funicles 92,00 seeds with funicle	Cannot digest seed
Seed only. 80% digestive efficiency (Mean=0,0452g)	7,67g seeds ie 169,66 seeds	Cannot digest seed
Funicle only 80% digestive efficiency (Mean=0,0226g)	4,90g funicle ie. 216,71 funicles	5,16g i.e. 228,57 funicles

* This figure is suggested by Uramoto (1961).

TABLE 8

A computation of total Kilojoule turnover (Existence metabolism) for 24 h in two Cape turtle doves.

MASS OF CONSUMED FOOD AND EXCRETA

Cape turtle dove	1	2
Mass of A. cyclops seed with funicle eaten in 36 h	7,00	3,84
Mass of A. cyclops funicle eaten in 36h	1,45	2,00
Mass of faeces after 48h	4,49	2,88
Digestive efficiency (see text)	46,8%	50,6%

CALORIFIC VALUES

Calorific value of seed with funicle KJ	170,66	93,61
Calorific value of funicle KJ	45,67	62,10
Total kilojaules ingested	216,41	155,71
Calorific value of faeces KJ	103,76	60,30
Total KJ used in 36h	112,65	95,41
Total KJ usage for 24h	75,02	63,54

Table 9 Treatments, germination patterns, percentage germination and percentage viability of _Acacia cyclops_ seeds. All batches comprised 100 seeds.

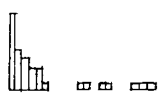
BATCH NO	TREATMENT	GERMINATION PATTERN	% GERMINATED	%VIABLE
1	nil		30	14
2	faeces adhered		22	16
3	nil		10	8
4	funicle attached		14	10
5	HCl pH 1,6		2	0
6	Sanded		25	20
7	Sanded alcohol		10	8
8	Alcohol		1	0
9	Burnt		33	13
10	control		12	7

Table 9 cont.

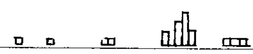
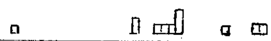
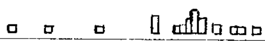
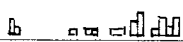
BATCH NO	TREATMENT	GERMINATION PATTERN	% GERMINATED	% VIABLE
11	HCl pH1,0		19	15
12	HClpH 2,0		12	6
13	Sanded		35	32
14	Pancreatin		17	11
15	Formalin		19	16
16	Burnt		2	0

TABLE 10

The results of Mann-Witney U tests and x^2 tests (performed on batches 1 and 2, and control batches 3 and 4 of A. cyclops seed), to compare the germination patterns and germination numbers at the conclusion of the experiment. The differences between the controls 3 and 4, and the defaecated seeds were considered sufficiently obvious (see Table 9) not to warrant statistical analysis.

	Mann-Witney Test	x^2
Batch 1 } 2	not significant $p > 0.10$	not significant $p > 0.50$
3 } 4	not significant $p > 0.10$	not significant $0.50 > p > 0.25$

TABLE 11

The results of Mann-Witney U tests and x^2 tests performed to compare the patterns and germination numbers in *Acacia cyclops* seeds between batches 5 to 9. Tests were performed only on those pairs of batches which appeared to have comparable results. Batches 5 and 8 had insufficient germinations for x^2 testing and were obviously different in pattern from 6, 7 and 9, not to warrant Mann-Witney U testing.

Tested between Batch and Batch	Result Mann-Witney U test	Result x^2 test
6 and 7	Not significant $p > 0.1$	Very significant $p < 0.001$
6 and 9	Not significant $p > 0.1$	NOT SIGNIF $p > 0.1$
7 and 9	Not significant $p > 0.1$	Very significant $p < 0.001$

TABLE 12

The results of Mann-Witney U tests and X^2 tests performed to compare the germination patterns and total number at conclusion of experiment respectively, of *Acacia cyclops* seeds in batches 11 to 15 compared to the control, batch 10. Batch 16 had insufficient germinations to warrant testing.

Tested between Batch	and Batch	Result Mann-Witney U test	Result X^2 test
11	10	Not significant $p > 0.1$	Significant $0{,}05 > p > 0.025$
12	10	Significant $0{,}025 > p > 0.01$	Not significant $p > 0.1$
13	10	Not significant $p > 0.1$	Very significant $p < 0.001$
14	10	Significant $0.1 > p > 0.05$	Not significant $p > 0.1$
15	10	Not significant $p > 0.1$	Significant $0{,}05 > p > 0{,}025$

TABLE 13

A comparison of seed production between *Acacia cyclops* and three South American leguminosae (data from this study and Janzen 1969)

SPECIES		CANOPY VOL. OF TREE (M^3)	G SEEDS/M^3 CANOPY	$\bar{X}$ NUMBER OF SEED/M^3 CANOPY
A. cyclops	calculated	14,10	2,58	63
A. cyclops	calculated	14,10	74,35	1645
A. cyclops		14.10	12,34	266
A. cyclops		4.20	2,52	50
A. farnesiana		14.10	0,43	5.9
A. farnesiana		14.10	11,56	124,6
Lysiloma bahamensis		14.10	26,81	141,8
Leucaena leucocephala		14.10	17,59	354,6

TABLE 14

A comparison of some nutritive components in Acacia cyclops seeds with those in other Acacia spp. seeds and a similar comparison between Acacia cyclops funicle and some tree fruits which are found in the diet of the Oilbird, Steatornis caripensis.

		% Protein	% Fat	% soluble carbohydrate	author
Seeds	Acacia hockis (Leguminosae)	25,92	4,16	31,68	Gwynne 1969
	A. sieberiana	18,95	3,56	53,33	" "
	A. nilotica sub sp. subalata	20,84	9,65	33,09	" "
	A. albida	28,36	2,55	58,71	" "
	A. saligna	24,7	10,4	41,5	David (unpubli.)
	A. cyclops (seed)	28,4	7,6	43,2	" "
Fruits	Acacia cyclops (funicle)	12,3	43,6	15,1	" "
	Cimramonnum elongatum (Lauraceae) Fruit flesh	9%	44%	-	Snow 1962
	Ocotea wachenheirmi (Lauraceae)	14%	34%	-	" "
	Dacryodes sp. (Burseraceae)	11%	24%	-	" "
	Bactris cuesa (Palmae)	13%	39%	-	" "

APPENDIX

TABLE 15

PERCENTAGE ABORTED OVULES

Sample	Total no. ovules	Viable ovules	% Age Loss
1	37	23	37,84
2	41	38	7,32
3	42	31	26,19
4	28	15	46,43
5	63	39	38,10
6	39	33	15,39
7	60	45	25,00
8	57	44	22,81
9	44	27	38,64

Mean	28,64
S D	12,62
S E	4,21

(Data by courtesy P. Linder (unpubl.)).

APPENDIX

TABLE 16

CALORIFIC VALUES

Ingested Food

	Funicle	Seed with funicle		Seeds alone
	30,19	24,07		19,92
	32,16	24,86		19,75
	30,81	24,22		
$\bar{X}$	31,05	24,38	$\bar{X}$	19,83
Sx	1,01	0,41		
$S\bar{x}$	0,58	0,24		

Faeces

	Dove 1		Dove 2
	23,06		21,87
	23,01		20,88
	23,27		20,08
$\bar{X}$	23,11	$\bar{X}$	20,94

TABLE 17 APPENDIX

Daily germination totals and calculation of mean time to germination for each seed batch.

1 - - - - - - - - - - - - - 2 2 4 10 12 12 12 12 12 12 12 14 14 16 16 16 16 18 20 20 20 20 20 24 26 28 28 28 28 28 28 28 28 28 28 30 30

2 - - - - - - - - - - - - - 2 2 4 6 6 6 8 8 8 8 8 8 8 8 8 8 10 12 12 12 12 14 16 18 18 18 20 20 20 20 20 20020 11 11 11 11

3 4 6 8 8 8 8 8 8 8 8 8 10 10

4 4 6 12 12 14 14 14 14 14 14 14 14 14 14

5 - - - - 1 1 1 1 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2

7 - - - - 2 2 3 4 6 9 9 9 9 9 9 9 9 9 10 10101010

9 - - - - 101519222526262627282829303030313**2** 3333

8 - - - - - - - - 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1

6 - - - 2 8 1113161718191919191919192122222232425

10 - - - - - 2 2 3 3 3 4 4 4 4 4 4 6 6 6 6 6 6 7 7 8 0 11 11 11 11 11 11 11 11 11

16 - - - - - - 1 1 1 1 1 1 1 1 1 1 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2

18 - - 2 4 5 8 9 1112121212121212131313141414151520212426231 31 31 31 32 33 33 34 34 35

15 - - - - - - 2 3 3 3 3 3 3 3 3 4 4 5 6 6 7 8 10 13 1314 16 17 19 19 19 19 19 19 19

14 - - - 1 1 1 11 2 2 2 2 2 2 3 3 3 3 3 3 3 3 5 5 5 6 8 11 13 13 14 14 15 16 17

11 - - - 1 1 1 1 2 2 2 2 2 2 2 3 4 4 4 4 4 4 4 4 8 11 15 17 17 17 17 17 18 18 19 19

12 - - - - - 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 3 3 4 5 6 9 9 9 9 9 9 10 10 10 11 12

mean time to germination: (From Jones 1963 formula in text)

1 =30 2 = 28 36 3 39,8 4= 37,57 5 = 7,0 7 = 9,2 9 = 8,85 8 = 0 6 = 9,8 10 = 16,9 16 = - 13 = 19,4 15 = 20,32

14 = 24,47 11 = 22,95 12 = 25,75.

APPENDIX

TABLE 18

Nos. banded — After Middlemiss 1960 - 1975 Annual reports of Rondevlei Bird sanctuary. Published by the Divisional Council of the Cape.

YEAR	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75
Sturnus vulgaris Starling			7	175	58	34	217	78	109	32	609	26	46	165	-	7	172	74	94	479	-	235	177	77
Cape turtle dove	10	114	136	345	448	216	204	118	50	68	115	49	62	43	-	23	366	74	117	147	-	103	26	15
Laughing dove	0	19	54	64	121	73	15	106	32	70	243	244	467	800	-	770	945	421	592	1134	-	1963	748	564
Total doves	10	133	190	409	569	289	219	224	82	138	358	293		843	-	793	131	495	709	1281	-	2066	774	579

Distances recovered

	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75
Starlings									2.6	3	4.5	5.1	5		3.1	5.1	6	5	9	3	4.7	12		
	Mean = 5.5 miles																							
Doves													3.5	2.0		2.0	3.8	3.1	3.1	3.5	4.4	3.0	6.5	7.0

Mean = 3.8 miles

APPENDIX

TABLE 19

ANALYSIS RESULTS OF SEED FROM ACACIA CYCLOPS AND A. SALIGNA.

	% Moisture	% Protein	% Crude fibre	% Fat (ether extract)	% Ash	% Soluble carbohydrate
A. saligna	5,0	24,7	19,0	10,4	4,4	41,5
A. cyclops (seed)	9,0	28,4	16,8	7,6	4,0	43,2
(funicle)	4,6	12,3	27,6	43,6 Believed to be partly due pigments.	1,4	15,1

(By courtesy of J. David, (unpublished)).