Seed Dispersal by Cassowaries (*Casuarius casuarius*) in North Queensland's Rainforests.

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ABSTRACT

Casuarius casuarius inhabits the rainforests of northeastern Australia and some of the islands to the north. It depends on fruit which has fallen from the middle and upper forest canopy. During the two-year study period diaspores of 78 plant species were found in cassowary dung. Although the germination percentage of seeds in dung were variable, some germination was observed for 70 species. The passage of most diaspores through a cassowary does not appear to greatly affect seed germination characteristics. These birds are the only extant frugivores large enough to effectively disperse many of the plant species found in the rainforests of this region.

CASSOWARIES ARE LARGE (standing to 1.5 m high), powerfully built, flightless birds which are found in or near rainforests in northeastern Australia, New Guinea, and some adjacent islands (Rand and Gilliard 1967). Of the three extant species recognised, *Casuarius casuarius* (L.) is the most widespread and is the only species now found in Australia. They are reasonably common in the lowland rainforest north of Ingham where their presence is indicated by tracks and piles of dung. The latter are readily recognisable, consisting of up to one kg of seeds and fruit fragments (Fig. 1). Crome (1976) used these dung components to identify the plant species contributing to their diet. The observation that seeds frequently germinated within the dung piles (Fig. 2) prompted the present study aimed at assessing the role of cassowaries in dispersing rainforest plant species. Although Ridley (1930) provides several reports of cassowaries dispersing seeds of some forest species on Ceram and the Aru Islands, the cassowary was not included in Snow's recent world survey of tropical frugivorous birds and their food plants (Snow 1981) and except for the notes of Crome (1976) and Frizelle (in White 1913) very little seems to be known of this bird's biology.

METHODS

The area chosen for this study was within Barong Logging Area on State Forest Reserve 755 (Lat. 17°32′S, Long.145°50′E) at about 60–120 m above sea level. The site lies 15 km to the southeast of the highest mountain (Mt. Bartle Frere 1622 m) in this region and about 55 km northwest of the study areas of Crome and Frizelle. The vegetation and physical environment of this region have been described by Stocker and Hyland (1981) and by Tracey (1982).

Collections of dung piles were made once every month from July 1977 to July 1979 inclusive, along and adjacent to, the final ten km of a logging road. Although most were made from open areas such as roads, logging tracks and loading ramps, many were also found on the floor of undisturbed parts of the forest. At each visit an attempt was made to collect a minimum of six fresh undisturbed droppings. They were placed in plastic bags and transported back to the laboratory in Atherton. As soon as possible, usually the following day, each dropping was washed and for convenience, sorted into three size fractions. The origin and fresh weight of the different materials in each fraction were noted. The numbers of larger ($\geq$0.5 cm diameter) seeds were also recorded. All the collected material was then placed in pots on a steam sterilized sand/peat potting medium in a heated (minimum 18°C) glasshouse. After a minimum of seven months the resulting seedlings were identified and the numbers of each species present were recorded.

RESULTS

The number of droppings examined averaged 5.52/month (range 0–8). They were usually easily found except during the first four months of 1979 when a total of only seven were collected. The average number of species of diaspore (as defined by van der Pijl, 1969) accumulated in each month's collection was 9.5 (range 2–21), and there was a tendency for the number of species collected to follow a seasonal pattern, the minimum number coinciding with the early part of the dry season. The species contributing to the cassowaries diet during the study period are listed in Table 1 which includes an indication of diaspore characteristics and some features of the parent plant. In this table the boundary between medium and large diaspore size was placed at the estimated upper limit of fruit size (eight cm^3) which can be swallowed by the large fruit pigeons of New Guinea (Frith *et al.* 1976). About one third of the species of diaspores collected is

FIGURE 1. A fresh pile of cassowary dung. The large seeds are from the fruit of *Elaeocarpus bancroftii*. A whole fruit (dia. 4.5 cm) of this species is shown to one side for comparison.

FIGURE 2. A clump of *Elaeocarpus angustifolius* seedlings from an old dung pile.

the 'large' category. Whole fruit either as drupes, berries, or synconia contributed much more to cassowary diets than arillate seeds or other forms of diaspore.

Species of Cyperaceae, Poaceae, and Compositae which appeared in the germination pots were not included in Table 1 for they were almost certainly derived from wind dispersed seeds blown onto the dung piles before they were collected. Two suspect species, however, were included; both were recorded only once. The first, *Castanospermum australe* [nomenclature of tree species follows Hyland (1982)] is a common leguminous tree which has a simple diaspore of a large brown seed devoid of a fleshy pericarp or aril. Its presence probably reflects either the rather non selective nature of the cassowary's foraging habits or an accidental inclusion in the dung sample by the collector. The second, *Trema orientalis,* has a small, fleshy drupe about two mm in diameter. It seems unlikely that a cassowary would deliberately eat a fruit this small and seeds of this species may have become attached to the dung after they were dispersed by smaller frugivores.

The largest fruits consumed by cassowaries in this study were those of *Beilschmiedia* sp. (Hyland 1982 #288). One dropping contained 13 of these fruit which had passed through the digestive system more or less intact. Each had a diameter of about six cm and weighed 52 g.

In addition to fruit and fruit derived materials, small amounts of other material were occasionally observed in the droppings. These included bracket fungi, land snail shells, portions of tree fern (*Cyathea* sp.) fronds and fragments of *Freycinetia* sp. inflorescences.

An indication of the germination percentage of seeds individually identifiable in the dung samples is given in Table 1. Only nine of the 78 species collected failed to produce some seedlings. In general, species in the Lauraceae and Myrtaceae germinated well. The best result was obtained from the large fruited laurel, *Beilschmiedia oligandra,* where only three of 400 seeds failed to germinate. One of the worst germinators was *Elaeocarpus foveolatus* with only six of 1851 seeds germinating; Other *Elaeocarpus* and *Acronychia* spp. also germinated very poorly. The germination of several species improved as the fruiting season progressed. Collections of *Prunus turnerana,* for example had germination percentages of zero for October, six for November, and 86 for December 1978. With the possible exception of a few species. *e.g., Rubus alceaefolius, Ficus* spp., and *Elaeocarpus* spp., observations of the remaining seeds at the time of germination assessment indicated that germination was complete.

The study also yielded some information on the frequency and duration of fruit production of many rainforest plant species. Although much of this information is more appropriately conveyed elsewhere, it is noteworthy that 56 of the 78 species listed in Table 1 appeared in only one fruiting season during the two year study period. There is also evidence to suggest that individuals of closely related species are all likely to fruit in the same season. This was especially noticeable for taxa in the Lauraceae.

DISCUSSION

The results confirm previous observations (*e.g.,* Crome 1976) that cassowaries are primarily dependent on the fruit of rainforest trees for their survival. They also show that many of the seeds passed by cassowaries retain their viability and that this bird is potentially an important disperser of many rainforest plant species.

Cassowaries seem to depend mainly on fruit which

TABLE 1. *Some characteristics of plant propagules collected in Cassowary dung.*

Taxa	Life form[a] of parent plant	Dispersal unit				Collection	
		Type	Size[b]	Colour	No. seeds	Frequency (months)	Germination[c]
Agavaceae							
Cordyline terminalis	pachycaul L	berry	small	red	4	3	n.a.
Annonaceae							
Polyalthia michaelii	tree M	berry	large	yellow	1	4	good
sp.	—	—	—	—	—	1	good
Apocynaceae							
Cerbera floribunda	tree M	drupe	large	blue	2	3	poor
Barringtoniaceae							
Barringtonia calyptrata	tree U	drupe	large	blue	1	3	good
Burseraceae							
Canarium muelleri	tree M	drupe	medium	blue	1–2	1	poor
Combretaceae							
Terminalia sericocarpa	tree U	drupe	small	purple	1	1	n.a.
Corynocarpaceae							
Corynocarpus cribbianus	tree L	drupe	large	red	1	1	moderate
Davidsoniaceae							
Davidsonia pruriens	tree L	berry	large	purple	1–2	6	moderate
Elaeocarpaceae							
Elaeocarpus angustifolius	tree U	drupe	medium	blue	1–4	3	moderate
E. foveolatus	tree U	drupe	small	blue	1	4	poor
E. stellaris	tree M	drupe	large	blue	2–4	2	poor
Himantandraceae							
Galbulimima belgraveana	tree U	berry	medium	red	7–10	1	poor
Icacinaceae							
Irvingbaileya australis	tree L	drupe	large	white	1	6	moderate
Lauraceae							
Beilschmiedia sp. (Hyland 1982, #288)	tree U	berry	large	black	1	2	good
B. oligandra	tree U	berry	large	black	1	4	good
Cryptocarya glabella	tree M	drupe	large	red	1	3	poor
C. hypospodia	tree M	berry	medium	black	1	2	moderate
C. mackinnoniana	tree M	berry	medium	black	1	4	good
C. oblata	tree M	berry	large	orange	1	1	good
C. sp. aff. *C. rigida*	tree L	berry	small	black	1	2	poor
Endiandra compressa	tree M	berry	large	yellow	1	1	moderate
E. cowleyana	tree U	berry	medium	black	1	3	good
E. sp. aff. *E. impressicosta*	tree M	berry	large	black	1	1	good
E. montana	tree M	berry	large	orange	1	3	good
E. sankeyana	tree M	berry	large	black	1	3	good
E. sp. aff. *E. hypotephra*	tree M	berry	medium	black	1	3	good
Leguminosae							
Castanospermum australe	tree U	seed	large	brown	1	1	poor
Melastomataceae							
Octanthera sp.	shrub D	berry	medium	pink	>10	12	n.a.
Meliaceae							
Amoora ferruginea	tree L	berry	medium	yellow	1–3	1	good
Dysoxylum sp.	—	—	—	—	—	1	moderate
Menispermaceae							
sp.	—	—	—	—	—	1	moderate
Moraceae							
Ficus congesta	tree L	syconium	medium	cream	>10	2	n.a.
F. crassipes	strangler U	syconium	large	yellow	>10	18	n.a.
F. obliqua var. *petiolaris*	strangler U	syconium	small	red	>10	1	n.a.
F. variegata	tree U	syconium	medium	cream	>10	7	n.a.
F. virens	strangler U	syconium	medium	yellow	>10	2	n.a.

TABLE 1. *Continued.*

Taxa	Life form[a] of parent plant	Dispersal unit				Collection	
		Type	Size[b]	Colour	No. seeds	Frequency (months)	Germination[c]
Myristicaceae							
Myristica insipida	tree M	arillate seed	medium	red	1	3	moderate
Myrsinaceae							
Ardisia pachyrrachis	shrub L	berry	small	red	1	2	n.a.
Myrtaceae							
Acmena divaricata	tree M	berry	large	red	1	13	good
A. graveolens	tree M	berry	large	red	1	2	moderate
Eugenia cormiflora	tree M	berry	large	white	1	3	good
Eugenia kuranda	tree M	berry	large	brown	1	2	good
Syzygium dictyophlebium	tree U	berry	medium	cream	1	3	good
Palmae							
Calamus australis	liane U	drupe	medium	yellow	1	1	n.a.
C. moti	liane U	drupe	medium	yellow	1	1	good
C. radicalis	liane U	drupe	medium	yellow	1	7	moderate
Linospadix microcarya	pachycaul L	drupe	small	red	1	8	good
Phytolaccaceae							
Phytolacca octandra	herb D I	berry	small	black	6–8	1	n.a.
Piperaceae							
Piper sp.	vine M	berry	small	red	1	1	moderate
Pittosporaceae							
Pittosporum rubiginosum	tree L	arillate seed	medium	red	2–4	1	n.a.
Podocarpaceae							
Podocarpus dispermus	tree L	arillate seed	medium	red aril, black seed	1	1	n.a.
Rosaceae							
Prunus turnerana	tree M	drupe	large	black	1	3	good
Rubus alceaefolius	scrambler D	aggregate fruit	medium	red	>10	4	n.a.
R. rosaefolius	scrambler D	aggregate fruit	medium	red	>10	1	n.a.
Rubiaceae							
Antirhea tenuiflora	tree L	berry	small	red	1–3	4	n.a.
Nauclea orientalis	tree U	aggregate fruit	large	yellow	>10	1	n.a.
Psychotria dallachyana	shrub L	berry	small	cream	2	4	n.a.
Rutaceae							
Acronychia acronychioides	tree L	drupe	medium	yellow	1–4	5	poor
A. vestita	tree M	drupe	medium	cream	1–4	4	poor
Sapindaceae							
Diploglottis pedleyi	tree L	arillate seed	large	red	1	1	good
Ganophyllum falcatum	tree M	drupe	small	orange	1	2	n.a.
Rhysotoechia robertsonii	tree L	arillate seed	medium	yellow aril, black seed	1–3	1	good
Sapotaceae							
Chrysophyllum chartaceum	tree L	berry	medium	purple	1–2	2	n.a.
Planchonella sp.	tree	berry	—	—	—	3	poor
Siphonodontaceae							
Siphonodon membranaceous	tree M	berry	large	orange	>10	1	poor
Solanaceae							
Solanum dallachii	shrub D	berry	medium	green	>10	3	n.a.
Solanum mauritianum	shrub D I	berry	medium	yellow	>10	1	n.a.
S. torvum	shrub D I	berry	medium	yellow	>10	10	n.a.

TABLE 1. *Continued.*

Taxa	Life form[a] of parent plant	Dispersal unit				Collection	
		Type	Size[b]	Colour	No. seeds	Frequency (months)	Germination[c]
Strychnaceae							
Strychnos minor	vine U	berry	medium	yellow	1–4	1	moderate
Ulmaceae							
Trema orientalis	tree D	drupe	small	black	1	1	n.a.
Verbenaceae							
Gmelina fasculiflora	tree M	drupe	medium	blue	1	3	moderate
Faradaya splendida	vine U	berry	large	white	1	1	good
Vitidaceae							
Cayratia clematidea	liane D	berry	small	black	3	1	n.a.
Xanthophyllaceae							
Xanthophyllum octandrum	tree M	capsule	small	black	1–2	1	n.a.
Zingiberaceae							
Alpinea caerulea	tall herb D	berry	small	blue	>10	1	n.a.
A. modesta	herb L	berry	small	blue	>10	3	n.a.
sp.	—	—	—		—	2	n.a.

[a] L, M and U denote that the species is typically found in either the lower (L), middle (M) or upper (U) levels of the primary forest canopy. D indicates that the species is usually found in heavily disturbed areas or on the forest edge; I, that it is an introduced seed.
[b] Small = <1 cm^3, medium = 1–8 cm^3, large = >8 cm^3.
[c] N.a. = germination occurred but no data on seed numbers in the collection(s) are available, poor = 0–3 percent, moderate = 3–30 percent, good = >30 percent.

has fallen from the middle and upper canopy levels of primary rainforest. Only 12 of the species listed in Table 1 (one caulicarpus tree; the remainder herbs, shrubs and scramblers) bear fruit within their reach. Furthermore, fruit production by understorey species was low except on recently disturbed sites where early secondary species such as *Solanum torvum* may produce heavy fruit crops. Although droppings generally contained a mixture of several species, there were occasions when seeds and fruit fragments of a single species made up most of a month's collections. Taxa in this latter category included *Beilschmiedia oligandra, Cryptocarya mackinnoniana, Elaeocarpus foveolatus, Prunus turnerana,* and several individual species of *Ficus, Acronychia,* and *Calamus.* There are no present indications that cassowaries are selective about the site they choose for defecation. Although most of the collections were made from disturbed sites we consider that this only reflects the greater visibility of dung piles at these locations.

During the initial sorting process it was observed that many fruit with firm pericarps, especially those not quite fully mature, appeared to pass through cassowaries almost unaltered. An apparently gentle digestive mechanism has been reported for other specialised frugivores and this probably serves to protect them from poisonous compounds in the seeds (McKey 1975). In this study it appears that this gentleness also ensures that a large percentage of seed with even the thinnest of seed coats can pass through a cassowary undamaged. However, while the cassowary is undoubtedly a specialised frugivore the incidental component of its diet recorded here and in Crome (1976) suggests that it is also something of a forest floor scavenger.

Although there are some indications that the germination characteristics of seeds which have passed through a cassowary are little different from those of seeds which have had externally adhering fleshy material removed manually (Stocker, pers. obs.), this question cannot be adequately answered without controlled studies using captive birds. The failure of nine of the 79 species eaten to germinate cannot positively be attributed to passage through a cassowary for seven of them were represented by less than six seeds. Furthermore, it was suspected that the seeds of some species may not have been viable because of immaturity or insect damage and that, in some months (especially October and November), hot dry weather conditions may have adversely affected the germination of seeds from some droppings collected from open areas such as roads and logging ramps. One of the remaining species, *Acronychia vestita,* occurred in larger numbers but rarely germinated reliably under a variety of experimental conditions (Stocker, pers. obs.).

Even if passage of seeds through a cassowary does not directly alter their germination characteristics, the digested flesh passed with them may affect germination and seedling establishment by retaining enough moisture to

prevent seeds with thin and presumably previous seed coats from being killed by desiccation and to enable seedlings to progress beyond the critical early establishment phase. This fine, digested material also appears to deter seed predating rodents; seeds in dung piles were scattered and predated less frequently than small piles of manually cleaned seeds of the same species. However, even in dung piles, seeds which had not germinated were eventually scattered and predated after one or two months of washing by rain. Species germinating in dung piles must usually, because of their proximity, face strong inter- and intra-specific competition. As a result large seeds appear to have an advantage over smaller ones as they usually grow more rapidly and shade out competitors. This may account for the dominance of single seeded diaspores recorded for those large fruited species primarily dependent on cassowaries for dispersal. Most of the many seeded diaspores are of small to medium size and appear to be widely dispersed by a variety of frugivores.

Unfortunately, not enough is known about the biology of the cassowary to make an assessment of its role in long distance dispersal. However, it must be important over shorter distances particularly in ensuring that large diaspores reach higher ground. It is hoped that further work can be undertaken to provide data on the time taken for seeds to pass through a cassowary's digestive tract and on the extent of their daily and seasonal movements. At the present time we have no information beyond the following scant observations: Ridley (1930) found that a captive cassowary fed fruits of *Chrysobalanus icaco* retained the seed for at least 10 hours 40 minutes; Fizelle (in White 1913) thought that they might have territories from 0.5–2 square miles. It has also been suggested that they shift in response to seasonal conditions, but the evidence is largely circumstantial. For example, Crome (1976) found low numbers of droppings in the February to May period and suggested that during this time the birds had either left the area, considerably extended their foraging ranges, or were starving. We also noted one period early in 1979 when droppings were difficult to find and concluded, rather tentatively, that they had moved from the area.

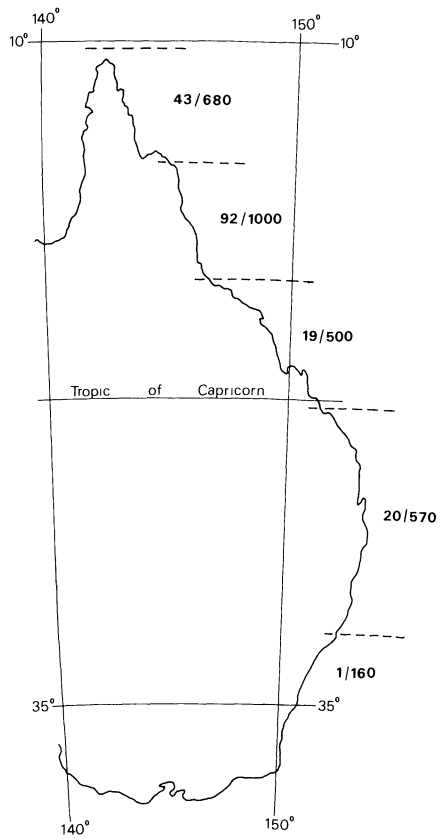

FIGURE 3. The eastern coast of Australia showing estimates of the number of large fruited species in the woody flora of the rainforests of different regions. Cassowaries are now only found in the two northern regions. In a transect through rainforest on the southern boundary of the second region only eight large fruited species were found in a total woody flora of 280 species (Irvine, pers. obs.). The estimates were made using data from Beadle *et al.* (1962), Hyland (1982), Tracey (1982 and pers. comm.), and Williams (1980) in addition to that from our own observations.

While the efficiency of cassowaries as long distance dispersers of seed cannot be critically assessed, we have seen them moving through open eucalypt woodland in northern Cape York Peninsula. Thus, they may be important in moving large seeds across areas of unfavourable environment, *e.g.,* from the gallery rainforest of one river system to the next. In prehistoric times it is conceivable that they could have carried plant species between Australia and New Guinea for Torres Strait is very shallow and was dry as recently as 8000 years ago (Nix and Kalma 1972).

In general most large diaspores from Australian rainforest have signalling colours and do not have a conspicuous smell or closed hard rind. These are the characteristics of diaspores dispersed by specialised frugivorous birds rather than mammals (van der Pijl 1969). Although it has been stated that some of the extinct marsupials may have dispersed large seeds (Janzen and Martin 1982), there appears to be no conclusive evidence for this suggestion. Certainly none of the extant mammals of the Australian—New Guinea region (with the exception of the fruit bats) appear to be as frugivorous as many of those in the American or African tropics or those parts of the Asian tropics west and north of Wallace's line. However, some plant species, *e.g.,* those of *Macadamia, Dendrocnide* and *Aleurites,* seem to be dependent on small

indigenous rodents (mainly *Rattus, Melomys,* and *Uromys* spp.) for their dispersal but these mammals don't have a capacity for dispersing large seeds comparable to that of the cassowary.

Most of the large-fruited rainforest plant species that we know or consider to be suitable as part of a cassowary's diet, are found within the cassowary's present range (Fig. 3). Cassowaries may not, however, be the primary dispersers of all these species for a few, *e.g., Eugenia kuranda, Ficus crassipes,* and *Barringtonia calyptrata* have dull-coloured fruits and various other characteristics suggested by van der Pijl (1969) as being typical of diaspores carried by fruit bats. Another small group of large-fruited species, *e.g., Aleurites moluccana, Castanospermum australe,* and *Macadamia* spp., had no diaspore characteristics which might suggest their dispersal by specialised frugivores and they were omitted from the data used to prepare Figure 3. A study of the distribution and reproductive ecology of some of the southern rainforest species with large diaspores having features characteristic of those which are bird dispersed could be rewarding for there is fossil evidence that cassowaries (Miller 1962) or at least their near relatives (the extinct Dromornithidae) (Rich 1979) were in southern Australia during the Pleistocene.

Since the tastes of man seem more closely related to those of frugivorous mammals than birds, the apparent absence from this region of plants whose disperasl is linked with large mammals may help explain the frequent observation (*e.g.,* Boland and Turnbull 1981) that there are few, if any, indigenous fruit species which might be developed for horticulture. Alternatively, it may be that the European background inherited by most of the present day inhabitants of the continent is unappreciative of the numerous fruits eaten by the aboriginal population who, in biological terms, are also recent arrivals.

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