

Dispersal of *Terminalia* seeds by the Northern Cassowary in the lowland forest of Papua, Indonesia

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ABSTRACT

The northern cassowary (*Casuarius unappendiculatus*) is an endemic large ratite bird in New Guinea and considered as the main frugivorous bird in the lowland forest. Many trees in the rainforests of New Guinea which have large fruits like *Terminalia* spp may be depending on the cassowaries for dispersal of their seeds. We investigated the dispersal of *Terminalia* seeds through collecting the cassowary droppings along a set of transects in five distinct habitats, ranging from undisturbed primary forest to logged forest and forest garden. We identified five *Terminalia* species and found a total of 529 seeds in cassowary droppings during the survey in 2011 and 2012. Four species are endemic to New Guinea region. *Terminalia* seeds were encountered in all habitats studied except in forest garden, and the number of seeds was significantly different between habitats. The highest number of seeds was obtained from secondary forest, intermediate number in primary forest and natural forest, and the lowest was in logged forest. These results suggest the importance of *Terminalia* fruits as food resources for the cassowaries and the birds as keystone species for seed dispersal of *Terminalia* trees.

Key words: Northern Cassowary, *Terminalia* species, seed dispersal, Papua Indonesia.

INTRODUCTION

Seed dispersal by vertebrate fauna has been identified as one of the key components of forest ecosystem. Up to 90 % of tropical tree species rely on frugivorous animals for the dispersal of their seeds (Howe & Smallwood 1982). On the other hand, a number of species of fruiting plants may play critical roles for maintaining frugivore populations especially during the lean periods, when other species are not producing fruits (Terborgh, 1986; Wright, 2005). This plant-animal interaction can determine the extent and patterns of plant regeneration (Wang & Smith, 2002), specifically that interaction is important for enhancing succession after deforestation and fragmentation. Therefore, the modification or loss of such interactions in the rainforest ecosystem may have profound implications for forest regeneration.

Tropical lowland forest in Papua has a high diversity and endemism of flora including genus *Terminalia* of the family Combrataceae. This plant group primarily inhabit the lowland rainforest, and might be often found in flat and swampy areas (Coode, 1978). Twenty two species were recorded from Papua Indonesia including one species, *Terminalia oreadam* which occurs in mid montane forest (*loc.cit.*). A number of *Terminalia* trees have potential to produce valuable timber and are therefore used by local communities for house construction. Several species are even amongst the frequently harvested trees in New Guinea for major exportable

hardwood (Conn & Damas, 2014). Moreover the kernels of certain *Terminalia* species such as *Terminalia cattapa* and *Terminalia kaernbachii* are edible nuts (Evans, 1999), which are consumed by local people either in Papua New Guinea or in Papua Indonesia. Since many *Terminalia* species produce fleshy fruits with high nutrition contents (Evans, 1999) corresponding to their zoochory, this plant group contributes considerably to the diet of vertebrate fauna in New Guinea. Many of them have large-sized fruits and hence their seeds' dispersal is a confined role of large-gaped frugivorous animals.

Amongst the major frugivorous vertebrates in New Guinea are the large flightless cassowaries. There are only three species in the family Cassuaridae, and the Northern Cassowary (*Casuarius unappendiculatus*) (Figure 1) is endemic to the northern lowlands of New Guinea. Cassowaries play significant roles in seed dispersal of numerous forest plants and have been considered as keystone species in forest ecosystems of New Guinea and Australia (Mack & Wright, 2005; Crome & Moore, 1990). All cassowary species are obligate frugivores (Stocker & Irvine, 1983) with about 90 to 99 % of their diet dependent on fruits (Bentrupperbaumer, 1997; Wright, 2005).

The Papuan rainforest is recognised as one of the last wilderness areas in the world but rapid development and human population growth in this region are leading to exploitation and conversion of its lowland

forest. Disturbance from logging operations and large-scale oil palm plantations are the major causes of the loss of lowland forest in Papua (Frazier, 2007). Large flightless forest birds such as cassowaries are especially likely to disappear if their habitat is disturbed (Bentrupperbaumer, 1997) and consequently would not only change the dispersal process of cassowary-dispersed plant species but may also affect the patterns of plant regeneration.



Figure 1. Northern cassowary, adult bird may weigh up to 50 kg. (Photo M. Pangau-Adam).

Despite the importance of cassowaries in forest ecosystems, little is known about the mutualism of interaction between Northern Cassowary (*Casuaris unappendiculatus*) and large-fruited forest trees in Papua. The aim of this study was to identify *Terminalia* species dispersed by the Northern Cassowary, and to assess if the diversity and number of seeds dispersed are varying with habitat types.

MATERIALS AND METHODS

The study was conducted in Nimbokrang rainforest in north-east Papua (formerly Irian Jaya), Indonesia. The lowlands consist of a mosaic of forest habitats including large part of intact forest. Due to the high diversity of endemic Papuan birds, Nimbokrang forest has become one of the international bird watching spots in Indonesia. Although forests around the villages had been cleared for timber and agriculture, large primary forest areas still remained. At an elevation ranging from 50 to 200 m above sea level, the vegetation of the study area is humid

(lowland) tropical rainforest subject to inundation (Conservation International, 1999). Typical canopy tree genera are *Instia*, *Terminalia*, *Pometia*, *Ficus*, *Canarium*, and *Alstonia* while understory trees include *Myristica*, *Syzygium*, *Garcinia*, *Elaeocarpus*, *Diospyros*, *Pandanus* and palms. Significant areas of the lowland forest are claimed as traditional forest of local people resulting in several land use systems and marginal forests (Pangau-Adam, Muehlenberg and Waltert, 2014). Primary forest and four different habitat types representing a gradient of disturbance were chosen, from unlogged but hunted natural forest (hereafter referred to simply as 'natural forest'), >30 year old secondary forest, < 3 year old selectively logged forest and forest garden. The census of cassowary fecal droppings was conducted in October to December 2011 and April to June 2012 using the line transect method. Ten transects were established systematically in each of the five habitats, resulting in a sample size of 50 transects across the whole study area. The transects were located at least 500 meters apart from each other, and the length of each transect was 2.5 km. Transects were walked slowly and scanned ca. 2 m on each side to census and collect the fecal droppings of cassowary. Cassowary droppings are conspicuous, may persist for weeks without decay and are unmistakable for any other animal dropping in New Guinea (Mack, 1995). We identified and recorded the seeds or fruits of *Terminalia* species in the droppings, and assessed the difference in seed numbers between habitats using the Kruskal-Wallis test. The fruiting *Terminalia* trees within 10 m of each side of the transects were recorded.

RESULTS

We obtained a total of 529 seeds and 7 fruits from 80 cassowary droppings and identified five *Terminalia* species from these seeds (Table 1). Cassowaries forage the fallen fruits directly from the forest floor and consume the ripened fruits. The arils of all *Terminalia* species recorded in this study are fleshy and the fruits were mainly orange, red and purple colored. Each dropping contained at least one *Terminalia* species, and eight droppings had two distinct *Terminalia* species. All seeds were large seeded as defined by Westcott *et al.* (2005). *Terminalia* seeds were found in all habitats except in forest garden. Two species, *Terminalia complanata* and *T. kaernbachii* were encountered in four habitat types including logged forest, while *T. impediens* was only recorded from natural forest (Table 1).

Table 1. *Terminalia* species found in the diet of the Northern Cassowary (*Casuaris unappendiculatus*), the number of seeds and fruits, seed diameter, and habitat where they were found (primary forest: p, natural forest: n, secondary forest: s, logged forest: l).

Species	No. seeds	No. fruits	Seed diameter (mm)	Habitat
<i>T. complanata</i> K.Sch.	194	7	28-37	p, n, s, l
<i>T. kaernbachii</i> Warb.	48		55-65	p, n, s, l
<i>T. copelandii</i>	147		23-30	p, n, s
<i>T. impediens</i>	6		25-35	n
<i>T. canaliculata</i>	134		15-20	p, n, s

The number of *Terminalia* seeds dispersed by the Northern Cassowary was significantly different between habitat types (Kruskal-Wallis ANOVA, $H = 10.48$, $df = 4$, $P < 0.03$). The highest number of seeds was found in secondary forest, intermediate number was in primary forest and natural forest, and the lowest number was in logged forest (Table 1). Several seeds were found with pulp still adhered, and seven intact fruits of *T. complanata* were recorded in one cassowary dropping from primary forest. The smallest seeds belonged to *T. canaliculata*, diameter 15-20 mm and 8-14 g weight, and the largest seeds were from *T. kaernbachii* with 55-65 mm in diameter and ca. 45-55 g weight. The fruiting *Terminalia* trees were found during the survey periods in all habitats except in logged forest (Table 2).

Terminalia complanata

This was the most frequently recorded *Terminalia* species from the cassowary droppings. A total of 194 seeds and 7 intact fruits were found in 19 droppings (Figure 2). The ripe fruit has red purple color and aromatic fleshy aril. This species is an emergent tree with a height up to 45 m. It mainly occurs in lowland swamp forest, and also at higher altitudes from sea level to 1500 m (Coode, 1978). *T. complanata* is endemic to New Guinea and its wood is amongst the major exportable hardwood from the island (Conn & Damas, 2014).

Terminalia kaernbachii

This species has the largest seeds (length = 80-90 mm; D = 55-65 mm) compared to other *Terminalia* seeds found during the study. A total of 48 seeds were dispersed by the Northern Cassowary in all habitat types except in forest garden. *T. kaernbachii* is endemic to New Guinea and Aru Island, where it is often cultivated (Coode, 1978). The kernels are edible, known as okari nut and common in local market in Papua New Guinea during the fruiting season (Evans, 1999). Although it is not found in the market around Nimbokrang, the local people usually consume the kernels during their activities of gathering non timber forest products (Figure 3).

Terminalia copelandii

This species was found in cassowary droppings from primary forest, natural forest and secondary forest. Its

seeds were encountered more frequently than other *Terminalia* seeds except *T. complanata*. A total of 147 seeds were found in 21 droppings from three habitat types. This species is distributed in other regions in Southeast Asia, including Sumatra, Borneo, Philippines, Lesser Sunda Islands, Celebes and Moluccas (Code, 1978).



Figure 2. Fruits of *Terminalia complanata* (red purple color) in cassowary dropping.



Figure 3. Seeds and kernel of *Terminalia kaernbachii*.

Table 2. Fruiting *Terminalia* trees recorded in each habitat site during the survey, N= number of fruiting *Terminalia* trees.

Habitat	<i>Terminalia</i> species	N
Primary forest	<i>complanata, kaernbachii, copelandii, canaliculata</i>	14
Natural forest	<i>complanata, kaernbachii, impediens</i>	5
Secondary forest	<i>complanata, kaernbachii, canaliculata, copelandii</i>	7
Logged forest	-	0
Forest garden	<i>complanata</i>	2

Terminalia impediens

There were only six seeds of this species found in two cassowary droppings from natural forest. *Terminalia impediens* produces fleshy fruits with red purple color (Figure 4), and the fruits are the second largest after those of *T. kaernbachii*. *T. impediens* is endemic to New Guinea. This species is an emergent tree and the timber is amongst the major exportable hardwood (Conn and Damas, 2014).



Figure 4. Fruits of *Terminalia impediens* with red purple color.

Terminalia canaliculata

A total of 134 seeds of *T. canaliculata* were found in 11 cassowary droppings from primary forest, secondary forest and natural forest. The aril of its fruit has bright yellow color. This species is also a large canopy tree with a height up to 45 m, and is considered as occasional timber species (Conn & Damas, 2014). *T. canaliculata* is endemic to New Guinea Island and occurs throughout the lowlands of mainland New Guinea especially in swampy areas (Coode, 1978).

DISCUSSION

This study may suggest that the Northern Cassowary is an important seed disperser of *Terminalia*. All the *Terminalia* species found in the diet of cassowary have large fruits, which can only be dispersed by frugivores with large gape. Large fruits are favored by frugivorous birds because the pulp content increases with fruit diameter (Wheelwright, 1993). Additionally, since cassowaries are non-volant, they can consume large quantities of fruit without ballast limitations experienced by volant frugivores (Wright, 2005).

Terminalia species are accounted as significant food resources for the Northern Cassowary, because they provide a variety of fleshy fruits in the lowland forest of Papua. A high number of *Terminalia* seeds identified in the droppings may indicate the diet preference of cassowary toward this plant group. Studies on the Dwarf Cassowary in Papua New Guinea showed that no particular families dominated the diet of the birds (Pratt, 1982), but the fruits of two *Terminalia* species were amongst 30

most important species by number of items in the diet of Dwarf Cassowary (Wright, 2005). It is assumed that the arils of *Terminalia* species found in study area are nutritious. Chemical analysis of the mesocarp of *Terminalia catappa* reveals significant nutrient content of *Terminalia* fruits including 40% carbohydrate, 6 % protein and 5.5 % fat (Bolaji, *et al.*, 2013). The bright-dominated color of *Terminalia* fruits (red, purple and yellow) might also be the main reason of fruit choice by the cassowary. Gautier-Hion *et al.* (1995) reported that diurnal frugivorous birds have special color vision and discrimination of red wavelengths, in concordance to the preferred consumption of fruits in red and purple color.

The Northern Cassowary disseminated a high number of *Terminalia* seeds in primary forest, natural forest and secondary forest and low number in logged forest. Cassowaries rarely visited logged forest seemingly because of the sparse food availability in this habitat. Logging has become the major threat to the population of Northern Cassowary, because unsustainable logging operation reduces habitat quality for cassowaries, especially if food plants are removed (Pangau-Adam, *et al.*, 2014). In our study *Terminalia* trees have been disappeared from logged forest (Table 2) due to intensive logging. Several *Terminalia* species are amongst the frequently harvested trees in New Guinea for major exportable hardwood (Conn and Damas, 2014).

Although the trees of *Terminalia complanata* and *T. kaernbachii* were absent in logged forest, their seeds were found in cassowary droppings collected from this habitat. The movement of cassowary from other habitats may apparently facilitate the seed dispersal process of these species. This might occur because three sites of logged forest where *Terminalia* seeds have been found were adjacent either to secondary forest or natural forest. Cassowaries may have been foraging in these forest sites and subsequently transported the seeds to the logged forest. Since cassowaries have large home ranges, they can disseminate a variety of plant species in large quantities over long distances (Bentrupperbaumer, 1997; Wright, 2005) even in degraded areas. Seed dispersal plays a significant role for the plant colonisation on degraded land and can strongly influence the patterns of plant regeneration on fragmented and disturbed forests (Zimmerman, Pascarella and Aide, 2000; Laurance, 2004).

Many forest plants in Papuan lowland forest have relatively large fruits and seeds. This indicates the importance of cassowaries having a large gape width, because Papua lacks large-bodied frugivorous mammals that would be important for dispersing large seeds (Mack and Wright, 2005). Disappearance of the Northern Cassowary as seed disperser may affect the abundance and extinction probability of *Terminalia* species that are dependent on the wide-gaped frugivores. In addition, because large frugivores like cassowaries are mostly dependent on the fruits of rainforest trees for their survival (Stocker & Irvine, 1983; Mack, 2007), loss of their food plant species may lead to the extirpation of this bird species. The mutual interaction between *Terminalia* and the Northern Cassowary may therefore play important roles for forest regeneration and biodiversity conservation in Papua.

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