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NOTES ON ECOLOGY OF WILD GOFFIN'S COCKATOO IN THE LATE DRY SEASON WITH EMPHASIS ON FEEDING ECOLOGY

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ABSTRACT

Experimental work on captive Goffin's cockatoos (*Cacatua goffiniana*) has highlighted the remarkable cognitive abilities of this species. However, little is known about its behavior in the natural habitat on the Tanimbar Archipelago in Indonesia. In order to fully understand the evolutionary roots leading to cognitively advanced skills, such as multi-step problem solving or flexible tool use and manufacture, it is crucial to study the ecological challenges faced by the respective species in the wild. The three-month expedition presented here aimed at gaining first insights into the cockatoos' feeding ecology and breeding behavior. We could confirm previous predictions that Goffin's cockatoos are opportunistic foragers and consume a variety of resources (seeds, fruit, inflorescence, roots). Their breeding season may be estimated to start between June and early July and they face potential predation from ground and aerial predators. Additionally, the observational data provide indications that Goffin's cockatoos are extractive foragers, which together with relying on multiple food sources might be considered a prerequisite of tool use.

Keywords: breeding, *Cacatua goffiniana*, extractive foraging, feeding ecology, predation

INTRODUCTION

Recent experimental work on captive Goffin's cockatoos (*Cacatua goffiniana*; Roselaar and Michels, 2004; [alternative common names: Tanimbar Cockatoo, Tanimbar Corella, Goffin's Corella; Mulawka, 2014]) has highlighted their advanced problem-solving abilities (Auersperg et al., 2013a; Auersperg et al., 2013b; Auersperg et al., 2014a; Auersperg et al., 2014b; all captive birds were obtained from CITES certified European breeders), a strong inclination for sophisticated and intrinsically structured object play (Auersperg et al., 2014a), as well as the capacity for various types of flexible tool use, manufacture and modification (Auersperg et al., 2012; Auersperg et al., 2014a). Despite these findings and the growing interest in this species in the scientific community and public, relatively little is known about its ecology and behavior in the wild. Current ecological knowledge about the majority of parrot species is scarce as observing wild individuals presents challenges associated with their ability to fly over long distances and spend a large portion of their life in forest canopies (Lambert et al., 2018). Filling these gaps will allow comparative testing of various hypotheses about the evolution of cognitive abilities (Seed et al., 2009; MacLean et al., 2012).

Two main theoretical approaches were proposed to explain the evolution of advanced cognitive skills, namely the extractive foraging hypothesis and social intelligence hypothesis.

The extractive foraging hypothesis (Parker & Gibson, 1977) describes the evolution of complex cognition in great apes as an adaptation for exploiting seasonally limited, high-energy, embedded food sources through intelligent tool use. In this initial form it is considered as an ecological model (see Huber & O'Hara, 2016 for a review). Extractive foraging without the use of tools but through manual techniques also seems to favor enlarged brain size in certain primate species (Gibson, 1986). An alternative approach is proposed by the social intelligence hypothesis which states that sophisticated, flexible cognitive abilities evolved as response to the challenges of living in complex social environment (Jolly, 1966; Humphrey, 1976). As most parrot species are social, this hypothesis was suggested to be key driver of their cognitive abilities (Emery et al., 2007) although so far little research has focused on parrot social cognition (Lambert et al., 2018). Regarding brain evolution, avian brains are structured differently from primate brains, most notably lacking the layered neocortex. However, large areas of the avian forebrain were proposed to be homologous to mammalian cortex (Pfenning et al., 2014) and seem to have a similar role in advanced cognitive functions (Güntürkün, 2005; Kirsch et al., 2008; Veit & Nieder, 2013). Additionally, large-brained corvids and parrots have forebrain neuron numbers comparable to or higher than primates with much larger brains (Olkowicz et al., 2015). Recent re-evaluation of both the extractive and social hypotheses provide suggestion that social group size does not explain the enlarged brain or advanced cognition in primates, whereas extractive foraging hypothesis is supported by data regarding tool use, social learning, and brain evolution (Parker, 2015). Contrary to considering these hypotheses as mutually exclusive, social and ecological intelligence hypotheses do not necessarily have to be regarded as alternatives (Reader & Laland, 2002). Theoretical models suggest that both the ecological and social measures should be included when investigating animal cognition and the ecological conditions which influenced the evolution of brains and advanced cognitive skills across taxa (Overington et al., 2008). Sociality is not independent of ecology (Dunbar & Shultz, 2007) and therefore investigations focused on foraging ecology represent one of the first crucial steps into gaining more insights about a species' wildlife ecology.

Endemic to a small archipelago of the Tanimbar Islands in the Southeast Moluccas region of Indonesia (approx. 5400 km^2), Goffin's cockatoos inhabit tropical dry and moist deciduous forest (Jepson et al., 2001). Despite significant trapping before international trade was banned within Appendix I of the 1994 Convention on International Trade in Endangered Species (CITES; Jepson et al., 2001), they maintained a substantial population of about 231,500 (Jepson et al., 2001), 255,000 (Cahyadin et al., 1994a) or 347,088 (Cahyadin et al., 1994b) individuals. As all birds belonging to the Corellas (*Licmetis*) subgenus (Forshaw & Cooper, 1989), the Goffin's cockatoo is likely to be a feeding generalist in its natural habitat. Captive Goffin's cockatoos happily accept a wide range of different foods ranging from seeds, cereals, nuts, fresh and dried fruits, berries as well as raw and cooked vegetables to a number of protein sources such as eggs, cuttlefish bone, milk products, soy yoghurt, mealworms and even meat (A. Auersperg, personal observation; Mulawka, 2014).

In terms of social structure, most species of parrots show complex social organization (Seibert, 2006) with the majority of cockatoo species studied in the wild exhibiting high sociability and little variation in their social structures (Mulawka, 2014). First insights into the social structure of wild Goffin's cockatoos are provided by field observations where individuals were observed either solitary, in pairs or in groups (Cahyadin et al., 1994a; O'Hara et al., 2018). A seemingly similar social structure was reported for a close relative (White et al., 2011), the Western Long-Billed Corella (*Cacatua pastinator*). There are three levels of social organization in this species that coincide with different movement patterns (Smith & Moore, 1992): (1) breeding adult pairs (long-lasting with moderate divorce rate of 15%; Smith, 1991), (2) family groups including juveniles guided by their parents, and (3) nomadic immature flocks. Both pairs and families seem to reside sedentary in fixed territories in the forest habitat, whereas nomadic immature flocks are subject to fission-fusion dynamics and range over areas of about 80 km^2. Environmentalists observed groups of one to six Goffin's cockatoos (mean group size: 1.5 birds) during population counts in the forest, whereas on agricultural lands flocks of two to 305 individuals (mean group size: 23) were encountered (Cahyadin et al., 1994a). These data led to the suggestion that the large flocks consist mainly of immature birds favoring the agricultural areas with abundant food (Cahyadin et al., 1994a; Jepson et al., 2001).

In order to advance the current state of knowledge concerning the origins of the sophisticated physical cognition skills observed in captive Goffin's cockatoos, this study had three key aims: (1) starting the investigation of the Goffin's cockatoos feeding repertoire using observational data in order to approximate niche breadth and diet diversity in their natural habitat, (2) to provide insights into the behavioral ecology of this species, and (3) to contribute current estimates of the conservation status of Goffin's cockatoos.

MATERIALS AND METHODS

Study sites

The Tanimbar Islands are a small island group (5440 km^2) in the Maluku Province of Indonesia (approx. 425 km east of Timor and 350 km north of Darwin, Australia) with human population of 105.341 in 2010 (Badan Pusat Statistik, 2010). The islands were formed from uplifted reef-limestone during the Pleistocene (Monk et al., 1997). We conducted our research on the island of Yamdena (7°36'S 131°25'E), the largest of the Tanimbar Islands (approx. 3260 km^2) which is largely covered with semi-evergreen (characterized by multi-storey canopy and a ground layer of logged and young trees) and monsoon forests (discontinuous canopy of tall trees at >30 m with continuous canopy of smaller trees up to 10 m; Cahyadin et al., 1994a). The coastline of the island includes agricultural areas with fruit tree plantations and dry land agriculture (beans and maize). The habitats found on Yamdena are representative of the other islands within the Tanimbar archipelago. We focused on investigating the habitats where Goffin's cockatoos were most frequently encountered during the population survey conducted by Jepson et al. (2001): forest and agriculture fields. Suitable study sites were established after discussing the project with village leaders and scanning nearby locations for cockatoo presence and logistic feasibility (see Fig. 1). The villages were chosen following locations visited by Jepson et al. (2001), in order to compare the current conservation status with the data collected in 1993.

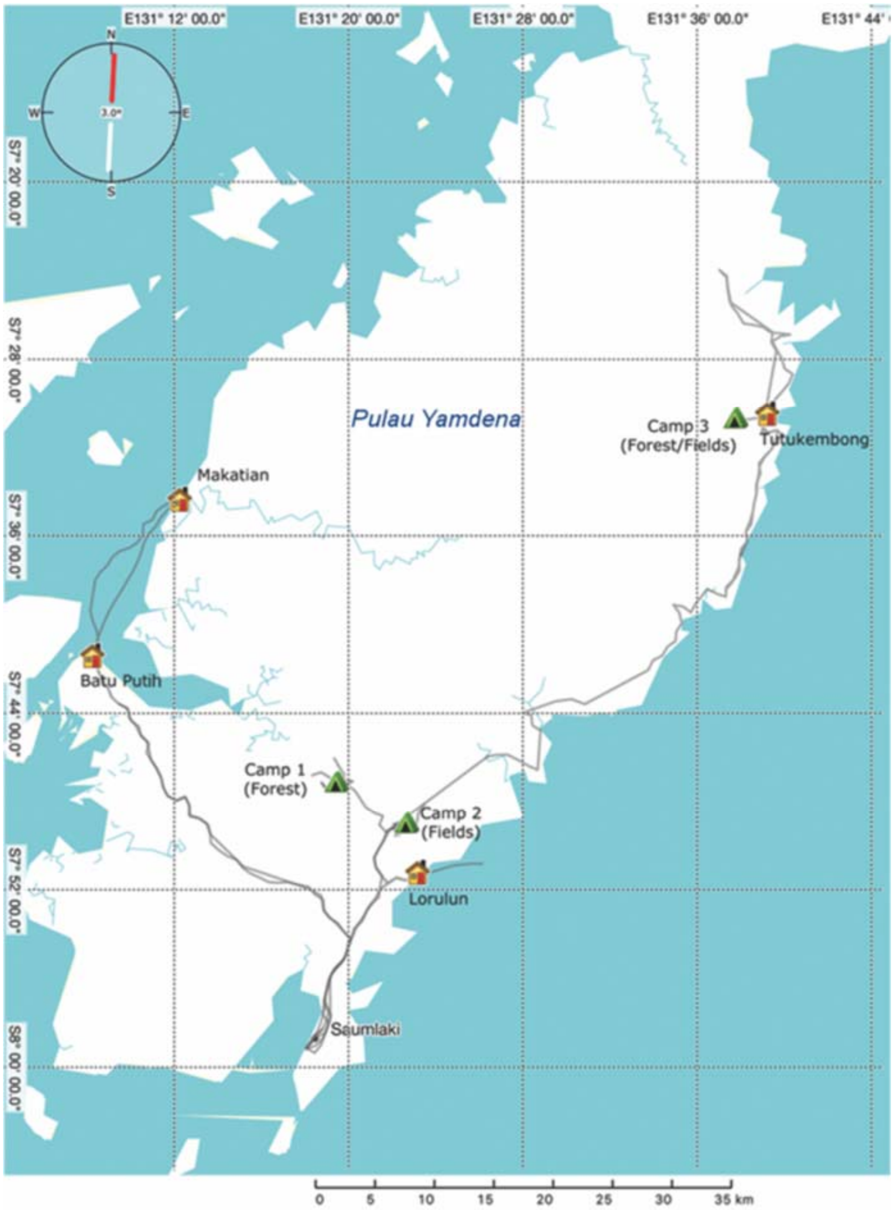

Figure 1. Overview of study sites. The house symbols mark villages surveyed for potential study sites, whereas the tent symbols mark established study sites. The coordinate grid is employing Datum Austria NS for referencing. Map and waypoints were created using Garmin Basecamp software and routable OSM.

The first two authors (BM and MO'H) spent a total of 72 days (end of September to end of November, dry season) on Yamdena, accompanied by TH for 53 days. The first field site (Camp 1, S7° 47' 07.0" E131° 19' 28.2") was located within the forest in the south of the island, the second site (Camp 2, S7° 48' 59.3" E131° 22' 41.2") – at the fields of Lorulun village, and the third study site (Camp 3, S7° 30' 41.2" E131° 37' 47.0") – in the north of the island approximately 3 km inland from Tutukembong village, consisting of fields bordering a partially logged forest.

Scanning

In order to investigate the Goffin's cockatoos' diet and behavior, daily treks were used to identify feeding, roosting and breeding locations at the forest sites, whereas at the field sites flocks of individuals were observed from concealed observation positions. Route selection aimed at including the various types of vegetation present on Yamdena: fields, forest, shrubs, and grasslands. Opportunistic observations of wild birds were also taken. Procedure at sighting Goffin's cockatoos was to record the number of observed individuals, an encounter category (either visual, both flying and stationary, or vocal) and to take behavioral data as well as photos and/or videos. If a nest, feeding, or roosting site was discovered, it would be revisited the next day to confirm cockatoos' presence. During the day birds were not active due to high temperatures and therefore the areas were scanned each day during the mornings (from sunrise until midday) and afternoons (from 4 pm until sunset).

In Camp 1, Lorulun forest (18 days: 26.09 – 13.10.15), the total time spent scanning the area amounted to 144 h (8 h per day). We established four routes, each of approximately 2 km long and mostly following pre-existing paths which allowed efficient exploration of the forest. The Lorulun forest was representative of the forest habitat occupied by Goffin's cockatoos. In Camp 2, Lorulun agricultural fields (16 days: 21.10 – 05.11.15), the Goffin's cockatoo presence at fields was established by initially interviewing local farmers. Total time spent scanning the fields amounted to 112 h (7 h per day). Three fields within the vicinity of Camp 2 were identified, where Goffins's cockatoos were regular visitors. In Camp 3, Tutukembong fields and forest (13 days: 07.11 – 19.11.15), the camp site was located at the fields and next to a forest which allowed for observations in the fields and day excursions into the forest alongside logging routes of local farmers. Total time spent scanning the area amounted to 91 h (7 h per day).

Plant sampling

Plants observed to be consumed by Goffin's cockatoos or reported by locals as cockatoos' food were collected for identification. Food sources were considered as suggested if at least two independent local hunters/farmers reported seeing the cockatoos consuming the plant in question and/or items with bite marks were found near feeding or roosting sites.

Confirmation of a food source required a direct observation of cockatoos feeding on that source. Plant samples were cut into pieces and sun dried for storage in paper envelopes labelled with scientific names if possible and placed inside a sealed plastic box filled with silica gel balls. For plants which were not possible to identify, the local name was used for labelling. Herbarium specimens were created using the leaves and fruit covered in commercially available alcohol solution, wrapped in cardboard and plastic bags for future identification at the Division of Botany, Research Center for Biology – LIPI.

RESULTS

Habitats and food sources

Samples of 23 different plant food sources were gathered and 18 samples were successfully identified to species. A further three samples could be identified to family level (see Table 1; see Fig. 2 for a food source example). Among the samples, 60.9% (14 out of 23) species of food plant sources were encountered in the forest, 34.8% (8 out of 23) species were encountered in the fields and 4.3% were both in forest and in fields. Recorded parts of plants being eaten were mostly fruit followed by seed pods and inflorescence, except for cassava where ingested parts also included roots.

In total, we recorded 448 contacts with Goffin's cockatoos, including 256 visual and 192 vocal encounters. There were more encounters in the fields than in the forests (see Table 2 for details). In the forests, vocal encounters were more frequent than visual ones, whereas in the fields visual encounters outnumbered the vocal ones. When spotted visually, the cockatoos were mostly: a) flying above the canopy (forest), b) flying above the fields (fields), or c) perching on top of trees (both forest and fields).

Goffin's cockatoos were observed feeding on the flesh and seeds of the papaya fruit while the fruit was hanging on the tree. In order to access the inside of a ripe papaya an animal has to bite through a thick (approx. 1 cm) and hard outer layer of the fruit (see Fig. 3). Furthermore, O'Hara et al. (2018) provide evidence for Goffin's cockatoos feeding on cassava roots and young coconuts. Cassava plants consist of large roots hidden in soil underneath, approximately at 5 – 10 cm depth. During this project half-eaten, excavated roots were encountered on agricultural fields which locals claimed to be excavated and eaten by the cockatoos (see Fig. 4). Similarly, coconut trees are cultivated on grasslands with Goffin's cockatoos being able to access young coconuts to forage on fruit water and flesh (O'Hara et al., 2018).

Nesting sites

The time period spent in forest Camp 1 (25.09 – 14.10.2015) coincided with the fledging of juveniles in three nests encountered. These nesting sites were located approximately 1 km from each other. Iron Trees (*Intsia bijuga*), New Guinea Rosewood

Figure 2. Goffin's cockatoo feeding on an *Osmoxylon insidiator* (local name: Mangmate Nglolan) in Lorulun forest (Camp 1).

Figure 3. Foraging on papaya fruit (*Carica papaya*) in Lorulun fields (Camp 2). Left: Goffin's cockatoo approaching a ripe papaya fruit. Right: eaten papaya fruit.

Figure 4. Excavated and eaten cassava roots in Lorulun fields (Camp 2).

(*Pterocarpus indicus*) and Blackboard Tree/White Cheesewood (*Alstonia scholaris*) were observed and reported by locals to be the preferred nesting trees of Goffin's cockatoos. All three nests were established in tree trunk cavities at approximately 25 – 30 m height (see Fig. 5). All nest trees were co-inhabited and also used for nesting by Tanimbar Starlings (*Aplonis crassa*) and Blue-streaked Lories (*Eos reticulata*), as well as serving as roosting locations for various pigeon species (Columbidae). At one site, starlings were repeatedly observed flying in and out of the cockatoos' nest cavity. However, this breeding tolerance does not extend to all species. Several incidents of Goffin's cockatoos engaging in agonistic behaviors, such as visual and acoustic displays followed by attempted displacements, towards Eclectus parrots (*Eclectus roratus*) at nesting sites were observed. In one incident, a pair of Eclectus parrots managed to take over a nest tree from two Goffin's cockatoos, whereas on another occasion three cockatoos succeeded in displacing a single male Eclectus (see Fig. 6). The Eclectus parrots have been observed nesting in late November.

Predation

Predation on the Goffin's cockatoos seems to be limited and during this project only one incident of a single Brahminy Kite (*Haliastur indus*) chasing two cockatoos was observed. During this incident, the chased individuals produced distinct alarm calls (loud high-pitched screeches). Potential further predators reported by locals may include the Varied Goshawk (*Tachyspiza hiogastra*), Bonelli's Eagle (*Aquila fasciata*), Yellow-throated Martens (*Martes flavigula*), feral cats (*Felidae sp.*), as well as the Western Pacific Monitor Lizard (*Varanus indicus*) and the Tanimbar Python (*Simalia nauta*), which are assumed to feed on cockatoos' eggs and/or nestlings.

Threats

Two threats to the population of Goffin's cockatoos were identified: habitat loss and trapping. Habitat loss occurs through continuous logging and wildfires created by uncontrolled burning of fields for farming. Logging companies target Iron, Manilkara (*Manilkara fasciculata)*, and Pacific Almond (*Canarium indicum*) trees as timber because these species yield the most profitable payoff. Unfortunately, these trees also play a major role in the ecology of Goffin's cockatoos as their nesting and feeding sites. Additionally, local farmers continue to trap wild cockatoos on their fields, either for private use (as pets or rarely even food), pet trade or as a measure to protect their crops.

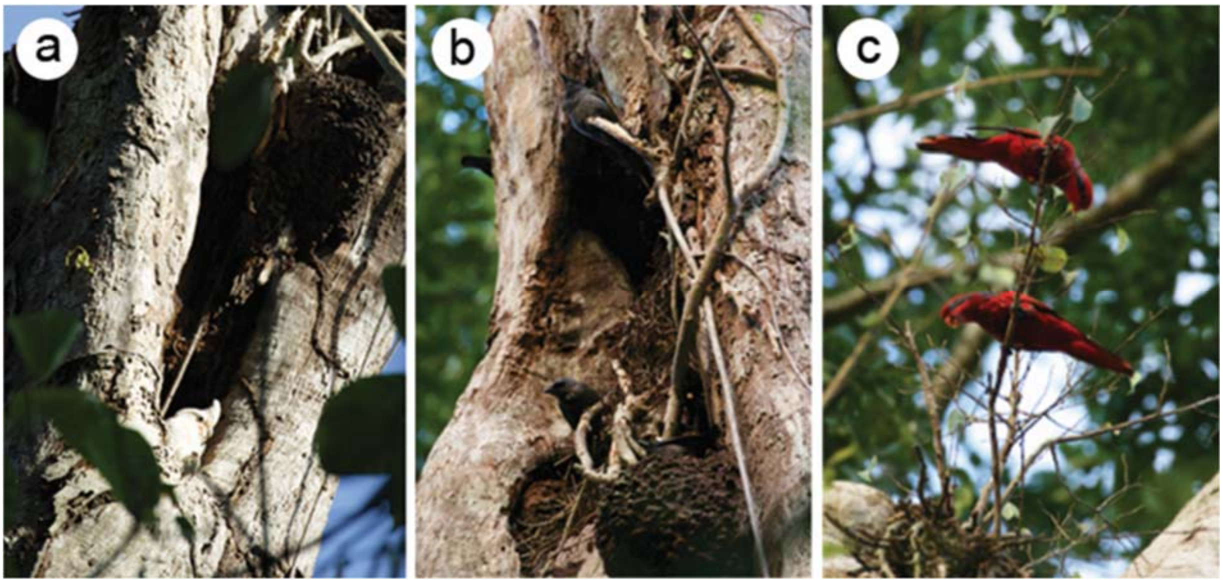

Figure 5. Interspecific nesting communalism in Lorulun forest (Camp 1). Within the same tree (iron tree, *Intsia bijuga*) nests of (a) Goffin's cockatoos (*Cacatua goffiniana*), (b) Tanimbar starlings (*Aplonis crassa*) and (c) blue-streaked lories (*Eos reticulatus*) can be found.

Figure 6. A group of three Goffin's cockatoos displacing and chasing a single male Eclectus parrot at the edge of the forest in Lorulun fields (Camp 2).

Table 1. List of encountered food items. "Feeding Status" indicates if plants were directly observed to be foraged on ("confirmed") or whether only indirect indication ("suggested") of consumption (reported by locals, items with bite marks found near feeding/roosting sites) was possible

Feeding status	Scientific name	Common name	Location found	Seasonality	Parts ingested
confirmed	*Acacia sp.*	local: Kamamase	forest	seasonal (dry season)	seed pods
	Canarium indicum	Pacific Almond	forest	all year	fruit flesh
	Carica papaya	Papaya	fields	all year	fruit flesh, seeds, inflorescence
	Cerbera manghas	Sea Mango	forest	seasonal (dry season)	fruit flesh
	Cocos nucifera	Young Coconut	fields	all year	fruit water and flesh
	Manihot esculenta	Cassava	fields	all year	roots and inflo-rescence
	Manilkara fasciculata	Manilkara	forest	unknown	fruit flesh
	Musa sp.	Banana	fields	all year	fruit
	Osmoxylon insidiator	local: Mangmate Nglolan	forest	all year	seeds within ripe fruit buds
	Passiflora foetida	Wild Maracuja	fields/forest	seasonal (dry season)	fruit flesh and seeds
	Phaseolus vulgaris	Common Bean	fields	Aug. – Sep.	seed pods
	Shorea polysperma	Tanguile	forest	unknown	fruit flesh
	Syzygium jambos	Rose Apple	forest	seasonal (dry season)	fruit flesh
	Vigna radiata	Mung Bean	fields	Sep. – Oct.	seed pods
	Vigna unguiculata ssp.	Long Bean	fields	Aug. – Sep.	seed pods
suggested	*Anacardium occidentale*	Cashew Nut	fields	seasonal (dry season)	reported; fruit flesh
	Calamus sp.	Rattan Palms	forest	all year	reported; fruit flesh and seeds
	Elaeocarpus ganitrus	Rudraksha	forest	unknown	reported; unclear
	Ficus variegata	Red-stem Fig	forest	all year	bite marks and re-ported; fruit flesh and seeds
	Garcinia dulcis	Mundu	forest	seasonal (dry season)	bite marks and re-ported; fruit flesh
	Maranthes corymbosa	Parinari	forest	unknown	bite marks and re-ported; unclear
	Pometia pinnata	Island Lychee	forest	seasonal (dry season)	bite marks and re-ported; unclear
	Tabernaemontana pandacaqui	Windmill Bush	forest	unknown	bite marks and re-ported; fruit flesh

Table 2. Number of visual and vocal encounters of Goffin's cockatoos in different locations and habitats

Encounter category	Location	Habitat	
		Fields	Forest
Visual	Lorulun	130	21
	Tutukembong	104	1
Vocal	Lorulun	86	59
	Tutukembong	47	0

DISCUSSION

Feeding ecology

The abundance of specific food sources appears to be subject to seasonal variation at the fields and possibly also in the forest (see Table 1). These results justify the assumption that the Goffin's cockatoo is an opportunistic feeding generalist dependent on many different (and at least partially seasonal) resources, with diverse feeding patterns including extractive foraging. However, our sample is only representative for the end of the dry season during which the data was collected. Cahyadin et al. (1994b) and several local farmers reported that Goffin's cockatoos feed also on agricultural maize (*Zea mays*) during the wet season. In contrast to popular local belief that Goffin's cockatoos feed mostly on corn, the majority of food sources were located in the forest.

Generalists inhabiting variable environments were suggested to exploit more resources, use a variety of habitats, be more flexible in their behavior, more explorative and less neophobic than dietary/habitat specialists (see Mettke-Hofmann, 2014 for a review). Innovations occur more often in generalists and correlate with low neophobia and high exploration (Reader, 2003). More specifically, habitat generalism correlates positively with food type innovations, whereas diet generalism has been suggested to correlate positively with food type innovations, technical innovations, and brain size, leading to the assumption that diet diversity may be a driver behind the evolution of advanced cognitive skills (Ducatez et al., 2015). Interestingly, Goffin's cockatoos seem to be both diet and habitat generalists. An example of such generalism is the observation of a cockatoo foraging on a Sea Mango (*Cerbera manghas*) on Tanimbar Islands, which is a member of the highly toxic Cerbera family (Carlier et al., 2014). A similar observation was made in Singapore (a novel environment) where feral Goffin's cockatoos were encountered feeding on a Pong-pong tree (*Cerbera odollam*) from the same family (Neo, 2012), also known as Suicide Tree due to its strong poisonous effects on humans.

Food sources that require extractive foraging, described as the consumption of embedded foods such as underground roots or hard-shelled nuts and fruits (Parker & Gibson, 1979; King, 1986; Huber & O'Hara, 2016), were particularly relevant for investigating the potential factors driving evolution of advanced cognition in Goffin's cockatoos. Such food items included: papaya seeds, flesh and water of young coconuts, and cassava roots. During this project only foraging on an already opened papaya fruit was encountered in the wild. However, wild-caught Goffin's cockatoos were observed to open the fruit by removing stripes of the thick outer layer, dropping the majority of the papaya flesh, and foraging on the seeds (O'Hara et al., 2018). Alternatively, as some pieces of the flesh were also superficially digested, most likely in order to absorb the fruit juice, papaya feeding might be argued to not represent a case of “pure” extractive foraging. However, as the embedded seeds were the main target, we consider papaya feeding as an example of extractive foraging. Similarly, Goffin’s cockatoos are able to gradually bite through the thick layer of young coconuts by removing stripes of the mesocarp, a process which might require several days to complete, in order to access the endosperm and fruit water (O’Hara et al., 2018). The cassava roots, located several centimeters underground, can be accessed by Goffin’s cockatoos through continuous biting at the bottom of the plant and then gradually removing soil with their beaks in order to expose the large starch containing tubers (O’Hara et al., 2018). Considered together with the encounter of excavated roots in the fields, it is suggestive that wild Goffin’s cockatoos are able to extract underground food sources. Other closely related Corellas (White et al., 2011) were also reported to forage on various roots (Little Corella, *Cacatua sanguinea*) and tubers (Western Long-billed Corella, *Cacatua pastinator*; Mulawka, 2014).

Extraction of food and reliance on multiple patchy food sources observed in wild Goffin’s cockatoos might be important ecological prerequisites for the evolution and development of their advanced cognitive skills in the physical domain, as is hypothesized for primates (Milton, 1981; Parker, 2015). Furthermore, these factors may have promoted the capacity to manufacture and use tools, as has been shown in the captive studies on Goffin’s cockatoos (Auersperg et al., 2012, 2014c). Tool use is often assumed to be rare in the wild because of the seemingly complex cognitive abilities required to manufacture and use tools acting as an evolutionary constraint. However, an alternative approach suggests that tools are rarely more useful than evolved anatomical adaptations in ecological contexts faced by wild animals (Hansell & Ruxton, 2008). Indeed, tools do not seem to provide additional advantage for parrots who mostly interact with their environment through the powerful beak employed for a variety of activities including exploring, object manipulation, foraging, climbing, and even acting as an additional limb with the strong, dexterous tongue of some species used as an appendage (Lambert et al., 2018; O’Hara et al., 2018). Due to this functional flexibility, the parrot beak is often described as a "multi-purpose tool" (Huber & Gajdon, 2006; Hansell & Ruxton, 2008; see Auersperg, 2015 for a review). Goffin's cockatoos were observed using their beak for digging in loose soil, shovelling clumps of hardened soil, tearing thick fruit layers, removing tree bark and dismantling rotting tree trunks (O'Hara et al., 2018). Additionally, the zygodactyl feet and long digits allow for a good grip, grasping of objects and even probing in holes (O'Hara et al., 2018).

On a qualitative level, the main difference in foraging behavior between the forest and the field sites seemed to constitute the level of descent of individuals to the ground. As the forest trees offer various kinds of fruits, inflorescence and seeds mostly at higher elevations

(>10 m), individual foraging or foraging in smaller groups (up to 10 individuals) might occur mainly there. However, this conclusion might be biased, as visual contact with ground dwelling individuals in forest areas is limited due to the dense vegetation. In contrast, agriculture fields require individuals to descend low in order to access beans, corn and cassava roots. A descent was only observed when a greater number of individuals was present (>15), possibly as an anti-predation mechanism according to the dilution effect proposed by Williams (1966) and Hamilton (1971). A similar feeding behavior was observed in feral Goffin's cockatoos in Singapore (Neo, 2012) where birds commonly foraged in groups of 15 individuals. While the Goffin's cockatoos were foraging on the fields, a small number of individuals (1-3) remained perched higher and potentially acting as sentinels, as has been also suggested for the Ducorps Cockatoo (*Cacatua ducorpsii*; Mulawka, 2014).

Breeding season

Considering data from captive breeders (incubation: approx. 28 days; time to fledging 70 – 84 days; Mulawka, 2014) together with the observations of fledging juveniles in the forest, we estimate the onset of the breeding season in wild Goffin's cockatoos between June and early July. This estimate differs from the breeding season suggested previously in the literature which was indicated to occur between December and February (Jepson et al., 2001). However, it should be noted that this previous assumption was based only on secondary sources, reports from local villagers, and not direct observations of breeding behavior. Alternatively, this incongruence might suggest that Goffin's cockatoos have multiple breeding seasons. However, captive cockatoo pairs have been reported to normally lay only one clutch per year (Mulawka, 2014).

The presence of nesting Eclectus parrots in late November potentially suggests that direct competition over nesting sites may have been resolved by temporal separation of the breeding seasons between these parrot species. Notably, the observed competition does not seem to extend to food resources as Goffin's cockatoos and Eclectus parrots have been encountered foraging peacefully in close vicinity on the same fruit trees.

Conservation efforts

Contrary to the projection of a gradual decrease in maize production (Jepson et al., 2001), corn has been sold since the late 1990s at local markets for human consumption and as chicken feed since around 2014 – 2015 (personal communication from local farmers). Thus, the maize crop continues to be grown on Tanimbar Islands and farmers reported that the maize season (February – April) attracts larger numbers of Goffin's cockatoos compared to the green bean season (August – September). Attitudes of locals towards Goffin's cockatoos vary between accepting if a flock raids crops (responsibility is then placed upon the farmer who failed to protect his field by scaring the birds away) to reporting anger upon discovering a raided field. Human perceptions of cockatoos seem partially unchanged since 1993 when the species was described by local people as "abundant, ugly, and stupid" (Jepson et al., 2001). However, many people during our study also referred to cockatoos as "smart", especially those who had contact with a pet cockatoo. Additionally, locals reported that since the CITES trade ban, there are more cockatoos kept as pets in private homes on Tanimbar Islands.

Local awareness of the legal status of Goffin's cockatoo and other wildlife seems low with many people not being informed about Goffin's cockatoos status as protected species in Government Regulation no. 7 of 1999 (DitGen. PHKA, 2007) and Ministry of Environment and Forestry Regulation no. 92 of 2018 (Menteri Lingkungan Hidup dan Kehutanan, 2018) and the legal consequences for trapping, killing and possessing of cockatoos under Article 21 and Article 40 (2) of the Law no. 5 of 1990 concerning conservation of living resources and their ecosystems (DitGen. PHKA, 2007). Educational programs regarding animal conservation and welfare would be of great importance for developing a sense of pride in the people of Tanimbar about their unique nature, as stated by the future directions of IUCN Red List of Threatened Species (BirdLife International, 2016; for examples of successful educational programs and campaigns see: Indonesian Parrot Project, 2016; ProFauna Indonesia, 2004). Further conservation efforts might include focusing on raising awareness about the current legislation and education regarding biodiversity preservation.

In terms of habitat protection, the Natural Resources Conservation Agency in Maluku (BKSDA Maluku) established several conservation areas across the Tanimbar Archipelago which are also inhabited by Goffin's cockatoos. Located on Yamdena island are a wildlife sanctuary "Suaka Margasatwa (SM) Tanimbar" (63,207 Ha) and a nature reserve "Cagar Alam (CA) Nustaram" (2,420 Ha). Further reserves on nearby islands include: "CA Angwarmase" (295 Ha), "CA Nuswotar" (2,052 Ha), "CA Larat" (4,505 Ha) and "CA Tafermar" (3,039 Ha; Balai Konservasi Sumber Daya Alam BKSDA Maluku, 2012). Their role under Law no. 5 of 1990 concerning conservation of living resources and their ecosystems (Article 15; President of the Republic of Indonesia, 1990) is to preserve plant and animal species diversity and therefore capturing of birds and logging in these areas are prohibited (Directorate General of Forest Protection & Nature Conservation, 2007).

The suggested population decrease due to habitat degradation and trapping (BirdLife International, 2016) seems likely as local farmers reported that currently there are less cockatoos and less forest than during their youth, around 40 years ago. Therefore, the establishment of conservation areas on Tanimbar Archipelago is an important initiative for the protection of Goffin's cockatoos and their natural habitat.

CONCLUSIONS

Consistent with our initial assumptions, we found the Goffin's cockatoos to be opportunist, generalist foragers that include seasonal resources into their foraging repertoire and potentially use sophisticated feeding techniques such as extractive foraging. We also managed to record information on the cockatoos' behavior and breeding habits, as well as their predators and conservation status. Nevertheless, the data gained within this project represents only some facets of the Goffin's cockatoos' ecology. Future studies should focus on investigating the ratio of consumed items in the Goffin's cockatoo diet in order to better assess the ecological significance of the various food sources (see Rutz et al., 2010 for an example). Importantly, establishing a catalogue of food sources consumed by Goffin's cockatoos in their natural habitat is a crucial information for successful rehabilitation and re-introduction of confiscated cockatoos from illegal trade, as well as supplementing current data on dietary needs for captive-bred Goffin's cockatoos. Investigations of the challenges parrots face in the wild are crucial for developing our understanding of the selective pressures that resulted in the evolution of their advanced cognitive abilities (Lambert et al., 2018). We believe that the information gained during this study represents an important step towards a deeper understanding of the ecology of wild Goffin's cockatoos and a starting point for further research.

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