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The impact of timber harvesting on nest site availability for the Cape Parrot *Poicephalus robustus* in native Southern Mistbelt forests of the Eastern Cape, South Africa

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Summary

The Amathole mistbelt forests in the Eastern Cape, South Africa harbour the largest remnant population of the nationally endangered endemic Cape Parrot *Poicephalus robustus,* a secondary-cavity nester whose persistence is limited by suitable nest sites. These are also the only forests within Cape Parrot range in which selective timber harvesting remains permitted, but the impact of harvesting on the availability of parrot nest sites has not been investigated. This study aimed to determine the degree to which current harvest selection criteria stand to impact nest site availability. Results showed that Cape Parrots have specific nest tree requirements; and that there is overlap in the species and condition of trees selected for nesting, and harvesting. The two yellowwood species found in the region, *Afrocarpus falcatus* and *Podocarpus latifolius,* represented the majority of both harvested trees (78%), and Cape Parrot nest trees (79%). Moreover, both Cape Parrot and harvest selection criteria require large (≥50 cm diameter at breast height; ≥12 m high), old, dead, dying, or crown-damaged yellowwoods, such that 32% of trees considered potential nest trees were also candidates for harvesting. Current selection criteria need to be revised to ensure that timber use is compatible with biodiversity conservation in the Amathole forests. We suggest that all harvesting of dead standing yellowwoods be discontinued; and that the harvesting of live trees with crown damage, which are frequently used by parrots for nesting, be limited by a species-specific maximum harvestable diameter.

Introduction

Cavity-nesting birds, especially secondary cavity nesters that do not excavate their own cavities, are dependent on large, old, and standing dead or dying trees for breeding (Newton 1994, Martin *et al.* 2004), which make a disproportionate contribution to tree cavity abundance, and hence nest site availability for cavity-nesting species (Paillet *et al.* 2017). However, these trees are often those harvested from forests under single-tree selection management regimes (Franklin *et al.* 2002, Lindenmayer *et al.* 2012). This is attributed to their economic value given their size, and that their selective removal is considered to ensure resource sustainability as they no longer contribute to stand growth (Seydack 1995). Losses in tree cavity quality and quantity associated with timber harvesting thus largely underpin increasing conservation concern for cavity nesting species globally (Remm and Lõhmus 2011, van der Hoek *et al.* 2017).

Cape Parrots *Poicephalus robustus* weigh 300–400 g and are secondary cavity nesters, known to nest predominantly in large, dead yellowwoods (Figure S1 in the online supplementary material), namely *Afrocarpus falcatus* and *Podocarpus latifolius* (Wirminghaus *et al.* 2001). More specifically, Cape Parrots are facultative excavators that modify natural or excavated cavities. They are the only endemic parrot species in South Africa, recognised globally as 'Vulnerable' given their small population size, currently estimated to be between 1,100–1,800 individuals (BirdLife International 2021). Its breeding habitat is restricted to montane mistbelt evergreen forests in the Eastern Cape and KwaZulu-Natal provinces, with a small, relict population in the northern province of Limpopo (Coetzer *et al.* 2019). While their historic range was much more extensive (Clancey 1964), range and population declines have occurred over the last century (Wirminghaus *et al.* 1999, Cooper *et al.* 2017). Key drivers of this have been habitat loss and degradation and associated losses of suitable nest sites, largely attributed to the extensive harvesting of yellowwoods that occurred between the late 19th century and 1939 (Wirminghaus *et al.* 1999, 2001). The southernmost population in the Amathole region in the Eastern Cape is the largest (Downs *et al.* 2019), and an important source population (Coetzer *et al.* 2019). It is thus essential that forests in this region are managed with consideration for Cape Parrot habitat requirements, particularly during critical life-history stages such as breeding.

The majority (70%) of indigenous forests in the Eastern Cape are state-owned, with the Department of Forestry, Fisheries and Environment (DFFE) responsible for their management (Berliner 2009). Specifically, the National Forest Act (1998) aims to address the dual need for the economic benefits of forests to be realised, while conserving forest biodiversity. While indigenous tree harvesting was outlawed nationally in 1939 (von Maltitz *et al.* 2003), harvesting of wind fallen, dead and dying indigenous trees has continued in the Amathole region (King 1941, Mpisikaya *et al.* 2007). Currently, a subset of forest compartments amounting to ~3,000 ha are managed for selective timber harvesting, with quotas set at 132 stems per annum based on a mortality pre-emption yield regulation system (Seydack *et al.* 1995). This system results in wind-fallen, crownless, crown damaged, dying, and recently dead trees being selected for harvesting, as has been the case for the past 80 years.

A recent study found cavity nesting forest birds to be particularly vulnerable in South Africa, with increased risk more strongly associated with loss of nesting - as opposed to foraging - sites (Cooper *et al.* 2020). Several authors have called for the termination of yellowwood harvesting given the negative impact it stands to have on already limited nest site availability for Cape Parrots (Wirminghaus *et al.* 1999, Downs and Symes 2004, Wilson *et al.* 2017). However, current knowledge of Cape Parrot nest site selection is limited, being based on two studies with small sample sizes conducted in KwaZulu-Natal (Wirminghaus *et al.* 2001, Symes *et al.* 2004). This study provides the first assessment of the impact of contemporary logging on nest tree availability for the Cape Parrot, in two harvested forests in the Amatholes. Specifically, we investigate: i) characteristics of Cape Parrot nest trees; ii) the nature and extent of contemporary logging (1992–2017); iii) current availability of yellowwoods, specifically those that are potential nest trees and candidates for harvesting, respectively; and iv) the impact of harvest selection criteria on nest tree availability by examining the extent of overlap between the two. Lastly, we provide a checklist of tree characteristics common across both nest and harvested trees, with the aim of providing policy-relevant research to mitigate potential harvest-mediated habitat degradation.

Methods

Study area

This study was conducted in the Hogsback region of the Eastern Cape, South Africa (Figure 1). The forests of this region are classified as Amathole mistbelt forests which occur along cool mountain slopes between 500 and 1,600 m above sea level (von Maltitz *et al.* 2003), and comprise the second largest indigenous forest complex nationally, managed under a multi-use approach (Vermeulen *et al.* 2000).

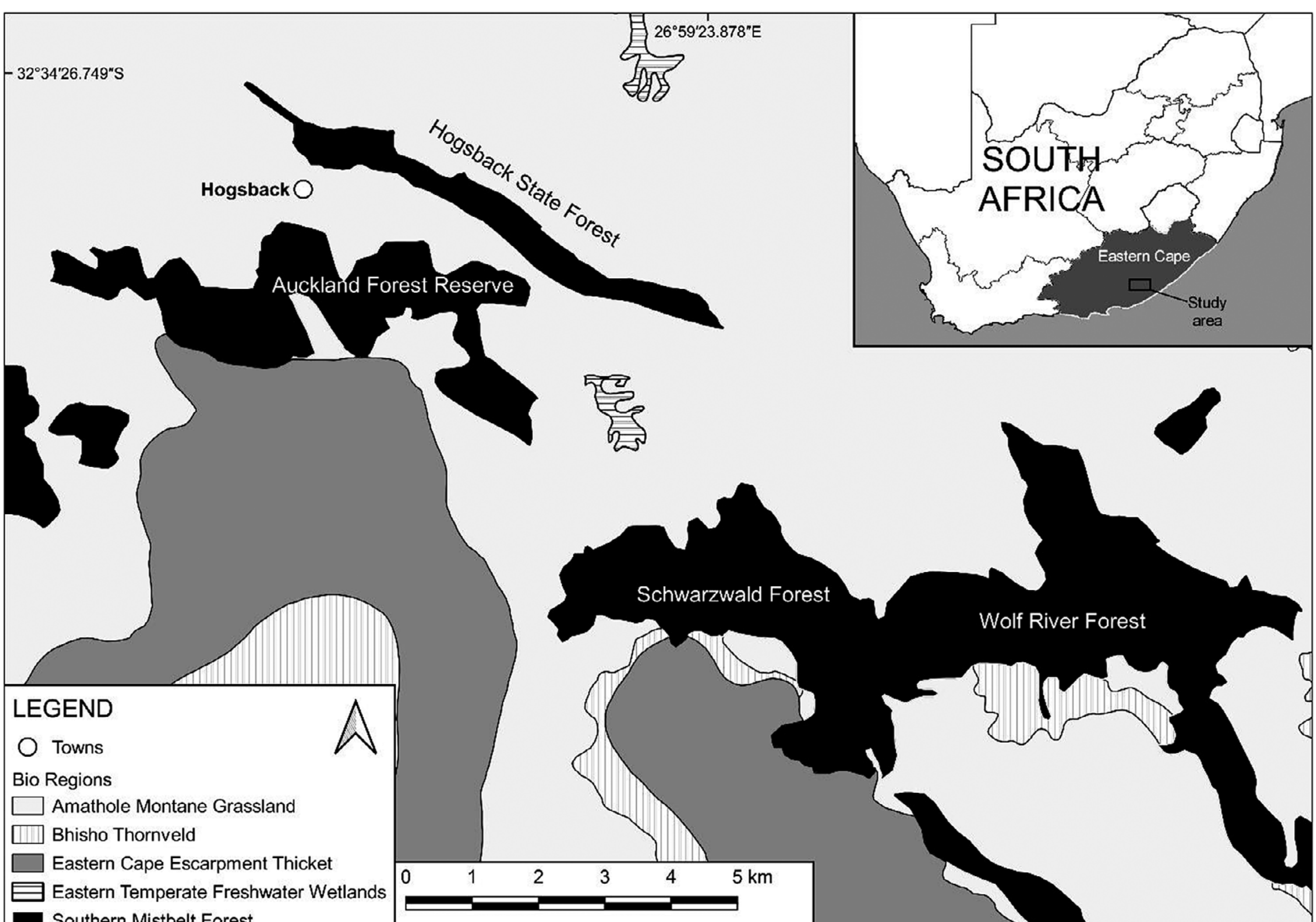

Figure 1. Study forests sampled in the Hogsback region of the Eastern Cape, South Africa.

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Schwarzwald Forest and Wolf River Forest comprised the main study forests, representing those managed for sustainable indigenous timber harvesting. The Amathole forests are multi-layered, comprising tall emergent trees, a tall (20–25 m), relatively open to closed canopy, a dense understorey dominated by *Trichocladus ellipticus*, and a well-developed herb layer. The landscape surrounding these forests is characterised by grassland and thicket, with much of this transformed to commercial exotic *Pinus* plantations, or stands of exotic and invasive tree species, namely *Acacia mearnsii* and *Acacia melanoxylon.* The climate is temperate with an annual average rainfall of approximately 800–1,800 mm, which falls over the summer months (October–February; von Maltitz *et al.* 2003).

Data collection and analyses

Cape Parrot nest trees

Cape Parrot nest tree data were obtained from an on-going database managed by the Cape Parrot Project (a project of the Wild Bird Trust), and included nest trees located during 2018–2020 from four forests in the Amathole region. Nests were located by following calls associated with nesting behaviour. Nest sites were often close to exotic plantations, but no nests occurred within these plantations, as they are mostly felled before trees develop hollows. While exotic trees have occasionally been used for nesting, these have been in sparsely scattered individual trees that had established within indigenous forests and were thus able to reach an older age. Nest trees were categorised as either confirmed nests (those confirmed as occupied by the presence of eggs or nestlings through nest observations made either by climbing up to the nest via rope access, or with a camera on an extendable pole) or possible nests (where Cape Parrot pairs had demonstrated territoriality/nesting behaviours but were not confirmed as occupied). Specifically, possible nests were defined where: i) Cape Parrots were seen making territorial displays and associated calls; ii) a natural or primary cavity had been observed in the tree; and iii) Cape Parrots were seen entering the cavity (Carstens and Carstens 2020). For all nest trees, the following data were recorded: species; diameter at breast height (DBH; cm); height (m); nest height (m), and decay stage (1 – 8: Downs and Symes 2004).

Cape Parrot nest tree characteristics were compared across the two predominant tree species used, i.e. the two yellowwood species (see section 3.1) using t-tests (for DBH and height); a Mann-Whitney Test (for nest height); and Chi-squared tests (for decay stage). Statistics were conducted in R (R Core Team, 2020).

Indigenous tree harvesting

We obtained DFFE records of trees harvested during 1992–2017 (26 years) from Schwarzwald and Wolf River forests. The following data were recorded for each harvested tree: forest; year harvested; tree species; diameter at breast height (DBH in cm); and description of tree condition (tree defect and reason for harvesting). These records were assessed to indicate: i) species selected for harvesting; ii) trends in harvest offtake over time; iii) trends in the mean DBH of harvested stems over time; iv) mean DBH of harvested trees at the species-level; v) diameter size-class distribution of harvested trees; and vi) condition of harvested trees (i.e. reason for harvest selection).

Assessing the impact of harvest selection on nest tree availability

The availability and characteristics of yellowwood stems (both species; DBH ≥30 cm) were assessed by sampling 20 circular plots in Schwarzwald and Wolf River forests, respectively. A minimum size-class of 30 cm DBH was selected both because Cape Parrots are known to nest in large trees (Wirminghaus *et al.* 2001), and to be consistent with previous monitoring efforts in the region (Mpisikaya *et al.* 2008). Five transects parallel to, and extending the length of the elevation gradient in each forest were evenly spaced across the extent of the forest, along which four plots were sampled. A minimum distance of 150 m was maintained between plots, and a minimum distance of 50 m was maintained between plots and the forest edge/forest roads (Obiri *et al.* 2002). Plots comprised concentric circles, with an inner circular plot of 0.04 ha (11.4 m radius) and an outer, larger plot of 0.2 ha (25.2 m radius). In the 0.04 ha plot, all live, intact/healthy (i.e. decay stage 0) Yellowwood trees were recorded by species and DBH (cm). In the 0.2 ha plot, trees with some level of crown loss/decay, i.e. trees in early stages of decay (stages 1–2); and standing dead trees, (stages 3–8) were recorded by: species (where confidently identified), DBH (cm), height (m) and decay stage (1–8, as per Downs and Symes 2004). The presence of natural (decay) and/or excavated cavities was searched for in dead and decaying trees by scanning them with binoculars from the ground. While excavated cavities were recognised by their circular shape, natural cavities were recorded where there was an apparent entrance hole roughly palm-sized or larger, and >10 m above the ground (Wirminghaus *et al.* 2001).

Characteristics of dead or decaying trees were compared across the two yellowwood species using a Mann-Whitney test (for DBH); and Chi-squared tests to assess if there was a difference in: i) the frequency of stems across the different decay stages; and ii) the presence of potential cavities (excavated and natural cumulatively) across the two species. To assess the impact of harvesting on potential nest tree availability, criteria were developed to define recorded yellowwood stems as: i) potential nest trees, henceforth, 'nestable' (based on finding of this study; see section 3.3.2), and ii) candidates for harvesting, henceforth 'harvestable' (based on DFFE guidelines). Further details on the criteria used to define harvestable and nestable trees; and the method used to assess the extent and nature of overlap between the two can be found in Appendix S1.

Results

Cape Parrot nest trees

The dataset of identified Cape Parrot nests consisted of 42 nest trees defined as confirmed ($n = 21$), or possible nests ($n = 21$). Nests were observed in six tree species, three of which were exotic: *Pinus patula* ($n = 5$), *Pinus pinaster* ($n = 2$) and *Eucalyptus grandis* ($n = 2$); and three indigenous: *A. falcatus* ($n = 26$), *P. latifolius* ($n = 6$) and *Olea capensis* ($n = 1$). Consequently, while Cape Parrots used alien trees for nesting, with these all located within indigenous forests, nests were located predominantly in native tree species, particularly the two yelllowwood species (cumulatively comprising 76% of nest trees, $n = 32$), with the majority of nests recorded in *A. falcatus* (62%), followed by *P. latifolius* (14%). Given that this study aims to investigate the impact of selective harvesting of native species on Cape Parrot nest tree availability, subsequent results pertain to the two Yellowwood species only.

Data on nest tree characteristics (DBH, tree height, nest height and decay stage) were available for 25 *A. falcatus,* and five *P. latifolius* nest trees. These data revealed that nest trees varied across the two Yellowwood species, with *A. falcatus* nest trees greater in DBH and height (Table 1). Selection of nest trees based on decay stage also appeared to vary across tree species, although this finding should be considered with caution given the small sample size of *P. latifolius* nest trees. Overall, these results indicate

Table 1. Characteristics of recorded Cape Parrot yellowwood nest trees in the Amathole region (n = 30). Figures presented are the mean ± SD (range). Significant differences are indicated in bold (P < 0.05).

Variable	*Afrocarpus falcatus* (n = 25)	*Podocarpus latifolius* (n = 5)	Test statistic
Number confirmed vs. potential	12 confirmed (48%); 13 potential (52%)	3 confirmed (60%); 2 potential (40%)	
DBH (cm)	144 ± 30 (86 – 216)	80 ± 23 (51 – 112)	t = 5.32; df = 7.43; ***P* < 0.01**
Tree height (m)	26 ± 5 (18 – 35)	14 ± 2 (12 – 17)	t = 8.50; df = 14.34; ***P* < 0.001**
Nest height (m)	18 ± 4 (12 – 25)	12 ± 2 (10 – 13)	W = 112; **p < 0.01**
Decay stage (underlined)	2: 13 (52%); 5: 5 (20%); 6: 7 (28%); Median: 5	6: 6 (100%); Median: 6	W = 27; ***P* = 0.01**

that a broad range of decay stages were used for nesting, particularly in the case of *A. falcatus* (stage 2–6). Importantly, the greatest proportion (52%) of *A. falcatus* nest trees were in early stages of decay, i.e. stage 2 (Figure 2).

Indigenous tree harvesting

Over the 19 years with harvest records, a total of 731 trees were harvested from the two study forests. The greatest number of trees were harvested in Wolf River (n = 472), while Schwarzwald had comparatively lower levels of harvesting (n = 259). Ten harvested species were recorded (Table S1). The two most frequently recorded species were *P. latifolius,* which represented the majority of harvested trees (n = 578; 79%), followed by *A. falcatus* (n = 119; 16%), together comprising 95% (n = 697) of all harvested trees. Given this predominance of the two yellowwood species, subsequent results presented are for these species only.

Figure 2. A Cape Parrot perched at the entrance to a nest cavity in a large, old, living, but canopy-damaged *Afrocarpus falcatus* i.e. decay stage 2. The extent of crown loss shown here deems this tree a candidate for harvesting under current selection criteria.

Harvest levels were variable over the 26-year period, and across the two yellowwood species (Figure 3). Overall, *P. latifolius* offtakes were higher than *A. falcatus.* Moreover, overall harvest rates were nearly five times higher during 1992–2003 (mean of 51 trees harvested per annum) compared to 2007–2017 (mean of 11 trees harvested per annum). No trees have been harvested from these forests since 2017 (M. Kitsi pers. comm. July 2020).

Mean annual DBH of harvested yellowwoods declined over time (Figure 4). Moreover, mean DBH of harvested trees was significantly higher during the more intensive harvesting period between 1992–2003 (158 ± 84 cm DBH) compared to that recorded during 2007–2017 (82 ± 54 cm DBH; W = 35,199, P <0.001). At the species-level, mean DBH of harvested *A. falcatus* (182 ± 75 cm DBH; range: 36–480 cm) was larger than that of harvested *P. latifolius* (134 ± 84 cm DBH; range: 28–490 cm; W = 19,442; P < 0.001).

The 20 tree conditions described on record were grouped based on keywords included in the original descriptions, resulting in a consolidated list of five harvested tree conditions, namely: i) Crownless, ii) Crown damage, iii) Dry standing, iv) Windfall, and v) Other (see Table S2). The most frequently recorded tree condition was "crownless" (49%; Figure 5). While "crown damage" comprised 18% of harvested trees across both species, and was the second most frequently cited reason for *P. latifolius* harvest selection, there was a large discrepancy across species in the proportion described as "dry standing". Specifically, "dry standing" (dead standing trees) was the second most frequently cited reason for harvest selection of *A. falcatus*, comprising 25% of harvested stems, compared to only 10% of harvested *P. latifolius.*

Assessing the impact of harvesting on nest tree availability

Dead and decaying trees (decay stages 1–8) comprised 42% of yellowwood stems recorded with *P. latifolius* (27 dead or decaying trees of 66 stems recorded) more abundant than *A. falcatus* (17 dead or decaying trees of 39 stems recorded). Dead or decaying *A. falcatus* were larger (DBH: 110 ± 56 cm vs. 58 ± 24 cm; W = 1,537.5; P < 0.001) and taller (Height: 18 ± 6 m vs. 12 ± 4 m; W = 1,502.5; P < 0.001) than *P. latifolius,* while the distribution of decay stage (Chi^2 = 10.86; df = 7; P = 0.15) and presence of potential cavities did not differ across species (Chi^2 = 0.50; df = 1; P = 0.48).

A. falcatus had a higher proportion of stems that were both nestable and harvestable compared to *P. latifolius* (Table 2). Importantly, the proportion of both nestable and harvestable stems increased substantially when assessed within the subset of dead or decaying trees relative to the proportion of stems overall, illustrating the disproportionate contribution that old trees make to both Cape Parrot nest site availability, and candidate stems for harvesting.

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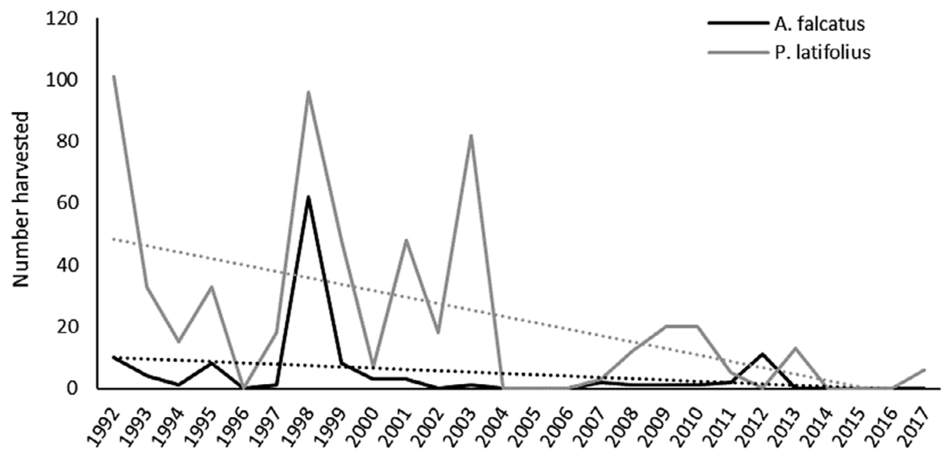

Figure 3. Number of *Afrocarpus falcatus* (= 119) and *Podocarpus latifolius* (*n* = 578) harvested annually during 1992–2017 from Schwarzwald and Wolf River forests in the Amathole region, Eastern Cape. Dashed lines show linear trends of harvest offtakes for both species.

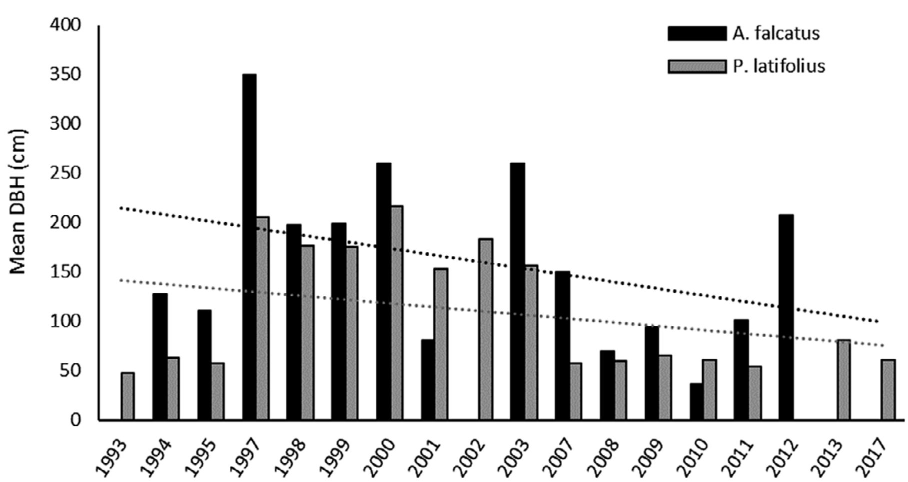

Figure 4. Mean annual diameter at breast height (DBH) of *Afrocarpus falcatus* (*n* = 119) and *Podocarpus latifolius* (*n* = 578) harvested during 1993–2017 from Schwarzwald and Wolf River forests in the Amathole region, Eastern Cape. Dashed lines show linear trends of harvested stem diameter for both species.

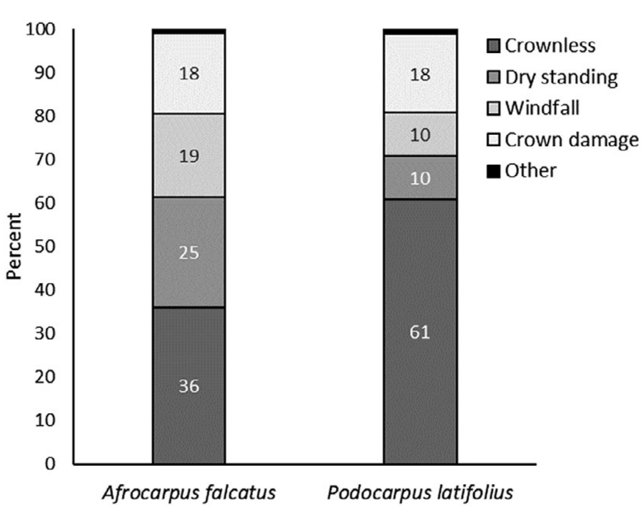

Figure 5. Conditions of *Afrocarpus falcatus* (*n* = 119) and *Podocarpus latifolius* (*n* = 578) stems harvested from Schwarzwald and Wolf River forests in the Amathole region, Eastern Cape.

Table 2. Percentage of sampled *Afrocarpus falcatus* and *Podocarpus latifolius* (DBH ≥30 cm) that were nestable and harvestable overall (i.e. decay stage 0–8) and within the subset of dead or decaying trees (i.e. decay stage 1–8). Number in parentheses is the sample size.

	Afrocarpus falcatus		*Podocarpus latifolius*	
	Overall (*n* = 39)	Dead or decaying (*n* = 17)	Overall (*n* = 66)	Dead or decaying (*n* = 27)
Nestable	38% (15)	88% (15)	24% (16)	59% (16)
Harvestable	18% (7)	29% (5)	9% (6)	22% (6)

A clear overlap was observed in the characteristics of Cape Parrot nest trees, and candidate trees for harvesting (Table 3). Specifically, yellowwoods with DBH ≥50 cm, and between decay stages 2 and 5 were associated with both nesting and harvesting, such that 32% of stems identified as nestable were also harvestable. Selection criteria used to identify trees as candidates for harvesting thus present a potential loss of Cape Parrot nest tree availability by close to a third.

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Table 3. List of characteristics defining candidate trees for harvesting and potential nest trees for Cape Parrots in the Amathole region, Eastern Cape. Text in bold indicates overlapping selection.

Dead or decaying characteristic	Harvestable	Nestable	Overlap
Species: *A. falcatus*	✓	✓	✓
Species: *P. latifolius*	✓	✓	✓
DBH: ≤ 50 cm	✓	×	×
DBH: ≥ 50 cm	✓	✓	✓
Decay stage: 1	×	✓	×
Decay stage: 2	✓	✓	✓
Decay stage: 3	✓	✓	✓
Decay stage: 4	✓	✓	✓
Decay stage: 5	✓	✓	✓
Decay stage: 6	×	✓	×
Decay stage: 7	×	✓	×
Decay stage: 8	×	×	×

The highest frequency of harvested stems was in large size classes, ≥100 DBH, while the occurrence of dead or decaying trees in these size classes was severely limited (42 stems recorded across 8 ha of sampling plots; Figure 6). In the case of *P. latifolius* - the most frequently harvested species - while the size class distribution of both available and harvested dead or decaying trees showed a generally unimodal distribution, peaks in relative frequency across size classes were non-overlapping. Specifically, available dead or decaying trees were most frequently recorded within size classes of 60–80 cm DBH, while harvested dead or decaying trees were most frequently 100–300 cm DBH. Similarly, the relative frequency of available dead or decaying *A. falcatus* across size classes ≥100 cm DBH declined as the relative frequency of harvested dead or decaying trees increased. Importantly, the size class distribution of Cape Parrot nest trees, particularly in the case of *A. falcatus* – the most frequently used species for nesting – reflected that of availability, suggesting that harvest offtakes of large dead or decaying *A. falcatus* represents a loss of potential Cape Parrot nest trees.

Discussion

Our findings show a strong overlap in traits that characterise trees as candidates for timber harvesting and as nest sites for Cape

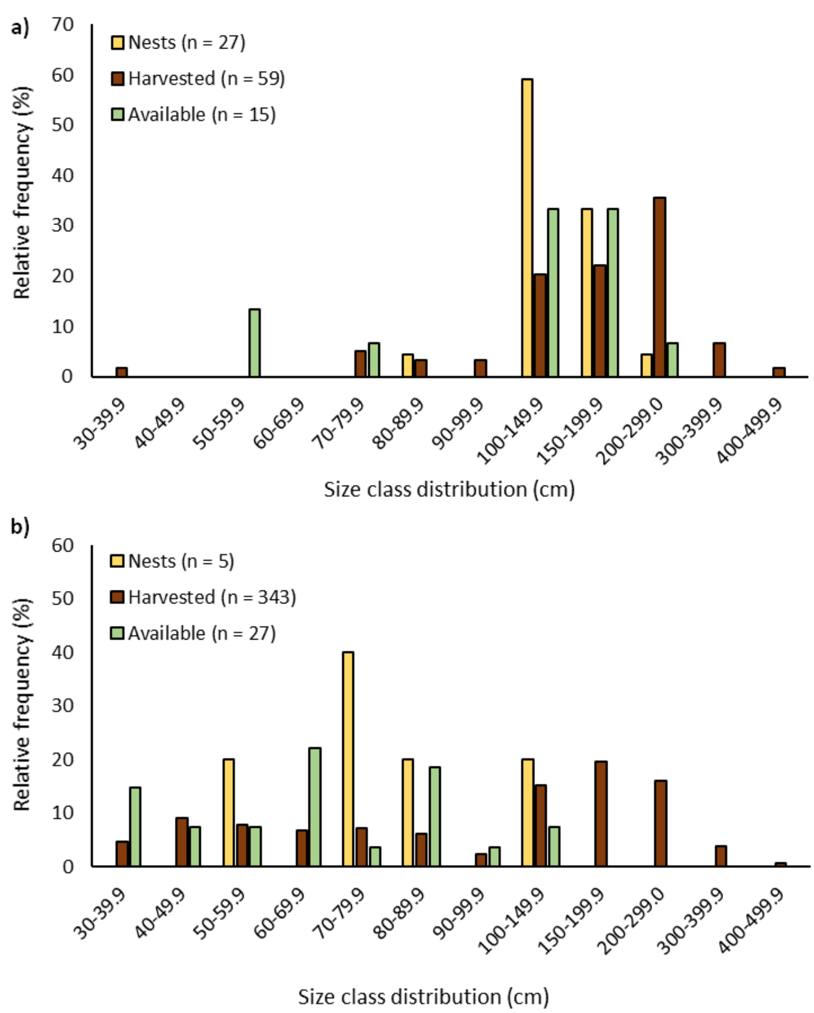

Figure 6. Stem size class distribution for diameter at breast height (based on relative frequency) of identified Cape parrot nest snags (yellow), harvested snags (red) and available snags (green) of **a)** *A. falcatus* and **b)** *P. latifolius* from two harvested forests (Schwarzwald and Wolf River) in the Eastern Cape.

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Parrots in the Amatholes. Specifically, both harvesters and parrots select for large (≥50 cm DBH) yellowwoods which are dead, dying or crown-damaged. Consequently, close to a third (32%) of potential nest trees were candidates for harvesting. This suggests a conflict in species conservation and resource use objectives. Given that tree characteristics such as species, decay stage affect nest site selection and nestling survival for a broad range of cavity-nesting birds (e.g. Mahon and Martin 2006, Schaaf *et al.* 2019), forest management which aims to balance timber harvesting with the persistence of cavity-nesting populations should focus on appropriate tree selection. While market demand for indigenous timber has declined (no trees have been harvested in the region since 2017), sustainable resource use remains a central management goal for these forests. Consequently, we suggest changes to harvest selection criteria to mitigate potential harvest-mediated declines in Cape Parrot nest site availability, should market demand increase in the future.

Tree species of high economic value are often those used by cavity-nesting birds as they tend to contain a higher number of cavities and have greater DBH values (Politi *et al.* 2009, Ruggera *et al.* 2016). In the Amatholes, two yellowwood species (*Afrocarpus falcatus* and *Podocarpus latifolius*) – among the largest trees found in these forests – represented the majority of harvested trees (78%) and Cape Parrot nest trees (79%). However, while *A. falcatus* was the predominant species used for nesting (64%) - as found in KwaZulu-Natal (Wirminghaus *et al.* 2001), harvesting focussed on *P. latifolius* (84%). In the context of higher overall availability of *P. latifolius* and relative scarcity of *A. falcatus*, this suggests selection of *A. falcatus* as nest trees. Additionally, trees need to be sufficiently large to provide suitable cavities: specifically, DBH and cavity height have been found to be strong determinants of tree use by cavity nesters, especially for larger birds such as parrots (Britt *et al.* 2014, Cockle *et al.* 2015). The preferential use of *A. falcatus* may thus be because they were larger on average compared to *P. latifolius*, for which dead or decaying trees ≥90 cm DBH were scarce, despite its relative abundance. What remains unclear is whether the observed higher use of *A. falcatus* is a true preference for this species, or a response to the comparative lack of sufficiently large *P. latifolius*, attributed to historical unsustainable harvesting of this species (Cawe and McKenzie 1989, McCracken 2004).

While further research is needed to investigate determinants of Cape Parrot nest site selection through resource selection analysis (e.g. Basile *et al.* 2020), findings of this study indicate that the sustained availability of sufficiently large *A. falcatus* stems is critical for Cape Parrot persistence, particularly in the context of previously logged forests. The concurrent preference of *A. falcatus* for nesting, and higher likelihood of individuals of this species being in a condition prone to harvest selection is thus of concern, particularly in light of its relative scarcity. Moreover, findings showed that large stems were disproportionately harvested, resulting in their depletion (i.e. "creaming effect"), as suggested by the decrease in mean annual DBH of yellowwoods harvested over the 26 years on record. This suggests a potential misapplication of the harvest selection method, a key advantage of which is that it is not based on a minimum harvest diameter given that mortality pre-emption, and thus harvesting, can and should occur across all merchantable size classes (Seydack 1995).

While crownless trees, which are likely unfavourable for cavity nesting (Spiering and Knight 2005), represented over half (57%) of harvested trees, there was considerable overlap in the decay stages of trees selected for nesting and harvesting. Specifically, Cape Parrots and harvesters showed a preference for earlier stages of decay and limited use of trees in advanced stages of decay. A key finding of this study is that Cape Parrots do not nest exclusively in dead trees, as previously suggested (Wirminghaus *et al.* 2001, Downs and Symes 2004), but make frequent use of live but crown-damaged trees. This has conservation implications for Cape Parrots given that yellowwoods in early- to mid-stages of decay were those preferentially selected for harvesting. Furthermore, criteria regarding crown damage were relaxed from 90%, as in the southern Cape forests where the criteria were developed (Seydack 1995), to 75% in the Amatholes (Mpisekaya *et al.* 2008) to allow for trees in earlier stages of decay to be harvested, given that the occurrence of dead or decaying trees is less common in these forests (Geldenhuys and Maliepaard 1983). We consider the relatively low availability of trees in mid-successional decay stages in the Amatholes (Wilson *et al.* 2017, CPP unpubl. data), to be an artefact of selective harvesting practices, supported by the relatively high abundance of these stems recorded in mistbelt forests in KwaZulu-Natal, where harvesting has not occurred for the past 80 years (Downs and Symes 2004). Harvest-mediated modifications to the population structure of dead and decaying trees represents a disruption to the decay process, which stands to negatively affect the availability of suitable cavities (Cockle *et al.* 2010, Politi *et al.* 2010, Schaaf *et al.* 2019). For example, Paillet *et al.* (2017) found that the decay process following tree death was the main mechanism in tree microhabitat production.

Large, old, and dead standing trees are keystone ecological structures (Lindenmayer 2017) given that their availability, while generally scarce, is a key determinant of tree microhabitat density (Paillet *et al.* 2017). The retention of large trees that are both dead, and alive but in an unhealthy state in forests managed for timber harvesting is thus critical for cavity-nester population persistence (Cockle *et al.* 2010, Politi *et al.* 2010). Retaining large, old, and standing dead yellowwoods in the Amathole forests is of particular importance given that the current composition, structure and dynamics of these forests have been affected by extensive logging during the 19th and early 20th centuries (Lawes *et al.* 2007, Adie *et al.* 2013). Specifically, historic over-exploitation of yellowwoods, which drove the removal of most trees above the minimum harvestable diameters applicable at the time, has resulted in a severely reduced availability of larger-sized trees approaching senility (Cawe and McKenzie, 1989, Seydack and Vermeulen 2004). Consequently, Seydack *et al.* (1995) note that "the application of the senility criteria yield regulation system presents itself particularly for primary forests or those only lightly harvested in the past". The use of this yield regulation system in the Amatholes, while allowing for mature stems to accumulate, may thus add pressure to an already depleted stock of rare and slow-to-recruit large, old and dead yellowwoods, thereby precluding the accumulation of nest trees to pre-harvest levels.

The loss of large, old live trees and standing dead trees through selective logging practices, and associated ecological impacts, is a global concern (Lindenmayer *et al.* 2012), with the cavity-nesting guild shown to be particularly at risk (Politi *et al.* 2009, Cockle *et al.* 2010). Several authors have thus urged for new policies to better protect and promote the retention and recruitment of existing large, old trees, and standing dead trees in logged forests (Cockle *et al.* 2010, Lindenmayer and Laurence 2016, Lindenmayer 2017). Harvest selection criteria based on tree mortality pre-emption are thus at odds with contemporary forest management recommendations aimed at balancing ecosystem integrity and resource use (e.g. Lindenmayer *et al.* 2014, Gustafsson *et al.* 2020). Illustrating this, of 17 *A. falcatus* stems showing signs of decay or that were

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already dead, 88% were potential Cape Parrot nest trees, while this group similarly had the greatest proportion of harvestable stems (29%). Consequently, we recommend first, that all dead standing *A. falcatus* and *P. latifolius* stems (decay stages 3–5) are retained in forests managed for timber harvesting. Given that trees in this condition comprised only 12% of harvested trees, exclusion of these trees for harvesting would not represent a substantial loss in yield. Second, for live but crown damaged/decaying trees (decay stage 2), we recommend a maximum harvest diameter be set beyond which trees are not harvested (Lindenmayer *et al.* 2014). For example, a maximum harvestable diameter may be considered as 100 cm DBH for *A. falcatus* and 90 cm DBH for *P. latifolius,* based on estimates of availability presented in this study. In this way, large, live trees with crown damage would be retained until mortality and into subsequent decay stages, facilitating the accumulation of large dead or decaying trees, i.e. potential nest trees, in the forest. To ensure that such a maximum harvest diameter does not result in a potential depletion of medium-sized trees, and subsequent future scarcity of large dead or decaying trees, it is further recommended that live, but crown-damaged trees be harvested across available merchantable size classes in proportion to their relative availability. This would require that resource inventories be compiled to provide detailed knowledge of the yellowwood resource base in all forests managed for timber harvesting, upon which appropriate forest-level harvest quotas could be set. To the authors' knowledge, no such inventories have been conducted, with the current harvest quota of 132 stems per annum broadly applied across the region, and size classes, despite significant variation in yellowwood abundance at the forest-level, and across size-classes (CPP unpubl. data). Findings of this study have been shared with relevant regional forest managers and a series of subsequent workshops planned, with the aim of governmental and non-governmental groups working collaboratively to see recommendations implemented.

While this study reports only on legal harvesting, yellowwoods are prone to high levels of informal harvesting, being one of the most commonly used species by forest-edge communities in the Amatholes (Gugushe *et al.* 2008, Opperman *et al.* 2018). Although used for poles and firewood (selective harvesting of small size classes), the sustainability, and potential impact of informal harvesting on future nest site availability for Cape Parrots should be investigated. Lastly, given that little is known about the success of Cape Parrot nests in alien species, such as *Pinus* and *Eucalyptus*, further research, including whether the proportional use of exotics for nesting increases in response to changes in yellowwood availability, is needed.

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References

Adie, H., Rushworth, I., and Lawes, M. J. (2013) Pervasive, long-lasting impact of historical logging on composition, diversity and above ground carbon stocks in Afrotemperate forest. *For. Ecol. Manage.* **310**: 887–895.

Basile, M., Asbeck, T., Pacioni, C. Mikusinki, G. and Storch, I. (2020) Woodpecker cavity establishment in managed forests: relative rather than absolute tree size matters. *Wildlife Biol.*: wlb.00564.

Berliner, D. D. (2009) *Systematic conservation planning for South Africa's forest biome: an assessment of the conservation status of South Africa's forests and recommendations for their conservation*. Doctoral thesis, University of Cape Town.

BirdLife International (2021) *Poicephalus robustus*. The IUCN Red List of Threatened Species 2021: e.T119194858A119196714. http://doi.org/10.2305/IUCN.UK.2021-3.RLTS.T119194858A119196714.en

Britt, C. R., García Anleu, R. and Desmond, M. J. (2014) Nest survival of a long-lived psittacid: Scarlet Macaws (*Ara macao cyanoptera*) in the Maya Biosphere Reserve of Guatemala and Chiquibul Forest of Belize. *Condor* **116**: 265–276.

Carstens, C. and Carstens, K. (2020) *Cape Parrot Data Collection Protocol 1: Nests and Cavities*. Johannesburg: Wild Bird Trust.

Cawe, S. G. and McKenzie, B. (1989) The afromontane forests of Transkei. IV: Aspects of their exploitation potential. *South Afr. J. Bot* 55: 45–**55**.

Clancey, P. A. (1964) *The birds of Natal and Zululand*. London: Oliver and Boyd.

Cockle, K. L., Bodrati, A., Lammertink, M. and Martin, K. (2015) Cavity characteristics, but not habitat, influence nest survival of cavity-nesting birds along a gradient of human impact in the subtropical Atlantic Forest. *Biol. Conserv.* **184**: 193–200.

Cockle, K. L., Martin, K. and Drever, M. C. (2010) Supply of tree-holes limits nest density of cavity-nesting birds in primary and logged subtropical Atlantic forest. *Biol. Conserv.* **143**: 2851–2857.

Coetzer, W. G., Downs, C. T., Perrin, M. R. and Willows-Munro, S. (2019) Influence of historical and contemporary habitat changes on the population genetics of the endemic South African parrot *Poicephalus robustus*. *Bird Conserv. Internatn.* **30**: 236–259.

Cooper, T. J. G., Norris, K. J. and Cherry, M. I. (2020) A trait-based risk assessment of South African forest birds indicates vulnerability of hole-nesting species. *Biol. Conserv.* **252**: 108827.

Cooper, T. J. G., Wannenburgh, A. M. and Cherry, M. I. (2017) Atlas data indicate forest dependent bird species declines in South Africa. *Bird Conserv. Internatn* **27**: 337–354.

Downs, C. T., Ally, E. and Singh, P. (2019) 22nd Annual Parrot Count – Report on the 2019 Cape Parrot Big Birding Day. Unpublished report.

Downs, C. T. and Symes, C. T. (2004) Snag dynamics and forest structure in Afromontane forests in KwaZulu-Natal, South Africa: implications for the conservation of cavity-nesting avifauna. *South Afr. J. Bot* **70**: 265–276.

Franklin, J. F., Spies, T. A., Pelt, R. V., Carey, A. B., Thornburgh, D. A., Rae Berg, D., Lindenmayer, D. B., Harmon, M. E., Keeton, W. S., Shaw, D. C., Bible, K. and Chen, J. (2002) Disturbances and structural development of natural forest ecosystems with silvicultural implications, using Douglas-fir forests as an example. *For. Ecol. Manage.* **155**: 399–423.

Geldenhuys, C. J. and Maliepaard, W. (1983) The causes and sizes of canopy gaps in the Southern Cape forests, *South. Afr. For. J.* **124**: 50–55.

Gugushe, N. M., Grundy, I. M., Theron, F. and Chirwa, P.W. (2008) Perceptions of forest resource use and management in two village communities in the Eastern Cape province, South Africa. *South For.* **70**: 247–254.

Gustafsson, L., Bauhus, J., Asbeck, T., Augustynczik, A. L. D., Basile, M., Frey, J., Gutzat, F., Hanewinkel, M., Helbach, J., Jonker, M., Knuff, A., Messier, C., Penner, J., Pyttel, P., Reif, A., Storch, F., Winiger, N., Winkel, G., Yousefpour, R. and Storch, I. (2020) Retention as an integrated biodiversity conservation approach for continuous-cover forestry in Europe. *Ambio* **49**: 85–97.

King, N. L. (1941) The exploitation of indigenous forests in South Africa. *South Afr. J. Bot.* **48**: 455–480

Lawes, M. J., Griffiths, M. E. and Boudreau, S. (2007) Colonial logging and recent subsistence harvesting affect the composition and physiognomy of a podocarp dominated Afrotemperate forest. *For. Ecol. Manage.* **247**: 48–60.

Lindenmayer, D. B. (2017) Conserving large old trees as small natural features. *Biol. Conserv.* **211**: 51–59.

Lindenmayer, D. B. and Laurance, W. F. (2016) The unique challenges of conserving large old trees. *Trends Ecol. Evol.* **31**: 416–418.

Lindenmayer, D. B., Laurance, W. F. and Franklin, J. F. (2012) Global decline in large old trees. *J. Sci.* **338**: 1305–1306.

Lindenmayer, D. B., Laurance, W. F., Franklin, J. F., Likens, G. E., Banks, S. C., Blanchard, W., Gibbons, P., Ikin, K., Blair, D., McBurney, L., Manning, A. D. and Stein, J. A. R. (2014) New policies for old trees: Averting a global crisis in a keystone ecological structure *Conserv. Lett.* **7**: 61–69.

Mahon, C. L. and Martin, K. (2006) Nest survival of chickadees in managed forests: habitat, predator, and year effects. *J. Wildl. Manage.* **70**: 1257–1265.

Martin, K., Aitken, K. E. H. and Wiebe, K.L. (2004) Nest sites and nest webs for cavity nesting communities in the interior British Columbia Canada: nest characteristics and niche partitioning. *Condor* **106**: 5–19.

McCracken, T. (2004) The history of indigenous timber harvesting in South Africa. In M. J. Lawes, H. A. C. Eeley, C. Shackleton B. Geach, eds. *Indigenous forests and woodlands in South Africa. Policy, people and practice*. Pietermaritzburg: University of KwaZulu-Natal Press.

Mpisekaya, S. R., Kameni, C. and Viljoen, I. (2008) Amathole forest Yellowwood harvesting levels. Department of Water and Forestry, Unpublished report.

Newton, I. (1994) The role of nest sites in limiting the numbers of hole-nesting birds: A review. *Biol. Conserv.* **70**: 265–276.

Obiri, J., Lawes, M. and Mukolwe, M. (2002) The dynamics and sustainable use of high-value tree species of the coastal Pondoland forests of the Eastern Cape Province, South Africa. *For. Ecol. Manage* **166**: 131–148.

Opperman, E. J., Cherry, M. I. and Makunga, N. P. (2018) Community harvesting of trees used as dens and for food by the tree hyrax (*Dendrohyrax arboreus*) in the Pirie forest, South Africa. *Koedoe* **60**: a1481.

Paillet, Y., Archaux, F., Boulanger, V., Debaive, N., Fuhr, M., Gilg, O., Gosselin, F. and Guilbert, E. (2017) Snags and large trees drive higher tree microhabitat densities in strict forest reserves. *For. Ecol. Manage.* **389**: 176–186.

Politi, N., Hunter, M. and Rivera, L (2010) Availability of cavities for avian cavity nesters in selectively logged subtropical montane forests of the Andes. *For. Ecol. Manage.* **260**: 893–906.

Politi, N., Hunter, M. and Rivera, L. (2009) Nest selection by cavity-nesting birds in subtropical montane forests of the Andes: Implications for sustainable forest management. *Biotropica* **41**: 354–360.

R Core Team (2020) *R: A language and environment for statistical computing*. Vienna, Austria: R Foundation for Statistical Computing. https://www.R-project.org

Remm, J. and Lõhmus, A. (2011) Tree cavities in forests – The broad distribution pattern of a keystone structure for biodiversity. *For. Ecol. Manage.* **262**: 579–585.

Ruggera, R. A., Schaaf, A. A., Vivanco, C. G., Politi, N. and Rivera, L. O. (2016) Exploring nest webs in more detail to improve forest management. *For. Ecol. Manage.* **372**: 93–100.

Schaaf, A. A., Tallei, E., Politi, N. and Rivera, L. (2019) Cavity-tree use and frequency of response to playback by the Tropical Screech-Owl in northwestern Argentina. *Forestry* **14**: 99–107.

Seydack, A. H. W. (1995) An unconventional approach to timber yield regulation for multi-aged, multispecies forests. *I. Fundamental considerations*. For. Ecol. Manage. **77**: 139–153.

Seydack, A. H. W. and Vermeulen, W. J. (2004) Timber harvesting from southern Cape forests. The quest for sustainable levels of resource use. In M. J. Lawes, H. A. C. Eeley, C. Shackleton and B. Geach, eds. *Indigenous forests and woodlands in South Africa. Policy, people and practice*. Pietermaritzburg: University of KwaZulu-Natal Press.

Seydack, A. H. W., Vermeulen, W. J., Heyns, H. E., Durrheim, G. P., Vermeulen, C., Willems, D., Ferguson, M. A., Huisamen, J. and Roth, J. (1995) An unconventional approach to timber yield regulation for multi-aged, multispecies forests. II. Application to a South African forest. *For. Ecol. Manage.* **77**: 155–168.

Spiering, D. J. and Knight, R. L. (2005) Snag density and use by cavity-nesting birds in managed stands of the Black Hills National Forest. *For. Ecol. Manage.* **214**: 40–52.

Symes, C., Brown, M., Warburton L., Perrin, M. and Downs, C. T. (2004) Observations of Cape Parrot, *Poicephalus robustus*, nesting in the wild. *Ostrich* **75**: 106–109.

van der Hoek, Y., Gaona, G.V. and Martin, K. (2017) The diversity, distribution and conservation status of the tree-cavity-nesting birds of the world. *Divers. Distrib.* **23**: 1120–1131.

Vermeulen W. J., Maseti, Z. A. and Kameni, C. (2000) Regulation of Yellowwood (*Podocarpus latifolius* and *P. falcatus*) harvesting in the Eastern Cape forests. In *Towards sustainable management based on scientific understanding of natural forests and woodlands. Proceedings: Natural forests and Savana woodlands symposium II*. Knysna, South Africa

von Maltitz, G., Mucina, L., Geldenhuys, C., Lawes, M., Eeley, H., Adie, H. (2003) *Classification system for South African indigenous forests: An objective classification for the Department of Water Affairs and Forestry*. Pretoria: CSIR.

Wilson, A-L, Bowker, M., Shuttleworth, A. and Downs, C. T. (2017) Characteristics of snags and forest structure in southern mistbelt forests of the Amatole region, South Africa. *Afr. J. Ecol.* **55**: 518–529.

Wirminghaus, J. O., Downs, C. T., Perrin, M. R. and Symes, C. T. (2001) Breeding biology of the Cape Parrot, *Poicephalus robustus*. *Ostrich* **72**: 159–164.

Wirminghaus, J. O., Downs, C. T., Symes, C.T., Perrin, M. R. (1999) Conservation of the Cape Parrot in southern Africa. *South Afr. J. Wildl. Res.* **29**: 118–129.