Mortality of Adult *Livistona australis* on Cabbage Tree Island, Australia

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An isolated population of *Livistona australis* (R. Br.) Mart. has been impacted by almost a century of browsing by European rabbits, *Oryctolagus cuniculus,* on Cabbage Tree Island, Australia. Ongoing adult mortality was documented in this study (n=19) between 1992 and 2001 in addition to a lack of seedling recruitment. Structural failure of the palm trunk or subsidence of the substrate was the prime cause of death in this palm population (63%) with natural senescence of mature palms making up the remainder of the sample. This represents an annual decline of 0.4% per annum and if continued without further recruitment would result in the adult population halving in 125 years. Rabbits were eradicated from the island a decade ago, and the recovery of the vegetation, including palm seedlings, gives hope that the hiatus in recruitment will not negatively impact on the structure of this unique island rain forest.

Cabbage Tree Island (herein abbreviated to CTI), also known as John Gould Island Nature Reserve, is about 1000 m long and 450 m wide reaching an altitude of 123 m (Fig. 1 inset) and is located at 32°41'S, 152°13'E. The island is situated 1 km offshore from the mid north coast of New South Wales, Australia (Fig. 1) and is aligned more or less north-south with a precipitous eastern seaward shore and a more gradual slope of approximately 30° on its sheltered western side. It is predominantly covered in rain forest dominated by *Livistona australis* in the two main gullies that cut into its western side (Fullagar 1976) (Fig. 2).

The CTI rainforest is a form of Dry rain forest Suballiance 23 (*Ficus-Streblus-Dendrocnide-Cassine*) (Floyd 1990). Despite the rock scree, the gullies support mature rain forest that increases in height on deeper soil on the lower reaches of the island's western side. There is evidence of past fire, with some of the taller palms bearing fire scars, but no fires have been recorded within the last century. There are approximately 500 adult *L. australis* palms on CTI, mostly confined within the 3 ha of the two main gullies, and a sample of these were studied between 1998 and 2001 (Carlile 2002). For that research and the present study, adults

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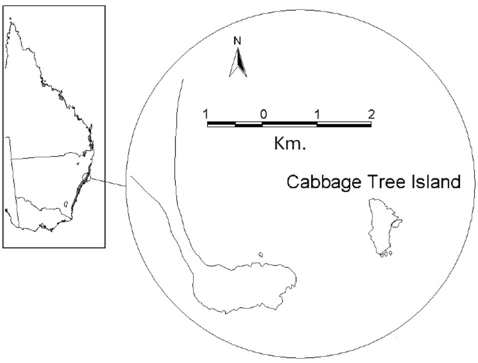


1. Study site for adult *Livistona australis* mortality, Cabbage Tree Island, mid-north coast of New South Wales, Australia. The distribution of the species along the east coast of Australia is indicated by shading.

are defined as individuals that have reached or exceeded the point of first reproduction (based on inflorescence scars) at approximately 5.2 m trunk height.

Cause of death of adult palms on CTI was recorded only for individuals previously known to be alive. This encompassed palms with dead crowns still attached or those that underwent structural failure resulting in their still-green canopies found on the forest floor. The observations covered a four-year period during the palm studies and six years previously spent undertaking other full-time research at this site (Carlile et al. 2003). No formal survey of adult palm survivorship was carried out, but the island was visited at least six months out of every twelve during the ten years. Palm canopies were easily observed as the population grows on steep slopes allowing horizontal views out over the forest. The structural failure of palm trunks was evident while carrying out ground-level activities in the gullies.

The mortality of adult palms on CTI needs to be viewed in context of the lack of seedling recruitment at this site. CTI had been infested by rabbits between 1906 and 1997 (Priddel et al. 2000). Rabbits were intentionally introduced in 1906 during the attempted development of a rabbit "pox" on a nearby island for their control on the mainland. The CTI population was eradicated in 1997 (Priddel et al. 2000). While rabbits existed on the island they altered the vegetation structure (Werren & Clough 1991, Carlile 2002) and suppressed seedling establishment of *L. australis* (Priddel et al. 2000, Carlile 2002). A seedling survival study on CTI between 1993 and 1996 showed survival was low in the presence of rabbits (Carlile 2002, Priddel & Carlile unpub. data). Twelve months after germination less than 24% of uncaged seedlings survived (n = 50) compared to 68% of caged seedlings. After 30 months only 6% of uncaged seedlings survived compared to 53% of caged seedlings. Further seedling experiments on CTI following the eradication of rabbits supported the previous caged results with both uncaged and caged seedlings achieving 72% and 68% survival after 30 months (Carlile 2002).

Observations

Observations revealed that there were different causes that resulted in the premature death of 12 adult palms (Tab. 1). Six incidents were recorded where the subsidence of substrate caused dislodgement of the root mass and for the palm to topple over and die.

Occasionally part of the trunk was partially or completely encased by an arboreal termite nest of *Nasutitermes walkeri* 2–7 m above ground. The nests of this species commonly encase large branches and tree forks (Hadlington 1987). The attachment of a termite nest, a dark and carton-like structure (Watson & Gay 1991), does not lead to the infestation of the inner tissue of the trunk. The pithy core of palms means they are not susceptible to internal attack. On two occasions it appeared that the weight of the termite nest had contributed to the palm toppling over. While the weight of these nests have not been reported elsewhere, on CTI they can be up to 1 m high and encase the trunk of a palm with the bulk of their structure on the down-hill side (mean circumference of adult palms at 1.5 m was 0.71 m, s.e. 0.02 m, $n = 28$). As termite nests are constructed principally of wood derivatives (Emerson 1938), their weight would impact on the stability of some palms. When these nests are abandoned and eventually dislodge the trunk is usually left with an indentation or scalloping of the trunk at the point of attachment. Some palms survived despite termite damage accounting for the loss of more than 75% of the trunk at the original point of nest attachment (Fig. 3). Individual palms surviving termite impact were located among the expansive canopies of Deciduous Figs, *Ficus superba,* where they were protected from winds and the resultant extensive lateral movement. On four occasions palms were observed to snap at this weak point.

Seven crownless adult palm trunks were encountered (Tab. 1). These individuals died

2. The northern of two gullies on Cabbage Tree Island's western shore dominated by *Livistona australis*.

despite the trunk remaining upright. The apex of the remaining trunk extended to a narrow point just below the crown. While some crowns were at canopy height, others were subcanopy individuals. It is probable that these are cases of natural senescence rather than premature death and did not necessitate the individual palm to be older and therefore taller than the surrounding palms.

3. The trunk of an adult *Livistona australis* showing wear (ca. 1 m above the persons head) associated with the attachment point of a termite nest.

Discussion and Conclusions

The process of senescence and death in natural populations of palms has rarely been thoroughly recorded. Most detailed observations have been restricted to cultivated palms (Dalrymple & Fisher 1994). From studies in these environments the mechanism that leads to thinning, impoverished crowns in the tallest of palms and eventual malfunctioning in vascular bundles that transfer nutrients throughout the plant, has been documented (i.e., Tomlinson 1990). This is natural senescence, and the dead palm is characterized by the remaining trunk tapering to a narrow

Table 1: Senescence and death by accident of adult *Livistona australis*, on Cabbage Tree Island, Australia from 1992 to 2001.

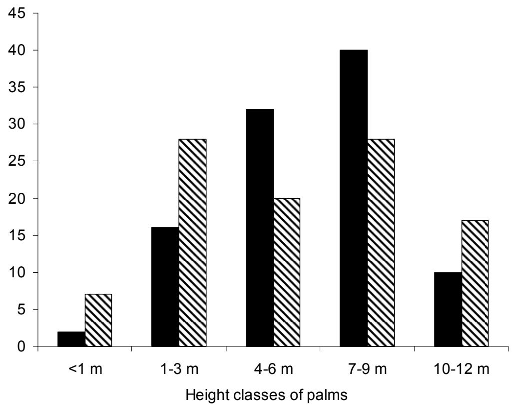
No. of Palms	Cause of death
6	Toppled from subsidence
2	Toppled from weight of termite nest
4	Snapped at narrow wear point from old termite nest
7	Death of crown

apex, where once the crown grew. From the study on CTI it is known that some *L. australis* in natural populations do survive long enough to reach this critical point.

This study reported several other causes of adult mortality. The sloping rock-scree on CTI (Fullagar 1976) contributed to several deaths where subsidence of the substrate had occurred. With many of these palms growing in what appears to be pure rock scree, the erosion that leads to subsidence is likely to be water induced. *Livistona mariae* was also found to be prone to death from toppling following scouring of the surrounding soil (Latz 1975) during periods of flooding. The effects of termites on the trunks of *L. australis* led to some adult palm mortality. No sign of arboreal termite nests had been recorded from other palm sites surveyed on the mainland as part of an extensive study into *L. australis* demography (Carlile 2002). It is likely that this feature is unique to CTI, possibly due to reduced host availability brought about by the confinement of *Nasutitermes walkeri* to the island. On CTI the termite also utilized several other tree species. On the Australian mainland *Eucalyptus* species are a common host for these biogenic structures (Hadlington 1987). The persistence of the termite nests on palms on CTI and their negative impact on adult longevity may be causing a higher adult mortality here than in other populations on the Australian mainland. From studies of other palms it appears that structural failure rather than natural senescence (Tomlinson 1979) determines the life span of palms (i.e., Piñero et al. 1984, Enright 1992).

Research into the causes of death in palms is scant. However, for cultivated palms, Dalrymple and Fisher (1994) provided insights into the morphology of certain species after catastrophic death. For naturally occurring palms, Zimmerman and Covich (2007) studied the dynamics of age structure of palm populations after hurricane impact. The survival of storm-damaged palms and their continued growth, quite apart from the mortality, has been used as a feature for aging these destructive events on forest communities (Sarukhán et al. 1985).

The impact of the loss of adult palms on the population structure and future recruitment for the CTI population is of concern. If the 19 palm deaths over 10 years in a population of approximately 500 (0.4% per annum) were maintained then the adult population would



4. A comparison of height classes (after Orscheg & Parsons 1996) of Cabbage Tree Palms (n = 50) with exposed trunks on Cabbage Tree Island (black) and the nearby mainland site (18 km NNE), the rainforest remnant of Mungo Brush 32°34′S, 152°16′E (hatched). Mean trunk height at first flowering is 5.2 m for CTI and 5.6 m for Mungo Brush.

be halved in 125 years if no recruitment from subadults occurred. Rabbits had been present on the island since 1906 and were eradicated in 1997, after 90 years (Priddel et al. 2000). In recent years rabbits had caused a marked suppression in the regeneration of *L. australis* (Carlile 2002, Priddel & Carlile unpub. data). The population structure of the CTI palms is markedly different to another studied site on the adjacent mainland, where rabbits are not a threat (Carlile 2002) (Fig. 4). Carlile (2002) determined that a larger proportion of the mainland population was subadult (46% compared to 34% on CTI), indicating a better potential here for recruitment into the reproductive population. On CTI however, the compounded effect of suppressed palm recruitment combined with adult senescence over the last 90 years may see a further decline in the number of adult palms on the island for the foreseeable future. While no premature death of subadult palms were recorded on CTI during this study, any loss within this group could further impact the population here.

The rate of growth and adult life-expectancy for palms on CTI has been approximated by Carlile (2002). The rate of growth of palms on CTI (n = 50) was estimated by measuring the change in distance between a fixed point high on the trunk and the point of bifurcation of the oldest leaf from the stem directly above this point. From this it was determined that palms on CTI grow approximately one meter every 25 years (Carlile 2002). The greatest height and therefore oldest palm in the sample was estimated to be 392 years (14.9 m). From seedlings planted in 1993 and monitored until 2001 it was determined that the maximum pre-emergent stem diameter of *L. australis* in the CTI population could take 60 years to develop. From flower scars on the trunks it was determined that reproductive height was reached at 5.2 m (s.e. 0.19, $n = 28$) or at 185 years of age. Of the palms regularly sampled on CTI, 66% ($n = 33$) of them were reproductive and many will reach senescence before the recently establish cohorts of seedlings become reproductive. This loss will cause a decline in reproductive palms on the island. Recruitment should be unbroken however, as the immature trunked-palms will, by this time, be producing seed. What is not known is how the resultant change in the rainforest canopy structure and height will affect its stability. While good recovery in palm seedlings has been noted since 1997 (Carlile 2002, Carlile & Priddel unpub. data) any large gaps appearing in the canopy will assist establishment of a range of aggressive weed species (including the locally problematic Bitou Bush *Chrysanthemoides monilifera*). The palm population will require further monitoring to track their continued persistence in this unique rainforest locality.

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