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SUDDEN DECLINE IN CABBAGE TREES (*Cordyline australis*)

by

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ABSTRACT

Cabbage trees provide New Zealanders with a sense of place, because the trees can survive adverse conditions and rejuvenate themselves indefinitely. Sudden Decline is killing thousands of trees, and public concern has led Government to fund an investigation into the symptoms, cause, and distribution of the disease. Aspects of the biogeography and ecology of cabbage trees are described. The symptoms of Sudden Decline and hypotheses on its cause are reviewed. Although the cause is still unknown, a range of conservation actions are already obvious, particularly the protection of key cabbage tree sites so the populations can regenerate themselves.

1 INTRODUCTION

The cabbage tree is revered in New Zealand. Thousands are planted in urban and rural gardens and parks. They line the streets in some cities, and stand at the doorways of some of our most important buildings. They are rued only by those with who express frustration at the very qualities that previously made the leaf fibres valued for the snares that caught the forest pigeon, kereru. They have been grown in enormous orchards, the young cooked in pit ovens called umu ti for a staple in the cool-temperate Polynesian diet (Fankhauser 1986). They have remained in the rural landscape where other native plants have succumbed, reflecting their ability to regenerate from beneath the ground. This ability is proverbial to Maori people, who might say upon the death of a loved one: Ehara i te ti, e wana ake -"This death is not like the cabbage tree which springs forth new shoots". This is why ti rakau (the tree ti) is a pro-life symbol for both Maori and Pakeha New Zealanders. It is a marker of place: for burial of the body after death, for burial of the placenta after birth, for identifying the boundary of a food gathering area, and for places of settlement, because the shoots of cabbage trees (the "cabbages") form a perennial supply of food.

People identify with the humble simplicity of ti rakau and are intrigued by its curious fibrous wood which questions its identity as a "real" tree. But most of all, people have high regard for cabbage trees because they are unique to New Zealand and can survive decades of grazing in the sea of grass that characterises the modern agricultural landscape (Fig. 1). Cabbage trees provide New Zealanders with a sense of place.

Fig. 1 Old but healthy cabbage trees in grazed pasture.

It is the regard that people have for these trees that heightened concern when the cabbage trees started to die several years ago. Reports in the media and speculation on the cause of death resulted in the provision of emergency funding. An interdepartmental strategy was devised: to map the occurrence of healthy and dying trees, study the normal growth pattern and ecology of cabbage trees, set up a monitoring system and, in particular, investigate the symptoms and the cause of the fatal die-back. Although one observer called it "Black Death", the die-back became officially known as "Sudden Decline". Never before has so much attention been focused on this national icon and regardless of whether the research is conclusive or not, significant conservation measures will result. The strategy began in earnest in October 1990, and only interim results are available at the present time (June 1991).

2 WHAT IS A CABBAGE TREE?

The cabbage tree is an arborescent species of *Cordyline* endemic to New Zealand. *Cordyline* includes about 20 species widely distributed from Africa to South America, and concentrated in eastern Australia (8 species) and New Zealand (5 species, Table 1) (Pedley 1984). The taxonomic affinity of *Cordyline* is uncertain, judging from the variety of published opinions. At present it is considered part of Asteliaceae (Dahlgren

et al. 1985), or Asphodelaceae (Heenan 1991), but previously was allied with *Agave* and *Yucca* in Agavaceae, or *Dracaena* in Dracaenaceae and previous to this, Liliaceae. It is popularly known as a tree lily. It is the habit and morphology of the cabbage tree which stamps affinity with other arborescent monocotyledons. Its North American equivalent is the Joshua tree, *Yucca brevifolia,* which forms huge woodlands around the margins of the Mojave Desert. In the Canary Islands the Dragons blood tree (*Dracaena draco*) can attain similar dimensions, while in Australia, the grass tree (*Xanthorrhoea*) adds a "pachycaulous"(thick-trunked) element to the eucalyptus forest. The anatomical feature which links these plants is the ability to form secondary "wood" in the trunk and branches through the activity of a type of "cambium", although this is quite different in origin and structure from the vascular cambium of conifers and dicotyledons. Nevertheless, the secondary wood facilitates sufficient mechanical support to enable aerial branching which is rare in the monocotyledons as a whole. The secondary wood, being very fleshy as well as fibrous, is also capable of storing water and, hence, these arborescent monocotyledons can withstand dry climates and are prominent in desert areas. The cabbage tree is unusual because, although it is conspicuous in some of the dry hill country and stony alluvial soils of New Zealand, it is primarily a wetland plant.

Table 1 *Cordyline* species in New Zealand

Botanic name	Maori name	Habitat	Distribution
C. australis	ti rakau ti kouka	Arborescent to 20 m	Lowland wetlands, throughout
C. kaspar	(unknown)	Arborescent to 6 m	Three Kings Islands
C. indivisa	ti toi	Caulescent to 8 m	Montane forest, throughout
C. banksii	ti ngahere	Caulescent to 4 m	Lowland forest, throughout
C. pumilio	ti rauriki	Acaulescent to 2 m	Shrubland, northern New Zealand

3 ECOLOGY OF CABBAGE TREES

The widespread occurrence and landscape prominence of ti rakau in New Zealand raises the question of its natural ecological affinity. It is a component of lowland swamp, lake and river margins, coastal vegetation, lowland forest margins, secondary forests of all kinds, and open agricultural grasslands, both moist-temperate and dry-temperate. Considering the affinity for dry environments and habitats of arborescent monocotyledons with secondary growth, one might be tempted to consider ti rakau as a dryland species in New Zealand. However, this is probably a reflection of "pre-adaptation" and also a consequence of widespread forest destruction in New Zealand, by people, over the last 500 years or so.

Cabbage trees have limited ability to grow in tall forest and inevitably succumb once the canopy closes above a maximum height of 15-20 m. They can survive only on forest margins. They occur in open grazing land because, although highly palatable, mature cabbage trees are able to withstand grazing: the distribution of xylem and phloem in vascular bundles throughout the trunk means that bark removal does not kill the tree (Fig. 1). However, the cabbage trees in farmland are old plants established before grazing began. There is rarely any regeneration of seedlings, and no chance for sprouts from beneath the ground to survive. Cabbage trees in grassland survive because of anatomical peculiarities, not because of any natural affinity for this habitat.

The clue to the choice of habitat of cabbage trees is found in the roots. The central conducting cylinder of the root is surrounded by a spongy aerenchyma, tissue capable of storing air and assisting growth in soils low in oxygen, namely wetland soils. Cabbage trees colonise the margins of wetlands and persist until subsequent tall forest excludes them. Lowland wetlands have been much maligned in New Zealand, and about 90% of them have been drained for agriculture. Consequently, the prominence of cabbage trees in open grassland, shrubland and regenerating forest is an artificial phenomenon related to their need for open sites and their ability to withstand grazing and drought. In fact, young cabbage trees are rare outside urban areas where they are planted by people. With the wetlands gone a vast proportion of the cabbage tree groves are geriatric. In Sudden Decline, regardless of its cause, we are witnessing a manifestation of stress resulting from many decades of increasing human impact.

4 SYMPTOMS OF SUDDEN DECLINE

The symptoms of Sudden Decline are summarised in Table 2 and shown in Fig. 2, and Fig. 3. Although based on numerous observations, it is still very difficult to accurately determine the earliest external signs and to chart the progress of Sudden Decline in any tree through space and time. In fact, every tree responds differently and there may be regional differences.

4.1 Yellowing of older leaves

This appears to be a natural feature of some individual trees. Leaves live for about two years in a healthy adult and die in the summer-autumn of the third year, after the new head of leaves forms as spring flowering progresses. In young plants, and vigorous reversion shoots of older plants, a conspicuous ruff or skirt of dead leaves remains below the living leaves. In plants with Sudden Decline this ruff usually falls. In any population a conspicuous yellowing of lower leaves occurs in certain individuals which can sometimes continue to look healthy after the yellow leaves fall. The significance of seasonal yellowing remains obscure.

Fig. 2 A sick cabbage tree showing symptoms of Sudden Decline.

Fig. 3 Cabbage trees which have succumbed to Sudden Decline. (*Photo Ross Beever, DSIR)*

Table 2 Physical symptoms of Sudden Decline in cabbage trees.

Phase *	Leaves	Branches	Trunk	Rhizome	Roots
Early	Oldest leaves drooping Oldest leaves[+] yellowing Leaf heads "untidy" Leaf tips brown, dead	Internal tissue healthy Occasional drooping Loss of tissue moisture	Light wood staining Brown lesions in cortex, especially near aerial root primordial	Healthy	Healthy
Mid	Leaf fall Only unopened leaves remain	Reduced radial growth of new tissue from apex Staining of wood	Lesions coalesce and cortex collapses Fermentation odour (secondary infection?)	Healthy	Fewer new roots formed
Late	Total defoliation	Total dehydration[+]	Outer wood decay spreads distally towards branches and proximally to ground level. Bark peels off	Healthy with underground or total decay (secondary infection?)[+]	Mature roots progressively dying[+]

* Phase of Sudden Decline.
[+] These symptoms are explained in more detail in the text.

4.2 Dehydration

Even after the tree is leafless and the trunk almost completely dead or decayed, the tips of branches can appear to be essentially healthy. Unless decay sets in, possibly from secondary fungal infection, the tip tissues simply dry out into a more or less mummified state. When hydrated in water, the tissues can appear relatively normal.

4.3 Rhizome decay

There are various indications that the underground vertical rhizome can gradually decay so that the tree totally dies, or that small rhizomes become isolated from the decaying mass, remain alive, and form vertical resprouts that emerge and grow into normal leafy shoots. Sometimes these resprouts succumb too. Monitoring over several years is required to characterise the typical pattern. Resprouting is an important characteristic in relation to advice to cabbage tree owners. The author's working hypothesis is that if the ailing tree is cut down at the earliest possible time after reliable symptoms appear and

secondary infection has not set in, then resprouts will replace the tree. The ability of the rhizome to resprout is clearly adaptive and is a normal and fundamental feature contributing to the longevity of cabbage trees. Trees with multiple trunks result.

4.4 Root system decline

Table 3 indicates that Sudden Decline strongly influences the root system even when the underground rhizome system appears healthy. The number of new roots formed decreases, there is a spectacular decrease in the number of healthy mature roots in late Decline, and a corresponding large increase in the number of dead roots during late Decline. In one healthy 16-year-old tree, 26% of the roots were dead, whereas in a tree with late Sudden Decline, 67% of the roots were dead.

Table 3 Numbers of young, mature and dead roots from three 16-year-old cabbage trees from the same locality in successive stages of Sudden Decline.

Tree	Young roots	Healthy mature	Dead	Total
Healthy	167	636	278	1081
Early SD (trunk decay)	115	739	305	1159
Mid-late SD (defoliated)	100	250	718	1068

4.5 Other observations on symptoms

1. Juvenile trees, that is, those that have not yet flowered and subsequently branched, very rarely show symptoms (Rees-George *et al.* 1990). However, some do die without any other apparent cause, and in those cases examined the underground rhizome has borne new vegetative sprouts.

2. In trees with multiple trunks, usually one trunk will show symptoms first and the symptoms may or may not spread to other trunks.

3. In single-trunked trees the first symptoms may be to one side of the trunk and extend to the branch system on that side. In such plants a localisation or walling off of decaying tissues can sometimes be observed.

4. Generally, declining tissues extend from the lower to ground level and the whole aerial shoot system dies. Sometimes, however, the lower trunk remains healthy above ground and vigorous leafy sprouts form.

5. Partial and gradual death of part of the aerial branch system can result from several causes, (e.g. scale insect infestation, stock damage on one side of the trunk), and it is often very difficult to be certain that Sudden Decline is involved.

The range of circumstances suggests that both acute (sudden total collapse) and chronic (gradual, partial collapse) forms of Sudden Decline might exist.

6. Typical Sudden Decline symptoms can appear after a tree has been stressed from some action, such as cutting off some of the root system, saturation of the soil by water, or bark chewing by cattle. Normally these actions in themselves would not cause the trees to die.

7. Seasonal variation in the onset of symptoms is well documented, for instance, by monitoring telephone calls from concerned tree owners in urban areas. Sudden Decline is most commonly noticed during summer when growth is most rapid and when the weather can be hot and dry.

8. A strong correlation between intensive flowering and Sudden Decline has been noted over the period that Decline has been observed. Although records are incomplete, there is circumstantial evidence that intensive flowering normally occurs once every few years, possibly about every seven years. Over the last few years, however, cabbage trees throughout New Zealand have flowered profusely. Renewal shoots are flowering after only one year of growth. For a plant which normally bears leaves which last for two years, this precocious flowering cannot continue without serious disruption to the long-term metabolism of the tree. In fact, a widely held view is that the cabbage trees are literally "flowering themselves to death". The fact that some similar plants do this, species both closely and distantly related to cabbage trees (some bamboos, palms, and *Agave*, for instance), is regarded as evidence for this view.

5 GEOGRAPHIC DISTRIBUTION

Since the first reports of Sudden Decline in northern New Zealand in 1987, a number of informal, formal, local, and national surveys have been undertaken. Detailed analysis of these surveys is not always possible because different observers have used slightly different methods and criteria for recognising the symptoms. However, an increasingly serious pattern has emerged. Sites described by Rees-George *et al.* (1990) have now been surveyed four times. A preliminary epidemiological analysis of these northern sites indicates that the incidence of Sudden Decline has increased from 16% in June 1988, to 48% in January 1991 (Beever 1991b) and is likely to affect most trees in northern North Island within the next 5 years.

Hosking and Hutcheson (1991) have data on over 600 sites throughout New Zealand and, while detailed analysis is not yet complete, an overall pattern is obvious. Sudden Decline symptoms now occur throughout North Island and occasionally in northern South Island (pers. obs.). The broad pattern to date is in Fig. 4.

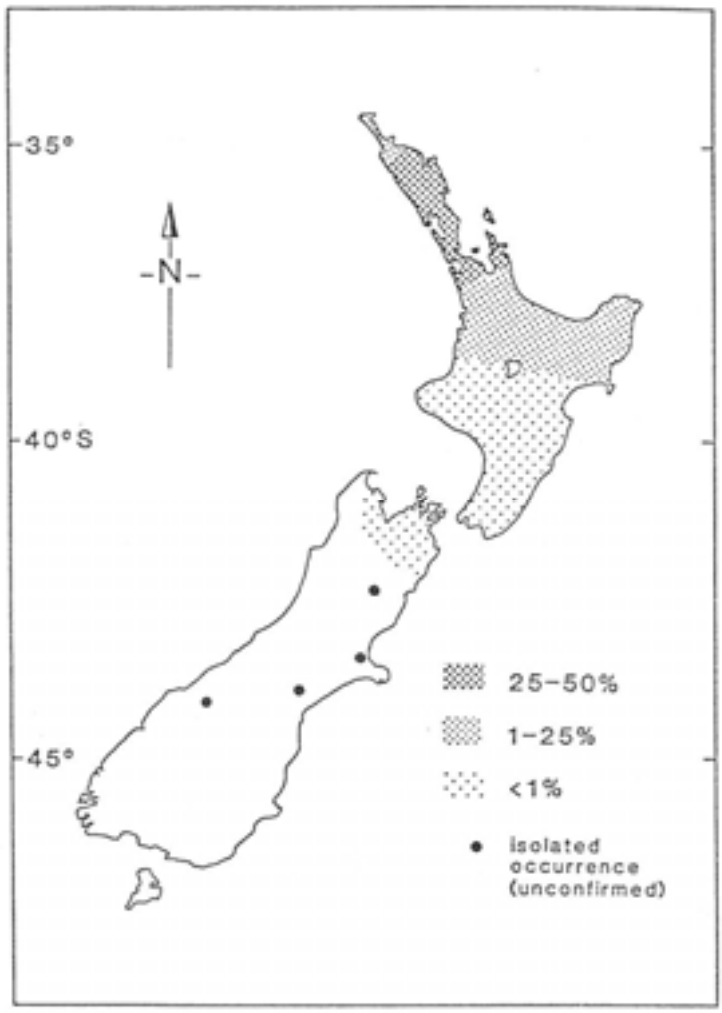

Fig. 4 Distribution of cabbage trees with Sudden Decline symptoms, expressed as percentage of number of plants.

6 ECOLOGICAL PATTERNS

The surveys suggest that there is a close relationship between the occurrence of Sudden Decline and disturbed ecosystems (Hosking and Hutcheson 1991). A vast proportion of examples occur in urban or farmed areas. Symptoms are absent from trees growing in natural plant associations on unmodified sites (Hosking and Hutcheson 1991). The incidence is strongly correlated with lowland sites and generally decreases with increasing altitude.

7 INCIDENCE IN RELATED SPECIES

Sudden Decline has been reported in all New Zealand species of *Cordyline,* and C. *bitecta,* a Norfolk Island species commonly grown in northern New Zealand. It has not been reported in the Australian species *C. rubra,* which is also common in urban gardens in northern New Zealadn. Further observations are required to confirm the

occurrence of Sudden Decline in *C. banksii* and *C. indivisa.* Sudden Decline does appear to be particularly common among hybrids between *C. banksii* and *C. australis* and is also common among bronze-leaved ornamental cultivars of cabbage trees.

There are scattered examples of dying *Yucca recurvifolia* and *Y. gloriosa* in New Zealand gardens and there is widespread occurrence of yellow leaf disease (a known mycoplasma) in *Phormium.* Both *Yucca* and *Phormium* are related to the *Cordyline,* and symptoms appear similar. Sometimes dying *Phormium* and *Cordyline* occur side by side. All of these issues increase the mystery surrounding Sudden Decline, particularly its cause.

8 CAUSE OF SUDDEN DECLINE

The death of thousands of trees of a species noted for its indestructibility has come as a shock to many New Zealanders. A common reaction is "Do they know what causes it?" or "Have they found a cure yet?" The short answer to both of these questions is "No". Yet it is obvious that future management of cabbage trees, including restoration of the depleted populations, has to be based on knowledge lest the management practices actually make the problem worse. Furthermore, there is a considerable trade in *Cordyline,* not only within New Zealand, but throughout the world, including the Pacific. It is even possible that a manufacturing activity involving fructose extraction from the stems, (Fankhauser and Brasch 1985), or involving the extraction of linoleic acid from the seeds (Morice 1965), could eventuate, involving plantations of cabbage trees. These actions would be fool-hardy in the absence of a known cause of the present demise, even if a specific cure is not practicable. Consequently, a major aspect of the current research strategy involves searching for a cause. Several hypotheses have emerged among wide public speculation.

8.1 Hypothesis 1: A pathogen

Several features of Sudden Decline suggest the influence of an organism:

1. Death can be rapid, usually between 2 and 6 months.

2. One plant can decline while an adjacent plant remains healthy.

3. Plants of all ages (possibly except juveniles) and all states of health are influenced.

4. The geographic distribution and epidemiology is consistent with the migration of the disease organism from a centre of origin.

5. The decline symptoms are similar to known pathogen-related wilts, yellows, and scorches.

The range of potential pathogens is being investigated by DSIR Plant Protection Division (Beever 1991 b). Although work will continue on all fronts as experience

with handling cabbage tree tissues and knowledge of the symptoms of Sudden Decline increases, it seems probable that nematodes, protozoa, fungi, and conventional plant pathogenic bacteria are not involved. However, interest in mycoplasmas and the so-called fastidious bacteria continues because of the similarity between Sudden Decline and Yellow Leaf in which is known to be caused by a mycoplasma (Ushiyama *et al.* 1969), the association together of affected cabbage trees and flax in many places in New Zealand, and the extreme difficulty of detection of these disease agents. Further background work on the morphology and anatomy of healthy cabbage trees is also required to structural interrelationships throughout the plant and the Sudden Decline symptoms at a histological level. The molecular techniques of identifying foreign nucleic acids is also continuing.

8.2 Hypothesis 2: Climate

Sudden Decline is occurring at a time of unprecedented recent climate change in New Zealand, resulting in:

1. Global warming, perhaps from the greenhouse effect of human-made gases such as carbon dioxide, methane and chlorofluorocarbons (CFC's).

2. Increased UV radiation as a result of a decrease in the thickness of the ozone layer in the upper atmosphere, again perhaps as a result of industrial products (CFC's)

3. The southern oscillation (El Niño and La Niña patterns) resulting in greater climatic extremes such as drought in eastern New Zealand (El Niño) and wet northern summers (La Niña).

Changes in climate, particularly warming, are thought to have triggered profuse flowering year after year. Some observers have tried to prevent Sudden Decline by removing the flowerheads, sometimes apparently successfully, sometimes unsuccessfully. The greater severity of Sudden Decline in the north and also to some extent in the east of New Zealand, where less cloud enables greater radiation to reach cabbage trees, is consistent with UV radiation being a factor in forcing trees to flower themselves to death. Higher altitude plants, presumably naturally adapted to higher UV radiation levels, are less influenced by Sudden Decline (Platt 1991). It is arguable that the range of UV radiation increase is not sufficient to cause Sudden Decline, and this hypothesis does not account for the good health of some trees nor the virtual absence of the symptoms in South Island populations which have also been flowering profusely. It seems more likely that flowering is a result of stress, rather than the cause, as is commonly observed in other plants. However, it is equally clear that a relationship between Sudden Decline, climate and perhaps flowering cannot be ignored and investigations into a possible causal relationship are continuing.

8.3 Hypothesis 3: Nutrients

Preliminary investigations suggest altered patterns of carbon and nitrogen distribution in cabbage trees with Sudden Decline (Potter 1991): carbon is concentrated in the

terminal leaves of affected plants. Profuse flowering may lead to reduced nutrient availability for root growth which, in turn, may limit the uptake of nitrogen. The impact of Sudden Decline on roots is indicated in Table 3. The mineral content of leaves has been reported on by Beever (1991b). Both studies are preliminary and will continue, particularly with regard to nitrogen metabolism. Maori observers report that the cure for ailing cabbage trees in former times was to plant shrubs around them. Potter (1991) reports that Sudden Decline is less prominent in shaded habitats. Hosking and Hutcheson (1991) report the absence of Sudden Decline in unmodified natural ecosystems.

Each hypothesis is based on intriguing observations, but final resolution remains a mystery. A central hypothesis that draws all the observations together is yet to be proposed. In the meantime Sudden Decline is spreading and also intensifying in severity although not necessarily in the rate of spread. The public want answers, and conservation managers want actions.

9 CONSERVATION ACTIONS

The problems for conservation created by Sudden Decline may be summarised as follows:

1. A vast number of cabbage trees, one of New Zealand's most revered plants, are dead and dying over the northern half of the country.

2. Most cabbage tree populations occur on private farmland because other preferred open habitats (e.g. wetlands) have largely disappeared through land development.

3. Grazing prevents regeneration of both seedlings and basal reversion shoots, so that most populations consist of very old trees (probably dating from the time of original forest clearance 100 years or more ago). Trees are frequently in ill-health as a result of stock damage to the bark and cambium.

4. Urban centres have concentrations of hybrids, cultivars, and a mixture of provenances from around the country. Dense populations of scale insects, cabbage tree loopers, and mealy bugs occur in urban areas, but seldom in wild stands. Genetic imbalance may be contributing to this susceptibility.

To counter these problems, a range of conservation measures are required:

1. Key sites, identified by a national survey, need to be protected from stock by fencing so that regeneration can take place and damage to trees ceases.

2. Restoration in the preferred wetland sites will require propagation and replanting.

3. An understanding of regional and habitat provenance variation is required avoid genetic pollution through uninformed movement of plants throughout New Zealand.

4. A Maori cultural perspective is important to preserve traditional knowledge of values, uses, and propagation, and to identify and protect historically important trees.

5. The ecological importance of cabbage trees as habitats for other plants and animals needs to be understood.

6. Monitoring is required to understand growth and reproduction biology of *Cordyline* species.

7. Trade in *Cordyline,* including possible economic value, needs investigation as an adjunct to ecological conservation.

All of these conservation measures are influenced by Sudden Decline. While most of these aspects can and are developing in the absence of conclusions on the cause of Sudden Decline, the reliability of these actions must remain in doubt. As is so often the case, understanding is limited until survival is threatened. Sudden Decline has resulted in a powerful advocacy campaign initiated by the media and taken up by conservation groups, sponsorship agencies, and scientists. I am confident, and so are the other members of the team of scientists working on cabbage trees, that a specific or general solution to Sudden Decline will be found. We believe that the knowledge gained along the way will ensure that this treasure of the South Pacific will be more appreciated, better protected, and ecologically healthier than it was before the mysterious tragedy left its mark.

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