Understanding fire in the forest

Fire is as natural a part of most Australian forests as gum trees and wattles. Bushfires can do enormous damage, but forest trees and shrubs are great fire survivors. The challenge is to manage fire so that people and their property don't get hurt and the forests are preserved.

Australia's eucalypt forests evolved with fire; if it was kept out permanently, big changes would occur in their composition and in the wildlife they support. The prospects of eliminating it are minimal, because the forests are highly flammable and lightning strikes as well as people start fires. But changes in the length of time forests go without fire and in the intensity of the fires when they come can also produce big and damaging effects.

The requirements of mountain ash, one of the most commercially valuable eucalypt species, provide a striking example. The trees are easily killed by fire, but in most areas they need fire for regeneration. If fire wipes out a stand before the trees start producing seed, which is usually about 20 years after establishment, then mountain ash is eliminated from the area. But if the forest doesn't burn within the lifetime of the trees—a maximum of about 400 years—no seedlings are established and the species again disappears.

Different types of forest have different responses to fire, and much remains to be found out about the needs of particular types. Big changes in fire frequencies and intensities have undoubtedly followed European settlement, but just what these changes have been in any area is usually impossible to determine.

Lightning

Before the Aborigines came to Australia, at least 30 000 years ago, lightning ignited the forests. Lightning still starts many forest fires—up to a quarter in coastal areas and a considerably higher proportion inland. The Aborigines used fire for, among other things, hunting and the production of fresh plant growth for game. They must have increased the frequency of widespread forest fires and no doubt this produced some changes in the forest plants and animals. But their influence was probably greatest in open woodlands and drier forests that have now been largely cleared for farming, because those were the areas where most lived.

The changes due to European settlement in the past 200 years are many and varied. Roads, towns, and cleared land have restricted the opportunities for fires to spread. So, of course, have the fire-fighting services. Before settlement, many fires would have run on for weeks or months, burning fiercely in some areas and at low intensity in others. Some parts would have remained unburnt. Now fires are usually stopped within hours and nearly always within a few days.

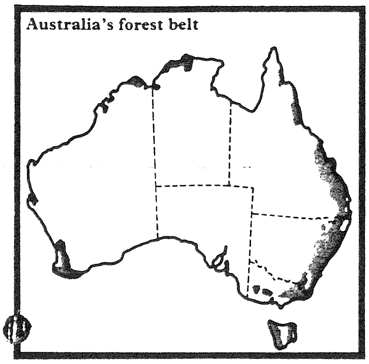
On the other hand, accidental lighting of fires has probably increased greatly. And in recent years foresters have begun making wide use of 'prescribed burning' to reduce the risk of uncontrollable forest fires. The method is to light fires at times of the year when fuel on the forest floor should burn away gently. Usually the plan involves a burn every 5–12 years. In some areas this probably results in a fire pattern quite like that existing when the Aborigines lived there. In others it probably produces a very different one.

If fire is to be successfully managed, its behaviour and effects must be thoroughly understood. Fire research has expanded rapidly in recent years, spurred on by disastrous bushfires like those that killed 71 people in Victoria in 1939 and 62 in Tasmania in 1967. At first most of the effort—by State forest services, CSIRO,

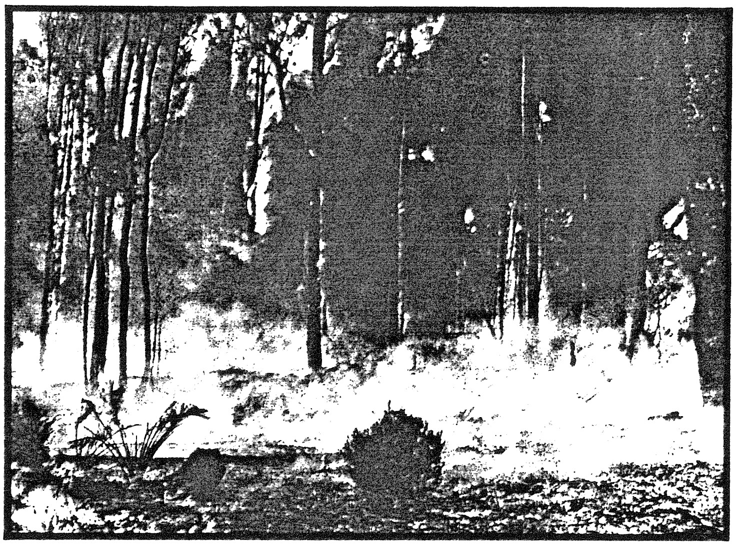
Below:
Scientists are making detailed studies of the effects of an intense fire lit in this jarrah forest last March.

Right:
Part of the 85-ha study area, before the fire . . .

. . . and after.



Except for pockets of rainforest and planted pine, Australia's tall forests are dominated by eucalypt species.



and universities—was put into working out how fires behave in different situations and improving control measures. Growing emphasis is now being placed on research into the effects of fire on forest plants and animals.

How hot?

The effects of a fire and the prospects for controlling it depend to a large degree on its intensity—the rate at which it releases energy. If all other factors remain constant, a doubling of the amount of fuel available—mostly fallen leaves, bark, and twigs—doubles the fire's rate of spread and produces a four-fold increase in intensity. This fallen litter is the material that supports forest fires; fire won't spread through a forest if the dead fuel layer is removed.

The litter builds up at rates depending on the amount of material falling from the trees and shrubs and the rate at which microorganisms decompose this material. Some years after a fire, a balance is reached and the build-up stops. The time to equilibrium varies widely with different forest types, and remains to be worked out for many areas. It appears to range upwards from about 3 years.

The main factors other than fuel quantity that affect fire behaviour are the moisture content of the fuel, air temperature, relative humidity, wind speed, and the topography of the land. Mr Alan McArthur and colleagues at the CSIRO Division of Forest Research—until last year the Commonwealth Forest Research Institute—did much of the original work on the relations between these variables and fire behaviour. State Department scientists have carried on the work, making adjustments for local conditions.

Fuel moisture is particularly important because it determines whether or not the litter will burn and, if it does, the rate of heat release. The Western Australian Forests Department has found that a moisture content between 10% and 18% of the dry weight of the litter is best for prescribed burning in the State's jarrah and karri forests. If it exceeds 18%, the burn is likely to be patchy, and if it falls below 10%, the fire is likely to be too hot.

The scientists have devised ways to work out the approximate moisture content of forest fuel from rainfall and relative humidity readings. They can estimate fuel quantities for different forest types from records of when areas were last burnt and how favourable the intervening seasons have been for tree growth.

Danger guides

One important outcome of the research has been the development of guides for working out fire danger. As an illustration of the way the flammability of forests changes, a light fuel layer of 7·5 tonnes per hectare probably would not burn on a day of low fire danger. But on a day of extreme fire danger it would blaze with an intensity of about 2000 kilowatts per metre of fire front and could be difficult to control. If the fuel load quadrupled to 30 tonnes per hectare, it would be likely to burn with a controllable intensity of about 1500 kW per m on a low fire danger day. On a day of extreme fire danger, a spark could set off a conflagration reaching an intensity approaching 40 000 kW per m.

Litter gathers in some eucalypt forests at rates of up to 7 tonnes per hectare per year, and in these forests the fuel layer can build up to quantities like 30 tonnes per hectare quite quickly. In the fast-growing karri forests of Western Australia and the stringybark forests of south-eastern Australia, for example, fuel quan-

Recovery 2½ years after an intense fire.

tities may exceed 50 tonnes per hectare after only 15 fire-free years.

Scientists sort out the factors controlling fire behaviour by lighting hundreds of small fires and measuring their intensity, flame height, rate of spread, and so on. Each fire is restricted to perhaps half a hectare of forest, and areas and times for burns are selected to cover a wide range of fuel characteristics, weather conditions, and slope.

As an illustration of what is involved, Mr George Peet, Mr Rick Sneeuwjagt, and colleagues from the Western Australian Forests Department have lit something like 250 half-hectare fires in the State's karri forests in the last 6 years to work out detailed guidelines for prescribed burning there. They have reached the stage where they can predict with about 70% accuracy how fast fire will spread in any part of the forest on any day. Earlier, about 400 fires were lit in jarrah forest areas to develop the guidelines used for prescribed burns there.

Routine

Prescribed burning is now a routine fire-control measure in all States, and it is probably the most important application of fire-behaviour research. More than a million hectares of forested land in State forests, national parks, and unoccupied crown land are burnt each year in spring or autumn—on days when conditions are right for a mild, slow-spreading fire that should not damage trees.

Foresters select different areas for burning each year, and aim at returning to any one area before the litter layer has built up again to dangerous levels. Planned rotation periods for various forest types range between 5 and 12 years.

Initially the burning was done by teams of men walking through the forest and lighting fires on a grid pattern. This is still the method in some areas, for example where variations in the terrain make careful selection of ignition sites necessary, but most prescribed burns are now lit from the air. Mr David Packham and colleagues in CSIRO's former Bushfire Section in Melbourne designed a cheap and effective incendiary capsule and developed aerial burning with Western Australian Forests Department scientists in the mid 1960s. From a low-flying light aircraft, foresters now ignite an average of about 4000 hectares in a day, and can ignite more than 8000 hectares on a particularly good day.

Prescribed burning is now a routine fire-control measure in all States.

Because not all the fuel in a forest area is equally flammable when prescribed burns go through, sections nearly always remain unburnt. The Western Australians aim at a 70% coverage in the jarrah forests, and expect fire-control problems if less than 60% is burnt. Typical coverage figures for burns in the Snowy Mountains, N.S.W., by contrast, are between 20% and 40%; Division of Forest Research scientists regard 25% as the lower limit for effective bushfire protection.

The object of prescribed burning is to reduce not only the risk of bushfires but also the intensity of those that occur, so that they do less damage and fire-fighters can control them. It undoubtedly works. Western Australia, the first State to bring in regular prescribed burning, began the practice in 1953 and stepped it up in 1961. Between 1953 and 1961, the area pre-

,cribed-burnt averaged 148 000 hectares a year; bushfire numbers per year in this period averaged 350, covering 26 000 hectares. Between 1961 and 1970 the annual prescribed-burning area more than doubled, to an average of 360 000 hectares. The yearly bushfire tally fell only slightly, to 290, but the average area affected in a year fell dramatically—to 7200 hectares.

Fire's impact

Research on the effects of fire on forest plants and animals has blossomed in recent years, partly because people have wanted to find out just what effects the changed burning patterns introduced with prescribed burning are having. Some areas—for example the mountain ash forests referred to earlier and Australia's rainforests, which are very sensitive to fire—clearly should not be included in the prescribed-burning cycle. What is best for some other forest types is much harder to determine.

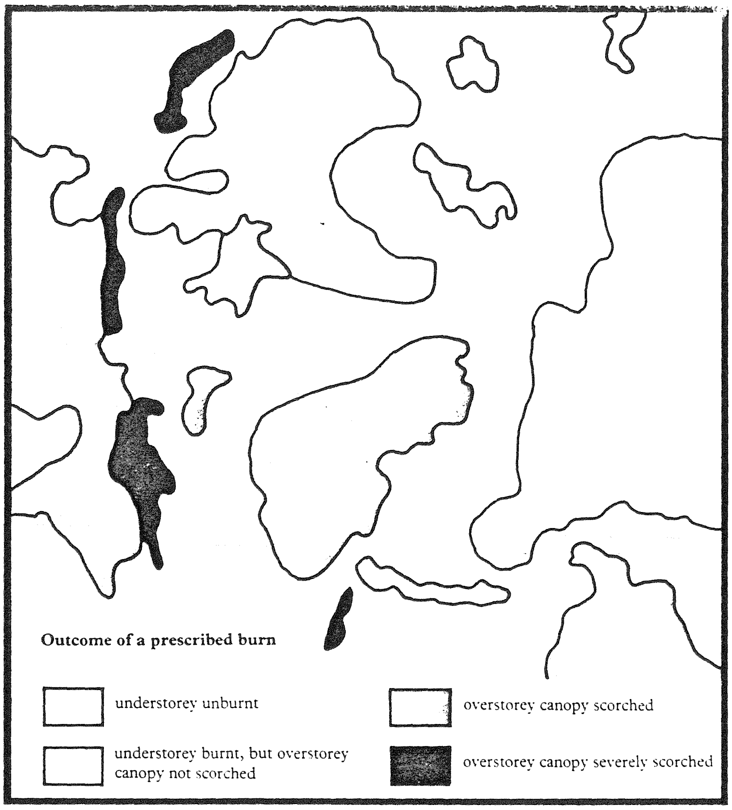
All the eucalypt forests have evolved with fire, but how often particular areas should burn to produce the best results, how hot the fires should be, and what times of year are best for burning are very difficult questions.

The ground litter in eucalypt forests is very flammable. Eucalypt leaves contain oils that produce heat rapidly when they burn, and encourage the leaf canopy in a forest to catch when a fire is burning below.

Mr Nick King and Dr Bob Vines, of the CSIRO Bushfire Section, have found that, even after the oils are removed by drying, the leaves of many eucalypts are unusually flammable. They attribute this to the leaves' low content of inorganic material. Mr Geoff Stocker of the Division of Forest Research has found that the litter under non-eucalypt monsoon forests in the Northern Territory is much less flammable than that under nearby eucalypt forests, even when it is completely dry.

So eucalypt forests are adapted to burn. And they are equipped to cope with fire, but not necessarily with all intensities and frequencies of fire.

One of the main protective features of most eucalypt species is a thick bark. This shields the cambium—the growing area of the tree and the supply route to the leaves and roots—from fire. The cambium is sandwiched between the wood grown in previous years and the bark. A few minutes' exposure to a temperature of 55 C can kill it, and at 65 C death is almost instantaneous. Flame temperatures in forest fires can be well over 1000°C.



This map, of 2 sq km of prescribed-burnt forest in Western Australia, shows a typical burning pattern. A considerable part, usually about one-quarter in Western Australia, remains unburnt.

Research on the effects of fire on forest plants and animals has blossomed in recent years.

Researchers including Dr Vines, Mr McArthur, and Dr Malcolm Gill of the CSIRO Division of Plant Industry have studied heat penetration through the bark of various eucalypt species, and have found that insulation of the cambium increases with bark thickness. Thickness generally increases with the age and diameter of trees, so mature trees are likely to withstand fires better than young ones.

Some eucalypts have much thicker bark than others, and big variations can exist between different species found in one forest. For example, measurements by Mr McArthur of two species growing together near Canberra show that the bark of mature trees of one species is twice as thick as that of similar-sized specimens of the other.

Bark as a buffer

Any tree would die if it was exposed to flame temperatures for more than a matter of minutes. The effect of the bark is to slow the rate of heating so that, if the flames pass quickly, the temperature at the cambium rises very little.

Mr McArthur and Mr Phil Cheney, also of the Division of Forest Research, have found that fire in fairly heavy eucalypt litter (25 tonnes per hectare) will flame at any spot for about 2½ minutes. In half that quantity of litter it will flame for about half that time. Heavy branches and logs in the litter will extend the flaming time, sometimes in an intense fire to 10 minutes or longer.

Their experiments indicate that, in a reasonably hot fire, the time of flaming needed to produce lethal temperatures in the cambium near the base of a tree is about 2 minutes when the bark is 1 cm

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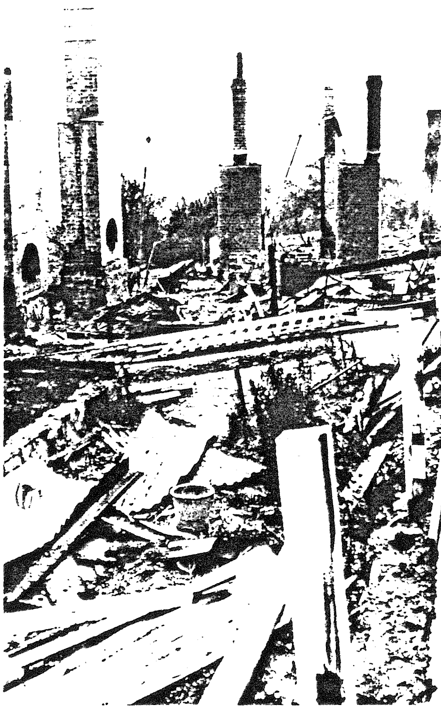
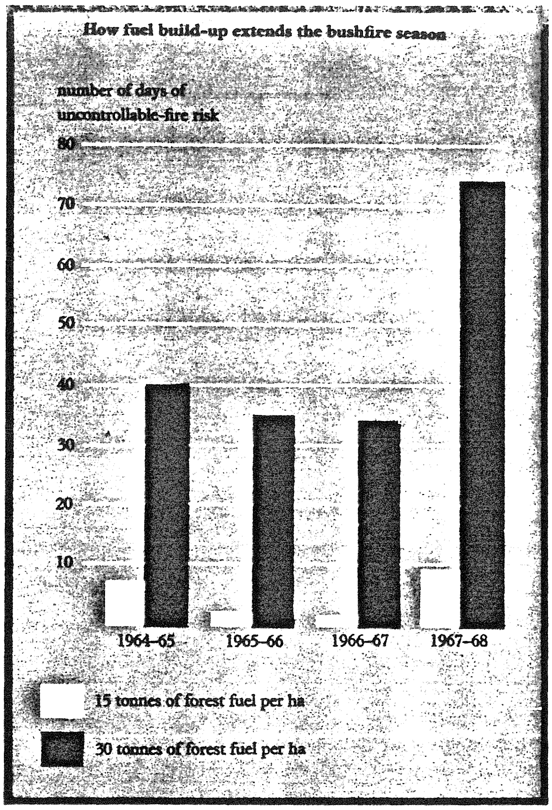


Some of the damage done by the 1967 Tasmanian conflagration.



Doubling the fuel quantity greatly increases the chance of fires that may be uncontrollable (more intense than 2000 kW per m). The figures here are for a central Victorian forest.

Fire and tree damage

Mr McArthur and Mr Cheney, of the Division of Forest Research, have drawn together information about the effects of fires of different intensities on the timber properties of eucalypts.

They conclude that fires up to an intensity of 350 kilowatts per metre do very little damage. Prescribed burns are generally below that level.

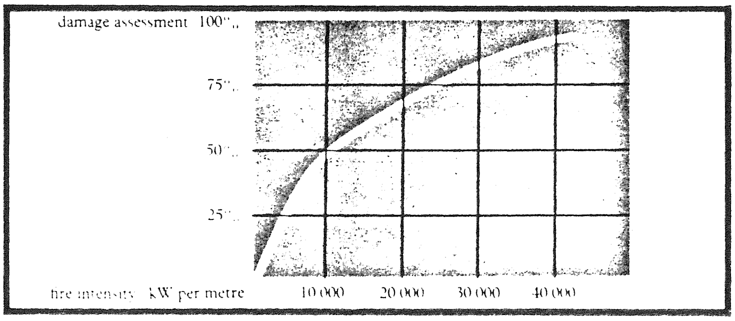
Between 350 and 1750 kW per m, fires may do slight damage—killing small outer branches and occasionally producing gum veins in a tree's stem.

Fires giving intensity readings between 1750 and 3500 are likely to have some effect on timber quality. They may damage stems and, because of foliage scorching, reduce trees' growth rates. Young trees up to a height of about 5 metres may be killed.

At intensities above 3500, damage varies widely among species; some are much more tolerant of heat than others. One of the most tolerant is the valuable timber species jarrah.

In 1961 a disastrous bushfire occurred near Dwellingup, south of Perth. Part of the forest burnt out was a 40-year-old stand of jarrah. The graph shows the relation between damage to the trees and the intensity of the fire as it swept through.

A 100% damage assessment means that no trees in the area will have commercial value, although it seldom means all the trees are killed. With a 50% assessment, most trees will be severely scarred; at least 20% of the timber available before the fire will be lost due to direct damage, plus about 5 years' normal growth.



ick and rises to about 12 minutes for a thickness of 4 cm.

Of course a fire passing through a forest subjects different parts of a tree to different amounts of heat. Even at a single height above the ground, the effects differ, so cambium on one side of a tree can be killed while the rest survives. The result is a fire scar. Dr Gill, and Dr Joe Walker and Dr Brian Tunstall, of the CSIRO Division of Land Use Research, are studying the ways heat is distributed around trees during fires. Early experiments indicate that the leeward side of a tree is exposed to considerably more heat than the windward side.

Dr Gill is also studying how the bark of various eucalypts recovers after some of it is removed. This is important because fires burn off some bark, leaving a tree with a thinner protective layer and therefore more vulnerable to future fires. Observations by other scientists indicate that recovery of former bark thickness over areas where a tree's cambium has survived can take from 3 to 20 years.

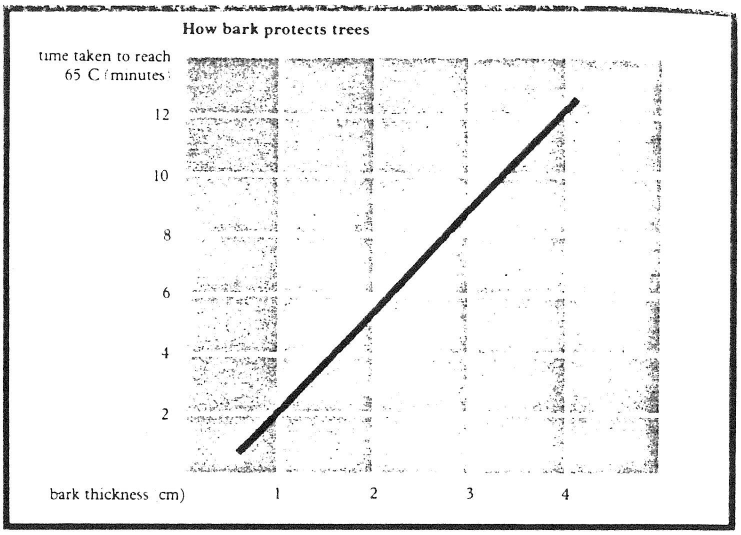
Trees are resilient

If the cambium right around its trunk is killed, the tree dies above that point. But don't say goodbye to the tree. All but about 15 of Australia's 600 eucalypt species have structures known as lignotubers, which sprout new stems when the original stem is killed. They tend to envelop the upper part of a tree's roots and are usually partially buried. Fire seldom damages them and they are the ultimate mechanism enabling most eucalypts to survive even the fiercest conflagration.

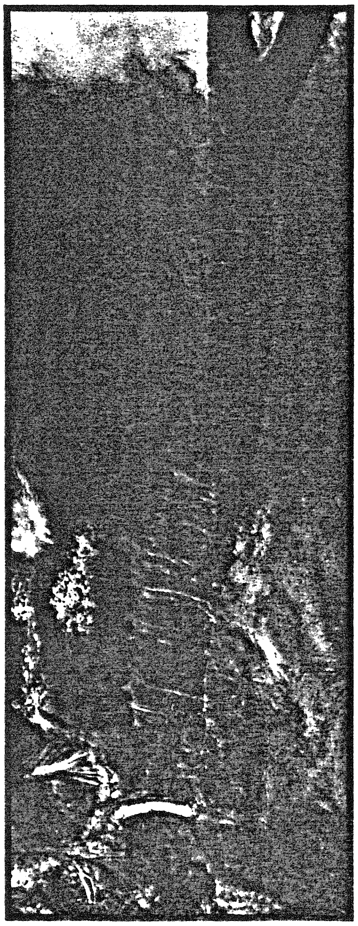
If a tree's stem survives but its foliage is destroyed, some more dormant buds will spring to life. These are located under the bark along the stem and branches, and produce what are known as epicormic shoots. The shoots keep the tree alive until new foliage is established. Then the tree sheds them.

The eucalypts best equipped with lignotubers and epicormic shoots appear in general to be those growing in climates where fire is common. Some species growing in wetter, less fire-prone areas—mountain ash is again a good example—are much more easily killed. Trees must then regenerate from seed. We have seen how vital fire is for the regeneration of mountain ash. It also promotes regeneration of many other eucalypt species.

The shrubs and other plants that grow in eucalypt forests are, like the trees, equipped to cope with fire, and some of

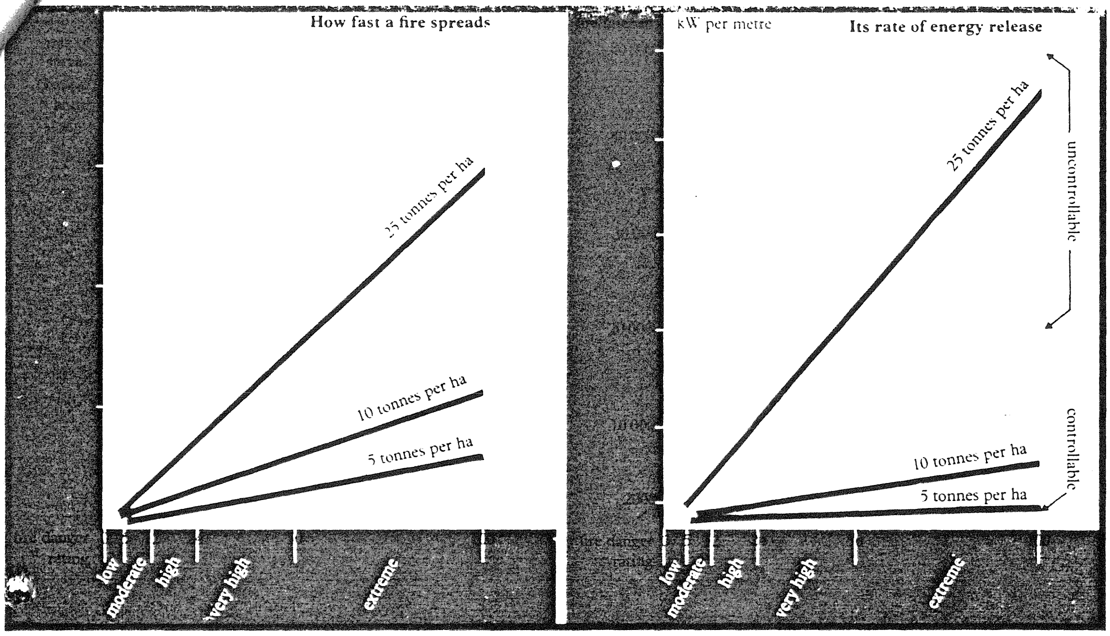


Mr McArthur subjected the outer bark surface of two eucalypt species to a constant temperature approaching 1000 C. The graph shows how long it took the inner surface to reach a lethal 65°C.



Wind-blown fire.

Banksia fruits.



The graphs show the big impact that rising fuel quantities and fire danger ratings have on fire behaviour.

them depend on it. For example, wattles have hard seeds that can remain dormant in the soil for many years. The seeds of some wattle species don't germinate until fire comes along; the heat of the fire sets them going.

Banksias have hard fruits (the banksia men of May Gibbs' children's classic 'Snugglepot and Cuddlepie') that protect their seeds during fire. The heat prompts some species to release the seeds, which then germinate in the soil. Banksias also regenerate from lignotubers.

Different understorey species respond [illegible]t to different fire frequencies and intensities, so when these change in a forest the species composition may change. Of course species do not have exacting requirements: they can cope with quite large variations in fire frequency and intensity. A eucalypt forest with a wattle understorey, for example, is likely to retain that understorey if fire goes through at intervals between 4 and 25 years.

This is because most wattles produce seeds from their third year onwards and live for up to 25 years. A succession of fires at intervals that don't give the wattles time to seed will probably produce a grass understorey. If fire is kept out beyond the lifetime of the plants, the wattles can be expected to give way to a heavy and very flammable layer of bark, twigs, and leaves.

Small plot trials

Experiments going ahead now will, hopefully, provide detailed information on the effects that fires of different frequencies and intensities burning at different times of the year will have on various forest plants. For example in the Tallaganda Forest, near Canberra, Dr Gill has recently fenced off similar 10- · 8-metre plots and is giving them a variety of fire treatments.

Fires are lit on different plots in spring, summer, or autumn, at intervals of 3, 6, or 12 years. Dr Gill records details such as the species present, the proportion of the plot covered by vegetation, and the height of the vegetation before burning and at intervals afterwards. He also measures the fire intensities.

The plots are fenced to keep out wallabies, wombats, and other animals that may graze and trample vegetation. On another series of plots, Dr John Leigh, also of the Division of Plant Industry, is comparing the effects of fires on fenced and unfenced areas to see how the animals influence the outcome. Dr Phil Price, from the same Division, has begun similar experiments in a wetter and more heavily vegetated forest near Eden on the New South Wales south coast.

Scientists in State forestry departments are studying changes in areas of forest and their animal inhabitants after prescribed burns and more intense fires.

In Victoria, for example, in 1968 scientists from the Forests Commission and Monash University began a study of the ecological effects of fire in dry eucalypt forests on the foothills of the Great Dividing Range. They have found that all the original plant species remain after low-intensity prescribed burns in spring. However, the density of shrubs is reduced at first and that of herbs and grasses promoted. Three years later the low shrub cover has flourished to become denser than it was originally. Seven years after, the understorey is virtually the same as before the fire.

A devastating bushfire in January 1969 presented the scientists with an opportunity to study the effects of a very hot fire in the same part of Victoria. With an intensity averaging 12 500 kW per m, it burnt out 2500 hectares, leaving only about 1% of the ground surface untouched. Virtually all the litter and undergrowth went up in flames, and the foliage of most trees was burnt or severely scorched. However, only 4–7% of the trees died.

New shoots from the roots and stems of trees and shrubs began to appear 4 weeks after the fire. Seed germination began the following winter. Herbs and annuals emerged in profusion in the spring, and shrub thickets developed within 2 years. The lasting effects of the fire on the vegetation were a reduction in tree canopy and the growth of a dense shrub layer.

How wildlife fares

Forest fires can kill animals and birds, but it seems that a mighty conflagration would be needed to wipe out the entire population of any species in an area. Like the forest plants, the animals have evolved with fire, and they know how to escape it by finding shelter or retreating to unburnt areas. However, each species has its own habitat requirements. If fires produce lasting changes in vegetation, changes in animal populations must follow. Some species may flourish, while others may die out in the area.

Animal and bird trappings and sightings by Mr Arnus Heislers and colleagues during the Victorian foothills forest study indicate that prescribed burning is having little effect there. The scientists have detected no significant change in the species composition.

After the fire goes through, areas that remain unburnt act as sanctuaries for some animals, such as the bush rat, which like dense cover. The animals recolonize the burnt areas as the understorey vegetation returns.

Kangaroos and wallabies show a preference for grazing new plant growth following fire. Some bird species also are attracted to newly burnt areas. Birds that live in the undergrowth remain in the burnt areas and continue to breed.

However, Mr Heislers says that, after three low-intensity fires in the past 15 to 20 years in some parts of the forest, the amount of dense shrub growth seems to be less than before. He suggests that, if this proves to be so, long-term changes in the animal population are likely.

As well as killing most of the understorey vegetation, the 1969 bushfire reduced the population of the principal mammal in the area, the brown phascogale, by 90 , and killed many kangaroos, wallabies, and ringtailed possums. Starvation and predation as well as incineration produced the fall in numbers of the phascogale, which is a small mammal. No sightings were made of another small mammal, the bush rat, for 2 years after the fire.

However, it took the phascogale only 2 years to regain its former abundance, and within 4 years kangaroos were at least as plentiful as before. The bush rat returned in bigger numbers than before, prospering in the dense shrub growth produced by the fire. So did shrub-inhabiting bird species. Possum numbers, on the other hand, remained lower than before the fire, probably because of their low reproductive rate compared with that of the small mammals and the slow recovery of the upper tree foliage. (The next issue of *Ecos* will report detailed studies, by teams led by Dr Alan Newsome of the CSIRO Division of Wildlife Research and Dr Harry Recher of the Australian Museum, Sydney, of the effects on wildlife of a raging bushfire on the New South Wales south coast.)

Western Australia's woylie.

If fires produce lasting changes in vegetation, changes in animal populations must follow.

Jarrah and karri

In Western Australia, Mr Per Christensen, Mr Peter Kimber, and colleagues in the Forests Department are studying the effects of prescribed burning on the plants and animals in the jarrah and karri forests. In the drier jarrah forest they have found that nearly all recovery of ground vegetation comes from root material rather than from the dormant seeds in the soil. The size and density of the ground cover shrubs return to the relatively sparse pre-fire levels in 2–3 years. The denser karri forest understorey regenerates primarily from seeds stored in the soil.

The effects on wildlife seem to be generally similar to those in Victoria. Small-mammal numbers fall greatly at first, but recolonization from unburnt areas begins quickly as the vegetation starts to recover. Numbers of larger mammals remain fairly constant. Bird populations show only small changes, with a tendency for numbers of some species to increase above pre-fire levels in the first or second year after burning.

The scientists are studying the habitat preferences of various animals and birds and seeing how these are related to different fire frequencies and intensities.

One scrub-inhabiting mammal, the woylie, seems to do best in areas of fairly frequent burning in the wetter southern forest and of less frequent burning in drier forest, where the understorey recovers more slowly after burning. The southern bush rat likes the dense undergrowth present shortly after fires. The mardo, another small mammal, prefers more advanced, less dense scrub.

The tammar, a small wallaby-like animal, likes a closed scrub canopy, open enough below to allow good visibility but sufficiently dense to slow pursuing predators. Periodic very hot fires seem to be best for achieving this sort of habitat.

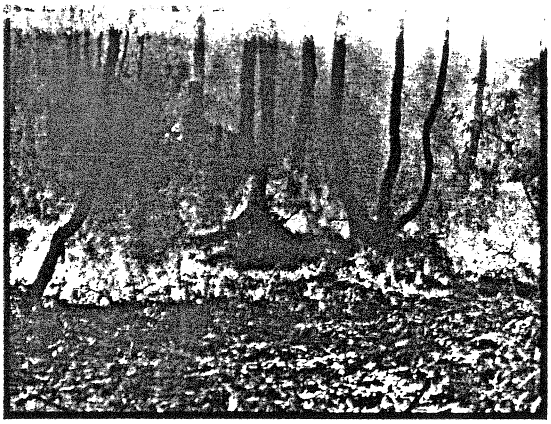
The Forests Department has designated two sections of State forest—one 20 000 ha and the other 40 000—as fauna priority areas. The concept is that the well-being of the fauna there takes precedence over timber-getting and all other forest uses. The research on the needs of wildlife is going on in these areas, where controlled fires of high as well as low intensity can be set off.

Effects underfoot

As well as affecting vegetation composition and wildlife, changes in a forest's burning routine can affect availability of nutrients in the soil. Most eucalypt forest soils are naturally very low in nutrients, and any further reductions could have serious effects.

During a fire, considerable amounts of some nutrients—for example nitrogen

A very gentle prescribed burn—25–50 kW per m.



A relatively hot prescribed burn—500–600 kW per m.

and sulphur—are lost in the smoke. (A later issue of *Ecos* will look at research on forest-fire smoke.) On the other hand, some unavailable nutrients in the litter and in the surface few millimetres of soil are changed by heat into available forms.

Immediately after the fire, these nutrients—in ash on the bare soil surface—are very vulnerable to being washed away by rain or blown away by wind. If the ash stays put, the fire has probably benefited the surviving vegetation by improving nutrient availability. But serious losses can occur in heavy rain or high wind, and soil erosion can compound the problem. A vital question is whether any fire-management practice in any forest causes long-term loss of nutrients.

Concern has arisen in Western Australia recently that prescribed burning may be reducing nutrient availability in the jarrah forest and possibly contributing to the spread of 'dieback disease' there. Scientists from the State Forests Department and the CSIRO Division of Land Resources Management are working together in a series of projects to find out whether this is so.

The nutrients lost in smoke have to be replaced if levels are to be maintained in a forest. Leguminous plants, which take nitrogen from the air and convert it in the soil into compounds that plants can assimilate, are the normal means of keeping up the nitrogen supply.

The main cause for concern in the jarrah forest is that the mild fires of prescribed burning produce very little regeneration of nitrogen-fixing plants, particularly wattles and ground-hugging kennedias. Foresters have recorded prolific regeneration of these legumes after intense fires. It seems that the jarrah forest wattles and kennedias need the heat of intense fire for seed germination and the extra sunlight that comes through a burnt tree canopy for healthy growth.

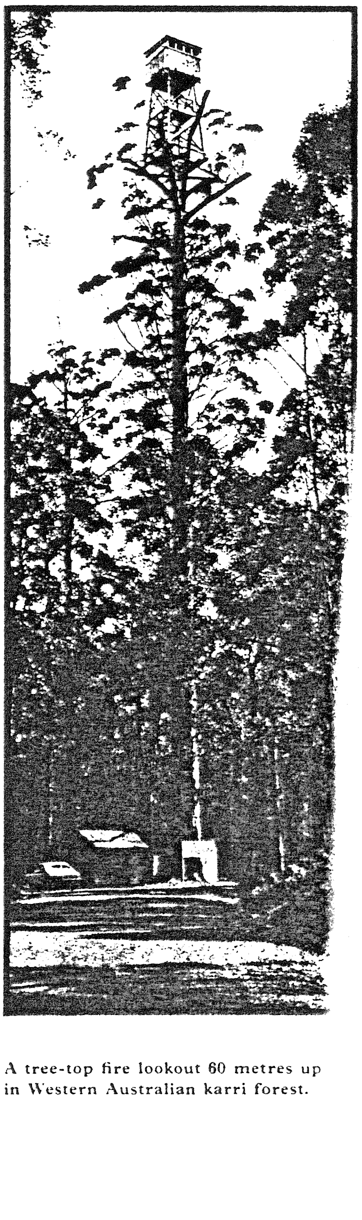
On a hot, windy day last March, the Forests Department put an intense fire through 85 ha of jarrah forest to enable scientists to study the effects of such a fire. Before the burn, the scientists recorded ground cover, analysed soil to establish nutrient levels, and made other measurements. Measurements are continuing as the vegetation regenerates.

In one series of experiments, Dr Frank Hingston and Dr Nick Malajczuk, of the Division of Land Resources Management, are attempting to estimate how much of the forest's nitrogen is added to the soil by wattles and kennedias. The scientists are sampling the plants during growth after the fire and working out how much nitrogen these are contributing. They are also monitoring nitrogen levels in the soil. Dr Jim Barrow, also of the Division, is examining possible effects of fire on phosphorus uptake by jarrah forest plants.

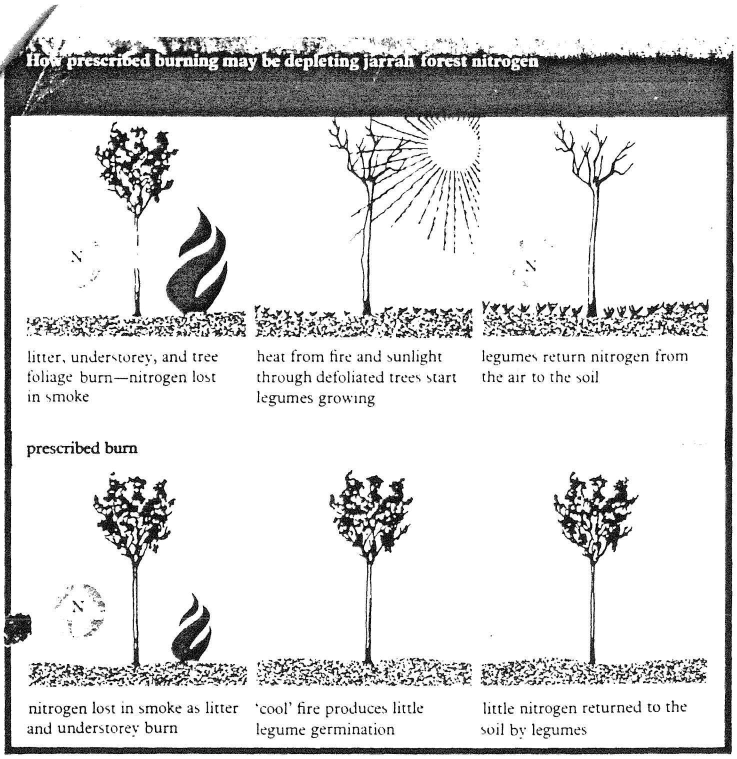
A link with dieback?

Dieback disease, caused by the fungus *Phytophthora cinnamomi*, is spreading through the jarrah forest at a rate of about 20 000 ha a year, killing the trees and much of the undergrowth as it passes. Dr Sid Shea of the Department and Dr Malajczuk of CSIRO are looking at the possibility that the failure of wattles to proliferate after prescribed burns may encourage the fungus. Also they are looking at the role of banksias, which regenerate profusely after the burns, in its spread.

Banksias are very susceptible to the fungus; their spreading matted roots appear to offer no resistance. They serve as launching pads for attacks on jarrah.



A tree-top fire lookout 60 metres up in Western Australian karri forest.



While burning makes some nitrogen in the litter available for plant growth, it also transfers some from the forest to the atmosphere. This lost nitrogen must be replaced if nitrogen levels are to be maintained.

The wattles, on the other hand, resist the fungus. One reason appears to be that their roots harbour microorganisms antagonistic to *Phytophthora.*

Many forest plants, including jarrah trees but not banksias, have fungi known as mycorrhizas, which resist *Phytophthora,* on some of their roots. The scientists have found that these fungi are much more abundant on roots in the litter layer than in the soil. So regular removal of the litter layer by burning may encourage dieback by reducing mycorrhiza numbers. It also destroys microorganisms in the litter, which decompose plant material and also seem to be antagonistic to *Phytophthora.*

Another possibility the scientists are looking at is that prescribed burning encourages dieback by improving conditions for *Phytophthora* in the soil. This fungus is most active in warm, moist soil. Prescribed burning in spring possibly promotes warming of the soil when it is still moist after the winter, by reducing the ground cover and allowing more sunlight through.

If the nutritional status of the forest is declining, this also could encourage dieback by reducing the resistance of plants to attack.

The spread of dieback is a very serious problem in the jarrah forest. Although a link with prescribed burning has not been established—the experiments are just beginning—the Forests Department is already considering adding hotter fires to its burning program to encourage wattles and hopefully slow the spread of *Phytophthora.* But that won't be simple; hot fires are hard to control. Of course if fire was kept out of the forest, the wattles might disappear altogether.

As all this shows, the relation between fire and a forest can be extremely complex. Maintaining Australia's forests and their wildlife is to a large degree a fire-management problem. Much remains to be learnt about what fire patterns are best for different areas. But we have come a long way since fire was seen as a purely destructive force that had to be fought and vanquished.

More about the topic

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