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PHYSICAL ENVIRONMENT

FORESTS OF VICTORIA

Introduction

The forests of Victoria are plant and animal communities of great diversity, ranging from the tallest of hardwood forests in the cool wet mountains to stunted mallee heathlands in the arid north-west.

The complex structures of the forest communities give them a resilience which enables them to withstand drought and fire, and makes them amenable to many forms of use. They are sustainable systems from which wood and other products can be harvested continually without detriment to their stability or productivity, and they provide shelter and food for a great variety of birds and animals.

One third of the total land area of Victoria is forested, and over 5 million acres, comprising approximately one tenth of the land area, is suitable for commercial timber production. More than 7 million acres of Victorian forest lands are permanently reserved, mainly as reserved forests, but also as national parks and for other purposes, thus conserving as natural habitat for native fauna more than 12 per cent of the total area of the State.

The plants of a forest usually form recognisable layers. Below the canopy formed by the crowns of the dominant trees, the shrubs and lesser trees grow at one or two distinct levels, and there is usually a layer of grasses, ferns, herbs, or mosses on the ground surface. Such strata are most numerous and conspicuously developed in tall mountain forests. Understorey and shrub strata are less luxuriant in the stringybark forests found at lower elevations and they are quite sparse in some open forests and woodlands. Eucalypts and wattles are the principal trees in all the major native forests. Radiata pine, the most widespread introduced tree, is used in commercial softwood forests which now comprise approximately 1 per cent of the total forest area.

The compositions of most areas of forest appear as mosaics of slightly differing associations of plants, or as gradually changing compositions, reflecting differences in soil, aspect, drainage, elevation, and fire history.

These forests grow in one of the most fire-susceptible regions of the world. Drought is a characteristic of the environment; most of the plant associations are inflammable; and lightning and man's activities cause many ignitions. Fires spread rapidly in hot dry windy weather, and they are most intense where heavy accumulations of forest debris occur on steep slopes.

Mountain forests

The forests of the cool, high rainfall areas of the mountain country are of three main types. On the rocky outcrops and upper slopes of the highest ranges and on the high plains the forests are short, sub-alpine woodlands interspersed with grassland, herbfield, and marshes. At elevations below 4,500 ft on less exposed sites adjoining the woodland, the forests are tall pure stands, mainly of alpine ash. They extend down to elevations of 3,700 ft and as low as 2,400 ft on southerly aspects. The very tall dense forests of mountain ash are at lower elevations on deep fertile soils and in sheltered sites in the mountains.

Alpine ash and mountain ash forests are Victoria's most valuable source of native timber, and they clothe the upper reaches of the principal catchments of most major streams. With their variety of wildlife, profusion of botanical attractions, and magnificent scenery, the ash forests rank highly as areas for public recreation and scientific study.

Ash timbers surpass all other hardwoods of south-eastern Australia for use as flooring, joinery and furniture stock, interior trim, and other mouldings. Selected logs are sliced into decorative veneers or may be peeled in a lathe to produce veneer for structural plywoods. Young wood from forest thinnings and residues from logging and sawmilling are used as raw material for paper making.

Sub-alpine woodlands and grasslands

The climate in the sub-alpine zone between 4,500 and 6,000 ft is characterised by frequent snowfalls in winter and severe frosts during the growing season ; the snow lies for about twelve weeks of the year. Bogong and Dargo High Plains and adjoining mountain tops, Mt Hotham and Mt Howitt, are typical areas. The general locations are shown on the map which accompanies this article (facing page 16).

Snow gum is the principal tree species of the woodland. It grows with deep crowns and short trunks. The ground cover is mainly austral snow grass. Near its upper limit the woodland has the form of a stunted scrub or wet mallee, interspersed with shrubby heath or grassland.

Golden shaggy-pea, leafy bossiaea and other legumes, heaths, mint-bushes, and kunzeas are the main shrubs. Shaggy-peas and bossiaea form low thickets where fires have been intense. Deep bogs of sphagnum moss occupy permanently wet sites, which are important sources of water flow in the high catchments during summer. Many bogs have been destroyed or badly damaged by fires and trampling cattle. The extensive grasslands are composed mainly of austral snow grass. Black sallee and Dargo gum occur in a few places in the woodland.

Snow gums on large areas of the north-eastern mountains have been severely damaged by wild fires. The bleached trunks of the trees still stand, and clumps of coppice shoots have grown from their bases. Young trees have also regenerated from seed.

Alpine ash forests

Alpine ash forests are widely distributed in numerous separate areas in the eastern highlands. There is a very small area also on Mt Macedon. Major forests of alpine ash are located at Nunniong, Mt Stirling, Mt Wills, Mt Ewen, Moroka River, Mt Skene, Mt Misery, Mt Whitelaw, and the Tea-tree Range. The climate in these areas is characterised by cold winters and heavy precipitation of 40 to 90 inches a year including snow. Generally, snow lies on the ground for eighteen weeks of the year, and there are up to about 200 severe frosts in a year. Summer temperatures seldom exceed 85° F.

Small areas of forest of alpine ash in mixture with candlebark and snow gum are found in the fringe of the pure stands along their upper limits. In a few places there are associated areas of mountain gum forests, with narrow-leaved or broad-leaved peppermints in mixture. Small areas of mountain ash and shining gum forests also occur with the alpine ash.

The best development of alpine ash forest is on soils derived from granitic and basaltic rocks and metamorphosed formations. Mature trees in such locations reach heights of 250 ft with trunks up to 140 ft long, and some have diameters of 10 ft. More usually, mature trees are 175 to 200 ft tall and their trunks are less than 6 ft in diameter. On poor soils and exposed sites at higher altitudes the trees have short trunks and large branches.

Understoreys in alpine ash forests vary with elevation, aspect, and fire history. At lower elevations the understorey is a tall stratum of blanket-leaf, hazel pomaderris, musk, and shining cassinia. Ferns, mosses, and other elements similar to those of the more luxuriant mountain ash forests form a lower stratum. In some places the understorey is a sward of austral snow grass with a few scattered shrubs. A shrubby understorey in which silver wattle, early hickory wattle, hop bitter-pea, and elderberry panax are most common is typical at high elevations. In the east Gippsland highlands there are some dense shrubby understoreys consisting mainly of waratah, prickly coprosma, and mountain pepper.

Growth

Vigorous dense forests of alpine ash grow about 280 cu ft of wood per acre in a year. The tallest trees on favourable sites may be 130 ft high at 30 years of age, and 180 ft at 70 years. All trees in a typical area of alpine ash forest are usually of the one age. They have their origin as seedlings germinating from the very small seeds of the previous crop scattered on the ground after a fire.

The mature trees produce a crop of seed each year. The process of budding, flowering, and development of the seed extends over three or four years. It begins in the axils of the leaves with the formation of buds which take two years to develop into clusters of flower buds ready to open. The seed is mature one year after flowering, but it is not usually shed until two years after, unless the trees are affected by a forest fire. The heaviest crops of seed are produced by trees which have large crowns in dominant positions in the canopy. The capacity of a forest to produce seed increases sevenfold as it grows from 50 years of age to 100 years. Stands on northern and western aspects produce almost twice as much seed as similar stands on southern and eastern aspects, and as many as six million seeds per acre may be produced in a single flowering season.

Insects use alpine ash seeds as food. A species of lygaeid bug and various small black ants are known to take large quantities of the seeds that fall to the ground.

Success of the seed crop in producing seedlings depends very largely on the condition of the ground surface. The seeds need conditions favourable to rapid development after germination because they contain only very small stores of food for the germinating seedlings, and the seedlings must develop strong root systems in the short time available before the surface soil dries in summer. A bare seed bed of loose soil exposed during logging, or by subsequent cultivation, or by burning the debris after logging is ideal. Weather conditions which favour rapid early growth are required for the seedlings to become established in sufficient numbers to restock the forest.

Seedlings grow most rapidly on a bed of ashes left by a hot fire, where the supply of nutrients is good and there are no weeds to shade the seedlings or compete with them for nutrients and water. Hot fires in logging debris in late summer and autumn produce very good seed beds. Fires in the spring allow a period of growth for shrubs, herbs, and grasses during the summer before the alpine ash seeds are able to germinate. Most of these will germinate only after they have been in cold moist conditions for some weeks, as in the mountains during the late autumn, winter, and spring. The main period of germination is October and November, shortly after the snow thaws.

Spring frosts may kill some alpine ash seedlings. Frost lifts the surface layers of moist loose soils on shaded slopes and in the shade of stumps, shrubs, and mounds of soil, and damages the seedlings by stripping the roots. In late spring there is a rapid change in conditions in the seedbed. The sun heats the ground and soil temperatures may rise as high as 160° F., killing the tissues in the seedling stems.

As seedlings enter their first winter they are subject to damage by snow and are affected by water from melting snow. This water may saturate the internal tissues of the leaves and kill them. Mortality due to this cause is least among seedlings growing on ash beds because they develop a thicker waterproof layer of waxy material on the leaf surfaces. The more robust seedlings on ash beds are also less prone to be pushed down to the saturated soil surface by the snow. Crops of young saplings of alpine ash are commonly very dense. At 5 years they may have 5,000 trees per acre. The numbers decline naturally at a steady rate, and 400 per acre is typical at 30 years.

Wild fire in alpine ash forests causes very serious damage. Although there is thick fibrous bark on the lower trunk of the alpine ash, the upper trunk and branches are poorly protected by thin bark and the trees are killed by severe fires.

Large populations of leaf-eating insects occasionally develop in alpine ash. Plagues of phasmatids defoliate large areas. The insects are widespread in the central highlands and north-eastern Victoria. The mountain ash forests also are attacked by phasmatids. Defoliations by phasmatids have caused many trees to die of starvation. Reserves of starch in the sapwood of the trees are depleted during the period of rapid growth in spring and summer, and if the trees are defoliated in two successive summers the crowns cannot produce enough starch to sustain them during the following spring. Saw-flies occasionally cause severe damage to the crowns of alpine ash and other eucalypts.

Mountain ash forests

There are larger, more continuous areas of mountain ash forests than of alpine ash, and they are more variable, with more complex structures.

Mountain ash forests in the central and eastern highlands and the southern uplands are on deep well-drained loamy soils derived from granites and sedimentary rocks. Well known locations of mountain ash forest are in the Yarra River valley, the Acheron River valley and at Noojee, Tanjil Bren, Erica, Kallista, and Beech Forest. They require a cool moist mountain climate, and grow best between 1,000 and 3,000 ft in areas where the annual rainfall exceeds 45 inches. At the lower elevations they are confined to damp southerly aspects.

The mountain forests of eastern Gippsland are located on the plateau and adjoining ranges of Mt Ellery. They consist mainly of shining gum with small areas of mountain ash and alpine ash. On the Goonmirk Range there is a mossy rain forest thicket comprising mountain pepper, waratah, and Christmas bush, above which mountain plum-pine rises to a height of 35 ft. This localised community appears to require a fire-free environment and to be in cloud for much of the year.

Composition

Typical mature mountain ash forest is a dense stand of trees of uniform age, over 200 ft high. All the dominant trees are mountain ash, and there are three distinct strata beneath them.

Under the high canopy of mountain ash trees there is an intermediate stratum of shade-tolerant trees about 100 ft tall. Blackwood and myrtle beech predominate in the cool moist gullies, and in a few places there are stands of southern sassafras. Silver wattles are numerous on the gentle lower slopes, especially where there are openings in the mountain ash canopy.

A dense mixed stratum of small trees and shrubs, mainly hazel pomaderris, prickly coprosma, musk, blanket-leaf, austral mulberry, sweet pittosporum, common cassinia, Christmas bush, and soft and rough tree-ferns occupies the lower levels up to 50 ft. The ground layer comprises wiregrass, smooth nettle, bracken, and other plants that tolerate the shady damp conditions at the forest floor. Tecoma and clematis climb from the ground into the crowns of the trees of the intermediate stratum. As the mountain ash canopy intercepts about 30 per cent of the sunlight, and the other trees and shrubs intercept a further 65 per cent or thereabouts, usually no more than 5 per cent of full daylight can reach the ground plants or litter.

In the Otway Range there is no southern sassafras but satinwood is common. Extensive stands of blackwood have replaced mountain ash forest in the eastern and western sectors of the range following a succession of wild fires which moved in from settled lands in the north and north-west. Shining cassinia and bracken thickets, and bracken fields, occupy many ridges and slopes that have been burnt repeatedly by wild fires.

The range of conditions under which mountain ash grows is varied enough to have allowed noticeable variations to develop within the species.

Seedlings from parents at the colder higher elevations have superior resistance to frost, and they grow more slowly than seedlings from trees from lower parts of the natural range. These and other small but significant natural variations in stock from different localities enable selected nursery stock to be raised to suit particular environments.

Wild fires may cause severe damage to the mountain ash forests. Mountain ash has a thin bark, and the trees are not usually capable of recuperating after wild fires ; but the seed capsules can survive the most severe fires to open and spread seed on the ground a few days later. Very severe fires in 1939 killed large areas of mountain ash forest, and most of the existing regrowth forests originated shortly after those fires. Very mild fires appear to have led to the development of a second storey of mountain ash trees within existing forests in some situations. The fires probably moved into the mountain ash forest at night, killing only understorey trees and shrubs and the weaker trees in the dominant stratum. Seedlings of mountain ash developed in this environment in time to form a second stratum.

Silver wattle and early hickory wattle germinate prolifically after fire from hard seeds which survive in the ground for many years, and they form dense stands with understoreys of bracken and shrubs. On the most exposed sites the understorey vegetation after fire is almost entirely bracken and common cassinia.

There are large areas of wattle scrub within the mountain ash forests in the central districts of Victoria. Silver wattle forms pure stands in gullies and on other sheltered sites, and hickory wattle predominates on ridges and exposed westerly aspects. The understorey plants of the mountain ash forest develop strongly under the wattle at first. When the wattle stand is 35 to 40 years old the trees reach heights of about 90 ft, and diameters of 16 inches are common. The scrub understorey plants are almost entirely suppressed.

Rain forest communities of plants are associated with the mountain ash forests in Victoria, especially in the Otway Range. They are water-loving, shade-tolerant vegetations, often dominated by myrtle beech. They occupy continuously moist and sheltered locations which are not subject to extremes of temperature. In the densest rain forest only 0.5 to 2 per cent of sunshine reaches the ground. Epiphytes and ground ferns are abundant. Eucalypts are only incidental in rain forest, and any eucalypt component in the vegetation fades away as the rain forest develops to its ultimate composition. Although the eucalypts which may occur in rain forest are the tallest trees they have a negligible effect on the habitat compared with the dense understorey of rain forest plants. Eucalypt forest does not encroach into patches of rain forest unless it is disrupted by fellings or fire.

Fauna

The dense layers of vegetation of mountain ash forests provide a variety of habitats for animals and birds. Crowns of tall trees provide food and shelter for the greater glider, sugar gliders, and fluffy gliders.

Hollows and branches of the smaller trees are nesting places for the ringtail possum and the brushtail. These possums feed on the crowns of the trees. Mountain possums feed on the ground and nest in hollow logs. Mountain ash regrowth forests, silver wattle, and shining gum stands are the habitat of Leadbeater's possum.

Swainson's phascogale shelters near the ground and seeks its prey among litter and low vegetation. Potoroos eat herbage, roots, tubers, and other vegetable food, and build nests in the low vegetation. Long-eared bats shelter in hollows in tree trunks and feed on flying insects. Hollow logs in rain forest within the mountain ash forests provide shelter for the tiger cat. Wombats burrow into the soft earth and sometimes shelter in hollows in logs and the butts of large trees. Black-tailed wallabies feed and shelter in thickets throughout the forest. Southern bush rats favour bracken scrubs in and adjacent to eucalypt and wattle stands where their preferred food is thin-stemmed grasses.

There is a similar range of bird habitats and foods, from the harvest of flying insects by swifts and swallows above the canopy, to the lyrebird's food and nesting sites amongst the dense undergrowth. The lyrebird is common throughout large areas of the ash forests and other forest types in the highlands. It is a special attraction to visitors in the Sherbrooke Forest.

The spotted pardalote and white-naped honeyeater feed in the mountain ash crowns. Shrike-tits seek their food under loose bark on the limbs, and white-throated tree-creepers on the tree trunks. Satin flycatchers and grey fantails catch insects in the air below the crowns of the trees. Brown thornbills find food in the crowns of the undergrowth, and the scrub-wren in the low ground cover.

Growth

Young mountain ash forests grow very rapidly. Saplings are 20 ft high within four years, and 50 ft by the time they are 10 years old. They are commonly 100 ft high at 20 years and even 150 ft on the very best sites. Thereafter height growth tapers off; at 60 years the tallest trees reach about 180 ft. An acre of forest of average quality has the capacity to produce 400 cu ft of wood a year; but in untended stands the poorer trees decline and die so that at 60 years the volume of living trees is about 19,000 cu ft per acre.

Foresters thin young mountain forests to harvest the wood which would be lost through mortality and to ensure that the productive capacity of the site is used by vigorous well-formed trees. Trees respond to thinning by development of their root networks and rapid expansion of their crowns. A thinning at 30 years to harvest the timber in the suppressed trees yields about 4,000 cu ft per acre; a second thinning at 50 years yields about 6,000 cu ft; and the stand will then grow vigorously, carrying about 13,000 cu ft per acre at 60 years of age.

Natural regeneration of mountain ash is not so densely stocked as alpine ash. Although there may be as many as 30,000 seedlings to the acre at the end of the first season, their numbers diminish rapidly during the next few years. After 5 years the stocking is about 3,000 ; at 30 years of age it is 200 ; and by the time the stand is 180 years old competition and suppression reduce the number to about 30 trees to the acre.

Young mountain ash trees shed their lower branches, as do most eucalypts growing in forest stands, producing clear smooth boles. Small limbs at the base of the crown die early, and a brittle zone forms near the base of the dead branch which soon breaks off leaving a stub. A second fracture develops across the base of the brittle zone and the stub is ejected from its socket as the diameter of the trunk increases. The wound grows over. In less dense stands, branches are thicker and many stubs persist in the trunks of the trees. Pockets of decayed wood form at the bases of the stubs, later extending into the wood of the trunk.

In the process of such rapid growth, with the suppressed trees dying and branches, leaves, and bark being shed, the forest produces a large quantity of litter. The dry weight of the annual litterfall in young stands exceeds 6,000 lb per acre, and it increases to about 7,300 lb at 45 years and thereafter. Less litter accumulates than in some stringybark forests because of its faster decomposition on the damp forest floor.

Natural regeneration of the mountain ash forest is achieved by the germination of seeds of mountain ash and acacias and some other understorey species, and by the regrowth of others from tubers, rhizomes, and bulbs. The seed crop of mountain ash, the dominant tree species, reaches only about 100,000 seeds per acre per year and is very variable. Seeds do not accumulate in the forest litter, and more than three quarters of the seeds which are shed by the trees are gathered from the ground by black ants and other insects. Successful regeneration of mountain ash must await a severe fire, or timber harvesting accompanied by preparation of a seed bed that will be suitable for the germination of seed from natural seedfall or from broadcast or aerial sowings. Exposed mineral soil is a favourable seed bed. The most favourable seed bed is produced by the effects of high temperatures and ashes deposited on the soil during the burning of accumulations of logging debris.

Flower buds of mountain ash develop for nearly two years before flowering, and the seed takes one year to mature after pollination. A seed capsule contains only two or three viable seeds. Capsules usually open during the late summer and autumn, shedding the seeds within a distance roughly equivalent to half the height of the parent tree, although some capsules fall from the tree without opening to release the seeds. Mountain ash seeds germinate late in the first autumn after they fall.

Seedlings of mountain ash cannot survive under the shade of other trees. Many die because there is insufficient light to support the level of photosynthesis required in their leaf tissues to sustain them. They are attacked by fungi which flourish in the dark humid conditions.

Reforestation of wattle and scrub areas with eucalypts requires spraying with hormone herbicides to kill the weed crop, followed about 9 months later by smashing down the dead trees and shrubs with an angledozer and then burning the debris to prepare receptive, weed-free seed beds for sowing with mountain ash, alpine ash, and other valuable eucalypt species.

Some areas of mountain ash forest have been established by planting.

The trees have developed very well in regularly spaced rows. One small area in south Gippsland has already been thinned, producing a large yield of pulpwood.

Stringybark forests

The stringybark forests do not match the grandeur of the mountain forests, but they produce a large proportion of the timber used in Victoria and have done so for many years. They are rich in shrubs and wild-flowers, and they provide a very large area of varied habitats for native animals and birds. Many of them protect the water catchments that supply domestic water to Victorian towns. The general term, stringybark forests, is used here to denote the numerous forest types in which various stringybark eucalypts and associated species occur. They include mixtures of stringybarks, peppermints, and gums, and also pure stands and mixtures of silvertop ash.

These forests are the most extensive of Victorian forest types. They comprise practically all the timbered country on the coastal plains and in the foothills north and south of the Dividing Range up to elevations of 3,000 ft. They also occupy parts of the Grampians and hilly western extensions of the Dividing Range, such as the Southern Pyrenees and Mt Cole.

Most of the stringybark forests are within the 25 to 40 inch rainfall zone, but the conditions of climate and soils where they flourish vary greatly. The inland soils are mainly loams derived from sedimentary rocks, and on the coastal plains they are mainly sands and gravels. There are extensive areas of these forests on shallow soils and steep slopes of the ranges and foothills.

The eucalypts which comprise these forests are described by names which refer to the distinct forms of bark on the trunks and large limbs of the trees.

A stringy bark consists of long-fibred strands. It may be pulled from the tree trunks in long strips. The peppermint bark consists of shorter strands with a fine interlaced appearance. Gum barks are smooth almost to the bases of the trees, and they are shed in ribbons or flakes. Silvertop ash is named for the white smooth bark of the upper branches, which contrasts sharply with the rough dark deeply-furrowed bark of the trunk.

The composition of the stringybark forests varies greatly from place to place. Sometimes localised patterns of different compositions follow the ridge and gully system of the terrain, drainage differences between sites, and the distribution of neighbouring soil types. Pure or almost pure stands of one overwood species can occur in patches or tongues which reflect such site differences. Changes in the composition of the overwood and understorey up long mountain slopes are sometimes related closely to elevation.

Messmate stringybark occurs on nearly all classes of country in the mixed forests, but is scarce in the mountains east of the King River in north-eastern Victoria. Mature trees of messmate have long trunks and rounded branching crowns. They attain diameters of 5 to 7 ft and heights of 160 to 200 ft on deep soils in the wet mountains. The many different associations of trees and shrubs which occur within this wide and extensive range of habitats are described by reference to the main geographical zones of the Midlands, the Otway Range, the Grampians, eastern Gippsland, the southern foothills, the north-eastern foothills and ranges, and several other small localities.

Growth

Well-stocked young stands of stringybarks, gums, or silvertop ash grow vigorously. Typical old-growth stringybark forest is not well stocked with vigorous trees, however, and the old trees grow slowly. There is a greater variety of sizes and ages of trees in these forests than in the alpine ash and mountain ash, and mixtures of trees of all ages from veterans over 200 years of age to new seedlings may be observed in places.

When fire, grazing animals, insects, or drought defoliate, kill, or badly damage eucalypt seedlings of these forests, new shoots grow from specialised woody structures known as lignotubers, which contain many dormant buds and a store of carbohydrates. They develop early in the life of seedlings of all eucalypt species in the mixed forests, and they enable these eucalypts to survive in harsh environments. The buds in the buried lower folds of a lignotuber survive the most intense fires. A crop of seedlings, each with the capacity to regenerate in this way after severe damage, constitutes a reserve from which the forest can recover if the overwood is killed or removed. Mountain ash and alpine ash do not have this means of survival.

As a rule numerous seedlings of stringybarks and associated species of the forests on moist fertile sites will occupy any gaps made by fellings. In the mountains and wet foothills, gaps and clearings in the forest are also quickly occupied by dense growths of acacias and other small trees and shrubs which compete strongly with the eucalypts. Eucalypts of the stringybark forests regenerate readily also by the growth of coppice shoots from the stumps of felled trees.

Messmate and silvertop ash saplings on favourable sites grow rapidly until they reach heights of about 50 ft. The rate of height growth then declines and the crowns of the trees become rounded and flatter on top. Other stringybarks and associated species grow less rapidly. On very poor dry sites the growth rate declines after the trees are 10 ft high.

Fire

Some of the stringybark forests in Victoria are among the most inflammable timberlands in the world. They shed great quantities of bark, large branches, branchlets, and leaves, which accumulate on the forest floor. Fine materials in this litter dry out rapidly after rain and during periods of low relative humidity. Fire will spread quickly in such heavy accumulations of fine fuel and high flames scorch the crowns of mature trees. Flames run up the trunks of stringybark trees into their crowns, and burning pieces of bark blow off and ignite spot fires ahead of the fire on the ground. Tubular ribbons of candlebark, especially those hanging from the trees, are borne aloft in the updraft of forest fires. They have been observed at 11,000 ft above an intense fire, and have been known to cause spot fires 18 miles from the original fire. The intensity of forest fires is influenced strongly by the quantity of fuel on the ground. Stringybark forests commonly accumulate as much as 20 tons of litter per acre and a vigorous dense stringybark forest of mature trees may have 100 tons per acre.

Cool controlled fires can be used to reduce the quantity of fuel, especially the fine materials which create the most serious hazard, without damaging the dominant trees of the forests. Fire for this purpose is controlled by igniting at a time and to a pattern determined by measurements of the quantites of fuel and observations of weather conditions. After a controlled fire the process of accumulation begins again at a rate of about one ton per acre per year. The intensity and rate of spread of fires increases fourfold as the amount of fine fuel increases from three tons to nine tons per acre. A stringybark forest made safe against fire by a controlled fire can accumulate sufficient fuel in the next four to six years to make fire fighting very difficult and dangerous, and the intensity of wild fires severe and damaging.

Any more than three tons of fuel per acre may burn on a summer day of moderate fire danger with an intensity of 100 British Thermal Units (B.T.U.) of heat per second per foot of fire edge. A fire of this intensity can kill foliage up to 60 ft above the flames. When the intensity exceeds 200 B.T.U. all the foliage on the tallest trees is killed, but the trees are seldom killed and they recuperate strongly from dormant buds in the branches and trunk. The feathery epicormic shoots which develop from these buds are characteristic of these forests after wild fires. Fire induces the formation of veins and pockets of gum in the new wood, and where the growing tissues of the wood have been killed, insects and decay fungi invade the tissues of the tree, leading to loss of vigour and to inferior timber quality.

Fauna

Stringybark forests are natural habitats of diverse populations of native birds and animals. The forests provide food, shelter, concealment from predators, and sites and materials for nesting. Leaves, flowers, fruits, seeds, and nectar of plants are food for many species and the insects, reptiles, and other animals which feed on them are themselves sources of food for other species. Worms, crustaceans, insects, and other animals in the soil are also important food sources. Undergrowths of silver wattle, blackwood, shining cassinia, leguminous shrubs, and bracken in gullies in the inland forests provide food and shelter for brown thornbills, blue and scrub-wrens, silver eyes, grey fantails, scarlet and yellow robins, grey thrushes, and red-browed finches.

The crowns of the stringybarks, gums, and peppermints produce foliage, flowers, fruits, and insect populations which are the food of crimson rosellas, striated thornbills, white-naped and yellow-faced honeyeaters, and golden whistlers. Moist gullies of the stringybark forests are the summer habitat of the satin flycatcher and the rufous fantail, while grassy ridges under broad-leaved and narrow-leaved peppermints are frequented by spotted quail-thrushes. Seeds of acacias are used as food by the bronze-winged pigeon and insects in the bark of trees are the food of orange-winged sittellas and white-throated tree-creepers.

The food plants of birds and animals regenerate abundantly from seed after fires, but if one fire follows another at an interval of less than 4 years some of the species of plants fail to regenerate and shrubs are replaced by herbs and tussock grasses. When this happens quail-thrushes and buff-tailed thornbills, which prefer grassy understoreys, may replace brown thornbills and scrub-wrens, which prefer scrubby understoreys. Shrubs may also die out under a forest canopy if a long period of years passes without any fire.

Some bird species range widely over the stringybark forests. White-winged choughs, grey currawongs, and black-faced cuckoo-shrikes inhabit many areas, and the pallid cuckoo and fantail cuckoo are seen in numerous localities in the summer. Dusky wood-swallows also inhabit these forests in the summer and the flame robin finds a warm winter habitat in them. Three nocturnal birds, the boobook owl, barn owl, and tawny frogmouth, may be found in them at any time of the year. Flowers of trees and shrubs are the food source of many birds characteristic of the stringybark forest. Nectar in eucalypt flowers attracts the swift parrot, crimson rosella, and the musk, purple-crowned, and little lorikeets. Banksia and melaleuca undergrowths in the coastal and western forests support large populations of eastern spinebills, white-eared honeyeaters, and yellow-winged honeyeaters. Seeds of banksias and casuarinas are eaten by yellow-tailed black cockatoos.

The wetter messmate stringybark forests in the hills below mountain ash forest provide habitats for pied currawongs, gang-gang cockatoos, and mountain thrushes. The rufous bristle bird is confined to coastal habitats from Nelson to Torquay except for an inland extension into the Otway Range. Lyrebirds are common east of Port Phillip Bay and their populations are adapted to the fire environment of the mixed forests. Many lyrebirds survived an intense wild fire that burnt 300,000 acres of Gippsland forests in 1965 and within 2 years the birds were common throughout the burnt areas. Lyrebirds thrive where there is a mosaic of unburnt and recently burnt patches of forest, the latter providing an abundance of food for them.

The different foods and habitats of the various forms of the stringybark forests also support various species of mammals. Thickets of acacias and other leguminous shrubs are favoured by the black-tailed wallaby, and grey kangaroos are found in open grassy areas. The red-necked wallaby also lives in woodlands of banksia and heaths associated with the stringybark forests, as do the pygmy possum, feather-tailed glider, and the short-nosed bandicoot.

Midlands stringybark forests

The northern and southern slopes of the Great Dividing Range from Ararat in the west to the Kilmore Gap just north of Melbourne form a distinct zone in which the stringybark forests are characterised by pure stands of messmate stringybark on sheltered aspects on the most favourable soils. Forests of messmate in mixture with manna gum, candlebark, and narrow-leaved peppermint are the most extensive in the region ; red stringybark, scent bark, and broad-leaved peppermint occur on the dry slopes. Blue gum and mountain grey gum occur along some of the streams flowing south from the Range.

Mining activity on the Ballarat and other goldfields in this region required very large quantities of mining timbers, mill logs, and fuel wood from these forests. Sawlogs and fuel were in demand again early in this century and the forests have been in use ever since, under more and more intensive management until the present day. After many years of production these forests are still in fine condition, well stocked with vigorous trees, growing mill logs, poles, and pulpwood. Growth is small compared with mountain ash, seldom exceeding 50 cu ft of eucalypt wood per acre per year, but it has supported several important local industries for many years.

Selective fellings in these forests have had the advantage of removing the oldest trees, the less vigorous, and least valuable, thus giving growing space to the better trees. The seedlings under the main canopy have developed slowly, staying in the lignotuber stage for many years until released by the formation of substantial openings. Restricted areas of the forests have a very uniform appearance. Small short trees and the less valuable of the dominant trees have been removed, leaving evenly spaced stands of good trees of uniform size. Growth of these will continue until all are ready for harvesting, after which the whole stand will be regenerated.

Grampians forests

Forests of brown stringybark, messmate stringybark, and long-leaved box with a continuous heathy understorey up to 4 ft tall form the most extensive communities in the Grampians. They occupy the sandstone ridges and the outwash slopes. The forest is generally less than 60 ft high but the eucalypts reach 120 ft on a few favourable sites where the soil is deeper and moister. Messmate stringybark and scent bark grow on drier sites, with the Grampians thryptomene in rocky areas, and heath woodlands of brown stringybark and messmate stringybark in mixture with scent bark and some peppermint on the flatter wetter sites. A native conifer, the Oyster Bay pine, occurs on some of the exposed ridges.

The tallest forests of the Grampians are found above 2,000 ft on the sheltered slopes of major gullies, and on moist sites in deep red soils in deeply recessed ravines on the easterly and southerly aspects down to 1,500 ft elevation. They attain heights of 150 ft and the dominant trees are mountain grey gum, messmate stringybark, and some brown stringybark. The understorey plants are pomaderris, blackwood, common cassinia, common correa, Christmas bush, native hibiscus, soft tree-fern, and other ferns.

The western slopes of the sandstone ridges are occupied by stunted forests of long-leaved box and brown stringybark with dry scrubs of the endemic Grampians gum which develops best on sheltered scarp faces. Shiny tea-tree, Grampians fringe-myrtle, and heaths up to 3 ft tall occur where the soil is too shallow and dry to support trees. Wet scrubs of cross-leaf honey-myrtle up to 12 ft tall occur along the banks of sluggish drainage lines and headwater streams of the Wannon and Glenelg Rivers. Tall shrub woodlands of yellow box and yellow gum dominate associations with manna gum and river red gum in some of the valleys. Yellow box is generally found on shallower soils than is yellow gum.

Swamp gum in mixture with messmate stringybark and manna gum, over a heathy understorey in which prickly tea-tree and honey-myrtles are common, is found along watercourses low down the slopes and in several valleys. In the Victoria Valley there is shrub woodland dominated by river red gum with yellow box in which the most common shrubs are black wattle, blackwood, and silver banksia which grow as trees up to 25 ft tall on the most fertile sites. A similar woodland occupies the Moora Valley. A distinct community of yellow box and black wattle forms a narrow transition zone between the stringybark forests and heath woodlands along the lower margins of outwash slopes.

Understoreys and heathland are rich in plants of the legume, myrtle, protead, lily, and orchid families. In no other part of Victoria is the common heath, the floral emblem of the State, so abundant and conspicuous.

Grey kangaroos and red-necked wallabies inhabit the Grampians and there are a few rock wallabies. Koalas are established in two colonies. Echidna, platypus, short-nosed bandicoot, and ringtail and silver grey possums are common, and more than 140 species of native birds have been recorded. Two introduced animals, the samba and red deer, are becoming more numerous in the Victoria and Wartook valleys. Foxes and rabbits are plentiful, while black, brown, and tiger snakes, and blue-tongue lizards are common.

East Gippsland forests

A distinctive feature of east Gippsland vegetation is the great range and variety of its plant communities. About half the State's complement of eucalypts and acacias grow there, and the forests are rich in ferns and mosses.

The composition of the dry lowland forests east of the Mitchell River varies with drainage, clay content of the soil, altitude, and aspect and terrain. In places as many as six species of eucalypt may be found in mixture within a few dozen acres of forest. Undergrowth consists of small leaved leguminous and proteaceous shrubs, chiefly acacias, bitter-pea, flat pea, banksia, hakea, and narrow-leaf geebung. Bracken is common in some places. Stands of silvertop ash and white stringybark occur on well drained ridges of granites, slates, and other sedimentary rocks. Red bloodwood and rough-barked apple occur in mixture with the silvertop ash and stringybarks in the extreme east.

White stringybark, southern mahogany, and yertchuk, with a lower storey of saw banksia, form another dry forest association on humus podsols over deep sands. Yellow stringybark and southern mahogany predominate on well drained clayey soils. Red ironbark occurs in some of the mountain grey gum and messmate stringybark associations, and on well drained ridges it predominates. Dry woodlands of white stringybark and southern mahogany, with banksia, shrubs, and bracken, occupy the poor soils on exposed sites near the coast.

Lowland woodlands on limestone near Buchan consist of manna gum and yellow box with an understorey of scattered shrubs and tussock grasses. Red stringybark, red box, and long-leaved box woodlands with a scattered undergrowth of shining cassinia and daphne heath and other shrubs occur on shallow soils on sandstone.

Where the annual rainfall exceeds 40 inches, and on very sheltered sites where the average rainfall is less, a wet form of lowland forest has developed, up to 200 ft tall on the best soil, comprising mountain grey gum, southern mahogany, and yellow stringybark with a dense understorey of hazel pomaderris and blanket-leaf, shrubs, and ferns. In the foothills there are wet forests of blue gum, brownbarrel, and river peppermint. Many of these wet eucalypt forests abut the rain forest into which they encroach following fires and in some places mature eucalypts overtop a mature lilly pilly stand.

Where sedimentary ridges run into black sands and alluvium along the coast there is a mosaic of mixed forests in which silvertop ash and white stringybark are the major trees. Messmate stringybark and mountain grey gum occupy some of the gullies, and on poorly drained sites yertchuk and mealy stringybark replace the silvertop ash and stringybarks. Stands on the ridges attain heights of 100 ft, but generally the forest is short, especially near the coast where the stunted trees seldom exceed 30 ft. Flat timbered ridges, gullies, and poorly drained sites are bordered by treeless swamps, many of which carry thickets of scented paperbark.

Understorey shrubs include sunshine wattle, golden and silver wattles, flax acacia, blanket-leaf, musk, prickly coprosma, gorse bitter-pea, hop goodenia, hop bush, and narrow-leaf geebung. Soft tree-fern, hard water-fern, coral fern, and bracken are common on wetter sites.

Coastal jungles in east Gippsland are patches of warm temperate rain forest with a dense canopy in which blackwood is often co-dominant with lilly pilly. Other trees which flourish in damp dark forest are kanooka, black oliveberry, yellow-wood, and sweet pittosporum. Up to five species of tree fern occur in some stands; many species of ropey lianes, ferny epiphytes, ferns, and mosses thrive in these shady sheltered communities. Cabbage fan palms up to 70 ft tall occur in rain forest near Marlo. Coastal rain forest reaches a height of more than 90 ft on rich alluvial loams and on friable soils on protected southern slopes.

At elevations above about 1,500 ft the lilly pilly forest is replaced by cool temperate rain forest of southern sassafras in which black oliveberry, mountain pepper, waratah, and blackwood are also abundant. Banyalla occurs in place of sweet pittosporum and, in contrast to rain forests in the southern uplands, there is no myrtle beech. Soft tree-fern is the main tall fern, and mosses are thick on tree trunks, fallen logs, and on rocks.

Otway Range forests

Growth is rapid and luxuriant in the wet forests of messmate stringybark, blue gum, manna gum, and mountain grey gum on the deep soils of the main ridge and elevated gullies and southern spurs of the Otway Range. The dense understorey is dominated by satinwood and acacias, hazel pomaderris, blanket-leaf, hop goodenia, bracken, and other ferns. High mats of wiregrass develop after fires and logging. Stands of blackwood and myrtle beech in which soft tree-fern, skirted tree-fern, and numbers of epiphytic and ground ferns thrive, occupy all the wetter gullies.

Drier foothills on the north of this coastal range support forests composed mainly of messmate stringybark, brown stringybark, narrow-leaved peppermint, and manna gum from 60 to 130 ft tall and an undergrowth dominated by leguminous and proteaceous shrubs. On the northern flanks the mixed species eucalypt forest runs into wet mallee heath, the tallest member of which is the small and often scrubby shining peppermint. The mixed forest and the mallee heath are bounded by treeless wet heath or grass-tree plains.

Foothills of the Dividing Range

On moist favourable sites in the southern foothills east of Melbourne messmate and manna gum form a tall forest below the mountain forests with mountain grey gum and narrow-leaved peppermint in the dominant stratum, and tall silver wattle and shining cassinia in the understorey. At lower elevations in the foothills silvertop ash is prominent in the mixture of dominant species. Messmate forests with manna gum and candlebark extend eastward into the high elevations.

There are forests of yellow stringybark, white stringybark, candlebark, and red ironbark across the foothills of northern Gippsland where the rainfall is low due to ranges of mountains to the south and west; and red stringybark, red box, and yellow box with a very sparse understorey of austral snow grass occupy the lower hills.

Narrow-leaved peppermint is widespread in the northern foothills. It is a dominant tree with blue gum, candlebark, and silver wattle on deep gully soils and on southern and eastern aspects, and with long-leaved box and red stringybark on dry ridges. Tall messmate forest occupies the best sites. Broad-leaved peppermint, white brittle gum, and red stringybark form a dry forest with austral snow grass on the north and western aspects.

Red gum forests

Red gum forests are the most widely distributed of all types of forest in Victoria. There are extensive pure forests of river red gum along the Murray River downstream from Cobram and along the northern reaches of its tributaries. Savannah woodlands of the river red gum also occur on the western plains, and they are common along seasonal watercourses and in drainage depressions.

Open woodlands of another species of red gum, Blakely's red gum, in which there are scattered trees of white box and long-leaved box, grow on the low rises above pure stands of river red gum on river flats in north-east Victoria. They are also found on the gentle slopes of a belt of country stretching from the Wodonga district towards Port Phillip Bay. A third species, forest red gum, forms scattered woodlands in Gippsland between Warragul and Bairnsdale. It occurs also as a riverine species in the La Trobe River valley and the lower valley of the Tambo River.

Forest red gum occurs also in the gorge of the Snowy River at various elevations up to the former level of flooding. Here the trees have huge butts and numerous small trunks that have developed after the crowns of the trees have been smashed during floods.

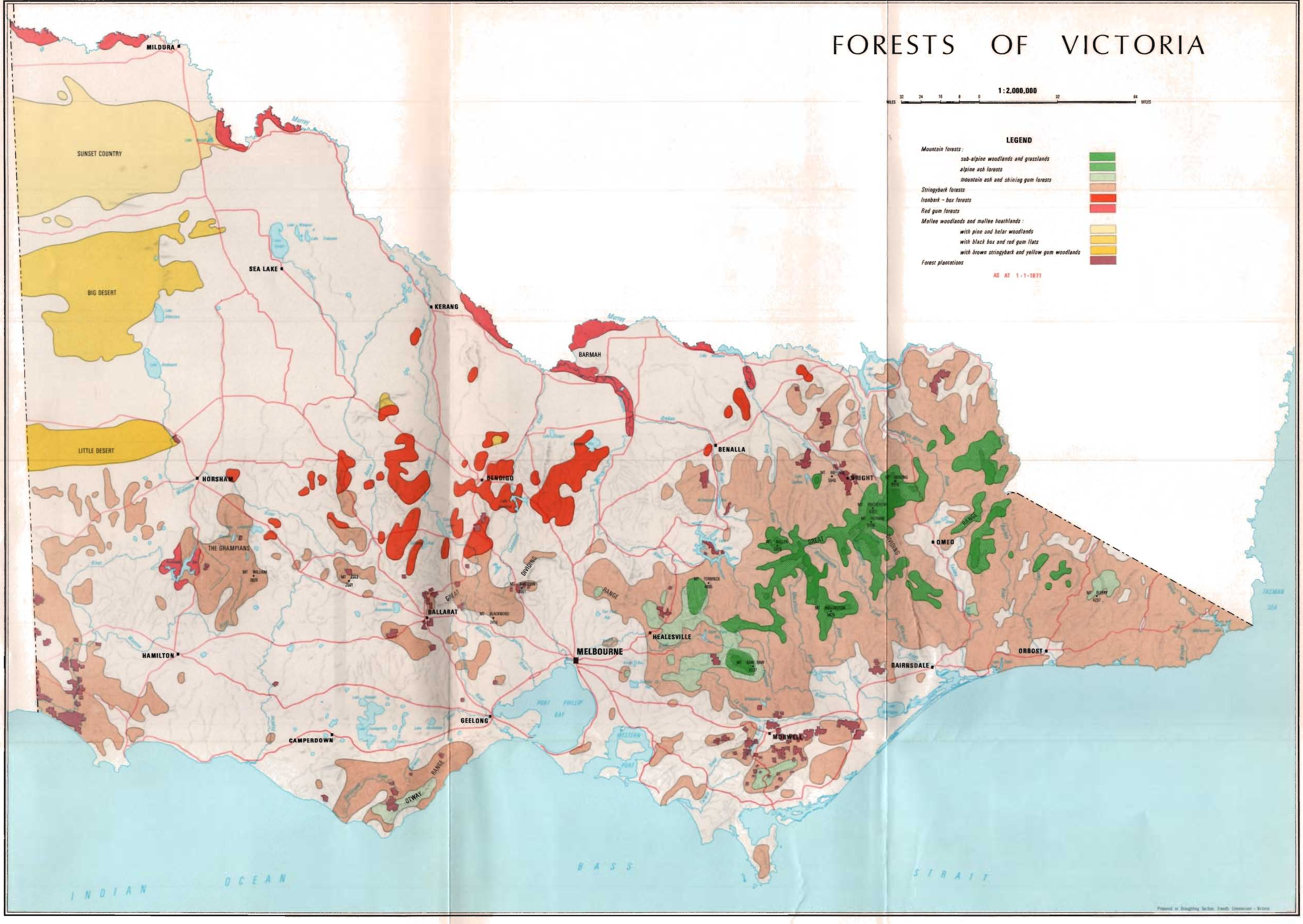
The open woodland and gentle slopes of the red gum forests are well suited for outdoor recreation. Roads and tracks are inexpensive to construct, and there are many good sites for camps and picnics. Streams and billabongs enhance the forests for those purposes, and the numerous species of birds and animals associated with the water are strong attractions. They are generally less inflammable than most forest types, having sparse undergrowth and only small amounts of litter on the ground.

Red gum timber is used for sawmilling, sleepers, posts, and piles. It is in strong demand for its strength and durability, and the appearance of its fine grain and deep red colour. The forests have supported a viable timber industry since the earliest days of settlement. Barmah forest and other red gum forests provide excellent grazing for cattle, and wild horses, sheep, and kangaroos also graze in them.

River red gum forests

Pure stands of red gum in the riverine forests follow the pattern of regular inundation in the Murray River flood plain, with some extensions

FORESTS OF VICTORIA



into sites where the subsoil receives water through sandy aquifers. The undergrowth is sparse over much of the river red gum forest. Moira grass is the main ground cover under the trees and on the treeless plains. Needle rush is the dominant species around the fringe of the flood plain and on those red gum sites that are seldom flooded.

Densely stocked areas of the forests on the best watered sites are up to 150 ft high, and the trees have long straight clear trunks. In the more open woodlands the trees develop short thick trunks and spreading crowns with several large limbs. Tongues of black box and yellow box forest occupy the sandy ridges and intrude into red gum stands on those sites where flooding is sporadic and brief. On the slightly higher ground red gum grows in pure stands or in association with black, grey, and yellow box trees.

Fauna

Red gum forests are most important areas of wildlife habitat. The Barmah forest has particular importance because of its geographical position in relation to other waterfowl areas in Australia, having become a major junction of the flyways of migratory waterfowl. Two hundred and eight species of birds have been recorded in this forest, of which fifty-six species are attracted to the area because of the water.

Water birds breed in large numbers in the Barmah forest because they find both trees and swamps there. The white-necked and white-faced herons, several species of cormorants, egrets, and spoonbills nest in colonies in the trees. Hollows in the forest trees are nesting places for the mountain duck, chestnut teal, and the maned goose. Several species of owls, parrots and rosellas, the kookaburra, sacred kingfisher, white cockatoo, galah, budgerigah, and the brown and white-throated treecreepers nest in hollows in trees.

Flooding at any season stimulates breeding of the white ibis and, at a later stage, the straw-necked ibis which is the main Australian species. The ibises depend on aquatic foods and suitable water conditions for breeding. They build their nests in cumbungi, lignum, and other low vegetation above flood level. Large breeding colonies depend on warm shallow flood waters for food. Other key ibis rookeries occur at the Kow Swamp near Gunbower, a natural marsh embanked to form an irrigation reservoir on a diversion of the Murray River, and the Kiewa Swamp.

Deeper water is used by diving ducks and cormorants, and a variety of environmental conditions provides suitable breeding places for swans, grebes, and other waterfowl. Waterfowl swamps and marshes hold great biological interest and are places of rare beauty ; in fact, red gum forests provide for many popular recreations and are situated in districts that enjoy hospitable climates.

Among the mammals of the riverine forests, the grey kangaroo, brushtail and ringtail possums, the yellow-footed and brush-tailed phascogales, and sugar glider are common. The little mastiff bat is plentiful in some places and the echidna is widely distributed throughout these forests. Eastern water-rats are abundant.

The foliage of red gum is prone to attack by several insects, notably lerp insects and larvae of the gum leaf skeletoniser moth. The crowns of the trees recover quickly by means of epicormic buds, but recovery is slow after repeated heavy attacks. A period of new growth to re-establish a vigorous leafy crown is required before a crop of flower buds can develop. The gregarious larvae of several species of saw-fly eat the leaves of eucalypts in the drier forests and woodlands. River red gum and yellow box trees are often completely defoliated.

Many insect colonies are destroyed by flooding, but seed-eating ants form colonies in trees above the high water level, and they are able to forage on the moist ground very soon after a flood recedes in the spring. The diminished frequency and extent of flooding in these forests has upset the former regime of natural control of insect populations which was effected by inundation of their habitats.

Flood waters in the river red gum forests enable crops of seedlings to develop. Ideal conditions for germination occur if the water recedes in spring, allowing the seed to germinate early on the damp soil and grow sufficiently to withstand the hot dry conditions of the summer. Huge quantities of seed fall to the ground as the capsules ripen after a heavy flowering. Mature stands produce more than 100 million seeds per acre in such a year. Much of the benefit is lost if the seed falls and germinates in cool wet weather before a flood, for the seedlings will be submerged and killed. However, the peak seed fall is usually in spring and summer, the spring peak coinciding with falls in the levels of the flood waters. Ants and other insects remove seeds from the soil, usually taking three quarters of the total seed fall and sometimes all of it, creating a major obstacle to natural regeneration.

Seedlings of river red gum develop a swelling near the base of the stem, from which new shoots may develop if the plant is injured, but they do not develop true lignotubers. They withstand long spells of dry weather by shedding most of their leaves and growing new shoots when water again becomes available.

Ironbark and box forests

Ironbark and box grow on poor soils in a region of low rainfall and hot dry summers. The main forests are mixtures of red ironbark and box eucalypts, and their local composition is largely a reflection of the fertility and water holding capacity of the soil. The soils are gravelly or sandy loams and clays, which are shallow and stony on the ridges and steeper slopes. The scars of gold mining, gravel stripping, and eroded areas are common.

The most abundant trees are grey box, red ironbark, and yellow gum, all of which produce very strong, durable dense hardwood. Red ironbark–grey box associations, usually 50 to 60 ft high, are found low down on well drained slopes. Pure patches of red ironbark occupy poor stony sites, and grey box predominates on the deeper sandy loams. Mixtures of grey box and yellow gum, up to 70 ft high, occur on broad alluvial flats and in gullies, the composition varying from pure grey box on the moister sites to almost pure yellow gum where the soil is very shallow.

Mixtures of red ironbark, red box, long-leaved box, and red stringybark occur on the poorest skeletal soils on the steeper slopes. Yellow box is most common along watercourses, and river red gum is restricted to the banks of the permanent streams and drainage lines with wetter subsoils. Occasional clumps of green mallee occur as an understorey in stands of red ironbark in the Rushworth district.

Generally, there is a sparse undergrowth of drought-resistant plants which may form three distinct layers under the eucalypt overwood. The low ground cover consists mainly of wattles, parrot-peas, bush-peas, bitter-peas, grevilleas, heaths, and several grasses. Hakea, acacia, sweet bursaria, cross-leaf honey myrtle, and shining cassinia are common in the tall shrub layer. The small tree layer consists of eucalypt coppice and seedlings, golden wattle, and occasionally, cherry ballart.

Dodder-laurel, an almost leafless parasitic twining plant, is widely spread in the central areas of the ironbark–box belt ; coppice stems, seedlings, and saplings of all the eucalypts, and most of the shrubs and other small trees, are hosts. The host plant loses vigour through direct parasitism and shading of its leaves, and eventually may die. Dodder also spreads by seed; it is a prolific seed bearer, and the seeds are eaten and spread by wallabies and other grazing animals.

Long-leaf mistletoe and other evergreen mistletoes are widespread hemiparasites of eucalypts in the ironbark–box forests where they appear as clumps of pendulous foliage in the crown. The small mistletoe bird and other species spread the sticky seeds on their beaks and feet.

These open forests, composed chiefly of trees with light crowns and persistent bark produce very small amounts of litter, less than one quarter of the weight produced by messmate stringybark forests.

There are very few eucalypt seedlings because good crops of seed are rarely produced by the mature trees, the forest floor is not favourable for germination, and the summer climate is harsh. Nearly all the viable seed shed from the trees is removed by ants and other seed harvesting insects. Small seedlings of red ironbark sometimes develop in a wet summer on fresh ash beds where wood and bark have been burned, or in pockets of loose earth washed into hollows. Few survive the soil-moisture stress and high temperatures and many are grazed by rabbits.

Ironbark–box forests are important refuges for wild life in a region of Victoria that otherwise has been largely cleared for pastures. Echidnas live throughout these forests, and the most common native mammals are ringtail and brushtail possums, the yellow-footed phascogale, the tuan, and the grey kangaroo. Squirrel gliders occur in forests where grey box predominates. The ironbark–box forests are important sources of nectar and pollen for commercial colonies of bees.

The eucalypts of the main ironbark–box belt occur in several other localities in Victoria. Yellow box is found in some of the mixed eucalypt forests in the Midlands and east Gippsland. Red ironbark occurs in pure and mixed stands in east Gippsland, near Aireys Inlet, and in the valley of the Lerderderg River. Red box and long-leaved box are widely distributed in the drier mixed forests.

Arid woodlands and heathlands

There are many distinct associations of plants and a wealth of plant species in the forests of the Murray Basin plain. The soils very largely determine the distribution of the various plant associations, and some are confined to one type of soil. Altitude varies from about 350 ft in the south to 150 ft in the centre and north, and the soils vary in texture from sands to clays. In the arid climate of this region forests have the form of low woodlands, mallee woodlands, and mallee heathlands.

Mallee woodland is a dense stand of eucalypts which have a very distinctive form characterised by several thin stems arising from a huge underground lignotuber. The stands are usually 9 to 15 ft in height, with a very sparse understorey. A stand of mallees usually contains several eucalypt species. Yorrell, oil, horned oil, yellow, red, hooked, and dumosa mallees occur throughout the region. Bull mallee is restricted to the south, capped mallee to the north-west, and black mallee box to the south-west and central west.

Yellow mallee is the most common eucalypt in mallee woodland and porcupine grass is the lower stratum. The mallee heathlands have a dense shrub layer in which mallee pine, broom heath-myrtle, broombush, and tea-trees are prominent. Yorrell predominates in those communities which have a dense understorey of salt tolerant shrubs.

In the Big Desert the irregular areas burned by wildfires have produced complex intermingled patterns of regeneration and vegetation change in pine–belah woodland, heaths, mallee woodland, and grassland. Various heaths are dominated by honeysuckle, Murray pine, slaty sheoak, and grass-trees. White cypress pine, belah, and sandalwood occur with scattered mallee eucalypts in the woodland formations. Red stringybark trees are scattered through some patches of mallee. River red gum and black box trees occur in widely distributed localities.

The sandstone rises, box flats, and sandhills of the Little Desert support shrub woodlands, shrub mallee, scrub, dwarf scrub, and heaths which are habitats for many mammals, birds, and reptiles. Wild fires have produced complex patterns of vegetation of varying composition and age. A profusion of more than 670 plant species, including many orchids, lilies, legumes, heaths, composites, and grasses contribute to the diversity of these ecosystems. Green mallee, narrow-leaved mallee, and yellow mallee are the most common eucalypts in the mallee and shrub mallee communities of the Little Desert.

Shrub woodlands dominated by yellow gum and brown stringybark are important habitats for birds and mammals. Dwarf scrub in which banksias, casuarinas, tea-trees, and grass-trees are the largest individual plants, is the last remaining refuge in Victoria for two rare birds, the samphire thornbill and rufous field-wren, which depend upon this particular habitat for shelter and food. Seed of the fringed heath-myrtle, which is abundant in the shrub mallee inhabited by the lowan or mallee fowl, is staple food for the lowan chicks as soon as they emerge from the incubating mound.

The scrub, predominantly broombush, honey-myrtle, and heath myrtle, and the shrub mallee vegetations are also specialised breeding and feeding habitats for birds. They require large areas of these native plant associations for nesting sites and territories in which to feed. Regeneration of broombush after fires provides the habitat for the western whipbird. It is found in areas of very dense waist-high broombush regrowth after recent fires, but is absent from tall stands of broombrush.

Nineteen species of native mammals and twenty-four of reptiles are known to live in the Little Desert. The south-western pigmy possum and Mitchell's hopping mouse, and three of the reptiles, the western blue-tongue lizard, the desert copperhead snake, and the desert snake are probably confined in Victoria to the Little Desert. Brushtail possums, fat-tailed dunnarts, feathertail gliders, and echidna are common. Black-faced kangaroos are also fairly common, and grey kangaroos move through the desert from time to time. Red kangaroos occur in the dry north-west corner, and red-necked wallabies and sugar gliders are found in the southern parts. Two species of bird, the red-capped robin and the crested bellbird, occasionally venture almost to Port Phillip Bay, by way of the Whipstick mallee near Bendigo, a forest of bull mallee near Bacchus Marsh, and callitris in the You Yangs.

Forest plantations

Species

The area of forest plantations in Victoria is approaching 250,000 acres. Most are softwood plantations established because of the very successful growth of a few introduced species of conifer in earlier years and the need to establish a supply of locally grown commercial softwood timber in the State. Forests of the native conifers, the Murray pine and the mountain plum-pine, were small in area, and only the Murray pine could contribute to any extent to the timber needs. Many species of pine were introduced and used in the search for a suitable tree for Australian conditions. It became apparent in time that the trees which grew naturally in environments that were similar to the messmate stringybark forests were most suited for Victoria.

Radiata pine is pre-eminent as a plantation species for softwood timber production in south-eastern Australia and Western Australia. It is by far the most widely planted and most productive species in Victorian forest plantations. Small areas of Corsican pine have been included in most plantations, and maritime pine is used on light sandy soils in some areas. On very good soils Douglas fir has been planted in limited areas adjacent to the radiata pine. Ponderosa pine was tried extensively, but it grew poorly. Mountain ash is the only native species that has been used extensively as a plantation tree.

Young forests planted since 1960 comprise more than half the area of coniferous plantations, and a large area was planted between 1925 and 1940.

Radiata pine

Distribution

Plantations of radiata pine flourish on sites which once supported brown stringybark and messmate stringybark forests in western Victoria, various stringybark forests in the north-east and Midlands, and mountain ash forest in the Otway Range, and west and south Gippsland. In districts where there are long hot spells in summer, an annual rainfall of at least 30 inches is required for it to grow as a commercial timber crop. Radiata pine thrives on suitable sites from sea level to about 3,000 ft elevation, but at higher elevations it is prone to snow damage on steep slopes, especially by heavy falls of wet snow which break the crowns.

Strains and variability

Radiata pine is a native of small forests at Point Año Nuevo, Monterey, and Cambria in California, and on Guadalupe and Cedros Islands near the Mexican coast. The Point Año Nuevo and Monterey strains are more suitable for plantations because they grow rapidly for some months after each burst of spring growth.

Radiata pine is a highly variable species. Trees in forest plantations vary in the vigour, shape, and density of their crowns, the number of whorls of branches produced each year, the length of trunk between whorls, the number and thickness of branches and their angle to the trunk, the number of cones formed on the trunk, the straightness and taper of the trunk, and the density of the wood. The wood in most trunks is essentially straight grained but in some it is spiral grained. Seasonal patterns of growth also are inherently variable.

Improved strains of radiata pine for plantation forestry can be developed by systematic selection and breeding. The quality of plantations for timber production can be raised by using seed collected from straight vigorous trees. Families of superior trees can be established with cuttings and grafted seedlings. Controlled cross-fertilisation in breeding arboreta produces superior seed.

Nutrition and soils

Radiata pine tolerates an acid soil well, except where the high acidity results from poor drainage, excessive exchangeable aluminium in the soil, or a low calcium : magnesium ratio. The species has a low tolerance to waterlogging, particularly in heavy clay soils and where there is a perched water table.

Forests of radiata pine remain healthy and vigorous on well drained sites provided soil moisture deficits in spring and summer are slight and the high demand for nutrients is satisfied. The deep coastal sands in western Victoria are deficient in zinc and phosphorus. Young pines are sprayed once with a solution of zinc sulphate to remedy zinc deficiency throughout their life. Zinc deficiency is rare in eastern Victoria. Symptoms of deficiency may show up on soils derived from igneous rocks or strata influenced by igneous activity.

Pines planted in the ash where debris has been consumed by intense fire grow much faster than nearby pines on unburnt areas. Improved availability of soil nutrients and moisture, and partial sterilisation of the soil appear to be contributing causes of the accelerated growth. Some soils in Victoria have supported three successive crops of vigorous radiata pine, but very light sandy soils are suspected of declining in fertility after pine forests have been grown on them and harvested.

The litter-soil zone in a pine plantation is a complex community. Its character alters as the stand develops. The ground between the small trees in a new plantation is covered by grasses and herbs, and a few woody plants. As the pines grow and their crowns form a closed canopy, a litter of needles accumulates and nearly all the understorey plants die out. The loose layer of litter insulates the soil against fluctuations in temperature and moisture. Soils under thick mats of pine needles change progressively ; there are complex differences between the soil under pines and those under native forest. Under pines they contain less organic matter and nitrogen ; the amounts of soluble salts and phosphorus are less ; and the cation exchange capacity is lower. Litter locks up large amounts of nutrients and their return to the soil is slow. Slow release of nitrogen and phosphorus from the litter can limit pine growth. Fungi are the chief agents which break down the needles and twigs.

Fungi play another important role in the nutrition of the pine. They invade the intercellular spaces in the pine roots without actually entering the cells. The roots release carbohydrate to the fungi, which provide the tree with phosphates. Toadstools are often abundant in radiata pine forests. The gaudy white-flecked red caps of the fly agaric, a very poisonous toadstool, make it the most conspicuous of these colourful gilled fungi. Lactarius, which has an orange-red cap with red blotches, and flamula which has golden brown caps, are numerous in older pine stands soon after the arrival of the damp autumn weather. Groups of glistening slimy caps of boletus, a thick fleshy pore-fungus, are typical members of the radiata pine community. Their honey-brown caps are sometimes a foot in diameter.

Growth

Radiata pine forests achieve rapid rates of growth because the trees have large crowns for photosynthesis, extensive systems of active roots, and the capacity to respond to warm moist conditions early in the growing season with a surge of growth. In favoured localities they grow at all seasons of the year. Well stocked pure stands of vigorous radiata pine produce an annual volume of about 300 cu ft of wood per acre over their life. Production ranges from 210 cu ft in typical plantations in the Ballarat and Macedon districts to 420 cu ft in the Aire River valley. Volume growth is most rapid at about 15 years. The initial density of the stands is about 600 trees per acre but the numbers are reduced by natural competition to about 400 trees per acre. More often the forests are thinned repeatedly after about 15 years of age until crops of 100 trees per acre or fewer remain.

Young radiata pines are very sensitive to competition from weeds. Severe competition from grasses and herbs can kill newly planted stock, and the survivors grow very slowly. Eucalypts and acacias in mixture with pine trees depress the production of pine wood markedly ; where there are many such trees in the forest, the production of softwood timber may be as low as 20 per cent of that of a pure stand of pines.

Fauna

Native animals have adapted themselves to living and feeding in pure crops of radiata pine, and in the mixed habitats created where eucalypts, acacias, and other undergrowth plants persist with the pines. Corridors and patches of native vegetation in the pine forests provide diversity of habitat. Lyrebirds live in pine plantations in north-east Victoria and elsewhere. The grey thrush, blue wren, southern yellow robin, and white-winged chough nest in pine forests. The nomadic yellow-tailed black cockatoo rips green cones of Corsican pine and radiata pine to obtain the seeds. Bronze-wing pigeons feed on seed from mature cones on the ground.

Firebreaks surrounding the compartments of pines in the Aire River valley in the Otway Range carry a dense vegetation of blackwood, satinwood, eucalypts, and other native plants. In the gullies in the forest there are thickets of musk, blanket-leaf, satinwood, soft tree-fern, and shield fern. Potoroos and possums occur, and grey and mountain thrushes, yellow and pink robins, rufous fantails, and crimson rosellas are common. Echidnas, bats, snakes, lizards, and frogs also live in the pine forests.

Possums and rats feed on the shoots and bark of the pines in several areas. Possums eat pollen cones in early spring. They live in old eucalypt stumps and logs, and also make nests of pine twigs. Water rats live along streams and water races and near fire protection dams. Southern bush-rats are common in some pine forests.

Sirex wood wasp, an insect introduced from Europe, is found in plantations in the central and western districts, around Port Phillip Bay, and in Gippsland. The female wasp bores through the thick bark of the pines with a long serrated ovipositor and lays eggs in tunnels in the wood in summer. The spores of a fungus carried in sirex are introduced into the tree when the eggs are laid. The fungus advances through the wood ahead of the larvae, which make galleries as they feed on the infected wood. Female wasps are attracted first to unhealthy and suppressed trees and to pruning wounds and other resinous surfaces. Vigorous trees in thinned plantations are resistant to sirex infestations. Wood tissues around the egg-tunnel produce much resin which slows down or stops the spread of the fungus.

Sirex populations have been controlled to a considerable degree by parasitic wasps which lay their eggs on sirex eggs or larvae, and also by infecting the sirex with nematodes. A small European wasp, *Ibalia leucospoides,* inserts her slender ovipositor into a sirex egg-tunnel and lays an egg on the sirex egg. Some species of large wasps are able to sense sirex larvae in the wood and bore through the bark and wood with a very long ovipositor to parasitise the larvae with their eggs. *Megarhyssa nortoni nortoni* from California, *Rhyssa persuasoria, Rhyssa himalayensis,* and other species of *Rhyssa* have been released. This biological control of an introduced wasp that attacks an introduced tree species by means of introduced parasites is an outstanding achievement in applied biology.

A free-living form of nematode lives on the fungus that is introduced into the pine by the female sirex, and a larger infective form breeds in the sirex larva. Infection of sirex by nematodes has the effect of sterilising the wasps.

Moths, sap-sucking aphids, thrips, and scale insects can disrupt the development of pine buds and foliage, but none has caused widespread damage. Many insects lay eggs on the pines but few are able to feed on them and survive. A native tube moth is slowly adapting itself to slow growing stands of pine south of Ballarat. Its larvae may destroy the new foliage during winter and spring every alternate year. Weakened and killed trees are susceptible to sirex wood wasp during the following summer. A species of bag moth also is an occasional defoliator of radiata pine.

Benefits of pine plantations

Pine forests have added variety to the landscape in many parts of Victoria. Abandoned farmlands have been reforested, and degraded natural bushland has been replaced with valuable timber crops. Increasing numbers of local residents and travellers appreciate the pine forests for picnics and other recreational uses.

The long-fibred wood of the pines is a versatile medium-density raw material, being used for sawn timber, plywood, papers and other pulp products, particle boards, poles and piles, and small round timbers. Sawn and round timbers are impregnated with creosote or waterborne salts to endow the wood with durability against fungi, insects, and marine borers.

Catchment areas where radiata pine forests are growing on deep soils in high rainfall areas have water yields similar to those from eucalypt forests. Where radiata pine forests have replaced native forest in the 25 to 30 inch annual rainfall zone there has been no appreciable alteration of streamflow, because rainfall and solar radiation are the main determinants of streamflow, and run-off and evaporation are largely independent of forest type.

Conclusion

The forests of Victoria are a priceless renewable resource. They protect the water catchments upon which cities and towns, industries, and farmlands depend for their prosperity. They provide a supply of wood and other forest products of many species for traditional and new markets. The diverse forest habitats are a haven for populations of native animals. Riverine and other woodlands provide grazing for cattle and sheep, particularly in times of drought.

The forests offer a remarkable variety of ecosystems for man to study and enjoy. Within relatively short distances in Victoria there are dark and mossy rain forests, lofty cool mountain forests with dense tall understoreys, quiet pine forests with spicy air and a soft litter of needles, stringybark-gum forests with a profusion of wildflowers and green panoramas over the foothills, and dry woodlands where undergrowth is sparse and litter scanty. State forests and forest parks are attracting increasing numbers of people who value the wide range of recreational opportunities that forests offer. Forests cater for the needs of hikers, anglers, artists, naturalists, photographers, youth camps, military manoeuvres, and the general tourist in all seasons of the year. Snowfields in the forests have been developed as ski resorts.

The virgin forests abundantly served the needs of the early Colony and the developing State. The northern and coastal forests yielded large volumes of strong, durable timbers for bridges, railways, wharves, telephone and electricity systems, and for fencing pastures and crops. The central stringybark and mountain ash forests supplied hewn and sawn timbers for houses, public buildings, and factories. Fuel wood and charcoal from the forests satisfied constant domestic and industrial markets. Tradesmen learned to use the unfamiliar woods of the native forests for furniture, boats, and vehicles. The forests yielded tannins and medicinal and industrial leaf oils for local use and for export.

Many regrowth forests, especially the mountain ash forests which regenerated after widespread fires in the 1920s and 1930s, are being managed to supply large sawmills, pulp mills, and other timber-using industries. Others will provide for bee keeping and grazing, and will yield a range of forest products for local use. Some are managed to conserve unique habitats for flora and fauna and for scientific studies, and as forest parks and other special recreation areas. All are managed so that they will protect water catchments adequately.

The pine and other softwood forests, and the new plantations that are being established by the State and by private companies, will provide various classes of wood for existing and new industries, principally in the south-western coastal districts, Gippsland, and in the north-east. Softwoods for particle boards, papers and other pulp products, sawn timber, plywood, poles and other round timbers are increasingly contributing to the State's economy.

Forests must be properly managed to improve their health and productivity, and to conserve them for future generations. Modern forest management draws heavily on the skills of biologists, economists, fire environment ecologists, wood technologists, marketing specialists, and on the particular aptitudes and training of field foresters. Modern technology finds many applications in forest protection, the regeneration and silviculture of timber crops, harvesting operations, and conservation of the forest environment.

List of plants

Alpine ash	*Eucalyptus delegatensis* R. T. Bak.
Austral mulberry	*Hedycarya angustifolia* A. Cunn.
Austral snow grass	*Poa australis,* sp. agg.
Banyalla	*Pittosporum bicolor* Hook.
Belah	*Casuarina cristata* Miq.
Bitter-pea	*Daviesia corymbosa* Sm.*var.laxiflora* J. H. Willis
Black box	*Eucalyptus largiflorens* F. Muell.
Black mallee box	*Eucalyptus porosa* F. Muell. Miq.
Black oliveberry	*Elaeocarpus holopetalus* F. Muell.
Black sallee	*Eucalyptus stellulata* Sieb. ex DC.
Black wattle	*Acacia mearnsii* de Wild.
Blackwood	*Acacia melanoxylon* R.Br.
Blanket-leaf	*Bedfordia salicina* DC.
Blakely's red gum	*Eucalyptus blakelyi* Maiden
Blue gum	*Eucalyptus stjohnii* (R. T. Bak.) R. T. Bak.
Boletus	*Boletus luteus*
Bracken (fern)	*Pteridium esculentum* (Forst.f.) Nakai
Broad-leaved peppermint	*Eucalyptus dives* Schau.
Broombush	*Melaleuca uncinata* R.Br.
Broom heath-myrtle	*Baeckea behrii* F. Muell.
Brownbarrel	*Eucalyptus fastigata* Deane et Maiden
Brown stringybark	*Eucalyptus baxteri* (Benth.) Maiden et Blakely
Bull mallee	*Eucalyptus behriana* F. Muell.
Bush-peas	*Pultenaea* spp.
Cabbage fan palm	*Livistona australis* Mart.
Candlebark	*Eucalyptus rubida* Deane et Maiden
Capped mallee	*Eucalyptus pileata* Blakely
Cherry ballart	*Exocarpos cupressiformis* Labill.
Christmas bush	*Prostanthera lasianthos* Labill.
Clematis	*Clematis aristata* R.Br.
Common cassinia	*Cassinia aculeata* R.Br.
Common correa	*Correa reflexa* (Labill.) Vent. *var. reflexa*
Common heath	*Epacris impressa* Labill.
Coral fern	*Gleichenia circinata* Swartz
Corsican pine	*Pinus nigra* (Arnold) *var. maritima* (Ait.) Poir.
Cross-leaf honey-myrtle	*Melaleuca decussata* R.Br.
Cumbungi	*Typha angustifolia* L.
Daphne heath	*Brachyloma daphnoides* Benth.
Dargo gum	*Eucalyptus perriniana* F. Muell. ex Rodway

Dodder-laurel	*Cassytha melantha* R.Br.
Douglas fir	*Pseudotsuga menziesii* (Mirb.) Franco
Dumosa mallee	*Eucalyptus dumosa* A. Cunn ex Schau.

Early hickory wattle	*Acacia obliquinervia* M. D. Tindale
Elderberry panax	*Tieghemopanax sambucifolius* Viguer

Flammula	*Flammula excentrica* Clel. et Ceel.
Flat-pea	*Platylobium formosum* Sm.
Flax acacia	*Acacia linearis* Macbride
Fly agaric	*Amanita muscaria* (L) Fr.
Forest red gum	*Eucalyptus tereticornis* Sm.
Fringed heath-myrtle	*Micromyrtus ciliatus* J. M. Black

Golden shaggy-pea	*Oxylobium ellipticum* R.Br.
Golden wattle	*Acacia pycnantha* Benth.
Gorse bitter-pea	*Daviesia ulicina* Sm.
Grampians fringe-myrtle	*Calytrix sullivanni* F. Muell.
Grampians gum	*Eucalyptus alpina* Lindl.
Grampians thryptomene	*Thryptomene calycina* Stapf.
Grass-trees	*Xanthorrhoea* spp.
Green mallee	*Eucalyptus viridis* R. T. Bak.
Grey box	*Eucalyptus microcarpa* Maiden

Hard water-fern	*Blechnum procerum* (Forst.f.) Swartz.
Hazel pomaderris	*Pomaderris aspera* Sieb ex DC.
Heath-myrtles	*Baeckea* spp.
Hickory wattle	*Acacia falciformis* DC.
Honey-myrtles	*Melaleuca* spp.
Honeysuckle	*Banksia* spp.
Hooked mallee	*Eucalyptus leptophylla* Miq.
Hop bitter-pea	*Daviesia latifolia* R.Br.
Hop-bushes	*Dodonaea* spp.
Hop goodenia	*Goodenia ovata* Sm.
Horned oil mallee	*Eucalyptus oleosa var glauca* Maiden

Kanooka	*Tristania laurina* R.Br.

Lactarius	*Lactarius deliciosus* (L.) Fr.
Leafy bossiaea	*Bossiaea foliosa* A. Cunn.
Lignum	*Muehlenbeckia* sp.
Lilly pilly	*Acmena smithii* (Poir) Merr. et Perry
Long-leaf mistletoe	*Loranthus miquelii* Lehm.
Long-leaved box	*Eucalyptus goniocalyx* F. Muell. ex Miq.

Mallee pine	*Callitris verrucosa* (A. Cunn. ex Endl.) F. Muell.
Manna gum	*Eucalyptus viminalis* Labill.
Maritime pine	*Pinus pinaster* Ait.
Mealy stringybark	*Eucalyptus cephalocarpa* Blakely
Messmate stringybark	*Eucalyptus obliqua* L'Herit.
Mint-bushes	*Prostanthera* spp.
Moira grass	*Pseudoraphis spinescens* (R.Br.) J. W. Vickery
Mountain ash	*Eucalyptus regnans* F. Muell.
Mountain grey gum	*Eucalyptus cypellocarpa* L. A. S. Johnson
Mountain gum	*Eucalyptus dalrympleana* Maiden
Mountain pepper	*Drimys lanceolata* (Poir.) Baill.
Mountain plum-pine	*Podocarpus lawrencei* Hook.f.
Murray pine	*Callitris preissii* Miq.
Musk (daisy-bush)	*Olearia argophylla* (Labill.) F. Muell. ex Benth.
Myrtle beech	*Nothofagus cunninghamii* (Hook.) Oierst.

Narrow-leaf geebung	*Persoonia linearis* Andr.
Narrow-leaved mallee	*Eucalyptus cneorifolia* DC.
Narrow-leaved peppermint	*Eucalyptus radiata* Sieb ex DC.
Native hibiscus	*Howittia trilocularis* F. Muell.
Needle rush	*Eleocharis acuta* R.Br.

Oil mallee	*Eucalyptus oleosa* F. Muell.
Oyster Bay pine	*Callitris rhomboidea* R.Br.
Parrot-peas	*Dillwynia* spp.
Pomaderris	*Pomaderris apetala* Labill.
Ponderosa pine	*Pinus ponderosa* Dougl.
Porcupine grass	*Triodia irritans* R.Br.
Prickly coprosma	*Coprosma billardieri* Hook.f.
Prickly tea-tree	*Leptospermum juniperinum* Sm.
Radiata pine	*Pinus radiata* D. Don
Red bloodwood	*Eucalyptus gummifera* (Gaertn.) Hochr.
Red box	*Eucalyptus polyanthemos* Schau.
Red ironbark	*Eucalyptus sideroxylon* A. Cunn. ex Woolls
Red mallee	*Eucalyptus calycogona* Turcz.
Red stringybark	*Eucalyptus macrorhyncha* F. Muell. ex Benth.
River peppermint	*Eucalyptus elata* Dehnh.
River red gum	*Eucalyptus camaldulensis* Dehnh.
Rough-barked apple	*Angophora floribunda* (Sm.) Sweet
Rough tree-fern	*Cyathea australis* (R.Br.) Domin
Sandalwood	*Myoporum platycarpum* R.Br.
Satinwood	*Phebalium squameum* (Labill.) Druce
Saw banksia	*Banksia serrata* L.f.
Scent bark	*Eucalyptus aromaphloia* L. D. Pryor and J. H. Willis
Scented paperbark	*Melaleuca squarrosa* Sm.
Shaggy-peas	*Oxylobium* spp.
Shield fern	*Polystichum aculeatum* (L.) Schott
Shining cassinia	*Cassinia longifolia* R.Br.
Shining gum	*Eucalyptus nitens* Maiden
Shining peppermint	*Eucalyptus nitida* Hook.f.
Shiny tea-tree	*Leptospermum nitidum* Hook.f.
Silver banksia	*Banksia marginata* Cav.
Silvertop ash	*Eucalyptus sieberi* L. Johnson
Silver wattle	*Acacia dealbata* Link
Skirted tree-fern	*Cyathea marcescens* N. A. Wakefield
Slaty sheoak	*Casuarina muelleriana* Miq.
Smooth nettle	*Australina muelleri* Wedd.
Snow gum	*Eucalyptus pauciflora* Sieb. ex Spreng.
Soft tree-fern	*Dicksonia antarctica* Labill.
Southern mahogany	*Eucalyptus botryoides* Sm.
Southern sassafras	*Atherosperma moschatum* Labill.
Sphagnum moss	*Sphagnum cristatum* Hpe.
Sunshine wattle	*Acacia botrycephala* (Vent.) Desf.
Swamp gum	*Eucalyptus ovata* Labill.
Sweet bursaria	*Bursaria spinosa* Cav.
Sweet pittosporum	*Pittosporum undulatum* Vent.
Tea-trees	*Leptospermum* spp.
Tecoma	*Tecoma australis* R.Br.
Waratah	*Telopea oreades* F. Muell.
Wattles	*Acacia* spp.
White box	*Eucalyptus albens* Benth.
White brittle gum	*Eucalyptus mannifera* Mudie
White cypress pine	*Callitris columellaris* F. Muell. sens. lat.
White stringybark	*Eucalyptus globoidea* Blakely
Wiregrass	*Tetrarrhena juncea* R.Br.
Yellow box	*Eucalyptus melliodora* A. Cunn. ex Schau.
Yellow gum	*Eucalyptus leucoxylon* F. Muell.
Yellow mallee	*Eucalyptus incrassata* Labill.
Yellow-wood	*Acronychia laevis* Forst. et Forst.f.
Yellow stringybark	*Eucalyptus muellerana* Howitt
Yertchuk	*Eucalyptus consideniana* Maiden
Yorrell	*Eucalyptus gracilis* F. Muell.

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GEOGRAPHICAL FEATURES

Area and boundaries

Victoria is situated at the south-eastern extremity of the Australian continent, of which it occupies about a thirty-fourth part and covers about 87,884 square miles or 56,245,760 acres.

The following table shows the area of Victoria in relation to that of Australia :

AUSTRALIA—AREA OF STATES AND TERRITORIES

State or Territory	Area	Percentage of total area
	sq miles	
Western Australia	975,920	32.88
Queensland	667,000	22.47
Northern Territory	520,280	17.53
South Australia	380,070	12.81
New South Wales	309,433	10.43
Victoria	**87,884**	**2.96**
Tasmania	26,383	0.89
Australian Capital Territory	939	0.03
Total Australia	2,967,909	100.00

Victoria is bounded on the north and north-east by New South Wales, from which it is separated by the Murray River and a boundary about 110 miles long running north-westerly from Cape Howe to the nearest source of the Murray River, being a point known as The Springs, on Forest Hill. All the waters of the Murray River are in New South Wales, the State boundary being the left bank of the stream. The total length of the New South Wales boundary is about 1,175 miles.

On the west the State is bounded by South Australia and on the south by the Indian Ocean and Bass Strait. Its greatest length from east to west is about 493 miles, its greatest breadth about 290 miles, and its extent of coastline 980 miles, including the length around Port Phillip Bay 164 miles, Western Port 90 miles, and Corner Inlet 50 miles. Great Britain, inclusive of the Isle of Man and the Channel Islands, contains 88,119 square miles, and is therefore slightly larger than Victoria.

The most southerly point of Wilsons Promontory, in latitude 39 deg 8 min S., longitude 146 deg 22½ min E., is the southernmost point of Victoria and likewise of the Australian continent ; the northernmost point is where the western boundary of the State meets the Murray, latitude 34 deg 2 min S., longitude 140 deg 58 min E. ; the point furthest east is Cape Howe, situated in latitude 37 deg 31 min S., longitude 149 deg 59 min E. The westerly boundary lies upon the meridian 140 deg 58 min E., and extends from latitude 34 deg 2 min S. to latitude 38 deg 4 min S.—a distance of 280 miles.

Physical divisions

This article should be read in conjunction with the articles on physical environment and land use, area, and climate.

The chief physical divisions of Victoria are shown on the map (Figure 1). Each of these divisions has certain physical features which distinguish it from the others as a result of the influence of elevation, geological structure, climate, and soils. The following divisions are recognised :

1. *Murray Basin Plains :*
    - (*a*) The Mallee
    - (*b*) The Murray Valley
    - (*c*) The Wimmera
    - (*d*) The Northern District Plains
2. *Central Highlands :*
    - A. The Eastern Highlands, within which
        - (*a*) the Sandstone Belt and
        - (*b*) the Caves Country may be distinguished from the remainder
    - B. The Western Highlands :
        - (*a*) The Midlands
        - (*b*) The Grampians
        - (*c*) The Dundas Highlands
3. *Western District Plains :*
    - (*a*) The Volcanic Plains
    - (*b*) The Coastal Plains
4. *Gippsland Plains :*
    - (*a*) The East Gippsland Plains
    - (*b*) The West Gippsland Plains

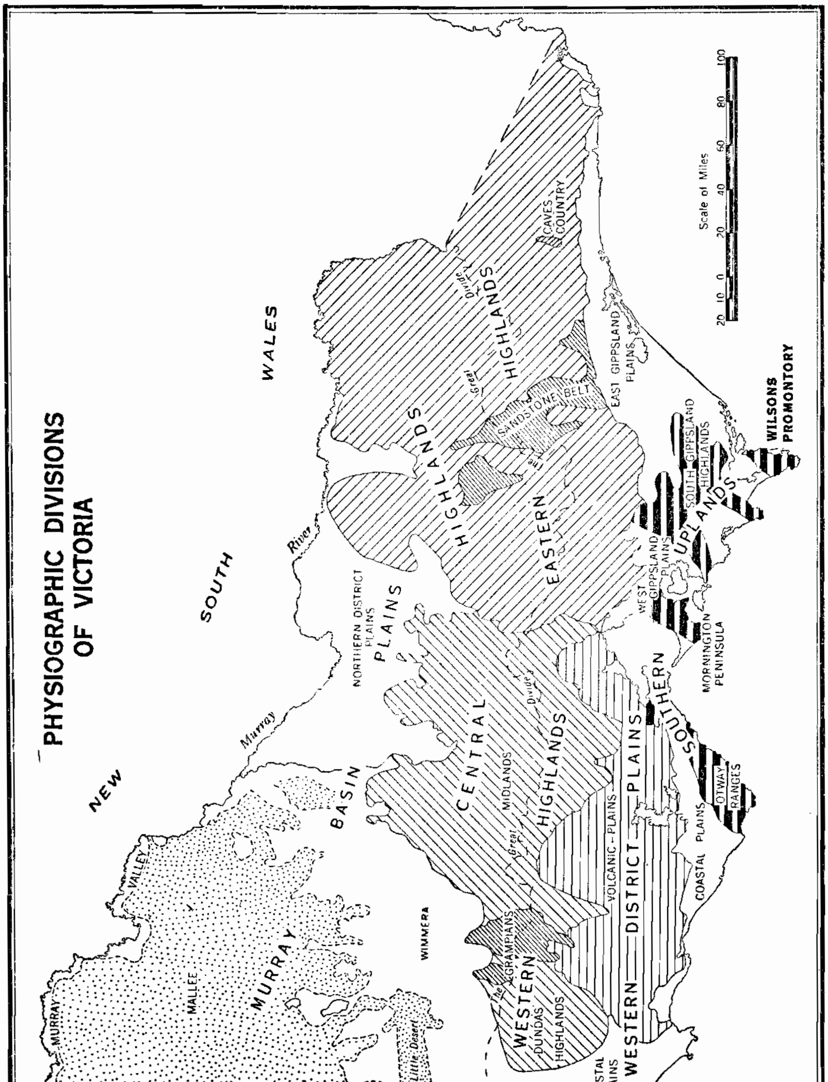


FIGURE 1.

5. *Southern Uplands :*
   (*a*) The Otway Ranges
   (*b*) The Barabool Hills
   (*c*) The Mornington Peninsula
   (*d*) The South Gippsland Highlands
   (*e*) Wilsons Promontory

Murray Basin Plains

These plains include the Mallee, the Wimmera, the Northern District Plains, and the Murray Valley itself. The most noticeable distinguishing features of the Mallee are the soils, vegetation, and topography. It is not a perfect plain, but exhibits broad low ridges and depressions which appear to be due to folding and faulting of the rocks. Sand ridges trending due east and west are an indication of a former more arid climate, but they are now fixed by vegetation. When cleared, the sand distributes itself irregularly without forming new ridges. There is evidence of a succession of former wet and dry periods in the Mallee, but at the present time all the streams that enter it lose so much water by evaporation and percolation that they fail to reach the Murray and terminate in shallow lakes, many of which are salt. The Murray Valley itself is cut into the higher Mallee land and is subject to periodic flooding by the river.

The Northern District Plains are formed from the combined flood plains of rivers flowing to the Murray, with an average gradient of between 3 and 5 ft to the mile, the surface being almost perfectly flat except where small residual hills of granite rise above the alluvium as at Pyramid Hill.

The Wimmera lies between the Western Highlands and the Mallee and is also composed mainly of river plains, except to the north of the Glenelg where old abandoned river channels contain a succession of small lakes. Most of the lakes of the Murray Basin Plains have crescentic loam ridges (lunettes) on their eastern shores.

Central Highlands

The Central Highlands form the backbone of Victoria, tapering from a broad and high mountainous belt in the east until they disappear beyond the Dundas Highlands near the South Australian border. They were formed by up-warping and faulting. The Eastern Highlands differ from the Western in their greater average elevation, with peaks such as Bogong, Feathertop, and Hotham rising above 6,000 ft, while the Western Highlands are generally lower, the peaks reaching above 3,000 ft, and the valleys being broader. Also, in the Eastern Highlands patches of Older Volcanic rocks occur, whereas in the Western the volcanic rocks belong mainly to the Newer Volcanic Series. Several well known volcanic mountains are still preserved, Mounts Buninyong and Warrenheip near Ballarat being examples.

Because of the great variety of geological formations in the Central Highlands and the effects of elevation and deep dissection by streams, the features of the country are very varied and there are many striking mountains and gorges. The severe winter climate, with heavy snow on the higher land, is also a special feature of the Eastern Highlands. Included in the area are several high plains such as those near Bogong and the Snowy Plains. Caves are well known in the limestone around Buchan.

In the Western Highlands the Grampians, with their striking serrate ridges of sandstone, may be compared with the belt of sandstone stretching from Mansfield to Briagolong in the east.

The Dundas Highlands are a dome which has been dissected by the Glenelg and its tributaries, the rocks being capped by ancient laterite soils which form tablelands with scarps at their edges.

Western District Plains

Many of the surface features of the Western District Plains are a result of volcanic activity, very large areas being covered with basalt flows of the Newer Volcanic Series above which prominent mountains rise, many of

Forests of Victoria

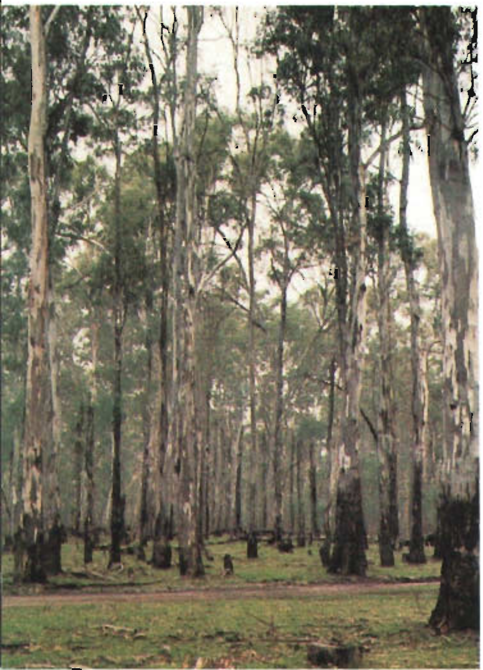
Myrtle beech and tree ferns in rain forest at Cement Creek.

Snow gum in sub-alpine woodland on Snowy Range.

Alpine ash forest at Mount Arbuckle.

Mountain ash forest at Noojee.

River red gum forest on the flood plain of the Murray River at Barmah.



Messmate stringybark forest in the Grampians.

Messmate stringybark and narrow-leaved peppermint at Daylesford.

Silvertop ash with southern mahogany at Orbost.

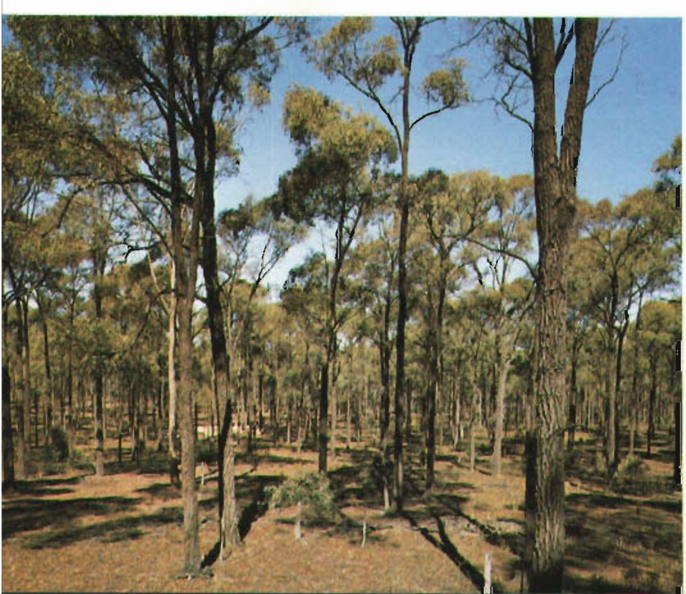
Manna gum forest at Mount Macedon.

Forest plantation of radiata pines at Macedon.

Corsican and radiata pines at Macedon.

Woodland of yellow gum at Dimboola.

Forest red gum at Briagolong.



Red ironbark and grey box forest at Rushworth.

Acknowledgments: Forests Commission, Victoria

them with a central crater lake. Some of the youngest flows preserve original surface irregularities practically unmodified by erosion, thus forming the regions known as " stony rises ".

The coastal plains of the Western District are for the most part sandy, the soils being derived from Tertiary and Pleistocene sedimentary deposits, which in places attain a thickness of some 5,000 ft, and yield considerable quantities of artesian water.

Gippsland Plains

Continuing the east-west belt of plains on the eastern side of the drowned area represented by Port Phillip Bay and Western Port are the Gippsland Plains. These are underlain by marine and non-marine Tertiary and Pleistocene sedimentary deposits, including the thick seams of brown coal of the La Trobe Valley. A notable feature is the Ninety Mile Beach and the lakes and swamps that lie on its landward side. This beach is an offshore bar on which aeolian sand ridges have accumulated.

Southern Uplands

Lying to the south of the plains above mentioned is a group of uplifted blocks for which faulting is mainly responsible, these constituting the Southern Uplands. The Otway Ranges and the South Gippsland Highlands are composed of fresh water Mesozoic and Tertiary sediments with Older Volcanic basalts in south Gippsland, and the Mornington Peninsula is an upraised fault block of complex geology, including granites. The Sorrento Peninsula is entirely composed of Pleistocene calcareous dune ridges which have been responsible for practically blocking the entrance to Port Phillip Bay.

Physical environment and land use

The Central Highland Zone (see Figure 1) is the dominant physiographic region of Victoria. The greatest importance of these Highlands is their influence on the drainage pattern of the State. They act as a drainage division and catchment areas between the long north and north-west flowing rivers which are part of the Murray System and the shorter south flowing rivers.

The Highlands are divided into two parts by the 1,200 ft Kilmore Gap, a natural gateway for transport routes leading north from Melbourne.

Eastern Highlands

To the east, the Eastern Highlands form a broad, rugged region of deeply dissected high plateaux with elevations of up to 6,000 ft. They form a barrier to east-moving air masses, giving rise to heavy orographic rainfall of over 50 inches a year in the higher parts. This is the wettest part of the State, and is the coldest region in winter with substantial snowfalls at higher elevations, a factor enabling the development of skiing resorts at locations such as Mt Buffalo, Mt Buller, Mt Hotham, and Falls Creek. Because of the elevation, this is also the coolest part of the State in summer. The rugged topography and dense forest cover of the Eastern Highlands makes them rather inaccessible and of little agricultural potential, so that they are the only large area of Victoria that is very sparsely settled and almost devoid of transport routes. However, the foothill zone adjoining the East Gippsland Plains is an important forestry area, while the lower slopes and valleys are used for grazing, particularly of cattle. High alpine grassland areas in the north-east, such as the Bogong High Plains, are used for summer grazing, this area being one of the rare cases of a transhumance farming economy in Australia. The high run-off and steep stream gradients have made the Eastern Highlands important for water storage and hydro-electricity generation at Kiewa, Eildon, and Rubicon.

Western Highlands

West of the Kilmore Gap, the Western Highlands are much lower than those to the east. These Highlands culminate in the west in a series of block mountains, of which the Grampians and the Dundas Highlands form the final western outlines of the Highland Zone. Stream gradients are more gentle than in the Eastern Highlands, so that hydro-electricity potential is low. However, the Rocklands Dam and the Eppalock and Cairn Curran Reservoirs are important storages for water supply to farms of the northern plains of Victoria.

The Western Highlands, because of their lower elevation, have a lower rainfall than the Eastern Highlands, and they do not act as a barrier to settlement and transport. The reasonably reliable rainfall of 20 inches to 30 inches a year, cool winters, warm summers, rolling topography, open dry sclerophyll forest and grasslands, and moderately fertile, although thin, volcanic soils offer an environment suitable for sheep grazing for wool and fat lambs, fodder cropping, dairying, and potato growing. Early settlement of the area was stimulated by the gold discoveries of the 1850s and 1860s in the Ballarat and Bendigo districts, and these two cities have developed as important regional centres. Castlemaine, Maryborough, and Clunes are additional service centres.

Murray Basin Plains

North of the Central Highland Zone are the flat Murray Basin Plains (see Figure 1). The western section is comprised of the Mallee–Wimmera Plain, characterised by areas of east-west running sand ridges, grey-brown and solonised Mallee soils, and some areas of sandy wastelands. Rainfall is around 20 inches a year in the southern Wimmera, but it decreases to under 10 inches a year in the north-western Mallee, which is the driest area of the State. As well as being low, rainfall is erratic and unreliable in the Mallee–Wimmera, but the warm winters and hot summers ensure a year round growing season where water is available. Early farms were too small, and over-cropping led to widespread crop failures and soil erosion. Since the 1930s farming here has become more stable as a result of the provision of adequate and assured water supplies from the Mallee–Wimmera Stock and Domestic Water Supply System, larger farms of over 1,000 acres, crop rotations, the development of a crop-livestock farming pattern, the use of superphosphate and growing of legumes to maintain soil fertility, and soil conservation practices. The winter rainfall maximum and dry summer harvesting period, the good rail and road network and bulk handling facilities, and scientific farming techniques have enabled the Wimmera to become a region of high-yielding wheat and mixed farms. The drier areas of the Mallee are characterised more by larger sheep properties.

Of great significance in the Mallee are the irrigation areas of the Mildura–Merbein–Red Cliffs and Swan Hill districts, with close settlement farming growing vines and fruits. Mildura, Ouyen, Swan Hill, Horsham, Warracknabeal, and St Arnaud are the main regional centres of the Mallee–Wimmera Plains.

The Northern District Plains form the narrower eastern section of the Murray Basin Plains. Here rainfall increases from 15 inches a year in the western part to over 30 inches a year in the eastern part of the plain adjoining the Eastern Highlands. Rainfall is more reliable than in the Mallee–Wimmera District. However, there is generally a summer water deficiency which restricts pasture growth, so that the Northern District Plains are characterised by extensive grazing and mixed wheat-sheep farms. Recently there has been increasing emphasis on " ley " farming (i.e., rotation of crops and pastures) in order to increase carrying capacities and productivity. The higher, eastern section of the Northern District Plains with more reliable rainfall is one of the best sheep and cattle grazing areas in the State.

There is a marked contrast in the Northern District Plains between the " dry " farming areas and those closely settled irrigation areas of the Murray and its tributaries, especially in the Kerang, Echuca–Rochester, Kyabram–Shepparton, and Cobram–Yarrawonga areas using water from the Loddon, Campaspe, Goulburn, and Murray Rivers, respectively. Fruits, vegetables, hops, and tobacco growing with local specialisations, and dairying based on improved pastures are the main activities in the irrigated districts. Shepparton has become an important centre for canned and frozen fruits and vegetables. These areas are also important as suppliers for the metropolitan fresh fruit and vegetable market.

In the Northern District Plains Shepparton, Wangaratta, and Benalla are large and expanding regional centres with manufacturing industries, while Echuca, Rochester, Kyabram, and Wodonga are smaller service centres with a small range of urban functions.

Coastal Region

South of the Central Highland Zone, coastal Victoria is readily divided into three regions.

The first of these is Port Phillip Bay and environs, bounded by the You Yang Range and Keilor Plain in the west, the Central Highlands in the north, the Dandenong Range and West Gippsland Plain in the east, and the Mornington Peninsula in the south-east. Melbourne, Geelong, and the developing Western Port area provide port facilities in this region. This region is dominated by the urban areas of Melbourne, which is the hub of the State's transport system, and Geelong. The urban areas are surrounded by intensively farmed rural landscapes in which market gardening is important in addition to cattle and sheep fattening, dairying, and fodder cropping. The bayside beach resorts and the seaside resorts of the Mornington Peninsula are the centre of an important tourist industry.

The second region of coastal Victoria is the extensive volcanic plain stretching westwards from the Port Phillip region. This is possibly the best agricultural region in Victoria. The rolling surface is characterised by volcanic plains and cones, lakes, and stony rises, with rich but shallow volcanic soils. Rainfall is above 20 inches a year in all areas, with a slight winter-spring maximum, and temperatures are warm in summer and mild in winter so that year round pasture growth and cropping are possible. Western District farms produce cattle, sheep for wool and fat lambs, fodder crops, and potatoes. This is also an important dairying district. Rural population densities, as well as those of the west Gippsland dairying country, are second highest in the State after the northern irrigation districts. Colac, Warrnambool, Portland, Hamilton, and Camperdown are the main regional centres. Portland has recently developed modern port facilities.

South of the Western District Plains lie the Otway Ranges, a sparsely populated region of rugged scenery and very high rainfall. The coastline between Anglesea and Apollo Bay has a number of popular tourist resorts.

The third region of coastal Victoria is Gippsland. Immediately east of the Bay are the West Gippsland Plains, which are sandy in their western section where large areas of swamp have been drained for market gardening. The South Gippsland Highlands, a sparsely populated area of little agricultural potential, is bounded by the West Gippsland Plain and to the east by a fault trough stretching from Warragul to the La Trobe Valley (included in East Gippsland Plains in Figure 1). The fault trough with its rolling hills, 30 inch rainfall, and year round pasture, is among the best dairying country on the Australian mainland, supplying the metropolitan wholemilk market. The La Trobe Valley towns have experienced rapid post-war development as a result of the brown coal mining operations in the Yallourn–Morwell area.

East of the La Trobe Valley, rainfall decreases to below 30 inches a year between Traralgon and the Gippsland Lakes. Here the coastline is characterised by sand dunes and lagoons, backed by the riverine plains of the La Trobe, Macalister, Avon, and Mitchell Rivers. The relatively low rainfall necessitates irrigation for cropping. Irrigated farming in the Sale–Maffra, Bairnsdale, and (further east) Orbost districts is based on maize, bean, potato, and fodder growing. Elsewhere the main land use is cattle and sheep grazing.

The plains narrow east of Lakes Entrance when the coastline becomes one of alternating river valleys and hilly headlands where the Eastern Highlands protrude south to the sea. Forestry is the main activity here, with some grazing and fodder cropping in the valleys and foothills. Tourism is important in the area around Lakes Entrance, which is also a fishing port. Gippsland is linked with Melbourne by the Princes Highway and by rail as far east as Orbost.

Mountain regions

The mountainous regions of Victoria comprise the Central Highlands and a belt known as the Southern Uplands lying to the south and separated from the Central Highlands by plains.

The Central Highlands form the backbone of Victoria, tapering from a broad and high mountainous belt in the east until they disappear near the South Australian border. In the eastern sector patches of Older Volcanic rocks occur and peaks rise over 6,000 ft, while in the western sector the volcanic rocks belong mainly to the Newer Volcanic Series and the peaks reach 3,000 ft.

The Highlands descend to plains on their southern and northern flanks.

On the south are the Western District Plains and the Gippsland Plains, and beyond these again rises a group of uplifted blocks constituting the Southern Uplands. The Otway Ranges and the hills of south Gippsland are composed of fresh water Mesozoic sediments and Tertiary sands and clays with Older Volcanic rocks in south Gippsland, and the Mornington Peninsula is an upraised fault block of complex geology, including granites.

By 1875 the mountainous areas of the State were embraced by a geodetic survey which had been started in 1856. This was the first major survey, although isolated surveys had been carried out as early as 1844. Further surveys were carried out by the Australian Survey Corps during the Second World War, and by the Department of Lands and Survey in the post-war years. Most recent values for some of the highest mountains in Victoria are Mt Bogong, 6,516 ft; Mt Feathertop, 6,307 ft; Mt Nelse, 6,181 ft; Mt Fainter, 6,157 ft; Mt Loch, 6,152 ft; Mt Hotham, 6,108 ft; Mt Niggerhead, 6,048 ft; Mt McKay, 6,045 ft; Mt Cobberas, 6,030 ft; Mt Cope, 6,026 ft; Mt Spion Kopje, 6,025 ft; and Mt Buller, 5,919 ft.

Further reference, 1962

Conservation on the Victorian coast

The ocean coast of Victoria is about 682 miles long, and to this may be added the shorelines of Port Phillip Bay (164 miles), Western Port (186 miles, including French Island), and Corner Inlet (300 miles, including the intricate island shores off Port Albert). In addition, there are shorelines of estuaries and coastal lagoons, the most extensive of which are the Gippsland Lakes, with a shoreline length exceeding 200 miles. Articles in previous *Year Books* have dealt with the geology, the geomorphology, and the plant ecology of the coast, indicating the rich variety of natural features found on this relatively short sector of the Australian coast. Here, as on other parts of the Australian coast, there has been increasing pressure for the development of coastal resources with demands that coastal land be utilised for port and industrial development, urban growth, and resort and recreational development. On the other hand, there have been demands for greater attention to the conservation of natural scenery and biological resources, and the attempt to reconcile these competing claims has led to recognition that planning is necessary to ensure a satisfactory pattern of coastal utilisation and development.

In one respect, Victoria has been particularly fortunate. In 1879 the Government decided that, with the exception of a few small areas that had already passed into private ownership, the coastal fringe of Victoria should remain Crown land, comprising foreshores reserved for (generally unspecified) public purposes under the jurisdiction of the Lands Department. In Victorian legislation the term " foreshore " (restricted in scientific usage to the zone between high and low tide marks) is generally taken to include also the coastal margin, inland as far as the boundary of the nearest freehold land. Thus Victoria has been able to avoid the problem where a programme of coastal conservation is impeded by the fact that long sectors of the coastline are in private ownership. But this freedom from private ownership carries with it a responsibility for individuals, organisations, and local and State authorities to see that the coast is wisely used, and to minimise damage and disturbance in the coastal environment.

Responsible authorities

Several authorities are responsible for the utilisation and management of the Victorian coast. There are 42 coastal municipalities, ten of them in the Melbourne metropolitan area, and an unincorporated area, French Island in Western Port. Under the *Land Act* 1958 committees of management are appointed to administer defined foreshore reserves : in many but not all cases, municipal councils have been appointed as the committees of management. The committees are required to provide facilities for visitors, including car parks and camping grounds, and at the same time to maintain the attractions of their coastal scenery by conserving vegetation, preventing erosion, and keeping the area tidy. The overall pattern of coastal development is guided by planning schemes drawn up by local municipalities and the Town and Country Planning Board : once approved, a planning scheme can only be changed with the approval of the Governor in Council. Several planning schemes are now approved and in operation, while on sectors of the coast where a planning scheme is still being prepared development is controlled by the terms of an interim development order. In addition, regional planning authorities are being formed to deal with specific regions. The first of these, established in 1969, is the Western Port Regional Planning Authority. A framework for planned development is thus coming into existence for the coast of Victoria, and should provide a means of achieving a balanced programme of utilisation and conservation.

The coast of the Melbourne metropolitan area also includes sectors under the jurisdiction of the Melbourne Harbor Trust and the St Kilda Foreshore Trust, and is subject to the Melbourne and Metropolitan Planning Scheme. The Port Phillip Authority is essentially an advisory body concerned with the coast of Port Phillip Bay and the ocean coast between Barwon Heads and Cape Schanck : its aim is to guide and co-ordinate development and conservation by the various municipalities and foreshore committees within this area ; much of Corio Bay, on the western side of Port Phillip Bay, is under the jurisdiction of the Geelong Harbor Trust, and the Portland Harbor Trust is similarly responsible for a sector in Portland Bay. A number of small coastal areas, mainly lighthouse reserves, are under the control of the Commonwealth of Australia. These include the western tip of the Nepean Peninsula, adjacent to the entrance to Port Phillip Bay, the site of a quarantine station and an Army officer cadet school.

Sectors of the coast within areas designated as national parks are under the management of the National Parks Authority, and similar sectors within State wildlife reserves (game reserves and faunal reserves) are managed by the Fisheries and Wildlife Department. Inevitably, a number of other departments are concerned with specific aspects of the coastal environment : the Melbourne and Metropolitan Board of Works is responsible for the protection and improvement of a 49 mile sector on the northern shore of Port Phillip Bay and for the treatment and disposal of sewerage from the metropolitan area ; the Public Works Department takes care of shore protection works on much of the Victorian coast ; the Soil Conservation Authority carries out anti-erosion works in the coastal fringe, especially on dune terrain ; the State Rivers and Water Supply Commission is concerned, together with a number of local and regional authorities, with the provision of water supply and sewerage for coastal townships ; the Land Conservation Council studies areas of Crown land and advises the Minister for Lands concerning its appropriate future use ; and the Environment Protection Authority will control the discharge of wastes into the environment to prevent or control pollution and to protect or improve the environment. Other authorities connected with activities and developments affecting the coast include the Mines Department, the Country Roads Board, the Forests Commission, and the Tourist Development Authority. Co-ordination of the aims and requirements of so many authorities is not a simple task : the Port Phillip Bay Authority does this for a particular coastal sector, and the various other planning authorities have been suggested to act as co-ordinating authorities on other parts of the coast, such as the Gippsland Lakes area. In addition, the Town and Country Planning Board can now prepare statements of planning policy for any area of the State which when approved become government policy for the planning of the area or resource concerned. The Board is currently studying the Victorian coast for this purpose.

National parks

Almost 120 miles of the Victorian coastline is now included in national parks. The largest of these is Wilsons Promontory, a magnificent national park by any standard, with a rocky granite coastline, sandy coves, and small areas of salt marsh and mangrove swamp on its northern boundary shore ; the adjacent dune landscapes on Yanakie isthmus have also been added to the park. Access to a number of bays on the west coast of Wilsons Promontory is provided by a main road running into the park headquarters at Tidal River, and beyond this walking trails give access to outstanding natural coastal scenery, free from any kind of development. The persistence of sectors of coastal landscape, unmodified by man-made structures, can only be guaranteed in reserves of this kind, managed by an authority which gives first priority to the conservation of natural environments. If this primary aim is to be achieved the extent of facilities and constructions in national parks would have to be assessed, and as the number of people wishing to see and enjoy a national park such as Wilsons Promontory increases year by year, it may be necessary to concentrate on catering for day visitors, rather than providing more overnight accommodation within the Park boundaries.

The Port Campbell National Park covers a 20 mile sector of coast, with fine cliff scenery and coastal heathlands. Wingan Inlet and Mallacoota Inlet National Parks comprise estuarine lagoons with adjacent bushland, heath, and dune landscapes on the east Gippsland coast, and The Lakes National Park is a segment of barrier heathland and woodland on Sperm Whale Head, with a frontage of sandy beaches and salt marshes bordering the Gippsland Lakes. There is still a possibility of increasing the proportion of coast in national parks, especially in east Gippsland, where a small national park has been declared at Point Hicks (formerly Cape Everard).

The following list shows the area of coastal national parks :

	acres
Port Campbell National Park	1,750
Wilsons Promontory National Park	102,379
The Lakes National Park	5,288
Captain James Cook National Park	6,700
Wingan Inlet National Park	4,730
Mallacoota Inlet National Park	11,225

Wildlife reserves

Several of the reserves managed by the Fisheries and Wildlife Department on and near the coast are primarily game reserves for the conservation of waterfowl. These include Long Swamp in the far west, Lake Connewarre near Geelong, Jack Smith's Lake and Lake Reeve behind the Ninety Mile Beach, McLeod's Morass and Jones Bay in the Gippsland Lakes region, and Ewings Morass, with Lake Curlip, near the mouth of the Snowy River. These are wetland areas comprising lakes and lagoons with reedswamp and saltmarsh habitats, and each carries important breeding colonies of waterfowl, especially wild duck.

State faunal reserves on or near the coast include Lawrence Rocks, off Portland, with various sea birds including a gannet colony ; Lady Julia Percy Island, a few miles to the east, a centre for sea birds and seals ; Mud Islands in Port Phillip Bay, a sanctuary for storm-petrels and fairy terns ; Quail Island and Chinaman Island, which are mangrove-fringed islands of salt marsh and woodland with varied wildlife in Western Port ; Seal Rocks with its seal colony off Phillip Island ; Cape Woolamai, a reserve with an important mutton-bird colony ; and Nooramunga, comprising the sandy and swampy islands of Corner Inlet, with their rich and varied wildlife communities.

Research is an important function of the Fisheries and Wildlife Department, and ecological investigations are in progress on several of these reserves. Conservation of coastal plant communities has received less attention so far in Victoria, but many of the critical vegetation types are contained within national parks and wildlife reserves. One exception is the vegetation of the Cape Liptrap area, which has a variety of plant communities, some not represented elsewhere, not yet protected by wildlife reserve designation.

The following list shows the area of coastal wildlife reserves :

	acres
Long Swamp State Game Reserve	5,830
Lawrence Rocks State Faunal Reserve	20
Lady Julia Percy Island State Faunal Reserve	330
Lake Connewarre State Game Reserve .	8,000
Mud Islands State Faunal Reserve	1,200
Quail Island State Faunal Reserve	2,000
Chinaman Island State Faunal Reserve	150
Seal Rocks State Faunal Reserve	7
Cape Woolamai State Faunal Reserve	320
Nooramunga State Faunal Reserve	24,600
Jack Smith's Lake State Game Reserve	2,609
Lake Reeve State Game Reserve	12,000
McLeod's Morass State Game Reserve	1,045
Jones Bay State Game Reserve	900
Ewings Morass State Game Reserve	10,980
Lake Curlip State Game Reserve	1,950

Some problems

Conservation of coastal landscapes and associated wildlife is a problem confronting not only sectors designated as national parks and wildlife reserves but also the management of coastal resources generally. Coastal landforms and biological communities are dynamic systems, subject to natural evolution, and likely to change in response to man's activities in the coastal region. Thus cliffed coasts recede as the result of weathering processes and wave action, beaches are subject to alternations of cut-and-fill and to longshore drifting by wave and current action, and coasts fringed by mangrove swamps, salt marshes, or reedswamp tend to advance seaward, especially if sediment is being carried into them by rivers. Interference with any of these processes—whether by building sea walls, breakwaters and groynes, by dredging navigation channels, or by destroying the vegetation which fringes and protects the shore—can bring about unfavourable changes. The disappearance of sand from Hampton Beach and its accumulation nearby behind the breakwater built at Sandringham is one example; another is the onset of erosion on the shores of the Gippsland Lakes following the disappearance of protective reedswamp, largely as the result of salinity increase after the cutting of an artificial entrance at Lakes Entrance eighty years ago. Biological resources are particularly vulnerable to the effects of man's interference. The ecology of shores exposed at low tide can be modified even by a few holidaymakers turning over rocks in search of crabs, while the impact of skindiving and underwater fishing in nearshore waters has become very widespread along the Victorian coast in recent years. Pollution, whether from the land by way of rivers and drains, or from ships at sea, can adversely affect marine ecology, and imbalance can develop following overfishing or the large scale cropping of particular species, such as the scallops in Port Phillip Bay. Evidence that coastal landforms and biological features can be changed as the result, directly or indirectly, of man's activities shows their intimate connection with the utilisation and development of coastal resources. The possible consequences of any project affecting shore features, especially vegetation cover, need to be assessed by careful survey and detailed research beforehand, and measures taken to avoid damage to coastal resources.

The major port and industrial development planned in the Hastings area in the next few years is likely to modify the environment of Western Port. Surveys are being conducted by a number of government and university departments to record the present environment and assess the possible consequences of proposed developments. Up to now, much of the northern shore of Western Port has retained essentially the features and qualities of a natural environment: the State faunal reserves at Quail Island and Chinaman Island are intended to conserve samples of this landscape and its wildlife. Western Port is also important as a fishery and an area for waterborne recreation. The mangrove fringe, which protects much of the northern shore, is particularly vulnerable to pollution damage, and if it is destroyed shoreline erosion will ensue, consuming land and releasing sediment into tidal channels, including the channels that have to be maintained for navigation.

Development in Western Port can protect the original environment if the port and industrial activity are confined to a particular zone, and landscape amenity, recreational opportunity, and wildlife interest conserved over the rest of the area, as required by the statements of planning policy approved by the Government in 1971 for Western Port and Mornington Peninsula. The same concept is applicable to Port Phillip Bay, which plays a vital role as a recreational area for the people of Melbourne, Geelong, and the bayside townships.

Mining has not affected the Victorian coast to the extent experienced in other States, largely because coastal quarrying has been limited and there has not been disruption of beach and dune landscapes for mineral sand extraction. Experience in other States has shown that this kind of mining involves the destruction of vegetation and natural scenery, and generally results in erosion and mobilisation of dune sands. Active movement of unvegetated dunes, probably accentuated in the past by grazing and burning of their scrub and woodland cover, is already a problem on the coast behind Discovery Bay, on the Yanakie isthmus, and towards Cape Howe, as well as on a smaller scale at other localities. Attempts by the Soil Conservation Authority to halt the active dunes have shown that this is a laborious and expensive process ; it is therefore important to preserve a vegetation cover on sectors where it still holds dune sands. Sectors of dune-fringed coast visited in summer by large numbers of holidaymakers (e.g., Lakes Entrance) also show actual or incipient erosion, and have had to be fenced and sown with such plants as marram grass as a prelude to the revival of a retentive vegetation cover, public access being confined to paved walkways. This is indicative of the kind of restriction that becomes necessary if intensive recreational use of the coast is to be reconciled with landscape conservation.

Subdivision of coastal land for holiday estate development proceeded on a large scale until it was restricted under the terms of an interim development order, pending the formulation and approval of planning schemes that will decide where such development should proceed. At present many of the subdivisions where coastal bushland has been cleared have only a few scattered buildings, often of poor quality in terms of amenity. Unrestricted development of holiday estates would eventually have led to the spread of a monotonous suburban coastal landscape at the expense of rural and natural coastal scenery. Suburban coast is already in existence along much of the eastern shore of Port Phillip Bay, and it is obvious here that this kind of development is inconsistent with the maintenance of variety in coastal landscapes. Zonation of coastal utilisation is a necessary element of planning schemes, some sectors developing as urban seaside resorts, others becoming primarily recreational, and others remaining essentially natural.

The central problem is one of access. Proposals have been made in recent years for the construction of roads along the coast in order to provide easy public access, but this leads merely to the spread of disturbance and damage to natural scenery and wildlife resources along the coastline, and makes for uniformity, instead of variety, in the coast environment. For better public access one solution advanced is the provision of feeder roads branching from inland highways to serve seaside resorts and sectors of particular interest and recreational value along the coast. In this way, utilisation and development could be arranged in such a way as to meet the demands of those who want to enjoy natural and unspoilt coastline as well as those who prefer recreational activities that require structural developments, such as boat ramps and marinas, surf clubs, car parks, and camping grounds, in the coastal region. Taken broadly, the aim of conservation on the coast is to provide a pattern of utilisation that will ensure the preservation of the finest natural scenery and most important wildlife resources at the same time as encouraging the development of recreational facilities for seaside holidaymaking on other specified coastal sectors. In this way it should be possible to satisfy most of the demands that are made for development and conservation on the coast of Victoria.

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Rivers

Stream flows

Water is a limited resource and a major factor in the development of the State. Hence a knowledge of its water resources is essential to their optimum use. Tabular data giving the mean, maximum, and minimum flows at selected gauging stations are published periodically by the State Rivers and Water Supply Commission in their *River Gaugings.* The data in the table below have been extracted from the latest published volume containing records of 175 gauging stations to 1965.

An average value such as the mean annual flow is a useful relative single measure of magnitude, but variability is equally important. Another crude measure of such variability is given by the tabulated values of the maximum and minimum annual flows ; however, the difference between these extremes, termed the " range ", will increase with increasing length of record.

Catchment and lengths

Other characteristics relating to streams are the size of the catchment and the lengths of the rivers. Areas of gauged catchments are given in *River Gaugings,* and the lengths of 230 rivers are tabulated on pages 31 to 35 of the *Victorian Year Book* 1963.

Catchments may be regarded as the hydrologically effective part of a " basin ", or the area from which there is " run-off " to the stream. Thus, the whole of any area may be subdivided into basins, but parts of some basins may be regarded as non-effective, being either too flat or the rainfall too small to contribute to normal stream flows. There is little or no contribution in the north-west of the State where the annual rainfall is less than 18 inches to 20 inches. Above this amount, roughly half the rainfall appears as stream flow.

Total flow

The current estimate of mean annual flow is 17 million acre ft each year, about half of which flows into the Murray ; the other half flowing southward to the Victorian coast. The geographic distribution of flow is heavily weighted towards the eastern half where the total flow is about 14 million acre ft (with about 8 million acre ft in the north-east and 6 million acre ft in the south-east) and hence leaving 3 million acre ft in the western half.

The following table shows the main river basins of Victoria and flows of the main streams :

VICTORIA—SCHEDULE OF MAIN STREAM FLOWS

Div.	Basin	Stream	Site of gauging station	Catchment area (square miles)	Year gauged from	Annual flows in '000 acre ft			
						Mean	No. of years	Max.	Min.
IV. Murray-Darling Division	1	Murray	Jingellic	2,520	1890	1,933	76	4,978	549
		Mitta Mitta	Tallandoon	1,840	1935	1,063	30	2,613	316
			Tallangatta	2,000	1886	1,147	49	3,460	203
	2	Kiewa	Kiewa	450	1886	518	80	1,684	144
	3	Ovens	Wangaratta	2,250	1941	1,308	25	3,367	271
	4	Broken	Goorambat	740	1887	205	79	887	15.5
	5	Goulburn	Murchison	4,140	1882	1,795	84	6,139	516
	6	Campaspe	Elmore	1,240	1886	192	78	667	0.6
	7	Loddon	Laanecoorie	1,610	1891	205	75	660	8.9
	8	Avoca	Coonooer	1,000	1890	63	76	321	3.8
	15	Wimmera	Horsham	1,570	1889	104	77	479	0
II. South East Coast Division	22	Snowy	Jarrahmond	5,000	1907	1,682	42	3,254	766
	23	Tambo	Bruthen	1,030	(*a*) 1906	179	29	575	50
	24	Mitchell	Glenaladale	1,530	1938	764	28	1,779	325
	25	Thomson	Cowwarr	420	1901	325	50	553	142
	25	Macalister	Glenmaggie	730	1919	477	47	1,277	181
	26	La Trobe	Rosedale	1,600	(*b*) 1901	777	51	2,634	362
	28	Bunyip	Bunyip	268	(*c*) 1908	124	47	246	56
	29	Yarra	Warrandyte	899	1892	685	48	1,215	265
	30	Maribyrnong	Keilor	500	(*d*) 1908	91	35	266	3
	31	Werribee	Melton	446	(*e*) 1917	68	49	259	5.3
	32	Moorabool	Batesford	430	(*f*) 1908	58	16	149	2.5
	33	Barwon	Winchelsea	370	(*g*) 1922	115	33	412	25
	35	Carlisle	Carlisle	30	(*h*) 1930	32	31	71	14.5
	36	Hopkins	Wickliffe	540	(*i*) 1921	28	34	103	1.4
	38	Glenelg	Balmoral	606	(*j*) 1889	117	60	439	2.5

Source : *River Gaugings to 1965*, State Rivers and Water Supply Commission.

Note	Years excluded in estimating mean	Note	Years excluded in estimating mean
(*a*)	1924–25 to 1937–38	(*f*)	1921–22 to 1945–46
(*b*)	1919–20 to 1936–37	(*g*)	1933–34 to 1943–44
(*c*)	1951–52	(*h*)	1943–44 to 1946–47
(*d*)	1933–34 to 1955–56	(*i*)	1933–34 to 1943–44
(*e*)	1952–53	(*j*)	1933–34 to 1938–39

Location of streams

The location of about 2,500 streams in Victoria may be obtained by referring to the *Alphabetical Index of Victorian Streams* compiled by the State Rivers and Water Supply Commission in 1960. Owing to the replication of names for some streams, there are over 2,900 names ; these have been obtained by examining Department of Crown Lands and Survey and Commonwealth Military Forces maps, so as to include names which have appeared on them. There are, in addition, many unnamed streams, those with locally known names, and those named on other maps or plans. No attempt was made in the Index to suggest a preferred name ; this is a function of the committee appointed under the *Survey Co-ordination Place Names Act* 1965.

Stream reserves

In 1881, under the then current Land Act, an Order in Council created permanent reserves along the banks of streams where they passed through Crown land. These are scheduled in the *Township and Parish Guide* reprinted by the Lands Department in 1955. This schedule indicates the

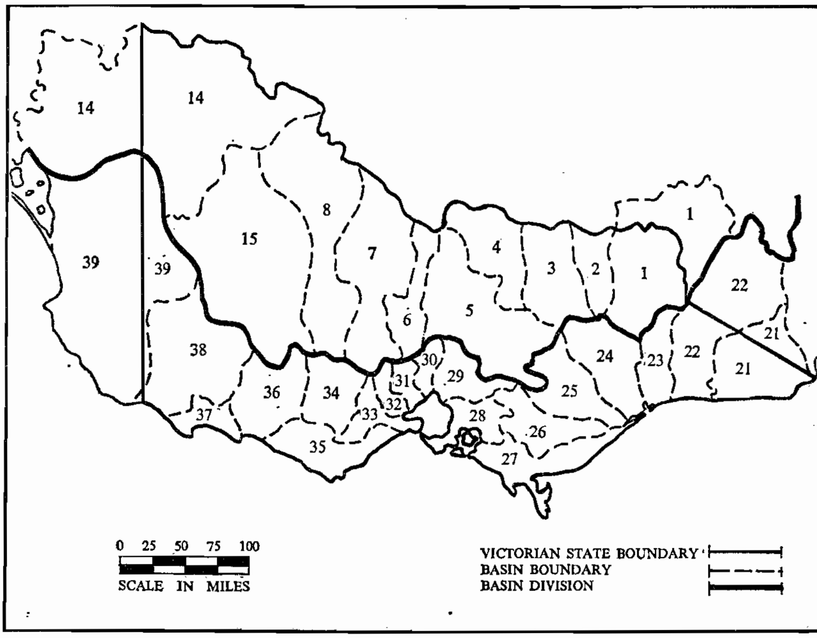

FIGURE 2. Relevant Basins of the two Divisions (South East Coast Division and Murray–Darling Division) which include Victoria and some adjacent areas. The Basins are numbered as shown on Map 3 (Sheet 2) in *Review of Australia's Water Resources,* published by Department of National Development, 1965.

SOUTH EAST COAST DIVISION

21. East Gippsland
22. Snowy River
23. Tambo River
24. Mitchell River
25. Thomson River
26. La Trobe River
27. South Gippsland
28. Bunyip River
29. Yarra River
30. Maribyrnong River
31. Werribee River
32. Moorabool River
33. Barwon River
34. Lake Corangamite
35. Otway
36. Hopkins River
37. Portland
38. Glenelg River
39. Millicent Coast

MURRAY–DARLING DIVISION

1. Upper Murray River
2. Kiewa River
3. Ovens River
4. Broken River
5. Goulburn River
6. Campaspe River
7. Loddon River
8. Avoca River
14. Mallee
15. Wimmera–Avon River

location and width of reservations for 280 streams which (except for the Murray) are 1, $1\frac{1}{2}$, or 2 chains wide on *each* bank of the stream. The areas thus reserved were not fully delineated until subsequently surveyed prior to alienation.

Further reference, 1963 ; Droughts, 1964

Floods

The natural history of unregulated rivers is largely the history of their floods and droughts. Rainfall intensity increases with decrease in latitude and consequently Victoria is less subject to floods than the northern States. The practical importance of floods is, however, largely related to the damage they do in occupied areas.

Flood damage usually occurs because of the occupation of flood plains, and once occupied there is a demand for protection which is commonly provided by levees. Such levees have been constructed along the major streams including the Murray, Snowy, and Goulburn, and also in urban areas occupying the flood plain of the Dandenong Creek. The objection to levees is that by restricting the flood plain, the flood level for a given discharge is increased, and if overtopping does occur, damage is more serious. Other flood mitigation measures used in Victoria, such as straightening the stream to increase the gradient and flow rate, have also been used on such streams as the Bunyip and the Yarra. Provision to prevent excessive scour may be necessary in some cases.

Lake level changes

Another form of flood damage that has occurred in the Western District is due to the increase in level of closed lakes flooding marginal land. This has been caused by a series of wet years since 1950 upsetting the normal balance between evaporation and inflow. In the decade since 1950 the winter rainfalls in the region of Lake Corangamite were 15 per cent above average, and the lake level rose 11 ft above its normal level of 380 ft to 391 ft to inundate about 20 square miles of adjacent land.

To reduce the inflow to this lake and hence the area flooded, a 28 mile channel, completed in 1959, diverts water to the Barwon River from the Cundare Pool. This pool, which was formed by building a low barrage across a shallow area at the head of the lake, acts as a temporary storage for the relatively fresh waters of the Woady Yaloak River which normally enter the lake.

The rate of diversion is governed by the level of the Cundare Pool and by the relative salinities of water in the pool and in the Barwon River. If the 60,000 acre ft diverted in 1960 had entered Lake Corangamite, the lake level would have been 9 inches above the maximum observed level. The level would have been almost as high again in late 1964—another very wet year—but for the diversion in the preceding five years of about 180,000 acre ft. These wet years have maintained the relatively high lake level.

Legislation has been passed to permit the Government to pay compensation on a special scale to landowners who may elect to surrender land up to 388 ft above sea level around Lake Corangamite, plus any higher land rendered inaccessible to the landowner by the initial surrender. The legislation also makes similar provision for the neighbouring Lakes Gnarpurt and Murdeduke.

Other floods

Owing to the tendency for major floods to overflow the banks and, in flat country, to pass down other channels which may not rejoin the main stream, it is often difficult to determine even the relative magnitude of major floods. The difficulty is magnified by the necessity for maintaining records of the level of the gauge in relation to a permanent datum, if a true comparison is to be made.

The year 1870 is regarded as the wettest that Victoria has experienced for over a century. As there were only thirteen rainfall stations whose records are available, the estimated average of 38 inches over the State is crude, but is 3 inches more than the next highest figure of 35 inches for

1956. River gauges in 1870 were practically restricted to the Murray, and consequently flood estimates on other streams are crude and can only be inferred from dubious evidence. Furthermore, subsequent to the 1870 floods, levees were constructed along the Goulburn and other streams and consequently heights of subsequent floods were augmented by the restrictions imposed.

In the north-east, floods occurred in the years 1906, 1916, 1917, and 1956. Although records of flood flows at gauging stations on the main streams have been published, such estimates are open to correction in the light of more recent evidence. Owing in part to under-estimation of earlier floods, the protection at the S.E.C. works at Yallourn was inadequate and the 1934 flood overflowed the banks of the La Trobe into the open cut at Yallourn. This flood was caused by a storm which is, on the basis of rainfall over large areas, the most severe that has been recorded within Victoria. An earlier storm of December 1893 which occurred over east Gippsland was heavier, but this also covered part of New South Wales.

Lakes

Lakes may be classified into two major groups : those without natural outlets which are called " closed " lakes and those with a natural overflow-channel which may be termed " open " lakes. For closed lakes to form, annual evaporation must exceed the rainfall : this is the case over most of Victoria.

Closed lakes occur mainly in the flat western part of the State. They fluctuate in capacity much more than open lakes and frequently become dry if the aridity is too high. Lake Tyrrell in the north-west is usually dry throughout the summer and can consequently be used for salt harvesting.

The level of water in an open lake is more stable because as the lake rises the outflow increases, thus " governing " the upper lake level and thus partially regulating streams emanating from it. This regulation enhances the economic value of the water resources of open lakes but Victoria does not possess any such large lake-regulated streams. However, there are small streams of this type in the Western District, such as Darlots Creek partly regulated by Lake Condah and Fiery Creek by Lake Bolac.

Salinity is often a factor which limits the use of lake water ; even the use of freshwater lakes is not extensive in Victoria due to the cost of pumping. The average salinity of closed lakes covers a wide range depending upon the geological conditions of the catchments and the water level.

Lake Corangamite is Victoria's largest lake. It can be regarded as a closed lake although during the wet period in the late 1950s it rose to within 4 ft of overflowing. The total salt content is about 16 million tons, giving the lake a salinity somewhat higher than seawater under average water level conditions.

The Gippsland lakes are a group of shallow coastal lagoons in eastern Victoria, separated from the sea by broad sandy barriers bearing dune topography, and bordered on the ocean shore by the Ninety Mile Beach. A gap through the coastal dune barrier near Red Bluff, which was opened in 1899, provides an artificial entrance to the lakes from the sea. However, sea water entering this gap has increased the salinity of some lakes, which in turn has killed some of the bordering reed swamp and led to erosion. The Gippsland lakes have been of value for commercial fishing and private angling and also attract many tourists. Coastal lagoons of this type rarely persist for more than a few thousand years and as deposition of sediment proceeds and bordering swamps encroach, the lakes will gradually be transformed into a coastal plain.

A number of Victorian lakes and swamps have been converted to reservoirs. Waranga Reservoir is an example of this, as are Fyans Lake, Batyo Catyo, and Lake Whitton in the Wimmera. A good example of lake utilisation is the Torrumbarry irrigation system on the riverine Murray Plains near Kerang in north-west Victoria.

Further reference, 1965; Natural Resources Conservation League, 1965

Survey and mapping

The Survey Branch of the Department of Crown Lands and Survey is responsible for the development of the National Geodetic Survey within Victoria, the preparation of topographic maps, the survey of Crown lands, and the co-ordination of surveys under provisions of the *Survey Co-ordination Act* 1958.

An Australia-wide primary geodetic survey was completed in 1966, and is continuously being improved and extended to provide a framework of accurately fixed points for the control of all other surveys and mapping. A State level network has also been completed, and will be based on a national mean sea level value, thus obviating the multitude of local datums currently in use.

As part of its mapping activity the Department provides an aerial photography service, and maintains an aerial photograph library where approximately one quarter of a million photographs are held, from which prints and enlargements may be obtained.

The official map of Victoria has been published in four sheets at a scale of 1 : 500,000 and shows highways, roads, railways, watercourses, towns, mountains, and other natural and physical features. A less detailed map of Victoria has also been published and is available in one sheet at a scale of 1 : 1,000,000.

Topographic maps at a scale of 1 : 250,000 covering the whole State have been published by the Royal Australian Survey Corps and the National Mapping Division. A joint State-Commonwealth mapping programme is now under way to produce a new series of topographic maps at a scale of 1 : 100,000 showing 20 metre contours, to replace the old 1 : 31,680 and 1 : 63,360 maps. A number of these maps have been published, and it is expected that the State will be covered by this series by 1975.

Large scale base maps have been prepared for rapidly developing areas throughout the State, including the outer metropolitan area, Mornington Peninsula, Ballarat, Geelong, Phillip Island, and a number of smaller towns. These maps were originally compiled at a scale of 1 : 4,800 with 5 ft contours, but because of the impending introduction of the metric system all new maps will be published at a scale of 1 : 5,000 showing 2 metre contours.

Smaller scale general purpose maps are required over areas covered by the large scale base maps, and another series of maps will be published at a scale of 1 : 25,000. The first maps of this series will cover Melbourne and environs. Concurrently with this work, the Division of National Mapping is compiling a series of maps over urban areas at a scale of 1 : 10,000 for census purposes. The Mines Department and the Forests Commission also contribute to State mapping by publishing maps for geological and forestry purposes.

In addition to geodetic surveys, cadastral surveys are carried out by the Department for the purpose of defining boundaries and for determining dimensions and areas of allotments for the subsequent issue of Crown grants. This information forms the basis for the compilation of county, parish, and township plans which are published at various scales and show details of the original subdivision of Crown lands.

Recently investigations have been made with the object of introducing a fully integrated topographic-cadastral mapping system at scales ranging from 1 : 500 to 1 : 100,000. This action has been prompted by the introduction of the metric system and the need for standardisation of map scales.

Complete information of survey and mapping activities may be obtained from the Central Plan Office, 2 Treasury Place, Melbourne, where maps, plans, and aerial photographs are available for purchase by the public.

CLIMATE

Victoria

Victoria experiences a wide range of climatic conditions ranging from the hot summer of the Mallee to the winter blizzards of the snow covered Alps, and from the relatively dry wheat belt to the wet eastern elevated areas where many of Victoria's permanent streams spring.

Circulation patterns affecting Victoria

The predominating pattern which affects Victoria is an irregular succession of depressions and anticyclones. Although these systems generally move from west to east, this is not always the case. Systems can develop or degenerate *in situ*. Their speed of movement can vary considerably. They can remain quasi-stationary for even a week or more at a time.

The mean tracks of the depressions and anticyclones show a marked annual variation across the Australian region. In winter, due to the cold continent, anticyclones are centred over inland Australia, and a series of depressions over southern waters provide a persistent zonal flow across southern parts of the continent. However, on occasions when an anticyclone develops a ridge to southern waters and a depression intensifies east of Tasmania, a " cold outbreak " occurs. This brings cold and relatively dry air from southern waters rapidly across Victoria, giving windy, showery weather with some hail and snow. On other occasions, when an anticyclone moves slowly over Victoria, a prolonged spell of fine weather with frost and fog results.

During the spring the average track of depressions and anticyclones shifts further south until in summer the average position for anticyclones is south of the continent. At this time of the year the troposphere is warmer, and therefore can hold more moisture. For this reason, rainfall during the summer months tends to be heavier. However, lifting agents in the form of cold fronts are weaker and are not as frequent as the succession of fronts that pass in winter and spring, and so rain days are less frequent in summer.

Heat wave conditions, which usually last between two and three days, and occasionally longer, are not infrequent in summer when a large anticyclone remains quasi-stationary over the Tasman Sea. Dry air from the hot interior of the continent is brought over south-eastern Australia, and hot gusty northerly winds strengthen with the approach of a southerly change. These changes vary in intensity and while some are dry, others may produce rain and thunderstorms.

During the autumn, the mean track of the anticyclones moves northwards and extremes of temperature become less frequent as the season progresses.

The circulation pattern at the surface does not always bear the same relation to the weather which occurs. Rainfall may be produced by a depression in the upper atmosphere without any indication at the surface. One of the greatest State-wide rain producing systems is a weak surface depression, centred over the State and extending upwards in the atmosphere to 20,000 ft and more. On occasions, the surface depression is not a closed system, but a trough extending south from northern Australia. These are more common in the summer months and when preceded by an extensive flow of moist humid air over Victoria from the Tasman Sea, very heavy rainfall can result.

The heaviest rainfall in east Gippsland is produced by intense depressions to the east of Bass Strait. These may have come from the west and intensified in this area, or alternatively may have developed to the east of New South Wales or further north, and moved southwards along the coast.

The distribution of the average annual rainfall in Victoria is shown in the map on page 53.

Rainfall

Rainfall exhibits a wide variation across the State and although not markedly seasonal, most parts receive a slight maximum in the winter or spring months. The relatively dry summer season is a period of evaporation, which greatly reduces the effectiveness of the rainfall. Average annual totals range between 10 inches for the driest parts of the Mallee to over 60 inches for parts of the North-Eastern Highlands. An annual total exceeding 140 inches has been reported from Falls Creek in the north-east; however, with the sparse population and inaccessibility of the highland localities, it is not practicable to obtain a representative set of observations from this area. Most areas south of the Divide receive an annual rainfall above 25 inches, with over 40 inches on the Central Highlands, Otway Ranges, and southern Gippsland. The wheat belt receives chiefly between 12 and 20 inches. With the exception of Gippsland, 60 to 65 per cent of the rain falls during the period May to October. This proportion decreases towards the east, until over Gippsland the distribution is fairly uniform with a warm season maximum in the far east. All parts of the State have on rare occasions been subjected to intense falls, and monthly totals exceeding three times the average have been recorded. Monthly totals exceeding 10 inches have been recorded rarely at most places on and south of the Divide, the chief exception being over the lowlands extending from Melbourne to the Central Western District. Occurrences are more frequent, but still unusual, over the north-east and East Gippsland and isolated parts such as the Otways. This event has rarely been recorded over the north-west of the State. The highest monthly total ever recorded in the State was a fall of 35.09 inches at Tanybryn in the Otway district in June 1952.

An estimate of the area distribution of average annual rainfall, and the actual distribution of rainfall in Victoria as shown by area for 1966 to 1970 are shown in the following table :

VICTORIA—DISTRIBUTION OF AVERAGE AND ANNUAL RAINFALL

Rainfall (inches)	Area ('000 square miles) (a)					
	Average	1966	1967	1968	1969	1970
Under 10	..	1.7	32.1	1.5	..	0.1
10–15	19.7	19.2	21.7	8.8	8.9	9.9
15–20	13.4	10.1	13.7	16.6	26.1	17.6
20–25	15.7	11.3	8.3	17.1	13.4	8.8
25–30	15.8	13.6	7.0	15.9	10.0	11.9
30–40	14.2	9.4	4.7	14.8	17.7	16.2
Over 40	9.1	22.6	0.4	13.2	11.8	23.4

(a) Total area of the State is 87,884 square miles.

The average annual number of wet days (0.01 inches or more in 24 hours) is over 150 on the west coast and west Gippsland, and exceeds 200 over the Otway Ranges. The average number of wet days a year is reduced to 100 at a distance of approximately one hundred miles inland from the coast.

District rainfall

Mallee and Northern Country

These districts receive very little rain from western cold fronts, and rain is usually brought by depressions moving inland, " upper lows ", and thunderstorms. The amount received is highly variable from year to year. The average rainfall is fairly even through the year, except near the northern edge of the ranges where more rain falls in winter than in summer.

Wimmera

Rainfall in this district is more reliable than further to the north, as cold fronts bring showers, particularly in winter. The average rainfall shows a slight maximum in the winter months. This district includes part of the Grampians, which receive much higher rainfall than the plains.

Western and Central Districts

Rain may fall in these districts in a variety of situations and they have the most reliable rainfall in the State. Most rain comes with the westerly winds and cold fronts which predominate in winter and the average rainfall shows a winter maximum which is most marked along the west coast. The heaviest rain falls on the Otways, the Dandenongs, and the Upper Yarra Valley, while the plain to the west and south-west of Melbourne has relatively low rainfall due to the " rain shadow " of the Otway Ranges.

North Central

Most of this district consists of elevated country surrounding the Dividing Range and rainfall is heaviest on the higher parts, particularly towards the east. There is a well marked winter maximum in the yearly rainfall distribution.

North-eastern

The greater part of this district consists of ranges, some mountains being 6,000 ft in elevation, and rainfall on this higher country is generally heavy. The higher peaks lie under snow cover for most of the winter. A marked rain shadow area is evident near Omeo, which receives only half as much rain as the highlands to the north-west or north-east.

West Gippsland

The western part of this district has a very similar rainfall régime to the Western and Central Districts. The heaviest rain falls on the ranges of the Divide and the south Gippsland hills. Towards the east, however, a " rain shadow " is evident in the Sale–Maffra area. This eastern section receives some of its rain from east coast depressions.

East Gippsland

Depressions off the east coast bring most rain to this district, and such rainfall can be very heavy. The average rainfall shows a summer maximum. Fronts moving in a westerly stream bring very little rain, and with north-westerly winds in winter, the coastal section has the mildest weather in the State. Rain shadows are evident along the valleys of the Mitchell, Tambo, and Snowy Rivers while the heaviest rain falls on the surrounding highlands.

A description of the State's agricultural districts will be found on pages 274–9.

VICTORIA—RAINFALL IN DISTRICTS
(inches)

Year	Districts							
	Mallee	Wimmera	Northern	North Central	North-eastern	Western	Central	Gippsland
1961	13.44	15.07	14.90	25.27	27.60	24.03	22.90	33.04
1962	11.29	17.69	18.85	27.77	33.78	25.99	26.07	31.41
1963	16.15	18.55	20.66	30.46	35.49	25.87	28.36	35.61
1964	16.14	25.02	20.93	34.40	40.27	38.69	35.40	37.99
1965	11.76	15.25	15.36	25.83	25.80	24.67	25.09	26.28
1966	12.48	16.47	20.28	31.97	41.26	29.35	32.08	38.97
1967	5.10	8.71	9.46	16.06	17.62	16.43	17.09	23.33
1968	13.68	19.68	20.93	34.66	39.51	33.54	28.84	34.04
1969	16.05	17.45	18.94	27.17	34.56	26.72	26.13	36.01
1970	14.44	18.64	20.29	33.20	39.10	33.72	36.87	44.16
Average (*a*)	12.87	17.94	18.45	27.91	34.12	28.45	29.25	33.94

(*a*) Average for 58 years 1913 to 1970.

Rainfall reliability

It is not possible to give a complete description of rainfall at a place or in a district by using a single measurement. The common practice of quoting the annual average rainfall alone is quite inadequate in that it does not convey any idea of the extent of the variability likely to be

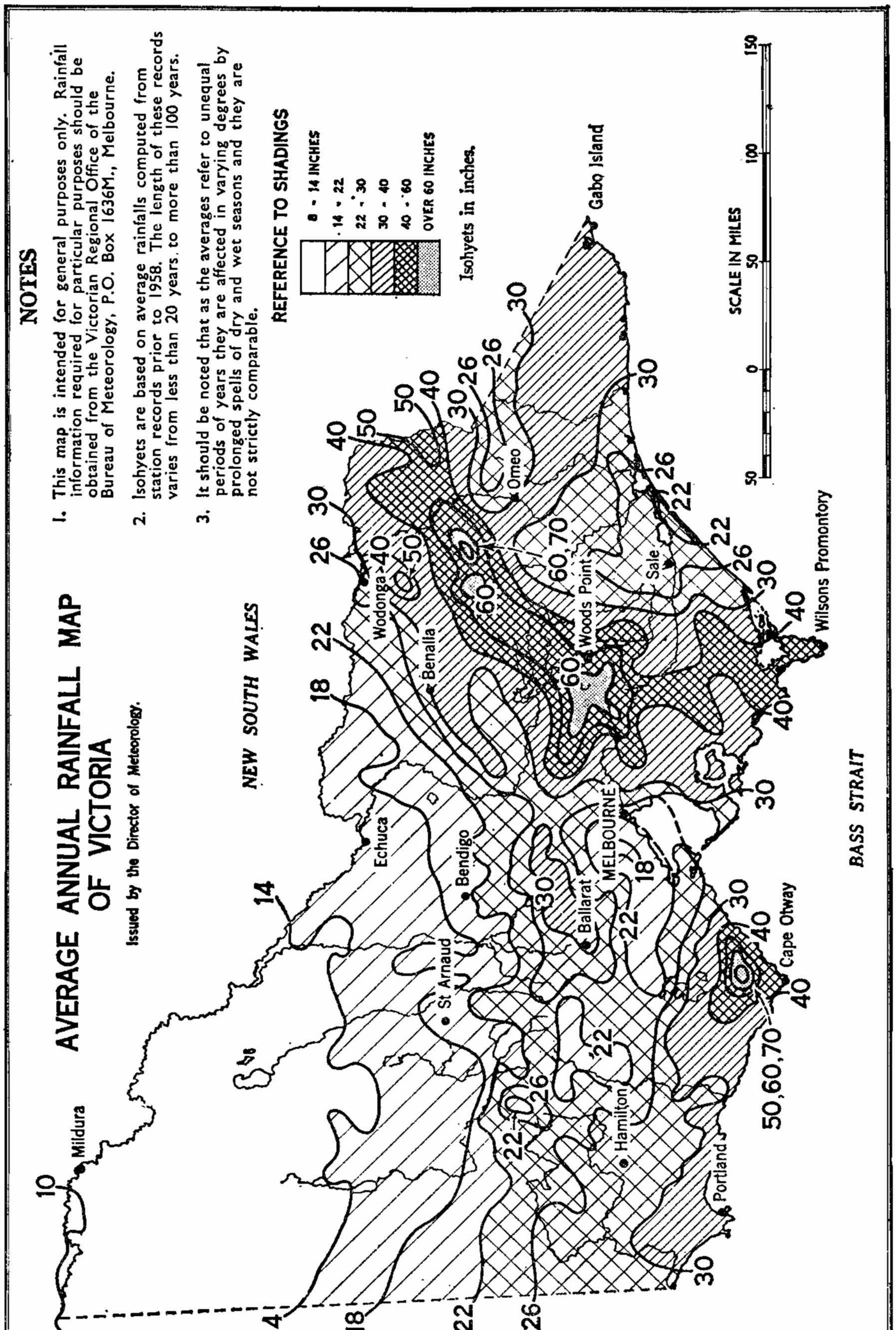
AVERAGE ANNUAL RAINFALL MAP
OF VICTORIA
Issued by the Director of Meteorology.
NOTES
1. This map is intended for general purposes only. Rainfall information required for particular purposes should be obtained from the Victorian Regional Office of the Bureau of Meteorology, P.O. Box 1636M., Melbourne.
2. Isohyets are based on average rainfalls computed from station records prior to 1958. The length of these records varies from less than 20 years to more than 100 years.
3. It should be noted that as the averages refer to unequal periods of years they are affected in varying degrees by prolonged spells of dry and wet seasons and they are not strictly comparable.
REFERENCE TO SHADINGS
8 - 14 INCHES
14 - 22
22 - 30
30 - 40
40 - 60
OVER 60 INCHES
Isohyets in inches.
SCALE IN MILES
50
0
50
100
150
NEW SOUTH WALES
SOUTH AUSTRALIA
BASS STRAIT
Mildura
Echuca
Bendigo
St Arnaud
Ballarat
MELBOURNE
Hamilton
Portland
Cape Otway
Wodonga
Benalla
Woods Point
Omeo
Sale
Wilsons Promontory
Gabo Island
50,60,70
60,70

FIGURE 3.

VICTORIA—DISTRICT MONTHLY RAINFALL: AVERAGE AND 1970

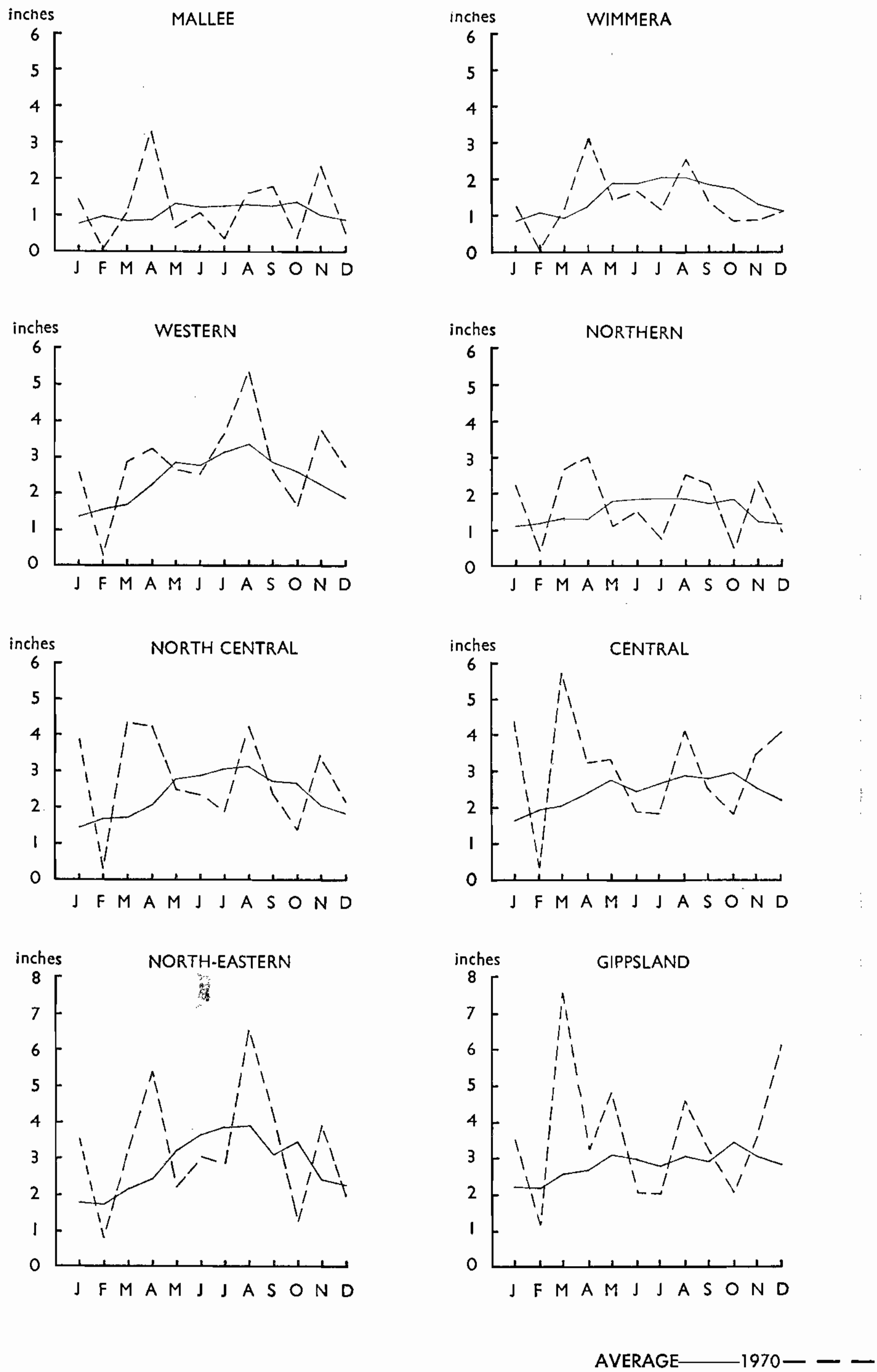

FIGURE 4.

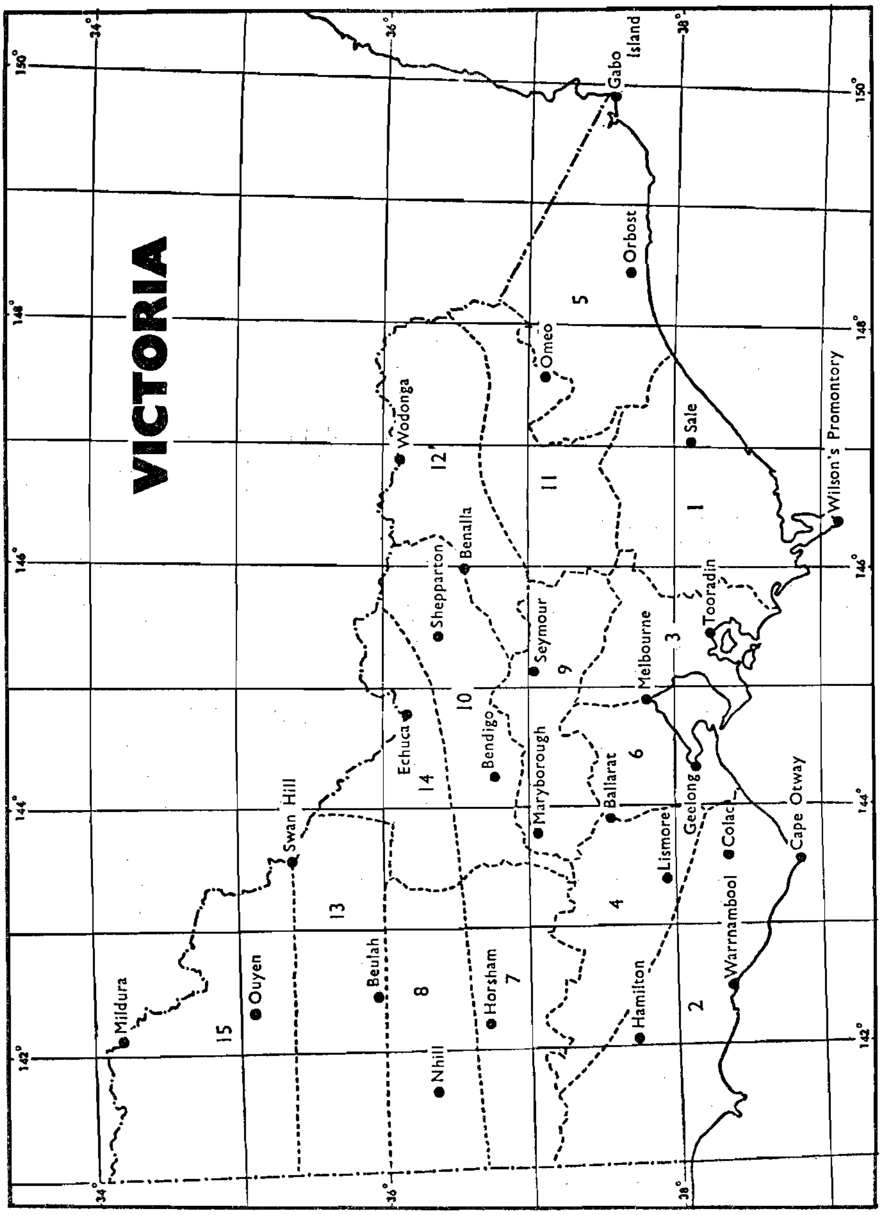

FIGURE 5. Relative rainfall variability districts. Names of districts are shown in the table on page 56.

encountered. Examination of rainfall figures over a period of years for any particular place indicates a wide variation from the average; in fact, it is rare for any station to record the average rainfall in any particular year. Thus for a more complete picture of annual rainfall the variability or deviation from the average should be considered in conjunction with the average.

Rainfall variability assumes major importance in some agricultural areas. Even though the average rainfall may suggest a reasonable margin of safety for the growing of certain crops, this figure may be based on a few years of heavy rainfall combined with a larger number of years having rainfall below minimum requirements. Variability of rainfall is also important for water storage design, as a large number of relatively dry years would not be completely compensated by a few exceptionally wet years when surplus water could not be stored.

Although variability would give some indication of expected departures from normal over a number of years, variability cannot be presented as simply as average rainfall.

Several expressions may be used to measure variability, each of which may have a different magnitude. The simplest measure of variability is the range, i.e., the difference between the highest and lowest annual amounts recorded in a series of years. Annual rainfall in Victoria is assumed to have a " normal " statistical distribution. These distributions can be described fully by the average and the standard deviation. To compare one distribution with the other, the coefficient of variation $\left(\frac{\text{standard deviation}}{\text{the average}} \times 100\right)$ has been used. The coefficient of variation has been calculated for the fifteen climatic regions of Victoria (see Figure 5) for the 58 years 1913 to 1970 and the results are tabulated below in order of rainfall reliability :

VICTORIA—ANNUAL RAINFALL VARIATION

District	Average annual rainfall (*a*)	Standard deviation	Coefficient of variation
	inches	inches	per cent
1. West Gippsland	36.11	5.71	15.8
2. West Coast	30.33	4.96	16.4
3. East Central	35.12	5.82	16.6
4. Western Plains	24.80	4.41	17.8
5. East Gippsland	30.43	5.58	18.3
6. West Central	23.85	4.68	19.6
7. Wimmera South	19.37	3.86	19.9
8. Wimmera North	16.14	3.35	20.8
9. North Central	27.91	6.08	21.8
10. Upper North	19.99	4.68	23.4
11. Upper North-east	43.66	10.43	23.9
12. Lower North-east	30.33	7.28	24.0
13. Mallee South	13.62	3.48	25.6
14. Lower North	16.81	4.57	27.2
15. Mallee North	11.81	3.41	28.9

(*a*) Average for 58 years 1913 to 1970.

The higher the value of the coefficient of variation of the rainfall of a district, the greater the departure from the average and hence the more unreliable the rainfall.

Droughts

The variability of annual rainfall is closely associated with the incidence of drought. Droughts are rare over areas of low rainfall variability and more common in areas where this index is high.

Since records have been taken, there have been numerous dry spells in various parts of Victoria, most of them of little consequence but many widespread and long enough to be classified as droughts. The severity of major droughts or dry spells is much lower in Gippsland and the Western District than in northern Victoria.

The earliest references to drought in Victoria appear to date from 1865 when a major drought occurred in northern Victoria, and predominantly dry conditions prevailed in the Central District. Another dry spell of lesser intensity occurred in 1868.

The most severe and widespread drought recorded since white settlement in Australia occurred in the period 1897 to 1902. Victoria was most affected in the south in 1897–98 and in the north particularly in 1902.

The next major drought commenced about June 1913 and continued until April 1915 in the north and west and until August 1916 in Gippsland. The worst period was from May to October 1914.

The period from 1937 to 1945 was marked by three major droughts. The first commenced in February 1937 and continued with a break in the succeeding spring and summer until January 1939, the effects being felt much more severely in northern districts than elsewhere. Good rains in 1939 were followed by another dry period from December 1939 to December 1940. The third drought of the period extended from 1943 to 1945 in which the worst period was from June to October 1944. The drought from 1967 to 1968 is described on pages 53 and 67 of the *Victorian Year Book* 1969 and other effects noted on pages 309–12 of the *Victorian Year Book* 1970.

Droughts of shorter duration and lower intensity occurred in 1877, 1888, in 1907–08 in Gippsland, and in the 1920s, particularly 1925, 1927, and 1929.

Readers are referred to the publication *Droughts in Australia,* Bulletin No. 43 of the Commonwealth Bureau of Meteorology, published in 1957, for a definitive treatment of the subject of droughts in Victoria.

1967–68 drought, 1969

Floods

Floods have occurred in all districts, but they are more frequent in the wetter parts of the State such as the north-east and Gippsland. However, although a rarer event over the north-west lowlands, they may result from less intense rainfall and continue longer because of the poor drainage in this section of the State. In many instances the frequency of flooding is increased by valley contours and damage is often greater because of the higher density of adjacent property and crops. (See also pages 45–7 and 62–3.)

Snow

Snow in Victoria is confined usually to the Great Dividing Range and the alpine massif, which at intervals during the winter and early spring months may be covered to a considerable extent, especially over the more elevated eastern section. Falls elsewhere are usually light and infrequent. Snow has been recorded in all districts except the Mallee,

VICTORIA—MEANS OF CLIMATIC ELEMENTS : SELECTED VICTORIAN TOWNS

Region	Locality	Legend (a)	Years of record	January	February	March	April	May	June	July	August	Sep.	October	Nov.	Dec.	Annual
Mallee	Mildura	1	23	68	93	98	55	123	93	107	105	103	120	97	81	1,143
		2	23	90.1	87.5	82.8	73.8	65.5	60.8	59.2	62.6	68.4	74.6	80.6	85.3	74.3
		3	23	62.0	61.1	56.9	50.0	45.3	41.6	39.8	41.4	45.1	49.8	53.6	58.1	50.4
	Swan Hill	1	85	75	88	89	93	134	144	123	132	121	135	97	96	1,327
		2	69	88.7	87.9	82.1	73.0	64.8	58.6	57.7	61.2	66.8	73.2	80.3	85.7	73.3
		3	63	59.6	59.7	55.2	49.2	44.3	40.6	39.3	40.7	43.9	48.1	52.8	57.0	49.2
Wimmera	Horsham	1	96	82	103	98	128	184	201	179	188	177	169	129	114	1,752
		2	61	85.7	85.7	79.8	70.5	62.7	57.0	55.9	58.9	64.0	69.9	76.9	82.0	70.8
		3	62	56.0	56.3	52.5	47.4	43.3	40.3	39.0	40.3	42.2	45.5	49.8	53.4	47.2
	Nhill	1	83	79	92	87	116	162	190	179	185	170	158	115	111	1,644
		2	64	85.3	84.6	79.5	70.5	63.0	57.5	56.4	59.1	64.3	70.0	76.9	82.1	70.8
		3	65	55.1	55.4	51.7	46.8	43.0	39.8	38.1	39.3	41.7	44.9	48.8	52.9	46.4
Western	Ballarat	1	59	136	189	181	218	266	249	279	300	290	266	220	210	2,804
		2	60	77.0	76.5	71.5	63.1	55.9	51.0	49.8	52.4	57.0	62.0	67.2	72.1	63.0
		3	59	51.1	52.8	49.9	45.5	42.5	39.5	38.1	39.0	41.0	43.5	45.9	49.0	44.8
	Hamilton	1	99	127	128	165	214	269	290	289	301	286	257	199	181	2,706
		2	83	78.1	77.9	73.2	65.6	59.2	54.8	53.5	55.6	59.6	63.7	69.0	73.8	65.4
		3	83	52.3	53.4	50.9	47.3	44.3	41.3	40.0	40.9	42.8	44.8	47.1	50.0	46.3
	Warrnambool	1	72	124	139	183	227	299	292	330	316	276	247	205	174	2,812
		2	66	71.5	71.6	69.7	65.1	60.5	56.8	55.7	57.1	59.8	62.9	65.8	68.7	63.8
		3	66	54.8	55.7	53.8	50.5	47.4	44.3	43.0	43.9	45.7	47.9	50.0	52.7	49.1
Northern	Bendigo	1	108	124	131	143	154	211	241	219	219	208	202	145	129	2,126
		2	103	85.1	84.3	78.7	69.6	61.1	55.2	53.8	56.9	62.2	68.6	75.5	81.2	69.4
		3	101	57.3	57.8	54.2	48.4	43.7	40.7	38.9	40.1	43.0	46.7	50.7	54.5	48.0
	Echuca	1	91	97	106	129	130	164	178	160	165	153	169	118	112	1,681
		2	87	87.6	86.8	80.9	71.7	63.2	57.4	55.9	59.2	64.8	71.7	78.8	84.2	71.8
		3	86	59.5	59.5	55.5	49.1	44.0	40.9	39.4	40.9	43.8	48.1	52.4	56.7	49.2

North Central	Alexandra	1	91	158	144	200	203	252	287	284	292	261	277	221	192	2,771
		2	48	84.8	84.7	78.8	68.9	60.6	53.7	53.1	56.9	62.7	68.5	74.8	81.2	69.0
		3	48	52.1	53.1	48.9	43.4	39.7	37.1	36.5	37.3	39.8	42.9	46.4	49.8	43.9
	Kyneton	1	95	148	155	182	215	294	355	324	328	290	273	204	197	2,965
		2	71	81.1	80.3	74.6	65.0	57.1	51.2	49.9	52.9	58.9	64.6	71.4	77.0	65.3
		3	65	49.6	50.3	47.2	42.1	38.4	36.1	34.8	35.5	37.9	40.6	44.0	47.5	42.0
Central	Geelong	1	99	118	147	160	177	196	192	179	188	202	203	186	157	2,105
		2	60	77.1	76.9	73.8	67.7	61.8	57.3	56.4	58.7	62.4	66.7	70.5	73.8	66.9
		3	61	55.6	56.8	54.5	50.5	46.5	43.2	41.6	42.5	44.6	47.3	50.2	53.4	48.9
	Mornington	1	79	168	160	190	243	276	280	279	275	281	275	232	203	2,862
		2	37	76.7	76.6	73.5	66.5	60.9	56.1	54.8	56.6	60.5	64.4	68.5	73.1	65.7
		3	35	55.6	56.6	54.9	51.2	48.2	44.9	43.3	44.1	46.3	49.0	51.3	53.7	49.9
North-Eastern	Omeo	1	90	197	208	212	181	206	226	208	213	243	283	238	246	2,661
		2	86	79.3	78.5	73.6	65.7	57.5	51.4	50.2	53.8	59.5	65.3	71.3	76.1	65.2
		3	85	48.8	49.2	46.1	40.7	35.9	33.7	31.8	33.1	36.8	40.2	43.6	46.9	40.6
	Wangaratta	1	91	138	150	184	185	223	288	254	249	231	247	180	169	2,498
		2	67	87.8	87.1	81.1	71.7	63.2	56.5	54.8	58.0	63.7	69.9	77.7	83.9	71.3
		3	66	58.9	58.6	53.8	46.9	41.7	39.0	37.9	39.4	42.5	46.7	51.4	56.0	47.8
West Gippsland	Yallourn	1	20	175	239	208	246	388	329	325	390	349	343	331	275	3,598
		2	20	76.9	75.3	72.6	65.6	58.1	54.5	53.1	55.3	59.5	63.7	67.3	71.5	64.4
		3	20	54.5	55.7	53.8	49.2	45.5	42.8	40.5	41.7	43.8	47.0	49.0	51.9	47.9
	Sale	1	26	173	180	214	185	239	195	164	206	197	274	258	231	2,516
		2	24	77.3	76.5	73.6	67.9	61.3	57.0	56.0	58.2	62.0	65.8	69.3	73.0	66.5
		3	24	54.2	55.4	52.5	47.3	43.3	40.0	38.3	39.6	41.9	45.8	48.4	51.9	46.6
East Gippsland	Bairnsdale	1	63	240	198	252	201	205	219	199	188	223	273	248	265	2,711
		2	63	76.3	76.4	73.5	68.5	62.6	57.8	56.9	59.4	63.4	67.2	70.9	74.1	67.3
		3	62	54.0	54.7	52.1	47.3	42.8	39.7	38.3	39.6	42.7	46.0	49.0	52.1	46.5
	Orbost	1	86	269	235	266	283	282	326	265	232	269	311	264	300	3,302
		2	29	77.1	76.9	74.5	69.0	63.2	58.8	58.0	60.0	63.5	67.0	70.2	74.1	67.7
		3	27	54.7	55.8	53.2	48.5	44.1	41.1	39.2	40.2	42.6	46.5	49.6	52.6	47.3

(a) Legend : 1. Average monthly rainfall in points : 100 points = 1 inch. (For all years of record to 1969.)
2. Average daily maximum temperature (°F.) (For all years of record to 1969.)
3. Average daily minimum temperature (°F.) (For all years of record to 1969.)

Wimmera, and northern country. The heaviest falls in Victoria are confined to sparsely populated areas and hence general community disorganisation is kept to a minimum. Snow has been recorded in all months on the higher Alps, but the main falls occur during the winter. The average duration of the snow season in the alpine area is from three to five months.

Temperatures

February is the hottest month of the year while January is only slightly cooler. Average maximum temperatures are under 75° F. along the coast and over elevated areas forming the Central Divide and North-Eastern Highlands. Apart from these latter areas, there is a steady increase towards the north, until, in the extreme north, an average of 90° F. is reached. Values decrease steadily with height, being under 70° F. in alpine areas above 3,000 ft and as low as 60° F. in the very highest localities.

Temperatures fall rapidly during the autumn months and then more slowly with the onset of winter. Average maximum temperatures are lowest in July ; the distribution during this month again shows lowest values over elevated areas, but otherwise there is practically no variation across the State. Day temperatures along the coast average about 55° F. in July ; much the same value is recorded over the wheat belt, and only a few degrees higher in the far north-west under conditions of few clouds and relatively high winter sunshine. The Alps experience blizzard conditions every year with minimum temperatures 10° F. to 20° F. less than at lowland stations.

In summer high temperatures may be experienced throughout the State except over the alpine area. Most inland places have recorded maxima over 110° F. with an all time extreme for the State of 123.5° F. at Mildura on 6 January 1906. Usually such days are the culmination of a period during which temperatures gradually rise, and relief comes sharply in the form of a cool change when the temperature may fall as much as 30° F. in an hour. However, such relief does not always arrive so soon and periods of two or three days or even longer have been experienced when the maximum temperature exceeds 100° F. On rare occasions extreme heat may continue for as long as a week with little relief.

Night temperatures, as gauged by the average minimum temperature, are, like the maximum, highest in February. Values are below 50° F. over the elevated areas, but otherwise the range is chiefly 55° F. to 60° F. The highest night temperatures are recorded in the far north and along the coast. In mid-winter average July minima exceed 40° F. along the coast and at two or three places in the far north. The coldest point of the State is the north-east alpine section, where temperatures frequently fall below freezing point. Although three or four stations have been set up at different times in this area, none has a very long or satisfactory record. The lowest temperature on record so far is 9° F. at Hotham Heights (station height 5,776 ft) at an exposed location near a mountain. However, a minimum of minus 8° F. has been recorded at Charlotte Pass (station height 6,035 ft)—a high valley near Mt Kosciusko in New South Wales —and it is reasonable to expect that similar locations in Victoria would experience sub-zero temperatures (i.e., below 0° F.), although none has been recorded due to lack of observing stations.

Frosts

Frosts may occur at any time of the year over the ranges of Victoria, whereas, along the exposed coasts, frosts are rare and severe frosts (air temperature 32° F. or less) do not occur. Frost, however, can be a very localised phenomenon, dependent on local topography. Hollows may experience frost while the surrounding area is free of frost.

The average frost-free period is less than 50 days over the higher ranges of the north-east while it exceeds 200 days within 50 miles of the coast and north of the Divide. The average number of severe frosts (air temperature 32° F. or less) exceeds 20 per year over the ranges. The average number of light frosts (air temperature between 32° F. and 36° F.) varies from less than 10 per year near the coast to 50 per year in the highlands of the north-east.

The first frosts of the season may be expected in April in most of the Mallee and northern country and in March in the Wimmera. Over the highlands of the north-east, frosts may be severe from March to November. Severe frosts on the northern side of the Divide are twice as frequent as on the southern side at the same elevation.

Humidity

Generally, humidity in the lower atmosphere is much less over Victoria than in other eastern States. This is because the extreme south-east of the continent is mostly beyond the reach of tropical and sub-tropical air masses. For several periods in the summer, however, air from the Tasman Sea has a trajectory over Bass Strait and other parts of the State, and it is then that the moisture content rises to show wet bulb temperatures above 65° F. The incidence of high humidity is important to the vine and fruit industry, tobacco growers, and wheat farmers.

Evaporation

Since 1967 the Class A Pan has been the standard evaporimeter used by the Bureau of Meteorology. This type is being progressively installed at evaporation recording stations in Victoria ; there were thirty-four at the end of 1970.

Measurements of evaporation have been made with the Australian tank at about thirty stations, about half of which are owned by the Bureau of Meteorology. Results from these stations show that evaporation exceeds the average annual rainfall in inland areas, especially in the north and north-west, by about 40 inches. In all the highland areas and the Western District the discrepancy is much less marked, and in the Central District and the lowlands of east Gippsland annual evaporation exceeds annual rainfall by 8 to 15 inches. Evaporation is greatest in the summer months in all districts. In the three winter months rainfall exceeds evaporation in many parts of Victoria, but not in the north and north-west.

Winds

The predominant wind stream over Victoria is of a general westerly origin, although it may arrive over the State from the north-west or south-west. There are wide variations from this general description, however, and many northerlies and southerlies occur. The latter is the prevailing direction from November to February with a moderate percentage of northerlies often associated with high temperatures. Easterly winds are least frequent over Victoria, but under special conditions can be associated with some of the worst weather experienced over the State. Wind varies from day to night, from season to season, and from place to place. Examples of the diurnal variation are the sea breeze, which brings relief on many hot days along the coastline, and the valley or katabatic breeze, which brings cold air down valleys during the night. The latter is well developed in many hilly areas of Victoria, being the result of differential cooling after sunset. It springs up during the night, often suddenly, and continues after sunrise until the land surfaces are sufficiently heated again. The sensitive equipment required to measure extreme wind gusts has been installed at only about five or six places in the State and to date the highest value recorded is just slightly over 102 mph at Point Henry near Geelong in 1962. There is no doubt, however, that similar gusts have been experienced in other parts of the State, although not in the vicinity of a recording anemometer. It is considered that any place in Victoria could feasibly experience at some time a local gust of 100 mph or more.

Thunderstorms

Thunderstorms occur far less frequently in Victoria and Tasmania than in the other two eastern States. They occur mainly in the summer months when there is adequate surface heating to provide energy for convection. Between ten and twenty a year occur in most of Victoria, but the annual average is about thirty in the north-eastern ranges. Isolated severe wind squalls and tornadoes sometimes occur in conjunction with thunderstorm conditions, but these destructive phenomena are comparatively rare. Hailstorms affect small areas in the summer months ; and showers of small hail are not uncommon during cold outbreaks in the winter and spring.

Hydrometeorology

Floods in Australia cost millions of dollars a year in loss of production and wages, damage to property, loss of stock and crops, and sometimes even loss of life. Eastern Australia suffers the severest floods because of the greater number of large river systems and the many swift flowing streams draining from the chain of highlands extending almost without a break parallel to the coastline.

The Commonwealth Bureau of Meteorology is responsible for the preparation and issue of flood warnings. Bureau meteorologists in regional offices use observations from the network of stations throughout Australia and adjacent islands to make frequent assessments of the likelihood of heavy rain occurring over the many catchment areas. Daily rain reports from a selected network of key observing stations are telegraphed to the forecast centre each day at 9 a.m. A general warning of possible flooding is issued whenever Bureau meteorologists assess that rain sufficient to cause river rises is likely to occur within the next one to two days. Automatic rain gauges which will automatically report by radio signal the amount of rain received have been installed by the Bureau at some reporting stations where existing communications are liable to interruption at critical times and more of these gauges are to be installed within the next few years.

During periods of floods rainfall and river height reports are received every three hours from selected networks of stations. Most of these stations are situated in flood-free areas but the observers have agreed to provide reports during flood danger periods as a public service to residents of flood-affected areas. Staff at the flood forecasting centre make forecasts every three hours of expected river behaviour at the likely flood area. A revised forecast is issued after each new set of rainfall and river information has been received and analysed at the forecast centre. The Bureau's river forecasts refer to expected river behaviour at specified reference gauges. Local authorities in the flood-affected areas assume responsibility for interpreting the forecasts in terms of the expected areas and depths of flooding if the river reaches its predicted height at a reference gauge. In Victoria quantitative flood forecasting systems are in operation on the Snowy River to Orbost and on the La Trobe River to Yallourn. In co-operation with other authorities, similar systems will be introduced progressively on other rivers in the State.

The Bureau is setting up the best service possible on the basis of data collected from rainfall and river height observing stations that have operated during past floods. Often the coverage of these stations has been inadequate, so the Bureau is extending the network of rain gauges, pluviographs, and river gauges to obtain more adequate information about future floods. Analysis of the data should then lead to better forecasting methods and more useful warnings of expected floods. A considerable amount of data from the present network of rainfall and pluviograph stations has been published and is in course of preparation for publication on behalf of the Australian Water Resources Council.

Agricultural meteorology, 1964 ; Maritime meteorology, 1966 ; Aeronautical meteorology, 1967 ; Meteorology in fire prevention, 1968 ; Meteorological services for commerce and industry, 1969 ; Meteorological observations, 1970 ; Computers in meteorology, 1971

Melbourne

Temperature

The proximity of Port Phillip Bay bears a direct influence on the local climate of the metropolis. The hottest months in Melbourne are normally January and February when the average maximum temperature is just over 78°F. Inland, Watsonia has an average of 81°F., while along the Bay, Aspendale and Black Rock, subject to any sea breeze, have an average of 77°F. This difference does not persist throughout the year, however, and in July average maxima at most stations are within 1°F. of one another at approximately 55°F. The hottest day on record in Melbourne was 13 January 1939, when the temperature reached 114.1°F. which is the second highest temperature ever recorded in an Australian capital city. In Melbourne, the average number of days per year with maxima over 100°F. is about four, but there were sixteen in the summer of 1897–98 and there have been a few years with no occurrences. The average annual number of days over 90°F. is approximately nineteen.

Nights are coldest at places a considerable distance from the sea, and away from the city where buildings may maintain the air at a slightly higher temperature. The lowest temperature ever recorded in the city was

27°F. on 21 July 1869, and likewise, the highest minimum ever recorded was 87°F. on 1 February 1902.

In Melbourne, the overnight temperature remains above 70°F. on only about two nights a year and this frequency is the same for nights on which the air temperature falls below 32°F. Minima below 30°F. have been experienced during the months of May to August, while even as late as October extremes have been down to 32°F. During the summer minima have never been below 40°F.

Wide variations in the frequencies of occurrences of low air temperatures are noted across the metropolitan area. For example, there are approximately ten annual occurrences of 36°F. or under around the bayside, but frequencies increase to over twenty in the outer suburbs and probably to over thirty a year in the more frost susceptible areas. The average frost free period is about 200 days in the outer northern and eastern suburbs, gradually increasing to over 250 days towards the city, and approaches 300 days along parts of the bayside.

Rainfall

The range of average rainfall from month to month in the city is quite small, the annual average being 25.79 inches over 143 days. From January to August monthly averages are within a few points of 2 inches; then a rise occurs to a maximum of 2.65 inches in October. Rainfall is relatively steady during the winter months when the extreme range is from half an inch to 7 inches, but variability increases towards the warmer months. In the latter period totals range between practically zero and over 8 inches. The number of wet days, defined as days on which a point or more of rain falls, exhibits marked seasonal variation ranging between a minimum of eight in January and a maximum of fifteen each in July and August. This is in spite of approximately the same total rainfall during each month and indicates the higher intensity of the summer rains. The relatively high number of wet days in winter gives a superficial impression of a wet winter in Melbourne which is not borne out by an examination of total rainfall.

The average rainfall varies considerably over the Melbourne metropolitan area. The western suburbs are relatively dry and Deer Park has an average annual rainfall of 19.10 inches. Rainfall increases towards the east, and at Mitcham averages 35.48 inches a year. The rainfall is greater still on the Dandenong Ranges and at Sassafras the annual average is 53.93 inches.

The highest number of wet days ever recorded in any one month in the city is twenty-seven in August 1939. On the other hand, there has been only one rainless month in the history of the Melbourne records—April 1923. On occasions, each month from January to May has recorded three wet days or less. The longest wet spell ever recorded was eighteen days and the longest dry spell forty days. Over 3 inches of rain have been recorded in 24 hours on several occasions, but these have been restricted to the warmer months, September to April. Only twice has a fall above 2 inches during 24 hours been recorded in the cooler months.

Fogs

Fogs occur on an average of four or five mornings each month in May, June, and July, and average twenty days for the year. The highest number ever recorded in a month was twenty in June 1937.

Cloud and sunshine

Cloudiness varies between a minimum in the summer months and a maximum in the winter, but the range, like the rainfall, is not great compared with many other parts of Australia. The number of clear days or nearly clear days averages two to three each month from May to August, but increases to a maximum of six to seven in January and February. The total number for the year averages forty-seven. The high winter cloudiness and shorter days have a depressing effect on sunshine in winter and average daily totals of three to four hours during this period are the lowest of all capital cities. There is a steady rise towards the warmer months as the days become longer and cloudiness decreases. An average of over eight hours a day is received in January ; however, the decreasing length of the day is again apparent in February, since the sunshine is then less in spite of a fractional decrease in cloudiness. The total possible monthly sunshine hours at Melbourne range between 465 hours in December and 289 in June under cloudless conditions. The average monthly hours, expressed as a percentage of the possible, range between 55 per cent for January and February to 34 per cent in June.

Wind

Wind exhibits a wide degree of variation, both diurnally, such as results from a sea breeze, and as a result of the incidence of storms. The speed is usually lowest during the night and early hours of the morning just prior to sunrise, but increases during the day especially when strong surface heating induces turbulence into the wind stream, and usually reaches a maximum during the afternoon. The greatest mean wind speed at Melbourne for a 24 hour period was 22.8 mph, while means exceeding 20 mph are on record for each winter month. These are mean values ; the wind is never steady. Continual oscillations take place ranging from lulls, during which the speed may drop to or near zero, to strong surges which may contain an extreme gust, lasting for a period of a few seconds only, up to or even over 60 mph. At Melbourne, gusts exceeding 60 mph have been registered during every month with a few near or over 70 mph, and an extreme of 74 mph on 18 February 1951. At Essendon a wind gust over 90 mph has been measured.

Thunder, hail, and snow

Thunder is heard in Melbourne on an average of 14 days per year, the greatest frequency being in the summer months. On rare occasions thunderstorms are severe, with damaging wind squalls. Hail can fall at any time of the year, but the most probable time of occurrence is from August to November. Most hail is small and accompanies cold squally weather in winter and spring, but large hailstones may fall during thunderstorms in summer.

Snow has occasionally fallen in the city and suburbs ; the heaviest snow storm on record occurred on 31 August 1849. Streets and housetops were covered with several inches of snow, reported to be 1 ft deep at places. When thawing set in, floods in Elizabeth and Swanston Streets stopped traffic, causing accidents, some of which were fatal. One report of the event indicates that the terrified state of the Aboriginals suggested they had never seen snow before.

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The means of the climatic elements for the seasons in Melbourne computed from all available official records are given in the following table :

MELBOURNE—MEANS OF CLIMATIC ELEMENTS

Meteorological elements	Spring	Summer	Autumn	Winter
Mean atmospheric pressure (millibar)	1015.1	1013.1	1018.3	1018.3
Mean temperature of air in shade (° F.)	57.8	66.7	59.5	50.1
Mean daily range of temperature of air in shade (° F.)	18.7	21.1	17.4	14.0
Mean relative humidity at 9 a.m. (saturation=100)	63	60	72	80
Mean rainfall (inches)	7.28	6.00	6.65	5.85
Mean number of days of rain	40	25	34	44
Mean amount of evaporation (inches)	10.28	17.34	8.13	3.79
Mean daily amount of cloudiness (scale 0 to 8) (*a*)	4.9	4.2	4.8	5.2
Mean daily hours of sunshine	5.9	7.7	5.2	3.9
Mean number of days of fog	1.5	0.6	6.5	11.7

(*a*) Scale 0 = clear, 8 = overcast.

In the following table are shown the yearly means of the climatic elements in Melbourne for each year 1966 to 1970. The extreme values of temperature in each year are also included.

MELBOURNE—YEARLY MEANS AND EXTREMES OF CLIMATIC ELEMENTS

Meteorological elements	1966	1967	1968	1969	1970
Mean atmospheric pressure (millibars)	1017.2	1018.1	1014.5	1017.5	1015.8
Temperature of air in shade (° F.)—					
Mean	59.3	59.5	60.2	59.4	59.1
Mean daily maximum	67.5	68.1	68.2	67.4	67.0
Mean daily minimum	51.1	50.9	52.1	51.5	51.3
Absolute maximum	102.8	105.2	110.6	101.6	99.1
Absolute minimum	32.9	34.2	35.2	30.5	33.0
Mean terrestrial minimum temperature (° F.)	48.4	48.6	49.6	49.6	48.5
Number of days maximum 100° F. and over	5	5	8	3	..
Number of days minimum 36° F. and under	7	4	3	3	3
Rainfall (inches)	26.81	13.06	20.96	24.60	31.63
Number of wet days	157	106	141	137	153
Total amount of evaporation (inches) (*a*)	47.08	55.15	59.56	56.60	57.39
Mean relative humidity (saturation = 100)	63	63	63	65	61
Mean daily amount of cloudiness (scale 0 to 8) (*b*)	4.8	4.4	4.8	4.7	4.9
Mean daily hours of sunshine (*c*)	6.0	6.5	6.4	5.8	6.3
Mean daily wind speed (mph)	6.9	5.9	6.2	7.2	7.1
Number of days of wind gusts 39 mph and over	47	46	79	41	62
Number of days of fog	6	24	3	7	9
Number of days of thunder	6	3	12	8	12

(*a*) Since 1967 evaporation has been measured by Class A Pan.
(*b*) Scale 0 = clear, 8 = overcast.
(*c*) Since 1968 sunshine has been measured at Laverton.

Victorian weather summary 1970

Rainfall for 1970 was above average over all of Victoria except parts of the Mallee and Wimmera. At some places in southern Victoria it was the wettest year on record. January, March, April, August, November, and December were notably wet months, while June, July, and October were dry.

On the first night of the year heavy rain fell in the Central and west Gippsland districts. In Melbourne 2.12 inches fell in eight hours, causing local flooding, and flooding occurred on the Avon, Macalister, Thomson, and La Trobe Rivers. On 8 January 4 inches of rain fell in three hours during a thunderstorm in the St Albans area, and on 9 January a severe storm with hail damaged vines and crops in the Swan Hill district. The weather was generally dry from mid-January to mid-March except in eastern Gippsland, but there was very little hot weather. Mean temperatures were well below normal in January and in Melbourne there were only ten days during the summer when the temperature exceeded 90°F., the lowest number for 45 years. No serious bushfires occurred during the 1969–70 season.

Heavy rain fell in all districts from 19 to 23 March. In Melbourne 3.31 inches fell in three days, the highest three day fall in March for 21 years. In south Gippsland 9 inches fell in this period causing flash flooding of coastal streams. More rain fell in all districts at Easter in the last week of March, and rainfall for April was above average throughout the State. Heavy rain fell in all districts on 21–22 April. Rainfall in May was again above average in Gippsland and Central Districts, but less than half normal in the north-west. Heavy rain in Gippsland at the end of May caused flooding in streams east of the La Trobe. On 6 May temperatures were well below normal with hail, showers, and snowfalls on the Dandenong Ranges. Rainfall was below average in all districts in June and in all but the west coast and west Gippsland in July. A few places in the northern Mallee received no rain in July for the first time on record. The last week of June was mild with mean temperatures well above average in the western half of the State.

On the night of 1 August severe thunderstorms occurred in southern Victoria and wind squalls caused structural damage in the Melbourne area. Very heavy rain fell in the north-east in the last week of August and the Murray River reached its highest level for many years at Albury and Corowa. Floods also occurred in most rivers in the north-east and Gippsland. Rainfall totals for August were above average throughout the State and the highest on record at some places in the Western District, while mean temperatures were below normal in most of the State in August and September. In Melbourne the temperature did not reach 69°F. in September for the first time on record. Further widespread rain fell in the last week of September, causing a renewal of flooding in the north-east and on the Murray. Flooding also occurred on the Barwon and Werribee Rivers from 23 to 25 September.

By contrast, October's rainfall was below average throughout the State. Many places in northern Victoria had their driest October for 30 years. Late frosts caused damage to wheat, fruit, and vegetable crops on 15 and 23 October. The night of 4–5 October was unusually warm and at midnight Melbourne's temperature was 80°F. On 11 November thunderstorms brought torrential rain to some places in northern Victoria, up to 3 inches being recorded in 3 hours. On 14–15 November up to 4.5 inches of rain fell in 8 hours in the south-west and some flooding occurred. Some places in the western Wimmera had their wettest November on record. Heavy rain fell in Gippsland on 9–10 December, up to 5 inches falling in 24 hours, and flooding occurred on rivers from the La Trobe to the Snowy. Following warm to hot weather at Christmas, heavy thunderstorms on 27 December presaged a week of cool and wet weather which continued into the first few days of 1971. Heavy rain fell in the eastern suburbs of Melbourne in the early hours of 30 December, over 2 inches falling in 2 hours, bringing the month's rainfall to the highest on record. It was also the wettest December on record at some places in Gippsland.