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# PHYSICAL ENVIRONMENT

## *Insects of Victoria*

### Introduction

Insects belong to the Class Insecta of the Phylum Arthropoda, by far the biggest Class in the Animal Kingdom, containing some one million named species.

Mature insects characteristically have an external skeleton or cuticle, one pair of antennae or feelers, three pairs of legs, and two pairs of wings (some species have a single pair of wings and a few are wingless).

The body is divided into three distinct regions : the head which carries the mouth parts and sense organs ; the thorax to which are attached the legs and wings ; and the abdomen which contains the reproductory and excretory organs. The body carries a number of spiracles or openings through which the insect obtains its supply of air.

Because its external skeleton is more or less rigid, insects cannot grow steadily, as mammals do. Increase in size, which occurs only in the larval stage is, therefore, by a series of moults during which the old, small, skeleton is discarded and a new and bigger one formed from a horny material called chitin.

The skeleton, with its waxy coating to prevent desiccation, has enabled insects to colonise a wide range of terrestrial environments during the course of evolution, but it, and the system of respiration, by means of air tubes branching throughout the body, have set an upper limit to the size to which they may grow.

The typical life cycle of an insect is egg–larva (nymph, grub, caterpillar, maggot)—pupa (resting stage)—adult. No feeding and virtually no movement occurs in the egg or pupal stage. Feeding is nearly always greatest in the larval stage ; adult insects sometimes eat the same substances as larvae of the same species, but more often their food is quite different and in some species the adults do not feed at all.

Some insects undergo great changes or metamorphosis in the pupal stage (e.g., caterpillar to butterfly), whereas in others the adult differs from the immature stages only in size and the possession of wings and fully developed sex organs.

The adult is the only stage in the insect's life cycle which has power of flight. Dispersal of most species is, therefore, greatest in this stage, although the larvae of some species can cover long distances by crawling or hopping. Other agencies, birds, animals, wind, water, and mechanical transport, also help in the dispersal of any or all stages of insects.

Within the Class Insecta there is enormous diversity of size, appearance, mobility, feeding habits, reproductive rates, habitat, etc. Some species (cicadas) need years to complete a single generation; others (aphids) only a few days.

If the rate of increase of insects were unchecked, they would literally cover the face of the earth in a few months. In reality, however, many natural factors (temperature, humidity, wind, fire, flood, light, availability of food, animal, bird and insect predators, parasites, disease organisms) operate to keep the numbers of any one species more or less constant. There are, of course, frequent short-term fluctuations, but over a long period, provided the environment does not change greatly, the insect population remains at a stable level.

There are a number of small species (springtails, spiders, mites, ticks, scorpions, millipedes, centipedes, slaters, slugs, snails, etc.) which superficially resemble insects, either in appearance or in the type of damage they do. Although they frequently come within the scope of work of the economic entomologist, they are not true insects in the zoological sense of the word and, except for Classes Collembola, Protura, and Diplura which were until recently regarded as Orders of the Class Insecta, will not be discussed in this article.

## Effect of Insects on Man's Activities

In Victoria, the greatest impact of insects is on primary production. Insects attack, often with disastrous results, all agricultural and horticultural crops and livestock species, pastures, forests and flower gardens, lawns, playing fields, etc. Even after produce is harvested, the attack and damage continue.

Precise figures for losses from insect damage to primary production are almost impossible to obtain, but estimates of 10 to 20 per cent losses before harvest and 4 to 5 per cent in storage after harvest are probably very conservative. Apart from their agricultural significance, insects (termites and borers) damage or destroy houses, while carpet beetles, clothes moths, and silverfish may ruin carpets, clothing, and books.

As well as destroying man's property, insects affect man and his domestic animals directly, by biting or stinging (mosquitoes, lice, bed bugs, fleas, sandflies, bees, wasps, March flies), transmitting disease (house flies), or merely by their irritating presence (bush flies, earwigs, moths, beetles).

Although insects cause great damage, only a small proportion of insect species do this. The great majority do not have any known effect on man or his property, and some are positively beneficial. Insects carry out very valuable tasks of pollinating crops, parasitising other insects which are harmful to man, destroying noxious weeds, cleaning up organic refuse, and, of course, producing honey.

## Study of Insects in Victoria

Because of the considerable effect of insects on our lives, it is essential to have some understanding of how insects breed, how far they can fly, what foods or plants they might attack, and how their detrimental activities can be controlled.

Entomology, or the study of insects, has many aspects. First, it is necessary to be able to identify insects quickly and accurately, for among the numerous species there are often very slight external differences between harmless species and pests. The basis of satisfactory identification is a comprehensive collection of named and systematically classified insect species. By far the biggest collection in Victoria is kept by the entomologists at the National Museum. Small collections, usually of a restricted group or species, are kept by other Government departments, universities, or private entomologists.

The largest group of entomologists in Victoria is employed by the Victorian Plant Research Institute of the Department of Agriculture which is responsible for research and extension on insects of agricultural and horticultural importance. Work on honey bees is handled by another section of the same Department.

Studies on biology, physiology, biochemistry, and genetics of insects are carried out at Victorian universities, where the broad aim is to secure greater basic understanding of insect processes, and in appropriate Government departments, where research of this type is directed to the solution of particular problems in agriculture, forestry, health, etc.

Small entomological sections are included in the Department of Lands, whose work includes the use of insect vectors for transmitting myxomatosis, and control of noxious weeds by insects ; the Forests Commission for dealing with outbreaks of such pests as Sirex Wasp or phasmatids ; and the Department of Health, whose interest lies in the control of pests such as house flies and cockroaches which could constitute a threat to public health.

The Commonwealth Department of Health, whose Victorian officers are also members of the Department of Agriculture, is responsible for the quarantine aspects of entomology in preventing accidental importation of new insect pests from abroad, and in supervising the introduction of beneficial species from other countries.

Some private firms dealing with manufacture or distribution of insecticide employ entomologists to evaluate their insecticides.

## Economic Entomology

Economic or applied entomology is the study of insects where the aim is primarily the control of insect damage or the utilisation of beneficial insects.

This work, according to the nature of the problem, is carried out mainly by the Government departments previously mentioned—Agriculture, Lands, Health, and Forests Commission, and to a lesser extent, by agricultural chemical companies. The aim is to obtain the fullest possible information of the biology, habits, host range, and reproduction of the insect pest concerned and then to attack it at its weakest point. It is rarely practicable to contemplate complete eradication of a well established pest species and usually the objective is to reduce the pest population to a level low enough to be tolerated.

The methods used to control insect pests are extremely varied. Sanitation and hygiene, involving destruction of the insect's food, or keeping it in insect-proof containers, are the cheapest and most effective means with pests such as house flies and stored product pests ; introduced parasites and predators have been used with success against some pests ; and modification in agricultural practices such as additional cultivation, irrigation, etc., sometimes give adequate control. In most cases, however, it is only possible to control the pest by using a chemical insecticide.

Unfortunately all the known insecticides are harmful to a greater or lesser extent to man, domestic animals, bees, fish, birds, or wild life. For this reason the registration, sale, and use of insecticides is controlled by comprehensive legislation administered by the Department of Agriculture and the Department of Health. Both Departments work in close liaison with the Government Pesticide Review Committee, which was established as the result of the Government enquiry into the effects of pesticides held in 1965.

## Insects Found in Victoria

In the following pages a brief account is given of the more important or interesting insects occurring in Victoria. The first three Classes, comprising insect-like forms long regarded as primitive wingless insects, are included here for convenience.

The Class COLLEMBOLA appears to have diverged from the insects very early in their ancestry, as a number of features indicate a relationship with millipedes. The legs and abdomen have a reduced number of segments, and there is a small appendage used for jumping. Springtails are tiny humus or plant-feeding creatures, inhabiting soil, decaying litter, or foliage, and rarely occurring in dry situations. Some are carnivorous, and live at the edge of the sea.

The introduced globular, bright green *Sminthurus viridis* is an important pest of improved pastures, chewing the leaves of clovers and other pasture plants. A predatory Bdellid mite exerts partial control, but is ineffective where large populations occur following autumn rains, and the hatching of the desiccation resistant eggs. A number of small greyish, or white species thrive in damp soil rich in compost and are sometimes found floating in large numbers on puddles after rain.

The Class PROTURA comprises very primitive, minute, insect-like creatures, lacking antennae, which are found under stones, etc., in damp localities. Little is known about the few Australian species.

The Class DIPLURA has several families of pale, elongated, insect-like creatures with long antennae and no eyes, found in damp soil. The Campodeidae are all very minute, with long tail filaments. *Campodea fragilis* is a common introduced species, while several native species have been described from the Dandenongs. The larger Japygidae have tail forceps. *Heterojapyx victoriae,* 1½ in long, is sometimes found in open forest country.

The Class INSECTA, consisting of all the true insects, is classified into a number of Orders, and these in turn are divided into Families (Family names always end in -idae).

ARCHAEOGNATHA (Bristletails) are rare wingless insects resembling large silverfish. The several Australian species are found along shore lines or in wooded hilly areas.

THYSANURA (Silverfish) so named from their silvery scaley covering, are small, tapered, primitive wingless insects, with three long tail filaments. They are widespread, but, owing to their concealed habits, are not readily observed. Little is known of their biology, apart from the introduced domestic species, which feed on starchy materials, damaging wall paper, book bindings, etc. A species of *Ctenolepisma* is the best known of these. The native species are found under bark, fallen logs or stones, or living in association with ants.

EPHEMEROPTERA (Mayflies) are a compact group, regarded as the most primitive of the winged insects. The adults are delicate insects, with gauzy wings and long tail filaments. The drab aquatic nymphs (larvae) with tail filaments and leaf-like gills, feed on algae, water weeds, or decaying vegetation. Some species are carnivorous.

Elsewhere, Mayflies are an important item of diet for fish, and the lore of fly fishing is based on this. However, the few local species do not breed where they are readily available to fish, and anglers have even advocated the introduction of English species to local trout streams. The nymph may take up to a year or so to reach maturity. From it emerges a dull, winged sub-imago, which soon sheds its cuticle to emerge as the adult, Mayflies being the only insects which have two life cycle stages with wings. The former is the " dun ", the latter the " spinner " of the fly fisherman.

The adults are usually encountered fluttering erratically over water at dusk. They do not feed, and die within a few days, after mating in mid-air and laying their eggs in masses in the water. *Atalophlebia costalis* is a common species with very long tail filaments, while *Coloburiscus haleuticus* is a fine alpine species. Little is known about these and other local species.

ODONATA (Dragonflies, damselflies) are of great antiquity. They are active, predatory, sun-loving insects, which catch and eat their prey on the wing. They have two similar pairs of gauze-like wings, prominent eyes, and an elongate abdomen. The dull-coloured nymphs live in streams and weedy lakes, feeding on prey captured with a curious hinged modification of the mouthparts which shoots forward. The usual life cycle is annual, but may take longer. Cast nymphal skins are a common sight along the banks of streams.

The smaller, and more delicate damselflies (Sub-Order *Zygoptera*) usually rest with wings folded together above the abdomen. The brilliant iridescent colouring of many species varies with temperature, and usually fades in pinned specimens. The nymphs, also relatively slender, have three tail gills. Victoria's most remarkable species is *Hemiphlebia mirabilis*, sole member of the Hemiphlebiidae and regarded as the most primitive living species in the Odonata. This small, rare metallic-green insect breeds only in certain weed-covered

billabongs on the river flats of the Yarra and the Goulburn which are subject to periodic flooding. The males have long, white ribbon-like appendages used in sex display. *Ischnura* and *Austrolestes* are two common genera.

The large stout dragonflies (Sub-Order *Anisoptera*) rest with their wings outspread. The nymphs are also stout bodied, breathing by means of gills inside a chamber at the end of the abdomen. *Aeschna brevistyla* and the bluish *Orthetrum caledonicum* are two common and widespread species. Most Victorian species are confined to hilly and mountainous areas.

ORTHOPTERA. This Order, now restricted to the grasshoppers, locusts and crickets, consists of moderate to large plant-feeding insects, typically with long jumping legs, and usually with wings.

Although there are numerous species of Acrididae of no economic significance in Victoria, some are important. The Australian plague locust (*Chortoicetes terminifera*) breeds in plague numbers in inland Australia under certain conditions, and the adults of the gregarious phase migrate in swarms for long distances, sometimes crossing well into Victoria. These swarms may completely destroy young cereal crops and pastures during a spring invasion. In 1946, for the first time in the world, aerial spraying methods, developed by the Department of Agriculture with the co-operation of the Royal Australian Air Force, enabled such swarms to be effectively destroyed. A quarter of a million acres were treated this way in the 1955 outbreak.

The small plague grasshopper (*Austroicetes cruciata*) is of sporadic importance in the northern half of the State, while the wingless grasshopper (*Phaulacridium vittatum*) occurs in localised swarms in the north-east and Western Districts. A number of grasshoppers are of elongate form, and others are well camouflaged against dry leaves. The five or six squat, dark, yellow-spotted *Monistria* species are flightless, alpine or Mallee grasshoppers, while the purely alpine genus *Kosciuscola* is represented by three species, which change colour, from blackish to green or blue, as the sun warms them. The small, well camouflaged Tetrigidae, with backwards elongated thorax, has several local species of *Tetrix* and *Paratetrix,* while the abundant Australian genus *Moraba* (Eumastacidae) is represented by only one Victorian species.

Tettigoniidae are characterised by very long antennae, and stout ovipositors. The green *Caedicia* species are well camouflaged amongst eucalypt leaves, while the large, stout-jawed *Apotrechus* and *Paragryllacris* species live in logs, sometimes coming indoors. In *Acripeza reticulata,* the short hump-backed female, when disturbed, elevates its brown wings, and displays vivid warning colours. This species occurs on the Mornington Peninsula as well as alpine areas. The closely related cave crickets (Rhaphidophoridae) are represented by *Cavernotettix buchanensis,* and other undescribed species.

Crickets (Gryllidae) are best known by the field cricket (*Teleogryllus commodus*) whose chirping may sometimes be heard even in the heart of Melbourne on hot summer nights. This widespread species breeds abundantly in the humid shelter provided by cracks in heavy soil, becoming a pasture pest under such conditions.

Several smaller crickets are also found locally. A constant trilling is also produced by *Gryllotalpa* (Gryllotalpidae), the brownish mole-cricket with strong digging fore-legs.

PHASMATODEA are the large, well camouflaged plant-feeding stick insects, which are sometimes winged. The females drop their hard eggs from the foliage into the forest litter below. The spur-legged phasmatid (*Didymuria violescens*) normally kept in check by birds, sometimes multiplies to plague proportions, defoliating tall eucalypt forests in the eastern ranges, and necessitating chemical control to safeguard catchment areas from possible erosion. The colour, normally brown with purple wings, changes somewhat in high density populations.

BLATTODEA (Cockroaches) are scavenging insects, related to the Orthoptera, which live under cover. They are flattened, often wingless, and with the thorax covering the head. The females transport the eggs in a hard capsule. The introduced German (*Blatella germanica*), Oriental (*Blatta orientalis*) and American (*Periplaneta americana*) cockroaches, and the Australian cockroach (*P. australasiae*) are domestic pests which thrive in warm situations providing shelter and starchy foods. The black or brownish native species are found under bark or stones, both in hilly country and the Mallee.

MANTODEA. The carnivorous, easily recognisable praying mantids, with their fore-legs modified for catching insect prey, are represented by several green or brown species in Victoria, but none are abundant enough to be regarded as important beneficial insects. Their brownish egg capsules are often seen on posts, etc. *Orthodera ministralis* is a common green species while the larger *Tenodera australasiae* is green, with purplish hind wings.

ISOPTERA (Termites or white ants) are delicate, soft-bodied social insects living in colonies of a few hundred to over a million individuals. The brown, winged males and females, which found new colonies, sometimes fly into houses at night, while the pale worker, and the large-headed soldier castes are often found in both green and seasoned timber. They shun exposure to light and low humidity, and live in galleries and tunnels constructed by the workers. Different species of termites feed on sound, or decaying wood, and sometimes plant material.

Only about twenty-three of about 180 different Australian species of termites are found in Victoria, none being confined to the State. Kalotermitidae live in simple colonies in irregular galleries in damp wood, in trees, or under badly ventilated buildings. There is a soldier caste, but no true worker caste. The large *Porotermes adamsoni,* and several *Kalotermes* species cause serious damage to the interior of commercial forest timber areas.

Other species of termites in Victoria live in small colonies, inhabiting irregular galleries excavated in wood or soil, but *Eutermes exitiosus* (Termitidae), *Coptotermes acinaciformis* (Rhinotermitidae), *C. frenchii,* and *C. lacteus* live in large, highly organised colonies in elaborate, spheroidal nests of honeycomb-like structure, a foot or more in diameter, hidden in tree trunks, or covered by a conspicuous earthen mound. From these nests, the termites move out through tunnels in the soil to attack timber many yards away. The first three

species cause serious economic damage to seasoned structural timber in poles, posts, and buildings, particulary in the more dry inland areas of Victoria. *Hamitermes neogermanus* (Termitidae), found in northern Victoria, feeds mainly on grass.

DERMAPTERA (Earwigs) have a characteristic pair of forceps at the end of the abdomen, and wings tucked away under short wing covers, so that the adults appear wingless. They feed at night on a wide range of plant material, and also live and dead insects.

The introduced European earwig (*Forficula auricularia*) is a well-known garden pest in Victorian urban areas, reaching plague proportions in some years, and invading houses in large numbers at night. However, the only harm it does is in the garden especially to young plants, and, particularly, passion vines. The few native species are of no economic importance, and normally live under bark or leaf mould. *Labidura* burrows in river banks, and the 1½ in long *Titanolabis colossea* is one of the largest species in the order.

PLECOPTERA (Stoneflies) are a small primitive group related to Orthoptera. The soft-bodied adults, with long antennae and long tail filaments, have two pairs of much veined wings which fold down over the abdomen. The aquatic nymphs, which resemble the adults, are usually sluggish, and feed on algae underneath stones, but some are swift carnivorous forms. When mature, they crawl out of the water, and the adult emerges, flying at dusk over streams. The life cycle is annual, or may be longer.

The Eustheniidae are large, often brightly coloured species, with fan-shaped hind wings. The black and reddish-brown *Thaumatoperla-alpina,* found on the Bogong High Plains, is the largest Australian stonefly. The dark-brown *Stenoperla australis* and *Eusthenopsis venosa* with purple hind wings, are also alpine species.

The Leptoperlidae have more normal hind wings, with fan-shaped lobes. Several species of *Trinotoperla,* and the rich brown coloured *Eunotoperla kershawi* are found in Victoria.

EMBIOPTERA (Web-spinners) are small, delicate, humus-feeding insects, winged sometimes in the males, which live in colonies in bluish-hued tunnels under shelter. They can run backwards or forwards with equal ease. The few Australian species exhibit considerable geographical variation, and collecting would probably reveal more races of these rarely seen, but locally common insects. Lichen encrusted wooden fences and under bark on gum trees are the preferred sites of *Aposthona gurneyi,* while *Metoligotoma minima* lives under fallen gum leaves, and *Notoligotoma nitens* favours well drained, lichen-encrusted sites.

PSOCOPTERA (Psocids) are small insects, sometimes winged, characterised by their bulbous heads, and chisel-shaped jaws used for feeding on vegetable matter, such as bark, and especially fungi and lichens. Various native species are often encountered under the bark of gum trees, and other sources of food materials. Book lice are small, introduced species which are rarely noticed unless present in large numbers infesting stored food products, papers, grain, or herbarium specimens, particularly where dampness has encouraged mould growth.

PHTHIRAPTERA are very small, flattened, wingless external parasites of warm blooded animals, often being of economic importance.

The Sub-Order *Mallophaga* (Biting lice) nibble away at skin, hair, or feathers, mainly attacking birds, but most domestic animals are host to one or more species, which cause irritation, thus reducing production. Poultry, and pigeons are each attacked by at least six different species, and man is sometimes attacked by lice which have left dead rats in search of food. Bird lice are usually specific to the host species.

The Sub-Order *Siphunculata* (Sucking lice) have similar habits, but feed by sucking blood from mammals only. Nearly all are introduced species, infesting domestic animals. One native species, *Polyplax bidentatus,* is found on water rats. The human lice, *Pediculus humanis* and *Phthirus pubis,* are now rarely encountered.

HEMIPTERA (Bugs, scales) are well represented in Victoria, many being of considerable economic importance. They have a sucking beak, and are mostly plant feeders, although some suck blood. There are two Sub-Orders, *Heteroptera* and *Homoptera,* based on wing and beak characteristics.

The small grey Rutherglen bug (*Nysius vinitor* : Lygaeidae) occurs in plague numbers on rare occasions, damaging stone fruits and crops, while *Oxycarenus luctuosus,* with reddish nymphs, sometimes swarms on posts, etc., in the Mallee. Home gardens adjacent to weed-covered land inevitably receive summer visitations of the red and black harlequin bug (*Dindymus versicolor* : Pyrrhocoridae). The crusader bug (*Mictis profana* : Coreidae) is a large brown bug with a yellow cross on the wings. Stink bugs (Pentatomidae) are a large, often colourful family. The red and black *Agonoscelis rutila* is a widespread species confined to horehound, while the green vegetable bug (*Nezara viridula*) attacks vegetables, especially beans and tomatoes. Some pentatomids have their wings fused together in a shield. Several species of Miridae are commonly found on lucerne, including *Megacoelum modestum,* sometimes associated with damage to french beans. With higher standards of living and sanitation, the bed-bug (*Cimex lectularius* : Cimicidae) is now rarely encountered.

A number of aquatic species of bugs, in several families, are found in creeks, and sometimes in swimming pools, as they can fly readily. The water-striders (Gerridae) run around on the surface film, while the backswimmers (Notonectidae) often rest upside down at the surface, diving when disturbed. The broader water-boatmen (Corixidae) also swim upside down, with oar-like hind legs. The slender *Ranatra australiensis* (Nepidae) has a breathing tube as long as the body.

The curious, flightless Peloridiidae, with characteristics linking both Sub-Orders of the Hemiptera, are represented by the rare *Hemidoecus wilsoni,* from Beech Forest. This ancient family, always associated with moss on *Nothofagus* trees, consists of some dozen species, found in Tasmania, New Zealand, and Patagonia.

Cicadas (Cicadidae) are well known for their sound production by the males. The species which is so deafening in suburban streets some summers is the large green or yellowish *Cyclochila australasiae,* which has a life cycle lasting some seven years. The large black *Psaltoda moerens* is common inland on red gums, while various small dark *Melampsalta* and *Diemeniana* species are found in low scrublands. The hairy, brown *Tettigarcta crinita,* from the alpine high plains, is a primitive, soundless species. *Macrotristria angularis,* from the Sunraysia district, is Victoria's largest cicada.

Nymphs of the related, but smaller froghoppers (Cercopoidea) cover themselves with froth while feeding on eucalypts, sometimes even living in a conical tube. The leafhoppers (Cicadelloidea) are a large group of sap-sucking insects which sidle out of sight, or jump when disturbed. They are mostly tree feeders, and rarely of economic importance. Some pale species occur in gardens, and pastures, and the common brown jassid (*Orosius argentatus* : Cicadellidae) is an important vector of tobacco yellow dwarf virus in the Murray Valley, as well as lucerne and tomato viruses. The chunky *Eurymela distincta* (Eurymelidae), navy blue, with white blobs, clusters on eucalypts, always attended by ants. Ten species of the acacia-feeding Membracidae, with curious elongations of the thorax, have been recorded locally.

The planthoppers (Fulguroidea) are a compact group of sap-feeding insects, the nymphs of which produce waxy tail filaments. The brownish, triangular *Scolypopa australis* (Ricaniidae) is a sporadic pest of passion vines and other garden plants.

Lerp insects (Psyllidae) often secrete scale-like coverings (lerps) in the nymph stage, those of *Spondyliaspis eucalypti* on gum leaves being known as " manna ". Several species of *Cardiaspina,* with lace-like lerps, may cause defoliation of eucalypts during outbreaks. *Trioza eugeniae* sits in hollows in lilly-pilly leaves.

White-flies (Aleurodidae) are minute white insects, which cluster on leaves, often laying their eggs in crescents. Greenhouse white-fly (*Trialeurodes vaporariorum*) was formerly an important pest of tomatoes and cucumbers, while citrus white-fly (*Orchamoplatus citri*) is common on citrus, especially in the Wangaratta area.

Victoria has some 68 species of aphids (Aphididae)—over half of the Australian total. All except two (*Ceriferella leucopogonis* and *Aphis acaenovinae*) are introduced, many being widespread and common vectors of virus diseases, as well as causing damage through feeding on a wide range of perennial and annual plants. Aphids are susceptible to extremes of temperature and become most numerous and damaging in spring and autumn. The green peach aphid (*Myzus persicae*), the melon or cotton aphid (*Aphis gossypii*), the grey cabbage aphid (*Brevicoryne brassicae*), the cowpea aphid (*Aphis craccivora*), and the rose aphid (*Macrosiphum rosae*) are some of the commoner and more important species.

Aphid transmitted virus diseases are being overcome by intensive breeding programmes and certified stock schemes for potatoes, strawberries, and pome and citrus fruits, the use of aphid-free districts, and control of alternate host plants.

The fluffy, gall forming woolly aphid (*Eriosoma lanigerum* : Pemphigidae) on apples is now largely controlled by a parasite and the use of resistant rootstocks. The underground *Viteus vitifolii* (Phylloxeridae) was responsible for a serious phylloxera outbreak in the 1890s which led to rigid legislation to protect Victorian vineyards.

The highly specialised scales and mealybugs have active juvenile crawlers, wingless, often sedentary females, and smaller, short-lived males. Victoria has a wide range of species, both native and introduced, which infest many trees and shrubs. Their presence is often indicated by black sooty mould fungus growing on their sugary waste products. The sweetness also attracts ants, which interfere with the beneficial wasp parasites.

Among the scale-covered Diaspididae, red scale (*Aonidiella aurantii*) is a serious pest of citrus, requiring expensive chemical spraying, but where yellow scale (*A. citrina*) is also present, wasp parasites provide a reasonable level of control. Oleander scale (*Aspidiotus hederae*) is widespread, but unimportant. San Jose scale (*Quadraspidiotus perniciosus*) is an important pome fruit pest, owing to quarantine requirements for completely scale-free export fruit.

Soft scales (Coccidae) are not covered, but the hardened body may resemble a true scale. Soft brown scale (*Coccus hesperidum*) is a widespread green to dark scale common on olives, citrus, and ornamentals. Black scale (*Saissetia oleae*), also common on citrus and olives, is dark, with H-shaped ridges. A *Pulvinaria,* with white egg masses, sometimes occur on hydrangeas, etc.

The mealybugs (Pseudococcidae) are whitish, mobile insects, often concealed under white fluff. The long tailed mealybug (*Pseudococcus adonidum*) often occurs on daphne and indoor ferns, and is a pest of sultanas and late-maturing table grapes. Outbreaks of the white and yellow *Nipaecoccus aurilanatus* on Norfolk Island pines are eventually controlled by the larvae, also white and fluffy, of the mealybug ladybird beetle (*Cryptolaemus montrouzieri*).

Victoria has at least eleven species of *Apiomorpha* (Eriococcidae), which produce galls on eucalypts, and no less than sixteen species of *Eriococcus* are present, the most common being the reddish white gum-tree scale (*E. coriaceus*) which clusters along the twigs of eucalypts, while *E. orariensis* is common on tea tree. Pink rounded galls on gum leaves are usually due to *Opisthoscelis* species, while *Dactylopius* sometimes destroys isolated clumps of prickly pear.

THYSANOPTERA. Thrips are tiny slender insects, normally with two pairs of delicate, strap-like wings fringed with hairs. They feed on leaves, blossoms, and sometimes plant roots, by lacerating the cells with their stylet-like mouth-parts, and sucking the sap. Plague thrips (*Thrips imaginis*) in some years causes severe blossom damage on apples and pears, adversely affecting the set of the fruit. Other economic species are onion thrips (*T. tabaci*) and gladiolus thrips (*Taeniothrips simplex*), both well-known to home gardeners and commercial growers. Some species are vectors of plant virus diseases. Possibly the largest of all thrips is the giant thrips (*Idolothrips marginatus*) approaching half an inch in length, sometimes found on fallen gum leaves. Some native thrips produce plant galls.

MEGALOPTERA. This Order of large, soft-bodied insects, with sub-equal membranous wings, related to the Orders Neuroptera and Mecoptera, is poorly represented in Australia. The larvae are aquatic and carnivorous.

The Corydalidae (Dobson-flies) are represented by the variable *Archichauliodes guttiferus,* whose large, powerful-jawed, greyish larvae, numerous in some running streams, form an important diet for fish. These pupate in soil, and the speckle winged adults fly at dusk. *Austrosialis australiensis* is the only local species of Sialidae (Alder-flies).

RAPHIDOPTERA. This Order, closely related to the Megaloptera, does not occur in Australia.

NEUROPTERA (Lacewings) include a number of families of primitive, slow-flying insects, recognisable by the fine network in the wing venation. The active predatory larvae have sharp pointed jaws used for piercing and sucking.

The Ithonidae (Moth-lacewings) are an ancient family closely related to the Megaloptera. The larvae attack scarab and other insect grubs in sandy soil, and themselves resemble scarab larvae. *Heteroithone pallida* occasionally swarms in large numbers at dusk in coastal areas. The tiny, whitish " dusty wings " (Coniopterygidae) are aberrant Neuroptera, with reduced venation, and larvae predatory on small Hemiptera. One species is sometimes found in large numbers on citrus near Wangaratta.

Green lacewings (Chrysopidae) commonly seen fluttering around street lights, or windows, have coppery eyes and long thin antennae. The eggs, on long thin stalks, are laid singly on foliage, and the fast-moving voracious larvae attack aphids, mealybugs, and scale insects, thus aiding biological control of pests, in particular, red scale of citrus in the Sunraysia District. *Chrysopa* larvae generally cover themselves with the empty remains of their victims as camouflage. Of the fifty known Australian chrysopids, only six, so far, have been collected in Victoria. The similar brown lacewings (Hemerobiidae) do not lay stalked eggs. *Micromus tasmaniae* is the most common species.

The silky-lacewings (Psychopsidae) are best known by the pretty *Psychopsis mimica,* with butterfly-shaped wings, which is common in northern Victoria, the larvae living under bark. *Porismus strigatus* (Osmylidae), with mottled black and yellow wings, is common in eucalypt forests, while several undescribed species of *Stenosmylus* are also present. The curious Mantispidae with their raptorial forelegs, closely resemble praying mantids. The ant lion lacewings (Myrmeleontidae) have stout bodied larvae which hide in sand or debris. Those of *Myrmeleon* and *Callistoleon* excavate small pits in dry, powdery soil, and insects falling in are quickly seized by the larvae lying in wait at the bottom.

COLEOPTERA (Beetles, weevils). This highly successful Order, the largest in the Animal Kingdom, is well represented in Victoria. Most species are rarely encountered, and the few beneficial species are outnumbered by the native and introduced species which are economic

pests. Coleoptera form a distinctive group, easily identified by the chitinisation of the forewings to form hard wing covers (elytra). Stiffened hind wings are normally present. The hard-bodied adults range from minute to very large, while the larvae vary from active predatory forms to soft, legless, plant-feeding grubs.

Carabs (Carabidae) are active, ground inhabiting beetles, mostly dull, but sometimes metallic. *Notonomus* is a common genus in Victoria. The green fringed *Catadromus* species, and *Hyperion schroetteri* are the largest carabs in Australia, together with *Euryscaphus waterhousei* with its huge jaws and wasp waist. The metallic green *Calosoma schayeri* ferociously attacks caterpillars. The closely related tiger beetles (Cicindelidae) are swift, often brightly coloured species which run down their prey. The creamy *Cicindela ypsilon* is found on beaches and sand dunes.

Several unrelated families have become adapted to an aquatic life, the adults being streamlined, with fringed, oar-like legs. The carnivorous Dytiscidae larvae are elongate, large jawed " water tigers " ; Gyrinidae typically swim in circles on the top of the water ; and some Hydrophilidae are quite large.

Carrion beetles (Histeridae) live in dung, carrion, or nests of ants and termites. The latter mutually beneficial association occurs in a number of families, including the tiny Pselaphidae which are very well represented in Victoria. Staphylinidae, characterised by very short elytra, are scavengers, living under carcasses of animals, etc. *Creophilus erythrocephalus,* black with red head, is a common species.

Scarabs are strong, stout-bodied beetles, with distinctive clubbed antennae, and forelegs often modified for digging. Their soil or humus inhabiting larvae are known as curl grubs. The stag beetles (Lucanidae) are large scarabs, the males of which have enormous mandibles. They live in rotting wood. The colourful *Lamprima latreillei,* usually golden-hued, flies around eucalypts in early summer.

Amongst the Scarabaeidae, the dung beetles (Coprinae) are poorly represented, and the introduction of overseas species to hasten the return of nitrogen to the soil has been proposed. *Onthophagus* makes large piles of soil around cattle manure. Christmas beetles are the large and colourful *Anoplognathus* species (Rutelinae) which swarm around gum trees in the summer. Aphodiinae are small, dark manure-inhabiting scarabs. The black-headed larvae of the pasture cockchafer (*Aphodius tasmaniae*), however, make tunnels in the soil, and emerge at night to feed on plants. This insect, Victoria's most important pest of improved pastures, is troublesome in areas exceeding 20 in of annual rainfall and requires regular insecticide treatment. The dark-brown adults fly on humid nights from January to March, and may be attracted to street lights in enormous numbers in Western District towns. Melolonthinae scarabs are usually dull black, or brownish, but *Diphucephala collaspidoides* is a brilliant bottle green. This small leaf feeder sometimes becomes numerous enough to damage fruit trees and gardens. *Phyllotocus macleayi* is attracted to flowers and even bee-hives in search of nectar. The stout-bodied, reddish to dark Dynastinae often have horns on the male head and thorax. Various of the three

dozen native species are sometimes abundant in pastures. The red-headed larvae of *Adoryphorus couloni* are attractive to birds, which pull up the turf searching for them.

The richly coloured jewel beetles (Buprestidae), popular with collectors, are well represented locally by numerous species usually found amongst flowering vegetation. Their wood-boring larvae have a characteristic broad, flattened thorax. *Stigmodera* is the dominant genus with many strikingly coloured species, some up to 2 in long in Victoria.

Click beetles (Elateridae) are dull, or metallic hued elongate beetles, familiar because of their ability to jerk themselves into the air with a snapping noise when placed on their back. Their shiny, elongate larvae, known as wireworms, feed on the roots of grasses and other plants, and sometimes cause economic damage. *Hapatesus hirtus* is a sporadic pest of potatoes in the Dandenongs. *Lacon* and *Conoderus* are the dominant genera. Several *Pseudotetralobus* species from the Mallee may exceed 2 in in length.

Lampyridae are best known by *Chaulignathus pulchellus,* with yellowish thorax and soft, green elytra, sometimes found swarming in large numbers on foliage.

Adults and larvae of the cadelle beetle (*Tenebroides mauritanicus* : Trogositidae) infest stored grain and flour. The Cleridae are a large family of beetles often predatory on wood-boring larvae. The large black and white *Trogodendron fasciculatum* moves around actively on logs, etc., even mimicking wasps with its vibrating yellow antennae. The small, white banded *Paratellus carus* is often associated with *Lyctus.*

The yellow and metallic blue *Laius bellulus* (Melyridae) sometimes invades gardens along the River Murray.

Several species of *Carpophilus* (Nitidulidae) are a nuisance with dried vine fruits and ripe stone fruits, acting as vectors of brown rot fungus. The saw-toothed grain beetle (*Oryzaephilus surinamensis* : Silvanidae) is an important secondary pest of stored grain.

Dermestidae, both larvae and adults, feed on dried animal matter. *Anthrenus* species attack carpets, woollen goods, furs, and museum specimens. The larvae are hairy brown grubs, and the tiny pill-like adults are sometimes seen on window ledges or flowers. *Dermestes* species are pests of skin and hide stores, and bacon and cheese factories. Native species of *Trogoderma* and *Anthrenocerus,* found under bark, etc., feed on insect remains.

The furniture beetle (*Anobium punctatum* : Anobiidae) attacks furniture, shelving, etc., made from imported softwood timber. The tobacco beetle (*Lasioderma serricorne*) and the drug-store beetle (*Stegobium paniceum*) are sporadic pests of tobacco and stored foods, as are also the round-bodied spider beetles (Ptinidae). *Ptinus exulans* is brown with white spots, while *Mezium americanum* has a shiny dark body. The large augur beetle (*Bostrychopsis jesuita* : Bostrychidae) with head tucked underneath the thorax, tunnels in various trees, especially if they are unhealthy, while the black and red *Mesoxylion collaris* sometimes emerges from green building timber.

The powder post beetle (*Lyctus brunneus* : Lyctidae) is universally present in new houses in Victoria, but as it attacks only the sapwood portion of the framework timbers, it does not cause structural damage.

The round, yellowish, or dark blue ladybird beetles (Coccinellidae) are mostly beneficial, being predatory on aphids, mealybugs and scale insects, although *Epilachna* sometimes damages vegetable crops. The most familiar species is the common ladybird (*Leis conformis*) with its bright yellow body with thirteen spots. Various species, such as the black and red cardinal ladybird (*Rodolia cardinalis*) and the blackish mealybug ladybird (*Cryptolaemus montrouzieri*) have proved valuable biological control agents when sent overseas. The tiny *Stethorus* are important predators of spider mites on fruit trees.

The Tenebrionidae are a large and varied family of beetles, generally dull in colour, which live on the ground, or under bark. *Adelium* is a well known genus, and *Chalcopterus* contains many metallic, bark inhabiting species. Various species of *Tenebrio* and *Tribolium,* and other species, are important and widespread stored-products pests. The curious pie-dish beetles have an oval flange around the body.

The elongate Longicorns (Cerambycidae) have long thin antennae. Their creamy larvae (witchetty grubs, or bardees), found in rotting logs or firewood, were considered a delicacy by the Aboriginals. Several species of *Phorocantha* can complete their life cycle in milled timber, and the adults may make large emergence holes through the plaster in new homes. The European house borer (*Hylotrupes bajulus*) which attacks seasoned softwood timber, has been the subject of eradication campaigns on the several occasions it has been detected in Victorian houses.

The leaf beetles (Chrysomelidae) are a large family of medium to small, rounded beetles, often brightly coloured. The larvae may feed on various parts of the plant and the adults are leaf feeders. Stripping and browning of wattle foliage was once thought to be " fire blight " disease until it was discovered that the greenish larvae of *Paropsis orphana* were responsible. Other colourful species of *Paropsis* are often found on eucalypts, *P. atomaria* sometimes severely defoliating shelter belt sugar gums. Considering their feeding habits, very few native chrysomelids have become agricultural pests, the several exceptions rarely causing damage south of the River Murray. When present in large numbers, the metallic blue or green *Haltica* species, which jump readily, may attack strawberry plants, and ornamentals, and are very fond of bidgee-widgee (*Acaena*). Two species of *Chrysomela* have been introduced to control St. John's Wort, but with limited success. *Acanthoscelides obtectus* (Bruchidae) is a small weevil-like beetle which attacks dried beans, leaving them full of round holes.

Weevils, the largest and most highly evolved group in the Coleoptera, are characterised by the jaws being at the end of a snout. In many species the elytra are fused together. The tiny, long-legged *Doticus pestilens* (Anthribidae) breeds in wattle galls and sometimes attacks apples left on trees. The elongated Belidae are not uncommon on wattles, while the slender reddish Brenthidae are found under bark on gum trees. The European seed-eating *Apion ulicis* (Apionidae)

introduced into Tasmania to control gorse, now occurs near Eltham and Ballarat. The Curculionidae are separated from other weevils by their elbowed antennae. Amongst the introduced species, the granary weevil (*Sitophilus granarius*) and the rice weevil (*S. oryzae*) are major pests of bulk-stored wheat in Victoria. Others include several species of *Otiorrhynchus,* the small grey *Sitona humeralis,* widespread on lucerne, the sporadic garden pests, *Phlyctinus callosus,* and Fuller's rose weevil (*Pantomorus cervinus*), and the vegetable weevil (*Listroderes costirostris*), a pest of vegetables in irrigation areas. The large grey native *Leptopius squalidus* has switched from wattle trees and is now known as a root borer of fruit trees. *Desiantha maculata* is a pest of carrots in the Dandenongs, and strawberries are sometimes attacked by *Rhinaria perdix* and *Ecrizothis inaequalis.*

STREPSIPTERA are minute, highly specialised parasitic insects, closely related to the beetles, which live in the body cavity of various insects. Only the males are free living, with vestigial fore-wings, and fan-shaped hind-wings. " Stylopised " hosts usually become sexually modified. Less than 100 species of this little studied Order have been found in Australia.

MECOPTERA. This small Order of insects is poorly represented in Victoria, and little is known about the local species which superficially resemble crane flies, but have two similar pairs of wings. The adults are predatory on insects, and have biting mouthparts carried at the end of a long rostrum, while the larvae are caterpillar-like creatures which pupate in the soil. *Harpobittacus nigriceps* was found to be an important predator preventing the establishment of the Cinnabar moth introduced to control ragwort in the coastal hilly regions of Victoria, while *H. australis* occurs inland.

SIPHONAPTERA (Fleas) are small, flattened wingless insects, with jumping hind legs. They feed by sucking blood from warm-blooded animals. Their tiny, worm-like larvae feed on scraps of organic matter, indoors or outdoors, sometimes breeding up in large numbers in back-yards irrespective of the presence of domestic animals. In some years whole suburbs may experience such outbreaks. Fleas are common parasites of domestic animals. The dog, cat, and human fleas, although distinct species, are not confined to these hosts, and may feed on any warm-blooded animal, including man. The introduced *Echidnophaga gallinacea*, confined to the Mallee, attacks mainly poultry, but also a wide range of mammals and birds, while the native *E. myrmecobii* is a vector of myxomatosis amongst rabbits.

DIPTERA (Flies) are characterised by their one pair of wings, the hind pair being reduced to small clubs called halteres. The sucking mouthparts are sometimes adapted for piercing as well. The legless larvae typically are maggots, living on animal matter, humus, or plant tissue, but may be aquatic or parasitic. This large and successful order, ranging from primitive to highly specialised species, is well represented in Victoria, many being of direct importance to man.

The long-legged Crane flies (Tipulidae) breed mainly in wet soil. *Clytocosmus* is an attractive yellow and black fly. Moth midges (Psychodidae) are tiny insects commonly encountered on herbage in

damp places, rising in clouds when disturbed. The harmless, mosquito-like Chironomidae breed in large numbers in mud in stagnant water, their thin larvae being bright red. Victoria has forty-two species in twenty-six genera, nine species having their nearest relative in South America. The tiny persistent biting midges, or sandflies (Ceratopogonidae) are localised pests, especially in some coastal areas, but little is known about their breeding requirements.

Mosquitoes (Culicidae) are represented by seventy-three local species of which *Aedes* is the dominant genus. Mosquitoes are most abundant during spring and summer, breeding in a wide variety of habitats containing fresh or salt water. Irrigation areas may produce large numbers, while the recent arrival *Culex pipiens molestus* breeds freely in septic tanks, especially in coastal holiday areas. Some species bite man, including *Anopheles annulipes,* which fortunately is locally not a vector of malaria. Bird-pox viruses, myxomatosis, and Murray Valley encephalitis are transmitted by local species. Although many species of the minute gall-midges (Cecidomyidae) have been described in Australia, few have been correlated with the plant galls they often produce. The brown humus-feeding larvae with heads, clustered in large numbers in garden or pasture soils, are Bibionidae. The delicate fungus-gnats (Mycetophilidae) breed in large numbers in damp, shady localities, sometimes becoming pests in mushroom cultures and damp lawns. After floods in northern Victoria, small blood-sucking black-flies (Simuliidae) may appear in numbers, annoying stock and humans. Others breed in swift streams.

Soldier flies (Stratiomyidae) breed in damp soil, or sometimes water, the larvae being flattened, brown leathery maggots. The shiny black adults of *Neoexaireta spinigera* are often seen on window panes, and the long-legged, wingless females of *Boreoides subulatus* attract attention when depositing their clusters of pale eggs in fence posts, etc., in the south-east suburbs of Melbourne. The blood-sucking March flies (Tabanidae), with large eyes and flattened abdomen, are widespread in Victoria, often becoming localised pests in some areas, including beaches. The little known carnivorous larvae normally breed in swampy areas. The primitive genus *Pelecorrhynchus* is also found in South America, while the abundant genus *Scaptia,* with fourteen species extending southwards into Victoria, is similarly distributed.

The small, elongate Leptidae, some species of which are blood-suckers, lie in wait for insect prey in shady places. Only six of the sixty-six known Australian species have been collected locally. Bladder-flies (Acroseridae) are small, hump-backed flies, with larvae parasitic on spiders. The black, soot-like egg clusters of *Oncodes,* normally found on rushes, are also deposited on fence wire, and even clothes lines. Some rather striking flies are found amongst the long-legged robber flies (Asilidae), which are actively predatory on insects of all sizes. The large, black and orange *Blepharotes coriareus* occurs along the Murray. Bee flies (Bombyliidae) are stout, often very hairy flies with slender legs. The slender Empididae, predatory on small insects, have elaborate courtship rituals. The related Dolichopodidae, also slender predatory flies, are metallic green or bronze.

*Eutermiphora abdominalis* (Phoridae) is a small wingless fly found in ant nests. Hover-flies (Syrphidae) have a variety of habits. The very common black and yellow *Syrphus viridiceps,* seen hovering over flowers, has green maggots which are predatory on aphids, and other small insects, while the bee-like *Eristalis tenax* breeds in liquid decaying matter, such as dead animals, septic tanks, etc. The larvae have long breathing tubes. Several species of *Eumerus* attack bulbs and onions.

Queensland fruit fly (*Strumeta tryoni* : Trypetidae) has become adapted to cooler conditions than in its native State, and is now established as far south as East Gippsland. The larvae attack a wide range of fruits, making it a serious potential pest, which could jeopardise export markets. Road-block checks, market inspection of interstate fruit, and several metropolitan and country eradication campaigns, following the first Melbourne outbreak in 1953, have prevented establishment of this pest. Fruit growing areas are monitored by male lure traps, which sometimes attract other local species.

The small Agromyzidae attack plants. *Phytomyza atricornis* larvae are leaf miners in cinerarias, etc., while *Fergusonina* species have an unusual life history, breeding in galls on eucalypts, in association with nematodes which are alternatively free living, and internal parasites. Larvae of the metallic green *Lonchaea* (Lonchaeidae) found in damaged tomatoes, are often mistaken for fruit flies. A number of small, closely related families breed mostly in humus, although some species attack plants. Ephydridae swarm on the mud around stagnant water, while the yellowish Coelopidae breed in rotting seaweed. The tiny ferment flies found near rotting fruit are Drosophilidae. Several species of *Gastrophilus* (Gastrophilidae) may attack horses in Victoria, the larvae living in the alimentary canal, while *Oestrus ovis* (Oestridae) breeds in the nasal cavities of sheep.

Calliphoridae are medium-sized green, blue, or brown blowflies which breed in animal matter, or excrement. The important sheep blowflies (*Lucilia, Chrysomyia,* and *Calliphora* species) breed in carrion, and also damp wool and flesh of sheep, sometimes causing considerable economic losses if preventive measures are neglected. Blowfly maggots found indoors have often come from bird or animal carcasses in the ceiling.

The bristly, blowfly-like Tachinidae, with some 500 species in Australia, are parasitic on other insects. The often large and colourful adults are usually collected around flowers. *Rutilia* is the dominant genus. The grey *Voriella uniseta,* and *Trigonospila brevifacies,* black with yellow bands, parasitise light-brown apple moth. The related Sarcophagidae are greyish, striped blowflies which breed in decaying animal or vegetable matter, or are parasitic. *Taylormyia iota,* which has red eyes and yellowish head, is a widespread, common species.

The moderate sized greyish or dark Muscidae breed mainly in decaying organic matter. The ubiquitous housefly (*Musca domestica*) is found near its breeding sites, typically vegetable garbage, or horse manure. Its indiscriminate feeding makes it liable to transmit disease. The very similar bush fly, which rarely comes indoors, is a different species, *Musca vetustissima.* Although this irritating pest can appear

[*Department of Agriculture*

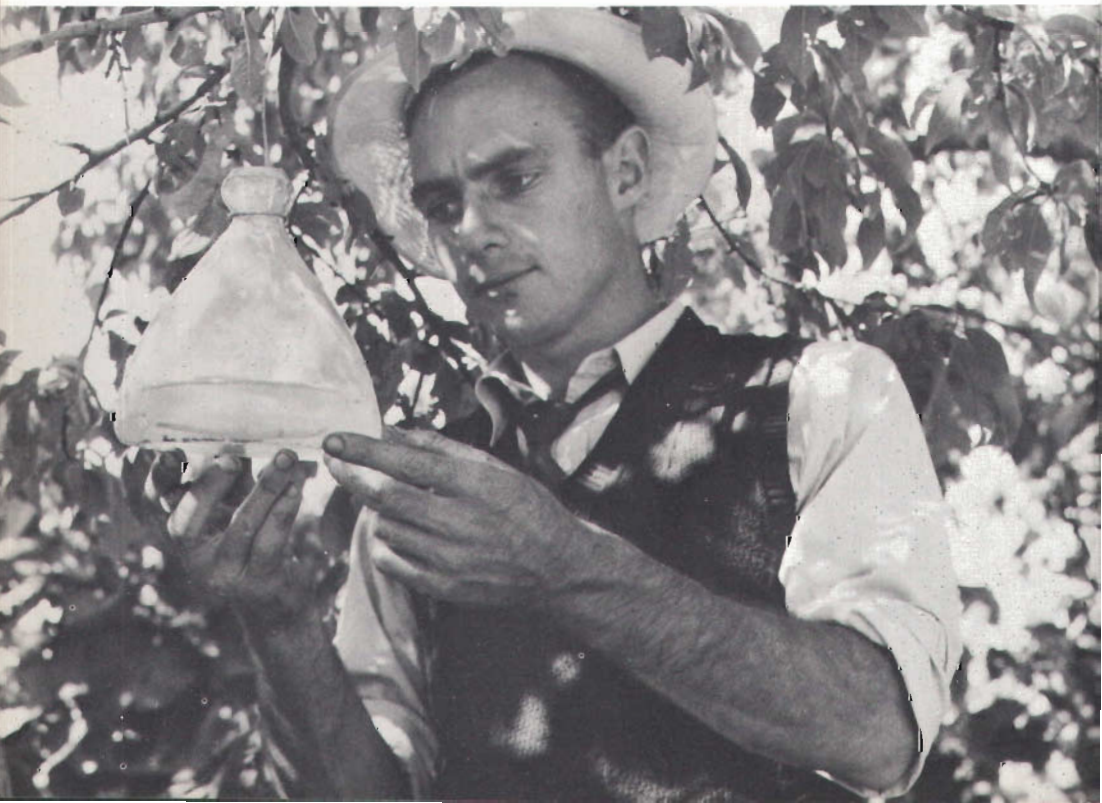
The most important factor affecting the distribution and abundance of insect species is man's manipulation of the environment, as, for example, in this scene of land clearing in Gippsland. The many species adapted to the specific conditions provided by the native vegetation are confronted with a hostile environment, and may die out. Some survive on the remaining trees, while a few may even thrive under the uniform conditions provided by man's monocultures, and become important pests.

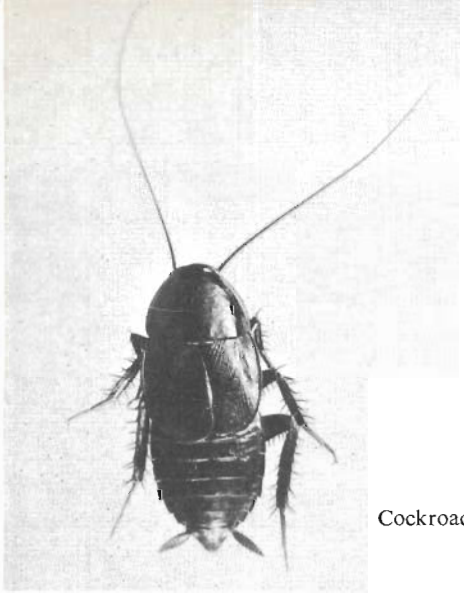
# *Insects of Victoria*

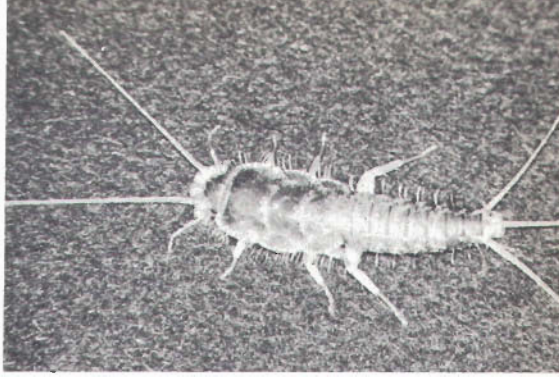
The seasonal use of chemical pesticides is the basis for the control of the established pests of stone and pome fruits in Victoria.

Eradication of local sporadic outbreaks of fruit fly, detected early through the use of lure traps, is the basis for controlling this serious fruit pest in Victoria.

[*Department of Agriculture*





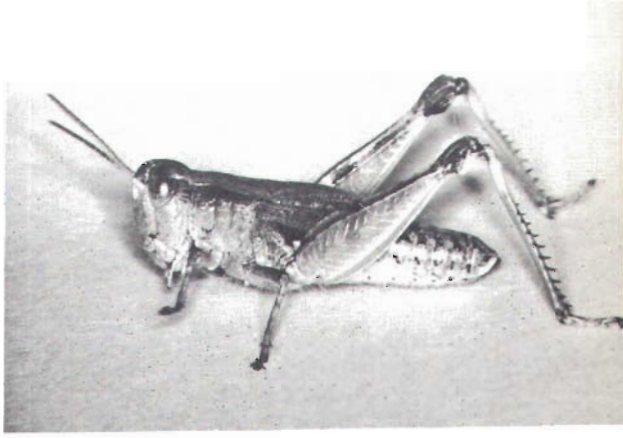


Silverfish (*Ctenolepisma longicaudata, Thysanura*)

Cockroach (*Blatta orientalis, Blattoidea*)

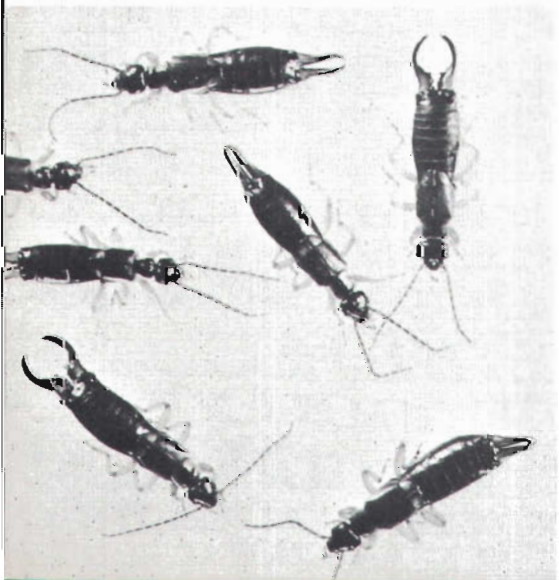
[*Victorian Plant Research Institute*

Female Embiid (*Embioptera*)



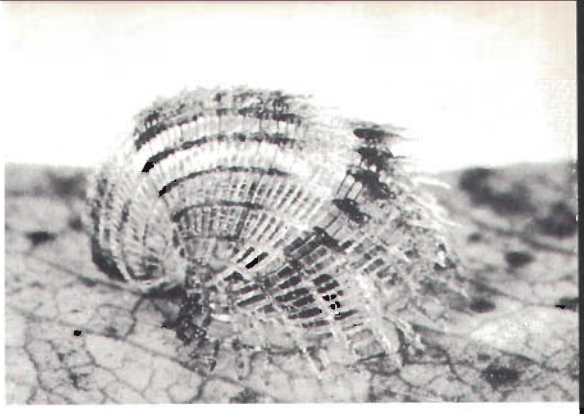
Wingless grasshopper (*Phaulacridium vittatum, Orthoptera*)

Earwigs (*Forficula auricularia, Dermaptera*)

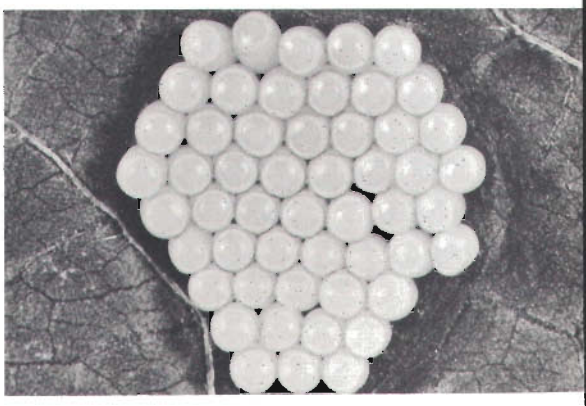


Worker termites (*Isoptera*)

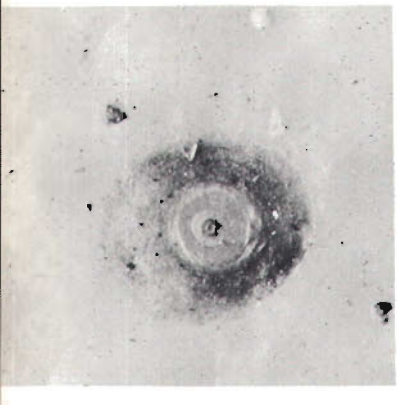
Harlequin bug
(*Dindymus versicolor, Pyrrhocoridae*)



Lerp on gum leaf (*Cardiaspina sp., Psyllidae*)

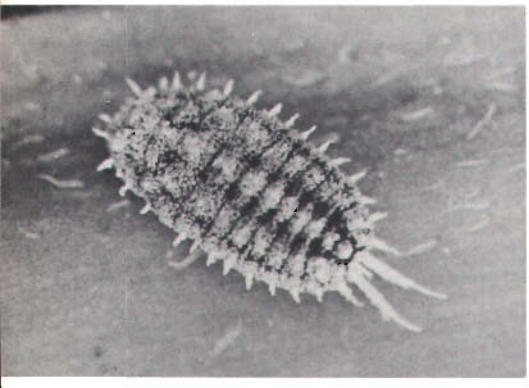


Eggs of green vegetable bug
(*Nezara viridula, Pentatomidae*)

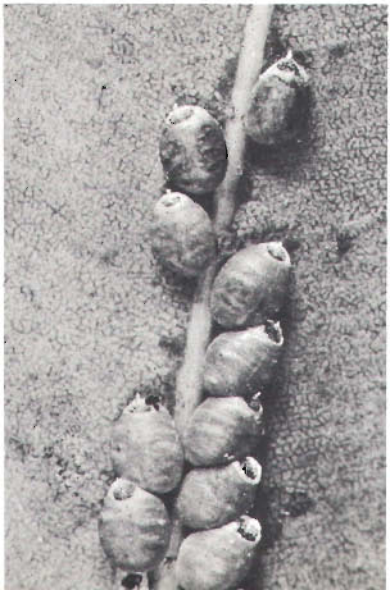


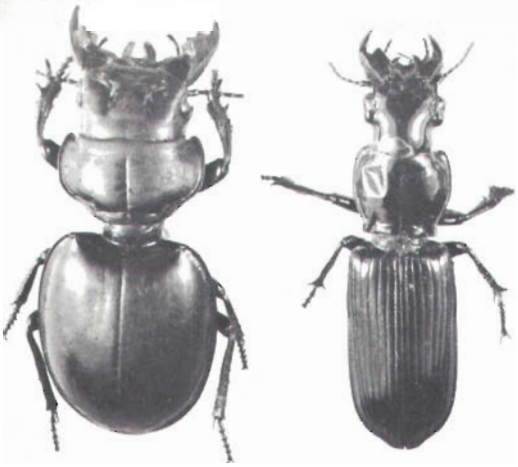
Citrus red scale
(*Aonidiella aurantii, Diaspididae*)

Gum tree scale
(*Eriococcus sp., Eriococcidae*)



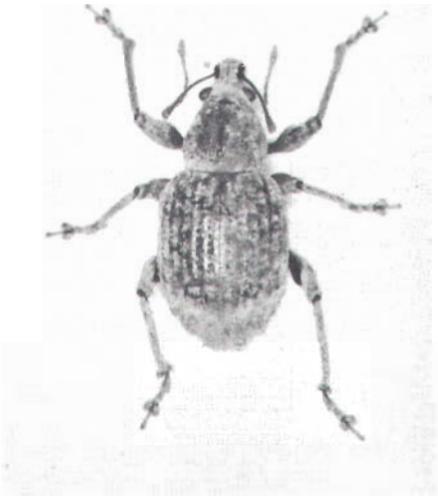
Mealybug (*Pseudococcus sp., Pseudococcidae*)
[*Victorian Plant Research Institute*





*Euryscaphus waterhousei, Carabidae*
*Hyperion schroetteri, Carabidae*

Fiddler beetle
(*Eupoecila australasiae, Scarabaeidae*)



South African vine weevil
(*Phlyctinus callosus, Curculionidae*)

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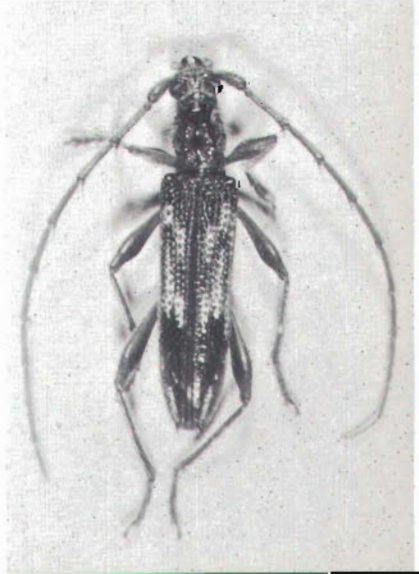
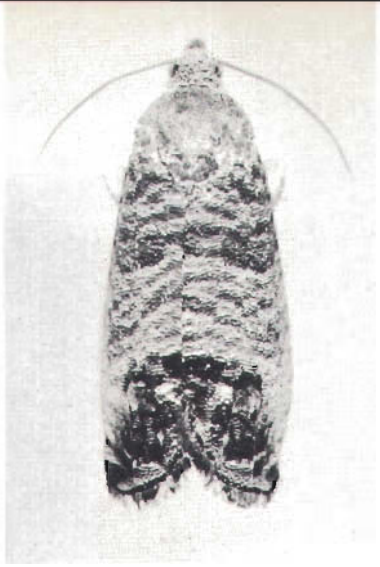
Giant thrips
(*Idolothrips marginatus, Thysanoptera*)

Variegated longicorn
(*Coptocerus rubripes, Cerambycidae*)

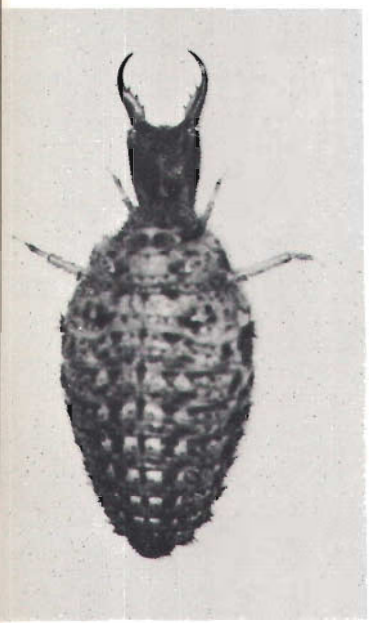


Red-headed pasture cockchafer larva
(*Adoryphorus couloni, Scarabaeidae*)

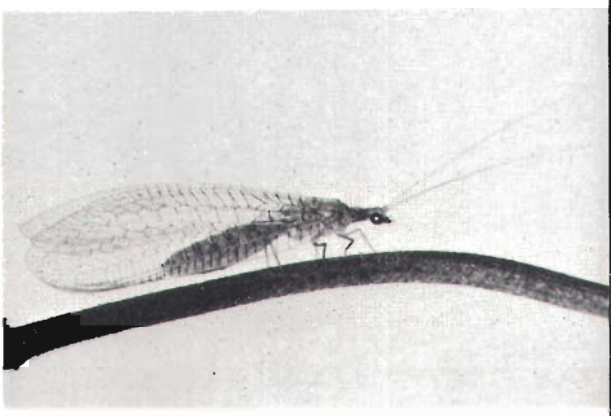
Bush fly (*Musca vetustissima, Muscidae*)



Codling moth
(*Cydia pomonella, Oleuthreutidae*)



Ant lion larva
(*Myrmeleontidae, Neuroptera*)



Green lacewing (*Chrysopa sp., Chrysopidae*)

Parasite of light-brown apple moth
(*Trigonospila brevifacies, Tachinidae*)

Hover fly (*Syrphus viridiceps, Syrphidae*)

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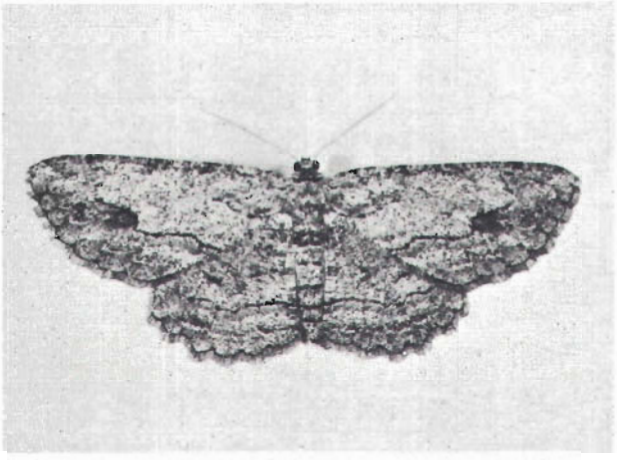
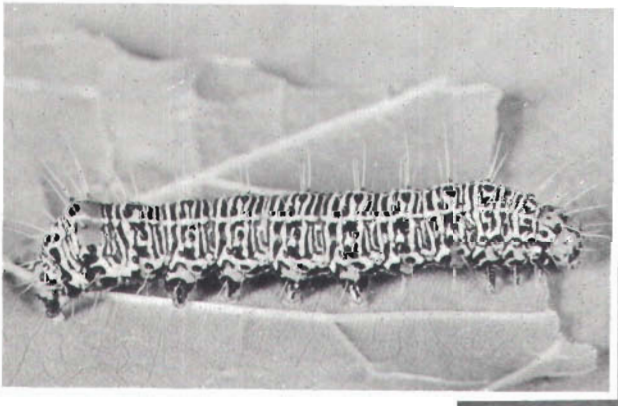
*Oxycanus fuscomaculata, Hepialidae*

Looper caterpillar (*Geometridae*)



*Ectropis excursaria, Geometridae*

Heliotrope moth
(*Utetheisa pulchelloides, Arctiidae*)



Larva of vine moth
(*Phalaenoides glycine, Agaristidae*)

Case moth larvae (*Psychidae*)

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Parasite of light-brown apple moth
(*Xanthopimpla rhopaloceros, Ichneumonidae*)

Pupal parasite of cabbage white butterfly
(*Pteromalus puparum, Pteromalidae*)

Larvae of sawfly wasp
(*Perga sp., Pergidae*)

Head of bulldog ant
(*Myrmecia sp., Formicidae*)

Larval parasite of cabbage white butterfly
(*Apanteles glomeratus, Braconidae*)

Wasp galls on red flowering gum leaf (*Chalcidoidea*)

*Persectania ewingii* (*Noctuidae*) larva killed by fungus
[*Victorian Plant Research Institute*

in plague proportions anywhere in Victoria, its breeding habits are largely unknown. The greyish, biting stable fly (*Stomoxys calcitrans*) breeds in horse manure, and sometimes in backyards housing large dogs. The onion maggot (*Hylemyia cilicrura*) attacks onions grown in soil rich in organic matter.

The flattened blood-sucking Hippoboscidae are external parasites on mammals and birds, and sometimes attempt to bite humans. *Ortholfersia* species attack marsupials, and the introduced *Pseudolynchia canariensis* attacks pigeons. *Melophagus ovinus* is a wingless species on sheep, known as the sheep ked.

TRICHOPTERA. Caddis-flies, closely related to the Lepidoptera, resemble small moths, but the wings are hairy instead of being scaly. The aquatic larvae usually live in small cases of sand, sticks, etc., and feed on water weeds, although some catch prey in silk nets. The pupae, which have strong mandibles to escape from the case, swim to the surface, where the adults emerge, flying usually at dusk in early summer, and rarely feeding.

Few species are recorded from Victoria, and further collection especially in alpine regions, should reveal many more of the 177 known Australian species. *Archaeophylax ochreus* breeds in streams on the Bogong High Plains. *Stenopsychodes montana* has wings speckled with black and yellow, while the males of *Smicridea* and *Asmicridea* have white or grey wings, giving the appearance of a snow storm when they are in flight. The females, by contrast, are dull brown. The black and orange *Plectrotarsus gravenhorsti* has the mouthparts in the male extended into a beak. The dominant family Leptoceridae have antennae often several times as long as the body.

LEPIDOPTERA (Moths and butterflies) are characterised by scales on the wings, and a proboscis which can be uncoiled to suck liquids such as nectar from flowers. A vast number are small and inconspicuous, but Victoria also has a range of the larger and more showy moths and butterflies, the latter, in particular, being of interest to amateur collectors. The elongate larvae (caterpillars) with six true legs, various abdominal prolegs, and biting jaws, are almost entirely plant feeders. Many species are of economic importance.

The primitive Ghost Moths (Hepialidae) are well represented in Victoria by a number of often large and attractive species. The greyish-brown and silver *Trictena argentata* emerges in numbers after the first autumn rains, leaving the empty pupa cases poking out of the soil under gum trees, the larvae being root feeders. The green or blue *Aenetus eximus* and related species feed on and in the stems of various native plants, protected by a felt-like covering. A number of mottled brownish hepialids are grass feeders, the larvae living in tunnels in the soil. The best known is the underground grass-grub (*Oncopera fasciculata*), an important pest of pastures. Such larvae are often attacked by the fungus *Cordyceps,* which completely replaces the tissue, producing the so-called " Vegetable caterpillars ". However, *Cordyceps* is rarely of economic importance.

The wood-boring Cossidae also contain a number of large species, such as the marbled greyish *Xyleutes liturata,* the 4 to 5 in long larvae of which tunnel in wattles. Fat, creamy Cossid larvae, usually obtained from eucalypts, were eaten by the Aboriginals.

Case moths (Psychidae) construct silk cases in which the larvae and the wingless females live. *Oikeuticus elongatus* makes long, twig-covered cases, while another smaller species uses leaves for camouflage, and may strip garden shrubs before being detected.

The small Tineidae are scavengers, eating a variety of materials, and sometimes living in portable silken cases. Several introduced cosmopolitan species attack undisturbed woollen clothing and carpets. Larvae of the metallic green clover seed moth (*Coleophora alcyonipennella* : Coleophoridae) live in cigar-shaped cases and feed on clover flowers.

The many similar species of the small delicate Gracillariidae, which characteristically rest propped up on their legs, usually have leaf-mining larvae. *Caloptilia azaleella* curls azalea leaves, and the minute *Acrocerops plebeia* blisters wattle leaves. The wriggly green larvae of the cosmopolitan cabbage moth (*Plutella xylostella* : *Yponomeutidae*) are pests of cabbages and other Cruciferae. The small metallic coloured *Glyphiteryx* species (Glyphiterygidae) breed on sedges, etc. The active Aegeriidae, with transparent wings, resemble wasps. The introduced *Synanthedon tipuliformis* tunnels in currant bushes. Amongst the numerous similar Oecophoridae, larvae of the yellowish *Philobota* species live in vertical tunnels in grasslands soil, while others live in leaf litter, or like *Wingia aurata,* feed on eucalypt leaves. The numerous large species of Xyloryctidae are wood borers. Larvae of the silky white *Cryptophasa unipunctata,* which normally attack wattles, sometimes ringbark and tunnel into branches of ornamental trees, while other species often attack *Banksia* and *Pultenea* shrubs. The introduced potato moth (*Phthorimaea operculella* : Gelechiidae) is an important pest of potato plants and tubers and the Angoumis grain moth (*Sitotroga cerealella*) is a stored products pest.

Larvae of the Tortricidae usually feed between folded or webbed leaves, or burrow into flower heads, etc. The light-brown apple moth (*Epiphyas postvittana*) with a wide range of native host plants, has become an important pest of pome fruits, vines, and ornamentals especially where chemicals kill off its parasites and predators. *Merophyas divulsana* rolls the leaves of lucerne. The well known codling moth (*Cydia pomonella* : Oleuthreutidae) is the most serious pest of apples and pears, while larvae of the oriental fruit moth (*Cydia molesta*), also introduced, tunnel into shoots and fruit of peach trees.

*Heliocosma argyroleuca* (Phaloniidae) is a comon alpine species. The larvae feed on snow daisies and buttercups, making small cases covered with dried petals.

The day flying Castniidae have clubbed antennae and resemble butterflies. Their soil inhabiting larvae feed on sedge roots, etc. A number of species of *Synemon* are present, particulary in inland areas.

Cup Moths (Limacodidae) have colourful slug-like larvae, armed with bunches of stinging spines. Their smooth brown cocoons are cup shaped following the emergence of the stout adults. The mottled cup moth (*Doratifera vulnerans*) attacks eucalypts, occasionally causing severe leaf damage.

The Orneodidae and Pterophoridae are slender moths with wings deeply cleft into a number of plumes. The white *Tipanaea patulella* (Pyralidae) is a stem borer of rushes and sedges, while *Hednota,* not regarded as a pest in Victoria, webs and feeds on grasses. The Mediterranean flour moth (*Anagasta kuehniella*) and the Indian meal moth (*Plodia interpunctella*) are cosmopolitan pests of processed grain and stored foodstuffs.

The long thin foliage-feeding Geometridae larvae progress in a looping motion, and are well camouflaged when motionless. Several brownish *Mnesampela* species attack garden shrubs, while *M. privata* skeletonises blue gum leaves, drawing them together as rough shelters. *Chlorocoma* species are a delicate green or yellow, but most Geometrids are inconspicuously coloured. The flightless females of *Zermizinga indocilisaria* have curious arched strap-like wings.

The stout furry Lasiocampidae have hairy night-feeding larvae. *Entometa* moths are brown and yellow.

The very hairy larvae of the Anthelidae, known as " woolly bears ", incorporate their hairs into their cocoons, and these can cause intense irritation if handled. *Anthela nicothoe* feeds on wattles, and *Anthela ocellata* and *Pterolocera amplicornis* feed on native grasses. The large bristly larvae of *Chelepteryx collesi* feed on eucalypts.

Victoria's largest and finest moth is the fawn Emperor gum moth (*Antherea eucalypti* : Saturniidae). Its huge colourful green caterpillars feed on eucalypts or pepper trees and pupate in tough brown cocoons. Although there are normally two generations a year, adult emergence may be delayed for up to ten years.

Amongst the few local species of the swift-flying streamlined hawk moths (Sphingidae) are the cosmopolitan silver striped *Hippotion lineata,* common inland, breeding on vines, and the brown and orange *Hippotion scrofa.*

Larvae of *Ochrogaster contraria* (Notodontidae), which construct bag shelters in Mallee wattles, move in long processions.

The tufted caterpillars of *Orgyia anartoides* (Lymantriidae) sometimes appear in large numbers on garden shrubs. The males are orange and brown, and the brown females are wingless. The hairy larvae of the mistletoe-feeding *Euproctis edwardsi* cause intense irritation if handled. Tiger moths (Arctiidae) include several large showy species, such as the spotted white and red *Spilosoma glatignyi,* and the smaller pinkish *Scoliacma bicolora.* The hairy *Roeselia* caterpillars (Nolidae) skeletonise gum leaves. The brightly coloured Agaristidae usually fly in bright sunlight. The black and cream *Phalaenoides*

*glycine* is a common native species whose blackish caterpillars, banded with white, now feed on vines. Males of *Hecatesia* make a whistling noise when flying at dusk.

The Noctuidae (cutworms, armyworms) contain a large number of rather similar medium-sized moths, some being serious economic pests. The southern armyworm (*Persectania ewingii*) is a regular spring pest of pastures and crops. In serious outbreaks the striped caterpillars may move forward in a long thin line, eating out everything as they go, hence the name " armyworm ". The fawn coloured native budworm (*Heliothis punctigera*) attacks pastures, crops, and vegetables, especially in the spring. The grey Bogong moth (*Agrotis infusa*), which breeds along inland river flats, migrates up to the alpine regions, where it spends the summer clustered in enormous numbers under overhanging rocks. Roasted over fires, the moths were a favourite food of the Aboriginals. The tapering green larvae of the looper caterpillar (*Plusia argentifera*) are sometimes found on garden vegetables. Large brownish grey moths, with a blue eye spot, sometimes found in houses, are *Dasypodia selenophora.*

Butterflies comprise several families of day-flying Lepidoptera with clubbed antennae, and include about 100 Victorian species. The sun-loving skippers (Hesperidae), found from spring to autumn, have interesting life histories, some being rare, or very localised. They are usually olive or brownish, with yellow markings, and a rapid undulating flight. *Taractrocera papyria* is one common species.

There are only four local swallowtails (Papilionidae), the most common being the black and greenish-white *Graphium macleayanus macleayanus. Papilio aegeus aegeus,* which breeds on citrus in northern districts, is Victoria's largest butterfly.

The small, often bluish Lycaenidae have specialised life histories, with the sometimes carnivorous larvae being attended by ants. The green slug-like larvae of the widespread *Zizeeria otis labradus* are found on lucerne, beans, and other legumes. *Orgyris* contains several beautiful species, while *Hypochrysops delicia delos* is metallic bluish or greenish.

The introduced cabbage white butterfly (*Pieris rapae* : Pieridae) breeds on cabbages and fodder crops, etc., while the native *Anaphaeis java teutonica,* whose early summer mass migrations from inland regions were once more common, breeds on capers. Several species of *Delias,* marked with black, white, crimson and yellow, breed on mistletoe.

The brownish Nymphalidae contain a number of well-known butterflies, such as the common brown and black *Heteronympha merope merope,* in which the sexes are marked quite differently. The banded caterpillars of the world-wide species *Danaus plexippus* and *D. chrysippus* are always associated with the introduced swan plant. The small orange-brown and black *Oreixanica* species appear late in the season. *Vanessa cardui kershawi,* which breeds on everlasting daisies and capeweed, is common in favourable seasons.

HYMENOPTERA (Wasps, bees, ants) cover a wide range of sizes. All, except sawflies, have a " wasp-waist ", and the two pairs of wings, hooked together in flight, have specialised and sometimes highly reduced venation. The female ovipositor is adapted for sawing, piercing, or stinging. The adults are either carnivorous, or pollen or nectar feeders, and the larvae vary from caterpillar-like plant feeders, to maggot-like parasites, sometimes with complex life cycles.

The introduced Sirex wasp (*Sirex noctilio* : Siricidae), is an important pest of pine plantations, especially unhealthy trees. The large, metallic-blue female sawfly deposits eggs and fungus spores in branches with a stout ovipositer, and the grub-like larvae tunnel through the timber, spreading the fungus, which weakens the tree. The dark, caterpillar-like grubs of several species of *Perga* (Pergidae) are a common sight in the bush, clustered in masses on eucalypts, and sometimes causing extensive leaf damage. They pupate in the soil, and the adult sawflies may take some years to emerge. The leaf-mining *Phylacteophaga eucalypti* (Tenthredinidae) produces blisters on gum leaves, *Pterygophorus cinctus* attacks docks, and the slug-like larvae of *Caliroa cerasi* are found on hawthorns and fruit trees.

The hard, shiny bodied, and often colourful Ichneumon wasps (Ichneumonidae) form an enormous family of insect parasites, usually attacking larvae of moths and butterflies, but sometimes other parasites. Some of the bigger species emit a strong odour when handled. *Echthromorpha intricata* is a common large black species, with yellow spots, and red legs and antennae, and *Ichneumon promissorius* is a common parasite of cutworm caterpillars. Males of *Lissopimpla semipunctata* have the curious habit, first noted by a Victorian naturalist, of pollinating *Cryptostylis* orchids by " mating " with the flowers. The introduced *Thyraeella collaris, Hymenobosmina rapi,* and several species of *Horogenes* help to control cabbage moth. *Xanthopimpla rhopaloceros,* pale yellow with black spots, parasitises light-brown apple moth pupae, while another native species, *Gambrus stokesi,* attacks codling moth pupae. The very long ovipositor of the introduced *Megarhyssa* enables it to parasitise Sirex wasp larvae in pine trees.

The closely related Braconid wasps (Braconidae), with similar habits, are another large group of considerable economic importance. The familiar *Apanteles glomeratus* produces masses of bright yellow cocoons alongside parasitised cabbage butterfly larvae, while other species produce masses of white cocoons. The light-brown apple moth parasite, *Apanteles tasmanica,* produces single cocoons. Some braconids parasitise aphids. Examples are *Diaeretiella rapae* on the cabbage aphid, *Ephedrus persicae,* and several species of *Aphidius.*

Chalcid wasps (Chalcidoidea) are an enormous group of tiny wasps, with elbowed antennae, mostly parasitic on other insects, and therefore of considerable economic significance. Some, however, produce plant galls. Some of the fairy-flies (Myrmaridae) are amongst the smallest insects known. *Aphelinus mali* (Eulophidae), released in 1924, has given good control of woolly aphid of apple. Several species of minute yellow *Aphytis,* imported from California, are being used for biological control of red scale of citrus. *Encarsia formosa* has been so effective

against the greenhouse whitefly that this once serious pest is rarely seen in large numbers. *Comperiella bifasciata* (Encyrtidae) with black bands on the wings, has become established as a useful parasite of red and yellow scales on citrus, while several species of *Aphycus* help to keep various scale insects under control. *Trichilogaster acaciae-longifoliae* (Perilampidae) produces " wattle apple " galls in place of the flowers of acacias. *Spalangia endius* and *Nasonia vitripennis* (Pteromalidae) are cosmopolitan parasites of house flies and blowflies. *Pteromalus puparum,* imported from New Zealand in 1941 by the Department of Agriculture, is a useful parasite for control of the cabbage white butterfly. Eurytomidae usually attack plants. *Bruchophagus gibbus* destroys clover and lucerne seed, while *Eurytoma* species produce galls on trees. The Chalcidae, with swollen hind legs used for jumping, are usually parasitic on caterpillars. *Brachymeria phya* attacks light brown apple moth.

*Megalyra fascipennis,* with a slender ovipositor three times the body length, belongs to the solely Australian family Megalyridae, which, like the similar Stephaniidae, with long slender antennae, is thought to be parasitic on wood grubs. The hatchet-bodied wasps (Evaniidae) with abdomen elevated on a long petiole, appear to be egg parasites of Orthoptera.

*Ibalia leucospoides* (Ibaliidae) has been introduced from New Zealand to combat Sirex wasps. Several native species of *Scelio* (Sceliondae) are parasitic on locust eggs, while various geographical strains of *Trissolcus* and *Telenomus,* introduced by the Commonwealth Scientific and Industrial Research Organisation, appear to have achieved good control of the green vegetable bug by parasitising the eggs. The metallic green or blue cuckoo-wasps (Chrysididae) which roll into a ball when disturbed, parasitise other Hymenoptera.

The hairy flower-wasps (Scoliidae) are richly coloured, dark winged burrowing wasps, probably parasitic on scarab larvae. This habit is true of the numerous flower wasps (Thynnidae) in which the males haunt flowers, while the females are wingless. The large, black and yellow *Zaspilothynnus variabilis* is a common species. However, the dark metallic " blue ant " (*Diamma bicolor*), which stings severely, parasitises mole crickets. The hairy, hard-bodied wingless females of the Mutillidae, typically found on warm sand dunes, parasitise other Hymenoptera.

Australia has some of the most primitive ants (Formicidae) in the world, including the ponerine ants, which sting readily, hanging on by their large jaws for leverage. The one inch long *Myrmecia,* represented by nineteen species in Victoria, nest in rotting logs or under stones. The smaller, black *Promyrmecia pilosula,* which jumps readily, is the commonest of the fourteen local species of this genus. The introduced Argentine ant (*Iridomyrmex humilis*), first discovered in Melbourne in 1939, is a serious pest of gardens and houses, requiring systematic insecticide treatment for control. Of the many native species of *Iridomyrmex,* the best known is *I. detectus,* which makes large, flat mound nests, covered with fine gravel. *Technomyrmex albipes* is a pest in kitchens at times, and the sugar ant (*Camponotus consobrinus*) also comes indoors. Several *Pheidole* and *Monomorium* species are sporadic pests of houses and lawns.

The Vespidae (social wasps), which have three distinct castes: workers (sterile females), males, and females (queens)—build community nests from chewed up wood fibres. The larvae in the cells are fed with masticated caterpillars, etc., and fresh colonies are founded each spring by the overwintering queens. The common black and dull brown *Polistes variabilis,* one of the paper nest wasps, makes mushroom-shaped honeycomb nests suspended under overhanging shelters. The introduced English wasp (*Vespula vulgaris*) builds multi-storied nests in cavities in the ground, dense hedges, or walls of buildings. The swift, silent yellow and black workers, which sting readily if annoyed, are attracted to sugar sources, such as flowers and ripe fruit. This pest, first discovered in 1960, is now slowly spreading through the eastern suburbs of Melbourne.

The slender waisted Sphecidae either burrow in sand, or make nests of daubed mud in sheltered sites. The common large yellow and black *Sceliphron laetum* may build its clay nests, stocked with spiders, inside buildings, while the short-winged *Sphex* wasps stock their sand burrows with caterpillars, paralysed by their sting. The long-legged sand wasps (Pompilidae), large predatory species with yellowish wings, also store paralysed spiders in their burrows. The black and yellow *Salius bicolor* is a common species. The solitary mason wasps (Eumenidae) build clay nests usually with a number of cells, but sometimes single vase-shaped cells, stocked with paralysed caterpillars.

The huge black and yellow *Exeirus lateritus* (Exeiridae) digs burrows in sandy soil to which it drags paralysed cicadas as food supply for its larvae. The Bembecidae take flies back to their burrows clustered together in sandy soil. The Nyssionidae have similar habits, *Sericophorus* being a useful predator of sheep blowflies. The thick set Larridae prey mainly on Orthoptera, but *Tachysphex australis* deposits its eggs, cuckoo fashion, in the spider filled cells of a mud-dauber wasp.

A number of families of native bees, characterised by plumose body hairs, are represented in Victoria, most of them being solitary insects which collect nectar and pollen from flowers. The medium to large hairy bees of the Colletidae, Anthophoridae and Andreidae nest in chambers at the base of tunnels in the soil. The numerous species of *Parasphecodes* (Halictidae) and *Halictus* have social castes, and community nesting areas, with broad cells opening off tunnels in the soil. *Halictus,* with more than one generation a year, exhibits colour variation, and parthenogenesis. The primitive Hylaeidae are well represented by many smooth, flower-haunting species, with a variety of nesting habits. Some of the leaf-cutting bees (Megachilidae) are fond of rose leaves for cutting out discs used in building their cigar-shaped nests, while others use resin from gum trees, or are parasitic on other native bees. The smooth, dark *Exoneura bicolor* (Ceratonidae) excavates in stems of plants, or even posts for its nests. The Apidae contains a number of small, dark, shining, stingless native bees, mostly *Trigona* species, which construct community nests in hollow trees. These were one of the few sources of sweetness available to the Aboriginals. The more industrious, introduced domestic honey bee (*Apis mellifera*) which has largely supplanted the native bees, is of immense value in pollinating plants, as well as producing honey.

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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.

It 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 Southern 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, Westernport 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 Wilson's 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.

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

AREA OF AUSTRALIAN STATES

| State or Territory | Area | Per Cent 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 |

## Physical Divisions

This article should be read in conjunction with the articles on geographical features, 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, as is recognised in popular terms such as Mallee, Wimmera, Western District, and so on. The following is a table of these divisions :

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

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

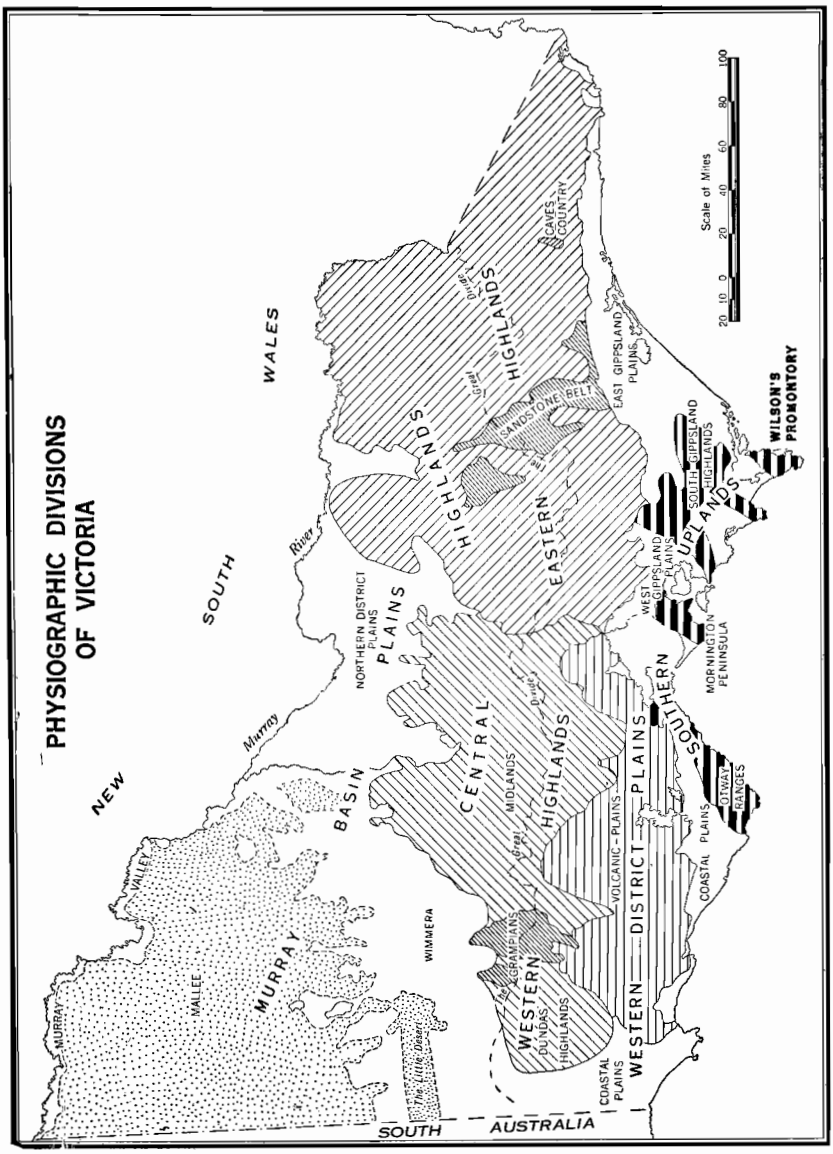


FIGURE 1.

*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 periodical 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 sandstones 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 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 Westernport Bay 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 Latrobe Valley. A notable feature is the Ninety Mile Beach and the lakes and swamps that lie on its landward side. This beach is an off-shore 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.

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## 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 airmasses, giving rise to heavy orographic rainfall of over 50 in p.a. 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 responsible for 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 in to 30 in p.a., cool winters, warm summers, rolling topography, open dry sclerophyll forest and grasslands, and moderately fertile if 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 in p.a. in the southern Wimmera, but it decreases to under 10 in p.a. 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 in p.a. in the western part to over 30 in p.a. 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 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.
Murray and its tributaries, especially in the Kerang, Echuca–Rochester,

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. Here are the main ports of Victoria : Melbourne, Williamstown, and Geelong. 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 Keilor and Western District volcanic plain stretching west from the Bay. 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 in p.a. 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, along with 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 as Victoria's third major port.

South of the Western District Plains lie the Otway Ranges, a sparsely populated region of rugged scenery and very high rainfall. The coastline between Lorne 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 Latrobe Valley. (Included in East Gippsland Plains in Figure 1.) The fault trough with its rolling hills, 30 in rainfall, and year round pasture, is among the best dairying country in the Australian mainland, supplying the metropolitan whole milk market. The Latrobe 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 Latrobe Valley, rainfall decreases to below 30 in p.a. between Traralgon and the East Gippsland Lakes. Here the coastline is characterised by sand dunes and lagoons, backed by the riverine plains of the Latrobe, 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.

Variety, then, is the keynote of Victoria's farming system and physiography. Generally, shortage of water is the main environmental problem for agriculture, especially north of the Highlands. Coastal Victoria has a more reliable rainfall. The Highlands are the only region where temperature extremes limit agricultural utilisation, and these are less intensively farmed than other parts.

Generally, Victoria's farmers practise progressive and productive agriculture. The State's 70,000 rural holdings produced $956.3m in 1966–67 which was 25.0 per cent of Australia's gross value of production. The importance of Victoria's farmers is seen when it is realised that they produce a substantial amount of Australia's farm output, e.g., 22 per cent wheat ; 32 per cent oats ; 11 per cent barley ; 69 per cent dried vine fruit ; 42 per cent mutton and lamb ; 20 per cent wool ; 26 per cent beef ; 20 per cent pigs, and 55 per cent butter.

## 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 more than 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 Mount Bogong, 6,516 ft; Mount Feathertop, 6,307 ft; Mount Nelse, 6,181 ft; Mount Fainter, 6,157 ft; Mount Loch, 6,152 ft; Mount Hotham, 6,108 ft; Mount Niggerhead, 6,048 ft; Mount McKay, 6,045 ft; Mount Cobberas, 6,030 ft; Mount Cope, 6,026 ft; Mount Spion Kopje, 6,025 ft; and Mount Buller, 5,919 ft.

**Further Reference, 1962**

## Marine Animal Ecology of Victoria's Coastline

*Introduction*

The primary marine ecological divisions are based on climate, being the Tropical, Temperate, and Polar Regions. These can be divided into tropical, sub-tropical, warm and cool temperate, sub-polar, and polar.

In Australia, as in other parts of the world, ecologists have studied the flora and fauna and mapped the distribution of species. Such mapping has shown that at certain points major changes occur in the species of both the terrestrial and marine environment and these can be grouped into provinces; the majority of species occurring in one province is different from those that occur in adjoining ones. South-eastern Australia lies within the Temperate Region with its more northerly and westerly sections being warm temperate and the southern part, including Tasmania, being cool temperate.

These provinces have been given the name Peronian for the eastern, Flindersian for the western, and Maugerian for the cool temperate southern section. Victoria lies within the cool temperate region but because of the complexity of the currents that bathe its shores, it has, particularly on its eastern and western limits, a blending of warm temperate species from the Peronian and Flindersian Provinces.

Beside latitude, the marine enviroment can be divided two other ways. First, by the substrate type whether it be rock platform, sand, muddy sand, grading to sandy mud, and finally mud; second, by the depth of water ranging from the splash zone above high tide, through the intertidal or littoral zone, and down into the benthic zone. Finally, the position of any particular spot is important as the amount of exposure to wind and wave action will affect the animals present at any given locality.

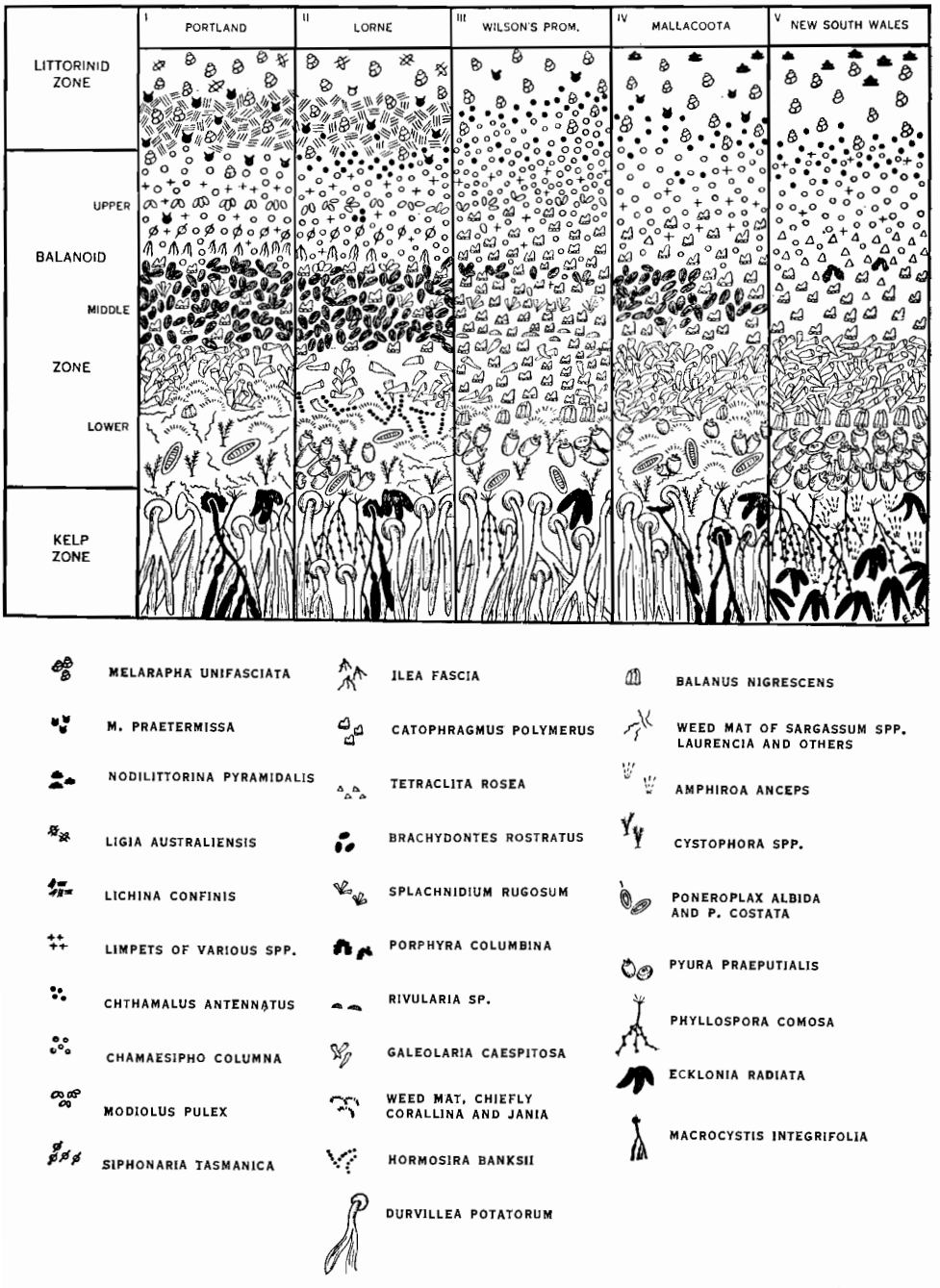



FIGURE 2.—Diagrammatic Representation of the Zoning of the Principal Intertidal Rock-dwelling Animals and Plants.

The most satisfactory basis for study is the communities occurring on each substrate type. The following divisions can be considered :

(*a*) Rock Platforms
Exposed Intertidal
Sheltered Intertidal
Benthic

(*b*) Sediments, Sand—Sandy Mud
Exposed Intertidal
Sheltered Intertidal
Benthic

*Rock Platforms*

Because of the interplay of the above factors together with several less obvious ones, ecologists have found that the inhabitants of exposed intertidal rock platforms reflect the character of the province in which they live most clearly.

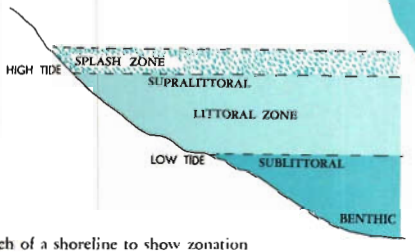
A great deal of the Victorian coastline is rocky and because of its situation, facing the Southern Ocean or the turbulent waters of Bass Strait, intertidal animals on the open coast have to withstand great wave and wind forces as well as lower temperatures than are found in the adjoining warm temperate Flindersian and Peronian provinces.

In this brief treatment mention is only made of those animal species that have special significance.

The two dominant species of the splash zone are the littorinid molluscs *Melarapha unifasciata* and *M. praetermissa,* but in the extreme east of the State, the Peronian species *Nodilittorina pyramidalis* also occurs. In the mid-littoral the Peronian Honey-comb barnacle, *Tetraclita rosea,* is replaced by a second species, *T. pubescens.* In the Peronian and Flindersian provinces the dominant species in the mid-littoral are barnacles but in Victoria the platform at this level is usually covered by large sheets of mussels *Brachydontes rostratus* and *Modiolus pulex.*

The tube worm *Galeolaria caespitosa* is a prominent feature of most New South Wales platforms but in Victoria it tends to seek places which are not completely exposed and afford it shelter from the full force of wind and wave. The cunjevoi (sea-squirt) *Pyura praeputialis* grows in sheets at low tide level on New South Wales rock platforms but it becomes sparser westward along the Victorian coast, until west of Port Phillip its occurrence is spasmodic and it has not been recorded on the open coast west of Cape Otway. The large acorn barnacle *Balanus nigrescens* occurs in the lower littoral of the Flindersian and Peronian provinces but is only found on the extreme west coast of Victoria at Cape Bridgewater.

The number of species present on a platform usually increases with shelter and in some instances an open coast species may be replaced by another closely related one in more sheltered waters of bays and inlets. Thus the Conniwink *Bembicium melanostonum* found in bays and mangrove swamps replaces *B. nanum* so common on the open coast. Another such example is the two species of carnivorous




Sketch of a shoreline to show zonation

FLINDERSIAN
PERONIAN
WARM TEMPERATE
MAUGIAN
COOL TEMPERATE
TEMPERATE OVERLAP OF PROVINCES

VICTORIA-MARINE ZONES AND PROVINCES

snail *Cominella*; *C. lineolata* is a predator of *Galeolaria* and *Brachydontes* on open coasts, and *C. eburnea* is found in sheltered waters.

Shallow water benthic rock platforms are always rich in both plant and animal species. Plants and the sessile colonial invertebrates such as sponges, hydroids, and bryozoans provide shelter and food for motile forms, particularly worms, molluscs, crustaceans, echinoderms, etc.

*Sediments*

Sandy beaches usually have a limited fauna because only a small number of animals are capable of coping with so unstable a substrate. This is particularly so on ocean beaches where the sand is continually moved by the force of the waves. The dominant species on sand beaches in Victoria are two molluscs, the wedge shell *Plebidonax deltoides* and its predator the sand snail *Conuber incei*. With increased shelter the number of species increases but because the bivalve molluscs are particularly well adapted for life in sand and sandy mud, they are usually dominant both in number of species and individuals within a species.

In more sheltered situations the clay content of the sand increases and the sand is replaced by various grades of silty sand to sandy clay and finally clay. With increased clay and organic matter and more sheltered water the number and variety of species increase and phyla other than the molluscs become important members of the community. Such communities are stable and the dominant species are usually present in proportionate numbers. In the intertidal area there is often an overlying changing population due to migrations, washes in, or flushes due to settlement of larvae from the plankton. These are purely transitory and do not alter the basic community.

Below low tide, benthic communities are stable and the animals present reflect the situation and type of sediment of the substrate. The animals of each community are so well adapted to a particular situation and type of substrate that the dominant species are closely related to those of similar " parallel " communities in other parts of the world.

In Port Phillip Bay with its great variety of sediments from gravel to clay, there are a number of bottom communities. The central basin below the seven fathom line is clay and silty clay and carries an Echinoderm community consisting of four dominant species, the urchin *Echinocardium cordatum,* the brittle star *Amphiura elondeformis* and two species of mud dwelling holothurians *Trochodota allani* and *Leptosynapta dolabrifera.* Minor differences in the sediments are shown in the species of Annelida present. In the north western silty clay *Chaetopterus* sp. is the dominant species.

Surrounding the central area there are silty clay sections that carry communities of the sea squirt *Pyura praeputialis,* the holothurians (sea-cucumbers) *Stichopus mollis* and *Pentacta australis,* and the star-fish *Tosia magnifica.*

In the extreme shelter of Swan Bay the clayey sand has a community of *Homalina deltoidalis.* Associated with it is the Cerithid mollusc *Zeacumanthus diemenensis.* This parallels the communities of the closely related genus *Macoma* of the northern hemisphere.

*Conclusion*

This very brief review indicates the uniformity of the sea and its fauna. Although only Victorian communities have been discussed these can be paralleled by other communities consisting of species representing the same genera inhabiting similar situations but replacing each other in each geographical region of the world.

There is a close connection between the animal community and the substratum whether it be rock surface or sediment, and some ecologists have argued that it is possible to postulate the community present from a study of the grain size group represented by the sediments. More detailed work has shown that this is only partially true and that the subtle factors influencing occurrence and distribution are not completely mirrored by grain size. The animals can make a much more detailed analysis of the substratum and their presence or absence is the best basis of ecological study.

There is strong evidence to suggest that the main variable factor in parallel communities is temperature. Each replacing species is adapted to the temperature of the place in which it lives. The marine ecologists and terrestrial ecologists find difficulty in assessing and appreciating each other's hypotheses. This is mainly because the terrestrial soil ecologist is dealing with complicated micro-climatic conditions which create problems unknown to the marine ecologist and which make it impossible to generalise.

The marine ecologist can use parallel communities for generalisation and is therefore in a position to bridge the gap from the marine to the terrestrial environment. This can best be done by using the simple marine community as a yardstick and considering each additional terrestrial factor as it occurs in the gradual path from the marine to the terrestrial environment.

**Hydrography of Coast 1966; Coastal Physiography 1967; Plant Ecology of Coast 1968**

## 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 has 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.

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 1,000 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 .. | Tallandoon .. | 1,840 | 1935 | 1,063 | 30 | 2,613 | 316 |
| | | Mitta .. | 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 | 1906 (*a*) | 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 | Latrobe .. | Rosedale .. | 1,600 | 1901 (*b*) | 777 | 51 | 2,634 | 362 |
| | 28 | Bunyip .. | Bunyip .. | 268 | 1908 (*c*) | 124 | 47 | 246 | 56 |
| | 29 | Yarra .. | Warrandyte .. | 899 | 1892 | 685 | 48 | 1,215 | 265 |
| | 30 | Maribyrnong .. | Keilor .. | 500 | 1908 (*d*) | 91 | 35 | 266 | 3 |
| | 31 | Werribee .. | Melton .. | 446 | 1917 (*e*) | 68 | 49 | 259 | 5·3 |
| | 32 | Moorabool .. | Batesford .. | 430 | 1908 (*f*) | 58 | 16 | 149 | 2·5 |
| | 33 | Barwon .. | Winchelsea .. | 370 | 1922 (*g*) | 115 | 33 | 412 | 25 |
| | 35 | Carlisle .. | Carlisle .. | 30 | 1930 (*h*) | 32 | 31 | 71 | 14·5 |
| | 36 | Hopkins .. | Wickliffe .. | 540 | 1921 (*i*) | 28 | 34 | 103 | 1·4 |
| | 38 | Glenelg .. | Balmoral .. | 606 | 1889 (*j*) | 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 |

### *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 1963 *Victorian Year Book.*

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 in to 20 in. Above this amount, roughly half the rainfall appears as stream flow.

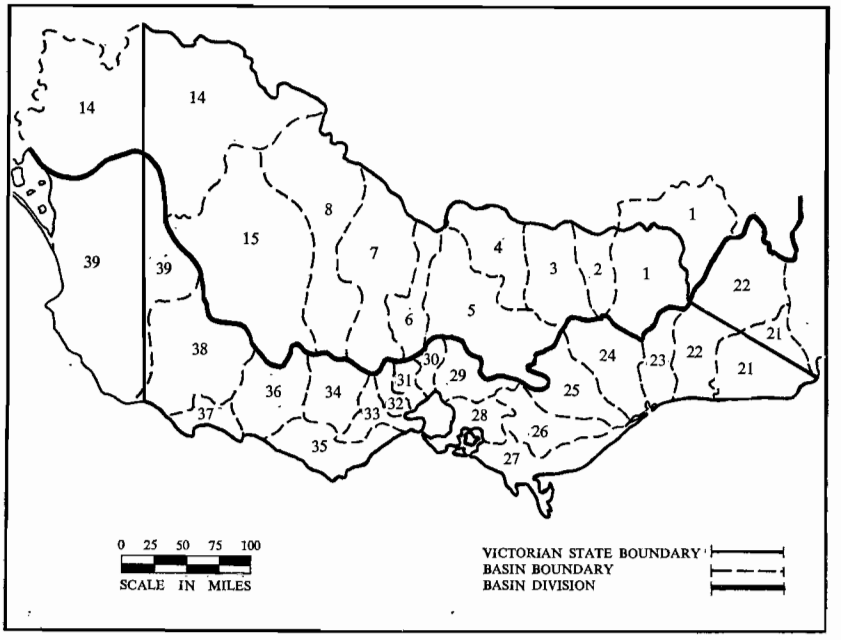



FIGURE 3.—Relevant Basins of the two Divisions (South East Coast Division and Murray–Darling Division) which include Victoria and some adjacent areas. The Basins are numbered as shown on Map 3 (Sheet 2) in *Review of Australia's Water Resources* (Published by Department of National Development, 1965).

| SOUTH EAST COAST DIVISION | | MURRAY–DARLING DIVISION |
|---|---|---|
| 21. East Gippsland | 30. Maribyrnong River | 1. Upper Murray River |
| 22. Snowy River | 31. Werribee River | 2. Kiewa River |
| 23. Tambo River | 32. Moorabool River | 3. Ovens River |
| 24. Mitchell River | 33. Barwon River | 4. Broken River |
| 25. Thomson River | 34. Lake Corangamite | 5. Goulburn River |
| 26. Latrobe River | 35. Otway | 6. Campaspe River |
| 27. South Gippsland | 36. Hopkins River | 7. Loddon River |
| 28. Bunyip River | 37. Portland | 8. Avoca River |
| 29. Yarra River | 38. Glenelg River | 14. Mallee |
| | 39. Millicent Coast | 15. Wimmera–Avon River |

### *Total Flow*

The current estimate of mean annual flow is 17 mill 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 mill acre ft (with about 8 mill acre ft in the north-east and 6 mill acre ft in the south-east) and hence leaving 3 mill acre ft in the western half.

*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 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 location and width of reservations for 280 streams which (except for the Murray) are 1, 1½, 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

*General*

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 in 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 R.L. 388, around Lake Corangamite, plus any higher land rendered inaccessible to the landowner by the initial surrender. The legislation makes similar provision also 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 in over the State is crude, but is 3 in more than the next highest figure of 35 in in 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 Latrobe 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 mill 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 Department of Crown Lands and Survey is responsible for surveying and mapping Crown lands (for the purpose of boundary definition) and for the preparation of maps.

Surveys are made to define boundaries and determine the dimensions of allotments for which Crown Grants are subsequently issued. Survey parties are mainly centred in country districts and are equipped with modern survey instruments. The information so obtained has always formed the basis of the parish plans which the Department is endeavouring to keep up to date and in many cases, to redraw, where the original is unsuitable for reproduction.

Geodetic surveys are also being carried out throughout Victoria to link the State's mapping with that of the rest of Australia, and to provide control for aerial photographs from which a series of maps is prepared by the use of stereoplotting equipment. The Department spends at least $70,000 annually to engage in aerial photography over selected parts of the State and this may be used for general small scale mapping or even, under special circumstances, for maps at a scale of 40 ft to an inch. Colour photography is being increasingly used, especially for forestry purposes. The very large scale maps are required for developmental purposes (such as design, street construction, sewerage, and drainage) and indicate all occupation, streets and street names, and natural physical features with contours shown at 1 ft, 5 ft, or 10 ft intervals. The geodetic survey parties are equipped with theodolites capable of reading direct to one second of arc, together with tellurometers (electronic distance measuring equipment) for determining the length of lines from 1 mile to 40 miles in length.

Two maps of Victoria, one in four sheets at a scale of 1 : 500,000 and the other in a single sheet at a scale of 1 : 1,000,000 have recently been published. These maps show in colour, highways, main and minor roads, railways, watercourses, names of towns, mountains, and natural physical features.

There is full co-ordination between the Lands and Survey Department of Victoria, the Department of the Army, and the Commonwealth Division of National Mapping in the preparation of small scale maps to cover Victoria. A ten year programme has been prepared and is expected to cover the State by topographic maps at a scale of 1 : 100,000 within this period. In the meantime a smaller scale series at 1 : 250,000 is nearing completion by the Army and Division of National Mapping. The existing topographic map at 40 chains to an inch is being discontinued but all the information will be used and converted to the universal scale of 1 : 100,000.

Maps covering the whole State have been prepared for the Country Fire Authority from compilations supplied by the Department of the Army and the Division of National Mapping. These maps are at a scale of 1 : 100,000 and will be the basic maps used for State fire control and other emergencies. Large scale mapping at 400 ft to an inch of Geelong, Bendigo, and Ararat is in progress. A series of maps at a scale of 1 : 25,000 in the Glenelg area is also planned. Complete information of survey and mapping activities is obtainable from the Central Plan Office in the New Treasury Buildings where maps, plans, and aerial photographs are available for purchase by the public.

**Further Reference, 1966**

## *Climate*

### Climate of Victoria

*General*

The State of 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 the Southern Ocean 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.

One of the greatest State-wide rain producing systems is a weak surface depression, whose centre moves inland across the State and which extends upwards in the atmosphere to 20,000 ft and more. When warm moist air from the Indian Ocean has been advected across the continent in the higher levels of the atmosphere, the presence of such a system can give very heavy rainfall. Not infrequently the "upper low" may be present without any indication at the surface. On occasions, these inland depressions are not closed systems, but are "troughs in the easterlies", and when moisture is present, these can also produce general rain. These are more common in the summer months, when moist, humid air from the Tasman Sea is brought over southern Victoria.

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 51.

*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 in for the driest parts of the Mallee to over 60 in for parts of the North-Eastern Highlands. An annual total exceeding 140 in 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 in, with over 40 in on the Central Highlands, Otway Ranges, and South Gippsland. The wheat belt receives chiefly between 12 and 20 in. 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 in have been recorded on rare occasions 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 in at Tanybryn in the Otway district in June 1962.

An estimate of the areas of the State subject to different degrees of average annual rainfall, and the actual distribution of rainfall in Victoria as shown by area for 1966 and 1967 are shown in the following table :

VICTORIA—DISTRIBUTION OF AVERAGE AND ANNUAL RAINFALL

| Rainfall (In) | Area ('000 Square Miles) | | |
|---|---|---|---|
| | Average | 1966 | 1967 |
| Under 10 .. .. .. | Nil | 1·7 | 32·1 |
| 10–15 .. .. .. | 19·7 | 19·2 | 21·7 |
| 15–20 .. .. .. | 13·4 | 10·1 | 13·7 |
| 20–25 .. .. .. | 15·7 | 11·3 | 8·3 |
| 25–30 .. .. .. | 15·8 | 13·6 | 7·0 |
| 30–40 .. .. .. | 14·2 | 9·4 | 4·7 |
| Over 40 .. .. .. | 9·1 | 22·6 | 0·4 |

*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 289 to 294.

VICTORIA—RAINFALL IN DISTRICTS

(In)

| Year | Districts | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Mallee | Wimmera | Northern | North-Central | North-Eastern | Western | Central | Gippsland |
| 1957 .. .. | 9·67 | 14·87 | 13·55 | 23·01 | 27·32 | 26·82 | 24·85 | 31·98 |
| 1958 .. .. | 15·45 | 17·65 | 21·40 | 31·57 | 37·78 | 29·05 | 28·99 | 35·42 |
| 1959 .. .. | 9·97 | 15·16 | 16·56 | 26·09 | 27·69 | 24·46 | 26·53 | 33·63 |
| 1960 .. .. | 18·08 | 24·75 | 22·70 | 38·45 | 40·16 | 36·01 | 34·98 | 37·26 |
| 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 |
| Averages* .. | 12·93 | 18·09 | 18·50 | 27·83 | 34·57 | 28·48 | 29·33 | 33·70 |

* Averages for 53 years 1913 to 1965.

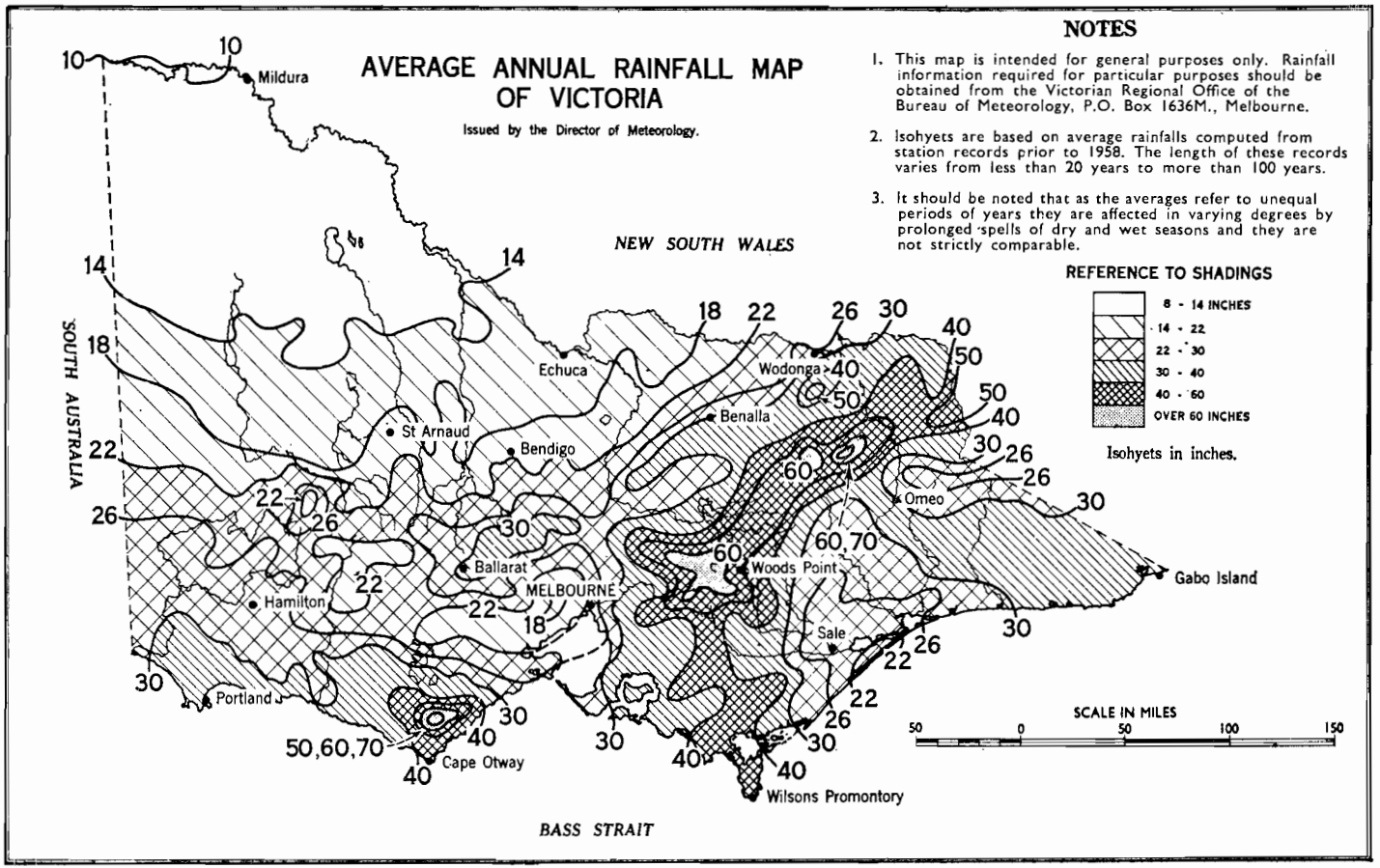

AVERAGE ANNUAL RAINFALL MAP OF VICTORIA
Issued by the Director of Meteorology.
NOTES
1. This map is intended for general purposes only. Rainfall information required for particular purposes should be obtained from the Victorian Regional Office of the Bureau of Meteorology, P.O. Box 1636M., Melbourne.
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
Wodonga
Benalla
St Arnaud
Bendigo
Ballarat
MELBOURNE
Hamilton
Portland
Cape Otway
Omeo
Woods Point
Sale
Gabo Island
Wilsons Promontory
10
14
18
22
26
30
40
50
50,60,70
60
60,70

FIGURE 4.

## VICTORIA—DISTRICT MONTHLY RAINFALL : AVERAGE AND 1967

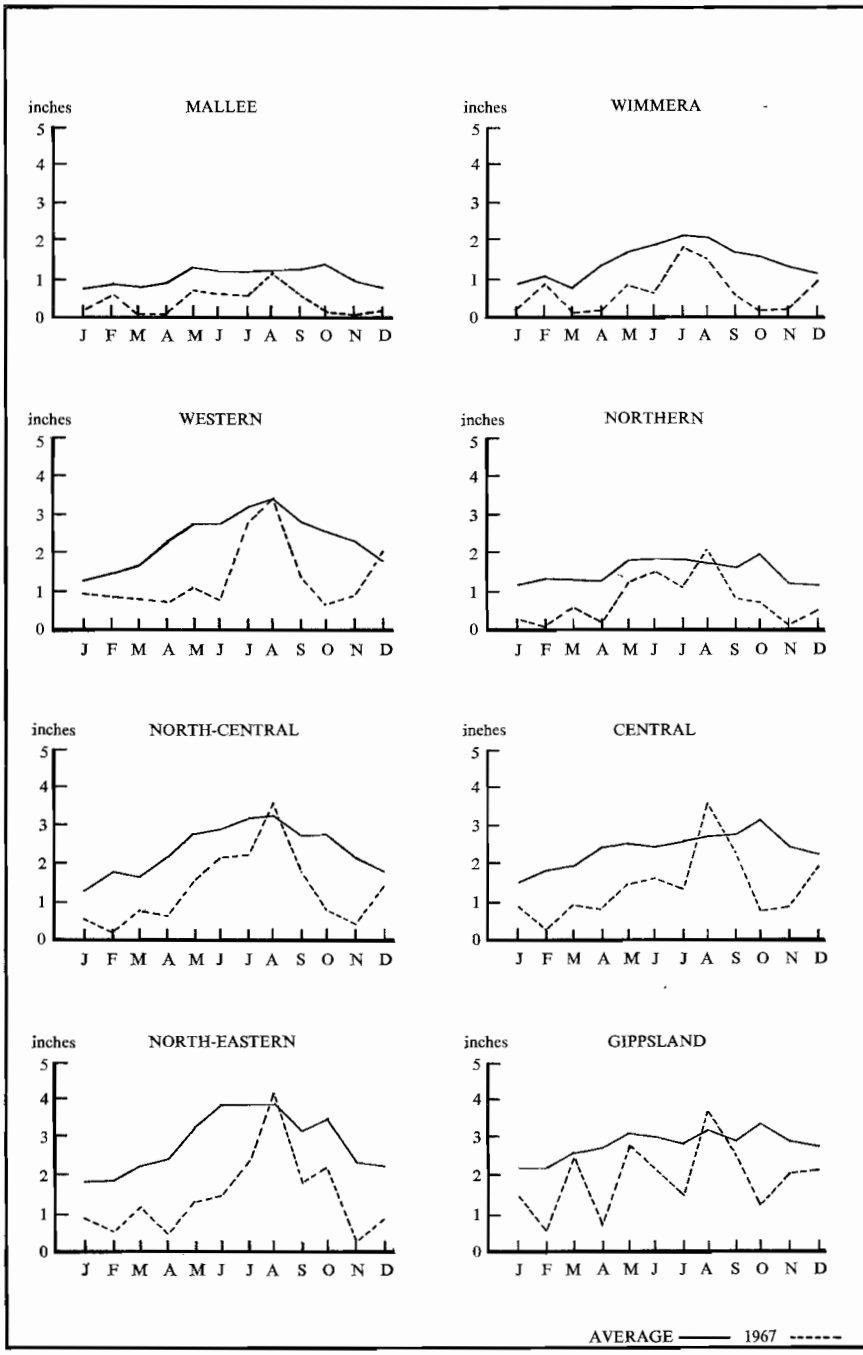



FIGURE 5.

*Drought of* 1967–68

After more than twenty years, Victoria suffered a drought in 1967. In the two previous years there had been some unusually dry periods of short duration. The first three months of 1965 were the driest for half a century in most districts, but widespread and substantial rain fell in April. September and October of that year were also very dry, but several wet periods in November relieved the situation. Even so, the wheat crop was reduced to 53 mill. bushels and East Gippsland experienced a very dry year.

The first half of 1966 had been dry in the south-west and the Wimmera, many places receiving less than half the normal six-monthly rain. However, substantial rain fell in the second half of the year. December was wet, and severe flooding occurred in the north-east.

In 1967, however, both the autumn and spring rains failed, particularly in the western half of the State. The first three months of the year were dry, the only areas to receive almost normal monthly rainfall being the west coast in January, the western border in February, and Gippsland and the lower Goulburn Valley in March. No break in the dry weather occurred in April, and this month proved to be exceptionally dry. The rainfall for the first four months of the year was the lowest for 40 to 60 years at many places and a record low at some. General rain did not fall until 19 May, and even then the amount received in the Western District was very small. In Gippsland, however, particularly in the eastern part, rain fell in the last ten days of May and monthly totals were above average. The rainfall for the first five months of the year was the lowest on record at many places including St. Arnaud, Bendigo, Ballarat, Geelong, Melbourne, Hamilton, and Warragul.

Fortunately, as a result of the favourable spring of 1966, a large quantity of hay had been conserved and stock came through the autumn in generally good condition.

Dry weather continued in June ; the west and the north-east received less than half the normal rain for the month. Between Coleraine and Ballarat, and in parts of the Otways, it was the driest June on record. By contrast, torrential rain fell on a small part of the Gippsland coast at the end of June. Port Albert received more rain in 24 hours than the south-west had received in six months.

At the end of June, little wheat had been sown in the central, northern, and western Wimmera, but in the other wheat areas there had been sufficient rain for sowing to be mostly completed. Six shires in the south-west of the State were declared drought relief areas in the second half of June, and the first of large stock reduction sales was held at Casterton in early July. General rain extended across Victoria on 10 July and for the next two months rain was fairly frequent in southern Victoria, although dry weather continued along much of the Murray Valley. The condition of the wheat crop generally continued to hold through the winter, and in pasture districts there were good prospects of early spring growth.

However, dry weather again became established after mid-September and very little rain fell in the next two months. The period from 14 October to 14 November was particularly dry ; no rain at all fell at several places including Warracknabeal, Echuca, Shepparton, and Geelong. The wheat harvest was estimated at 22 mill. bushels, less than one third of the 1964 crop, while the oat crop was almost a total failure. Very little hay was cut in the drought affected districts, although large quantities were made in irrigated areas, usually from grain crops which had failed to mature. Large numbers of stock were being moved from the west of the State to Gippsland and parts of New South Wales.

By mid-November, concern was being voiced even in Gippsland, which had escaped any serious effect up to that time. Fires had been burning in many forested areas since the last week of October, fanned by several periods of strong westerly winds. The area of forest burnt approached half a million acres, but grasslands were sufficiently green to prevent the fires spreading to them. On 15 November moderate to heavy rain fell throughout Gippsland, and further rain fell near the end of the month, but even so monthly totals were below average. Little rain fell in the west or north of the State until December, when widespread rain fell on four occasions and monthly totals were above average in the Western District and West Gippsland.

Although the late rain helped to raise the wheat crop from an estimated 22 to 28 mill. bushels, it was too late to benefit pastures in the west. Six more shires in the west had been declared drought relief areas in early July, and by the end of 1967 the total had risen to sixty-five, covering most of the western half of the State.

As irrigation storages in the State were not filled during the winter and spring, they began to fall again after September. By the end of 1967, the two large storages, Hume and Eildon, contained only 30 per cent and 60 per cent of their capacity, respectively. This was in marked contrast to the end of 1966 when most storages were full. Little extra water could be expected from the Snowy Mountains, as that system contained only 25 per cent of capacity. Storages in the Grampians area, which are used to fill dams in the Mallee and Wimmera during winter and spring, were particularly low. The largest, Rocklands, was empty at the end of 1967.

Despite the rainfall of July and August, Melbourne's water supplies were at a low level in early September, and restrictions on the use of water were imposed on the 15 September. The restrictions were progressively tightened during the spring, until, by December, a complete ban on sprinklers and hoses applied. Many other cities and towns in the State were restricted in their use of water.

Widespread rain fell on 20 January 1968 and totals for the month were above average in a large part of northern Victoria. February, however, was very dry, the only rain of any consequence being due to thunderstorms in the north-east on 12 February. Many places in Gippsland had record low rainfall in February, and by the end of the month, that province was feeing the effects, with pastures dead and streams at very low levels. Eight more shires had been declared drought relief areas by the end of February.

In March 1968 useful rains fell in all districts of Victoria but falls were still less than normal over more than half the State. The main areas with above average rainfall were the Mallee, the Wimmera, and the West Coast districts.

Most of Victoria had above average rainfall in April and the City of Melbourne's rainfall was above average for the first time in eight months.

The rains continued in May with falls well above normal in all districts; in fact some crops and farming operations were affected adversely by the wet conditions. Despite the good rains the increase in the main water storages in Victoria was not spectacular and at the end of May the Hume and Eildon reservoirs contained only 5 per cent. and 34 per cent of their capacity, respectively. Much more rain was still needed to ensure that there would be sufficient water for the coming summer.

*Comparison with Past Droughts*

The rainfall for 1967 was the lowest ever recorded in about two-thirds of the area of Victoria. A comparison with other dry years is given in the following table :

VICTORIA—DROUGHT PERIODS

| Year | Percentage of State Receiving Less than 10 in | Percentage of State Receiving More than 20 in |
|---|---|---|
| 1888 .. .. .. .. | 19 | 44 |
| 1902 .. .. .. .. | 30 | 39 |
| 1914 .. .. .. .. | 34 | 27 |
| 1938 .. .. .. .. | 33 | 35 |
| 1944 .. .. .. .. | 33 | 37 |
| 1967 .. .. .. .. | 37 | 23 |

NOTE.—The year 1865 was very dry in much of Victoria, but rainfall records are too few for an overall picture to be obtained.

Comparison of rainfall over calendar years does not tell the full story, as droughts may extend from the middle of one year to the middle of the next. The distribution of rainfall through the year is very important. Although yearly totals in 1914 were generally higher than in 1967, rainfall during the vital growing period from August to late November was very much less in 1914 than in 1967. Wheat yields were 1·3 bushels per acre in 1902–03, 1·4 bushels per acre in 1914–15, and 1·6 bushels per acre in 1944–45. The figure of about 8 bushels per acre in 1967 compares favourably with these.

The effects of drought were not so marked in 1967 as in past years. Larger water storages, pasture improvement, better methods of fodder conservation and general farm management, and better control of stock disease have all helped to mitigate the effects of the driest calendar year in Victoria's history.

*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 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 " 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 6) for the 30 years 1931 to 1960 and the results are tabulated below in order of rainfall reliability :

VICTORIA—ANNUAL RAINFALL VARIATION

| District | Average Annual Rainfall* | Standard Deviation | Coefficient of Variation |
|---|---|---|---|
| | in | in | per cent |
| 1. Western Plains .. .. .. | 24·90 | 3·34 | 13·4 |
| 2. West Coast .. .. .. | 30·34 | 4·64 | 15·3 |
| 3. West Gippsland .. .. .. | 36·06 | 5·67 | 15·7 |
| 4. East Central .. .. .. | 35·27 | 5·74 | 16·3 |
| 5. East Gippsland .. .. .. | 30·20 | 5·25 | 17·4 |
| 6. West Central .. .. .. | 23·89 | 4·41 | 18·5 |
| 7. Wimmera South .. .. | 19·53 | 3·78 | 19·4 |
| 8. Wimmera North .. .. .. | 16·30 | 3·37 | 20·7 |
| 9. North Central .. .. .. | 27·83 | 6·07 | 21·8 |
| 10. Upper North-East .. .. | 43·77 | 10·05 | 23·0 |
| 11. Mallee South .. .. .. | 13·66 | 3·44 | 25·2 |
| 12. Lower North-East .. .. | 30·27 | 7·68 | 25·4 |
| 13. Upper North .. .. .. | 20·01 | 5·19 | 25·9 |
| 14. Lower North .. .. .. | 16·86 | 4·65 | 27·6 |
| 15. Mallee North .. .. .. | 11·86 | 3·36 | 28·3 |

*Average for 53 years 1913–1965.

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.

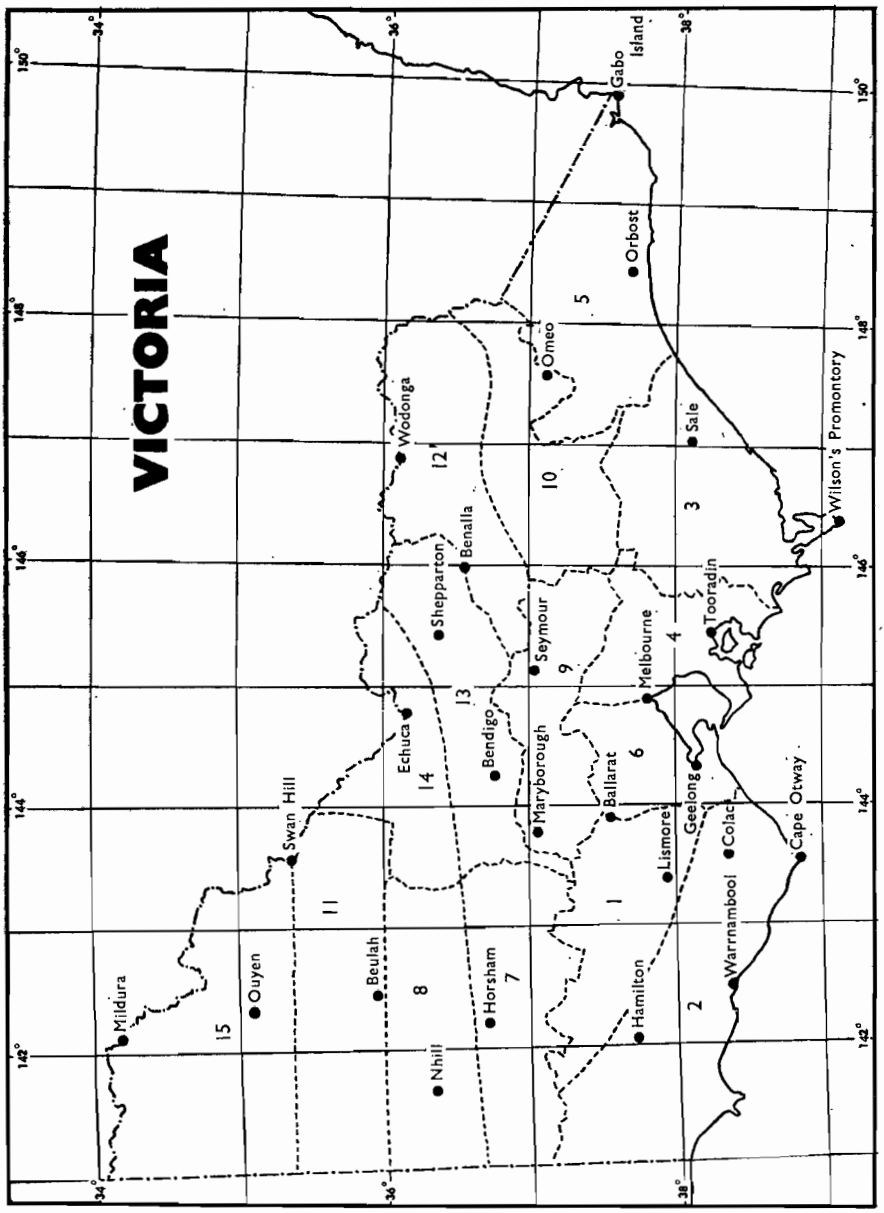



FIGURE 6.—Relative rainfall variability based on district annual rainfall. Names of districts are shown in table on previous page.

Most of the elevated areas of eastern and southern Victoria normally receive over 40 in and over 60 in in some wetter sections. Interspersed between these wet mountainous areas are sheltered valleys which are deprived to some extent of their rainfall by neighbouring highlands. Along practically the whole south coastline of Victoria the average number of wet days (0·01 in or more in 24 hours) is over 150, with an average rainfall below 30 in. The average number of wet days a year is reduced to 100 at a distance of approximately 100 miles inland from the coast.

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.

*Droughts*

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

The next major drought commenced about June 1913 and continued until April 1915 in the north and west and 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.

Droughts of shorter duration and lower intensity occurred in 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.

*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 owing to 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 43–5.)

*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, 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 with January only slightly cooler. Average maximum temperatures are under 75° F. along the coast and over elevated areas forming the Central Divide and North-East 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 a significant feature is that apart from this orographically induced area, 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.

Conditions of extreme summer heat 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 with rapid temperature drops of 30° F. at times. 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 Mount 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*

With the exception of the exposed coast, all parts of Victoria may experience frost, but frequencies are highest and occurrences usually more severe in elevated areas and valleys conducive to the pooling of cold air. All inland stations have recorded extreme screen temperatures less than 30° F., whilst at a large number of stations extremes stand at 25° F. or less. Thus frost may be expected each year over practically the whole of the State, but the bulk of the occurrence is restricted to the winter season. Spring frosts may constitute a serious hazard to agriculture, and in some years a late frost may result in serious crop damage. Periods of frost lasting for more than three or four consecutive days are unusual.

*Humidity*

By and large, 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*

Measurements of evaporation in Victoria are made with the standard form of evaporation tank at about 29 stations, about half of which are owned by the Commonwealth 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 in. 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 in. 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.

Since 1967 the " Class A Pan " has been the standard evaporimeter. This type is being progressively installed at evaporation recording stations in Victoria.

*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 are experienced. 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 90 m.p.h. There is no doubt, however, that stronger gusts have been experienced over the State, although not in the vicinity of a recording anemometer. A number of tornadic squalls have been experienced and from the severe local damage engineers have estimated wind strengths over 100 m.p.h. It is considered that any place in Victoria could feasibly experience at some time a local gust of 100 m.p.h. 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. On an average, more than 20 per year occur on the North-Eastern Highlands and in parts of the Northern Country, but particularly in the north-east. Melbourne has an average of less than three per month from November to February. 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.

## Meteorological Services for Commerce and Industry

Agriculture, aviation, shipping, and many aspects of commerce and industry depend very much on the weather . The onset of cold weather, low cloud, and rain can cause a rapid rise in the consumption of electricity and gas. The demand for many perishable foodstuffs can vary considerably with the weather. Building construction, particularly the laying of concrete, can be interrupted by rain. In the case of tall buildings, strong winds are hazardous ; thus, architects take meteorological factors into account in planning and design.

The Bureau provides a special forecasting service for power generating authorities. Each morning a forecast for that day and the next day, and an outlook for two days beyond that, are made available, together with specific forecasts for the time of peak demand for electricity and gas.

The development of oil drilling off the Victorian coast has caused an increased demand for background studies and for forecasts. Each drilling rig receives a forecast every eight hours for the succeeding twelve hours. This includes specific forecasts of the height of the waves and swell to be expected. Considerable research is being carried out on waves and swell and their relationship to winds over the ocean.

Data on past weather is frequently required by industry. Each month the Bureau publishes a review of the weather in the State over the past month, and every three months a Seasonal Summary is issued. Data for specific meteorological stations for many years past is made available for a moderate charge.

The planning of future expansion or the establishment of a new industry may require a study of the climate of the area. The Bureau has published climatic studies of many parts of Australia, and provides a consultative service, so that clients may make the best use of the available meteorological data.

**Agricultural Meteorology, 1964; Maritime Meteorology, 1966; Aeronautical Meteorology, 1967; Meteorology in Fire Prevention, 1968**

## Climate of 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 is just over 78° F. Inland, Watsonia has an average of 81° F., whilst along the Bay, Black Rock, subject to any sea breeze, has 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 have been years with up to twelve and also 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, whilst 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 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 rainfall from month to month in the City is quite small, the annual average being 25·93 in over 143 days. From January to August, monthly averages are within a few points of 2 in ; then a rise occurs to a maximum of 2·69 in in October. Rainfall is relatively steady during the winter months when the extreme range is from half an inch to 7 in, but variability increases towards the warmer months. In the latter period totals range between practically zero and over 8 in. 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 19·01 in. Rainfall increases towards the east, and at Mitcham averages 35·95 in a year. The rainfall is greater still on the Dandenong Ranges and at Sassafras the annual average is 53·83 in.

The highest number of wet days ever recorded in any one month in the city is twenty-seven in August. 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 sixteen days and the longest dry spell forty days. Over 4 in of rain have been recorded in 24 hours on several occasions, but these have been restricted to the warmer months, September to March. Only once has a fall above 2 in during 24 hours been recorded in the cooler months. Fogs occur on four or five mornings each month in May, June, and July, and average twenty-one days for the year. The highest number ever recorded in a month was twenty in June 1937.

## VICTORIA—MEANS OF CLIMATIC ELEMENTS: SELECTED VICTORIAN TOWNS

| Locality | | Legend No.* | January | February | March | April | May | June | July | August | Sept. | October | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MALLEE .. | Mildura .. | 1 | 71 | 79 | 71 | 63 | 103 | 119 | 90 | 102 | 91 | 107 | 79 | 74 |
| | | 2 | 89·8 | 90·0 | 84·4 | 74·5 | 66·9 | 60·4 | 59·5 | 63·9 | 69·9 | 76·5 | 83·2 | 88·2 |
| | | 3 | 61·0 | 61·7 | 57·2 | 50·5 | 45·6 | 41·3 | 40·5 | 42·5 | 46·1 | 50·9 | 55·4 | 59·6 |
| | Ouyen .. | 1 | 77 | 94 | 81 | 81 | 128 | 127 | 122 | 128 | 125 | 146 | 100 | 98 |
| | | 2 | 89·4 | 86·0 | 82·1 | 73·1 | 65·7 | 59·4 | 58·7 | 62·8 | 68·9 | 74·1 | 79·9 | 86·7 |
| | | 3 | 58·7 | 58·4 | 54·1 | 47·8 | 44·5 | 40·7 | 39·8 | 40·6 | 43·3 | 47·2 | 52·6 | 56·0 |
| WIMMERA .. | Horsham .. | 1 | 85 | 104 | 99 | 131 | 186 | 207 | 175 | 188 | 179 | 170 | 129 | 115 |
| | | 2 | 85·1 | 86·3 | 80·2 | 70·7 | 63·0 | 56·6 | 56·0 | 59·0 | 64·1 | 70·2 | 77·2 | 82·7 |
| | | 3 | 55·2 | 55·9 | 51·9 | 47·0 | 42·9 | 40·2 | 38·8 | 39·9 | 41·9 | 45·1 | 49·6 | 53·2 |
| | Nhill .. | 1 | 82 | 93 | 88 | 119 | 163 | 196 | 174 | 184 | 172 | 158 | 113 | 108 |
| | | 2 | 84·3 | 85·0 | 79·6 | 70·5 | 63·3 | 57·0 | 56·5 | 59·4 | 64·4 | 70·4 | 76·9 | 82·2 |
| | | 3 | 55·2 | 56·3 | 52·8 | 47·6 | 43·9 | 40·4 | 38·6 | 40·1 | 42·5 | 45·7 | 49·7 | 53·8 |
| WESTERN .. | Ballarat .. | 1 | 142 | 193 | 182 | 215 | 269 | 262 | 274 | 293 | 294 | 273 | 218 | 210 |
| | | 2 | 75·7 | 76·9 | 71·6 | 63·0 | 56·3 | 50·4 | 49·8 | 52·5 | 57·1 | 62·4 | 67·4 | 72·5 |
| | | 3 | 50·5 | 52·9 | 50·1 | 45·8 | 42·6 | 39·5 | 38·4 | 39·4 | 41·2 | 43·6 | 46·0 | 49·3 |
| | Hamilton .. | 1 | 132 | 126 | 168 | 216 | 269 | 297 | 285 | 300 | 289 | 261 | 196 | 178 |
| | | 2 | 77·3 | 78·7 | 74·2 | 66·3 | 60·1 | 55·1 | 54·1 | 56·2 | 59·9 | 64·8 | 69·1 | 74·0 |
| | | 3 | 50·7 | 52·4 | 49·9 | 46·3 | 43·2 | 40·2 | 39·3 | 40·4 | 42·3 | 44·0 | 46·3 | 49·2 |
| | Warrnambool | 1 | 127 | 137 | 184 | 226 | 294 | 296 | 318 | 306 | 272 | 245 | 198 | 166 |
| | | 2 | 69·9 | 70·9 | 69·1 | 64·6 | 60·5 | 56·3 | 55·6 | 56·9 | 59·4 | 62·6 | 64·8 | 67·9 |
| | | 3 | 54·7 | 56·0 | 54·2 | 51·0 | 47·8 | 44·8 | 43·6 | 44·4 | 46·2 | 48·1 | 50·2 | 53·0 |
| NORTHERN .. | Bendigo .. | 1 | 128 | 133 | 144 | 155 | 210 | 246 | 216 | 215 | 207 | 205 | 147 | 126 |
| | | 2 | 83·0 | 83·9 | 78·1 | 68·8 | 61·3 | 54·8 | 54·2 | 57·0 | 62·5 | 68·9 | 75·2 | 80·5 |
| | | 3 | 56·5 | 58·3 | 54·0 | 48·2 | 43·7 | 40·7 | 39·4 | 40·2 | 43·0 | 46·7 | 50·9 | 54·9 |
| | Echuca .. | 1 | 100 | 109 | 129 | 132 | 162 | 181 | 161 | 164 | 154 | 173 | 121 | 110 |
| | | 2 | 86·2 | 86·8 | 80·7 | 71·1 | 63·6 | 56·7 | 56·0 | 59·0 | 64·7 | 71·7 | 78·5 | 84·1 |
| | | 3 | 58·9 | 60·1 | 55·9 | 49·3 | 44·5 | 41·3 | 40·2 | 41·2 | 44·3 | 48·6 | 52·7 | 56·9 |

| | | | Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| North-Central .. | Alexandra .. | 1 | 162 | 146 | 200 | 202 | 250 | 293 | 278 | 290 | 258 | 282 | 224 | 187 |
| | | 2 | 84·6 | 85·3 | 78·8 | 69·1 | 61·3 | 53·9 | 53·6 | 57·3 | 62·6 | 69·2 | 75·7 | 81·9 |
| | | 3 | 52·5 | 53·7 | 49·1 | 43·8 | 39·7 | 37·5 | 36·8 | 37·8 | 40·3 | 43·3 | 46·7 | 50·7 |
| | Kyneton .. | 1 | 152 | 159 | 187 | 215 | 290 | 359 | 317 | 322 | 288 | 276 | 206 | 190 |
| | | 2 | 81·2 | 81·5 | 74·7 | 65·0 | 57·5 | 51·0 | 50·1 | 53·1 | 59·1 | 65·2 | 72·3 | 77·5 |
| | | 3 | 49·8 | 50·5 | 47·2 | 42·3 | 38·5 | 36·2 | 34·8 | 35·3 | 37·9 | 40·4 | 44·1 | 47·6 |
| Central .. | Geelong .. | 1 | 122 | 148 | 163 | 174 | 197 | 198 | 178 | 183 | 204 | 206 | 188 | 155 |
| | | 2 | 76·2 | 77·3 | 73·9 | 67·6 | 62·1 | 57·2 | 56·5 | 59·0 | 62·8 | 67·3 | 70·3 | 73·8 |
| | | 3 | 55·4 | 56·9 | 54·7 | 50·7 | 46·6 | 43·1 | 42·0 | 42·9 | 45·0 | 47·5 | 50·4 | 53·7 |
| | Mornington | 1 | 174 | 158 | 190 | 242 | 271 | 286 | 275 | 270 | 280 | 281 | 232 | 203 |
| | | 2 | 76·5 | 77·1 | 73·9 | 66·8 | 61·5 | 56·3 | 54·9 | 56·7 | 60·6 | 64·4 | 69·0 | 73·6 |
| | | 3 | 55·2 | 55·9 | 54·4 | 50·5 | 47·8 | 44·5 | 42·9 | 43·8 | 45·9 | 48·4 | 51·1 | 53·4 |
| North-Eastern .. | Omeo .. | 1 | 205 | 215 | 214 | 182 | 208 | 230 | 207 | 213 | 245 | 282 | 235 | 239 |
| | | 2 | 77·8 | 78·7 | 73·0 | 65·2 | 57·9 | 51·4 | 50·5 | 54·0 | 59·7 | 65·4 | 71·2 | 75·9 |
| | | 3 | 48·3 | 48·9 | 45·8 | 40·2 | 35·8 | 33·0 | 31·9 | 33·2 | 37·3 | 39·7 | 43·2 | 47·1 |
| | Wangaratta .. | 1 | 144 | 153 | 188 | 187 | 221 | 296 | 252 | 250 | 229 | 245 | 181 | 166 |
| | | 2 | 86·7 | 87·5 | 80·9 | 71·3 | 63·5 | 56·4 | 55·2 | 58·3 | 63·8 | 70·2 | 78·2 | 84·1 |
| | | 3 | 58·5 | 59·3 | 54·0 | 46·9 | 41·9 | 39·3 | 38·1 | 39·7 | 42·8 | 46·7 | 51·4 | 56·3 |
| West Gippsland .. | Wilsons Promontory | 1 | 199 | 190 | 280 | 336 | 423 | 487 | 446 | 446 | 380 | 373 | 284 | 247 |
| | | 2 | 66·7 | 68·2 | 66·4 | 62·3 | 58·6 | 55·1 | 53·9 | 55·1 | 57·3 | 60·3 | 62·2 | 65·1 |
| | | 3 | 56·9 | 58·7 | 57·4 | 54·7 | 52·1 | 49·0 | 47·7 | 47·7 | 48·8 | 50·3 | 52·2 | 55·1 |
| | Yallourn .. | 1 | 194 | 272 | 198 | 241 | 419 | 360 | 344 | 399 | 364 | 380 | 344 | 266 |
| | | 2 | 77·7 | 77·4 | 74·3 | 65·8 | 60·7 | 55·3 | 54·9 | 57·3 | 62·0 | 66·3 | 70·2 | 75·3 |
| | | 3 | 53·7 | 54·7 | 49·1 | 48·2 | 43·9 | 40·5 | 38·8 | 40·5 | 42·5 | 45·7 | 49·1 | 52·3 |
| East Gippsland .. | Bairnsdale .. | 1 | 252 | 205 | 260 | 200 | 204 | 224 | 202 | 187 | 225 | 269 | 241 | 257 |
| | | 2 | 75·3 | 76·1 | 73·0 | 67·5 | 62·5 | 57·5 | 57·0 | 59·5 | 63·2 | 67·5 | 70·6 | 74·0 |
| | | 3 | 53·5 | 54·5 | 51·7 | 46·9 | 42·5 | 38·8 | 38·1 | 39·6 | 42·7 | 46·1 | 49·0 | 52·4 |
| | Orbost .. | 1 | 279 | 236 | 272 | 285 | 275 | 329 | 268 | 229 | 274 | 311 | 254 | 296 |
| | | 2 | 76·5 | 75·6 | 73·1 | 67·5 | 62·5 | 57·9 | 58·0 | 60·0 | 64·0 | 66·4 | 70·2 | 74·3 |
| | | 3 | 54·3 | 54·5 | 52·5 | 48·2 | 44·2 | 40·3 | 38·5 | 39·7 | 42·1 | 45·9 | 49·7 | 52·0 |

(Points : 100 = 1 inch).

* Legend : 1. Average Monthly Rainfall in Points. (For all years of record to 1963). 2. Average Daily Maximum Temperature (°F.). (For 30 years 1911–40). 3. Average Daily Minimum Temperature (°F.). (For 30 years 1911–40).

*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 nearly 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, etc., 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 streams, and usually reaches a maximum during the afternoon. The greatest mean wind speed at Melbourne for a 24 hour period was 22·8 m.p.h., whilst means exceeding 20 m.p.h. 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 m.p.h. At Melbourne, gusts exceeding 60 m.p.h. have been registered during every month with a few near or over 70 m.p.h., and an extreme of 74 m.p.h. on 18 February 1951. At Essendon a wind gust over 90 m.p.h. has been measured.

There have been occurrences of thunderstorms in all months; the frequency is greatest during November to February. The greatest number of thunderstorms occurring in a year was twenty-five. This figure was recorded for both 1928 and 1932.

*Hail and Snow*

Hailstorms have occurred in every month of the year; the most probable time of occurrence is from August to November. The highest number of hailstorms in a year was seventeen in 1923, and the greatest number in a month occurred in November of that year when seven hailstorms were reported. 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 aborigines suggested they had never seen snow before.

## Victorian Weather Summary 1967

For almost two-thirds of Victoria, 1967 will be remembered as the driest year ever recorded. The main areas where rainfall was *not* the lowest on record were in the Northern Country and in Gippsland. Over one-third of the State received less than 10 in, and only 23 per cent received more than 20 in. In an average year the whole State receives at least 10 in, and 62 per cent receives over 20 in.

January rainfall was below average except for small areas in the Otways and in South Gippsland. It was, however, a cool month, in contrast to February, when two heat waves caused mean temperatures to be well above normal. The western border areas received above average rainfall in February, but elsewhere the month was very dry. A severe storm with large hailstones and wind squalls caused much damage in the Tocumwal–Cobram area on 28 January.

Except in South Gippsland, dry weather continued in March, particularly in the north-west of the State, and April was very dry throughout. April was also a warm month, and warm dry weather continued through the first half of May. In Melbourne, the temperature exceeded 75° F. on three consecutive days for the first time in May since 1905. The break came on 19 May, but rainfall for the month was still well below normal in the west and the north-east.

Dry weather continued in western Victoria in June; for the country between Coleraine and Ballarat and in parts of the Otways it was the driest June on record. However, June rainfall was above average in the Goulburn Valley and along the lower Campaspe, while a small depression off the Gippsland coast brought torrential rain at the end of the month. A fall of 5·70 in at Port Albert was the highest 24 hour total in 100 years of record. Mean temperatures were well above average in June and fog was widespread from 5 to 9 June, persisting throughout the day in Melbourne.

The blocking anticyclones which had been the prime cause of the dry weather continued in early July, but a change occurred on 10 July, as general rain extended across Victoria. Rain was fairly frequent for the rest of the month, and totals were above average in the Western and Southern Wimmera Districts. The westerlies continued through August, and rainfall was above average in the greater part of the State. Snow fell on the lower parts of the Divide on 12 and 13 August.

Although rain fell on several occasions during September, totals for the month were below average except in East Gippsland and October and November saw a return to very dry conditions. The period from 14 October to 14 November was particularly dry, there being no rain at all at several places. The first large bushfire of the season occurred in the Anakie ranges on 25 September, and many serious bushfires broke out on 24 October. By mid-November almost half a million acres of forest had been burnt*; however, rain then put most of the fires out. On 19 November isolated heavy rain fell in the Mitcham-Vermont area and on 25 November an outbreak of cold southerly air brought severe squalls and thunderstorms to southern Victoria.

December was a cool month with fairly frequent rain in southern Victoria. Rainfall was above average in the Western District and in the ranges to the east of Melbourne but very dry weather continued along the Murray.

* Mostly in East Gippsland.

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) .. .. .. | 7·36 | 6·05 | 6·63 | 5·89 |
| 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)* .. .. .. | 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 |

* Scale 0 = clear, 8 = overcast.

In the following table are shown the yearly means of the climatic elements in Melbourne for each year 1963 to 1967. The extreme values of temperature in each year are also included.

MELBOURNE—YEARLY MEANS AND EXTREMES OF CLIMATIC ELEMENTS

| Meteorological Elements | 1963 | 1964 | 1965 | 1966 | 1967 |
|---|---|---|---|---|---|
| Mean Atmospheric Pressure (millibar) .. .. .. | 1017·2 | 1014·2 | 1017·3 | 1017·2 | 1018·1 |
| Temperature of Air in Shade (° F)— | | | | | |
| Mean .. .. .. | 59·5 | 58·6 | 59·3 | 59·3 | 59·5 |
| Mean Daily Maximum .. | 68·0 | 66·5 | 67·8 | 67·5 | 68·1 |
| Mean Daily Minimum .. | 51·0 | 50·7 | 50·9 | 51·1 | 50·9 |
| Absolute Maximum .. .. | 99·0 | 103·3 | 106·9 | 102·8 | 105·2 |
| Absolute Minimum .. .. | 29·3 | 36·0 | 32·4 | 32·9 | 34·2 |
| Number of Days Maximum 100° F and over .. .. .. | 0 | 4 | 7 | 5 | 5 |
| Number of Days Minimum 36° F and under .. .. | 12 | 1 | 10 | 7 | 4 |
| Mean Terrestrial Minimum Temperature (° F) .. .. | 48·5 | 47·7 | 47·9 | 48·4 | 48·6 |
| Rainfall (inches) .. .. | 29·04 | 27·80 | 23·24 | 26·81 | 13·06 |
| Number of Wet Days .. .. | 149 | 166 | 122 | 157 | 106 |
| Total Amount of Evaporation (inches) .. .. .. | 37·79 | 35·54 | 44·87 | 47·08 | 55·15 |
| Mean Relative Humidity (Saturation = 100) .. .. .. | 67 | 66 | 62 | 63 | 63 |
| Mean Daily Amount of Cloudiness (Scale 0 to 8)* .. .. | 4·7 | 5·1 | 4·4 | 4·8 | 4·4 |
| Mean Daily Hours of Sunshine .. | 5·5 | 5·4 | 6·2 | 6·0 | 6·5 |
| Mean Daily Wind Speed (m.p.h.) .. | 7·5 | 8·4 | 7·2 | 6·9 | 5·9 |
| Number of Days of Wind Gusts 39 m.p.h. and over .. .. | 52 | 97 | 62 | 47 | 46 |
| Number of Days of Fog .. | 20 | 12 | 21 | 6 | 24 |
| Number of Days of Thunder .. | 12 | 12 | 9 | 6 | 3 |

* Scale 0 = clear, 8 = overcast.