# Chapter 2
# Early History: 7,000,000 Years Ago to 1901 C.E.

When domesticating a plant or animal species, it is useful to know something about the history of that species, and particularly something about the evolutionary forces that may have modified its genes and how alternative versions of its genes (called **alleles**[G]) are organised within and among populations. Furthermore, it is useful to know how much of its natural genetic variation is likely to have been included in the populations being domesticated, and which native populations have not yet contributed potentially useful genetic variants to the breeding lines in use. Besides being useful to breeders, such knowledge is often interesting and satisfying in its own right, and we hope you will find that to be the case with radiata pine.

## 2.1 Five Small Native Forests[1]

The present and prehistorically recent native forests of radiata pine (henceforth called "radiata") occur in only five general locations, three coastal in California and two on Mexican islands (Fig. 2.1). These five locations differ substantially from each other with respect to soil, elevation and winter rainfall (Table 2.1). They share a special variant of a regional Mediterranean-type climate, namely a cold ocean current to windward that produces fogs among the trees on most days during the almost rainless summer. The reduced evaporation due to fogs and the supplementary soil moisture from fog drip allows the pines to grow even though the amount of rainfall in these populations is relatively low. Their temperatures are usually moderated throughout the year by onshore winds, and generally stay above 0°C and below 30°C, although occasional days with lows down to −8°C and highs up to 40°C have been recorded, with little or no damage to the native

[1]This section represents a minor revision, with some updating, of Libby (1997).



R. Burdon et al., *Domestication of Radiata Pine*, Forestry Sciences,
DOI 10.1007/978-3-319-65018-0_2

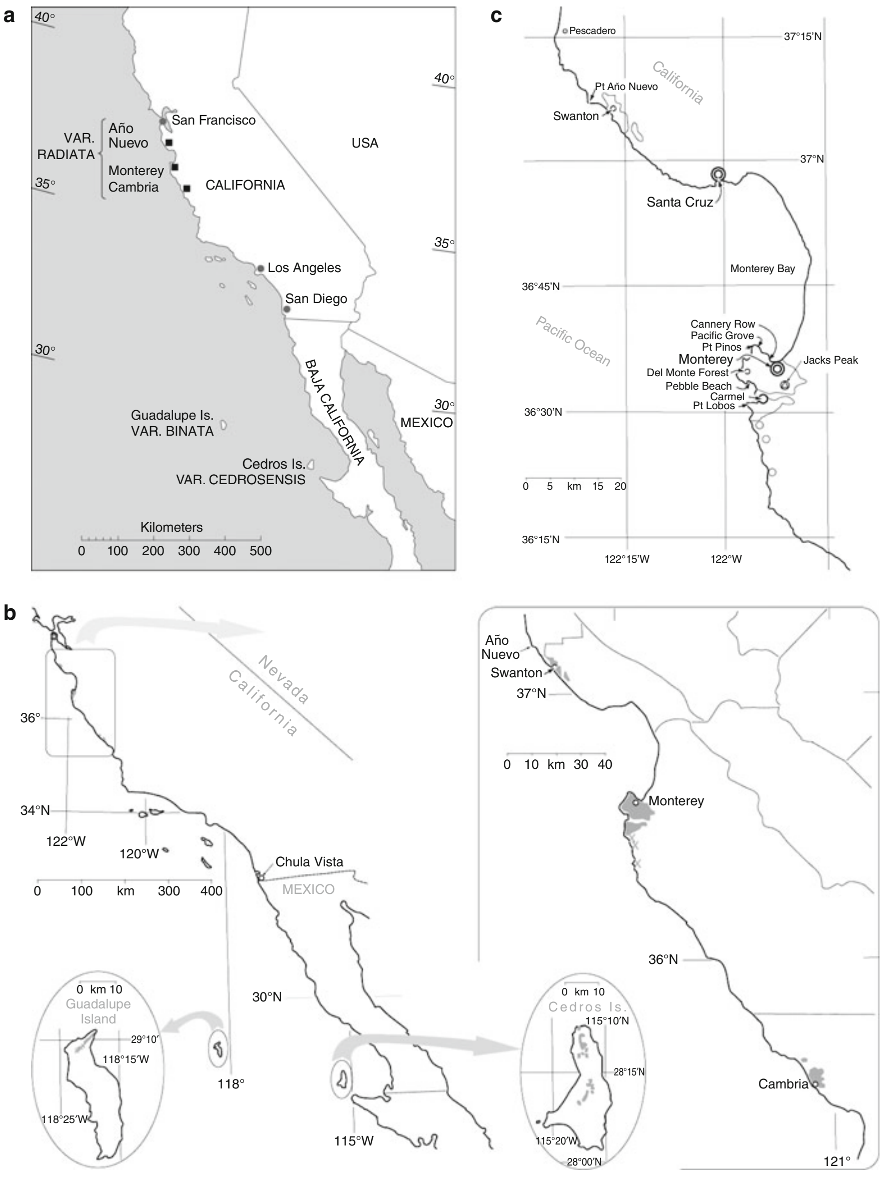


**Fig. 2.1** Maps showing locations of (a) native stands of radiata (after Burdon, 2004, permission Elsevier), (b) over total range (after Critchfield and Little 1966) and (c) detail in Monterey locality (After Forde 1964a)

trees. Effective rainfall is typically limited to late autumn to early spring, with a peak in midwinter (Scott 1960). In some years, one or both island populations receive occasional but substantial rainfall from "runaway" summer tropical storms (Oberbauer 2006) (Box 2.1).

**Table 2.1** Particulars of native populations of radiata (After Forde 1966; Burdon 2001; Rogers 2002; Oberbauer 2005, 2006)

| Population | Lat. (°N) | Rainfall (mm/yr) | Altitude (m asl) | Exposure | Soil - parent material and depth and texture | Extent (ha or trees) | |
|---|---|---|---|---|---|---|---|
| | | | | | | Current | Historic |
| Año Nuevo | 37 | 675–900? | 10–330 | Varied | Mainly mildly calcareous argillites, depth variable | 450 | 450 |
| Monterey | 36½ | 400–700? | 10–580 | Varied | Very varied: granites, sediments, and marine terraces of varied weathering status. | 3000 | 7,400 |
| Cambria | 35½ | 450–575? | 10–200 | Mainly mild | Sandstone, sandy loam, variable depth and drainage. | 800 | 1,400 |
| Guadalupe | 29 | 330–510? | 330–1,155 | Severe | Basaltic, rocky loam | <200 trees | 640 |
| Cedros | 28 | 150? | 275–640 | Locally severe | Mainly ancient sediments or metamorphics, soils skeletal | 130 | 130 |

1. Precipitation figures shown include allowances for altitudinal gradients (cf Forde 1966), but effect on hydric regimes of additional rainfall at higher altitudes may be offset on mainland by less influence of coastal fog. 2. All mainland populations have small areas of coastal sand. 3. Guadalupe trees do not include very recent regeneration. Question marks denote considerable uncertainty.

**Box 2.1 Natural Range**

Radiata occurs naturally in five discrete populations, three on the Californian mainland and two on Mexican islands. While geographically separated, the populations share a peculiar, localised variant of a Mediterranean climate caused by a cold ocean current. Differences exist among the populations, but the magnitude of the differences between pairs of the populations varies widely. Historically, domesticated radiata evidently came from only the two northernmost populations.

All five populations have some remarkably sharp boundaries, with few or no large outlying native trees beyond the outer edge of the forest. The native populations generally occur as mosaics of even-aged stands, which form part of a complex fire ecology with fires of widely varying severity (Stephens et al. 2014). Radiata forests regenerate vigorously after severe fire (Fig. 2.2) or other massive

**Fig. 2.2** Dense radiata regeneration after a 1987 fire on Monterey Peninsula (Photo WJL March 1990)

disturbance, and this pine is thus a good coloniser of cleared sites both within its native forests (Forde 1966) and as an exotic plantation species (Bannister 1965).

The mainland populations have been subject to considerable human disturbance (Libby 1997), while the Guadalupe population has been catastrophically affected by introduced goats (Ledig et al. 1998; Oberbauer 2006), leaving the Cedros population as the only one nearly free of human influences.

### *2.1.1 Mainland Populations*

In all three of these native mainland populations, radiata pine now grows from just above sea level to upper elevations of about 200–300 m (500+ m at Carmel Highlands in the southern Monterey population), stopping at an inland boundary where coastal fogs are dissipated in the hot summer sun. All natural stands are within 8 km from the sea. Prior to burning or clearing by humans, each of these pine forests was nearly continuous on the north- and sea-facing slopes, and windward from its interior edge towards the coast. At the lower elevations, the pines grow on the dunes or bluffs very close to the sea. There, buffeted by wind and burned by salty moisture, the mature trees grow low to the ground or pressed against the face of the bluff, yet these stressed, sea-edge pines are typically laden with cones. The trees reach their best development near the bottoms of sheltered valleys, with such sites in all three mainland populations containing large, tall and (often) straight pines. Radiata grows on a variety of soils, but relatively shallow soils of sandstone, shale or other sedimentary origins are the most common (Lindsay 1932; Scott 1960) (Fig. 2.3).

**Fig. 2.3** View from roadside of native radiata stand on a comparatively infertile site on Huckleberry Hill, Monterey Peninsula (Photo RDB 1972)

#### 2.1.1.1 Extent

The radiata population on and near the Monterey Peninsula, near 36½°N latitude, is by far the largest of the five, with undeveloped forest land currently totaling about 3800 ha (9400 acres). Various categories of developed forest land (urban, suburban, golf courses, city parks, etc.) occupy another 4100 ha. These are generally characterised by interrupted and depleted native stands mixed with planted trees of both native and exotic species. Shortly before humans arrived on the scene, the Monterey population occupied an uncertain but probably slightly larger area than the current natural extent of 7900 ha (Jones and Stokes Associates Inc. 1994). This population is now substantially urbanised, with Monterey, Carmel, Pacific Grove and several extended communities being largely or wholly contained within the population limits.

The Cambria population, about 130 km (80 miles) south-east of Monterey, is the second-most extensive of the native populations. It currently occupies about 900 ha, reduced by various human activities from about 1400 ha. A mature nearly-square 260-ha stand about 5 km north of the main population, although genetically consistent with the main Cambria population, may have been planted.

**Fig. 2.4** Native stand of radiata at Cambria, showing sapling regeneration in foreground (Photo RDB 1972)

As at Monterey the Cambria population is now substantially urbanised, with the town of Cambria occupying the central part of the main population (Coffman 1995). In addition, current and recent ranching has reduced numbers of trees per hectare north and east of the urban limits within its recent natural range (Fig. 2.4).

The northernmost of the five populations, about 80 km north of Monterey, has its northern edge opposite Point Año Nuevo (now an island) and is thus identified by that name. Its area of about 450 ha (calculated by M.H. Bannister, NZ Forest Research Institute, from distributions mapped by Forde 1964a, 1966) is essentially the same today as it was prior to the arrival of humans, but details of its distribution have been moderately changed by human activities.

#### 2.1.1.2 Associate Tree Species and Soils

In the Monterey radiata pine population, Douglas-fir and redwood also occur in mixture with radiata on a few sites with deep moist soils, mostly near the southern end of this population but rare elsewhere. Granites underlie about 13% of the population (Dunning 1916; Jones and Stokes Associates Inc. 1994). Monterey cypress (*Cupressus macrocarpa*) (also called macrocarpa [cypress]) occurs as two very small sea-edge native populations, both flanked by and grading into radiata forest. Coast live oaks are increasingly common on the more inland sites, and recently appear to be replacing radiata where fire and other disturbances have long been excluded. Near the centre of the Monterey Peninsula, pockets of bishop pine (*Pinus muricata*) (also called muricata pine) and another cypress (*Cupressus goveniana*) (Gowen cypress) occupy strongly-weathered marine terraces (Rogers 2002), where the soil has developed an impervious layer and has become more acidic and infertile. (The Gowen cypress also occurs on a similar site further south within the Monterey radiata population.) The two pines grow intermixed at the edges of this muricata pine population, and groups of radiata tower above the muricata pine within it along stream edges and in pockets where the soil is better. Natural hybrids of muricata and radiata pines and their hybrid derivatives are very rare, if indeed they exist at all (Griffin 1970 p. 90).

In the area occupied by the Cambria population radiata is the only **conifer**[G]. In all three mainland populations, coast live oak is the most common tree growing in association with radiata; several other **hardwoods**[G] are less-frequent associates. Except for a small area of coastal sand, the Cambria population occupies a single sedimentary formation, which produces a sandy loam, although rock outcrops remain.

In the Año Nuevo population, radiata grows in nearly pure stands on some slopes, and intermixed with Douglas-fir and coast redwood on the better sites, those with deeper, moister soils. Soils are derived from marine sediments and are sometimes appreciably calcareous (Rogers 2002). The Año Nuevo radiata also grows with knobcone pine (*Pinus attenuata*) in a narrow, discontinuous transition zone on ridgetops along the inland boundary of the radiata distribution. Natural hybrids between these two species (named *Pinus* × *attenuradiata*), and various second- and later-generation derivatives of such hybrids, occur at low frequency in and near this transition zone.

### *2.1.2 Island Populations*

The two island populations, like the Cambria pines, have no other associated conifers and, like all three mainland populations, have distributions on the islands closely correlated with the local occurrence of persistent summer fog (Fig. 2.5).

**Fig. 2.5** Aerial view of the main northern radiata subpopulation on Cedros Island. The pines occur on the windward slopes of the ridges, with hard desert below them on the lee slopes. The bare ground in the canyon between the pines is the result of earlier copper and gold mining (Photo WJL 1964)

The southernmost population (28°N latitude) occurs on Cedros Island, which in only very recent geologic time separated from mainland Baja California, and was only recently (Axelrod 1980; Bannister; McDonald 1983) accepted as belonging within radiata rather than bishop pine (*P. muricata*). Thus, the native plants and animals on this island are largely the same species as those on similar mainland sites. Although other tree species are native on Cedros Island, the pines grow in essentially pure stands with few or no other associated trees. They occur on about 130 ha, in two similar-sized subpopulations. One subpopulation is on the high central ridges of the island and the other, 15 km distant, is on the upper ridges and windward cliffs of the island's northern point. The often thin soils in these subpopulations are mostly of sedimentary origin, but some in the northern subpopulation are derived from granites or mineralised metamorphic rocks.

Unlike the mainland populations, which mostly grow at relatively low elevations, the pines on Cedros Island occur only on the ridgetops and upper windward slopes (Fig. 2.5), at elevations between about 275 and 640 m (Libby et al. 1968). The lee-side transitions are spectacular, changing in a distance of 2–3 m from moist pine forest with ferns in the understory to hard desert with widely-spaced plants such as prickly pear and barrel cactus. The abundance or absence of fog drip is responsible for these transitions. As wind-blown fog crests the ridge through the pine forest, moisture condenses on the pine needles and drips to the ground. Tree-rings observed on old cut stumps in the northern Cedros Island population have an unusual pattern (WJL personal observation 1968). The earliest (central) rings are very narrow and then, over a 10–20-year period, the rings become progressively wider. Apparently the young pines condensed and dripped more moisture each year as their growing crowns became taller and broader and thus intercepted larger quantities of fog. In some years, no rain has been recorded in the distant fishing village on Cedros Island, and in such years perhaps all life-sustaining moisture had to be wrung from the passing fogs. Still, some of these pines have reached reasonable sizes, with measurements of 32 m height for one and 77 cm diameter for another (Libby et al. 1968).

Of the five natural populations, that on Guadalupe Island is now by far the smallest in both area occupied and number of living trees, because of its relict status resulting from the introduction of goats. It exists over a linear distance of about 8 km on the single ridgetop and windward cliffs of the northern quarter of the island (Fig. 2.6), being remnants of a largely pure stand estimated to have covered 650 ha (Oberbauer 2005). As on Cedros Island, most of the pines grow at a substantial elevation above sea level, between about 485 and 880 m. A small sub-population is much higher, near the main peak between 1120 and 1155 m elevation, 1.5 km distant from the rest and separated by a barren rocky slope. At present, the pines throughout the Guadalupe population are widely scattered. In 1964, there were only 383 pines over the entire 8-km length of the population, and as of 2002 there were only about 200 alive (Rogers 2002; Rogers et al. 2005). Regeneration of the pines effectively ceased well over 100 years ago as a result of the introduction of goats. However, following eradication of goats in

**Fig. 2.6** The lower (northern) part of the Guadalupe Island population of radiata, showing the pines on the upper windward slope and ridgetop (Photo WJL 1964)

2004, very promising regeneration of pines has occurred (Vargas-Hernández et al. 2013).

Guadalupe is an oceanic island, and has been far distant from the mainland ever since it emerged about seven million years ago. This island is the partial rim of a volcano that rises about 5000 m from the ocean floor (Moran, 1996). Relatively few plant and animal species have colonised the island. The pine probably arrived as seeds in still-closed cones that were attached to floating logs, between one and four million years ago. The only two tree species currently growing with the pines are island oak and a palm. The palm and the latitude (29°) suggest a warm site. However, because of the cold ocean current near the windward side of the island, many days are foggy and chilly in and near the pines; ice and snow have frequently been observed there (Moran 1996). The soils, mostly of basaltic origin, are very thin. But the pines' roots penetrate the fragmented volcanic rock and some trees have attained large sizes. The tallest pine measured on the island in 1965 was 33 m and the largest diameter, attained by a different tree, was 211 cm at breast height. This latter is the largest diameter recorded in any of the five native populations of radiata (Libby et al. 1968). Unlike those mainland radiata pines that are exposed to onshore winds, which lean and twist or even grow prostrate, the Guadalupe Island pines are unusually straight and often surprisingly tall despite all growing in extremely exposed windy conditions.

### *2.1.3 Paleohistory and Taxonomy*

While paleohistory and taxonomy are not the same thing, systematic taxonomy attempts to reflect evolutionary lineages by its constructed hierarchical relationships among species and larger groupings; thus the former supports the latter even though taxonomic groups are based on much more than fossils. Various systematic-taxonomy treatments have been published for the pine (Price et al. 1998). Each differently used and interpreted the various shared and divergent traits likely to have resulted from shared ancestry followed by migration into different environments and then independent adaptive evolution. This investigation is still very much ongoing, with new techniques (especially DNA analysis) and information resulting in further advances in our understanding of the evolutionary history and the modern relationships of the pines.

#### 2.1.3.1 Fossils and Evolution

The lineage of the over 110 tree species now classed in the genus *Pinus* (Richardson 1998) came into existence on Earth at least 130 million years ago, perhaps as long as 225 million years ago, during or before the Cretaceous Period of the Mesozoic Era (Millar 1993). Pines apparently differentiated from earlier conifers in mid-latitudes of "Laurasia", the northern supercontinent that later separated into Eurasia and North America (Mirov 1967; Mirov and Hasbrouk 1976; Millar and Kinloch 1991). In North America, they first spread east and west in a broad temperate zone, then episodically north to arctic regions and south to present-day Mexico and Central America and to islands in the Caribbean Sea (Millar 1999). They also spread throughout Eurasia, barely touching the Southern Hemisphere in Sumatra, but nowhere did they make it further south (Mirov 1967). Prior to their recent introductions by humans, pines did not grow on the many Southern Hemisphere sites for which they are wonderfully adapted, simply because they had not previously managed to get there.

As with most species, exactly when, where and how radiata became a new species are not known. The immediate ancestors and closest relatives of radiata appear to have evolved between about 30 and 15 million years ago, in the uplands of present-day Mexico (Axelrod 1967a; Millar 1993, 1999). During this time, the pines that became the muricata, knobcone and radiata species (Millar 1986) migrated west from higher ground to near the Pacific Ocean. The present-day Sea of Cortez, which might have blocked such a migration, did not then exist (on many maps, this is called the Gulf of California). These ancestral pines, along with some cypresses, then migrated north-west and met Douglas-fir and redwood migrating south from their more-northern origins. Fossils of evolving radiata have been found in the coastal area of present-day California in various strata deposited between seven million and about ten thousand years ago (Jones and Stokes 1994), and biochemical evidence suggests that radiata or its immediate ancestors had evolved as a separate lineage somewhat before seven million years ago (Millar 1999). Thus, the radiata species appears to be about 30 times as old as the human species (cf Lerner and Libby 1976).

The coast of modern-day California has been geologically active during the past 10 million years, with the coastal strip of land bumping and grinding north-westward along the gigantic San Andreas Fault. Furthermore, during this period, the level of the ocean has fluctuated greatly as global ice ages came and went. Any species that lived near that coast had to be fairly mobile, migrating inland as the ocean rose and flooded the lower-lying land, and then back as the ocean level fell and the coastline moved out. Many of these species were also island-hoppers as islands were cut off from the mainland, or rose from the sea, or were inundated (Valentine and Lipps 1967; Weaver and Doerner 1967). Although these habitable sites were coming and going with geologic swiftness, their climate was equable, particularly compared to the much greater climate changes occurring during the last ten million years in more inland areas. Nevertheless the general California climate was changing to become seasonally hotter and drier, and radiata was adapting to these changes (Axelrod 1981; Millar 1999).

Fossils of radiata have been found from near Tomales Bay (north of San Francisco) to Chula Vista (near the Mexican border), and in many locations in between that are not currently occupied by radiata (Jones and Stokes 1994; Millar 1999). At least two scenarios are possible. In one, the radiata forest was much larger in the past than it is today, and today's three mainland populations are the greatly reduced remnants of that larger forest (Axelrod 1967a, b; Griffin 1972; Jones and Stokes 1994). In a second scenario, relatively small discrete populations have been more or less typical throughout most of the past million or more years of radiata's history. The modern populations of radiata (and probably others now **extirpated**[G]) have migrated back and forth as more-or-less discrete populations, within the coastal region between and perhaps beyond the present locations of Tomales Bay and Chula Vista, up and down the coastal slopes, and perhaps on and off islands, as climates and sea-levels changed (Millar 1999). It is not currently possible to determine whether either or some combination of these two scenarios is correct, but the genetic architecture of modern radiata (Burdon 1992) seems to favour the second.

The pine fossils from these California mainland sites are mostly cones, twigs and needles, with some chunks of wood. In the strata including fossils from radiata forests that existed a million or more years ago, most of the cones are small and symmetrical and the needles are mostly in bundles of two. The radiata pines that today exist in the Monterey and Año Nuevo populations bear cones that are generally much larger than those fossil cones, and cones in the warmer and drier Cambria population are even larger. It has been suggested that the larger seeds contained in the large cones store more nutrients; these give germinating seedlings a better start in the harsh Cambria environment (Axelrod 1980). Yet the cones and seeds on the even harsher and drier Cedros Island are, on average, the smallest in the species.

With few exceptions, cones from the present-day mainland trees are strongly asymmetrical (Fig. 2.7) and **reflexed**[G], with large woody scales on the side of the cone away from the branch. Mature needles of modern mainland radiata are usually in bundles of three, with bundles of four or five being common on juvenile trees (as many as nine needles in a bundle have been observed). By contrast, trees on or from the two modern island populations of radiata have small symmetrical


**Fig. 2.7** Cones of modern radiata, all from representative trees grown in the same common-garden plantation in California. Opened and partially-opened cones are in the upper row, and closed cones in the lower. There are four cones from each of the five populations, left to right, Año Nuevo, Cambria, Cedros Island, Guadalupe Island and Monterey. Note the average differences in cone size, cone shape, and thickness of the cone scales among the populations, and the variation in these traits among cones within each population. Each cone is from a different tree (1996 photo Iris C. Libby 1996)

cones and mature needles in bundles of two, with three-needle bundles being common on juveniles. A few trees from the island populations have cones that are larger, and/or have asymmetrical scales swollen on the outside, like those of the mainland populations. But the average cone sizes, cone shapes and needle numbers are clearly and distinctly different between the mainland and island populations, based both on trees growing in the native populations and on samples from them grown together in plantations (Moran 1996).

For several traits, evolution seems to have proceeded more slowly on Baja California's offshore islands than it did on the mainland, a sharp contrast to the situation Darwin and others found on the Galápagos Islands. In the Galápagos, evolutionary changes have occurred with dramatic rapidity; plant and animal species found on different islands in the Galápagos Archipelago differ greatly from each other, and from their more slowly-evolving mainland relatives. For many animal and plant species that currently exist on both California's mainland and the offshore islands, the island populations seem more like their fossilised mainland ancestors than like their current living mainland relatives (Mason 1932; several chapters and published discussion in Philbrick 1967 particularly the contributions of Raven). The pattern of fossil and modern radiata is consistent with this generalisation.

The greater frequency and severity of fire during the transitions between moist cool glacial periods and hot dry interglacial periods is currently considered to have been a major force affecting the evolution of pines, the pines evidently having been most abundant during these transition periods (Millar 1999). The evolution of larger asymmetrical cones with particularly large woody scales facing out seems to have been an effective fire adaptation, better allowing some of the seeds beneath the thick insulating scales to survive a hot fire. The trait of keeping their cones closed until they are opened by heat is not only a good adaptation to fire, but it has incidentally provided protection to radiata seeds as the cones floated to and from islands. Large fires are less frequent on the offshore islands than along the nearby mainland, in part because the islands are smaller targets for lightning starts, and in part because ground-strike lightning is less commonly generated over the cool offshore currents than in the updraft conditions of coastal mountains. There have, however, been forest fires in both the Cedros and Guadalupe pine stands during the past century (Libby et al. 1968). Whether these were human-caused or were ignited by lightning strikes from occasional summer tropical storms is not clear.

Larger, thickened scales may give some of the seeds protection against squirrels as well (Linhart 1978). Since squirrels and other cone-eating mammals are less common or absent on the islands, this may have also contributed to the differences in cone size and morphology between the island and mainland populations. It is also possible, even likely, that the reduction in summer rainfall that occurred during the last million years of the evolution of these pines selected for larger seeds in larger, more asymmetric cones, particularly in the Cambria population (Axelrod 1980; Millar 1999).

Why mainland radiata evolved an additional needle per bundle is anybody's guess. The current mainland and island populations differ in many other traits that cannot presently be easily studied in fossils, and the alternative forms of some of these traits in the island populations are likely to be useful as radiata is being domesticated.

#### 2.1.3.2 The Naming of Radiata

The first attempt by Western science to acquire the pine from Monterey began in the 1780s. A gardener named Collignon (spelled Colladen or Colligon in some accounts) accompanied the French "Lapérouse" expedition of reconnaissance, exploration and biological collection. In September 1786, he observed and collected many plant species from the Monterey Peninsula. He later sent a package, including a mixture of pine seeds, cones and needles thought to be from Monterey, to Paris' Museum of Natural History (McKelvey 1994). The European naming of radiata did not begin until 1812, when the French taxonomist G. Loiseleur des Longchamp named that mixture of pine specimens *Pinus californiana*. Later, it became apparent that this sample contained parts of several different species of pine, some of which were from radiata. Because of this confusion, this name was not retained (Millar 1986). Another historical version has Loiseleur describing *P. californiana* from a tree in the Jardin des Plantes in Paris, grown from one of the seeds in a second package sent by Collignon directly to the Jardin. Because it had subsequently died and was thus unavailable for confirmation, the name assigned by Loiseleur was passed over (from Veitch's 1881 Manual, 1900 edn; Boardman 1996). Indeed, this botanical name has now been formally rejected (Anon. 2013a).

Thomas Coulter, an Irish botanist and adventurer, collected cones close to the beach at Monterey in 1829, and sent them to England. There is no record of any seeds being included in the cones or in the collection. In 1835, the species was scientifically described from the cones sent by Coulter and officially named by David Don, an English taxonomist. Don called it *Pinus radiata*, for the esoteric feature of radiating lines on the exposed faces of the cone scales.

As is so often the case with both scientific and common names, this species bore multiple names in the hundred or so years following its recognition by Europeans (Gordon 1875; Elwes and Henry 1910; Dallimore and Jackson 1954). For a time, *P. insignis* was its dominant scientific name. This name, which means "distinguished" or "remarkable," was given to it by David Douglas in 1831, to emphasise the rapid growth that makes the species remarkable (Coffman 1995). Douglas had made a thorough collection and set of observations of the pine at Monterey but, unfortunately, his collection and description of the trees lay in a herbarium box with his assigned name until it was accepted and published in 1838 by Loudon, another taxonomist (Millar 1986; Boardman,1996). According to the rules of taxonomy, the name *P. radiata* was validly published first and thus, after a bit of academic bickering, it was accepted over Douglas' and Loudon's better-described *Pinus insignis*.

Since 1835, various collections of herbarium material have been made from radiata pine in California, and various taxonomists have identified populations of other pine species as belonging in the radiata species, or have placed some of the radiata populations in other species. That now seems sorted out, and today it is clear that the five populations at Año Nuevo, Monterey, Cambria, Guadalupe Island and Cedros Island are all radiata, and that these five are the only extant native populations of *P. radiata*.

There has been some continued taxonomic quibbling about subspecific names (Millar 1986). The varietal names *P. radiata* var. *cedrosensis* and *P. radiata* var. *binata* are generally accepted for the pines from Cedros and Guadalupe Islands, respectively. The *binata* varietal name recognises the fact that the needles are in bundles (**fascicles**[G]) of pairs, which however is typical of the pines of both islands. The name *P. radiata* var. *macrocarpa* has sometimes been used for the pines of the Cambria population, in recognition of the much larger cones in that population. However, the three mainland populations are generally placed together, in *P. radiata* var. *radiata*. Nevertheless, as we will show in later chapters, radiata pines from the Año Nuevo and Monterey populations also differ appreciably in several traits, in some of which trees from Monterey are more like trees from Cambria than like trees from Año Nuevo. Rather than get tangled up in further taxonomic detail, it seems sensible to just remember that each of the five populations is non-trivially different from all of the others, and that they are all radiata.

While the name *P. radiata* has endured, several features of the species have been highly conducive to taxonomic confusion. In the genus *Pinus* the difference between needles being generally grouped in threes (on the mainland) and twos (on the islands) usually corresponds to substantial species differences. And the large tree-to-tree differences in size and shape of cones, which are among the favourite criteria of herbarium taxonomists, have also proved confusing. Indeed, even within the mainland populations confusion persisted among some taxonomists for nearly 100 years as to whether one or two species were involved (Forde 1964b). Despite the wide tree-to-tree variation, recent population-architecture studies show that unusually high percentages of the genetic variation occurs among populations compared with other conifer species, Thus among-population differences, apart from being confusing for taxonomists, are of special significance as sources of genetic variation.

This species was and is known by many common (non-scientific) names. The Native Americans and (perhaps) the Native Mexicans had their local names for these useful trees, as do Spanish-speaking, French-speaking, English-speaking and other-speaking peoples who now grow them. American-speaking people in California most often call them "Monterey pine," although "Cambrian pine" is sometimes used for those in the Cambria Forest. American speakers often drop the tilde from Año when discussing or writing about the Año Nuevo native population, which may bring a gasp or laugh from Spanish speakers. For the domesticating populations, "radiata pine" has become generally accepted, but is conversationally abbreviated to radiata.

### *2.1.4 Native American Impacts*

While Native Mexicans no doubt visited and even lived on some parts of Cedros Island, particularly near the Cerros Mountain springs and along the coast, the pines are remote from these locations. Some reliable springs were close to the pines on Guadalupe Island, lying below the main population and fed by fog-drip from them. But the pines and springs on Guadalupe are a long hard climb from safe landing beaches and it is 250 km from the nearest point on the mainland. Thus, it seems likely that Native Mexicans rarely visited the pines on these two islands, and had little impact on them when they did.

Native Americans have seasonally or permanently lived in all three mainland populations for millennia before European activity there. Some areas had been occupied for at least 3000 years, others for perhaps as long as 30,000 years (Mann 2011). The Spaniards called all Native Americans living along California's central coast the Costeños, or "coast people" (later Costanoans or Costenones). However, the so-called Costeños were not a cohesive nation such as the Apache or Navaho. About 40 different groups wandered from shore to marsh to oak grove in this coastal region, hunting and gathering deer, birds, salmon, acorns, grass seeds and shellfish. They spoke 12–14 distinctive languages, and communication among the different language groups was limited. Different peoples inhabited each of these radiata populations, the Ohlone at Año Nuevo (B. McCrary pers. comm. to WJL 1996), the Rumsen at Monterey (Croft pers. comm. to WJL 1996; Engbeck pers. comm. to WJL 1996; Lydon 1996) and the Chumash at Cambria (Coffman 1995).

It seems likely that their cultures, and thus their interactions with the pines, differed not only among these tribes but also, over time, within them. We know little about them today, as their cultures and population numbers quickly collapsed following European contact (Howard 1972). The policy of the Spanish missions was to convert these pagans to Christianity, and part of this policy was to stamp out so-called pagan practices and all memory and record of them. While this policy was highly successful in obliterating their cultures, a combination of cruelty and disease succeeded in converting most of them from the living to the dead, rather than from pagan to living Christian (LeBoeuf and Kaza 1981).

These Native Americans no doubt used dry pine branches and cones for fuel, and they cut or basal-burned live pines for light construction or even for their great longhouses. However, their main impact on the evolution of these pines was probably through area-burning fire, in some cases used intentionally and skillfully, and in others as unintentional wildfires that escaped a campfire, religious ritual or small purposeful burn. In the hunting-and-gathering cultures of the coastal Native Americans, the skillful and purposeful burning was most frequently done by the women of the tribe. This practice preceded the arrival of Europeans, but did not cease upon their arrival. For example, a 1783 letter from the Governor of Alta California to the mission fathers at Carmel and Santa Cruz requested them to warn the Christian Indians, and particularly the old women, to curb their destructive practice of burning in the forest (Gordon 1977; Hillyard 1996).

The largest population of the Costeños, about 4000 at the arrival of the Spanish in 1769, was on the Monterey Peninsula. There, and nearby at Point Lobos, the Rumsen people set fire to the pines and burned them down to get at the seeds in their cones. In general, the pine seeds were obtained by roasting the closed cones, after which they were eaten whole or crushed into meal (LeBoeuf and Kaza 1981). Preferential felling of those trees with the larger cones and seeds might well have selected against the evolution of even larger cones at Monterey and Año Nuevo, compared to the situation at Cambria. They probably chose trees with delayed cone-opening (serotiny) as well. Their frequent area-burning fires would have intensified selection for serotinous cones. Such frequent fires would have been of lower intensities than previous natural fires, which were less frequent but often stand-replacing. These lower-intensity fires might have been particularly effective in selecting those trees with thicker bark (at least on the lower bole), a trait that is most developed in the Monterey population (Burdon et al. 1992a, b; Stephens and Libby, 2006). So, as in the story of The Three Bears, the fires needed to be neither too hot nor too cool, but somewhere near just right. Whether the coastal Native Americans figured this out, or whether fires of about the right frequency and intensity for the pines just happened, would be interesting to know.

The Ohlones living among and near the Año Nuevo pines were among the largest populations of the Costeños, perhaps second only to the population at Monterey. They enriched berry crops by burning the local blackberry sites within the pine population, and they also burned the coastal bench areas to facilitate deer hunting and favour the grasses used for basketry and gathered for their edible seeds. Escaped fires apparently burned well beyond these intended sites, and some of these frequently-burned areas were noted as being nearly free of pine in the diary kept in 1769 by Father Crespi, a member of the first party of European visitors to the area. He also noted that the smaller houses in the village at Whitehorse Creek were built of split pine wood (LeBoeuf and Kaza 1981), although the major structures there were probably built of redwood and/or Douglas-fir.

Whether and how much the Chumash used fire as a management tool at Cambria is uncertain, but some combination of natural fires and perhaps human-set fires is likely to have been a particularly important selective force in evolving the large asymmetrical cones that characterise the Cambria population. While the traits of the mature bark are not well known from fossil evidence, modern mainland pines differ from the island pines in that the mainland trees consistently have much thicker mature bark, at least on the lower bole, a likely adaptation to the more frequent low-intensity ground fires in all three mainland populations. Such fires would select for thicker bark, while infrequent but intense stand-replacing fires would little affect the evolution of bark thickness.

Although large, intense fires can and do occur in the native populations, the foggy climate there seems likely to make such fires unusual. Natural fire-return frequencies on the Monterey Peninsula have been estimated to have been in the range of 70–150 years (Cylinder 1996), while fires set by Native Americans were apparently much more frequent (Greenlee and Langenheim 1990). Adaptations such as the asymmetrical heavy-scaled cones and thicker bark may well have largely occurred as a result of the more frequent use of fire by Native Americans in these forests. A period of 3000 or so years seems ample to have **natural selection**[G] favour fire-adapted trees. However, preferential felling of trees with larger cones for eating the heavier seeds would complicate the selection pressures.

### *2.1.5 Spanish, Mexican and Californian Impacts*

While there are tales and some evidence of earlier visits to the Monterey region by ships from China (Howard 1972), Spaniards were the first Europeans to see and then extensively use the native radiata forests. And, of course, the Native Americans remained as an important presence after the arrival of the Spanish, and their influence on the forest continued both independently and as labourers on the ranches and settlements developed by the colonists.

The pines at Monterey and Año Nuevo had been sighted and recorded by Juan Cabrillo on 16 November 1542. Next, 60 years later, Sebastian Vizcaino and his crew spent two weeks ashore, studying the area near the harbour at Monterey (Encyclopedia 1979; LeBoeuf and Kaza 1981; Clark 1991), and making the journal notation: "… great pine trees, smooth and straight, suitable for the masts and yards of ships" (Larkey 1972). Father Antonio, chaplain aboard Vizcaino's ship, noted a headland as they sailed north on 3 January 1603 and commemorated the sighting by naming it "Punta de Año Nuevo," the Point of the New Year (since then, it has become Año Nuevo Island). However, a permanent onshore European presence didn't begin among the pines for another 160 years, when a Spanish base was established at Monterey in 1763 to counter the British victory over the French in eastern Canada (Weber 1992). Six years later, while trekking north-west from San Diego on behalf of Spain in 1769, Gaspar de Portolá noted and recorded the pine in the vicinity of Cambria. His expedition proceeded to and through the pines at Monterey, and later stopped in the middle of those at Punta de Año Nuevo. There they feasted on the abundant blackberries, which, according to Father Crespi, a member of Portolá's exploration party, had the joint effect of giving many of the men diarrhoea and curing the scurvy beginning to affect them.

As he passed near present-day Cambria during his 1793 coastal voyage, George Vancouver noted that "very large" trees "with spreading branches" were "distributed in detached clumps," indicating a fragmented pine forest well before substantial European use began in those stands. Very little of the Cambria pine population has escaped intensified human influence during the past 150 years. By the mid-1800s, the entire Cambria area was contained in a single Mexican "rancho." As deduced from an 1850 map prepared by Julian Estrada of his Rancho Santa Rosa, some of the pine forests then shown as continuous have later been substantially reduced or further fragmented. Sawmilling and lumber-exporting occurred some or all of the time in the latter half of the 1800s and continued until 1971, when the last sawmill in the Cambria forest ceased operation. However, the activities of cattle ranchers and dairy farmers, who cleared and burned the forest to increase pasturage, seem to have had a larger impact on the area occupied by the Cambria forest than did 100-plus years of locally patchy logging (Coffman 1995).

The naming of Monterey perhaps gives some insights as to how it was seen and then used (Clark 1991). When Juan Cabrillo observed the bay in 1542, he named it "Bahia de los Pinos," the Bay of Pines. He described this bay as extending from Point Pinos (the north-western point of the modern Monterey Peninsula) to what later became known as Año Nuevo Point, thus including part of the Monterey and all of the Año Nuevo populations of radiata in his Bay of Pines. Sixty years later, Sebastian Vizcaino renamed the bay "Bahia de Monterrey," in honour of Gaspar de Zuñiga y Azevedo, then Viceroy of the Americas' New Spain. Azevedo, also the 5th Condo de Monterrey, had been born in Monterrey, Spain, a city at the foot of a forested mountain named Monte Rey, or Mountain of the King. The extra "r" was later added to be sure people pronouncing it gave emphasis to "the KING." (The New Americans later de-emphasised the king.) But there may be more to this than the title and birthplace of Vizcaino's commander. Vizcaino may have thought it particularly appropriate to commemorate his viceroy at this place because the wooded hill on the peninsula resembled the wooded mountain near Azevedo's home. Later, in 1850, Mariano Guadalupe Vallejo gave some weight to the idea that the presence and nature of the pine played a part in the naming, noting that another meaning of "monterey" is "king of the forest," and possibly also "King's wood." In Vallejo's opinion, the name was not only honouring Vizcaino, but "honoring also the neighboring forest of massive pines and other trees."

After arrival of the Spaniards, human use of the Monterey radiata forest became the most intense of that at any of the five native populations. The easy access to good timber influenced the siting of the Spanish base there in 1763. Father Junipero Serra, head of the California missions, arrived and began settlement on 3 June 1770, establishing the Monterey and Carmel missions in 1770 and 1771. Spain designated the town of Monterey as capital of both Baja (Lower) and Alta (Upper) California in 1776. Following Mexico's 1822 secession from Spain, it remained capital of both regions under Mexican rule until 1846, when a naval expedition captured the town for the United States. This occupation lasted for two years, until all of Alta California became part of the United States in 1848. The oldest known radiata on the Monterey Peninsula in 1994 was 192 years old (Nedeff 1994), indicating that most or all extant pines there have begun their lives since the Spanish colonization.

The good harbour and excellent offshore fisheries had quickly resulted in the town of Monterey becoming a major fishing port and seafood-processing city, well described in John Steinbeck's famous 1945 novel *Cannery Row*. These activities resulted in the radiata forest in the vicinity of the town of Monterey being logged more frequently than any other forest in the western United States. Those radiata stands entered by selective loggers, in the Spanish era and later, typically suffered severe **highgrading**$^{G}$ (called "creaming" in New Zealand), as the straightest and strongest trees were selectively cut for shipmasts and fort palisades, and for building construction ranging from mission buildings to canning factories (Curator, Carmel Mission pers. comm. to WJL 1962).

Nearing the end of the Spanish and Mexican colonization, 300 years after its sighting by Cabrillo, R.H. Dana described the Monterey area in his 1840 *Two Years Before the Mast* thus: "… the shores are extremely well wooded (the pines abounding upon them) …" (Clark 1991). An 1827 watercolour picture, however, indicates few pines in a landscape on the Monterey Peninsula where now there is heavy forest (Hillyard 1996). During Mexican rule, much land on the peninsula had been cleared for pasture (Fig. 2.8), as hides and tallow became important trade items from the 14 ranchos located in the Monterey region. Perhaps Dana and the watercolour artist were viewing different parts of the Peninsula—or perhaps Dana unknowingly described the aggressive retaking of abandoned grazing land by young pines.

In the 1860s, most of the pines on 2800 ha in the north-western part of the Monterey Peninsula were cut and milled at the Sawmill Gulch sawmill (Larkey 1972; Jones and Stokes 1994), perhaps providing easy picking of cones for seed export during that period. Beach whaling, beginning in the early 1860s, was sufficient to make the beaches near the present Pebble Beach Golf Course "white with bones" (Larkey 1972), and cones may have also been easily gathered there from the pines cut and burned to render the whale oil.

Later, fuel was needed for trains, and to provide heat for the homes in town, for the military presidio and for the canneries (Fig. 2.9); pine cordwood was the

**Fig. 2.8** Present-day "New Monterey," including the future site of the Monterey Aquarium in the right foreground. In this 1880 photo, a few pines remain in the developing town, and near the ridge-line, with pasture in between. (Photo C.W.J. Johnson, permission Pat Hathaway Photos, Monterey)

**Fig. 2.9** Stacked radiata cordwood, probably used to fuel trains and/or the canneries. (1901 photo C.A. Culp, permission Pat Hathaway Photos, Monterey)

main fuel on the Peninsula until about 1910 (Dunning 1916). Entire forest stands were clearfelled during these decades to create additional pasture and for fuel. On the main part of the Monterey Peninsula, cutting of the pine was unregulated and often heavy prior to 1896 (Dunning 1916). The railroad had arrived in Monterey

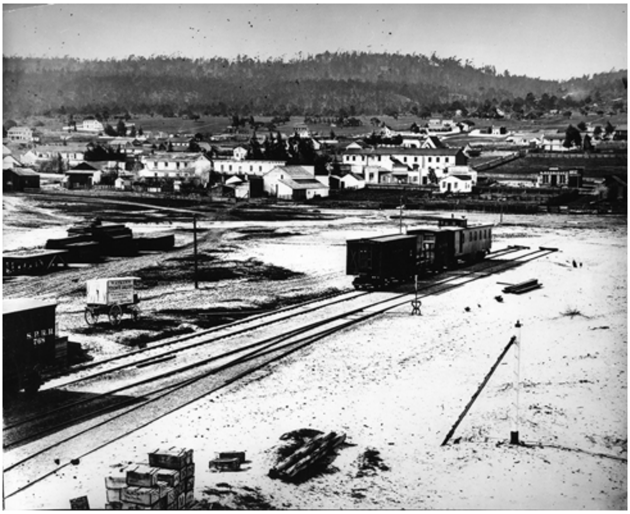

**Fig. 2.10** An 1880 photo of just beyond the Monterey train depot. Seed collectors during the 1850s, 1860s and 1870s might well have stayed in Monterey, and collected cones from the scattered trees in the pastures above town. (Photo C.E. Watkins, ca. 1880, permission Hathaway Galleries, Monterey)

**Fig. 2.11** An 1885 view across the town of Monterey from the Presidio, showing thoroughly cleared land, grazing cattle, and scattered pines in and near the town. (Photo C.W.J. Johnson, permission Pat Hathaway Photos, Monterey)

in 1874, and was later extended elsewhere on the peninsula (Fig. 2.10). Thus, rather than the earlier **dysgenic**$^{\mathbf{G}}$ selection of the mission and fort period, chance and location often decided which few trees would remain following such forest clearing (Fig. 2.11). Some of these surviving trees were later to become the parents of extensive new pine forests that followed the major fires that occurred on the Monterey Peninsula between 1900 and 1907, and that invaded the former grazing land as it was converted to urban and suburban homesites. The Del Monte Forest, occupying much of the peninsula, was about 80% forested by 1915, about a quarter of that forest being about 15 years old owing to the 1900 fire. However, over a third of that forested area was composed of uniform stands of 40–60-year-old pine, these mostly having regenerated naturally after the extensive logging in the 1860s and 1870s (Dunning 1916).

Not all the native radiata stands in the Monterey population experienced these fates. For example, the forest on the Old Capitol Site remained a forest when plans to build the capitol of the brand new State of California in Monterey fell through, and the seat of state government moved to San Jose, then to Benicia, and finally to Sacramento. This forest was burned in one or more of the 1900–1907 conflagrations (Jones and Stokes 1994), but seeds from the burned cones had established a new native forest of radiata by 1910. Similarly, the radiata pines in Pescadero Canyon, near Carmel, grow on the poor soils of a series of elevated marine terraces. It is unlikely that builders in search of good timber would have chosen many or even any of the relatively small pines growing on those soils.

In 1915, Samuel F.B. Morse arrived to administer the development of much of the Monterey Peninsula. He had the vision to keep the forest intact during that development. (However, following World War II, from 1946 through the 1950s, sawmills in Pacific Grove and Carmel cut local radiata for home construction—Jones and Stokes 1994). By 1970, some 2000 homes were nestled within the forest matrix, along with three golf courses and such amenities as the Pebble Beach Lodge and equestrian facilities. In 1971, the S.F.B. Morse Botanical Reserve was dedicated in the upper part of Pescadero Canyon to preserve the enduring qualities of the forest so valued by Morse (Larkey 1972).

It is now unclear which stands within the native populations are still a good sample of the radiata forest as it existed before the arrival of humans. The genetic constitutions of most stands were probably changed substantially by the Spanish-era highgrading, or by new stands on cleared land being founded by only a very few parents. As one example, the present-day Point Lobos State Park has an essentially continuous stand of radiata, and one might think it has been preserved as a good sample of the native forest. However, not only did the Rumsens burn the pines to get at their cones on Point Lobos, and later engage in ranching there under the control of the Carmel Mission, but gold prospecting, granite quarrying, shore whaling, abalone canning, dairying, farming and other disruptive human activities, followed by several decades of complete fire suppression, occurred within the boundaries of this presently-protected "native stand" (Drury and Neasham 1954).

The whalers, about 20 Portuguese, rendered the whale oil on shore between 1861 and 1884, an important period for the export of radiata seed. While not specifically mentioned, it seems likely that pines would have been cut and used as fuel to boil the whale oil, as well as to provide wood for other purposes in the whalers' small village. The radiata seed sent overseas during this period might have been easily collected there, as well as near the Pebble Beach shore whalers, in Sawmill Gulch, and near the town of Monterey. On Point Lobos, the whalers' pigs, goats and cows browsed through the forest, and land was cleared for gardens. Monterey cypress (macrocarpa) trees were planted near the whalers' cottages in 1875 (Drury and Neasham 1954), raising the possibility that pines may also have been planted (perhaps dug locally, perhaps not). Coal was later briefly mined in the area (1888–1896), but after the whaling and seed-export period.

In the 1890s, Japanese built a small town and cannery on the Carmel Bay side of the point to support abalone diving and canning, an enterprise that lasted until 1928. Much of the rest of the point was devoted to dairying and some farming between 1897 and 1930. Beginning in 1916, several movies that required a number of small forest fires to be set were made on Point Lobos.

In 1933 Point Lobos was made a State Park, and many of the buildings were demolished to return it to a more natural state—but during World War II in the early 1940s the U.S. military set up coast defences there (Lydon 1996). Following these various disturbances, this tough radiata species retook cleared parts of the point (Fig. 2.12), and it now appears to be a natural forest.

Another present-day forested park, at Jack's Peak, was in historical times largely open ground. In 1994, an elderly Monterey resident recalled planting (pers. comm. to WJL) radiata seedlings there as a boy, for a Boy Scout project. There is also a substantial plantation of now-large radiata and macrocarpa cypress trees

**Fig. 2.12** Aerial view across Point Lobos and Carmel Bay with the Monterey Peninsula in the background. This 1949 view shows Point Lobos after the military returned it to full park status, at a time when the pine forest is retaking the point. One may see that the main Monterey Peninsula is nearly fully reforested. (Photographer unknown, permission Pat Hathaway Photos, Monterey)


**Fig. 2.13** A 1905 street scene in Carmel (corner of Eldorado and Acacia), showing radiata trees planted in 1903. (Photo R.A. Cohen, permission Pat Hathaway Photos, Monterey)

near the inland edge of the population high above Point Lobos, with a mystery as to who planted it and why. Individual homeowners and municipalities have, since about the turn of the century, replanted radiata near homes on cleared properties and along streets (Fig. 2.13). The California highway department has certainly planted non-native radiata along highways within the native stands since the mid-1900s. Many of the seeds for the mid-20th-century and later urban and highway plantings came from New Zealand plantations.

Although we have learned of these examples of documented and likely radiata planting within the Monterey population, such activities were unusual before about 1900. Furthermore, despite such post-1900 plantings, almost all the present-day mature forest in the Monterey population was established by natural regeneration, particularly following the 1901–1907 fires, with the trees that were left during earlier logging and land-clearing serving as the parents. Thus, the radiata pines in the present forest at Monterey, while in some cases are the offspring of trees in essentially undisturbed stands, are more likely descended from the survivors of earlier dysgenic logging, or from trees left on the edges of cleared pastures or of clearfell logging. Important for our story of early domestication, most of the seeds that were collected from the Monterey population prior to about 1880, which gave rise to the land races in Australia, New Zealand and elsewhere, came from trees that had regenerated naturally in the native populations prior to these dysgenic influences.

The story at Año Nuevo is quite different (LeBoeuf and Kaza 1981, B. McCrary pers. comm. to WJL 1996). The major genetically-important differences among the three mainland radiata populations were probably influenced by the abundant redwood and Douglas-fir near Año Nuevo, the scarcity of these two species near Monterey, and their absence near Cambria. Near Año Nuevo, from the earliest Spanish mission-builders on, those seeking timber for missions, forts, general building construction and many other uses, would have chosen the straight durable redwoods, or the strong timbers of Douglas-fir, over the generally crooked, decay-susceptible, and only moderately strong radiata. Thus, while highgrading and its attendant dysgenic effects tended to dominate several cycles of radiata logging at Cambria and Monterey, where radiata was effectively the only available species, highgrading by Spanish, Mexicans and Californians probably affected the genetic constitution of the Año Nuevo radiata population little, if at all. Earlier construction of longhouses and other structures by the Ohlone peoples may have creamed the best radiata trees, but this is speculation.

The Spanish mission, built at nearby Santa Cruz during 1791–1794, soon began large-scale cattle raising, and by 1814 there were 2900 head of cattle in and near the pines. Russians were also active there hunting sea otters, and the Portuguese engaged in shore whaling from this region between 1862 and 1895. After Alta California became American, Isaac Graham (a cousin of Daniel Boone and himself a famous frontiersman) bought Rancho Punta del Año Nuevo, and in 1851 established a sawmill. There was extensive logging of redwood and Douglas-fir nearby, and milling of these species within the Año Nuevo population by the New Americans from about 1860 on. William Waddell milled and exported lumber from a harbour and dock near the middle of the radiata population from 1864 through the 1870s, but little of it was radiata. (Waddell himself was killed on the property by a grizzly bear in 1875.) In 1908, a railroad was built to and beyond the small town of Swanton, within the Año Nuevo population, with steep grades that needed Shay engines to bring more-distant redwood and Douglas-fir down from the mountains of the Coast Range. Logging continues within this population to the present, as does occasional milling of the native Año Nuevo radiata.

In 1861 the Steele brothers, a leading dairy family, leased and then bought 2800 ha in and near the pines. Using mostly Native American labourers, they produced cheese and butter. In the early 1860s, during the American Civil War, they made a gigantic wheel of cheese 6 m in circumference, 46 cm thick and weighing 1750 kilograms. This was then successfully transported from Año Nuevo to San Francisco by road, where it was carved and auctioned, with proceeds going to the forerunner of the Red Cross. Thus there must have been a respectable road in the 1860s, and seeds could have gone by the same route from the pines at Año Nuevo to scientists and seed dealers in San Francisco.

While some radiata trees of questionable origin have been planted along the highway, the current radiata component of the forest at Año Nuevo seems likely to be descended with little modification from pre-European native forest. Although the New Americans probably changed the genetic structure of the radiata forest very little at Año Nuevo, they did change its shape. Some areas of forest were converted to pasture or cropland. Other areas returned to forest as the New Americans ceased the burning practices of the Native Americans and instituted instead fire protection and fire suppression. For example, the barren area noted by Father Crespi now supports a substantial stand of naturally regenerated radiata. More recently, the percentage of radiata has increased in some of the mixed stands, with young pines encroaching on areas previously occupied by the preferentially logged Douglas-firs and redwoods in those stands (Forde 1962, 1966; Mirov 1967). A recent population study of turpentine composition (Burdon et al. 1997) suggested that rather than being relatively stable, this population had been reduced to a limited "core" area from which recolonisation has occurred.

On Cedros Island (Libby et al. 1968; plus interviews by those authors with local Mexican officials), there has been some early-1900s exploration and mining for copper and gold in the mineralised rocks in the canyon below the northern subpopulation. Some nearby pines were cut for mine timbers and probably for fuel. But relatively few trees were taken, and the Spanish and Mexican owners of Cedros Island seem to have influenced these pines only a little.

In sharp contrast, the recent influence of humans on the Guadalupe Island pines, while indirect, has been devastating. The island was sighted and recorded during Vizcaino's 1602 voyage, visited by galleons returning from the Philippines en route to Acapulco on the Mexican mainland, and charted and surveyed in 1837 by a French expedition (Moran 1996). The pines were not "officially discovered" until 1875 (Elwes and Henry 1910, Millar 1986). There was an old ranch, or perhaps several ranches, on Guadalupe Island near the springs, and the pines were probably used by the ranchers. The tenure and extent of the ranches are not clear, and only remnant adobe ruins remain (Moran 1996).

The most important human-mediated event occurred in the early 1800s, when whalers released goats on the island. Their purpose was to have a supply of fresh milk and meat available on subsequent visits, with little likelihood of crew jumping ship to such an inhospitable place. By 1880, these goats had multiplied to exceed the carrying capacity of the island, numbering in the hundreds of thousands and concentrating near the springs below the pines. Mice arrived in 1875, and these ate and continue to eat the seeds of the pines (Moran 1996). In 1893, there was still evidence of dense pine forest that had clothed most of the upper north-western slopes, and of one or more large forest fires (Moran 1996). Except for two saplings growing on an outcrop inaccessible to the goats, for over 100 years no new pine seedling was able to grow large enough to be safe from the goats. Meanwhile, the large pines died of various natural causes. The dense forest of radiata that was observed a century or so ago on Guadalupe Island was reduced to scattered survivors. The springs that might have supplied visiting Native Mexicans with fresh water in earlier times became unreliable or completely dry; the fog drip that charged their aquifers waned as the large pines died and the survivors' seedling offspring fell victim to the starving goats (Libby et al. 1968; Moran 1996).

There is recent good news for the local flora, including the pines. Successful efforts by the Mexican Government to eliminate the goats have resulted in many young pines regenerating among the old survivors (Fig. 2.14).

**Fig. 2.14** Young seedlings thriving on Guadalupe Island in 2008 after elimination of goats in 2004 (Courtesy Deborah L. Rogers)

## 2.2 Early Institutional and Political Factors in Plantation Forestry

In the 1800s, the earliest collectors of most plant species were professional botanists. After studying what they needed from the collection at hand, they often exchanged seeds and plants with fellow botanists. The more promising species among their collections were usually sent to interested fanciers and progressive landowners, or to commercial nurseries. Later, for some of those species, commercial seed merchants became involved in larger-scale seed collections. Records were generally better kept and maintained by the botanists for their earliest collections than for subsequent exchanges and for commercial collections. In general, this pattern was true for radiata.

While a few organizations planned and established plantations of radiata before 1900, this activity generally began in earnest in the first half of the 20th century. In the latter half of the 19th century, the important institutions affecting the later development of plantation forestry with many species were those that acquired the seed and planted the first generation or so of the tree species grown in each region. These early trees not only drew attention to radiata as a candidate for the 20th-century plantations through their relative performances, but also often supplied locally-grown seed for later plantations. In these latter cases, and particularly for radiata, they became the founders of each region's land race(s). Thus knowing their origins is important for understanding the subsequent domestication of radiata.

In Australia, New Zealand and later Chile, “old boy” networks among botanic gardens, and then seed dealers, nurseries and landowner enthusiasts, served to move and establish these early radiata collections across large regions in each country. In particular, landowner enthusiasts responding to the then-current craze for new conifers (Shepherd 1990) drove the early introductions. Typically, it began at specimen-tree scale, in parks and gardens, and as trial windbreaks. This was followed in a few years by some landowners establishing plantations including this remarkable pine. Governments then became formally involved, often in response to perceived future timber shortages and the demonstrated success of the pioneer plantations.

### *2.2.1 Australia*

The colonial history of the continent (1788–1900) is important background to the region’s forest policies and administration; until the end of this period Australia was a set of essentially autonomous colonies. Of these colonies, South Australia was the first to have a forest service of its own—one of the first public forestry departments in the British Empire. It was formally established in 1883, and promptly engaged actively in plantation forestry. Victoria, however, did have as State Government Botanist Dr Ferdinand von Mueller (Home et al. 1998), based at the Melbourne Botanic Garden, who enthusiastically promoted radiata (http://adb.anu.edu.au/biography/mueller-sir-ferdinand-jakob-heinrich-von-4266) and who also had influential connections. He owned property in the Mt Lofty Ranges of South Australia, where F.E.H.W. Kirchauff, a Member of the House of Assembly of that state, was his neighbour.

We will now address the story in South Australia, leaving development of institutions in the other states until the next chapter.

Even before human impacts, less than 1% of South Australia supported closed-canopy high forest. Aboriginal practices then affected these and other native Australian forests in important ways, particularly through the extinction of some of the large animal species (Flannery 1994); but the early activities of European colonists depleted the already very restricted South Australian forests at an alarming rate. Just 34 years after the founding of the colony, attention of some far-sighted people was focused on the lack of natural forest resources. In response, an initiative to establish a forest service came from the Surveyor-General, G.W. Goyder, and in 1870 this proposal was carried successfully to the South Australian Parliament by Kirchauff (Lewis 1975).

Among other things, Kirchauff’s legislative action creating the forestry department clearly included the establishment of plantations as a supplement to natural regeneration in designated forest reserves. An *Act to Encourage the Planting of Forest Trees* quickly followed, in 1873. In 1875, Parliament created the Forestry Board, with Goyder as Chair, and put 79,000 ha in its care. South Australia at this point was the first of the colonies in the South Pacific to establish an organization charged with the development of timber plantations. The Woods and Forests

Department replaced the Forestry Board in 1882, becoming the first state organization on Earth to designate plantations of exotic species as the primary source of forest products.

It was soon decided to grow quality timber on the forest reserves, with preference to be given to good species with rapid growth. By 1881, enough had been known to focus on “Mediterranean-climate” pines (maritime pine (*Pinus pinaster*), Corsican pine (*Pinus nigra*), Canary Island pine (*Pinus canariensis*) and Aleppo pine (*Pinus halepensis*)) as being well adapted to quickly produce good-quality timber on many of South Australia’s forest reserves (Lewis 1975; Boardman 1988, 1996).

### *2.2.2 New Zealand*

The islands that are now New Zealand were settled by Maori, evidently beginning around 800 years ago. During the following several centuries, the Maori population increased greatly, and severe impacts on the native fauna and forest came within 200 years (Halkett 1991). This began in earnest with Maori using fire for hunting moas, large flightless birds, including the largest bird surviving at the time. All nine species of moa were evidently hunted to extinction, which is thought to have been virtually completed for the giant species during the 14th century. Also, many other native birds were either hunted to extinction, or their habitats were so modified as to help cause their extinction (Flannery 1994). After the moa-hunting phase, some forest destruction may have continued partly because of accumulation of fuels from what the moas might have consumed if still present. The most severe impacts on the vegetation and birds probably came within 200 years of initial settlement, but there would have been continued forest clearance by Maori, largely to promote growth of bracken fern, of which the roots were a food source, and for ease of travel. Thus between 1200 and 1800, the native forest that had covered about 75% of the land area was reduced by a third (Sutton, 1991). However, the introduction of the true potato in 1772 or 1773 by Europeans led to a new round of forest destruction (Cameron 1964). Whereas the staple cultivated vegetable, the kumara, was suited only to special sites, the potato, being far more tolerant of cool sites, was grown in shifting cultivation in ash beds created by felling and burning of forests. Indeed, it is thought that the rate of such destruction may have matched that wrought subsequently during European settlement for farming.

Beginning in the 1790s, a few Europeans lived with the Maori or in small enclaves. The first were mostly spar-cutters and other timber cutters (Simpson 1973), plus a few deserting sailors, and then came increasing numbers of sealers, whalers, missionaries, traders and early settlers. In 1840, some of the Maori chiefs and the British Crown signed the Treaty of Waitangi. Both the treaty and the events that precipitated it catalysed large-scale immigration, largely from Great Britain. The 1840s and subsequent years featured settlers attempting to get clear title to real estate, and then building homes, clearing land, establishing crops and herds, and dealing with the immediate problems of survival (Sinclair 1959; Belich 1994).

In several North Island regions, mutual distrust between colonists and Maori was building. The 1858 census marks the first time colonists outnumbered Maori. The Maori Wars of the 1860s particularly disrupted development in central North Island, but the South Island was essentially free of such preoccupation. Even so, there were numerous landowners in both islands who for various reasons were actively planting exotic tree species. Among those species radiata featured from after about 1860, albeit almost incidentally at first.

The New Zealand political character was evolving rapidly during this period, which included increased and often organised introduction and generally informal trials of many exotic forest-tree species. Although forestry and politics are frequently indirectly linked, one noteworthy happenstance closely linked the two in 1876. A forests bill had been introduced in 1873 by Julius Vogel, the aggressive and expansionary national treasurer of that era. Vogel had hoped that good husbandry of the forests, already important national assets, would strengthen the country's development (Roche 1990). While the bill was passed in 1874 it was greatly weakened by provincialist politicians. This was doubtless among the factors that led Vogel to manoeuvre the abolition of the provincial governments in 1876, leaving a single national government. This contrasted strongly with the political development of Australia, among other things resulting in the early centralization of forestry research in New Zealand and its fragmentation in Australia. By the end of the 19th century, New Zealand was perhaps the most radical nation in the world, described as "a laboratory in which political and social experiments are every day made for the information and instruction of the older countries of the world" (Sinclair 1959). This general willingness to innovate had effects on forestry as well as on many other New Zealand institutions.

To satisfy the colonial settlers' demands for cropland, pasture and wood, as was the pattern elsewhere, the most accessible forests were cleared. Although there was then substantial demand for timber for construction and export, the pace of forest conversion was such that only a small percentage of New Zealand's forest was harvested for timber during the 19th and early 20th centuries. A much larger percentage was simply felled and burnt to make way for pasture. In such circumstances, little institutional attention was directed to reforestation with native species, much less to establishing plantations of exotic species. However, a provincial bill in support of tree planting in Canterbury had its purposes extended to the entire country by the 1871 *Forest Trees Planting Encouragement Act*. The central government established a small forestry department with the successful passage of the *1874 Forest Act*, but with the relative abundance of apparently inexhaustible native forest, the Forestry Department was not supported well and was disbanded in 1888 (Roche 1990, p. 98).

In 1892, the Minister of Lands was also made Commissioner of Forests, and four years later a State Forest Branch was set up in the Lands Department. Its primary duties were modest afforestation and operation of nurseries. Its nurseries were both for its own plantings and to supply the public as a way to encourage private tree-growing (Allsop 1973). In the 1890s, the government took its next tentative steps in evaluating exotic forest species, by planting research plots in the

Otago and Canterbury regions of South Island, and then beginning the Whakarewarewa Forest near Rotorua on North Island. These trials focused on proven timber species, such as Corsican pine and larch from Europe, and Douglas-fir and ponderosa pine from North America. At Whakarewarewa, radiata pine was included as a shelter tree, protecting the valuable young seedlings of the more favoured species in the trials (Hegan 1993).

From very early days of intensive European settlement private commercial plant nurseries were established readily, doubtless in response to lively demand.

#### 2.2.2.1 Canterbury

Unlike in the rest of 19th-century New Zealand, where there was an abundance of timber in the native forests, there were problems of timber supply in the eastern part of South Island. Also, various of the British landholders (freeholders or leaseholders) in this region had arrived with sufficient capital, and could afford the start-up expenses of planting substantial numbers of trees. Moreover, in that windswept region, establishing trees to shelter homesteads was often a pressing need. Furthermore, there was often enthusiasm for collecting recently discovered tree species, and conifer species were favoured because their seeds were usually relatively easy to import in a viable state.

In a response to the local timber shortage, and encouraged by the 1871 Canterbury *Forest Trees* bill, many plantations of species better-known than radiata were established in this region in the 1870s. By the 1890s, however, the first sawmilling of surprisingly large young radiata pines that had been used in shelterbelts or included in mixed plantings took place and in response, some commercial radiata plantations were being established in various localities (Burdon and Miller 1992).

#### 2.2.2.2 The Wellington Botanic Garden

Sir James Hector arranged for most of the currently-known well-documented importations of radiata seeds into New Zealand during the late 1860s and the 1870s (Burdon and Miller 1992). While serving as Director of both the Wellington Botanic Garden and of the Geological Survey, he used these joint offices to effect an evenhanded distribution of these early radiata acquisitions throughout New Zealand (Shepherd and Cook 1988; Shepherd 1990). This was professionally brilliant, and surely served to distribute similar proportions of the two native provenances to many locations. Although they had been preceded by some significant introductions, Hector's distributions are likely to have been much the most important. His country-wide distributions of seed and/or planting stock accounts well for what appear to be similar proportions of Año Nuevo and Monterey ancestry among the regional land races within New Zealand (Burdon 1992; Burdon et al. 1997).

Several groves and individual trees from the 1870s acquisitions of radiata still exist in the Wellington Botanic Garden. These are surely among the best, and are probably **the** best, of documented samples of the founding generation of radiata in New Zealand. How appropriate that they are on the site from which Hector made those early distributions! Unfortunately, the records do not clearly tie particular plantings to particular native origins. However, with molecular fingerprinting techniques now available, they may soon be used to tie these century-old veterans to the precise native stands where they were conceived as seeds and in whose environments they evolved.

### *2.2.3 South Africa*

South Africa had very small areas of original native forests, and much of those forests had already been destroyed by the 1870s (King 1938). Despite the limited history of forestry, or because of it, a Superintendent of Plantations was appointed at Cape Town, in 1875, in recognition of the need for plantations. The Cape *Forest Act* was passed in 1888. Wattles (*Acacia* spp.) were also planted for fuel and huts from 1898. The Woods and Forest Department of Cape Colony made vain efforts at natural regeneration of commercial native forests (King 1938). Otherwise, they were evidently monitoring plantation areas more than being actively involved in species testing and afforestation.

Meanwhile, early plantations of exotic tree species were being established, mostly by private industry, whose plantings commenced in 1870—wattle for tan bark, and wattle and eucalypts for mining timbers (Sherry 1971).

No date of radiata's first importation has been traced, and thus when, how and from where it arrived remains unknown. It seems that radiata arrived there before it got to Australia and New Zealand, since radiata trees were producing seed there by 1857 (Poynton 1960). While small plantings and individual trees of radiata did well in much of the Cape Colony no major planting of it appears to have been done in the 19th century. The first record of establishing an actual plantation of radiata was in 1885 at Tokai Forest Reserve, Cape Town (Donald 1993). Little other concrete information seems available for this period.

### *2.2.4 Chile*

One might think, with the substantial ship-traffic stopping in Chile on the way to or from California, and with the trading directly between Chile and California in the mid-1800s, that radiata would have been repeatedly introduced to Chile during or even before this period. In puzzling about this, J.S. Krebs (1973) invoked a quote from James Michener's 1968 *Iberia*: "It was unusual to find a Spaniard who spoke with such love of rivers and meadows and mountains, for Spain more than any other European nation has abused its land." The Spanish emphasised livestock raising, and other aspects of agriculture, but colonial Spain had very little if any record of afforestation. However, there was more to it than that. Unlike South Australia and the Canterbury region of New Zealand, there was abundant high-quality timber available in Chile. Furthermore, pre-Columbian native building construction (Mann 2011) was only slightly modified by the Spanish tradition of building with mortar and stone. Thus, in spite of the relatively much greater danger of collapse and injury associated with mortar and stone buildings during earthquakes, the demand for wood in building construction was not great.

The dominant culture in Chile in the mid-1800s was Spanish. The Spanish did bring their native maritime pine (*P. pinaster*) early, and it was widely planted. Furthermore, it frequently reproduced naturally in the vicinity of the planted trees, and did this so often that it was soon considered by many to be native to Chile. Even if a few radiata pines did make it to Chile during this period, it seems their fate was to be largely unappreciated or ignored (Krebs 1973).

Although the Spanish had been in Chile for many years, the area south of the River Bío Bío long remained the frontier, under the control of the native Araucanians. This also was the approximate northern edge of continuous forest, unattractive and even repellent to Spanish more comfortable in the Mediterranean-climate woodlands and chaparral further north (Krebs 1973). In 1881, the holdout Mapuche tribe finally surrendered at Nacimiento and the conquest of the Araucanian frontier was complete (Clapp 1995). Meanwhile, beginning in 1856, a substantial German settlement had been established farther south, in Valdivia, with its people and influence soon expanding elsewhere. Shortly thereafter, experimentation in Chile with exotic trees began in earnest (Junge 1953; Clapp 1995), as did a greater use of wood in building construction. While preoccupation with the native Araucanians perhaps delayed attention to reforestation and afforestation opportunities in Spanish-culture Chile, German-culture Chileans were at the forefront of these new ventures.

## 2.3 Early Plantings

People introduce non-native plants and animals for a variety of reasons. Among these reasons are one-upmanship among fanciers, curiosity, aesthetic perceptions, need, hope of economic gain, nostalgia and professional activity. Whatever the motives for original introductions, the follow-up introductions and planting generally depended on how the species performed, in terms of their growth, site tolerances and uses. With respect to motivations to introduce radiata in the 19th century, one-upmanship and curiosity seem to have dominated initially, to be slowly superseded by its ability to fill needs and eventually by hope of economic gain. As radiata became massively planted as an exotic its aesthetic appeal to people generally disappeared, despite the magnificence of some of the earliest plantings. While reports of the giant conifers of western North America often fired the imagination, those were just a few of the many conifers that had recently been discovered there. Elsewhere in the world, notably in northern India, other impressive conifers were being discovered too. It became fashionable for well-to-do British landowners to collect newly-discovered exotic conifers. And, while many were probably competitors, these collectors eagerly swapped seed and other propagules in order to broaden their collections (Box 2.2).

**Box 2.2 Evolution of Planting Status**
Radiata was initially planted as a botanical curiosity during a period when Europeans were discovering many "new" conifers. Many botanic gardens, and landowners eagerly collected such new discoveries, for specimen-tree plantings. In Australia and New Zealand, in particular, the success of specimen-tree plantings led to more extensive plantings for shelter and fuel, and eventually for producing timber. In Chile, this process was foreshortened, following a later initial introduction.

This fashion spread to the British colonies of the Southern Hemisphere. It doubtless ensured that many obscure and even unlikely species, such as radiata, were tried as exotics there. Curiosity seems a likely motivator, in both Britain and her colonies, but mostly for a relatively few well-informed fanciers. It must have powerfully complemented the role of the botanic gardens that were generally established promptly in those colonies. These factors doubtless ensured that many obscure and unlikely species, such as radiata, were tried as exotics alongside the wider-spread and more valued New World conifers such as redwood and Douglas-fir. Radiata's natural range was so small that most 19th-century colonial gardeners and farmers would not have even heard of this obscure and often unprepossessing pine.

European exploration and colonization was occurring along the Pacific coast of North America in the 17th and 18th centuries. The early trade routes from Europe to the New World and beyond generally had ports of call in Spain, and ships usually called in Chile and/or South Africa. It is curious that radiata was not effectively introduced into regions where it has now become an important plantation tree, particularly in Spain and Chile, until the middle of the 19th century or even later. It seems logical that new botanical findings from California would have been tried in those similar climates long before they were tried in Australia and New Zealand. Yet, surprisingly, they were not, at least not at an intensity that stimulated further plantings or the keeping of long-term records of the trials.

Most of the new British colonies had an abundance of native forests. Cutting these to clear land for homes and farms, incidentally using some of the felled trees to satisfy immediate needs for wood, was more a focus of thought and action than planting new species for future harvests. South Australia and New Zealand's Canterbury were the two colonial settlements that were short of timber almost from their founding, and thus forest-tree plantations were begun early there.

Hope of economic gain motivated the establishment of few if any forest plantations in the Southern Hemisphere countries in the 18th and 19th centuries, although such activity was then long-established in China, Japan and parts of Europe.

Nostalgia motivated many Southern Hemisphere colonists to bring or send for familiar plants and animals, mostly from their previous European homelands. Yet superimposed upon the nostalgic motivation was the strain of curiosity and collectorship.

Gold miners, heading to the newer mid-19th-century finds in Australia and New Zealand, were the majority of the earliest immigrants from California, and it has been speculated that some of them might have brought tree seeds with them. But miners in those gold-rush days were not typically motivated by nostalgic commitment to something as long-term as a tree nor by botanical collectorship, and the records do not point to their having played any part in the global spread of radiata.

So radiata was only incidentally included in the various activities that resulted in many species being introduced and extensively tried in many countries around the world. It was largely professional activity, in the form of botanic-garden and arboretum collections, followed by the networking connections to tree-planting enthusiasts, which gave radiata its first chances to excel.

For reasons we hope will become clear below, these early introductions have taken on enormous importance in the development of radiata as a domesticated crop.

During the 1850–1880 period, when several of the land-race-forming seed collections were sent to New Zealand from California, all three mainland native populations of radiata were known. More important, all were accessible, and various enterprises in and near them were engaged in active commerce and trade. Not only was Monterey a thriving and developing community, but a stage route went north to San Francisco through the heart of the Año Nuevo population, and Rancho Santa Rosa had long been engaged in trade from Cambria. During this period, trade was active between California and much of the rest of the world (stops by passing ships at Guadalupe and Cedros Islands were recorded, but infrequent, and the pine stands were inaccessible). Thus, radiata seeds could have been shipped directly to the various countries beginning to plant radiata, or through the intermediaries of seed dealers and botanic gardens in third countries. The accounts indicate some but surely not all of what in fact occurred.

There is some reason to wonder if, prior to 1857, goldminers and/or ship ballast might have passively brought seeds of radiata to Australia, New Zealand and elsewhere, most likely contained in closed cones and then released when the cones dried out and were exposed to heat (Harris 1991). Such passive importation, or even a purposeful introduction by a miner or other early traveler, has not been documented, nor would it have been likely to be reliably documented. The first documented trees and seeds did not come directly from California, but came from England and Scotland, in 1857 (Fielding 1957a, 1957b; Shepherd and Cook 1988; Shepherd 1990). At least some of them probably came from stored quantities of David Douglas' 1831–1832 seed collections in or near Monterey, or from cones produced by trees raised in England and Scotland from Douglas' seeds (Shepherd 1990).

Despite many records of importations of radiata seeds to various countries, very little is explicitly recorded concerning the native-population origins of land-race stocks. Laboratory results and circumstantial considerations point to land races having originated entirely from the two northernmost populations, Año Nuevo and Monterey, the contribution of the former being very disproportionately high in relation to the population sizes (Burdon et al. 1997 and references therein; Aragonés et al. 1997). Californian ancestry of domesticated populations, and perhaps even of individual trees, should become identifiable in greater detail using using recently-developed DNA markers.

### 2.3.1 European Seed Collections and Plantings

Douglas was not the first to send radiata seeds to Europe. During 14–24 September 1786, personnel from the two ships of the French "Lapérouse expedition" not only fulfilled orders to evaluate the Spanish military garrison and to make botanical and zoological collections at Monterey, but they also cut and loaded all the wood the ships could hold, which probably included some radiata. Three months later, on 27 January 1787, two packages containing the Monterey collections were dispatched by Collignon, the expedition's botanist, to Paris from Macao. A year after that, in February 1788, the two ships called at Botany Bay in Australia, but there is no record of radiata seeds being left there. Soon afterwards, both ships sank in the Solomon Islands, and all on board were lost (McKelvey 1994).

The radiata seeds from Monterey in the package sent by Collignon to the Paris Museum were mixed up with collections from other species. One plant, recorded as from this Paris Museum collection and identified as *Pinus californiana*, was still living outdoors in the Jardin des Plantes in 1812. It seems likely that this tree from the museum collection was some pine other than radiata, perhaps Italian stone pine (Elwes and Henry 1910). However, Collignon's second package was sent directly to the Jardin des Plantes, and seeds from that package were planted there in 1787. Collignon's notes, apparently included with those seeds, indicate that they were collected "from the shores of Monterey Bay." Although their existence was perhaps unknown to the taxonomist Loiseleur, the 12 trees that grew from them were radiata. They, or perhaps their offspring, survived in the Jardin des Plantes until 1830, when they were killed by a severe spring freeze. In Loudon's 1838 publication taxonomically describing radiata and naming it *P. insignis*, he noted that another tree of *P. insignis* from that Collignon collection had been growing in Dublin, Ireland, and it was also killed in severe spring weather in 1830. However, seeds or possibly seedlings from the trees growing in Paris were planted in the Royal Horticultural Society's Garden in London about 1829 (Boardman 1996), thus continuing Collignon's collection line at least there and perhaps elsewhere as well.

At least a few of the radiata pines in and around London survived killing frosts in 1838 and 1839, and similar frosts in England killed or severely damaged even large radiata pines in 1867 and again in 1908 (Elwes and Henry 1910). The frosts were and are even more severe in central France. All of the radiata pines in or around Paris were killed by such frosts in the 1830s, and radiata pines planted near Paris in the mid-1970s suffered the same fate. The frequency of such radiata plantings is not clearly recorded for those generally mild regions of Europe, which, however, are subject to periodic cold-air masses from the interior of the continent. It is possible that some later radiata pines, descended through two or more generations from the Collignon collection in the Jardin des Plantes, Dublin and perhaps elsewhere, were available to produce seeds and offspring for some of the exports from various places in Europe during the period 1850–1900.

While botanical collections had been made during 1825 through 1828 in the Monterey region, it is not clear that any radiata seedlings from them were planted in Europe (Millar 1986). From some of the radiata seeds collected in 1831 and 1832 by David Douglas in or near Monterey, trees were planted in 1833 in and around London. Most of these young pines had died by 1839, but some at the Horticultural Society of London's garden in Chiswick and elsewhere survived those first winters (Boardman 1996). In 1838, Richard Forest's Nursery in Kensington, England, had *P. insignis* for sale at prices from 21 to 100 shillings each (Shepherd 1990), and young radiata pines were being sold in France and Germany as well (Bannister 1973).

Douglas, being a Scot, also sent seeds to the Edinburgh Botanic Garden. Most of the radiata from that shipment that were subsequently planted in northern England and interior Scotland died in the severe winter of 1860–1861, and later plantings in this region similarly failed. In the context of European experience with conifers, those planted near the western coast of Scotland, in Ireland and in Wales grew exceptionally well (Elwes and Henry 1910).

In 1839, K.T. Hartweg also sent a collection of herbarium specimens and seeds from Mexican conifers to the Horticultural Society of London (Boardman 1996). Hartweg's collection reportedly included *P. insignis* from "southern California" (possibly Cambria, which like Monterey was then still part of Mexico) and also the two-needled *Pinus binata* variety from Guadalupe Island. However, the lack of literature references to Hartweg in relation to that variety suggests that the reported collection from Guadalupe Island was of no ongoing significance.

It is possible that seedlings from the Hartweg collection, as well as those from the Douglas collection, were later planted in the Horticultural Society's "pinetums" at Woburn, Hackney, Syon House, White Knights, Pain's Hill and especially at Dropmore in Buckinghamshire. These pineta helped spark a world-wide interest in the horticultural cultivation of pines and other conifers, and spread their use in shelterbelts and hedgerows (Boardman 1996).

The Dropmore radiata, planted in 1839, had reached 27 m height in 1891 after only 52 years, impressive by European standards. Interestingly, some of the radiata planted at Dropmore in 1839[2] were rooted cuttings, reported in 1882 to be somewhat smaller than the seedlings but otherwise growing as well as the seedlings (Elwes and Henry 1910; Bannister, 1973). By 1910, radiata had become a proven and valued tree in shelter and ornamental plantings in south-western

[2]It appears that nurserymen of the time would often endeavour to extend scarce supplies of novelty seed by multiplying seedlings as cuttings.

England, Wales and Ireland. Its high growth rate was attracting speculation as to its possible rough-timber uses, such as for pit props in mines, or even for finer uses from older closely-grown trees (Elwes and Henry 1910).

Two decades after the Dropmore plantings, seeds and small trees began to be sent to the Southern Hemisphere colonies in large numbers. In his 1966 manuscript, Joseph Ewan (1973) set the scene, as follows: "It is not easy to realize the zeal of the Englishman for his garden and stove a century ago. While orchids, aroids and other choice exotics were the prizes for the well-to-do, the middle class were gaining leisure and some affluence with the Victorian graces, cultivating their perennial borders, mulching the favorite conifer or tending the tender subjects in his glasshouse … William Lobb, then, was in the parade of collectors for great horticultural establishments led by the heroic David Douglas who was followed by Thomas Coulter and Karl Theodore Hartweg."

Lobb collected as an agent of Veitch who began his nursery operation in Exeter and purchased the Royal Exotic Nursery in Chelsea, London, in 1853. Lobb went first to South America, and later arrived in California in mid-1849, at the height of the gold rush. The following spring, Lobb and T.L. Andrews went to Monterey and the nearby Santa Lucia Mountains. According to Ewan (1973), "Veitch had instructed Lobb to collect seeds of several of the conifers discovered by Douglas and Coulter which were not yet introduced into English gardens." Certainly the high point of the year 1850 was his successful shipment of Santa Lucia fir to Veitch and its introduction into horticulture. It seems likely that Lobb would have included radiata seeds in that shipment.

In 1851 Lobb was mostly in the upper Sacramento River valley, where among other things he discovered incense-cedar. In 1852 he returned to northern California from the Columbia River through Oregon, collecting conifer seeds along his route. He was back in Monterey in 1853, where he learned of the discovery of giant sequoia, journeyed to the discovery site at North Grove Calaveras, and returned to England with the first seeds, seedlings and specimens of the most massive tree seen by humans before or since—his most famous collection. But did he also bring radiata seeds from Monterey?

Lobb returned to California in early spring of 1854, and from then through 1856 little is known of his whereabouts. He reportedly visited Cedros Island during this period, but the records are not clear on that possibility. He may have been ill with a tropical disease contracted during his earlier collecting period in South America. In 1857, he left the employ of Veitch and collected for Clapton Nursery in 1858. By 1862 he was no longer active, and he died in San Francisco in 1864.

In preparing his 1973 monograph on Lobb, Ewan was frustrated in obtaining correspondence between Lobb and Veitch that documented all of the seeds that were collected and shipped. Ewan noted the secretiveness enforced by Veitch on Lobb with respect to details of the species Lobb collected and shipped to England, and the evident destruction of Lobb's letters and the firm's records before it went out of business. That secretiveness has impeded scientists 140 years later from learning interesting and possibly important details of the work accomplished. Radiata (or its synonyms) is nowhere mentioned among those records of Lobb's collections from Monterey that still existed in 1965 (Ewan 1973), although the 1910 book *The Trees of Great Britain & Ireland* (Elwes and Henry 1910) implies that radiata seeds were in Lobb's 1850 and 1851 consignments to Veitch. As noted below, Veitch subsequently made at least two shipments of radiata seeds to help found the plantations in New Zealand, and possibly those in Australia as well. As it is highly likely that those were collected by Lobb, it would be useful to know when and, more important, where Lobb made those collections. It is also interesting that Lobb's fame was based on his acquisition of Santa Lucia fir and giant sequoia seeds, and that records of his radiata collections were not even maintained. Yet, a century later, the impact of his radiata collections on Earth's forest resources dwarfs those of his other collections.

Near the close of the century, early documented shipments of radiata seeds to Chile took a different but perhaps genetically similar route. Those shipments were also accomplished through connections with Europe rather than with North America. Arturo Junge, who owned an ornamental nursery near Concepción, had received his training at the horticultural school in Erfurt, Germany. In 1886 he ordered seed samples of 50 conifer species for Chile from three European suppliers: Schmidt in Erfurt, Von Spreckelsen in Hamburg and Vilmorin in Paris (Junge 1953). Those seeds arrived in late 1886 or early 1887, to be sown in the winter of 1887. Seeds supplied by Vilmorin as Douglas-fir (Contesse 1987) produced seedlings that were clearly another species, but the seedlings performed outstandingly, and were identified by a Dr Neger as radiata.

In summary, it seems likely that most of the mid-to-late-19th-century radiata seeds in and disseminated from Europe came from Lobb's collections for Veitch, or perhaps from some other unknown collector working for Veitch. Some of the seeds, however, came directly from the Douglas collections, and/or secondarily from trees in England and Scotland grown from the Douglas and/or Hartweg collections, and/or even tracing back to Collignon's 1787 collection. Importantly, it appears that most or all of them trace their likely origins to somewhere in the Monterey population. Additional trees, of the *binata* variety of radiata, are recorded as growing at Kew in England in 1910, originating from collections sent from Guadalupe Island in 1875, 1892 and 1896 (Elwes and Henry 1910), well after the main period of seed export to the Southern Hemisphere.

### *2.3.2 Australia*

The date for Australia's first importation of radiata is unclear. Several early importations, of seed or seedlings, were of unspecified pines (Shepherd 1990) which may or may not have included radiata. Shepherd (1960) found, in the archives of the Sydney Botanic Garden, a record "1 insignis plant from Kew, 1 insignis plant from Veitch in 1854." A more specific record involves the arrival, dated as 13 December 1857, on a ship from England (Plymouth and London); one potted "*P. insignis*" was received by the Sydney Botanic Garden, and other potted trees and a consignment of seeds of *P. insignis* went on to the Hobart Royal Botanic

Gardens in Tasmania and the Melbourne Botanic Gardens in Victoria. Von Mueller listed radiata as growing at the latter in 1858 (Fielding 1957a, 1957b).

It is very likely, however, that several other importations of radiata had arrived in Australia before 1857. There are unsubstantiated reports that a radiata was growing on the grounds of Entally House, near Launceston, Tasmania, dating back to the 1840s. The Sydney Botanic Garden received a mixed lot of California pine seeds in 1851. Other shipments of radiata seeds seem to have arrived during the early- and mid-1850s without currently-known documentation. For example, the Hobart Botanic Gardens recorded *P. insignis* as present there after 1855, with seeds from cones produced by these trees being sent to the Melbourne Botanic Gardens in 1865. *P. insignis* was listed for sale in 1857 by Adcock's Nursery in Geelong, and by five others by 1865 (Brookes and Barley 1992), and as under cultivation in the Gardens in 1858 (but not in 1857) (Mueller 1858a, b). Moreover, a radiata plant, reputedly three years old, is recorded as having been imported from Sydney to New Zealand in 1859 (Shepherd 1990), which would presumably put Australian possession of radiata seeds back to 1856 or before.

In 1861, von Mueller distributed 400 seedlings of "*P. insignis*" from the Melbourne Botanic Gardens; in 1862 he recorded receipt of a shipment of unspecified California pines from C. Walker, a San Francisco nurserymen; and in 1866 he distributed 4500 "*P. insignis*" seedlings (S. Maroske, Melbourne Botanic Garden, pers. comm. to K.G. Eldridge). In these early days, radiata was being planted for shelter, firewood and as amenity trees, particularly in Victoria and Tasmania. By 1866, potted radiata pines donated by von Mueller had been planted in an avenue in South Australia's Adelaide Botanic Gardens, and they were reported as thriving and over 16 m tall by 1879. A large purchase of radiata seeds from "Europe" was recommended (and presumably made) in 1869. An 1891 report by von Mueller, who had become an enthusiastic promoter of this species, noted radiata as having been "… extensively distributed through the Colony of Victoria and also some other parts of Australia since 1859 …" (Mueller 1895).

For a while, there was speculation that Australia's several land races of radiata all traced back to the few trees received by the Melbourne, Hobart and Sydney (New South Wales) Botanic Gardens in 1857. But the Hobart Botanic Garden records, the nursery advertisements, and the extensive distributions beginning in 1859 by von Mueller and others, make it unlikely that Australia's land races originated from only those few trees.

In addition to active private nurseries (Brookes and Barley 1992), four state nurseries, producing stock of numerous forest-tree species, had been established in Victoria by 1901, the first at Mt Macedon in 1872. Several species were established in an adjacent 50-acre plantation commencing in 1873; radiata was added there in 1880 and soon after at two other sites. Unfortunately the Macedon nursery and associated plantations were burnt in 1883 (Algar 1988; Moulds 1991).

Early plantings of radiata in New South Wales were made in substantially different climates (Grant 1989): a 0.8-ha private plantation near Albury in 1878, 83 trees among maritime pines (*P. pinaster*) in a small pilot planting by the state in 1885 near Cootamundra, and further very small plantings at Gosford in 1888 and

1894. In Western Australia the first recorded trial plantings of pines had been made on coastal dunes near Bunbury in 1897; they failed (R. Underwood pers. comm. 2012). In following years plantings of radiata had mixed success, continuing to do poorly on the poor sandy soils where it was mostly planted. In both of these states significant follow-up planting of radiata occurred only slowly. We have traced no such early records of radiata plantations in Tasmania.

Among the Australian states, South Australia is the only one where there are sufficient records for this period to warrant more detailed treatment, which now follows. Because of their small area of diminishing native forests, South Australian foresters had to learn to manage forest plantations early. The first period in the development of plantation forestry in South Australia focused on the most pressing needs: to conduct species trials, and to mill locally-grown wood of radiata and other candidate species to demonstrate the feasibility of the proposed plantation enterprise (Boardman 1988).

Credit for recommending the extensive testing of radiata in the early 1870s perhaps belongs to Edwin Smith. Smith was a Scottish-trained nurseryman who saw the potential in this remarkable pine. He was also well-placed to be effective, being both brother-in-law and advisor to Goyder, the Surveyor-General (Carron 1985).

A curious note concerning Australia's 19th-century radiata trees takes place in South Australia about 1878. Forest Conservator J. Ednie Brown began a set of large-scale species-introduction trials. While seed acquisitions of most of the included species are well documented, radiata by any name is not mentioned in those records. Bob Boardman (1996), a student of the origins of South Australia's land races, has suggested that the radiata seeds did not need to be purchased. He reasoned that shortly before the species-introduction trials were established at Bundaleer and Mt Gambier, the young trees in the avenue of radiata in the Adelaide Botanic Garden were probably bearing many cones. Unlike seeds of most of the other species in the trial, seeds of radiata did not need to be purchased abroad; they could just be picked from the trees in Adelaide. Anyway, the first recorded forest plantation in South Australia was at Bundaleer in 1876 (Lewis 1975), perhaps in advance of any systematic species-introduction trial, and radiata was presumably included.

There is a record of a purchase of "*Pinus radiata* true to name" by South Australia in 1881, from Lawson's Seed Merchants in Edinburgh, but where the supplier obtained the seed from is conjectural. By good luck, adjacent compartments of an 1882 plantation on the Wirrabara Forest Reserve were planted with seedlings of "regular *Pinus insignis*," probably from seed collected from the Adelaide trees or from other trees tracing to von Mueller, and seedlings of "*Pinus radiata* true to name" from the 1881 importation of seed from Edinburgh. That plantation was harvested in 1920, the first major sale of plantation timber in South Australia (Boardman 1996). As such, it attracted much attention. By more good luck, the Conservator at the time was Walter Gill, also a professional photographer. His several photographs, included in the 1920–1921 Annual Report of the South Australian Woods and Forests Department, included views of the adjacent compartments that had been called "*Pinus insignis*" and "*Pinus radiata*" when planted. They showed trees that had no noticeable differences in average appearance, a conclusion reinforced by the recollections of Robert Stolz, a cadet forester in 1920 at Wirrabara and familiar with that early plantation. Furthermore, the pictured trees from these two seed sources of radiata were fully consistent with trees later grown in the region from known samples of the Monterey population, and did not closely resemble trees later grown there from the other native populations (Boardman 1996).

This history, and the performance of the trees in the 1882 Wirrabara plantation, has led Boardman (1996) to infer that all of the radiata planted in South Australian plantations in the late 19th and first half of the 20th centuries traced their lineages exclusively to the Monterey population, and conceivably to the original collection made by David Douglas. This possibility cries to be checked by molecular techniques that are still becoming fully available. If so, this perhaps narrow genetic base was propagated and continued through several generations of South Australian plantations. It seems likely that South Australia did not receive the major seed importations that other Australian states did during the first half of the 20th century.

### *2.3.3 New Zealand*

Perhaps the most remarkable things about radiata's introduction into New Zealand are how soon that introduction occurred after colonization began in earnest (Sinclair 1959), and then how quickly this little-known tree was put to widespread use.

There have been some unsubstantiated reports of early importations of radiata to New Zealand. While Shepherd (1990) postulated that Andrew Sinclair may have been involved in introducing radiata to New Zealand as early as 1844, we have found confirmation to be notably absent. Shepherd also mentioned old radiata pines in Isel Park, Nelson, with a date of about 1850; However, personal inspection (RDB) of the map of the old trees and the recorded planting dates (Douglas 1975) gave no compelling reason to believe that any radiata were planted there before the early 1860s. Shipments documented only as including seeds of various conifers were received in New Zealand during 1854–1857 from Veitch and Sons, Veitch's seed company. Those shipments may well have included some radiata pine seeds. A plausible case of introduction around 1856–1858 involves trees at Pah Farm, Auckland, involving a landowner with links to San Francisco (John P. Adam pers. comm. 2012). It is based on photographs of radiata trees some years after planting, on the appearance in the photographs of those trees beside a house, and on circumstantial evidence as to the date of the photographs.

The first clearly recorded introduction of living radiata was in 1859, to J.B.A. Acland for the Mt Peel sheep station in South Canterbury. It was a three-year-old potted plant from Shepherd & Co.'s Darling Nursery in New South Wales (Shepherd 1990). Also it is specifically documented that Veitch shipped radiata seeds to New Zealand in 1859 and again in 1863 (*op. cit.*). In all, about 20 importations of radiata seeds into New Zealand were recorded during the period 1859–1885 (Shepherd and Cook 1988; Shepherd 1990). Nurserymen's newspaper advertisements started featuring radiata from 1862 (D.J. Mead, pers. comm. 2013).

The earliest recorded importations were small, on a specimen-tree scale, but the success of radiata as a young tree quickly led to larger importations beginning in the mid-to-late 1960s.

Unfortunately, none of the records available from those shipments indicate where the seeds were collected (Shepherd and Cook 1988; Shepherd 1990). Most shipments originated from and were labeled merely “San Francisco” or “Santa Rosa” or “Europe.” Furthermore, these records do not indicate how many or which sub-populations were sampled (particularly interesting would be samples of native stands occupying ecologically different sites within the same population), nor how many trees provided seeds for each collection. Principles of evolution and population biology were not an established part of botanical thinking or commerce in that period. While several of these records are good as to the quantities of seeds received, questions of place of origin and numbers of seed parents apparently were not considered.

The “San Francisco” collections do have some further documentation (Shepherd and Cook 1988; Shepherd 1990). As demand for radiata seed built, an 1868 consignment was from Professor Albert Kellogg through the California Academy of Sciences in San Francisco. Subsequent larger consignments from “San Francisco” were from Miller & Sievers, a commercial seed, nursery and florist business in San Francisco. As mentioned in Sect. 2.1.3.2, the earlier botanists in North America and Europe seem to have received most or even all of their radiata collections from Monterey. By the 1860s, however, there was much commerce between San Francisco and the dairy farms and sawmill in the nearest radiata population, at Año Nuevo. We (WJL and RDB) have personally noted that closed, seed-containing cones have appeared more abundant at Año Nuevo than at Monterey, and that may have been the case in the 1860s and 1870s as well. Thus our recent observations on cone abundance and these historical records make it possible, even likely, that the radiata seeds sent to New Zealand came first from a few small collections in the Monterey population, and later from larger collections that might have originated in any of the mainland populations, but seem likely to have been collected at Año Nuevo. (Subsequent research, see Burdon 1992; Burdon et al. 1997, makes this very plausible.)

The available historical records document a minimum estimate of how many introductions were made to New Zealand, and provide data on how large some of them were. Kellogg’s records, which might have been the best for the consignments from California, were evidently destroyed in the fire that followed the 1906 San Francisco earthquake. The documented shipments indicate a range from as few as two seed parents to about 200,000 seeds, probably from several to many trees; if all of those imported seeds were sown and germinated at typical rates, they could have produced about 500,000 seedlings.

After 1882, most of the radiata planted in New Zealand almost certainly came from seeds collected from cone-bearing trees in New Zealand. By then abundant closed cones containing viable seeds would have been available locally. Locally collected seeds would then have come disproportionately from the earlier of the then-extant introductions that, being older, would have been producing heavier crops of cones. A shift in seed sources was indicated by the subsequent absence of radiata in tree-seed acquisition records and in the trend to lower prices in nursery lists. The price of radiata seedlings fell sharply, presumably as inexpensive local seeds replaced expensive imported seeds. Thus, the New Zealand land races were most likely founded by the population samples imported prior to 1882, and were then shaped largely by subsequent natural (and semi-natural) selection in New Zealand.

There appear to have been several networks involved in the early introductions of radiata. A loose network evidently existed very early on between New Zealand landowners and nurserymen in Sydney, the latter having evidently obtained radiata seed and at least one small potted tree through Veitch in England. Another loose network may have existed among general merchants, between Auckland and San Francisco, with some migration each way; for them, movements of plant material would have been an incidental activity. Later on, there was the documented, country-wide network run by Hector from the Wellington Botanic Garden. Other networks, however, could well have existed.

#### 2.3.3.1 Canterbury

While over 50% of New Zealand was forested at the time of European colonization, the windswept plains of Canterbury, in eastern central South Island, were essentially treeless. "The dream of Canterbury was the dream of a tree, and thousands upon thousands were planted across the Plains to provide shelter for agriculture and settlement, and to create the now-green city of Christchurch" (Hegan 1993).

New Zealand's first clearly recorded radiata, planted in 1859 at the Mt Peel sheep station in South Canterbury (Sect. 2.3.3) is still thriving (Mead 2013, fig. 1.2). Measured at slightly over 50 m tall (Burstall and Sale 1984), its recent breast-height diameter measurement (R. Woollons pers. comm. to RDB 2011) was just over 3 m ( based on 9.43 m circumference), but this diameter is inflated by some fluting from both ground level and large low limbs. In the same district, on the property of a Mr Grey on the present outskirts of the township of Geraldine, two specimen trees of radiata were planted in 1860 (Burstall and Sale 1984) among European hardwoods. One of these trees, the "Grey pine" (Fig. 2.15) is still alive and is also enormous. Nearly 50 m tall, with a very cylindrical bole, it has a breast-height diameter of 2.67 m; unfortunately, in 2006 it suffered significant snow damage, but it is still showing good vitality.

Notable early planting of radiata in South Canterbury took place at Albury Park, initially in 1868, and on a larger scale a few years later with a stand that was still in good condition at around age 105 years (Fig. 2.16).

A key player in the early radiata acquisition and subsequent acceptance drama was T.W. Adams, who emigrated from England in 1862 at age 19. After three years working for an earlier settler, he purchased a farm at Greendale, west of Christchurch. He started planting trees in 1866. His trials were systematic, with good records of plantings and their growth, and he wrote about them in a series of articles appearing mostly in Canterbury publications between 1886 and 1913. By 1910, his plantations covered over 60 ha and contained 800 species of timber

**Fig. 2.15** The "Grey pine," Geraldine, New Zealand, during the 1960s

trees, fruit trees and shrubs in trials and in his arboretum. He had received seeds from botanists and collectors all over the world. As they grew, his trees are likely to have been sources of both information and seeds for the plantations then being established in Canterbury by the Selwyn Plantation Board. His passion for forestry was legendary, but there are reports that his five sons would sometimes have preferred to play sport on Saturdays rather than plant trees (McKelvey 1991).

Radiata may not have technically qualified as a suitable tree in the terms of the 1871 Forest Trees Planting Encouragement Act. Rather, radiata was often planted in the 1870s by "independent farmers who had dared to plant trees which were then officially considered fit only for firewood" (Simpson 1973). There was doubtless a rapid increase in plantings of radiata to provide windbreaks and other shelter on the windswept Canterbury Plains. Prime requirements for a shelter tree were rapid growth and bulk; radiata quickly proved to provide both of these, and within 10 years of its introduction it had become the species of choice for shelter and then firewood in Canterbury (Hegan 1993). Advertisements from a Canterbury nursery listed 500,000 radiata seedlings for sale in 1873, and 100,000 in 1876 (Shepherd 1990). Unfortunately, no records of the origins of these seedlings have

**Fig. 2.16** Early exotic radiata planting (in background), Albury Park, South Canterbury, New Zealand, being felled at around age 105 and milled into lumber (Photo RDB 1993)

been found, nor have we been able to confirm the actual numbers. A "plantation" area (in unstated species) of 3284 ha was reported in Canterbury as of 1881 (Burdon and Miller 1992). By the 1890s, the Selwyn Plantation Board was systematically establishing plantings on the Canterbury Plains.

#### 2.3.3.2 Auckland

While it now appears that the first plantings of radiata in New Zealand may have been in the Auckland region, there are better-documented plantings that were made there in the following few years. During the late 1850s and early 1860s Sir George Grey regularly imported plants and seeds (including pines) to Auckland from Sir William Hooker, Director of London's Kew Gardens. Indeed, very old radiata pines, which appear to have originated from the Monterey population, are still present on the property once owned by Grey on Kawau Island. In 1862, David Hay advertised metre-tall *P. insignis* plants from his Auckland nursery (Shepherd 1990). These were probably mostly sold and distributed as individual specimen trees.

One of the earliest documented plantings in New Zealand took place in 1866 in the Auckland area of North Island. Mr W. McLaughlin, a retired merchant from Peru whose hobby was tree planting, imported radiata seeds from "Santa Rosa," California, in 1865. He raised seedlings that year on his Puhinui Estate near the Auckland suburb of Papatoetoe and planted them out as a shelter belt the following year. He later cut out an orchard and planted radiata in plantation form as an investment. This plantation was regarded as having outstanding growth and form. But when it was eventually felled in 1959 (New Zealand Forest Service 1959), no seeds had reportedly been collected from it for use elsewhere (Healy 1982). (It is intriguing that Santa Rosa, California, is where a famed fruit-tree breeder, Luther Burbank, did his major work—but he did not begin this work until 1875—Encyclopedia 1979).

The record of McLaughlin's seed import suggests that Rancho Santa Rosa in the Cambria population was the source of this earliest and highly successful for-investment plantation in New Zealand. However, Martin Bannister and Margot Forde, both familiar with the native radiata populations, visited the plantation before it was felled, and Forde was firmly of the opinion that it was Monterey-origin stock (M.H. Bannister pers. comm. to RDB 1965). Otherwise, the native-population origin of this early Auckland plantation remains an intriguing mystery. The same applies to how the seed came to be imported, although it is suspected that a network of general merchants between Auckland and San Francisco would have been involved.

Another documented 1866 planting in Auckland, involving six trees of radiata among 18 other exotic conifer species, revealed its much superior growth rate, with trees up to 18 m tall by 1879 (Gillies 1879).

Later on, the multiple, widespread distributions of seed and/or nursery seedlings by Hector from the Wellington Botanic Garden contributed to plantings of radiata in this region, presumably along with various unrecorded private importations.

#### 2.3.3.3 Elsewhere in New Zealand

In the 1860s, most radiata planted in parts of New Zealand other than Canterbury were for shelterbelt and aesthetic purposes (Burdon and Miller 1992). The distributions from the Wellington Botanic Garden (Sect. 2.2.2.2), plus various private acquisitions, were no doubt used in a great variety of ways. Of particular note, plantations of radiata and maritime pines were established in 1873 near Matamata, south of Auckland in the eastern Waikato Region, presumably from private seed importations. When compared with the performance of maritime pine there, the greatly superior growth and straightness of the radiata contributed importantly to the decision to extensively plant radiata pine in the 1920s (Page 1923).

### *2.3.4 South Africa*

Three exotic pine species were effectively introduced into South Africa well before radiata—Scots pine sometime before 1714, and maritime pine and Italian stone pine (*Pinus pinea*) in the late 1700s, with commercial pine plantations started in 1825 (Poynton 1977). Viable seeds were recorded from radiata pines in the Caledon District in 1857, indicating an early and unrecorded importation as seeds or young plants, probably before 1850 (Poynton 1960, 1977).

Radiata and several other pine species were recorded as growing at the Cape Peninsula by 1865, long before colonists discovered gold in South Africa. It is possible that some South Africans were also seed or potted-tree customers of Veitch & Sons, or received additional seed of radiata from other sources, at about the same times that the first radiata pines were arriving in Australia and New Zealand. However, its larger-scale importation, or perhaps the local collection of seed from the few radiata planted earlier, began in the late 1870s or early 1880s. The first mention of its use in plantations was in 1883 (Scott 1960), 250 radiata seedlings (possibly inbred) derived from the seeds of a single Cape Town Botanic Gardens tree of unknown origin being recorded in the Tokai Plantation nursery (Poynton 1977). However, Poynton also noted that very little commercial planting of radiata was done before 1910.

### *2.3.5 Chile*

The first recorded introduction of radiata to Chile had occurred inadvertently, in seed ordered by Arturo Junge from Vilmorin in Paris, when a seedlot labelled Douglas-fir proved to be radiata (Sect. 2.3.1). Its very rapid growth and its identification as radiata presumably led to an order specifically for radiata. Of recent German extraction, Junge kept meticulous records. He paid 9 marks for 227 grams of radiata seed, received as *P. insignis* from Erfurt, Germany, in 1890 (Krebs 1973). That was the first recorded case of intentional importation of radiata pine into Chile. Compared with the dominant Spanish-colonial view, north-western Europeans of the mid-to-late 1800s had an almost reverential attitude toward nature, trees and forests; Junge seems to have shared this attitude. His journals include details on hundreds of tree species that he and his nursery staff received and tried in the vicinity of Concepción. Of these, only radiata, macrocarpa cypress, bluegum (*Eucalyptus globulus*) and the Lombardy poplar clone showed sufficient promise for widespread planting. Radiata's attractiveness as an ornamental was quickly apparent, and Junge's nursery donated some to the city of Concepción for planting, including on the site of the University of Concepción (Krebs 1973). At least some of these donated trees were planted on the Cerro Caracol within the city and were still standing in 1978 (RDB personal observation), and may well be the oldest radiata in Chile. During the same visit to Chile RDB observed some very large, old radiata pines in Parque Saval, Valdivia, where the original German settlement occurred.

Radiata's performance in species trials around Concepción led naturalist Federico Albert to both recommend and provide seedlings of radiata to landowners in coastal areas in the mining region. Since the local coastal forests that had supplied timbers for the mines were nearing exhaustion, both pines and eucalypts were planted to replenish the supply (Clapp 1995). Sr Cousiño, one of the mine owners, also had radiata planted in his botanical park ("Parque Cousiño"), at Lota, slightly to the south of Concepción. The park had been developed during 1862–1874. In the early 1970s, the tallest radiata pines in the park were 40 m high, and of a diameter too large for available increment corers. The caretaker claimed they were 130 years old, thus planted in the 1840s, but there were no corroborating records. A smaller radiata at the park edge was cored and had 65 rings, so its age was not noteworthy and it may have been younger than the largest individuals. It is possible that all of these radiata pines were added to the park plantings well after its original establishment, and thus are probably from the Junge importations (Krebs 1973).

In addition to the radiata pines on Cerro Caracol and near Concepción, plantations near Lota were personally noted by RDB in 1978 to have relatively small cones strongly suggestive of the Monterey native population (Fig. 2.7). Those recent Lota plantations were presumably descended from plantings made there during 1907–1912 (Contesse 1987). Seedlots collected further to the south, in the nearby Arauco peninsula, during the 1970s, contained smaller seeds than seedlots from other regions (CONAF Centro de Semillas records), also suggesting a Monterey origin. This in turn suggests that stands in that part of Chile had originated from one or more early importations by Junge.

Junge had received his training at the horticulture school in Erfurt, from where he ordered his radiata seeds. The supplier there, Schmidt, apparently got seeds from England. It is not clear whether, by 1890, these English-source seeds were still coming from the Douglas collection and their offspring, or from some other lineage growing in England, or perhaps they had been acquired more recently from somewhere in California. Common-garden trials and DNA studies may help sort this out.

### *2.3.6 Spain and Portugal*

While Spain was slow to begin to recognise and use radiata from its Californian colony, at least a few were planted in early decades after the colony was lost. Even earlier, there is a record of an importation through France in 1840 for planting in an unidentified Spanish botanical garden (Mead 2013). A famous specimen tree was planted in 1860 in a park at Lequeitio, 40 km west of San Sebastian; it measured over a metre in diameter in 1928 (Scott 1960). This was reportedly the parent and then ancestor of a high proportion of later plantings in Spain (L.D. Gea pers. comm. 2011). Similarly, a radiata planted tree sown in 1883 at Camancha, on the Portuguese island of Madeira, was 30 m tall at age 24, and others there were growing "with extraordinary rapidity" by 1910 (Elwes and Henry 1910).

Recent DNA research (Aragonés et al. 1997) indicates that the radiata land race in the Basque Country of Spain originated mainly from the Año Nuevo population.

### 2.3.7 The British Isles

Radiata pines from the Douglas and possibly Collignon collections of Monterey-population origins were being grown with marginal success in coastal England and Scotland during the latter half of the 19th century. Conceivably, some trees of Cambria origin (the Hartweg collection) and some from among three or more Guadalupe Island collections may have made their way from sexually competent parents at Kew and various pineta into general use by the turn of the century.

Radiata pines, probably of mostly Monterey origins, were performing much better in Wales, coastal Scotland and particularly Ireland during this period, in some areas "thriving amazingly" (Elwes and Henry 1910). All plantings during this period, however, seem to have been only on an amenity scale.

### 2.3.8 Other Countries

In most other regions, such as those bordering all coasts of the Mediterranean Sea, in East Africa, and in South America, extensive trials of this species had not yet begun by 1900. Interestingly, two very large radiata pines, clearly of Guadalupe Island origin, were identified growing in La Jolla, near San Diego, California (WJL), but no record of their planting date or seed collection could be found.

## 2.4 Summary of Domestication Progress

The activities of Native Americans doubtless had some influence on the genetic makeup of mainland populations, especially Monterey. There, the practices of frequent burning and harvesting of seed for food would have entailed selection through survival of future parent trees with thicker bark and smaller cones and seeds, but cannot be counted as actual domestication. The Spanish colonists then had modest influences, with some selective cutting of the straighter trees around Monterey which would have been dysgenic, and some cutting of mine timbers on Cedros Island. Then US settlers basically "mined" native stands at Monterey, for some sawn timber but mainly as fuel for whale oil extraction and railroad engines, which would have tended to be dysgenic where trees were selectively logged for timber.

First steps towards domestication arguably occurred with English nurserymen in the 1830s propagating the species as rooted cuttings, presumably to extend the small available amounts of seed as a novelty species. Introduction of radiata elsewhere began mainly during 1840–1860, initially as an ornamental or a botanical curiosity, followed by larger plantings for producing shelter and firewood. Its introduction to Chile, however, was not until 1884, and was apparently accidental.

While some substantial exotic plantings of radiata were soon established, and it was locally an important source of native sawn timber at Monterey and Cambria, only very small amounts were sawn into lumber elsewhere before 1900, in areas within Australia and New Zealand that had very limited supplies of native timber. Indeed, no major commitment to its development as a timber crop was made before 1920. Long before then, however, local exotic stands had become the basis for self-sufficiency to meet national seed requirements, at least within New Zealand.

Impending exhaustion of virgin timber supplies in several countries was giving impetus to create large resources of forest plantations. In this connection, the work of enthusiastic proponents had helped set the stage for a dramatic upsurge in planting radiata which came after World War I in New Zealand. It had become a favourite quick-growing tree for shelter and firewood there and elsewhere in the Southern Hemisphere, and in near-coastal California for parks and new residential areas.

## References

Algar WH (1988) Forestry and forest products. Australian Academy of Technological Sciences and Engineering, Parkville, p 60. Reprinted from (pp. 193–252) Technology in Australia 1788–1988 for Australian Forest Development Institute on the occasion of The International Forestry Conference for the Australian Bicentenary 1988

Allsop F (1973) The first fifty years of New Zealand's forest service. Government Printer, Wellington, p 123

Anon (2013a) To reject *Pinus californiana* Loisel. (Pinaceae). Taxon 62(6):1321

Anon (2013b) Updated Chile forest incentive scheme winners and losers. South Hemis For Ind J 18(3):4

Aragonés A, Barrena I, Espinel S et al (1997) Origins of basque populations of radiata pine inferred from RAPD data. Ann For Sci 54:697–703

Axelrod DI (1967a) Evolution of the Californian closed-cone pine forest. Philbrick, pp 93–149

Axelrod DI (1967b) Geologic history of the Californian insular flora. Philbrick, pp 267–315

Axelrod DI (1980) History of the maritime closed-cone pines, Alta and Baja California. University of California Publications in Geological Sciences Vol 120: p 143

Axelrod DI (1981) Holocene climatic changes in relation to vegetation disjunction and speciation. Am Nat 117:847–870

Bannister MH (1965) Variation in the breeding system of *Pinus radiata*. In: Baker HG, Stebbins GL (eds) The genetics of colonising species. Academic Press, 353–374

Bannister MH (1973) The origins of radiata pine in cultivation. What's new in forest research 2. New Zealand Forest Research Institute, Rotorua, p 4

Bannister MH, McDonald IRC (1983) Turpentine composition of the pines of Guadalupe and Cedros Islands, Baja California. N Z J Bot 21:373–377

Belich J (1994) Making peoples: A history of the New Zealanders, from polynesian settlement to the end of the nineteenth century. University of Hawaii Press, Honolulu.

Boardman R (1988) Living on the edge—the development of silviculture in South Australian pine plantations. Aust For 51:135–156

Boardman R (1996) 1 October letter to WJL

Brookes M, Barley R (1992) Plants listed in nursery catalogues in Victoria 1855–1889. Ornamental Plant Collections Association Inc., South Yarra, p 316

Burdon RD (1992) Genetic survey of *Pinus radiata*. 9. General discussion and implications for genetic management. N Z J For Sci 22:274–298

Burdon RD (2004) Genetics of *Pinus radiata*. In: Burley J, Evans J, Youngquist JA (eds) Encyclopedia of Forest Sciences 3. Elsevier Academic Press, Oxford, pp 1507–1516

Burdon RD (compil.), Miller JT (ed) (1992) introduced forest trees in New Zealand: recognition, role and seed source. 12. Radiata pine (*Pinus radiata* D.Don). FRI Bulletin 124. New Zealand Forest Research Institute. Rotorua, p 59

Burdon RD, Bannister MH, Madgwick HAI et al (1992a) Genetic survey of *Pinus radiata*. 1: Introduction, description of experiment, and basic methodology. N Z J For Sci 22:119–137
Burdon RD, Bannister MH, Low CB (1992b) Genetic survey of *Pinus radiata*. 2: population comparisons for growth rate, disease resistance and morphology. N Z J For Sci 22:138–159
Burdon RD, Broekhuizen P, Zabkiewicz JA (1997) Comparison of native-population and New Zealand land-race samples of *Pinus radiata* using cortical oleoresin monoterpenes, pp 50–56 in Burdon RD and Moore JM (eds) IUFRO '97 Genetics of Radiata Pine. Proc NZFRI-IUFRO Conference 1–4 December and Workshop 5 December, Rotorua, New Zealand. FRI Bulletin 203.
Burstall SW, Sale EV (1984) Great trees of New Zealand. AH & AW Reed. p x + 283
Cameron RJ (1964) Destruction of the indigenous forests for maori agriculture during the nineteenth century. *N Z J For* 9:98–109
Carron LT (1985) A history of forestry in Australia. Australian National University Press, Canberra, p x + 355
Clapp RA (1995) The unnatural history of the Monterey pine. Geogr Rev. 85(1):1–19
Clark DJ (1991) Monterey county place names. Kestrel Press, Carmel Valley, p 737
Coffman T (1995) The Cambria forest. Coastal Heritage Press, Cambria, p 77
Contesse (González) D (1987) Apuntes y consideraciones para la historia del pino radiata en Chile. Boletín de la Academía Chileno de la Historia No. 97a [1986]: 351–373
Critchfield WB, Little EL (1966) Geographic distribution of the pines of the world. U.S. Department of Agriculture, Forest Service, Miscellaneous Publication 991, Washington
Cylinder P (1996) 11 October 1996 report at Carmel Pitch Canker Symposium, and personal communication to WJL
Dallimore W, Jackson AB (1954) A handbook of coniferae including Ginkgoaceae. Third edn, with supplement. Edward Arnold & Co, London, p xvi + 686
Donald DGM (1993) Radiata pine in southern Africa. Lewis and Ferguson, pp 353–364
Douglas B (1975) Isel park—a woodland garden. Royal New Zealand Institute of Horticulture, National Diploma of Horticulture thesis. p 101+
Drury A, Neasham VA (1954) History at Point Lobos. In: Drury A, Engbeck JH (eds) Point Lobos: interpretation of a primitive landscape. University Extension. University of California, Berkeley, pp 67–73. 80
Dunning D (1916) A working plan for the Del Monte Forest of the Pacific Improvement Company. MS thesis in Forestry, University of California, Berkeley. p 78
Elwes HJ, Henry A (1910) The trees of Great Britain & Ireland. *Pinus radiata*. Vol V. Privately published in Edinburgh, pp 1079–1084
Encyclopedia 1978–79 The new illustrated Columbia encyclopedia. Vol 1–24. Columbia University Press, NY
Ewan J (1973) William Lobb, plant hunter for Veitch and messenger of the big tree. University of California Publications in Botany 67. University of California Press, Berkeley, p 36
Fielding JM (1957a) The breeding of Monterey pine in the Australian Capital Territory. Paper to 7th British Commonwealth Forestry Conference, Australia and New Zealand, p 19
Fielding JM (1957b) The introduction of Monterey pine to Australia. Aus For 21:15–16
Flannery TF (1994) The future eaters. Reed Books, Port Melbourne, p 423
Forde MB (1962) Variation in the natural populations of Monterey pine in California. PhD dissertation. University of California, Davis, p 291
Forde MB (1964a) Variation in native populations of *Pinus radiata*. 1. Sampling methods and branch characters. N Z J Bot 2:213–236
Forde MB (1964b) Variation in native populations of *Pinus radiata* 4. Discussion. N Z J Bot 2:486–501
Forde MB (1966) *Pinus radiata* in California. N Z J For 11:20–40
Gillies TB (1879) Notes on the growth of certain trees on scoria soil near Mount Eden, Auckland. Trans R Soc N Z 12:357–358

Gordon BL (1977) Monterey bay area: natural history and cultural imprints, Second edn. Boxwood Press, Pacific Grove, p 300
Gordon G (1875) The pinetum. A synopsis of all the coniferous plants at present known, 2nd edn. Simpkin Marshall & Co, London, p xxii + 353
Grant TC (1989) History of forestry in New South Wales 1788 to 1988. The Author, Sydney, p 320
Greenlee JM, Langenheim JH (1990) Historic fire regimes and their relationship to vegetation patterns in the Monterey Bay area of California. Am Midl Nat 124:239–253
Griffin J (1970–1990) (Personal communications to WJL, Dr James Grifffin, University of California Hastings Natural History Reserve)
Griffin J (1972) What's so special about Huckleberry Hill on the Monterey Peninsula? In: Howitt BF (ed.) Forest heritage: a natural history of the Del Monte Forest. Del Monte Forest Foundation, Pebble Beach, pp 3–7. p 56
Halkett JC (1991) The native forests of New Zealand. GP Publications, Wellington, p 149
Harris JM (1991) Radiata pine in New Zealand. Chapter 1. In: Kininmonth JA, Whitehouse LJ (eds) Properties and uses of New Zealand radiata pine. NZ Forest Research Institute, Rotorua, pp 1-1–1-7
Healy B (1982) A hundred million trees. The story of N.Z. Forest Products Ltd. Hodder and Stoughton, Auckland, p 222
Hegan C (1993) Radiata, the prince of pines. N Z Geogr 20(Oct–Dec):88–114
Hillyard D (1996) 11 Oct. 96 talk at the Carmel Pitch Canker Symposium, and personal communication to WJL
Home RW, Lucas AM, Maroske S et al (1998) Regardfully yours: selected correspondence of Ferdinand von Mueller. Volume 1, 1840–1859. Peter Lang, Bern, p 842 plus two subsequent volumes
Howard D (1972) Indian shell-midden sites. In: Howitt BF (ed.) Forest heritage: a natural history of the Del Monte Forest. Del Monte Forest Foundation, Pebble Beach, pp 39–43. p 56
Jones & Stokes Associates Inc. (1994) Final. Monterey pine forest ecological assessment: historical distribution, ecology, and current status of Monterey pine. September 12. (JSA 94-083) Sacramento Ca, USA. Prepared for The Nature Conservancy, Sacramento Ca, and the California Department of Fish and Game, Monterey, Ca
Junge A (1953) Historia del 'pino insigne' en Chile, y el premio 'Arturo Junge Sahr'. Chile Maderero 3(10):4
King NL (1938) Historical sketch of the development of forestry in South Africa. *J S Afr For Assoc* 1:4–16
Krebs JS (1973) Monterey pine: an introduced species in Chile. PhD dissertation. Department of Geography, University of Colorado. Boulder, p 386
Larkey FB (1972) Footnotes to the history of the Del Monte Forest. In: Howitt BF (ed.) Forest heritage: a natural history of the Del Monte Forest. Del Monte Forest Foundation, Pebble Beach, pp 43–48. p 56
LeBoeuf BJ, Kaza S (1981) The natural history of Año Nuevo. Boxwood Press, Pacific Grove, p 425
Ledig FT, Vargas-Hernádez JJ, Johnson KH (1998) The conservation of forest genetic resources: case histories from Canada, Mexico, and the United States. J For 96:32–41
Lerner IM, Libby WJ (1976) Heredity, evolution and society, 2nd edn. W.H. Freeman & Co, San Francisco, p 431
Lewis NB (1975) A hundred years of state forestry—South Australia 1875–1975. Woods and Forests Department, Adelaide, (A Centenary Publication) Bulletin No. 22. p 122
Libby WJ (1997) Native origins of domesticated radiata pine. Burdon & Moore, pp 9–24
Libby WJ, Bannister MH, Linhart YB (1968) The pines of Cedros and Guadalupe Islands. J For 66:846–853
Lindsay AD (1932) Monterey pine (*Pinus radiata* Don) in its native habitat No. 10. Bulletin, Commonwealth Forestry Bureau, Canberra, p 57

Linhart YB (1978) Maintenance of variation in cone morphology in California closed-cone pines: the role of fire, squirrels and seed output. Southwest Nat 23:29–40

Lydon S (1996) March e-mail to WJL. Professor of History, Cabrillo College

Mann CC (2011) 1491: New revelations of the Americas before Columbus, 2nd edn. Vintage Books, New York, p 553

Mason HL (1932) A phylogenetic series of the California coastal closed-cone pines suggested by the fossil record. Madroño 2:49–55

McKelvey P (1991) Thomas William Adams 1842–1919. Early farm forester. N Z J For 36 (2):23–25

McKelvey SD (1994) Early botanical explorations 1790–1850. Fremontia 22(3):14–19

Mead DJ, (2013) Sustainable management of *Pinus radiata* plantations. FAO Forestry Paper No. 170. FAO, Rome. p xv + 246

Millar CI (1986) The Californian closed cone pines (Subsection *Oocarpae* Little and Critchfield): a taxonomic history and review. Taxon 35(4):657–670

Millar CI (1993) Impact of the Eocene on the evolution of *Pinus* L. Ann Mo Bot Gard 80:471–498

Millar CI (1999) Evolution and biogeography of *Pinus radiata*, with a proposed revision of its quaternary history. N Z J For Sci 29:335–365

Millar CI, Kinloch BB (1991) Taxonomy, phylogeny, and coevolution of pines and their stem rusts, pp. 1–38. In: Hiratsuka Y, Samoil JK, Blenis PV, Crane PE, Laishley BL (eds) Rusts of Pines. Proceedings of the 3rd IUFRO Rusts of Pines Working Party Conference. 18–22 September 1989, Banff, Alberta. Foresty Canada Information Report NOR-X-317. Edmonton, Alberta

Mirov NT (1967) The genus *Pinus*. Ronald Press, NY, p 602

Mirov NT, Hasbrouck J (1976) The story of pines. Indiana University Press, Bloomington, p 148

Moran R (1996) The flora of Guadalupe Island, Mexico. California Academy of Sciences, San Francisco, p 190

Moulds FR (1991) The dynamic forest. Lynedoch Publications, Richmond Victoria, Australia, p 232

(von) Mueller F (1858a) On a general introduction of useful plants into Victoria. Trans Philos Inst Vic 2:93–109

(von) Mueller F (1858b) Annual report of the government botanist and director of the Melbourne Botanic Garden. Government Printer, Melbourne

(von) Mueller F (1895) Select extra-tropical plants. Government Printer, Melbourne, p 390

Nedeff N (1994) Address to the 22 April 1994 Monterey CA symposium—Monterey Pine, Our Vanishing Ecosystem

New Zealand Forest Service (1959) Old exotic stand, Auckland. Newsletter 9(2), Feb. 1959, Supplement, p 2

Oberbauer T (2005) A comparison of estimated historic and current vegetation community structure on Guadalupe Island, Mexico. In: Quatrini L, Steele C, Glassow M (eds) Proceedings of the Sixth California Islands Symposium, Ventura, California, December 13, 2003. National Park Service Technical Publication CHIS-05-01. Institute for Wildlife Studies, Arcata, pp 143–153

Oberbauer TA (2006) La vegetación de isla Guadalupe: entonces y ahora. In: Peters E, Santos Del Prado K (eds) Restauración y Conservación de la Isla Guadalupe. Instituto Nacional de Ecología, Mexico, pp 39–53

Page PM (1923) Pine plantations, Matamata estate, Waikato, New Zealand. In: Goudie HA (eds) The remarkable Pine: *Pinus radiata* in New Zealand. State Forest Service Circular No. 3. Government Printing Office, Wellington, pp 11–14. p 14

Philbrick RN (ed.) (1967) Proceedings of the symposium on the biology of the California islands. Santa Barbara Botanic Garden, Santa Barbara, p 363

Poynton RJ (1960) Notes on exotic forest trees in South Africa. (2nd edn, revised). Department of Forestry, Government Printer, Pretoria, p 186

Poynton RJ (1977) Tree planting in South Africa. Volume 1. The pines. Department of Forestry, Republic of South Africa, p 576

Price RA, Liston A, Strauss SH (1998) Phylogeny and systematics. In: Richardson DM (ed) Ecology and biogeography of *Pinus*. Cambridge University Press, Cambridge, p 49–68

Richardson DM (ed.) (1998) Ecology and biogeography of *Pinus*. Cambridge University Press, Cambridge, p xvii + 527

Roche MM (1990) History of New Zealand forestry. New Zealand Forestry Corporation in association with GP Books, Wellington, p 466

Rogers DL (2002) *In situ* conservation of monterey pine (*Pinus radiata* D.Don); information and recommendations. Genetic resources conservation program report No. 26, Division of Agriculture and Natural Resources, University of California. p xi + 80

Rogers DL, Vargas Hernández JJ, Matheson AC et al (2005) Conserving the pines of Guadalupe and Cedros Islands, Mexico: An international collaboration. In: Aldemaro R, West SF (eds) Environmental issues in Latin America and the Caribbean. Springer, Dordrecht, p 31–54

Scott CW (1960) *Pinus radiata*. FAO Forestry and Forest Products Studies No. 14. FAO, Rome, p 328

Shepherd RW (1990) Early importations of *Pinus radiata* to New Zealand and distribution in Canterbury to 1885: implications for the genetic makeup of *Pinus radiata* stocks [2 parts]. Horticulture in New Zealand 1(1): 33–38; 1(2):28–35

Shepherd W, Cook W (1988) The Botanic Garden, Wellington. Millwood Press, Wellington, p 396

Sherry SP (1971) Black wattle. University of Natal Press, Pietermaritzburg, Republic of South Africa, p 451

Simpson TE (1973) Kauri to radiata: origin and expansion of the timber industry of New Zealand. Hodder & Stoughton, Auckland, p 442

Sinclair K (1959) A history of New Zealand. Penguin Books, Harmondsworth, p 320

Stephens SL, Libby WJ (2006) Anthropogenic fire and bark thickness in coastal and island pine populations from Alta and Baja California. J Biogeogr 33:648–652

Stephens SL, Piirto DD, Caramagno DF (2014) Fire regimes and resultant forest structure in the native Año Nuevo Monterey pine (*Pinus radiata*) forest, California. Am Midl Nat 152:25–36

Sutton WRJ (1991) New Zealand radiata pine plantations: an example of sustainability. Plenary paper, Society of American Foresters National Convention, San Francisco, p 5 (metric version)

Valentine JW, Lipps JH (1967) Late Cenozoic history of the southern California islands. Philbrick, p 21–35

Vargas-Hernández J, Rogers DL, Hipkins V (2013) Restoration of *Pinus radiata* on Mexico's Guadalupe Island. In: Bozzano M, Jalonen R, Thomas E, Boshier D, Gallo L, Bordács S, Smith P, Loo J (eds) Genetic considerations in ecosystem restoration using native species. A thematic study of the state of the world's forest genetic resources. FAO, Rome, p 236–239

Weaver DW, Doerner DP (1967) Western Anacapia: a summary of the Cenozoic history of the northern Channel Islands. Philbrick, p 13–20

Weber DJ (1992) The Spanish frontier in North America. (see p. 237 for Monterey base). Yale University Press, New Haven, p 579