REPORT
of the
OXFORD UNIVERSITY EXPEDITION
to
NEW CALEDONIA

DECEMBER 2000 – JANUARY 2001

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Front cover: *Araucaria nemorosa* de Laub. (Araucariaceae). Photograph: S. T. Turvey
Back cover: Illustration of immature female cone (*Waters 161*, **FHO**) of *Araucaria nemorosa* by S. T. Turvey.

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"*New Caledonia is a fascinating spot … It has more of the past – and more of the future, too, for that matter – than any other place, and somehow it manages to keep them almost separate.*"

John Wyndham & Lucas Parkes, *The Outward Urge*, 1962

1. ABSTRACT

The critically endangered New Caledonian conifer *Araucaria nemorosa* de Laub., endemic to a strip of coastal forest in southern Grande Terre and previously regarded as being known from only one locality, is reported from eight discrete populations in the Port Boisé area. The positions of these populations are indicated on a 1: 50 000 map of the area: the total area of occupancy of the species is less than 2 km^2. Photographs of branch, pollen-cone and seed-cone morphology are provided. Demographic analyses of these populations suggest that while regeneration is ongoing, recruitment may be episodic rather than continuous: a pattern familiar from ecological studies of other southern hemisphere conifers. Dendrochronological work is largely uninformative, but is not inconsistent with the hypothesis that the present age-structure of the population is the result of logging in the nineteenth century. However, the data on recruitment are insufficiently definitive to allow any room for complacency over the conservation of this species, and it is clear that without a marked increase in recruitment, the number, extent and size of populations of *Araucaria nemorosa* are likely to decline: *ex situ* conservation measures should be intensified and research into seedling biology conducted as a matter of urgency. The small, apparently declining, size of the populations of this species and their limited number and geographic extent support continued listing of the species by the IUCN as Critically Endangered (CR), under the criteria **B1** and **B2**. Appendices to the Expedition report provide collection data, equipment notes, medical notes, accounts, and details of Expedition personnel and itinerary.

2. INTRODUCTION

2.1 Introduction to the Expedition

In the summer of 1999, two of the authors of this report (TW & NMW) decided to organize an Oxford University Expedition to New Caledonia. A special issue of *Curtis's Botanical Magazine* (volume 16, part 3) had alerted us to the extraordinary diversity of conifers on the island and the range of threats that they face, and it was determined that the primary focus of the expedition would be the conservation biology of conifers. Helpful advice from Stephen Harris of the University of Oxford and from Aljos Farjon of the Royal Botanic Gardens, Kew provided a basis for our expedition proposal, and for contacts with Tanguy Jaffré of the Centre IRD in Nouméa, and F. Devinck & Bernard Suprin of the Environment Service of South Province. The expedition would focus on the population biology of the extremely restricted species *Araucaria nemorosa* de Laub. (Araucariaceae), classified by the IUCN as Critically Endangered and endemic to a narrow strip of coastal forest at Port Boisé, near the southern tip of the island.

The membership of the expedition fluctuated somewhat, and we are extremely sorry that it proved impossible for either Thora Herrmann or David Shackleton to accompany us in the field. The expedition was led by Timothy Waters, with Chloé Galley acting as Medical Officer, Russell Palmer as treasurer and driver, Samuel Turvey as photographer and entomologist, and Nicholas Wilkinson as secretary and ornithologist. The expedition left the UK on 3 December 2000 and returned on 11 January 2001, having been in New Caledonia from 7 December to 7 January. This Report was co-written by all five of us, with Timothy Waters acting as general editor.

2.2 New Caledonia: biological and geological history

The French overseas territory of New Caledonia is a southwest Pacific island archipelago with an area of *c.* 17 000 km^2, situated at the southern extremity of Melanesia between 19° 30' and 22° 40' S latitude, c. 1200 km east of Queensland and 1500 km north-northwest of New Zealand. The principal island, Grande Terre, is approximately the size of Wales, with an area of 16 890 km^2; it is 390 km long and approximately 50 km wide, oriented along a NNW-SSE axis, with extensions in both directions to several smaller, geologically related islands (Îles Bélep, Baaba and Balabio to the NNW; Île Oveu and Île des Pins to the SSE). The archipelago also consists of the geologically distinct Loyalty Islands (Ouvéa, Lifou, Tiga and Maré), situated 200 km to the northeast of Grande Terre; a number of small, isolated islands (the Chesterfields, Beautemps-Beaupré, Walpole, Hunter and Matthew); and several reefs (Bellone, d'Entrecasteaux and Astrolabe) (Lowry 1998).

Grande Terre is one of the most ancient landmasses in the southwest Pacific. Its oldest deposits, of Carboniferous or Devonian age, formed along the active continental margin on the east of the Australian section of Gondwana, near

(*a*) Rain forest in the upper basin of the Rivière Bleue, southern New Caledonia. The large emergent tree in the centre is *Agathis lanceolata* (Sebert & Pancher) Warb. (Araucariaceae) *Photograph: S. T. Turvey*.

(*b*) The Rivière des Lacs, near the Chute de la Madeleine, flowing through *maquis minier* vegetation on the Plaine des Lacs, a large area of poorly drained metalliferous terrain in southern New Caledonia, with numerous mining operations. *Photograph: S. T. Turvey*.

PLATE 1. Habitat diversity in New Caledonia.

(*a*) *Nepenthes vieillardi* Hook.f. (Nepenthaceae), a scrambling carnivorous plant of poor soils such as those of maquis minier and forest edges. *Photograph: S. T. Turvey*.

(*b*) *Xanthostemon aurantiacum* Schlecter (Myrtaceae), a common plant of the maquis minier, endemic to New Caledonia. *Photograph: S. T. Turvey*.

(*c*) Probably *Calophyllum inophyllum* L. (Clusiaceae). Found along Indo-Pacific shores, occasionally with stilt-roots. Scale in cm along top of ruler. *Photograph: S. T. Turvey*.

PLATE 2. Flowering plants of southern New Caledonia.

present-day Queensland (Balouet 1991). The island may not have emerged above the ocean until the late Jurassic or early Cretaceous, when high-pressure metamorphism generated considerable uplift (Flannery 1995). Prior to the Late Cretaceous, Grande Terre remained connected to Gondwana via New Zealand and the Norfolk Ridge, with these three peri-Gondwanan terranes comprising a landmass known as 'Tasmantis', and lay at *c.* 60° S. Tasmantis began to rift from both Australia and Antarctica and drifted northeast 80-90 million years ago during the Rangitata Orogeny, which also initiated the formation of the Australian Alps. Grande Terre reached a latitude of *c.* 30° S by 60 million years ago; its position remained relatively unchanged until around 20 million years ago, when it began a northward drift to its present latitude, and its distance from Australia remained relatively constant throughout the Tertiary (Raven 1980; Flannery 1995). Large regions of the island underwent a series of submersions during the Eocene, with most deposits until the early Miocene consisting of ophiolitic sequences (Brothers and Black 1974); by the late Eocene, nearly all of island was covered by peridotites and serpentinites, ultrabasic igneous rocks formed from overthrusted oceanic crust (Paris *et al.* 1979). Shallow marine rocks characterize the Miocene succession of Grande Terre, representing the beginning of a period of progressive uplift which has continued to the present day (Balouet 1991). Volcanic activity occurred on Grande Terre at various times between the late Cretaceous and early Oligocene, and again in the Miocene (Flannery 1995). The topography of present-day Grande Terre is dominated by a chain of high mountains running along the entire length of the island, with many massifs above 1000 m and five summits over 1500 m (Lowry 1998). The Loyalty Islands are much younger than Grande Terre, having formed through volcanic activity in their present position 9-11 million years ago; they may have emerged from the sea less than 2 million years ago, as a result of upwards flexure of the lithosphere caused by subduction of the Indo-Australian Plate beneath the New Hebrides Arc (Kroenke 1984). The other small islands in the New Caledonian archipelago are also geologically young.

New Caledonia has been of interest to botanists since its discovery by Cook in September 1774, as Grande Terre represents one of the most unusual Pacific islands, with some of the highest levels of floristic diversity and endemism in the world. The island's botanical individuality has been acknowledged in its phytogeographical designation as, variously, the Région Canaque (Guillaumin 1928, 1934), the New Caledonian Sub-Region (Thorne 1963), the New Caledonian Region (Balgooy 1960, 1971; Good 1964), and the New Caledonian Sub-Kingdom (Takhtajan 1969). The evolution of Grande Terre's flora and vegetation has been strongly influenced by its geological and tectonic history, stemming from its former isolation, its unusual geological substrates, and climatic variability resulting from the island's relief. The other islands of the New Caledonian archipelago are depauperate and species-poor by comparison, with no unique vegetation types and very few endemic species (Lowry 1998).

The New Caledonian flora has been well studied and documented over the last 125 years compared to that of most other tropical areas (Lowry 1998). Most of this floristic effort has been in the last forty years (Lowry 1998), as the critical *Flore de la Nouvelle Calédonie et Dépendances* – the modern critical flora of New Caledonia published by the Muséum National d'Histoire Naturelle (MNHN) in Paris – has been produced, building on earlier work such as that of Guillaumin (1928, 1934, 1948), Sarlin (1954), & Virot (1956). Approximately 4780 plant species are presently known in the territory, of which 3380 are indigenous and 1400 are introduced or cultivated. Over 70% are covered by modern taxonomic treatments, but it is estimated that 5-10% remain to be described, with a resultant estimated total indigenous flora of 3550-3770 species (Morat 1993; Lowry 1998). New Caledonia has been estimated to contain 192.4 species per 1000 km^2, third only to Puerto Rica (308.5) and Jamaica (262.8) amongst other botanically diverse tropical and subtropical areas (Lowry 1998). 76.4% of the 3137 indigenous angiosperm and gymnosperm species and 14% of the 763 genera recorded from New Caledonia are endemic (Jaffré *et al.* 1993). For example, all of the 31 species of New Caledonian palms are endemic, as are 15 of the 16 genera (Jaffré and Veillon 1988). Five angiosperm families, the Amborellaceae, Oncothecaceae, Paracryphiaceae, Phellinaceae and Strasburgeriaceae, are also endemic, representing 3% of the 169 indigenous families; endemic plant families are otherwise only present in Australia, Madagascar and Fiji (Mittermeier *et al.* 1996). New Caledonia displays the fourth highest level of floristic endemicity in the world, after Hawaii (89.2% or 980 species), New Zealand (81.9% or 2066 species) and Madagascar (*c.* 80% or *c.* 10000 species) (Lowry 1998).

However, the floristic composition of New Caledonia is unbalanced in comparison with other tropical and subtropical regions. It contains numerous 'relict' endemic lineages, notably of conifers, of which there are 43 species, all endemic. These include 13 species of *Araucaria* Juss. out of a global total of 19, as well as *Parasitaxus usta*[1] (Vieill.) de Laub., the only known parasitic gymnosperm, and *Dacrydium guillauminii* J.Buchholz & *Retrophyllum minus* (Carrière) C.N.Page, (Plate 3*a*) the only known rheophytic gymnosperms (de Laubenfels 1972, Schmid 1981; Morat 1993; Lowry 1998). This genus-rich assemblage of conifers contrasts markedly with adjacent biogeographic areas such as New Guinea (de Laubenfels 1996) and suggests a degree of geological stability over time (de Laubenfels 1996). Several 'primitive' angiosperm families also occur on Grande Terre, such as the Amborellaceae, Annonaceae, Chloranthaceae, Monimiaceae and Winteraceae. These groups may represent survivors of the late Cretaceous-early Tertiary Gondwanan Australasian flora, which persisted in the equable Tertiary climate of Grande Terre but became extinct or greatly reduced in the increasingly dry Neogene conditions across much of the rest of Australasia (Raven 1980; Lowry 1998). *Amborella trichopoda* Baillon (Amborellaceae) has recently been identified as basal to all[2] other angiosperms on molecular evidence (Mathews & Donoghue 1999), supporting the idea of Grande Terre as an ecological 'ark' for ancient

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[1] All names of conifers in this report follow Farjon (2001), except names in the genus *Agathis* Salisb., which follow Whitmore (1980). Plant names are given with author abbreviations following Brummit & Powell (1992) on first use and without author details subsequently. Animal names are not given with authors, except for the bird lists in Appendix 3: bird nomenclature largely follows Peters *et al.* (1931-1987) The widely used conifer names *Parasitaxus ustus* and *Retrophyllum minor* are erroneous (non-agreement of specific epithet with gender of generic name) and are therefore corrected here (Greuter *et al.* 2000: Articles 61.4 & (explicitly) 62.2). Other names generally follow the *Flore de la Nouvelle-Calédonie et Dépendances*, published in fascicles by the Muséum National d'Histoire Naturelle, Paris.

[2] or almost all: it now appears that *Amborella* is sister to the Nymphaeaceae, and the two together are sister to all other flowering plants (Bowe *et al.* 2000).

angiosperm lineages. The persistence of conifers and early angiosperm groups in New Caledonia indicates that it is highly unlikely that all of Grande Terre was submerged during the Eocene.

Other groups seem to have reached New Caledonia after its separation from Gondwana, as part of the widespread movement of Indo-Malesian elements expanding into Australasia in the early-mid Tertiary (Lowry 1998). The four largest New Caledonian families, the Myrtaceae (including *Xanthostemon*, Plate 2*b*), Rubiaceae, Orchidaceae and Euphorbiaceae, which together comprise 26.9% of the New Caledonian angiosperm flora, represent this second group of plants. Some of these Tertiary arrivals speciated extensively, such as *Phyllanthus* L. (Euphorbiaceae) (111 New Caledonian species), and are now amongst New Caledonia's largest genera. Conversely, several families otherwise well-represented in the tropics are either absent from New Caledonia (e.g. Ochnaceae *sensu stricto*, Begoniaceae) or contain very few New Caledonian species (e.g. Asteraceae, Melastomataceae: Morat 1993; Lowry 1998, Pintaud *et al.* 2001).

The evolution of New Caledonia's unusual floristic composition is in part the result of its unusual substrate composition. The unusually abundant ultramafic peridotites and serpentinites form ultrabasic, lateritic soils (Plate 4*a*) containing high levels of nickel (Ni), chromium (Cr), cobalt (Co) and manganese (Mn), elements normally toxic to plants, and very low levels of nitrogen (N), phosphorus (P), potassium (K), calcium (Ca) and aluminium (Al). These chemical imbalances have produced a wide variety of edaphic substrates all unbalanced in mineral nutrients, ranging from eutrophic brown hypermagnesian soils to oxidic highly desaturated soils (Jaffré 1980, 1993). The extent of the ultrabasic substrates or 'terrains miniers' has been reduced by erosion, but they still cover *c.* 5500 km^2, approximately one-third of the area of Grande Terre, and constitute one of the island's important large-scale structural geological elements (Jaffré *et al.* 1987a; Jaffré 1993). Thorne (1965) suggested that older Australasian lineages which adapted to living on ultrabasics were able to persist in New Caledonia, as later invaders, which would otherwise be likely to suppress the rarer elements of such insular floras by interspecific competition, were unable to colonize this specialized substrate. However, different 'primitive' groups show different substrate preferences today (Lowry 1998). Neogene colonisation of the previously unoccupied, vast ultrabasic areas of Grande Terre is likely to have prompted a large wave of diversification and adaptive radiation in both old and new members of the flora, especially in sclerophyllous groups such as the Proteaceae and the Cunoniaceae (Plate 4*b*) which were pre-adapted to living on poor soils (Jaffré *et al.* 1987a), and many species appear to have adapted to the high metal content of such ultrabasic soils: Baker *et al.* (1999) record 50 metal hyperaccumulator plant species from New Caledonia. Microendemism and vicariance in the New Caledonian flora would have been promoted by fragmentation of the ultramafic outcrops through erosion (Morat 1993), with local variation in nutrients and metal concentrations allowing different plant species to become specialized for different microenvironments (Flannery 1994). The number of spermatophyte (angiosperm and gymnosperm) species on ultrabasic and non-ultrabasic substrates is very similar (1844 vs. 1840), but ultrabasic species display higher rates of endemism (20.7% vs 9.4%); 98.0% of the 1176 species found exclusively on ultrabasics are endemic, and only 23.4% of New Caledonia's non-endemic species occur on these substrates (Lowry 1998).

Three main categories of primary vegetation type occur in Grande Terre, with their distribution determined primarily by the island's physiognomy and to a lesser extent by climatic conditions (Morat *et al.* 1981). Moist evergreen forest or 'rain forest' (Plate 1*a*), of which three subcategories are recognized (Morat *et al.* 1984), consists of a closed canopy of moderately sized trees (up to 20 m at lower elevations) which occurs on both ultrabasic and non-ultrabasic substrates (Morat *et al.* 1984; Lowry 1998). This vegetation type occurs predominantly on the eastern side of Grande Terre, which receives between 2500 and 4000 mm of annual rainfall; the western side of the island is in the rain shadow of the central mountain chain, and receives less than 1500 mm. Maquis minier (Plate 1*b*), a characteristic low, sclerophyllous, evergreen heath-like formation, often very species-rich (Suprin, undated) is largely restricted to ultrabasic substrates at various altitudes on Grande Terre (Lowry 1998). Its primary nature has been challenged by some authors (e.g. Jaffré 1993); although some may be considered as primary formations, the extent and physiognomic configuration of many areas of maquis may be due to fire. Sclerophyllous or dry tropical forest, consisting of a dense, closed canopy of semideciduous trees *c.* 10-12 m tall accompanied by a woody evergreen sclerophyllous understorey and a discontinuous herbaceous layer of Cyperaceae and Gramineae, was once widespread on non-ultrabasic, sedimentary substrates (e.g. chert, sandstone, limestone) in the drier west of Grande Terre (Morat 1993; Lowry 1998). Mangroves and swamp vegetation also occur in New Caledonia, in areas subject to tidal influence or with periodic standing water.

These vegetation types do not share same specific richness or floristic originality. Moist evergreen forest has an exceptional concentration of species and genera relative to the area it occupies, being similar in diversity to Amazonian forest plots (Morat 1993); 1792 angiosperm and gymnosperm species and 416 genera have been recorded from this vegetation type, of which 87.2% of species and 20.0% of genera are endemic, with 597 species occurring per 1000 km^2 (for the original vegetation cover of the island) (Lowry 1998). Maquis minier is also species-rich, largely due to the diversity of biotopes and their associated plant formations it contains (Jaffré 1993), with 1082 species (91.2% endemic) and 306 genera (19.0% endemic) and 240 species per 1000 km^2 for original vegetation cover (Lowry 1998). Sclerophyllous forest, the only completely non-ultrabasic major primary vegetation type, is composed of a relatively young flora which dates largely from the Neogene, and has only 379 species (58.8% endemic), 227 genera (4.8% endemic) and 84 species per 1000 km^2 for original vegetation cover (Lowry 1998); however, these figures may have been lowered through habitat degradation.

New Caledonia's terrestrial fauna has been described as characteristic of an isolated island (Carlquist 1974, followed by Mittermeier *et al.* 1996); however, the general faunal pattern is probably best explained by a radiation of pre-Eocene stock through long isolation, with subsequent modification by mobile colonizing taxa dispersing from different origins at different times (Chazeau 1993). Vertebrate groups are disproportionately represented. New Caledonia has no indigenous

(*a*) *Retrophyllum minus* (Carrière) C.N.Page (Podocarpaceae), locally known as *bois bouchon*, is a rheophytic gymnosperm endemic to a few rivers in southern New Caledonia. The baobab-like trunks and the habit are highly distinctive. *Photograph: S. T. Turvey*.

(*b*) *Neocallitropsis pancheri* (Carrière) de Laub. (Cupressaceae), a rare conifer endemic to New Caledonia and once exploited for its fragrant timber, the oil in which was extracted and sold as 'oil of araucaria' (Mabberley 1997). *Photograph: S. T. Turvey*.

PLATE 3. Conifers of southern New Caledonia.

(*a*) Ultrabasic rocks and lateritic soils on the Plaine des Lacs, southern New Caledonia. Large emplacements of such substrates during the Eocene (Paris *et al.* 1979) have shaped the flora and fauna of New Caledonia, with radiations of a number of plant and animal groups – for example the Cunoniaceae R.Br. (Jaffré *et al.* 1987b) and the Gekkonidae (Flannery 1994). *Photograph: S. T. Turvey.*

b) A species of *Cunonia* L. (Cunoniaceae), probably *C. macrophylla* Brongn. & Gris, in maquis vegetation in the upper valley of the Rivière Bleue. *Photograph: S. T. Turvey.*

c) A species of *Rhacodactylus,* probably *R. leachianus*, the largest gecko in the world, excellently camouflaged against a tree-trunk in coastal forest near Port Boisé. *Photograph: S. T. Turvey.*

PLATE 4. Ultrabasic substrates and the flora and fauna of New Caledonia.

amphibians, snakes or non-volant mammals[3], and only a single freshwater fish not derived from brackish water ancestors. However, birds and lizards display relatively high diversity and endemicity, with 30 endemic subspecies, 18 endemic species, four monotypic endemic genera and one endemic family of birds, and 48 indigenous species of skinks and geckos, of which 41 are regional endemics (Barré & Dutson 2000; Bauer & Sadlier 1993). Novelties amongst these groups include the Kagu (*Rhynochetos jubatus*), the only surviving representative of the Rhynochetidae; the New Caledonian Imperial Pigeon (*Ducula goliath*), the world's largest arboreal pigeon; and *Rhacodactylus leachianus*, the world's largest gecko. Some of these species, such as *Rhacodactylus* geckoes, also show an exclusive distribution with ultrabasic soils (Bauer & Vindum 1990). Flannery (1994) explained the New Caledonian reptile radiation in terms of the island's low productivity, relatively small size and position in the tropics, factors which could select for ectotherms with small home ranges.

As for most areas of world, the invertebrate fauna of New Caledonia is largely undescribed. 4000 insect species have so far been described, demonstrating high endemism at specific and generic levels; the total number is projected to number up to 20 000 (Chazeau 1993). The indigenous terrestrial mollusc fauna is 100% endemic (Tillier & Clarke 1983). Grande Terre also hosts the only family of spiders endemic to an island, the Brachystichidae (Platnick 1993). The shallow platform on which Grande Terre and its geologically associated islands lie is rimmed by the world's second largest barrier reef, over 1300 km in length; the location of New Caledonia close to the global centre of coral reef diversity, combined with the large area and variety of reef types, ensures very high diversity, with 1950 fish species, 5500 molluscs, 5000 crustaceans, 600 sponges and 300 corals so far described (Spalding *et al.* 2001).

Although New Caledonia is politically and economically stable in comparison to many other tropical areas (Lowry 1998), active conservation remains a priority in the territory. Human arrival in New Caledonia *c.* 3500 years ago led to the introduction of non-indigenous food plant species, hunting and land clearance by repeated burning. The arrival of Europeans and their associated domestic animals has affected all habitat types, with forested areas reduced in area from 90% to 20%, of which only half is considered undisturbed (IUCN 1986). Sclerophyllous forest, the only major habitat type restricted to non-ultrabasic and therefore fertile soils, has been worst affected by anthropogenic modification of the environment, now occupying only *c.* 100 km^2 (2.2% of an original area of *c.* 4500 km^2) with an additional 250 km^2 of degraded or secondary stands (Morat 1993; Lowry 1998). Various anthropogenically degraded forms of vegatation, including savannas dominated by niaouli (*Melaleuca quinquenervia* (Cav.) S.T.Blake (Myrtaceae)), now cover over 50% of New Caledonia. Nickel mining, bush fires and logging, along with the introduction of invasive species such as pigs, rats, dogs, the Timor deer (*Cervus timorensis*), snails such as *Achatina fulica* (giant African land snail) and the fire ant *Wasmannia auropunctata*, continue to threaten the indigenous

[3] the tooth of a supposed Pleistocene diprotodontid marsupial, *Zygomaturus diahotensis*, has proved to be that of an imported rhinoceros (Balouet 1991).

flora and fauna (Hunt *et al.* 1996; Mittermeier *et al.* 1996; Jourdan 1997; Ekstrom *et al.* 2000).

The arrival of the first human colonists to New Caledonia coincided with a wave of extinctions[4]. Extinctions have continued into the historical period, with 50 plant species threatened with immediate extinction or already lost (Lowry 1998). Due to a relatively poor understanding of the status of even the vertebrate fauna of New Caledonia, however, it is uncertain whether species such as the New Caledonian rail (*Gallirallus lafresnayanus*), the New Caledonian lorikeet (*Charmosyna diadema*), the terror skink (*Phoboscincus bocourti*) or the varanid *Varanus* cf. *indicus* have become extinct or survive in small numbers (Balouet 1991; Flannery 1994; Ekstrom *et al.* 2000). Because of their association with ultrabasic soils, many surviving plant species have highly restricted distributions and often consist of a very limited number of populations which are small and localized even by the standards of island populations, so that further extinctions are inevitable. Reserves cover only 9% of the total area of the territory, including only regions of evergreen forest and maquis; many exist only on paper and provide no legal protection (Veillon 1993; Mittermeier *et al.* 1996; Ekstrom *et al.* 2000), and it is clear that the present reserve system does not provide anything like an adequate level of protection for the New Caledonian biota (Jaffré *et al.* 1998).

This combination of high biodiversity and high threat is increasingly being recognized (e.g. Mittermeier *et al.* 1996), with the IUCN conferring New Caledonia with its highest ranking for conservation in the entire Oceania region. The territory was identified as one of world's top ten 'threatened hotspots' by Myers (1988, 1990), and further publicized as a hotspot by Myers *et al.* (2000). Further conservation work in New Caledonia is thus crucial, to ensure the survival of its unique flora and fauna.

2.3 The genus *Araucaria* and its ecology

The genus *Araucaria* Juss. (Araucariaceae) has approximately nineteen species worldwide (Farjon 2001), and is found only in the southern hemisphere where it has a markedly disjunct distribution. The other genera of the Araucariaceae (*Agathis* Salisb. and *Wollemia* W.G. Jones, K.D. Hill & J.M. Allen) are also largely confined to the southern hemisphere, with only a couple of species of *Agathis* extending north of the equator in Malesia (de Laubenfels 1988) Two of the species of *Araucaria* are found in South America, a further two in New Guinea (one of which is shared with Australia), one is endemic to mainland Australia, and another is found only on Norfolk Island in the Tasman Sea. The remaining thirteen species in the genus are endemic to New Caledonia (de Laubenfels 1972), where they occur on a wide range of soils and at altitudes ranging from sea level to over 1000 m (Jaffré 1995, de Laubenfels 1996). A phylogenetic study by Setoguchi *et al.* (1998), based on analysis of the *rbc*L gene, supports the monophyly of the genus

[4] Examples include the extinctions of the large galliform bird *Sylviornis neocaledonicus*, the giant horned turtle *Meiolania mackayi* and the unusual tribodont terrestrial crocodilian *Mekosuchus inexpectatus*, the subfossil remains of which have been found in archaeological sites on Grande Terre (Balouet 1991; Flannery 1994).

and also of the thirteen New Caledonian species, and provides phylogenetic structure for the non-New-Caledonian species in the genus, but within the New Caledonian clade provides no resolution beyond supporting a sister-group relationship between *Araucaria muelleri* (Carrière) Brongn. & Gris and *Araucaria rulei*. The Araucariaceae appears to be sister to the Podocarpaceae (Chaw *et al.* 1997, Stefanovic *et al.* 1998), and the two families together are often referred to as the 'southern conifers' (*vide* Enright & Hill 1995).

Araucaria ecology is highly variable, and it is difficult to make generalizations about the genus beyond that the trees are typically extremely long lived, retain their leaves for many years, and have poorly-marked growth rings (Brison *et al.* 2001; Falcon-Lang 2000). Until recently no demographic studies on New Caledonian species of *Araucaria* – indeed, on any New Caledonian conifers – had been carried out (Enright and Ogden 1995). Work by Enright & colleagues on *Agathis ovata* (C.Moore ex Vieillard) Warburg and *Araucaria laubenfelsii* Corbasson has begun to address this problem, although the New Caledonian species of *Araucaria* remain poorly known by comparison with their congeners elsewhere.

The best studied species, in terms of our understanding of their autecology in their natural environment are *Araucaria hunsteinii* K.Schum. from New Guinea (Havel 1971; Gray 1975) and *Araucaria araucana* (Molina) K.Koch (Veblen 1982; Burns 1993) from the Chilean & Argentinian Andes. The Brazilian paraña pine *A. angustifolia* (Bertol.) Kuntze, and *A. cunninghamii* Ait. ex D.Don, the hoop pine from eastern Australia and New Guinea have been investigated largely from the point of view of their silvicultural potential (Webb & Tracey 1967; Ntima 1968), but the ecology of wild populations of *A. cunninghamii* in Australia & New Guinea has also been studied (Havel 1971; Gray 1975; Enright & Watson 1991; Enright, Franco & Silvertown 1995).

Araucaria species have often been regarded as 'relicts' in evolutionary and biogeographic terms (Aubréville 1965), with their long fossil record reaching back to the Jurassic (Stockey 1982). Some authors have taken the view that they have also a relict ecology, and are being progressively displaced by angiosperm species in their present habitats, unable to compete with modern flowering plants (Womersley 1958, Aubréville 1965). This view has been challenged (Veblen 1982) and there is certainly evidence that many species of *Araucaria* may be regenerating with the same gap-phase dynamics as are typical of angiosperm forest tree species (Veblen 1982, *citing also* Havel 1971; Gray 1975). A study of the social status and regeneration dynamics of *Agathis macrophylla* (Lindley) Masters, a species in the sister genus to *Araucaria* (Setoguchi *et al.* 1998) supports this interpretation (Whitmore 1966). More recently however, Bond (1989) has resurrected the idea that large disturbances are necessary for gymnosperm persistence in angiosperm-dominated environments, arguing from considerations of seedling physiology, a central aspect in the comparative study of the regeneration strategies of tree species (Whitmore 1989).

Enright & Ogden (1995), in a review of the ecology of the 'southern conifers', concluded that whilst life-history strategies predicated on episodic major disturbance providing recruitment opportunities were common among the southern conifers (*i.e.* Araucariaceae and Podocarpaceae), they were not universal – *Araucaria cunninghamii* (Section *Eutacta* of the genus, as is *A. nemorosa*) – being an important exception. Further, such strategies are not unique to the southern conifers, for 'regeneration gap' stand structures indicating similar strategies are now known from both northern hemisphere conifers such as *Sequoia sempervirens* (D.Don) Endl. (Cupressaceae) and *Sequoiadendron giganteum* (Lindley) J.Buchholz (Cupressaceae) (Dale *et al.* 1986). Even some angiosperms show such stand structures, for example the evergreen tree *Nothofagus dombeyi* (Mirb.) Oerst. (Nothofagaceae) from South America, which with a longevity of up to 500 years is comparable with the conifers (Enright & Ogden 1995; Veblen *et al.* 1981).

What remains important is that the longer life spans of conifers typically allow them to adopt regeneration strategies dependent on less frequent events and greater disturbance sizes than angiosperms, and that such adaptation differentiates conifers ecologically from their angiosperm competitors (Enright & Ogden 1995; Enright *et al.* 1999). The life-history strategy of *Araucaria nemorosa*, as investigated in this report, is therefore of considerable scientific interest in the context of the range of strategies deployed by both congeneric and other closely related species, and an understanding of the ecological relationship between *A. nemorosa* and the angiosperm trees with which it shares the coastal forests of southern New Caledonia is essential to the successful conservation of the species.

2.4 History of the Port Boisé area[5]

European settlement and forest exploitation at Port Boisé began in 1867. The investigation and charting of the island's coasts by Sébert had revealed vast easily exploitable forests at the southern tip of the island Governor Guillain sent 33 men, mostly convicts or soldiers, to establish a logging industry in the extensive forests of the island's southern tip, following the investigations by Sébert of the island's coasts: *boisé* is the French for 'wooded'. The small colony apparently flourished until logging was discontinued in the early twentieth century (when transportation of convicts ceased) and the settlement abandoned. The jetty, and some ruins from this period, can be seen along the coastal path on the northeast side of the bay.

The main trees exploited for their timber were the kaori (*Agathis lanceolata* (Sébert & Pancher) Warb.) and chêne-gomme (*Arillastrum gummiferum* (Brongn. & Gris) Pancher ex Baillon[6]), and the former of these at least is now rare or absent in the area. The extent of general deforestation in the area is uncertain but the forest, once apparently extensive, is now only patchily distributed along the southern coasts (IGN 1987; Morat *et al.* 1981). There is no evidence that *Araucaria nemorosa*

[5] The information in this section is derived from (a) the interpretative signs at Port Boisé provided by the Service de l'Environnement, Direction des Ressources Naturelles (DRN 2000); and (b) our own enquiries and observations.

[6] This species has several synonyms which are still widely used and may be encountered in the literature, including: *Spermolepis gummifera* Brongn. & Gris; *Myrtomera gummifera* (Brongn. & Gris) Stone; *Spermolepis tannifera* Heckel [used on DRN 2000]; and *Spermolepis rubra* Vieill. ex Guillaumin (Dawson 1992: 6-10).

(*a*) A narrow strip of *Araucaria columnaris* (J.R.Forst.) Hook., *c.* 10 m wide, lines the coast of much of southern New Caledonia., including this small bay between Port Boisé and Cap Ndoua. When similar populations were observed from out at sea by J. R. Forster, the naturalist on board Cook's ship *HMS Resolution* which discovered New Caledonia in 1774, he presumed that they were basalt pillars (Hoare 1982). *Photograph: S. T. Turvey.*

(*b*) As well as the domed crown visible on the front cover of this report and in the tree in the centre here (population 1, Port Boisé), *Araucaria nemorosa* may have a more columnar form, as at the far left and to the right in this photograph, although such trees are usually flatter-topped than *A. columnaris*. *Photograph: S. T. Turvey.*

PLATE 5. Diversity of form in *Araucaria* species at Port Boisé.

(*a*) The bark of *Araucaria nemorosa* is slightly peeling, and has many small horizontal fissures *c.* 5 – 10 cm long. It is often greyer than that of *Araucaria columnaris*. Population 5, near Port Boisé. *Photograph: S. T. Turvey*.

(*b*) Adult secondary branches of *Araucaria nemorosa* show varying width along the length of the branch, an unusual character in the genus *Araucaria*, though known from *Wollemia* W.G. Jones, K.D. Hill & J.M. Allen, another genus in the Araucariaceae. The shorter leaves are typically more divergent than the longer leaves. Herbarium specimens from this population (population 1) (*Waters 160, 161, 162, 163, 168, 169, 194*) are in the Daubeny Herbarium, Oxford University Herbaria (FHO). *Photograph: S. T. Turvey*.

PLATE 6. Morphological characters of *Araucaria nemorosa* de Laub.

was either deliberately exploited for timber or, conversely, that it was left untouched: *A. columnaris* (G.Forst. & J.R.Forst.) Hook.f., which lines the coasts of the bay at Port Boisé, is of great symbolic importance to the indigenous Kanak peoples (Kasarhérou & Wedoye 1998) but we have found no published evidence on whether this status applies also to other members of the genus such as *A. nemorosa*. The species was not discovered by scientists until the 1960s, when it was described by D. J. de Laubenfels (de Laubenfels 1969).

Today there is a small Kanak community at Port Boisé and there are a few very small farmsteads (mainly growing bananas) nearby. Mining concerns are now active in the hills to the northwest of the bay; and around the nearby Baie du Prony. At the north-eastern end of the bay of Port Boisé the *Gîte Kaa-Nua* complex, consisting of a campsite and a few luxury beach cottages, has recently opened: this property is owned by the Attiti brothers, Robert & Alexandre, the sons of the local chief. In 1997 a road suitable for all vehicles reached Port Boisé by extending the Yaté-Goro (RM5/RM2) road, and access to the area is now easy: the road goes straight through one of the largest populations of *Araucaria nemorosa*. There is no formal reserve for the populations of *Araucaria nemorosa*, and their continued existence is dependent upon the goodwill of the landowner.

2.5 *Araucaria nemorosa*: taxonomy and autecology

Araucaria nemorosa was described by D. J. de Laubenfels in 1969, and is described and illustrated (illustration by Hélène Lamourdedieu) in the *Flore de la Nouvelle Calédonie* (de Laubenfels 1972). Two Sections are recognized within the genus *Araucaria* (de Laubenfels 1988), section *Eutacta* Endl. and section *Araucaria*. *Araucaria nemorosa* belongs to section *Eutacta*, which is distinguished from section *Araucaria* by its 4 epigeal cotyledons[7], juvenile leaves acicular and terminal pollen cones. The 15 species of Section *Eutacta* are found in New Guinea & Australia (1 species), Norfolk Island (1 species), and New Caledonia (13 species). Phylogenetic studies in the genus *Araucaria* suggest that the New Caledonian taxa form a monophyletic group to which the Norfolk Island species, *Araucaria heterophylla* (Salisb.) Franco is basal, with the Australia & New Guinea species *A. cunninghamii* Aiton ex D.Don basal to the rest of the Section (Setoguchi *et al.* 1998). Almost nothing is presently known about the phylogenetic relationships within the New Caledonian clade, and the sister species of *Araucaria nemorosa* is unknown. Work is ongoing at the Royal Botanic Garden Edinburgh to investigate such questions as part of a major project on the New Caledonian species of *Araucaria*.

Araucaria nemorosa is one of a group of about four New Caledonian species in which the mature leaves are triangular or quadrangular in section and are usually less than 3 mm wide (de Laubenfels 1972). The leaves are typically of varying lengths

[7] *Araucaria hunsteinii* K.Schum. (Section *Araucaria*) from New Guinea has been placed in a monotypic Section *Intermedia* on the basis that it differs from the other species in Section *Araucaria* in having 4 cotyledons rather than 2. Other sections have also been recognized for individually distinctive species, both fossil & extant, here assigned to Section *Araucaria*. de Laubenfels (1988) and Setoguchi *et al.* (1998) provide further information on these taxa. Stockey (1982) argues for the usefulness of such monotypic (among living species) sections in interpreting the fossil record.

along the branches, with the longer leaves the more imbricate and the shorter leaves the more divergent (Plate 6*b*). The trees as a whole often have a domed crown (see front cover) although this varies (Plate 5*b*): they are however almost always distinguishable from nearby individuals of *Araucaria columnaris* which is invariably columnar in form (Plate 5*a*). The pollen cones of *Araucaria nemorosa* are also distinctive: the pollen cone of *A. nemorosa* contains divergent microsporophylls and is subtended by linear sterile bracts, about 10 – 12 mm long, narrowing from 3 mm at the base to 1 mm at the tip (Plate 7*a*). These bracts are unique in the genus. The bark is slightly peeling, with small horizontal fissures *c.* 5 – 10 cm long, and is often greyer than that of *Araucaria columnaris* (Plate 6*a*). As both the pollen cones and the mature leaves are borne high up in the tree, and the pollen cones are on the tree for only short periods of time, identification is usually performed on fallen branches and cones, abundant on the forest floor (Plate 7*b*). Some authors have regarded seedling morphology as important in the systematics and evolution of the Araucariaceae (Rouane & Woltz 1979, 1980), and seedlings of *Araucaria nemorosa* are morphologically distinctive, and easily distinguished from those of *A. columnaris*. *Araucaria nemorosa* seedlings are paler green with longer, more divergent leaves than those of *A. columnaris*. Voucher specimens for our identifications have been deposited in the Daubeny Herbarium, Oxford University Herbaria (**FHO**).

Araucaria nemorosa is known only from the region around Port Boisé, south of the Plaine des Lacs, east of the Baie de Prony and southwest of Goro. Although populations have been reported from a number of sites between Cap Ndoua and Cap Reine Charlotte, almost all of these (with the exception of one tiny inland population discussed in section 3.1), are in coastal forest less than 2 km inland (usually less than 1 km inland) and at altitudes less than 100 m (usually less than 20 m) above sea-level. Annual rainfall in the Port Boisé area is approximately 2500-3000 mm (ORSTOM 1981); soils and underlying rocks in the Port Boisé area, are impoverished indurated ferritic soils overlying peridotites, as throughout the southern part of Grande Terre (ORSTOM 1981). The coastal forest at Port Boisé has been characterized as low altitude dense evergreen forest (Morat *et al.* 1981), and the angiosperm trees within it form a canopy at a height of *c.* 10 m. The coastal rocks and adjacent cliffs support an extremely narrow (< 10 m wide) and extremely dense population of *Araucaria columnaris*, a formation described by Jaffré (1995) and first noted in 1774 (Hoare 1982). As well as coastal forest and isolated human settlement, there are extensive areas of scrub on black laterized rock (known as *cuirasse* (Enright and Goldblum 1998)) *c.* 1 m to 1.5 m high, often dominated by *Baeckea ericoides* Schlect. These areas are typically slightly further inland than the forest and possibly represent secondary vegetation after deforestation or fire, although there is no evidence of either forest exploitation or a history of recent fire. This comparatively depauperate formation blends into typical maquis *sensu* Morat *et al.* (1981), which is slightly higher (*c.* 2 m or more) and with abundant *Gymnostoma* L.A.S.Johnson. Occasional stands of the common New Caledonian tree *Melaleuca quinquenervia* are also present, with thick deposits of fallen leaves and little or no understorey.

3. METHODS

3.1 Map calibration

Although both the 1:50 000 map of Port Boisé (IGN 1987) and the Magellan 2000 XL GPS unit were nominally basing their position co-ordinates on the WGN1972 datum, the presence of systematic error in the GPS unit rapidly became obvious. Identifying some key features of the landscape allowed us to estimate the magnitude and direction of this error and all GPS readings were subsequently corrected before being plotted onto the map. Both corrected and uncorrected datasets are maintained by the Expedition and will be deposited with an appropriate repository as well as being made freely available to *bona fide* researchers.

3.2 Mapping procedures & software used

Approximate positions of the principal stands of *Araucaria nemorosa* were located by taking bearings from of vantage points around the Port Boisé area, such as wharfs and hilltops. The populations so identified were then visited on foot. Insofar as was possible, every tree on the perimeter of each population was visited, by proceeding round populations clockwise from tree to tree ensuring that there were no individuals of *Araucaria nemorosa* on the left and the rest of the population on the right. GPS readings were entered into Microsoft® Excel® and transferred into the vector graphics program CorelXara® (the use of both pieces of software enabled both easy access to raw data and the visualization of that data as on-screen maps. From these maps, we were able to identify areas that had been missed, gaps in the data, potential 'outliers', and other anomalies, which were subsequently returned to and checked. These readings were used to produce a map of the populations of *A. nemorosa* at Port Boisé (reproduced as the fold-out map at the back of this Report); a further, tiny population of no more than 50 mature trees was subsequently discovered by the Expedition *c.* 4 km inland from Port Boisé (map reference UTM 58 696 8 E 7535 0 N (IGN 1987)) and another population has recently been discovered near Cap Reine Charlotte (T. Jaffré, *pers. comm.*), approximately 3 km east of Port Boisé. A number of small, outlying individuals of *Araucaria nemorosa* were identified in addition to these six stands, but the vast majority of mature trees in the area studied – indeed, in the world – are enclosed within the perimeters mapped by the expedition.

3.3 Plot selection method

Seven 0.25 ha plots were analysed, three in population 1, and two each in populations 2 and 4 (population terminology follows the fold-out map at the back of this Report). Plots were selected pseudo-randomly within each population. Rectangular bounds were measured on our electronic maps, to enclose each of the stands identified. Taking each of these boundaries in turn, we then used

Microsoft® Excel®'s random number generation function to select a pair of co-ordinates that lay within the rectangle. A 0.25 ha square was plotted on our map in CorelXara® which had these points as their south-west corner, and sides of 50 m stretching north and east. If this square lay entirely within the population, then it was selected for analysis. If not, it was discarded and a second pair of random co-ordinates was generated. This process was repeated until a set of non-overlapping 0.25 ha plots for analysis had been obtained, all within the population boundaries. Co-ordinates of these plots are given in Table 1. Plots 1A, 1B, 1C are in population 1, plots 2A and 2B in population 2 etc.

PLOT	UTM GRID REFERENCE OF SOUTHWEST CORNER
1A	58 702 396E 7527 040N
1B	58 702 128E 7526 991N
1C	58 701 933E 7527 150N
2A	58 701 037E 7525 671N
2B	58 700 907E 7525 791N
4A	58 699 700E 7534 136N
4B	58 699 538E 7524 041N

Table 1. Location of plots of *Araucaria nemorosa* studied at Port Boisé, Province Sud, New Caledonia. Plot numbers correspond to their location in numbered populations (*see fold out map at back of this Report*). These coordinates were generated randomly within the boundaries of each population to avoid any potential bias: all parts of the plots fall inside the mapped boundaries of the populations. Plot boundaries ran 50 m due north and east of these points to enclose an area of 0.25 ha.

3.4 Plot investigation method & techniques pursued

Analyses of the 0.25 ha plots selected (Table 1) were carried out within the principal non-contiguous stands of *Araucaria nemorosa*. Stand structure, or population composition, was investigated by categorizing individuals of *Araucaria nemorosa* by diameter at breast height (taken to be 140 cm above ground level) (hereafter *dbh*), with the aim of providing basic demographic information which could be used to assess the autecology of the species in comparison with that of other species, and to indicate demographic issues of particular conservation concern, in the context of the IUCN categorization of conservation risk which uses levels of "continuing decline, observed, inferred or projected…." in population size to delimit levels of threat (Farjon & Page 1999).

Several other studies have used stand analysis based on either height, *dbh*, or both, to understand population composition, as information for silvicultural practice (*e.g.* Newton & Smith 1988), evidence of natural regeneration (Engelmark *et al.* 1994, Poorter *et al.* 1996, Rigg *et al.* 1998) or trying to understand rarity. Population structures are the result of past processes of regeneration, establishment and mortality, thus the pattern (of population structure) observed can be used to infer possible processes. Several major types of population structure are commonly encountered, each giving an indication of different population dynamics and thus allowing the projection of future stand structures. For example, stands with sufficient regeneration and surviving mature individuals (a 'reverse-J' distribution) suggest no projected decline in numbers, or a "stationary pattern in the landscape" (Engelmark *et al.* 1994). By contrast, stand structures where particular size classes are absent or anomalously low, or with little or no regeneration, or where the stand is mostly made up of more mature individuals, may suggest seedling regeneration, recruitment or establishment problems from which projected population decline may be inferred. Thirdly, variable population structure [when looking at several different populations] with 'regeneration gaps' at different stages, indicating sporadic regeneration and establishment, where regeneration occurs in 'waves' in different regions (Poorter *et al.* 1996; Silvertown & Dodd 1999).

Any prominent gaps in size class should be apparent from the structure analysis, highlighting any size classes for which there is or has been an interruption to processes of continuous recruitment. Such problems may take two forms: either gaps could be persistent through time (*i.e.* this size class is failing to regenerate continuously, and recruitment is either only sporadic or wholly absent), or such gaps could be transient (*i.e.* either regeneration occurs in regular waves, or there has been a 'one-off' event, such as a fire, killing seedlings '*x*' years ago (where *x* corresponds to the age of that size class) (Rigg *et al.* 1998)). Whereas the transient recruitment problem would not necessarily suggest a serious long-term problem in terms of population persistence, evidence indicating persistently low levels of recruitment beyond a particular size-class may be indicative of either more serious demographic problems, or alternatively a life history strategy based on irregular, infrequent episodic recruitment as has been hypothesized for many southern hemisphere conifers (Enright & Ogden 1995).

Population structures presented do not necessarily represent age structure of the population, as individuals are classified according to *dbh*. Although a relationship between age and *dbh* is believed to exist, there are difficulties with the quantification of this relationship which are discussed in section 3.4.

Within each plot (numbered 1A, 1B, 1C, 2A, 2B, *etc.*: the number represents the population number and the letter the plot within the population (see fold-out map)), all individuals of *Araucaria nemorosa* were counted. Plants ≤ 30 cm in height were classified as seedlings (following Rigg *et al.* 1998) and not measured for diameter. Plants of height > 30 cm but ≤ 140 cm were measured at ground level for their diameter; plants > 140 cm were measured with a tape measure for *dbh*. Frequency distributions for these measurements were constructed using 5 cm diameter classes for all stands (following Rigg *et al.* (1998)). The height of every tree > 30 cm was measured either directly using a tape measure, or (for larger trees) indirectly with a clinometer.

These data were broken down into size classes of trees, based on *dbh*, at 0.05 cm intervals. Seedlings have been included in the 0.00 – 0.05 cm *dbh* category. The data have been presented as histograms illustrating size class distribution, to allow population structure to be visualized.

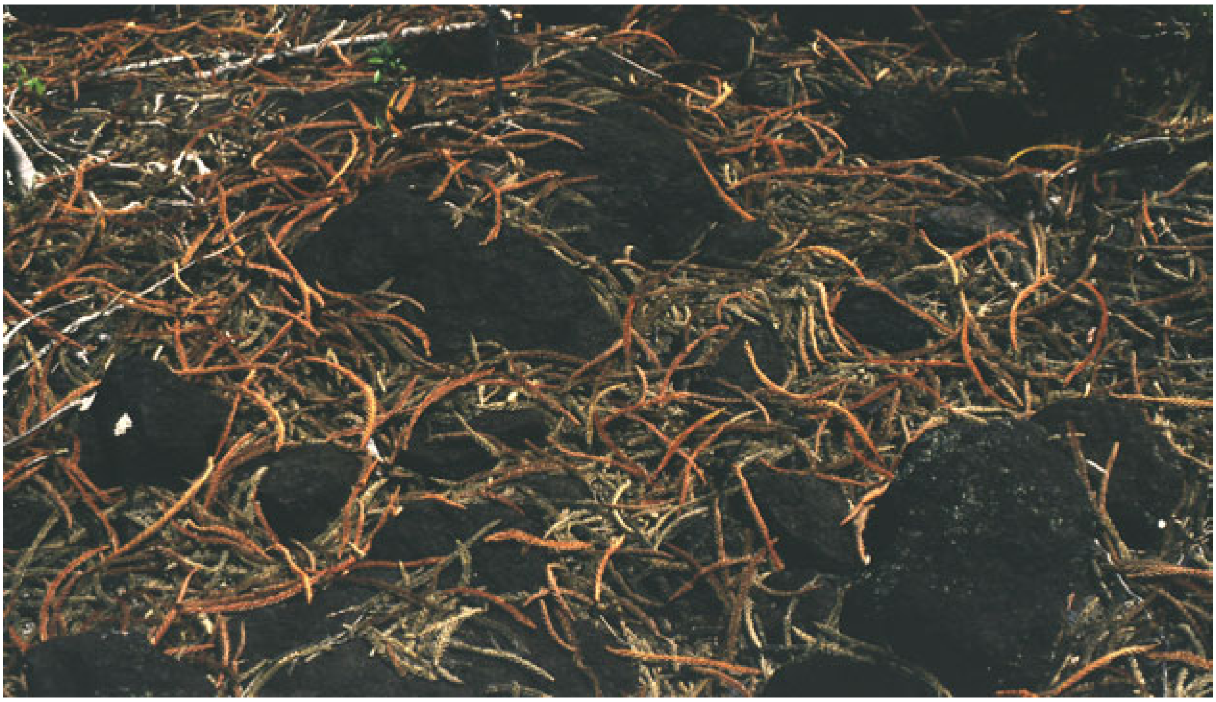
Although data for each plot were recorded separately, it is arguable that although the plots and populations are spatially discontinuous on the ground, there may be a metapopulation structure to the separate populations which renders such separation misleading: equally, if the individual populations are genetically distinct, then the presence or absence of gene flow between adjacent populations will affect the value of different representations of the data. An agnostic approach to such issues is appropriate in the absence of further information, so histograms are therefore presented for individual plots, for amalgamations of plot data for each population, and for all populations considered together. Amalgamation of data within populations may enable a more accurate interpretation of the stand structure, with respect to projection or inference of stand dynamics, if each stand, being continuous, is assumed to be cohesive and thus to need to be considered as a whole; conversely, if there is ecological differentiation between plots or populations this will only be evident from consideration of the data for individual plots.

Differences in size-class distributions between plots were tested with a Kolmogorov-Smirnov two-sample test (Sokal & Rohlf 1981), with seedlings counted as individuals with 0.00 m < *dbh* < 0.05 m. Seedlings were not left out of the analysis, despite the possibility that the large number of individuals in this category might affect results (Rigg *et al.* 1998), as the variation in the numbers of seedlings between plots was striking and might have represented an important aspect of differing population ecologies.

3.5 Dendrochronological techniques

Dendrochronological sampling was undertaken to provide support for the use of *dbh* data as a surrogate for age. Although it is widely accepted that in temperate regions, and in some tropical montane trees, growth patterns represent annual rings, the absolute frequency of rings in tropical climates is less clear (Schweingruber 1992). Seasonal changes may be less severe, inducing often less than annual rings, or alternatively, trees may be very sensitive to small, localized climatic fluctuations, inducing multi-annual rings. However, a review of growth dynamics in tropical trees by Worbes (1995) suggests that annual rings may even be found in certain tropical trees if the climatic fluctuations enable this: an "annual dry season with a length of 2-3 months, with less than 60 mm of monthly precipitation would induce...[these]" (Worbes 1995). Although bi-annual rings (rings occurring twice in a year) are acknowledged in some species, these tend to be restricted to

(*a*) The pollen cones of *Araucaria nemorosa* are distinctive: the pollen cone of *A. nemorosa* (left) is subtended by linear sterile bracts (arrowed), about 10 – 12 mm long, narrowing from 3 mm at the base to 1 mm at the tip, a character unique in the genus. These contrast with the larger pollen cones of *Araucaria columnaris* (right) which lack the distinctive bracts. These cone specimens (*Waters 169*, *Galley 1*) have been deposited in the Daubeny Herbarium, Oxford University Herbaria (FHO). *Photograph: S. T. Turvey*.



(*b*) Fallen leaves of *Araucaria nemorosa* on the forest floor, near Port Boisé. Fallen leaves and pollen cones are usually the easiest way to identify mature individuals. *Photograph: S. T. Turvey*.

PLATE 7. Taxonomic differences between *Araucaria nemorosa* and *A. columnaris*.

(*a*) The domed crown of *Araucaria nemorosa*, emergent above other forest trees, is highly distinctive. *Photograph: S. T. Turvey.*

(*b*) Members of the Expedition sort a mixed pile of cones and branches to confirm their ability to differentiate *Araucaria nemorosa* from *A. columnaris*. *Photograph: S. T. Turvey.*

(*c*) The two species of *Araucaria* that grow at Port Boisé can be separated on details of the morphology of the seedlings, juvenile branches, adult branches & pollen cones. On the left, *Araucaria nemorosa*; on the right, *A. columnaris*. *Photograph: S. T. Turvey.*

PLATE 8. Learning to distinguish *Araucaria nemorosa* & *A. columnaris*.

more equatorial regions such as Sumatra, Borneo and Sulawesi; the Congo basin and southern Sudan; southern Columbia and northern Peru (Worbes 1995). *Araucaria nemorosa* was therefore not expected to have bi-annual rings, as Port Boisé is more than 22° south of the equator.

Tree-rings in the Araucariaceae are notoriously hard to interpret (Falcon-Lang 2000; Brison *et al.* 2001). Despite this, several studies of closely related taxa or taxa in similar environments exist, which have used independent methods for estimating the age of trees. These studies suggest that rings may indeed be annual. Studies include calibration of rings in *Araucaria hunsteinii* K.Schum. by radiocarbon dating (Enright & Hartshorn 1981), by past stem growth data in *Agathis ovata* (C.Moore ex Vieillard) Warb. (Enright & Goldblum 1998), or by knowledge of climatic fluctuation to which the species is most sensitive, in the Australian species *Araucaria cunninghamii* Aiton ex D.Don (Ash 1983).

Cores for dendrochronological analysis were bored from 30 trees within Population 1, using a 5 mm Swedish increment borer, all at 140 cm above ground level, the height at which *dbh* was measured. The use of stem disks, or removal of several cores from one individual, is more informative, being able to distinguish between annual growth rings/zones, and non-annual (less distinct) growth zones (Schweingruber 1992), but it was not possible to carry out such work for legal reasons. A vegetable gum normally used in grafting procedures was inserted using a syringe into the bored hole, to minimize the risk of infection and damage to the tree. Cores were later sectioned along their length, sanded and stained with solid paraffin, promoting visibility of any growth bands within the wood. Intact cores were mounted and a 6× stereo-microscope used to count rings. Linear regression analysis of ring counts on *dbh* for 21 of these samples was performed.

4. RESULTS & DISCUSSION

4.1 Locations of stands

The usual description of the distribution status of *Araucaria nemorosa* as a single locality at Port Boisé (Jaffré 1995; Jaffré *et al.* 1987b; de Laubenfels 1972, 1996; Watt 1999) is somewhat misleading (see fold-out map at back of Report). Six discrete populations were identified in forest on both sides of the bay at Port Boisé and stretching along the Ko Mwa Nüri coast from Koé Vané to Baa Vu (place-names follow IGN (1987), all population names throughout this report follow the fold-out map at back of report). A further population was subsequently discovered by the Expedition *c.* 4 km inland from Port Boisé (map reference UTM 58 696 8 E 7535 0 N (IGN 1987): referred to as population 7 in this report), only part of which could be surveyed and mapped; another population has recently (*c.* 2000) been discovered near Cap Reine Charlotte (R. Attiti, *pers. comm.*; T. Jaffré, *pers. comm.*), approximately 3 km east of Port Boisé. Some of the populations have relatively distinct boundaries and might be considered to be 'groves' rather than 'stands', following Whitmore (1966): in particular, populations 4 and 5 have clear boundaries that may be seen from the 121 m high hill in grid square UTM 58 699 E 7524 N, whereas the boundaries of populations 1 and 6 are less distinct. The road to the Gîte Kaa-nua complex runs through population 1 (road is visible as the black line on the map). Populations 2 & 3 can be reached by a narrow path through thick maquis from the 4×4 track leading towards Koé Vané, as can population 5 by a further path following the coast line south of la Concession. Population 4 can be reached easily from a 4×4 track in the Ko Mwa Nüri area. Population 6 is a short walk from the cluster of houses at the western extremity of the bay of Port Boisé. A few scattered, outlying individuals of *Araucaria nemorosa* were identified in addition to these stands.

The populations identified in this Report are separated by scrub, maquis or simply stretches of coastal forest in which the trees do not appear to occur. The inland boundaries of populations 1-6 usually coincide with those of the forest, though Population 1 also covers some areas of maquis (map reference UTM 58 702 E 7527 N (IGN 1987)). The majority of the trees within the populations are at altitudes between 10 and 30 m, and the seaward boundary is seldom less than 10 m inland. Unlike other forests in New Caledonia (e.g. those in the upper basin of the Rivière Bleue, Plate 1*a*), forests containing *Araucaria nemorosa* have a comparatively open understorey, often strewn with large rocks: large gaps in the canopy are present but uncommon. *Araucaria nemorosa* usually forms an emergent layer above the rest of the canopy, reaching maximum heights of *c.* 21 m.

4.2 Stand structures of plots and populations

Size structures for the plots studied all show a type of 'reverse-J' distribution of individuals, in terms of the abundance of individuals in the smallest size class (0 - 5 cm *dbh*) compared to those in larger size-classes (Table 1, Fig. 1, Fig. 2). Plot 1C shows a classical 'reverse-J' distribution, but some other plots (*e.g.* 1B, 2A, 4A) show gaps in the stand structure which are inconsistent with uninterrupted continuous recruitment.

Unlike some other endangered conifers, such as *Torreya taxifolia* Arn. (Schwartz *et al.* 2000), the regeneration (i.e. the production of abundant and viable seed) of *Araucaria nemorosa* is unproblematic: in every 0.25 ha plot studied there were over 100 plants with *dbh* < 5 cm and in three such plots (2A, 2B, 4B) there were over 1000 such plants. The rate at which these seedlings are recruited to the mature population cannot be derived from a single study of the present population structure, but can only be estimated very approximately from the ratio of individuals in the 5 cm < *dbh* < 10 cm size class to those in the < 5 cm size class. This ratio varies from 2.08×10^{-4} in plot 2A to 3.08×10^{-1} in plot 1A: more than a thousandfold difference, although aggregated plot data for comparison of populations show a lesser difference in magnitude (Table 3).

Perhaps surprisingly, Kolmogorov-Smirnov tests on these plot data as broken down by size class[8] show no significant differences between plots 2A and 2B or between plots 4A and 4B. Within population 1, there is no significant difference between plots 1B and 1C, but both of these plots are significantly different from 1A ($p < 0.01$). This difference is explicable in terms of the very low seedling density in plot 1A (Tables 2 and 3), as the Kolmogorov-Smirnov *d*-value for this size class in the 1A/1B comparison is 0.354, which as the largest *d*-value in the comparison is the test statistic *D*. The critical value here for $p < 0.01$ is 0.144, so the difference in seedling density is responsible for an extremely significant difference in stand structure as 0.354 >> 0.144. The equivalent values for this size class for the 1A/1C comparison are *d*-value = 0.352, which as the largest *d*-value is *D*, and critical value for $p < 0.01$ is 0.136. By contrast, plots 4A and 4B have very different seedling densities, but the difference in the structure of the size class data is not statistically significant. Summing plots within each population, to provide a basis for comparing populations, gives no significant difference between populations 2 and 4 nor between populations 1 and 4, but populations 1 and 2 are significantly different in structure ($D = 0.068$, critical value for $p < 0.01 = 0.043$), a result which suggests a continuum of variation in stand structure with populations 1 and 2 as extremes, rather than large interpopulational difference in stand structures. between plots 1B and 1C, but both of these plots are significantly different from 1A ($p < 0.01$). This difference is explicable in terms of the very low seedling density in plot 1A (Tables 2 and 3), as the Kolmogorov-Smirnov *d*-value for this size class in the 1A/1B comparison is 0.354, which as the largest *d*-value in the comparison is the test statistic *D*. The critical value here for $p < 0.01$ is 0.144, so the difference in structure as 0.354 >> 0.144. The equivalent values for this size class for the 1A/1C

[8] Given the potential for error in the measurement of *dbh*, it would be misleading to do these analyses on the raw diameter calculations from each tree as this would give a false impression of accuracy.

Plots/Populations	Diameter (*dbh*) size classes/cm														
	$0 < dbh < 5$	$5 \leq dbh < 10$	$10 \leq dbh < 15$	$15 \leq dbh < 20$	$20 \leq dbh < 25$	$25 \leq dbh < 30$	$30 \leq dbh < 35$	$35 \leq dbh < 40$	$40 \leq dbh < 45$	$45 \leq dbh < 50$	$50 \leq dbh < 55$	$55 \leq dbh < 60$	$60 \leq dbh < 65$	$65 \leq dbh < 70$	$70 \leq dbh < 75$	**TOTAL**
1A	104	32	10	12	7	3	1	1	0	0	0	0	0	0	0	**170**
1B	510	3	1	4	1	1	1	5	2	0	0	0	0	0	0	**528**
1C	909	15	4	2	3	3	2	4	0	0	1	0	0	0	0	**943**
1 (1A + 1B + 1C)	**1523**	**50**	**15**	**18**	**11**	**7**	**4**	**10**	**2**	**0**	**1**	**0**	**0**	**0**	**0**	**1641**
2A	4817	1	0	0	3	4	3	5	4	0	0	0	0	0	0	**4837**
2B	6870	4	2	1	3	2	1	1	3	2	2	1	0	1	0	**6893**
2 (2A + 2B)	**11687**	**5**	**2**	**1**	**6**	**6**	**4**	**6**	**7**	**2**	**2**	**1**	**0**	**1**	**0**	**11730**
4A	156	1	0	0	1	1	1	0	0	0	0	0	0	0	0	**160**
4B	1184	9	8	5	13	3	3	2	3	0	2	0	1	0	0	**1233**
4 (4A + 4B)	**1340**	**10**	**8**	**5**	**14**	**4**	**4**	**2**	**3**	**0**	**2**	**0**	**1**	**0**	**0**	**1393**
All Plots	**14550**	**65**	**25**	**24**	**31**	**17**	**12**	**18**	**12**	**2**	**5**	**1**	**1**	**1**	**0**	**14764**

Table 2. Stand structures of sampled plots of *Araucaria nemorosa* at Port Boisé: frequencies of different size classes (along top of table) across seven plots in three discrete populations are given. Locations of plots studied are given in Table 1, population nomenclature follows fold-out map at back of this report. See also Figures 1 and 2.

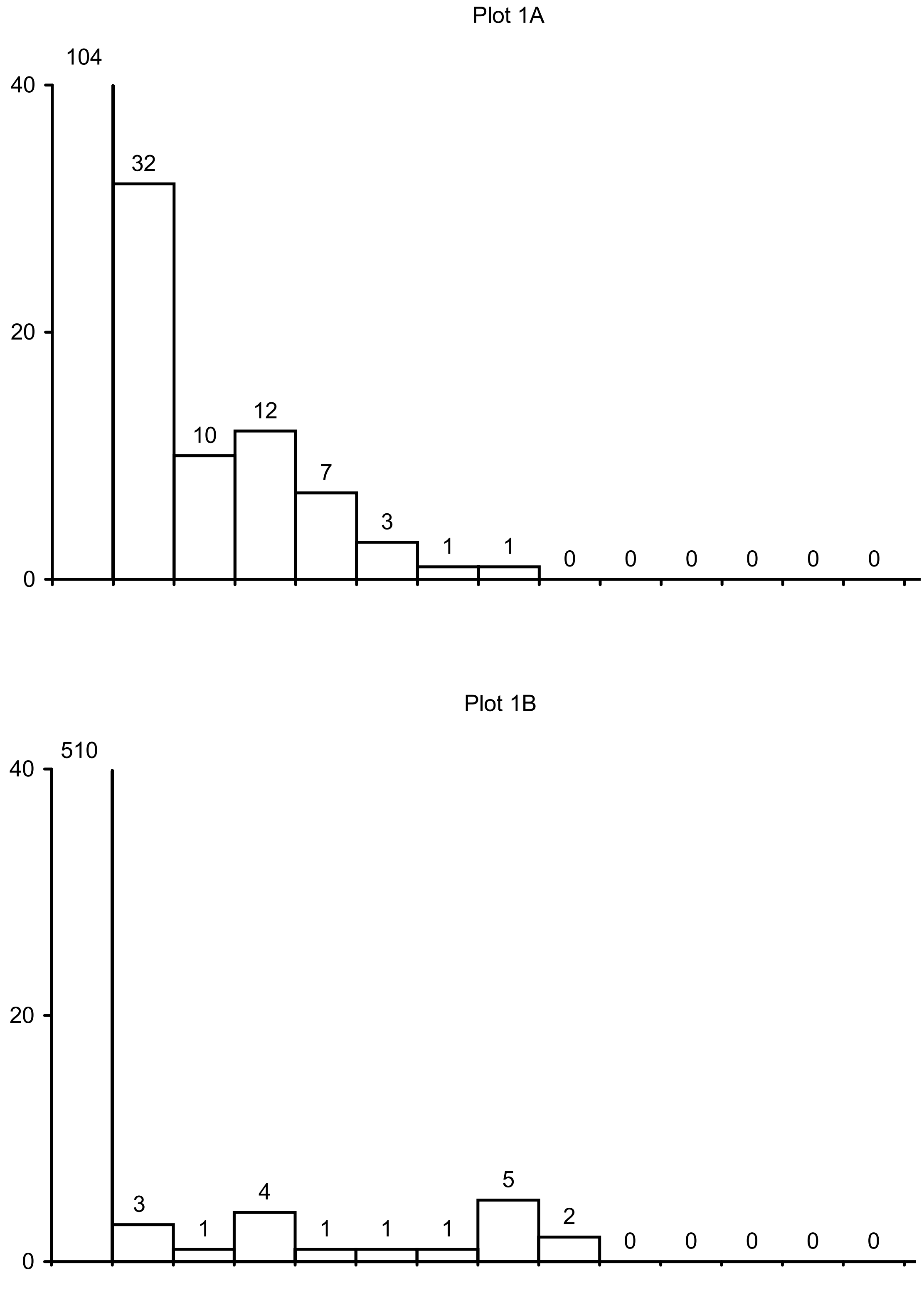
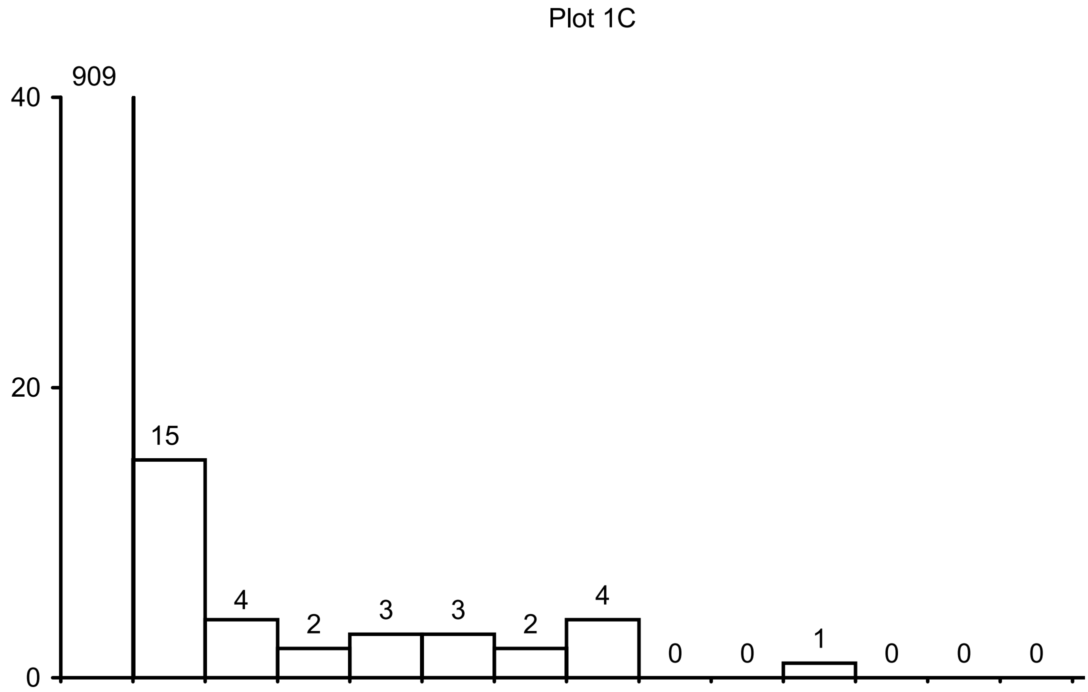


Fig. 1. Stand structures of sampled plots of *Araucaria nemorosa*. Divisions of the horizontal axis represent successive 5 cm wide *dbh* classes, beginning with 0 cm to 5 cm and continuing through 5cm to 10 cm, 10 cm, to 15 cm, etc. Numbers above the bars provide precise frequencies for each category. Open topped bars are used for frequencies too high to be displayed on the histograms. (*continued on pp. 22 –24*).



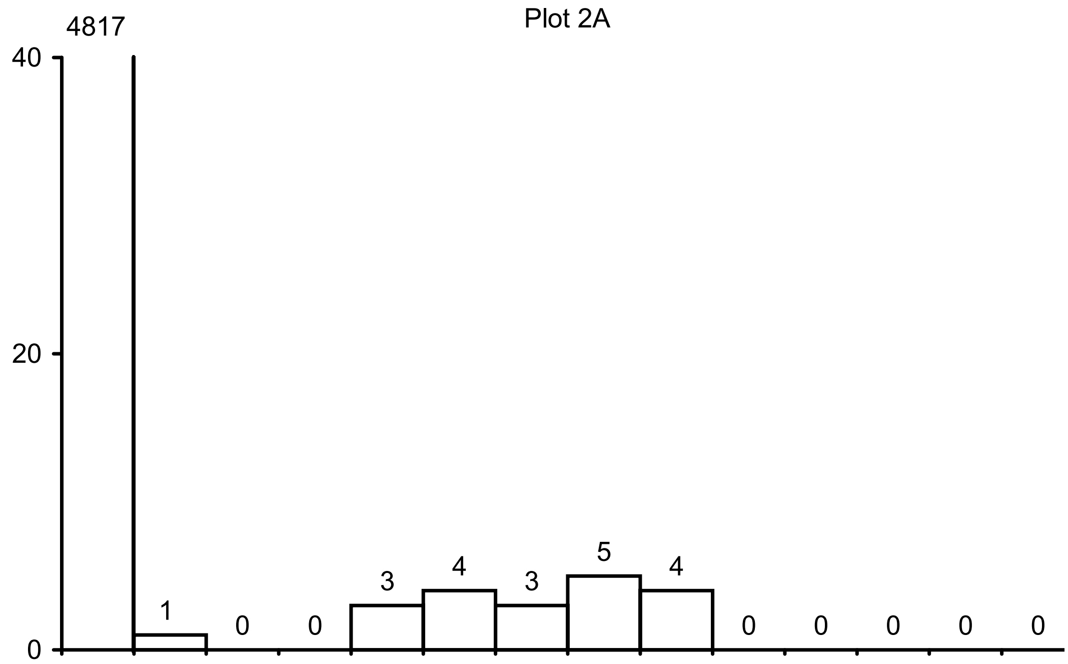
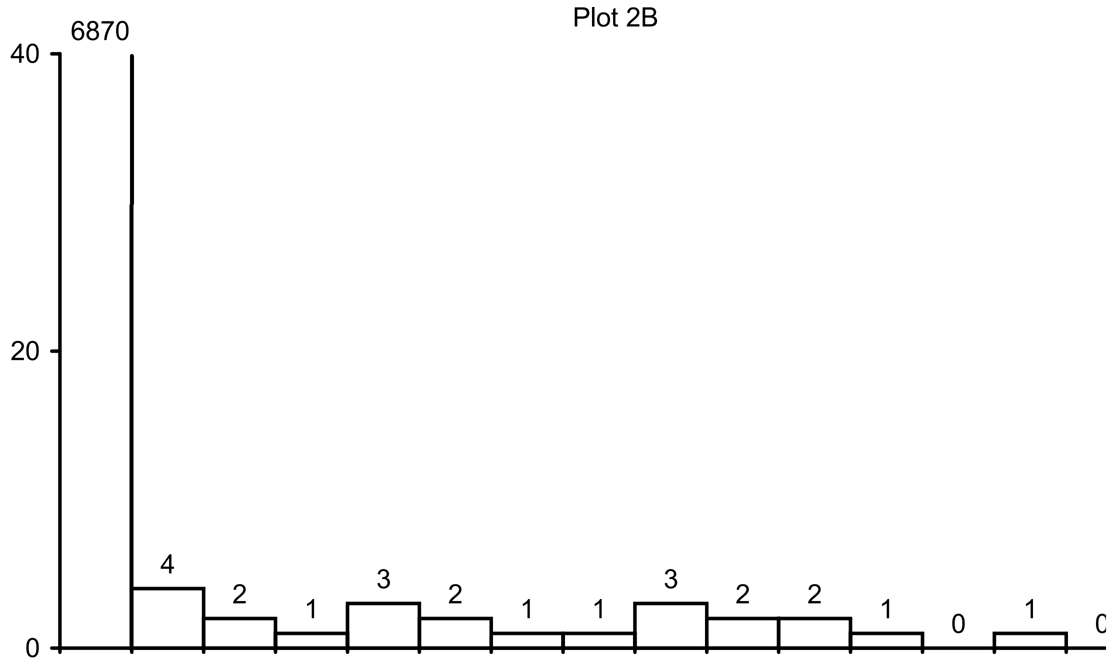


Fig. 1 – *continued.*



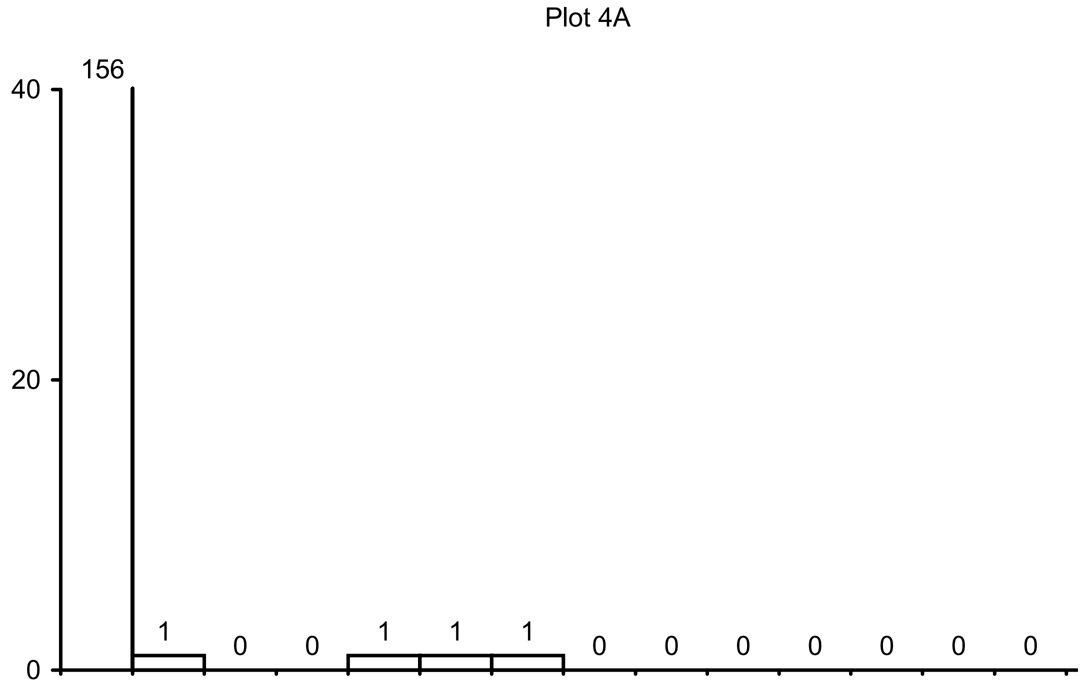


Fig. 1 – *continued.*

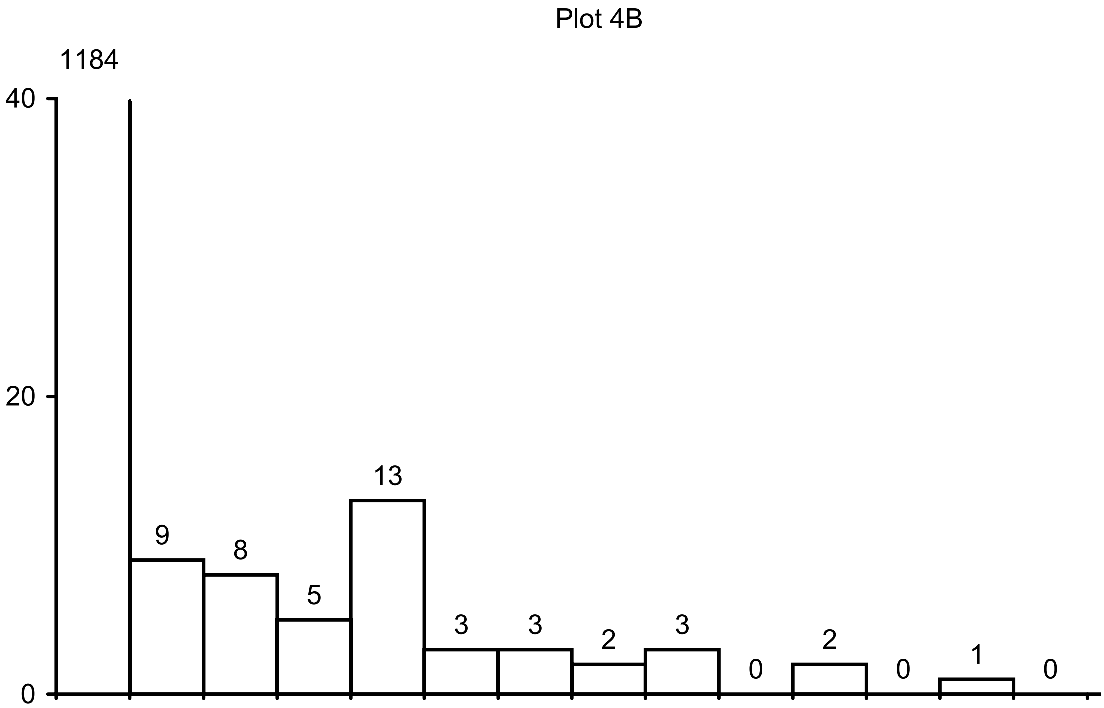
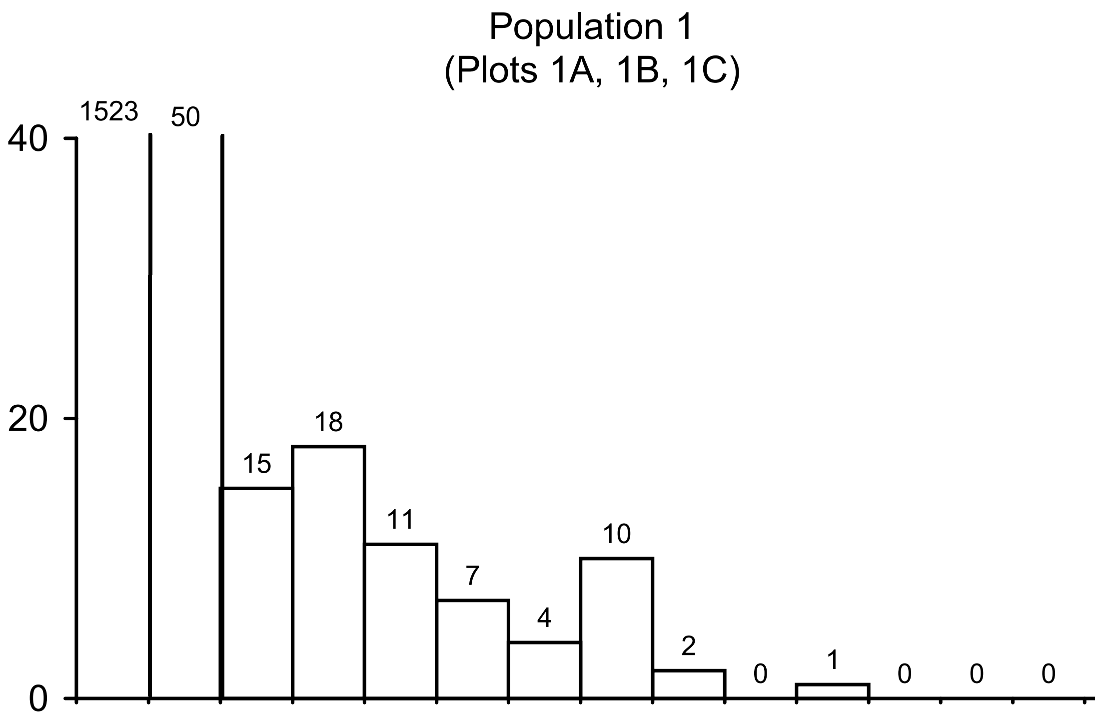


Fig. 1 – *continued*.



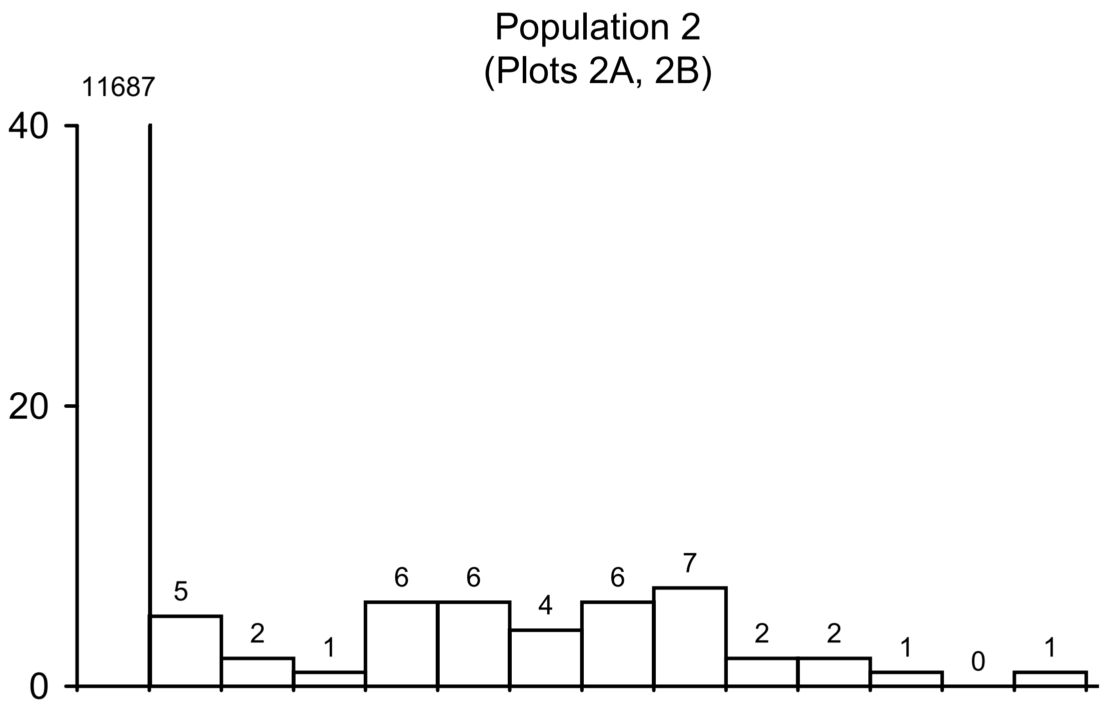
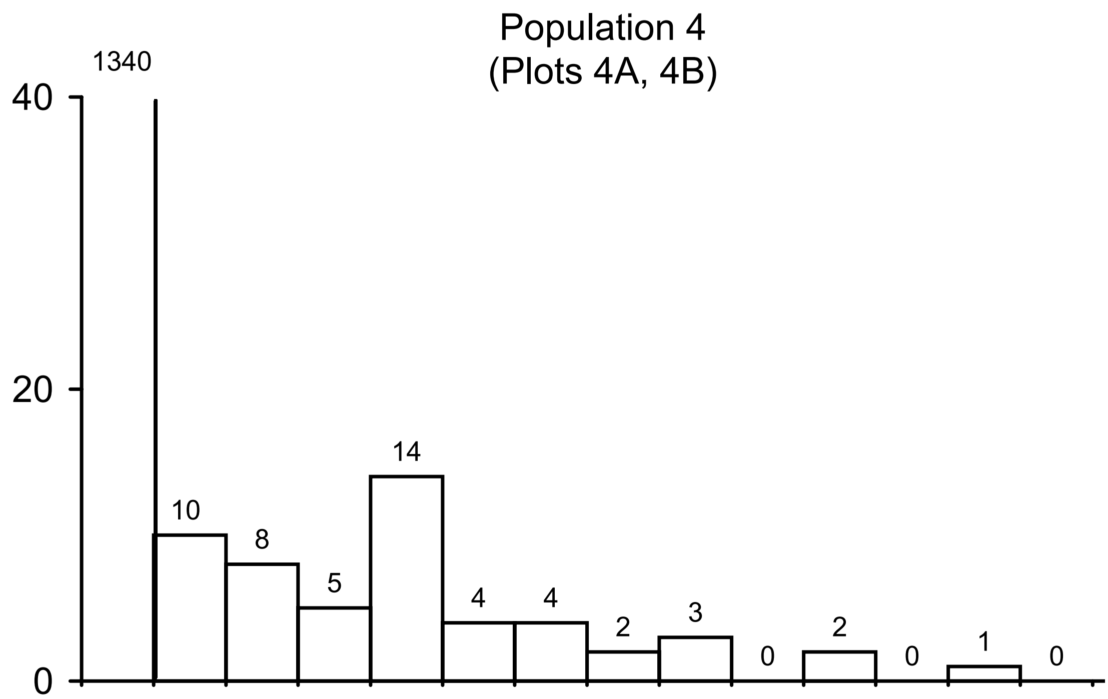


Fig. 2. Stand structures of sampled populations of *Araucaria nemorosa*, amalgamating individual plot data as indicated for each histogram (*top row*: population 1, population 2; *bottom row*: population 4, all populations). Divisions of the horizontal axis represent successive 5 cm wide *dbh* classes. Numbers above the bars provide precise frequencies for each category. (*continued on page 26*).



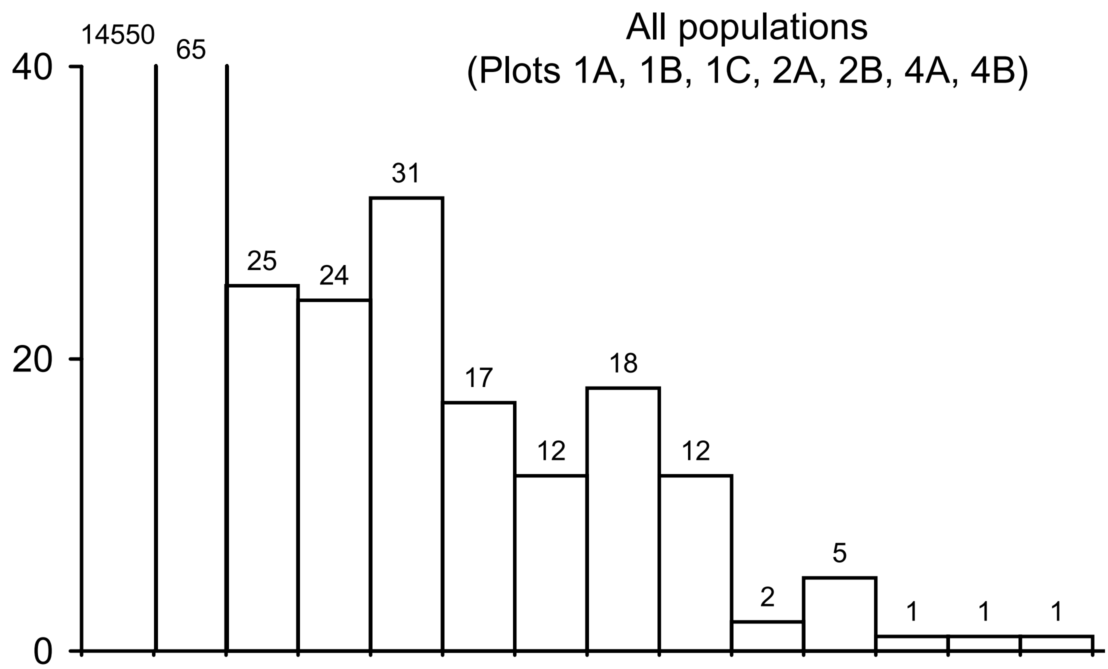


Fig. 2 – *continued.*

PLOT/POPULATION	FREQUENCY, (α) 0 cm < *dbh* < 5 cm (including all plants < 140 cm high)	FREQUENCY, (β) 5 cm < *dbh* < 10 cm	$\beta/\alpha \times 10^3$
1A	104	32	308
1B	510	3	5.88
1C	909	15	16.5
1 (1A + 1B + 1C)	**1523**	**50**	**32.8**
2A	4817	1	0.208
2B	6870	4	0.582
2 (2A + 2B)	**11687**	**5**	**0.428**
4A	156	1	6.41
4B	1184	9	7.60
4 (4A + 4B)	**1340**	**10**	**7.46**
ALL PLOTS	**27760**	**120**	**4.32**

Table 3. Recruitment of *Araucaria nemorosa* de Laub. The ratio of individuals of *Araucaria nemorosa* in the second-lowest size class to those in the lowest size class, for seven 0.25 ha plots of *Araucaria nemorosa* studied, and aggregated plot data for each population. The ratio, here multiplied by 10^3 and given to three significant figures for ease of comparison, provides an estimate of the proportion of seedlings which are recruited into the population of mature and semi-mature trees: the ratio varies more than thousandfold between plots 1A and 2A Actual values for this transition probability, such as would be needed to construct a matrix model similar to those used to analyse the demography of *Araucaria cunninghamii* by Enright & Watson (1991), cannot be obtained without tracking cohorts of individual trees over a number of years. Locations of plots studied are given in Table 1.

seedling density is responsible for an extremely significant difference in stand comparison are *d*-value = 0.352, which as the largest *d*-value is *D*, and critical value for $p < 0.01$ is 0.136. By contrast, plots 4A and 4B have very different seedling densities, but the difference in the structure of the size class data is not statistically significant. Summing plots within each population, to provide a basis for comparing populations, gives no significant difference between populations 2 and 4 nor between populations 1 and 4, but populations 1 and 2 are significantly different in structure ($D = 0.068$, critical value for $p < 0.01 = 0.043$), a result which suggests a continuum of variation in stand structure with populations 1 and 2 as extremes, rather than large interpopulational difference in stand structures.

Plot	1A	1B	1C	2A	2B	4A	4B
Basal area (m^2ha^{-1})	4.80	4.52	5.52	7.04	9.16	0.72	10.04
Stem density, not including seedlings (ha^{-1})	332	272	492	1976	1288	16	780
Stem density, including seedlings (ha^{-1})	680	2112	3772	19348	27572	640	4932
Seedling density (m^{-2})	0.035	0.184	0.328	1.737	2.628	0.062	0.415

Table 4. Total basal area and stem density recorded for seven 0.25 ha plots of *Araucaria nemorosa* studied. Locations of plots are given in Table 1.

The lack of clear differentiation in stand structures in the different plots and populations may be an artefact of the extremely restricted range of *Araucaria nemorosa* rather than a particular feature of its autecology – a problem alluded to by de Laubenfels (1996). However, in all plots, individuals with *dbh* between 0 cm and 5 cm are far more common than those of any other size-class, and to varying extents, the plots exhibit a paucity of individuals in the 5 to 20 cm *dbh* size classes, indicative of a lack of recruitment of seedlings into the mature population. Plot 2A shows only 1 individual with a *dbh* between 5 and 20 cm, and plots 4A and 4B show similar patterns, with fewer individuals in this size range compared to the number of larger individuals, rather than a greater number as would be expected from a continuously recruiting species.

Basal area of *Araucaria nemorosa*, a measure of the density of at which the species is present in the forest as calculated from the raw data on the *dbh* of every trees, varied between 0.72 m^2ha^{-1} and 10.04 m^2ha^{-1}, with considerable difference between the plots analysed (Table 4). Within Population 4 basal area varied almost fifteen-fold between plots 4A and 4B. Seedling and non-seedling densities also varied markedly, though for both basal area and seedling density plot 4A exhibits very low, possibly anomalous, population density. If this plot is disregarded, basal area has a mean of 5.29 m^2ha^{-1}, with standard deviation 2.58 m^2ha^{-1}.

4.3 Dendrochronological results

The results of dendrochronological analyses of 21 wood samples extracted from trees in Population 1 (*Waters s. n.*, **FHOw)** are presented in Fig. 3. Regression analysis shows a clear correlation between radius of tree and ring count ($r^2 = 0.707$, $p < 0.001$) The line in Fig. 3 is the line of best fit for the data, with an equation of *radius/mm* = 9.8 + 0.452 *rings*. If rings were annual, this relationship would predict an age of 420 years for a tree of 40 cm *dbh*: however, given that there are trees of approximately this diameter which were planted on 18 May 1981[9], in the arboretum at the Parc Provincial de la Rivière Bleue, Province Sud, it

[9] Metal plaque at foot of tree.

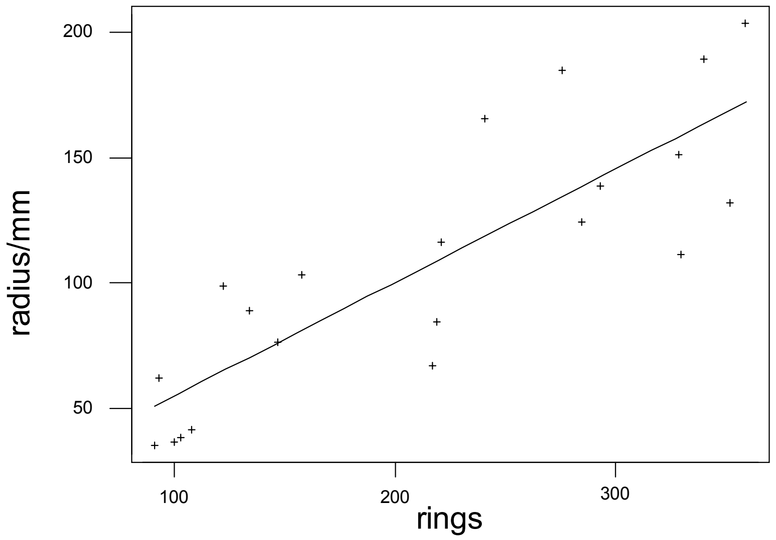


Fig. 3. Relationship between tree radius and ring number in *Araucaria nemorosa*, as inferred from a sample of 21 wood-cores. The line plotted represents the equation of the regression analysis, *radius/mm* = 9.8 + 0.452 *rings*. $r^2 = 0.707$, $p < 0.001$.

seems extremely unlikely that the identified growth zones correspond to annual rings. Further studies will be needed to identify their biological significance, but they are uninformative on the age of individuals in the populations of *Araucaria nemorosa* at Port Boisé.

4.4 Evidence for hybridization of *Araucaria nemorosa* with *A. columnaris*

Bernard Suprin (*in litt.*) has suggested that hybridization may be taking place between *Araucaria nemorosa* and *A. columnaris* at Port Boisé. Although almost all trees encountered could, with practice, be assigned without difficulty to one species or the other on the basis of branch or pollen cone morphology, one individual possessed typical *Araucaria nemorosa* pollen cones, with the linear subtending bracts, and typical flattened, imbricate, *A. columnaris* leaves. Owing to an oversight we did not collect a specimen of this tree: the approximate UTM grid location for the tree is:

UTM 58 700 604 E 7524 765 N

Notes taken at the time by the expedition members who spotted the tree (RP, STT, NMW) identify it as having two large trunks from ground level and being easy to spot. The clear importance of such a putative hybrid for the understanding of *Araucaria* evolution and the processes which maintain the species as separate is such that further investigation of this tree would be highly desirable.

4.5 Discussion

The existence of at least eight discrete populations of *Araucaria nemorosa*, albeit all within 3 km of another, suggests that the former distribution of the species may have been more widespread, and raises the question of the relative genetic isolation of each of these populations. The population genetic patterns of fragmented plant populations exhibit great variation (Young *et al.* 1996) and are not always as would be predicted from simple genetic models (Young *et al.* 1996). Population genetic work in the Araucariaceae to date has been limited, but studies of *Agathis borneensis* Warb. in Borneo, and of *Araucaria araucana* (Molina) K.Koch in Chile, have both indicated higher intrapopulational than interpopulational diversity (Kitamura & Rahman 1992; Rafii & Dodd 1998). Studies of the phylogeography of *Araucaria nemorosa*, especially with regard to the outlying, inland population (on the other side of a high ridge, in the Forêt Nord at UTM 58 696 8 E 7535 0 N, (IGN 1987)) would illuminate not only the spatial pattern of variation but also the time-interval over which disjunctions in distribution have occurred – whether they are the result of nineteenth century logging, of enviromental disturbance in the aftermath of human settlement of New Caledonia *c.* 3300 BP[10], or of Pleistocene (*e.g.* Pintaud *et al.* 2001) or even earlier events, pre-dating human arrival in the archipelago.

These results may be compared with methodologically similar studies of the ecology of the other *Araucaria* species. Comparison with forest populations of *A. laubenfelsii* on Mont Do, as studied by Rigg *et al.* (1998)[11] suggest that seedling densities for *A. nemorosa* are more variable, and basal areas & stem densities lower, than in that species. The New Guinean species studied by Gray (1975) were sorted into size classes differently, but 214 specimens of *A. nemorosa* with *dbh* > 0.05 m in a total of seven plots may be compared with Gray's totals of 50 trees of *A. cunninghamii* and 19 of *A. hunsteinii* with *dbh* > 0.03 m in an area of four plots (each 0.25 ha, as in this study). Clearly, *A. nemorosa* stands are much denser than either of the New Guinea species and approach the densities of *A. laubenfelsii* on Mont Do.

The vegetational history of Port Boisé, as discussed in section 1.4, is also crucial to our understanding of the demography of *Araucaria nemorosa*. The extent of late nineteenth century deforestation may well have shaped the present stand structure of the species by providing a stand-level disturbance *sensu* Enright and Ogden (1995), that provided an opportunity for recruitment much greater than that available today. Disregarding ring data, but assuming a correlation between age and *dbh* and allowing for trees in the arboretum to have grown at a rate up to twice as fast as those at Port Boisé and for those plantings to have been five years old when planted in 1981, the oldest trees sampled at Port Boisé would still be only *c.* 80 years old, making it unlikely that the oldest trees in the present population

[10] Approximate date, from Sand (2001) and Kirch (1997). We thank Katherine Szabo of the Australian National University, Canberra, for her advice on reliable dates for the first human occupation of New Caledonia. *See also*: Stevenson, J. (1999). *Late Quaternary environmental change and the impact of Melanesian colonization in New Caledonia*. Unpublished PhD thesis, University of Sydney, Australia.

[11] Although in the Rigg *et al.* (1998) study, not every seedling was counted and these figures were estimated from sampling of subplots: the data should be compared carefully.

structure pre-date nineteenth century forest exploitation. If *Araucaria nemorosa* is regenerating as a normal component of the forest, in the manner described for *Agathis macrophylla* (Lindl.) Mast. on Vanikoro[12] by Whitmore (1966), the paucity of saplings (individuals with 5 cm < *dbh* < 20 cm) in some of the plots is very difficult to explain. If, however, the species is dependent on large-scale disturbances of its environment to provide it with the opportunity to recruit in large numbers, an ecological strategy common among southern hemisphere conifers (Bond 1989; Enright and Ogden 1995), then the observed stand structures are less surprising. The plots studied here exhibit considerable variation, and it is worth noting the tremendous difference in the ratio of saplings : seedlings between plots (Table 3), and the apparently continuous recruitment in population 1A, must be understood partly in terms of statistical artefact because we have data for so few plots, but partly also in terms of the ecology of population 1: with a graded road through the middle of it (see fold-out map at back of report) connected to the recent development on the seaward side at Gîte Kaa-nua, it is also the population for which the evidence of recent disturbance is most striking and therefore for which such a population structure would be most likely to be discovered if recruitment were indeed episodic and dependent on major disturbance.

The distinction between landscape-scale, episodic recruitment and 'standard', gap-phase dynamics is primarily a difference of scale rather than of kind (Enright and Goldblum 1998). Variation in stand structures among investigated populations of *Araucaria nemorosa*, small population size and small area of occupancy make it difficult to provide definitive answers to demographic questions that may themselves be scale-dependent (de Laubenfels 1996) and renders firm conclusions problematic but the hypothesis put forward here on the basis of these studies is that *A. nemorosa* does, at least to some extent, rely on major disturbance events for recruitment. Whitmore (1966, 1989) laid stress on the ecological importance of the simple distinction between trees whose seedlings are shade-tolerant and trees whose seedlings are shade-intolerant. Although itself a matter of degree, this difference appears to underpin the difference between species capable of recruiting continuously and those where recruitment is confined to a narrow time window following a major disturbance event – 'pioneer' species *sensu* Whitmore (1989). *Ex situ* experimental tests of the prediction of seedling shade-intolerance which this hypothesis entails would be highly desirable. The results of such work should form a key element of a conservation strategy for the species, which should aim to expand present populations within the coastal forest through appropriate forest management, and to consider the introduction of the species into suitable forests further inland, or augmentation of the populations already there through both *in situ* & *ex situ* propagation (see section 5.3).

[12] An island of the Santa Cruz Group, Solomon Islands; famous for being the site of the wreck of the La Pérouse expedition to the Pacific in 1788. 'Vanikolo' is an alternative spelling.

5. CONCLUSIONS

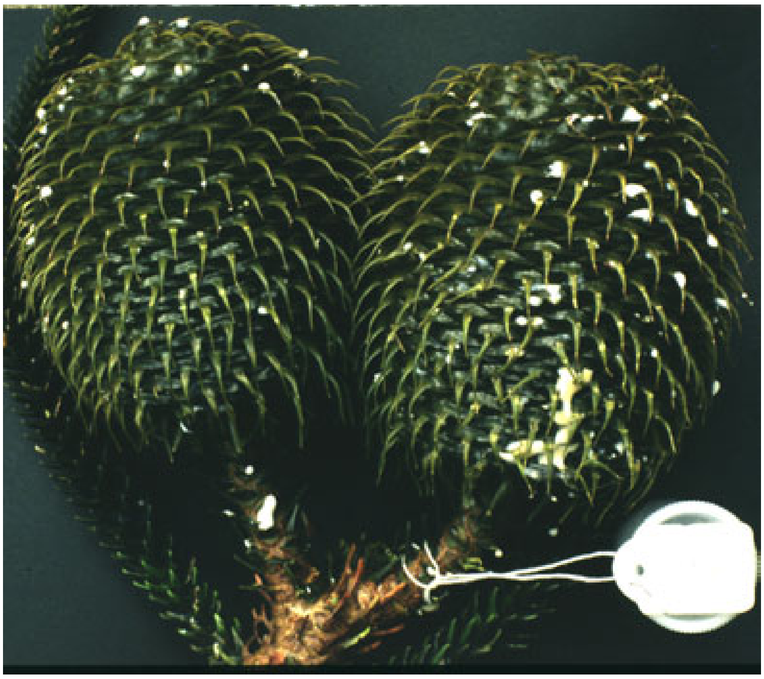
5.1 Population biological conclusions

Araucaria nemorosa is an extremely rare tree, but shows significant variation in population structure across seven plots in three populations analysed. Population structure varied from a classical 'reverse-J' structure in plot 1C to a total absence of individuals in the 10 cm < *dbh* < 15 cm and 15 cm < *dbh* < 20 cm size classes in plot 2A. At a populational level, a paucity of saplings compared to the numbers of more mature trees was evident from the aggregated plot data in populations 2 & 4 but not from plots in population 1. Statistical tests on aggregated plot data suggest that populations 1 and 2 may be considered as extremes of a continuum of population structures, being significantly different from one another but not from the aggregated plot data from population 4. Without data from many points in time as well as in space, we cannot provide accurate data on transition probabilities between size-classes but can only estimate such probabilities from the "stationary pattern in the landscape" (Engelmark *et al.* 1994). Estimated levels of recruitment of seedlings to the population of semi-mature trees are very low (Table 3: overall mean = 0.00447), but are markedly higher in population 1 (= 0.328), bisected by a pair of roads, adjacent to a holiday complex and evidently the most recently disturbed population. The density at which *Araucaria nemorosa* is found in the landscape is also highly variable, but appears to be intermediate between that of the New Guinea *Araucaria* species studied by Gray (1975) and that of *A. laubenfelsii* on Mont Do, further north in New Caledonia (Rigg *et al.* 1998).

Whilst the data are by virtue of the restricted range of the species insufficient to provide an authoritative classification of the life-history strategy of *Araucaria nemorosa*, these data suggest that the successful regeneration of *Araucaria nemorosa* may be disturbance-dependent and therefore potentially episodic rather than continuous. We suggest that major disturbance of the forests by logging in the past 150 years has structured present populations, although we have been unable to test this hypothesis as thoroughly as we would have wished owing to the difficulties encountered in making sense of our dendrochronological dataset. We advocate tests on seedling physiology similar to those outlined and conducted by Whitmore (1966) in his study of *Agathis macrophylla*, and the continued monitoring of Population 1 (in particular) to analyse recruitment patterns and processes in a successfully recruiting population.

5.2 Recommendations for IUCN classification

Araucaria nemorosa is currently classified in the IUCN conservation concern category 'Critically Endangered' (**CR)** in the *Status Survey and Conservation Action Plan: Conifers* (Farjon & Page 1999), as it fulfills criteria **B1** and **B2c** for this category, as follows:



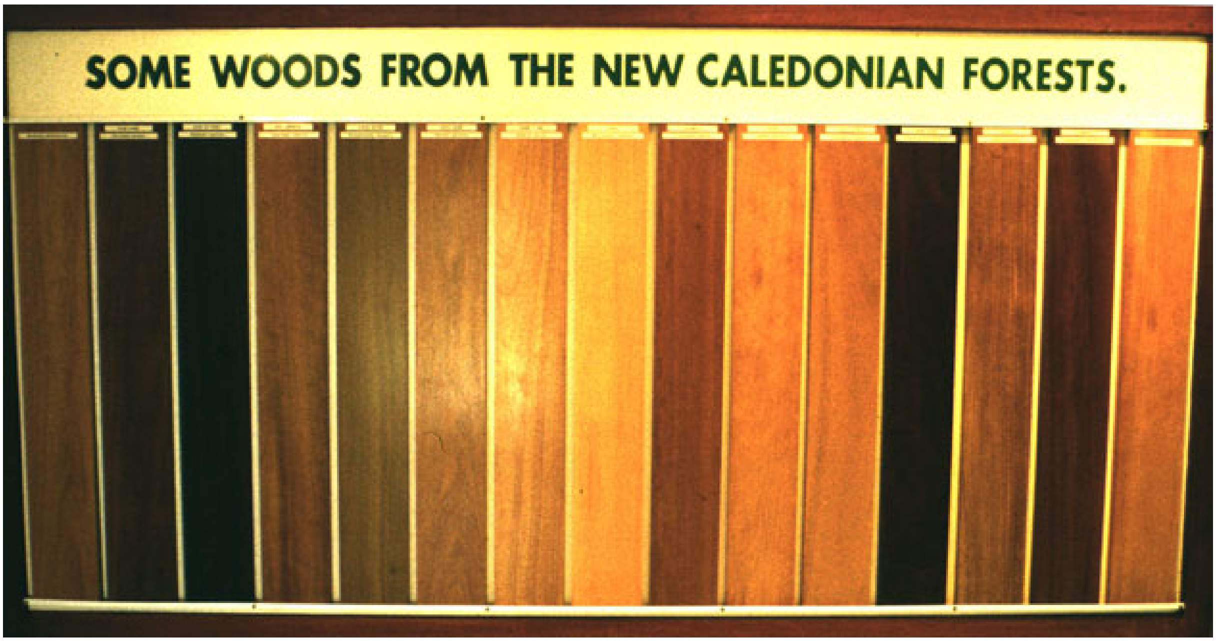
(*b*) (*above*) A female cone specimen (*Waters 163*) is photographed before being soaked in petrol to help preserve it, wired to prevent shattering, and sent to the Daubeny Herbarium, Oxford University Herbaria (**FHO**). *Photograph: S. T. Turvey.*

(*a*) (*above left*) A member of the Expedition (TW) extracts a core for dendrochronological analysis from a tree of *Araucaria nemorosa* in population 1. The procedure minimizes harm to the trees. Cores (*Waters s.n.)* are deposited in the Xylarium, Oxford University Herbaria (**FHOw**). *Photograph: S. T. Turvey.*

(*c*) Four members of the Oxford University Expedition to New Caledonia, near Port Boisé. From left to right: N. M. Wilkinson, R. Palmer, C. A. Galley & T. Waters. S. T. Turvey, the other member of the Expedition, is taking the photograph. The trees in the distance at the right hand side are *Araucaria columnaris*.

PLATE 9. The Expedition in the field.

(*a*) Doniambo, just outside Nouméa, is a huge nickel smelter which processes much of the nickel ore mined in New Caledonia. Nickel is the country's most important export in financial terms, and a new processing plant is presently being built less than 6 km from Port Boisé. Nickel mining represents a major threat to many landscapes and plant communities in New Caledonia. The shrub in the foreground is the invasive tropical legume *Leucaena leucocephala* (Lam.) de Wit. (Leguminosae), which is increasingly common in anthropogenically-degraded areas of New Caledonia. *Photograph: T. Waters.*



(*b*) A display of different types of wood from the forests of New Caledonia, at the Parc Forestier Michel Corbasson, Nouméa. Many of these timbers command a high price owing to their versatility and strength, notably *Agathis lanceolata* (Sebert & Pancher) Warb. (Araucariaceae) & *Arillastrum gummiferum* (Brongn. & Gris) Pancher ex Baillon (Myrtaceae). The area around Port Boisé was exploited for timber in the nineteenth century, and many parts of New Caledonia have been deforested through extensive logging. *Photograph: S. T. Turvey.*

PLATE 10. Potential threats to the future of *Araucaria nemorosa*.

B: Extent of occurrence estimated to be less than 100 km^2 or area occupancy estimated to be less than 10 km^2, and estimates indicating any two of the following:

1. Severely fragmented or known to exist at only a single location.

2. Continuing decline, observed, inferred or projected in any of the following:
a) extent of occurrence
b) area of occupancy
c) area, extent and/or quality of habitat
d) number of locations or subpopulations[13]
e) number of mature individuals

These categories have since been revised (IUCN 2001), and now the comparable criteria under which *Araucaria nemorosa* may be classified as Critically Endangered are as follows:

B: Geographic range in the form of either **B1** (extent of occurrence) OR **B2** (area of occupancy) OR both:

1. Extent of occurrence estimated to be less than 100 km^2, and estimates indicating at least two of a–c:
a. Severely fragmented or known to exist at only a single location.

b. Continuing decline, observed, inferred or projected, in any of the following:
(i) extent of occurrence
(ii) area of occupancy
(iii) area, extent and/or quality of habitat
(iv) number of locations or subpopulations
(v) number of mature individuals.

c. Extreme fluctuations in any of the following:
(i) extent of occurrence
(ii) area of occupancy
(iii) number of locations or subpopulations
(iv) number of mature individuals.

2. Area of occupancy estimated to be less than 10 km^2, and estimates indicating at least two of **a–c**:
a. Severely fragmented or known to exist at only a single location.

b. Continuing decline, observed, inferred or projected, in any of the following:
(i) extent of occurrence
(ii) area of occupancy
(iii) area, extent and/or quality of habitat
(iv) number of locations or subpopulations
(v) number of mature individuals.

c. Extreme fluctuations in any of the following:
(i) extent of occurrence
(ii) area of occupancy
(iii) number of locations or subpopulations
(iv) number of mature individuals.

Our work supports an area of occupancy of *Araucaria nemorosa* of approximately 2 km^2 (see fold-out map at back of this report), and supports an extent of occurrence

[13] For IUCN purposes, a population consists of all the individuals belonging to a single species. We regard this terminology as confusing: the entities referred to in this report as "populations" are to be understood as "subpopulations" on the IUCN definition.

of much less than 100 km^2 (the total land area covered by map at back of report is itself less than 100 km^2). Mapping work carried out has shown that the population does exist at more than one locality: multiple discrete populations have been located. Insofar as some of these populations are separated by distances of *c.* 3 km and a mountain ridge, the species qualifies as severely fragmented as transfer between populations is likely to be limited if not absent across such distances and terrain.

We found no quantifiable evidence that the area, extent and/or quality of the habitat is under decline but neither did we find firm evidence that it is not, so we cannot make a recommendation on those grounds. However, data from population analyses carried out in Populations 1, 2 and 4 suggest a projected decline in the number of mature individuals in at least Population 2 (one of the larger populations identified) owing to the paucity of trees in the 10 cm < *dbh* < 15 cm and the 15 cm < *dbh* < 20 cm size-classes. In Population 2 the number of individuals with 5 cm < *dbh* < 25 cm is only 61% of the number of individuals with 25 cm < *dbh* < 45 cm.

The criterion **B1** is satisfied as the extent of occurrence is less than 100 km^2 and two subcriteria, **B1a** and **B1b(v)**, are met; similarly, criterion **B2** is satisfied as area of occupancy is less than 10 km^2 and two subcriteria, **B2a** and **B2b(v)** are met. In conclusion therefore, our results indicate that the conservation classification of *Araucaria nemorosa* should remain Critically Endangered (**CR**), but that there are a number of ecologically and spatially distinct populations (subpopulations *sensu* IUCN) and that in this respect the assessment of Farjon & Page (1999) should be updated.

5.3 Conservation recommendations

Conservation strategies should where possible be informed by an understanding of the biology of the species they seek to conserve, and a population structure that would be considered a cause of grave concern in a continuously recruiting species might not be so alarming in a species with episodic recruitment. Nonetheless, we do not regard it as clear that recruitment is usually episodic, despite the presence of such a strategy in related species, and there can be no room for complacency in planning the management of a species as rare as *Araucaria nemorosa*. Studies on other species in the Araucariaceae have shown higher intrapopulational than interpopulational genetic diversity (Kitamura & Rahman 1992; Rafii & Dodd 1998), so conserving large populations of *Araucaria nemorosa* may be as important as conserving many populations.

On present information, the conservation strategy for this species should involve both *in situ* and *ex situ* approaches: *ex situ* because of the extremely restricted and vulnerable distribution of *Araucaria nemorosa*; *in situ* because an increase in the number of mature and semi-mature trees in present populations of *A. nemorosa* would be the most reliable way of increasing the probability of the species persisting in its present locations.

Ex situ conservation should take the form of cultivation at a number of suitable sites elsewhere in New Caledonia (e.g. at the new botanic garden presently being laid out in Nouméa, at the Arboretum at the Parc Provincial de la Rivière Bleue, at other sites with appropriate soil and climatic conditions elsewhere in New Caledonia) and overseas: seedlings, which are abundant, should be sent to botanic gardens in Australia and further afield (there is only one plant in the United Kingdom presently[14]), aiming to provide different gardens with plants from different, identifiable populations (precise locality data, or population nomenclature following this report) such that the conservation genetic value of such material is maximized.

In situ conservation practices for a species whose recruitment processes are not known with certainty must necessarily be extremely cautious. Noting that population 1 appears to be recruiting adequately presently, and that the inland limits of the coastal populations are largely set by the cuirasse rocks, we suggest that seeds are distributed in different areas of coastal forest presently devoid of concentrated populations of *Araucaria nemorosa* (occasional outliers may already be present) to assess the suitability of such sites for the expansion of present populations *in situ*.

The question inevitably arises as to whether or not some form of reserve is needed to conserve these populations. This has evidently been considered in the past (Watt 1999), but at present, perhaps 70% of the total population (Populations 1-6) is on the land of the Attiti brothers (Robert & Alexandre), and in the vulnerable habitats of coastal forest or coastal forest/maquis minier ecotone. Since the brothers are clearly interested in the welfare of these populations, knowledgeable about their distribution and have a good working relationship with the Service de l'Environnement (Devinck, *pers. comm.*), there may seem no great urgency. However, any possible expansion of the gîte complex at Kaa-nua or any logging or other industrial activities in the area should be considered carefully and monitored closely for their effects on the populations of *A. nemorosa*, whether direct or indirect. Statutory protection for *Araucaria nemorosa* under New Caledonian law, presently afforded only to *Parasitaxus usta* among New Caledonia's conifers (Watt 1999), should be introduced to provide a framework for the legal safeguarding of this species.

The problems of the present reserve system in New Caledonia and the urgent need for its reform have been highlighted already by Jaffré *et al.* (1998). In the longer term, it would be highly desirable for reserve status to be accorded to the coastal forests of the southern tip of New Caledonia, to protect their unique, wonderful conifer and the associated plant and animal species of these forests (e.g. the highly diverse bird community, in which a species previously unknown from New Caledonia was recorded by the Expedition: see Appendix 3).

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[14] at the Royal Botanic Gardens, Kew

5.4 Useful future research

The literature on *Araucaria nemorosa* is extremely limited: we believe this to be the first published study to concentrate on *A. nemorosa* rather than discussing it primarily as part of an analysis of the comparative biology of the New Caledonian species of *Araucaria* (e.g. de Laubenfels 1972, Veillon 1978, 1980; Rouane & Woltz 1979, 1980; Jaffré *et al.* 1987b). As well as the investigation of the putative hybrid mentioned in section 4.4, three particular questions arise in regard to the biology of this species which we suggest might repay further scientific enquiry, as set out below. We would be delighted to offer any assistance by way of collected specimens, more detailed maps or our own raw data to anyone interested in investigating the biology of *Araucaria nemorosa*.

a) Dendrochronology: what is the timescale over which patterns and processes in the population biology of the species occur, and how old are the oldest trees in modern populations of *Araucaria nemorosa*?

b) Are the seedlings of *Araucaria nemorosa* shade-tolerant or not – does their physiology provide a clue towards the elucidation of their life-history strategy and whether recruitment in populations of this species is continuous or episodic?

c) The fragmentation of the populations of *Araucaria nemorosa* stands in obvious contrast to the continuous narrow population of *Araucaria columnaris* that lines much of the coast of southernmost New Caledonia. What is the genetic structure of *Araucaria nemorosa*, and is there a phylogeographic pattern to the distribution of populations in the coastal forest (populations 1-6 on the fold-out map at the back of this report) and population 7 in the Forêt Nord on the other side of an inland ridge?

6. EXECUTIVE SUMMARY RÉSUMÉE EXÉCUTIVE

6.1 English

Araucaria nemorosa de Laub. is an extremely rare and poorly known species, endemic to the Port Boisé region in the far south of New Caledonia. It is classified as Critically Endangered by the IUCN, the highest level of conservation concern accorded to any member of the genus *Araucaria*. The safeguarding of populations of *Araucaria nemorosa* should be regarded as a high priority for conservation efforts within New Caledonia.

A number of illustrations of the morphology of the species are provided (the first since 1972) and a total of eight discrete populations are identified, seven of which are scattered along the coast near the bay of Port Boisé and one of which occurs further inland. The precise boundaries of seven of these populations are mapped, and the location of the other population indicated.

Although the species is more widely distributed than published descriptions suggest, its habitat is restricted, fragmented, and extremely vulnerable to fire and to man-made disturbances. Analyses of the population structures in seven 0.25 ha plots in three of these populations reveal adequate regeneration of seedlings but low rates of recruitment in some plots. Such a population structure is a major cause for concern in a species as rare as this.

Conservation strategies should be informed by an understanding of the ecology and the genetics of the species they seek to conserve. For *Araucaria nemorosa*, an understanding of the ecology of closely related species is essential to the interpretation of population structure, as many southern hemisphere conifers show regeneration strategies characterized by great longevity and episodic rather than continuous recruitment. Low rates of recruitment could be typical of the species rather than a cause for urgent concern, but further research will be necessary to establish this and the possibility should not be a cause for complacency. Studies on other species in the Araucariaceae have shown higher intrapopulational than interpopulational genetic diversity, so conserving large populations of *Araucaria nemorosa* is as important as conserving many populations.

Further basic research is urgently needed to address the following questions:

(i) How old are the oldest trees in modern populations of *Araucaria nemorosa*?
(ii) Are the seedlings of *Araucaria nemorosa* shade tolerant or not – is recruitment continuous or episodic?
(iii) What is the genetic structure of the species, and is there a phylogeographic pattern to the distribution of populations?

The results of such studies should inform the development of conservation policy. On present information, the conservation strategy for this species should involve both in situ and ex situ approaches, because of the extremely restricted distribution of *Araucaria nemorosa*. Whilst the establishment of a formal reserve for the protection of the species would be highly desirable in the longer term, an agreement between the Service de l'Environnement and local landowners on the management of the populations would be equally effective in the short term.

6.2 Français[15]

Araucaria nemorosa de Laub. est une espèce très rare et peu étudiée, endémique à la région de Port Boisé au Grand Sud de la Nouvelle Calédonie. Elle est classifiée comme «Critically Endangered» (CR) par l'IUCN, le plus haut grade de conservation qui a été accordé jusqu'au présent à un membre du genre *Araucaria*. La protection des populations d'*Araucaria nemorosa* doit être donnée la priorité au sein des efforts de conservation des espèces en Nouvelle Calédonie.

Ce rapport presente un nombre d'illustrations de la morphologie de cette espèce (les premières illustrations depuis 1972) et un total de huit populations discrètes ont été identifiées, parmi lesquelles sept sont distribuées le long de la côte à proximité de la baie de Port Boisé et une population apparaît plus à l'intérieur de Grande Terre. Les limites exactes de sept de ces populations ont été cartographiées, et la location de l'autre population a été indiquée.

Cependant, l'espèce a une distribution plus large que les descriptions publiées suggèrent, son habitat est réduit, fragmenté, et extrêmement vulnérable au feu et aux perturbations anthropogènes. Des analyses de la structure de la population dans sept parcelles de 0.25 ha dans trois de ces populations montrent une régénération adéquate des jeunes plantes mais des quote-parts basses de recrutement ont été constatés dans quelques unes des parcelles. Une telle structure de population est une source majeure d'inquiétude dans une espèce si rare que celle-la.

Des stratégies de conservation devrait être informées sur la connaissance de l'écologie et des génétiques des espèces qu'elles souhaitent protéger. En ce qui concerne *Araucaria nemorosa*, la connaissance de l'écologie des espèces proche à elle-même est nécessaire pour l'interprétation de la structure de la population, puisque beaucoup des conifères de l'hémisphère du sud montrent des stratégies de régénération qui sont caractérisées par grande longévité et un recrutement plutôt épisodique que continué. Des quote-parts basses de recrutement pourraient être plutôt typique pour ces espèces qu'une cause pour une protection urgente, mais des recherches supplémentaires seront nécessaires pour pouvoir établir cela et cette possibilité ne devrait pas être une cause pour contentement. Des études sur autres espèces dans la famille des Araucariaceae ont montrés une plus haute diversité génétique intrapopulationelle que interpopulationelle, donc de conserver des

[15] Translated by Thora Herrmann, Russell Palmer & Chloe Galley.

grandes populations d'*Araucaria nemorosa* est aussi important que de conserver beaucoup de populations.

Des recherches basiques supplémentaires sont nécessaires pour répondre a des questions suivantes:

(i) Quel âge ont les arbres les plus âgés en populations modernes d'*Araucaria nemorosa*?

(ii) Les jeunes plantes d' *Araucaria nemorosa*: sont-ils sciaphiles ou non – le recrutement, est-il continué ou épisodique?

(iii) Quelle est la structure génétique de cette espèce, et est-ce qu'elle existe une apparence phylogéographique dans la distribution des populations?

Les résultats de telles études devraient informer le développement de la politique de conservation. Basé sur l'information actuelle, la stratégie de conservation pour cette espèce devraient intégrer les approches *in situ* et *ex situ*, à cause de la distribution extrêmement réduite d'*Araucaria nemorosa*. Alors qu'une mise en place d'une réserve formelle pour la protection de cette espèce serait très désirable à l'avenir, un accord entre le Service de l'Environnement et les propriétaires locaux sur la gestion des populations serait également effective à court terme.

Des recherches basiques supplémentaires sont nécessaires pour répondre a des questions suivantes:

(i) Quel âge ont les arbres les plus âgés en populations modernes d'*Araucaria nemorosa*?

(ii) Les jeunes plantes d' *Araucaria nemorosa*: sont-ils sciaphiles ou non – le recrutement, est-il continué ou épisodique?

(iii) Quelle est la structure génétique des cette espèce, et est-ce qu'il existe une apparence phylogéographique dans la distribution des populations?

Les résultats de telles études devraient informer le développement de la politique de conservation. Basé sur l'information présent, la stratégie de conservation pour cette espèce devraient intégrer des approches *in situ* et *ex situ*, due à la distribution extrêmement réduite d'*Araucaria nemorosa*. Alors qu'une mise en place d'une réserve formelle pour la protection de cette espèce serait très désirable dans le future, un accord entre le Service de l'Environnement et les propriétaires locaux sur la gestion des populations serait également effective à court terme.

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Alistair Watt, Victoria, Australia

APPENDIX 1: PLANT COLLECTIONS

Thirty-one plant collections, usually in duplicate, were made by the expedition: unfortunately many of these deteriorated during shipment back to Oxford. The list below gives details of the specimens as collected: the data are identical with those presented to the Direction des Ressources Naturelles on 3 January 2001, prior to exporting specimens. They are sorted first by family, and then by chronological order of collection.

GENUS, SPECIES	COLLECTION SITE	COLLECTION TYPE	QUANTITY	DATE & COLLECTION NUMBER
Araucaria nemorosa (Araucariaceae)	près de la route de Goro à Port Boisé, c. 1,3 km de Port Boisé	Echantillons d'herbier (rameaux) et des cones, et des feuilles pour les études de l'ADN	1 échantillon d'herbier, 1 échantillon des cones, 1 échantillon des feuilles pour les études de l'ADN, dans un petit sac plastique.	25.12.2000 TW 0160
Araucaria nemorosa (Araucariaceae)	près de la route de Goro à Port Boisé, c. 1,3 km de Port Boisé	Echantillons d'herbier (rameaux) et des cones, et des feuilles pour les études de l'ADN	1 échantillon d'herbier, 1 échantillon des cones, 1 échantillon des feuilles pour les études de l'ADN, dans un petit sac plastique.	25.12.2000 TW 0161
Araucaria nemorosa (Araucariaceae)	près de la route de Goro à Port Boisé, c. 1,3 km de Port Boisé	Echantillons d'herbier (rameaux) et des cones, et des feuilles pour les études de l'ADN	4 échantillons d'herbier, 4 échantillons des cones, 1 échantillon des feuilles pour les études de l'ADN, dans un petit sac plastique.	26.12.2000 TW 0162
Araucaria nemorosa (Araucariaceae)	près de la route de Goro à Port Boisé, c. 1,3 km de Port Boisé	Echantillons d'herbier (rameaux) et des cones, et des feuilles pour les études de l'ADN	2 échantillons d'herbier, 2 échantillons des cones, 1 échantillon des feuilles pour les études de l'ADN, dans un petit sac plastique.	26.12.2000 TW 0163
Araucaria columnaris (Araucariaceae)	près de la mer, Port Boisé.	Echantillons d'herbier (petites plantes jeunes, de moins de 10 cm)	6 petites plantes.	27.12.2000 TW 0164
Araucaria columnaris (Araucariaceae)	près de la mer, Port Boisé.	Echantillons d'herbier, rameaux jeunes	4 échantillons d'herbier.	27.12.2000 TW 0165
Araucaria columnaris (Araucariaceae)	près de la mer, Port Boisé.	Echantillons d'herbier, rameaux jeunes	3 échantillons d'herbier.	27.12.2000 TW 0166
Araucaria columnaris (Araucariaceae)	près de la mer, Port Boisé.	Echantillons d'herbier (rameaux), et des feuilles pour les études de l'ADN	3 échantillons d'herbier. 1 échantillon des feuilles pour les études de l'ADN, dans un petit sac plastique.	27.12.2000 TW 0167

GENUS, SPECIES	COLLECTION SITE	COLLECTION TYPE	QUANTITY	DATE & COLLECTION NUMBER
Araucaria nemorosa (Araucariaceae)	près de la route de Goro à Port Boisé, c. 1,3 km de Port Boisé	Echantillons d'herbier (petites plantes jeunes, de moins de 10 cm)	6 petites plantes.	27.12.2000 TW 0168
Araucaria nemorosa (Araucariaceae)	près de la route de Goro à Port Boisé, c. 1,3 km de Port Boisé	Echantillons d'herbier, cones à pollen tombés.	1 bouteille	27.12.2000 TW 0169
Araucaria nemorosa (Araucariaceae)	près de la route de Goro à Port Boisé, c. 1,3 km de Port Boisé	Echantillons du bois.	1 boîte, d'environ 25 échantillons	27.12.2000 TW *sine numero*
Araucaria columnaris	près de la mer, Port Boisé.	Echantillons d'herbier, cones à pollen tombés.	1 bouteille	29.12.2000 CG 0001
Araucaria bernieri/scopulorum (Araucariaceae)	au Bois du Sud, près du camping	Echantillons d'herbier, et des feuilles pour les études de l'ADN	3 échantillons d'herbier. 1 échantillon des feuilles pour les études de l'ADN, dans un petit sac plastique.	2.1.2001 TW 0178
Araucaria ?laubenfelsii (Araucariaceae)	au Bois du Sud, près du camping	Echantillons d'herbier, et des feuilles pour les études de l'ADN	3 échantillons d'herbier. 1 échantillon des feuilles pour les études de l'ADN, dans un petit sac plastique.	2.1.2001 TW 0179
Araucaria muelleri (Araucariaceae)	à la plantation près de l'entrance du Parc Provincial de la Rivière Bleue, (avec la connaisance d'un agent du Parc.)	Echantillons d'herbier, et des feuilles pour les études de l'ADN	1 échantillon d'herbier. 1 échantillon des feuilles pour les études de l'ADN, dans un petit sac plastique.	2.1.2001 TW 0185
Araucaria nemorosa (Araucariaceae)	à la droite, en route de La Capture au village à Port Boisé, dans la Forêt Nord.	Echantillons d'herbier (rameaux jeunes)	2 échantillons d'herbier	3.1.2001 TW 0186
Araucaria nemorosa (Araucariaceae)	à la droite, en route de La Capture au village à Port Boisé, dans la Forêt Nord	Echantillons d'herbier (rameaux jeunes)	2 échantillons d'herbier	3.1.2001 TW 0187
Araucaria nemorosa (Araucariaceae)	à la droite, en route de La Capture au village à Port Boisé, dans la Forêt Nord	Echantillons d'herbier (rameaux), et des feuilles pour les études de l'ADN	4 échantillons d'herbier, et 1 échantillon des feuilles pour les études de l'ADN, dans un petit sac plastique.	3.1.2001 TW 0188
Araucaria nemorosa (Araucariaceae)	à la droite, en route de La Capture au village à Port Boisé, dans la Forêt Nord	1 petite plante jeune.	1 échantillon d'herbier	3.1.2001 TW 0189

Genus, species	Collection site	Collection type	Quantity	Date & collection number
Araucaria nemorosa (Araucariaceae)	à la droite, en route de La Capture au village à Port Boisé, dans la Forêt Nord	Echantillons d'herbier, cones à pollen tombés.	1 bouteille	3.1.2001 TW 0190
Neocallitropsis pancheri (Cupressaceae)	200 m nord de la Reserve de la flore de la Madeleine, au bord de la rivière et près d'un camping.	Echantillons d'herbier (rameaux), et des feuilles pour les études de l'ADN	4 échantillons d'herbier, 1 échantillon des feuilles pour les études de l'ADN, dans un petit sac plastique.	30.12.2000 TW 0173
Dacrycarpus viellardii (Podocarpaceae)	Au Parc Provincial de la Rivière Bleue, près du <<Kaori géant>>	Echantillons d'herbier (rameaux)	2 échantillons d'herbier	2.1.2001 TW 0180
Retrophyllum minus (Podocarpaceae)	A la Plaine des Lacs, au nord des Murielles	Echantillons d'herbier (rameaux), et des cones.	1 échantillon d'herbier, 1 échantillon des feuilles pour les études de l'ADN, dans un petit sac plastique.	30.12.2000 TW 0170
Retrophyllum minus (Podocarpaceae)	A la Plaine des Lacs, au nord des Murielles	Echantillons d'herbier (rameaux), et des cones, et du bois.	3 échantillons d'herbier, 1 échantillon des feuilles pour les études de l'ADN, dans un petit sac plastique; et 2 petit échantillons de bois.	30.12.2000 TW 0171
Dacrydium araucarioides (Podocarpaceae)	A la Plaine des Lacs, a l'ouest des Murielles	Echantillons d'herbier (rameaux)	3 échantillons d'herbier	30.12.2000 TW 0172
Dacrydium araucarioides (Podocarpaceae)	Près de la route, au nord de la Reserve de la flore de la Madeleine.	Echantillons d'herbier (rameaux jeunes)	3 échantillons d'herbier	30.12.2000 TW 0174
Lycopodium? (Lycopodiaceae)	Au Parc Provincial de la Rivière Bleue, près du sentier aux Kaoris.	Echantillons d'herbier	3 échantillons d'herbier	3.1.2001 TW 0181
Amborella trichopoda (Amborellaceae)	Près du sentier de l'hôtel <<Evasion 130>> au Plateau de Dogny, Sarraméa.	Echantillons d'herbier (rameaux), et des cones, et du bois.	3 échantillons d'herbier, 2 bouteilles des fruits à 1'alcool, 1 échantillon des feuilles pour les études de l'ADN, dans un petit sac plastique; et 4 petit échantillons de bois.	31.12.2000 TW 0177
Melaleuca sp. (Myrtaceae)	Plateau de Dogny, Sarraméa.	Echantillon d'herbier, les fleurs à l'alcool	1 échantillon d'herbier, 1 bouteille des fleurs à l'alcool.	31.12.2000 TW 0176
Metrosideros sp. (Myrtaceae)	Plateau de Dogny, Sarraméa.	Echantillon d'herbier, les fleurs à l'alcool	1 échantillon d'herbier, 1 bouteille des fleurs à l'alcool.	31.12.2000 TW 0175

Genus, species	Collection site	Collection type	Quantity	Date & collection number
Dubouzetia confusa (Elaeocarpaceae)	Au sud du Pont Perignon, Parc Provinciale de la Rivière Bleue	Echantillon d'herbier, les fleurs à l'alcool	1 échantillon d'herbier, 1 bouteille des fleurs à l'alcool.	2.1.2001 TW 0183
?*Uncinia* ?*dawsoni* (Cyperaceae)	Au Parc Provincial de la Rivière Bleue, près du sentier aux Kaoris.	Echantillon d'herbier	1 échantillon d'herbier	2.1.2001 TW 0182
? ? (Gramineae)	Au Parc Provincial de la Rivière Bleue, près du <<Sentier aux Kaoris>>.	Echantillon d'herbier	1 échantillon d'herbier	2.1.2001 TW 0184

APPENDIX 2: OTHER COLLECTIONS

The list below gives details of the specimens as collected: the data are identical with those presented to the Direction des Ressources Naturelles on 3 January 2001, prior to exporting specimens. They are sorted first by family, and then by chronological order of collection. Insect specimens have been deposited in the Hope Entomological Collections of the Oxford University Museum of Natural History, Parks Road, Oxford, UK.

COLLECTION SITE	COLLECTION TYPE	QUANTITY	DATES
Port Boisé, près de la mer.	Echantillons des insectes, à l'alcool.	16 petites bouteilles, 2 grandes bouteilles.	15.12.2000-27.12.2000
Port Boisé, près de la mer.	Echantillons des papillons de nuit.	Une boîte, de c. 20 papillons de nuit.	15.12.2000-27.12.2000
Au camping, Bois du Sud.	Echantillons des insectes, à l'alcool.	2 petites bouteilles, 2 grandes bouteilles.	28.12.2000, 01.01.2001-03.01.2001
Au Plateau de Dogny, près de Sarraméa.	Echantillons des insectes, à l'alcool.	1 petite boouteille, 1 grande bouteille.	31.12.2000
Port Boisé, près de la mer.	Lichens	1 grande bouteilles, 2 petites bouteilles	15.12.2000-27.12.2000

APPENDIX 3: BIRD LISTS

A3.1 Birds seen in the Port Boisé area, 11 December to 29 December 2000

The symbol ⋆ denotes a species endemic to New Caledonia, and @ denotes a bird for which the sighting represents the first in New Caledonia. Bird names and sequence largely follow Peters, J. L. *et al.* (1931-1987). *Checklist of the Birds of the World*. Museum of Comparative Zoology, Cambridge, Massachusetts.

	SCIENTIFIC NAME	ENGLISH NAME
	Egretta novaehollandiae (Latham)	White-Faced Heron
	Egretta sacra albolineata (G.R.Gray)	Pacific Reef Egret
	Pandion haliaetus melvillensis Mathews	Osprey
	Haliastur sphenurus (Vieillot)	Whistling Kite
	Circus approximans approximans Peale	Swamp Harrier
⋆	*Accipiter haplochrous* Sclater	White-Bellied Goshawk
	Gallirallus philippensis swindellsi (Mathews)	Buff-Banded Rail
	Larus novaehollandiae forsteri (Mathews)	Silver Gull
	Columba vitiensis hypoenochroa (Gould)	Metallic Pigeon
	Chalcophaps indica chrysochlora (Wagler)	Emerald Dove
	Ptilinopus greyii Bonaparte	Red-Bellied Fruit Dove
⋆	*Ducula goliath* (G.R.Gray)	New Caledonian Imperial-Pigeon
	Cyanoramphus novaezelandiae saisseti† J.Verreaux & Des Murs	Red-Fronted Parakeet
	Trichoglossus haematodus deplanchei J.Verreaux & Des Murs	Rainbow Lorikeet
	Cacomantis flabelliformis pyrrophanus (Vieillot)	Fan-Tailed Cuckoo
	Chrysococcyx lucidus layardi (Mathews)	Shining Bronze-Cuckoo
@	*Hirundapus caudacautus* (Latham)	White-Throated Needletail
	Collocalia esculenta uropygialis G.R.Gray	Glossy Swiftlet
	Collocalia spodiopygius leucopygia Wallace	White-Rumped Swiftlet
	Todirhamphus sanctus canacorum (Brasil)	Sacred Kingfisher
	Lichmera incana incana (Latham)	Dark-Brown Honeyeater
⋆	*Philemon diemenensis* (Lesson)	New Caledonian Friarbird
⋆	*Myzomela caledonica* W.A.Forbes	New Caledonian Myzomela
⋆	*Phylidonyris undulata* (Sparrman)	Barred Honeyeater
	Gerygone flavolateralis flavolateralis (Gray)	Fan-Tailed Gerygone
⋆	*Eopsaltria flaviventris* Sharpe	Yellow-Bellied Robin
⋆	*Pachycephala caledonica* (Gmelin)	New Caledonian Whistler
	Pachycephala rufiventris xanthetraea (Forster)	Rufous Whistler
	Rhipidura fuliginosa bulgeri Layard	Grey Fantail
	Rhipidura spilodera verreauxi Marié	Streaked Fantail
	Myiagra caledonica caledonica Bonaparte	New Caledonian Flycatcher
⋆	*Corvus moneduloides* Lesson	New Caledonian Crow
	Lalage leucopyga montrosieri J.Verreaux & Des Murs	Long-Tailed Triller
	Artamus leucorynchus (*A.l. melaleucos* (Wagler)	White-Breasted Woodswallow
⋆	*Coracina caledonica caledonica* (Gmelin)	Melanesian Cuckoo Shrike
⋆	*Aplonis striata striata* (Gmelin)	Striated Starling
⋆	*Zosterops xanthochroa* (G.R.Gray)	Green-Backed White-Eye
⋆	*Erythrura psittacea* (Gmelin)	Red-Throated Parrotfinch

† treated as a separate species by Juniper & Parr (1998).

Doughty *et al.* (1999) describe *Cyanoramphus novaezelandiae saisseti* as an uncommon, localized and declining inhabitant of undisturbed dense primary forest, providing possible information on the vegetational history of the region containing the inland *Araucaria nemorosa* population (population 7: see discussion in section 3.1). However, Ekstrom *et al.* (2000) reported that the bird was fairly common in most of the forest sites visited by the *Diadema 98* Expedition, and found that birds were able to use very small patches of stunted forest within a maquis landscape, thus allowing the bird to be well distributed over much of the island. As such, its usefulness in determining the vegetational history of the inland population is less evident.

The sighting of *Hirundapus caudacutus* has now been published in *Le Cagou, Bulletin de la Société Calédonienne d'Ornithologie* (Wilkinson 2001), under the following description:

> **Le Martinet à gorge blanche** *Hirundapus caudacutus,* nouveau visiteur pour la Nouvelle-Calédonie.
>
> Deux grands martinets caractérisés par leur taille (envergure 2 fois plus grandes que celle des Salanganes), la base des ailes large, la queue courte et carrée leur donnant une allure costaude (« muscular appearance ») et la gorge et les sous caudales blanches ont été observés dans un vol de Salanganes à Port Boisé le 14 décembre 2000 à 10h 30. Ces oiseaux avaient un vol très rapide, avec de longs planés entrecoupés de virages brusques sans battements d'ailes. Ils ont été observés quelques minutes puis ont disparu vers le sud. C'est la première observation de ce visiteur australien en Nouvelle-Calédonie.

A3.2 Birds seen elsewhere in New Caledonia, 7 December 2000 to 7 January 2001

The symbol ⋆ denotes a species endemic to New Caledonia, and # denotes a species introduced from elsewhere. Birds seen at Port Boisé and also elsewhere are not listed; nor are birds seen solely in captivity listed – those recorded below as having been seen at Parc Forestier Michel Corbasson were not captive there.

	Scientific name	English name	Locality
	Phalacrocorax melanoleucos melanoleucos (Vieillot)	Little Pied Cormorant	Parc Provincial de la Rivière Bleue
	Puffinus pacificus chlororhynchus (Gmelin)	Wedge-Tailed Shearwater	offshore near Cap Ndoua
	Anas superciliosa pelewensis Hartlaub & Finch	Pacific Black Duck	Chutes de la Madeleine
	Nycticorax caledonicus caledonicus (Gmelin)	Rufous Night-Heron	Parc Forestier Michel Corbasson
	Falco peregrinus nesiotes Mayr	Peregrine Falcon	Nouméa
⋆	*Rhynochetus jubatus* J.Verreaux & Des Murs	Kagu	Parc Provincial de la Rivière Bleue
	Sterna bergii cristata (Stephens)	Great-Crested Tern	offshore from Nouméa
	Sterna sumatrana sumatrana Raffles	Black-Naped Tern	offshore from Nouméa
	Sterna nereis exsul (Mathews)	Fairy Tern	offshore from Nouméa
	Sterna fuscata serrata Wagler	Sooty Tern	offshore from Nouméa
	Anous minutus minutus Boie	Black Noddy	offshore from Nouméa
⋆	*Drepanoptila holosericea* (Temminck)	Cloven-Feathered Dove	rain forest between Sarraméa and the Plateau de Dogny
#	*Streptopelia chinensis* (Scopoli)	Spotted Dove	Nouméa
#	*Geopelia striata* (Linnaeus)	Zebra Dove	Parc Forestier Michel Corbasson
⋆	*Gymnomyza aubryana* (J.Verreaux & Des Murs)	Crow Honeyeater	Parc Provincial de la Rivière Bleue
#	*Acridotheres tristis* (Linnaeus)	Common Myna	Nouméa
#	*Pycnonotus cafer* (Linnaeus)	Red-Vented Bulbul	Nouméa
	Zosterops lateralis griseonota G.R.Gray	Silver-Eye	Nouméa & Parc Forestier Michel Corbasson.
#	*Estrilda astrild* (Linnaeus)	Common Waxbill	Nouméa
#	*Passer domesticus* (Linnaeus)	House Sparrow	Nouméa
#	*Lonchura castaneothorax* (Gould)	Chestnut-breasted Munia	Nouméa

APPENDIX 4: EXPEDITION EQUIPMENT AND MEDICAL NOTES/SAFETY

Vehicle

A Daihatsu Terios 4×4 was hired from ADA Location des Voitures, Rue Georges Clemenceau, Nouméa. There were no mechanical problems with this vehicle, although for five people plus equipment and food it was extremely small. Owing to a misunderstanding over the cleaning protocol to be followed on the iron-rich soils of the Port Boisé area, we were unfortunately fined 100 000 CFP francs (£500 – this absorbed most of our contingency funds) on return of the vehicle, although there were no other difficulties and the staff at *ADA* were sympathetic.

Population and mapping work

For plot work, manual compasses, three 25 m measuring tapes and several balls of string[16] were used to mark out study plots. A handheld clinometer was used for measuring tree height and a tape measure used to measure *dbh*. Two Swedish increment borers were used to obtain increment cores for dendrochronology. In Oxford, a 6× stereo-microscope was used to analyse the cores. A Magellan® Global Positioning System (GPS) unit was invaluable for mapping work in the field. Maps of the area at a 1 : 50 000 scale (Institut Géographique National 1987) had been scanned into the vector graphics program CorelXara, on a laptop (Pentium II®, running Windows® 98) which was taken to New Caledonia. It was therefore possible to construct preliminary maps in the field.

Plant specimen collection

Two conventional plywood plant presses provided by the Fielding-Druce Herbarium, University of Oxford (**OXF**) were used to press plant specimens collected; newspapers were used as flimsies and drying paper was purchased from the supplier Watkins & Doncaster. Petrol was used to kill *Araucaria* cones and branches rapidly to prevent cone shattering and leaf-drop: such specimens were soaked in a bucket of petrol for 12-36 hours. An aluminium pole pruner, bought locally from a garden centre (by the *Continent* hypermarket at Normandie, outside Nouméa) was vital, and was used to reach cones and branches high in trees. Sealable plastic bags for rapid dehydration of DNA specimens were kindly made available by the managers of the Oxford University Herbaria (**FHO** & **OXF**), and desiccant gel for these collections was purchased from the supplier Watkins & Doncaster.

[16] In total over 2 km of string was bought by the Expedition, and each ball was reused several times.

Insect specimen collection

For collection, a pooter, sweepnet, white cloth (for 'beating' collections) and pitfall/funnel traps were used, all purchased from the supplier Watkins & Doncaster. Ethyl actetate was used to kill insects from the pooter, sweepnet and beating methods, as described. Larger insects, especially moths, were killed humanely by injection of ethyl acetate. 40% ethanol was used in the collection tubs in order to preserve specimens until they arrived back in Oxford. Antifreeze (ethylene glycol) was used in the pitfall traps to kill insects, which unlike the ethyl acetate/ethanol used for other purposes, evaporates much less readily.

Medical issues

A comprehensive medical kit was brought out, comprising prescription drugs from the Oxford University Occupational Health clinic, and a first aid kit and other items from BCB International Ltd. We had been advised that although the water might contain high levels of heavy metals, the short duration of time we would spend there meant this should pose only a very slight health risk. There were no other problems with water.

Although malaria is not believed to be endemic to New Caledonia, dengue fever is. Precautions such as wearing long sleeves/trousers and the use of MOSIGUARD® mosquito repellent were therefore adopted. As with any work in the tropics involving walking long distances, great care was taken to prevent fungal and bacterial diseases, using most importantly CANESTEN® cream and MYCIL® foot powder. Only mild cases of fungal disease were encountered and no other serious pathogenic illnesses or conditions arose.

There were a couple of cases of cut fingers and a cut face, for which the application of antiseptic cream and regularly changed plasters was adequate. One case of possible mild sunstroke was dealt with by allowing the afflicted individual to sit down out of the sun for a few hours. There were no other physical accidents.

Safety & insurance

Responsibility for safety on the expedition rested with the Medical Officer (in an advisory capacity) and of course the Expedition Leader. Possible hazards – from landowners to centipedes – were discussed by the Expedition as a whole when first encountered, so as to reach a consensus decision before proceeding: on occasion the decision was made not to proceed with a line of work because of the possible dangers. The author of this section (TW: as Expedition Leader) is not aware of any disquiet felt by any member of the expedition at the safety procedures followed.

No member of the expedition was ever permitted to travel away from the rest of the expedition alone, whether on foot or by car, because of the risks of getting lost as much as anything else; similarly when working in the field where the mapping team would have both the map and the GPS, both teams would always have a compass and precise arrangements were always made and adhered to for the collection of the population survey team. When possible, our two A-level-or-above French speakers were placed in separate teams so that a translator was always on hand for those with a lesser grasp of French in the event of meeting local people in the forests. To avoid the risk of personal incompatibility or boredom, personnel on the teams were regularly switched.

Our car-hire contract provided insurance for our vehicle and we also had emergency medical, personal, equipment and legal insurance from the University.

APPENDIX 5: RESEARCH LEADING ON FROM THE EXPEDITION'S WORK

It is expected that a paper based on this report will be presented at the IDS First International Symposium on the Araucariaceae in March 2002, and will subsequently appear in the published proceedings of that conference.

One of the authors (TW) has received a NERC D.Phil. studentship to work on the systematics of the genus *Agathis*[†] in the Department of Plant Sciences, University of Oxford, and at the Royal Botanic Gardens, Kew, and will be using several of the collections made during this expedition. Biogeographic information from this report has already been passed on in preliminary form to scientists at the Royal Botanic Gardens, Edinburgh, who are engaged in an exhaustive study of the genus *Araucaria* in New Caledonia, and the herbarium and DNA specimens collected would normally be available on loan, at the Curator's discretion, to researchers at other herbaria who wish to apply[‡] to the Daubeny Herbarium (**FHO**).

Full datasets collected by this expedition are available on request to all *bona fide* researchers, by contacting the author for correspondence at the address given.

As identified in section 5.4, we see a number of possible further avenues of research leading on from our results, either with fresh analyses of our data or analysis of questions arising from the present study: we would be extremely happy to offer any assistance and advice to anyone considering embarking upon such an investigation.

[†] In the preliminary report this is (correctly) given as *Araucaria*: the change occurred between the two reports, so as to avoid duplication of a large project then beginning in Edinburgh.

[‡] Address for enquiries: Druce Curator of the Oxford University Herbaria and Xylarium, Department of Plant Sciences, University of Oxford, South Parks Road, Oxford, OX1 3RB, United Kingdom.

APPENDIX 6: EXPEDITION WEBSITE

The expedition has a regularly updated website on an Oxford University server, which contains a variety of information on the expedition as well as PDF (Adobe® Acrobat readable) versions of the original expedition proposal and the preliminary report. We intend that this Report (other than the map, which is subject to copyright restrictions: an overlay at the correct scale will be provided instead) will also be made available on the website in PDF (Adobe® Acrobat readable) format.

. The URL is:

http://users.ox.ac.uk/~scat1055/expedition/

APPENDIX 7: ACCOUNTS

The following pages present a breakdown of our finances, detailing both the sources of our income and the manner in which it was disbursed.

A7.1 Payments made to the expedition

The expedition raised over £7000 in addition to personal contributions totalling £5000 to fund our expedition. These funds were kindly provided by the following sources, to whom we are extremely grateful.

Expeditions Council, University of Oxford	£2059
British Ecological Society	£1000
Royal Geographical Society	£1000
Mike Soper & Jimmy Elliot Memorial Fund, Department of Plant Sciences, University of Oxford	£800
Bullock Travel Awards, St Catherine's College, Oxford	£750
Gilchrist Educational Trust	£750
Doris Field Charitable Trust	£250
The Worshipful Company of Armourers & Braziers	£250
St Catherine's College JCR	£200
Wadham College, Oxford	£200
Keith Ewart Charitable Trust	£200
Total external funding	**£7259**
Personal contributions	£5000
Total funds raised by expedition	**£12259**

A7.2 Payments made by the expedition

These are arranged by size of payment made, with the claculations in smaller type providing a breakdown of the summary figures. They are necessarily to some extent incomplete as we obviously cannot yet entirely account for the cost of the production, packaging and dissemination of this report. However, we have obtained a number of estimates for these costs and our figures are based upon these: any excess costs will be met by expedition members. As demonstrated below, we foresee a slight deficit of *c.* £10 which will be met by the expedition members, and we do not foresee that there will be a surplus remaining thereafter.

Clearly, the cost of the production of this report is the largest remaining item and inaccuracy in calculating this cost will lead to inaccuracy in reporting total expenditure, but we have obtained estimates which we believe to represent good value and we would be surprised were the final cost to be markedly above or below this figure. In the event that the cost of production of the report is significantly less, and that the cost of so doing does not outweigh the amount available, money will be recredited to our financial supporters (excluding expedition members) in proportion to their contributions.

For payments made in New Caledonia, a basic exchange rate of £1 = 200 Pacific francs has been assumed; payments in Australia assume £1 = AS$3.00. These figures represent approximate figures rather than precise ones (actual values when we were in the field were respectively between 189 and 197 Pacific francs, and c. AS$2.8) but were the basis for our accounting and purchasing.

Item	Cost
Return flights to from the UK to Australia for 5 people (Malaysian Airlines, Heathrow via Kuala Lumpur to Sydney)	£4115.50
Return flights from Australia to New Caledonia (Qantas/Aircalin codeshare, Sydney to Tontouta)	£2206.40
Food and other miscellaneous living costs in Australia & New Caledonia	£1594.42

A precise breakdown of this figure is not possible as many of the relevant receipts became mouldy when the wet season began in late December: however, non-accommodation living costs were kept right down to less than £8 per person per day (40 days, five people) – with New Caledonian food prices significantly higher than those in the UK this was a substantial achievement. The figure is calculated on the basis of knowledge of all non-food expenditure on expedition and knowledge of the amount of money taken away and brought back.

Production & administration costs (total, partly estimates):	£1140.40

Printing costs, Expedition proposals, 30 ×((5 × 10) + (11 × 4))/100	£28.20
Binding of 30 Expedition propoals, 30 copies (in small orders) @ £2.70	£27.00
Expedition leaflets, 60 @ 20 pence each plus 4 pence for accompanying letter	£81.00
Printing costs, short report, 2001, 40 copies each of 5 colour pages (10 pence each) and 12 black and white pages (4 pence each): 40 × ((5 × 10) + (12 × 4))/100	£39.20
Binding costs, short report, 2001, 40 copies each @ £2 (bulk discounted rate)	£80.00
Printing, binding & postage cost of this Report (60 copies – for botanic gardens and universities who have expressed an interest, copies to all sponsors, expedition members, and others to distribute as requested subsequently – money will be recouped from later distributions): *c.* 40 pages double sided black & white @ 5 pence each, *c.* 10 pages colour @ 50 pence (glossy paper and cost of ink) each; binding @ £4.00/copy (many more pages = higher cost, tho' still discounted – estimate from our usual binders); 50 large envelopes @ *c.* 40p each, postage at *c.* £2.00 for UK & EU copies (*c.* 35) and *c.* £5 for US and NC copies (projected eventually *c.* 15 such). [60 × ((40 × 0.05) + (10 × 0.50) + 4)] + [(35 × (2 + 0.40)) + (15 × (5 + 0.40))]	£885.00
Car hire	**£840.00**
Car deposit (see equipment section for explanation)	**£500.00**
Accommodation	**£432.00**
7 days in youth hostel (4 at beginning, 3 at end), Nouméa, for five people, 35 × £7	£245.00
Camp space at Port Boisé, 18 days × £9	£162.00
Accommodation in Sydney for 6 nights (stayed with relatives of expedition member to minimize costs, this figure is the cost of a present for their kindness)	£0.00 £25.00
Expedition equipment	**£301.08**
inverter to power laptop from car cigarette lighter	£120.00
head torches batteries & other batteries	£45.00
Entomological canisters (costs of nets, etc, were recovered after their purchase by an expedition member)	£31.08
pole pruner	£80.00
25 × 100 m balls of string, £1 each	£25
Laptop computer hire	**£300.00**
Photographic costs (total)	**£218.81**
Expedition film	£180.79
slide film development	£38.02
Oxford University Exploration Club, cost of *Bulletin* publication (condition of university funding)	**£200.00**

Medical kit (antibiotics and other pharmaceuticals requiring prescription)	£150.00
Insurance from the University policy	£138.40
Medical kit (plasters, bandages, gloves, antispetics, rehydration salts, etc.)	£65.00
Australian entry visas (5 @ £13 each)	£65.00

Total costs of expedition, realized & projected	**£12267.01**
Total income of expedition	**£12259.00**
Projected overspend (to be met by expedition members)	**£8.01**

APPENDIX 8: EXPEDITION PERSONNEL

Brief biographies are here presented of the members of the Expedition, indicating particular interests relevant to the aims and work of the Expedition:

Timothy Waters (*Expedition Leader*) – 20 at time of Expedition, undergraduate biologist at St Catherine's College, Oxford. Now a D.Phil. student, Department of Plant Sciences, Oxford, working on systematics of *Agathis* (Araucariaceae). *Interests, etc.*: systematics, conifer ecology, Pacific biogeography. Speaks passable French, holds full driving licence.

Chloé Galley (*Expedition medical officer*) – 20 at time of Expedition, undergraduate biologist at Wadham College, Oxford. Now an M.Sc. student, University of Edinburgh/Royal Botanic Garden Edinburgh, studying Plant Taxonomy and Biodiversity, shortly to take up a Ph.D. studentship, Institute of Systematic Botany, Zürich *Interests, etc.*: forest ecology (especially in Malesia), systematics, conservation. Speaks fluent French, holds wilderness medical qualification.

Samuel Turvey (*Expedition photographer & entomologist*) – 23 at time of Expedition, then and now a D.Phil. student in trilobite palaeontology in the Department of Earth Sciences, Oxford. *Interests, etc.*: systematics, conservation biology, herpetology, entomology, Pacific biogeography. Speaks passable French.

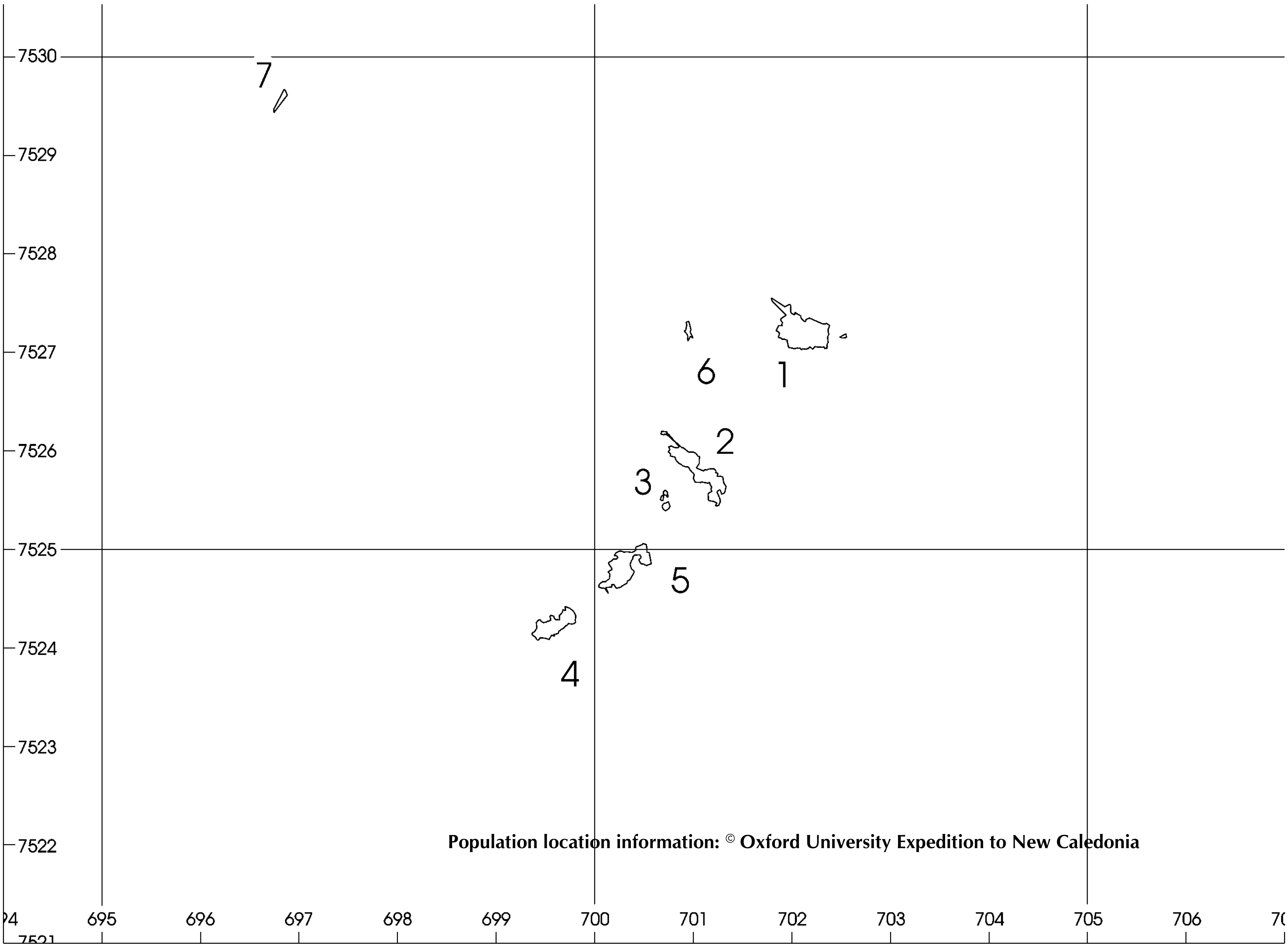
Russell Palmer (*Expedition treasurer & driver*) – 21 at time of Expedition, then an undergraduate materials scientist at St Catherine's College, Oxford. Now works in the energy industry. *Interests, etc.*: graphic design, computer programming, mathematics, France. Speaks good French, holds full driving licence, a qualified first aider.

Nicholas Wilkinson (*Expedition secretary & ornithologist*) – 21 at time of Expedition, undergraduate biologist at St Catherine's College, Oxford. Now working in conservation biology in Sulawesi, Indonesia. *Interests, etc.*: ornithology, conservation, ecology & evolutionary biology.

APPENDIX 9: ITINERARY

The expedition left the United Kingdom on 3 December 2000 and returned on the 11 January 2001. The table below gives details of our activities between those dates. Our original plan of working on *Neocallitropsis pancheri* (Plate 3*b*) or on *Araucaria muelleri* immediately after our work on *Araucaria nemorosa* was complete was unfortunately rendered impractical, to our regret and to the regret of the Director of Natural Resources. This was due to Bernard Suprin, the botanist from the Service de l'Environnement with whom we had been expecting to work, having severely damaged his back and being consequently unable to take us to the very few and very difficult-to-find sites for these taxa. We instead used those few days to ensure that we had ample voucher material from both the Port Boisé and the new population we discovered of *Araucaria nemorosa*, and that we collected material of other New Caledonian conifers for our scientific advisors in the UK. As discussed above, our work on *Araucaria nemorosa* has led to our being invited to return to New Caledonia to carry out work on the population structure of *Neocallitropsis pancheri* in the future.

3 December	Depart London for Sydney
4 December	Arrive Sydney, Australia
5 December to 6 December	In Sydney: visiting *Araucaria* specimens in the Botanic Gardens
7 December to 11 December	In Nouméa, New Caledonia, picking up collection permits and discussing practicalities with the Service de l'Environnement.
12 December to 29 December	At Port Boisé, New Caledonia, working on population biology of *Araucaria nemorosa* sites in the Port Boisé area as well as entomological work on *Araucaria* branch faunas.
30 December to 4 January	Based at Bois du Sud, between Yaté and Nouméa, Province Sud, New Caledonia, collecting herbarium material of conifers for our scientific advisers and writing up much of this report.
5 January to 7 January	In Nouméa, New Caledonia, packing up and posting scientific specimens to Europe.
8 January to 10 January	In Sydney, Australia
10 January	Depart Sydney for the UK
11 January	Return to UK



Overlay at scale 1: 50 000 of the Port Boisé area, showing the locations of seven identified populations of *Araucaria nemorosa* de Laub.

The boundaries of populations are represented on this map by thick black lines enclosing each population, adjacent to the number used to identify that population in this report. The grid shown is that of the Universal Transverse Mercator (UTM) projection: New Caledonia is in UTM zone 58. Intervals of one unit on the map represent 1 km on the ground. The page should be photocopied onto a clear acetate sheet, and used in conjunction with Série Orange map 4837, obtainable from the Service des Ventes et Editions, 107 rue la Boétie, 75008 Paris, France. Map features and symbols follow Série Orange map 4837, not reproduced here for copyright reasons.

Population numbering is arbitrary (it reflects the order of discovery) but is used consistently throughout this report. Grid references for 1 km^2 grid squares designate the southwest corner of each square.

Approximate positions of populations on the map above are given below as the 1 km^2 grid square into which most of each population falls. Locations of the plots sampled within these populations are given in Table 1 of this report: plots 1A, 1B, 1C are within population 1; plots 2A, 2B are within population 2, etc.

Population 1	702 E 7527 N
Population 2	701 E 7525 N
Population 3	700 E 7525 N
Population 4	699 E 7524 N
Population 5	700 E 7524 N
Population 6	700 E 7527 N
Population 7	696 E 7529 N

An additional eighth population has recently been reported near Cap Reine Charlotte, in the area of grid square 705 E 7528 N (T. Jaffré, pers. comm.)