Donald P.A. Sands · Tim R. New

Conservation of the Richmond Birdwing Butterfly in Australia

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(see Fig. 1.10)

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Preface

Members of the butterfly family Papilionidae, the swallowtails and their allies, are amongst the most generally admired and popular of all insects – rivalled, perhaps, only by some of the larger beetles as foci for collection and as important flagships for conservation advocacy and garnering public approval of invertebrates. Amongst these, the colourful and spectacular 'birdwings', the largest of all butterflies, are the most charismatic and have gained a unique reputation amongst naturalists since their discoveries from the nineteenth century. Reflecting their rarity and restriction to remote and difficult-to-access parts of the Indo-Australian tropics and subtropics, several birdwing species became objects of wonder, as well as of desire, and also commercially rewarding – so that supply of cabinet specimens of rare species to wealthy collectors, mostly in Europe, was a popular and lucrative activity for explorers, aided by the perceived 'romanticism' of the butterflies and their largely unknown tropical forest and montane environments. However, many of these butterflies, depending on the resources furnished within primary tropical forests, have become increasingly vulnerable as those forests have been cleared or otherwise changed, and are now of serious conservation concern. Conservation of birdwings must occur largely in regions in which resident entomologists and conservation biologists are few, political and social sensitivities may be acute, and in which such activities necessarily have low priority in relation to solving the needs of human welfare.

These scenarios differ fundamentally from the more familiar contexts for butterfly conservation in temperate regions, areas peopled by those both sympathetic to conserving insects and having the resources and drives to do so, under conditions that can be coordinated, monitored and publicised effectively. Conservation measures must draw on biological knowledge and understanding, but progress also depends heavily on the goodwill and support of local people.

Approaches to conserving poorly known and rare taxa in remote areas contrast markedly with many of the more familiar site-specific conservation exercises for relatively well-understood butterflies in accessible temperate regions. Simply gaining the foundation information for action and the capability to pursue the aims of any conservation management plan are formidable obstacles. Understandably, adding further to difficulty, conservation of strongly flying birdwings – their popular name reflecting both appearance and activity – has tended towards the landscape scale rather than focusing on small sites. It has emphasised the need for security of the parental forest environments on which the butterflies depend, through formal protection and sympathetic management to prevent their destruction.

These themes are discussed further in this book, in which we summarise and describe the continuing conservation programme developed for an unusual birdwing, the Australian endemic *Ornithoptera richmondia* (Gray), the Richmond birdwing butterfly, that has undergone substantial decline due to habitat loss and resource alienation but for which coordinated and persistent effort has done much to redress these impacts. The project has been pioneering in many ways and has an important place in the development of insect conservation in Australia; it also provides information of considerable value for related species. The enduring commitment and support of people over the entire historical range of the butterfly has been (and remains) pivotal to progress.

More broadly, butterfly conservation in Australia has advanced considerably in recent decades, and a national Action Plan for Australia's Butterflies (Sands and New 2002) remains the only such compilation for any invertebrate group. In that document, we reviewed the conservation status and needs of all Australian species and subspecies and included individual dossiers on all taxa then of possible concern. Many of these taxa were then poorly known. The bulk of subsequent activity has emphasised ecologically specialised butterflies with restricted ranges and which are perceived as threatened in the south-east of the continent (New 2011c). The long-running conservation campaigns for the Eltham copper (*Paralucia pyrodiscus lucida* Crosby) and Bathurst copper (*P. spinifera* Edwards and Common) (Lycaenidae) are the only long-term parallels in Australia to that for *O. richmondia*. Each focuses on a notable regional flagship taxon, for which public support and local pride have been garnered and sustained, and for which a strong sense of 'community ownership' remains of key importance. However, the contrast between focusing on the tiny isolated urban remnant sites – such as those on which the Eltham copper persists near Melbourne – and on entire landscapes is immense. Together these examples span the range of scale of species-orientated conservation exercises and of constituent and political influences that can occur.

One purpose of this book is to document how such problems of scale can be addressed in attempting to study and conserve a wide-ranging flagship taxon, and how interest in doing so has been encouraged over more than two decades. It is also the first such account for any birdwing butterfly in Australia. The only related programme is the very different scenario for Queen Alexandra's Birdwing, *Ornithoptera alexandrae* Rothschild, noted in the introductory chapter. Interest in that magnificent insect continues, and unlike the remote areas of Papua New Guinea where this birdwing is endemic, *O. richmondia* occurs within an Australian region in which conservation sensitivities are well understood and where tangible support is available (although in a politically complex context, in which individual priorities are very varied), and the lessons learned have far wider relevance. Any such exercise becomes one of continuing compromise. To quote from New et al. (1995), referring to New Guinea birdwings, 'practical involvement of local communities is an integral facet of conservation management for these "rare butterflies" and *O. richmondia* in Australia represents a similar strategy in a more developed country'. That story is the core of this book.

Following a general introduction to the birdwing butterflies and their conservation needs, the history of interest in the Richmond birdwing is reviewed and its biology and decline summarised. The critical importance of larval food plant resources and their propagation and use for habitat extension and rehabilitation are discussed, together with the ecology and composition of biotopes within which these vines occur. The development of conservation interest and the progressive involvement of community groups, culminating in a dedicated volunteer network, are the major themes of the second half of the book. We attempt to display how biological knowledge, public goodwill and political support have been integrated towards this common endeavour, and to discuss the complex issues and conflicts that have arisen. Implicit in the entire project has been a variety of community efforts, through which well-coordinated activities and effective communication and education have helped to assure the future of one of Australia's most charismatic endemic butterflies. The lessons contribute widely to more general progress of butterfly conservation.

Brisbane — Donald P.A. Sands
Melbourne — Tim R. New

Acknowledgements

Any project of the extent, complexity and duration of that summarised here depends to a large extent on the interest and goodwill from local communities, and we owe much to its numerous participants and supporters. Our concern in attempting to acknowledge this participation fully is that of omitting key players from our listing of thanks; at the outset, we apologise for any such inadvertent neglect.

Sands' initial interest was supported as part of his professional duties at CSIRO, where the then Chief Executive (the late Malcolm Macintosh) and the successive Chiefs of the Division of Entomology (most recently Deputy Chief, Dr. Gary Fitt) fully recognised this role. Concerns were raised by, and opinions and advice received from, the most leading lepidopterists in the region who also responded generously to our queries over the years; many are acknowledged by name in the text, but others include A.N. Burns, I.F.B. Common, M. DeBaar, E.D. Edwards, A. & K. Hiller, M. Horak, J.F.R. Kerr, R.L. Kitching, J. Macqueen, R. Mayo, J. Nielsen, A.G. Orr and G. Sankowsky. Likewise, botanical and ecological advice throughout the project came from leading botanists and ecologists, amongst them P. Grimshaw (whose enduring interest spans the entire life of this campaign), G. Gymer, W. McDonald, E.M. Ross, J.G. Tracey and L.J. Webb.

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J. Richardson, S. Rielly, A. Scott, R. and P. Seddon, J. Turnbull, A. Vacek, A. Wilson, G. Wilson and Youning Su, with the spectrum of varied community activities all contributing to the common aim of conservation. Their enthusiasms have been instrumental in any successes achieved, not least through gaining support and sponsorships to allow plans to be brought to fruition.

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Contents

Chapter 1
Birdwing Butterflies and Their Conservation Needs

1.1 Introduction

Butterflies are undoubtedly the single most popular group of insects, and this status has fostered considerable and widespread sympathies for their conservation in many parts of the world. The foundations of butterfly conservation – indeed of wider invertebrate conservation – have been set amongst studies of butterflies in northern temperate regions, predominantly those of the United Kingdom, parts of western Europe and North America. These foundations have most commonly reflected concerns for individual butterfly species (or subspecies) that are perceived to have declined in distribution and abundance and for which management can be based on reasonably sound biological and distributional information in well-documented faunas. They have led to emulative projects in southern temperate regions, predominantly South Africa and Australia, the latter additionally encompassing the sub-tropical and tropical forest regions that are the major focus of this account. For many individual butterfly species and subspecies in parts of the northern temperate regions, detailed conservation programmes and recovery plans can be based on an understanding of their ecology, distribution, and threats to their welfare, accumulated over many years.

Some butterfly conservation cases are models of how the minutiae of ecological information can be incorporated into practical and successful management, with the success of conservation depending heavily on attention given to ecological detail, as well as community and political support. Most such focal taxa (species or subspecies) have been threatened predominantly by loss of habitat, both in extent and quality, and much remedial effort has necessarily focused on the few small sites on which the threatened taxa have been known to occur. Many of the threatened species and subspecies involved have demonstrably declined to the extent that their distributions have become fragmented and confined to small habitat patches, on which they now occur only as small remnant populations that are increasingly vulnerable to processes such as bush fires, invasions by alien animals and plants, and stochastic loss. Much of the development of butterfly conservation has been driven by

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'crisis-management' exercises for taxa that have already suffered substantial loss and, in many instances, have become highly susceptible to inbreeding effects, extirpation or even extinction. Habitat security and restoration of critical resources are recurring themes in butterfly conservation.

Over much of the rest of the world, including the tropics, far higher butterfly species richness and far less biological knowledge go hand-in-hand. Resident lepidopterists are almost invariably fewer in tropical regions than in northern temperate regions. Societal demands, capabilities and priorities are commonly very different, so that 'conservation' is an activity far secondary to meeting human needs. Very few individual butterfly taxa have been the focus of serious conservation efforts, despite the clear needs for these. The most familiar global scenario of butterfly species-level conservation in a region has thus become largely site-based conservation management, with token acknowledgement that the wider landscape provides an enveloping context for this, and thus that landscape-level manipulations may then be critical in countering the consequences of site or population isolation. Although many butterflies are indeed relatively sedentary, not all species are strictly site-bound and the above emphasis on species that are ecologically specialised and those presumed to be poor dispersers, represents only one facet, albeit an important one, of butterfly conservation. For most taxa, the form and dynamics of any metapopulation structure remains unknown and can only be inferred. Other taxa may range widely as strong flyers (and closely related butterflies may differ dramatically in their dispersal ability), and their conservation necessitates a wider perspective on landscapes to reflect major vegetation types and their dispersion. Some are now restricted to remnant corridors or patches, and to habitats that are vulnerable – so that, of greatest relevance here, tropical forests have been extensively cleared in the interests of agricultural, forestry, industrial and urban development. Both site-based and landscape-based conservation measures are needed.

Forest loss has undoubtedly become the major threat to a considerable variety of forest-dwelling animals and plants. Practical consequences include the inevitable transition to site-focus as such formerly extensive biotopes become reduced to discrete fragments remaining as their only representatives. This site focus couples with need to maintain connectivity on a wider scale wherever possible, to facilitate normal dispersive behaviour between those remnant patches. One outcome of habitat fragmentation and loss of connectivity is change of population structure, whereby previously functional metapopulations may be transformed into residual closed populations. Some migratory butterflies have had their dispersive behaviour disrupted by habitat loss. For example, the Brown awl (*Badamia exclamationis* (Fabricius) (Hesperiidae)) in Queensland is believed to have suffered from progressive isolation of populations on small habitat patches (Valentine 2004), so that its characteristic long distance migrations can no longer take place. Declines in abundance, or extirpation, can potentially result through genetic isolation and inbreeding depression in this, and many other species.

Within any habitable area, the critical, and often specific, consumable resources needed are food plants for the larvae and nectar sources for the adult stage. Birdwing larvae feed exclusively on forest vines of the family Aristolochiaceae, and many of the species of birdwing butterflies only develop on one or two species. These vines usually grow in rainforest where they have suffered heavily from extensive forest clearing. In addition, very few vines remain protected in national parks. The food plant vines used by Australian birdwings often occur on steep slopes and prefer basaltic soils, but grow also on rich alluvial loams bordering rivers and streams. Unfortunately, in many countries where the birdwings occur, the areas with such rich soils were eagerly sought and disturbed in various ways for forest timber plantations, agricultural purposes or oil palm plantations.

1.2 The Birdwing Butterflies

The birdwings are one of the paramount groups of flagship insect species, believed to have suffered very severely from extensive forest clearing over many parts of their collective range. They include the largest and most spectacular of all tropical strongly-flying butterflies, as a much-admired group of swallowtail butterflies (Papilionidae). They are restricted to the Indo-Australian region of the Old World tropics and subtropics, with species occurring from northern India and southern China, extending from Indonesia, Malaysia, Philippines, the Solomon Islands (Tennent 2002) and Papua New Guinea to tropical and sub-tropical eastern Australia. Females of Queen Alexandra's birdwing (*Ornithoptera alexandrae* Rothschild) are the largest butterflies known, with wingspans sometimes approaching 30 cm! Within their broader generic ranges, most species are very restricted in distribution.

The birdwing butterflies (now generally appraised as comprising members of three genera, *Ornithoptera* Boisduval, *Troides* Hubner and *Trogonoptera* Rippon) have aroused wonder amongst generations of naturalists since they were first known, and the writings of pioneer collectors (such as Meek 1913) reveal the excitement and emotions accompanying sightings and capture of these remarkable insects. That sense of wonder is summarised well by accounts of early collectors, whose words have been quoted repeatedly to convey the sentiments to more recent readers. Thus, Wallace (1869) recorded his reaction to his discovery and initial capture of the first golden-orange coloured male of *Ornithoptera croesus* Wallace as one of 'intense excitement', as (p. 336) 'On taking it out of my net and opening the glorious wings, my heart began to beat violently, the blood rushed to my head, and I felt much more like fainting than I have done when in apprehension of immediate death. I had a headache for the rest of the day, so great was the excitement produced by what will appear to most people a very inadequate cause'. He went on to describe his endeavours to capture a series of specimens 'obtaining on an average one specimen a day' for a long time, but 'on good days two or three specimens'. Meek's (1913, p. 142) reaction to receiving a captured male of *Ornithoptera chimaera* Rothschild rivals Wallace's sentiments, as 'I felt more pleased than if I had been left a fortune … A fine discovery of that sort stirs the heart of a collector. He forgets hardships and troubles …'. Collecting series of such elusive species is hard work, and even viewing individuals in remote areas is notoriously unreliable. As another famous quotation, Meek (1913, p. 161) again reported that, having encountered a female of *Ornithoptera alexandrae*, '…it was not until a year or two afterwards that I obtained a male specimen'. The appeals to collectors based on appearance, size and rarity, and the romanticism associated with exploration and unusual collecting methods, such as shooting high-flying specimens with dust shot (the method used to obtain the type specimens of both *O. alexandrae* and *O. victoriae* Gray), commenced from the earliest years of their discovery, and has persisted.

Parsons (1999) used the term 'mystique' to help convey the fascination of the birdwing butterflies for the people of Papua New Guinea, who have traditionally cultured their food plants to attract the butterflies into their gardens (Parsons 1992a; Sands and Scott 2002) and to use them for ornaments (Barrett and Burns 1951). Vividly coloured and often considered the most attractive of all butterflies, birdwings have long been desired by collectors, and specimens have been sought for displays and mounting in cabinets; their financial worth has long been a component of conservation inducement, initially puzzling but later appreciated by local people. Their 'mystique' has undoubtedly been fostered by their occurrence in some remote parts of the world (such as parts of Indonesia and Papua New Guinea), that have long been considered exotic and untamed to visitors, so that (other than the most intrepid explorers), many early expatriate collectors seeking specimens had little realistic chance even of seeing the rarer species in the wild, let alone of capturing them. Even the more common birdwings, spectacular to observe when visiting flowers, are equally impressive when seen in flight, and can be difficult to catch. Most have high-flying and colourful males, while the larger females are mostly brown/black and white, and often secretive in behaviour, and well camouflaged while they seek suitable larval food plants in the understorey, on which to lay their eggs. Fewer than 40 species of birdwings are recognised widely, but the precise number is debated continually, as the various local colour forms of species have been regarded subjectively as 'varieties', subspecies, or at times full species. The taxonomic identities of several species, status and combinations have often been modified – and will assuredly continue to be debated both objectively and at the more transient whims of collectors and dealers.

The birdwings are a potent group of insects to represent the 'small animals' in conservation advocacy, with conservation values fostered by their massive appeal both to experienced naturalists and conservationists and to people encountering them anew – including those whose directives may affect changes in land use (New 2011a, b). The limited distributions of most taxa, accompanied by severe threats to their habitats, and sometimes highly emotive debate over effects of over-collecting and illegal trade to satisfy collector demand, have given them a very high profile in insect conservation issues, as 'flagship' species. Not least, birdwings are amongst the relatively few tropical butterflies to gain high prominence in the wider discussions of insect conservation need. In Dennis' (1997) terms, birdwings have a 'high conservation load' fostered by concerns and advocacy from many parts of the world. Somewhat unusually, much of the concern for birdwing conservation has arisen from people who have not seen the butterflies in the wild but nevertheless accept the importance of conserving them, both for their own sake and as umbrella symbols for the myriad taxa associated with tropical rainforest habitats.

Outside Australia, most concerns for birdwing conservation have been for species on the mainland and islands of New Guinea (western section Papua, previously referred to as West Papua or West Irian [Indonesia]; eastern part, Papua New Guinea) where forestry activities continue to have a massive impact on their habitats. A detailed history of conservation efforts for the Papua New Guinea fauna was summarised by Parsons (1992a), Parsons (1999), drawing on his extensive earlier studies and involvement. Several features are central to constructive conservation concerns for the birdwings, and indicate how practical salvatory measures might be pursued (New 2002), as:

1. The primary habitats for many species, particularly those at higher elevations, are remote and difficult to access. This restricted access is sometimes exacerbated by the sentiments of local people and traditional landowners, who see imposed expatriate interests by visits to traditionally-owned land as interference, or threatening and exploitative to their life styles, whilst also providing landowners with little or no financial return.
2. Threats to birdwings are often unspecified beyond general comments on habitat loss through deforestation and implications of overexploitation for commercial sale of specimens.
3. Information on conservation need and the impetus for conservation management mostly arises from studies by visitors to butterfly habitats, based on relatively short-term field work that is sometimes viewed by local landowners with suspicion – notwithstanding some notable examples of conservation partnerships built on mutual trust.
4. Biological and ecological knowledge of each species is sparse, and butterfly population sizes, fluctuations and structures are extremely difficult to estimate over ranges of tens to hundreds of square kilometres of poorly explored terrain, often with unknown densities of food plants in dense forests where the levels of birdwing mobility are unknown, although inferred to be considerable, and
5. Continued pressures to circumvent well-intentioned regulations that have been instigated to counter possible overexploitation for commercial purposes.

Even the best-documented species of birdwings of conservation concern in Papua New Guinea are difficult to survey and study and, despite wide acknowledgement of needs for conservation, the lack of local priority and within-country logistic support renders local progress difficult. In this book we deal with a major exception to this scenario – the biology and conservation of a birdwing butterfly that has proved accessible to study, and is in serious need of conservation in Australia, and where conservation interests and expertise have been fostered to develop a conservation programme now in operation for more than 20 years. The endemic subtropical Richmond birdwing, *Ornithoptera richmondia* (Gray), has become a cause célèbre in Australian butterfly conservation, and the story of progress toward its conservation has much wider relevance in the development of insect conservation interest in the country. It is also providing lessons that may be transferable to aid related birdwings in other countries in the region. The study is helping to demonstrate that butterfly conservation can indeed be pursued purposefully at the landscape level.

This first chapter provides some general background and perspective to birdwing butterflies and their conservation.

1.3 Birdwing Relationships and Distribution

Adult birdwing butterflies are relatively easily recognisable amongst Papilionidae, but their precise taxonomic status has in the past been debated extensively. They are classified by most workers in the tribe Troidini in the subfamily Papilioninae, together with several other (non-birdwing) genera (*Battus* Scopoli, *Euryades* C. and R. Felder, *Cressida* Swainson, *Parides* Hubner, *Atrophaneura* Reakirt). In all of these genera the larvae feed on plants in the family Aristolochiaceae, and are thus grouped by Collins and Morris (1985) and Parsons (1996a). Weintraub (1995) reviewed some early examples of host plant misidentifications within Troidini: some errors persisted for many years, and others were presumed to represent 'transient larvae' – individuals feeding on small herbaceous aristolochias may need to move between different plants as they develop, in order to gain sufficient food, and so can be found resting on non-hosts during transit.

Although the 'birdwings' are nowadays grouped as three genera, *Troides*, *Ornithoptera,* and *Trogonoptera*, as above, some authorities (such as Hancock 1983; Miller 1986) earlier followed the precedent of Rothschild (1895) by allocating all birdwings to one single genus *Troides*. However, *Troides* and *Ornithoptera* appear very distinct based on features of both adult and larval structure (Parsons 1996a; Parsons 1999). Parsons (1996a) emphasised the differences in male hind wing androconia in the two genera, but *Troides* and *Ornithoptera* cluster together in recent phylogenetic interpretation drawing on molecular data (Braby et al. 2005), and their close taxonomic relationship seems to be well-supported. The small genus *Trogonoptera* has characteristics justifying generic separation, and may be the sister-group to '(*Ornithoptera* + *Troides*)', with the three genera clearly constituting a monophyletic group within the Troidini.

Attempts to subdivide birdwings further, amongst four or five genera or subgenera (with a maximum of seven in some schemes), have generally induced confusion rather than clarity. One dilemma has been that it is possible to manipulate cross-pairings between captive *Troides* and *Ornithoptera* to produce intermediate-looking hybrid forms. Natural hybrids between the two genera occur but are rare; for example Sands and Sawyer (1977) reported a field pairing of a male *T. oblongomaculatus papuensis* Wallace with a female *O. priamus poseidon* Doubleday from Papua New Guinea, from which two hybrid males were reared. Within *Ornithoptera*, strong cases have been made that the anomalous taxon known as *O. allottei* Rothschild, is in reality a rarely-occurring hybrid from mating between *O. priamus urvillianus* (Guerin) and *O. victoriae* (McAlpine 1970). More recently in the 1980s, Ray Straatman (pers. comm. to Sands) confirmed this cross-mating of species resulted in hybrids that resemble *O. allottei*, and has left little doubt about the hybrid origin of this taxon in the wild. Since then several other cases of natural hybrids have been reported and traded as such.

Troides includes about 17 species; *Ornithoptera* includes 19 species and *Trogonoptera* two, giving a global total of about 38 species, some of which are contentious in taxonomic status. Ambiguities of allocation of species names are perhaps inevitable amongst a group in which individual and local variation within putative species is high. The tendency to 'over-name' variation is understandable with the strong philatelic appeal of specimens to collectors, amongst whom the propensity to formalise trivial variety and name local populations, based on relatively small features – most commonly of wing markings or colour – is widespread. Birdwings are by no means the only group of butterflies having received such 'splitting' of taxa and proliferation of varietal names. Even amongst some European butterflies, interpretation of species limits and within-species variation remains problematical (Descimon and Mallet 2009). In short, the genetic bases for much butterfly variation are unclear, and inevitably this is much more so for species found in remote parts of the world where comprehensive field studies (and, even more, laboratory rearing studies) are extremely difficult to pursue, and for which material available for critical study may be very restricted. And, whereas many names for birdwings were introduced simply to be descriptions of local 'forms', a trinomial name is formally a subspecific and acceptable one, with the consequence that synonymising such names must result from rigid formal scientific scrutiny rather than casual opinion, as can be applied to most 'forms'. This book is not a forum to review the internal classification of birdwings, but it is important to emphasise that many strongly-held disparate views exist on the validity of particular species or subspecies, so that different compendia of taxa may present these at different levels. It is consequently important to be clear about the position adopted when discussing any individual taxon. Understanding the integrity of butterfly subspecies poses complex problems of interpretation, and much relevant discussion to their roles in conservation was given by Braby et al. (2012).

The three genera are distributed as in Fig. 1.1. The distributions of *Ornithoptera* and *Troides* overlap on the mainland of New Guinea and on some islands, but *Troides* is by far the more widespread genus, extending westward as far as northern India. The range of *Trogonoptera* is much more limited and circumscribed. The major focus here is on *Ornithoptera*, a genus with a distribution that encompasses mainland New Guinea and some island groups to the east, and which is the only birdwing genus found in Australia. According to Parsons (1996a, c), *Ornithoptera* is believed to be Gondwanan in origin and the genus evolved as the Australian plate drifted northward. Its relatively recent evolution was thus wholly independent from *Troides*, in which diversification occurred on the South-east Asian or via the Indian plates. If this is so, the most southerly Australian taxon *O. richmondia*, is likely to be an ancestral member of the genus (Parsons 1996a), representing the stem from which the more northern taxa have separated and diversified. Details of their historical biogeography are perhaps more complex (Braby et al. 2005), but with the origin of Troidini in remnant Gondwana supporting the phylogeny they advanced.

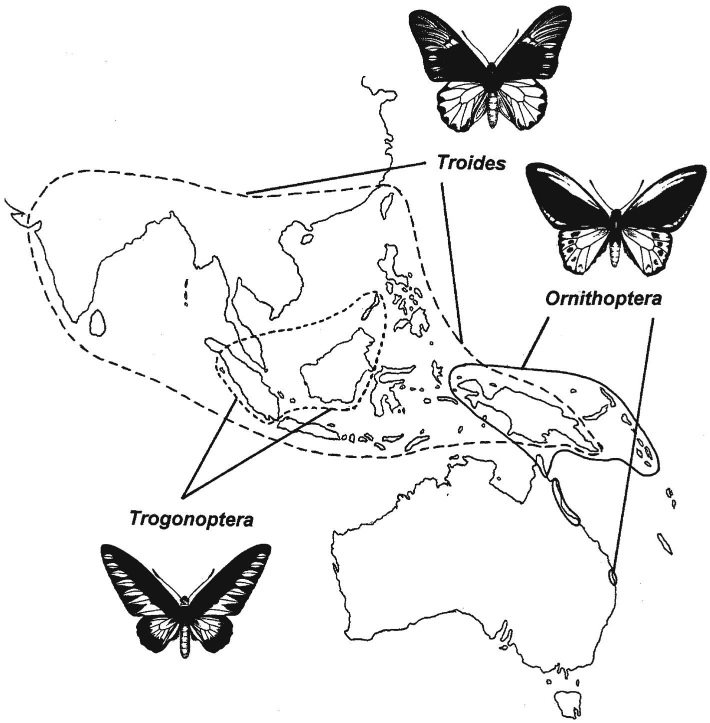

Fig. 1.1 Broad global distribution of the three recognised genera of birdwing butterflies

The striking appearance of birdwings has induced several authors to produce lavish publications in which numerous specimens are illustrated in colour, and the illustrations supported by texts of varying accuracy and complexity. As examples of these, see D'Abrera (1975, revised 2003), Haugum and Low (1978–1985) and several highly impressive Japanese books by Ohya (1983), Sumiyoshi (1989) and Matsuka (2001), some with biological information and photographs of early stages. Technical texts include a taxonomic catalogue by Ohya (2009) as well as inclusions in regional butterfly faunas (such as Braby 2000; Parsons 1999; Tennent 2002). Numerous web sites also include abundant illustrations and texts on birdwings; one of the more comprehensive is at 'www.nagypal.net' (accessed April 2010), another relating to the Richmond birdwing is at 'www.richmondbirdwing.org.au'.

1.4 Australian Birdwings and Their Identities

The Australian representatives of *Ornithoptera* are each found in relatively restricted areas of the eastern coastal regions of Queensland and northern New South Wales (Fig. 1.2), and do not extend further south. Historically, the taxonomy of the birdwings found in tropical and sub-tropical eastern Australia has been somewhat confused. Initially (as in books by Rainbow 1907; Waterhouse 1932; Braby 2000) the various populations of Australian birdwings were regarded as geographical races, subspecies or varieties of a single species, the widely-distributed *Ornithoptera priamus,* a very variable species that occurs in many parts of the New Guinea archipelago. The genera (with earlier allocations to *Papilio* or *Troides*) and species names for these birdwings were variously combined until Hancock (1991) applied the genus *Ornithoptera* to the Australian species and recognised the three taxa as distinct and allopatric species. The separation of the subtropical Richmond birdwing, *Ornithoptera richmondia* (sometimes cited as '*richmondius*') as a distinct species was first suggested by Zeuner (1943). Later, Common and Waterhouse (1981) considered *O. euphorion* Gray to be an Australian subspecies of *O. priamus* and regarded *O. richmondia* as a distinct species. Most recently, Braby (2004) recognised three of the geographically-separated populations as distinct species: *O. priamus, O. euphorion* and *O. richmondia*, and this status is now the one most widely accepted. Based on their morphological and biological characteristics, Hancock's (1983) earlier arrangement indicating that there are three allopatric Australian species of *Ornithoptera* (Figs. 1.3 and 1.4), *O. priamus* (with three subspecies: *O. p. macalpinei*, *O. p. poseidon*, *O. p. pronomus*), *O. euphorion* and *O. richmondia* is recognised widely. The latter two are distinct, endemic Australian species, whereas *O. priamus* has several subspecies extending in range from Cape York Peninsula, through the Torres Strait Islands, to New Guinea and most of the neighbouring islands. *O. richmondia* is the only species occurring in the subtropical parts of Australia, with an obligatory over-wintering pupal diapause which enables it to survive the cool winter climate. Although over-wintering pupal diapause is common in many other Papilionidae, pupae are not known to undergo diapause in the other two Australian birdwings, *O. euphorion* and *O. priamus*, in which protracted development is a well-known response to lowered temperatures, particularly during winter.

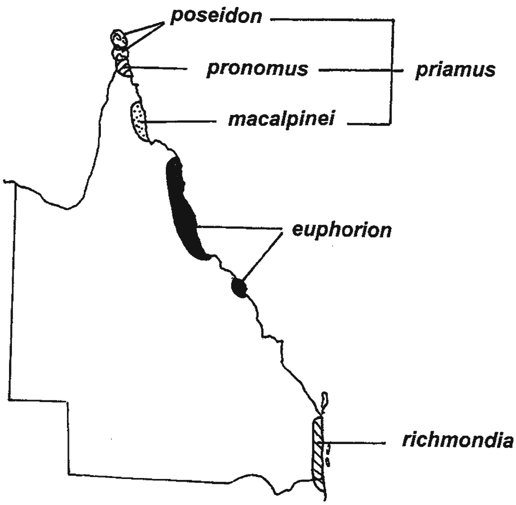

Fig. 1.2 Distribution of Australian birdwing butterflies, *Ornithoptera* spp.

The Australian taxa can be distinguished by differences in appearance and wing patterning (most easily of the upper side of either sex), as listed below (Figs. 1.3 and 1.4). Sizes overlap considerably, but *O. richmondia* is characteristically the smallest of the Australian taxa. As in other birdwings, sexual dimorphism in *Ornithoptera* is extreme – the larger females marked with cream and yellow on dark brown, and the vividly coloured males varying in the extent of iridescent green or, rarely, blue (Fig. 1.5a, b) and gold, or the yellow and black spotting on the hind wing. The colour of males of all three Australian birdwings, *O. priamus*, *O. euphorion* and *O. richmondia*, is often variable and the proportion of blue, green and yellow spots on the underside of the hind wing of *O. euphorion* and *O. richmondia* (Illidge 1927), and the gold spots on the upperside of the hindwing also vary (Fig. 1.5c). Rare forms in both species are known in which the green on the upper surface is replaced by blue (Fig. 1.5a, b) and even rarer examples are known in which the green colour is replaced by golden yellow. At the ventral base of the wings of many birdwings, including *O. richmondia*, both sexes have a distinctive red patch or spot that first becomes visible when an adult is enclosing from the pupa (Fig. 1.6). While the wings begin to expand, this red patch is very easily seen and it is believed to be a warning to would-be predators at a stage when no escape is possible. It is also considerably larger in females than males, and could possibly confer protection during oviposition.

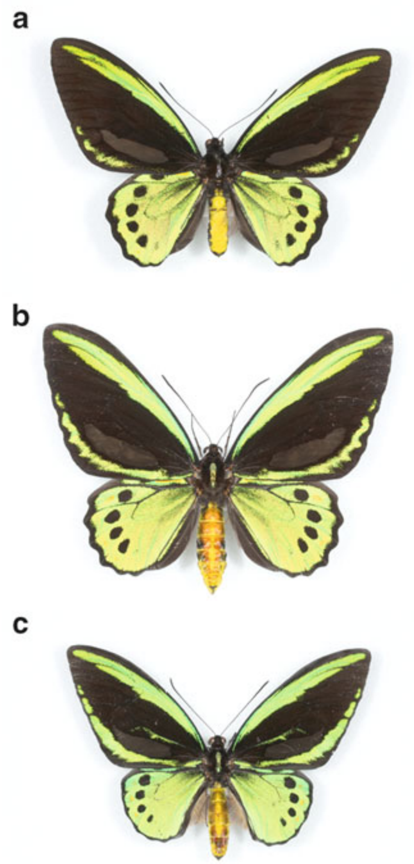

Fig. 1.3 Males of the three Australian species of *Ornithoptera*: (**a**) *O. richmondia*; (**b**) *O. euphorion*; (**c**) *O. priamus macalpinei*

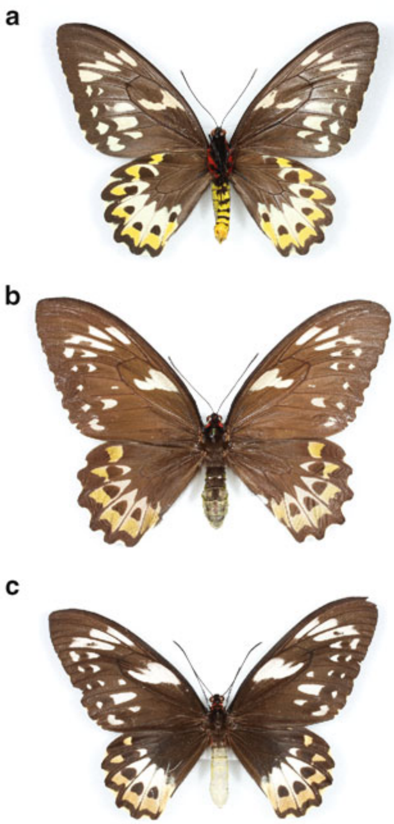

Fig. 1.4 Females of the three Australian species of *Ornithoptera*: (**a**) *O. richmondia* (underside); (**b**) *O. euphorion*; (**c**) *O. priamus macalpinei*

Some variation occurs in *O. richmondia*. The green inner marginal bands, the green termen at the tornus of the fore wing and the black inner margin spots on the hindwing all vary in *O. richmondia* and are sometimes absent. In particular specimens from Lismore, Ballina and the Richmond River generally, near the current southern limit of the range, may vary in the extent or presence of green on the inner margin with this reduced in some individuals. The "form *reducta*" of *O. richmondia* was described and figured by Haugum and Low (1979) for males with less green and wider black termen of the hind wing (Fig. 1.7). The specimens were collected many years ago near Grafton on the Clarence River but are insufficient to distinguish this possibly now-extinct population from some males now occurring near the Richmond River and in the present southern part of the range.

The type locality for *O. richmondia* is the Richmond River, New South Wales (NSW) (Howarth 1977), a region where extensive variation is commonplace. Variation within the existing range of this species does not show sufficient differences in colour and morphology to justify recognition of any distinctive subspecies in *O. richmondia*. Several other male specimens from the current southern range, for example from near Ballina and Lismore, are also without the forewing green

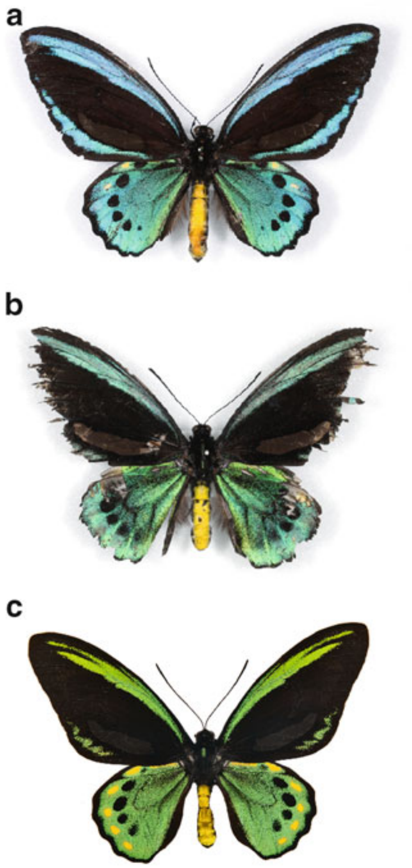

Fig. 1.5 Some colour varieties of Australian *Ornithoptera* males: (**a**) a blue *O. euphorion* [ANIC]; (**b**) a (very worn) blue *O. richmondia* (I. Gynther)*;* (**c**) a male *O. richmondia* with enlarged gold spots on hind wing (Mount Warning, T. Worden and G. Newland)

band but the black band of the hind wing is not as wide as in the original Grafton specimens and there are many examples from these localities where the areas of green are as extensive as those, for example, on specimens from Queensland. From other localities in NSW, dark male specimens are also known, suggesting dark variants are common but none are as extreme as those specimens from Grafton or the Clarence River. Unfortunately no recent specimens have been available for comparisons from the southern extreme of range, either from Grafton, NSW or the Clarence River, but several males from Mallanganee, near the upper reaches of the Richmond and Clarence Rivers, appear to be consistently darker than specimens from further north and it is possible that a partial latitudinal cline in this feature occurs, possibly related to temperature. Colour variation in female *O. richmondia* is also more common towards the southern edge of the range; particularly when the

Fig. 1.6 Living male (**a**) and female (**b**) *O. richmondia*, showing underside and ventral red thoracic patch; (**c**) mating pair (R. Booth)

extent of white patches on both wings and the black background is sometimes replaced by dark grey. For example, females from south of Murwillumbah often have few, or no pale spots in the central parts of the fore wing (as in the figure by Newland and Turnbull (2012)), and the sub-basal band may be wider (Fig. 1.8). The yellow or brownish-yellow sub-terminal spots on the hind wing are also variable in brightness and size but are consistently brighter on the underside.

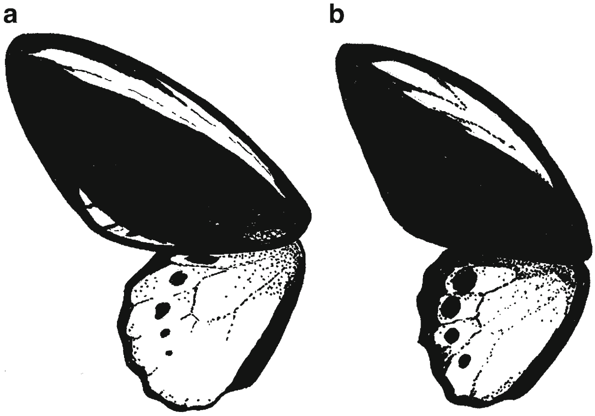

Fig. 1.7 Line drawings to show decreased marking from typical male *O. richmondia* (**a**) found in 'form *reducta*' (**b**) as diagnosed by Haugum and Low (based on Haugum and Low 1979)

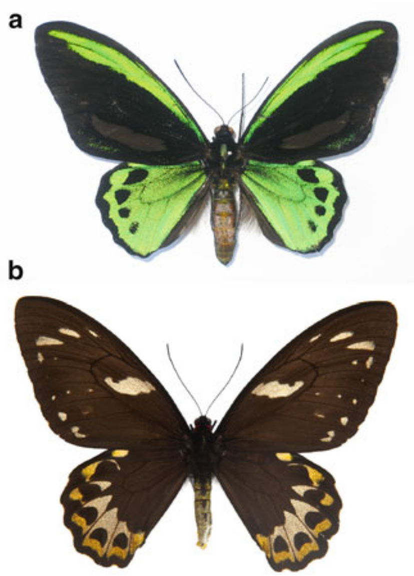

Fig. 1.8 Representatives of *O. richmondia* from southern part of range, approaching form '*reducta*' in appearance: (**a**) male from Mallanganee (D. Sands); (**b**) female from Mount Warning (T. Worden and G. Newland)

Some seasonal variation in size of *O. richmondia* is evident, with both sexes sometimes smaller when emerging in spring, compared with individuals emerging in warmer months. This can be due to loss in mass by over-wintering pupae but is also likely to be due to the low nutrient concentrations in leaves, for example, when larvae have been feeding in autumn when new growth of the food plant is retarded by lower temperatures or moisture. Temperature regimes during development can influence colours and areas of patterns in many birdwing species. In addition the black spots on the upperside of the hind wing are often larger and gold spots on the hind wing are more likely to be present and larger than specimens taken in warmer months.

The following wing measurements, and colour notes, together with differences in hind wing shape, aid recognition and separation of the Australian taxa:

Males (Fig. 1.3):
O. richmondia. Wingspan ca 115–130 mm; fore wing length ca 62 mm (57–65, n = 5); fore wing with green sub-terminal band at tornus less than half length of termen, not reaching base, or absent; no median green lines on cell vein(s); hind wing termen weakly bowed.

O. euphorion. Wingspan ca 150–160 mm; fore wing length ca 76 mm (74–79, n = 5); fore wing with green sub-terminal band at tornus extending more than half length of termen, band on inner margin reaching base; no median green lines on cell vein(s); hind wing termen strongly bowed and weakly scalloped.

O. priamus:

ssp. *macalpinei*, wingspan ca 125–130 mm; fore wing length ca 64 mm (63–65, n = 5); median green line on cell vein weakly branched, less than half length of fore wing, sometimes obscure or absent; hind wing termen weakly bowed.

ssp. *pronomus*, wingspan 120–140 mm; fore wing length ca 72 mm (69–75, n = 4); fore wing (all subspecies) with green sub-terminal band at tornus more than 3/4 fore wing length, extending almost to apex, band on inner margin reaching base; median green line on cell vein(s) variable ca half length of fore wing; hind wing termen almost straight.

ssp. *poseidon*, wingspan 121–145 mm; fore wing length ca 74 mm (71–78, n = 5), similar to ssp. *pronomus*, but green areas of underside more extensive; hind wing termen weakly bowed almost straight.

Females (Fig. 1.4):
O. richmondia. Wingspan ca 130–150 mm; fore wing length ca 71 mm (69–75 , n = 5); abdomen dorsally grey-brown; fore wing black with broad grey-white median band extending ca 1/3 width from costa to cell; hind wing with broad sub-terminal white spots and patches, yellowish-brown closer to termen.

O. euphorion. Wingspan ca 160–170 mm; fore wing length ca 84 mm (82–85, n = 5); abdomen dorsally brown; fore wing dark brown with narrow pale grey median band, extending from costa to cell; hind wing with dull orange-grey sub-terminal spots and patches.

O. priamus:

ssp. *macalpinei,* wingspan ca 150–165 mm; fore wing length ca 79 mm (75–81, n = 5); abdomen dorsally pale whitish-grey; fore wing dark grey-black with white patches; well defined greyish-cream subterminal band on hind wing.

ssp. *pronomus*, wingspan ca160–190 mm; fore wing length ca 88 mm (80–100, n = 4); abdomen greyish white; fore wing dark grey with greyish white patches; broad grey-white median band extending ca ½ width from costa to cell; hind wing with sub-terminal spots and patches white and grey-brown.

ssp. *poseidon*, wingspan ca 160–195 mm; fore wing length ca 90 mm (82–102, n = 5); abdomen dorsally grey; fore wing grey-black, with broad grey-white median band extending from costa to cell; hind wing with subterminal spots and patches white and grey-brown.

In addition to the above wing features derived from series considered to represent the 'normal' range, several other distinctive characters can be used to separate the species, and include the male genitalia, colour and length of spines of larvae, and colour of pupae. Thus, spines on later larval instars of *O. richmondia* are proportionally shorter than those of *O. euphorion*, and pupae are bright green in *O. richmondia*; brown and yellow in *O. euphorion*, and variably golden brown with darker markings, and dark brown in *O. priamus*.

Authors of several books on Australia's butterflies (including Waterhouse 1932; Common and Waterhouse 1981; Braby 2000; Sands and Scott 2002) have contributed to the increasing knowledge of the systematics, biology and ecology of the birdwing butterflies, including the Richmond birdwing. The three species are very closely related (Hancock and Orr 1997). Within the New Guinea region, particularly on islands, many authors have commented on the extent of individual variation in wing colour and markings within populations of all the subspecies of *O. priamus*. The three Australian subspecies of the Cape York birdwing, *O. priamus,* are geographically distinct: *O. priamus macalpinei* occurring coastally north from Silver Plains, and from Coen to the Claudie River and Iron Range, and *O. priamus pronomus* occurring between Bamaga and Somerset on northern Cape York Peninsula and Thursday Island, and *O. priamus poseidon* on forested Torres Strait Islands, from Moa and Badu to Saibai, Darnley and Murray Islands, and also found commonly in lowland rainforests (below 1,500 m) of mainland New Guinea.

Although geographically separate from other birdwings and a distinctive taxon, *O. richmondia* has also been regarded at intervals as a subspecies of *O. priamus* (Waterhouse 1932; Matsuka 2001). Braby (2000) summarised the outcomes of hybridisation experiments undertaken by various workers between *O. priamus* subspecies and *O. richmondia* and suggested that (whilst range differences would preclude any such cases occurring naturally), further population genetics studies might be helpful in reaching a firmer consensus. Hybrids between the two were said to be sterile (Common and Waterhouse 1981) in contrast to fertile hybrids between some forms of 'true *O. priamus*' recently reported. However, hybridisation attempts between all three Australian species have not yet confirmed sterility between the species. In view of the ease with which hybridisation (also between genera) can be achieved artificially, it is clear that sterility, or fertility in hybrids between birdwing species or even genera (Sands and Sawyer 1977) especially if they allopatric, are not good indicators for specific status.

The name '*richmondia*' as applied to the Australian subtropical birdwing, has been subject to questioning for its validity. Edwards (2008) pointed out that the widely-used name for the butterfly, *Papilio (Ornithoptera) richmondia*, applied by

Gray (Fig. 1.9), was not the earliest published scientific name for this taxon. Edwards provided a fascinating insight into how in 1853, the first scientific name applied to this birdwing, *Amphrisius australis* Swainson, had been overlooked. This original name was published in a newspaper, the Sydney Morning Herald, in August 1851 in a review of a then yet-to-be published book written by A.W. Scott. Scott had allocated manuscript names, but his colour plate (Fig. 1.10) of Richmond birdwing was not included in his book. It eventually appeared in an historical retrospective by Ord (1988). Since 1851, this name has never been officially used, or re-instated as the appropriate scientific name for the Richmond birdwing butterfly! However, as Edwards (2008) indicated, the International Code for Zoological Nomenclature can allow suppression of an original scientific name when a more recent name has been more widely used – as is the case of current use of '*richmondia*'. Gray was clearly, and unsurprisingly, unaware of Swainson's earlier name.

Fig. 1.9 The original diagnostic plate containing *'Papilio (Ornithoptera) richmondia'* (Plate II from Gray 1953). Upper four figures are all O. *richmondia*, bottom is a female *P. euphorion*

Fig. 1.10 The plate of *O. richmondia* (labelled in footer as '*Ornithoptera australis* Scott') prepared for publication in A.W. Scott's 'Australian Lepidoptera' (Courtesy of the Australian Museum, Sydney)

1.5 Conservation Concerns

Much of the general conservation concern for birdwings flows from two main issues, namely their attraction and commercial value to collectors, and the increasing scarcity and vulnerability of various taxa as their rainforest habitats continue to suffer loss and degradation. The desirability of birdwings, arising from their spectacular appearance – in both colour and size – and their notoriety as rarities that have been difficult to obtain, has led to the scarcer and geographically more restricted species being avidly sought and traded. However, in Papua New Guinea in 1966, prices paid (or demanded) for good specimens increased dramatically when many of the rarer species were listed as protected species, so that collecting from the wild was prohibited. This led to a lucrative trade in smuggled specimens which gained momentum when all species, whether common or endangered, were listed under the Convention on International Trade in Endangered Species and Wildlife (CITES) as prohibited exports or imports. Even at that time, a single specimen of Queen Alexandra's birdwing (*Ornithoptera alexandrae*) fetched more than Au $1,000 on the black market, and considerably higher prices have appeared in dealers lists at intervals since then! Wealthy enthusiasts have long been willing to pay substantial sums for premium cabinet specimens of the rarest birdwing species, and concerns for effects of exploitation have led to formal measures to prevent or control trade, a step conducive to development of more clandestine 'black market' operations to provide specimens. However, simply legally ordaining protection of these butterflies from collecting has done little towards their survival and the number collected poses relatively little threat when compared with widespread habitat destruction. Most species of birdwings have declined in abundance from loss of their rainforest habitats and the food plants, and several species may now be threatened with extinction primarily from these impacts.

All birdwing species except one are currently listed on CITES Appendix 2, with the intention to monitor numbers legally traded. The exception is *O. alexandrae*, a species placed on Appendix 1, in which trade is fully prohibited. The strong lead given by Papua New Guinea by, in the 1960s, listing seven species of *Ornithoptera* as protected and designating them the 'National Butterflies of Papua New Guinea' (Mitchell n.d.) drew attention to the importance of these butterflies. The more controversial step of 'listing all species' under CITES, by which common and widespread species were afforded the same level of 'protection', as truly threatened taxa, reflects the practicality of monitoring the trade. Quarantine officers, border protection officers and others responsible for detecting smuggled butterflies, cannot reasonably be expected to be expert taxonomists able to differentiate closely similar and 'look alike' forms. The general appearance of birdwings, however, is unmistakable, so that the legal precaution is to attempt to avoid smuggling of threatened species by encompassing them within this broader image. Strongly antagonistic reactions occurred through collectors then not being able to obtain freely specimens of even the common species, and the practical ramifications have been discussed, inter al., by Parsons (1992a, b), Parsons (1999) and New (1997b).

Over-collecting of butterflies is an emotive topic, with concerns over its impacts a persistent theme in butterfly conservation discussions. A major dilemma in rationalising its impacts and conservation significance is that of accumulating any objective evidence that levels of collecting being undertaken in New Guinea and elsewhere are unsustainable. Whilst it may indeed be wise to take the precautions demonstrated through CITES designation in any cases of doubt, three counter-arguments are advanced frequently:

1. Prohibitions of collecting by 'protective listing' of any sort, whilst condoning continued destruction of primary habitat – in this context, of primary forest for oil palm establishment, shifting agriculture, mining and timber extraction – is a relatively minor contribution to practical conservation.
2. In Australia, and other places in which locally resident entomologists and hobbyists are able to study the birdwings, imposition of collecting bans is likely to deter the interests and enthusiasm of the very people whose dedication and goodwill is essential to gain the information that underpins enlightened conservation practice.
3. Prohibition without perceived justification or evidence that collecting is harmful is seen as unnecessary, and induces development of illegal trade through which actual take of specimens may be increased but remain clandestine and unmonitored, as a black market trade with unregulated prices.

The most innovative step taken to overcome overexploitation of birdwings by collecting from the wild was (pre-2010) in Papua New Guinea, to develop a practice of 'butterfly ranching' (or 'butterfly farming') linked with centralisation of trade in dead butterflies through a government agency (the Insect Farming and Trading Agency, IFTA). This was the main legal path for commercial export of specimens (with the requisite CITES documentation and except for approved scientific purposes) from the country, and through which the trade could be monitored. This development recognised that the birdwing butterflies are a sustainable resource with considerable financial reward, and from the outset emphasised the wellbeing of people in rural surroundings 'where there is little other chance of employment, and where the insect resources present great potential' (Pyle and Hughes 1978). Local operations provide a rationale for forest conservation, as a resource on which continuing commercial success depends.

Ranching is based on habitat enrichment, in this context by the concentrated planting of larval food plant vines in gardens and clearings, and the detailed development of the scheme is described by Parsons (1992a, 1999), based on his innovative inputs over many years. A butterfly farming manual (Parsons 1982, 1995) includes extensive practical advice of much wider relevance in birdwing conservation, in establishing suitable butterfly gardens and enriching habitats. Thus, to attract *O. priamus, O. victoriae* and *T. oblongomaculatus* Goeze, up to 500 plants of the common vine *Aristolochia acuminata* (previously known as *A. tagala*) can be planted in areas of only around 0.2 ha in the appropriate parts of Papua New Guinea, to grow upward into shade trees (such as *Leucaena*), and the whole plot surrounded by nectar-rich plants attractive to the butterflies. However, such formal 'farms' were rare in relation to the more widespread practice of simply planting vines wherever suitable support trees occurred in and around a village (Fig. 1.11). Butterflies are attracted to the concentration of planted vines, on which they oviposit, and the developing larvae can be reared under confined conditions to protect them from predators and parasitoids. A proportion of the ensuing adults are taken for trade, and others released into the field population.

Fig. 1.11 Garden cultivation of *Aristolochia acuminata* to attract birdwings in New Britain, Papua New Guinea

The wider ramifications of planting butterfly food plants to support conservation interest include:

1. Providing a tangible reward (cash for reared specimens) that is obtained from a forest product (birdwings) whose sustainability depends on continued management of key resources (vines and the forest itself), linking with -
2. A means to purchase food and other human needs, so (a) reducing needs to clear forest for agriculture and (b) providing an incentive to protect forest against wider intrusions; and
3. Emphasising the sustainable nature of birdwings as a source of income, by taking only a proportion of the reared individuals, and by releasing others, whilst also not capturing additional, often worn or damaged, specimens for sale.

These principles were amply demonstrated by Parsons (1982), and led New and Collins (1991) to suggest that the approach may have a central role in conservation practice. Social and economic changes for many human communities have been substantial, and have spurred emulation elsewhere and for a variety of commercially desirable insects that can be 'harvested' for trading without increasing the vulnerability of wild populations. Whereas the bulk of birdwing specimens passing through IFTA were common species, including the two most widespread in Papua New Guinea (*Troides oblongomaculatus*, *Ornithoptera priamus*), the experience accumulated from rearing these in quite large numbers has been important in developing parallel exercises for other species and in other places.

The foundation aims of establishing IFTA (as summarised by Parsons 1992a) thus had fundamental conservation importance. They were:

1. To promote the production and sale of butterflies as an alternative source of income for subsistence farmers, especially in less commercially advanced areas of Papua New Guinea.
2. To restrict trade in insects to Papua New Guinea citizens.
3. To ensure that fair/reasonable prices are paid to collectors and farmers and to assure expedient payments for butterflies and other insects.
4. To provide a centralised body as a communication centre for sellers and purchasers, and to serve as an official agent for business from overseas buyers.
5. To ensure the highest possible quality of stock, including locality data for specimens.
6. To act as an educational centre for instruction in insect farming and rearing methods, and to provide basic equipment for participants.
7. To ensure that insects are treated locally as a renewable resource.
8. To promote the conservation of butterflies and their habitats.

The demonstrated success of ranching birdwings based on habitat enrichment is important for the Australian study discussed in this book but, whereas the practice has become wide-ranging in both scope and purpose, it has not wholly replaced the need for additional species-focused conservation measures. Perhaps understandably, in view of the dearth of concerned resident entomologists and the pressing problems of human welfare, such conservation concerns tend not to be seen to help solve these problems in Papua New Guinea. Much butterfly conservation advocacy for the mainland of New Guinea and nearby islands has been something of an ‘armchair exercise’ urged from afar but with the practicalities and restrictions not appreciated fully by the proponents. Again, the philosophical and practical issues have been summarised effectively by Parsons (1999). Parallel cases developed later in China, and Indonesia added to the concepts and experience, with varying success (Parsons 1995).

The predominant generalisation for conservation of New Guinea birdwings is simply that primary rainforest habitats must be protected effectively from logging and other disturbances. Although ranching is an invaluable conservation tool, not all species have yet proved amenable to this, and it cannot be viewed as a substitute for loss of resources from the wild; protection of natural forest habitats remains a paramount concern. However, it seems that in New Guinea the distribution of some birdwing species may actually have been extended by translocations of individuals undertaken to establish local populations to found ranching operations. The apparently recent expansion of *Troides oblongomaculatus* eastward may be one such case (Parsons 1999).

1.5.1 Ornithoptera alexandrae

The major focus on conservation of any individual birdwing species has been on the Queen Alexandra’s Birdwing as a leading flagship and icon species, known at least by reputation to biologists throughout the world, as well as being the largest and putatively the most threatened of all members of this group. It was first collected by A.S. Meek, perhaps the most famous of Lord Walter Rothschild’s many commercial collectors, and it appears even then (1906 on) to have been elusive. The type female, considerably smaller than many specimens captured subsequently, was from a locality far beyond the current species' range. More recently, *O. alexandrae* has been known only from parts of the Oro (formerly Northern) Province, and from only 14 of the 10 × 10 km square mapping units used for plotting distributions of Papua New Guinea butterflies, so appears to be highly restricted geographically. It occurs on the lowlands around Popondetta and in some highland forested areas, particularly around Afore on the Managalas Plateau, and in both these regions (separated by about 40 km) it has been the focus of considerable field survey to clarify its distribution and status. Practical conservation efforts (Parsons 1992b; Parsons 1999) later involved an international programme including Australian foreign aid to develop the 'umbrella' values of the butterfly to facilitate providing alternative livelihoods for local residents and emphasise the importance of conserving primary forest habitats, rather than continuing to see these lost for conversion to oil palm plantations (around Popondetta) or timber extraction (Managalas Plateau, with logging also around Popondetta).

A brief summary of that extensive programme (New 2007) noted some of the practical difficulties that eventuated in working toward the five main aims of this ambitious enterprise, namely:

1. Research, to enhance understanding of the distribution, biology and ecology of *O. alexandrae*.
2. Conservation of primary Habitat Areas to maintain the existence of all important primary habitat areas.
3. Education and awareness: to promote knowledge of and concern for *O. alexandrae* throughout the country.
4. Economic and social issues: to provide economic and social incentives and measures for conserving *O. alexandrae* habitat.
5. Project management: to coordinate and manage inputs and implement activities.

The project was able to draw on the extensive management recommendations arising from studies by Orsak (1992), Mercer (1992), Parsons (1992b) and others, that laid a well-informed foundation, in conjunction with capitalising on the existing notoriety of the butterfly – such as it figuring on the provincial flag. However, in common with other such elusive and wide-ranging butterflies, *O. alexandrae* is extremely difficult to survey. Its presence may be confirmed by sighting of either adults or the large larvae (through binoculars: Mercer 1992) but, as Fletcher (2002) commented on *O. paradisea* Staudinger in lowland rainforests, 'gathering quantitative data on a rare butterfly in a rainforest habitat with limited scientific resources is both difficult and time consuming'.

1.5.2 *Troides aeacus*

This very variable species has five subspecies distributed in south eastern Asia, from western China to Taiwan and Sumatra. Collector pressure is considered a primary threat to some birdwings, with collection of the more common species for construction of artifacts (such as framed 'butterfly wing pictures') a common occurrence. In China, *T. aeacus aeacus* (Felder and Felder) is used for this purpose and, although very widely distributed, some populations are probably vulnerable through being small, and their food plants in decline, and the butterfly now occurs only in remnant habitat patches within largely anthropogenic landscapes. A butterfly farming operation established in Xishuangbanna led to success in ranching *Troides helena* (L.) within a few months of planting *Aristolochia acuminata* cuttings, with similar outcome following for *T. aeacus* (Parsons 1995). This butterfly varies considerably in biology in different parts of its range in China. In the northernmost parts of its distribution (Southern Gansu province) it is univoltine, but further south (Guangzhou city) six or seven generations occur each year (Li et al. 2010). Although generally regarded as common, conservation concerns for forms of *T. aeacus* have been raised in different parts of its range; however, as with some other birdwings, contrary opinions occur. The Taiwanese subspecies *T. a. kaguya* (Nakahara and Esaki) (perhaps more properly referred to as *T. a. formosanus* [Rothschild]: see Wu et al. 2010, who emphasised the molecular delineations of subspecies, undertaken in part to monitor and trace inter-population mixtures arising from translocations associated with butterfly farming operations) was formerly considered to be threatened by trade (Collins and Morris 1985) and by over-collection from its lowland habitats. However, its conservation needs (after 30 years of protection: Wu et al. 2010) appear to be less than for the other birdwing in Taiwan, *T. magellanus* (Felder). The local Taiwanese form of that species (sometimes distinguished from the Philippines populations by the subspecies name *sonani* Matsumura), occurs only on Orchid Island (Yang and Fang 2002).

In general, the categories of conservation concern exemplified for these two taxa have been raised for other birdwing taxa, with varying parallel evidence or concern and the twin threats of habitat loss and over-collecting cited repeatedly. The Yellow birdwing, *Troides helena*, is often common and widely distributed. However, conservation concerns have arisen from its markedly reduced abundance in Penang, Malaysia, with current interest and support promoted through the Penang Butterfly Farm (Goh pers. comm. 2012; www.butterfly-insect.com). Threats listed involve changes to natural habitats, including deforestation, and forest disturbance associated with food plant losses, inbreeding resulting from population isolation, and more gradual natural environmental changes such as climate change. In common with other birdwings, *T. helena* is a protected species under the Malaysian Wildlife Conservation Act 2010.

The habitats of concern for all regional birdwings are essentially tropical or subtropical rainforest, or particular species of larval food plants. Deforestation is undoubtedly the most pervasive threat, so that – in common with many other forest inhabitants – birdwings are at one level ‘flagships’ or iconic species, treated as surrogates representing the vast number of other forest invertebrates, as well as biodiversity generally, occurring in this richest of all terrestrial biomes.

1.5.3 Other Non-Australian Birdwings

In their global overview of Papilionidae, Collins and Morris (1985) listed four species of birdwings as threatened. *Troides dohertyi* Rippon (the Talaud black birdwing), as ‘vulnerable’ was the only member of this genus so noted, as under pressure from lowland developments on the two small islands of northern Indonesia (Talaud, Sangihe) on which it occurs. The *Ornithoptera* species cited were *O. meridionalis* Rothschild and *O. croesus* Wallace as 'vulnerable', and *O. alexandrae* as 'endangered'. Another six birdwing taxa (two *Troides* spp., four *Ornithoptera* spp.) were 'indeterminate'. For several of these, Collins and Morris noted comments of possible foreboding. Thus, for *T. andromache* (Staudinger) (a high elevation species from north Borneo, notably the Mount Kinabalu region of Sabah) they noted (p. 266) 'there is little doubt that threats to its habitat are multiplying', and this sentiment has been echoed by more recent commentators, with hope that it might be practically protected within the Mount Kinabalu National Park and with support from a local butterfly tourist operation. The threats reflect increasing human populations, growth of shifting agriculture, and commercial logging. Many of these activities are predominantly at the more accessible lower elevations, so that some montane taxa may be less vulnerable. For all these species, Collins and Morris (1985) also urged the need for greater biological knowledge. Since then, some birdwings such as *O. rothschildi* Kenrick and *O. tithonus* de Haan, both locally endemic around the Arfak Mountains of Papua (Indonesia), have become the main focus for development of ranching/captive breeding exercises established near Manokwari as a World Wide Fund for Nature (WWF)-based Arfak Mountains Butterfly Farming Project, with its early development described by Craven (1989). *O. tithonus* proved unexpectedly easy to ranch, following host plant establishments, with Parsons (1995) reporting that almost every planted vine hosted a larva, and occupation probably facilitated by nearby presence of pristine forest areas. This success was mainly in mid-montane levels, whilst *O. rothschildi* was successfully ranched at upper montane levels. Other candidate taxa occurred at lower levels, and were considered likely to benefit from parallel habitat enrichment.

The more recent and extended accounts of *O. croesus* and *O. meridionalis* by Parsons (1999) give a somewhat more reassuring impression of their status than earlier assessments had done. *O. croesus*, taxonomically, was believed to 'almost certainly' represent a distinct form of *O. priamus*, with the early stages of the two butterflies being very similar. *O. meridionalis* was known to Parsons from three areas of Papua in Indonesia, and 'at least seven localised populations' in Papua New Guinea, so that it is far more widespread than realised previously; in some places it 'appears to be reasonably common'.

1.6 Conservation of Australian Birdwings

Within Australia, most attention to butterfly conservation has been concentrated on the southern half of the continent, predominantly on members of endemic radiations of the families Hesperiidae, Nymphalidae: Satyrinae and Lycaenidae (Sands and New 2002; New and Sands 1996, 2002a, b; New 2011c). Some threatened species in these groups have proven to be of serious concern and have become important flagships for insect conservation in the region. Papilionidae are not within that regional spectrum of priority concern, and many of the above species occur only on small, remnant habitat patches – in some instances within or near urban regions – so that the conservation needs are strongly site-orientated and remedial measures can be defined clearly. Very local endemism of many of the taxa ensures that even whole-of-range conservation management is focused within rather small areas and, sometimes, very restricted biotopes. Several are known from only single sites or other tiny areas, reflecting small natural distribution or consequences of extensive habitat loss.

The two endemic tropical species of birdwings found in eastern Australia, *O. priamus* and *O. euphorion*, have not been considered to be at risk (Sands and New 2002), due to their ability to breed on several different and relatively common species of Aristolochiaceae. These plants often occur in a range of different plant communities. For example in north eastern Queensland, *Aristolochia acuminata*, the most common food plant for both birdwings, is widespread in the lowlands and is not confined to rainforest. *Pararistolochia deltantha* (F. Muell) Michael J. Parsons continues to be a common food plant on the ranges. While the tropical birdwings prefer rainforest habitats, representative areas of their rainforest habitats in northern Queensland have been protected from destruction. In addition, there are several different *Aristolochia* spp. that serve as food plants in dry woodlands. One notable example is *A. pubera* R. Br., a food small plant for *O. euphorion* noted by Waterhouse (1938) and probably the main food plant species on Magnetic Island near Townsville (Common and Waterhouse 1981). *A. chalmersii* O.C. Schmidt is a semi-deciduous woodland food plant for *O. priamus macalpinei* occurring near Coen, and other localities west of the Main Divide on Cape York Peninsula (Sands and Kerr unpublished). An unidentified species of woodland *Aristolochia* also appears to be an important food plant for *O. priamus macalpinei* near Iron Range, northern Queensland (unpublished).

The Cairns birdwing, *O. euphorion* is widely distributed in northern Queensland from south and west of Mackay, to north of Cooktown (Braby 2000). While the species and its food plants are secure (within the 'Wet Tropics' protected areas) over much of the range, near Mackay many of its habitats have been cleared for farmlands. The Cairns birdwing has several generations each year on the coast and offshore islands, but breeds only in the warmer months on the mountains. Its food plants include *Aristolochia* spp. and *Pararistolochia* spp., vines that are common in rainforest. However, several low-growing species of *Aristolochia* (for example, *A. pubera* and *A. thozetii* F. Muell.), also serve as food plants for the Cairns birdwing in moist woodlands (Waterhouse 1937; Braby 2000). The toxic introduced *Aristolochia* species, *A elegans* Mast[1] and *A. ringens* Vahl, are poisonous to the larvae, when larvae hatching from eggs deposited on the leaves of these species of vines attempt to feed. Both species are common weeds in northern Queensland and may potentially become 'threatening' in peri-urban areas where the indigenous food

[1] Throughout this book we use the name '*Aristolochia elegans* Mast' for the introduced Dutchman's Pipe vine of concern in conservation of *O. richmondia* in Australia. Application of this name does not follow the conventional synonymy of *A. elegans* (named in 1885) with *A. littoralis* Parodi 1878 as the earlier available name. The two have sometimes been considered separate species (for example, by Hou 1983) and we are aware of debate over the integrity of the species involved. The name '*elegans*' has been used almost universally in literature (for example in Bostock and Holland 2010) when related to butterfly biology in Australia. It is used here for familiarity and convenience, and no formal taxonomic action or revision is intended by this use.

plants are sometimes low in density and where the habitats have been invaded by weeds. Should those weeds invade natural ecosystems, the level of threat to the birdwings is likely to increase. These threats from exotic aristolochias may be offset by the popularity of growing *A. acuminata* as a vine for cultivation on fences and in gardens, where for example, *O. euphorion* has been observed by Peter Bakker, Peter Valentine, and Steve Johnstone breeding successfully in heavily disturbed suburbs near Townsville.

Ornithoptera euphorion, and the three *O. priamus* subspecies have until recently, been considered threatened in Queensland but this may have been due to the concerns about excessive collecting of specimens for trade, rather than the threats from loss of habitats, while *O. richmondia* is considered vulnerable and a 'protected species' in Queensland but not in New South Wales. Thus, formal concerns for the wellbeing of *Ornithoptera* were controversial. In 1974, birdwing butterflies, together with the Ulysses swallowtail (*Papilio ulysses joesa* Butler, a notable tourist icon) were added to Queensland's list of protected fauna under the Fauna Protection Act, apparently on the grounds that they were likely to be overexploited. This move was undertaken without consultation with the Queensland entomological fraternity, and was opposed by the Entomological Society of Queensland. One outcome was a compulsory royalty of Au$20/specimen for every individual captured or retained in a collection, after permits were selectively granted for this. This was later deferred. Moreover, New South Wales legislation was subsequently proposed in 1970, to list several insect species (including *O. richmondia*) as protected under the New South Wales National Parks and Wildlife Act. Whilst the National Parks Service acknowledged that this legislation was not meant to impede genuine research and that their reaction would be sympathetic to entomological interests, adverse comments from entomologists led to its non-formalisation.

In a broad survey in which Australian entomologists were asked to nominate insects thought to be of genuine conservation concern in Australia, no respondent to Hill and Michaelis (1988) mentioned any birdwing or other papilionid. *O. euphorion,* and the Australian subspecies of *O. priamus* are now regarded as 'common' and no longer attract conservation concerns. Although they are seasonally rare at times and during drought, they are not considered to be at risk. The abundance of *O. euphorion* and *O. priamus* is mostly related to the abundance of food plants and the appropriate phenotypic expression (for example, toughness) of leaves, and some ant predators (such as *Oecophylla smaragdina* (Fab.), attacking larvae) and mites (*Charletonia* sp., attacking eggs), rather than natural enemies of other Papilionidae such as hymenopterous parasitoids, which are relatively uncommon and do not significantly reduce the survival of larvae and pupae. In contrast, the Richmond Birdwing has become of serious conservation concern, and the focus of one of the most enduring campaigns for conservation of any butterfly in Australia. The conservation campaign discussed in this book is the first such long-term study of any threatened birdwing butterfly in a region where such an exercise is both socially acceptable and logistically possible. It covers the history of attempts to recover the Richmond birdwing, methods to stimulate community awareness, and how State agencies can work together with the wider community towards recovering the butterfly from threats of extinction.

Chapter 2
The Richmond Birdwing Butterfly

2.1 The Richmond Birdwing: Distribution and Decline

In the early 1900s, the Richmond birdwing (at that time referred to widely as 'the Trojan' in northern New South Wales, and more formally considered generally to be a variety of '*Troides priamus*' for example by Rainbow 1907), was known to have had a patchy distribution from near Grafton and the Clarence River, New South Wales, to Maryborough, Queensland (Illidge 1898; Rainbow 1907; Waterhouse 1932; Common and Waterhouse 1981) (Fig. 2.1), thus incorporating a range far beyond the current distributional extremes for both the butterfly and its major food plant. The historical distribution was likely to have been limited in subtropical Australia, linked with the distribution of its lowland food plant, *Pararistolochia praevenosa*, with both food plant and butterfly dependent on the restricted climatic envelope suitable for their growth, development and reproduction. By the early 1930s the butterfly had become scarce at the northern and southern parts of the range, prompting Waterhouse (1932) to state: 'Very few specimens are now to be found at Maryborough and Gympie…, or on the Clarence River…' (Fig. 2.2). By 1959 the last natural breeding colony near Mary River Heads was cleared of birdwing food plants for urban development (Sands and Scott 2002) and by the mid 1980s, the small birdwing habitat patch with rainforest and food plant vines near Rainbow Beach was observed being destroyed during logging operations. In 1984, a male birdwing was seen near this site by the late Murdoch De Baar and Sands: it was probably the last individual seen in the former northern habitats between Gympie and Maryborough. Birdwing distribution had by then contracted to about two thirds of the original range and the numbers of habitat patches supporting the butterfly were declining rapidly. A recent (2011) report of birdwings seen on Clarence Peak near the southernmost recorded range margin requires confirmation, but some apparently suitable plant communities remain to the east of Grafton that may continue to support the butterfly and its food plant in some remote areas. Detailed surveys are needed to determine whether this is so.

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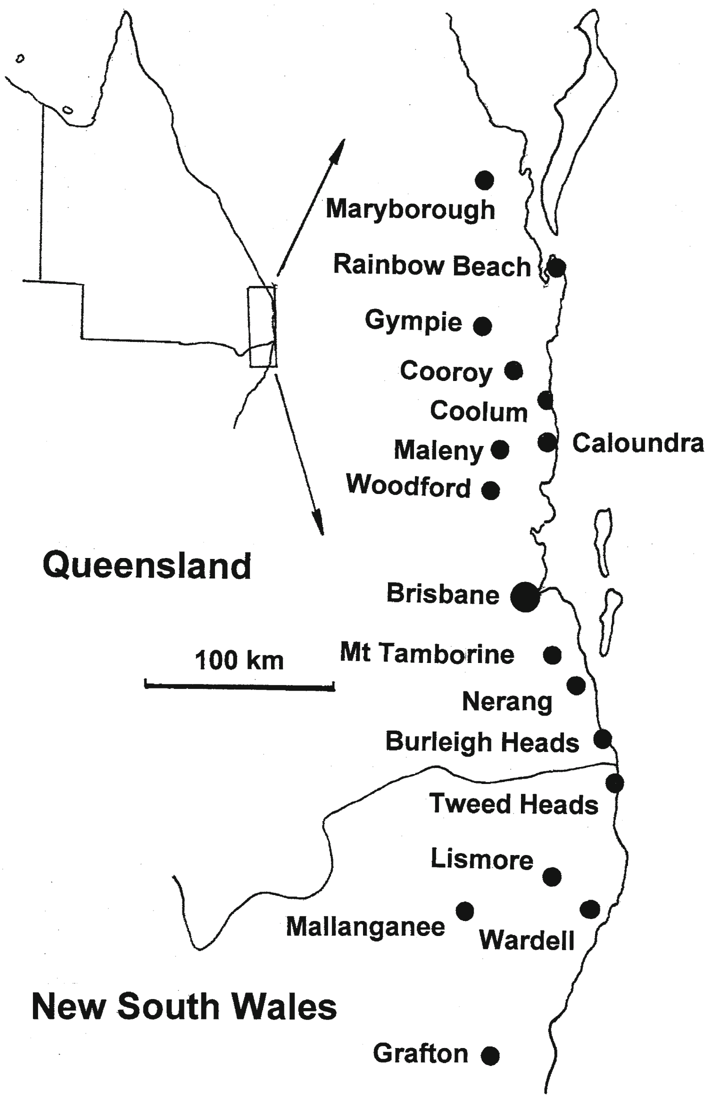

Fig. 2.1 Map to indicate localities of some key places that are mentioned in text

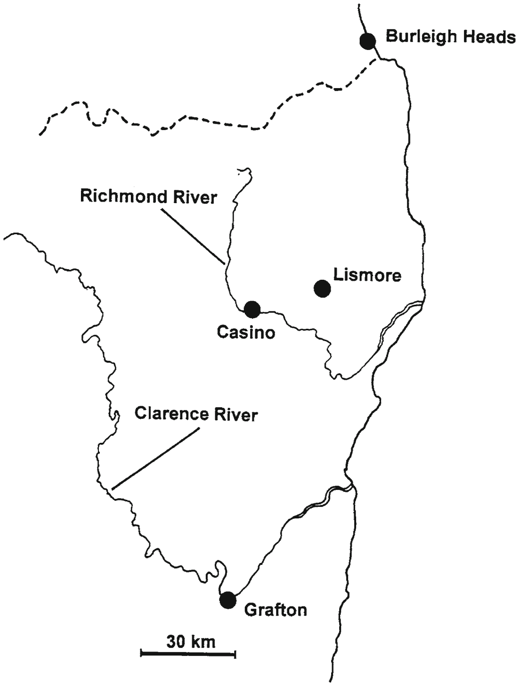

Fig. 2.2 Map to indicate localities of some key places within the area of New South Wales shown in Fig. 2.1

The type locality for *P. praevenosa* is the Clarence River, NSW (Parsons 1996b incorrectly cited Clarence River as in Queensland). Barrett and Burns (1951) also mentioned the Clarence River as the southern limit of the birdwing, as did a report of a birdwing seen on Susan Island, near Grafton in the 'early 1950s', and northern range contractions of *O. richmondia* were discussed by Sands and Scott (2002), who showed the last reported northern sightings of adults and several vines of *P. praevenosa* were at Mary River Heads in 1959. That birdwing habitat became a residential area and by the late 1960s, no food plants or birdwings could be seen in the area. The western limit of the birdwing is not known but it definitely occurred, based on several sightings of adults by the late Jack Macqueen, on the escarpment of the Main Divide and at Middle Ridge near Toowoomba, but the local whereabouts and identity of its food plant was unknown. The Richmond birdwing became rapidly extirpated from the northern, southern and central former range between 1960 and 1990, due mostly to habitat disturbance and fragmentation. At the time that conservation measures were considered, its range had been divided into two discrete parts – to the north and south of Brisbane (Fig. 2.3).

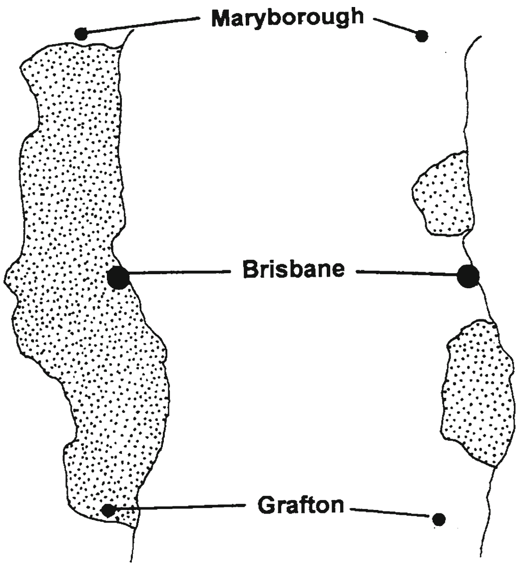

Fig. 2.3 Historical (*left*) and recent (*right*) distribution range of *O. richmondia* in eastern Queensland and New South Wales

In the central part of its range near Brisbane, the Richmond birdwing had been reported occurring in large numbers in the city in 1870 (Illidge 1927). Rowland Illidge (1924b), an early Queensland naturalist, also noted that the Richmond birdwing had declined in abundance since the early 1900s at Bulimba, a Brisbane suburb. According to Hughes (2006) very few breeding sites for the birdwing remained intact after the 1940s in Brisbane's Western Suburbs, and most suffered from clearing of rainforest along water courses, and wherever riparian areas were to be used for farmlands. Declines in birdwing sightings in Brisbane continued to be reported until the 1960s, prompting a suggestion by Sands (1962) that the butterfly's food plants might be planted in gardens, to encourage breeding to counter the declining birdwing numbers. In an address to the Royal Zoological Society of New South Wales, Sands proposed that Brisbane residents could follow the lead taken by people in Townsville, northern Queensland, who successfully attracted the Cairns birdwing into their gardens, by planting a local food plant (*Aristolochia acuminata*), a vine that was locally obtainable. In the 1970s, Gary Sankowsky at Mount Tamborine and Tony Hiller at Mount Glorious encouraged growing native food plants for butterflies, including those that had become uncommon. The plants included the lowland birdwing butterfly vine (*Pararistolochia praevenosa*), and Sankowsky and Hiller both generously made plants, seeds and cuttings available for propagation by Sands at Chapel Hill in Brisbane. Sands' garden contained a fragment of rainforest along a stream originating on Mount Coot-tha. With advice from Dr Len Webb and Geoff Tracey, rainforest experts and colleagues from CSIRO in Brisbane, many rainforest plants and birdwing butterfly vines were planted there in order to provide resources for birdwings and several other local and rare butterflies. That foundation advice had a major influence on the subsequent directions taken for restoring habitats for Richmond birdwings in south-eastern Queensland and in north-eastern NSW. Meanwhile, in the mid 1980s the few remaining birdwing habitats near Brisbane, notably one at Mount Nebo and another at Bardon, were cleared of their birdwing food plants. Elsewhere, the natural breeding sites near Caboolture north of Brisbane, and those near Nerang south of Brisbane, were also cleared for development. Further north and at about the same time, birdwing and food plant extirpations were confirmed at Pomona, in Noosa National Park, along the Mary River, and to the south, between the Richmond River and Grafton in NSW.

The recent distribution of the Richmond birdwing extends in a south-western direction along ranges from Kin Kin, Queensland to Wardell, NSW but most coastal colonies in Queensland are badly fragmented. Within this range, most permanent breeding sites have been north of Brisbane, from Mount Mee on the D'Aguilar Range to the Blackall and Conondale Ranges, and south of Brisbane from Ormeau to the Queensland-NSW Border. Occasional breeding occurs in the western and eastern suburbs of Brisbane and a sighting in Brisbane City in 1966 was reported by Orr and Kitching (2010). The last permanent breeding sites in Brisbane suburbs were destroyed by housing developments near The Gap, by clearing of riparian rainforest at Bardon in the mid 1980s, and from a housing development at Chapel Hill in the late 1990s. Breeding in the fragments of peri-urban habitats has been temporary, due to the insufficient numbers of food plants and inbreeding problems (see Orr 1994). Sporadic re-colonisation was thought to have resulted when females immigrated from the D'Aguilar Range to the northwest to colonise the western suburbs of Brisbane. One recent report of breeding next to the Brisbane River occurred in the late 2000s near Indooroopilly in an area where food plants were cultivated by local resident, Richard Bull.

2.2 Biology

Adult Richmond birdwings are attracted by flowers of many indigenous and exotic shrubs and trees (see Hughes 2006), particularly if red or white, and feed on nectar of flowers from a wide range of plants. The flowering periods of many suitable nectar plants (Table 4.1, p. 83) are seasonal and may sometimes be variable but indigenous plants that flower in spring (for example, *Hymenosporum flavum* (Hook.) F. Muell.) soon after over-wintering pupae have emerged, tend to attract most butterflies. In summer and autumn the flowers of all eucalypts are popular, and adults of both sexes will travel some distance from the breeding sites to feed, particularly when freshly emerged, to visit gardens. Flight is often at tree-top level, 30 m or more above the ground, but both sexes will come within a few metres of the ground when feeding at flowers. Feeding occurs mostly during sunny periods early in mornings (08.00–10.00 h) or in the afternoon until sunset (15.00–18.00 h) and both sexes if freshly emerged, will share the flowers on one plant without males harassing feeding females. Males are not sexually mature until 2–3 days after pupal eclosion and during this period show little interest in mating, whereas females are sexually mature immediately after eclosion. After first feeding, males will spend short periods finding circuits and corridors for flight and eventually will set up ‘waiting perches’, resting on sunlit leaves with wings closed during the warmest mid-day periods. Males will live for about 20–30 days and females 25–45 days, depending on availability of nectar and avoidance of desiccating low humidity. Adults have not been seen feeding at wet sand, a behaviour well known in many tropical butterflies including the Rajah Brooke’s birdwing (*Trogonoptera brookiana* (Wallace)) in Malaysia, in which freshly emerged males imbibe moisture and obtain sodium, needed to mature their reproductive systems.

After reaching maturity, the flight of males becomes more rapid, continuing for periods of 10 minutes or more, as they claim territories and flight corridors when searching for a mate, or briefly intercepting and engaging in combat other males if these are potential mating competitors. Males will attempt to drive away other large butterflies, regardless of colour or similarity, and may chase moderately-sized (up to about 20 cm) birds when they enter their territories, before returning to ‘their’ perch. Male birdwings usually patrol at the edge of sunlit rainforest canopies but sometimes patrol hilltops, a behaviour common in many species of butterflies, and with representatives from all Australian families, including other Papilionidae. Between patrols adults rest on foliage for 5–10 minutes in sunlit positions that give them maximum visibility when searching for females. They will compete with other male birdwings, especially when a female visits the hill, and ‘claim’ flight corridors of 50 m or more between periods of settling on the canopy. Male birdwings are not known to patrol on hilltops when they are more than 3 km from breeding sites. When freshly emerged from a pupa, and if disturbed when the wings are insufficiently hardened for flight, adult birdwings sometimes perform a defensive aposematic display, by bringing the fore wings forward and curving the abdomen in a way similar to that in *O. priamus*, which is said to mimic a wasp in the act of stinging (Common and Waterhouse 1981).

Females usually mate only once and often immediately after eclosion but according to Rosemary Booth and Jacqui Seal (pers. comm.), some individuals are known to have mated twice in captivity. No sphragis is produced. After mating a female birdwing will reject males that approach and can take avoidance action by flying rapidly or low into undergrowth. The courtship process is often prolonged, with male and female alternating their positions above one another – often in almost stationary positions, and hovering for some time prior to mating. Mating usually continues for several hours with both sexes opposite under a leaf while holding wings closed. Hand-mating was successfully manipulated when outcrossing was required for inbreeding depression studies (Chap. 8, Fig. 2.4).

Fig. 2.4 Ovipositing female of *O. richmondia*: note conspicuous thoracic red patch (L. Forster)

2.2.1 Effects of Plant Nutrients on Larval Development and Adults

The distribution of *Pararistolochia* vines, and several other rainforest plant genera in Australia and Papua New Guinea, indicates the dependence of birdwing immature stages on nutrient-rich food plants that grow on nutrient-rich soils, particularly basaltic soils or volcanic alluvium such as that surrounding the volcanic core of Mount Warning (Fig. 2.5). Although a number of species of *Ornithoptera* (including *O. euphorion, O. priamus*) feed readily on both *Pararistolochia* spp. and *Aristolochia* spp., larvae of the rarer birdwings from Papua New Guinea (such as *O. alexandrae, O. meridionalis, O. paradisea*) are specifically adapted to one or few species of *Pararistolochia* and depend on the nutrient-rich vines growing on volcanic soils. It is not only leaves of the food plants that are consumed by birdwing larvae, and many or the New Guinean and Australian species, including *O. richmondia*, *O. euphorion* and *O. priamus*, will feed on buds, flowers, seed capsules and stems, sometimes ring-barking or severing the vines. In the case of the New Guinean *Ornithoptera goliath* Oberthür, a very large birdwing (female wingspan to 27 cm), its maturing larvae will truncate the old and woody stems after feeding on the leaves and before pupating. It is also likely that stem feeding in some species of *Ornithoptera* is related to the nutrient demands of larvae. While the ecological significance of stem feeding by maturing larvae of birdwings is not understood fully, it is thought to be a way of: (i) utilising higher concentrations of solids and less moisture than in leaves, or (ii) taking advantage of nutrients in the interrupted sap flow.

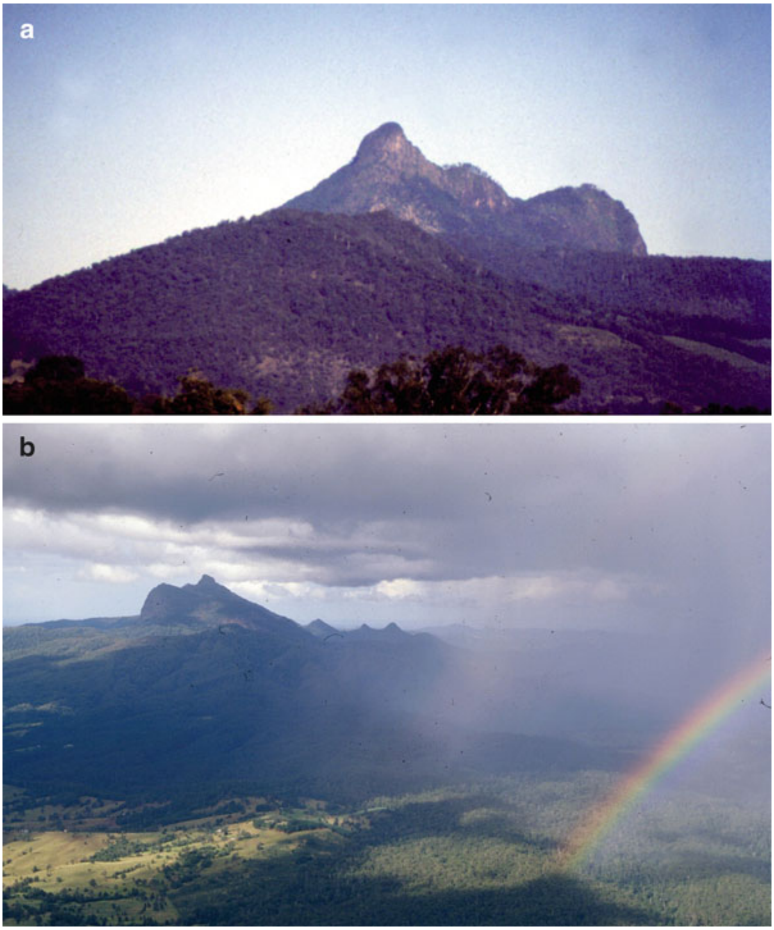

Fig. 2.5 Mount Warning, New South Wales: (**a**) from east; (**b**) from west

Nitrogen concentration in food plants of Lepidoptera is known to influence numbers of instars, rates of development in larvae, and size and fecundity in adults of Lepidoptera (Taylor 1984; Taylor and Sands 1986). In preliminary experiments, to determine the effects of nitrogen in the food plant (% dry weight of leaves measured as by Williams and Twine 1967) on larvae of *Ornithoptera richmondia,* fertiliser with three different levels of nitrogen (N) was added to potted food plants (*Pararistolochia praevenosa*) and the leaves fed to newly-emerged larvae (5 larvae each N treatment) until pupation. The trial compared effects of larvae fed fertilised plants with larvae fed unfertilised control plants and aimed to determine: (i) larval development times and numbers of instars, (ii) ovariole development in newly-eclosed adult females, (iii) pupal weight and adult size (fore wing length) and (iv) adult longevity. In each trial fertilised and unfertilised vines both had actively-growing terminal shoots growing up stakes.

The significance of results was limited by low replication. Insufficient numbers of each sex and mortality limited the number of larvae reaching the adult stage, but trends based on means and measurements from each experiment indicated that: (i) more first instar larvae survived when fed soft leaves with high N concentrations than larvae fed unfertilised vines with firmer leaves, (ii) larval development times were more rapid on fertilised vines (with high N) than unfertilised controls (with low N), (iii) the numbers of instars of larvae fed plants with high N was always 5, compared with occasionally 6 instars completed by low N control larvae, (iv) ovariole development in newly-eclosed females adults indicated more advanced oocytes were present in adults fed high N than in low N controls, (v) pupal weight was heavier when larvae had fed on fertilised vines, and the resulting size of both sexes (fore wing length) was greater than those fed unfertilised vines, and similar to maximum fore wing lengths of adults seen in the field, and (vii) adult longevity was increased in females given high N in food plants, but not in males. The preliminary outcomes suggested substantial impacts of food plant quality.

2.3 Times of Appearance, Dispersal, Population Changes and Migration of Adults

At all locations the rates of development of immature stages vary with season and for the larvae, the quality (reflecting texture and nitrogen content of leaves, as above) of the vines available. During warm weather, food plants on nutrient-rich soils (such as basalt) rapidly take up more nitrogen during moist weather and the development of the larvae feeding on these plants is much more rapid than during cool weather and when plants are growing on nutrient-poorer soils (such as alluvial soils or sand). The influences of temperatures, soil moisture and nutrients, day length and food plant quality provide the primary cues for times of appearance, dispersal, population changes and the occasional migration of adults.

Considerable overlap occurs across generations in warmer months, particularly if adequate rainfall prevents the problems caused by prolonged diapause in pupae in spring and summer. However, little is known of the way diapause regulates emergences except when day length increases, temperatures rise and rainfall in late winter triggers the development of pupae followed by adult emergences in spring. The rate of immature development is always dependent on temperatures but it also relates to the quality of the food plant. During prolonged moist weather, *P. praevenosa* produces robust growth of climbing stems and the alternate leaves containing high nitrogen and other nutrients expand more rapidly. Instars 1–3 receiving an increase in nitrogen concentrations develop more rapidly, and the larvae become larger than when the larvae are fed on less nutritious leaves. The resulting pupae and adults are larger and female fecundity is greater when larvae have consumed leaves with higher levels of nitrogen. Moreover, oocyte development takes place more rapidly as the stored 'fat body' increases the rate of development of eggs prior to oviposition.

The pattern of seasonal development differs in relation to climate and elevation, as shown in Fig. 2.6, with characteristic contrast between lowland and higher elevation localities.

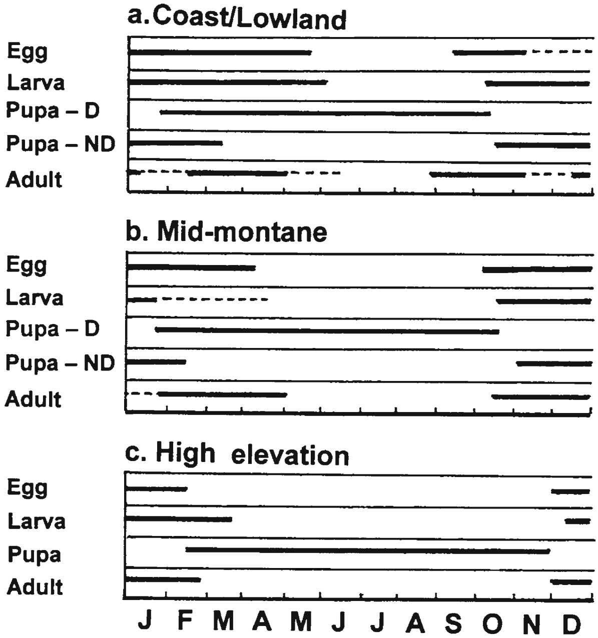

Fig. 2.6 Patterns of seasonal development of *O. richmondia*: incidence of different growth stages by month (initial letters from January to December) in (**a**) coastal and lowland regions; (**b**) mid-montane sites; (**c**) high elevation sites (D, diapausing; ND, non-diapausing)

2.3.1 Lowland and Coastal Localities

At coastal localities where the food plant is *P. praevenosa* there are two or three annual generations of *O. richmondia,* depending on spring rainfall frequency and temperatures. In years with an average to above normal rainfall, and higher than average temperatures, most overwintering pupae break diapause, and produce adults from September (rarely August) to mid October. Eggs deposited in early spring develop and emerge as adults in December to February, providing the second generation. Eggs deposited by these adults develop rapidly and pupae will eclose from March to April, while others enter diapause and overwinter as pupae. In dry seasons eggs deposited in late spring and larvae develop slowly, producing adults from February to March, and overwintering pupae may not produce adults until November through to the following January. On the coast, a spring emergence of adults (September-October) normally follows break in diapause in overwintering pupae, and is sometimes followed by a second emergence mid-year (December-February), while one generation always occurs in late summer and autumn (February-March).

2.3.2 Lower Slopes and Mountains

Two generations are usual, adults occurring from November to January and those of the second generation occurring from February to March. On the rare occasions when breeding on *P. laheyana* persists at higher elevations only one generation occurs at elevations above 600 m, when pupae survive winters.

2.3.3 Migrations

The cues for adult dispersal or occasional migrations by the Richmond birdwing are not understood fully, but observations have shown that females will usually leave a breeding site soon after they emerge and, if suitable sheltered flyways are available (for example in rainforest corridors or forested watercourses) adults will use these to move to other sites. This appears to be an entrenched behaviour pattern and has been observed in some other Australian butterflies, for example *Cressida cressida*, as likely to counter inbreeding depression (Orr 1994). Males are less likely to disperse and will set up patrolling sites soon after feeding. Annual population changes in undisturbed habitats are linked to climatic variation and the responses to food plant growth and phenotypic plasticity.

In South America, increases in abundance and migrations are known to occur in at least one aristolochia-feeding butterfly. In some years, *Battus polydamus archidamas* (Boisduval) undergoes 'population explosions'. Hundreds of adults have been seen flying out into the Pacific Ocean from the western coast of Chile, and later their bodies observed washed back onto the coast and beaches (Pena and Ugarte 2006).

On rare occasions broad scale migrations of Richmond birdwings from the breeding sites have followed increase in numbers benefitting from high food plant quality (Sands and Scott 2002) and this phenomenon possibly led to the earliest reports of migrating Richmond birdwings seen in Brisbane: '…in the year 1870 it occurred in very great numbers in the town, and boys were chasing and capturing many.' (Illidge 1927). These migrations of large numbers of both sexes of *O. richmondia* have occasionally been observed on the mountains of the Queensland-NSW Border Ranges followed by migrations down the slopes. At Cudgen, NSW in April 1969, Greg Newlands observed migrating adults flying in a north-easterly direction towards the coast and migrations occurred from the Border Ranges and Mount Warning, and from Tyalgum Tops near Murwillumbah in January, 1994 (Sands and Scott 2002). From mid-December 1993 to early January 1994, numbers of adults were seen (G. May) at the edge of rainforest between The Pinnacle and the Limpinwood Nature Reserve, and at about the same time hundreds of Richmond birdwing adults were observed (M. Houston) at Christmas Creek, on the western side of the Lamington Plateau, Queensland.

Many people provided valuable observations about migrations of *O. richmondia* in early 1994. One enthusiastic member of the community made observations of the 1993/1994 birdwing migration from the high country of the Border Ranges: 'We live at the base of the Border Ranges at Limpinwood and for about 4 days we were literally inundated with adult Richmond birdwings. There is a very steep escarpment behind our property rising to the Border Ranges and the Lamington plateau where the butterflies seemed to be flying in a very narrow strip, and then over our property, all flying in an easterly direction. I have lived in and around the Richmond River and Tweed valleys for 43 years and have never seen such numbers of birdwing butterflies.' Some migrating adults from the mountains flew towards the west where suitable breeding sites supporting the lowland vine *P. praevenosa* were unlikely to be present.

The cues for developing these large numbers of birdwing butterflies are not known but it appears likely that moist and warm winters are pre-disposing conditions enhancing over-wintering survival of pupae at higher elevations. Such events are indeed sufficiently rare to attract attention and comments such as that above. Many individual butterflies were destined to die after migrating without reproducing and without finding food plants, a behaviour sometimes observed in other migrating butterflies in Australia, for example the Caper White butterfly (*Belenois java teutonia* (Fabricius) [Pieridae]), that often migrates out to sea after southward migration, without any opportunity of reaching a breeding site.

2.4 Life History, Recognition of Early Stages

Many aspects of the behaviour and development of *O. richmondia* are displayed in a commercially available dvd on the butterfly's life history by Richardson (2009).

After mating, female birdwings begin depositing eggs on the undersides of leaves of their food plant or, rarely, on the stems. Leaves on vines chosen for oviposition are usually sub-apical (30 cm or more from the tip), fully inflated, pale green and not stiff in texture. The soft and often hairy apical and unopened leaves are avoided for egg deposition and sometimes older, firm leaves are selected but they are avoided if softer leaves are available nearby, but females do not oviposit on terminal leaves at times they are expanding rapidly. In the field one egg per leaf is usually laid, less commonly 2 or 3, and rarely more are deposited (Fig. 2.7). Depending on temperature, eggs hatch within 7–13 days, becoming dark a day before hatching when the larva becomes visible through the chorion. Eggs measured by Selvey (2008) were 2.3–2.5 mm in diameter and are at first greenish yellow, becoming pale yellow within a few days and yellow-brown a day or two before hatching. After hatching, larvae first consume their egg shells and then search for a soft leaf where they can commence feeding. Eggs are very prone to predation, including cannibalism by first instar birdwing larvae that have just consumed their own egg shell. There are usually five larval instars (Fig. 2.8) but occasionally six when nutrient concentrations in leaves are low. Ecdysis usually takes place beneath a leaf of the food plant but occasionally larvae will leave the food plant and remain dormant for 2–3 days on the underside of a nearby shrub or tree until the skin has been cast.

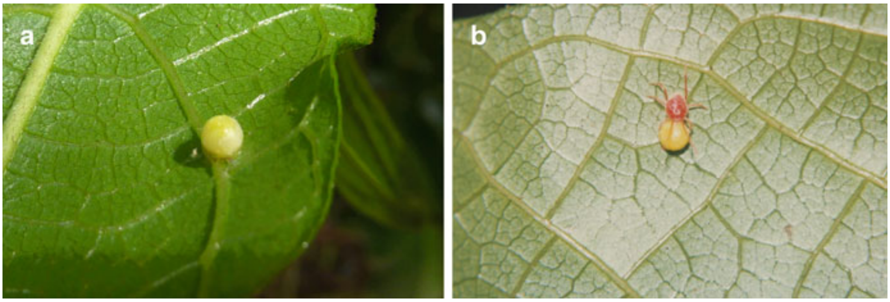

Fig. 2.7 *O. richmondia*: (**a**) egg on *Pararistolochia* leaf; (**b**) egg being attacked by predatory mite, *Charletonia* (A. Powter)

Heavy rainfall has been observed washing eggs from the underside of vine leaves. However, during dry periods, many first instar larvae starve or are lost when they fail to find a leaf with suitably soft texture on which to commence feeding, or fall prey to ants and other predators. First instar larvae often move from stem to stem for up to 2 days in search of suitable leaves. First and second instar larvae are black with long and soft tapering black spines on all segments except on segment 6, on which the spines are bright yellow and tipped with black, and the head is black. Instars 3 and 4 are black or purplish-brown with similar yellow spines at segment 6, while instars 5 and (when present) 6 are variable in body colour; ranging from black, brown or cream and with spines at segment 6 orange-brown and tipped with black. When fully grown a larva may reach 7 cm in length. Large larvae (instars 4 and 5) of *O. richmondia* are usually uniformly pale grey to dark brown or occasionally black, when found in coastal areas, and are often black in the mountain localities. The differences in colour are not wholly constant. The spines of *O. richmondia* are moderately uniform in appearance: orange-brown tipped black except with the spines at segment 6 basally pale yellow-orange (Fig. 2.8). The head of larvae is dark brown with a yellow 'collar' between it and first thoracic segment where the yellow-coloured osmeterium is held when retracted. Larvae extrude this paired tubular organ when alarmed and it produces a volatile odour that is thought to repel would-be predators (Common and Waterhouse 1981; Feeny 1995). When not feeding, larvae rest under leaves where they also complete ecdysis and they will always consume their cast skin before feeding on leaves. Larval feeding continues from 22 to 46 days until the pre-pupal stage (Fig. 2.9), the periods varying with temperatures and nutrient concentrations in the leaves. In contrast, it is interesting that the development of larvae of *O. euphorion* is reported to occur much more rapidly and in as little as 14 days (Common and Waterhouse 1981).

When preparing to pupate, fully-grown larvae usually leave their food plants and move to a suitable shrub or tree nearby. After searching for a day or two for a suitable large leaf, they will eject dark fluid (meconium), spin a thin pad of silk across the underside of a leaf, attach the caudal segment and terminal proleg to the pad with a silken cremaster, and then spin a silken girdle that will support the weight of the larva and eventually the pupa, which is positioned head upward as in other large Papilionidae. Before casting its final skin the larva contracts in length and expands in width and remains quiescent for about 2 days. Final ecdysis takes place rapidly as the larval skin is rolled back and finally ejected by a flick of the terminal segment, before it is re-inserted into the cremaster attached to the silken pad on the leaf. The whole process from cessation of feeding to the final cast of larval skin takes about 3–4 days. When alarmed, all instars of larvae will arch backwards and extrude the fleshy, two-pronged and yellow osmeterium from the anterior end of the prothoracic segment.

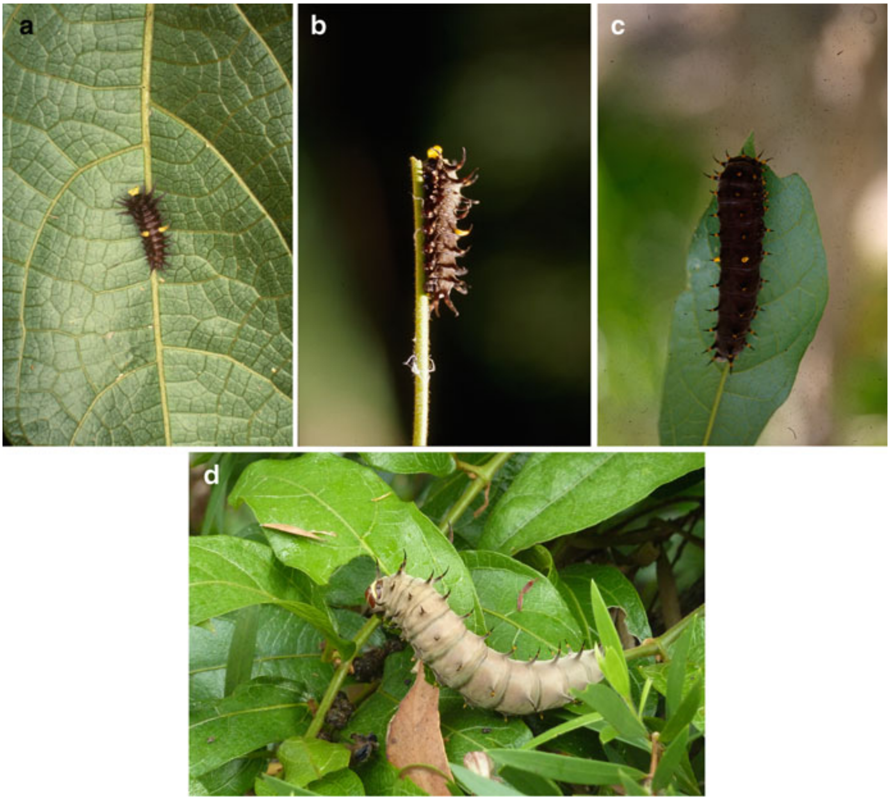

Fig. 2.8 *O. richmondia*, larvae at different growth stages: (**a**) first instar, with osmeterium extended; (**b**) third instar; (**c**) fifth (final) instar, dark form; (**d**) final instar, *grey* form (H. Melrose)

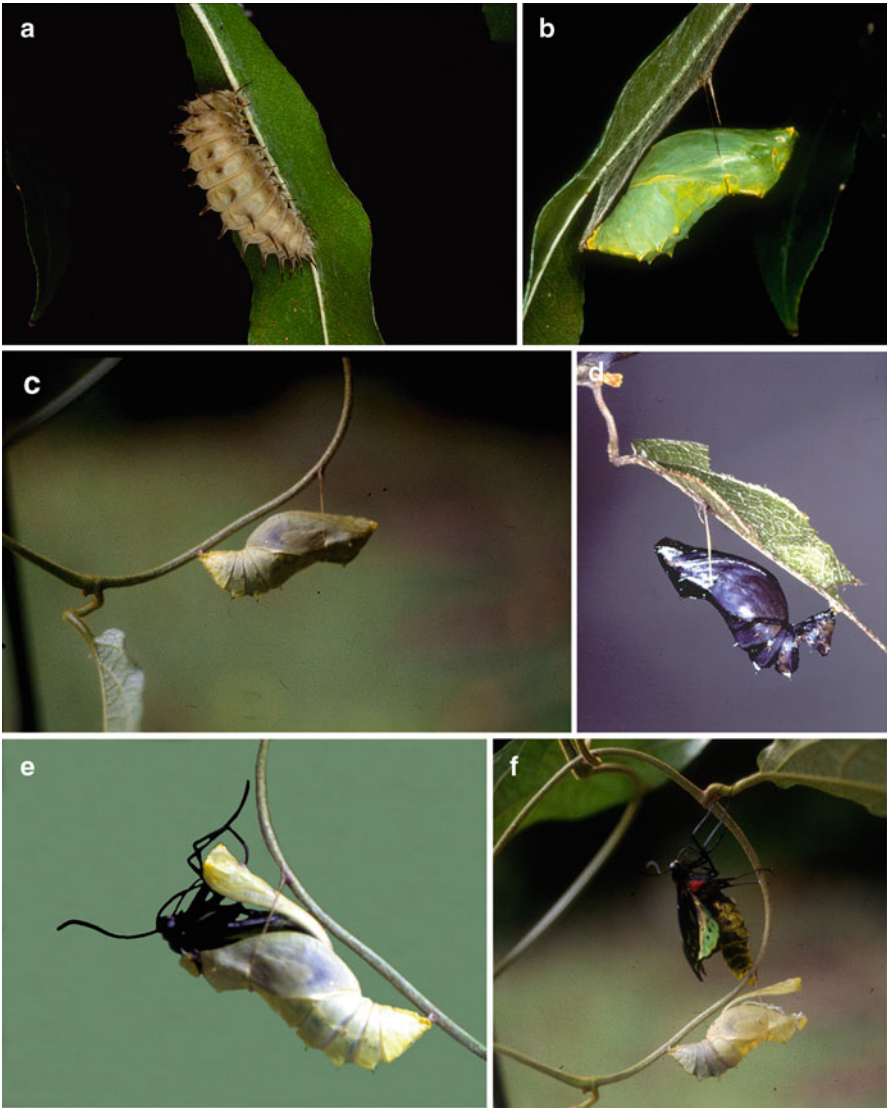

Fig. 2.9 *O. richmondia*: (**a**) prepupa; (**b**) healthy pupa; (**c**) pupa shortly before hatching; (**d**) diseased pupa; (**e**) emerging adult; (**f**) newly emerged adult

Fully-grown Richmond birdwing larvae are very distinctive when compared with larvae of the two northern species of birdwings, *O. euphorion* and *O. priamus,* and not so brightly coloured. The fleshy spines of *O. richmondia* are shorter and less brightly coloured than in *O. euphorion*, as shown in the book by D'Abrera (1971), and *O. priamus* in which larvae are usually black and the fleshy spines orange-yellow on most segments with a brightly coloured cream-orange spine on segment 6.

Some factors causing mortality have been noted above. The most significant mortality factor in the life history of the Richmond birdwing is cannibalism. First instar larvae after having consumed their own chorion will attack and consume any other eggs, regardless of age, when deposited in their vicinity, on the same or on adjacent leaves of the food plant, or when they are in search of soft leaves. One larva has been seen to attack and partly consume eight eggs. All instars are cannibalistic but the first two instars tend to be the stages most frequently seen feeding on eggs, other larvae, especially when in ecdysis, and less commonly when instars 3–5 will feed on pupae.

Larvae of *O. richmondia* are thus very prone to cannibalism both in the wild and in captivity. Inactive larvae are particularly susceptible while they are in ecdysis, and are eaten even when soft subterminal leaves of the food plant are nearby. Cannibalism has a direct effect on the carrying capacity for larvae on *P. praevenosa*, reducing the number of larvae able to complete development on a vine. Presence of many terminal stems with young growth may help to prevent contact between larvae. Larvae while searching for suitable leaves will attack pre-pupae or other larvae while they are feeding. On rare occasions Bob Moffatt (pers. comm.) observed pupae attacked by conspecific larvae in the field, when up to one third of the pupal mass was consumed. The species of food plant appears to influence the incidence and extent of cannibalism by larvae; for example, *P. praevenosa* seems to 'promote' cannibalism by larvae but many larvae can occupy one plant of *P. laheyana* without cannibalism, even when larvae are short of food. Moreover, in cage experiments with larvae fed the woodland vine, *A. meridionalis* E.M. Ross (Chap. 3) some larvae ignore the soft leaves and in preference, will attack larvae of their own species!

The pupae of *O. richmondia* are almost always bright green with a cream edge to the wing cases (Fig. 2.9), and very rarely pupae are tinged brown or, even more rarely, yellow (Common and Waterhouse 1981). The description by Rainbow (1907, based on Matthews 1888) of the pupa as 'amber-brown colour' probably refers to that of *O. priamus*, as the pupa of *O. richmondia* never corresponds to that descriptor. The duration of pupal development may be temperature-dependent, when pupae are not in diapause between October and January (38–50 days), or variably protracted (127–285 days) when pupae overwinter in diapause. There is a possibility that pupae will enter diapause in warmer months during severe periods of summer drought, an inference based on very limited data on protracted development. Pupae that are formed in autumn will lose weight while over-wintering, when the pupal mass reduces and the pupa become shorter in length. In this way large larvae may eventually develop to produce small adults, particularly after the winter humidity has been low. Pupae are very prone to prolonged low temperatures and desiccation is a major cause of mortality at some locations, especially at higher altitudes. Variation in pupal survival probably contributes to the occasional 'boom' and 'bust' cycles of adults that sometimes follow periods of suitable weather and abundant and suitable plant phenology. Food plant quality is the other major factor that can cause declines in abundance of birdwings, particularly when drought stress reduces the production of the soft, sub-terminal leaves of *P. praevenosa* needed to support first instar larvae after they have eclosed.

2.4.1 Natural Enemies

Eggs of *O. richmondia* are prey to several predators including a range of native ants (*Myrmecia* spp.) and exotic ants (such as *Tetramorium* sp., *Pheidole megacephala* [Fab.]) and in particular, a long-legged red mite, *Charletonia* sp. (Erythraeidae). No parasitoids have been reared from eggs of *O. richmondia* but emergence holes resembling those made by *Ooencyrtus* spp. (Encyrtidae) have been observed on rare occasions. Of these natural enemies only the predatory mite, *Charletonia* sp., appears to respond in abundance with host density; mite numbers certainly increased during periods with the greater birdwing densities between 1995 and 2010. However, the mite is known to be a generalist, feeding also on eggs of other Lepidoptera, suggesting that the response could result from other favourable conditions and not simply higher numbers of eggs. *Charletonia* Oudemans includes around 50 species and is distributed across all continents other than Antarctica. Whilst adults and nymphs are free-ranging predators, larvae are ectoparasites. Most records are of larvae found attached to hosts, and corresponding adults have sometimes been described in *Sphaerolophus* Berlese. The generic synonymy was discussed by Southcott (1991), in whose account 14 Australian species were diagnosed from larvae. Most of these were collected from acridid grasshoppers as ectoparasitic stages, with one reported from larvae of an anthelid moth. Very little is known of host specificity of these mites, but within Lepidoptera, Southcott noted records from Anthelidae, Geometridae, Lycaenidae, Noctuidae, Notodontidae, Pyralidae and Thaumetopeidae. We have not traced any previous associations with Papilionidae.

There have been reports of parasitoids (Hymenoptera and Tachinidae) emerging from the pupae of *O. richmondia* but they must be extremely rare parasitoids in the sub-tropics, and more abundant in the tropics on other species. In contrast, death of pupae from suspected virus and fungal attacks seems to be common.

2.5 Introduction to Concerns and Detection of Threats

The naturalist Rowland Illidge noted (1927) the decline of Richmond birdwings in Brisbane that began in the early 1900s, and subsequently led to its contraction in range, as noted by Waterhouse (1932), and the extinction of populations over more than two thirds of its original range reported by Sands et al. (1997). In south-eastern Queensland where the butterfly was once common, impacts from the clearing of rainforest for farming, forestry and urban development have resulted in fragmentation of the few remaining breeding sites, for example in Burleigh Heads National Park. Until about 1960, the clearing of rainforest patches with *Pararistolochia praevenosa* occurred in many peri-urban areas, and raised concerns with butterfly enthusiasts. They feared that the butterfly, once seen commonly near Brisbane was, together with its food plant, declining in distribution and abundance and in about 1989, people belonging to local environmental groups became concerned by the disappearance of the Richmond birdwing from areas where it had been seen frequently, and they recognised some of the threats that were leading towards local extinctions of the butterfly throughout its range, particularly in Queensland where few breeding areas were protected in national parks.

Weeds caused major problems by invading natural habitats and displacing the understorey vegetation. The habitats for the vine and butterfly that were relatively viable until the 1970s became replaced by weed thickets along the river and stream embankments, sometimes breaking free during floods and leading to collapse and massive erosion of the embankments. Several important soil-binding plants, for example, *Lomandra hystrix* (R. Brown) L.R. Fraser and Vickery, were displaced by weedy grasses and these areas became unsuitable for recruitment by most rainforest plants. Destruction of habitats for the Richmond birdwing and loss of its food plant were the obvious threats identified in Queensland and in northern NSW, invasions by the exotic vines, particularly Madeira vine (*Anredera cordifolia*), Morning Glory (*Ipomoea purpurea*), and Cat's Claw (*Macfadyena unguiscati*), threatened the birdwing habitats and food plants by smothering foliage and constricting the stems by their climbing. These and other introduced vines (see Chap. 3) continue to be amongst the important threats arising to all wildlife in the riparian fragments of subtropical Australia. In addition to the Richmond River, the most extensive areas affected are along the embankments of the Tweed and Clarence Rivers, New South Wales, where the majority of rainforest trees have been cleared to create farmland.

The declines in abundance of Richmond birdwings continued for more than 30 years after the problem of habitat loss was raised by Rowland Illidge in 1927. Since then, one threat that had become apparent to entomologists was the declining abundance of the lowland food plant, *Pararistolochia praevenosa*. While working with CSIRO in Papua New Guinea (1972–1978), Sands' interest in growing food plants for conserving birdwing butterflies broadened from seeing many other spectacular species, and by traditional cultivation of *Aristolochia acuminata* on fences in New Britain, Papua New Guinea (Fig. 1.11, p. 21). These vines were often grown for attracting birdwings including *O. priamus*, to breed in gardens where they could be admired, or used as a 'head-ornaments', as illustrated in their book by Barrett and Burns (1951). In the 1980s while living in Brisbane, Sands noted *O. richmondia* had become extinct from almost all except one or two of the original urban habitats but it continued to be abundant on the Sunshine Coast, and at Burleigh Heads and on nearby ranges. The losses of habitats near Brisbane were mostly from clearing of natural vegetation for urban development.

In Queensland, destruction of rainforest continued in the 1980s in several areas critical for survival of the butterfly habitats, including the Conondale, Blackall and d'Aguilar Ranges (Fig. 2.10), *Eucalyptus grandis* growing in rainforest gullies was seen being felled for timber and the residue was often burnt afterwards to stimulate regrowth of seedlings. These stands were often in the riparian zones where the rare vine *P. praevenosa* could usually be found. One destructive practice was to log the slopes for other eucalypts and dispose of the 'trash' by

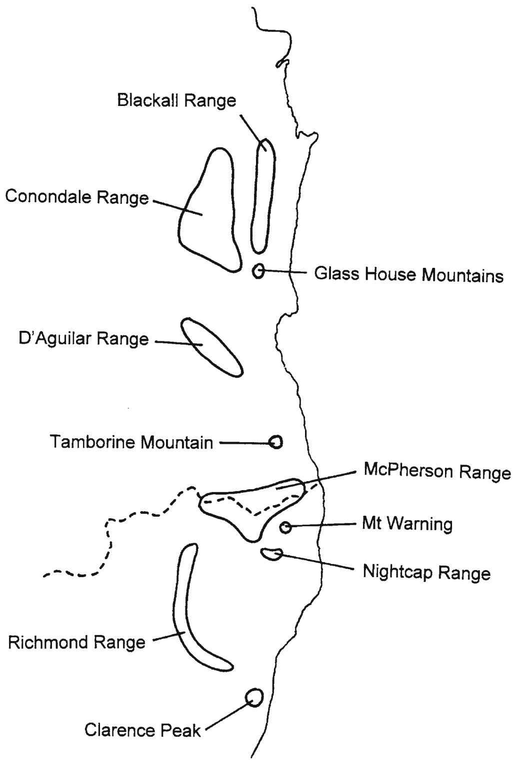

Fig. 2.10 Locations of upland areas mentioned in discussion of range of *O. richmondia* (state border indicated by dashed line)

throwing it into the gullies and later burning it when dry, in the belief that this would open up the rainforest and stimulate germination of seeds and growth of eucalypt seedlings. After removal of timber and when some of these areas were eventually transferred for management as National Parks, many of the former habitats had become infested with weeds, including African grasses (such as *Megathyrsus maximus* (Jacq.) B.K. Simon and S.W.L. Jacobs, and lantana (*Lantana camara* L.), in the early 1990s. Repeated burning destroyed many remaining pockets of rainforest with *P. praevenosa*, as well as other fire-sensitive plants, including orchids, and regular use of fires during periods of drought destroyed the growth and recovery of rainforest trees. In New South Wales the 'Big Scrub', the lowland subtropical rainforest growing mostly along the Richmond and Tweed Rivers, was almost completely cleared by logging, for farming and for urban settlements. This was undoubtedly the most serious loss of the rainforest plant communities and its associated animals, both vertebrates and invertebrates. Despite cessation of broad scale rainforest clearing in Queensland and New South Wales in the late 1990s, the rainforests have continued to suffer from displacement by exotic weeds, deliberately-lit fires during periods of plant dormancy and drought, and mining seams of volcanic rocks in riparian habitats.

2.6 History of the Richmond Birdwing Conservation Project

Proposals for increasing the food plant numbers in peri-urban bushlands and gardens were first discussed in 1989 when Sands met Ranger Bob Moffatt from the National Parks Service in New South Wales. They met to discuss an interesting form of a rare lycaenid butterfly, *Hypochrysops digglesii* (Hewitson), breeding on mistletoes growing on banksias, in a property adjoining the Broken Head National Park and were most impressed with the healthy densities of *P. praevenosa* and how the vines were supporting one of the most stable populations of Richmond birdwings in the State. They were concerned about the future of the Richmond birdwing in both range states, and its chances of surviving the declines in abundance, and how the major threat was the widespread losses of the habitats with old stands of the food plant (*P. praevenosa*). Remote from urban areas a major concern recognised was the on-going clearing of rainforest containing *P. praevenosa* and this called for a review of 'what was being protected' in the remaining rainforest habitats. Very few *P. praevenosa* survived in protected areas of south-eastern Queensland but some 'old growth' (100 years +) examples had been well protected in north-eastern New South Wales, for example, in the Mount Warning National Park and Broken Head National Park. Sands and Moffatt discussed how the threats and declines in birdwing numbers might be offset by growing sufficient numbers of the vines as food plants in gardens, school yards and at bush regeneration sites. This meeting in Broken Head National Park between Sands and Moffatt led to the formation of a Richmond Birdwing Conservation Project. The Project began by gathering information about cultivating the food plants, and planning where they could be planted to attract the birdwings, and also sought to identify the threats and the best ways to prevent their continuing harmful impacts on the birdwing, its habitats and food plants.

In 1994 the Richmond birdwing was listed as a 'protected species' of butterfly in Queensland and subsequently the species was listed as Vulnerable by the State agency. Although a comprehensive dossier was prepared (Sands and Scott 1996) as a Draft Recovery Plan (p. 112), the document was not formally published. This document contained details of the basic biology of *O. richmondia* which, although incompletely understood, provided sufficient foundation to confirm that conservation was an urgent need if the butterfly was to withstand continuing threats to its habitat, and that considerations of food plant availability and distribution were among the key considerations to help recovery of the butterfly and restore it across its former range.

These themes remained central to the expanding conservation endeavour and are discussed in later chapters, following further ecological perspective, but are noted here as the major guiding elements for conservation as practical perspective and measures were developed.

Chapter 3
The Food Plants of the Richmond Birdwing

3.1 Introduction: Historical and Biological Background

The larvae of many Papilionidae feed solely on the leaves, and at times the flowers, stems and seed capsules, of plants in the family Aristolochiaceae (Straatman and Inoue 1984), with this host specificity marked and well entrenched in some groups. Most Troidini and Zerynthiini feed exclusively on these plants, as does the parnassiine *Archon appolinus* (Herbst). In North America, for example, the troidines known as the Polydamus Swallowtail (*Battus polydamus* (L.)) and the Pipevine Swallowtail (*Battus philenor* (L.)) feed on indigenous American aristolochias and the well known introduced Dutchman's Pipe vine (*Aristolochia elegans*) (p. 108), a native of South and Central America.

The chemistry of aristolochias is intricate, complex, and of considerable importance in view of the extensive values of these plants in traditional medicine. It has been investigated in considerable detail. Wu et al. (2004) reviewed the medical uses of *Aristolochia,* noting some 35 species with roles in traditional or folklore medicine and about 20 with ethnopharmacological information; many plant parts and countries contribute to these roles, largely through terpenoids or aristolochic acids. *Battus philenor* is known to sequester aristolochic acids; the acids occur in all life stages and are presumed widely to be the principle cause of the unpalatability conferring the butterfly's role as a model in an extensive Batesian mimicry complex (Brower 1958). Some aristolochic acids are extremely toxic to vertebrates and may be toxic to invertebrates if the plants containing these acids are not their natural host plants. Host plant selection by females for oviposition relies largely on initial visual cues, followed by chemical cues from tarsal contact once the host plant has been discovered (Rauscher 1995). However, the potential toxicity to larvae cannot be detected by females if they oviposit on foreign *Aristolochia* species, and they may make mistakes in their choice of plant species that can lead to the death of larvae (Straatman 1962). The major relevance of this syndrome in Australia is *Aristolochia elegans*, above (Chap. 5), which is a serious threat to

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O. richmondia through inducing mortality of the larvae that fed on it. The common name of Dutchman's Pipe vine refers to the trumpet-shaped flowers likened to the traditional smoking implement long popular in Europe and, whilst unambiguous in Australia, this name is applied to a number of similar species of *Aristolochia* elsewhere. Alternative common names for *A. elegans* include calico flower, elephant's foot, duck flower and guaco, and it is a perennial shrub cultivated widely as an ornamental plant in many parts of the world.

In southern Europe, larvae of the Aristolochia Butterfly, *Zerynthia polyxena* (Denis and Schiffermueller) feed on *Aristolochia clematitis* L. and *A. rotunda* L. (Lepidopterologen-Arbeitsgruppe 1987). However, many published host records for troidine caterpillars are imprecise, with some given simply as '*Aristolochia* sp.', or similar general name (Weintraub 1995). The overall host range is perhaps more restricted than supposed widely by earlier workers, and the level of specialisation by troidines to Aristolochiaceae may render them highly unlikely to colonise other food plant taxa (Feeny 1995). Aristolochiaceae-feeding swallowtails may be restricted to these plants because of their low levels of monooxygenase enzymes – perhaps reflecting need to avoid metabolising the aristolochic acids sequestered by caterpillars, as these constitute important components of defence against predators (Berenbaum 1995). However, the extent to which different species sequester these alkaloids is rather variable, as is their presence in different species of Aristolochiaceae: Mebs and Schneider (2002) noted that many food plant aristolochias are free of aristolochic acids or contain only trace amounts.

Aristolochic acids (of which about 14 different types known) can also be larval phagostimulants (Nishida and Fukagami 1989). Intriguingly, the apparent absence of these acids in a food plant of *Luehdorfia japonica* Leech (Zerynthiini), namely the wild ginger, *Heterotropa aspera* (Maekawa), and the apparent feeding stimulant being a flavonoid glycoside, may represent an ancestral link with Papilioninae and now lost in Troidini. Within their use of Aristolochiaceae as food plants, many swallowtails have substantial host-plant specificity, with chemical-related specificity perhaps fostered through long-term coevolution, and in some cases revealed by experimental trials on oviposition site selection. *Luehdorfia puziloi* (Erschoff), a sister species of *L. japonica* and found mainly in northern Japan, is a specialist feeder on *Asarum sieboldii* Miq.. *H. aspera* contains a chemical that is a powerful antifeedant and significantly deters feeding by *L. puziloi* (Honda et al. 1995). Oviposition trials on *Atrophaneura alcinous* (Klug) from Japan (Nishida 1995) showed that it did not respond to methanol extracts of a range of other plants used by species of *Papilio*. However, the roles of volatile chemicals produced by aristolochias, and their influences on butterfly behaviour and feeding are complex. The volatile compounds of *Aristolochia chilensis* Bridges ex Lindl., for example, include at least 53 components (Pinto et al. 2009), and determining which of these are important to the butterfly, and in which combination, is clearly a demanding exercise. The specific blend of these components causing attraction has not yet been clarified. In this case, both adults (of both sexes) and larvae of *Battus polydamus* *archidamas* (Boisduval) respond to the mixture of volatiles from this plant, in several different ecological contexts. Experiments indicated that olfactory cues are used by females seeking oviposition sites, large larvae searching for new host plants, and (possibly) males looking for mates (Pinto et al. 2009).

In addition to chemical defences against herbivory, physical condition such as leaf toughness is a defensive strategy employed by many Aristolochiaceae, and is important in the present case. From study of *Battus philenor* and *Aristolochia erecta*, Dimarco et al. (2012) believed that plant traits that offered mechanical resistance to larval feeding may be more important defences than chemical features.

In Australia, the larvae of several swallowtails feed on native vines (*Aristolochia* spp. and *Pararistolochia* spp.) growing in tropical and subtropical rainforests, but some of these swallowtails (including *Cressida cressida* (F.) and *Pachliopta* (or *Atrophaneura) polydorus* (L.)) feed on low, scrambling vines (all of them *Aristolochia* spp.), in woodlands and sometimes in areas receiving moderately low rainfall. About 20 native species of Aristolochiaceae occur in Australia and wherever they occur, the larvae of one or more swallowtail butterflies, including birdwings, utilise them as food plants. Surprisingly few thorough surveys have been made of the plant family Aristolochiaceae in Queensland, the Northern Territory and New South Wales, but since the 1990s increasing interest in the vines and their distributions has been spurred on by recognising their importance as food plants for several swallowtail butterflies. For example, Parsons (1996b) when examining herbarium and other pressed specimens from New Guinea and Australia, recognised the range of different species serving as food plants for the birdwing butterflies. As so often occurs in butterfly biology, butterfly enthusiasts were far more aware of the different food plant species than were professional scientists, and sometimes found them by careful searching after the butterfly had first been seen in an area. For many of the species the correct botanical identities or definition as butterfly food plants could not be understood until Parsons (1996b) reviewed the genus and described several new species. For example, *A. meridionalis* (or a related species) was known to occur as far south as Trial Bay, NSW where Sands observed it was probably the food plant of *Cressida cressida.* This small scrambling plant was not described and named until relatively recently (Ross and Halford 2007), and for many years was referred to as *A. pubera*, now known as a species with a more tropical distribution.

In subtropical eastern Australia, natural habitats for the Richmond Birdwing are mostly rainforests where the lowland food plant vines (*Pararistolochia praevenosa*) are sufficiently abundant to support and sustain breeding populations. In years of early European settlement, many of the coastal, eastern-flowing rivers were lined with patches of rainforest. The patches of food plants were either sufficiently large (such as in the Northern Rivers region of NSW) or close to one another (for example, surrounding Brisbane), to allow movement of individual birdwings between patches, or for them to move through corridors and minimise the likelihood of inbreeding depression (see Chap. 8). However, since the 1890s most of the rainforest on the eastern sub-tropical coast of Australia has been cleared for farms and urban settlements, logged, burnt, fragmented in various ways and has been degraded by invasive competitive weeds. These pressures on habitats have minimised chances of viable populations being sustained, and exacerbated inbreeding depression in susceptible species, including the Richmond birdwing – although comparable details are lacking for many other species whose ranges have also been fragmented. However, losses in the abundance and distribution of the food plants have become the most serious threatening process for the Richmond birdwing, and their impacts rectified during the current conservation effort by enhancement of larval food plants (p. 75).

Rainbow (1907) referred to food plants of northern Australian birdwings as: '…*Aristolochia* sp., and curiously also the native nutmeg, *Myristica insipida*', and this is the only record for birdwing larvae using *M. insipida* R. Br. (Myristicaceae), a well-known tropical rainforest tree reaching 30 m or more in height. We suggest that the record of *Myristica* as a food plant for birdwings is likely to be incorrect, as it is not otherwise known to be a food plant for swallowtail butterflies in Australia.

3.2 Taxonomy and Ecology of the Food Plant Vines

Parsons (1996b) reviewed the identities of the aristolochias and their roles as birdwing food plants, and divided the genus *Aristolochia* from the Australia/New Guinea Region into two genera. The seed capsules of Australian *Aristolochia* spp. develop after pollination into oval or globular fruit, becoming dry when mature and dehiscing on the vine to liberate the wind-dispersed seeds. The seed capsules of *Pararistolochia* in Australia and New Guinea develop in a similar way but when ripe they become soft and fall while intact, instead of opening on the vine as in *Aristolochia*. After falling to the ground, capsules of *Pararistolochia* often fracture and the seeds are disseminated by animals. The seeds of *Pararistolochia* in Australia and New Guinea are dispersed by megapodes (Sands and Scott 2002; Fletcher 2002). Brush turkeys (*Alectura lathami* [Gray]) (Fig. 3.1) have been observed to break up the capsules to feed on the pulp within the fruit, and the seeds are buried when the birds scratch the soil while feeding.

Parsons (1996b) described new species of the group, reviewed the status and made several new generic combinations. For example, of the indigenous food plants for the Richmond birdwing, *Aristolochia praevenosa* was transferred to become *P. praevenosa,* and *Pararistolochia laheyana* was raised to specific rank. It was previously known as *Aristolochia deltantha* var. *laheyana*, but 'true' *deltantha* occurs only in northern Queensland and possibly in Papua New Guinea. Subsequently Ross and Halford (2007) described several other new Australian taxa. In Australia, there are about nine species of native *Aristolochia* and several sub-species, while two others, *A. acuminata* and *A. ringens*, are exotic introductions and have become weeds that are toxic to livestock and to larvae of birdwing butterflies.

Fig. 3.1 Australian brush turkey, *Alectura lathami*: the major agent of seed dispersal of *Pararistolochia* spp. within the range of *O. richmondia*

Seven species of *Pararistolochia* are known from Australia (Bostock and Holland 2010) and other undescribed taxa are known from Cape York Peninsula. *Aristolochia* and *Pararistolochia* serve as food plants for the birdwing butterflies, with varying degrees of specificity for each butterfly species. One common and widely-distributed vine, which supports the greatest diversity of birdwing butterflies is the tropical *Aristolochia acuminata* (=*A. tagala*), which occurs north from about Sarina to Cape York Peninsula, and extends its range to Torres Strait, through New Guinea and nearby islands to much of South East Asia as far north as Hong Kong, China. All known species of *Pararistolochia* are rainforest food plants for birdwing larvae. The local taxa are eaten by larvae of the Cairns birdwing *O. euphorion*, where the birdwing is seasonally abundant on the sub-coastal mountains and Atherton tablelands.

Thus, two species of subtropical vines, the lowland *P. praevenosa* and the montane *P. laheyana*, are the only confirmed natural food plants for the larvae of the Richmond birdwing. However, there have been reports of birdwings seen in relatively remote areas of south-eastern Queensland, some of them localities separated from rainforest by dry woodlands that would initially appear to be unsuitable for breeding by the butterflies. This has raised a question about how far a gravid individual butterfly might fly, or if woodlands might contain previously unrecognised food plants that could act as 'stepping stones' for breeding by butterflies, linking remote areas with more obviously suitable habitats. For example, at some localities such as at Toowoomba, Queensland, no *Pararistolochia* food plants have been recorded but birdwings have been seen in past years by the late Jack Macqueen, raising the possibility of presence of an alternative food plant at intervening localities.

Most eucalypt woodlands in south-eastern Queensland support one or two small, low-growing species of *Aristolochia*, but they tend to be uncommon vines and could not be expected to have sufficient biomass to support feeding and development by even a single large butterfly larva. This possibility is discussed and the hypothesis presented here may indicate how Richmond birdwings may have been able to breed at sites between isolated rainforest habitats, and how inbreeding depression may have been minimised or avoided by this process.

Birdwing butterflies only occur where there are adequate densities of aristolochias to support breeding by the butterflies, this usually being the presence of about 30 or more vines at each suitable locality. Most aristolochias are vines but some are shrubs. As discussed above, many aristolochias are said to be toxic to vertebrates but there are no records for the distastefulness of the butterflies to birds (Common and Waterhouse 1981). There has been one observation by Sands of a Currawong (*Strepera graculina* Shaw) attempting to feed on a pupa of *O. richmondia* but then rejecting it, presumably as distasteful. Other birds reported as predators on birdwing stages include the Pied Butcherbird (*Cracticus nigrogularis* (Gould)), Spangled Drongo (*Dicrurus bracteatus* (Gould)) and Black-faced Cuckoo-shrike (*Coracina novaehollandiae* Gmelin).

3.3 Biology of the Vines: Pollinators, Seed and Capsule Development

P. praevenosa flowers mostly in spring but may vary in frequency and season, and between localities, with some vines producing more flowers than others at the same localities. Young and terminal growth of the vines exposed to periods of sunlight will always produce more flowers than shaded individuals. The flowering season usually extends from September until November, but prolonged drought or erratic rainfall events may defer flowering until January or later. If moisture is abundant, flowering may continue until April. Low humidity will cause abortion of the development or opening of flowers and cause desiccation of buds and the growing tips. The flowers of aristolochias are very variable in shape but all have a characteristic bulbous and basal expansion enclosing the reproductive organs. Large pipe-shaped flowers are characteristic of many American species, but these shapes are not usual in species native to Europe or the Pacific region. There, aristolochia flowers have a somewhat ‘tubular throat’ made up of fused sepals with a small opening to allow entry by pollinators. Some species from New Guinea, for example *P. dielsiana* O.C. Schmidt, have a shorter tube, widely expanded at the opening with sepals distally tapered (Hou 1983).

In common with many other Aristolochiaceae, Australian species have protogynous flowers that attract and trap small Diptera. Pollination of the aristolochia flowers is facilitated by small flies attracted by compounds (perhaps including nectar and stigmatic secretions: Hou 1983) secreted near the stigma at the base of the flower. In some cases a strong sex-bias of the attracted flies has been reported, with males predominant in samples taken from flowers (Hall and Brown 1993). After entering a flower small insect pollinators become temporarily trapped by retrorse hairs on the flower tube, but are released when hairs collapse a day or so later when anthers have ripened. The flies carry pollen when attracted to another flower the next day (Hou 1983 referred to an earlier report [Petch 1924] of as many as 1–8 flies found in a single flower of *A. elegans*). Amongst the variety of saprophagous flies implicated as pollinators, Phoridae have been most commonly reported, although Sakai (2002) listed Anthomyiidae, Chloropidae, Milichiidae, Phoridae, Sarcophagidae and Syrphidae as pollinators within the family. His records for Drosophilidae and Cecidomyiidae from the (non-trapping) *Aristolochia maxima* Jacq. in Panama, augment these. However, in a broader survey, spanning records from 35 Aristolochiaceae species, Berjano et al. (2009) noted a collective 39 families of Diptera present, with individual *Aristolochia* species yielding from one to 15 fly families. Phoridae were the only group reported with pollen loads from *A. elegans*, but no records from *P. praevenosa* or *P. laheyana* were included. However, Phoridae were the most frequently recorded family, from flowers of 24 species, followed by Chloropidae (14) and Drosophilidae (12) (Berjano et al. 2009). Within the Phoridae, species of the large and diverse genus *Megaselia* Rondani are commonly associated with aristolochias, with seven species reported from *A. littoralis* in Florida (Hall and Brown 1993), and this genus was predominant amongst flies retrieved from an Argentinian species (Trujillo and Sersic 2006). Disney and Rulik (2012), in reporting species of *Megaselia* from *Aristolochia* species in Italy, noted 'Phoridae appear to be important pollinators of *Aristolochia* across the world'. Limited dissections of *P. praevenosa* flowers have yielded small numbers of about three species of Phoridae, all apparently *Megaselia*, but no other Diptera: it thus seems reasonable to suggest that these might be the true pollinators. *Megaselia* is diverse in Australia, and the complexities of identification were exemplified by Disney (2008), in appraising a small collection of Phoridae from Tweed Heads (within the distribution range of *O. richmondia*) in mid-winter. A short water-trap collection from a garden yielded 10 species of scuttle flies, nine of them *Megaselia* and of which Disney described six as new! The perspective of inadequate knowledge of the Australian phorid fauna is helped also by a further comment by Disney (2008) as 'the number of named species from mainland Australia is about the same as the number of named species I have recorded in gardens in the city of Cambridge' (UK).

The pollinators of Australian *Pararistolochia* species have thus not been identified fully. Following a comment by Jebb (1991, on New Guinea taxa) that 'small midges' (later identified informally as '*Forcipomyia* spp.', Ceratopogonidae) had been found in flowers of *A. acuminata* (as A. tagala) and were implicated as pollinators, this reference has been extrapolated widely to cite *Forcipomyia* as pollinators of Australian species. Direct evidence for this is lacking. However, Razzak et al. (1992) stated that *Forcipomyia* was the only pollinator they found for *A. bracteolata* Lamk. in Pakistan. In India, Murugan et al. (2006) reported another family of Nematocera, Chironomidae, as pollinators of *A. tagala*. The name '*Forcipomyia*' has become somewhat of a holding genus for a large number of tiny and biologically diverse Ceratopogonidae. Many of these, in common with Phoridae, frequent habitats such as decaying vegetation, carrion or dung. As implied above, the Phoridae are also taxonomically complex and most have poorly-known life-histories. The pollinators will remain difficult to identify until a specific project is undertaken to study the pollinator-flower interactions of the species of *Pararistolochia.* Such a comprehensive study of the pollinators of Australian aristolochias is considered a high priority for understanding the needs of conservation management for the birdwings and their food plant vines. Substantial further collections are needed to both accumulate material of Phoridae for critical taxonomic appraisal and to determine whether *Forcipomyia* or other Diptera may also be pollinators.

Pollination levels and development of seed capsules vary from year to year and are dependent on rainfall or periods of drought. Expanding capsules following successful pollination may abort during periods of unseasonal low rainfall. To produce viable seed capsules the vine requires shaded rainforest with deep leaf-litter loads as part of the breeding arena of the pollinators, at present believed to be wholly Diptera but which, as noted above, have not been formally identified. In addition, there is little doubt that decreased abundance of these pollinators occurs during drought, and that frequency of drought may influence the number of seed capsules developing, and may be implicated in the declines in numbers of capsules seen on wild vines since about 2009.

The leaves of aristolochias are alternate and never opposite as in some vines otherwise similar in general appearance (for example, *Parsonsia* spp.) and they sometimes have twisted petioles, without the distinctive swellings seen in most Menispermaceae. *Aristolochia* vines do not have independent tendrils. Within each species, leaves vary considerably in size according to local environmental conditions, particularly the soil type, available moisture, nutrients and light. The leaves of *Aristolochia* and *Pararistolochia* vary in size, shape and texture, and according to species. Leaves of *Aristolochia* are often heart-shaped (as in *A. chalmersii*) or sub-triangular, while leaves of *Pararistolochia* have oblong blades with tapered apices (as in *P. praevenosa*). Many aristolochias are erect rainforest vines but some native species are low-growing and scrambling vines, occurring in woodlands or dry rainforests. Most of the species are hosts for northern swallowtail butterflies throughout the range of their associated plant communities.

The pH of surface soils is likely to be a factor influencing germination of seedlings and density of the vines. Following recommendations from Len Webb and Geoff Tracey, preliminary experiments were conducted by Sands near Brisbane with natural alluvial soils treated with varying amounts of dolomite. The soils with varied pH were monitored for seedlings after fall of capsules from overhead *P. praevenosa* vines, to estimate seed germination and seedling abundance. The trials indicated that the optimum pH for soils, germination and subsequent resistance to seedling damping off lies within the range of pH 6.5–6.8. This pH is not uncommon over basaltic soils but is mostly lower for all other soils in the natural range.

3.4 Identities of the Subtropical *Aristolochia* and *Pararistolochia* Vines

3.4.1 The Lowland 'Birdwing Butterfly Vine': P. praevenosa *(F. Muell.) Michael J. Parsons*

Lectotype ex. Clarence River, NSW, designated by Parsons (1996b).

Pararistolochia praevenosa is the principal lowland food plant for the Richmond birdwing. When growing naturally, it is a robust, multi-stemmed and long-lived vine adapted to lowland coastal or mid-montane (<600 m elevation) rainforest plant communities. An estimated decline of more than 90 % has occurred in abundance of this vine over the past 100 years, both in south-eastern Queensland and north-eastern NSW, accompanied by a decrease in two-thirds in the distribution range, based on data from known specimens in institutions. The original distribution of the vine is not known completely, but it is thought to have occurred wherever specimens of Richmond birdwing have been recorded (Waterhouse 1932). The vine is likely to have been more extensive in subtropical coastal regions than currently known by specimens in herbariums. Waterhouse (1932) followed Illidge (1927) when he referred to the vine *P. praevenosa* (as '*pervenosa*'), and both these authors clearly recognised this vine as the primary food plant for *O. richmondia*. Richmond birdwing larvae have since been found to use only two species of vines as natural food plants, the lowland 'birdwing butterfly vine', *P. praevenosa* and the 'mountain butterfly vine', or 'mountain aristolochia', *Pararistolochia laheyana*. However, the distribution of *O. richmondia* is linked to its dependence on adequate densities of the lowland (<600 m) food plant, and it does not breed continuously on the mountain food plant. Occasionally (for example, in 1994) *P. laheyana* has been used as a food plant when climatic conditions were favourable to the survival of over-wintering pupae.

P. praevenosa is currently known from near Lake Eacham on the Atherton Tablelands, northern Queensland (arrowed on Fig. 3.2, and some 1,500 km north of Brisbane) but it is absent from lowland rainforest between Cairns and Maryborough. In south-eastern Queensland it occurs mostly on ridges and very rarely on the coast, from east of Gympie to the Tweed River and in north-eastern New South Wales (NSW) from the Tweed River to the Richmond River (Fig. 3.2). In south-eastern Queensland, *P. praevenosa* occurred north of Mary River Heads until about 1959 and now occurs in rainforest fragments between Kin Kin and Tewantin, and patchily at Eumundi. *P. praevenosa* can be found most abundantly along the embankments of Kin Kin Creek and in riparian rainforest and basalt caps of the Blackall and Conondale Ranges. Fragmented populations occur at Mount Eerwah, Mount Cooroy, Point Arkwright, Nambour, Tanawah, Obi Obi Gorge, Stanley River, Neurum Creek, London Creek on the northern D'Aguilar Range. South of Brisbane, it occurs at Upper Ormeau, Nerang, Mount Tamborine, Burleigh Heads, Canungra, in the Tallebudgera Valley and foothills of the Border Ranges. In northern NSW, *P. praevenosa* once occurred in coastal rainforests from the Tweed River to Broken and Brunswick Heads. However, most of these rainforest patches are now separated by urban settlements and roads. *P. praevenosa* is also recorded from Whian Whian, Alstonville, at the base of Mount Warning and near Ballina. It no longer occurs near Grafton or on the lower Clarence River. The south-western limit is now thought to be in Mallanganee National Park, near the upper slopes of the Richmond (eastern) and Clarence River (western) Catchments.

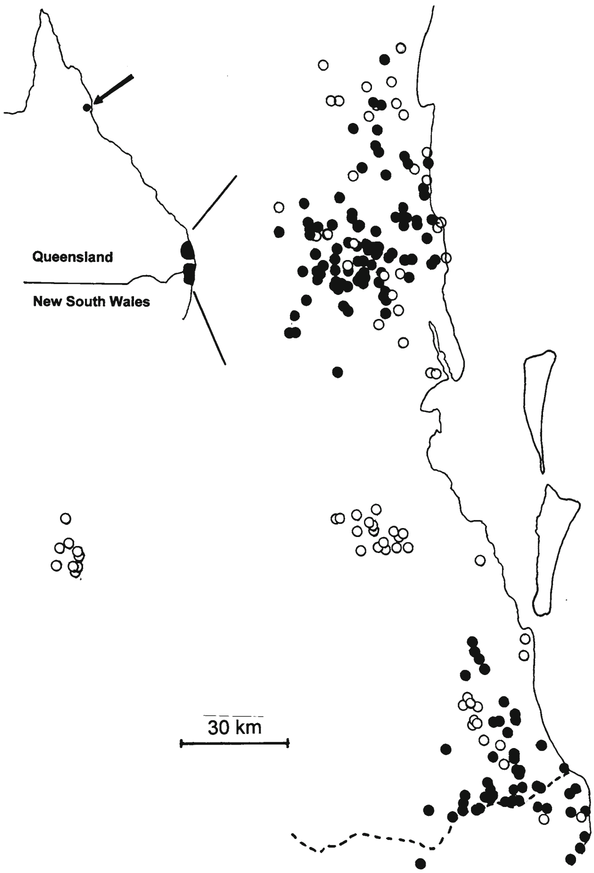

Fig. 3.2 Distribution of *Pararistolochia praevenosa*: solid spots, natural records; open spots plantings, data as at 2010. Arrow on insert indicates Atherton Tablelands, site of the northerly tropical locality of the vine

P. praevenosa occurs naturally on steep slopes with basaltic soils or on rich alluvial loams bordering rivers and streams. Occasionally vines occur on old, nutrient-rich sand dunes or other soil types. The areas with nutrient-rich soils were eagerly sought for agricultural purposes, especially in the 1800s, and most habitats for the vine and birdwing butterfly were destroyed around that period.

P. praevenosa is thus a locally-distributed vine that mostly occurs in patches of subtropical, lowland notophyll rainforest. The vine occurs on river banks, riparian alluvium and near streams but also basaltic slopes. It requires permanently moist, well-drained soils. Occasionally, old sand dune loams rich in organic, or overlying volcanic soils support the vines. Associated 'companion vines' include *Flagellaria indica* L., *Calamus muelleri* H. Weddl. and *Cissus antarctica* Vent., and all three may naturally and commonly inter-twine with *P. praevenosa*. Vines in cultivation are very adaptable to a range of soils, particularly alluvial and if fertilised, but they do not usually grow rapidly or mature until at least 3 years after planting, and prefer a soil pH between 6.5 and 6.8. Old vines are easily recognised beneath the rainforest canopy by the distinctive architecture of the bark. Seedlings rarely germinate in heavily shaded areas but will respond rapidly in areas exposed to broken sunlight. Seedlings are weak and not competitive; they suffer seriously from displacement by invasive introduced grasses and weeds.

The vines occur naturally as multiple erect stems, or entwined with other vines in dense undergrowth. Large vines branch close to ground level, or from rhizomes, producing somewhat flattened stems with widely-spaced nodes. On older plants, stems are often upright but sometimes emerge horizontally and layer, developing clumps of vines with stems that climb vertically. The dark brown bark of mature stems of *P. praevenosa* has a distinctive cellular and reticulated pattern. Mature stems, oval in cross section, may be 1–8 cm wide and sometimes fuse when with other ascending stems. The surface roots are extremely fine (said to resemble cotton wool) and emerge from underground rhizomes on the larger plants. Roots are prone to suffer from desiccation during periods of prolonged drought and die after fires. Vines produce growth throughout the year, particularly after rain during autumn and winter. They may ascend 15 m or more into the canopy but usually only reach around 7 m. In common with some other species of *Pararistolochia*, the alternate mature and dark green leaves of *P. praevenosa* are very tough. Young, paler green leaves are somewhat hairy but become smoother and much tougher about two months after their emergence. They vary in texture and size according to shade, soil, nutrients and moisture. Leaves are usually 12–18 cm long and 3–7 cm wide, but occasionally reach 25 cm or more. The venation is distinctive with the sub-basal vein very long and often reaching the margin near the mid length of a leaf (Figs. 3.3, 3.4, and 3.5).

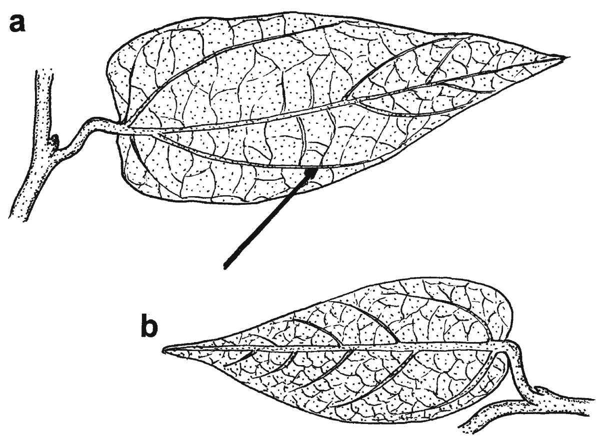

Fig. 3.3 *Pararistolochia*: underside of leaves to indicate position of subbasal vein (indicated): (**a**) *P. praevenosa*; (**b**) *P. laheyana*

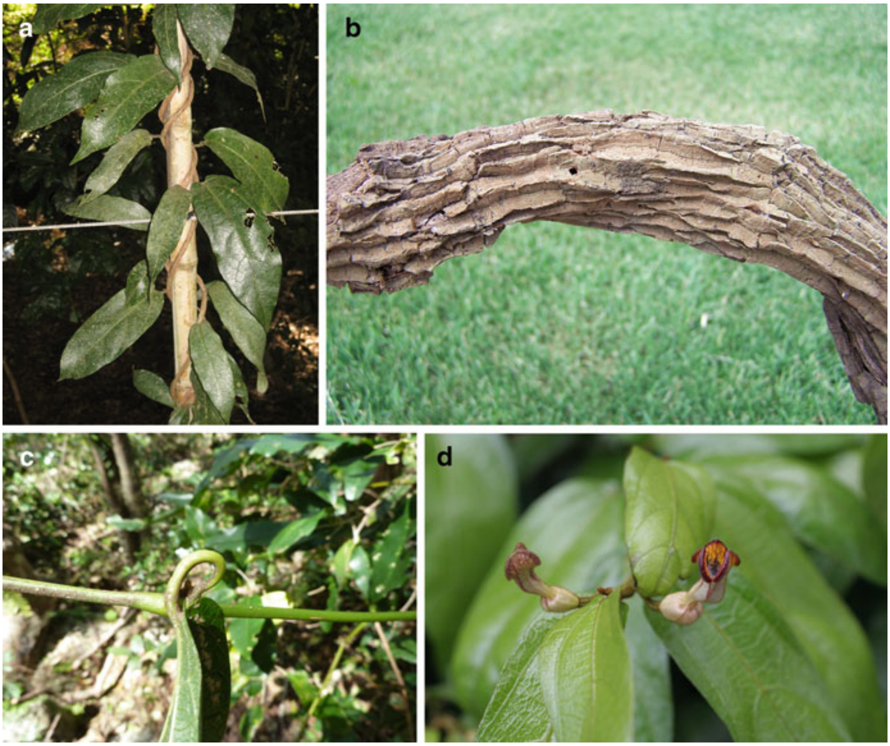

Fig. 3.4 *Pararistolochia praevenosa*: structure and recognition: (**a**) vine ascending stake; (**b**) stem with reticulated bark; (**c**) twisted petiole; (**d**) flower and bud (A. Juen)

The length of each flower is about 2.5 cm, and flowers are tubular and purple veined externally, with the sepals bright yellow internally. Flowers are not known to secrete nectar. The small flies implicated as key pollinators are probably attracted to flowers by kairomones, as mostly males have been found in flowers and the flies are believed to breed in wet leaf litter or moist sand near watercourses. Individual plants vary greatly in the number of flowers produced and seed capsules that develop. Under the rainforest canopy very few flowers become pollinated and capsules tend to develop more frequently when plants are in exposed positions. After pollination the young green seed capsules expand before turning bright yellow, and become similar to a soft fruit when ripe and fall from the vine, often fracturing on impact. Seed capsules range from about 25–60 mm in length and usually ripen in late summer and autumn. Each capsule when ripe has longitudinal ribs and contains about 20–60 flattened seeds. These remain viable for long periods if kept moist but become sterile after a few weeks if they become dry. Seeds buried by brush turkey activity often germinate in batches, resulting in naturally-occurring clumps of seedlings. Silvereyes (*Zosterops* spp.) have been seen to feed on the fruit by Arthur Powter, but their role, if any, in seed dispersal has not been determined.

Fig. 3.5 Seeds and seed capsules. *P. praevenosa*: (**a**) unripe seed capsule; (**b**) ripe seed capsule (P. Grimshaw); (**c**) individual seeds

Growing vines are only capable of ascending stems when these are no more than 6 cm in diameter, and will fall or slide to the ground if unable to reach lateral growth when attempting to grow up supporting trunks of young trees when they have a greater diameter.

3.4.2 The 'Mountain Aristolochia', Pararistolochia laheyana *(F. M. Bailey) Michael J. Parsons*

Holotype ex. MacPherson Range, Queensland (designated by Parsons 1996b)

Pararistolochia laheyana has earlier (for example by Common and Waterhouse 1981, Henderson 1993) been incorrectly referred to as a form of *Aristolochia deltantha* (F. Muell) Michael Parsons, a tropical species restricted to northern Queensland. The two were then thought to be varieties of the same species, but after they were separated as two species by Parsons (1996b), *P. laheyana* has been shown to be restricted to the Queensland-NSW Border Ranges and nearby mountains above 400 m (Harden et al. 2007). *P. laheyana* occurs commonly at elevations above 600 m (usually 700–1,000 m) surrounding Mount Warning and on neighbouring ridge tops in Queensland, from upper parts of Tallebudgera Creek to Springbrook, Binna Burra, Lamington Plateau, Roberts Plateau, O'Reilly's, the Border Track, above Canungra, Mount Wagawn, Mount Merino, eastern Macpherson Range and western rim. Its presence on the Main Dividing Range near Toowoomba has not been confirmed or validated with recent specimens. In New South Wales *P. laheyana* occurs on the Tweed Ranges surrounding Mount Warning, and on the summit of Mount Warning, the Western Rim, Mount Bithongabel, Wiangarie State Forest, Whian Whian, Richmond Range, Nightcap Range, and Mount Nardi. *P. laheyana* is very common vine on the volcanic rim of the two States at elevations above 600 m and on the summit of Mount Warning (Fig. 3.6).

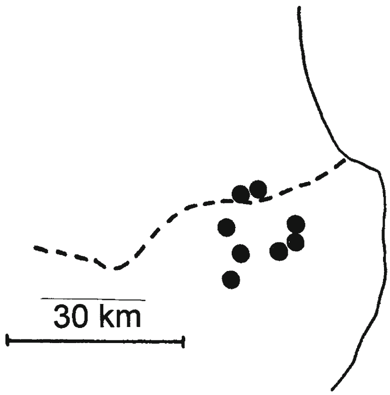

Fig. 3.6 Distribution of *Pararistolochia laheyana*: natural records in northern New South Wales, state border between New South Wales and Queensland indicated

Although *P. laheyana* is common in protected areas at higher elevations, and well within the natural range of Richmond birdwings, few sightings of adults or their immature stages have been reported on the mountain food plant since the 'boom' in 1994 (Sands and Scott 2002), with the exception of a few seen along the escarpment where warmer updrafts from the coast moderate the temperatures. In the Queensland-New South Wales Border Ranges pupae of the Richmond birdwing rarely survive winters even though the higher areas support *P. laheyana.* From limited observations, pupae usually die in the cooler months between July and August, unless winters are unusually mild and moist. Richmond birdwings may frequently visit the higher locations on the Queensland-NSW Border Ranges where ample food plant vines occur but the offspring from ovipositing females rarely survive. The most recent large scale winter survival of pupae produced abundant adults on the Border Ranges in 1994. *P. laheyana* would appear to be an ideal food plant for *O. richmondia*, with softer leaves than *P. praevenosa,* but the temperatures in mountains (>600 m elevation) where *P. laheyana* occurs are mostly too severe for survival of birdwing pupae, and prevent generations continuing to develop each season. Larvae can consume leaves, green stems and seed capsules, leaving no foliage intact on a vine. However, most vines recover from this defoliation.

Flowers of *P. laheyana* are produced from February to October. They are about 20–30 mm long with swollen base and vary in colour (Fig. 3.7) depending on locality. The sepals are usually broad, internally pale pink, and speckled with maroon through to bright yellow, with maroon venation externally. Mature seed capsules of *P. laheyana* are light green or greenish-yellow, smooth, somewhat glossy and narrower and more elongate than those of *P. praevenosa*. Seed capsules range from about 30–50 mm in length. The Australian brush turkey is the only agent observed feeding on ripe capsules and dispersing the seeds. *P. laheyana* occurs naturally on volcanic soils, mainly basalt but sometimes rhyolite. The vine rarely occurs near streams, and unlike *P. praevenosa*, is often found entwined in low growing shrubs, where it may ascend up to 5 m into the understorey. Its slender stems usually arise from a basal broad (5 mm) stem but occasionally the slender stems arise directly from ground level. The leaves and stems of *P. laheyana* are smaller than those of *P. praevenosa*, its leaves are smooth above and the old leaves are much softer in texture than those of *P. praevenosa,* and the older leaves of *P. laheyana* are edible by birdwing larvae.

This low, shrub-climbing and slender-stemmed vine is adapted to mountain rainforest communities. Its stems will branch amongst shrubs and ascend low trees in heavily shaded areas. Little decline in abundance is estimated to have occurred in its distribution or abundance since European settlement and much of the habitat has been protected in national parks in both States.

3.4.3 Other Food Plants for the Richmond Birdwing Butterfly

Although not a natural food plant for the Richmond birdwing, a vine from northern Queensland, *Aristolochia acuminata* Lamarck (J.B.A.P. de Monnet) has been used in the past as a food plant for rearing Richmond birdwings in captivity. This vine, sometimes referred to as 'Native Dutchman's Pipe', is distributed widely throughout much of the south east Asia region. It was known for many years as *Aristolochia tagala* Chamisso but this was shown by Bosser (1997) to be a synonym of *A. acuminata*, one of the common food plants for the Cairns Birdwing (*O. euphorion*) and Cape York Birdwing (*O. priamus* ssp.) (Braby 2004). This vine is fast growing but it has not been recommended for growing in gardens to encourage colonisation of the Richmond birdwing due to the toxicity of foliage to eggs if they are deposited on the young leaves. In series of field experiments carried out in Brisbane from 1994 to 1998, hatch of eggs deposited by female Richmond birdwings on *P. praevenosa* was compared to hatch on *A. acuminata*. Whereas eggs deposited on *P. praevenosa* all hatched, more than 60 % of eggs deposited on young *A. acuminata* leaves failed to hatch, and were accompanied by the formation of necrotic leaf tissues at the contact zone of leaf and egg. In contrast, eggs deposited on old leaves as well as

Fig. 3.7 *Pararistolochia laheyana*: structure and recognition (**a**) leaf and petiole; (**b**) flower (P. Grimshaw): (**c**) capsule and buds; (**d**) mature vine

stems of *A. acuminata* emerged normally. Also by contrast, freshly-eclosed larvae placed on the vine appeared to develop normally but an observation was made by Ray Seddon that pupae attached to leaves of *A. acuminata* often failed to eclose, accompanied by discoloration at the point of attachment of the cremaster. Before *A. acuminata* is used more extensively for captive rearing of Richmond birdwings, further studies are needed to see if larvae that pupate normally eventually develop into adults capable of healthy reproductive development.

Although *A. acuminata* has at times been considered a suitable alternative food plant for *O. richmondia*, it does not occur naturally in the range of this birdwing, and the leaves clearly have some toxic properties which affect egg viability in localities where *A. acuminata* and *P. praevenosa* have been planted together.

Despite birdwing specimens being known from more northerly localities, there are no confirmed records for *P. praevenosa* from north of Kin Kin, except for an isolated record from Eacham, on the Tablelands in northern Queensland (Queensland Herbarium records). It has not been possible to determine where, and if, *P. praevenosa* occurred between Gympie and Maryborough, the former northern range of the birdwing, except for one sighting of the vine and a male butterfly at Rainbow Beach, with another seen near Gympie in 1984 (Sands and Scott 2002). This raises questions about the distribution of the Richmond birdwing and its possible food plants: (i) the birdwing and *P. praevenosa* were both seen at Mary River Heads in 1984 by Sands but no other vines have since been located there, or between Maryborough, Gympie and Kin Kin, and (ii) whether other natural food plants for *O. richmondia* supported breeding from Gympie to Maryborough between 1907 and 1932. The possibility of this second hypothesis can be strengthened by observations on use of certain low-growing aristolochias by the Cairns birdwing as follows: as well as several larger vines (*Pararistolochia* spp., *Aristolochia* spp.), the usual food plants of *O. euphorion* in northern Queensland, two small scrambling species, *A. pubera* R. Br. and *A. thozetii* F. Muell. were reported by Waterhouse (1938) to be food plants. Both are remarkably small vines considering they are known to be able to support large larvae and each rarely spreads over the ground or climbs more than 0.5 m into surrounding vegetation.

3.5 The ‘Stepping Stone’ Hypothesis

To explain reports of *O. richmondia* from northern localities (and west at Toowoomba), outside of the accepted natural range (Common and Waterhouse 1981) of *P. praevenosa*, two other natural food plants, *Aristolochia pubera* and *Aristolochia meridionalis,* have been implicated as food plants in patches of suitable woodland vegetation, especially if the patches are between its preferred rainforest biotopes. *A. meridionalis* is a small deciduous vine with a thickened rhizome, most characteristically scrambling and prostrate, straggling on the ground, climbing rocks or rarely upright on slender stems or over low shrubs, as shown by Leiper et al. (2009) but will opportunistically ascend vertically 1 m up stems of plants, or into low leaves of plants, for example *Macrozamia* spp. (Fig. 3.8). It has single or multiple stems up to about 1.5 m in length, which bear up to 40 alternate leaves about 6×3.5 cm but sometimes as large as 10×5 cm on upright growth. The leaves are pale dull green, cordate with curved margins and tapered apices, and rarely hastate. Leaves have blunt (obtuse) or tapered (acute) leaf apices, and in shape are not unlike those of the much larger-leaved tropical *Aristolochia acuminata.* The slender, tubular and greenish flowers with a brown bulbous base and slender maroon hood above the aperture are about 22 mm in length. The seed capsule is almost round, green becoming pale brown and dehiscent, turning brown after fracturing to release about 18–30 black seeds.

Fig. 3.8 *Aristolochia meridionalis* supported by a cycad (*Macrozamia* sp.)

Aristolochia meridionalis can sometimes be confused with *A. pubera*, a similar scrambling vine that is more abundant in northern parts of the south-eastern Region. *A. meridionalis* is distributed from northern NSW to about Maryborough, Queensland, where it grows on very low-nutrient soils, mostly in open woodlands, on rocky or shale slopes or sand dunes. *A. meridionalis* is most commonly found in open dry and wet eucalypt woodlands, sand dunes and occasionally moist gullies or open grasslands. Plants can be found behind sand dunes or along rainforest margins, on shaded creek and river banks, ridge tops or on steep slopes from sea level to about 600 m, preferring shale or sandy soils. It is the usual food plant in south-eastern Queensland for the 'Big greasy' butterfly *Cressida cressida*. Unlike birdwing butterflies, the larvae of this swallowtail prefer to feed on small vines growing only to less than 1 m in height. Compensating growth of the vine occurs rapidly after or during feeding by larvae of insect herbivores, including *C. cressida.* North from Rockhampton, *A. pubera* and other low-growing species are important food plants for *C. cressida*. *A. meridionalis* is becoming rare due to prolonged drought and is very susceptible to winter burning practices. It is easily propagated from seed but difficult to maintain in pots. This vine is partially deciduous during dry and warm periods but responds rapidly after rain periods with vegetative growth, drawing on nutrients stored in its swollen rhizome. During periods of drought, green vegetative growth may fail to appear above ground for long periods. When not in flower, it may resemble *Polymeria calycina* R. Br. (Convolvulaceae) in growth and leaf shape.

Aristolochia pubera and *A. meridionalis* are at times very abundant. For example, large numbers of *A. meridionalis* were once observed on embankments of the Mary River in the 1990s by Sands and Sue Scott. *A. meridionalis* is much more widespread and extends from Rockhampton to north-eastern NSW. Moreover, in preliminary experiments, Sands, Ian Gynther and Jacqui Seal experimented with larvae of *O. richmondia* fed on *A. meridionalis*. The larvae completed development, pupated and emerged as normal adults, but the rate of larval development was faster for larvae fed *A. meridionalis* than for larvae from the same batch of eggs that were fed *P. praevenosa*. It is not known if female birdwings will oviposit on *A. meridionalis* in the wild but they will certainly deposit eggs on *A. acuminata,* and also on the poisonous South American vine *A. elegans*, even when *P. praevenosa* is growing close by, as seen by Peter Chapman and Sands. Trials with caged gravid female *O. richmondia* offered *A. meridionalis* were inconclusive. However, oviposition trials under field conditions are needed to determine if *A. meridionalis* can act as a host of *O. richmondia.*

The breeding of the northern tropical birdwings outside rainforest environments may throw light on the way the Richmond birdwing could sometimes breed away from the usual rainforest habitats of *P. praevenosa,* or extend its distribution to regions where the rainforest vine has not been recorded. *O. euphorion* and *O. priamus* both sometimes breed in eucalypt woodlands in northern and inland Queensland habitats, and the two woodland vines *A. thozetii* and *A. pubera*, are both recorded as hosts of *O. euphorion* (Waterhouse 1938). The most common food plant for *O. euphorion* is *A. acuminata*, a vine sometimes found behind coastal sand dunes, in moist heath lands as well as in rainforest. Observations in 1950 on Magnetic Island by George Weymouth, confirmed that larvae of *O. euphorion* often feed on a low-growing (unidentified) aristolochia in dry woodlands (Common and Waterhouse 1981), as did larvae of the Red-bodied swallowtail, *Pachliopta polydorus queenslandicus* (Rothshild). *O. euphorion* can sometimes be abundant where there is little or no rainforest, for example in Townsville as noted by Peter Bakker, where the food plants for this birdwing were low-growing and unidentified aristolochias. Moreover, in the early 1980s, larvae of *Ornithoptera priamus macalpinei* Moulds were observed by Sands and John Kerr, breeding at the edge of dry deciduous vine thickets, south-west of Coen. The food plant was a scrambling vine, *Aristolochia chalmersii* O.C. Schmidt and the birdwing larvae were accompanied by larvae of *C. cressida* (Fig. 3.9) and *P. polydorus queenslandica*. On Cape York Peninsula, *A. chalmersii* tends to be overlooked as it is a deciduous low-growing vine (growing up to 3 m, but more often on the ground). The Cape York and Cairns birdwings have several main food plants, especially *A. acuminata* (= *A. tagala*) near the eastern coast and *A. deltantha* in the montane rainforest regions, but breeding in dry vine thickets had not been previously observed. Subsequent observations suggest that the Cape York birdwings opportunistically breed in dry vine thickets and can thus extend their distribution into the western parts of Cape York during wet periods. *A. chalmersii* is deciduous but during moist times of the year it becomes a rapid-growing food plant for the three swallowtails.

Based on the woodland food plants of northern birdwings, it seems possible that the Richmond birdwing may breed during favourable climatic conditions in the drier plant communities, using alternative food plants such as *A. meridionalis* or *A. pubera*. Corridors with these food plants could help to promote gene flow between butterfly populations that are usually only found in rainforest. This behaviour could explain occasional unexpected sightings of birdwing adults in places such as the Goodnight Scrub west of Bundaberg (S. Scott unpublished) or breeding in western localities on parts of the Great Divide, where *Pararistolochia* spp. have as yet not been recorded.

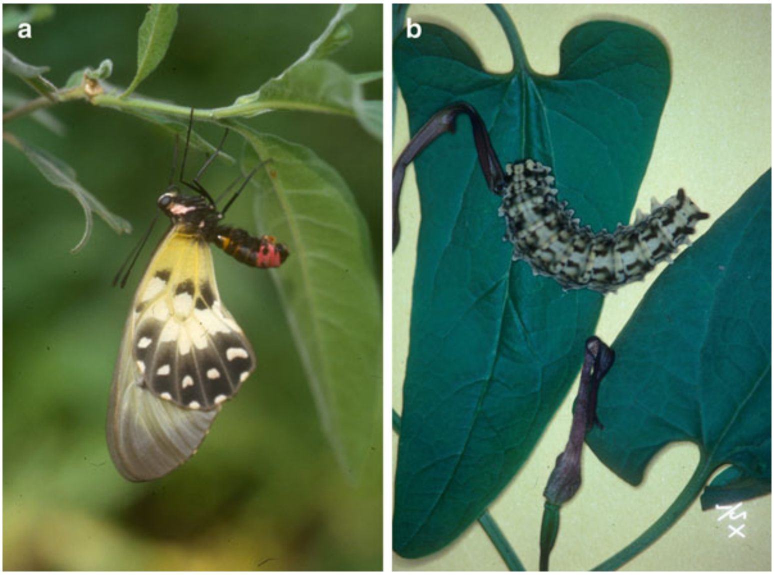

Fig. 3.9 The 'Big greasy' butterfly, *Cressida cressida*: (**a**) adult, (**b**) larva feeding on *Aristolochia meridionalis*

Aristolochia meridionalis and *A. pubera*, by occurring in northern parts of the Richmond birdwing's range could thus provide the necessary food for larvae in woodlands between the more permanent colonies of the rainforest *P. praevenosa* (Sands 2008). In addition to the laboratory trials with *A. meridionalis* noted previously, further support for this hypothesis comes from the seasonal responses of this small vine to prolonged moist weather in south-eastern Queensland, known to stimulate rapid growth and increase the biomass of vines of *A. meridionalis*. Perhaps this vine (if the foliage on an individual plant was sufficient to feed a caterpillar!) could support occasional breeding of birdwings in woodland habitats, where *P. praevenosa* would not naturally occur, and between tracts of rainforest. It is therefore quite possible that the remote sightings of Richmond birdwings and distant dispersals may be promoted by presence of a transitory food plant for the Richmond birdwing when sufficiently abundant in dry woodlands, or the non-rainforest vegetation behind the sand dunes: habitats often occupied by *C. cressida*.

3.6 Recording the Distribution of *Pararistolochia praevenosa* and *P. laheyana*

Details of the localities searched for *Pararistolochia praevenosa* and *P. laheyana* were recorded using the GPS devices that had by then become commonplace, but there was always a problem when taking accurate latitude, longitude and elevation readings under a rainforest canopy but the advice to 'get a reading in the open before walking in' enabled participants in the surveys to gather many new records. Until mid-2010, members of the Richmond Birdwing Recovery Network (RBRN) and community groups participated in the search for wild vines, breeding colonies and sightings of the Richmond birdwing butterfly, resulting in the discovery of new localities and sometimes, revealing the loss of earlier habitats. Continued searching for vines in the wild is a core activity of the conservation programme, but its value clearly depends on good 'quality control' to assure accurate and consistent outcomes.

From 2006 to 2011, the RBRN hosted a series of training workshops (Chap. 7) in southeastern Queensland (15) and northern NSW (2) with one of the aims being to provide guidelines on how to identify the food plant vines, find new breeding sites for the birdwing and encourage people to participate in the mapping process. The workshops attracted more than 700 participants, and survey sheets handed out at the workshops proved to be the most successful way of gathering information, especially on the whereabouts of the wild vines. When survey sheets were returned, information was transferred to a database held by RBRN where it was mapped and made available to anyone interested via the RBRN website (richmondbirdwing.org.au). With these data it was then possible to follow up validating the sites and, with 'permits to collect plant specimens', accumulating specimens if they are needed as vouchers (for the Queensland Herbarium).

3.7 Distinguishing the 'Look-Alike' Vines from *Pararistolochia* spp.

The two species of *Pararistolochia* (*P. praevenosa* and *P. laheyana*) from south-eastern Queensland can be distinguished from other vines by combining the characteristics of the leaves, petioles, stems, flowers and seed capsules (Harden et al. 2007) Some of these 'look-alike vines', with foliage easily mistaken for that of *P. praevenosa*, are listed in Table 3.1. The guide below is used to help distinguish these from the true birdwing vines, with recognition of some taxa facilitated through a dichotomous key.

Leaves of *Pararistolochia* spp.

- *Arrangement;* alternate on stem, never opposite.
- *Petiole*: slightly or prominently twisted, without obvious swellings at attachment of leaf blade (Fig. 3.3, p. 59) or stem; tendrils absent.
- *Shape:* simple, not divided or lobed; much longer than wide, elliptical with curved edges (oblong-ovate), base junction at petiole rounded, or slightly heart-shaped (cordate), tip (apex) bluntly pointed (acuminate).
- *Veins:* with a prominent network seen beneath leaf blade (reticulated), sub-basal vein (2nd closest to petiole) nearly half as long as leaf blade.
- *Colour:* medium to dull green (*P. praevenosa*) to dark green above (*P. laheyana*), paler beneath, smooth or slightly hairy (*P. praevenosa*).
- *Texture:* only young leaves soft, older leaves (4–5 from apex) becoming firm or leathery, especially when in exposed situations or during drought.

Table 3.1 Some rainforest vines commonly mistaken for *P. praevenosa*

Deeringea arborescens (R.Br.) Druce
Climbing Deeringea
Amaranthaceae
Parsonsia straminea (R.Br.) F. Muell.
Silkpod, Monkey rope
Apocynacaeae
Carronia multisepalea F. Muell.
Carronia
Menispermaceae
Hypserpa decumbens R.Br. ex Benth. (Diels)
Hairy hypserpa
Menispermaceae
Pleogyne australis Benth.
Pleogyne
Menispermaceae
Sarcopetalum harveyanum F. Muell.
Pearl vine
Menispermaceae
Stephania japonica (Thunb.) Miers
Snake vine
Menispermaceae
Smilax australis R.Br.
Lawyer vine, Barbwire vine
Smilacaceae
Cissus antarctica Vent.
Kangaroo vine
Vitaceae

Stems

- *Pararistolochia* vines twist anticlockwise up stakes and supporting stems (when viewed from above).
- When older, vines often retain their leaves beneath the canopy while most other older vines will drop their leaves from old stems.
- Apical tip of growing vine has leaves progressively expanding as they emerge.
- Old stems are slightly oval in cross section with shallow reticulated, criss-crossing pattern of slender cells on bark (but slender and almost smooth in *P. praevenosa*),

Flowers

- *Arrangement*: singly or sometimes branched (on a raceme) from apical and younger lateral growth and more abundant when exposed to sunlight.
- *Shape*: tubular calyx (about 3 cm long), base prominently swollen, fused and tubular apical opening with three lobes (almost fuchsia-like), stamens and anthers not visible.
- *Colour*: purplish-brown or yellowish, tube strongly veined, interior lobes yellow or purple.

Capsules and Seeds

- Fruity capsules are oblong, rounded (about 1.5 × 3 cm), yellow (*P. praevenosa*) and fleshy when mature, fall to ground without opening (indehiscent).
- Seeds are flattened, surrounded by soft pulp that is attractive to brush turkeys.

A simplified vegetative key to the common 'look-alike' vines that may be associated with *P. praevenosa.*

1. Tendrils present	e.g. *Cissus* spp.
Tendrils absent	2
2. Leaves opposite on stems	e.g. *Parsonsia* spp. Apocynaceae
Leaves alternate on stems	3
3. Sub-basal vein apex reaching margin less than 1/3rd length of leaf from base	Menispermaceae
Sub-basal vein apex reaching margin near mid-length of leaf	4
4. Petioles expanded at apex or both ends	*Hypserpa decumbens*
Petioles not expanded, often twisted or base expanded on stem	5
5. Leaves rounded, petiolate	Menispermaceae
Leaves longer than wide, not petiolate	*Pararistolochia praevenosa*

3.8 Food Plants: Central Importance in Conservation Planning

Developing a conservation management plan for any phytophagous insect requires a thorough understanding of the identities and the ecology of its food plants. With the birdwing butterflies, the identities of *Aristolochia* species as food plants for the larvae need to be determined accurately in view of the monophagous needs of some of the species that thus depend on maintenance of a very specialised and specific interaction. But as plant names change and new species of vines are described, development of recovery plans using the 'correct' vines for the butterflies becomes a challenge, especially when the food plants are to be propagated as part of the recovery process. For example, all species of Aristolochiaceae from Australia and New Guinea were initially placed in one genus, *Aristolochia,* before they were reviewed taxonomically by Parsons (1996b). Some of the vine species were then un-named or incorrectly thought to be forms or subspecies of known species. Parsons (1996b) described several new species from Papua New Guinea and Australia and he reviewed the genus, splitting off some species from *Aristolochia* and combining them with a different genus, *Pararistolochia*. Other new species were described later by Ross and Halford (2007), including the low-growing *Aristolochia* spp. from South-eastern Queensland, *A. meridionalis* and its subspecies.

The formal transfer of *Aristolochia praevenosa* to the genus *Pararistolochia*, the raising of *A. laheyana* to specific rank and its recombination as a species of

Pararistolochia, and the separation of *P. laheyana* from the northern *P. deltantha* provided an essential and – for the first time – reliable taxonomic basis for planning recovery of the Richmond birdwing in helping to recognise the food plants accurately and consistently. It was also essential to discover or predict the original natural range for these two species of food plants. Estimates for abundance of *P. laheyana* were relatively easy to obtain; as a montane vine occurring mainly above 600 m and with excellent botanical records, the natural distribution of this food plant was relatively easily confirmed. However, the natural distribution of *P. praevenosa* was by no means as clear: (i) as noted above, birdwing specimens had been collected or reliably observed in areas well to the north, south and west of specimen-backed records, and outside of the natural range for the known food plants, and (ii) repeated visits to these 'outside' areas by experienced botanists failed to locate any naturally-occurring vines (except for the observation of *P. praevenosa* at Mary River Heads: Sands and Scott 2002).

The first plans for defining the range-wide arena for recovery of the Richmond birdwing were therefore based on known natural distributions of the vines (in 1996), the tenure and safety of habitats from future disturbance, and how to overcome the complexities of growing, dispersing and establishing sufficient food plants to offset past losses. The considerable numbers of vines needed for each recovery area, providing connectivity between fragmented populations and developing educational programmes to popularise focussed conservation efforts, provided challenges that were then thought feasible to address.

Correct identification, conserving natural habitats and propagation of the food plants had been seen as the collective basis for recovering the butterfly. Because the decline in distribution and natural abundance of *P. praevenosa* was seen to be closely associated with the population trends in the butterfly, early focus was given to propagation and cultivation of the food plants to recover the butterfly, as suggested by Sands (1962). In the 1980s both *P. praevenosa* and *P. laheyana* were successfully grown from seeds and cuttings, but the ecological requirements for successful cultivation and planting out of the vines were not well understood. First, collecting plant materials from the wild could only carried out in south-eastern Queensland when appropriate permits (for example for study of protected species, or access to national parks) had been issued. At an early stage the wisdom of moving plant stocks from one area to another raised concerns about losing the integrity of local genotypes ('local provenance'), and the possible detrimental effects on indigenous plants in any areas for introductions was always considered. Local morphological variation was already known in both vines; leaf shape and size in *P. praevenosa* and flower shape and colour in *P. laheyana*. But, fortunately for the project, expert advice was obtained from Estelle Ross, a botanist with the Queensland Herbarium, who had observed extensive variation in both species of vines throughout their range. Subsequently, preliminary genetic studies (by Stephen Petrovich) on *P. praevenosa* indicated that although genetic variation within populations of the vine was considerable, any fixed differences between samples of vines from near the extremes of the range in Queensland could not be detected or confirmed.

The evidence that planting vines could encourage the butterfly to extend its distribution was a major factor of the project. Gary Sankowsky, who had a native plant nursery at Tamborine Mountain, began growing *Pararistolochia praevenosa* in the 1970s. Kate and Tony Hiller at Mount Glorious then propagated both this species and *P. laheyana* (then referred to as *A. deltantha* var. *laheyana* [Stanley and Ross 1995]). In the late 1970s, Sands obtained seedlings of *P. praevenosa* from Sankowsky and began planting them in his garden at the foot of Mount Coot-tha. After a number of years these vines became sufficiently established and the butterflies began laying their eggs on the foliage by about 1984, demonstrating that planting vines can attract the butterflies into gardens. Before long the vines flowered and began setting seed. Sands also obtained seed and plant material from a number of other locations and built up stocks of seedlings. The main source of supply was from vines growing at Nerang where abundant seed capsules were easily obtained. By about 1988, Sands began campaigning for people to grow the vines in their gardens

In 1994, Balunyah Nursery at Coraki, NSW (Fig. 3.10) began a programme cultivating both food plants for the Richmond birdwing and concentrated on propagating *P. praevenosa*, under guidance of Scott Heard, Nursery Manager, and Bob Moffatt, Senior Ranger with the NSW Parks and Wildlife Service at Alstonville. The lowland vine *P. praevenosa* was easily propagated at Coraki, and the potted vines at least 2 years old were successfully planted by the public and used for school projects. These vines originated from various localities in northern NSW, Nerang and Tamborine Mountain, Queensland but were mostly grown from seed capsules collected from the wild. Moffatt and a colleague dug up and potted more than 600 seedlings grown by Sands, in order to get the vine cultivation project underway. He also collected plant material from numerous locations in northern New South Wales that were given to Balunyah Nursery to use for stock. Initially *P. laheyana* proved to be more difficult to grow from cuttings and it did not thrive when grown at lower elevations, but some plants from the Richmond Range were successfully propagated from seed capsules. *P. laheyana* was not widely sold or distributed to the public but later, in 2006–2007, this species was easily propagated at Toowoomba by Hugh Krenske for distribution to private properties and reserves on the Main Dividing Range.

By 2001 sales and planting of more than 32,000 vines of *P. praevenosa* in gardens and at bush regeneration sites slowly but surely provided corridors between habitats and supporting new colonies. In 1991, Moffatt provided 40 schools in the Richmond River Valley area with six vines each to plant in their school grounds. This schools involvement stimulated a high level of community interest. As an example, one small country school, Modanville Public School, just north of Lismore planted many vines in the school grounds. Their teacher (Julie Short) organised the children to produce a special dance about the 'Plight of the Richmond birdwing' that the children performed at many functions throughout the region.

Identifying areas where the alien Dutchman's Pipe vine was abundant became important so that efforts to plant *P. praevenosa* were not wasted due to the preference for birdwing butterflies to lay on the poisonous vine instead of *P. praevenosa*, when

Fig. 3.10 Entrance to Balunyah nursery, New South Wales: the first nursery to propagate *P. praevenosa* and *P. laheyana* (*left* to *right* R. Moffatt, S. Heard, W. Vidler)

both plants were growing in the same area. Options in such areas begin with a control programme for the poisonous and weedy vine by cutting the stems, applying herbicide to the freshly cut area, or digging out root stocks, to reduce the abundance of the weed, and eventually to eradicate it from areas being rehabilitated, requiring long-term efforts by community members. One strategy that proved to be helpful was to truncate the Dutchman's Pipe vine close to the ground or no higher than 1 m from ground level, during the flight periods for the birdwing. In the 1990s, in the Burleigh Heads National Park, this truncation method proved to a useful, but temporary, way of deterring female birdwings from ovipositing on the poisonous vine. It was based on the preference by birdwing female butterflies to oviposit on the natural food plants more than 1 m above ground level. Provided the leaf quality of *P. praevenosa* is optimal for attracting oviposition, the average preferred height above ground for oviposition is between 1.5–3 m.

3.9 Propagation and Cultivation of the Food Plants

Growing *P. praevenosa* and planting it in suitable areas as a food for the larvae of Richmond Birdwing Butterfly, can contribute to rehabilitation of the butterfly and reduce the likelihood of its extinction. Provided there are breeding colonies within about 30 km of sites selected for planting, it has been presumed that the wandering female butterflies can eventually find the planted vines to lay their eggs, if the vines are healthy. The assisted movement of adults or larvae was not recommended while the research on inbreeding was continuing.

Pararistolochia praevenosa has become rare due to the clearing and disturbance of its rainforest habitats, and by urban and commercial development, forestry and mining or inappropriate burning, from which the vine does not recover. In Queensland permits are required: (i) to collect or take any parts of the vine from the wild, and (ii) a Permit to Propagate is required if vines are to be propagated for dispersal or commercial purposes. The first Birdwing Butterfly vines were grown

Fig. 3.11 Propagation of *Pararistolochia praevenosa*: (**a**) a struck cutting (G. Wilson); (**b**) seedlings in trays before individual potting; (**c**) nursery potted vines ready for distribution; (**b**, **c** at ProPlant nursery, courtesy of G. Einam)

from seeds and cuttings originating from near Nerang and Tamborine Mountain, Queensland and from near Lismore, New South Wales. Balunyah Nurseries (Coraki, NSW), Currumbin Sanctuary (Gold Coast, Qld) and ProPlant Nursery developed the best methods for growing the vines from seeds and cuttings, and are mostly similar to those described below (Fig. 3.11).

The now largely standardised methods for propagation and planting out of *P. praevenosa* and *P. laheyana,* from seeds or cuttings, were developed initially by Scott Heard, Manager of Balunyah Nurseries, and these were later modified after experiments conducted by students involved in the CSIRO Double Helix Science Club's birdwing project in the 1990s (p. 116). The methods have since been used by nurseries to guide their own propagation of *P. praevenosa* and *P. laheyana*. Full details of all these methods are given as Appendix 1. This summarises the contents of advisory papers developed at community workshops, and distributed widely, and also shows the sensitivity and attention to detail that is needed for success.

Chapter 4
The Natural Habitats and Resources for the Richmond Birdwing

4.1 Introduction: Ecosystems Supporting the Richmond Birdwing and Its Food Plants

In this chapter we provide background information on the environments frequented, or historically frequented, by the Richmond birdwing, to furnish the ecological context within which efforts for the species' conservation are being undertaken. The major focus addresses the supply of the most critical consumable resource, the vine *Pararistolochia praevenosa*, and the environments and vegetation associations in which it thrives. Techniques developed for propagation and plantings (Appendix 1) to contribute to the understanding of habitat enhancement and extension and their roles in defining suitable environments are also discussed. As with any specialised insect herbivore, the nature of threats to the food plant(s) and prospects for mitigation and recovery must be evaluated before recovery is attempted. In the case of the Richmond birdwing, its lowland food plant has become rare in the wild and is considered to be at risk in Queensland. The birdwing recovery programme has therefore also focussed on understanding the ecology of the food plant and protecting remaining suitable habitat patches, as well as on propagating more food plants and managing the ongoing threats to breeding birdwing populations.

O. richmondia is known to breed wherever the lowland *P. praevenosa* occurs in sufficient numbers (about 30 or more vines per patch) to support a population of the butterfly. However, without sufficient food plants or corridors to support movement of adults, inbreeding depression occurs within very few generations. Most birdwing habitats are in riparian rainforest growing on alluvial soils, or on basalt slopes not associated with water courses, but occasionally the vines grow in open, wet coastal woodlands edging rainforest, where fire has been excluded by large rocks and boulders. These habitats must also be within the 'climatic envelopes' that support survival of all birdwing stages, and the feeding and reproduction of adults. With the

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exception of the occasional, but probable dry-country habitats with the low-growing vines *Aristolochia pubera* and *A. meridionalis* (Chap. 3), the major rainforest habitats for *P. praevenosa* characteristically support a variety of shrubs, trees, sedges and vines that are adapted to growing on well-drained (but permanently moist) nutrient-rich soils with high water tables.

Climatically, the subtropical region experiences cool winters and warm to hot summers, unlike other parts of Australia except for the high and cool parts of tropical northern Queensland. Moderate to high annual rainfalls of 800–1,500 mm occur in south-eastern Queensland, whereas in parts of montane northern NSW, the average rainfall may reach 1,800 mm. Rainfall regionally is dependent on latitude, elevation, proximity of mountains to the coast (and aspect of slope); rivers, catchments and other landforms. The climate suitable for the lowland *P. praevenosa* is 'sub-tropical', indicated by the natural distribution of the vine (Fig. 3.2, p. 58) in areas with warm and moist summers and cool winters. The vine does not occur on the coast among botanically similar ecosystems north of Bundaberg, Queensland or south of Grafton, New South Wales (for example, at Coff's Harbour) indicating that its distribution is climatically limited. Other than for the outlying tropical population of *P. praevenosa* near Lake Eacham (p. 58), the vine is only known to occur at those elevations where the temperatures are much cooler than the surrounding lowlands, and somewhat similar to the sub-tropical parts of south-eastern Queensland. The subtropical birdwing food plants occur from sea level to about 600 m, rarely more than 60 km from the coast, in areas with an average annual rainfall above 900 mm, and mostly above 1,200–1,500 mm. In lower rainfall areas the vine only grows close to watercourses and on embankments where the moisture supports other rainforest plants with similar requirements, but in higher rainfall areas the plants will grow on slopes or cliffs where underground moisture is always present. The environmental conditions suitable for *P. praevenosa* appear to relate mostly to the climate and necessary pre-disposing conditions of soils that will support survival and germination of seeds and seedlings. In particular the nutritional requirements appear to be unusual for a rainforest plant and this is an area of research requiring much more information before the needs of the vine, its germination and seedling survival can be understood and applied to cultivation.

The amount of light reaching the wild vines influences the flowering, and the majority of flowers on any vine are produced on the most exposed terminal shoots. The same correlation applies when vines are cultivated, often flowering best in relatively open, exposed areas. Pollination may also be more effective on cultivated vines when they are exposed to moderate amounts of light, especially when vines are kept well mulched and free of weeds. Despite evidence for reduced pollination and seed set in the wild since the 1980s, vines in shaded canopies of 'old growth rainforest' continue to produce a few seed capsules. Light may influence the attraction of pollinators to flowers and the subsequent formation of healthy seed capsules. Once seeds have germinated in soil, light also plays an important part in the growth rate of seedlings or young vines of *P. praevenosa*. If seedlings develop under shaded canopies, the growth can be very slow regardless of existing suitable nutrients, moisture and drainage. In common with many rainforest plants, germination of seeds and rapid growth occurs most often in places where a limb or tree has fallen, providing a temporary ‘light gap’ to illuminate the ground surface. Similarly, seed germination can be frequent at the edge of rainforest canopies, allowing light into areas where brush turkeys have been scratching the soil containing seeds. Brush turkeys are attracted to the pulp from fallen seed capsules and also to the soils where seedlings are actively germinating or growing in natural bushland or gardens.

4.2 The Bioregions and Limited Distribution of Vines

Subtropical landscapes covering the coastal plains, waterways, hills and mountains of north-eastern NSW and south-eastern Queensland support some of the richest biodiversity in Australia, with the range of endemic invertebrates in this region as significant, or sometimes more so, as the species of the wet tropics of northern Australia. The Richmond birdwing and its lowland food plant originally occurred between the eastern slopes of the Main Dividing Range and the eastern coast in northeastern NSW and southeastern Queensland. The two state regions occupied by the butterfly were affiliated with several major river systems with their headwaters descending eastwards from the Main Divide, draining more or less towards the coast. From north to south the major river systems (Fig. 4.1) have broad, nutrient-rich and moist alluvial soils on flood plains, often surrounded by volcanic ranges. In Queensland these are the Mary, Stanley, and Brisbane Rivers and in NSW, the Tweed, Richmond and Clarence Rivers, based on the major catchments. These bioregions include the known distributional boundaries of the Richmond birdwing butterfly and its food plants, as well as many other endemic subtropical insects. Past climates, soils and natural (that is, not human-imposed) fire regimes are the major forces that influenced the evolution and diversity of the Australian plants and animals. The southeastern part of Queensland has been considered a distinct bioregion with Regional Ecosystems (Bean et al. 1998; Sattler and Williams 1999), based on plant species and plant communities. Included in this subtropical bioregion, is a semi-rectangular area (about 330 km long and 130 km wide) bounded to the east by the Pacific Coast, to the west by the main Divide, and extending south from the Mary River to the Queensland-NSW Border. In NSW, a similar bioregion extends west from the Tweed River, to the Main Range and Richmond Range, south to the Clarence River. Rainfall in Queensland is seasonally moderate near Brisbane (approximately 1,000 mm) but higher and annually more uniform (ca 1,500 mm) to the north and south of Brisbane. In NSW high rainfall occurs from the State border to the Richmond River, but it declines south in the Clarence River Catchment and on the floodplains approaching Grafton.

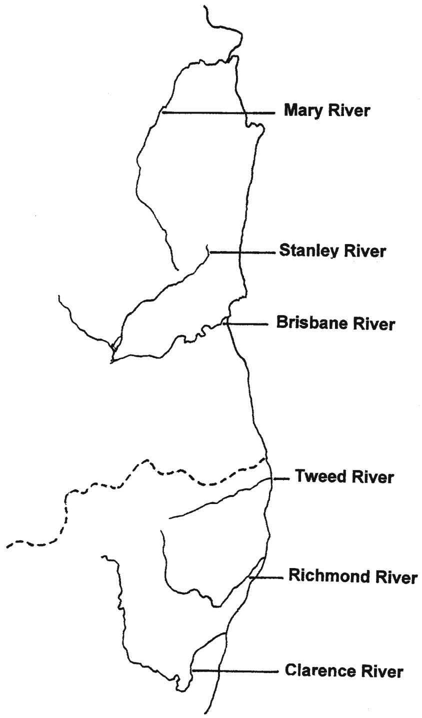

Fig. 4.1 Major river systems in region, as possible guide to restoration sites. Note that Stanley River is a tributary of the Brisbane River (State border indicated by dashed line)

In layman's terms, the major habitats supporting breeding populations of Richmond birdwings are: (i) riparian rainforest, growing on steep embankments or alluvial slopes; (ii) floodplains, with high water tables where rainforest often merges with riparian slopes; and (iii) basaltic caps and rock-strewn (volcanic) steep slopes. The Main Dividing Range supports many unique species of invertebrates and plants adapted to the cooler and wetter climate, especially near the Queensland-New South Wales (NSW) border. Biodiversity is especially rich in the area where the Macpherson Range intercepts the Main Range, near Mount Barney, and to the east where a volcanic rim encircles Mount Warning, the core of an extinct volcano. In NSW, Mount Warning was the volcanic core and origin of basaltic flows that formed rich soils supporting the habitats for the Richmond birdwing butterfly. In south-eastern Queensland, including the Glasshouse Mountains and north to Mount Eerwah, remnants of earlier volcanic plugs and basaltic flows (Willmott 2007) have contributed to the formation of two sub-coastal ranges, the Blackall and Conondale Ranges (Fig. 2.10, p. 47). Their rich soils and high rainfalls support suites of distinctive plants and subtropical invertebrates. Extending to the north and from west of Brisbane, the dryer D'Aguilar Range supports habitat remnants (including those of the Richmond birdwing) in the very few protected areas, near Mount Glorious, Mount Mee and Mount Coot-tha (formerly referred to as part of the 'Taylor Range'). However, reflecting their proximity to Brisbane these areas have suffered most from logging, farming, burning, weeds and urban development. Several species of insects are known only from the D'Aguilar Range (for example, the wood moth, *Endoxyla pulchra* (Rothschild) Cossidae), and may now be extinct, and the habitats for many other Lepidoptera are few, fragmented or confined to the northern end of their original range.

The underlying rocks and soils supporting naturally-growing *P. praevenosa* have several characteristics in common but the vines grow only on well-drained soils that do not dry out. However, they never grow on flat and swampy soils and the slopes preferred have high underground water flows. Sub-tropical rainforest plant communities are the basic arenas for the Richmond birdwings and habitats for its lowland food plant vine.

These ecosystems were designated by the Australian Commonwealth Government as Critically Endangered Ecosystems (2011) and only very small areas remain intact in Queensland and New South Wales. The formal title for these ecosystems, declared on 25 November 2011, is 'Lowland Rainforest of Subtropical Australia', with the comment that the epithet 'Subtropical' is used to describe the climatic zone in which the community generally occurs, rather than a specific kind of rainforest. The advice to the Minister preceding listing noted its primary occurrence from Maryborough to the Clarence River, with isolated more southerly outliers, on basalt and alluvial soils. Although not mentioning *O. richmondia* specifically, that advice noted the substantial number of species found there (63 plants, 42 animals) that were listed under national or state legislations by early 2011. Many of the animals and plants in these ecosystems continue to be threatened by various commercial activities, fragmentation, weed invasions and human 'use' of the natural resources, such as mining of volcanic rocks for road bases, and unregulated horse and bike riding. The advice also acknowledges that 'Fragmentation can affect invertebrate species dramatically as they are short-lived and sensitive to fine-scale environmental variation' (p. 20). The community was declared eligible for listing on four of the Act's criteria: (Criterion 1) 'decline in general distribution is severe'; (Criterion 2) 'geographic distribution is very restricted and nature of the distribution makes it likely that the action of a threatening process could cause it to be lost in the immediate future'; (Criterion 3) 'the decline of functionally important species is severe and restoration is unlikely to be possible in the near future'; (Criterion 4) 'the ecological community has undergone a severe reduction in community integrity such that regeneration is unlikely within the near future'. Lack of quantitative information precluded eligibility under the other two criteria referring to rate of detrimental changes and quantitative estimates of probability of extinction. It is hoped that the EPBC designation will ensure protection of remaining natural fragments of the rainforests in subtropical regions in a way similar to the protection requirements of tropical rainforests of northern Queensland. However, the Minister decided not to have a recovery plan for this ecological community as 'the planning, implementation and coordination of recovery actions does not involve complexity beyond that which can be managed through existing management plans and processes'.

The soil types most favoured by *P. praevenosa* are usually rich in nutrients and decomposing plant materials. Preferred are basalt 'basic' soils with a pH between 6.6 and 6.8, on which vines may form large colonies of 'old growth birdwing vines', sometimes with 50 or more old stems arising from rhizomes in clumps (Fig. 4.2). In the old vines**,** upright stems are often widely-spaced when arising from rhizomes or branch laterally near the bases of the stems. In the more acidic soils (pH 6.2–6.6), the vine densities become fewer as the pH decreases. *P. praevenosa* is naturally most abundant on moist/wet volcanic soils, particularly the basaltic soils on slopes (including those above sea fronts), caps and flows. Volcanic soils derived from basalt or rhyolite, and low in silica, are those most commonly associated with *P. praevenosa* but occasionally the food plant will grow on soils derived from metamorphic rocks, or rarely, soils based on shale, sandstone or sandy loam. The main features of the associated rainforest communities relate to the permanent underground moisture and flows, and streams with some flow and little stagnation. Vines often grow on moderately or steeply-sloped embankments, or in riparian vegetation near streams. A further 'preference' for the vines is rhyolite soils edging stream embankments, followed by nutrient-rich riparian alluvium supporting plant species with similar environmental requirements.

Fig. 4.2 Old vines of *P. praevenosa* in the field: (**a**) vines growing into roots of a fig (*Ficus virens* Aiton) supporting a mature vine of *P. praevenosa* (P. Grimshaw); (**b**) vines ascending into forest canopy (P. Grimshaw)

The habitats thereby range from flat, flood-prone plains to steep volcanic slopes near the sea and mountainous country. Rarely are old nutrient-rich sand dunes, or shale-based soils colonised. Least commonly the vine occurs in rainforests growing on old, nutrient-rich and coastal sand dunes, or sand over volcanic soils. These sand-based habitats are rare and a few that were formerly present near the coast in Queensland have now been destroyed by sand mining, logging, weed invasions and urban development. One such habitat remains relatively intact at Cudgen Nature Reserve, NSW but a similar old sand dune system at Point Arkwright, Queensland, with many rare plants

Table 4.1 Indigenous nectar-producing flowers most attractive to adult *Ornithoptera richmondia*

Common name	Scientific name
Blue Quandong	*Elaeocarpus grandis* F. Muell. Elaeocarpaceae
Black Bean	*Castanospermum australe* Hook. Fabaceae
White cedar	*Melia azedarach* L. var. *australasica* (Francis). Meliaceae
Red cedar	*Toona australis* (F. Muell.) Haines. Meliaceae
Eucalypts	*Eucalyptus* L'Her. spp. Myrtaceae
Bottlebrush spp.	*Melaleuca* L. spp. Myrtaceae
Brush Cherry	*Syzygium australe* (Link) B. Hyland. Myrtaceae
Weeping Lillipilly	*Waterhousia floribunda* (F. Muell.) B. Hyland. Myrtaceae
Native Frangipani	*Hymenosporum flavum* (Hook.) F. Muell. Pittosporaceae
Red Silky Oak	*Alloxylon pinnatum* (Maiden & Betche) P.H. Weston &Crisp (>600 m). Proteaceae
White Yiel-Yiel	*Grevillea hilliania* F. Muell. Proteaceae
Grevillea spp. and hybrids	*Grevillea* J. Knight spp. Proteaceae
Wheel of Fire	*Stenocarpus sinuatus* (Loudon) Endl. Proteaceae
Butterfly Bush	*Pavetta australiensis* Bremek. Rubiaceae
Pink Euodia	*Melicope elleryana* (F. Muell.) T.G. Hartley. Rutaceae
Native Tamarind	*Diploglottis australis* (G.Don.) Radlk. Sapindaceae
Grass Trees	*Xanthorrhoea* Sol. ex Sm. spp. Xanthorrhoeaceae

affected, was partly destroyed for housing development (Sands and Scott 2001). *P. praevenosa* does not grow on alkaline soils such as limestone-based soils and prefers almost neutral, slightly acidic soils. *P. praevenosa* is sometimes protected from being burnt by large volcanic rocks surrounding the base of the vines.

4.2.1 Flowers as Nectar Sources for Adult Birdwings

The Richmond birdwing will search for flowers of many rainforest trees close to the breeding sites, or travel considerable distances into more open or dryer areas to obtain nectar from woodland species or even exotic plants, for example lantana. However, rainforest flowering trees are the favoured sources of nectar for adults in lowland birdwing habitats (Table 4.1).

Flowering by *Eucalyptus grandis* W. Hill occurs intermittently but this species is an important source of nectar for adults, while other eucalypt species growing outside of the rainforest, are visited. The Black Bean, *Castanospermum australe* Hook., is a prolific flowerer but it is very seasonal (November), producing its red and yellow flowers abundantly and often visited by birdwings and birds when both are seeking nectar at the same time. Another important source of nectar is the native frangipani, *Hymenosporum flavum* (Fig. 4.3), a hardy tree producing cream flowers, darkening to yellow and produced in great profusion in spring. It is sometimes the only plant providing nectar for adult birdwings at that time of the year and during periods of prolonged drought. The flowers of *Melaleuca quinquenervia* (Cav.) S. T. Blake, are also a favoured source of nectar, across a wider seasonal range.

Fig. 4.3 Flowers of *Hymenosporum flavum*: an important nectar source of birdwings in spring

The plants most often associated with *P. praevenosa* were discussed by Sands and Scott (1996) and the list was revised in 2010 (see Table 4.2) Some palms are commonly associated with *P. praevenosa* and they can often tolerate flooding, desiccation and/or fire. For example, *Archontophoenix cunninghamiana* is commonly associated with the vine. The palm is very fire sensitive and usually grows close to running water where the palm can tolerate regular flooding, unlike *P. praevenosa.* The Cabbage palm, *Livistona australis,* is sometimes associated with *P. praevenosa* (for example, in Burleigh Heads National Park, Queensland), particularly when in more open types of rainforest, or areas exposed to sea mists. This palm can regrow after fire and sometimes occurs with *P. praevenosa* on flat alluvial soils or moist volcanic soils on moderate slopes. *L. australis* is one of the few rainforest palms in Australia that can recover after being burnt, and is sometimes seen when rainforests are burnt during forestry operations aiming to induce seedling germination of eucalypts. Both *A. cunninghamiana* and *Livistona australis* occasionally grow in the same areas as *P. praevenosa*. The walking stick palm, *Linospadix monostachya*, a small understorey palm, provides a good indication for types of soils that are most suitable for *P. praevenosa*, where it may occur uncommonly at the higher and wetter sites and on soils rich in nutrients.

4.2.1.1 Plants Supporting Climbing Vines

The most abundant rainforest trees and vines associated with *P. praevenosa,* and those that provide support for the climbing vines, are listed in Table 4.2. Support to *P. praevenosa* by other vines is often mutual, adding strength as they twine into the canopy. The common vines associated with *P. praevenosa*, are referred to as 'companion vines', and include a prickly-stemmed palm, the 'lawyer vine' *Calamus muelleri*, and 'supplejack', *Flagellaria indica*, a slender-stemmed, bamboo-like vine. *F. indica* is one of the most reliable 'indicator' plants that is used when searching for the environmental conditions suited to *P. praevenosa*. Hoop Pine (*Araucaria cunninghamii* Aiton ex A. Cunn. Var. *cunninghamii*) and Flooded Gum (*Eucalyptus grandis*), although often found in rainforests with *P. praevenosa*, do not alone

Table 4.2 Plants often associated with the habitats of *P. praevenosa*

Trees and shrubs
Cordyline R. Br. spp. Agavaceae
Araucaria cunninghamii Aiton ex G.Don. Araucariaceae
Aphananthe philippinensis Planch. Cannabacaeae
Elaeocarpus grandis F. Muell. Elaeocarpaceae
Sloanea woolsii F. Muell. Elaeocarpaceae
Eupomatia laurina R. Br. Eupomataceae
Castanospermum australe A. Cunn ex Muo. Fabaceae
Cryptocarya hypospodia F. Muell. Lauraceae
C. obovata R. Br. Lauraceae
C. triplinervis R. Br. Lauraceae
Neolitsea dealbata Br. (Merr.) Lauraceae
Endiandra pubens Meissner. Lauraceae
Argyrodendron trifoliolatum F. Muell. Malvaceae
Wilkiea macrophylla (R. Cunn) A.DC. Monimiaceae
Ficus coronata Spin. Moraceae
F. fraseri Miq. Moraceae
F. watkinsiana Bailey. Moraceae
Ficus macrophylla Pers. Moraceae
Streblus brunonianus (Endl.) F. Muell. Moraceae
Eucalyptus grandis Hill ex Maiden. Myrtaceae
Syzygium francisii L.A.S. Johnson. Myrtaceae
Waterhousia floribunda (F. Muell.) B. Hyland. Myrtaceae
Grevillea robusta A. Cunn. ex R. Br. Proteaceae
Arytera lautereriana F.M. Bailey (Radlk). Sapindaceae
Diploglottis australis Cunn. (Radlk). Sapindaceae
Dendrocnide excelsa (Wedd.) Chew. Urticaceae
D. photinophylla (Kunth) Chew. Urticaceae
Gmelina leichardtii (F. Muell.) Benth. Verbenaceae
Vines and palms
Deeringia arborescens (R.Br.) Druce. Amaranthaceae
Melodorum leichhardtii (F. Muell.) Benth. Annonaceae
Archontophoenix cunninghamiana (H.A. Wendl) H.A. Wendl & Druce. Arecaceae
Calamus muelleri H.A. Wendl. Arecaceae
Livistona australis (R. Br.) C. Martius. Arecaceae
Flagellaria indica L. Flagellariaceae
Carronia multisepalea F. Muell. Menispermaceae
Pleogyne australis Benth. Menispermaceae
Sarcopetalum harveyanum F. Muell. Menispermaceae
Hypserpa decumbens (Benth,) Diels. Menispermaceae
Cissus antarctica Vent. Vitaceae
C. hypoglauca A. Gray. Vitaceae

provide the support necessary for vines ascending into the canopy. Many species of trees and shrubs serve as natural supports for *P. praevenosa* in rainforest and only a few are referred to here. One of these, the 'Gympie stinger' *Dendrocnide excelsa*

(Wedd.) Chew is an important support tree and curiously, it has been the fear by loggers of making contact with the foliage and stems of this tree that has spared both the stinging tree and several of the 'old growth' birdwing vines. Rainforest-adapted eucalypts including *E. grandis*, do not appear to act as supports for vines, probably due to their smooth, broad trunks preventing adhesion for climbing by the vines. Several different species of *Ficus* are important as supporting frameworks for *P. praevenosa*. They include *F. virens* Aiton, a deciduous tree that in spring as temperatures rise, promotes rapid growth of *P. praevenosa* following leaf fall, and when sunlight reaches the vine apices. The fall of pupae attached to dropping leaves from this tree is sometimes avoided by the larva spinning silk around the leaf petiole and then silk is spun to circle the stem, preventing both leaf and pupa being shed. Other tall species of figs, *Ficus rubiginosa* Desf. ex Vent. form *rubiginosa, F. superba* var. *henniana* (Miq.) Corner, *F. macrophylla* Desf. ex Pers. form *macrophylla* and a strangler fig, *F. watkinsiana* F.M. Bailey, will support large and ageing vines, often with the stems arising from between the buttress roots of figs where they are largely protected from disturbance. The large buttress roots of figs provide pockets of shelter and permanent moisture that assist survival in dry periods and the buttress roots may also protect the moist leaf litter, enabling seedlings to survive. The combination of fig buttress roots and roots binding large rocks, provides one of the most important habitats for protection and survival of 'old growth' vines.

4.3 Subtropical Plant Communities Associated with *P. praevenosa* in New South Wales and Queensland

The major structural types of Australian rainforests were broadly proposed by Webb (1978) and described in more detail by Webb et al. (1984). Using this scheme, subtropical habitats for the Richmond birdwing can be referred to as (i) Complex notophyll vine forest – seasonal wet/moist, and (ii) Araucarian notophyll vine forest. In Queensland the plant communities have also been classified according to bioregions, soil types and plant associations. This three-point numerical system has been used to define 'regional ecosystems' (REs); the first number indicating bioregion (12 = SE Qld); the second number, soil types and the third number, plant communities. The constitutions of the various relevant communities are listed in Appendix 2, in which the considerable subtle variety in this botanically rich region is very evident.

4.4 Possible Impacts from Climate Change

Concerns have been expressed by many biologists over the possible ways in which changing coastal climates, driven by the recent and rapid increases in ocean temperatures (currently estimated at around 0.8 °C), are affecting the distribution and survival of plants and plant-dependent animals in Australia. The impacts are likely to be felt most strongly amongst subtropical endemic species having narrow ranges of adaptation to temperatures and moisture, especially when the subtropical ecosystem remnants are already small and fragmented. Prolonged periods of drought between 2002 and 2008 had a particularly serious impact on naturally occurring vines and several growing naturally in Burleigh Heads and Neurum National Parks died completely. For *P. praevenosa,* adaptation to subtropical climates is likely to have determined the distribution of the vine in eastern Australia, with no evidence of this plant occurring between the small area occupied on the Northern Tablelands and the current distribution south of Maryborough. This suggests a former but wider distribution into parts of the tropics. Without further loss of habitats and taking into account the slow reproduction of *P. praevenosa,* the vine may be a candidate for extirpations occurring in the northern parts of its range due to increasing temperatures and to prolonged droughts.

For the birdwing butterfly and its early stages, sensitivity to extreme temperatures outside of previous 'normal' subtropical ranges can be expected to lead to extirpations, even if the food plant can survive and reproduce. The current distribution of *O. richmondia* indicates that the species is adapted to cool winters needed for diapausing pupae but desiccation occurs when temperatures are abnormally high. Emergence of adults usually occurs over a relatively short season (of about six weeks) when day length, temperatures and moisture increase in spring. The winter diapause indicates a life history different from the tropical species, including *O. euphorion*, in which protracted development is temperature dependent. Outside of the natural range of *O. richmondia*, in coastal regions north of Maryborough, climates are unlikely to be suitable; for example erratic emergence of adults would occur following break in diapause throughout the cooler months. Similar disruption in development occurred during the prolonged drought of 2001–2012 in south-eastern Queensland, when occasional winter emergences occurred at times when the individuals were unable to find a mate, and eggs deposited by unmated females were infertile. If climate change disrupts break in pupal diapause over a long period, individuals will not only emerge when densities are too low for reliably finding a mate but mating by siblings is more likely to lead to inbreeding depression. Overall, the disruption to any developmental cycle that leads to protracted emergences of adults is likely to lead to inbreeding effects. Clearly, the details of any such projected impacts must be speculative, and assessed against the mobility of the birdwing and its possible future distribution, as well as that of its critical resources.

The most likely relevant effects from climate change will be on the distribution, survival and reproduction of *P. praevenosa* in subtropical Australia, particularly through its pollinator/s. The vine occupies a definite subtropical 'climatic window'. It is not known from coastal localities north of about Maryborough and the only other northern locality known, the Atherton Tablelands, also has a subtropical climate. Although there are many remaining small pockets of lowland rainforest (such as those near Rockhampton, Mackay and Proserpine) and some on the ranges, there are no records of *P. praevenosa* from these localities, suggesting strongly that the climate, although within apparently suitable ecosystems, may have been too warm for survival and reproduction of the vine. This presumption also applies to several other subtropical plants that are associated with the climatic regions where *P. praevenosa* occurs naturally. With an average increase of only 0.5 °C on the coast, the vines would be unlikely to survive or reproduce north from about Brisbane and on the lower mountains they could also retreat from places such as Eumundi and the Conondale Ranges. Changes in rainfall cycles are also predicted to affect the growth of the vines following climate change, particularly the erratic production of soft leaves that follows long drought periods; the vines are always dependent on abundant moisture.

Other animals are associated with birdwing habitats through regular association or also feeding on vines. Brush turkeys were always present at the natural sites where they provided a major, or the only natural activity (by scratching) that leads to burial and germination of seeds of both *Pararistolochia* spp. On one occasion at Eerwah Vale, Queensland, seedlings were observed germinating on the embankment of a creek, thought to be due to the carriage of the seeds or the capsules downstream by floodwaters. However, this was not a common occurrence and seed recruitment was nearly always only observed very close to the parent plants that were producing seeds. Insects associated with the habitats for the food plants included the minute pollinators of the vines and occasionally the larvae of a moth**,** *Tiracola plagiata* (Walker) (Erebidae), a widespread polyphagous species which is sometimes a serious pest of crops, observed feeding on the young leaves of *P. praevenosa*, particularly during winter months when no larvae of *O. richmondia* are present. In addition, the 'Big greasy' (*Cressida cressida*), will oviposit on small vines (usually < 1 m) of *P. praevenosa* and use the low-growing and younger vines as a food plant for its larvae, especially if they are growing in areas exposed to sunlight, and when growing near the usual food plant, *Aristolochia meridionalis*.

Predatory insects, especially ants, spiders and mites (*Charletonia* sp.) are often seen on the leaves of *P. praevenosa* and at times, may become important predators of the eggs and larvae of the Richmond birdwing (Chap. 2).

4.5 Locating Habitats with the Birdwing Food Plants and Protecting Their Tenure: What Is Now Needed?

Surveys and mapping. Since interest in conserving the habitats of the Richmond birdwing began in the early 1990s, surveys and some distribution mapping of the principal food plant, *P. praevenosa,* have been carried out in the better-known parts of southeastern Queensland, but far fewer records have been accumulated from the remote areas of Queensland and New South Wales. Many of the records have come from native plant enthusiasts, members of Landcare and other community groups. Land with various tenures, including State and council owned parks, forestry areas and private properties has been surveyed for the vines. Participants all helped by gathering information on the whereabouts of the vine and the tenure of the habitats and initially the records were lodged with the Queensland Herbarium. However, it soon became clear that misidentification of vines by non-botanists sometimes hindered assembly of accurate information on *P. praevenosa.* Only the collection of voucher specimens or detailed and close-up photographs could confirm the identities and legal requirement for a permit to collect this protected vine was a deterrent to collection of voucher specimens. By 2000, as good quality and reasonably-priced digital cameras became popular, high resolution close-up pictures enabled increased levels of accurate identification using images of leaves, stems, flowers and seed capsules of the vine. By the time the Richmond Birdwing Recovery Network Inc. (RBRN) was formed in 2005, the identities of vines could be confirmed relatively easily without the widespread need for voucher specimens. Several RBRN members, including Philip Moran and Andrew Wilson, developed simple methods to distinguish common ‘look-alike’ rainforest vines (p. 69) from *P. praevenosa* and these were included with suitable images (Fig. 4.4) in the series of Workshop Supplements. Accurate identification of the poisonous Dutchman’s pipe vine (*A. elegans*) also formed an important part of the workshop proceedings but infestations of this weedy vine were not included in the surveys.

Fig. 4.4 Look-alike vines: Workshop Bulletin (**a**) cover; (**b**) page details to characterise each local species

4.6 Needs for Remnant Habitat Conservation

Australian National Parks have been considered to be the most appropriate tenure to protect natural habitats for fauna and flora in Australia, particularly for those species that are designated as rare or threatened, and those that need specific and/or undisturbed habitats. In the past, Australian National Parks, once designated as protected areas, have been managed as places where the threats to their ecosystems are least, or where threats can be addressed. However, the security of many of these sites began to change in the 1990s with weed invasions, damage from animals such as deer, foxes and hares, and domestic dogs and cats that have become feral. Recent management of many national parks has become seriously deficient with loss of personnel and erosion of support resources and finance, and deliberately-lit fires have sometimes placed pressures on the integrity of these ‘indefinitely-protected’ areas and the survival of many species of plants and small animals. Since 2000 it has become a matter of concern that the tenure of national parks in Australia is not always secure; most are in practice State-owned parks, where management by the state agencies may vary with each government elected, and for which long-term conservation planning and security is not assured.

Only rarely does national parks management in Queensland extend to controlling invasive weeds, exotic animals such as foxes, or excluding fire from fire sensitive ecosystems. Management is needed to protect habitats against these threats when recovering the Richmond birdwing. Very few national parks contain *P. praevenosa* naturally, and fewer than 20 % of the subtropical rainforest communities protected in national parks are known to support the vine. Outside of national parks almost all other habitats for the vine are potentially at risk from clearing of natural vegetation, weed invasion, commercial development and mining. In Queensland the most important areas for long-term protection of habitats and food plants for *O. richmondia* are on privately-owned land and national parks in the Conondale and Blackall Ranges. In New South Wales, the Mount Warning and Broken Head National Parks are the best known habitats already protected as well as several other important protected areas (such as Mount Nardi) of lowland subtropical rainforest that are inhabited by the Richmond birdwing.

For some sites now rehabilitated and planted with *P. praevenosa*, the lack of secure tenure has continued to be of concern, with protection of wild populations of the Richmond birdwing seen as needing securely protected national parks with commitment and obligation to protect the key habitats for the future. However, In Queensland only 4.8 % of the State is currently declared as national parks. The protection of these parks may, since 2012, no longer be sufficiently secure to prevent various new sources of disturbance (now reported to be 'opened up' for recreational activities), following recent suggested changes to usage threatening many species that are dependent on these parks for their remaining habitats. On privately-owned land in Queensland provision has been made for securing tenure of privately-owned land as 'nature refuges', by an individual agreement reached between land owner and government agency, but since 2012, new threats to the stability of this tenure mean that managers of national parks can no longer guarantee habitat security. Despite these concerns, nature refuges established on privately-owned land are believed to be the best way of protecting the approximately 75 % of Richmond birdwing habitats, for areas where *P. praevenosa* is growing naturally. A further option is for landowners to choose to protect patches of birdwing habitat through local council covenants but the security of these is now also in doubt in some municipalities, particularly when ownership is transferred, and new owners have different priorities.

4.7 Restoring Bushland Habitats on Private and Public Land

With fewer than 15 % of known localities where *P. praevenosa* occurs sited in national parks in south-eastern Queensland, planning is needed to: (i) ensure protected areas such as national parks are indefinitely secured against human disturbance, (ii) increase the number of wild vine sites protected on privately-owned land, and (iii) identify suitable government-owned land for rehabilitation as core areas, to be planted with *P. praevenosa*. All categories of land tenure may contribute to such measures to ensure the habitats can be protected against disturbance, and managed to protect the food plants and butterflies. While similar programmes have been in place in Victoria for other butterflies for many years (for example, to protect the Eltham Copper butterfly in Victoria: New 2011c), 'species habitat focus' for conserving and rehabilitating threatened species of invertebrates has not been developed in Queensland. However, one locality in Queensland, the Mary Cairncross Scenic Reserve at Maleny, has expanded an area edging a natural birdwing habitat, by planting a selected area with *P. praevenosa* on a complex of specially-constructed trellises (Fig. 4.5c). By 2009 these plantings had produced exciting results, first by encouraging public interest in planting vines and viewing the butterflies but also evidence that birdwing numbers are stabilizing and perhaps even increasing in the area. Mary Cairncross Scenic Reserve can now be recognized as one of the few secure and government (Sunshine Coast City Council) owned 'core habitats' that are contributing to recovery of the Richmond birdwing. With substantial areas of intact rainforest this Reserve is a wildlife refuge that protects many other subtropical and threatened animals and plants. Emulation of the effort to produce other 'core areas' as major habitat foci for *O. richmondia* is highly desirable.

Fig. 4.5 Trellises constructed in the field for establishment of *P. praevenosa*: (**a**, **b**) recent plantings in a school ground near Brisbane; (**c**) maturing vines in a public area and education deck, Mary Cairncross Scenic Reserve; (**d**) small trellis at site near Brisbane

The twin foci for habitat recovery actions reflect (i) individual sites and (ii) connectivity. The key recovery actions for the Richmond birdwing will both depend on providing sufficient food plants in suitable places to sustain breeding populations of the butterfly throughout its former natural range, whilst also mitigating threats. Riparian vegetation 'corridors' that will allow and promote movement between breeding populations are also essential to facilitate outcrossing between genetically different populations, as a means to prevent inbreeding depression. In addition, 'core recovery areas' are needed where habitat and food plants are sufficient to sustain local breeding as well as enriching 'core breeding sites', areas where breeding has continued but the densities of food plants have been insufficient to sustain local populations indefinitely. Additional flowering trees and shrubs are also needed in some areas despite the often suitable nature of exotic flowering plants that often provide adequate nectar.

Major efforts were made from 2005 to 2009 to plant hundreds of *P. praevenosa* vines, and this proved to be the most popular way of monitoring the health and progress of the vines by members of the community. Sites planted on privately-owned land were recorded on a database as 'links' (with owners' permission) and sites planted on government-owned land were referred to as 'stations'. With more than 2,000 vines planted during that period, monitoring the growth, stagnation or death of vines provided information on a wide range of factors, including the best soils, shading and supports for the vines, to guide future efforts. Most of the causes of vine death were identified. For example, when the disastrous floods in January 2011 swept through south-eastern Queensland, many of the vines were planted too close to the creeks in flood on embankments and were swept away, indicating that vines need to be secured above the 'high-water' levels of creeks when they are prone to flooding. To continue recovery efforts for the Richmond birdwing the methods used for planting *P. praevenosa* in links and stations need to be extended and, if possible, supported by local councils under their plant rehabilitation programmes. In addition, more formal plans are needed to link the fragmented sites, both with planted and natural vines, as parts of corridors to enable breeding colonies to move appropriately and avoid inbreeding depression. This somewhat idealistic approach is 'what is needed' as part of the practical recovery process for the threatened butterfly.

The plans for core recovery sites and habitat stepping stones have driven many of the conservation actions since establishment of the first southern core recovery site at the Canungra military base in early late 1990s. Experience implies that key or core recovery sites should be planted with at least 30 *P. praevenosa* per 'patch' and these maintained (through regular watering and mulching) at each site and spacing between adjacent sites should ideally not be more than 5 km, in 'planted corridors' to ensure the average range of dispersal of butterflies will occur in the areas marked for recovery. Since the interest in conserving the Richmond birdwing began in the 1990s, an overall aim of the project has been to 'Bring the Richmond birdwing back to Brisbane', and to locate and protect any remaining breeding populations in the municipality. Suitable habitats may have been present at Breakfast Creek, or at South Bank, on the Brisbane River but no remnant vegetation survived the floods of 1972. It was not known where the original habitats for the Richmond birdwing were located but it is probable that until the 1940s, suitable rainforest patches in the suburbs supported the butterfly at Ithaca Creek near Bardon, at Brookfield and along Moggill Creek to the west (as evident from the early Illidge [1924a] sightings) near Bulimba Creek to the east and at Mount Cotton to the south of Brisbane. These localities had plant communities suitable for *P. praevenosa*, based on existing plants usually associated with the vine, and historical sightings of adults. Since about 1992, the increasing numbers of enthusiastic conservationists involved in the Richmond birdwing project searched the Brisbane suburbs for remnant patches of rainforest with the food plants, and to identify areas of plant communities where *Paristolochia praevenosa* could be successfully planted. With much clearing and urbanisation near Brisbane that followed observations of birdwings by Illidge (1927), little rainforest vegetation has remained, and the search concentrated on surviving 'habitat indicator' plants (such as *Flagellaria indica*) on the major creeks. In the 1970s and as a result of the 1972 floods in Brisbane, waterways and streams became widened or deepened for flood mitigation; and many streams were confined in pipes and buried before over-laying with urban developments and open parklands. Almost all remaining potential habitats became infested with exotic weeds and this led to clearing and mowing of most riparian vegetation near the City. Planning habitat restoration in Brisbane by planting food plant vines began in about 1978 and plans for identifying potential sites commenced in 1989, after difficulties with producing healthy seedlings had been overcome.

Planting more food plant vines from 2010 is continuing as a key objective for the Wildlife Preservation Society of Queensland, now hosting the community Group, the Richmond Birdwing Conservation Network (Chap. 7). The first 'core' site proposed for Brisbane was the University Mine site at Indooroopilly, close to the Brisbane River and only about 5 km from Brisbane City. Although all natural habitats around Brisbane had been destroyed by about 2000, in 2010 this area at Indooroopilly was identified as capable of providing the necessary habitat for the butterfly and its food plant and it has been planted with more than 80 vines of *P. praevenosa* in a flood-free area, numbers thought capable of supporting a birdwing colony. Several adults have been sighted in Brisbane since the sighting by Jonsson (2008) and birdwing larvae have since been seen in 2010 by Richard Bull, near the core site at Indooroopilly. By taking advantage of the suitable soils, slopes and central location the Indooroopilly site was considered suitable for providing one valuable habitat stepping stone in an old corridor, near the Brisbane River.

In 2005, creek catchments in Brisbane, proposed by members of the Richmond Birdwing Recovery Network for rehabilitation and planting of *P. praevenosa,* included Western Suburbs: Pullen Pullen Creek, Moggill Creek, Cubberla Creek, Enoggera Creek below Enoggera Dam, Ithaca Creek at Bardon; Eastern Suburbs: Downfall Creek, Bulimba Creek; Southern and eastern Suburbs: Buhot Creek, Tingalpa Creek, Oxley Creek, Eprapah Creek in Redlands Shire and Logan River. The western localities were mostly riparian patches edging creeks, and except for Cubberla and Witton Creek, water courses drained areas of riparian rainforest that alternated with dry patches of non-rainforest trees including casuarinas, eucalypts and *Melaleuca* spp., along the creeks. One or two small creeks close to the Brisbane River, rehabilitated and planted with vines over 2005–2008, were badly damaged by floodwaters in January 2011.

The broadscale planting programme began in Brisbane in the Western suburbs by selecting riparian public areas that could be recovered by weed removal, and suitable peri-urban private gardens where remnants and planted native vegetation provided the necessary shading and support for the food plant vines (Fig. 4.6). Finding ways to encourage return of birdwings to Brisbane continues to be a key objective for Network members for the decade from 2010 (Sands 2008) and can only be achieved by: (i) restoring patches of habitats in Brisbane suburbs, and planting adequate numbers of *P. praevenosa,* and (ii) rehabilitating suitable corridors by planting rainforest trees with the food plant vine. A longer-term objective is to promote movement of birdwings through corridors, and to establish breeding colonies between Brisbane, the Gold Coast and Sunshine Coast.

At least one major Core Recovery Site planted with sufficient numbers of *P. praevenosa* and managed for weeds is required for the recovery of birdwing butterflies in each sub-bioregion. For example at least three sites are needed in Brisbane, on the Sunshine and Gold Coasts, and at the base of the Scenic Rim (and foothills of the Macpherson Range), particularly when closing the gap through increasing connectivity in the distribution of the Richmond birdwing from the north and south of Brisbane. Ideally Core Recovery Sites should be spaced within about 30 km of other sites planted with *P. praevenosa* to ensure they lie within the predicted flight range of a gravid female birdwing.

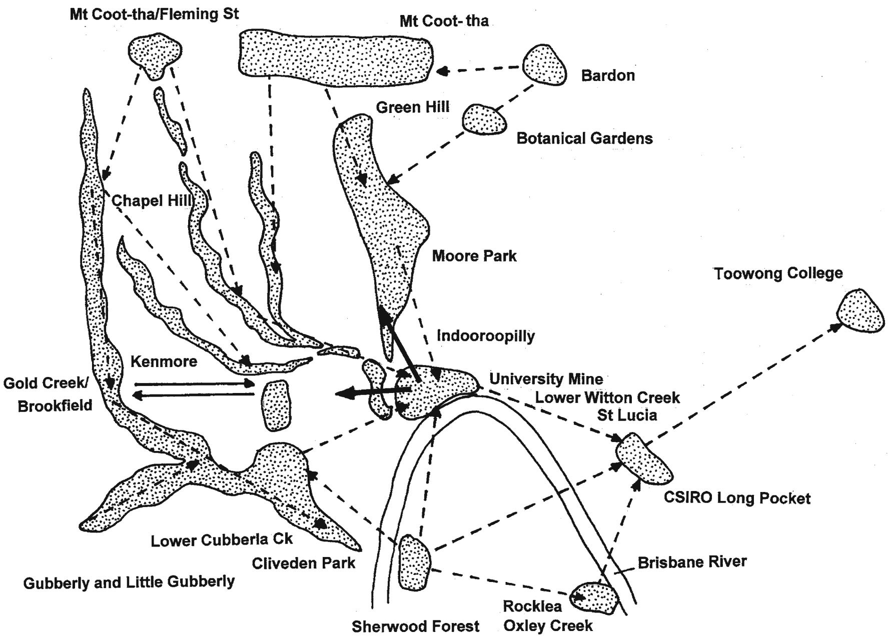

Fig. 4.6 The corridor planning habitat restoration for *O. richmondia* for the western suburbs of Brisbane (Based on map by R. Bull)

4.8 Cultivation and Distribution of the Birdwing Butterfly Food Plants: A Core Recovery Activity

For some time the propagation of the lowland food plant had been considered an important step towards recovering the Richmond birdwing (Sands 1962)**.** The first large-scale propagation of *P. praevenosa* began after 1990 when Moffatt and Sands proposed that the vine could be raised in nurseries in sufficient numbers for planting in school yards, gardens and at bush regeneration sites. Large scale production of vines was seen as a way to compensate for the declining numbers of wild food plants, lost from bushland sites, and to provide a greater abundance of vines closer to urban areas, to encourage the birdwing to breed. Soon afterwards Moffatt provided several schools near Lismore, NSW with the vines to attract the birdwing butterfly into the school grounds. These schools were not far from national parks where the birdwing colonies and natural vines had remained intact, and within a few years the vines he had distributed were large enough to attract the butterflies. This move triggered the expanding interest by students and the community in northern NSW, and later spreading to Queensland. Moffatt was the first to notice on vines in his garden, that the birdwing larvae were cannibalistic, especially when soft leaves were in short supply, and he noted that instars 1–3 readily fed on eggs and larvae and that larger larvae even attacked pupae.

Moffatt provided Balunyah Nursery at Coraki, northern New South Wales, with some of the vines which initiated the larger scale propagation programme. Staff at Balunyah developed methods for propagating the two indigenous species, *P. praevenosa* and *P. laheyana* and, guided by the Manager Scott Heard, by 1993 the Balunyah Nursery had sold 3,500 vines to schools and the community. Within three more years, more than 15,000 *P. praevenosa* vines were sold to the public. The Nursery became well known for its Birdwing Butterfly Vines and the excellent quality of plants. Five other nurseries in northern New South Wales soon followed by propagating *P. praevenosa,* and by 2001 it was estimated that more than 32,000 vines had been sold to the public. Balunyah Nurseries also developed methods to grow the mountain vine, *P. laheyana,* but sales of this vine did not prove to be very popular. However, some colour, size and flower forms were found that could have been of gardener interest, including one discovered in the ranges north of Kyogle, and nick-named ‘Birdwing Buttercup’ by the nursery staff. The impressive yellow flower variety (figured by Sands and Scott 2002) had the potential to become a horticultural novelty as well as a mountain food plant for the birdwing butterfly. Further cultivation of *P. laheyana* was not attempted until about 2005 when Hugh Krenske began cultivating the vine at Toowoomba, for planting on the Main Dividing Range.

In Queensland, stocks of *P. praevenosa* were easily propagated in nurseries and distributed to the public from the late 1990s. The vines originated from various localities in northern NSW, mostly Nerang and Tamborine Mountain, Queensland, often selected by propagating seeds from individual plants that produced healthy capsules. In Queensland, Arthur and Narelle Powter began a major project to propagate *P. praevenosa* following the successes in northern New South Wales.

Powter attended a field day at the Beerwah Field Study Centre where Sands talked about the plight of the Richmond birdwing in south-eastern Queensland, and later observed a small colony of the birdwing butterflies breeding on his property at the foot of Mount Mellum, at the southern end of the Blackall Range. He began collecting seed capsules from his wild vines and started to propagate the seeds, and to distribute the vines locally to the local community with help from Caloundra Council. Powter propagated at least 1,000 vines and planted more than 200 in his own garden, where he observed the butterflies build up in numbers, and where they were often found breeding on every vine that he planted. By 2004 the Caloundra Council (later the Sunshine Coast Regional Council), took on a major role with help from Powter and volunteers, by growing *P. praevenosa* and helping distribute the vines to members of the community. Many others became enthusiastic with the concept that the Richmond birdwing could be 'recovered' on the Sunshine Coast. From 2005, several plant nurseries, including that owned by Gary Einam, have continued to cultivate the vine and produce very healthy plants suitable for planting by members of the community.

Following from the work by Powter, on an adjoining property at Beewah, Ray and Pam Seddon grew many *P. praevenosa* and by 2010 they had distributed for planting at least 11,000 vines, including those planted on a trellis (Fig. 4.5c), designed by Ray and built at Mary Cairncross Scenic Reserve, at Maleny. This Reserve has become an important tourist centre, where visitors can view the relatively natural and intact lowland rainforest shrubs, orchids, ferns and trees; they can watch the marsupials and butterflies, and hear many species of rare rainforest birds. Easily viewed by the public are some 'old growth' vines (*P. praevenosa*) where the birdwings breed on representatives of complex stands of vines that are more than 100 years old, now very rare even in national parks. These natural vines help to sustain local breeding by the Richmond birdwing and their habitat is supplemented by more than 30 vines that have been planted on trellises since about 2005. The Reserve has become one of the most important breeding sites for many species of rare rainforest butterflies and it contributes significantly to recovery of the Richmond birdwing in south-eastern Queensland. Close to Brisbane from 2005 onwards, Richard Bull at Indooroopilly, and Dale Borgelt and Prof. Graeme Wilson, Manager of Moggill Creek Catchment Group's nursery at Gold Creek Reserve, propagated several hundred *P. praevenosa* for local distribution.

In response to publicity, people working on restoring riparian rainforest west of the Border Ranges, reported a significant site for breeding populations of the Richmond Birdwing along Armitage Creek, Canungra. The extensive area with mature *P. praevenosa* vines was considered to be a critical habitat on Commonwealth-owned land for the butterfly in the area. Within a year of clearing of the lantana by Green Corps, the lush growth from the base of the *P. praevenosa* vines began to attract egg-laying birdwings and later supported significant populations of larvae. By 2000, the site had been replanted with a range of native plant species including more than 50 additional *P. praevenosa* vines. The Canungra site later became the most significant breeding area for dispersal of populations north and south of the Gold Coast and into the mountains of the border ranges.

Most of the initial difficulties with propagation of *P. praevenosa* were overcome by nurseries between 1990 and 2010; however these were followed by three simple and important recommendations accompanying protocols (Appendix 1) for planting the vines: (i) young tube stocks should not be used for planting directly into the ground, as substantial mortality commonly ensues, (ii) potted plants grown in large (12 cm or more in diameter) pots should be at least 2 years old before planting, and (iii) dolomite (10 % by volume) should be mixed with soils used to back-fill around the roots when planting in the ground. By 2011, approximately 58,000 vines had been cultivated by nurseries and distributed for planting by the community. Quality vines of *P. praevenosa* have continued to be cultivated by several nurseries on the lower Sunshine Coast and Gold Coast, Queensland and in northern NSW, while the methods for planting out vines into their final positions have overcome the earlier slow growth and wasteful mortality of the vines. By pooling experiences from growers, most limitations to obtaining healthy growth were overcome and only the effects of prolonged drought have continued to have uncertain and detrimental effects on cultivation of the vines. *P. praevenosa* is now regarded as easily propagated but the planting methods require careful attention, not unlike those for many other rainforest plants. Once the vines are planted in their final place, the needs (moisture, nutrients, dolomite mix for backfill, drainage, light etc.) of most rainforest plants are not too dissimilar.

The culture of Birdwing Butterfly Vines has been a strictly not-for-profit exercise, mostly due to the time required (more than a working minimum of 2 years) before the vines are ready to plant out in the ground. As a protected species of plant, the propagation of vines in Queensland requires the issue of permits, or endorsement on permits issued by the State agencies with tags bearing permit numbers: obligations many nursery owners felt were too time consuming for a small financial return. On occasions concerns were expressed by members of the community that they were unable to obtain local provenance vines – believing that each small catchment area might have once had vines with special inherited characteristics. Originally a forestry term, 'local provenance' was not earlier understood in relation to the genetic and phenotypic influences on plant architecture, or suitability for certain soil types. Eventually, most of these concerns were addressed when preliminary studies showed that, while extensive variation could be seen in leaf form, colour of flowers, frequency of flowering and seed capsule formation of *P. praevenosa*, there was no evidence for unique genotypes in any of the populations studied using readily available molecular methods.

In the last 20 years, propagation in Queensland of *P. praevenosa* has stimulated considerable interest among nurserymen, towards growing a range of food plants for the larvae of subtropical butterflies and moths. Butterfly Gardening has become a popular technique for urban gardens and articles now appear in well-known gardening magazines, for Subtropical Gardening (Plant 2012), as well as several books that focus on this subject, for example the books by McDonald (1998) and Schwenke and Jordan (2005). The need for butterfly food plants has challenged many nurserymen and garden enthusiasts, to find and grow other rare plants that were previously considered to be "too hard" to cultivate. Cultivation of *P. praevenosa* is likely to continue as a means of attracting the Richmond birdwing to return to breed in areas where it has become extirpated, to plant in corridors for restoring connectivity between breeding patches, or as a way of reducing the rarity of both butterfly and its food plant. More plant nurseries are always needed to fill the demands for readily available and inexpensive 2 year-old (or preferably slightly older) *P. praevenosa* vines, and to have stocks of potted vines readily available to the public for planting in gardens, and to community groups involved with bushland rehabilitation. Each such nursery must be responsible for obtaining the correct permit, with the relevant permit number attached to the pots or accompanying every vine sold.

4.9 Other *Aristolochia* Species as Possible Food Plants for the Richmond Birdwing

Occasionally plant nurseries have marketed *Aristolochia acuminata* (= *A. tagala*) as a food plant for the Richmond Birdwing, unaware of the toxic properties now known when the females deposit their eggs on young leaves of this plant (Straatman 1962). Curiously although larvae will develop by feeding on its leaves, eggs of the Richmond birdwing and possibly pupae attached to the leaves may suffer when toxic compounds migrate into the tissues of eggs or base of the pupae. This does not occur when the northern birdwings *(Ornithoptera euphorion* and *O. priamus*) oviposit or pupate on the leaves of their indigenous and common food plant, *A. acuminata*. Plant nurseries in the subtropical regions have therefore been asked not to cultivate this tropical vine whereas in northern Queensland nurseries are encouraged to grow and sell *A. acuminata* as a food plant for *O. euphorion*. Experiments with the low scrambling and woodland species, *Aristolochia meridionalis* and *A. pubera,* are continuing. Although both the vines can be grown in pots from seeds, methods to germinate the seeds, maintain the vines in large pots and find out suitable soils for their sustaining growth have not yet been refined. Other species of Australian *Aristolochia* and *Pararistolochia* (such as *P. deltantha*), from northern Queensland and outside of the natural range of the Richmond birdwing, have not yet been evaluated for suitability as subtropical food plants for this birdwing.

There appears to be no appropriate substitute for using the subtropical lowland vine, *P. praevenosa* as the most suitable food plant for cultivation and distribution for planting on private and public land as a means to provide sufficient food plants to ‘bring back’ the Richmond birdwing to breed over its original range in southeastern Queensland and northeastern New South Wales. It may be possible to find more suitable ‘strains’ of this vine for cultivation, for example, forms with softer and more palatable leaves, more suitable for young birdwing larvae, or to select stocks that will survive better through the drought periods now expected to increase over the next decades. Provision of suitable food plants will remain a major focus of the conservation programme.

Chapter 5
Conservation Needs and Early Concerns

5.1 Summarising the Scenario: An Initial Perspective

The general and urgent need for conservation of *O. richmondia* devolves largely on the losses of rainforests in the region, a process that has had severe impacts on many native animals and plants, and for which the Richmond birdwing has become a notable flagship species to publicise the less heralded plight of many other invertebrates, and also some of the basic principles of landscape ecology and the critical specialised needs of interdependences between species in communities. Whilst loss of lowland rainforests of subtropical eastern Australia, and the food plant vine *P. praevenosa* are regarded as principal threats to the Richmond birdwing, the implications of those losses are very broad, despite notional formal protection of the communities. As emphasised earlier, suitable forest areas are now highly fragmented. In Queensland, this type of lowland rainforest survives only as fragments near the coast along Kin Kin Creek, east of Pomona, near Caloundra, and at Burleigh Heads National Park. Lower sub-coastal birdwing habitats are further inland on ridges and low valleys of the Blackall, Conondale and D'Aguilar Ranges, at Mount Tamborine, and NSW Border Ranges. In NSW there are coastal birdwing habitats in national parks, patchily distributed from the Tweed River, Byron Bay and Broken Head National Parks on the coast, and on Mount Warning and further inland near Mallanganee, near the Richmond Range. Although the vine was previously known in the area, it is not known if there are any rainforests where *P. praevenosa* is currently present in the Clarence River Catchment, where almost all riparian rainforest was cleared for grazing cattle in the late 1800s and early 1900s. The conservation status of *P. praevenosa* has been evaluated by the State Government, to be 'lower risk' in Queensland while the vine is not considered to have conservation significance in New South Wales.

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In Queensland and New South Wales, several categories of lowland rainforest were considered formally by the Australian Government (EPBC Act 1999) to be threatened and have been classified according to the plant communities they support, under the banner of Lowland Rainforests of Subtropical Australia (p. 81). However, these lowland subtropical rainforest remnants and the fauna they support continue to be threatened with extinction from clearing, mining for road base, invasion by weeds and human disturbance. Some endemic fauna and flora are now threatened by drought associated with climate change. The rainforests depend on rich volcanic soils or alluvial soils of volcanic origin with annual rainfall of around 1,300 mm and, together with the lower moist ranges, are the habitats for a number of subtropical insects, including the Richmond birdwing, the southern pink underwing moth (*Phyllodes imperialis smithersi* Sands) occupying the same type of habitat (Sands 2012), and several other butterflies, for example, the rare lycaenids *Pseudodipsas cephenes* Hewitson and *Hypochrysops miskini* (Waterhouse). Many such species are at the southern edge of their ranges and their distributions are confined to the southern coastal pockets of rainforest, clearly separated from northern populations by the dry coastal ‘barrier’, between Mackay and Rockhampton and some species having distinctive morphological or biological characteristics. These small butterflies are good examples of other subtropical rainforest species threatened with extinction from invasive introduced animals and weeds.

5.2 Threats

The most serious threats to the Richmond birdwing have been destruction and disturbance of rainforest habitats that support its lowland food plant, in subtropical eastern Australia. The butterfly’s range contraction between about 1950 and 1990 is an important indicator for the impacts of these threats. These are closely followed in importance by the rising impacts on the food plant from prolonged drought and invasive exotic weeds, and fragmentation of existing habitats leading to inbreeding depression. Major needs for conservation of the Richmond birdwing were recognised long ago, and were assembled under the Draft Recovery Plan in 1996 (p. 112). They include: (1) preservation of remnants of subtropical rainforest, and planned restoration of others; (2) progressive eradication of the alien *Aristolochia elegans* wherever it occurs, and discouraging any further plantings or expansion: (3) propagation and planting of *Pararistolochia praevenosa*, to enhance and extend its presence throughout the butterfly’s historical range; whilst (4) undertaking further biological research, for example on the food plant pollinators, is needed to enable the birdwing and its food plant to achieve a reduced level of conservation need.

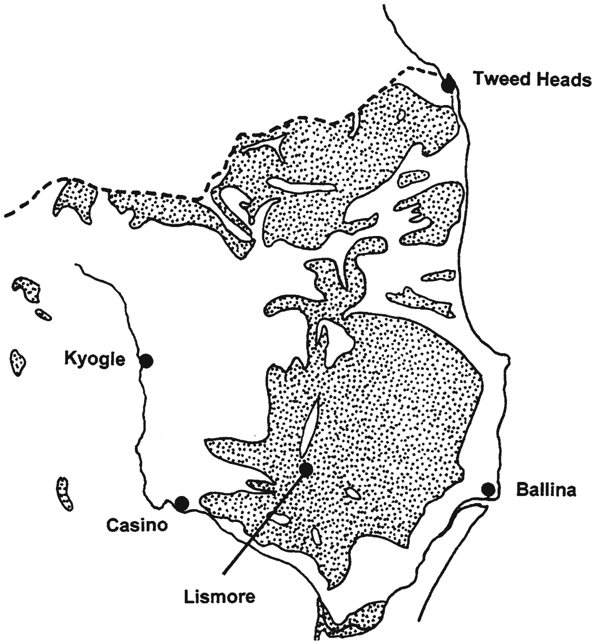
The wax scale insect *Ceroplastes ceriferus* (Fabricius) has been observed infesting the stems and exposed roots of *P. praevenosa* but it is usually maintained at low levels by a complex of natural enemies (Waterhouse and Sands 2001).

The major threats are discussed separately below.

5.2.1 History of Rainforest Destruction

A wide area of north-eastern New South Wales once supported extensive subtropical lowland rainforest (Fig. 5.1), and the extent of its loss is illustrated well by the decline of the 'Big Scrub' area to the east of Lismore. This major biotope formerly extended over some 75,000 ha (Fig. 5.2), but from the 1840s on was cleared extensively to leave only remnants by the end of the nineteenth century. By the early 1990s, only approximately 556 ha of extensively fragmented rainforest remained (Lott and Duggin 1993). The lowland topography rendered much of the area amenable to clearing for agricultural conversion, with dairying widespread in the initial decades following widespread timber extraction (predominantly for the Australian red cedar, *Toona australis*). More recent impacts include diversified cropping, including fruit crops such as avocado and macadamia nuts, excessive removal of healthy stream flows by pumping, and extended urbanisation around towns. Remnant forest patches are recognised as important for biodiversity, and support significant numbers of rare plant and vertebrate species but, unfortunately, these rainforest habitats have been, and continue to be destroyed for farming, clearing, road works or urbanisation. Information on invertebrates of the Big Scrub is relatively scarce, but more concerted information on those of the more southerly Manning Catchment forests of New South Wales gives some flavour for the enormous variety likely to be present (Williams 1993). The Manning Catchment is beyond the range of both *O. richmondia* and its food plant. However, despite increasing pressures, many of the Big Scrub remnants have not decreased in size over the last half century, and some are now the focus of active restoration and replanting programmes as a trend of wide general conservation importance across the region. Declines in broad-scale farming have enabled some natural regeneration, but also led to increases in weed infestations, with weed control also an important and rising conservation need. Restoration work on the Big Scrub has been pursued actively for many years, and substantial progress has been made with revegetation targeted to expand and progressively link the various fragments. The Big Scrub Rainforest Landcare Group (more recently 'Big Scrub Landcare') was founded in 1992 and has been the key driving force behind this long term programme. Its activities now span both practical work and conservation advocacy, with an impressive record of fund raising and cooperations. Substantial weed control programmes are involved, and 'The landscape is increasingly containing elements of the original rainforest within a mosaic of production horticulture.' (Parkes et al. 2012, p. 219).

Fig. 5.1 Former extent of subtropical rainforest (shaded) in New South Wales (Based on Floyd 1990)



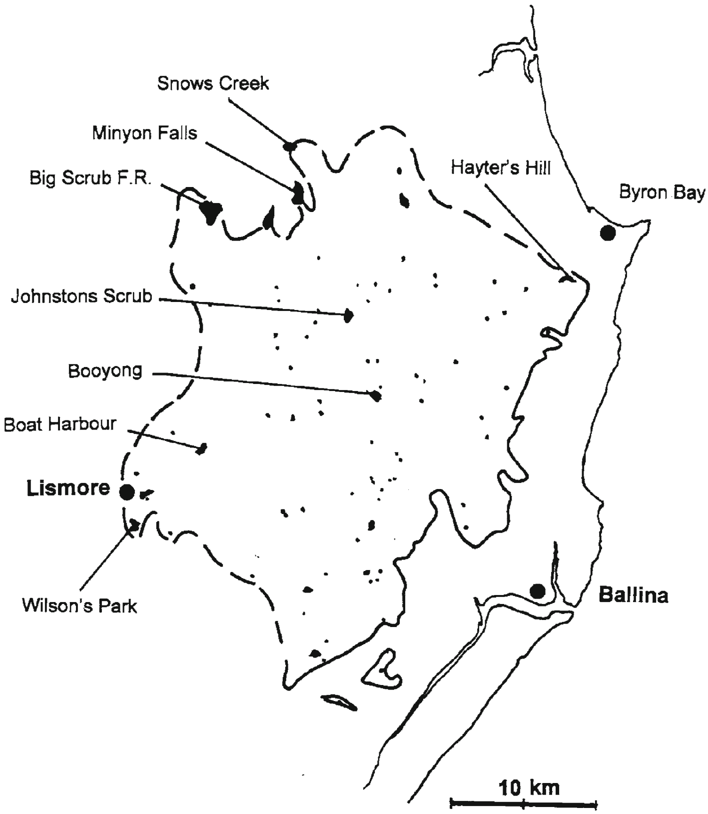


Fig. 5.2 Loss of forest in New South Wales: the area of the 'Big Scrub', showing extent of remaining fragments within former forested areas (After Lott and Duggin 1993)

The largest remnants are the Big Scrub Flora Reserve (148 ha), and Minyon Falls (68 ha), whilst many others are less than 3 ha; the sizes of many have been increased for clarity in Fig. 5.2. Long-term viability of the largest remnants appears good, because these are sufficiently large to retain a relatively intact rainforest core, and also abut extensive eucalypt forests. These are regarded as sites of the highest conservation significance. Lott and Duggan (1993) recommended establishing regrowth corridors helping to link remnants of the Big Scrub, and noted that 'Remnants should be expanded by direct planting of rainforest species on the surrounding lands, by connecting remnants with planted corridors and/or improvement of the regrowth corridors by weed removal and rainforest plantings'. This principle of promoting fragment connectivity is central to the birdwing conservation programme.

5.2.2 Prolonged Drought and Floods

Prolonged periods of drought since the mid 1980s, accompanying climate change, have had major impacts on the survival of the immature stages, with abnormally high temperatures and low humidities resulting in desiccation of the living eggs, larvae and pupae. For example, on several occasions between 1994 and 1996, and 2001 and 2007 in south-eastern Queensland, eggs thought to be healthy failed to hatch, some pupae developed black markings before becoming desiccated, and cessation of pupal diapause followed by adult eclosion became unusually protracted. More recently in spring of 2012, lack of rainfall may have been responsible for abnormal adult eclosion. Eggs failing to hatch may have also resulted from eggs deposited by unmated females.

A major impact from prolonged drought is that it leads to toughening of leaves of the food plant, those leaves then becoming inedible by freshly-eclosed first instar larvae. Toughening of leaves is a drought-resistance strategy, and accompanied by declines in nutrient (mostly nitrogen) concentrations occurs when the vines are stressed. It is possible that temperature extremes may enhance responses of microsporidia that could be benign under normal climatic conditions but become pathogenic when stressed by drought, an effect known in other Lepidoptera. However, no evidence of spores of microsporidia have been found in several dead and discoloured pupae. Prolonged drought can result in death of wild food plant vines, as seen in several protected areas (for example, Burleigh Heads National Park) during the dry periods that affected much of eastern Australia from 1995 to 2009. Again in August and September 2012, absence of rainfall near Brisbane caused otherwise healthy vines to die unless hand watering was maintained. Prolonged drought has had the most serious impacts on both species of food plant vines, whether the vines were wild or planted, and it continues to be a serious threatening process associated with climate change in south-eastern Australia. At higher elevations (>600 m), prolonged drought in 1995–1996 was thought to be responsible for disappearance of all stages of the Richmond birdwing in areas where they had been previously been breeding on *P. laheyana* (Sands and Scott 1996). There is little doubt that climate change, accompanied by increasing drought events, disrupts pupal diapause and reduces the production of soft and palatable leaves of the larval food plant, and will become a serious and increasing threat in future decades.

Floods, also associated with climatic extremes, caused many losses of the vines in 2010 when vast areas of otherwise healthy riparian rainforests became inundated, killing the plants sensitive to lack of drainage and sweeping away many vines growing on, or planted on, embankments. The root system of *P. praevenosa* is fragile and the soils are easily undermined. The rhizomes do not penetrate deeply from surface soils into sub-soils. On older vines with more extensive rhizomes portions have been swept away by floodwaters, leaving the exposed sections on the surface where they readily desiccate. Flooding has commonly undermined the trees supporting old growth vines, resulting in masses of *P. praevenosa* and other companion species collapsing into heaps that usually fail to re-grow. During the floods that affected the Brisbane River a number of planted vines were probably killed by salt water or other dissolved materials.

5.2.3 Corridor Fragmentation

Fragmentation of habitats and loss of corridors, particularly when due to expanding urban development, have been implied to lead to inbreeding depression and extirpations. Corridors normally support dispersing butterflies, allowing them to move between habitats, or provide stepping stones that potentially facilitate genetic interchange between populations. Loss of corridors can lead to the losses of isolated populations for the butterflies even if the food plants are able to persist. Sites with low densities of vines are susceptible to frequent extirpations of the birdwing when the vines are not producing sufficient young leaves to support the larvae. This has been observed in natural situations where the numbers of vines are low, for example in the northern parts of the range, where the ‘rarity’ of the vines can usually be associated with the low level of nutrients failing to support this nutrient-demanding vine.

Adult dispersal is important also in considering the incidence of temporary mountain populations (Chap. 2). Rarely can the pupae of the Richmond birdwing survive the climates at high elevations (>600 m) even though these areas are suitable for growth of *P. laheyana.* From limited observations, pupae will die in July and August most years unless the winters are unusually mild and moist. While the Richmond birdwing frequently visits the higher locations on the Queensland-NSW Border Ranges, and there is ample presence of food plant vines, the offspring from ovipositing females rarely survive. An example of winter survival of pupae producing adults on the Ranges (above 600 m) was monitored in 1994 (p. 39) (Sands and Scott 2002) and earlier observations were known. It is always possible that the higher altitude population will appear more frequently under the influence of increasing temperatures, but if winter periods of prolonged drought and very low temperatures continue to occur it is unlikely that pupae will undergo changed survival rates at these elevations.

5.2.4 *Natural Mortality*

As well as in subtropical regions, *Pararistolochia praevenosa* also occurs near Lake Eacham on the Atherton Tablelands in northern Queensland, where the Richmond birdwing is replaced by the Cairns birdwing (*O. euphorion*). While there is a range of potential natural enemies of birdwings in their tropical habitats, none has been known to lead to extinctions or destabilise birdwing populations. Addressing the causes of natural mortality of the butterfly and vine, and how (and if) these have changed to become increased threats, is difficult but occasionally the threats can be alleviated in areas where intensive management is practiced. For example, protecting young vines with wire guards from being dug up by brush turkeys is a useful method for reducing mortality of planted vines. Although the brush turkey plays an essential part in the life cycle of the vine by dispersing the seeds, in bush regeneration areas and gardens this megapode has become very common and has often become a destroyer of the vines, digging them up wherever they have been planted, in its search for invertebrate food in the moist soils maintained to keep the vines healthy. This behaviour, also noted in the wild, confirms the strong attraction of the bird to all parts of the vine but it appears to be a major mortality factor for young seedlings and could be responsible for the 'thinning out' of seedlings that are often seen germinating in groups but rarely growing on to produce more than one or two undisturbed plants.

5.2.5 *Collecting Specimens*

There is no evidence that collecting of specimens has been a threat to the Richmond birdwing, or to either food plant, despite suggestions that this practice has influenced conservation status of the butterfly and lowland food plant. When the few specialist collectors were asked why they rarely keep more than one or two specimens of the Richmond birdwing, several reported that 'the specimens take up too much cabinet space.'! The generalist collectors tend to take male specimens and keep in their collections specimens of the two larger, but otherwise similar birdwings, Cairns Birdwing (*O. euphorion*) and the Cape York birdwing (*O. priamus* ssp.). A risk might indeed occur if specimens are taken from isolated colonies where lowering of numbers might lead to inbreeding depression but the chances of capturing, and detrimentally reducing the numbers of such a high-flying species, are not likely to have an impact on the integrity of populations. Commercial exploitation or trade in specimens has not been a problem and the few breeders of the Richmond birdwing rear the specimens from immature stages – usually eggs or larvae – in order to obtain perfect specimens for trade. Unlike Queen Alexandra's birdwing from Papua New Guinea which has conspicuous brown and gold pupae, the pupae of the Richmond birdwing are very difficult to locate in the wild by would-be collectors. The green pupae are always well camouflaged where they are attached beneath leaves and the pupation sites chosen by the larvae are often some distance from the food plant. Whilst indiscriminate collecting should not be condoned, it is not at present considered a significant threat to *O. richmondia*.

5.2.6 Invasive Woody Weeds and Grasses

A number of exotic weeds threaten the Richmond birdwing and its lowland food plant by displacing whole plant communities, competing with any regenerating growth for light and soil moisture, and can smother the growth of seedlings. These plants are mostly garden escapes and some, for example varieties of lantana (*Lantana camara* L.), have been spreading into natural bushlands for more than 100 years. This woody shrub is very competitive after clearing, burning and forestry disturbance, particularly in riparian situations. In addition, several exotic trees are invading subtropical rainforest habitats, including a Chinese Elm (*Celtis sinensis* Pers.), the Asian Camphor laurel (*Cinnamomum camphora* (l.) J. Presl.), the South American Tipuana (*Tipuana tipu* [Benth.] Kuntz) and two privets (*Ligustrum sinense* Lour. and *L. lucidum* W.T. Aiton). All prefer moist soils with high water tables and the majority can develop competitive mono-stands and thickets. Other woody weeds of significance include the large shrubs, Indian Hawthorn (*Rhaphiolepis indica* (l.) Lindl. ex Ker Gawl.) and Ochna (*Ochna serrulata* (Hochst.) Walp.). Both continue to be widely cultivated and have proven to be competitive displacers of native vegetation in riparian vegetation. A rising threat for many native forests is the rapid spread into native forests by exotic *Pinus* spp., and the ability of the trees to displace rainforest trees and change the natural soil structures and chemistry. Stands developing from seedlings at the edge of softwood plantations form dense growth at roadsides and spread into nearby moist forests and riparian rainforests, particularly near embankments of streams where *P. praevenosa* becomes rapidly overwhelmed and the understorey native vegetation becomes sterilized. Regrettably, most conservation agencies in Australia have not appropriately recognized the threat of such weeds to native biodiversity and no action has being taken in Queensland to control the escape of pines from forestry areas. With increasing temperatures and the impacts of prolonged drought, problems from invasive weeds in subtropical forests seem destined to increase.

Several exotic vines threaten *P. praevenosa* and other native vines by competition for light, while some cut off sap flow by the constricting twining stems. A vine with tendrils, Cat's Claw Creeper (*Macfadyena unguis-cati* (L.) A. Gentry), can kill support trees, while vines with reproducing aerial bulbous stems, for example Madeira Vine (*Anredera cordifolia* (Ten.) Steenis) or those with branching underground rhizomes including Morning Glory (*Ipomoea indica* (Burm. f.) Merr) and *I. purpurea* L. (Roth.) and Mile-a-Minute (*Ipomoea cairica* Sweet), can disrupt soils and kill the root systems, while above ground they can overwhelm the foliage. Balloon Vine (*Cardiospermum grandiflorum* Sweet) is particularly well adapted to riparian vegetation and threatens the most favoured habitats of *P. praevenosa,* as does climbing asparagus fern (*Asparagus setaceous* (Kunth) Jessop), currently a less invasive species.

Unfortunately *P. praevenosa* has on occasions been misidentified as an invasive weed when the exotic undergrowth invading bushland is being cleared. With several exotic vines now invading natural rainforest there is a tendency for land managers to poison or slash vines indiscriminately and to encourage vine-free undergrowth or canopies that are free of vines, regardless of whether they are detrimental to growth of native trees and shrubs. Increasing in importance are the invasive vine 'glycine' (*Neonotonia wightii* (Wight & Arn,) J.A. Lackey), that has become a strangler of native vines and small trees, and the Singapore Daisy (*Sphagneticola trilobata* (L.) Pruski), a ground cover plant well adapted to invading the moist understorey of rainforest, where it can out-compete the low growth of most native plants, including seedlings of *P. praevenosa*. Both species are also capable of displacing the plants on compost-based breeding sites used by the pollinators of the vine.

Several invasive exotic grasses have become well adapted to moving from pastures into rainforests and becoming very competitive and will displace native vegetation as their regrowth recovers after being burnt. For example, Guinea grass (*Megathyrsus maximus* (Jacq.) Simon & Jacobs), Signal Grass (*Brachiaria decumbens* Stapf.), Molasses Grass (*Melinis minutiflora* P. Beauv.), South African Pigeon Grass (*Setaria sphacelata* (Shumach) Stapf. & Hubb.) and *Paspalum* spp., all proliferate on moist soils and have become invasive in rainforest habitats of *P. praevenosa*. These grasses were introduced into Australia for pasture improvement but most are of very limited value to the cattle industry in coastal regions. Several of these, and other grasses, most of African origin, have become widely established and are becoming invasive in rainforest, particularly after any disturbance of soils. Some form extensive and highly flammable stands which, if burnt frequently, prevent recruitment of many native flora and gradually lead to increased flammability of vegetation over extensive areas. The combination of competition and high flammability of the grasses has become a long-term 'deadly cocktail' for rainforest ecosystems which they invade, and for the threatened animals and plants they harbour. Most known control measures for exotic grasses are temporary and only biological control could provide the effective control strategy that is now needed for a wide range of the exotic woody weeds, vines and grasses that are expanding their impacts on threatened plants and plant communities in Australia. Use of fire for controlling invasive grasses has proven to be counter-productive with re-growth of the exotic species far out-competing the growth of native species and by increasing the ground level fuel loads to pre-burn levels. Exotic grasses are the most important threat to natural recruitment of *P. praevenosa* and are now thought likely to be responsible for displacing the breeding habitats for the minute fly pollinators.

5.2.7 The Dutchman's Pipe Vine and Other Weed Vines

The introduced vine, Dutchman's Pipe vine (*Aristolochia elegans*), originally from South America, has contributed to the decline of the Richmond birdwing, and is recognised as a key threat that is not currently amenable to management in Australia. Dutchman's Pipe (Fig. 5.3) is well adapted to the same soils, water tables and climates preferred by *P. praevenosa* and it can out-compete and displace *P. praevenosa*, as well as poison the larva of Richmond birdwings (Chap. 2). The seeds of Dutchman's Pipe are carried long distances into native forests by air currents and the vine will colonise areas less accessible to other weedy vines. Adult birdwings lay their eggs on the leaves of the Dutchman's pipe vine but its leaves are poisonous to young caterpillars when they attempt to feed. In field studies adult birdwings are actually *more* likely to lay their eggs on a Dutchman's pipe vine than on *P. praevenosa* when a choice is available. Dutchman's Pipe was introduced into Australia as a decorative garden plant in the late 1800s and as is the case with all exotic plants and animals introduced at that time, the introduction did not take into consideration any 'non-target effects', including toxic compounds in the plants, poisoning of browsing livestock or the capacity for the vine to become an invasive weed in the forests of eastern Australia. At first it was assumed that the abundance of this exotic vine would be beneficial to birdwings, when females were seen ovipositing on the vine and young larvae were seen on the leaves. For example, soon after the Dutchman's Pipe was introduced into Burleigh Heads National Park, Richmond birdwings were observed laying on the introduced vine in preference to *P. praevenosa* (A. Burns pers. comm.) even when both vines were growing near one another. Around that time several well-intentioned popular articles on 'butterfly gardening' advocated planting this vine for the birdwing. It was not until sometime later that Straatman (1962) and Common and Waterhouse (1981) reported toxicity of the vine to larvae of some swallowtails when they attempted to feed on the leaves. Since the 1960s Dutchman's pipe has become a serious weed of forestry and threatened several species of swallowtails that are attracted to the vine for oviposition.

Leaves of *Aristolochia elegans* and *A. ringens* are toxic to the larvae of *O. euphorion* in northern Queensland. Some early literature includes reports of *O. priamus*

Fig. 5.3 Dutchmans Pipe Vine (*Aristolochia elegans*): (**a**) flowers; (**b**) immature seed capsule; (**c**) dehisced seed capsule; (**d**) foliage

and *O. euphorion* using *A. elegans* as a food plant (Common and Waterhouse 1981) but it is doubtful if the observations included complete development by larvae fed on this vine. Observations since made at several bushland sites in south-eastern Queensland between 1978 and 2010, by Sands and Sue Scott, confirmed the report by Straatman (1962) who showed that when eggs are deposited by *O. richmondia* on *A. elegans*, the larvae seem to emerge successfully but fail to survive beyond the 3rd instar after they commence feeding on the leaves. Meanwhile in northern Queensland, from about 1990, *A. ringens* has also become an invasive weed where it threatens swallowtail butterflies, including the Cairns birdwing, by poisoning the early instar larvae. Similarly, the toxicity by *A. elegans* to young larvae of

O. priamus has been reported from Papua New Guinea but on one occasion larvae were seen by Fred Dori to complete development by feeding on its flowers and seed capsules. Subsequently Parsons (1998) reported toxicity of *Aristolochia odoratissima* L., another introduced vine, to larvae of *O. priamus*. It appears that exotic *Aristolochia* species are likely to be toxic to the larvae of Australian birdwings and their increases in density and distribution through both cultivation and spread into natural environments need to be recognised as major threatening processes for these butterflies.

A. elegans is easily distinguished from other Aristolochiaceae from subtropical regions but the heart shaped leaves bear some similarity to those of *Aristolochia chalmersii.* The large expanded flowers and parallel-sided dehiscent capsules of *A. elegans* are distinctive (Fig. 5.3).

5.2.8 Altered Fire Regimes

Pararistolochia praevenosa is one of several indigenous rainforest vines that cannot survive being burnt. On occasions the deliberate use of fire for fuel reduction burning programmes has become a most serious threat to conserving invertebrates in Australia and has also had major impacts on many rainforest plants, including *P. praevenosa* and moist forest and wetland plants. *P. praevenosa* and many other fire-sensitive plants die if rainforests are burnt and no regeneration from rootstock occurs, unlike many fire-adapted plants. One serious rising problem is the post-fire invasion by competitive weeds including African grasses that most effectively displace native plant regeneration and prevent even many fire-adapted plants from recruiting. The other problem that is becoming an increasing threat is allowing fires started to reduce fuel in dry periods in adjoining woodlands to continue burning into the forest understorey, killing many of the plants that cannot survive fires. Although agencies have been advised to avoid burning rainforests, it remains a common practice when carried out during dry periods and particularly when fires are allowed to 'burn themselves out'. Recently agencies (State Government and Councils) have avoided burning rainforest but burning logs have often been seen to roll down steep slopes into rainforest where they may smoulder and eventually ignite the rainforest, particularly when dry during periods of drought. The high flammability of exotic *Pinus* spp., unlike the indigenous rainforest pines (*Araucaria cunninghamii* and *A. bidwilli*), and extreme heat generated by *Pinus* spp. during wild fires, can threaten all fire-sensitive plant communities when near pine plantations.

Justified by the often-voiced beliefs that 'Australian plants (all species) evolved with fire', 'the need to reduce fuel' and 'how traditional occupants used it', fire has been used since European settlement to burn patches of rainforest, particularly after logging or clearing, and at times during dry periods when natural fires started by lightning strikes would never have burnt rainforest or its plants. The most serious impacts to threatened terrestrial invertebrates from fires have been from the (i) scale, (ii) inappropriate seasons, (iii) frequency of deliberately-lit fires and (iv) lack of un-burnt refuges (New et al. 2010). The balance between using fire as a manipulable management tool in Australian ecosystems and fire management methods becoming a major threat to ecosystems, human property and other assets, is often a very fine one, and the potential fates of many species are simply serendipitous. Dimensions of a planned and ecologically sensitive fire regime are, in practice, often treated as secondary to simple expediency and pressures to achieve area-based control burned targets. Whilst the practice of deliberately burning rainforest in Queensland has declined over recent years, its legacy has included the impacts of invasive weeds as noted above. Regulation of control burns is ecologically complex, and is a politically charged process.

5.2.9 Inbreeding Depression

This problem was demonstrated in captive studies of several Australian Papilionidae, including *O. richmondia*, by Orr (1994). Substantial effects on egg hatching rate and larval survival and developmental rate were found with inbreeding (Fig. 5.4). Orr regarded inbreeding depression as 'potentially severe', and warned against reliance on captive breeding programmes for conservation unless care is taken to sustain a wide gene pool and avoid excessive inbreeding. Species that were previously distributed widely and now suffering from habitat reduction and fragmentation, may be those most at risk. 'Inbreeding depression' has many symptoms in reducing viability, condition, and overall 'performance'. Whilst some aspects have not been investigated experimentally in *O. richmondia*, the information provided by Orr is a salutary indication of problems that may arise, and that must be considered in a conservation strategy, with due attention to prevention of population isolation and size reduction.

There is little doubt that fragmentation of habitats and loss of corridors has led to inbreeding depression and extirpations of the Richmond birdwing under field conditions, particularly when habitat fragmentation has been due to expanding urban development, essentially providing physical barriers to natural dispersal. Loss of corridors has led to the losses of isolated populations for the butterflies even where undisturbed food plants have persisted in moderate densities, for example, in Burleigh Heads National Park, Neurum Creek National Park, and in several isolated pockets of rainforest between Brisbane and the D'Aguilar and Conondale Ranges.

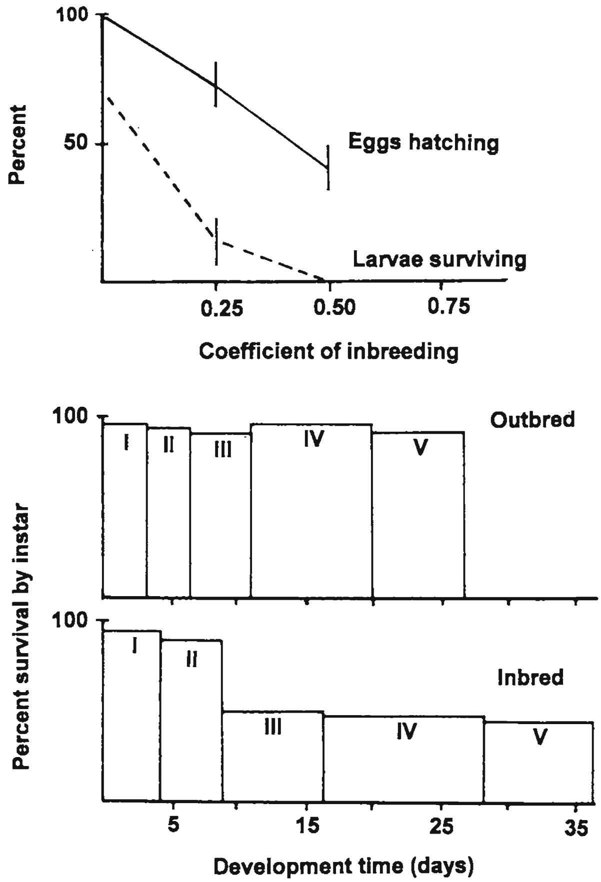


Fig. 5.4 Laboratory evidence for inbreeding impacts in *O. richmondia*: data obtained by A. G. Orr (From Orr 1994, with permission from the Queensland Museum, Brisbane)

5.3 The Draft Recovery Plan (1996)

In 1996 a Recovery Plan for the Richmond birdwing was lodged with the Commonwealth agency, the Australian Nature Conservation Agency, and was supported at that time by representatives from Queensland and New South Wales government agencies. The Recovery Plan was developed under the umbrella of CSIRO's Double Helix Science Club and CSIRO Entomology, and produced as the 'Draft Richmond Birdwing Butterfly (*Ornithoptera richmondia* [Gray]) Recovery Plan, 1996–2001, 1 May 1996'. Sands and Scott (CSIRO Entomology, Science Education Centre) were principal investigators, and the recovery team also included R. Moffatt (NSW National Parks and Wildlife Service), N. Markus

(Currumbin Sanctuary, Queensland) and P. Grimshaw (Queensland Herbarium). Although intended as a draft, the document is entitled simply 'Recovery Plan', implying a higher level of completion. The 'Draft' Recovery Plan recognised the participation of community groups in the programme, and was designed to ensure co-ordination of community organisiations, state agencies and other interest groups, and provide a plan for practical and sustainable conservation leading to the Richmond birdwing butterfly. The plan flowed in part from the December 1994 listing in Queensland of the Richmond Birdwing as a protected species under the Queensland Fauna Conservation Act. It represented the most complete summary then possible of the history of the birdwing, and the genesis of conservation concern, need, and action. It remains highly relevant.

A recovery team was formed in October 1995 with the collective affiliations noted above. The plan was lodged with the Australian Nature Conservation Agency and distributed to the Queensland Department of Environment and New South Wales National Parks and Wildlife Service on 1 May, 1996.

The Draft Recovery Plan was based on the following objectives:

- Implement strategies known to increase the declining *O. richmondia* abundance and restore the original distribution of the birdwing. Strategies include manipulating and increasing abundance of the food plants, minimising natural enemy impact and relocating individuals if genetic enhancement proves effective.
- Conduct a feasibility study for the captive rearing of *O. richmondia*, with aims to: (i) re-establish populations in areas where they have been extirpated, and (ii) enhance genetic diversity of inbred colonies of birdwings and (iii) produce live examples for public display and education.
- Form an incorporated group to encourage community participation in an ongoing conservation project on the Richmond birdwing butterfly.
- Educate the community against growing *A. elegans* (Dutchman's Pipe), and other exotic *Aristolochia* spp. that are detrimental to birdwing survival; identify methods for control and spread of these and other threatening exotic vines.
- Understand the key natural mortality factors (including natural enemies, birdwing/food plant interactions) that affect the survival of all stages of *O. richmondia*.
- Document and protect plant communities in NSW and Queensland that are breeding habitats and flight corridors for the Richmond birdwing.
- Expand the project for cultivation and distribution of larval food plants by community groups; encourage students to fulfil the breeding requirements of colonising birdwings in urban gardens, schools, reserves and other disturbed areas.
- Improve sustainable populations of *O. richmondia* in national parks where populations of birdwings are depleted, by enrichment planting with food plants.
- Develop links between state agencies and community groups for a collaborative sustainable conservation plan for the Richmond birdwing butterfly.
- When recovery has been achieved, down-list the conservation status of *O. richmondia* from "threatened" to an appropriate lower rank, accompanied by a management plan.

The plan also specified recovery criteria (Chap. 9) and, somewhat unusually for the time, listed the actions needed for each, with nomination of lead agency and timing, as well as including a 5-year estimated budget that totalled $678 926 over the 5 years from 1996/7 to 2000/01. This draft Recovery Plan was intended to guide the recovery of the Richmond birdwing until 2000, when it would be revised and new directions added (see Sands and New 2002). Although the plan was apparently never officially ratified by State agencies, it proved an excellent informal 'working guide' to the conservation measures needed. Its development and influences, in the context of ameliorating the threats outlined here, are discussed in the next two chapters.

Chapter 6
Foundation of the Programme: Engaging the Community

6.1 Perspective

The formal project on conservation of the Richmond birdwing programme began in 1992, and was progressively re-organised from 2001 to follow guidelines in the Recovery Plan (1996). Under different groups, coordination of the activities by widely distributed members of the community was needed, following the conclusion of the school-based Adopt-a-Caterpillar Scheme (p. 121). That project had received substantial funding from donors but members of the community wished to see other birdwing recovery actions coordinated by a community-based group, particularly cultivation, planting, monitoring and mapping the food plant vines, and longer-term plans to restore habitat corridors for the birdwing over a substantial area in south-eastern Queensland and north-eastern NSW. 'Recovery' activities by all groups, followed the basic objectives and criteria listed in the Draft Recovery Plan (1996), and these were used in many successful bids for external funds from government agencies and industries, with some of those bids including informal reviews of progress since 1996. The first substantive review of progress was made by Sands and Scott (2001), and later commentaries made by Sands (2008) and most recently by Valentine and Johnston (2012).

Many of the themes introduced in the Draft Recovery Plan have depended largely for their development on extensive inputs from the wider community, working with government agencies and interested scientists, with the various themes of conservation intertwined intricately. The encouragement and maintenance of community interests in the Richmond birdwing are discussed in the following two chapters. The early developments, involving engagement of young people and school programmes, and the progressive biological and restoration outcomes, are noted here (Fig. 6.1).

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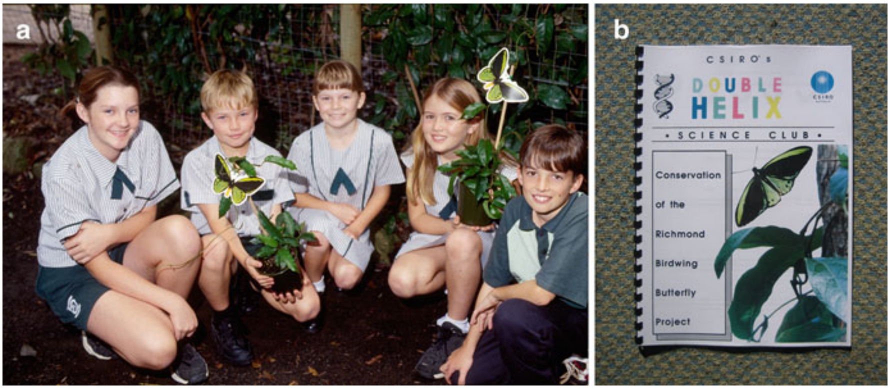

Fig. 6.1 School activities through the Double Helix Club: (**a**) group of school children (Sands and Scott 2002); (**b**) cover of instruction booklet

6.2 Education Programmes: School Involvement and Publicity

The Commonwealth Scientific and Industrial Research Organisation (CSIRO) is Australia's leading national research organisation, in which scientists and support staff are employed to address a range of research topics across the broad disciplines of agriculture, environment, forestry and industrial research. Scientists with the then Division of Entomology (now incorporated in the broader Division of Ecosystem Sciences) focus on solving arthropod pest and exotic weed problems, while CSIRO taxonomists work on Australia's unique arthropod biodiversity, and are responsible for the Australian National Insect Collection (ANIC), based in Canberra. As well as scientific Divisions, CSIRO hosts educational programmes, through which the Double Helix Science Club with science educational officers, helps teachers to organise science programmes for schools. Double Helix officers aim to make science attractive to school students and encourage them to appreciate the need for scientific research, and also encourage students to take up science as a profession. Double Helix officers visit schools and, at the CSIRO's Education Centres, introduce students to scientists to learn about their research projects. As opportunities arise, students are encouraged to contribute to 'hands on' research projects.

With growing impacts on biodiversity from urban development, mining and farming, many animal and plant taxonomists and ecologists in Australia have became concerned about losses of the non-marine invertebrate species, particularly insects of conservation concern and those that were becoming rare (Marks 1969). Many insects that are uniquely Australian have attracted interest in the past from taxonomists and members of the community (New 1991; Yen and Butcher 1997; Sands et al. 1997). Sands, a CSIRO scientist specialising in insect-plant interactions, in the 1990s became interested in finding ways to implement practical conservation activities by working with the community to advance understanding of the needs of the Richmond birdwing.

Early conservation work on the Richmond birdwing butterfly caught the attention of the Double Helix officers at the CSIRO Science Education Centre, at Indooroopilly, Brisbane, as a project where students could potentially contribute to conserving the butterfly, and learn about its interactions with its food plants. At about the same time in the 1990s, Arthur Powter, while living near Bellbird Creek at the base of Mount Mellum, Beerwah, met scientists from CSIRO to discuss ways he could enhance his habitat for the Richmond birdwing, and very soon afterwards, he become an ambassador for the Richmond Birdwing butterfly on the Sunshine Coast. After attending a talk some years earlier, Powter discovered he had the vines occurring naturally in his rainforest gully and began propagating vines to distribute to neighbours. He encouraged them to protect the vines growing on their properties and to help conserve the natural habitats for the birdwing, he and several of his neighbours registered their properties as Land for Wildlife conservation areas, while the Council began purchasing nearby areas of land supporting Richmond Birdwing colonies. The activities by the Caloundra Council (now Sunshine Coast Regional Council) helped to establish a corridor for the birdwings and their larval food plants in the area from north of the Glasshouse Mountains to the more intact habitats on the Blackall Ranges. Powter's experiences together with trials by Sands (p. 73) indicated several themes that could help engage the interest of young people in the conservation project.

Sue Scott, then Manager of the CSIRO Double Helix Science Club in Brisbane, began a new project for school students in 1992. Experiments concentrated on (i) leaf toughness measurements using a leaf penetrometer, (ii) determining the effects of age, light and nutrients on growth of *Pararistolochia praevenosa,* (iii) aseptic germination and production of seedlings in sealed plastic bags, (iv) seasonal flowering, growth of stems, internodes and leaves and (v) finding pollinators trapped in the flowers and examining them under the microscope. Several aspects of practical management and study were very suitable for school projects, with standard advice provided though Double Helix, who also coordinated the outcomes and provided feedback on the results. These themes included those discussed below, and the schools project was launched officially by the then Queensland Minister for Education in 1993. Within a year more than 130 schools had joined the conservation project and this rose to more than 420 participating schools by 1998, by which time more than 29,000 vines had been distributed.

6.2.1 Cultivation of Food Plants in School Grounds

The first experiments on the growth of *Pararistolochia praevenosa*, were based on measurements of plants within the school grounds and monitored and tended by the students. By 1996, schools such as Modanville Public School, in northern NSW, had begun campaigns to raise community awareness, using the Richmond birdwing in concerts, with uniforms and dances by young students. Julie Short (Modanville Public School) and Karen Court released a CD of a song about the plight of the Richmond birdwing butterfly and in 1996, Modanville Public School won the Earthworms Environmental Award. In 1997, teacher Short received a BHP Science Teacher Award for efforts involving the school to promote the conservation of the Richmond Birdwing. As CSIRO's Double Helix Club expanded its activities involving the butterfly and its food plant in schools, an Advisory Committee was established to help with the designing the projects and later, the community projects.

At first referred to as 'Conservation of the Richmond Birdwing', within 12 months of its beginning more than 130 schools had joined the Project, covering an area from Grafton in NSW to Maryborough in Queensland – the full latitudinal range of the butterfly. Students at Holland Park State School, Brisbane for example, successfully raised seedlings from seeds from their own vines. The Ingleside State School in the Tallebudgera Valley (near the New South Wales border) began cultivating vines from local genetic stock to plant in areas where the birdwing butterfly had become rare. For many years teachers at Ingleside State School and the students have maintained an ongoing interest in the Richmond birdwing, and as recently as 2010, hosted their own workshop, and, with more than 90 local residents attending, discussed the needs, importance and progress towards recovery of the Richmond birdwing butterfly. The concept of school involvement with planting vines became popular in northern NSW and south-eastern Queenland, and to cope with the demand for school projects and presentations, Sue Scott was approached to co-ordinate the educational parts of the Project. Afterwards the school birdwing project extended the activities in Queensland and NSW. Among their major experiments students gathered valuable information about the seasonal growth of the vines (see Chap. 3). While many schools and members of the community found the vines unpredictable in their growing habits with some vines growing vigorously and others dying, many reports came in from the school and community surveys of successful vine cultivation. Ingleside School and Tweed River State High School both reported having birdwings visiting their vines and the students observed larvae developing on their vines.

6.2.2 Recognising the Poisonous Dutchman's Pipe Vine

Early in the programme, Double Helix officers introduced school students to the South American Dutchman's Pipe Vine (*Aristolochia elegans*), providing information on its toxicity, how to distinguish it from other (native) vines, and how to remove this introduced weed from gardens and bushland. Students found this part of the programme quite difficult as the vine was then widely grown on fences for its large and spectacular flowers. The nursery trade subsequently outlawed culture of the vine to protect the birdwing and later the vine was listed by Federal agencies as a serious weed, not for cultivation.

6.2.3 *Seed Germination and Propagation of the Birdwing Butterfly Vine*

Simple experiments were designed for young students to find out the best and quickest way to germinate the seeds of *P. praevenosa*, how to use different soil mixes for potting up the seedlings and how to measure the growth rate of vines. *P. praevenosa* vines were easily propagated from seeds but were not so easily grown from cuttings. Sometimes seedlings were relatively slow in growth, sensitive to damping off and fungus attack, and potted plants were very prone to desiccation after planting out, especially if the roots of young vines (<2 years old) were not well developed. Experiments undertaken with potted plants evaluated outcomes from using different soil mixtures, soil pH and buffers, fertilisers, light regimes, pruning and stakes. Many results from these experiments were of interest and of considerable value for future commercial propagation, including the way seeds could be first germinated aseptically in plastic bags to encourage rapid growth, before the seedlings were potted up. The rate of growth of the vines was measured according to light and (variable) temperature regimes, and the length of internodes and leaf size was also compared with seasonal growth. Seedlings were shown to dampen off unless containers were kept moist, but not wet. Seed trays and potted vines required adequate drainage, but once placed on a bench, potted vines required protection from air rising through the slatted benches and burning the roots. This was easily overcome, for example by placing a plastic sheet or stiff board under the pots and over the benches, methods since adopted for general use by all nurseries. Indeed, many of the details included in Appendix 1 as ‘best practice’ had their gestation in the Double Helix programme.

Vines grown in pots were later used by students for various experiments, for example to study the influence of climatic variation on various growth parameters, and in particular leaf toughness, which was found to be a critical survival factor for newly-eclosed and young (to 3rd instar) larvae. The major factors influencing leaf toughness of plants were found to be temperature, rate of growth, moisture available via roots, soil nutrients and exposure to light. Higher temperatures (between 22°C and 27°C) accelerated growth but only when soils were very moist, not saturated and well drained.

6.2.4 *Leaf Toughness and Survival of Larvae*

The effects of climate on growth of the food plants of Lepidoptera and the flow-on effects on immature development are well known, for example, tough leaves of food plants affect the survival of larvae of fruit-piercing moths (*Eudocima* spp.) when they attempt to feed on them. In some plants the leaves do not vary greatly with toughness but in certain species, toughness develops rapidly with aging, imparting resistance to feeding by young larvae when they have small and weakly developed mandibles. The toughness of the *P. praevenosa* leaves increases with age, and the effects on larvae of the Richmond birdwing when they feed are important interactions that influence the populations of the butterfly. For example, starvation in newly-eclosed larvae was often observed to be associated with absence of soft leaves of the food plant during periods of drought or low rainfall.

During the Double Helix Science Club school programs on birdwing food plants, a leaf penetrometer was developed to quantify leaf toughness and relate it to the feeding capabilities of first instar larvae, using leaves of differing toughness. External funds were used when CSIRO designed a basic mechanical leaf penetrometer that used a simple probe. Once the toughness was measured, groups of freshly-eclosed larvae were held in small gauze bags on individual leaves of potted plants of *P. praevenosa* with varying toughness until larvae commenced feeding or died. Using the leaf penetrometer measurements in the field, the range of toughness of leaves acceptable for feeding could then be related in the field to (i) abundance of 'soft' leaves on each vine, (ii) survival of larvae and (iii) the relationship between moist weather conditions and (iv) predictions for populations of birdwings developing in each area. More experiments for students involved testing the toughness of leaves of potted *P. praevenosa* to quantify the limits of acceptable toughness for the first instar butterfly larvae. The first instrument used was one described by Sands and Brancatini (1991), a very simple unit that was made from a gram dial tension gauge, to measure leaf resistance to penetration by a probe linked by compression and expansion tension springs. Later, a more complex device with a pistol-grip, based on the same principle, was developed by Peter Bakker (Fig. 6.2). Students were also encouraged to look for natural enemies of the immature stages of the Richmond Birdwing and to report details of the localities where birds, ants or predatory bugs had been seen feeding on larvae, or to take photographs of the incidents.

Fig. 6.2 The leaf penetrometer designed for use by school groups

6.2.5 The Richmond Birdwing 'Adopt-a-Caterpillar' Scheme

This Project was established, with funding support from Bayer Australia, where students at selected schools were provided with birdwing larvae to determine if they could be successfully hand-reared, with the biology of the butterfly and growth of the vines the main focus. The programme was launched in April 1999 at Tingalpa State School, Brisbane, with the judging of a national 'Butterfly Detectives' poster competition (coordinated by CSIRO and Bayer) that attracted more than 400 entries. A second event was a Masquerade Picnic at the Brisbane Botanic Gardens, which attracted more than 600 school children wearing home-made insect masks.

The aims of the scheme were:

1. To actively involve students and community members in a practical conservation project and stimulate interaction between schools and their local communities through joint participation in saving a local threatened species.
2. For school children and community participants to gain valuable experience in handling the immature stages of the Richmond birdwing and, through gaining understanding and appreciation of insect life cycles and biology, learn the importance of scientific research in conservation projects and in finding solutions for environmental problems.
3. To enable participants to gain an awareness of historically uncontrolled habitat destruction and its consequences on Australian flora and fauna.

From September 1999 through to April 2000, six schools were selected to hand-rear Richmond Birdwing larvae in their classrooms. The larvae were supplied by CSIRO (under the requisite permit) and the students enjoyed adoption ceremonies when the larvae were delivered to the schools. The schools in Queensland involved were St Francis College, Crestmead; Jindalee State School; Chapel Hill State School; Mount Crosby State School; Springwood Central State School; and Sunnybank Hills State School. Ingleside State School, in the Tallebudgera Valley, also participated by studying larvae as they developed after hatching from eggs laid on the vines in their school grounds.

Modanville Public School in northern New South Wales reared larvae from the garden of a teacher who regularly had birdwings visiting and depositing eggs on planted vines. There was always excitement when the birdwings successfully emerged from pupae and flew around the school gardens – much to the delight of the children and relief of the teachers! The students discovered that the Richmond Birdwing larvae are quite difficult to rear as they have specialised requirements in relation to the toughness of their food plant leaves. As one young student from St Francis College observed – '"Spike" walks up and down the stem, testing the leaves until he finds the right one to eat'. Also, the children found it quite a challenge to keep the larvae away from one another in order to prevent cannibalism. They were amazed by how many leaves each caterpillar ate. Teachers involved commented on the valuable learning experience that raising the larvae was for their students and the school community.

The information contributed to estimates of food consumption, and led to a generalisation that each larva needs about a square metre of foliage to complete its development; this has since been reevaluated to suggest that up to two square metres may be required, depending on the condition of the plants (Sands and Grimshaw 2013). This earlier estimate had wide value in estimating needs for planting in the field and of predicting carrying capacity of a site.

6.3 The Birdwing Propagation House

The 'Birdwing Butterfly House' at the CSIRO laboratories sponsored by Bayer Australia was used for growing *P. praevenosa* in pots and on stakes until they were about 50 cm high, and fertilised until they had sufficient new growth for supporting young birdwing larvae. For the Adopt-a-Caterpillar Scheme, eggs of the birdwing were held in containers until they hatched and the larvae were transferred to the potted plants where they were held while they fed until they were large enough for students to look after. The greenhouse was later used for experiments on potted vines and the information on light, watering and drainage requirements was later used by most commercial nurseries.

6.4 Increasing Awareness

After Moffatt began his active campaign in New South Wales for the growing of vines by the community and removal of *Aristolochia elegans* in the late 1980s, he encouraged local governments to feature prominent signage throughout north-eastern NSW to increase community awareness. Moffatt initiated a signage system to protect remnant patches of vegetation containing *P. praevenosa* vines on both private land and reserves. Since then publicity signage has been used widely in this project (Fig. 6.3). Community awareness attracted substantial media coverage, first in relation to the poisonous *A. elegans* that has led to its removal from suburban gardens and local group efforts to eradicate it from reserves. The removal of a substantial *A. elegans* infestation at Burleigh Heads National Park on the Gold Coast, Queensland, an operation led by ranger Peter Chapman, led to lower mortality of larvae in the park, and birdwing populations soon responded very well to this treatment.

Fig. 6.3 Examples of the publicity signage deployed for the Richmond birdwing (**a**) permanent installation at the Brisbane Botanic Gardens, Mt Coot-tha; (**b**) larger information board at Mary Cairncross Scenic Reserve; (**c**) collapsible notice board, as used at field days and workshops

A notable publicity highlight occurred at the 2000 Olympic Games in Sydney, where a presentation was made to the visiting media by CSIRO scientists, about the community and school involvement in the project. The Richmond birdwing project was chosen as one of two science and education projects that had become popular with the national and international press. Demonstrations included a live display of the birdwings, with one of them emerging from a pupa attracting a lot of interest and publicity, as well as the wide range of activities showing how members of the community were involved in recovering the threatened butterfly.

The most significant publicity for the various stages of the Richmond birdwing conservation project came through the wide range of Newsletters circulated by local Catchment and Community groups, including those of the Noosa and District Landcare Group, Mary River Catchments Coordinating Committee, Moggill Creek Catchment Group, The Hut Environmental and Community Association and the Land for Wildlife Program South East Queensland, supported by South East Queensland Catchments.

6.5 The Environmental Caretaker Network for the Richmond Birdwing Butterfly (1999–2000)

The Environmental Caretaker Network for the Richmond Birdwing Butterfly developed as a cooperative venture between the CSIRO Science Education Centre at Indooroopilly, and The Hut Environmental and Community Association (THECA), based at Chapel Hill, Brisbane. The Network gained support and funds from CSIRO, and a Threatened Species Network/World Wide Fund for Nature Community Grant, from the Federal Government's Natural Heritage Trust.

The Caretaker Network began with its objectives based on the Draft Recovery Plan (1996, p. 112), and the activities were summarised as:

- Identify and find ways to protect natural habitats for *O. richmondia*, including investigating conservation management agreements for private properties and acquisition of land by local governments.
- Map and record natural sites for breeding by *O. richmondia* and its food plants.
- Replant the Birdwing butterfly vine (*Pararistolochia praevenosa*) to enrich the values of rehabilitated plant communities,
- Map and establish corridors between existing breeding sites, and develop plans to extend the existing habitats towards the limits of the original range.
- Create signage for prominent vine sites, to raise awareness and properly protect the sites.
- Identify the plants and plant communities associated with *P. praevenosa*.

The concept of running workshops, and how to introduce uninformed members of the public to information about conserving the Richmond birdwing, was initiated in the late 1990s at two workshops held at Currumbin Wildlife Sanctuary on the Gold Coast, and at the Australia Zoo on the Sunshine Coast and one in 2005, at the Brisbane Forest Park Headquarters, The Gap in Brisbane. Five coloured display boards describing the biology and with images of the Richmond Birdwing Butterfly were erected at sites at the Stanley River, Mary Cairncross Park, Maleny, THECA, Chapel Hill, Canungra Land Warfare Training Centre, and near Alstonville, New South Wales. Two Facts Sheets were compiled by the Double Helix Club and published in 1999. The first two 'How to identify the Richmond Birdwing Butterfly' and 'How your garden can help save the birdwing Butterfly' were published and distributed to schools that were involved in the Project.

6.6 Overseas Collaboration

Links were established with overseas groups working in countries on other birdwing projects, for example in 1996, CSIRO hosted members of the Oro Conservation Project – an AusAID funded project on Queen Alexandra's birdwing, *O. alexandrae* (Chap. 1), which is confined to small areas of the Oro Province in Papua New Guinea. Sands was the CSIRO consultant for developing a research schedule for the research project and worked closely with the research team based in Oro Province. In September 1998 Dr Yaw-Long Yang visited Brisbane from the Taiwan Endemic Species Research Institute where they are investigating the biology of *Troides magellanus* (Chap. 1) and developing methods for its rehabilitation.

6.7 The Roles of Government Agencies and Local Community Groups

Support for the Richmond birdwing project by local government Councils in south-eastern Queensland has been remarkable by providing funds through the community groups, or in the case of the Sunshine Coast Regional Council, establishing tenure and protection and rehabilitation of at least three habitats. Most notable on the Sunshine Coast has been construction of a 'birdwing walk' with trellises at Mary Cairncross Scenic Reserve, Maleny (p. 91) and the rehabilitation of the hilltop reserve above the town of Maleny. Several other sites have been dedicated to conservation of the Richmond birdwing, including the reserves at Mount Mellum and on the Stanley River. Most of the reserves are owned by the local governments and have community volunteers, sometimes members of local catchment groups, who carry out activities ranging from weed removal, re-planting of native flora including butterfly food plants, to guiding and attending to visitor enquiries. The only major losses of important birdwing habitats have occurred on the Sunshine Coast near Coolum Beach, in Fauna Terrace and at Point Arkwright near Coolum, and at Bli Bli.

The Brisbane City Council has since 2005 provided several grants to help rehabilitate bushlands and plant birdwing food plants and to map potential sites for rehabilitation. Local government officers working in 'Land for Wildlife' programmes have been very supportive, by encouraging community landowners to participate in various conservation agreements, particularly environmental covenants, helping to locate wild *P. praevenosa* vines in reserves and on private properties, participating in surveys for butterflies and their vines, cultivating the vines for distribution (by some Councils) and providing financial support for community workshops, printing newsletters and supplements, or providing venues for meetings. Considerable support was also provided by South-East Queensland Catchments, towards providing community members with substantial numbers of vines planted mostly in the Western Suburbs of Brisbane but also for several isolated areas where the birdwing had been seen in past years.

6.7.1 Working with Conservation Agencies: Legislation and Its Effects on the Programme

The State Government in Queensland has made important contributions to research on the birdwing, particularly by establishing a captive rearing programme at the David Fleay Wildlife Park, West Burleigh. Officers have also been actively involved in surveys for wild vines, selecting populations of the butterfly for out-crossing experiments and developing experimental field methods to address this inbreeding problem. Since 2008, Officers from the State Department of Environment and Resource Management (DERM) made considerable progress towards understanding inbreeding depression at the facilities based at Moggill and have made preliminary releases of out-crossed stocks in areas where inbreeding depression was known to occur.

Queensland's first Richmond birdwing butterfly reserve started on the Stanley River (Fig. 6.4) in 1992, when it received support from the Queensland Department of Primary Industries and a local landcare group ensured preservation of a breeding site for the birdwing butterfly after it had been seriously disturbed. Since 2005, considerable support has been received from the Brisbane City Council and South-East Queensland Catchments towards bush rehabilitation projects and, most recently, the Council has promoted surveys of the municipality, to identify local government land suitable as core recovery areas, where substantial numbers of the food plant vines could be established in attempts to bring back birdwings into Brisbane (see Chap. 8).

Very recently, since 2012 the Tweed Shire Council has started to prepare a major new habitat for the birdwing at Chick Park, on the banks of the Tweed River, opposite Stotts Island where there is a small resident population of the butterfly. This site is being planted with nursery-grown *P. praevenosa* as the first of several planned sites (core recovery sites or stepping stones) on waterway embankments to link isolated existing sites in far northern New South Wales.

Fig. 6.4 Stanley River Park: Queensland's first dedicated reserve for the Richmond birdwing butterfly (J. Chamberlain)

6.7.2 Permits for Propagating Protected Food Plants

In Queensland, the Environment Protection Agency (EPA) requires permits for propagators of all protected plants, including *Pararistolochia praevenosa* and *P. laheyana*. In 2005, the Agency issued a permit that allowed endorsement of members of the then Richmond Birdwing Recovery Network (RBRN) on one permit, alleviating the need for separate permits, providing the permit was used for non-commercial purposes. For other people and nurseries selling protected plants, applications independent of RBRN would be required. Permit tags were also required for each potted plant sold. A simple adhesive sticker attached to each pot with permit number or alternatively a special plant tag with permit number and details of the plant, its cultivation or an illustration, were considered by the Department as acceptable. Each propagator was required to keep records of the number of plants sold or dispersed to community members, or used in bushland rehabilitation projects. A separate permit was required (by EPA and DERM) for the collectors of any protected plant materials (leaves, stems, roots, flowers or seeds). For 5 years of operation under RBRN, the permits and endorsements have been managed to everyone's satisfaction.

6.8 Development of Wider Community and Agency Interests

Planting vines and continuing vine and corridor surveys has become an active and ongoing part of the collaboration between the members of RBRN and RBCN and several Community Catchment Groups, particularly on the Sunshine Coast. In Brisbane, The Hut Environmental and Community Association (THECA) played a major part with CSIRO, in establishing the Environmental Caretaker Network for the Richmond Birdwing Butterfly. A flight cage constructed by RBRN at Gold Creek for the first captive rearing studies later became a major facility for cultivation of *P. praevenosa* and other plants by the Moggill Creek Catchment Group. Subsequently from 2009 to 2012, the captive rearing methods were adapted for inbreeding studies at the David Fleay Wildlife Park, West Burleigh by the Queensland Parks and Wildlife Service (implemented by I. Gynther, R. Booth, J. Seal). This work became the basis for extending on-going collaboration between the community, RBCN Members and the Queensland Department of Environment and Heritage Protection.

At the northern regions of the Sunshine Coast, the Mary River Catchment Coordinating Committee and Noosa and District Landcare made major contributions to surveys for wild vines, sightings of adult birdwings, providing venues for workshops and cultivating *P. praevenosa* in their nursery for distribution to the community. In northern NSW, the NSW Parks and Wildlife Service has provided considerable practical help with surveys and advice and recently, the Tweed Shire Council provided support for a workshop held at Murwillumbah and Rainforest Rescue helped with a workshop held at Mullumbimby. The coordination of the peripheral birdwing projects continued since 2010 with substantial help from RBCN Committee Members and from the Wildlife Preservation Society of Queensland in Brisbane.

With many interested parties dispersed over the full range of the birdwing, coordination of activities, and recording and dissemination of information and news became important issues in the programme.

Chapter 7
Expanding the Programme. The Development of Community Networks: Their Achievements and Roles in Conservation and Recovery

7.1 The Richmond Birdwing Networks

Much of the recent community enthusiasm and their roles in conservation progress has been coordinated through extensive and expanding networks of expertise and interest, bringing together the various members of the constituency concerned with the wellbeing of *O. richmondia.* These successive networks have matured and changed somewhat in character, whilst maintaining the primary focus. The community networks were initiated following the continuing interest in the birdwing conservation project, highlighted when the Project was announced to the journalists attending the Olympic Games in Sydney in 2000. In the years following, CSIRO scientists helped to form three community-based groups, the Richmond Birdwing Conservation Project 1999–2004 (RBCP, later becoming a section of The Hut Environmental and Community Association, THECA), the independent Richmond Birdwing Recovery Network Inc. (RBRN), from 2005–2010, and the Richmond Birdwing Conservation Network (RBCN) formed in 2010 to absorb RBRN members, and initiated under the broader umbrella of the Wildlife Preservation Society of Queensland. Members of earlier networks supervised schools projects and later propagated and dispersed for planting in excess of 30,000 vines from 1994 to 2002. Subsequently approximately 12,000 vines were planted between 2005 and 2011 by various community catchment groups. RBRN continued to map the location of wild food plants and began recording data on adult butterfly sightings in 2006.

The three community-based network groups (RBCP, RBRN, RBCN) administered their activities as other incorporated community groups. They held regular meetings and organised field days, often at peripheral locations to benefit country members, and organised a series of (18) training Workshops (Fig. 7.1; Appendix 3); published a newsletter 3–4 times per year and workshop proceedings as supplements; developed a website (richmondbirdwing.org.au) to publicise progress with recovery of the birdwing and its food plant vine, and to advertise activities. The annually elected committees worked closely with State conservation agencies for issuing collecting permits, and to allow cultivation and dissemination of the

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protected food plants. The networks aimed to strengthen links with community and catchment groups, develop plans for establishing corridors, surveys for wild vines and organise habitat recovery by planting the food plants throughout the previously-recorded subtropical range in Queensland and NSW.

Fig. 7.1 Richmond birdwing workshop in progress (Mary Cairncross Scenic Reserve)

The Richmond Birdwing Recovery Network Inc. (RBRN), was formed at an environmental field day on the Gold Coast on 7 June 2005, and the Inaugural Meeting was held at the Headquarters of Brisbane Forest Park, at the base of Mount Coot-tha, in Brisbane's Western Suburbs. The first AGM and a Planning Workshop were held on 8th October 2005, when the Network was officially launched by Brisbane City Councillor Helen Abrahams, followed by the endorsement and good wishes of Brisbane City Council's Western Suburbs representative, Councillor Margaret de Wit.

Thus, two Local Government Councillors welcomed the formation of the new Network and the meeting was attended by more than 40 new members and people from the local community, staff from the Queensland Parks and Wildlife Service, and the Queensland Department of Environment and Conservation. Sue Scott was appointed at the meeting as Chair of the Network, and presentations at the meeting gave an introduction to the biology and conservation significance of the butterfly. A major objective recognised by all participants in the new Network, was the need by members to address the loss and on-going fragmentation of birdwing habitats throughout its contracting range. Other priorities discussed were how best to identify and map existing habitats for the butterfly, confirm old records and newly-discovered localities with wild food plant vines, and how members might restore corridors between habitat patches by planting the Birdwing vine.

The stated objectives for this network were:

1. Planning and re-establishing food plant corridors by planting vines in catchments and along watercourses from the D'Aguilar Ranges to the Brisbane River and beyond.
2. Propagating, planting out and caring for vines in private gardens, school grounds and on public land.
3. Strengthening outlying breeding populations and re-establishing new corridors to the east and south of Brisbane.
4. On Kin Kin Creek planting vines to connect the northern outlying populations east and south of Gympie.
5. Continuing and expanding information sessions, workshops and newsletters to raise public awareness about conservation of the birdwing and the associated subtropical flora and fauna (especially threatened insects).
6. Revising and updating the Draft Recovery Plan.

Within 6 months of its formation RBRN had attracted more than 230 members, and became incorporated, in the meantime developing policies and activities relating to conservation of the birdwing. Links were formed with more than 23 regional catchment and community groups, with representation on the coast extending from northern NSW to Pomona, and west to the Main Dividing Range at Toowoomba. The Facts Sheets first published by the CSIRO Double Helix Club in 1999 were being revised in 2013 for publication by the Wildlife Preservation Society of Queensland.

7.1.1 Network Meetings, Workshops, Displays, Publications and Database

By December 2009, membership of RBRN had risen to 467, with RBRN members participating in their field days and displays, presenting talks at their meetings and giving practical displays on how to successfully cultivate and grow *P. praevenosa*. RBRN held 3–4 General Meetings each year with invited speakers, sometimes conservation experts from interstate, and mostly included speakers involved in other invertebrate projects. A Newsletter started by the Environmental Caretaker Network, was modified from No 3 as the Richmond Birdwing Recovery Network Newsletter; published 3–4 times each year and registered as a publication for distribution to members, societies and libraries. Later editions were included electronically on the RBRN website. From 2005 to 2010, RBRN Editors produced 18 Newsletters, initially only with text but from Newsletter No. 7, the series was highlighted by coloured illustrations on the cover (Fig. 7.2), mostly from paintings by renowned butterfly artist Lois Hughes. Added was a midsection with coloured images of butterfly stages, food plants, community gatherings and sometimes, distribution maps.

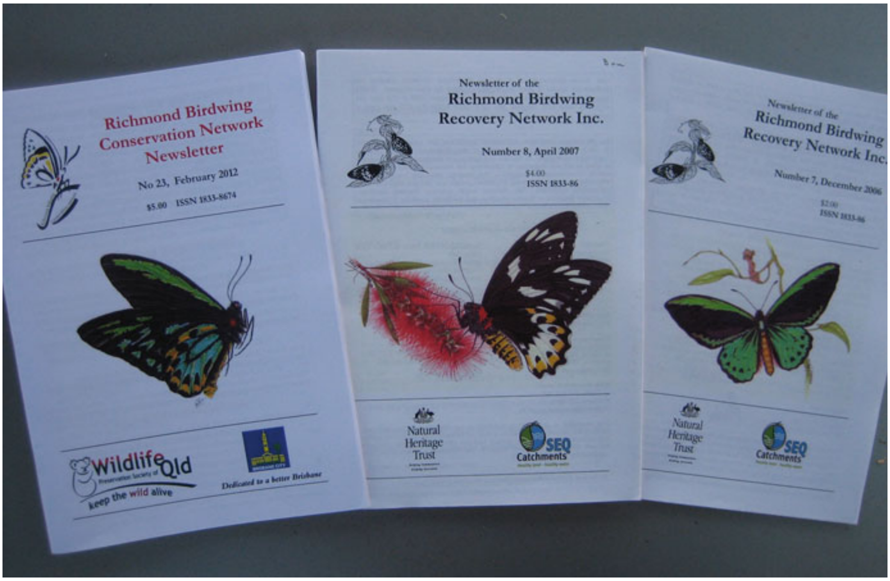

Fig. 7.2 Representative newsletters produced by the Richmond Birdwing networks: these are amongst a series with cover adorned by paintings by Lois Hughes

The first workshop organised by RBRN was held at Coolum Beach in 2005 near a beautiful locality behind the ocean beach, backed by steep slopes and covered in low rainforest, where birdwing butterflies were regarded by local residents as part of their every-day enjoyment. Unfortunately the two major breeding sites with wild vines at nearby Point Arkwright, were disturbed when much of the birdwing habitats were converted for housing developments. Following these events, RBRN was asked by several local environmental groups to run similar workshops, eventually leading to the series of 18 workshops hosted jointly by local government, environmental groups and RBRN. Workshop agendas had similar themes (Appendix 3) with speakers introducing the birdwing butterfly, discussing its conservation, threats and causes of shrinking distribution, its dependence on lowland food plants, mapping methods for the food plant, and the 'look-alike' vines, vines that are similar in appearance to the food plants, and methods to record sightings of adult butterflies and location with wild and planted vines. At each workshop a free vine ready for planting was given to each participant. The outcomes thus included increased both dissemination of much practical information across the butterfly's range and the numbers of people participating by planting vines.

The costs of hiring venues, workshop materials, catering, and supplying potted vines mostly came from grants. In all, more than 700 people attended the RBRN (later, RBCN) workshop series, held at locations throughout the original range of the butterfly, from Maryborough, Queensland to Mullumbimby, New South Wales.

7.1.2 *Developing the RBRN Database*

The database was designed to store historical and current records of localities supporting wild *P. praevenosa*. It was initiated by compiling records from the Queensland Herbarium, Brisbane, and from 2005 onwards, data were added by RBRN, and later RBCN members, supervised by Hugh Krenske. Storage of information on the life cycle stages and provision for observations of the butterfly was also built into the database but will be entered at a later date. The database was developed to provide a central location where records can be accessed using the internet, and its aims included:

- To encourage local groups to verify existing information on natural habitats, update and add new records relevant to birdwing localities or catchments.
- To provide information on historic data and evidence for changing the conservation status accompanying losses of the food plant vines and changes to the tenure of habitats.
- To provide a record for the impacts from threats, such as development, drought and climate change, that can be viewed statistically and graphically over time.
- To enable data to be downloaded into an Excel spreadsheet that can be used with catchments or local government software, to produce maps and overlays for a variety of purposes, including conservation activities.
- To provide data for revising the Richmond Birdwing Recovery Plan and for developing a plan for its lowland food plant vine.

Some limitations are:

- Only a small number of the early records have valid and sufficiently precise latitude and longitude details.
- A significant number of records have only locality names to identify where the vines were once located; most more precise location values are limited without latitude and longitude co-ordinates or GPS references.
- As data are sourced from several locations, locality references can sometimes be entered more than once or by different people, without this being recognised.

Many of the wild vines occur on private property in Queensland, but access to confirm the presence of the butterfly and the larval host plants is often restricted. Privacy laws restrict automatic access to data about vines located on privately owned properties. While mapping activities may include these data, access to confirm or establish the state of the vines is limited unless the landowners are happy to publicise the information. Fortunately, the land owners of many of the major habitats for food plants have entered into conservation agreements to facilitate indefinite protection on their land.

State laws differ between conserving plants on public land and those on private land. In Queensland there is no conservation regulation applied to rare or threatened vines on private land, and there are no controls or limitations placed on individuals, landowners or developers with regard to destroying the host vines for the larvae of the Richmond Birdwing larvae. The database can provide information that will reinforce the need for protecting wild vines on private property.

7.1.3 Recording 'Wild' and Planted Vines

Planted vines are included in the database, and historical records of wild vines include some locations where they no longer occur, having disappeared through drought, forestry, farming practices, mining, development or ignorance. In order to reduce impetuous records of recent plantings, planted vines have been included in the database only when they satisfied a set of criteria, for example, when the number of nodes exceeded 50 per vine, the stage at which a vine might be large enough to support a birdwing larva. Regional coordinators and members of community groups were encouraged to keep their own records for vines on public and private land. In areas where the butterfly no longer occurs, records of planted vines, together with their health and status, have been used to guide re-introduction of the butterfly to an area when the numbers and quality of food plant vines became adequate.

7.1.4 Activities and Influences: Sustaining Interest and Effective Coordination

Regional coordinators have maintained local interest and members of community groups have helped to compile and update information about vines in their area of responsibility to enable the status of these vines to be determined. Where vines identified in the database died or no longer exist, these records were identified with a termination date for the observation. This enabled updates on maps and pull-up boards for presentation at meetings, or publications, allowing distribution comparisons with older records. The annually elected network committees worked closely with State conservation agencies to coordinate activities such as issuing collecting permits, and to allow cultivation of the protected food plants. The networks aimed to strengthen links with community and catchment groups, developed plans for establishing corridors, surveys for wild vines and organise habitat recovery by planting the food plants throughout the previously-recorded subtropical range in Queensland and NSW.

7.1.5 Publicity and Sponsorship

Sands, Moffatt and Scott each presented numerous talks and displays throughout the 1990s in south-eastern Queensland and northern New South Wales, the first at the Australian Entomological Society's 25th AGM (September, 1994). Significant coverage by the national and international media followed the conservation efforts by the Double Helix Club from the beginning of the Project, with more than 45 articles in newspapers, popular magazines and scientific publications. Local radio and television reports including Channel 10's 'Totally Wild', Channel 9's 'Burke's Backyard' regularly featured the birdwing, and overseas, progress with the Richmond birdwing Project was reported by NHK Broadcasting in Japan. A paper was presented to the Invertebrate Biodiversity and Conservation Conference (Melbourne, November, 1995), later published (Sands et al. 1997), and a second paper was presented at the World Wide Fund for Nature Australia Conference in 1998, and later published (Sands and Scott 2001). Renowned Australian artist Don Waters was contracted (by Bayer Australia) to create a beautiful outdoor mural of the Richmond birdwing butterfly, the food plant and its habitat, for display near the entrance to the Botanic Gardens at Mount Coot-tha, Brisbane. Waters was assisted by the winner of a butterfly poster competition, a High School student Casey Taylor. The mural depicts the butterfly in its natural rainforest environment and it continued to attract interest and enquiries from many members of the public who visited the Gardens during its presence there.

More broadly, publicity for the Richmond birdwing conservation activities has helped draw attention to the ongoing destruction of remaining rainforest patches which were supporting the birdwing and many other species of rare plants and small animals. During the whole period from 1980 until 2010 various destructive activities continued to erode the last remaining habitats and had a profound effect on the vitally important corridors linking populations, mostly those in Queensland. Television programmes gave considerable publicity from 1999 to 2001 with some special programmes on the birdwing project produced by Channel 10's 'Totally Wild' and broadcast nationally. Publicity also helped to highlight the importance of inbreeding depression in fragmented animal populations and helped stimulate interest in carrying out research by other scientific groups, and to consider inbreeding depression as a major and developing wider threat to Australian biodiversity.

Several awards presented to community members for their regional birdwing butterfly efforts were publicised in local newspapers or via radio interviews. In 2003, Arthur Powter was awarded the Sunshine Coast Environmental Council's Biodiversity Initiatives Award for his talks and demonstrations to schools about local birdwings, and for commencing the large-scale propagation of birdwing vines, a project later taken over by the Council, and subsequently by Ray and Pam Seddon in 2005. Newspaper articles gave generous publicity to the plight of the birdwing and its habitats, discussing many of the activities listed in the Recovery Plan (1996) and early school activities, particularly CSIRO's 'Adopt-a-Caterpillar' Scheme (p. 121). Publicity was given to Modanville State School (NSW), Tallebudgera Valley, Ingleside, Jindalee, and Peachester (Queensland). Newspaper articles appeared in The Courier Mail, the Queensland Times, The Chronicle (1999), and Westside News. Meanwhile in 2000 the Financial Review Magazine awarded winner of its National Sponsorship Awards to CSIRO's Richmond Birdwing Conservation Project and Adopt-a-Caterpillar Scheme, jointly sponsored by Bayer Australia. Several natural history journals gave publicity and promoted the project, including the Australian Geographic (October-December 1993, 1997, 2008), Australian Plants (September 1999), Ecos (January-March 2001), Better Homes and Gardens (January 2000), Wildlife Australia (Sands 1996a), Nature Australia (Sands 1996b) and Subtropical Gardening (Issue 28, 2012). These widely-read publications gave readers a wide range of information on the biology and conservation efforts being made by members of the community to recover the birdwing butterfly.

In some of the articles a popular term for Dutchman's Pipe Vine, the 'fatal attraction' for the Richmond birdwing, attracted a lot of attention and helped to carry the message about needs for its eradication. Ecos (January–March 2001) provided a column entitled 'Tips on making the recovery list', subsequently found useful for preparing several other generic documents on recovery plans for threatened species, particularly reviews for progress and status. Some of the journal articles referred to demise of the major rainforest birdwing habitats including the Big Scrub in northern NSW north of the Clarence River (p. 102) that was cleared of almost all its vegetation for farms by the late 1800s. Other articles were on propagating and where to plant numbers of food plant vines and some referred to conserving the butterfly and its wild food plants, and how to control the poisonous Dutchman's Pipe vine.

The Australian Geographic (April–June 2008) publicised the Australian Aboriginal name for the Richmond Birdwing butterfly – Jalngay Ngahriyan – in the Yugambeh language of south-eastern Queensland. According to linguist Dr Margaret Sharpe and her colleague Dr Sylvia Haworth, 'Jalngay' is derived from 'light' or 'bright'. 'Ngahriyan' means 'dancing' or 'playing', with the combinations providing a traditional name for the Richmond birdwing, and meaning 'dancing lights'.

Excellent publicity for the Richmond birdwing community efforts has appeared in the Regional Council's environmental Newsletters and Land for Wildlife Newsletters. The Council's articles (such as Anon 2012, in Environmental Matters, Summer 2013) have been particularly valuable, providing information to ratepayers about the butterfly, its food plant and the poisonous Dutchman's Pipe Vine. The Newsletter of the Butterfly and Other Invertebrates Club (later Metamorphosis Australia), sometimes had news of adult sightings (for example, No 4, 1996, No. 8, 1998, No. 49, 2008) and one of these, the sighting of two male birdwings on Coochiemudlo Island by DeBaar (1996) is of particular historical (1951–1960) significance and one of the few confirmed records for the Moreton Bay Islands, near Brisbane. The only other nearby record for the islands was from North Stradbroke Island, by Illidge (1921). The report by Arthur Powter (1998) on the predatory mite, *Charletonia* sp. (identified by Matthew Shaw) was an early record subsequently found to be an important natural enemy of the Richmond birdwing eggs. Interesting comments by Sankowsky (2001) included his reference to a method recommended by James Beale (2001), using *Aristolochia tagala* (=*A. acuminata*) as a food plant for the Richmond birdwing. It is now known that this vine is mildly toxic to the developing eggs (see Chap. 3), and is not recommended for rearing the immature stages. Selvey (2008) contributed interesting notes on eggs and feeding by young larvae of the Richmond birdwing and subsequently (Selvey 2009) observed ants attacking a birdwing larva when it was preparing to pupate.

7.2 Richmond Birdwing Conservation Network

The second major group managing recovery of the Richmond birdwing, RBRN, contained in its Constitution a specific clause that required a review of RBRN activities after 5 years from the formation date, together with a decision for members over whether the Organisation would then continue in its existing form, merge with another conservation group, or be dissolved. At the Annual General Meeting of RBRN held in 2009, members resolved to accept an invitation to become a new Network under the umbrella of the larger organisation, the Wildlife Preservation Society of Queensland (WPSQ).

Amalgamation took place in July 2010 when RBRN became one of the 'fauna networks' under the umbrella of WPSQ, under the name of Richmond Birdwing Conservation Network (RBCN). The group has continued with many community activities and the Newsletter, and expanded its activities to work more closely with scientists from Queensland's Department of Environment and Natural Resources, on a new project to study inbreeding depression (see Chap. 8). In 2009 officers from the Department formed a collaborative project with RBRN Members to continue the preliminary studies on captive rearing, with these leading to more detailed investigations on inbreeding depression. This collaboration enabled the handling and captive rearing of a protected species to continue, processes requiring various permits issued by the State Department. The Department continued studies and collaboration with RBRN and RBCN (2009–2013), using flight cages and other facilities at the David Fleay Wildlife Park at West Burleigh on the Sunshine Coast. Other facilities were assembled for holding the immature stages of birdwings of different origins, held in smaller cages at the Queensland Park and Wildlife Centre at Moggill.

7.2.1 Birdwing Network Newsletters and Related Activities

The first two Newsletters (Nos 1–2, 1999–2001) were produced as stapled A4 pages by CSIRO's Double Helix Science Club and circulated to participating schools and local environmental groups. Most articles were authored by the Editors, Sue Scott and Sands. Published by the Richmond Birdwing Conservation Project, with support from Bayer Australia, this Newsletter contained an introduction to the biology and identity of the Richmond Birdwing, its lowland food plant vine *P. praevenosa*, and the identification of the poisonous South American Dutchman's Pipe Vine. Articles explained to readers how they could help with the conservation of the birdwing, or how students could become involved in the Adopt-a-Caterpillar Scheme. This edition contained the first survey form for monitoring growth of planted vines and the data collected became a foundation for the development of cultivation techniques.

Newsletter No 2 (April 2001) referred to a new community group, the TSN Environmental Caretaker Network, set up by The Hut Environmental and Community Association (THECA) and funded with a grant from the Federal Government's Natural Heritage Trust and the World Wide Fund for Nature (Threatened Species Community Grant and WWF). Newsletter 2 described the first major attempts to integrate community efforts to save a remnant of birdwing habitat on the Stanley River at Peachester, and how at this site Jill Chamberlain from the The Wildlife Preservation Society of Queensland supervised the weeding, removal of Dutchman's Pipe Vine, caring for more than 100 wild vines, and planting 240 propagated *P. praevenosa* vines (Chamberlain 2001). Newsletter No 2 reported an unusual overlap in distribution of the lowland food plant (*P. praevenosa*) with the mountain food plant (*P. laheyana*) in the Tallebudgera Valley on the Gold Coast. Also reported in this edition was progress being made with planting vines at Ingleside School, and the rehabilitation of birdwing habitats in the rainforest remnants at the Canungra Army Training Centre, under the careful guidance of Don Lynch and Will Miller. The newsletter quoted early observations on the birdwing in Brisbane and on the Blackall Range by Rowland Illidge (1924b, 1927) and presented the first notes on 'Growing Richmond Birdwing Vines'.

The first RBRN newsletter (in A5 format), reported on progress with planting vines by community groups and the school projects, including the Adopt-a-Caterpillar Scheme. In this Newsletter (No 3), details were announced of the first Annual General Meeting of RBRN held on 8 October 2005 to appoint a committee, expand its membership and hear addresses by four speakers. This meeting was followed by a planning workshop. Newsletter No 3 proposed the concept of 'Stations' for identifying potential habitats to be intensively planted with the birdwing butterfly vines and presented a brief history of the birdwing conservation work that had developed between 1989 and 2001. Newsletters 3–5 (2005–06) followed a similar format with popular and technical articles, highlighting the development of 'corridor contacts' for each local region; members of RBRN who were willing to guide the recovery activities, particularly the cultivation and planting of food plant vines. From No 4 onward, an insertion figured a range of coloured images including the birdwing stages, food plants and their cultivation, and community meetings. Letters from members reported on sightings and progress with rehabilitation of sites for vines. Many of the articles highlighted the benefits of garden cultivation and how the birdwings responded to the healthy vines maintained during periods of drought. Scott (2006) emphasised the problems caused by toxic species of aristolochias and how they had been sometimes mis-identified as herbal medicines, especially if in imported products. On the back cover details of annual general meetings and speakers were advertised, while other occasional advertisements, for example, for birdwing T-shirts, were included. After becoming an incorporated group in 2006, RBRN changed the format of the Newsletter from No 6 until No 23, to include coloured cover and a larger centre insert with images from workshops, meetings and field events, and of birdwing stages and the life cycles, distribution maps, landscapes, birdwing identities, flight cages, food plant vines and flowers, pollinators, fruit, seeds and planting techniques.

The Newsletter covers featured images of adult birdwings, their immature stages or their food plants; the majority of them were from paintings by well-known butterfly artist Lois Hughes. When the Richmond Birdwing Conservation Network (RBCN) was formed in 2010, RBCN Newsletters 19–23 maintained the same format as RBRN Newsletters Nos 3–18, and the contents followed similar themes. Contents included letters to the editor, corridor coordinators' reports, and articles about habitat restoration, and the range of invited speakers appeared on the back cover. The texts covered a range of birdwing-related topics, summarised as follows: (i) tissue culture of the food plant vines, (ii) feasibility of overcoming inbreeding depression and its genetics, (iii) developing the rearing facility at Gold Creek, Queensland, and gathering data on adult longevity, fecundity and immature development, (iv) progress towards managing Dutchman's Pipe vine in the wild (Newsletter No. 22) and (v) key objectives of the networks and administrative structures for developing RBCN and its Sub-fund, to manage financial matters.

Talks by visiting speakers became a well-attended feature of most Network Meetings. They were planned to broaden the interests and awareness of invertebrate conservation matters, through introducing members to a variety of related topics. Several speakers discussed the future of networking, newsletters, meetings, school and community projects. At subsequent general and Annual General Meetings speakers included Professor Roger Kitching on insects in the treetops, Dr Samantha Lloyd on pollination ecology, Professor Tim New on recovery plans for insects, Philip Moran on birdwing vine identification, Dr Peter Mackay on moths in the tropics, Ted Edwards on Australian sun-moths, Dr Alan Yen on invertebrate conservation, Dr Don Sands on birdwing recovery and networks, Nick Clancy led a tour of birdwing breeding sites on the Sunshine Coast, Dr Scott Burnett spoke on conservation programmes for quolls, Drs Rosie Booth, Ian Gynther and Jacquie Seal on captive rearing the Richmond birdwing, Dr Albert Orr on habitat fragmentation and swallowtails, Dr Ross Field on Threatened butterflies in Victoria and most recently, Dr Elizabeth Williams on using ant diversity to assess recovering landscapes. The Richmond birdwing project was thereby placed in a wider picture of related conservation activities in Australia.

Chapter 8
Habitat Restoration and Outcomes

8.1 Planning Habitat Restoration

The general themes for restoring habitats for *O. richmondia* are fundamentally simple in principle – namely, to increase supply of suitable *P. praevenosa* and nectar plants, and to remove *A. elegans* from sites that are otherwise secured against further degradation. However, the variations in climate, site condition and topography across the butterfly's range introduce many complications. Individual site differences in general condition, weed invasion and susceptibility to other threats mean that these common themes may need to be tailored for each individual locality. Overlying the entire programme is the target of area-wide (that is, range-wide) restoration of landscape hospitality and connectivity.

Restoration of Richmond birdwing habitats began in the 1990s, with the aim to replant sufficient food plants and establish corridors (Fig. 8.1) to sustain breeding populations in fragmented subtropical areas of eastern Australia where the butterfly had become extirpated. The range chosen for rehabilitation of habitats was defined by the historic distribution of specimens in museum collections, the published literature and from early observations. Occasional sightings from outside the accepted breeding range for the butterfly, for example, adults reported at Hervey Bay, north of Maryborough, Queensland and Coffs Harbour, south of Grafton, NSW, were not considered to represent part of the original breeding range of the Richmond birdwing but an indication of vagrancy by this strongly flying species. As detailed earlier, the natural distribution of the birdwing was related to the coastal and subcoastal rainforest patches from Maryborough, Queensland, to Grafton, NSW, and west to Toowoomba, on the Main Dividing Range, Queensland.

D.P.A. Sands and T.R. New, *Conservation of the Richmond Birdwing Butterfly in Australia*,
DOI 10.1007/978-94-007-7170-3_8,

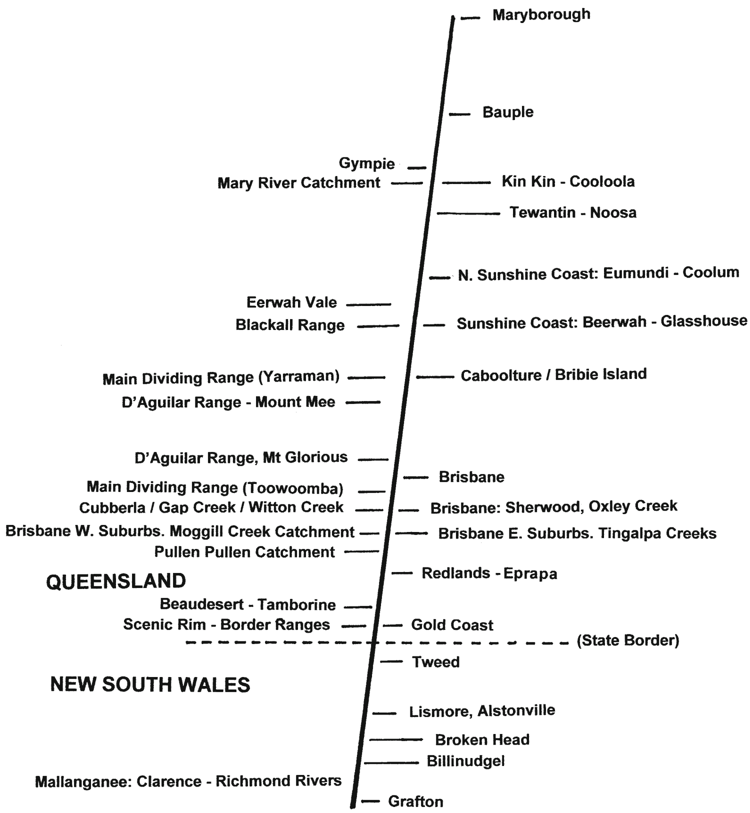

Fig. 8.1 The network of planting corridors planned for restoration of *O richmondia*

Rehabilitation at each site provided many challenges to achieve successful establishment of the food plants, for example the local soils were not always suitable, trees used for supporting vines sometimes proved to be unsuitable (for example, deciduous), or the diameter too large (> 10 cm), or stems and mature trunks were too smooth (as in some eucalypts) to support climbing vines. Often vines were planted too close to the base of trees intended as supports for the climbing vines (a minimum 1 m from the base is needed), but the competition for moisture retarded growth and the vines did not thrive. Determining exposure to the 'right' amount of light required early experiments when it was found that *P. praevenosa* planted in full shade did not grow well even when soils were suitable. Watering at regular intervals in areas subject to prolonged drought became an on-going challenge, especially when vines were planted in school grounds and not easily maintained in holiday periods. At all sites where the vine was planted as part of bushland restoration projects, regular watering was necessary for all rainforest plants if they were to survive.

Understanding the drainage requirements for *P. praevenosa* required years of experimentation before it was realised that vines would not survive in soils that occasionally became dry, too acidic, or in poorly drained areas with high permanent water tables. Permanent surface moisture was important and planning therefore required focus on the water requirements that promoted healthy growth of *P. praevenosa*. In particular, soils must be well drained and preferably on a slope whilst remaining moist. Flooding from extreme rainfall events on four occasions in south-eastern Queensland, was responsible for sweeping away planted vines in several riparian areas.

8.2 Reducing the Detrimental Attraction of Dutchman's Pipe Vine

Local threats varied for each site, but widespread tangible threats include the abundance of *Aristolochia elegans* and invasive grasses. These weeds could only be managed by manual removal or herbicide applications, and by replacing weeds in infested sites with native plants – processes that are ongoing and laborious tasks. Dutchman's Pipe can usually be controlled but eradication of this toxic vine from large areas can be very difficult. Reducing its density can be achieved by herbicide applications and by digging out the roots, but the best method is to cut off vines near the ground and apply the concentrated herbicide to the cut surface, allowing the severed vine in the canopy to dry out. Care must be taken to correctly identify the vines before they are severed. Unfortunately the wind borne seeds continue to disperse and if they produce seedlings, they also need to be controlled by herbicide.

The Dutchman's Pipe vine continues to threaten *P. praevenosa* by competition and the birdwing by its toxicity to larvae (Chap. 2). The vine does not grow at the higher elevations (>600 m), where *P. laheyana* is the major food plant for the butterfly, and is therefore not a threat to the mountain food plant. It competes with *P. praevenosa* for light and supporting vegetation. Unfortunately, Dutchman's Pipe also prefers the similar moist riparian habitat as *P. praevenosa* and because it is much more vigorous, its climbing stems can cut off the sap flow of *P. praevenosa* when the two vines ascend the same canopy. A method to temporarily reduce egg deposition by the birdwing on the toxic vine, has been used with some success, when it and the natural food plant are growing in manageable areas, for example at Burleigh Heads National Park. At times when gravid females were present, the stems of Dutchman's Pipe were cut between ground level and about 1 m high, and this was followed by the upper leaves and stems becoming desiccated and losing their attraction for oviposition. The butterflies will avoid depositing eggs on the very low re-growth of Dutchman's Pipe and their attraction to *P. praevenosa* is relatively increased when it is growing nearby.

8.3 Priority Sites

The tenure of land targeted for rehabilitation was considered to be important in dictating likely security. For example, the future conservation value of privately owned rural properties and gardens even when fully rehabilitated, may not be assured unless covenants or a status such as 'nature refuges' is applied to the land. However, the management of the small and garden sites was often found to be adequate. For example, when land owners watered at regular intervals during drought periods, the quality of the food plant vines at sites was often superior to that of nearby wild vines, and in many cases the butterflies tended to prefer planted vines, especially if they were producing soft sub-terminal foliage.

Early planning in the 1990s usually followed from the local enthusiasm of residents, predominantly in areas where the birdwings were occasionally sighted and where members of local communities were keen to replenish *P. praevenosa*, either in their gardens or together with other native plants at bushland rehabilitation sites. Two notable areas with early signs of local recovery of birdwing populations, the direct outcome of planting *P. praevenosa*, were both in regions with moderate to high rainfalls, on the Sunshine Coast to the north and the Gold Coast south of Brisbane. These areas were mostly old grazing lands or areas heavily logged for timber, for example, north from Brisbane near Beerwah, at the southern end of the Blackall Range and south of Brisbane in the upper Tallebudgera Valley, close to the NSW-Qld Border Range. These local regions benefited from the considerable efforts by the community for protecting small patches of rainforest containing natural *P. praevenosa* and by enrichment planting with vines in the nearby gardens. In the early 1990s Lyndria Cook first began monitoring the birdwing breeding sites in the upper Tallebudgera Valley, where she encouraged other residents of the Valley to be aware of the few remaining vines of *P. praevenosa*, and to plant the vines in their gardens to supplement the declines in wild vines. Prior to this local interest at Tallebudgera, very few vines in patches of rainforest escaped the early clearing programs for dairying and farming. However, there were vines growing in situations such as those 'within a cluster of basalt boulders around a fig tree'. Lyndria began extensive surveys and developed maps showing locations of the vines in the Tallebudgera and Currumbin valleys, and even located one or two *P. laheyana* vines that had unusually established below the escarpment in this region. These early plantings of vines resulted in definite localised recovery of the butterfly by 2010 in this important southern lowland area.

In the Tweed Valley and near Lismore, northern New South Wales, interest in planting *P. praevenosa* began in the mid 1990s, prompted by Bob Moffatt, through Balunyah Nursery at Coraki (Chap. 3), but it was not until many years later that the vine was included in the range of native plants being distributed by other nurseries. Most recent interest in restoring habitats in northern NSW, resulted from the two community workshops run by RBRN at Mullumbimby and at Murwillumbah, when interest in cultivating the vines by native plant nurseries began again rapidly. By 2012 the Tweed Shire Council began cultivating *P. praevenosa* and making the vines available to members of the community through its Landcare Group. Two Council staff, John Turnbull and Greg Newland, promoted the local interest and the Council printed an excellent poster on which most of the subtropical butterflies from south-eastern Queensland and northern NSW were figured, and with a male and female birdwing taking a prominent position.

North from Brisbane in 1997, Jill Chamberlain and members of the Wildlife Preservation Society of Queensland, Caloundra Branch, were joined by Barung Landcare and members of the local community, and received a Natural Heritage Trust grant to care for and revegetate Stanley River Park near Peachester, below the southern end of the Blackall Range (p. 127). The riparian site was originally used as an overnight camp for bullock teams engaged in the timber industry in the early 1900s, but it later became a main roads reserve when a new bridge was built over the river. Remnant rainforest, containing a few old Richmond birdwing vines on the high embankments bordering the river, was left uncleared from the base of the Range and extending along the Stanley River. Members of the community group began clearing the area of weeds, including lantana, *Aristolochia elegans* and exotic grasses, and there they planted more than 240 vines together with some 500 other trees and understorey plants, to expand the rainforest section around a bend in the river, and around the old camping area. By 2000 this site had become a major nucleus site for abundant food plants and breeding by the birdwing, and it formed the most southerly site below the Blackall Range. This was the first link in the projected corridor from the Stanley River, southwest of the Glasshouse Mountains, and linking with Neurum Creek and the northern D'Aguilar Range. By 2010 there were definite signs of local recovery in this area but there remains (at 2012) a gap between these habitats and the southern colonies on Neurum Creek, where inbreeding is likely to occur until intermediate 'stepping stone' habitats can be established from between the Stanley River and the sites at Mount Mee, on the D'Aguilar Range.

8.4 Outcomes of Flagship Sites and Corridors

In the 1980s, Moffatt and Sands recognised that Broken Head National Park was the most significant natural 'Flagship site' (that name later replaced by 'Core recovery site') for the Richmond birdwing near the coast in NSW, and the Park has since then continued to support substantial populations of birdwings. Broken Head and a patch at Iluka are the only intact rainforest patches remaining on the coast in northern New South Wales but *P. praevenosa* has not been recorded at Iluka, while other populations to the north have been mostly destroyed by urban development. The Broken Head birdwing population seems to have persisted healthily each year since 1980 and it seems that as an isolated island of rainforest well separated from other birdwing habitats, the population has not suffered from inbreeding depression. This may be due to coastal rainfall maintaining healthy food plants and butterflies, reflected by the rather stable numbers of adults observed every year.

Some key sites for restoration are noted below.

Burleigh Heads National Park (Fig. 8.2), a volcanic headland at the mouth of Tallebudgera Creek, is the most prominent natural landmark on the Gold Coast. Since the early 1940s, this reserve was known as a unique habitat for rainforest fauna and flora, including a range of subtropical butterflies (Smales and Ledward 1942, 1943), and it has always been an attraction to international visitors who regularly visited the Park and walked its encircling trail, to enjoy spectacular ocean views of the coastline, and to see the wildlife. Larger animals included padymelons, which lived in the rainforest and grazed on fallen leaves, while koalas and wallabies occupied the open forest slopes to the west. As well as *P. praevenosa*, other rare vines on the eastern slopes included *Tinospora tinosporoides* (F. Muell.) Forman, a rare food plant for several subtropical moths. Burleigh Heads is one of the few places where this vine continues to survive in Queensland (Leiper et al. 2009). The headland with its rainforest, surrounding wetlands and the mangroves edging Tallebudgera Creek to the south, supported many species of butterflies, some of them localized or rare and of conservation interest, and including the Regent skipper (*Euschemon rafflesia* (W.S. Macleay)), the Cephenes blue (*Pseudodipsas cephenes* Hewitson), Miskin's Jewel (*Hypochrysops miskini* (Waterhouse)), the rare and predatory Illidge's Ant blue (*Acrodipsas illidgei* (Waterhouse & Lyell)), and the Swordgrass brown (*Tisiphone abeona morrisi* Waterhouse). The latter butterfly was once common in the wetlands but is now almost extinct from all of south-eastern Queensland.

Fig. 8.2 A key restoration site: Burleigh Heads National Park. (**a**) the park in the distance viewed from the town centre; (**b**) the main track within the park; (**c**) forested slope looking toward township from near summit

Fig. 8.2 (continued)

Burleigh Heads National Park has been considered to be a ‘Flagship site’ in far southern Queensland for Richmond birdwings for many years but since the 1960s the Park has been subjected to many different types of disturbance including weed invasions, including the Dutchman’s Pipe Vine. Before urban development, including high-rise buildings and a major coastal road, the vegetation at Burleigh Heads was connected to western habitats by vegetated corridors and other patches of rainforest, to a steep gully at Currumbin. The forest corridors previously extended to patches of rainforest at Upper Tallebudgera Creek and south-west to a well-known fauna sanctuary, the David Fleay Wildlife Park at West Burleigh. Until the 1950s, many of the moist gullies in the area contained rich stands of *P. praevenosa* supporting birdwings (Burns 1972, 1973) but only those on Burleigh Heads and some (very few) vines at Currumbin have survived to the present. Monitoring of numbers since 1972 showed that birdwing populations persisted at Burleigh Heads and could be seen each year until about the mid 1990s. However, in the following years, drought stress, low numbers of vines able to support larvae, and western fragmentation of connecting habitats led to inbreeding depression in the Richmond birdwing. Since 2000, birdwings have either not reappeared or have declined in abundance after temporary recolonisation, but since about 2011, plans were made to rehabilitate this National Park as a Flagship site for the birdwing, first by removing weeds (including *A. elegans*) and after planting many more food plant vines to supplement the natural population of *P. praevenosa*. There are still insufficient wild food plant vines in Burleigh Heads to stabilise the birdwing populations in the Park. Its distance from other birdwing habitats, compounded by roads and urban development, may add to long-term difficulties in permanently re-establishing the butterfly in the Park. However, the site can continue to be recognised as a Flagship site for the Gold Coast and has the potential to regain its ability, by improving management, to maintain populations of the birdwing butterfly at a site that is very accessible to the public and at which the values of conservation can be demonstrated clearly.

Southwest of Burleigh remnant patches of rainforest extend towards the Border Ranges, and some of these harbour *P. praevenosa*. These are important areas needed for protecting the butterfly and rehabilitating habitats with its food plant. Forest corridors extend to the base of the lower mountains from Tamborine Mountain and Binna Burra, south towards the main range and west to Canungra. This is likely to be an important region for survival of the birdwing, if the temperatures continue to rise in south-eastern Queensland, being some distance from the coast, and with cooler night time temperatures.

A small island remnant of the once extensive rainforest, Mary Cairncross Scenic Reserve at Maleny, is one of the most important habitats for rare rainforest mammals, birds, invertebrates and ‘old growth’ plants on the Sunshine Coast. Mary Cairncross Scenic Reserve has been a ‘Flagship site’ for birdwings for more than 20 years and, owned by the Sunshine Coast Regional Council (previously Caloundra Council), has been carefully and skillfully managed to protect wildlife by staff from the Local Government and volunteers. Its plant communities have provided the best, and perhaps only, place for visitors to see mature rainforest trees that once occurred commonly on the Blackall Range. The Reserve supports about 15 'old growth' vines (more than 100 years old) of *P. praevenosa* and where Richmond birdwings have continued to breed and have now been supplemented by more than 40 vines planted on trellises, and part of a 'Birdwing Butterfly Walk' (Fig. 8.3). Here visitors can see the immature stages and adults depositing eggs at the appropriate time of the year, and the males that patrol the nearby rainforest canopy. The Butterfly Walk has become a major site for public (seasonal) viewing of birdwings and their immature stages, with informative signage on their conservation and biology. West of the Blackall Ranges, relatively intact rainforest supporting breeding colonies of the Richmond birdwings is now mostly included in the boundaries of a national park. This is also a very important large area needed for protecting the butterfly and its food plant and it may become the most important area for survival of the birdwing if the temperatures continue to rise in south-eastern Queensland, as they have done in the last 20 years. It is further from the coast than most other habitats in the State and has cooler night temperatures, likely to help temper the extremes expected.

Fig. 8.3 Mary Cairncross Scenic Reserve: (**a**) view south across the Glasshouse Mountains; (**b**, **c**) forest edge abutting visitors' carpark

Fig. 8.3 (continued)

At Beerwah, food plant vines cultivated and planted by Arthur Powter and Ray Seddon had a notable influence on subsequent restoration of habitats on the lower Blackall Range, and the appearance of birdwing adults in the urban areas near Maleny and at the Mary Cairncross Scenic Reserve. Powter lived at the foot of Mount Mellum on the south-eastern edge of the Blackall Range, where very few patches of natural rainforest remained intact and most had been logged for timber, burnt, cleared for farms, or opened up for urban and commercial settlements. In the early 2000s, the planting of *P. praevenosa* on local properties was widely extended by Powter's next door neighbours, Ray and Pam Seddon, and rainforest conservation activities were then encouraged by Caloundra Council, with the focus on propagating many vines for planting by community members under the Land for Wildlife Scheme. The vines propagated by Powter and Seddon were almost continuously planted from mid 1990s to 2011, in properties from the Glasshouse Mountains to Maleny, north as far as Eerwah Vale and west to Peachester. To the east of the Blackall Range, propagation of *P. praevenosa* was earlier carried out at the nurseries of the Beerwah Field Study Centre, headed by Jan Oliver, and the interest extended later to planting the vines at the well-known Australia Zoo on the lower Sunshine Coast, where a project was initiated to encourage birdwings to breed in the surrounding wildlife-friendly gardens, to the east of the range at Maleny. The vines have remained healthy and as recently as 2010, larvae have been seen feeding on several of the larger vines planted in the grounds of Australia Zoo.

At the northern end of the range in 2000, near Eumundi and Lake Macdonald, efforts to re-plant *P. praevenosa* were coordinated by Heather Melrose and Helen Hepburn. Both propagated vines in their gardens, and they encouraged neighbours to do the same in those northern areas where most natural breeding sites had been destroyed by urban development. However, as recently as 2012, local breeding by the birdwings had been observed on Hepburn's vines at Eumundi and as their biomass increased and provided sufficient food for larvae the number of sightings of adults has continued to increase.

From these observations, it has become clear that it takes several years – probably at least a decade – before any areas planted with *P. praevenosa* can be expected to support a breeding colony of the butterflies, but sustained breeding will always depend on some genetic exchange, through habitat corridors or from nearby natural habitats, if inbreeding depression is to be avoided. At the edge of the birdwing's northern distribution in the 1990s, at Elander Point, National Parks Ranger Richard Winter began cultivating *P. praevenosa* to plant back into heavily disturbed and previously-grazed riparian parts of lower Kin Kin Creek. As recently as 2011, female birdwings had been seen in the area and some larvae were observed feeding on the vines planted in the Park's nursery. Upstream on the property of Jenny Nicholas, birdwings became re-established following releases of out-crossed larvae, and these populations had rapidly dispersed towards the east to Lake Catharaba.

Each of the above sites, treated above from south to north, has its individual features for conservation emphasis – but all are relatively rural. The problems differ somewhat for more intensively urbanised areas, such as around Brisbane.

The University Mine site at Indooroopilly is to be recognised as the 'Flagship site' (Core recovery site) for Brisbane, but although many vines of *P. praevenosa* have been planted there, butterflies have not yet been able to easily locate the site for breeding, or to bridge the gaps from the nearest other habitats. The locality had an interesting early history as a Brisbane suburb and as a mine for silver and lead, but these commercial activities were eventually abandoned as nearby housing developments expanded. The site was taken over by the University of Queensland and buildings and laboratories were erected to be used for teaching purposes. In 2010 a decision was made by the University staff to remove the weeds and restore the grounds using indigenous local plants and fauna. With rich and partially volcanic soils, the potential to plant the site with *P. praevenosa* was considered and after some early trials with the vine, 75 vines and many other local native plants were planted in the first round of recovery. This has become a 'Butterfly garden' at Indooroopilly and it is rapidly developing the potential to provide sufficient food plants to support a colony of birdwings close to Brisbane. Members of RBCN hope that this can become a major refuge and site for recovery for the birdwing and its food plant, as well as other butterflies that have been lost to Brisbane.

A similar habitat restoration effort is planned for the Sunshine Cost at Witta, where a substantial and secure patch of rainforest is to be enriched by planting large numbers of food plant vines. A similar number of vines are to be planted at the David Fleay Wildlife Park on the Gold Coast, on land owned by the State Government, and it is hoped that this site will provide part of a corridor to enable movement of adult birdwings and to form a link with Burleigh Heads.

Since 2011 habitats for restoration and of other special significance have been referred to as Core Recovery Sites, rather than Flagship Sites, a term likely to be used for all notable areas being rehabilitated and which have secure tenure. The Canungra Military Training Centre is one such site that was established and managed (by Don Lynch) as a birdwing habitat. It is relatively close to the Gold Coast, Tamborine Mountain and the Border Ranges. Ideally, at least three major Core Recovery Sites are needed for the Sunshine Coast, the Gold Coast and the outer suburbs of Brisbane, and corridors planted with vines should be extended north, from Kin Kin to Gympie and Maryborough in Queensland and also from Billinudgel to Grafton, in New South Wales, to restore habitats throughout the original distribution of the butterfly and its food plant. During drought periods requiring watering, town water supplies were often restricted in urban areas and many of those un-watered plants, mostly near Brisbane, withered and died. Despite these difficulties, many sites maintained are now becoming more significant as habitats for the future.

Most recently, the Tamborine Forest Skywalk – a property edging Cedar Creek on the northern escarpment of Tamborine Mountain – has been designated a flagship site for *O. richmondia* This privately owned property, managed by the Moore family, has 11.5 ha of beautifully preserved rainforest where densities of natural *P. praevenosa* have been enhanced by more than 30 planted vines that are attracting birdwings to visit and breed near the entrance to the skywalk.

8.5 Monitoring and Recording

Several different methods have been used for validating the presence, or determining the abundance of Richmond birdwings, or its early stages. Adults are most easily observed and counted but various behavioural aspects needed to be taken into account on monitoring days. For example, birdwings remain inactive on cloudy or rainy days, when the adults invariably rest high among the forest vegetation and under the overhanging shelter of leafy canopies. The flight of males tends to be restricted to certain patrol areas, often difficult to locate, and they will chase off other males, preventing accurate counts being made in any one site. Females fly beneath the canopies in search of young leaves (usually 14–50 days old preferred) of the food plant on which to lay their eggs. Both males and females can be best observed and counted when visiting flowers to feed on the nectar, usually in early morning hours (0800–0930) or in late afternoon (1600–1830) but only during periods of sunlight. Eggs are the best stage to observe and counts can be made to reflect the number of immature stages likely to develop to adults in a closed habitat. Eggs are most easily seen beneath leaves where they remain, unless consumed by another larva, or become prey to ants, bugs or mites, or become infested by fungi. Egg remnants, or scars on leaves, do not remain visible for long because the leaves become discoloured as they harden and age. All larval instars are also relatively easily seen and counted (unless they are on vines high in the canopy) but the most advanced larvae will prey on the younger larvae when accessible, so that the final numbers do not reflect actual numbers of eggs deposited on any one plant. The bright green pupae are well camouflaged unless they are about to eclose, and a larva will usually leave the food plant and find a leaf of a shrub or tree before pupating beneath it, making them very difficult to find.

Adults and eggs were the two most appropriate stages for monitoring the presence and numbers of birdwings present at any one habitat. Adult males will set up life-long patrolling sites, using the same trees and often the same leaves, for resting during the hot periods during the day. Females, by contrast, rarely remain in one area once they have mated and will disperse well away from their natal or mating sites for maturation, in search of suitable oviposition sites, and making butterflies almost impossible to recognise individually in flight.

One method useful for identifying individual adults, was initially developed for monitoring Queen Alexandra's Birdwing (*Ornithoptera alexandrae*) in Papua New Guinea, by using white or pale coloured (tinted with dyes) 'correction fluid', painted as spots or small bands on the underside of the fore wings. These markings were placed at various positions under the main vein of the fore wing, using at least three prominent positions near the base, middle or near the apex of the wing. There they remain for the life of the adults without any apparent effect on their behaviour or longevity, and the markings can be used on both sexes. With the aid of binoculars, these painted bands or spots are useful for tagging for 'mark and re-sight' population estimates, or for determining longevity, periods of residence, and evidence for dispersal from closed populations.

8.6 Internet Website

The idea of using a database to record the location of Flagship areas (later and currently referred to as Core Recovery Areas), Links (patches of planted vines on private properties), Stations (patches of planted vines on Government-owned land) and corridors, gained value when the internet site (richmondbirdwing.org.au) was set up on behalf of the Richmond Birdwing Recovery Network, by Hugh Krenske, in 2006. The website was used to record localities where *P. praevenosa* had been planted, and as a focus for members of the community to see readily how the growth of vines had progressed and if they had attracted the birdwing butterflies to breed. Details for sightings of birdwing stages were also included on the website. However, although initially enthusiastic, the interest in updating information on the website by community members waxed and waned, partly due to the damage done by climatic extremes, notably the floods and prolonged droughts that destroyed many planted vines between 2005 and 2011. Details of localities (including latitude and longitude, date of planting, instigator/site manager, and provision for updating) were also updated on the website for the Flagship sites, Links and Stations, to provide readily accessible data for anyone wishing to find out where the rehabilitation sites were located and how many vines had been planted.

8.7 Addressing Inbreeding Depression and Ex Situ Conservation

Orr's results from laboratory rearing trials (Chap. 5) helped to explain observations made at several field localities, that showed habitat fragmentation was likely to be causing local inbreeding, and that this loss of genetic variation was compromising the viability, genetic diversity, fecundity and generation times of wild populations. Field observations made between 1980 and 2000 indicated the expression of these effects at Chapel Hill, Brisbane; Burleigh Heads, Sunshine Coast; Tamborine Mountain and at several other locations including Kin Kin Creek and the Sunshine Coast, so were widespread across the butterfly's range. Egg sterility was most commonly detected, followed by abnormal immature development and deformed adults after eclosion. High mortality of immature stages was thought to lead to local extinctions, exacerbated by climatic events such as prolonged drought, already known to disrupt pupal diapause. In collaboration with scientists from the Queensland Department of Environment and Resource Management, and using permits they issued to collect specimens for scientific purposes, a series of experiments were conducted by RBCN Members, and these provided the basic data for developing an out-breeding project to overcome the loss of genetic diversity in populations of the Richmond Birdwing butterfly.

Various methods can be used to address inbreeding depression in field situations, to prevent the local ‘bottle-necking’ that can result from sibling matings. For example larvae can be moved from one area to another to increase genetic variability and when adult densities become low in one particular area. Inbreeding is also exacerbated by the effects of drought on the immature stages and the lowland food plant but local extinctions have occurred most commonly where breeding corridors have been severed and disrupted by human activities. Selection of genetic stock for release will in future experiments be based on mating males and females from widely-separated populations. An important theme to clarify was distance needed between the localities selected for collecting founder parents, to assure isolation and that can be considered adequate to ensure that genetic variation is likely to reduce depression in their offspring. It was known that a female birdwing had been observed about 30 km from the nearest breeding site and a decision was therefore made to refer to 40 km as an appropriate minimum distance for selecting parents for mating and releases of offspring.

8.7.1 Captive Rearing Facilities

Prior to the more complex studies undertaken by the Queensland State Department, in 2007 a feasibility study on captive rearing of *O. richmondia* was undertaken using a flight cage erected at Gold Creek, a western suburb of Brisbane, using methods described by Sands and Richardson (2008). The flight cage (Fig. 8.4) was designed to evaluate cage adaptation to monitor adult birdwing longevity, flight behaviour, feeding, oviposition, egg and larval survival, as well as to identify methods to avoid predatory intruders coming into the cage. The flight cage was constructed as large as possible and mounted beneath a rainforest tree (*Glochidion ferdinandi* (Muell. Arg.) Bailey), where it was shielded from direct sunlight, and mounted with the axis parallel to the stream flow. To maximise humidity, the facility was erected approximately 10 m from a flowing stream (Gold Creek). The arena was intended to simulate as far as possible, the breeding environment suitable for Richmond birdwings in a natural site. The cage facility measured 15 × 4 × 2.5 m (high) and was supported by a rigid tubular plastic frame with a curved roof and covered with black shade cloth. At one end a security cubicle was constructed with the same materials to avoid escape of adults and minimise entry by unwanted animal intruders, including spiders, marsupial mice and reptiles. The base of the cage was covered with plastic sheet and then covered with 5 cm of hoop pine mulch, and the roof frame was fitted with eight overhead mist sprinklers to boost humidity as required. Water from an external tank was provided for misters and watering for the potted plants including the food plant vines.

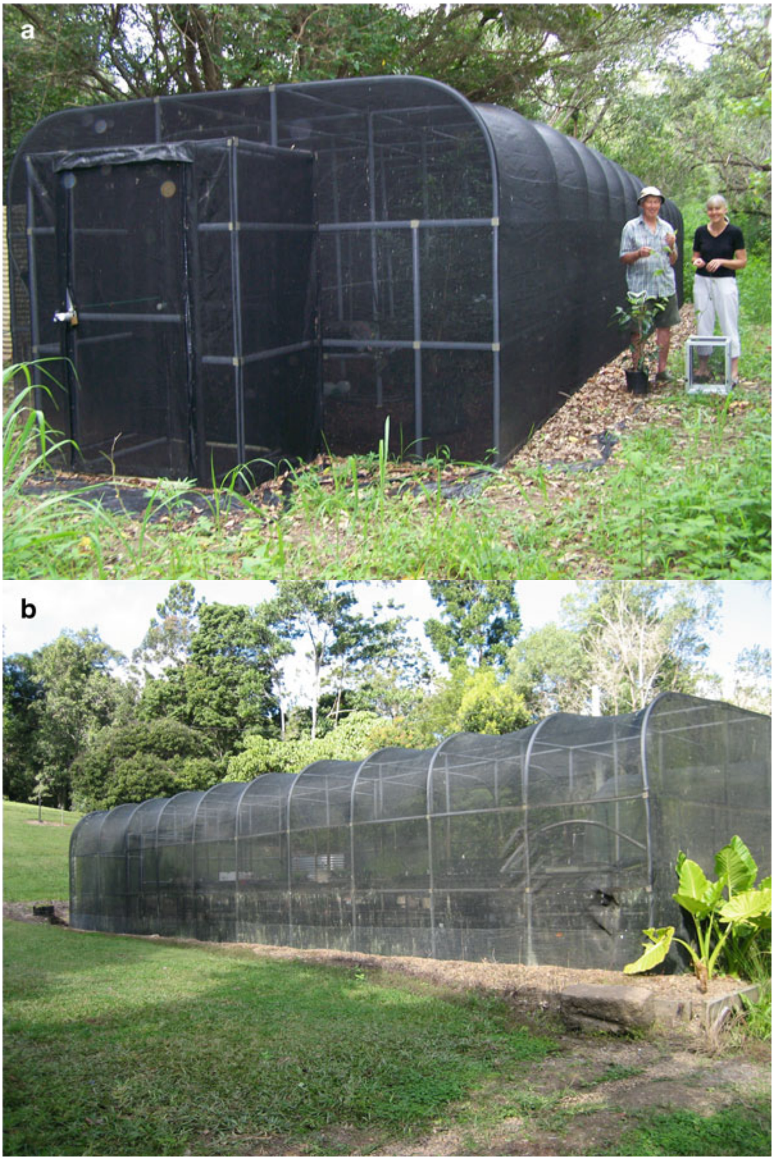

Fig. 8.4 Captive rearing facility at Gold Creek, Moggill Catchment: (**a**) the initial breeding house, outside; (**b**) reconstructed after destruction by flooding

Large potted rainforest plants, *Elaeocarpus eumundii* Bailey (two) and *Syzygium australe* (H.I. Wendl. Ex Link) B. Hyland (six) were positioned in the flight cage close to the potted *P. praevenosa* to allow larvae to behave naturally and transfer from the food plants when ready for pupation. To attract oviposition by gravid adults, 11 potted (pot diameter 16 cm) *P. praevenosa* producing actively-growing soft terminal leaves, were encouraged to grow up erect cords, and then along horizontal cords mounted beneath the roof. The vines and potted rainforest plants were moved randomly from time to time in the flight cage so that broken sunlight would vary in intensity and optimise the attraction for female butterflies. Vines with soft leaves and runners at least 2 m in length, were guided up the cords and the runners were tethered onto horizontal cross-mounted cords to encourage runners to grow laterally, produce many shoots and allow maximum space for larvae to move from one stem to another. Ten smaller (1/2 m high) potted *P. praevenosa* vines ascending stakes were spaced at approximately 30 cm intervals along a central bench. Plants were watered every second day and by natural rainfall. Nectar for adult butterflies was provided initially using bouquets of cut flowers from eucalypts, pentas, buddleia, *Impatiens*, *Melaleuca* spp. and bougainvillea but after adults had become acclimatised to the cage, artificial feeders made from red plastic saucers (approximately 12 cm diameter) and containing white plastic beads, were half-filled with diluted honey-water, replenished every second day. These were readily used by the butterflies.

The initial trials to evaluate feasibility of captive rearing at Gold Creek were carried out with three Richmond birdwing females captured at Beerwah on 30 January 2008, and held in the cage until all had oviposited, or died. Fresh adults were known to live about 30 days and these captured adults were estimated to have lived for up to 2 days before capture, based on their very slight wing wear when captured. The adults and all stages reared in the facility were monitored for development rate and any causes of mortality. Adults were observed feeding from day one on cut flowers, mainly during early morning (before 10.00 h) and late afternoon hours (16.00–17.00 h). The three females began depositing eggs on 1 February (day 2 from introduction) and the last egg was deposited on 21 February, 22 days after they had been introduced to the cage. A total of 50 eggs were deposited with the maximum deposited on 6 February (day 7). Forty six eggs hatched (92 %), three died and one was taken by a spider. Survival from egg to late 3rd instar larvae was 83 %. All surviving larvae were transferred for release on wild food plants at Beerwah, close to the origin of the three female founders.

The studies on mating and oviposition by adults in the flight cage came to an abrupt halt when floodwaters in November 2008 rapidly filled the dam above Gold Creek, and water poured over the spillway and flooded the riparian area where the cage was erected, sweeping away most parts of the cage, including benches and potted plants, some of which ended up more than 1 km downstream (Wilson 2010)! Many parts of the cage including the frame sections and black shade cloth were subsequently recovered from downstream and the cage was re-assembled in 2009, the cloth re-stitched and the facility then re-located on higher ground, and has been adapted for use as a plant greenhouse by the Moggill Creek Catchment Group (Fig. 8.4).

A second rearing facility (Fig. 8.5) was assembled at the David Fleay Wildlife Park, West Burleigh, somewhat different in dimensions (8×3.5×4 m high) from those used for the Gold Creek facility, and made by converting an enclosure that previously held koalas (Gynther et al. 2010). This captive rearing study aimed to evaluate conditions needed for mating and oviposition, using confined adults from different genetic stocks (that is, from geographically separated sources), using large potted food plants held in the cages, and then to raise larvae to third or fourth instar stage so that large batches (30–60) could be released into the wild at target sites. Because of the need to maintain separate genetic stocks of *O. richmondia* for this research, a separate stock was held at Moggill (western Brisbane), again in a dedicated bush house (7.7×2.4×2.4 m high)

Fig. 8.5 Captive rearing facility at the David Fleay Wildlife Park, West Burleigh (**a**) outside; (**b**) inside, with potted vines

one of a bank of wildlife pens, with potted vines. This smaller cage did not allow for voluntary matings, but was used to rear larvae to the pupal stage. As at West Burleigh, individual insects could be reared in small enclosures within the larger facility. Also at West Burleigh, two smaller shade houses were used to house male and female butterflies to be held separately, so avoiding unplanned matings. The project planned to make releases of 30–60 well-grown larvae into wild populations.

Fig. 8.6 Experimental captive rearing facility at Moggill: (**a**) outside; (**b**) inside, with individual planted vines

A third set of cage facilities was set up at Moggill to enable separate colonies of different birdwing from different origins to be maintained (Fig. 8.6).

The Project at West Burleigh began in 2009 and was followed by the first releases at Kin Kin Creek in 2011, and at one of six localities where inbreeding depression had been observed occurring (by Sands and Paul Grimshaw) since 1994. Subsequently, releases of out-crossed larvae were made at two other sites where inbreeding had occurred, and at these sites the populations appeared to be responding favourably. One of the new initiatives at Burleigh was the success of hand-mating techniques, enabling newly emerged females of known origin to be hand-mated with males of other origins, with the option of using captured or cultured males.

Chapter 9
Revising the Draft Recovery Plan

9.1 Introduction

The Draft Recovery Plan (1996, p. 112) for *O. richmondia* was prepared following the enthusiasm by members of the community to become involved in practical recovery activities. By around that time, awareness of the butterfly's increasingly parlous status and its conservation need had become widespread. The CSIRO Double Helix Science Club (Chap. 6) had introduced conservation projects for the butterfly to more than 300 schools in south-eastern Queensland and northern New South Wales and students pursued a range of experiments with the food plant, which itself had become rare and attracted conservation concerns. The plan was designed to promote coordination of community groups, state government and other interest groups in the expectation that this would lead to a practical and sustainable conservation plan for the Richmond birdwing butterfly, and promote action to address the conservation issues then deemed important. In the sense implied here, 'Recovery' is 'the process by which the decline of an endangered, threatened or extirpated species is arrested or reversed, and threats are removed or reduced to improve the likelihood of a species' persistence in the wild' (BCIRT 2008), ideally using a recovery strategy that 'reflects the best available knowledge and experience, setting recovery goals and objectives, and recommending approaches to recover the species'.

Any recovery plan or broader management plan for a species is an interim document, based on the best information available at the time of its compilation and, ideally, couched in terms by which it can be assessed objectively at some future date through provision for periodic formal or independent review, and for revision. Any such review is likely to reveal new information that could lead to changes in the plan's scope and priorities amongst actions and objectives. In short, a recovery plan is a dynamic basis for adaptive management toward a desired and defined outcome. It will almost always include a variety of proposed actions falling under the two major categories of 'research' and 'practical management', the second informed by the first. Gaining any basic biological, distributional or evolutionary information is highly desirable, and practical honing of management approach and actions may flow from this. However, in the

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Table 9.1 The Draft Recovery Plan (1996): stated recovery criteria for the Richmond birdwing

1	Implementation of conservation strategies which will satisfy requests for community and school involvement. Increase knowledge and extend coordination of the Richmond birdwing project
2	Increase in abundance of Richmond birdwings and recolonisation of former habitat sites, and its reappearance at sites where the species has become extinct
3	Control of *A. elegans* (Dutchman's Pipe) and other exotic, invasive vines such as *Ipomoea* spp., including *I. purpurea* (Morning glory), *Macfadyena unguis-cati* (Cat's claw) and *Anredera cordifolia* (Madeira vine) at breeding sites
4	Accumulation and publication of extensive biological and ecological knowledge of *O. richmondia* and its larval food plants as a basis for conservation of the birdwing
5	Development of methods for measuring *O. richmondia* populations taking into account natural cycles of abundance. The reestablishment of permanent *O. richmondia* colonies within 20 % of the current areas of extinction within the next 5 years (2001). The reestablishment of colonies within 60–80 % of the former range within 10 years (2006)
6	Formal identification and preservation of plant communities and remnant breeding or habitat sites for *O. richmondia* in New South Wales and Queensland
7	Successful cultivation of birdwing food plants, particularly of *A. praevenosa*, by schools and the community and continued sale of vines to the general public by nurseries
8	Overcome difficulties associated with captive breeding and developing methods, such as food quality and availability, managing diseases and other mortality factors in larvae and pupae. Approval and support from conservation agencies for a captive rearing programme
9	Agreement between federal and state authorities and the Recovery Team on the direction of the research, educational and conservation strategies

context of a conservation management plan 'research' must be well-focused, and address particular relevant objectives and hypotheses rather than becoming 'open-ended' in scope and duration. In itself, 'research' is not practical conservation, just as listing a species for legal protection may simply help to indicate the need and progressively clarify and stimulate implementation of the measures needed.

Much of the content of this book has flowed directly from directions proposed in the Draft Recovery Plan (p. 112), and there has been no formal external review of that document in the intervening years. Each of the 'recovery objectives' was accompanied by a set of recovery criteria, actions needed – each with several complementary facets – and, highly unusually for the time, indicative costings and suggested duty allocation for each. Although it was never adopted formally by management agencies, this plan has driven much of the project. The recovery criteria (Table 9.1) and overlapping actions proposed are discussed here, as a partial (informal) review of progress and to evaluate and suggest what has been achieved and how best now to make further progress.

9.2 Reviewing What Has Been Accomplished

Any such complex conservation plan that (1) involves many different constituent interests and priorities in the wider community and (2) includes innovative and original approaches and needs for continuing research, is likely to face problems and controversy as it progresses, not least reflecting the diversity and changes in the participants and the variety of opinions and knowledge they may contribute. Many people keen to help, and commit to long-term interest in *O. richmondia* conservation lack formal biological training, and the necessary symbioses between state agency, scientists and wider community interests require clarity, tact and understanding.

Many of the main proposals of the Draft Recovery Plan have been advanced constructively, with the impetus of community interest and involvement critical in all such achievements. Community involvement has been pivotal to any success achieved. Indeed, that enthusiasm has sometimes been difficult to harness or document properly – one recent trend, both intrinsically rewarding and thwarting formal assessment, is that the numbers and distribution of *A. praevenosa* from commercial nurseries have expanded to the extent that it is no longer practicable to maintain complete centralised records of their spread and propagation. Thus, some aspects of 'monitoring' for the butterfly have become a more opportunistic exercise, but with the strong likelihood that sightings and presence of early stages will be more frequently reported. Formal quantified assessment has thus been overtaken by highly satisfying and encouraging, but less easily appraised, outcomes.

Recording the number of active breeding sites and their locations has been considered the most important method for monitoring declines or recoveries. One major difference from many other butterfly conservation campaigns has been that it has not been feasible to estimate population sizes of *O. richmondia*. Strongly dispersive behaviour over large areas has rendered direct counts of adult butterflies (either directly or by mark-release-recapture approaches) redundant. This has transferred evidence of conservation success to the sightings of adults (taking into account many misidentifications) or the reported presence of early stages on planted or natural vines, but with 'new records' from observations providing strong evidence of spread. Records of birdwings on planted vines, some of them far from previously known populations, continue to accrue and to be reported in the network Newsletters.

The 'report card' on outcomes from the Draft Recovery Plan is in places encouraging, both in terms of effort and achievement. Each of the 10 recovery criteria can be appraised separately, and the synergies also assessed. However, only two of those objectives have not demonstrated significant progress, with the balance of early effort reflecting relative urgency and the needs for major focus on engaging community interest and emphasising habitat restoration through food plant propagation. Thus, objectives 1 (CSIRO's Double Helix Science Club and increasing community participation and knowledge) and 7 (Enhance cultivation and distribution of larval food plants) have been notably successful, as the major planks of practical conservation and education. Most others have been advanced substantially, with documentation and fundamental study and field surveys continuing; each has revealed gaps in present endeavour but, for the most part, these are subsidiary to the progress already achieved. Some could not have been anticipated fully, and could not have been achieved without the substantial network (thus coordinated) support now evident.

The objectives that have not yet been fulfilled substantially are parts of numbers 2 (namely, that dealing with relocation of individual birdwings to counter genetic deterioration) and 6 ('documenting plant communities', for which, despite considerable advances in documentation much remains to be completed), and 8 (improving the survival of birdwings in National Parks….). The last has become a politically intricate exercise in Queensland, flowing from the government policy changes in 2012 and its decreasing support for these protected areas, so that they are no longer primarily conservation areas but are progressively given priority for other purposes, including exploitation. Reportedly impending legislative changes appear likely to weaken protection of biodiversity in these areas. The Richmond birdwing campaign has opted to focus efforts more on other areas for which chances of security seem more assured, despite the vagaries of future uses of privately owned lands. For privately owned land, covenants are available. For example, the State-designated nature refuges and Local Government environmental covenants are both valuable designations through which land owners agree to protect the natural features on their land. Several such properties in Queensland are now protecting areas of birdwing habitats and will act as a 'substitute' for the low densities of habitats protected on State-owned land. However, the tenures of these are not entirely secure. For example, mining leases can be taken out legally over any of these categories of protected land.

Similar achievement levels can be suggested for the nine 'Recovery criteria' listed in the Draft Recovery Plan; again, most (despite some being couched rather loosely in scope) have proved generally satisfactory, but two merit comment. One (No. 8, increasing abundance of local food plant genotypes) has not been attempted, and there is still no sound information on genetic variety within *Pararistolochia* species. At the time of this plan, suggestions of likely geographically based genetic variations prompted this precaution, emphasising that local stocks should be used for enhancements. General increase in abundance and accessibility of vines for butterflies has been considered a wider critical priority. The other (No. 10, agreement between parties) has led to development of some fruitful joint exercises and agreements, but many of these have been undertaken on relatively informal levels involving individuals rather than full institutional agreements. This itself has considerable merit in avoiding imposition of strictures and 'officialdom' on volunteer activities. Whilst the specific achievement levels listed in '5' were overly ambitious, not least in ability to measure the outcomes in the detail suggested, the *P. praevenosa* plantings undertaken may well be sufficient for these reestablishments to occur as the vines become increasingly mature.

The collective 'actions needed' (Table 9.2) explored what were then considered the best ways by which to pursue the recovery criteria. They are all couched in broad terms, allowing flexibility in approach. As for the recovery criteria, laudable elements of idealism are implicit, and most have been important in advancing the project. The only one with minimal advance (seven, plant genotypes) reflects the comment above on criterion eight, which has been treated as very low priority. The major positive outcomes have been in extended awareness, community concern and active participation in vine cultivation and widespread plantings as habitat

Table 9.2 The Draft Recovery Plan (1996): stated actions needed for the Richmond birdwing

1	School and community participation in conservation actions
2	Enrichment planting and replanting of larval food plant vines
3	Investigation of control measures for *A. elegans*
4	NSW National Parks and Wildlife Service – Community awareness programme
5	Research plan for the insect/plant interactions of *O. richmondia* and its larval food plants
6	Measurement of abundance and distribution of *O. richmondia* and its larval food plants
7	Enrichment planting of larval food plant genotypes
8	Feasibility study for a captive breeding programme
9	Development of strong collaboration between the recovery team and federal, state and local government conservation authorities in implementation of recovery plan

enrichment and area increase for the butterfly, coupled with widespread education and publicity for the butterfly and knowledge of threats to its wellbeing and measures to reduce these. The collective threats noted in Chap. 5 gave clear directions for need, and, whilst the balance between them has changed somewhat over the years – for example, in increased concerns over invasive weeds as their impacts have intensified – awareness of those concerns is widespread. Some threats, however, are beyond the capability of non-government organisations to undertake. The most effective and sustainable method for controlling many invasive weeds is undoubtedly through carefully planned and sensitively implemented biological control programmes that are potentially capable of targeting all categories of weedy plants, whether grasses, shrubs, vines or trees. However, in Australia there has been reluctance by state agencies to recognise threats posed to biodiversity by invasive weeds, unless they also have an impact on crops, pastures or forestry. Whilst control, through physical removal or herbicides, of Dutchman's Pipe has been a staple activity in the birdwing conservation programme over its entire existence, the control of invasive grasses and other environmental weeds needs strong government agency support. These needs seem destined to increase but will need a commitment to make more funds available for non-commercial biological and ecological research.

9.3 Research Needed

Despite the desirability of a formal review of the 1996 Draft Recovery Plan, much of the Plan remains highly relevant and the augmentations needed are largely suggested to endorse its recommendations, and to render some actions more effective in the light of greater knowledge and experience (together with hindsight!) now available. Based on the progress of addressing threats identified in the initial Recovery Plan (Sands and Scott 1996), ongoing practical actions and several new items needing research have been identified (for example, by Sands 2008 and through wide consultation in 2010), and are intended to form part of a revised Recovery Plan. The themes that merit further consideration and any actions recommended are summarised briefly below.

9.3.1 Monitoring Birdwing Populations and Maintaining Permanent Records

The effectiveness of the initial recovery activities, including widespread propagation of the food plant, is permanently recorded and needs to be incorporated as part of the ongoing recovery actions. A centralised database (in addition to using the dedicated website 'richmondbirdwing.org.au') and publications (such as the Newsletter of the Richmond Birdwing Recovery Network) need to be maintained for recording progress, and documenting both successes and failures. Monitoring sites for return of birdwings to areas planted with the vine will be the only way of appraising success for planning and planting future habitats, for determining where inbreeding effects are occurring, and how often releases of out-crossed birdwing stages are required. The presence of gravid females in an area is best confirmed by using large and potted, healthy sentinel vines to attract egg lay. This 'sentinal' method for exposing potted plants in the wild has proven to be a useful way to assess host selection, proportion and times of appearance of healthy eggs deposited in several other Lepidoptera, and is potentially the best way of recovering sterile eggs laid by females, as a possible indication of inbreeding. Actively increasing the number of rehabilitated sites, particularly those for corridors, will be needed for some time to come, accompanied by monitoring. More formal recording of all these activities is needed, together with comments on outcomes.

9.3.2 Continuing Propagation of the Food Plant

Propagation and distribution of *P. praevenosa* for planting in broad-scale restored habitats and on small-scale, privately owned sites, should be continued in collaboration with local community and Landcare groups. Propagation needs little further modification to the methods used since 2000, but there is a need to find further ways to improve the vigour and survival rates for vines, after they have been planted in the ground, especially in the face of the increasing periods of prolonged drought that began in the 1990s and continued until 2012.

Many, in some places all, vines were lost through unusual levels of drought, to the extent that the integrity of some planned corridors has been compromised. Thus, few of about 30 vines planted in the Upper Brookfield – Moggill Creek area, west of Brisbane in October 2011, have survived and grown into upright vines. For future plantings, availability of water or capacity to artificially provide water for plants as needed must be an increasing consideration. Individual plants, or plants from some populations may yet be found that will be better adapted to drought and these can be propagated for planting in dryer areas and be invaluable if drought periods increase even more widely. An effective moisture-retaining compound may be found that will not disrupt the formation of very fine roots when incorporated in the soil when planting out vines, or trials could be extended to find better ways of maintaining moisture near the roots of young planted vines, as suggested by Sue Scott (pers. comm.).

9.3.3 Stations, Links, Corridors and Stepping Stones

The landscape perspective for conservation activity has focused on the availability of *P. praevenosa* in places that may help to (1) increase effective areas of occupancy and (2) reduce isolation between populations of *O. richmondia* whilst also providing opportunity for new populations to establish. Between 2005 and 2012 the numbers and locations of habitats restored and planted with *P. praevenosa* depended largely on the interest of local communities, and their willingness to maintain the vines by removing weeds and watering vines during periods of drought. In most suburbs, urban gardens were the sites selected for planting the vines and these were often given more care with management than rural and local government bush regeneration sites, reflecting the individual attention from householders. However, there is still need to extend and expand these projects if the Richmond birdwing is to return to areas from which it has become extirpated, for example in the suburbs of Brisbane. All habitat rehabilitation requires guidance, including coordination of activities from experienced members of the community, to focus on environmental details of habitats. For example, understanding the nature of soils, water tables, vegetation, and drainage, and what is required by the vines for healthy growth, including trellises or other supports, all requires access to information gathered by people who have suitable practical experience, some having been involved over many years. The network newsletters play a valuable role in spreading this practical information. Likewise, an increase in numbers planted and the density of vines in any patch may be important for improving hospitality of key sites such as those with low drought risk and assured water supply. Mapping of sites and records of tenure and tenure changes should become part of the permanent record of conservation activity. We are aware of the deterrent effect of overly burdensome requirements for such administration amongst volunteer groups, but see this as a vital component of any revised plan.

9.3.4 Core Recovery Sites and Flagship Sites

Specific areas for rehabilitation will be needed for some time to achieve recovery, particularly finding land with secure tenure that can be kept free from disturbance for the longer term. Special areas or parklands, similar to the ‘birdwing park’ section at Mary Cairncross Scenic Reserve, need representation for all local government land where the butterfly once occurred, and to provide an opportunity for community and volunteers to manage the habitats. These and especially any designated. Core Recovery Sites could be based on portions of local government parklands, or ideally each form part of an arboretum for native rainforest trees (within their natural range), and include a constructed trellis from which at least 30 planted vines can be allowed to ascend into the canopies of indigenous trees. A long term plan is needed to secure such sites, and to rehabilitate them with at least one such birdwing park in each municipality, preferably with no more than 30 km spacing between each site, depending on availability, watercourses and other landforms. The overall conservation plan depends on promoting inter-site connectivity, using habitat corridors of restored indigenous vegetation. A focus on restoring riparian vegetation is seen to be the best option for enhancing future widespread recovery. Carefully planned publicity for such sites may be a useful lever for future efforts, coupled with the present capability to demonstrate their values through successful expansion of the birdwing's range. The Brisbane focus (p. 152) has immense value in garnering awareness within the community, towards restoring degraded rainforest habitats to benefit local native species.

9.3.5 Alternative Food Plants: Addressing Potential Toxicity

The major focus on *P. praevenosa* and, to a far lesser extent, *P. laheyana*, appears well justified, and is likely to continue. Prospects for finding new drought-hardy food plants do not appear promising, and many exotic vine species introduced into Australia have all proven to be weedy or toxic, in a way similar to Dutchman's Pipe vine as noted by Straatman (1962). However, novelty and diversity are sought continually by the nursery trade, so that consideration of any additional candidates is important in fostering that support and developing improved husbandry methods.

Additional species of *Aristolochia* or of *Pararistolochia* (such as *P. deltantha*) from northern Queensland might be found and planted in special reserves in large enough numbers, and if not toxic to *O. richmondia,* and not having the capacity to become weedy, such plants could be introduced into the new and disturbed areas (including gardens) to reinforce the subtropical range of the butterfly. The tropical vine, *Aristolochia acuminata* has been proposed in the past (Chap. 3) as a substitute food plant for *O. richmondia* but its toxicity to eggs, probable toxicity to the pupae and possible detrimental effects on reproduction after larvae have fed on the vine, needs evaluation before *A. acuminata* is recommended for planting on a large scale as a potential food plant for the Richmond birdwing. Non-toxic varieties of *A. acuminata* may occur but the use of varieties of this species as a food plant would require propagation of plants from many different locations in northern Queensland, before selective trials to determine toxicity to immature *O. richmondia.* The chemical basis for toxicity of foliage of Dutchman's Pipe Vine (*A. elegans*) may be worth investigating to see if *O. richmondia* could be genetically manipulated, or non-toxic varieties of the vine selected, to enable immature stages to successfully develop on this exotic vine. However, these options remain largely impracticable, and have only very low priority in relation to other measures of more direct restoration at present. Such novel and essentially speculative proposals are intriguing but should not be encouraged at the expense of other higher priority activities involving planting indigenous food plants.

9.3.6 Managing Weeds

Environmental weeds are becoming a very serious threat to indigenous insect and plant biodiversity throughout Australia, and their effects on *O. richmondia* serve to indicate aspects of their wider impacts. In Queensland, some weeds that threaten *Pararistolochia praevenosa* have already been targeted in biological control programmes. For example, Cat's Claw Creeper (*Macfadyena unguis-cati*) and Madeira Vine (*Anredera cordifolia*) are probably two of the most serious invasive vine weeds targeted in biological control programmes, but the success of any of these programmes is yet to be evaluated.

Invasive grasses of African origin, notably Molasses Grass, Green Panic and Signal Grass have recently become very serious environmental weeds in subtropical eastern Australia (Elliott 2008), moving from their intended pastures to invade moist forest ecosystems, where their competitive impacts on native flora following burning programmes are severe, and their competitive responses to prolonged drought are followed by increases in the intensities of wet periods. An impact sometimes overlooked is the ability of the African grasses to out-compete regrowth of most indigenous plants and prevent recruitment by seedlings after sub-surface disturbances, including fires. In addition, understanding the ecological roles of control burning practices throughout the range of *O. richmondia* may provide valuable lessons for integration with weed management.

9.3.7 Addressing the Impacts from Climate Change

The contraction in northern range of both *P. praevenosa* and the butterfly, and apparent declines also in abundance of pollinators for the vine, is thought to be partially related to global warming. These contractions in distribution prompt the opportunity to create new habitats south of the previously-known natural range of *O. richmondia* in northern NSW and also raise the associated possibility of assisted migration (below). For example, the food plant vines and the Richmond birdwing could be moved south, to take up new habitats with cooler climates. Such a move would address the probability that pollinators and/or their capabilities to cross-pollinate flowers of *P. praevenosa*, have become reduced over the last 30 years. The project would not be a short-term exercise and once a site is located, it is likely that vines would require at least 20 years before they were sufficiently large and vigorous to support birdwing populations. There are several forested areas between Grafton and Coffs Harbour, so extending from the southernmost parts of the current documented range that may be suitable for translocation of *P. praevenosa* into existing rainforest riparian patches. Some of these are only about 40 km from the pre-1950s southern limit for the birdwing, and might even be colonised naturally under suitable conditions. For this work, the involvement of a community group in site selection, weed removal and site preparation and maintenance would be essential, and before extensive and time-consuming efforts are made by volunteers, the tenure of the selected areas must be secured for long-term protection and rehabilitation. The provenance of the vines used for planting outside of the range may need to be considered and the stocks taken from localities under currently marginal conditions but that are predicted to be best adapted to cooler climates. For example stocks from near Mallanganee, a locality at the western limit of the natural range in NSW, may be most suited for translocation to localities further south. Although unlikely, there may be local varieties of *P. laheyana*, that are better adapted to drought than *P. praevenosa*, and these could be propagated for the lower altitudes being proposed as habitats, for the southern parts of the range. 'Assisted migration', has been used in the past to move animals and plants to habitats that have become climatically more suitable due to warming, and is advocated widely as a serious option in species management for the future. This method could be used for establishing food plants and butterflies in new areas south of their original natural range, in areas that were once too cool but where the climate has become warmer, and is now suitable for successful birdwing and food plant translocations and their establishment. Any such exercise would be pioneering amongst Australian butterflies. Its long-term and highly idealised nature are both deterrents to adoption. We note the option here mainly to emphasise the need for a long-term visionary perspective for any such recovery programme in which sensitivity to climate change may be implicated.

The effects of climate change on adaptability of the Richmond birdwing to the cooler temperatures at higher levels of the Border Ranges (>600 m), would be informed by monitoring in view of the usual susceptibility of the immature stages of the butterfly to cold. At present, *P. laheyana* is common in mountain rainforests on the volcanic rim surrounding Mount Warning (p. 36), and occurs from Springbrook and Binna Burra, Queensland via the Western Rim and over the State Border, to the Nightcap Range and east as far as Mount Nardi in NSW. Many of the slopes and valleys below these mountain ridges already support *P. praevenosa* at lower altitudes. The expected increases in temperatures at elevations above 600 m may reduce mortality of these stages currently experienced in the areas where *P. laheyana* is known to be a suitable food plant, capable of sustaining breeding in the mountain areas. This could become an example for a lowland-adapted species moving to higher elevations to breed on a food plant always palatable to larvae, but previously growing only outside of the climatic envelope suitable for the birdwing butterfly to persist.

Climate matching of the habitats of the vine with these southerly eastern areas in NSW may provide a key to compensating for the habitats lost in the northern part of the range. For example, the suitable climatic limits where *P. praevenosa* occurs naturally at Eacham, on the Atherton tablelands, and those of the original range from Maryborough to Grafton might be definable in terms of seasonal temperatures, rainfall and characteristic plant communities. Such data could be used to match localities that were previously too cool to support the butterfly or its food plant, but which may come 'on line' as conditions change, and predict those southern areas where translocation (following assurance of adequate food availability) could be attempted if both vine and butterfly were likely to become established in the new range. Critical preliminary assessment of the values and feasibility of any such predictive exercise is needed.

9.3.8 Genetic Studies on the Richmond Birdwing

The need to extend studies on inbreeding depression remains important and, while the initial methods to release outcrossed larvae into the wild are showing promise, the frequency of outcrossing required to maintain variation that will prevent inbreeding, has yet to be determined. Until 2012, outcrossings of adults and the release of the outcrossed larvae, have been done in Queensland by scientific staff from the Department of Environment and Heritage Protection. The methods could be streamlined so that captive rearing work could be continued in conjunction with trusted community groups, relieving the time of government staff and pressures on their facilities. Under supervision, captive rearing of the Richmond birdwing could be effectively managed by the community to stimulate interest with the public, and with the capacity to breed larger numbers of individuals than is now possible with the limited government facilities available. However, we urge effective coordination and documentation of all such effort for a threatened species, by the appropriate conservation agency. The question remains of how often, and how many, outcrossed birdwings should be released into a population at each site suffering (or likely to suffer) from inbreeding depression and if these actions should be adjusted according to local climatic extremes that have affected birdwing and food plant populations. These issues have not yet been resolved and can only be determined when inbreeding has returned and is again occurring in populations that have temporarily been recovered. The time for further releases and the numbers required, may vary for each locality, as well as the genetic origin of the founders.

Genetic markers for inbreeding would enable monitoring of populations, to find out how many generations of inbreeding can occur before detrimental effects are expressed, and to identify those populations least likely to suffer from inbreeding depression. Orr's (1994) trials suggested likelihood that impacts might occur rapidly, within two generations. Finding resistant founder stocks most suitable for redistribution to affected areas, would become an important part of the recovery process. DNA analysis may reveal or provide the means to search for other 'external' factors influencing inbreeding, for example, *Wolbachia* infections or similar disease associated with genetic phenomena. Such genetic markers could be used to improve the methods for monitoring recovered populations, and detecting developing problems in isolated populations.

9.3.9 Aristolochiaceae: Pollination Studies

A major gap in knowledge of the food plant biology remains recognition and understanding of the insect pollinators and their biology (Chap. 3). In general, very little is known about the pollination biology of the Aristolochiaceae, or the identity of their pollinators in Australia or Papua New Guinea. As noted earlier, the identification of insects found in the flowers of Australian species is uncertain, but with strong implication that Phoridae may be important pollinators.

There is some evidence that the number of seed capsules developing to maturity declined on wild vines during the 1970s and 1980s. However, the declines in seed set did not become apparent on all vines cultivated in gardens, especially in areas where moisture was maintained around the vines. In these garden areas, unidentified small flies thought to be pollinators were much more abundant than in the wild, suggesting they were breeding in the decomposing vegetation or soils that had been kept constantly moist by watering. Production of seedlings from seed germination in gardens was also more often observed than near wild vines. To understand the ecology of *Pararistolochia* spp., and hence apparent rising threats to reproduction of the vines, the taxonomy and biology of the pollinators needs to be investigated, based on adequate and well-documented collections taken from across the distribution of the vines. An initial need is to determine if only one genus of small flies are the pollinators, and if only one, or several different species of flies, pollinate each species of vine as seemingly occurs elsewhere (p. 55). There is also need to locate their breeding sites, determine if they are dependent on particular soils or decomposing vegetation, identify their adult food needs and pollination specificity, and if both sexes are involved. Probable *Forcipomyia* spp. midges have been observed by Sands feeding on the haemolymph of large larvae of Lepidoptera in the rainforest habitats of the Richmond birdwing, and it is possible that these midges may eventually prove to be pollinators of *Pararistolochia* spp. in subtropical eastern Australia. At present, however, Phoridae appear to be the principal candidates for future evaluation.

9.4 Planning for the Future

Protection of remaining natural habitats and corridor fragments, and their enhancement and enrichment together with foundation of new patches, will continue to be the most important objectives for a future recovery plan until birdwings are: (i) able to maintain breeding colonies within the current range and (ii) move back to occupy rehabilitated areas throughout the original range. These areas will need to be sufficiently close to encourage individuals to move between them. In some areas restoration of birdwing habitats will be dependent on small-scale cultivation of the food plant vines, for example in domestic gardens, particularly in areas where there are no natural areas suitable for re-planting with the rainforest plants that are part of natural communities.

Permanent protection of plant communities in which birdwing habitats can persist can automatically protect other rare and threatened species of flora and fauna known to be associated with *P. praevenosa*, including trees and shrubs (such as the common species listed in Table 4.2, p. 85), orchids, sedges and easily-overlooked ground cover plants and many other invertebrates. The 'umbrella value' of *O. richmondia* has as yet unrealised potentials in conservation advocacy. There are suitable sites that can be rehabilitated easily, for example many degraded weedy creek embankments abound near towns, and in country areas of south-eastern Queensland and north-eastern NSW, where weed removal and replanting with several native tree species and the food plant vines could probably result in birdwings moving back into restored areas within 15 years. Many community environmental groups willingly participate in this type of restoration and often they can obtain assistance from local governments to help with purchase of mulch and plants, and general maintenance such as weed control and watering. It is possible that such activities could flow from the current network interests. Such a scale of bushland rehabilitation may not be seen as viable unless several species of conservation interest, and plants and other animals acknowledged as also needing conservation, are included in a master plan for ecosystem rehabilitation. Ideally for an ecosystem approach, one supervisory group with the key objective of birdwing butterfly conservation could be represented by members from targeted municipalities. Such a group might work with members of Landcare groups and encourage participation by interested local governments, but it would need to be built on past examples demonstrated by smaller-scale successes.

Pararistolochia praevenosa could be promoted for inclusion in the batches of native plants, known to be indigenous to particular localities (for example in Hacker et al. 1994). Such plants are regularly handed out to local rate-payers in each municipality, with instruction on how to grow the vine and request for recipients to keep records on their survival and growth, and keep simple records for the appearance of the immature stages of the birdwing when they appear in gardens or rehabilitated areas. This was a major role for the Richmond Birdwing Recovery Network from 2005 to 2011, but the activities and record-keeping became too complex for one community group of voluntary participants, and there was no public funding available to provide a salary to appoint people to handle the coordination.

To summarise, to answer the question 'where to from here' (Sands 2008) and anticipate needs beyond 2012 for the Richmond birdwing conservation project, several points arise. First, a paid coordinator is needed by an appropriate community incorporated group, to (i) help with the development of a revised, national (Queensland and New South Wales) Recovery Plan, aiming principally for habitat and corridor rehabilitation for the Richmond birdwing, (ii) the Recovery Plan (guided by a Recovery Team) should be based on ecosystem rehabilitation, referring to other fauna and flora that will benefit alongside the birdwing and its food plant, (iii) keep central records of vine plantings and monitor their growth and survival, and make them available to community members (perhaps through a website) (iv) continue to lobby state and local governments towards protecting permanently, the tenure of birdwing habitat, and (v) explore opportunities for sponsoring higher degree students to work on targeted areas of research (such as vine pollinators) and (vi) help publicise progress of the project and importance of working with invertebrates in habitat rehabilitation.

By 2012 there were definite signs of recovery of the Richmond birdwing in south-eastern Queensland in areas following extreme drought and where the butterfly had declined but had not become extirpated, and the positive response could be attributed directly to increasing the local abundance of the food plants, by planting *P. praevenosa* vines in gardens and rehabilitated bushland areas. For example, at Tallebudgera and Maleny, where the birdwing had become rare by the 1900s, by 2000 the butterfly had become more abundant and by 2011, was no longer regarded as a rare species in both areas despite the destructive effects of periods of drought. This period provided evidence of the excellent response by butterflies breeding in managed areas such as gardens, when watering regimes helped maintain the quality of the vines needed by larvae to offset their starvation.

Problems likely to be encountered span almost every aspect of the project. Maintaining the activities by community members is likely to be a challenge and once the birdwing becomes abundant locally, interest and efforts towards maintaining recovery efforts are likely to wane. Keeping a supply of quality *P. praevenosa* available for purchase by the public will be necessary, and growers must avoid the temptation to sell seedlings as tube stock that when planted, are likely to result in high mortality.

Several other important focused recovery measures in progress will continue to link these themes. They include:

Bringing birdwings back to Brisbane. One of the long-term aims of the project has been to restore corridors, habitats with adequate numbers of *P. praevenosa,* planted in Brisbane suburbs, to allow movement of individuals with sufficient genetic variation into restored habitats, and to continue movement between Brisbane and more distant colonies. This is the only way known to address the problem with inbreeding depression that has probably been occurring in the vicinity of Brisbane since the 1920s. Although several sightings of adults occurred since the 1980s (for example by Jonsson 2008, John Moss pers. comm.) including some breeding observed by Richard Bull in 2010 few separate breeding events have occurred in the peri-urban parts of Brisbane. The last regular breeding at Chapel Hill probably failed to continue after about 2000, despite adequate quantities of food plants (>20 mature vines).

The need to secure tenure for wild birdwing habitats. As noted earlier, by 2010, only 4.8 % of land area was thought to be secure in National Parks in Queensland, and the proportion of subtropical lowland rainforest represented in these parks, remained very small. Very few areas of lowland (<200 m) coastal rainforests are protected in national parks in Queensland, or the remains of a vast original area in New South Wales, and it is often these coastal rainforests, as well as heathlands and wetlands that are habitats for unique invertebrate biodiversity. All coastal subtropical rainforests are especially vulnerable to invasions by exotic weeds, particularly African grasses and lantana (*Lantana camara*), and the terrestrial invertebrates they support are most at risk due to lack of focused weed management practices. More recently in Queensland and New South Wales changes are being made in the criteria for protecting the national parks to conserve fauna and flora, to ‘opening up’ the national parks for sport and recreational activities, and resorts. In Australia the State governments can vary the management and use from time to time and according to political views, without the need to take into account Federal policies for protecting biodiversity, due to the anomalous use of the term ‘national’ parks in Australia.

Less than 20 % of the small area of subtropical lowland rainforest in Queensland’s national parks support natural ecosystems for the Richmond birdwing and the food plant vines, the remainder of this type of habitats being mainly on local government land or privately-owned land. One option for increasing the areas for breeding by the birdwings might be to artificially plant sufficient vines in selected (environmentally suitable) national parks as a means of attracting new colonies or to enhance the ability for populations to increase in already-occupied parks, by increasing the densities of vines. The second option is more desirable and could contribute to overcoming inbreeding depression noted in areas where the densities of the birdwings are low due to scarcity of food plants.

Chapter 10
Broadening Perspective

The story of the Richmond birdwing conservation project so far contains some very pertinent messages for advancing butterfly conservation. It has been undertaken in a milieu that contrasts markedly with most butterfly species conservation campaigns in Europe or North America, in which a groundswell of interest, goodwill and involvement has been evident for decades, or longer. Under those circumstances public support can commonly be presumed, and garnered easily, in any such initiative, as an invaluable component of the conservation programme. In Britain, for example, concerns for butterfly wellbeing extend from the nineteenth century, with the continuing campaigns for the Large copper (*Lycaena dispar* (Haworth)) and more recently the Large blue (*Maculinea arion* (Linn.)) amongst the leading global efforts for individual taxa and supported by wide community interest and concern throughout their history, leading to effective international cooperations over the European ranges of these taxa. The ongoing efforts to re-introduce *L. dispar* (from European stock of closely related subspecies) to Woodwalton Fen and more recent consideration for extending this effort to the Norfolk Broads (Pullin et al. 1995), and the dramatic success of bringing *M. arion* back to southern England from a Swedish stock (Thomas et al. 2009) have both had wide benefits in advancing appreciation of the subtle biological idiosyncrasies of these taxa, and the care needed to provide for these in the receiving environments. These two projects have also demonstrated that such exercises are not to be regarded as a 'quick fix', but that enduring effort and commitment may be needed over several decades, or more. Those benefits have extended to important widening of awareness to a broad public constituency in which appreciation of natural history has strong traditional foundation, and amongst whom the detailed biological idiosyncrasies of individual ecologically specialised species can also be appreciated and catered.

Likewise, concern for some North American butterflies, such as the, now-extinct, Xerces blue (*Glaucopsyche xerces* (Boisduval)) in the United States (Pyle 2012) and the major campaign to save the El Segundo blue (*Euphilotes battoides allyni* (Shields)) on coastal dunes adjacent to Los Angeles International Airport (Mattoni 1992, for history) has done much to introduce such ecologically specialised

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butterflies to the public, to stimulate their interest and assure their place on wider conservation agendas and legislation. The extensive publicity wrought by some important campaigns with strong political aspects has been effectively coordinated, in recent years increasingly through organisations such as Butterfly Conservation in the United Kingdom (expanded recently to found Butterfly Conservation Europe) and the Xerces Society in North America. With the former, for example, membership is such that it enabled 10,000 people to participate in a single butterfly count in Britain in 2010 (Warren 2012). The interest is complemented by, sometimes controversial, legislation that lists species deemed in need of individual protection as their status becomes parlous. Listing commonly leads to preparation of 'recovery plans' of varying scope and levels of commitment (New 2009; New and Sands 2004), but despite ambiguities over the listing process and its intended outcomes, this step is often a prerequisite for eligibility for government funding or agency support, as over much of Australia.

As in the above examples, most such intensively pursued cases of butterfly conservation have been strongly site-focused, with efforts directed primarily to protecting and restoring small sites occupied by highly localised focal species or subspecies. Whilst landscape issues have indeed been acknowledged for dispersive species – for example the need for nectar supplies during the migratory flights of the Monarch (or Wanderer, *Danaus plexippus* [Linn.]) in North America (Brower 1995; Brower et al. 2012) – almost all butterflies of greatest conservation concern have been those regarded as relatively sedentary, with ranges reflecting narrow range endemism or the outcomes of extensive landscape fragmentation that has left them only on small, often isolated, remnants of formerly more extensive habitat. Some taxa are known from only single sites, so that initial management must be site-focused. In some examples, later efforts have involved translocations from either captive-reared or field stock, to increase numbers of field sites or viability of populations. Increased appreciation of the roles and diversity of metapopulations (flowing largely from the parallel pioneering studies on checkerspot butterflies undertaken in northern Europe and the United States: Ehrlich and Hanski 2004) has also been pivotal in understanding the importance of local extirpations and how to address these in conservation management. In contrast, and despite long awareness of range-wide declines and changes in many species, practical conservation of butterflies that range widely over the landscape has only rarely been addressed in detail – in part reflecting the difficulties of effective coordination and the need, in some, to transcend political or administrative boundaries, rather than focusing on management of bounded, definable and restricted sites. 'Whole of range' conservation for the large and showy Richmond birdwing is very different from 'whole of range' conservation for many small and restricted lycaenids found, for example, on a single site or in a few urban remnant patches. Attempts to restore a species over its entire known historical range, covering several hundred kilometres of latitude, can raise many problems when integrating political variance and landscape ecology with the biology of a species. Yet *O. richmondia* is indeed an ecological specialist, with its consumable resource needs just as constraining and precise as those of many smaller and supposedly more sedentary butterflies. Whilst dispersal capability and ecological specialisation are frequent predictive correlates for vulnerability and conservation need, this combination of features is relatively unusual.

Ornithoptera richmondia has been important in the development of butterfly conservation awareness and practice in Australia, for several reasons. First, the campaign described here is the largest and most enduring programme undertaken so far in the country for any insect species, and particularly so when being considered as occurring in a landscape scale, rather than confined to small isolated habitats, as above. Second, it has focused on an incontrovertible flagship species, long impressive and of interest, and for which widespread public sympathy has been apparent throughout the period of conservation concern, so that its plight has received sympathetic attention from many quarters. It is a member of what is arguably the most charismatic family of insects, attracting wide international interest and having regional relevance well beyond a strictly Australian focus. Third, linked strongly with this, practical community interest has been fostered and sustained throughout the project, contributing to welcome publicity and advocacy, to successes based on increasing biological understanding and to defined inspection procedures accepted and understood by the participants.

It is important to note that such high community involvement for butterfly conservation, whilst relatively commonplace in parts of the northern temperate regions, is not so in Australia and generating that support has itself been a pioneering exercise. The programme has provided lessons of much wider relevance both in butterfly conservation and in the wider context of an umbrella role for threatened subtropical forests that support numerous endemic and characteristic fauna and flora. The Project also transcends state boundaries, with Queensland and New South Wales legislations influencing processes, and so also the outcomes of conservation activities, with potential for fragmentation of effort unless these are coordinated effectively.

Public support for butterfly conservation in Australia must be applied and nurtured carefully. There is no societal equivalent in Australia to the North American and European organizations noted above, each having thousands of dedicated members, and the number of lepidopterists in Australia, whether professional or hobbyist, is small. Several States have a regional Entomological Society, or interested Landcare or natural history groups, that have been important in fostering awareness of biodiversity conservation, but much of the support for any individual species has come from local ‘friends groups’ or some functional equivalent of local concern, in many cases initiated and sustained through the zeal of individual proponents. For any wide-ranging species, the network of individuals or affected constituents is likely to be far greater than those concerned with a single small site, although the latter may have strong local support in dealing with a tangible context that can increase chances of support for local administrative attention and funding. It is pertinent also to note that the extent of government agency expertise and especially financial support for invertebrate conservation, is very low in Australia, so that much of the practical work involved, as well as major impetus for actions, is community driven rather than agency dictated and continues to rely heavily on community support.

Prominent flagship taxa have the potential to enlist and stimulate support from all levels of society – so that education and publicity on species such as *O. richmondia* conveys strong public messages. The values of this programme thereby extend to a broad increase in awareness of butterflies and other invertebrates and needs for their conservation. In conserving the Richmond birdwing, many participants have come face-to-face with the problems of butterfly conservation for the first time, with many young people introduced to insect biology, taxonomy and conservation through school participation and the regional integration and dissemination of information and advice. In this regard 'flagship' or 'icon' species are an important theme in invertebrate conservation. The vast array of species that may need conservation in some way cannot all be treated individually with the very limited resources and expertise available. Selection of the major focal species for conservation should ideally take this into consideration in anticipating the widest possible benefits, and with realisation that any form of triage that leads to selection of one (or some) species for attention may be effectively depriving others of support and, possibly, increasing risk of their demise. Whereas such selection is often subjective, based on individual appeal of the species or zeal of the proponents, more objective assessment against agreed criteria of risk may be important. This dilemma is central to suggestions that the 'species level' of insect conservation should increasingly be replaced by ecosystem, wider 'community' or 'habitat' focus, whereby numerous resident species might benefit from the equivalent endeavours. However, to many people 'species' provide a meaningful level for conservation attention, by focusing on an identified taxon: a particular butterfly or beetle (or mammal or bird) is a tangible and understandable entity, whereas 'a rainforest' or 'an alpine grassland' is more difficult to understand in such circumscribed terms. People relate more easily to species – in particular, spectacular, unusual or otherwise notable species can promote wide sympathy and interest and become important in conservation advocacy well beyond their immediate individual fate. In such cases, species level focus can often be seen to have wider benefits in conserving complex habitats, so that 'a rainforest' is indeed seen as a tangible critical resource for less heralded biodiversity and publicised as such within a species' conservation programme. In such instances, as for the Richmond birdwing, the individual appeal and recognition of vulnerability according it flagship status also confers these wider 'umbrella' values.

Flagship butterfly taxa in Australia, as commonly elsewhere, are associated strongly with local pride, and a sense of local community 'ownership'. It is no accident that many such species have received patronymic common names aiding this local proprietorship. In Victoria, the Eltham copper (*Paralucia pyrodiscus lucida* Crosby) and the Altona skipper (*Hesperilla flavescens flavescens* Waterhouse) are both named for the outer suburbs of Melbourne where they have received most conservation attention; in New South Wales, *Paralucia spinifera* Edwards and Common, is known as the Bathurst copper or the Lithgow copper, after the two major towns within its circumscribed range. These, and others, tend to be geographically much more restricted than the wide-ranging *O. richmondia* and most are considered poor dispersers. Their conservation requirements have strong site-focus, with the habitats presumed to be remnants of a formerly wider extent of habitats but now clearly within the governance of one or more towns or suburbs, as above. The species involved are almost all members of diverse endemic radiations, mostly within Lycaenidae or trapezitine Hesperiidae, but with some Nymphalidae: Satyrinae also of considerable interest (New 2011c). Practical conservation for most of these has involved assuring site security and maintenance, and augmenting supply of local resources. In contrast, conservation of *O. richmondia* has necessitated a much wider geographical perspective, but still focuses on key patches with characteristic plant communities within the range – either as those currently occupied or those targeted for restoration as core recovery sites or lesser stepping stones.

The spatial configuration of habitat patches across a landscape can affect the conservation of a species. A fundamental principle in conservation biology, this linked with the dispersal capabilities of the species of interest and its population (or metapopulation) structure and dynamics. Two related contexts arise for the Richmond birdwing, with the recognition that dispersal prowess itself is unlikely to be limiting within the region of interest. The figure used as a reference guide in this project, of a 30 km linear flight distance between sites, is based on the confirmed identity of a gravid female approximately this distance from the nearest available breeding site. These contexts are that the physical and biological features of inter-patch areas over much of the range are not (other than through major alienations such as urbanisation) major deterrents to that dispersal, but may influence survival, and that colonisation and establishment can be fostered by management once butterflies arrive by either migration or longer-term diffusion. As Dover and Settele (2009) noted, the interaction of the physical structure of the arena with processes affecting a species – such as whether the landscape poses 'barrier effects' – can constrain colonisation. The strongly flying *O. richmondia* clearly has the capability to move through landscapes that would be impenetrable to many other butterfly species. However, areas of urban development and absence of consumable resources are putative barriers, and have fundamentally reduced the range of occupation from historical times. Dennis (2010), drawing on his numerous earlier papers, has developed the concept of resource-based habitat, essentially more continuous and graded than the more traditional dichotomy of 'habitat' (occupiable) and 'matrix' (not occupiable) long appealing to butterfly ecologists. The recent discussion by Dover and Settele (2009) provides sound introduction to these topics, together with listed key points for each of the many interacting themes. They point out that the habitat/matrix division 'may actually impair our understanding of landscape–level processes', with the resource-based concept a far more useful paradigm for the future. Under discussion of corridors, they noted that (1) corridors do not necessarily involve continuous unbroken physical links, and 'stepping stones' may be sufficient; and (2) a corridor is not necessarily the shortest route between two patches. Both these principles have been important for the Richmond birdwing – with resource-enriched stepping stones dictated largely by availability of sites where plantings could be undertaken and nurtured under secure conditions. If, as supposed, butterfly dispersal is not itself limiting, patch quality may be more important than patch size (assuming that smaller patches can be protected, with additional potential edge effect problems such as increased weed invasions demanding increased attention), as indicated by threshold numbers of *P. praevenosa* vines recommended for restoration, although individually large vines when mature cannot each provide sufficient foliage for more than very few larvae, due to cannibalism, so that multiple vines are critical.

Restoration of habitat networks is a critical aspect of connectivity in conserving any species within a highly fragmented landscape. As McIntyre et al. (2007) emphasised, any such effort necessitates combining biological information on the species involved with 'the landscape, economic and social realities of the restoration effort'. Within the constraints of the landscape (such as condition, topography, and land tenures and ownerships), restoration commonly involves providing enhanced or new potential habitat that can aid connectivity or persistence. *O. richmondia* exemplifies well the values of both enhancing already occupied habitats, and of providing new patches (many on private land) between those already existing. The roles of modelling in such enterprises are complex and, perhaps, of greater importance for relatively sedentary butterflies than for wide-ranging ones. Some of the problems were described for Fender's blue (*Icaricia icarioides fenderi* Macy, in prairie remnants in North America (Schultz 2001), with that study extending over 14 years (McIntyre et al. 2007). It remains simplistic to imply that the current practices for *O. richmondia*, undertaken without formal modelling, are ideal – but, due to the willing participation of many people in the activities (largely overcoming the economic and resource constraints evident in many similar projects), the outcomes have been highly encouraging.

The aesthetic and popular appeal of this spectacular butterfly has been instrumental in engendering and sustaining concerns and interest, with effective cooperation between scientists, conservation agency personnel and the wider community initiated early in the programme and demonstrating some ways in which this mutual involvement can be fostered. Such support is critical (New 2010) but is often far easier to deter than to sustain. The *O. richmondia* programme has been particularly instructive in encouraging sustained interest, which continues to increase and diversify. Major elements for successful community participation in conservation include communicating a sense of ownership and identification with the project, rather than more remote 'direction', and the factors noted more generally by Williams (1996, Table 10.1) convey well its focus – with wide consultation from the project's commencement ensuring that the 'encourage' factors were implicitly addressed. Planning at all stages involved the constituency and, although not planned deliberately to do so, the early phases also involved the parameters emphasised by Craig et al. (1996) and successively and successfully incorporated these as the project progressed. The pivotal role of education and the importance of initiatives, including a draft recovery plan (1996), involving young people cannot be overstated. Much of the subsequent habitat enhancement and monitoring flowed from that impetus, and the driving of interest through involvement of schools. The 'Double Helix Science Club component' of the *O. richmondia* programme was of critical significance in fostering lasting appreciation and interest over a wide area.

The later, more complex, recovery networks emphasised further the central importance of trust and a 'belief in ownership', not least through regular communications

Table 10.1 Points to help foster community interest and involvement in species conservation programmes (after Williams 1996)

1	Have a focus for conservation interest that the community or community group identifies with personally (effective focus)
2	Encourage community involvement from the earliest developmental stages of a conservation or species recovery initiative (sense of ownership)
3	Develop programmes that are beneficial to the community as well as to conservation (what does the community 'gain' from the exercise and effort)
4	Listen to the community's concerns (constructively incorporate them into the conservation goals)
5	Gain the community's trust (personal interactions and considerations important)
6	Provide the community with the appropriate information at the appropriate level and at the appropriate time (regular review and feedback; effective communication)

and group meetings. Thus progress and problems could be assessed without undue delay, and ideas exchanged to provide opportunity for adaptive management as knowledge and field results become evident. Sustained interest from the public in single species conservation is a valuable but fickle commodity, and effective communication is vital to retain this – as Nally (2003) demonstrated effectively for the Bathurst copper, without this communication public support can decline rapidly. In a community-based programme all relevant interest groups need to understand what is expected from them, how they can participate effectively and be involved, and be acknowledged properly. For continued confidence, the progress in any conservation programme should be both documented (with permanent records) and communicated effectively. Ideally the entire enterprise should flow from a well thought-out but adaptable 'management plan' that incorporates both research and practical needs and aims, and sets these out clearly together with the means by which they will be pursued and progress will be measured.

Species management plans for insect conservation vary widely in scope and complexity, as well as attainability, and in part this often reflects legal obligations brought about by 'listing' the species (New 2009) and which vary considerably in their specific demands. It is still rare for prior planning to be fully comprehensive, not least because many exercises flow from rapid need for 'crisis management' and for urgent ameliorative measures. Nevertheless, whenever possible, the factors noted in Table 10.1 and discussed by New (2009) merit early consideration in planning management, as collectively serving to guide the project, foster support, sustain progress and plan for accountability and monitoring of outcomes. No such plan is likely to proceed unaltered. Additional information, varying unpredictable changes in levels of support, and changes of agency personnel and priorities are among the many influences that may advise or dictate changes of project direction and priority. Management should thereby be adaptable, and responsive to such influences, whilst not deviating from the primary conservation aims and recovery actions, and objectives. However it is incumbent on the initial planning team to assure comprehensiveness of approach, and that all the affected constituencies within the community and management groups have been consulted adequately at

Table 10.2 Factors that may discourage community interest and participation in species conservation programmes (after Williams 1996)

1	Failing to recognize the community's understanding of ecological concepts can create resentment
2	Failing to appreciate what the community hopes to gain from participation can dampen enthusiasm
3	Failing to provide appropriate support after community-based programmes have been initiated can threaten continued commitment
4	When an agency starts to behave as if management belongs only to it, the community may be discouraged from developing a personal responsibility for conservation

this stage. Ideally, also, the various objectives are set out clearly at this stage, with realistic assessment of how they will be achieved, and who will be responsible for each of them, together with an indicative budget. Increased use of 'SMART' objectives is recommended strongly, to help progress being monitored rather than allowing the project to 'drift' and in some cases not to be sufficiently accountable. Perhaps the two most difficult parameters to assure are 'time-bound', as the final component of 'SMART', and sustaining external interest over the long period needed for completion. The first is particularly sensitive when working with community groups and volunteers who, understandably, may object to imposed deadlines for tasks which are seen as completely unrealistic or dictatorial, and be alienated by any such demands on their time and (often, self-funded) contributions. Second, whilst initial interest may be aroused by novelty and perceived urgency, sometimes with an accompanying flurry of media publicity, sustaining that interest over a decade or more may be complex. The Richmond birdwing project is a prime example of how this can succeed through cooperative endeavour and activities such as newsletters and regular meetings or field days to sustain interest. In contrast, some other projects have floundered within much shorter periods, and the 'discourage' factors listed in Table 10.2 should be avoided carefully if possible. Difficulties are confounded if leading agency or scientist personnel change, their primary duties are changed, new constituencies of interest arise, changes in political/administrative boundaries affecting the species occur, or anticipated funding or other support is lost. It is not unusual in Australia for a species supported by a government agency to effectively become 'orphaned' due to retirement or transfer of a single supporting officer. Membership of management teams is also likely to change, and good record-keeping is important in aiding smooth and sympathetic transitions and succession without impetuous revision of existing plans.

The early Richmond Birdwing Recovery Plan (1996, p. 112) has provided sound guidance, and was based on sufficient foundation knowledge and experience to render it of enduring relevance and importance. The major aims have remained current, and the intervening years have seen many of these pursued diligently, with changes in emphasis reflecting adoption of adaptive management as information from monitoring data accumulated and dictated changes in emphasis or priority. The twin strands of (1) threat reduction by removal of a toxic alien plant and increasing security of remnant habitat patches and (2) enhancing a key resource food plant to increase both population sizes locally, and availability of this within the wider landscape, have proved highly complementary in generating favourable outcomes that have been combined progressively with consideration of additional stressors such as inbreeding depression and climate changes as these have become apparent.

Success of any species conservation plan depends on acceptance that the species is indeed worth saving, a judgement in which aesthetic and ethical appeal can be enhanced markedly by some ‘official recognition’ that its conservation is needed. Most commonly, this is by election to some formal schedule of ‘Threatened Species’ or ‘Endangered Species’, based on risk of extinction. In the past, many species have been listed in this way on grounds of rarity, without evidence of any actual threat. The two conditions must be distinguished carefully in conservation planning, in order to avoid commitment of the very limited support resources to numerous non-threatened taxa that have low abundance, small distributions and are ecological specialists but whose condition and range is apparently stable and wholly natural. For butterflies, including birdwings, the emotional connotations (however sincerely intentioned) of over-collecting as a threat, are an important and influential syndrome in conservation. The Queensland birdwings were amongst the first butterflies to be fully protected by listing and total prohibition of take in Australia. Together with the spectacular *Papilio ulysses* L. (the Ulysses swallowtail, a notable tourist icon for tropical Queensland), they were listed under the Queensland Fauna Conservation Act in 1974, intriguingly with the then formal need to declare them by government decree as ‘fauna’ because the Act defined this as indigenous mammals and birds only! The major stated reason for listing these species was to control the perceived threat by illicit trade. *O. richmondia* has indeed been identified in trade (Hawkeswood et al. 1991), with importing countries including Colombia, Japan, France and the United States, but large numbers of butterflies were probably not involved. All birdwings were listed on CITES, but the Queensland listing led to two major concerns (Monteith 1980; Hill and Michaelis 1988), namely (1) that over-collecting was not a threat and that the legislative protection itself deterred hobbyist interest in contributing to knowledge of the species, and (2) that the listing in itself was viewed by many people as ‘real conservation’ rather than as a facilitating mechanism or tool, and was not accompanied by adequate measures to protect habitat. Parallels elsewhere are not uncommon – one relevant here is the listing of ‘all jewel beetles’ for protection in Western Australia, whilst condoning clearing of large areas of their prime mallee habitat (Douglas 1980). Hill and Michaelis (1988) did not report any Australian Papilionidae as ‘Threatened’ amongst the 260 arthropods listed as of concern by respondents to their nationwide survey. Nevertheless, losses of subtropical rainforest in southern Queensland were substantial by that time, and concerns over decline of this prime habitat for *O. richmondia* led to its rapid adoption as a flagship species for this complex and poorly-known habitat. Its striking appearance was undoubtedly an influence in its acceptance as ‘worthy’ of conservation, and the initial impetus from activities in New South Wales spread rapidly in Queensland.

Major outcomes of the Richmond birdwing conservation project include important initiatives that have contributed significantly to wider understanding of butterfly conservation. At one level, the recovery programme focused on consumable resource enhancement, coupled intimately with removal of the alien, toxic vine from the areas of interest within the historical range of *O. richmondia*. The essential conservation module was thus the usual bipartite one of 'insect plus food plant', a far more straightforward template than the complex tripartite association of 'insect plus food plant plus mutualistic ant' needed for some Lycaenidae. However, this limited interpretation is often deceptively simplistic, and the module of core species more extensive. In this case, pollination of the vines appears to depend on very specific associations involving particular Diptera, including species of Phoridae and, possibly but needing confirmation, of biting midges (*Forcipomyia* spp., Ceratopogonidae). The recognition of species in both these groups is complex. As Debenham (1987) noted, *Forcipomyia* are amongst the most commonly encountered members of the family in Australia, and a complex array of flies have been allocated uncritically to the genus. The biology of most is unknown in any detail, although the *Aristolochia*-associated forms are suspected to occur in wet leaf litter. In her revisions of the genus in Australia, Debenham (1987 and later papers) recognised around 25 subgenera. Disney's (2008) checklist of Australian Phoridae shows the apparent predominance of *Megaselia*, the genus implicated as pollinators here, but also the potentially enormous richness of species awaiting diagnosis and formal recognition. Other than obvious need for the pollinators to be active during the flowering season of the aristolochias, namely late spring to early summer, the dynamics of these vectors are unknown. As noted earlier, many other saprophagous Diptera have been suggested also to be pollinators of Aristolochiaceae, as they have been found within the flowers in many other parts of the world. Clarification of this aspect of the vines' biology may have considerable relevance in future conservation planning, as an augmentation to the module of species of functional concern. It is a clear priority for future research, and also exemplifies the much wider scenarios of unknown factors that need urgent clarification to underpin more 'obvious' conservation factors, and without which the long-term effort may be seriously deficient.

Largely as a consequence of this project, the ecology of the butterfly and its foodplants are reasonably well understood, and sufficient for well-informed management on resource manipulations to be undertaken. Further work on genetic constitution and inbreeding effects, and the butterfly's climatic tolerances in relation to future anticipated range changes may be worthwhile. For example, with global warming, it is likely that upland sites may become less marginal for habitation than at present, and become parts of the species' permanent range. It may become important to provide connectivity of lowlands with the upland areas now colonised only sporadically and temporarily as they become progressively suitable for permanent occupation with changing climate. However, phenological changes may also eventuate, and the synchrony with resources alter, together with compositional changes in local communities as additional taxa are also driven upward. The strong dispersal capability of *O. richmondia* may indeed prove advantageous, with the present programme owing much to the butterfly's ability to track scattered resources dispersed widely in a landscape, over tens of kilometres or more. With an adult female lifespan of 4–6 weeks, dispersal potential may be considerable, and the butterfly's conspicuousness facilitates accurate recording of incidence, in a region where confusion of identity is unlikely because no other similar taxa occur. The delight of people discovering the butterfly on vines they have planted locally, perhaps several years previously, is clear from a number of comments in the various network newsletters

Increased sightings of *O. richmondia* in recent years, clearly demonstrates some recovery within the natural range, linked with availability of *P. praevenosa*, and progressive linking and enrichment of forest habitat patches. They give cautious optimism for the butterfly's future wellbeing and indicate that *O. richmondia* has been at least in part recovered from being seriously threatened and is no longer amongst the most threatened species in the region. The apparent recovery can be attributed largely to the conservation measures described in this account, and possible only through the continuing high levels of community interest and support. Sands and New (2002) commended the provision in much Australian conservation legislation to de-list taxa once they were regarded as secure. Two scenarios dominate any such decision. First, that increased survey and investigation following formal listing (and in many cases possible only after listing has enabled support for those activities) reveal that the taxon is more secure or more widely distributed than initially supposed, so that threat status is not warranted. Second, that those conservation actions have restored a genuinely threatened species to a state of security, again so that it is no longer threatened and should not qualify for listing. The second of these is relatively unusual, and may represent the outcome of considerable effort, perseverance and expense over a long period.

The campaign described in this book is one such example in which a case for de-listing could now be made. However, should such a species be de-listed, there is always some risk that threats might recur, without special provisions for on-going actions, and possibly unnoticed the butterfly could again become endangered. Sands and New (2002) suggested that such 'conservation investment' could be safeguarded by signalling such species for post-delisting monitoring or regular inspection to, at the least, provide for early detection of any such renewed risk whilst releasing the major resources committed previously to conservation measures for other, now higher priority, taxa. The term 'rehabilitated species' was suggested to designate such taxa, and a case could be made for *O. richmondia* to enter this category, but such recognition has not yet been made possible. It would need very careful consideration, not least to prevent the current emphasis on its conservation from dissipating. Discussion of this dilemma at a recent (October 2012) workshop on recovery planning in Queensland elicited very mixed responses and several related issues were raised, for example, whether a 'recovery plan' should be an 'automatic' consequence of listing for threatened taxa, and if delisting following recovery actions, might lead to re-emergence of threats. Indeed, need for the formal obligation for recovery plans of the kind central to this campaign is widely queried. Planning is seen to confer obligations beyond what is possible or practicable, and some authorities prefer not to have such 'millstones', as noted below.

O. richmondia is only one of a range of butterflies acknowledged as threatened in Queensland, but is the only one for which wide landscape-level planning was needed, and has proved feasible. The focus on corridor construction and enhancement is a key component and, whilst each corridor has been under the watchful eye of an individual 'coordinator', the need for constructive liaison and range-wide coordination will need to continue. Commercial production of *P. praevenosa* for restoration activities also continues, and is likely to do so and maintain the conservation impetus, notwithstanding the apparently increased security of the butterfly. Much of the butterfly's historical range is still to be re-occupied, particularly the original northern range, and continued monitoring to detect range recovery or expansion and changes in abundance are activities that are sufficiently cohesive to sustain interest for the future.

The diversity of views reflects considerable variation in opinions of the value of (and need for) recovery plans of any kind for formally recognised threatened species. Throughout Australia, many critically endangered and endangered animal and plant taxa do not have recovery plans. Burbidge (1996) listed reasons for this, and believed that 'Having hundreds of recovery plans and hundreds of recovery teams is not possible with present or anticipated resources.... it would not be cost-effective and should not be contemplated'. The four reasons were (1) numerous taxa are threatened; (2) conservation agencies have been slow to prioritise threatened taxa in terms of degree of threat; (3) 'flagship taxa', or taxa for which research data are available, tend to be treated first; and (4) there are insufficient data on the limiting factors for many taxa and defining recovery actions is often difficult or cannot be done with any degree of certainty. *O. richmondia* is an excellent example through which to endorse the third of these, and the attention paid to it over more than 20 years does not mask that numerous other taxa are at least equally deserving of parallel conservation attention. The interest and knowledge evident from the commencement of conservation interest in the butterfly ensured that the Draft Recovery Plan was indeed well-informed and reasonably comprehensive. Both (1) that such a plan was initiated to guide management efforts, and (2) that it has not been found seriously deficient, are unusual features, and endorse that more recent adaptive management continues to build on strengths of purpose and approach. Dependence of the birdwing on climax and near-climax forest biotopes, has added important umbrella roles for the species and accompanying educational exercises. Whilst *Ornithoptera richmondia* appears to be well on the road to recovery, due largely to the efforts discussed in this book, it is salutary to reflect that without this campaign this magnificent insect might by now have declined further, or even have been lost completely.

Appendices

Appendix 1: Propagation of *Pararistolochia praevenosa: Summary of Advice; See Also Sands and Grimshaw (2013)*

Propagating P. praevenosa *from Seeds*

- When the seed capsule is ripe and seeds inside are ready to plant (mostly February – May) the fruity capsules become soft, bright yellow or orange.
- With gloved hands, prepare the seedling bed using a suitable tray with drainage holes (e.g. plastic foam tray), or a large shallow pot.
- First place a moistened layer of peat moss (about 1 cm deep) at the bottom then fill the container to 2/3rd of its depth, using a good quality potting mix (e.g. Searle's© Potting Mix).
- Choose a greenhouse bench for the container, with broken but not bright light; direct sunlight can burn seedlings or cause excessive condensation and total shade can promote damping off.
- Break up each soft seed capsule in a bowl holding about 1 l of water (1–2 capsules per bowl), then make a slurry of the pulp and seeds.
- Pour the slurry over the surface of the seed bed and cover (about 1/2 cm) it with potting mix. Sprinkle from above and press the moistened surface gently (base of empty pot ideal) to make the surface firm.
- Place the container with seeds on a flat bench covered with sheet of plastic (to avoid aeration causing root burn). Cover the container with a loose but transparent plastic sheet, and hold in place until the seed leaves appear*.
- Keep soil regularly moistened (at least once every 3 days) but not wet, using a fine mist or spray. Always replace the loose plastic covers after watering and inspections.
- Seeds take from 6–12 weeks to several months (8–16 weeks, or up to 3 years) to germinate after sowing, depending on seasons and temperatures. Fresh seeds planted in a warm greenhouse in March often germinate from June-August.

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- When seed leaves appear, remove the plastic sheet but make sure the seed bed is always kept moist using a misting nozzle, until the seedlings are potted up.

  * NB *Containers and pots with seeds and seedlings must be kept moist but not 'wet'.*

Potting Up Seedlings and Growing the Vines Up Stakes

- Seedlings can best be potted up after the second pair of leaves has emerged above the opposite seed leaves and when branching root growth has developed.
- A good quality potting mix (e.g. Searles Potting Mix©) is recommended for potting up seedlings
- Seedlings are easily 'pricked out' using the handle of a teaspoon to loosen the soil before the seedlings are lifting out and immediately potted up.
- Seedlings are best transferred into plastic pots (minimum 14 × 13 cm diameter) for their major growth phase stage growth (tubes are far less suitable).
- Insert dead (bamboo preferred) stakes (ca 60 long × 1 cm diameter) into each pot and coax the shoots to climb (clockwise facing upwards).
- Hold plants in pots for 2 years until they develop climbing shoots and the stems become firm before planting out. The tips can be pruned if growth is too vigorous or tangling by growing into other plants.
- After 1 year in the posts, fertilise every 4 months with a good liquid fertiliser (e.g. Aquasol©) until the vines are ready to plant in the ground.

Propagating **P. praevenosa** *from Cuttings*

- Prepare a cutting bed using a suitable container: e.g. plastic foam tray with drainage holes, or a large (>12 cm) shallow pot.
- Before filling with a cutting mix, add a moistened layer of peat moss (about 1 cm deep) at the bottom of tray or pot.
- *A simple medium* for striking cuttings can be made from 'Sharp' sand with 10 % peat moss added, *or* -
- *A more effective medium* can be made (4 litres batch) from: (i) 4 parts washed river sand, (ii) 2 parts perlite granules, (iii) 2 parts peat moss, and (iv) 4 spoons of micro-Osmocote© or Nutricote©.
- Prepare cutting from sections of firm, older stems (at least one year old, 2–3 mm thick, not soft and green) into lengths 10–12 cm. (Best time to take cuttings: March to September).
- Cut stem lengths with 3 nodes on each cutting and retain the two upper leaves on each. Cut off other lower leaves, any side shoots or soft growth using secateurs.
- Cut the remaining half of the remaining leaf using secateurs and roughen the bark on the basal length for 1 cm, using the blade.
- Dip the base of the cutting in hormone root powder before planting.

- Make a hole with a pencil, insert 2–3 cm of cutting with striking medium into the hole and gently press the mix around the base of the cutting. (Recommended rooting powders containing 0.4 % Indol-3-butyric acid).
- Cover the seed container with a transparent plastic sheet or bag to maintain humidity, and replace it after watering until the rooted cuttings are ready to pot up.
- Lift the plastic to sprinkle the cuttings with water and ensure the cutting mix is always kept moist at least once every 3 days, preferably by misting for 15 min.
- After 4–8 months test each cutting for the formation of roots. Test for presence of roots by soaking the container to loosen mix and gently lift cuttings to observe root formation. Take care: young roots are very fragile and easily broken off!
- Cuttings take 2 months form callos and 4–8 months for sufficient root growth needed for potting up. Using a heat bed will enhance root formation.

Potting Struck Cuttings of **P. praevenosa** *and Growing Up Stakes*

- Rooted cuttings can usually be potted up when 8–12 months old and when roots are about 2–5 cm long. Hold the plants with stakes in pots for 2 years before planting in the ground.
- Coax shoots to climb up (clockwise facing upwards) dead bamboo stakes (ca 750 cm long × 1 cm diameter) inserted in pots. Tips can be pruned when growth is too vigorous to plant out.

Planting Vines in the Ground

- Make sure the potted vines are at least 2 years old and climbing up a stake held in the pot before planting. Don't bother planting tube stock directly into the ground but tube stocks can be matured in larger pots and successfully planted when about 2 years old.
- Select the final place where the vine is to climb: e.g. an evergreen tree (not deciduous), trellis, fence or another vine (companion vines).
- A hole should be dug at least twice the width (ca 20 cm) and twice the depth of the pot before planting.
- Semi-shade is preferred. Avoid choosing a site for planting exposed to direct sunlight or in complete shade. The edge of a forest or in front of a group of trees is ideal.
- If the vine is to grow up a tree, dig the hole at least 1.5–2 m from its base (to avoid competition for moisture). Vines can be easily grown up a string into a canopy.
- (i) Mix the soil removed from hole with 10 % (by volume) dolomite for back-filling around the roots; *or* (ii) add 10 % dolomite to a good potting mix and then back-fill and water in the mix around the roots of the plant.

- Wet the soil around roots as soon as possible after planting. Insert base of stake (2–3 m, dead bamboo) into the ground near base of vine and tie the upper end of stake to tree or final support for the vine. Do not press down the soil with shoes as this will fracture the roots.
- Provide a broad circular band (diameter ca 1 m, depth 20 cm) of good quality mulch (e.g. sugarcane) around the base of the vine and thoroughly soak the mulch and soil around the vine.
- Coax new apical growth by carefully removing the lower and older leaves with secateurs, leaving only the top two expanded leaves. Do not remove the growing shoot.

Planting P. praevenosa

Richmond birdwing vines prefer semi-shaded positions with rich, moist basaltic or alluvial soil (pH 6.5–6.8) and good drainage (10–30° slope). However, the vines will tolerate less-suitable conditions as long as soils do not dry out and they have good drainage. A hollow log segment (<30 cm) promotes early establishment when slightly sunk into the ground and back-filled with a good soil mix containing with 10 % dolomite, the nutritional needs can be met. The vines prefer to climb into canopies of trees or grow on a trellis. If sites selected are temporary, the vines do well in large tubs and can then be easily moved. Relocation of mature vines should be avoided as damage to mature roots invariably results in losses.

Watering

- Unless rainfall is frequent water vines at least once per week for 2 months after planting. Afterwards watering frequency will depend on soil moisture but must be maintained at intervals until vines are at least 2 years old after planting.
- During periods of extreme drought watering plants in the ground may be required every 3 days.

How to encourage healthy climbing growth. It is unwise to plant the vines during the dryer seasons from July to October unless there have been recent rains or during periods of prolonged drought. Vines can be encouraged to grow into a canopy by coaxing the shoot along a cord tied to a upward-sloping branch or up in the canopy. Once growth is in a canopy 3 m or more above the ground the vines will branch and climb among stems of a supporting tree. Do not use deciduous trees as the butterfly chrysalis is usually formed on the supporting plant and will be lost when the leaves are shed. Lillypillies (*Syzygium* spp.) are one of the best groups of well known low-growing shrubs that will support a growing vine. Birdwing vines are not aggressive and do not normally smother plants supporting them.

Maintaining healthy vines to attract the Richmond birdwings. Vines need to be kept continuously moist in the dry season unless there is good ground water. They like fertiliser to become established and will grow much more rapidly if Osmocote© or something similar is provided frequently for the first 2–3 years. Unlike many Australian plants, they like fertilisers rich in phosphate. Richmond birdwing vines prefer semi-shaded positions with rich, moist basaltic or alluvial soil (pH 6.5–6.8), a slope (>10–30°) and good drainage. However, the vines will tolerate less than suitable conditions as long as soils do not dry out and they have good drainage. Weed removal and on-going control is often essential, and fire must be excluded for any site being restored. Invasive grasses and vines are the worst threats to bushland restoration.

A hollow log segment (<30 cm) can promote early establishment when drainage is not good, if sunk into the ground and back-filled with a good soil mix containing with 10 % dolomite, the nutritional needs can be met. Vines need to be kept moist continuously in the dry season unless there is good ground water. They like fertiliser and will grow much more rapidly if Osmocote[C] or a similar fertiliser is provided frequently for the first 2–3 years. Unlike many native plants, the vines will tolerate fertilisers rich in phosphate. The vines prefer to climb into canopies of trees or grow on a trellis. If sites selected for growing vines are temporary, the vines do well in large tubs and can then be easily moved. Relocation of mature vines by digging them out and translocating them should be avoided as damage to mature roots invariably results in losses.

Planting Out Vines to Encourage Healthy Climbing Growth

A common problem with planting potted vines that has stalled community enthusiasm related to prolonged dormancy of vines after they were planted in the ground. Even with appropriate light, moisture and drainage, vines would sometimes fail to grow as expected. However, in a series of experiments (2006–2010) in Brisbane the growth of vines was shown to be respond and could be accelerated by back-filling each hole after planting, with a mix of good-quality potting mix combined with 10 % dolomite. This method for mixing dolomite with soils to be used for back-filling became the recommendation for all sites, except where 'basic' basaltic soils were present. The use of 10 % dolomite mixed with good quality mulch for back-filling the hole when a vine is planted, is regarded as a standard procedure that promotes early growth. Areas with moist soil are always essential.

Appendix 2: Subtropical Plant Communities and Soil Types Associated with *P. praevenosa* in New South Wales and Queensland (Northern Tablelands Excluded)

RE 12.2.1 Notophyll/evergreen vine forest. Plant communities include abundant *Archontophoenix cunninghamiana* and associated species of Lauraceae, Myrtaceae, Elaeocarpaceae and vine *Flagellaria indica* diagnostic. The plants occur on moist or wet, valley floors of parabolic high sand dunes.

RE 12.2.2. Mixed microphyll / notophyll vine forest. Plant communities include Myrtaceae, *Cupaniopsis anarcardiodes, Flindersia schottiana, Alectryon coriaceus, Polyalthia nitidissima, Mallotus discolor* and the vines *Flagellaria indica* and *Calamus muelleri.* The plants occur on coastal dunes and behind beach ridges.

RE 12.3.1 Complex to simple notophyll vine forest and gallery rainforest edging stream channels. Prominent species include *Waterhousea floribunda, Cryptocarya hypospodia, C. obovata, C. triplinervis, Argyrodendron trifoliolatum, Ficus coronata, F. fraseri, F. macrophylla, Aphananthe philippinensis, Elaeocarpus grandis, Grevillea robusta, Castanospermum australe* and *Syzygium francisii.* Eucalyptus emergents (e.g. *E. grandis*) and *Araucaria cunninghamii* may also be present and vines *Flagellaria indica* and *Calamus muelleri*. The plants occur on quaternary alluvial soils and plains, edging stream channels and embankments in high rainfall areas.

RE 12.3.2 Tall, wet sclerophyll forest, with vines and rainforest understorey. Prominent mixed understorey species include *Lophostemon confertus, Eucalyptus grandis*, and sometimes the vines *Flagellaria indica* and *Melodorum leichhardtii*. The plants occur on soils of alluvial plains, fringing streams and narrow gullies in high rainfall areas.

RE 12.5.13. Microphyll and notophyll vine forest. Prominent species include *Araucaria cunninghamii, Cupaniopsis parvifolia, Dendrocnide photinophylla, Flindersia* spp.*, Olea paniculata* and often *Araucaria cunninghamii* and vine *Flagellaria indica.* The plants occur on soils over lateritised basalt (River Heads, Mary River).

RE 12.8.3 Complex and wet notophyll vine forest. Prominent species include *Archontophoenix cunninghamiana, Livistona australis, Olea paniculata*, *Neolitsea dealbata*, *Ficus macrophylla*, *Podocarpus elatus*; vines *Flagellaria indica, Tinospora smilacina* and *Calamus muelleri.* The plants occur on soils over igneous rocks, especially basalt.

RE 12.8.4 Complex Araucarian notophyll vine forest. Prominent species include scattered *Araucaria cunninghamii* and *Araucaria bidwillii* (in northern regions), *Dendrocnide excelsa*, *Toona ciliate, Brachychiton acerifolius* and vine *Flagellaria indica:* vines *Flagellaria indica* and *Calamus muelleri*. The plants occur on soils over igneous rocks including basalt and lateritised basalt.

RE 12.8.13 Microphyll/notophyll rainforest. Prominent species include *Araucaria cunninghamii* and *Araucaria bidwillii* (in northern regions)*, Flindersia* spp., *Dendrocnide photoomophylla, Rhodosphera rhodanthema*, *Olea paniculata,* and sometimes vine *Flagellaria indica.* The plants occur on soils on Cainozoic igneous rocks, especially basalt.

RE 12.11.1 Simple notophyll vine forest. Evergreen with closed canopy, prominent species include *Archontophoenix cunninghamiana, Lophostemon confertus* and plant families Lauraceae, Myrtaceae and Elaeocarpaceae. Often growing on gully floors on Paleozoic and older, deformed metamorphosed sediments and inter-bedded volcanic rocks.

RE 12.11.2 Tall moist-adapted eucalypt forest with rainforest understorey. Prominent species include *Eucalyptus grandis, E. microcorys, E. acmenoides, Lophostemon confertus, Pittosporum undulatum* and *Cryptocarya glaucescens*.

The plants occur on soils over strongly metamorphosed sedimentary and inter-bedded metamorphic rocks.

RE 12.11.10 Evergreen notophyll vine forest. Prominent species include *Lophostemon confertus*, *Araucaria cunninghamii, Ficus macrophylla, Grevillea robusta, Argyrodendron trifoliatum* and plant families Lauraceae, Myrtaceae and Elaeocarpaceae. Vines include *Melodorum leichardti* and *Cissus antarctica*. The plants occur on soils are over metamorphosed sedimentary and sometimes inter-bedded metamorphic rocks.

RE 12.12.16 Notophyll vine forest. Prominent species include *Lophostemon confertus*, *Araucaria cunninghamii Argyrodendron trifoliatum.* The plants occur on soils over on mesozoic – proterozoic igneous rocks.

Subtropical plant communities and soil types associated with *P. laheyana* in New South Wales and, possibly, Queensland.

12.8.6 Simple notophyll fern forest (>800 m). Prominent species include *Nothofagus moorei, Doryphora sassafras, Calduvia paniculosa, Orites excelsa* and *Aloxylon pinnata*. The plants occur on rich 'basic' soils over basalt.

12.8.18 Simple notophyll vine forest (>600 m). Prominent species include *Ceratopetalum apetalum, Lophostemon confertus, Caldcluvia paniculosa, Geissois nenthamii, Orites excelsa*, and the vine *Parsonsia tenuis.* The plants occur on soils over Cainzoic rocks including rhyolite.

Appendix 3: Workshop Series, Hosted by the Richmond Birdwing Networks

Title	Venue	Date	Hosts/collaborative organisations
Richmond Birdwing Planning Workshop	The Gap, Brisbane Qld	8 October 2005	Queensland Parks and Wildlife Service
The Richmond Birdwing Recovery Network	Luther Heights Coolum, Qld	12 April 2006	Coolum Coastcare, Maroochydore Shire Council
Identification and Propagation of Birdwing Vines	Maleny, Qld	22 November 2006	Mary Cairncross Scenic Reserve
Saving the Richmond Birdwing Butterfly and Vine	Eumundi, Qld	18 February 2007	Maroochy Shire Council
Richmond Birdwing Corridors – for the Noosa Shire	Noosaville, Qld	16 June 2007	Greening Noosa, Noosa Parks Association
Richmond Birdwing Corridors – for Mount Tamborine	Eagle Heights, Tamborine	22 September 2007	Tamborine Mountain Natural History Association
Richmond Birdwing Corridors – for Noosa and Beyond	Noosa, Qld	8 March 2008	Noosa and District Land care Group
Bring Back the Richmond Birdwing to Toowoomba	Toowoomba, Qld	19 April 2008	Friends of the Escarpment Parks
Richmond Birdwing Corridors – Gold Coast to the Scenic Rim	Burleigh, Qld	21 June 2008	Gold Coast City Council
Richmond Birdwing Habitats for Brisbane's Western Suburbs	Pinjarra Hills, Qld	16 August 2008	CSIRO
Richmond Birdwing Recovery – from Range to the Bay	Burpengary, Qld	11 October 2008	Caboolture Region Environmental Education Centre
Richmond Birdwing Recovery. Corridors for the Cooloola Region	Gympie, Qld	28 February 2009	Gympie Regional Council
Richmond Birdwing Recovery for Ipswich and Bremar Catchments	Middle Park, Qld	5 September 2009	Queensland Department of Main Roads

(continued)

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Title	Venue	Date	Hosts/collaborative organisations
Restoring Richmond Birdwing Habitats on the Fraser Coast	Maryborough, Qld	6 November 2010	Mary River Catchments Coordinating Committee
Bringing Back the Birdwing Butterfly to the NSW North Coast	Mullumbimby, NSW	13 March 2011	Rainforest Rescue
Richmond Birdwing – Recovery in the Tweed Valley	Murwillumbah, NSW	15 August 2011	Tweed Shire Council

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Index[1]

[1] Note: The three major focal taxa discussed in this book, the Richmond birdwing (*Ornithoptera richmondia*) and its two larval food plants (*Pararistolochia laheyana and P. praevenosa*) are not included in this index, as they are mentioned frequently throughout the text.

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