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.

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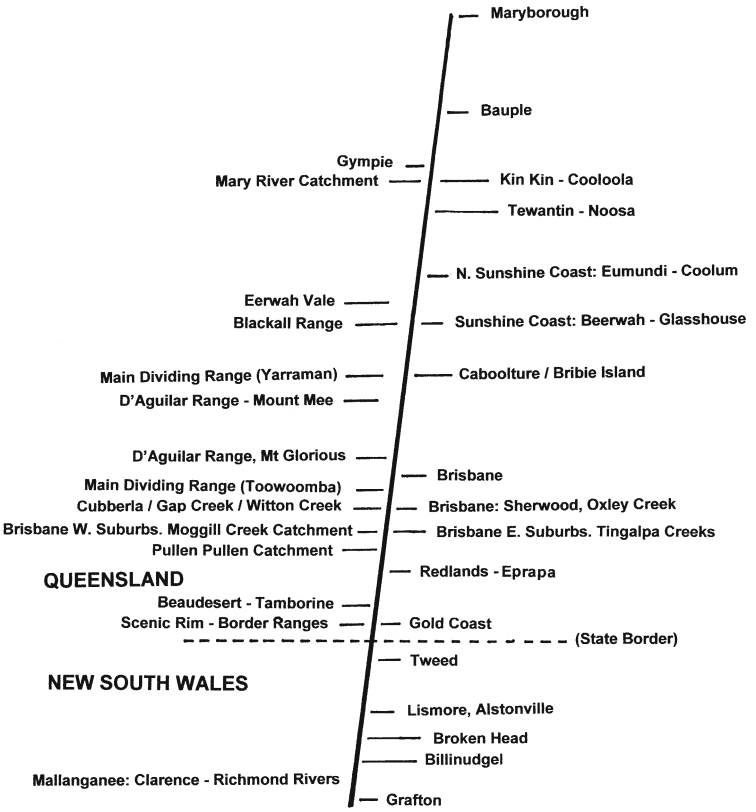

Fig. 8.1 The network of planting corridors planned for restoration of *O richmondia*

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 Cathariba.

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 $15 \times 4 \times 2.5$ 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.

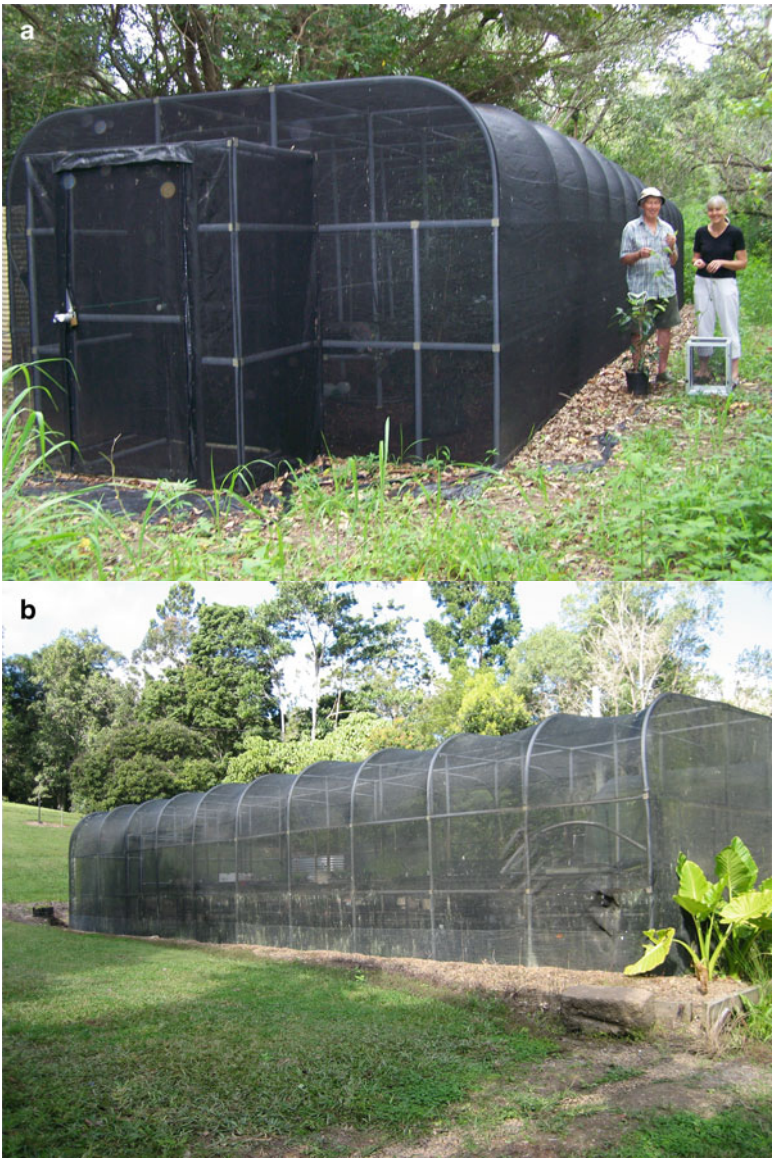

Fig. 8.4 Captive rearing facility at Gold Creek, Moggill Catchment: (**a**) the initial breeding house, outside; (**b**) reconstructed after destruction by flooding

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.