Ecological Approaches in Designing Neighbourhood Green Spaces As Urban Wildlife Habitat in the Klang Valley, Peninsular Malaysia

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Abstract

This study examines the ecological approaches adopted by a group of landscape architects in their design of neighbourhood green spaces that have successfully in the conservation, enhancement and/or creation of wildlife habitats. The study, therefore, has sought to investigate through a combination of surveys, case studies, interviews and observations on landscape architects and residents in the Klang Valley. This study revealed the design approaches employed by landscape architects in the design phases have successfully culminated in the conservation, enhancement and/or creation of new wildlife habitats. However, there are different levels of adoption observed in the design phases of site planning, conceptual master planning, planting design and plant selection, and in the construction phase and use of green materials. The findings indicate that landscape architects who collaborated with relevant agencies, and who have the support of their clients were more effective in their design efforts. An overall positive attitude towards urban wildlife was definitely visible. The findings from the residents' attitudes survey strongly demonstrated a selective preference towards common urban wildlife. This study also identified the main constraints impeding landscape architects from adopting landscape ecology principles in their design efforts. It is envisaged that the findings of this study will contribute to reaffirm the broad definition of ecological landscape design, and contribute to the knowledge of sustainable ecological landscape within the regime of landscape architecture.

Keywords: Designing neighbourhood green spaces; Ecological approaches; Wildlife habitat

Introduction

This paper examines the approaches adopted by landscape architects in their design of neighbourhood green spaces. Collectively, these case studies provide a reference point for good practice within the profession of landscape architecture. This study highlight how far landscape architect adopted the landscape ecology approach and principles into their design process of neighbourhood green spaces that culminate in the conservation, enhancement or creating of new habitats. This study interests to investigate the design approaches employed that have culminated in the conservation, enhancement, and/or creation of urban wildlife habitats; and to identify the constraint that impede most landscape architects from designing wildlife habitats.

Literature Review

2.1. Approach of landscape ecology in greenspace design

Views from Dramstad et al. (1996); Lyle (1985); and Forman and Godron (1986) indicated most appropriate method to approach the design of several factors should be taken to approach the design of urban green space including the sociological and ecological advantages that is offered by a holistic design approach, and past successes associated with the approaches adopted at a neighbourhood hierarchy.

This study adopted landscape ecology approach in analysing neighbourhood green spaces. Studies by Farina (1998), Forman and Godron (1986), and Grant and Manuel (1996), provided a comprehensive understanding on the theoretical basis of landscape ecology, while Dramstad et al. (1996) provided the basis for application of methods and principles to be utilised. Farina (1998) observed that landscape design is an important component in practical landscape ecology as it expresses the relationship of spatial patterns and processes in a practical manner. It provides in depth understanding on wildlife habitats and movements and biological interdependency within a region.

Landscape ecology relates to the spatial patterns of landscape features and since landscape design directly influences this arrangement, the two disciplines should be complementary. Landscape ecology offers insights on how to optimise the use of space while conserving and enhancing the environment (MacArthur and Wilson, 1967; Forman and Godron, 1986).

Studies of landscape ecology indicate that its principles have been successfully implemented in green space plannings and designs. Jim and Chen (2003) provided a framework for a greenspace system for Nanyang City, China that integrates the metropolis, city and neighbourhood scales of landscape based on landscape ecology principles. Green wedges in the metropolis, link the countryside to the central city. In the city, major greenways including the Inner-Qinhuai River and the canopy-road greenways link to existing parks. Comprehensive trail systems, shaded sidewalks and riparian greenways provide opportunities for residents in residential neighbourhoods to come in close contact with wildlife. Meanwhile, landscape ecology principles were adopted in the urban greening master plan of Beijing Province, linking regional, city and neighbourhood scales (Li et al., 2004). The greenway system encompasses extensions and connections of riversides, roads, streets, parks and vertical planting. A system of linkages also connects isolated green spaces to public parks and other extensive green spaces. Greenways are termed as 'park connectors' in Singapore specifically targeted asphalt tracks, drainage reserves and road reserves for greenway development (Tan, 2006). Despite a successful adoption of the landscape ecology approach in conceptual city master planning, this study opines there is a need to provide practical application of landscape ecology principles into each phase of green space design at the local community level. This study aims to explore how these principles can be adopted in design phases by practitioners.

2.2. Principles of landscape ecology

The basic principles of landscape ecology are patch, corridor and mosaic and they work equally well for disturbed urban areas and pristine natural areas (Forman and Godron, 1986).

2.2.1. Patch

Patch is a homogenous nonlinear area that has a different surface cover compared to its surroundings (Forman, 1995). In residential communities, patches are found in the form of neighbourhood parks, linear parks, pocket parks, playgrounds, playing fields, secondary forests and other communal green spaces provided (Figure 1). Important patch configuration that influences diversity and abundance of wildlife consist of size, shape and number of patches, and their proximity to each other (Cook, 2002; Dramstad et al., 1996; Forsyth and Musacchio, 2005). Besides these factors, other characteristics included density of buildings adjoining the patch, density of shrubs within a patch, and distance to the nearest trail and water body (Tilghman, 1987).

2.2.1.1. Size

A large patch contains more habitats, thus containing a greater number of species than a small one. Vegetation in small parks is found to be suitable habitat for generalist wildlife species and functions as stepping stones to other habitats. Raedeke and Raedeke (1995) suggested the following minimum patch size for habitat design:

- 1.4 acres (0.57 ha) for amphibians and reptiles
- 1.6 acres (0.65 ha) for small mammals
- 12.5 ha (5.05 ha) with a minimum 200 m diameter of patch for invertebrates

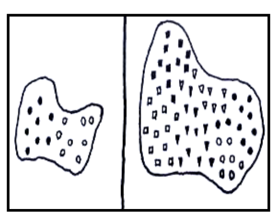

Fig. 1. Relationship between patch size and species diversity.

Source from *Landscape Ecology Principles in Landscape Architecture*, Dramstad et al., 1996.

As most neighbourhood green spaces in the Klang Valley comprise small parks, they can be appropriately designed to encourage species dispersal, and to provide escape covers for small mammals. Small parks are most suitable for generalist species that are not area-sensitive.

The species include selected birds, butterflies, amphibians such as frogs and toads, and small mammals such as rabbits and squirrels (Forsyth and Musacchio, 2005).

2.2.1.2. Shape

This influences the number of edge and interior species that live within a patch. A convoluted shape will have a higher proportion of edge habitats than a circular shaped patch area.

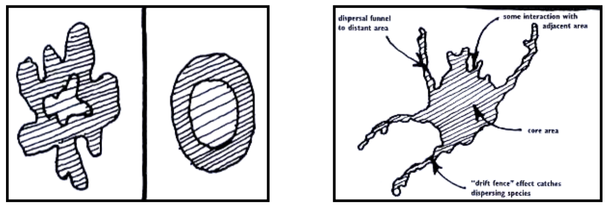

Fig. 2. a) Patch shape and edge habitat. b) Ecologically - optimum patch shape.

Source from *Landscape Ecology Principles in Landscape Architecture*, Dramstad et al., 1996.

2.3.2. Edge

An edge refers to a common boundary where two habitat types meet and it supports a higher density of wildlife. A naturally-occurring edge is often curvilinear, organic and meandering whilst those produced by humans are usually harsh, lack transition, and are straight with few variations. Farina (1998) observed that a convoluted patch encourages species to interact with the surrounding matrix. Similarly, Dramstad et al., (1996) noted that a curvy edge with small patches of intermixed vegetation has several ecological benefits compared to one which has a straight boundary. The former provides wildlife greater opportunities to exploit.

As edge species are more prevalent on built landscapes compared to forests, landscape architects and landscape planners concerned with conserving interior species must minimise the fragmentation of large patches (Soule, 1991).

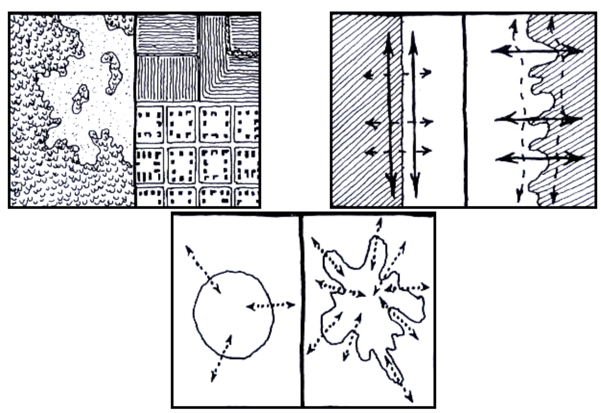

Fig.3. a) Natural and human-made edges. b) Straight and curvilinear boundaries. c) Interaction with surrounding.

Source from *Landscape Ecology Principles in Landscape Architecture*, Dramstad et al., 1996.

2.3.3. Corridor

In America, Korea, Canada and Singapore, greenways have been designed as corridors for wildlife and human movement (Little, 1990; Flink and Searns, 1993; Foo, 2001). This study draws from Ahern (1995) who defined greenways as networks of land containing linear elements that are planned, designed and managed for multiple purposes including ecological, recreational, aesthetic or other purposes compatible with the concept of sustainable land-use. This study contextualises greenways as corridors within the framework provided in the planning system in Malaysia. This includes trails for jogging tracks, pedestrian walkways and cycling tracks; scrubs and water edged vegetation along natural and constructed water bodies within a residential development.

Dramstad et al. (1996) emphasised that greenway corridors within the neighbourhoods are most effective as stepping-stones and can be used to link together habitats and form routes from residential schemes to larger urban green spaces. A row of stepping-stones maximises connectivity in providing wildlife movement between patches.

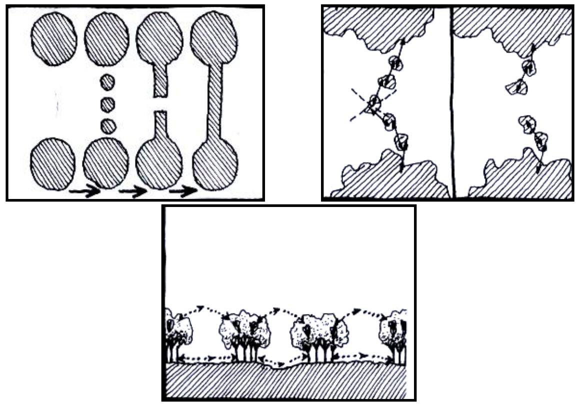

Fig. 4. a) Stepping stone connectivity. b) Loss of stepping stones. c) Distance between stepping stones.

Source from *Landscape Ecology Principles in Landscape Architecture*, Dramstad et al., 1996.

Loss of a patch normally inhibits movement and thereby increases patch isolation. However, according to Dramstad et al. (1996), corridor with gaps can still be effective as a wildlife movement conduit if the gap is less than the specific scale of movement. Most common urban wildlife are small in size, thus, it is imperative that the gaps in the corridors be kept small. Natural corridors including rivers, ridges and animal trails are often found in a meandering, organic form, while human-designed corridors are straight and linear (Dramstad et al., 1996). Soule (1991) suggested that landscape architects design corridors to mitigate wildlife habitat fragmentation.

2.3.4. Mosaic

Mosaic significantly influenced the abundance and diversity of wildlife species as it forms a movement corridor for wildlife (Savard et al., 2000). Franklin (1997) conceptualized small parks as being embedded in its surrounding 'matrix' of land parcel connected by greenway corridors. Thus, the landscape architect should understand how a site fits into the larger mosaic around it before the planning process began (Russ, 2002). Once understood, the landscape architect is better able to incorporate the principles of patches, edges, and corridors into green space plan.

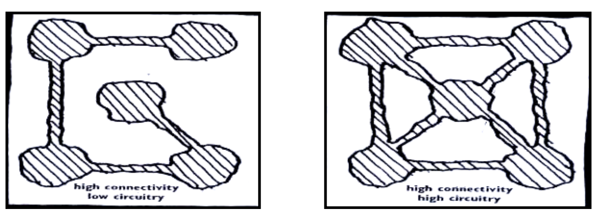

Fig. 5. Network connectivity and circuitry.

Source from *Landscape Ecology Principles in Landscape Architecture*, Dramstad et al., 1996.

2.4. Application of Landscape Ecology Principles in Greenspace Design

Lagro (2001) observed that more emphasis has been placed on the product, and that relatively little attention was given to explain the factors that influenced the designs. Thus, this study delves into the design phases of neighbourhood green spaces. The process of landscape design is divided into Site Planning, Conceptual Master Planning, Planting Design and Plant Materials, Construction Documentation (methods and materials), and Implementation. Landscape ecology principles are utilised to gear the process of green space design towards a sustainable landscape design paradigm. Each phase of the design process of green space is discussed as following:

2.4.1. Site Planning

The objective of site planning is to limit destruction to existing habitats and to monitor any action that will reduce biodiversity and ecosystem processes and functions.

Development can be designed to minimise these developmental impacts and mitigate environmental damage (Russ, 2002). Grant (1996) highlighted the importance of considering site ecology in the earliest stage of planning and integrating it into landscape master planning. Russ (2002) provided a set of guidelines including the re-use of existing buildings and infrastructure to increase the efficiency of material use, to preserve natural landscape including habitats and significant trees and to use green materials. The 'sieve-mapping' technique provides a simplified approach to studying a site's ecosystem involving the mapping of natural physical features (including vegetation, topography, hydrology and geology).

2.4.2. Conceptual Landscape Master Planning

The conceptual master planning phase addresses the spatial organisation and articulation of a site (Lagro, 2001). Although the landscape matrix is often beyond the scope of sites allocated for green spaces, it is critical to first view the site as part of a larger landscape matrix. Subsequently, the landscape architect is able to articulate the conceptual plan and optimise connectivity and linkages by adopting the principles of patch, edge and corridor. The ideal ecological master plan for sustainable communities should be an interconnected single ecosystem where wildlife species can traverse across the entire landscape and habitats remain undisturbed by impervious surface, roadways or buildings (Yeang, 2008).

2.4.3. Planting Design and Plant Materials

Planting design provides significant functional, ecological and aesthetic roles in urban landscape and is much more than a cosmetic treatment to be applied to insensitive architecture (Robinson, 2004). There is a consensus among literatures on wildlife habitats that planting design is a primary influence on the success of green spaces utilised as wildlife habitats (Rosli, 2004; Ong, 2003; Walker, 1991).

2.4.3.1. Planting design

Planting designs to encourage wildlife diversity should incorporate the species diversity, structural diversity, edges and trees as habitats. Species diversity refers to the variety of plants present (Robinson, 2004; Barnes, 2005). Providing a variety of evergreen and deciduous species of trees, palms, shrubs and groundcovers means wildlife will have more to choose from. As they are more likely to find what they need, this will attract and sustain a diversity of wildlife species. Similarly, plants that have fruits, seeds, nectar, grains, berries and nuts, at different seasons of the year will also ensure a continuous food supply for wildlife. A habitat should have a mix of deciduous and evergreen plants. It was suggested that at least 25% of the trees and shrubs should be evergreen (ibid). The aim is to increase diversity in plant selection that ultimately will attract and sustain a diversity of wildlife species.

Structural diversity refers to the number of vegetative layers present. Based on resource partitioning, plants in natural habitats grow in many layers and each layer provides a home for specific wildlife species. Planting many layers of vegetation allows wildlife to select the layer to which they can best adapt to survival. Raedeake and Raedeake (1995) observed that birds inhabit different stratas of the forest floor, lower canopy and upper canopy of vegetation. Vertical and horizontal structural diversity allows greater diversity of habitats leading to greater possibilities of species survival (Cook, 2002). Planting design should encourage ecotones to function as boundary habitats. Convoluted boundary edges will create a greater diversity of habitats and encourage higher species diversity compared to straight edges that tend to have more movements across (Dramstad et al., 1996; Walker,1991). The longevity and size of trees make them unique and important individually and collectively. Ecologically, the special qualities of trees mean that each of them is an independent habitat. Keystone species including the Rain Tree (*Samanea saman*) and Beringin (*Ficus benjamina*) provide habitats for the fruitivorous, insectivorous and nectarivorous species. There is a diversity of wildlife living on, in or under the roots, trunk, branches or leaves.

Fig. 6. Plants' structural diversity.

From this perspective, individual trees can be looked on as isolated fragments of landscape with patterns of migration and colonisation between them (Kendle and Forbes, 1997). Climbing trees including ivy can be introduced to mature trees (Soepadmo, 1998; Robinson, 2004). The ivy provides nectar for bees that in turn attract insectivorous birds. Besides getting a constant supply of food, the birds can also roost and nest on climbers.

2.4.3.2. Plant materials

The selection of an appropriate plant species is based on its quality to provide food, shelter and cover for wildlife (Wee, 2003). Howes (2009) observed that, native plants are more appropriate in providing the right kinds of food, shelter and diversity needed by wildlife. Cook (2002) noted that native plants support ten to fifty times more native wildlife than exotics plants. When it is not possible to use native plants, introduced plants or naturalistic plant species that have adapted to local site conditions could be selected as they have evolved in the local areas. These include trees, shrubs, and groundcovers that produce seeds, fruits, berries, nectar, grains and nuts in large numbers and are available throughout the year. *Ficus* spp. is best known as food source to birds and mammals (Ong, 2003). Some *Ficus* spp. bear fruits a few times throughout the year, thus filling the gap when other trees are not fruiting. Meanwhile, Nor Ain (2008) suggested planting food plants including Mata Pelanduk (*Ardisia elliptica*), Senduduk (*Melastoma malabathricum*) and Kemunting (*Rhodomytus tomentosa*) for bird parks. Many forest trees are highly ornamental and serve as food plants (Kingham, 2008).

These trees including Penarahan (*Knema hookeriana*), Kayu Arang *(Diospyros pillosanthera*), Pokok Daun Salam (*Syzygium polyanthum*), Nutmeg (*Marystica fragrains*), Gonchak (*Antidesma coriaceum*), Nyatoh (*Payena lucida*) and Kemunting (*Rhodomyrtus tomentosa*) attract thousands of birds and mammals, including squirrels, to feed on their sweet fruits and nuts. According to Kingham (2008), the primary criterion in choosing forest species for urban planting is that they must produce prolific fruiting. A combination of fruiting plants that provide fruits at different times of the year will ensure a constant supply of food thus attracting birds and other wildlife. The demand for forest plants in arose from the need to find alternative plants from the present ornamental plants used in urban landscape. Besides having a longer life span, forest species are more appealing due to the increasing recognition of their intrinsic and aesthetic values (Soepadmo, 1998).

2.5. Construction Methods and Materials

Inappropriate methods and processes taken or done during construction often resulted a direct impact on the quality of wildlife habitats. They might also indirectly influence the quality of habitats and wildlife populations in the long term, by changing the optimum conditions of a habitat (Addis and Talbot, 2001). Sustainable construction, proponent advocate a two-fold to mitigate these impacts to wildlife (Russ, 2002; Addis and Talbot, 2001). Each step of construction process should minimise site disruption (eg. excessive grading, blasting, clearing) and resource degradation (eg. stream siltation, ground water contamination) and air pollution. It also stresses the use of green materials in hardscape design including paving materials, landscape furniture and constructed wetlands.

The cement and concrete widely used in Malaysia's construction industry is damaging to water bodies as the alkaline character of cement may result in runoff water that is particularly harmful to aquatic life (Russ, 2002). Besides this, Russ (2002) also cautioned against using treated wood in direct contact with water bodies or wildlife as the water-based preservative used in treated wood contains high levels of chromated copper arsenate (CCA), contains arsenic and chromium elements that are toxic for human and animal. Oil based preservative is often used in treated wood forms a film on the surface of water bodies, thus, preventing oxygen from entering water bodies.

3. Research design and methodology

The research design employed in this study comprises case studies, interview of landscape architect and observations. A total of two townships and five residential schemes in Klang Valley were selected as case studies. These case studies are Putrajaya and Shah Alam (representing townships), Bukit Gita Bayu, Sentul Raya, Bukit Jelutong, Kota Kemuning and Setia Eco Park (representing neighbourhoods).

3.1. Case Studies

3.1.1. Putrajaya

Putrajaya, the new Federal Government Administrative Center of Malaysia was developed by Putrajaya Holdings Berhad in 1996, and covers 4,931 ha. The master plan for the development incorporates comprehensive policies and guidelines for landscaped areas for its estimated 330,000 inhabitants. Fourteen precincts were developed as residential precincts, while six other precincts include government and mixed developed as residential precincts include government and mixed development projects. The original site comprised the secondary forests regenerating from previous oil palm and rubber estates where these mono culture plantations provided low wildlife diversity compared to that of tropical forests (Lim et al., 1998).

3.1.1.1. Green spaces and wildlife habitats

Among the main green spaces provided in Putrajaya are Putrajaya Lake and Wetlands (600 ha), Taman Botani (92 ha), Taman Rimba Alam (193 ha), the Agricultural Heritage Park (14 ha) and Taman Putra Perdana (62.4 ha). This study focuses on Putrajaya Lake and Wetlands, and Precint 8, representing township and neighbourhood respectively. The Putrajaya Lake covers 600 ha and was created by damming Chuau River and Bisa River. It is one of the largest fully constructed freshwater wetland in the tropics (Lim et al., 1998). Each cell of the wetland system is made up of the Wetland Zone (permanently flooded) and Zone of Intermittent Inundation (fringing marsh and swamp forest). The swamp forest bordering entire Putrajaya wetland system connects habitats along the Putrajaya waterways. The wetland ecosystem offers a diversity of habitats to attract wildlife including Little Egrets, Little Green Herons, Cinnamon Bitterns, and migratory birds from Northern Hemisphere. It also functions as breeding grounds and nurseries for, invertebrates, mammals, reptiles, amphibians and fish (Perbadanan Putrajaya, 1999).

Precinct 8 Neighbourhood is one of the fourteen residential precincts provided in the periphery of Putrajaya. The lake adjacent to the residential blocks filter polluted water before it reaches the main lake. The lake helps to connect habitats along Putrajaya waterways and provides sanctuary to migratory purple herons, little egrets and storks. Promenades adjacent to the residential block follow the natural meandering form and gentle slopes of existing landform. Besides the existing Rain Trees (*Enterolobium saman*), Jambu Laut (*Eugenia grandis*) and Beringin (*Ficus benjamina*), new plantings include Orchid Tree (*Bauhinia purpurea*), Yellow Saraca (*Saraca cauliflora*) and Sea Apple (*Eugenia grandis*). In Putrajaya, the linear parks, promenades and waterways are designed as an integrated network of green corridors that help to ease movement for urban wildlife, especially for resident and migratory birds (Noriah, 2007). The linear parks link the residential schemes to the promenades and most of the linear parks meander along existing gentle landform. The major designs of promenades provided comprised meandering walkways along waterfronts and formal, hard-edged surfaces along urban and protocol areas.

3.1.2. Bukit Gita Bayu

Bukit Gita Bayu is located in Cheras. Covering 120 acres, it is a mixed residential development supported by a pavilion-style clubhouse. It is a low density development with an overall density of 4.3 units per acre (Bukit Gita Bayu, 2001). Among the awards it received are the FIABCI award for the Best Residential Development (2003) and the Best Landscaping for Resort Tourism Complex Category (2003). Bukit Gita Bayu evolved from a piece of undulating land with a distinct hill which formed part of Kelton Estate, one of the oldest rubber estates in the country.

The main characteristic of Bukit Gita Bayu is the existing rubber trees, Brazilian Rubber Trees (*Hevea brasiliensis*). The concept for Bukit Gita Bayu was never consciously formulated, instead it evolved due to a combination of natural topography, its location and the aspirations of the developer to provide a development that would be less "traumatic" for the environment (Zainuddin, 2007). This was formulated into a development concept which maximised the conservation of the sanctuary with minimum changes to the natural environment, including the existing terrains and vegetation. The building structures have been architecturally planned and designed to retain as much of the natural habitats as possible and to blend in with the surroundings (Landscape Architecture Malaysia, 2003). Priority was also given to natural and local materials in the selection of building materials and plant materials. Priority was also given to natural and local materials in the selection of building materials and plants materials. Earthwork was minimised while the roads constructed are parallel to the contours.

3.1.2.1. Green spaces and wildlife habitats

Several green spaces function as significant wildlife habitats. This includes the Clubhouse Area (Kebun Mimpi) where the main planting scheme is based on existing vegetation. Many existing trees such as Trumpet Tree (Tabebuaia pallid), Fishtail Palm (Caryota mitis), Pokok Cucur Atap (Baeckia fructocosa), Fern Tree (Cyathea letebrosa) and Crinum spp., are retained with new plantings of lower trees, flowering shrubs and groundcovers added to the site. Several dry gardens provide transitional spaces leading to the pavilion and lake. As the areas do not receive much sunlight, dry gardens are planted with Yellow Bamboo, existing rubber trees and Cuphea spp.

There are numerous pockets of vegetation in the courtyards and deck areas. Besides providing garden habitats for invertebrates and small mammals, these small patches serve as linkages within club. The planting design of each courtyard emphasises layers of naturalistic planting planted in big pots and provide abundant fruits, seeds and nectar for birds, squirrels, butterflies, and moths to feed on. The clubhouse is built overlooking two lakes where a tomber deck is provided at the water edge between existing Pulai (*Alstonia angustiloba*) trees. Besides fulfilling recreational needs, the main lake also functions as a silt trap before the water flows into another lake, Tasik Duyong. Both of these wetlands provide a diversity of habitats of frogs, toads, iguanas and tortoises. Linkages in the development are provided by roads, avenues, pedestrian walkways and trails. Forest trees including Large-Leaved Khaya (*Khaya grandiflora*) and Pulai spp. (*Alstonia angustiloba*) are used as avenue planting while *Tecoma* spp. are planted for service road planting. Besides these species, Common Kelat (*Syzgium lineatum*), Simpoh Air (*Dillenia sucrophylum*), Ara (*Ficus benjamina*) and Fishtail Palm (*Coryota mitis*) are also used in avenue planting.

3.1.3. Sentul Raya

The name of the development is derived from Sentul Tree (*Sandoricum koetjape*) which is a fast growing tree that can grow up to 150 ft at maturity. The development covers 294 acres of freehold land and comprises 7,000 units of residential lots, commercial offices and retail outlets (Sentul Raya, 2002). The site is divided by the track of Sentul KTM into two halves, thereby forming the unique Sentul West (186 acres) and Sentul East (107 acres). The development received FIABCI Award for the Best Masterplan Development (2007).

3.1.3.1. Green spaces and wildlife habitats

The developer, YTL Land & Development Berhad allocated 30% of the development area for open spaces (YTL Land & Development Berhad, 2007). Sentul West represents the elite area of the development where the main green space area provided is Sentul Park, which is Malaysia's first private gated park. Among the prominent features of Sentul Park are the green spaces that include a 35-acre Forest Park, central lakes, wildflower meadows, mazes, frog ponds and herb gardens. The Sentul Forest covering 9 ha has been preserved to retain urban woodland habitat. While most native trees are retained, other forest trees have also been added. The existing features on the site include the Forest Walk, Bird Island and Camp Ground. There are many shrubs associations and heavy forest litter. Numerous bird species including Black-naped Orioles (*Oriolus chinensis*), Common Golden Woodpeckers (*Dinopium javanese*) and Blue-throated Bee-eaters (*Merops viridis*) can be seen or heard.

Three fields also function as grassland habitats for herbivorous birds. The development includes two lakes where the lake has a natural, organic form water edge planting. An island is created with a slight expansion of the lake and a slight exaggerated form of the edges. Except for Cattails (*Typha angustifolia*), there are no other water edge planting. However, matured Yellow Flame (*Pelthoporum pterocarpum*) and Red Flame (*Delonix regia*) trees close to the water edge provide ample shade and cover for aquatic wildlife.

The main characteristics of Sentul West is the conservation of specimen trees including the Rain tree (*Enterobium saman*), Beringin (*Ficus benjamina*), Yellow Flame (*Pelthoporum pterocarpum*), Mexican Lilac (*Gliricidia sepium*) and Common Ru (*Casuarina equisetifolia*). The huge trees are located sparsely form each other, and stand at a minimum height of 100 ft. They provide a distinctive microclimate apart from fulfilling nesting and cover needs for birds, invertebrates, squirrels and other wildlife.

3.1.4. Setia Eco Park

Setia Eco Park was developed by SP Setia Berhad and is located in Section U13, Shah Alam. The gated and guarded residential development covers 791 acres of freehold land and comprise semi-detached and bungalows units with a low density rate of 3.7 units per acre (Institute of Landscape Architecture Malaysian, 2007). The developer has allocated 183 acres of green spaces constituting 23% of the total land area. Since its inception, the development has received numerous awards. These include The Edge Malaysian Top Property Developers Awards (2005, 2006 and 2007), the World Best Master Plan Development in FIABCI Malaysia Property Award (2006), and the Property Man of the Year (2007) Award in the FIABCI Malaysia Property Award. The development is contiguous to the Bukit Cahaya Forest reserve and is easily accessible by an extensive network of highways including the NKVE-Setia Alam Link.

3.1.4.1. Green spaces and wildlife habitats

The development plan divided the township into sub-precincts where each sub-precinct is allocated ine acre of neighbourhood park (Institute of Landscape Architecture Malaysia, 2007). As the parks and waterways were designed as habitats for selective wildlife, they were named after these wildlife species (Setia Insight, 2008). Several green spaces that are significant as wildlife habitats will be discussed. The Butterfly Creek in Precinct 3 was designed with various themes including Paddy terrace, Aroma Walk, Creeper's Trail, Bougainvillea Creek and Palm Groove. Besides functioning as a retention pond, the Rainbow Creek is also used for jogging and other recreational activities. The Swan Lake is a man-made lake covering 25 acres and primarily functions as a retention lake in Precinct 3. Pockets of islands were built in the lake serving as nesting grounds for birds and swans.

The Forest Park is a 56 acre existing forest occupying the steepest, northern section of the land and is contiguous to the Bukit Cahaya Forest Reserve. Meanwhile, the Heritage Trail is a linear park with specific features to encourage specific wildlife to colonise. These features include Butterfly Colonies where various food plants and nectar plants are scattered around the lake park. The first targeted colony is the Leopard Butterflies which feeds on the Weeping Willow (*Salix babylonica*). The linkages within the development are provided by walkways, waterways, creeks, bicycle crossings and supported by traffic calming devices. The paved areas in the development consists of only 65% of the overall road reserves and all telephone, electricity and other utility cables are laid underground while the rest of the land is designed as green corridors with an open lawn known as the Green Street.

3.2. Interviews with Landscape Architects

The researcher selected seven interviewees for Sentul Raya, Bukit Gita Bayu, Bukit Jelutong, Kota Kemuning and Setia Eco Park. The particulars of the interviewees are listed in Table 1.

Table 1. Landscape Architects Interviewed for the Case Studies.

Project	Practice	Interviewee	Position
Putrajaya	Perbadanan Putrajaya	Madam Noriah Mat	Deputy Director, Dept of Landscape and Parks
Shah Alam	Majlis Bandaraya Shah Alam	Mr. Tahir Man	Director, Dept. of Landscape MBSA
Sentul Raya	Seksan Design	Mr Ng Sek San	Managing Director
Bukit Gita Bayu	Eco Design Sdn Bhd	Mr Zainudin Ismail	Managing Director
Bukit Jelutong	Guthrie Landscaping Sdn. Bhd	Mr Saiful Azmi b. Abdul	Landscape Architect
Setia Eco Park	SP Setia Bhd	Mr Abdul Rahman	Senior Landscape Manager Landscape Unit
		Mr William Rachaganathan	General Manager, Landscape Unit

Semi-structured interviews were conducted on the landscape architects. The researcher also obtained the assistance of other key personnel for several case studies. They included Mr. Foo Soh Yong, Senior Operations Manager of Yee Seng Heights Sdn Bhd, the development company for Bukit Gita Bayu; Mr.Phang of Sentul Raya and Mr. Nizar Sharidan, officer with the maintenance company engaged by Perbadanan Putrajaya. They shed more supplementary information pertaining to the case studies.

The major approaches taken by the respondents in designing, during construction and beyond construction of the neighbourhood green spaces were identified and organised. The approaches taken in each design phases were analysed based on landscape ecology principles relevant to the scope of study. The analysis was carried out concurrently with data collection. The key responses from the interviewees were compared for similarities and differences, trends and patterns. The information provided further insight into the case studies themselves and provided explanations why some particular decisions were taken.

3.3. Observations

During the site visits, observations on the application of ecology principles, especially on the adoption of landscape ecology principles, the planting design, selection of plant materials and hardscape materials were recorded. Photographs were taken of relevant aspects of site. Another round of site visits was conducted after the interviews to ensure all information pertaining to the case studies were covered and to reconfirm the facts obtained during the interviews were accurate.

4. Findings in discussion

4.1. Site planning

Site planning aims to protect the ecological integrity of a site by minimising the environmental impact of development. As different sites pose different opportunities and constraints, the approaches taken by landscape architects depends on their ecological sensitivity besides meeting the demands of their clients.

4.1.1. Site assessment to minimise disturbance

It is one of the most important aspects to determine the best methods to lay down the structures in order to protect the natural environment. Russ (2002) observed that the design should retain as much of the original terrain and the character of the site as possible. Minimising the amount of disturbance on a site will help to conserve wildlife habitats. In the case of Putrajaya, physical planning came after environmental planning (Noriah, 2007). Due to this fact, the planning of Putrajaya entailed a comprehensive study on the existing site conditions and explored the opportunities of the site. Before Putrajaya Wetlands was conceived, the site had an undulating topography interspersed with steep sided hills and the valley floors were flat resulting in significant floodplain storage during floods. Besides this, the layout of Putrajaya Wetlands was constrained by the long linear configuration and the steep sided slopes of Sungai Chuau and Sungai Bisa. Subsequently, the wetland design followed the natural contours of the terrain. The design of the water levels in the wetland cells is an iterative process that took into account the existing topography, depth of water of the functional zones, the surface area required and the extent of earthworks needed to achieve an optimum design layout. The designed water levels created a cascading effect and enhanced aeration of water as the flow passed through the wetlands. Hence, the concentration of dissolved oxygen is maintained sufficiently high to ensure the sustainance of aquatic wildlife (Perbadanan Putrajaya, 1999).

Fig. 7. The wetland cells
Source from Perbadanan Putrajaya, 1999.

The developer, known as an active advocator of conservation of natural environment employs audit consultant, ARUP Consultant Berhad to monitor the design development of the master plan where the audit process covered areas including ecology, landscape, microclimate, materials and water. The landscape architect then drew upon the potential of existing forest, water bodies, building materials, railway tracks and warehouse to be incorporated into design.

Fig. 8. Conservation of Sentul Warehouse into design

4.1.2. Conservation of wildlife habitats and vegetation

Most landscape architects concurred that they have taken the necessary precautions within their power, to conserve existing vegetation. Nevertheless, various site constraints had induced them to adopt different measures to minimise felling of existing trees. There were no primary forests on the original site for Putrajaya. The closed canopy resulted in only 10% to 20% of sunlight reaching the ground. Subsequently, ground vegetation was made up of native, shade-tolerant fern such as Bakong (*Hanguana malayan*). Together with the emergent plant species from Chuau River and Bisa River, these native plants were transferred to the new wetlands hence providing much food for wildlife. The landscape architect of Bukit Gita Bayu was strongly encouraged to maximise the retention of 3,000 Brazilian Rubber Trees (*Hevea brasiliensis*) besides other trees including Mahang Merah (*macaranga triloba*) and Pulai (*Alstonia angustiloba*).

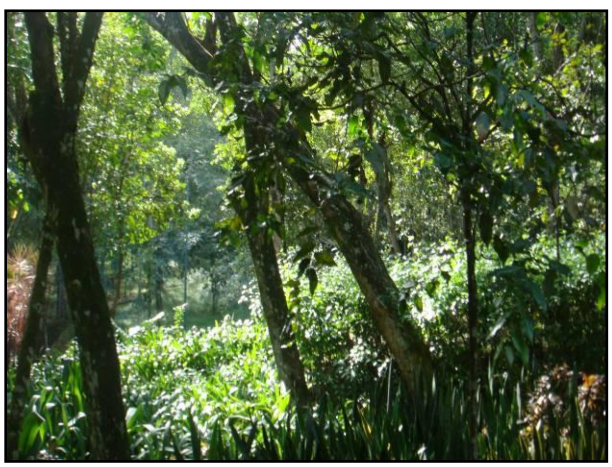

Fig. 9. Rubber trees at clubhouse

The retention of the existing trees was extended to the avenues resulting in some paths of the walkways running off-course, so as to accommodate Common Kelat (*Syzygium lineatum*) and Beringin (*Ficus benjamina*). Before construction, the existing forest tree species including the Large-Leaved Khaya (*Khaya grandiflora*) and Pulai (*Alstonia angustiloba*) were transferred to the nursery after which they were transplanted to the new locations. Small indigenous tree like Simpoh Air (*Dillenia spp.*) and Fishtail Palm (*Caryota mitis*) were also left on their original site. The tree, *Dillenia* spp. was protected by curbs to prevent injury to them.

The landscape architect of Sentul Raya made similar efforts to conserve existing trees and other vegetation. Three distinct layers of vegetation of 9ha Sentul Forest, comprising canopy layer, dense understorey and secondary bushes were largely retained and forest trees were added. As a flock of hornbills has been sighted in Sentul Forest, the trails were located at the furthest end of the furthest end to minimise disturbance to its habitat. Huge individual trees including the Rain Tree (*Enterobium saman*), Beringin (*Ficus benjamina*), Yellow Flame (*Pelthoporum pterocarpum*) and Mexican Lilac (*Gliricidia sepium*) have been retained as habitat providers. These trees support a diversity of wildlife that will otherwise disappear if the tree were felled. Standing at a height of at least 30 m with huge, wide canopy, the individual trees provide a distinctive microclimate with habitats for birds, invertebrates, squirrels and other wildlife. These matured trees by the edge of lake also allow for ducks to bask especially during hot days.

Fig. 10. Matured trees conserved in Sentul Raya

The approach taken was to let the old trees dictate their habits. Thus, the parasitic and epiphytic plants that have formed a long-term relationship with the trees were retained. This helped the trees to sustain the wildlife they have supported all along. Oak Leaf Fern (*Drynaria quercifolia*), an epiphytic plant is found growing on trees for support including the trunks of Rain Tree (*Samanea saman*). The nest and foliage produced by these epiphytes have accumulate moisture, debris, nutrients and humus over the years that have sustained the population of invertebrates including stick insects, beetles, bugs and centipedes. These in turn, provide food source for insectivorous squirrels, lizards, geckos and tree shrews. A Beringin tree (*Ficus benjamina*), parasites to the Rain Tree (*Samanea saman*) was also retained.

4.2. Conceptual landscape master planning

The research identified that all case studies were provided with landscape master plans. It was also observed that all landscape architects interviewed for Setia Eco Park, Sentul Raya and Bukit Gita Bayu were involved in conceptualising the landscape master plans. As such, this has enabled the landscapearchitects to actively participate in the development at the earliest planning stage. Together with the other professionals, the landscape architects were able to varying degree, incorporate their ideas with regard to the conservation and creation of habitats. The analysis of master plan for the case studies is based on the principles of landscape ecology comprising patches of green spaces (size, shape and number), edges, corridors and the mosaic of development.

4.2.1. Patch of green spaces

4.2.1.1. Size, shape and number.

Master plan of Putrajaya considered environmental planning first before the physical planning itself where the topography was planned and designed with minimum disturbances to the natural environment. The master plan was designed along an axial tangent form northeast to southeast taking full advantage of the natural surroundings. In Putrajaya, an unprecedented total of 37% of the development area was designated for natural and man-made green spaces. Subsequently, this placed landscape architects in the frontline of development.

It was observed that the numbers of green patches and their sizes are sufficient to encourage the existence urban wildlife. The urban patches include Putrajaya Lake (400 ha), Wetlands (197 ha), Botanical Garden (85 ha), Taman Rimba / Taman Jati (193 ha), Taman Putra Perdana (62 ha) and Taman Warisan Pertanian (85 ha).

The number and size of neighbourhood patches allocated are also sufficient. These communal open spaces include neighbourhood parks, community parks, linear parks and children playgrounds vary in size and are categorised according to their usage, spatial characteristics and locations. The Guideline for Open Space and Recreational Facilities provided by Perbadanan Putrajaya (2004) clearly provides for longer parks compared to the guidelines provided by other local authorities. The neighbourhood parks vary in size from 0.5 to 2 ha, while community parks ranged between 2 to 10 ha. Similarly, the landscape master plan for Setia Eco Park provided 23% of land area for parks and waterways (Institute of Landscape Architecture Malaysia, 2007). There is a 25-acre lake park and a 56-acre forest park while 120 acres of land is set aside to create 26km of waterways, lakes and creeks. These parks can accommodate approximately 14,000 users at any one time. The convoluted and meandering lines are often integrated in the planting design for hedges and low plantings. Greenways including wetlands, trails, promenades and jogging track consist mostly of naturalised design including linear, loop, meandering or convoluted lines. The meandering and organic shaped patches were observed especially in the design of edges of constructed wetlands. These include the Putrajaya Lake and Wetlands system, the Bukit Gita Bayu Lake and the Sentul Lake.

4.2.1.2. Edges.

The edge design of green spaces is an important ecological consideration because these edges have a different ecological structure and function than its interior habitat, and they influence the diversity and composition of wildlife found in the edge habitat. It was observed that most landscape architects in the case studies have emphasized edge design in constructed wetlands. In Putrajaya, the swamps and marshes designed along the wetlands have varying depths, curvilinear edges and native aquatic plants. The value of wetland habitat at Bukit Gita Bayu lakes was enhanced by the placementof boulders and wooden boards with hollows. It is also a sprawning place for toads and fish. As the amphibians spend part of their life cycle out of the water, the landscape architect placed natural boulders to ease their movement out of water. Long grass and dense ground covers provide cover for iguanas, monitor lizards and toads. The lake is designed with varying depths between 2m to 3m by using boulders instead of artificial materials to cater to the spawning activities of the frogs and toads.

Fig. 11. Putrajaya wetland cell
Source from Perbadanan Putrajaya, 1999.

Fig. 12. Bukit Gita Bayu lake

Fig. 13. Sentul lake

The lake in Sentul Raya was exaggerated with marshes at the edge for butterflies and birds to establish their colonies. The marshes support frogs and toads, numerous invertebrates, iguanas, monitor lizards, wading birds, ducks and geese while the matured overhanging trees provide shade and roosting areas for water birds. The gentle slopes provide a suitable ramp for amphibians and small mammals to enter and leave the water easily.

4.2.2. Corridors

4.2.2.1. Roads, promenades, walkways and trails.

The landscape architects for Putrajaya were specifically instructed to plan and design networks of interconnected green spaces (Lim et al., 1998). This culminated in a master plan that successfully integrated the core and the peripheral areas to form a continuous Green Connodium.

Fig. 14. Permeable fencing

The landscape architects designed promenades, linear parks and waterways as an integrated network of green ways. The linear parks function as transitional zones between buildings and provide routes for wildlife, especially for resident and migratory birds. In line with this, the design of linear parks incorporated meandering and curvilinear edges along the existing landform and natural slope conditions. In Sentul Raya, the landscape architect provided linkages in the form of trellis, walkways and trails. A 100m trellis planted with climbers, Grape Ivy (*Ciissus nodosa*) vines provide linkage to the condominium. Combined with a mass of groundcovers planted along the trellis, this created movement routes for invertebrates. The long grass bordering the lakes was left uncut, thus facilitating movements of amphibians and small reptiles in the wetland. Across the wetland, natural trails were left in their original form. The continuous network of linkages encourages a high diversity of wildlife to utilise the wetland, woodland, grassland and parkland habitats within the green spaces. The promenades appeared as meandering walkways with scattered trees and mass planting along the waterfronts of residential precinct. These vegetated, meandering promenades are found in Precincts 1, 2, 3, 4, 8, 10, 11, 13 and 16. Interaction is encouraged by installing 'permeable fencing' in the form of landscape treatment of hedge, shrubs and trees to allow amphibians, small mammals and reptiles for movement corridor to wetlands or forested areas. A similar approach is adopted in the neighbourhood design of Bukit Gita Bayu and Setia Eco Park.

Fig. 15. Corridor in Sentul Raya

4.2.2.2. Waterways.

As the main linkage provided in the conceptual master plan of Setia Eco Park is by waterways, the landscape architect provided a functional waterway for both humans and wildlife. The approach was to provide these corridors through parallel greenways comprising waterways such as creeks, lakes, and vegetated walkways. In total, there are 183 acres of waterways and parks, totalling 23% of the development area and linking 26 km of the Setia Eco Park enclave. These are designed to meander into every precinct of the development and were given names including Butterfly Creek, Creepers' Trail, Swan Lake and Eco Park Heritage Trail to relate to specific wildlife (Setia Eco Park, 2007).

Fig. 16. Waterway in Eco Setia Park

The waters were kept shallow at 2 m to encourage and sustain wildlife, and the velocity of water is slow and maintained by the tiered design. This creates a mini waterfall that helps to oxygenate the water. The water birds depend on the waterways for drinking and basking purposes.

4.2.2. Mosaic

Putrajaya is located within Langat Basin, which comprises three districts, Hulu Langat, Kuala Langat and Sepang. All together, there are nine forest reserves in Langat Basin, including Kuala Langat Utara (1,265 ha), Air Hitam (1,120 ha) and Hulu Langat (31, 364 ha) covering 35,825 ha (Lim et al., 1998). The forest reserves were identified to be the reservoirs for wildlife in Putrajaya. Hence, landscape architects involved in the landscape master planning optimised the adjoining forest reserves by adopting the mosaic approach and by providing numerous green corridors to the Lembah Langat Forest Reserve (ibid).

The residential precincts comprising Precincts 8, 9, 10 and 11; were identified in the Putrajaya Master Plan to be connected to the Lembah Langat Forest Reserve (Jabatan Perlindungan Hidupan Liar dan Taman Negara, and Perbadanan Putrajaya, 1998).

That is one of the reasons why the development of Putrajaya starts from the northern region and transcends to the southern region (Noriah, 2007). It was envisaged that these movement corridors be designed to facilitate birds such as the purple herons, egrets and storks; and mammals including wild boars, monkeys and wild cats, to systematically move to the contiguous Lembah Langat Forest Reserve.

4.3. Planting design and plant materials

The aspects of planting design that influences the establishment of wildlife habitats are discussed below:

4.3.1. Structural and species diversity

Planting design for Putrajaya Wetlands took into consideration the functional processes and the need to have suitable morphologies to enhance treatment processes as well as being ecologically adaptable to the water regime (Lim et al., 1998; Perbadanan Putrajaya, 1999). As such, the depths of wetland cells were designed with increasing depths from one end to the other. As each cell is unique in its shape, configuration and depth, the structural composition of plant species differed in terms of height and species. The combination of different species within a cell ensured efficient cleansing of the water by the different cleansing ability of each species of plant.

Fig. 17. Plant diversity attracts migratory birds
Source from Perbadanan Putrajaya, 1999.

The water in the Wetland Zone is sufficiently shallow for emergent plants, providing habitats for fish and refuge when the cell dries up during the drought season. As Zone of Intermittent is only seasonally flooded, the landscape architects recreated a swamp forest as habitat for indigenous wildlife. The swamp forest, extending from 0.3 m to 1.5 m above water level, consists of diversified fruit tree species such as Nangka (*Artocarpus heterophyllus*), Langsat (*Lansium domesticum*) and Manggis (*Garcinia mangostana*). At Precinct 8, the landscape architect conserved the tall, matured trees close to the promenade. The planting structure and selection of plant species were then enhanced by introducing epiphytic plants and climbers on the tree trunks.

Fig. 18. Structural and species diversity for woodlands in Sentul

In Sentul Raya, Various forest tree species including Gonchak (*Antidesma coriaceum*), the Butterfruit Tree (*Diospyros discolor*) and Penarahan (*Horsfiieldia superba*), were added. Smaller forest species including Rambai (*Baccaurea scortechinii*), Potato Tree (*Solanum wrightii*) and Kemunting (*Rhodomyrtus tomentosa*) helped to enhance the under storey layer. Various gliding animals including lizards, tree shrews and tree geckos then takes advantage of the forest structure by gliding between the tree trunks a few meters above ground level. Numerous forms of invertebrates, such as termites and centipedes also help to maintain a constant recycling of nutrients in the forest. The complexity of the grassland habitat was increased by allowing selected grassed area to grow long. Grass is mowed bi-annually, thus, providing wildlife such as iguanas to utilise as cover. Overgrown grass along the edges of lake provide shelter for many other wildlife.

In Setia Eco Park, it was decided in the early stages of planning that the development should strive towards living in a ‘niche’, rather than just a home. Thus, an eco-friendly planting approach was proposed to create habitats for birds, butterflies and fish. The landscape architects collaborated with the Penang Butterfly Farm, the KL Bird Park and the Fisheries Department on creating a conducive breeding environment for butterflies, birds and fish. Prior to designing, field research was conducted by these organisations as part of site planning to identify the colonies of butterflies and bird species residing in the area (Setia Insight, 2008).

Structural and species diversity were then adopted in various planting design of waterways. Varied plant species including trees, palms, shrubs and groundcovers of different heights and species were planted, thus providing structural and species diversity. However, as the client wished to attract only selective wildlife perceived as ‘friendly wildlife’, the landscape architect selected plant materials that have food value for them. Terraced planting composition for the waterways in Bougainvillea Creek provided a tiered effect as food and nectar plants are planted densely along the trails.

Fig. 19. Structural and species diversity for wetland habitat in Setia Eco Park

In addition, a lush and dense environment for butterflies and birds to establish their colonies at The Rainbow Creek was created by planting Fishtail Palm *(Caryota mitis)*, Bottle Brush (*Callispermum* spp.), and ‘Dutchman’s Pipe (*Aristolochia* spp.) vines together with other dense shrubs and groundcovers. This multi-layered planting concept was repeated in many areas of the creek thus creating an interesting association of plants. Being the most striking insects in the Asian tropics, the female Common Birdwing (*Troides helena*) butterflies seek out and lay their eggs on the vines of ‘Dutchman’s Pipe (*Aristolochia* spp.), the only plants on which caterpillars feed on.

4.3.2. Plant materials as source of food and cover

The Putrajaya Wetlands and Lakes intensively to fulfill their functions as filtration system and wildlife, the plant materials selected for each wetland zone were based on their food and cover value. The emergent wetland vegetation selected comprised of species adapted to growing in water or in a water-saturated soil, in anaerobic root conditions. Many plant planted in the swamp areas of Putrajaya Wetland are functional as keystone species. Bees and flies pollinate the flowers of Common Kelat (*Syzygium longiflorum*), whilst the fruits are eaten by birds, and at the same time it is pollinated by bees and moths. The sticky seeds of Beringin (*ficus benjamina*) are resurgitated by the Scarlet-backed Flowerpeckers onto other areas, thus, other resulting in cross-pollination that produce better quality off springs.

Meanwhile, the Zone of Intermittent Inundation is planted with vegetation tolerant to intermittent inundation and drought. Besides improving the water quality for the wetland cells, the swamp forest also provides food and shelter to aquatic, terrestrial and arboreal fauna. The wetlands, with their large expanse of aquatic plants, trees and bushes lining the littoral zone, form an important green corridor linking Taman Botani, Taman Jati, Taman Putra Perdana and other green spaces to the adjacent forest reserves. Planting a diversity of plant species is also an effective and safe measure to control pests (Jabatan Perlindungan Hidupan Liar dan Taman Negara, and Perbadanan Putrajaya, 1998). Fruit trees including Nangka (*Artocarpus heterophyllus*), Kemunting (*Rhodomyrtus tomentosa*) and Manggis (*Garcinia mangostana*) are planted in the swamp forest. Besides providing nuts, fruits, seeds, and nectar to arboreal birds, flying foxes, bats, squirrels, beetles, butterflies and dragonflies, these fruit trees also feed on bees and caterpillars, which in turn, became prey to birds. Thus, the food web of the wetland ecosystem is complete.

An inventory carried out by Perbadanan Putrajaya in 1999 recorded 81 species of birds, where seven are migratory species. The survey also recorded 21 species of butterflies, five species of moths and three species of dragonflies. Indigenous fishes including those feeding on mosquito larvae, such as Pelaga (*Beta pugnax*) and Sepat Siam (*Trochogaster pectoralis*) were introduced into the wetland cells. Meanwhile, in the deeper Central Wetlands and Putrajaya Lake, fresh water fish species including Patin (*Pangasius pangasius*), Baung (*Mystus* spp.), Seberau (*Hampala macrolepidota*) and Temoleh (*Probarbus julleieni*) are introduced. These species of introduced fishes represent the full spectrum in the food chain, from plankton feeders to herbivores, carnivores, and omnivores. Primary vegetation of Banat (*Typha angustifolia*), Bakong (*Hanguana malayana*) and Rumput Bulat (*Scirpus grossus*) provide fruits and seeds to most water birds besides giving shelter for water and arboreal birds. Besides providing nuts, fruits, seeds, and nectar to arboreal birds, flying foxes, bats, squirrels, beetles, butterflies and dragonflies, these fruit trees also feed on bees and caterpillars, which in turn, became prey to birds. Thus, the food web of the wetland ecosystem is complete.

In Setia Eco Park, the landscape architect designed Swan Lake to specifically attract bird population to the area. These include resident bird species such as the Ruby-cheeked Sunbirds, Chirping Sparrows, White-breasted Kingfishers, Common Quails, Peaceful Doves, White-breasted Waterhens and Magpie Robins. The developer consulted the Kuala Lumpur Bird Park on methods to attract and sustain the colony of these birds in Eco Park. Subsequently, suitable species of trees providing fruits, seeds and nectar for birds were identified and planted at the Swan Lake.

Similarly, the Penang Butterfly Farm conducted a field inventory to identify species of resident butterflies at an adjacent palm oil estate. Resident butterflies such as Chocolate Pansy, Plain Tiger, Dark Blue Tiger, Lemon Emigrant, Blue Glassy Tiger and Common Sergeant were then brought in to colonise in the park. In addition, several new species were introduced to enrich the variety of butterflies in the park. Prior to bringing in the butterflies, specific food plants and nectar plants were planted at Butterfly Creek, Butterfly Trail and the Swan Lake. These plant species include Simpoh Air (*Dillenia sucrotasa*) and *Ixora* spp.(*Ixora sunkist*) and other flowering plants such as *Cassia surrettensus, Aristolochia tagala, Urena procumbers, Cassia alata, Murraya koenigii, Hemigraphis colorata* and *Micromelum minutem.*

4.3.3. Native and Naturalistic Plants

Both landscape architects for Bukit Gita Bayu and Sentul Raya incorporated numerous native or naturalistic trees as possible in their planting design while conserving the existing trees. In the case of Sentul Raya, native trees were added to enhance the canopy layer of the existing forest. These forest and timber tree species comprised Gonchak (*Antidesma coriaceum*), Kayu Arang (*Diospyros discolor*), and Penarahan (*Horsfiieldia superba/ Knema hookeriana*) and they enhanced the canopy layer. Smaller forest trees such as Rambai (*Baccaurea scortechinii*), Potato Tree (*Solanum wrightii*) and Kemunting (*Rhodomyrtus tomentosa*) were added to enrich the under storey layer. Collectively, these forest tree species succeeded in attracting thousands of birds, including interior species such as hornbills, and pigeons. By retaining these native trees, wildlife is thus familiar with the microclimate and habitat conditions of the original site. At the same time, habitat enhancement was carried out by adding new native trees as food plants. More native trees including the Rain Tree (*Enterobium saman*), Yellow Flame (*Pelthoporum pterocarpum*), Sentul (*Sandoricum koetjape*), Bungor (*Lagerstroemia floribunda*), Tembusu (*Fragrea fragrans*), Cenderai (*Microcos tomentosa*), Jejawi (*Ficus microcarpa*), Pokok Mertajam (*Lepisanthes rubiginosa*) and Kemunting (*Rhodomyrtus tomentosa*) were added to increase the biodiversity of the site.

4.4. Construction methods and materials

The overriding concern of this study is to investigate how the materials and methods used in the case studies directly affect the health of wildlife species or how they indirectly degrade the quality of habitats which in turn, influence the abundance and quality of food and cover. This section will focus on the construction methods and the materials used primarily in green space design. These include but are not limited to pavement and trail materials, landscape furniture (pergolas, trellis, arbors, benches and the likes), and the structural components of constructed wetlands.

4.4.1. Methods and processes

The biggest challenge in the Putrajaya Wetlands project stemmed from the sheer size of the project and the tight construction schedule. Based on the Environmental Management Plan formulated for the control of erosion and sedimentation, the exposed time of cleared land was kept to a minimum. Therefore, the exposed surface is protected during rainfalls and thus also retards surface flow velocity to a non-eroding velocity. In addition, the construction of weirs and the shaping of cells were undertaken in stages so that land disturbances at any one time could be confined to a manageable size. Erosion control and slope stabilising measures were implemented progressively as each area was opened up.

These measures included construction of silt fences and silt traps, catch drains, sedimentation ponds, bunds and geotextile blanket covers. Where possible, earthworks on steep slopes were undertaken during the dry season. All these measures effectively minimised sedimentation in ponds and cells. Despite attacks from stem-borers, leaf-eaters, armyworms and aphids, only narrow -spectrum pesticides or bio-pesticides such as Bt. (*Bacillus thuringiensis*) were applied on specific targets. For the same reason, grass cutting was carried out at long intervals. When carried out, the grass cutting activity was kept away from the waterways so as to prevent oil spillage from polluting the water. Besides this, grass and weeds were pulled out manually in areas close to water edges.

Fig. 24. Rafts used to transfer plants
Source from Perbadanan Putrajaya, 1999.

Fig. 24. Grass at wetland parks
Source from Perbadanan Putrajaya, 1999.

4.4.2. Green materials

The most common natural materials used such as timber, stones and concrete, are easily sourced in Malaysia. In Bukit Gita Bayu, most hardwood timber from the Dipterocarpaceae family such as Red Balau (*Shorea collinaa*), Merawan Siput Jantan (*Hopea* spp.) and Cengal (*Neobalanocarpus* spp.) were locally sourced from Kelantan and Terengganu. As the landscape architect preferred the timber used in exposed areas to weather naturally, these timbers were deliberately unstained thus requiring no regular re-staining. They were extensively used for the floorings and railing of deck area, boardwalk, bridge, trellis, pavilion and banisters for the clubhouse and the sales office. As weathered timber required less maintenance than stained timber, this also helped to reduce maintenance cost. The unstained timbers in Bukit Gita Bayu were not treated with anti-fungal solution to control the leaching action of rainwater would eventually carry the toxic chemical into the lakes, thus polluting the aquatic ecosystem, subsequently causing aquatic life to die (Foo, 2007). It was noted that some timber areas looked unkempt and dilapidated due to the weathering condition of the untreated timber. Bukit Gita Bayu used Nipah (*Sabal palmetto*) for the ceilings of gazebos.

This material is produced locally so that the Maintenance Department would not encounter any problems when replacing the Nipah ceilings. Both developments at Bukit Gita Bayu and Sentul Raya used coco peat and shredded bark as organic mulching materials to help control moisture loss through evaporation from soil surface. This also helped to increase the organic content of the soil. The landscape architect of Bukit Gita Bayu re-used oil palm shells and cocoa pods found in the development area. Local materials including chippings, small boulders recovered from earthwork in other sites, and wire mash were re-used in Sentul Raya. Besides these local materials, red bricks and grass were laid in intermittent horizontal strips and utilised for the parking area. Original railway slippers were re-used from abandoned railway tracks. The combination of bricks, chippings and railway slippers effectively enhanced the aesthetic of design, besides keeping maintenance cost low. Fertiliser is used on the grass and new plantings only when necessary. During applications, the dosage is kept to a minimum, and in such circumstances, only organic manure was used. The control on the use of fertilizer helped to protect the lakes from eutrophication. This contributed to the sustenance of a rich diversity of wildlife in the lake. Large numbers of water birds, frogs, toads, tortoises and iguanas are found at the edge of the lakes in the late evening. On a hot day, dragonflies and butterflies can be seen seeking cover by the edge of the lake.

Fig. 25. Natural materials used in Bukit Gita Bayu

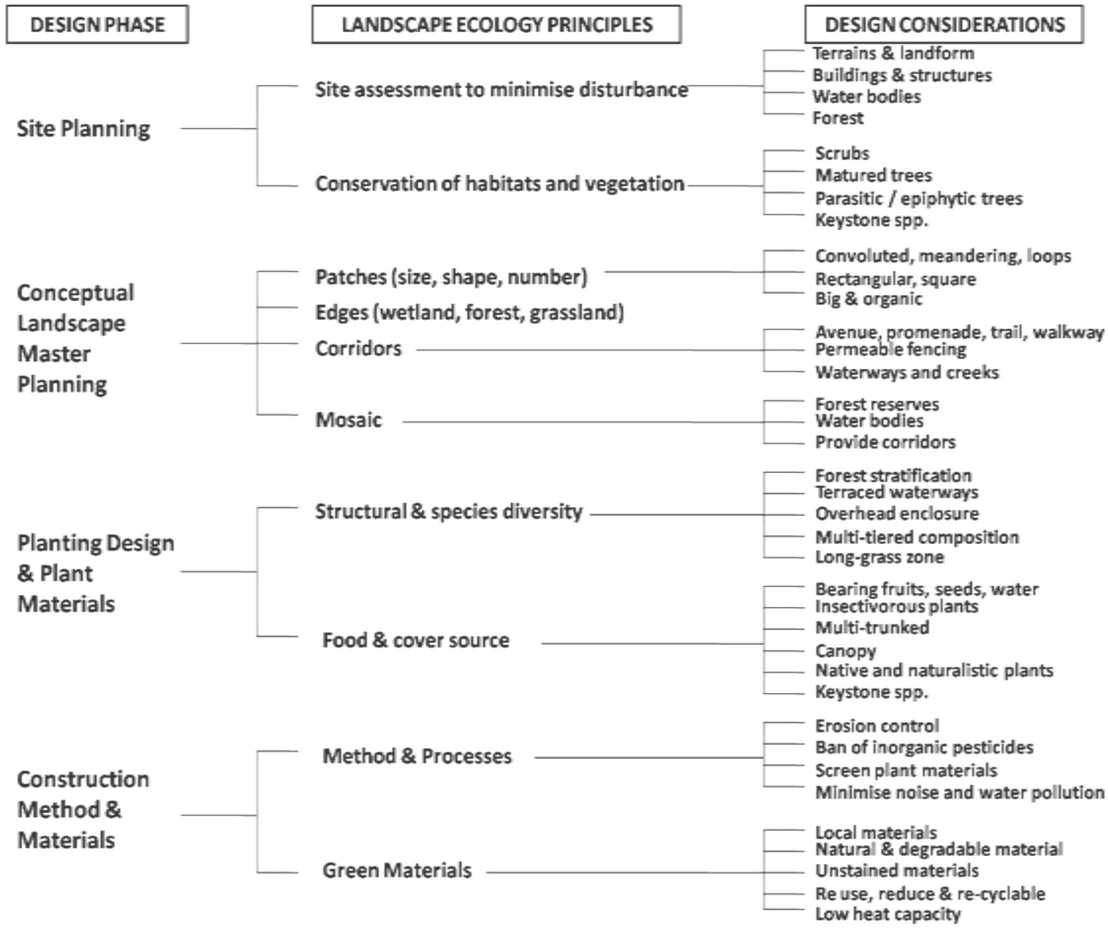

Fig. 25. Relationship between design phases, principles & strategies

The development of Setia Eco Park was in compliance to statutory requirements provided in the guidelines, where more than 70% of the materials used were both local and natural (Setia Eco Park, 2007). Environmentally-friendly policies such as re-cycling, re-using and minimising waste are also implemented.

Fig. 26. Green materials used in Sentul Raya

Conclusions

This study is to summarise the principle discussion and interpretations of the findings of the research. The research findings are presented to underline the aim and objectives of the research. Several practical recommendations related to the applicability of landscape ecology approaches and principles in designing neighbourhood green spaces that could culminate in wildlife habitats, are presented for stakeholders in the Malaysian landscape industry.

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