INCLUDING BIODIVERSITY AS A COMPONENT OF SUSTAINABILITY AS AUSTRALIAN CITIES GROW: WHY AND HOW?

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INTRODUCTION

This paper explores the incorporation of biodiversity into Australian cities through the planning, design, construction and maintenance of urban developments. Biodiversity is a term used to describe all living things and includes plants, animals, fungi, and micro-organisms. It describes the variation *within* and *between* species and the ecosystems they inhabit, including urban ecosystems that can be rich in biodiversity.

Urban biodiversity exists in parks, street plantings, private gardens, vacant lots and along waterways. With development, urban environments can change quickly and dramatically because they are designed, constructed, managed and controlled by humans. It is important to understand the impacts and interactions of humans, the built form, and residual and emergent biodiversity.

While biodiversity must be considered at all stages of development, making it a priority during the planning and design phases will improve outcomes for developers, future residents, and the local environment. Opportunities may exist to improve the quality and function of the urban ecosystem at degraded sites, whereas at sites with existing habitat environmental degradation can be mitigated. Biodiversity-positive outcomes can be enhanced by a landscape-scale view, addressing the cumulative impacts of new and pre-existing developments, and maximising habitat corridors throughout the urban matrix.

There are many benefits derived from biodiversity in urban developments, including the conservation and intrinsic value of habitat and wildlife and the provision of ecosystem services. Further, developers and residents can potentially save money, add value and increase amenity and marketability.

WHAT IS BIODIVERSITY AND WHY IS IT IMPORTANT?

Biodiversity is a term used to describe all living things and the variation within and between them. It includes plants, animals, fungi, and micro-organisms, and can be considered at various levels of complexity:

- GENETIC DIVERSITY describes the variation *within* a particular species;
- SPECIES DIVERSITY describes the variation *between* different species; and
- ECOSYSTEM DIVERSITY describes the variation *within* and *between* different ecosystems of the world, comprising habitats, the species that they contain and the processes and interactions occurring between the biological and physical components.

Biodiversity provides a variety of services to humanity, termed ecosystem services. These include the moderation of climate, the purification of air and water, the fertility of soils and the decomposition of wastes. Further, nature and natural processes provide resources including building materials, pharmaceuticals, fuels, and locations where we recreate. These products, places, and processes underpin human health and economic prosperity. Society also places a value on maintaining biodiversity for future generations for its scientific, educational and aesthetic values and also for its intrinsic value[1].

Recently, the focus of biodiversity research has been on the functioning of ecosystems and the role of species diversity. The general conclusion is that a variety of species covering a variety of structural and functional roles engenders some resilience to natural systems. That is, diversity provides an 'insurance policy' so that systems can recover from disturbances such as drought, fire and flood. Such thinking is only starting to be applied to urban ecosystems.

The incorporation of biodiversity into urban developments enables us to take advantage of the services it provides while also saving money, adding value, improving amenity and advancing the conservation of nature. Residents benefit from direct interaction with nature and the continuity of natural processes. To realise these benefits during development we must retain existing biota and create an environment where biodiversity can flourish.

THE CHANGING BIODIVERSITY OF AUSTRALIA

Over many millions of years, Australia's environment has changed as the continent has moved northward. The drying trend in Australia's climate has resulted, for example, in the contraction of once widespread rainforests to moist coastal refugia. Australia's isolation and long periods of geological stability has seen the evolution of a unique biota and around 80% of the species that occur in Australia are endemic[2].

The arrival of people to the continent over 40 000 years ago induced further environmental change. Aboriginal land management has traditionally made use of fire to maintain a mosaic diversity of habitat patches. This land-use has undoubtedly changed the landscape, although the extent of their impact is the source of considerable debate.

Since European colonisation, changes have been rapid, dramatic and widespread. For example, since 1600, one-third of global mammal extinctions have been in Australia, with 22 species of mammals recorded as extinct[3]. Further, many new species have been introduced and conditions have been improved for some native species allowing them to become overabundant.

It is important to consider how biodiversity responds to significant change. Firstly, through the process of natural selection, the mix of species (the species assemblage) will change to match new conditions. Secondly, individuals of some species may move to new areas with more favorable conditions, that is, suitable habitat. Some plants, animals and micro-organisms are capable of moving great distances over time. However, most species have a limited ability to adapt to drastic environmental change because they are habitat specialists or have poor means of dispersal. The expansion of cities, roads, and cultivated areas can prevent plants and animals from locating or moving to suitable new environments.

Rapid industrialisation, urbanisation, population growth and resource consumption in Australia have modified the environment and these factors will continue to drive change. Importantly, changes that reduce the ability of ecosystems to function will increase the difficulty and cost of obtaining resources and removing wastes, and reduce the aesthetic and recreational benefits we derive from nature. We now have the knowledge and capability to influence future environmental change in a positive way. In order to reduce the negative impacts of climate change, water shortages and the loss of biodiversity, cities must be developed to incorporate, and therefore take advantage of, natural processes[4].

BIODIVERSITY IN URBAN DEVELOPMENTS

Urban areas can be rich in biodiversity[5]. Strategies to create biodiversity-positive outcomes in urban developments must consider that urban areas in Australia exhibit extreme environmental change. For example, cities have become hotter, have substantially altered and novel water flows, exhibit idiosyncratic soil compaction and composition, and remaining natural habitat has been fragmented[6-9]. These changes have consequences in developed areas, both for the residents, and for the biodiversity potential.

The displacement of the natural environment within cities has made many residents physically, intellectually, and emotionally distanced from all but a highly modified form of nature. Natural settings in urban areas can help promote social interaction, physical activity and mental health. Further, the environmental attitudes of urban residents are largely formed by interactions with their local environment[10, 11]. Therefore, backyards and suburban parks provide vital access to nature.

In urban developments, plants and the vegetation cover that they comprise are crucial landscape features. Benefits of vegetation include its roles in the cycles of water, nutrients and energy, as well as the provision of shade, shelter for wildlife, aesthetic appeal and functional roles such as sports fields for human activities. Plant assemblages include both introduced species (alien and exotic) as well as relict indigenous species.

Remnant vegetation provides important “stock” which is adapted to local climatic and soil conditions and provides a continuity of habitat through time for local animal species. The maturity of existing vegetation is impossible to replace and the diversity of natural plant assemblages is difficult to emulate[6]. Further, where local species are threatened, urban areas can include them and make a contribution to their conservation. Preservation of existing natural and remnant vegetation is the most efficient way to incorporate biodiversity in urban developments.

In addition to remnant vegetation, street trees, grassy parks, vacant lots, flowerbeds and front lawns contribute to urban biodiversity. These locations can support indigenous species that are adapted to local climatic and soil conditions and provide food and habitat for native wildlife with minimal maintenance requirements. Native Australian species from other localities and exotic species can also make positive contributions to local biodiversity. In some cases these species are better adapted to the conditions of the highly modified environment and may require less water or maintenance, establish more quickly to reduce the erosion of soils, be less likely to become invasive, or be required to fulfill a specific function – like the hardy grass on a sports field.

Importantly, the flora of a city, in conjunction with the built structures, provides habitat for fauna. An increase in plant cover and structure in an urban area typically increases the abundance of animal species[6]. Three terms have been used to describe the strategies of wildlife in response to urban development: avoiders, adapters, and exploiters[6, 12].

Urban avoiders cannot survive in the built environment as they cannot tolerate fragmented habitat, reduced food or shelter resources, environmental pollution, or introduced competition or predation. Large, mammalian predators are usually identified as urban avoiders, in some cases more because people *avoid* allowing them in, rather than the animal *avoiding* urban areas. Thus, the dingo has potential for inclusion as an avoider, although it may benefit from urban waste as a food source. The eastern grey kangaroo can also be considered an urban avoider as, although it can proliferate at the interface of urban and rural lands and visit urban areas to browse, it cannot survive in the fragmented habitat of exclusively urban areas.

Urban adapters benefit from developed environments because there are increased food sources or shelter sites. Australian examples (both native and introduced) are brushtail possums, foxes, blackbirds, magpies and bluetongue lizards. All of these species do well in developed areas, although they persist in the less anthropogenically-disturbed areas outside of cities and towns.

Like the adapters, urban exploiters benefit from food sources and shelter sites that are afforded by urban development, but these species are now so reliant on human activities that they are primarily, if not only, found in dense settlements like cities. Australian examples are black rats, redback spiders and spotted turtle-doves.

INCLUDING BIODIVERSITY IN URBAN DEVELOPMENTS

Increased community awareness of environmental issues is creating a demand for change in urban development[13]: people want to live in healthy environments. Opportunities for including biodiversity will differ between sites with different development histories. In some cases, spectacularly diverse ecological communities can be “built” from remnant biodiversity in conjunction with careful, direct design and spontaneous introductions. To this end, development needs to include space for

biodiversity, maximise habitat corridors throughout the urban matrix and include a diverse range of flora with a complex structure. In addition, it is important to manage and limit pest animal species or weedy plant species while encouraging native or beneficial species, and planning must acknowledge the potential effects of climate change in the local context.

The development history of a site dictates whether new works should seek to preserve or “rebuild” local biodiversity. Brownfield sites may present opportunities to ameliorate environmental contamination and re-establish vegetation and wildlife communities. It is important to consider, however, that long abandoned sites can have ecological value in the plant and animal species that have emerged through neglect[14]. Greenfield sites may also have degraded environments, particularly through their use for agriculture. Where valuable species or communities exist, the mitigation of significant impacts on the quality and function of the local environment is of paramount importance.

The biodiversity potential of a new development is influenced by the land-use in surrounding areas: urban, rural, or conservation lands. A landscape-scale view, including the cumulative impacts of new and pre-existing developments is essential in understanding how biodiversity can be maintained or improved. For example, habitat corridors in new developments are of limited value if they do not connect throughout the urban matrix and beyond it.

The built environment provides many obstacles for the survival of plants and animals. Some species, including most birds, are able to disperse easily through urban areas[5] while for others, boundaries abound. For example, for slow-moving bluetongue lizards, roads are dangerous boundaries. Therefore, linkages, or corridors for biodiversity, are important within urban developments.

Habitat corridors allow biota to find food and shelter, and to breed and disperse, both within a development and in connection with the surrounding landscape. They are a key to maintaining urban biodiversity at the genetic and species level by preventing species from becoming isolated from nearby populations. Further, as the environment changes, locations that are favourable for plant and animal species also change and corridors allow them to disperse to suitable sites.

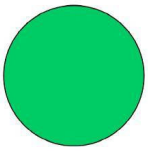
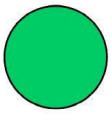
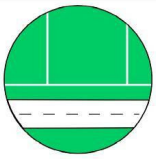
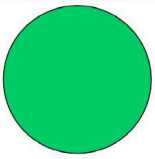
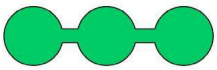
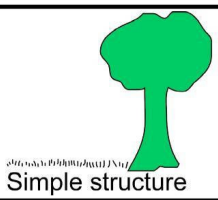
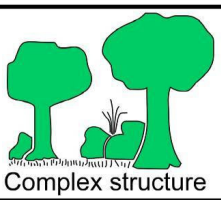
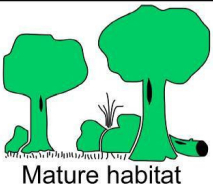
While corridors are often maintained along waterways and roadsides, they can suffer from being too narrow or too few and it is important to consider how they can be connected within the urban matrix. Parks, backyards, and remnant bushland all provide potential connectivity, but obstructions to the dispersal of biota must be limited: fences can be minimised or removed, roads and footpaths can be narrowed and traffic can be “calmed” where wildlife is known to cross roads, and underpasses[7] can be maintained where fences and roads prevent biota from dispersing through important corridors.

The structural diversity of urban areas is important to biodiversity. A variety of trees, shrubs, and groundcovers provide habitat and food for a variety of wildlife. Conversely, homogeneous plantings are susceptible to pests and diseases, and provide habitat for a limited range of species. Built structures, including rockeries, log piles, stormwater pipes, and vacant areas under houses, also provide habitat and protection for wildlife, and wildlife can be attracted to urban areas by feeding or the provision of nest boxes.

Parks that can support complex vegetation assemblages are a vital component of urban biodiversity. As a general rule, large parks are better than small ones because they provide more habitat and inner areas are buffered from anthropogenic disturbance[7]. Large parks also afford space for populations of large trees, where many individuals can be required to maintain a healthy population. In urban settings, however, there is often not enough space to allow for large parks.

On their own, small “pocket parks” generally lack biodiversity value, because small patches of habitat are more highly disturbed, can be prone to weed invasion, and difficult for wildlife to access. However, small patches can be of use to some species. For example, in northern Canberra the threatened Regent honeyeater feeds and breeds within isolated and scattered clumps of yellow box with an absolutely disturbed understorey. Hence, to improve urban biodiversity, large parks should be a priority, but smaller parks and other vegetated areas are also valuable. Further, the interconnection of many small biodiverse areas can emulate many of the benefits of larger, more intact habitats.

Environmental conditions have changed dramatically since pre-European times. Moreover, recent accelerated climate change makes it important to consider what environmental conditions will prevail in the future. For example, water regimes in cities have been drastically modified, largely regulated, and future supply is uncertain. Australia wide, recent droughts and water restrictions have affected gardening and have led to a focus on indigenous, drought tolerant plant species. However, some species do better than others in the modified environments of cities[5] and native plants are not always the best option to provide biodiversity in urban areas. Conversely, it must also be stressed that introducing non-native species must be undertaken with caution. Exotic species must be selected carefully to ensure they are non-invasive and suit current environmental conditions and expected environmental change.

Biodiversity value		Comments
Inferior	Superior	
 Small patch of habitat	 Large patch of habitat	More species can persist in a large patch of habitat with more food and shelter resources and less disturbance.The larger a patch of habitat, the more diverse and resilient it is.
 Increased edges	 Decreased edges	Patches of habitat with a high proportion of edges offer less shelter for the species that inhabit them and allow greater disturbance through trampling and weed invasion.
 Fragmented habitat	 Intact habitat	Intact habitats function better than fragmented habitats. Boundaries prevent plants and animals from dispersing through urban environments to find food and shelter resources.
 Disconnected patches	 Connected patches	The interconnection of many small biodiverse areas can emulate the benefits of larger, more intact habitats. Corridors allow biota to disperse through urban environments.
 Simple structure	 Complex structure	A complex assemblage of vegetation is better for wildlife, adapts better to change, and is more highly appreciated by people than a simple assemblage.
 Immature habitat	 Mature habitat	A mature assemblage of vegetation provides habitat for wildlife in logs and tree hollows. It takes many years of succession to establish a complex and healthy ecosystem.

Principles of habitat size, shape, and structure to improve biodiversity in urban areas. Based on the concepts of Diamond 1975 and Soulé 1991

BENEFITS

The benefits of biodiversity in urban developments include increases to: land value, marketability, amenity, conservation of nature, and human wellbeing. Most people prefer to live and socialise in settings that include natural elements: trees, lawns, water and wildlife. Biodiversity adds to a sense of place and builds place identity.

People are willing to pay for the amenity of biodiverse developments, but it is difficult to calculate the exact economic value of natural assets. However, it has been shown that people pay more for houses with trees[15], close to parks and with views of parks [16], or water. There are also benefits in marketability. For example, houses with biodiverse surroundings sell faster than those without[17]. Further, planning with biodiversity in mind can save time and money by pre-empting obstacles in the development approval process, such as might occur with the clearance of habitat, removal of significant trees, or the modification of watercourses.

Biodiverse developments also benefit society through better environmental functionality. Vegetation provides abatement of noise and smell[18], diffusion of light, protection from wind, stabilisation of soil[15], sequestration of carbon[8], and cleansing of pollutants from the air. Vegetation also slows water flows and increases infiltration and evapotranspiration, assisting stormwater management by reducing peak-flows[4, 8]. Trees shade houses, thereby reducing cooling costs by blocking direct sun and through the cooling effect of evapotranspiration[8]. On a larger scale, increased vegetation reduces the temperature of cities by lessening the heat island effect. Vegetation also provides food and shelter for wildlife, and animals provide environmental services including the disposal and decomposition of wastes, nutrient cycling in soils, and seed dispersal and the pollination of plants.

Biodiversity adds to a sense of place and builds place identity. People identify with their local flora and fauna[4] and rare species are of particular concern[13]. To this end, developed areas can play a role in conserving indigenous biota[9]. Many endangered species already inhabit urban areas[6]. For example, marbled velvet geckos are rare in South Australia but are abundant in urban areas. Endangered species from around the globe can be protected, as long as they are not dangerous or invasive.

Urban communities benefit from interaction in, and with, the natural environment. Nature can be beautiful, symbolic, calming, challenging, and beneficial for human health[19]. Intellectual stimulation and mental health benefits are derived from recreation and mere association, by feeling space, exploring natural complexity, and pondering existence. People enjoy socialising in urban environments that include biodiversity, and the more biodiverse an area is, the more people benefit from visiting it. In these ways, biodiversity can add value to urban developments in economic, environmental, and social terms.

COSTS

A biodiversity-positive development can save money and time. Additional and non-traditional costs may be incurred during development to ensure biodiversity-positive outcomes. Extra planning and design work may be required, construction and lot creation may require non-traditional methods, and post-development maintenance may be increased. However, extra costs can be recouped through increased property values and marketability[17].

During the planning and design phases, costs incurred to assist in improving environmental outcomes may include biodiversity surveys and environmental management consultancies. However, careful planning and design will reduce costs during lot creation, with less land clearance, excavation, and disturbance of watercourses. The diversion of natural processes, like the modification of watercourses, is often more costly than maintaining them. Further, the resources used in planning and design may improve the efficiency of the development approval process, or avoid the penalties of non-compliance to planning codes and environmental protection legislation. Savings are made by including biodiversity in urban developments because houses with biodiverse surroundings sell faster, and for higher prices, than those without[17].

Additional costs may also be incurred in maintaining vegetation prior to sale, including watering, pruning, mowing, and fertilising. However, sensible planning, taking advantage of remnant vegetation, and planting indigenous and drought tolerant species, will reduce ongoing maintenance. Arrangements with local government should negate ongoing costs with street plantings and parks.

RISKS

The increase of the risks associated with planning for biodiversity-positive outcomes, above the risks involved in any urban development, are minimal. Risks might include:

- Fire risk if houses are close to fire interface areas such as bushland, pine forests or agricultural grassland;
- Flooding;
- Soil movement from tree roots if houses or trees are positioned poorly;
- High maintenance vegetation;
- Poisonous plants and dangerous animals, including snakes;
- The introduction of pest plants and animals including invasive plants and overabundant species;
- Personal injury from falling branches and fruit; and
- Personal injury on footpaths

Good planning in the design phases is paramount to mitigate these risks. For example, firebreaks and buffer zones can reduce fire and flood risks. In the case of flooding, a low-impact housing development in California, Village Homes, was the only area in its County not to flood when storms hit in 1975[4].

Education is an important tool in mitigating risks associated with urban biodiversity. Community education can reduce risks presented by wildfire, where residents learn how to reduce the potential for fires, the severity of their impacts, and how to respond in fire situations. Education can also benefit residents who live in close association with dangerous wildlife, such as snakes, by helping residents to identify animals that *are* dangerous, as well as animals that are not.

There are risks in *not* incorporating biodiversity in urban developments, both local and global. Cities are growing in size and population, and as they grow their influence over natural systems increases. Climate change and water shortages are two concerns that can be addressed in cities, partly through the inclusion of biodiversity. In cities, biodiversity can improve water and waste management, soil health and productivity, and reduce winds, soil erosion, ambient temperatures, noise, smell, and light pollution. Further, including biodiversity in cities can also reduce the chance of species extinctions, both directly through conservation, and indirectly through education.

As more people live in cities, the influence of city dwellers over the conservation of the global environment increases. To understand nature and natural processes, and to promote the conservation of them, people need to experience the natural environment. Moreover, having natural settings available in urban areas improves mental health and social interaction. Therefore, urban areas require biodiversity to increase quality of life and allow people to be in contact with nature, albeit in a highly modified form.

BARRIERS

All levels of Australian government are committed to policies of “sustainable development” and seek concurrent economic, social, and environmental outcomes. Yet it is difficult to achieve consistency between policy and practice unless individuals and corporations seeking financial return are largely responsible for a common good[13], such as the improvement of biodiversity in urban developments. However, it is now well recognised that the incorporation of biodiversity can be cost effective, improving land value and amenity, so developers can profit from taking a lead with the objectives of sustainability.

With the current drive towards sustainability, barriers to projects that incorporate biodiversity-positive outcomes should be relatively few. However, non-traditional planning and design may prove to be barriers if planning codes lag behind developer-driven initiatives. For example, narrowing roads and footpaths may increase land available for vegetation and reduce development costs, but may not be permissible under planning regulations.

BENCHMARKS

In Australia, benchmarks for the inclusion of biodiversity outcomes in urban developments are limited. Benchmarks exist in legislation and voluntary codes. Where legislation exists, it varies between jurisdictions. Voluntary codes have been developed in Victoria and Queensland. It can be beneficial to adopt one of the voluntary benchmarks as they establish procedures for including biodiversity outcomes during development. Further, attainment of the benchmark can be beneficial in the marketing of the project.

Environmental impact assessment (EIA) is generally the most detailed form of environmental assessment, and considers impacts on biodiversity where relevant. Typically, private projects are not required to undergo EIA unless they are deemed of 'major significance' or trigger the Commonwealth Environment Protection and Biodiversity Conservation Act, 1999 (the EPBC Act)[20]. For example, at a federal level, a development that has, or may have, a significant impact on a World Heritage Area, a wetland of international significance (a Ramsar wetland), or the habitat of a threatened species or ecological community may by law require thorough assessment and appropriate planning. The EPBC Act allows for developments to be assessed with regard for their cumulative impacts at a landscape level, and, where appropriate, in accordance with local and regional planning schemes.

By far the majority of development proposals are environmentally assessed through the land use planning process at a local government level as opposed to the application of formal EIA. State legislation may also apply where species are locally threatened, land is being cleared, or a development may damage natural or cultural resources. For example, in New South Wales, fauna impact statements exist [21](but are only required if a species is directly threatened). In South Australia and other States vegetation clearance controls exist. At all levels of government, these measures are designed to discourage environmental damage rather than promote biodiversity-positive outcomes.

Open space schemes also exist in various forms around the country. For example, in South Australia, land divisions of over 20 allotments, where at least one allotment is less than one hectare, require input into the Open Space Contribution Scheme. A land area of 12.5% is defined, but may be offset by financial contributions. Smaller land divisions may also require a financial contribution. This method is useful in improving developments, as biodiversity and natural processes do benefit from an increased allocation of space[7, 8]. There are, however, no prescriptions as to where, and under what criteria, this open space is allocated for any development. Often the open space is simply the unusable or poorest quality land in the development. Hence, while these measures are designed to maintain open space, they often do not, in themselves, promote biodiversity-positive outcomes.

Voluntary codes are being developed that address the sustainability of urban developments. For example, VicUrban, Victoria's urban development agency, has released the VicUrban Sustainability Charter[22]. It includes benchmarks for native plantings (50% throughout a development, and 100% along waterways) and light spill (minimised light spill into the night sky and onto adjacent developments), and discusses the protection of biodiversity and the use of corridors on a site-specific basis.

EnviroDevelopment[23] is a voluntary code developed by the Urban Development Institute of Australia (Queensland). It allows developers to gain accreditation by following a set of sustainability criteria. In terms of biodiversity, the criterion include surveying for biodiversity, minimising the alteration of natural topography, maintaining existing biodiversity, utilising native and local plant species, maximising greenspace, and maintaining wildlife corridors.

PLANNING AND DESIGN

It is important to establish what biodiversity outcomes are desired early in a project as they will influence later stages of development and, therefore, the costs and feasibility of a project. Once established with other project targets, biodiversity targets will guide planning and design. It may be beneficial to adopt one of the voluntary benchmarks as they establish procedures during development. Further, attainment of the benchmark can be used in the marketing of the project. It is also important to assess the occurrence of any threatened species or communities in the development area, and any laws or regulations that are applicable to them.

Prior to designing a new development, the existing environment needs to be understood, including biodiversity and natural processes[4, 5, 17, 24]. A biodiversity survey, to compile a list of local species, will assist in devising planting strategies for well-adapted, fauna-friendly vegetation after construction. A biodiversity survey can also identify any weed species or feral animals that are present in order to plan eradication or management programs. Importantly, a comprehensive survey must account for seasonal variation in plant and animal presence.

A site inventory of plant and animal species will form only part of the required information to ensure biodiversity-positive outcomes. Mature trees and useful vegetation should be mapped and their root zones included for consideration during the design and construction phases[17]. The types of native wildlife present need to be recorded and the land area and physical requirements for their persistence must also be considered during site design[7]. In Australia, the biodiversity of many urban areas has been assessed, so a review of this information is useful. Where significant biodiversity exists prior to development, or where it is encouraged by development, it is wise to have it protected by conservation agreements.

It is inefficient to simply remove vegetation and topsoil and then replant street trees and gardens after development. Such activities undervalue the existing vegetation. The local provenance, adaptation, and the maturity of existing vegetation are all valuable. Importantly, removing vegetation also removes the animals that rely on it for food and shelter[6, 24]. It is more efficient, both in time and money, to instigate biodiversity-positive actions during development, rather than retrofitting existing urban areas[7]. The same is true for Water Sensitive Urban Design. Indeed, the improvement of biodiversity and sustainable water management are mutually beneficial in urban developments.

The design of new developments should consider:

- Suitable building sites should be planned that mould the streets and infrastructure to the landscape[17]
- Wherever possible, water courses should be left intact[17] and vegetation left along waterways, or replanted[4]
- Avoid fragmenting existing vegetation and habitat
- Design biodiversity corridors within developments that link with surrounding environments
- Where roads bisect the habitat of wildlife, traffic calming designs may be useful
- To mitigate the impact of development on aquatic biodiversity, limit impervious surfaces[4]
- Maintenance costs, resources, and effort can be reduced by using indigenous species[17]
- Vegetation should be water sensitive, non-invasive, a sensible mixture of natives and exotics; consider all biodiversity (not just trees and grass)
- Urban consolidation reduces the impact of cities on the surrounding landscape, but can reduce biodiversity and the natural environments within cities. For this reason, consideration must be given to increasing urban biodiversity in innovative ways, including rooftop gardens[8, 25]

CONSTRUCTION

Where significant biodiversity exists prior to development, it is wise to develop a management plan that addresses its protection during construction. The plan can address habitat protection, use of machinery, dealing with existing fauna, and worker education. All people working on the site should comply with such a plan.

Where development will temporarily disturb habitat, wildlife can be caught and relocated before work begins. As it is difficult to relocate some animals, such as territorial species, some fauna may need to be housed in captivity until the disturbance is complete, and then returned to where they were found. Vegetation that is to be preserved can be fenced or flagged to make it obvious and reduce the access and trampling associated with construction works. To avoid soil compaction, heavy machinery should not be used in close proximity to vegetation. Where significant biodiversity exists, footwear and machinery may need to be washed before entering or leaving the construction site to reduce the spread of weeds and pathogens.

Biodiversity, both terrestrial and aquatic, is greatly damaged by land clearance. Along watercourses, the damaging effects of vegetation clearance and soil disturbance may be carried downstream to estuarine and marine environments. Further, the quantity and intensity of water flows are increased by the removal of vegetation and an increase in impervious surfaces, such as pavement and roofs. Greater water flows cause erosion of stream banks and modify the habitat of aquatic species[4]. Therefore, when establishing infrastructure and creating lots, land and vegetation clearance should be minimised. Further, stockpiles of soil should be protected from erosion and if significant native vegetation is within or alongside a development, imported soils must be free from weed seeds and pathogens.

COMPLETION

From an ecological perspective, there is no 'completion' point because biodiversity represents a continually changing and evolving community. Once a development is *completed*, both public and private areas can be managed to continue its improvement.

It is beneficial to combine a mix of management regimes[13]. Some areas should be highly managed, such as mown lawns and productive gardens, some visited infrequently, and some designed to be virtually neglected. Biodiversity can be rich in neglected areas, but a variety of land use and maintenance regimes will produce the best results[9].

Biodiversity-improving strategies will be more successful with the involvement of new residents. Resident participation will help develop a sense of ownership and community unity. It is important that new residents are aware of strategies that have been used to improve the biodiversity of the development, and secondly, they should be encouraged to contribute to ongoing strategies. Some methods of educating and enabling residents to contribute are:

- Providing information on local natural history, perhaps through a handbook or website;
- Establishing a domestic pet policy that will reduce the impact of cats and dogs on wildlife by keeping them indoors at night or even prohibiting them within the development;
- Providing a planting guide for residents that includes local native plants, suitable exotic plants, and wildlife-attracting plants; and
- Assisting the establishment of a local environmental-care group such as Landcare.

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