CTENVIRONMENTAL

Parramatta River Catchment Ecological Health Project

Prepared for Parramatta River Catchment Group

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Project Name	Parramatta River Catchment Ecological Health Project
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Executive Summary

This study identifies five iconic species from the Parramatta River catchment that are valued by community and whose presence and habitat requirements link to the goal of the Parramatta River Catchment Group to make the river swimmable by 2025. The iconic species selected by nearly 5000 community votes include:

- Powerful Owl (*Ninox strenua*)
- Southern Myotis (*Myotis macropus*) or Fishing Bat;
- Bar-tailed Godwit (*Limosa lapponica*);
- Eastern Long-necked Turtle (*Chelodina longicollis*),
- Striped Marsh Frog (*Limnodynastes peronii*).

The study links the ecological needs of these iconic species to the ecological services provided within the catchment and recommends a hierarchy of actions based on the need to protect existing habitats, manage habitats that remain and where possible create new habitats.

Each iconic species has ecological and environmental requirements that are needed to maintain viable populations and communities. Common requirements for all five iconic species include the need for complex habitat features, reliable food resources and a regulated stream hydrology to lessen the negative impacts associated with urban development. Some of the iconic species have adapted to or have attributes that enable them to live within the urban environment including being able to tolerate water that is not at standards suitable for swimming.

Consequently, for some actions there is not a direct and causative relationship between the ecological needs of each iconic species and a swimmable river. The challenge and opportunity therefore is the narrative created around the value these iconic species provide to the community and collectively how the sum of management actions contribute to improving the ecological needs and success of these iconic species within the urban environment. Many recommendations directed to protecting, maintaining and creating new habitats are likely to have complementary and synergistic benefits to other flora and fauna species across the catchment.

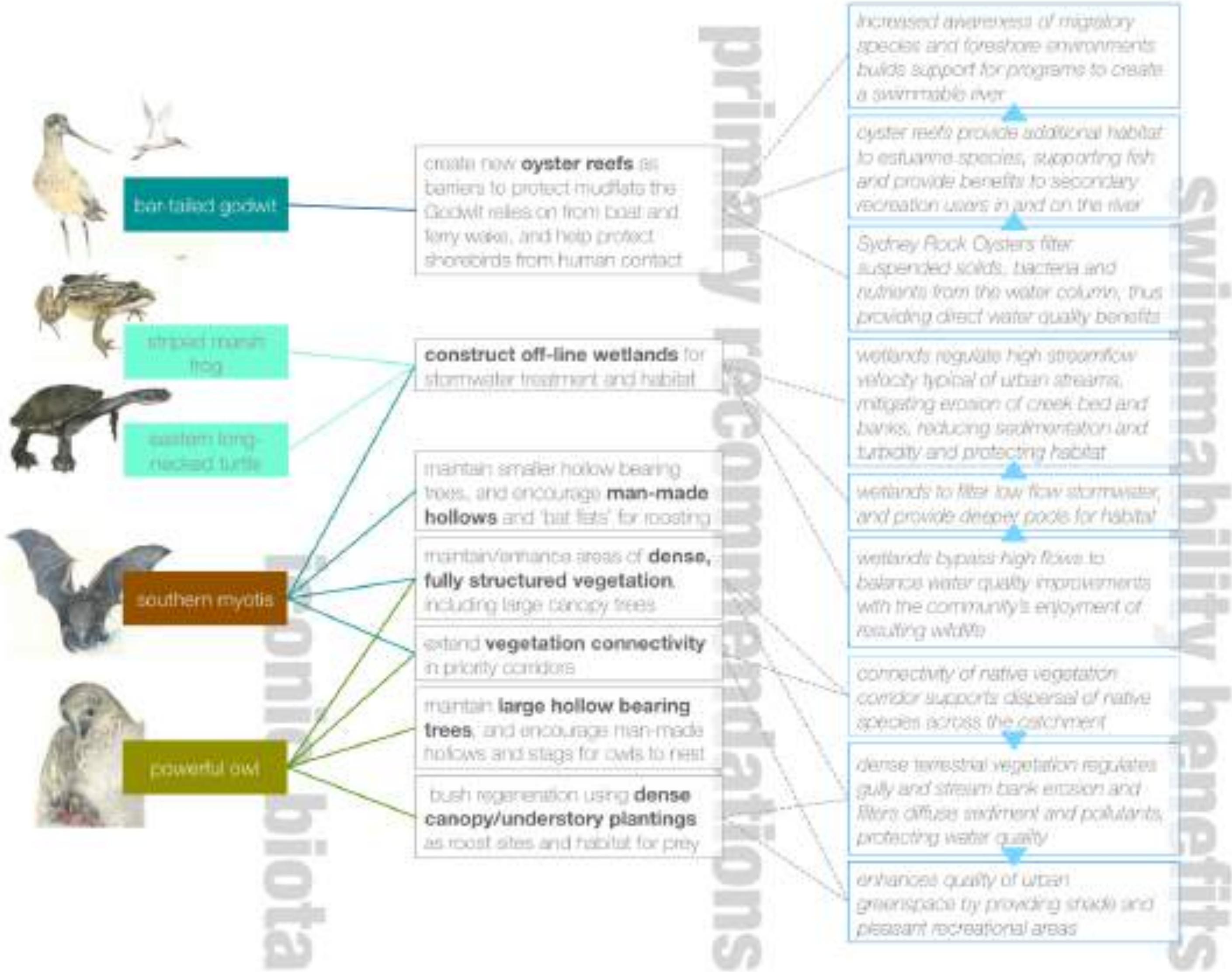
In this study a socio-ecological systems-based approach has been utilised to select the species that will be used to represent the heath of the catchment. This departs from conventional ecologically-based approaches that traditionally identify indicator species selected by ecologists. The community selected iconic species reflect locally-based ecological values, knowledge and preferences. The species provide a focal point for community engagement in environmental monitoring programs which in turn provide a scaffold to support the primary needs of the selected species and reveal how these needs are impacted by urbanisation. Consequently, environmental attributes that are necessary to support and improve the intrinsic health of the catchment for the iconic species and achieve a swimmable river for the community are revealed, and thus provide support for community involvement in understanding and promoting the health of the river.

Monitoring and evaluation frameworks to assess the success of the recommended management strategies are presented and are based on a combination of a citizen science program, reflecting the underlying community-based philosophy of this study, supported by a more rigorous

environmental science approach. Both approaches are designed to provide data on changes to the species and underlying catchment conditions that may affect the species and their ecological needs which can then feedback to management plans and the overarching protect, manage and create strategy.

Responsibility for the actions, monitoring and evaluation will rest with many stakeholders including government, industry and the community. To protect and manage existing habitats will require a coordinated and consistent approach to ensure the small but cumulative activities account for and consider the needs of the iconic species and the swimmability goal as well as the substantial efforts involved in habitat creation.

The figure below illustrates the five iconic species selected by the Parramatta River catchment community. The key habitat and ecological needs of these species are shown and are linked to how they contribute to a swimmable river. Critically, there is a need to protect and manage existing habitats that face considerable pressure from urban development. Opportunities to create new habitats are available but should be seen as supporting and supplementary strategies that complement the existing natural systems that remain within the catchment.



iconic biota
primary recommendations
swimmability benefits
bar-tailed godwit
striped marsh frog
eastern long-necked turtle
southern myotis
powerful owl
create new **oyster reefs** as barriers to protect mudflats the Godwit relies on from boat and ferry wake, and help protect shorebirds from human contact
construct off-line wetlands for stormwater treatment and habitat
maintain smaller hollow bearing trees, and encourage **man-made hollows** and 'bat flats' for roosting
maintain/enhance areas of **dense, fully structured vegetation**, including large canopy trees
extend **vegetation connectivity** in priority corridors
maintain **large hollow bearing trees**, and encourage man-made hollows and stags for owls to nest
bush regeneration using **dense canopy/understory plantings** as roost sites and habitat for prey
Increased awareness of migratory species and foreshore environments builds support for programs to create a swimmable river
oyster reefs provide additional habitat to estuarine species, supporting fish and provide benefits to secondary recreation users in and on the river
Sydney Rock Oysters filter suspended solids, bacteria and nutrients from the water column, thus providing direct water quality benefits
wetlands regulate high streamflow velocity typical of urban streams, mitigating erosion of creek bed and banks, reducing sedimentation and turbidity and protecting habitat
wetlands to filter low flow stormwater, and provide deeper pools for habitat
wetlands bypass high flows to balance water quality improvements with the community's enjoyment of resulting wildlife
connectivity of native vegetation corridor supports dispersal of native species across the catchment
dense terrestrial vegetation regulates gully and stream bank erosion and filters diffuse sediment and pollutants, protecting water quality
enhances quality of urban greenspace by providing shade and pleasant recreational areas

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1. Study Aim

The aim of this study is to identify five iconic species that live in the Parramatta River catchment that are valued by community and whose presence and habitat requirements link to the goal of the Parramatta River Catchment Group to make the river swimmable by 2025. It provides a foundation for a citizen science environmental monitoring program for the catchment and has established a method for community engagement bridging environmental sciences and community knowledge, values and understanding. The species identified by the community are designed to reflect locally-based ecological values, knowledge and preferences. These in turn provide a scaffold to support the primary needs of the selected species and reveal how these needs are impacted by development (past and present) and consequently what is necessary to do to support and improve the intrinsic health of the catchment for the species and achieve a swimmable river for the community.

The study forms part of a suite of interrelated reports commissioned by the Parramatta River Catchment Group designed to achieve the vision of a swimmable river by 2025. These include the Our Living Catchment – Fauna and Habitat Report (Applied Ecology 2014), Parramatta River Coastal Zone Management Plan, Strategic Analysis of Water Quality in the Parramatta River catchment (Khan and Jacobs 2016), the Parramatta River Master Plan Water Quality Modelling Project (in progress) and the Parramatta River Masterplan Waterway Governance project (in progress). Collectively these reports will inform the final Masterplan.

With an area of approximately 27,000 ha, Parramatta River catchment is one of Sydney's major river basins. From the headwaters in Blacktown and The Hills Shire, Parramatta River and tributaries flow through multiple Local Government Areas. At the time of writing these include Blacktown City, City of Parramatta (including former areas of The Hills, Auburn City, Holroyd City and Hornsby Shire), Cumberland (including former areas of Auburn City, Parramatta City and Holroyd City), Inner West (including former areas of Ashfield, Leichhardt and Marrickville), City of Canada Bay, Strathfield, Burwood (merger of these three councils is pending), City of Ryde and Hunters Hill (a merger including these two councils with Lane Cove is also pending), City of Canterbury Bankstown (including former areas of Canterbury and Bankstown) and The Hills Shire.

Due to the relatively flat terrain and rich soils, the Parramatta River catchment fast became the major agricultural production centre of early colonial Australia (Higginbotham and Johnson 1989). Early Europeans efficiently cleared the landscape to establish farming communities and set in motion a history of degradation which continues to this day.

Since European colonisation the Parramatta River catchment has become one of the most highly urbanised catchments in Australia. As a result, many pressures, such as loss of native vegetation, stormwater, sewage, weed and exotic vertebrate invasion and creek bank erosion have resulted in the degradation of ecological systems (Applied Ecology 2014).

Urbanisation is a major driver of degradation to freshwater and estuarine ecosystems (Kennish 2002, Wright et al 2007). Paul and Meyer (2001) coined the phrase 'the Urban Stream Syndrome' to describe the common symptoms of degradation to waterways caused by urbanisation which include declining water quality, loss of biodiversity, altered flow regimes, invasion of pest flora and fauna and the modification of vegetation communities.

In recent times, major interest in the 'health' of waterways has led to a number of waterway ecosystem health initiatives. These programs typically measure a diverse range of biotic and abiotic factors such as water quality, invertebrate, algae and fish communities, vegetation cover and/or condition and flow and channel form.

In most urban areas across Sydney, creek corridors and estuarine foreshores typically provide pockets of bushland and refuge for numerous native species. The Parramatta River catchment is no exception to this, providing a very important ecological resource. The creek lines, riparian corridors and foreshore of the River make up a significant proportion of green space where current and future residents recreate, commute and interact with nature. The ecosystem services provided to the communities of the Parramatta River catchment by these areas play an important role in enhancing the liveability of area.

A significant ecosystem service identified by the Parramatta River Catchment Group (PRCG) is recreation, and the Group has launched an initiative to make the River "swimmable" by 2025. This vision suggests the ultimate goal, however the PRCG stress that:

> "*a swimmable river is about more than just swimming. It is a clean and healthy river, with vibrant and active spaces that everyone can easily get to and enjoy in different ways"*

Via a community voting process, this project identifies five 'iconic' species (or mascots as they have been termed for community engagement) that express aspects of the complex ecology of the catchment environment.

Environmental and/or habitat conditions required to sustain viable populations of the five iconic species are identified such as species inter-dependence and those with focus on requirements linked to waterway improvements such as flow, water quality and vegetation quality which ultimately will enhance the swimmability of the Parramatta River.

Specific management actions to enhance habitat and indices for monitoring are identified for each iconic species. While these have not been specifically selected as *umbrella species*, management interventions are likely to have benefits for the broader ecological community they belong to.

Outcomes of this work will build on the Our Living Catchment – Fauna and Habitat Report (Applied Ecology 2014), Parramatta River Coastal Zone Management Plan, Strategic Analysis of Water Quality in the Parramatta River catchment (Khan, S and Jacobs 2016) and the Parramatta River Master Plan Water Quality Modelling Project (in progress).

This body of work will provide direction for the PRCG and its member agencies to meet the mission of making the Parramatta River swimmable and to enhance the overall liveability of the catchment

2. Study Limitations

The aims of this study depart from conventional ecologically-based approaches to identify indicator species for catchment health and uses a social-ecological systems approach. In doing so it places the responsibility for species selection directly with the community. The role of the ecologists is then to map back the needs of the species identified by the community to the ecological requirements, threats and what actions are necessary to address the threats and contribute to a swimmable river. Given that the catchment is heavily modified many of the surviving species will have modified their behaviours and adapted to the changes in the environment including being able to survive in degraded or otherwise modified conditions. In this regard there may not be direct and causative relationships between ecological needs and a swimmable river. The challenge and opportunity therefore is the narrative created around the value of the species and the community's connection to these. Collectively the needs of each of the five identified species should be the driver for change, not whether one particular attribute of one species relates to a swimmable river.

From a data perspective, this study has drawn on currently available desktop information provided by the Parramatta River Catchment Group and otherwise publicly available through records such as BIONET (NSW OEH 2016). The species mapping illustrated in this report reflects these data sources and have not been supplemented or validated via additional ground-truthing as part of this study. The authors recommend additional ground-truthing of species presence, frequency and habitat requirements would be required prior to targeted land and water management actions if the success of such actions are to be directly linked to an increase in targeted species presence or change.

3. Parramatta River Catchment

Location

Parramatta River (the river) is the major tributary of the iconic Sydney Harbour. The River flows eastwards from the headwaters in Blacktown and The Hills local government areas (LGA) to its confluence with Land Cove River and Sydney Harbour around the Woolwich Peninsular and Cockatoo Island. The total area of the catchment is 26,590 hectares.

The estuarine portion of the river covers approximately 12 km^2 with the tidal limit extending approximately 30 km upstream to Charles Street Weir in Parramatta (Applied Ecology 2014). Major tributaries of the River include Hunts Creek, Toongabbie Creek, Subiaco Creek, Haslams Creek, Dobroyd Canal (Iron Cove Creek), Hawthorne Canal (Long Cove Creek), Powells Creek, and Duck River.

The catchment is relatively flat with elevation ranging from approximately 140 m in the North West of the catchment to sea level in the east. Areas in the western portion of the catchment are characterized by lower rainfall averaging 800-900 mm per annum, compared to up to 1100 mm in eastern areas nearer to the coast (BOM 2016).

Due to the relatively flat terrain and rich soils, the Parramatta River catchment became a focal point for development and agricultural production for the British colonial settlement of Sydney (Higginbotham and Johnson 1989). The impact of land clearing and development, first for agriculture and later for industrial and residential activities have left legacy environmental impacts contributing to the decline in the health of the Parramatta River and supporting ecological systems (Applied Ecology 2014).

Urbanisation is a major contributor to the degradation to freshwater and estuarine ecosystems (Kennish 2002, Wright et al 2007), and the phrase 'the urban stream syndrome' was coined to describe the multiple factors which negatively affect urban waterways (Paul and Meyer, 2001). These impacts include a decline in water quality, changes to water chemistry, loss of biodiversity, altered flow regimes, invasion of pest flora and fauna and the modification of vegetation.

As at November 2016 there are eleven local government areas within the catchment, noting that this may change as a result of the current process by the State Government for local government amalgamations. The councils include Parramatta (including former areas of The Hills, Auburn City, Holroyd City and Hornsby Shire), Cumberland (including former areas of Auburn City, Parramatta City and Holroyd City), Inner West (including former areas of Ashfield, Leichhardt and Marrickville), Canada Bay, Strathfield, Burwood (merger of these three councils is pending), Ryde, Hunters Hill (a merger Ryde and Hunters Hill with Lane Cove is pending), Canterbury-Bankstown, The Hills Shire and Blacktown (**Figure 1**).

Water and waste water services are provided by Sydney Water Corporation, stormwater services are mostly owned and operated by local government, the road network is shared between state (major) and local government (minor), bushland reserves are mostly owned and managed by local government with National Parks the responsibility of the State and transport and utility corridors falling to the respective state or privately owned utilities. This creates a matrix of land tenure and management that involves public (government) and private (residents and industry/utilities).

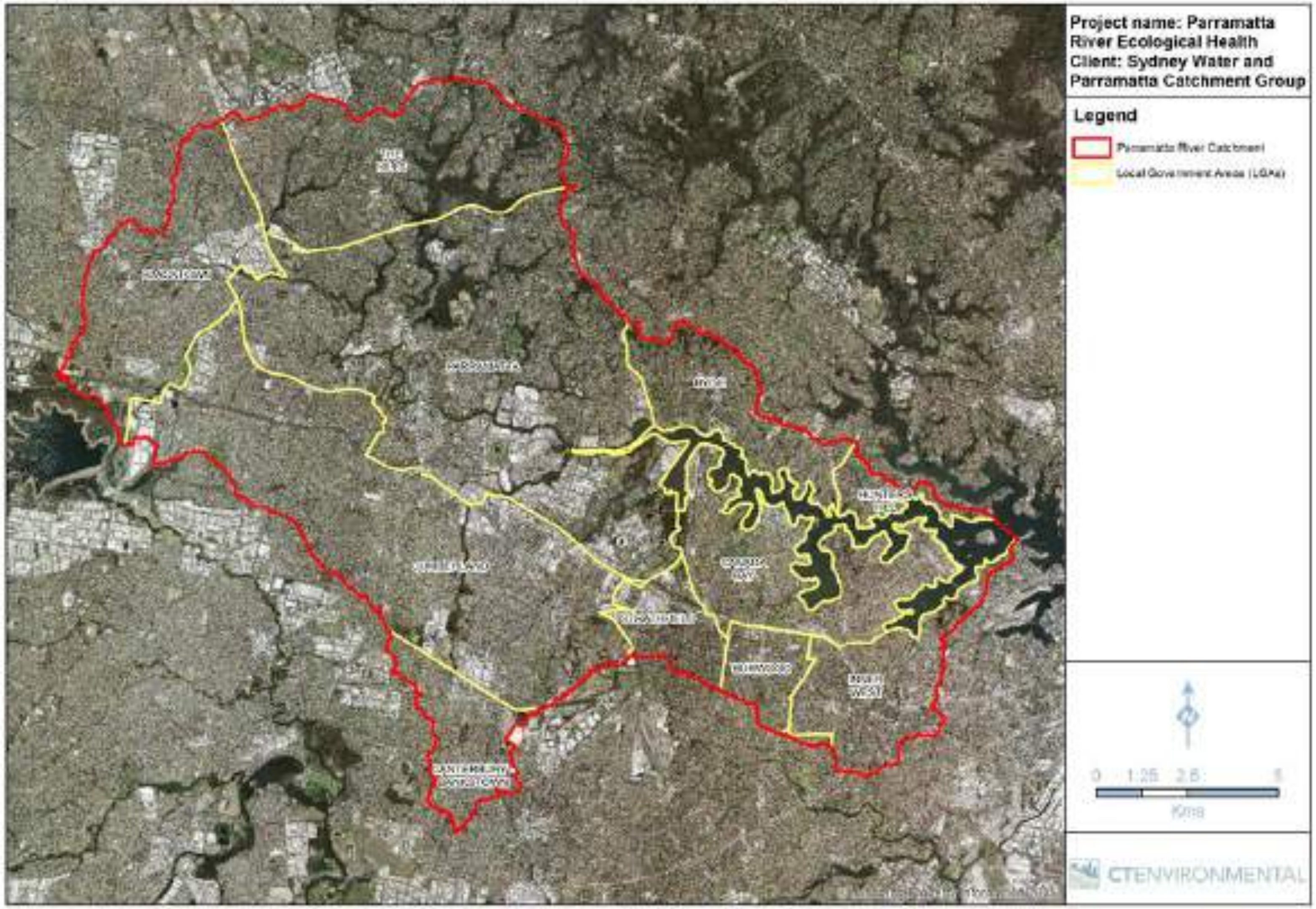

Figure 1: Local government areas of Parramatta River catchment.

4. Ecology of the Parramatta River Catchment

An overview

The ecology of the Parramatta River catchment reflects the changes from the pre-European flora and fauna to a modified landscape as a result of over 200 years of more intensive land use changes associated with colonial settlement. This is evident when comparing the presence of species and compositions of plants and animals within the relatively intact and larger bushland areas and that of the urban and industrial centres that dominate many parts of the catchment.

Although the Parramatta River catchment is heavily modified, numerous small pockets of bushland remain. These remnants provide refugia for several threatened plant and animal species, and function as corridors or stepping stones for movement of fauna.

Terrestrial Fauna

In 2014, PRCG commissioned Applied Ecology to undertake a comprehensive review of fauna records across the Parramatta River catchment. Results of this study show that, since 2000, 378 fauna species have been recorded across the catchment. The most prolific group of species were birds (305 species) followed by mammals (35 species), reptiles (24 species), frogs (13 species) and a single species of snail (see Applied Ecology 2014).

Abundance counts of the top five species in each Class as reported by Applied Ecology (2014) are shown in **Table 1.** It appears many of these results are likely biased toward targeted species surveys and may not be a true representation of the abundance (or distribution) of species which have adapted to inhabiting the urban environment.

For example, the Green and Golden Bell Frog (*Litoria aurea*) is a threatened species with very limited distribution across the catchment (Applied Ecology 2014), however this species has the highest abundance count of frog species found across the catchment.

Additionally, Applied Ecology (2014) acknowledge that the top five bird species (Aves) and abundance of the Grey-Headed Flying-Fox (*Pteropus poliocephalus*) are influenced by targeted wading bird surveys and Flying Fox counts.

Table 1: Top five most common taxa for each class recorded across the Parramatta River catchment (Applied Ecology 2014).

Class	*Scientific Name*	Common Name	Abundance
Amphibia	*Litoria aurea*	Green and Golden Bell Frog	5194
Amphibia	*Limnodynastes peronii*	Striped Marsh Frog	5097
Amphibia	*Crinia signifera*	Common Eastern Froglet	3860
Amphibia	*Litoria peronii*	Peron's Tree Frog	3335
Amphibia	*Litoria fallax*	Eastern Dwarf Tree Frog	945
Aves	*Himantopus himantopus*	Black-winged Stilt	23132
Aves	*Anas castanea*	Chestnut Teal	19193
Aves	*Threskiornis molucca*	Australian White Ibis	13490
Aves	*Chroicocephalus novaehollandiae*	Silver Gull	12336
Aves	*Anas gracilis*	Grey Teal	10845
Mammalia	*Pteropus poliocephalus*	Grey-headed Flying-fox	303009
Mammalia	*Vespeduelus regulus*	Southern Forest Bat	192
Mammalia	*Tadarida australis*	White-striped Freetail-bat	134
Mammalia	*Chalinolobus gouldii*	Gould's Wattled Bat	108
Mammalia	*Trichosurus vulpecula*	Common Brushtail Possum	102
Reptilia	*Eulamprus quoyii*	Eastern Water-skink	201
Reptilia	*Tiliqua scincoides*	Eastern Blue-tongue	154
Reptilia	*Lampropholis delicata*	Dark-flecked Garden Sunskink	137
Reptilia	*Physignathus lesueurii*	Eastern Water Dragon	41
Reptilia	*Chelodina longicollis*	Eastern Snake-Necked Turtle	30
Gastropoda	*Meridolum corneovirens*	Cumberland Plain Land Snail	12

As part of the same study, Applied Ecology (2014) conducted targeted bird surveys of nine reserves across Auburn and Blacktown LGAs. Results of these surveys show the most common taxa were Noisy Miner (*Manorina melanocephela*), which was recorded in all nine reserves, followed by the Magpie (*Cracticus tibicen*) (recorded in 6/9 reserves), Magpie Lark (*Grallina cyanoleuca*) (recorded in 5/9 reserves) and Australian White Ibis (*Threskiornis moluccus*) (recorded in 5/9 resreves).

The top five most abundant species recorded by these surveys was the Noisy Miner (*Manorina melanocephela*) with 59 individuals, followed by Australian White Ibis (*Threskiornis moluccus*) and Australian Wood Duck (*Chenonetta jubata*) (*n*=31), Grey Teal (*Anas gracilis*) (*n*=23) and Crested Pigeon (*Ocyphaps lophotes*) (*n*=19).

A comparison of results from Applied Ecology (2014) with results from the 2015 Birds in Backyards survey (Australian Museum 2015) shows none of the bird species shown in **Table 1** were identified by the Birds in Backyards survey as one of the 30 most common species.

However, comparison of results of targeted surveys conducted by Applied Ecology (2014) show 19 of 45 species recorded were in the 30 most common species recorded by the Birds in Backyards survey (Australian Museum 2015). It is likely the results of targeted surveys represent a more accurate representation of the urban bird community across the catchment than those presented on **Table 1**.

Fish and Key Fish Habitat

Information relating to survey of fish populations across the catchment are limited and have to date focused primarily in and around Sydney Olympic Park and Parramatta CBD.The studies by Bio-Analysis (2000) and Australian Museum (2014) in and around Sydney Olympic Park identified the diversity, distribution and abundance of fish within wetlands and waterways. They reported 33 species of fish and crustaceans including many popular recreational species such as Yellowfin Bream (*Acanthopagnes australis),* Tailor *(Pomatomus saltatrix)* and Dusky Flathead *(Platycephalus fuscus).* A review of recreational fishing websites indicate these species are widespread across the estuarine reaches of the catchment. Two exotic species were present which were Common Carp (*Cyprinus carpio*) and Mosquito Fish (*Gambusia holbrooki*).

The Upper Parramatta River Fish Survey commissioned by the former Parramatta City Council and undertaken by Cardno from 2010-2014 and identified 21 species of fish between the Charles St Weir and Marsden St Weir, including 5 species that are not native to the Parramatta River. The fish population in this reach was rated as fair to good, with the most abundant species surveyed being freshwater mullet, sea mullet, Port Jackson perchlet, Australian bass, Common Carp and long-finned eels.

In NSW, ‘Key Fish Habitats' are defined as aquatic habitats that are important to maintain sustainable recreational and commercial fishing industries, maintain fish populations and ensure survival and recovery of threatened aquatic species. Key Fish Habitat includes all marine and estuarine habitats up to highest astronomical tide level and most permanent and semi-permanent freshwater habitats. Under Depatment of Primary Industries Key Fish Habitat guidelies, small headwater creeks and gullies (first and second order Strahler streams) are not considered Key Fish Habitats as these are not considered as permanently flowing water bodies (DPI 2012).

The Review of Key Fish Habitat Mapping (DPI 2012) shows numerous waterways across the Parramatta River catchment are mapped as Key Fish Habitat. Key Fish Habitat areas include the Parramatta River, parts of Subiaco Creek and Duck River to the north and south, the north-western tributaries Hunts Creek and Darling Mills Creek which drain Lake Parramatta and the deeper northern bushland gullies, and part of Toongabbie Creek at the head of the catchment (**Figure 2**).

Although these waterways have been mapped as KFH, habitat sensitivity and KFH class (DPI 2013) cannot be determined without undertaking on-ground field assessments.

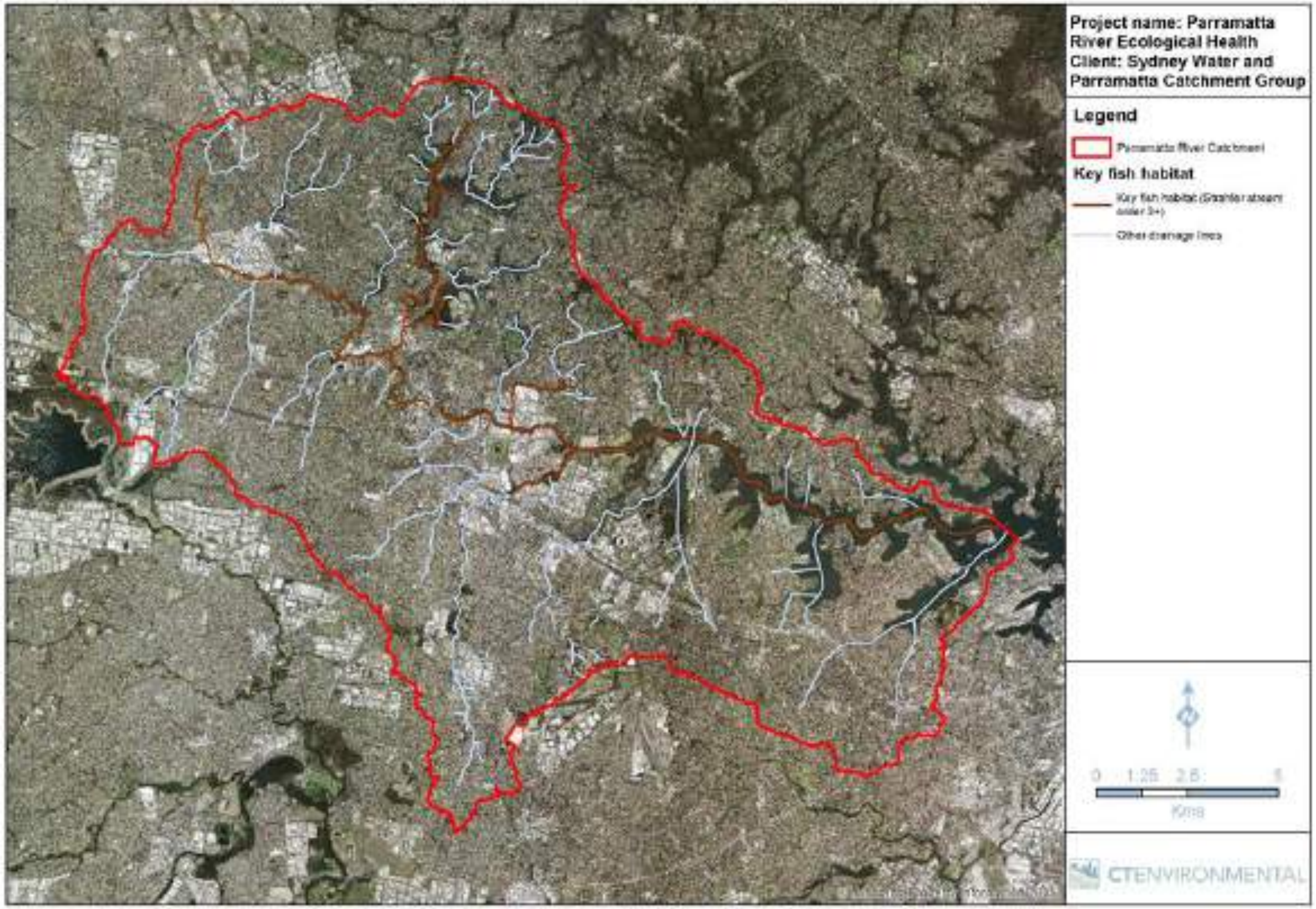

Figure 2: Mapped Key Fish Habitat of Parramatta River Catchment (DPI 2012).

Application of the Strahler steam order system (DPI 2012) across the Parramatta River catchment revealed a total of 210.8 km of creek lines or streams ranging from 1st to 4th order (**Figure 3**). The method for assessment is based on creek lines shown on the NSW 1:25,000 topographic map series.

As shown in **Table 2,** approximately 75 per cent of streams in the catchment are either 1st or 2nd order streams. Natural bifurcation of streams can be seen in the north-west corner of the catchment however in most other parts of the catchment bifurcation has been lost due to the historical piping and channelisation of waterways. As a result, lengthly reaches of low order streams are present which are reflective of the network of concrete stormwater channels across the catchment.

This is common across urban catchments as low order streams are often piped or channelised as part of stormwater drainage systems. Historically, urban drainage systems have been constructed from concrete with pipes and culverts designed to improve hydraulic performance, however this approach has resulted in severe desgradation of aquatic ecoystems and stream function.

Table 2: Strahler stream order and total length of ordered creeks within Parramatta River catchment.

Stream Order	Length (km)
First	102.3
Second	56.3
Third and Higher	52.2
Total	210.8

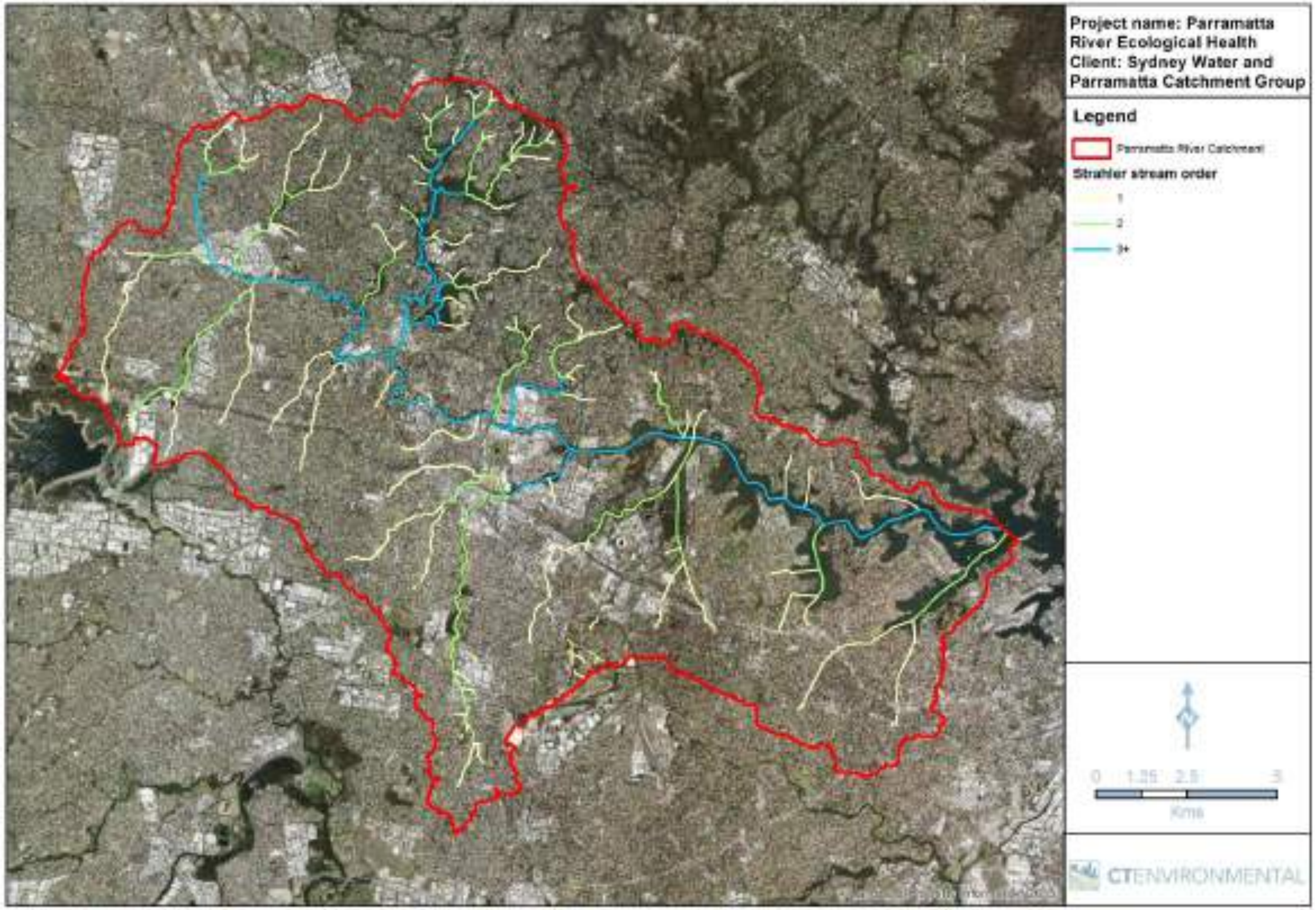

Figure 3: Strahler stream order of creeks in the Parramatta River catchment.

Native vegetation

Prior to European settlement, the Parramatta River catchment was extensively vegetated with woodland, forest and rainforest communities, mangroves and saltmarsh. Most native vegetation has been extensively cleared although some important pockets remain because of deliberate protection, such as designated bushland reserves, their natural attributes that limited development, such as deep gullies or flood affected land, or by virtue of land reservations such as rail corridors.

Twenty seven distinct native plant community types (PCT) occur within the Parramatta catchment occupying the terrestrial, riparian, estuarine and aquatic environments (**Table 3**). The native plant communities occupy 1,624 hectares and are primarily distributed in the northern and upper reaches of the catchment (**Figure 4**). These plant communities do not contain others lost because of clearing or development. Notable across most plant communites is that they have been extensively cleared, not only across the Parramatta River catchment, but throughout the Sydney Basin (**Table 3**), and what native vegetation does remain is mostly found in deep gullies and isolated remant patches.

Air-photo interpretation in 2012 (OEH 2013) estimated that 3370 hectares of natural vegetation remains across the catchment. This includes native plant communities (1,624 hectares), urban plant communities (both exotics and natives 1546 hectares), weeds and exotics (188 hectares), water bodies (11 hectares) and artificial wetlands (33 hectares) (**Table 3**). The three most extensive native plant communities are the Coastal Enriched Sandstone Sheltered Forest (267 hectares), Blue Gum High Forest (184 hectares) and Coastal Enriched Sandstone Moist Forest (172 hectares) (**Table 3**).

Of the existing native vegetation forest and woodland types, 83.6 ha is mapped as being undisturbed and in good condition, 422.3 ha with low disturbance, 258.7 ha moderately disturbed, 443.3 ha with high disturbance and 226.2 ha as highly disturbed (**Table 3, Figure 5**). Areas of mixed native/exotic and certain estuarine macrophyte communities do not have condition data and are excluded from these totals. Individual or scattered trees in urban or suburban yards are not mapped or included in the above calculations.

Table 3: Vegetation type and condition across the Parramatta River catchment and estimate of percentage cleared across the Sydney basin (OEH 2013).

Plant Community Type	Not Assessed	No Visible Disturbance	Low	Moderate	High	Very High	Total	% Cleared Syd. Basin Estimate*
Artificial Wetland	33.0						33.0	N/A
Castlereagh Ironbark Forest			8.5	17.0	17.7	17.5	60.8	80-95%
Castlereagh Shale-Gravel Transition Forest						0.1	0.1	65-75%
Coastal Enriched Sandstone Sheltered Forest		36	189.9	22.8	7.3	10.4	266.3	15-30%
Coastal Sandstone Foreshores Forest				3.0	13.8	0.8	17.6	unknown
Coastal Sandstone Sheltered Peppermint-Apple Forest		1.9	3.5				5.4	15-30%
Hornsby Enriched Sandstone Exposed Woodland		3.2	10.0	0.9			14.1	10-25%
Castlereagh Scribbly Gum Woodland				0.8			0.8	30-50%
Coastal Flats Swamp Mahogany Forest					1.2		1.2	75-90%
Hinterland Riverflat Paperbark Swamp Forest				0.6			0.6	15-30%
Cumberland Riverflat Forest			1.2	1.5	54.5	3.9	61.1	80-95%
Cumberland Swamp Oak Riparian Forest				0.3	12.8		13.0	75-95%
Estuarine Swamp Oak Forest	11.7	1.3		0.2	14.5		27.6	80-95%
Coastal Freshwater Reedland	2.5				0.4		2.9	30-70%
Estuarine Reedland	0.7				0.9		1.6	unknown
Cumberland Shale Hills Woodland				1.8	2.8	3.6	8.1	75-90%
Cumberland Shale Plains Woodland			17.5	21.9	49.6	49.8	138.8	75-95%
Coastal Headland Banksia Heath				2.3			2.3	5%
Coastal Sandstone Gallery Rainforest		2.0	3.8	7.6	5.8		19.3	5-10%
Coastal Warm Temperate Rainforest					2.6		2.6	5-15%
Estuarine Mangrove Forest	144.7			0.5	1.1	0.2	146.6	25-50%
Estuarine Saltmarsh	25.7	0.6					26.3	<50%
Seagrass Meadows	5.0						5.0	unknown
Blue Gum High Forest			28.7	56.0	62.0	37.2	184.0	>90%
Coastal Enriched Sandstone Moist Forest		36.0	71.2	51.9	10.6	1.8	171.6	unknown
Coastal Shale-Sandstone Forest		2.7	41.9	13.1	16.3	29.3	103.3	30-50%
Sydney Foreshores Shale Forest				0.2	1.3		1.5	unknown
Sydney Turpentine-Ironbark Forest			46.1	56.3	139.1	67.9	309.5	<10%
Undifferentiated Regenerating Shrubs	0.2						0.2	N/A
Urban Exotic/Native	1,539.4				6.9		1,546.3	N/A
Water	10.9						10.9	N/A
Weeds and Exotics	165.9				22.1		187.9	N/A
Total	**1,939.6**	**83.6**	**422.3**	**258.7**	**443.3**	**222.6**	**3,370.2**	**N/A**

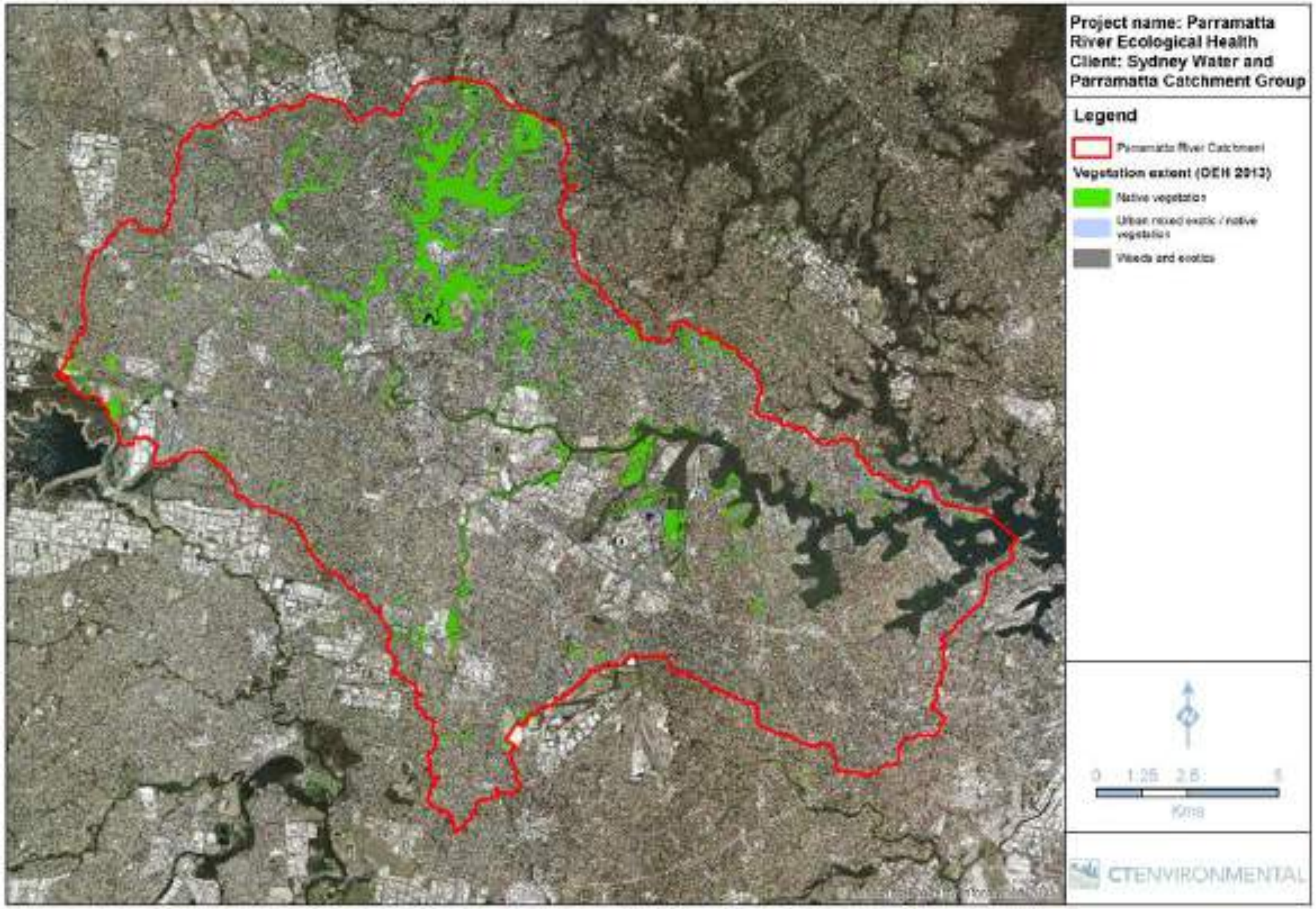

Figure 4 Extent of native vegetation across the Parramatta River catchment as of 2013.

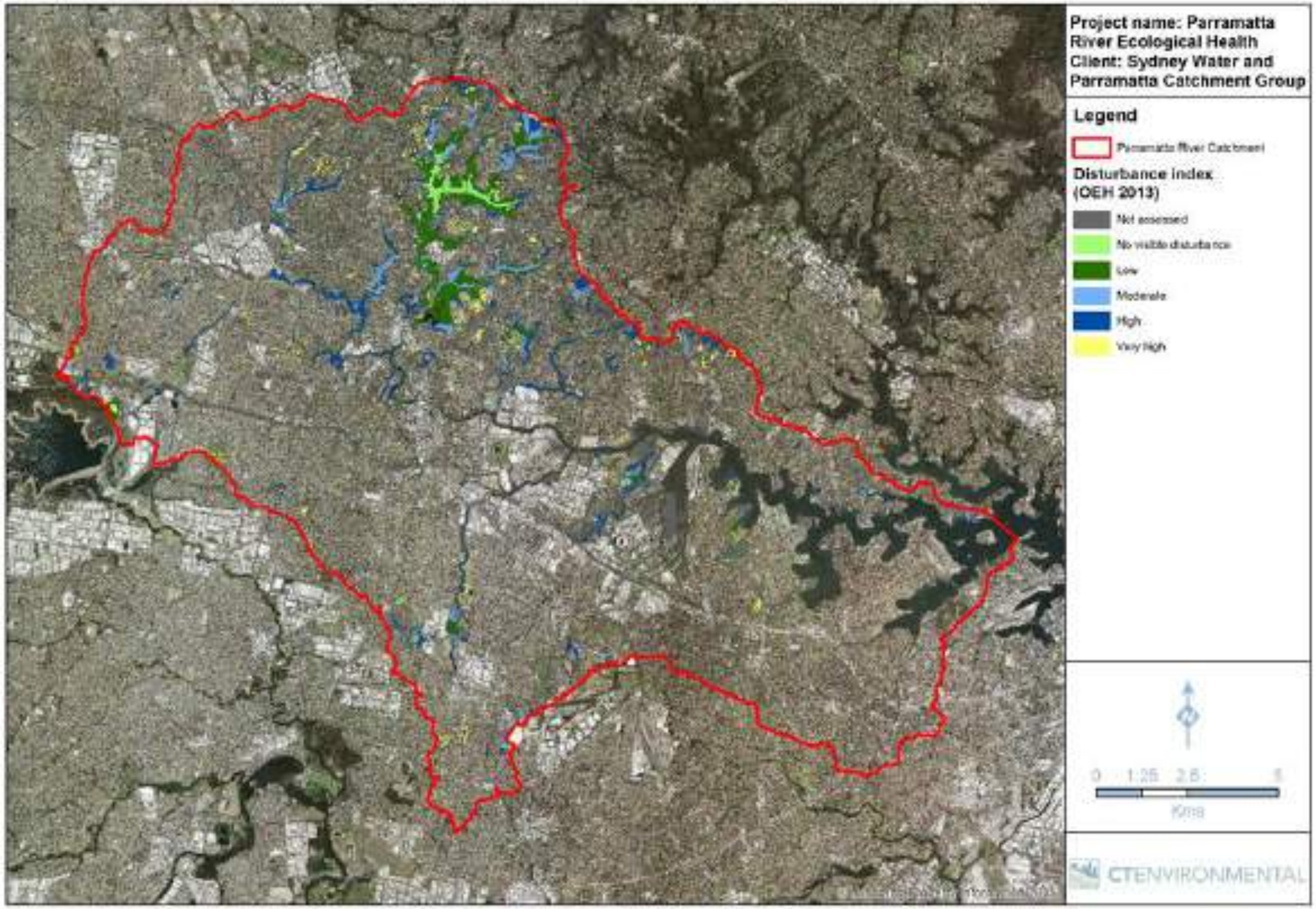

Figure 5: Condition of native vegetation across the Parramatta River catchment as of 2013.

Endangered Ecological Communities

Parramatta River catchment contains 11 endangered ecological communities (EEC) listed under the NSW *Threatened Species Conservation Act 1993* (**Figure 6**). The *Threatened Species Conservation Act 1993* enables the listing of plant and animal species, communities and geographic populations as threatened, endangered or critically endangered. Listing of these communities reflect the extensive clearing of the vegetation for agriculture and other development when compared to an estimate of pre-1750s vegetation distribution and structure.

Sydney Turpentine-Ironbark Forest is the most prevalent EEC across the catchment followed by Blue Gum High Forest. The other communities include; Castlereagh Scribbly Gum Woodland; Cooks River/Castlereagh Ironbark Forest; Cumberland Plain Woodland; Coastal Saltmarsh; Freshwater Wetlands on Coastal Floodplains, River-Flat Eucalypt Forest on Coastal Floodplains; Shale Gravel Transition Forest; Swamp Oak Floodplain Forest; and Swamp Schlerophyll Forest on Coastal Floodplains (**Figure 6**)

Threatened Species

A desktop review of the Atlas of NSW Wildlife identified 148 threatened flora and fauna species recorded in the Parramatta River catchment (**Figure 7**). These include 72 plant species, 45 bird species, 23 mammal species, four frog species, two reptiles and two snail species (**Appendix 3**).

Distribution of threatened species across the catchment is primarily restricted to creek corridors and remnant patches of native vegetation. **Figure 7** shows the majority of threatened species records cluster around Prospect Reservoir in the west Sydney Olympic Park in the east, Rookwood Cemetary in the south and the network of reserves in the north. This pattern of distribution reflects the detrimental effects of habitat loss and habitat fragmentation that is so commonly the result of urbanisation.

A desktop review of the Threatened and Protected Species Records Viewer (DPI 2016) showed no records of threatened fish species recorded in the Parramatta River catchment.

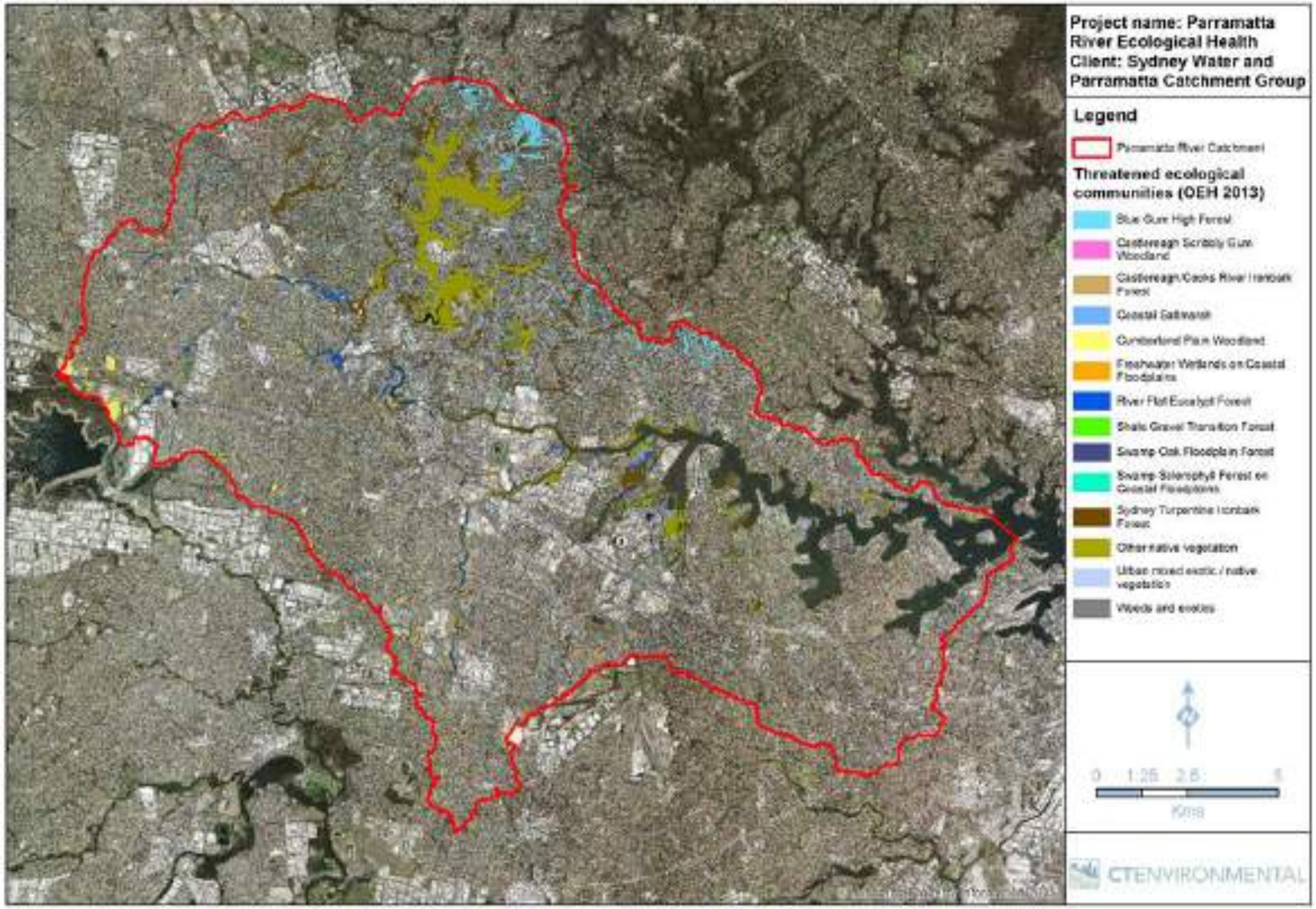

Figure 6: Listed Endangered Ecological Communities of Parramatta River catchment.

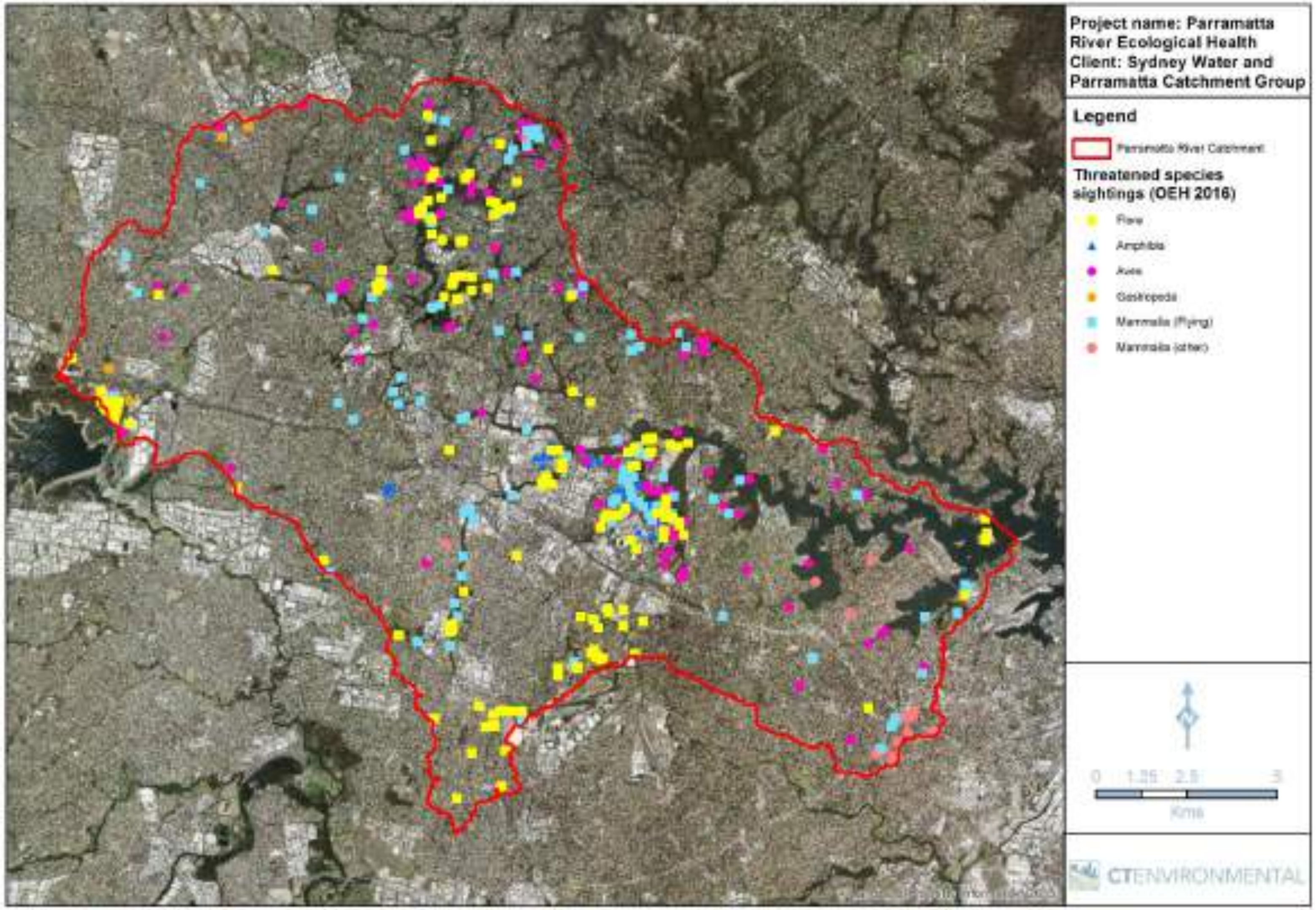

Figure 7: Threatened flora and fauna species records from across Parramatta River catchment

5. Urban Ecology

Urban ecosystems represent the integration of natural, built and socio-economic systems. They include heterogeneous land uses that make up the built environment of cities, natural areas and those new or modified ecosystems that represent the interaction of human-natural ecosystems (Picklett et al., 2001).

The ecology of urban ecosystems has been categorized according to incremental understanding of how cities relate to the natural environment (Wu, 2014). The study of urban ecology initially focused on non-human organisms in urban environments which is the 'ecology in cities.' This ecology was examined by botanists and zoologists focussing on species abundance and distribution. From the late 1980's there was an increasing interest in the study of biodiversity in cities and the relationship to the environmental impacts of urbanisation. The term 'ecology of cities' is used to describe a more interdisciplinary approach in which the city is considered as a whole ecosystem. From the year 2000 there has been an increasing understanding of the complexity of urban ecology and how human and environmental systems are coupled. The term 'sustainability of cities' is used to describe this complexity and considers the city as providing ecosystem services and supporting human well-being as well as sustaining the intrinsic function of natural systems. This concept of the 'sustainability of cities' is a particularly apt term to describe the approach adopted by the Parramatta River Catchment Group and its vision to make Parramatta River swimmable by 2025.

While this theoretical understanding of urban ecology and its importance and interrelationship with human environments has developed, biodiversity loss in cities is continuing (Eigenbrod et al., 2011). This is due to many factors including a decrease in size and quality of habitat, fragmentation and isolation of remaining natural areas, an increase in ecological disturbance, a change in species composition (including a rise in invasive species and the native species who have adapted to the new environments) and the pollution of the land, water and atmosphere (e.g. discussion in Borgström et al., 2006).

These impacts on urban ecology outcomes reflect past and present socio-political norms and values assigned to biodiversity as reflected within laws, policies, priorities and practices of government, industry and the community (Ives et al., 2010). There has also been a failure to understand and quantify the benefits of ecosystem services to cities (Folke et al., 1998; Lee, 1993). These benefits can be ascribed across spatial, temporal and functional scales. Spatial discrepancies occur at an administrative and jurisdictional level (within and between levels of government) and in how ecological systems are defined (for example by jurisdiction such as a National Park or catchment boundary).

For the Parramatta River Catchment Group, the spatial discrepancies are evident by multiple councils and state government authorities managing their land according to different rules, standards and operating guidelines. Temporal discrepancies occur at multiple levels. For example, these can be based on the 4-year state and local government political cycles, the 10-year community strategic planning as required by councils or the strategic land use planning cycles set by the state government that vary from 10 to 30 years. Functional discrepancies often reflect our incomplete understanding of ecosystems. For example, monitoring and evaluation programs designed to measure changes in ecological systems may not adequately reflect impacts of the underlying pressures to these systems or be sensitive to the outcomes of remediation actions to provide adequate feedback for ongoing program design and implementation. For many species and ecological communities, the tipping point after which systems collapse and cannot be returned to their former condition is not known.

This can lead to 'extinction debt' (Hahs et al, 2009) within cities, whereby many species are beyond the point of recovery, irrespective of legislative intervention (such as listing them as threatened and requiring special consideration in planning decisions and management practice).

Despite these failings there is however recognition that nature in cities provides many services for cities. Examples include local climate regulation (ranging from the shading of one tree to landscape scale vegetation arresting the urban heat island effect), pollination and biological control for parks and gardens, pollutant reduction and improved health and wellbeing (Tzoulas et al., 2007; Taylor & Hochuli, 2014; Luck et al., 2011).

For governments tasked with the responsibility of identifying where and how to accommodate ever increasing populations and maintain the socio/economic/environmental benefits of ecosystem services, new ways of thinking and practice are required. These will need to depart from the present approach in which change is captured by agency and community inertia (Bai et al., 2010) to a more transformative way (Geels, 2002). Setting an aspirational vision, such as a swimmable urban waterway, that has political, administrative, industry and community support can be a vehicle for transformative change.

In the context of the Parramatta River Catchment Group, the swim in Parramatta River by 2025 mission is one that links socio-economic and environmental frameworks within the concept of a liveable city. The term liveability can be used to encompass all of the things that contribute to quality of life and make a city enjoyable to live in. This includes employability, affordability, community, amenity, accessibility, aesthetics, environmental sustainability and resilience (McCrindle, 2016). While a liveable city may not necessarily always align with biodiversity goals (Dunn et al., 2006; Ives & Kelly, 2016), it can particularly where the natural environment is intrinsically linked to a city's character, such as Sydney.

6. Ecosystem services and socio-ecological systems

Ecosystem services emerged as a framework for ecological functions, dynamics and interactions and their (marginal or incremental) value to the human economy. These draw on accepted ecological economics concepts of natural capital goods (the stock of ecosystem resources) and services (the flow of ecosystem functions). The term 'function' is used in the systems engineering sense of a process, action or task that a system is able to perform, rather than the stricter meaning applicable in mathematics (a relation that associates an input to a single output) or different concept in biology (which relates to natural selection).

Natural capital stocks can accumulate or be diminished (e.g. by natural growth or over-harvesting) over time. Ecosystem services flow from and depend on the capital stock and ecosystem dynamics and include: basic ecosystem building blocks and processes such as geomorphic, soil formation, water source, nutrient cycling, photosynthesis, genetic diversity and habitat/refugia; regulating services such as moderating climate, disturbance, erosion, pollination/reproduction, as well as air and water filtration, regulation of water flows, and carbon sequestration and; material products provided by ecosystems such as raw materials, energy, food and fibre, genetic and ornamental resources (MEA 2005).

Ecosystems, by definition, provide benefits to living organisms. Recognition of the concept of ecosystem functions, services and their economic and other value to modern human society has been notable from the mid-1960s and early 1970s (for example King, 1966; Helliwell, 1969; Hueting, 1970; Odum and Odum, 1972). The analogy to traditional economic goods and services is deliberate: much of this effort attempts to assign meaningful economic value to ecosystems, in order to increase their protection or enhance their management. The value of ecosystem services to the global economy for 2011 was estimated as $125-145 trillion/year in 2007 dollars (Costanza et al 2014).

Despite this, ecosystem services are often 'delivered' and 'consumed' without directly entering the financial economy. For example, a consumer may buy an air-conditioner, but doesn't pay (directly at least) for shade, cooling transpiration or a refreshing breeze. So, these services (and the natural capital stock they depend on) are often ignored or discounted in decision making processes as environmental externalities and thus fall outside the explicit scope of local and regional agency budgets and accounting.

To remedy this, these ecosystem services were incorporated within a decision-making matrix for the management of Sydney by the former Sydney Metropolitan Catchment Management Authority (SMCMA). The SMCMA proposed three categories of ecosystem services 'life-enabling', 'life-supporting' and 'life-fulfilling' (**Figure 8**). The standard typology (De Groot et al 2002) was extended to 39 ecosystem service and social value functions, assigned within the three SMCMA categories and applied to spatial, temporal and functional scales for Sydney and its constituent places which included the Parramatta River catchment (SMCMA 2012, Birtles et al 2013).

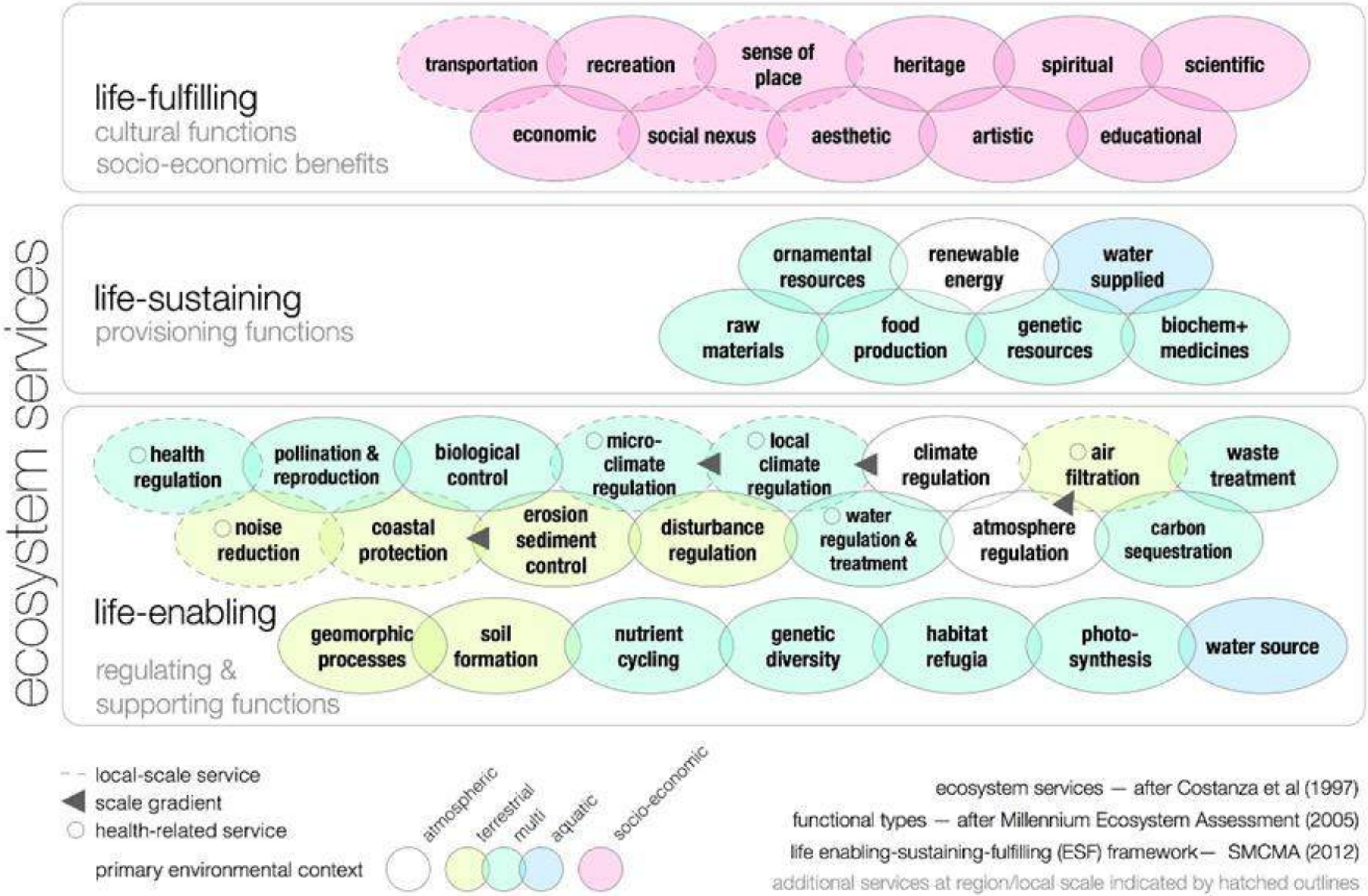

Figure 8: Ecosystem services for the Sydney region (Birtles et al 2013).

A detailed analysis of the selected iconic species in relation to the life-fulfilling activities relevant to Parramatta River catchment is included in **Appendix B**. The specifics of selecting iconic species for this project are discussed below.

In the context of the PRCG goal of a swimmable river, the 'life-fulfilling' elements (which are functions, activities and benefits valued by the human residents of the city) depend on the 'life-enabling' and 'life-supporting' services provided by the ecosystems at various scales. Recreation and aesthetics are provided by clean water and the many functions of catchment vegetation, for example, which in turn depend on underlying biological and geological processes.

The ecosystem services identified by the Sydney regional framework (SMCMA 2012) can be applied directly to the habitat needs of the iconic species identified through this project, and the four land and water 'domains' that inform and impact on the environmental condition of the Parramatta River catchment. These include:

- the estuarine domain including the estuarine reach and embayments of the river,
- the freshwater domain including freshwater creeks and Lake Parramatta,
- the riparian domains including the vegetated transition between zone between water bodies and terrestrial bushland,
- the terrestrial domain including suburban bushland pockets and bushland reserves.

How ecosystem services, iconic species and swimmability are linked can be drawn from the example of the Powerful Owl (which was chosen as an iconic species and features in more detail in following sections of this report).

A community vote nominated the Powerful Owl rather than the complex and biodiverse forest and woodland communities in which it inhabits as being iconic. However, the Powerful Owl can provide a focal point by which the community connects with and perhaps eventually understands the benefits that complex forest/woodland communities have on a river catchment such as the extraordinary positive impact on water quality and flow (and of the profound negative impacts of vegetation clearing).

Despite this, many people will remain oblivious to the connection, and ask 'what have trees got to do with swimming?' A key element to understanding the answer to this type of question is to focus on an icon like the Powerful Owl and teach, trace and engage with the connections from there.

7. What is an iconic species?

Ecosystems are characteristically complex systems that include multiple species and trophic inter-relationships. They are both complicated, with large numbers of diverse elements, and complex, in that relationships between these elements are highly diverse in both temporal and spatial scales. The selection of any species to represent an entire system, whether undertaken by an ecologist or the community, will be faced by insufficient and inadequate data on the species at spatial, temporal and functional scales. For this reason ecologists have developed a suite of terms used to describe the role and function of a species, be it an icon, keystone, indicator, flagship, umbrella or as an apex predator (Barua 2011, Verissimo et al 2011) (**Table 4**).

In this report, iconic species are used as a simplified and tangible representation of complex ecosystem concepts. It can apply to either an animal, plant or ecological community that has social or cultural importance. It is through this socio-ecological lens that the community play the primary role in identifying the icons, rather than the ecologists. The ecologist role is to understand how the iconic species relates to the urban environment and how its needs can be serviced or provided by changes to the catchment and waterways. Iconicity of species is conventionally identified by their inclusion in traditional activities such as local cultural or religious practices and/or local or wider recognition of their existence and aesthetic values. Species may be iconic not only to people interacting with them regularly or directly, but also to those who live farther away. They may see them infrequently, or not at all, but still derive a sense of identity or value from knowing that such species exist. Species used exclusively for economic reasons are not key criteria, but economic value doesn't exclude species that are also culturally significant.

As this selection of the iconic species is one driven by community and cultural processes, it also stands to reason that the term iconic species can itself be changed if another word or phrase has greater resonance, such as 'mascot'. What is of most importance is how the species can be used to inspire transformation change to how the catchment and water systems are planned and managed.

Table 4: Common terms used to describe species and their socio/ecological roles

iconic species	animals, plants or ecological communities that are recognisable or important to cultural identity
keystone species	critically located at the foundation of their ecosystem, loss of these species results in significant ecosystem degradation or collapse
indicator species	selected as a means of identifying tipping points or measuring ecosystem condition
flagship species	chosen as icons for conservation programs
umbrella species	where positive management is likely to benefit a wider range of biota
apex predator	located at the top of the ecosystem food chain

For the purpose of community engagement to select the final set of iconic species (described below) the term 'mascots' was used in PRCG communications via web and live events. This usage refers to the 'iconic species' described in this report (despite the more limited scope of 'mascot' as a semantic signifier).

Selecting the iconic species

A four-stage process was applied to determining which species are iconic to the Parramatta River catchment.

Stage 1. A desktop review of Council and community group websites was undertaken to identify potential species of interest (**Figure 9**). This review examined groups that had a particular or singular focus on a species, such as a bat, or had a more general interest in the environment and being in contact with nature, such as bushwalking clubs. Approximately 55 active community groups or community activities were found to be operating across the Parramatta River catchment. Of these, approximately 50 have a bushland focus, with the remaining a mix of fishing, wetland protection, bird watching and water quality focused groups (**Appendix C)**.

For this study, iconic species of the Parramatta River catchment have been identified as species that are of direct or indirect interest to environment-focused community group activity.

The short list of potential iconic species was divided to represent several ecological domains that describe the primary environment/habitat in which each species is most commonly found: described as *terrestrial, riparian, freshwater* and *estuarine* domains (the latter dividing the broader aquatic domain used initially). These domains correspond to the socio-ecological systems 'urban bushland reserves/urban with bushland pockets', 'urban freshwater creeks' and 'estuaries, bays and lagoons' respectively (**Figure 9**).

Stage 2. A desktop review of threatened species records (BIONET 2016) from across the catchment was undertaken. A number of threatened species with links to swimmability were identified as potential icons.

Stage 3. A short list of species and communities or assemblages were presented to the PRCG and their links to swimmability illustrated (**Figure 9**). The PRCG also consulted a panel of experts and community representatives. In consultation with PRCG the short list presented in **Figure 9** was reduced to 19 species (discarding consideration of communities or assemblages as icons) and were listed for popular vote to select iconic species for the Parramatta River catchment. Communities or assemblages were not included, as it was considered that each individual species would act as representative of its community or assemblage. Appendix F lists the primary domain, secondary domains, community and habitat requirements for the 19-candidate species (the five selected by poll are indicated in bold). The table also details the links to a swimmable Parramatta River in each case.

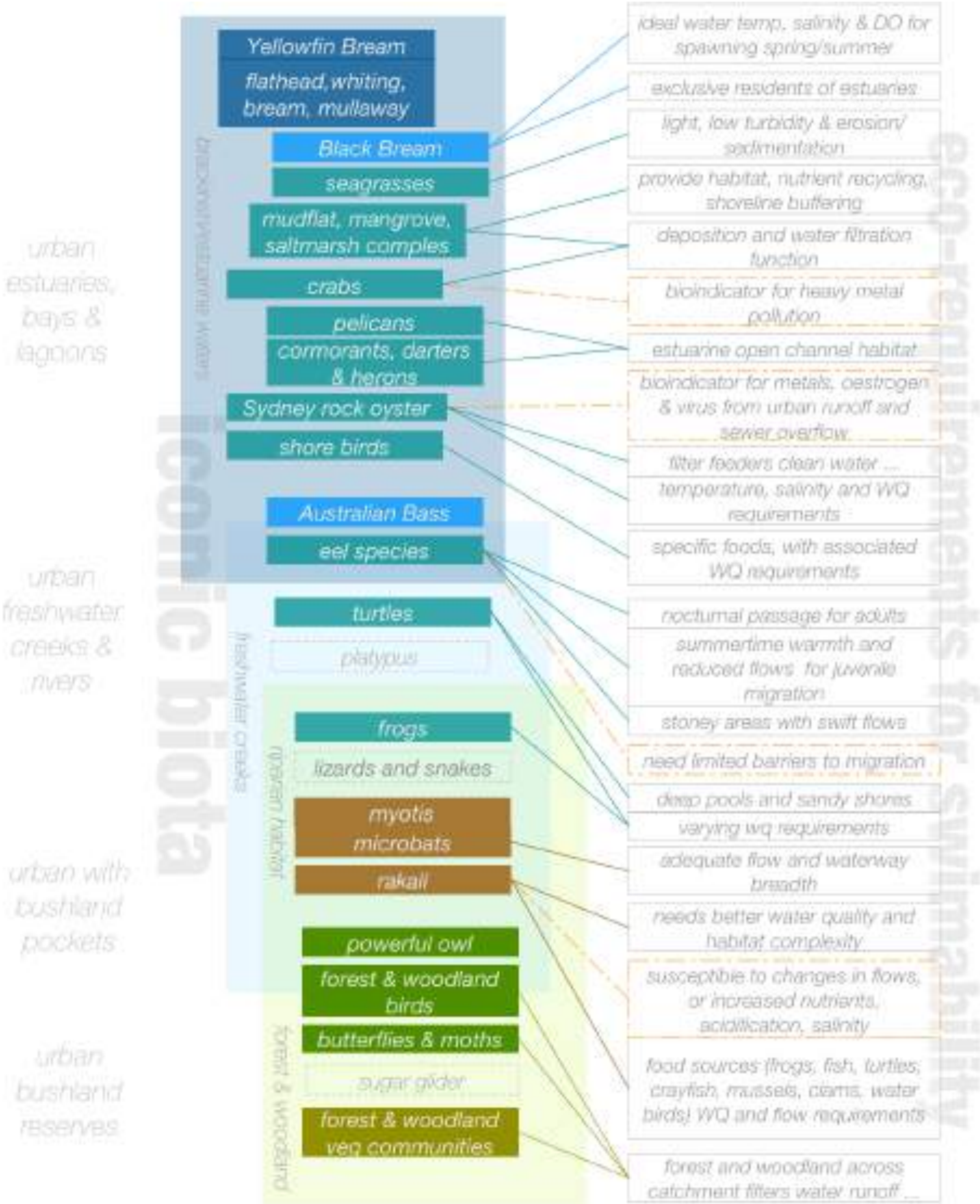

Figure 9: short listed iconic species, assemblages and communities with their socio-ecological systems (left) biomes (centre) and, ecological requirements (right) that contribute to swimmability.

Stage 4. Public voting on the species was carried out via an online voting portal. Participants were asked to vote for their favourite species. Voting was open for three weeks during which time nearly 5000 votes were tallied (**Appendix E**). This resulted in the selection of five species. This involved a popular choice for each of the four domains plus an additional species in the freshwater domain.

Each species represented an ecological domain:

- Powerful Owl (*Ninox strenua*) inhabiting terrestrial forest and woodland;
- Southern Myotis (*Myotis macropus*) or Fishing Bat inhabiting the riparian zone;
- Bar-tailed Godwit (*Limosa lapponica*) foraging along the estuarine foreshore;
- the Eastern Long-necked Turtle (*Chelodina longicollis*) and the ubiquitous Striped Marsh Frog (*Limnodynastes peronii*), inhabiting freshwater creeks and wetlands.

8. Iconic Species for Parramatta River Catchment

The five iconic species represent environmental domains of terrestrial to aquatic habitats, and the species assemblages or relevant communities they form part of. Sections 9-12, describe each of the five-iconic species: Powerful Owl, Southern Myotis, Eastern Long-necked Turtle, Striped Marsh Frog and Bar-tailed Godwit. Their presence within and throughout the Parramatta River catchment reflects their cultural and social relevance. Importantly the habitat and needs of these species requires a healthy ecosystem which in turn provides the ecosystem services that can create a swimmable Parramatta River.

A literature review of (peer-reviewed) academic journals and government resources was conducted to understand the specific environmental and ecological conditions for each species to maintain a viable population within the urban landscape. Quantitative limits or ranges of particular conditions have been determined as minimum requirements to maintain viable populations and communities. Where this has not been possible, due to a lack of scientific certainty or knowledge, qualitative statements are provided on the environmental and ecological requirements.

The environmental and ecological requirements of the iconic species are characterised by synergistic (positive) links and antagonistic threats or pressures (often a result of urbanization). These natural and human threats and pressures are mapped to the habitat of the species and in turn to how this influences swimmability of the river (**Figure 10**). Trophic (food chain) links are delineated between the iconic species, its specific foods, and the supporting habitat. Ecosystem services in the social domain and related human activites are also included. This simplified model is applied to each species as illustrated in **Figures 13, 15, 17, 19 and 21**.

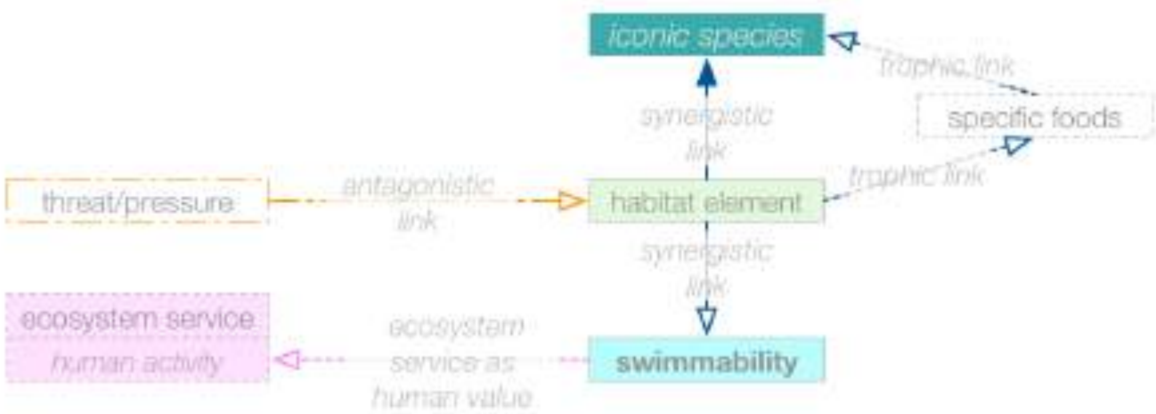

Figure 10: Basic diagram schema for species web diagrams (Figures 13, 15, 17, 19 and 21).

Following the iconic species profiles, recommendations for their management are discussed. While the iconic species are not specifically chosen as *umbrella species*, management interventions are likely to have benefits across the applicable domains, and for the river system itself. Based on the information presented in this study, the recommendations have been made to protect, enhance and restore habitat of the nominated iconic species or mascots. These recommendations are likely to have broader ecosystem outcomes for many other flora and fauna species across the catchment.

The iconic species identified and described have ecological and environmental requirements that they rely on to maintain viable communities. Common requirements across all icons of the Parramatta River catchment relate to complex habitat features, reliable food resources and regulated stream hydrology. Therefore, the recommendations made for each iconic species are based around the approach of habitat protection, management and creation.

9. Terrestrial Domain

Powerful Owl (*Ninox strenua*)

Domain – *terrestrial*, Community – *Woodland and Forest Birds*

Conservation Status

Commonwealth– Not listed; NSW - Vulnerable

Distribution

The Powerful Owl is endemic to eastern and south eastern Australia and is a locally iconic species. It is the largest owl in Australasia and adults can grow up to 60cm in length often with a wingspan of 140cm and has an approximate lifespan of up to 10 years (OEH 2016, NSW Scientific Committee 2008).

The Powerful Owl is distributed across a relatively small area east of the Great Dividing Range stretching from Mackay in Queensland to the south west of Victoria as a single continuous population (OEH 2016 and NSW Scientific Committee 2008). Within New South Wales the Powerful Owl is found widely distributed throughout remaining pockets of forest from the coast to the tablelands, with some scattered sightings through the western slopes and adjoining western plains (OEH 2016). Most records for the Powerful Owl within the Parramatta River catchment are located in the north-west portion where suitable forested habitat remains (OEH 2016) (**Figure 11**).

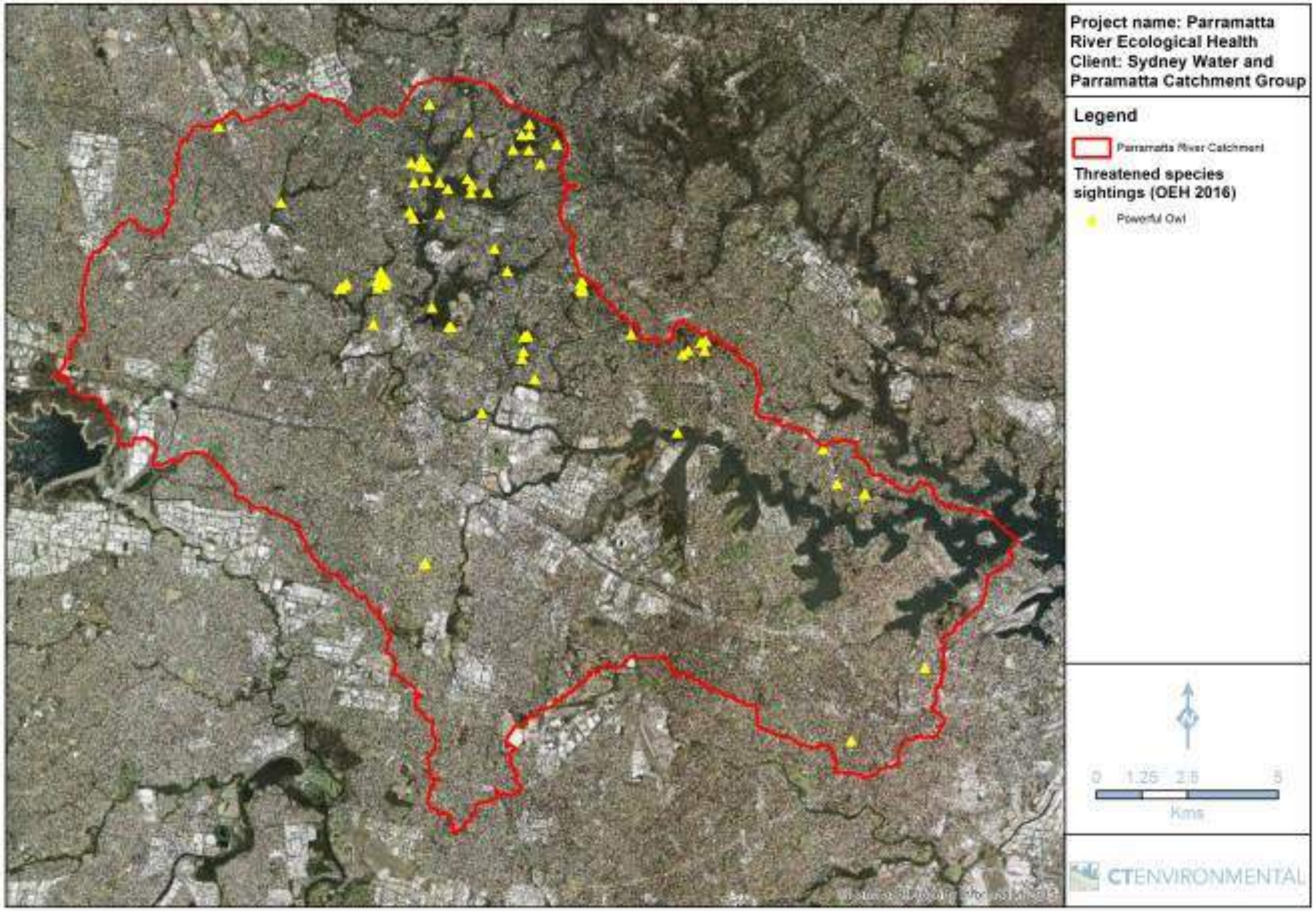

Figure 11: Recorded occurrences of Powerful Owl (*Ninox strenua*) within Parramatta River catchment (OEH 2016).

Reproduction

Powerful Owls are monogamous and mate for life. Breeding usually occurs from late summer to mid-winter with an approximate incubation time of 38 days (NSW OEH 2016 and NSW Scientific Committee 2008).

Habitat Requirements

- The Powerful Owl will inhabit hollows in a range of habitats from temperate rainforest, open tall wet forests and eucalypt forests, to woodland and sclerophyll forests (Soderquist and Gibbons, 2007).
- Breeding is supported by large living or dead trees often with a “breast height diameter” between 80 and 120 cm and over 150 years old (NSW OEH, 2016). Large tree hollows within mature sized eucalypts, living or dead are used for nesting. Trees hollows need a minimum depth of 0.5m.
- Breeding and hunting most often occurs in open or closed sclerophyll forests or woodlands, with occasional hunting in open habitats.
- The Powerful Owl will roost by day in trees with thick canopies such as Turpentine, She-oak, Blackwood, Rough-barked Apple several Eucalypt species.
- Owls prefer approx. 200m buffer of sufficiently dense vegetation to protect the nesting site and provide roosting cover from harassment by small birds particularly the Noisy Miner (*Manorina melanocephala*) during the day.
- Many of these habitats are directly dependant habitats for the Powerful Owl’s common prey sources as well (NSW OEH 2016 and NSW Scientific Committee 2008).
- Within healthy habitats, the Powerful Owl can reportedly survive within a territory of approximately 400ha. In fragmented habitats, such as occur in the Parramatta River catchment and cleared lands where tree hollows are depleted, up to 4000 ha may be required to find ample prey sources (NSW OEH 2016 and NSW Scientific Committee 2008).

Food Requirements

The Powerful Owl is a skilled hunter with prey varying depending on habitat.

- They predominantly feed on medium sized arboreal marsupials, particularly the Common Ringtail Possum, Sugar and Greater Gliders (Olsen et al 2011; Kavanagh 2002a, Fitzsimons and Rose 2010).
- Other prey items such as flying foxes, rats, birds and even domestic cats have been documented as food sources for the Powerful Owl (Kavanagh 2002a, NSW OEH 2016 and NSW Scientific Committee 2008, McNabb & Greenwood 2011; Menkhorst et al 2005).

Threats

Several threats are described by the NSW OEH (2016) and the NSW Scientific Committee (2008) including:

- Habitat loss through land clearing, agricultural practices and urban development fragments.
- A decline in Greater Glider populatios, the main prey source of the Powerful Owl, which impacts on the natural home range habitat.
- Loss of large hollow bearing trees, which both the Powerful Owl and its prey sources depend on.
- Inbreeding caused by fragmented habitat impacting juvenile dispersal ranges, which can be up to 18km.
- High frequency hazard reduction may affect prey availability.
- Insensitive removal of invasive weed species by land managers when restoring native habitat such as broad scale weed tree eradication (McNabb and McNabb 2011).
- Disturbance during the breeding season, especially near nesting sites can be detrimental to breeding success.
- Predation of fledglings by dogs, cats and foxes (OEH 2016 and NSW Scientific Committee 2008).

Habitat management

A schematic diagram summarizing ecological requirements, threats and link to swimmability is illustrated in **Figure 12**. The recommendations to maintain this species is outlined below. The primary focus must be the retention of large connected areas of native vegetation. These areas provide habitat, shelter and food and deliver ecosystem services including management of nutrients and runoff that can lead to cleaner water for the Parramatta River. Implementing the recommendations will also provide significant beneficial outcomes for other terrestrial and aquatic species which rely on similar habitat characteristics as the Powerful Owl such as the woodland/forest bird communities, arboreal mammals, microbats and flying foxes.

The schematic diagram (**Figure 12**) can be used to trace trophic, synergistic and antagonistic links, and relationship to human values provided by iconic species (refer to legend at **Figure 10**). For example, the Powerful Owl needs dense canopy cover for roosting and foraging, and large hollow-bearing trees for breeding. Complex vegetation also supports the owl's specific foods: possums, gliders and flying fox. The same vegetation cover provides the link to a swimmable river, regulating flows and filtering nutrients and sediment to provide clean swimmable water.

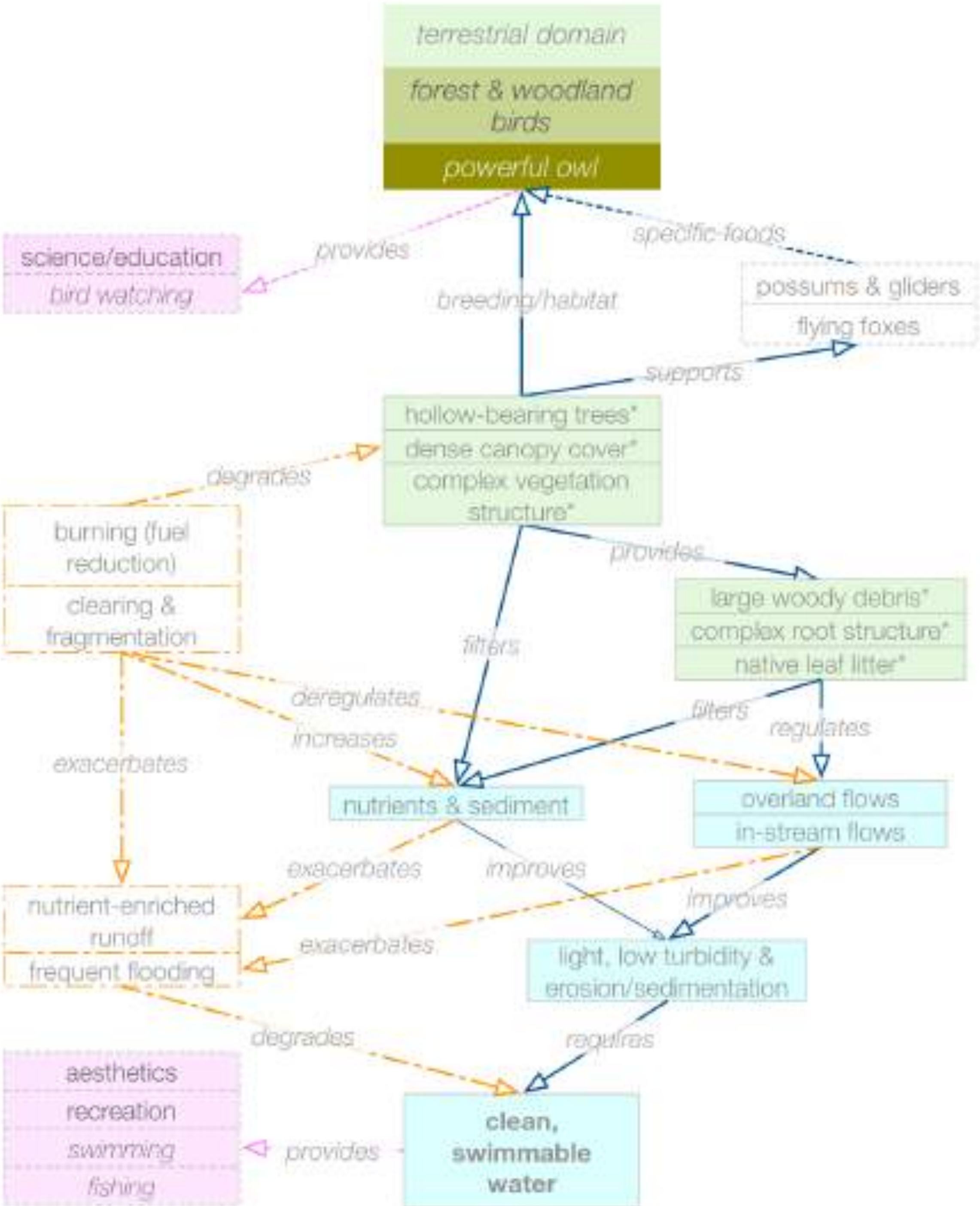

Figure 12: Schematic ecological requirements and threats for Powerful Owl (*Ninox strenua*) and links to swimmability.

Recommendations

Habitat Protection

1. ***Protect and manage patches of native vegetation with dense riparian and gully vegetation and large canopy trees***. This habitat provides Powerful Owls with important roosting and nesting sites and supports prey species. **Figure 13** highlights core Powerful Owl habitat (yellow square) and areas which may be considered for ongound works to expand potential habitat for both Powerful Owl and prey species.

2. ***Protect areas with known populations of Powerful Owls and important prey species by incorporating core areas into biodiversity offset schemes such as BioBanking.*** Areas within the north west of the catchment have been identified by this study as core habitat for the Powerful Owl due to the density of species records, density of arboreal mammal records and the presence of larger tracts of native vegetation in good condition (**Figure 13**). These areas are recommended for maintaining and improving Powerful Owl habitat as these are known to be inhabited by the species, have established and suitable habitat, contain numerous records of prey species and are contiguous with Powerful Owl records form the neighbouring Land Cove River catchment. PRCG and stakeholders should investigate the feasibility of incorporating core areas into the NSW biobanking scheme which would provide a level of conservation status and potential management funding to ensure the biodiversity values within these areas are appropriately managed.

3. ***Protect mature trees in urban areas.*** Application of tree preservation and protection measures is recommended to maintain a network of habitat trees across the urban landscape. This would include listing and enforcing tree preservation orders on private land and public land.

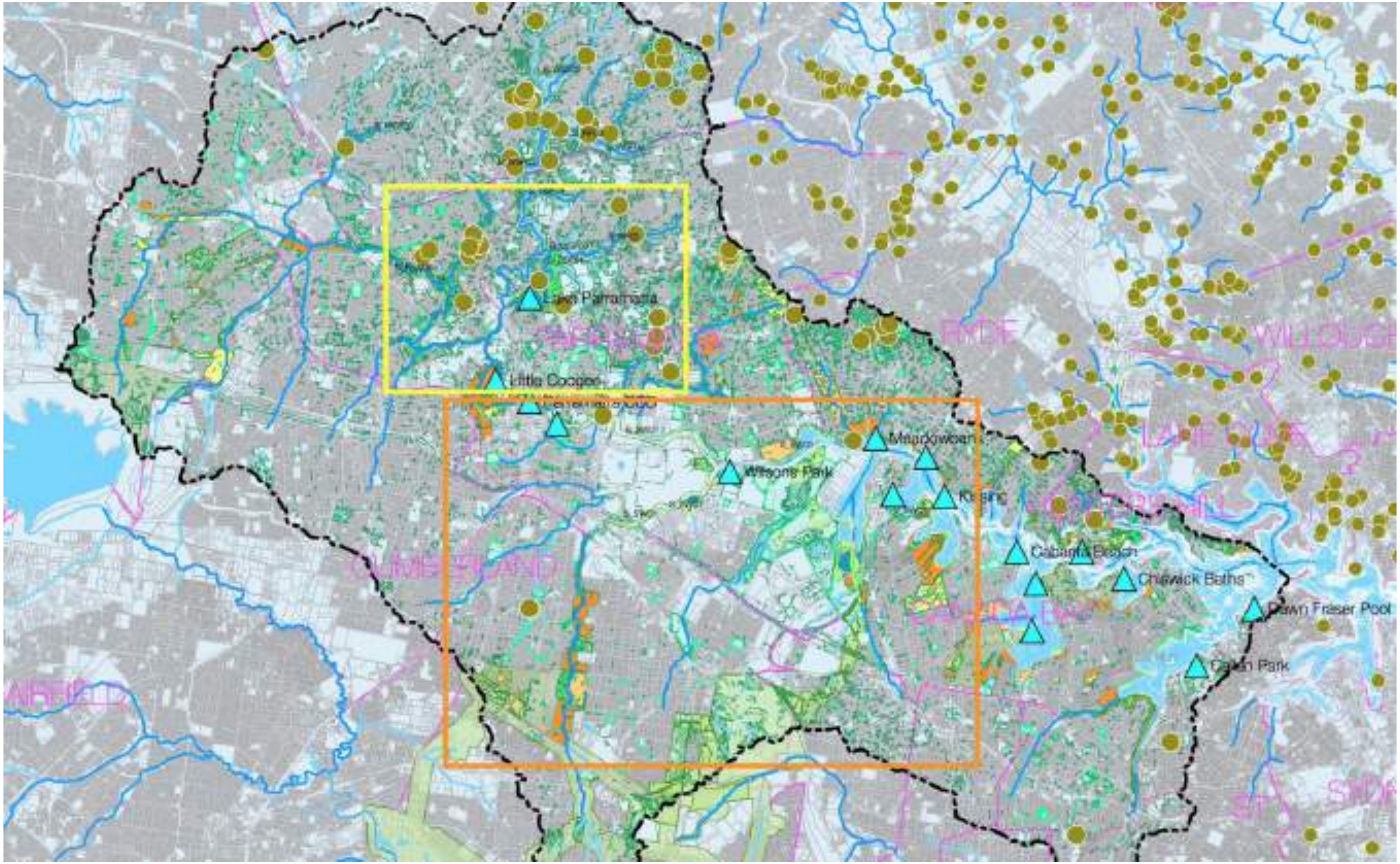

Figure 13: Recorded observations of Powerful Owl (olive circles). Yellow rectangle indicate area covered by Figure 15; orange rectangle indicates that covered by Figure 19. Blue triangles denote location of potential swimming sites.

Habitat Management

1. ***Manage and create Powerful Owl and prey species habitat by revegetating riparian and bushland areas with dense canopy vegetation***. Revegetation and restoration of urban bushland to enhance Powerful Owl habitat should have dual focus to provide/maintain/enhance suitable Owl habitat and to provide/maintain/enhance suitable habitat for arboreal mammals, in particular habitat of the Ringtail Possum (*Pseudocheirus peregrinus)* which is the preferred prey species of the Powerful Owl.

   Ringtail Possums prefer dense stands of vegetation in which they forage and constructs dreys (like a nest) for sleeping. Revegetation of riparian and bushland areas should include dense plantings of native canopy trees to provide habitat for both the Powerful Owl (as roost sites) and habitat for prey species. **Figure 14** shows an example of a densely revegetated riparian corridor from the nearby Cooks River catchment (planted circa. 2010).

   Care is required planning and executing revegetation projects. In urban areas, exotic species – including Privet and Lantana – may provide the dense cover function that owls and other woodland bird species need to shelter from aggressive smaller birds like the Noisey Miner. Dense stands of Privet in riparian zones and gullies is likely to provide roosting habitat for Powerful Owls and therefore Native bush regeneration and revegetation should be staged to maintain sufficient dense cover.

Figure 14: Example of dense riparian plantings to provide roost habitat for Powerful Owls and preferential habitat for Ringtail Possums, the preferred food source of Powerful Owl.

2. ***Manage bushland areas to maintain the presence of large hollow bearing trees in natural areas***. Powerful Owls prefer hollows more than 8-10 m from the ground with an entrance of approximately 50 cm and a depth of more than 50 cm. Hollows generally develop in trees 100-150 years old, and trees with many hollows of this size can be up to 350 -500 years old. Core areas that are likely to provide suitable sized nesting trees are identified in **Figure 15**. These trees should be identified and protected where possible from adverse outcomes associated with hazard reduction burning or clearing for the maintenance of fire trails and utilities.

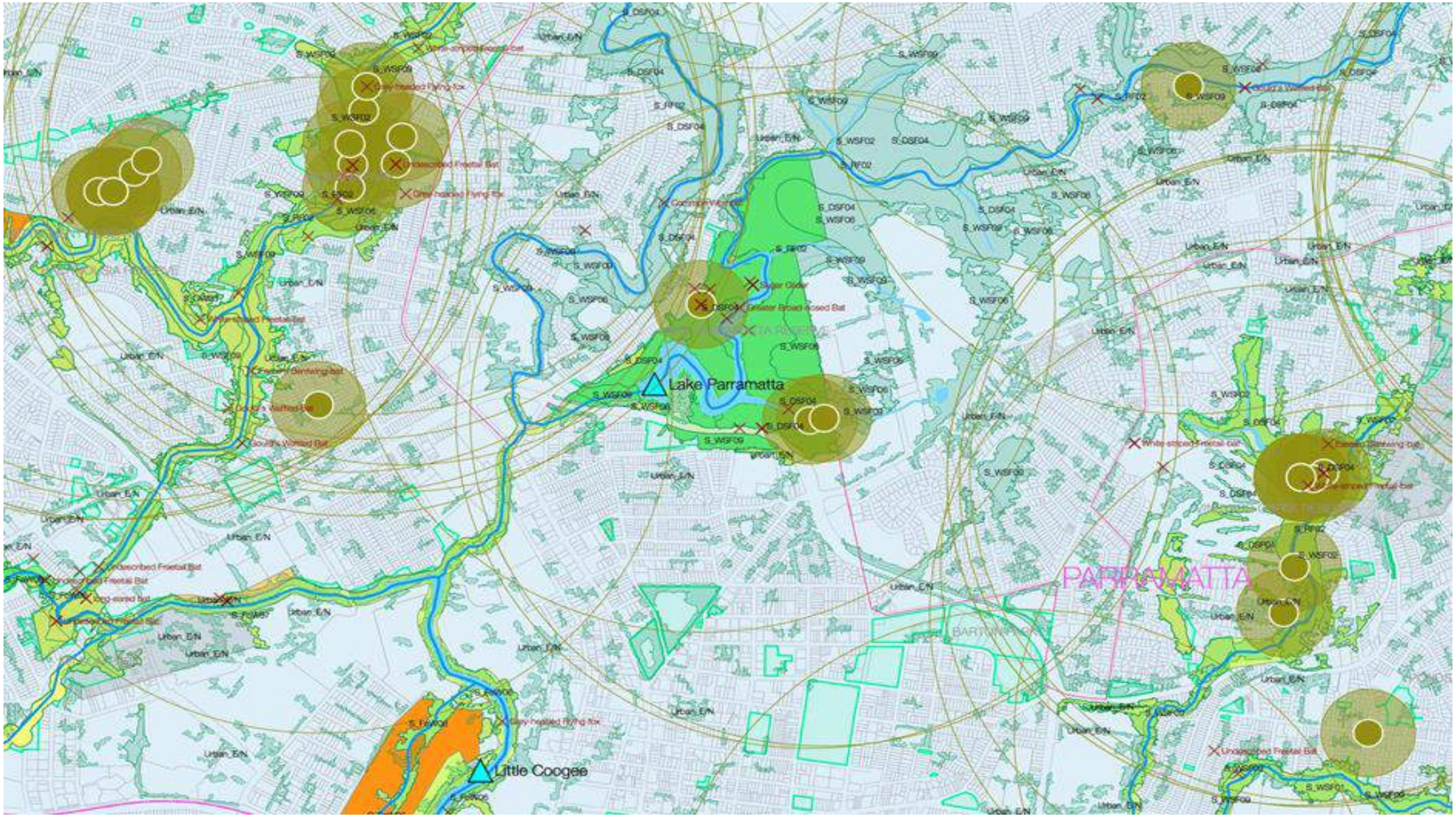

Figure 15: Recorded observations of Powerful Owl (olive circles) and prey species (crosses) within the forested gullies in the north-western catchment area are more frequent than in areas lacking well-structured vegetation or sufficient riparian buffer width (native vegetation indicated light blue-green, corridor/reserve areas in good condition green, fair condition yellow, poor condition orange). Note owl records are shown with 200m buffer (olive fill) representing preferred vegetation buffer for roosting and nesting, and 1700m buffer (outline only) representing notional foraging radius in moderate habitat condition (per Bilney 2013 and OEH 2006). Blue triangles denote location of potential swimming sites.

Habitat Creation

1. ***Create artificial habitats by forming artificial hollows and re-standing of dead trees.*** This can involve transforming trees identified for removal to provide an artificial habitat that would otherwise be removed (Sydney Arbour 2016) (**Figure 16**) or re-standing dead hollow bearing trees. This approach has been applied to mine site rehabilitation whereby large trees that have been cleared due to mining operations are stockpiled and re-stood in areas undergoing rehabilitation. To ensure stability, a hole is dug in which 30% of the dead tree is buried, leaving 60% of the tree above ground, providing instant habitat (*pers comm*, Werris Creek Coal 2016) (**Figure 17**).

Figure 16: Interior view of artificial hollow (left) and exterior view of artificial hollow with recapped front plate (right). Note; the images show hollows for smaller animals, however this approach can be scaled up to provide hollows of appropriate size for Powerful Owls.

Figure 17: Example of hollow bearing trees re-stood as part of mine rehabilitation activity.

2. ***Create multiple revegegation/landscaping options to improve habitat***. Installation of artificial hollows and standing dead trees should be combined with dense understory and canopy vegetation plantings ensuring habitat creation for both Powerful Owl and prey species. Careful installation and landscape planning is necessary, in accessible recreation areas and other locations with frequent human activity. Re-stood dead tree locations should be combined with dense understory and canopy plantings to recreate forest habitat and proximity to walking tracks excluded to a radius exceeding the height of the trunks as to mitigate against injury in the event a re-stood tree falls.

   Alternately areas with little human activity or within the core revegetation areas unlikely to experience significant human visitation such as in bushland reserves or private property may be readily utilised. When combined with dense riparian and understory revegetation this approach provides an accelerated method of creating complex habitats that have the potential to fulfil the ecological requirements of many native species.

3. ***Create habitat through the Sydney Green Grid to support movement within and between catchments***. Expand habitat trees through strategic planting programs, such as Green Grid. This should enhance existing corridors to the north and build corridors to the south and western parts of the catchment Opportunity may exist to expand the range of the Powerful Owl to other parts of the catchment, such as the southern side of the Parramatta River where records indicate limited sightings have occurred and opportunity may exist to connect the northern Parramatta Owl habitats with the habitats found further south in the Cooks River Catchment. However, to expand the range, suitable habitat including roosts, nesting hollows and viable numbers of prey species are required (McNabb and Greenwood 2011).

Improving connectivity and vegetation structure and providing habitat in areas with strategic corridor potential is also recommended. While sightings (within the catchment) are relatively sparse south of the Parramatta River, PRCG's Native Habitats and Fauna Study (Applied Ecology 2015) documents an inventory of potential corridors and corridor enhancement work. Habitat connection may also be possible between the Parramatta River and Cooks River populations.

For the Powerful Owl, there may be potential to provide connectivity between the main river corridor and the more extensive bushland areas to the south. This is illustrated in **Figure 18**. For highly mobile avifauna, 'corridors' may be supplemented or flanked by bushland patches and pockets, and individual large trees. In urban/suburban landscapes idealized connectivity may be an aspirational or longer-term goal. Consequently, attention to iconic species and prey requirements may necessarily be flexible and opportunistic.

Figure 18: Recorded observations of Powerful Owl (olive circles) and prey species (crosses) along the Olympic Park foreshore and north-south corridors: Owl records are sparse but owl habitat may be improved via corridor vegetation enhancement (yellow and orange areas are corridor parcels which lack well-structured native vegetation) and provision of nesting hollows. Blue triangles denote location of potential swimming sites.

Detailed information on artificial hollows and next boxes for Powerful Owls and other fauna and recovery plan for the Powerful Owl can be found in;

1. McNabb and Greenwood (2011) A Powerful Owl Disperses into Town and Uses and Artificial Nest Box. Australian Field Ornithology, 28, 65-75.
2. Greater Sydney Local Land Services (2015) Hollows for Habitat Forum Proceedings, Sydney 20th May 2015.
3. Department of Environment and Conservation (2006) NSW Recovery Plan for Large Forest Owls Powerful Owl (*Ninox strenua*), Sooty Owl (*Tyto tenebricosa*) and Masked Owl (*Tyto novaehollandiae*)

Table 5: Management recommendations summary table for Powerful Owl and link to swimmable river.

Domain/System	Species	Ecological Requirements	Threats	Recommendation	Link to swimmable River
Terrestrial *Urban bushland reserves* *Urban with bushland pockets*	**Powerful Owl** *Ninox strenua*	**Habitat** Home ranges of between 400-4000 ha. Intact forest and woodland with large trees, dead or alive. A preference for nesting hollows more than 8-10 m off the ground with an entrance diameter of approximately 50 cm and a depth of approximately 80 cm. Dense riparian and gully vegetation for roosting and hunting **Food** possums, gliders, flying fox, occasional large birds	Habitat loss through land clearing, agricultural practices and urban development. Loss of large hollow bearing trees that both Powerful Owl and prey species depend on for domicile and breeding. Fragmented habitat increases inbreeding and weakens genetic diversity by constraining juvenile owl dispersal ranges. High frequency hazard reduction burns may affect prey availability. Insensitive removal of invasive weed species (such as broad scale weed tree eradication) by land managers when maintaining aesthetics or restoring habitat. Disturbance during the breeding season, especially near nesting sites. Predation of fledglings by dogs, cats and foxes.	***Manage*** patches of native vegetation with dense riparian and gully vegetation and large canopy trees. ***Protect*** areas with known populations of Powerful Owls and important prey species by incorporating core areas into biodiversity offset schemes such as BioBanking. ***Protect*** the presence of large hollow bearing trees in natural areas. ***Protect*** mature trees in urban areas for the habitat of owls and their prey. ***Create*** Powerful Owl and prey species habitat by revegetating riparian and bushland areas with dense canopy vegetation taking care when replacing exotic species that also provide dense cover. ***Create*** artificial habitats by forming artificial hollows and re-standing of dead trees ***Create*** and expand habitat through the Sydney Green Grid to support movement within and between catchments.	Dense terrestrial vegetation regulates overland flows and provides surface resilience, inhibiting gully and stream-bank erosion. Vegetation filters diffuse sediment and pollutants generated and carried by overland flows before they enter waterways, mitigating degradation of water quality. Fully structured vegetation optimally enhances the quality of urban green space by providing microclimate control, aesthetics and pleasant recreational areas for the community.

10.Riparian Domain

Southern Myotis (*Myotis macropus*)

Domain – Riparian, Community – Microbats

Conservation Status

Commonwealth - Not listed; NSW- Vulnerable

Distribution

The Southern Myotis is one of two endemic Australian species of fishing bats (Law and Anderson 1999). It occurs along coastal and sub-coastal areas extending from the northern Kimberly Coast, Western Australia (Australian Department of Environment 1999, Menkhorst and Knight 2010, Atlas of Living Australia 2016), along the eastern seaboard from south-east Queensland to Victoria and into South Australia and along the River Red Gum Forests of the Murray (Law and Urquhart 2000, NSW Office of Environment and Heritage 2015) and Murrumbidgee Rivers (NSW Office of Environment and Heritage 2015). Although having a wide habitat range its distribution is patchy depending on the suitability of the habitat (Lumsden and Menkhorst 1995). It is possible the species has declined along inland waterways, especially across southern New South Wales (Australian Department of Environment (1999). Records of the Southern Myotis within the Parramatta River catchment are concentrated around Sydney Olympic Park and a small number of sites within the north-west of the catchment (**Figure 19**). The lack of formal records for the species (within BIONET) is likely due to the combination of its natural rarity, small size, nocturnal habits and lack of a historical survey.

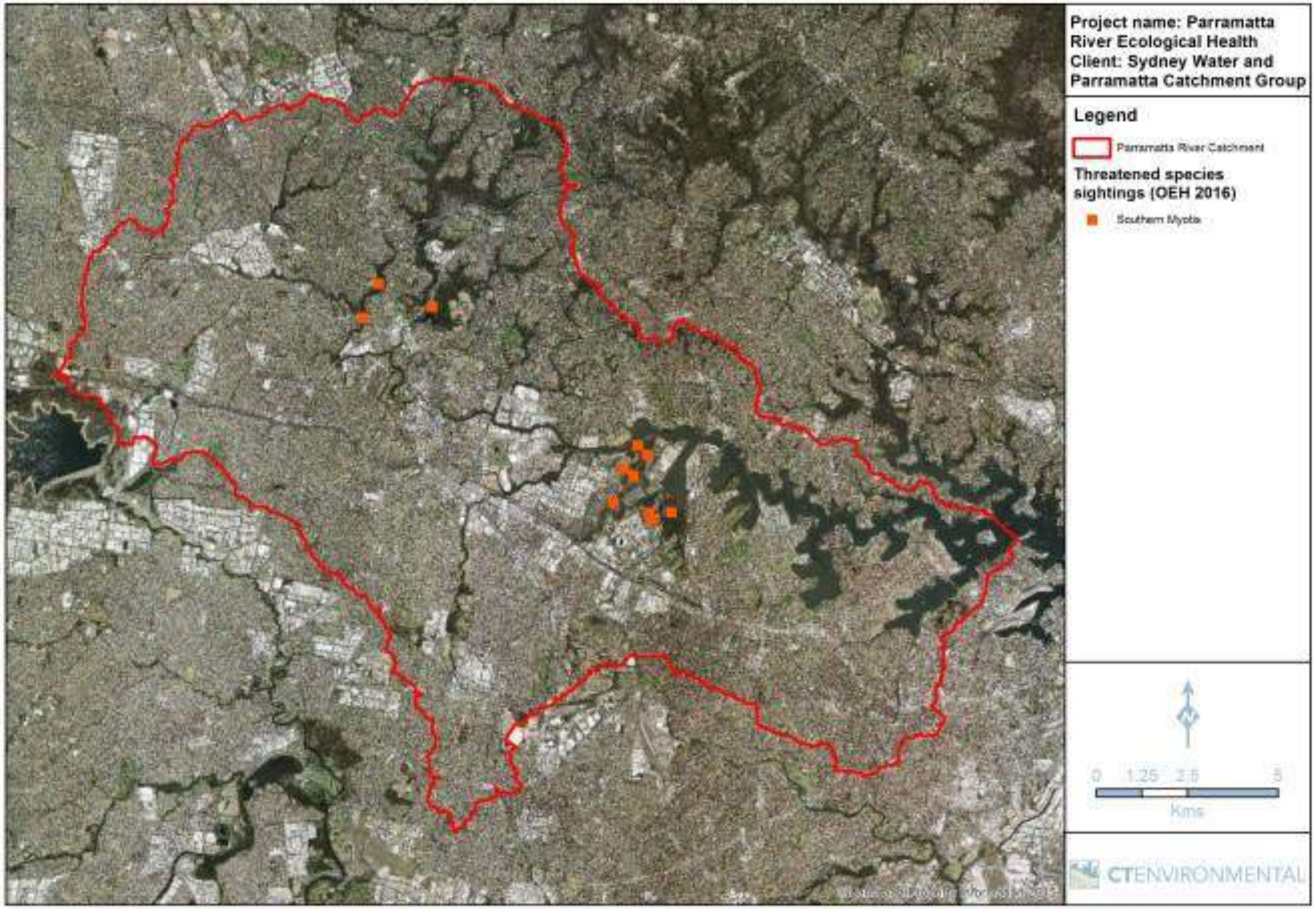

Figure 19: Recorded occurrences of Southern Myotis (*Myotis macropus*) across Parramatta River catchment.

Reproduction

Adults roost in tree hollows, bridge culverts, caves, mineshafts and dense foliage where they can produce up to three offspring per year (Menkhorst and Knight 2010) however species in NSW tend to produce one offspring per year which is born between November and December (NSW Office of Environment and Heritage 2015).

Habitat Requirements

- Riparian habitats are preferred by this species (Law and Anderson 1999).
- Roosts naturally in caves, tree hollows and dense vegetation near bodies of slow-flowing or still water (including estuaries) and utilises aqueduct tunnels, mines, road culverts and bridges as artificial roosts (Law and Anderson 1999, Australian Department of Environment 1999, Menkhorst and Knight 2010, NSW Office of Environment and Heritage 2015).
- Some populations roost exclusively in tree hollows in partly submerged dead trees and in live trees close to the water (Caddle 1998).
- Is likely to be vulnerable to changes in water quality, eutrophication and altered flow regimes due to the effects these factors have on prey species (Law and Anderson 1999, Australian Department of Environment 1999, NSW Office of Environment and Heritage 2015).

Food Requirements

- Exclusively forages over water (rivers, streams, dams) for aquatic prey in a variety of forest types (Law and Urquhart 2000, Australian Department of Environment 1999, NSW Office of Environment and Heritage 2015).
- 99% of prey species are associated with aquatic environments. Fish account for only 1% of prey (Law and Urquhart 2000).
- Species is reliant on up to 10 taxonomic groups for prey which include Diptera, Tricoptera, Corixidae, Gerridae, Gyrinidae, Coleoptera, aquatic insects and fish (Law and Urquhart 2000).
- Most prey species are air breathing aquatic insects (Law and Urquhart 2000).

Threats

- Loss or disturbance of roosting sites through vegetation clearing (NSW Office of Environment and Heritage 2016, Environment Australia, 1999)
- Clearing of foraging areas (NSW Office of Environment and Heritage 2016, Environment Australia, 1999)
- Prey species are susceptible to changes in water quality which result from vegetation clearing, sewage, pesticide and herbicide run-off (Law and Urquhart 2000, NSW Office of Environment and Heritage 2016, Environment Australia, 1999). The majority of prey species do not require pristine aquatic conditions however many are vulnerable to changes in altered flow and declining water quality, linked to urabanisation (Law and Urquhart 2000, Chessman 1995, NSW Office of Environment and Heritage 2015, NSW Office of Environment and Heritage 2016, Environment Australia, 1999)

Habitat Management

A schematic diagram summarizing ecological requirements, threats and link to swimmability is illustrated in **Figure 20**. The recommendations to maintain the presence of this species are outlined below. Implementing the following recommendations will also provide beneficial outcomes for other terrestrial and aquatic species which rely on similar habitat characteristics as the Southern Myotis such as the woodland/forest bird communities, arboreal mammals, other species of microbats, flying foxes, reptiles, frogs and native fish species such as Australian Bass (*Macquaria novemaculeata*).

Figure 20 can be used to trace trophic, synergistic and antagonistic links, and relationship to human values provided by iconic species (refer to legend at **Figure 10**). For example, the Myotis needs small hollows or other shelter for roosting and breeding, and slow moving open water for foraging. Waterways and complex riparirian vegetation support the Myotis' specific foods: air-breathing aquatic insects. The same vegetation cover provides the link to a swimmable river, moderating flows and protecting creek channels from erosion to help provide clean swimmable water.

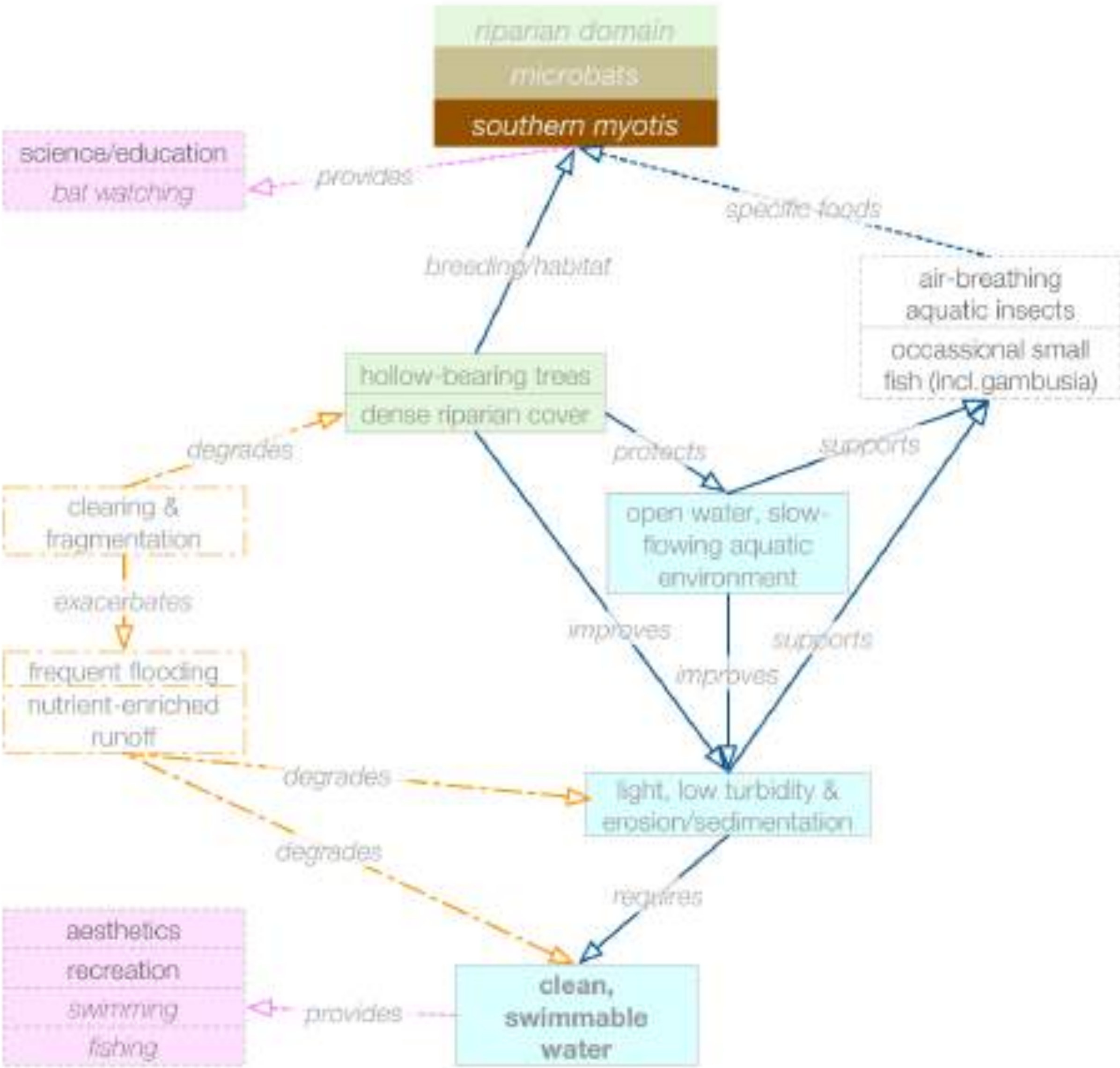

Figure 20: Schematic ecological requirements and threats for Southern Myotis (*Myotis macropus*) and links to swimmability

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Recommendations

Habitat Protection

1. ***Protect and manage patches of native vegetation with dense riparian and gully vegetation and hollow bearing trees.*** This habitat provides the Southern Myotis with important roosting sites and flyways for hunting over aquatic habitat. Areas near Lake Parramatta and Sydney Olympic Park have been identified by this study as core habitat for the Southern Myotis due to the density of species records (**Figure 21**). Areas highlighted in **Figure 21** are recommended for maintaining and improving Southern Myotis habitat as these areas are known to be inhabited by the species and have established and suitable habitat.

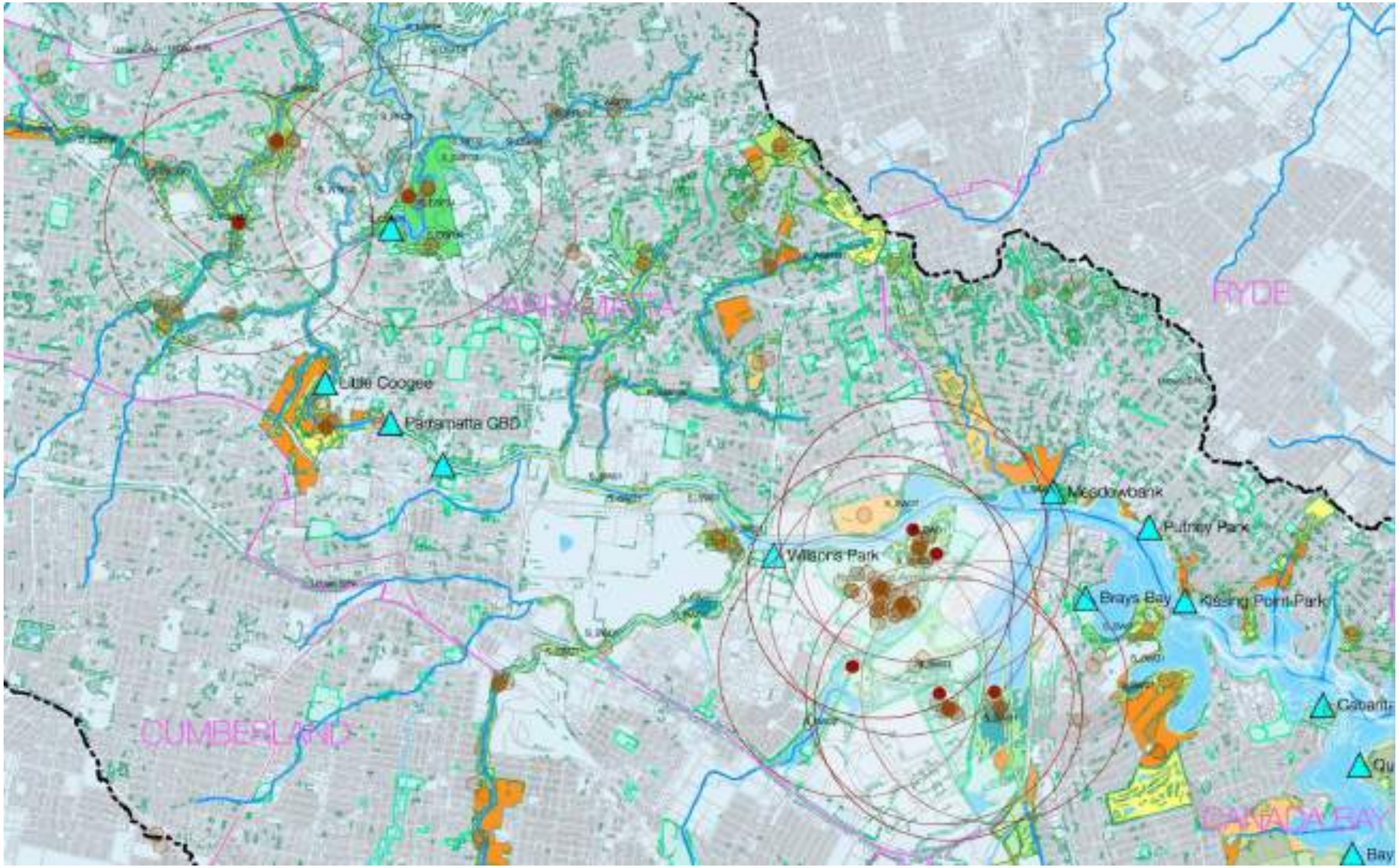

Figure 21: Recorded observations of Southern Myotis (dark brown circles) and other bats (light brown). Myotis records include a 1500 metre buffer indicating a notional short-term foraging range (Anderson et al 2006). Myotis habitat may be improved via corridor vegetation enhancement (yellow and orange areas are corridor parcels which lack well-structured native vegetation) and provision of microbat flats (nesting hollows). Blue triangles denote location of potential swimming sites

Habitat Mangement

1. ***Manage existing riparian corridors with dense plantings and trees for future roosting habitat.*** *On-ground works to enhance Southern Myotis habitat should concentrate on r*evegetating riparian corridors with dense plantings of native canopy trees which will provide roosting habitat and dense foliage cover of flyways (see example in **Figure 22**). Opportunity exists to apply focus to revegetation of riparian corridors which link know populations of Southern Myotis around the Parramatta CBD and Sydney Olympic Park.

Figure 22: Example of dense riparian plantings of native canopy and understory species. Planting is approximately 5 years old.

Habitat Creation

1. ***Create riparian planting programs to revegetate stream corrodors***. Opportunity to expand the range of the Southern Myotis to other parts of the catchment is likely, such as the Duck River subcatchment and areas within the North West. However, to expand the range, suitable habitat including densely vegetated riparian corridors, culverts and bridges and are required.

2. ***Create new habitats by installation of artificial hollows, roosting boxes and re-standing dead hollow bearing trees***. A novel approach to habitat creation for this species is the installation of artificial hollows. Although there is limited literature on the occupation of artificial hollows or nest boxes by microbats, Goldingay and Stevens (2009) reported the use of artificial hollows and roost boxes by several species.

   Artificial bat flat creation involves carving hollowed sections from the trunk and/or branches of a large tree (dead or living). A section of tree is removed exposing the core of the branch or trunk, this is hollowed out and the outer layer of the branch/trunk is reattached to create a hollow (Figure 30). This approach accelerates the hollow forming process which usually takes 50-100 years to form (species dependant) under natural conditions. The installation of artificial hollows has been undertaken at multiple sites across the Parramatta LGA, and although the majority of these works have targeted creating hollows for bird species, a number of 'bat flats' have been installed. This approach has also been applied by City of Sydney Council in Sydney Park (**Figure 23**).

An additional approach to habitat creation is the re-standing of dead hollow bearing trees (stags). This approach has been successful at recolonizing mine rehabilitation sites with microbats on the Whitehaven Coal Mine site and Werris Creek (**Figure 17**) (*un-published data, pers comms* Ecoplanning 2016).

Figure 23: Two styles of artificial 'bat flats". Left: 'bat flat' constructed into trunk of tree (Parramatta, Sydney Arbour 2016). Right: retrofitted 'bat flat' to standing tree (Sydney Park).

3. ***Create off-line wetlands to create and expand habitat diversity and foraging opportunities***. The preferred feeding habitat for the Southern Myotis is over expanses of still/slow flowing water bodies. However, streams in urban areas have altered hydrology due to the connection of the urban stormwater drainage systems which results in flashy, high volume, high velocity flows. These altered stream conditions degrade potential feeding areas for the Southern Myotis and may therefore be a limiting factor in the distribution of the species across the catchment.

   To overcome the immediate habitat limitations created by high velocity and infrequent flowing streams and to provide foraging and roosting habitat for the Southern Myotis, off-line wetlands can be constructed.

   Offline wetlands can also have a dual benefit of stormwater treatment and habitat creation. Wetlands should be designed to bypass high flows and to balance water quality improvements with the community's desire for healthy and productive wetlands that support wildlife. An example of this design can be seen at Cup and Saucer wetland in the Cooks River catchment (**Figure 24**).

Construction of off line wetlands which incorporate dense fringing and riparian vegetation and artificial hollows and re-standing dead stage trees provides an optimal combination of habitat niches for multiple species.

Figure 24: Cup and Saucer wetland. An example of a constructed wetland which provides potential foraging habitat for Southern Myotis and provides water quality treatment.

Detailed information on managing habitat requirement for Southern Myotis and other microbat species can be found in;

1. Gunnell K., Grant G. and Williams C (2012) Landscape and Urban Design for Bats and Biodiversity. Bat Conservation Trust.
2. West Gippsland Catchment Management Authority (2003) The Bat Roost Box Kit.
3. Department of Environment and Energy (1999) Action Plan for Australian Bats.
4. Greater Sydney Local Land Services (2015) Hollows for Habitat Forum Proceedings, Sydney 20th May 2015

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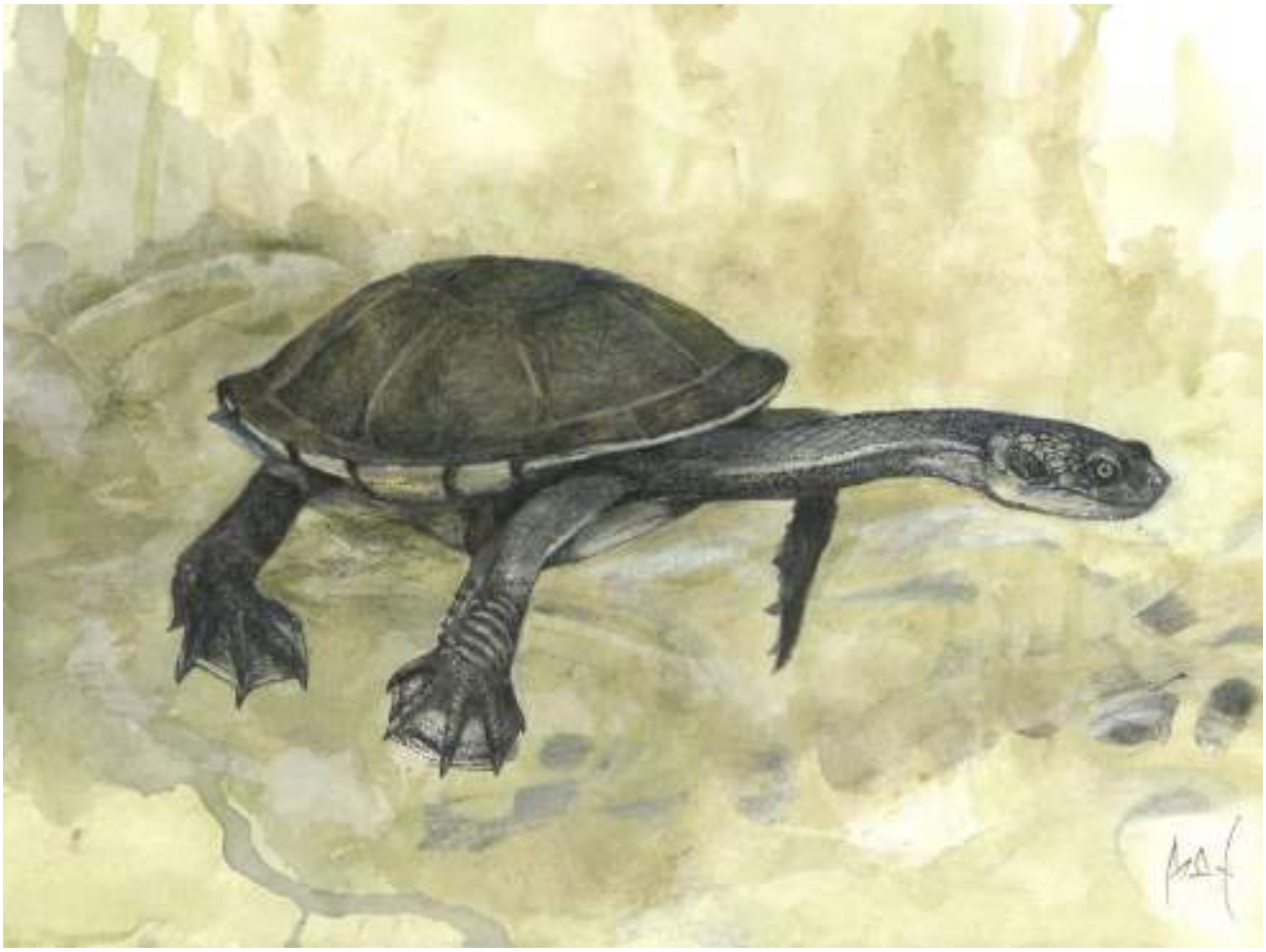
Domain/System	Species	Ecological Requirements	Threats	Recommendation	Link to swimmable River
Riparian *Urban freshwater creeks and rivers*	**Southern Myotis** *Myotis macropus*	**Habitat** Riparian habitats are preferred by this species. Roosts naturally in caves, tree hollows and dense vegetation near bodies of slow-flowing or still water (including estuaries) and utilises aqueduct tunnels, mines, road culverts and bridges as artificial roosts. Some populations roost exclusively in tree hollows in partly submerged dead trees and in live trees close to the water. Exclusively forages over water (rivers, streams, dams) for aquatic prey in a variety of forest types. **Food** Species is reliant on up to 10 taxonomic groups for prey including *Diptera, Tricoptera, Corixidae, Gerridae, Gyrinidae, Coleoptera,* aquatic insects and fish. The majority of prey species are air breathing insects, which account for approximately 99% of prey species, while fish account for only 1%. Most prey species do not require pristine aquatic conditions however many are vulnerable to changes in altered flow and declining water quality.	Loss or disturbance of roosting sites through vegetation clearing. Clearing of foraging areas. Prey species are susceptible to changes in water quality which result from vegetation clearing, sewage, pesticide and herbicide run-off. Prey species and riparian habitat are vulnerable to alteration of flow regime.	**Manage** patches of native vegetation with dense riparian and gully vegetation and large canopy trees which support hollows. **Create** future roosting habitat by regenerating existing riparian corridors with dense understory and canopy plantings. **Create** new habitats by installation of artificial hollows, roosting boxes and re-standing dead hollow bearing trees. **Create** off-line wetlands to expand habitat diversity and foraging opportunities.	Dense riparian vegetation stabilises banks and mitigates stream bank erosion. Riparian vegetation and constructed wetlands filter diffuse sediment and pollutants from entering the waterways, therefore mitigating degradation of water quality. Riparian vegetation and wetlands enhance instream processes such as nutrient recycling and flow retention which provide benefits to water quality. Constructed wetlands regulate flow velocity thus reducing erosion and degradation of instream habitat. Enhances connectivity of native vegetation corridors which enables dispersal of native species across the catchment. Enhances the quality of urban green space by providing shade and pleasant recreational areas for the community.

Table 6: Management recommendations for the Southern Myotis and link to a swimmable river.

11.Freshwater Domain

Eastern Long-necked Turtle (*Cheladina longicollis*)

Domain – Freshwater, Community – Reptiles



Conservation Status

Commonwealth - Not listed

NSW- Not listed

Distribution

The Eastern Long-necked Turtle, also known as the Common Snake-Necked Turtle occupies large expanses of North and South Eastern Australia. It can be found covering most of Victoria, eastern New South Wales and South Eastern Queensland. (Chessman 1988, Kennett *et al* 2009). This species has a broad distribution across the catchment with numerous records located in and around Sydney Olympic Park (**Figure 25**).

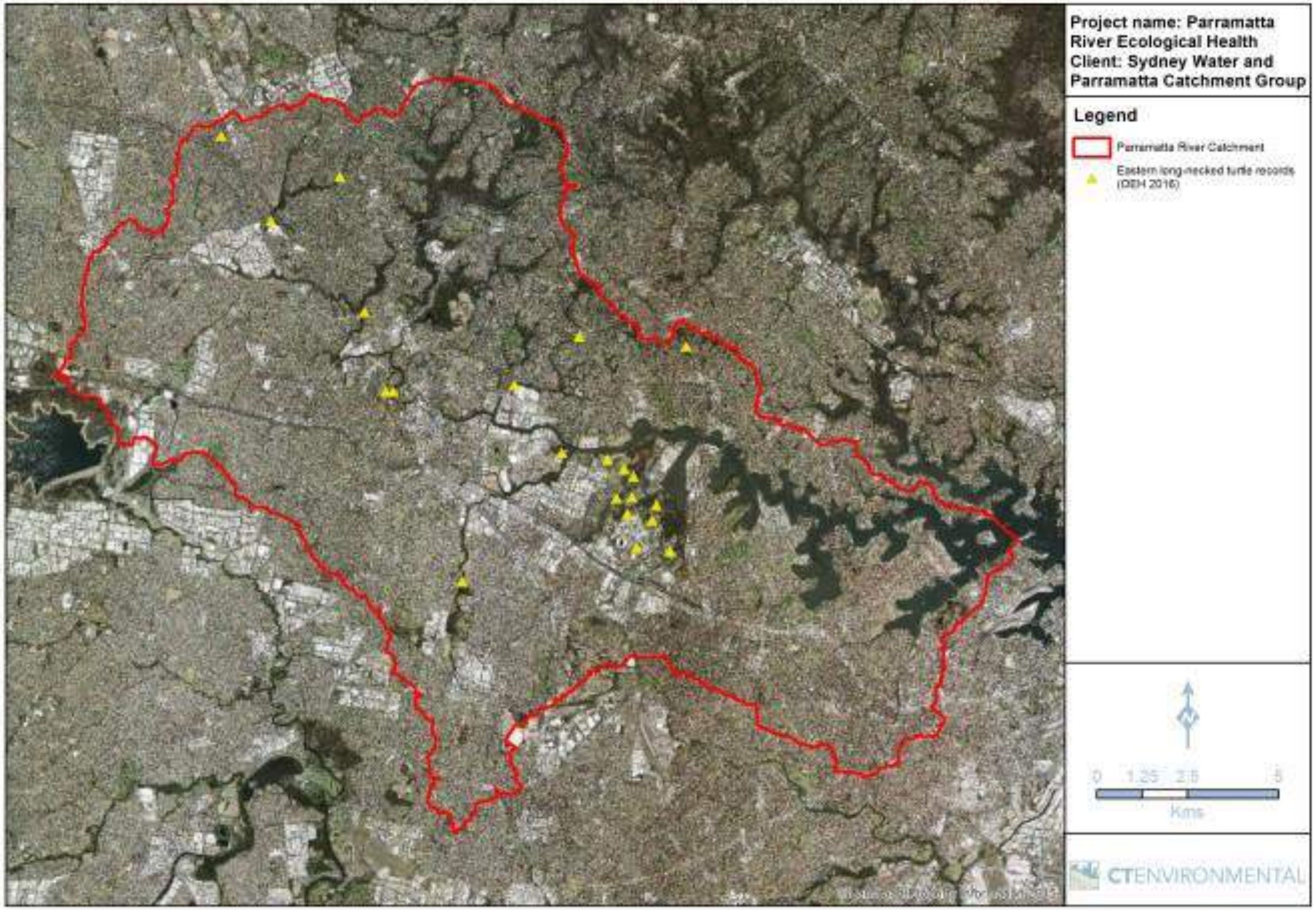


Figure 25: Recorded occurrences of Eastern Long-necked Turtle (*Cheladina longicollis*) within Parramatta River catchment.

Reproduction

Adults can produce up to 3 clutches of between nine and 23 eggs during spring and late summer each year (Kennett et al, 2009). Higher productive wetlands with lower competition are better environments for turtle reproduction resulting in stronger growth rates (Kennett and Georges 1990, Roe and Georges 2008a and Kennett et al 2009).

Habitat Requirements

- Inhabits a wide range of ephemeral and permanent waterways including chain of ponds and wetlands (Chessman 1988 and Kennett et al 2009). (New South Wales Office of Environment and Heritage 2016).
- Possess a great ability for terrestrial migration and are well suited to chain of ponds wetlands (Burgin and Renshaw 2008). It allows them to exploit highly productive ephemeral wetland habitats with minimal competition from fish and other turtle species unable to penetrate these unique environments (Stott 1987, Chessman 1988, Roe et al 2008 and Kennett et al 2009).
- Known to utilise terrestrial refuges beyond the narrow wetland buffer zone, often for extended periods of time (Roe and Georges, 2007).
- Maintain an association with several spatially and temporally variable wetlands throughout the year, even if greatly dispersed (Roe and Georges, 2007).

Food Requirements

- Opportunistic carnivore with a diverse diet that varies geographically (Georges et al, 1986).
- Food can include plankton, nekton, macroinvertebrates and carrion.
- Also feed on terrestrial organisms that fall into the water (Parmenter 1976, Chessman 1984, Georges et al 1986 and Kennett et al 2009).

Threats

- Predation, especially nest predation from introduced species including cats, foxes and pigs. It has been found that areas with high fox predation have a lower proportion of juvenile turtles than adult turtles (Thompson 1983).
- Road mortality through habitat fragmentation during migration between waterways.
- Competition for food and habitat from introduced turtles (especially in Sydney).
- Alteration to water quality and or flow regimes.
- Water pollution events.
- Blue-green algae blooms.
- Habitat modification.
- Wetland habitat loss from drought (Kennett et al 2009 and New South Wales office of Environment and Heritage 2016).

Striped Marsh Frog (*Limnodynastes peronii*)

Domain – Freshwater, Community – Frogs

Conservation Status

Commonwealth - Not listed

NSW- Not listed

Distribution

The Striped Marsh Frog (*Limnodynastes peronii*) is a medium to large sized frog found along the east coast of Australia from northern Queensland through to Tasmania. It is commonly found within the Sydney region and has adapted well to survival in a changing urban environment (Hengl and Burgin, 2002).

This species has a broad distribution across the catchment and appears ubiquitous with any waterbody (**Figure 26**).

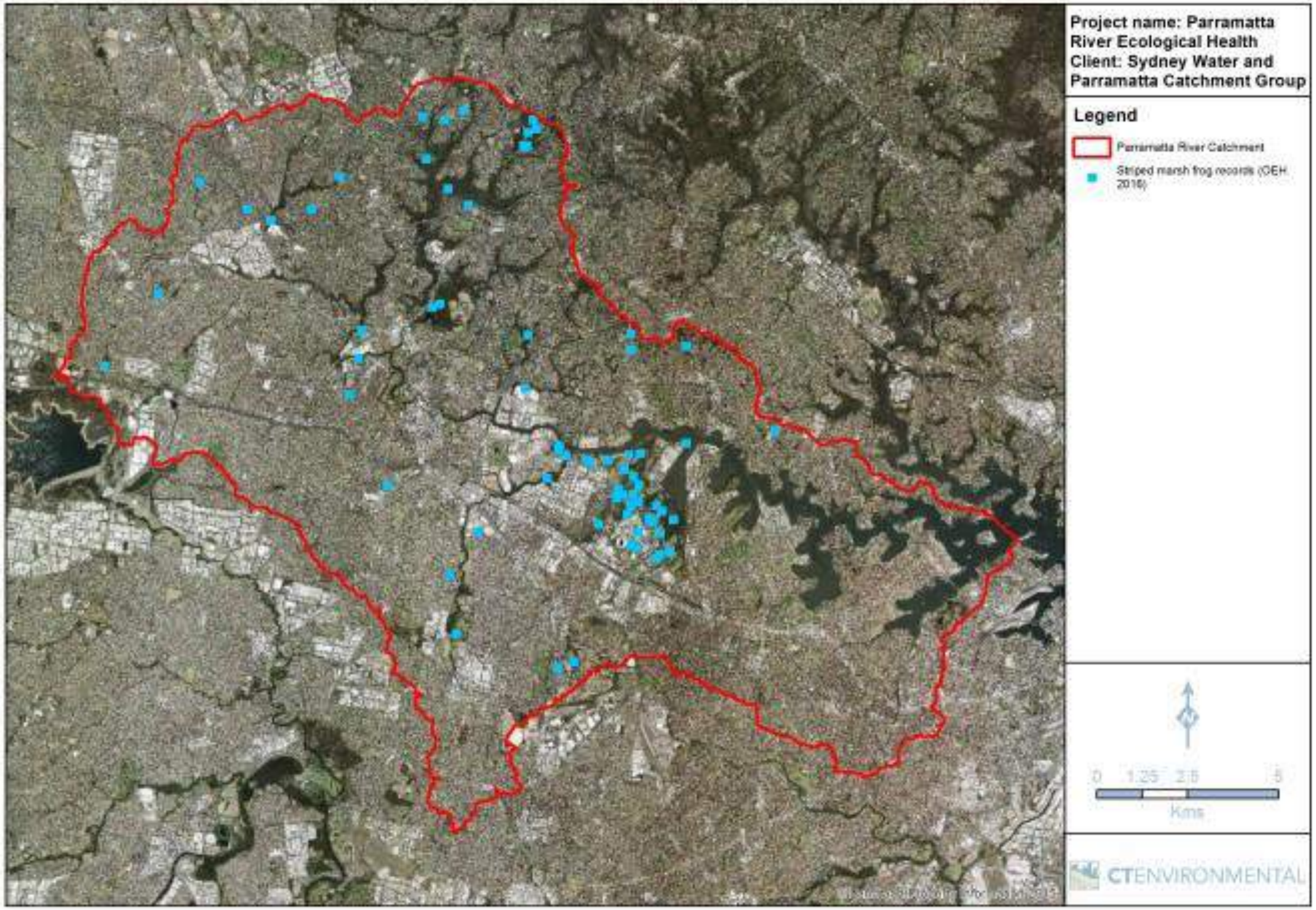


Figure 26: Recorded occurrences of Striped Marsh Frog (*Limnodynastes peronii*) within Parramatta River catchment

Reproduction

The Striped Marsh Frog usually breeds between late spring and summer. However, it has been known to breed throughout the entire year, taking advantage of rainfall for breeding in autumn and winter (Schell and Burgin 2012). High breeding rates have also been observed within urban water bodies and garden ponds (Queensland Government 2016, Parks and Wildlife Service Tasmania 2016, NSW National Parks and Wildlife 2016).

Adults require abundant marginal, semi aquatic submarginal and submerged aquatic vegetation to protect and stabilize the foam nest in which the eggs are laid (Queensland Government 2016, Department of Primary Industries, Parks, Water and Environment, Tasmania 2016, Forest Practice Authority of Tasmania 2011).

The tadpole larval stage can last up to 12 months until tadpoles emerge as juvenile frogs. Ideal breeding habitats will be within sections of waterbodies no deeper than 1.5m. Juveniles also require connected vegetation between waterbodies for dispersal to new breeding areas and continued successful breeding of new adults (Queensland Government 2016, Department of Primary Industries, Parks, Water and Environment, Tasmania 2016, Forest Practice Authority of Tasmania 2011).

Habitat Requirements

- It can be found in many habitats including a variety of natural and artificial wetlands from permanent freshwater waterbodies, lagoons, ponds, swamps, marshes, agricultural dams, quarries, garden ponds, roadside ditches and even dogs drinking bowls (Hengle and Burgin 2002).
- Prefers shallow waterbodies with abundant marginal, submarginal and submerged vegetation for cover from predation and breeding purposes (Australian Museum 2016, Queensland Government 2016, Forest Practice Authority of Tasmania 2011).
- Also use vegetated areas outside of the breeding season for hibernation and juvenile dispersal such as damp long grass, dense ground vegetation, fallen logs, stones and even leaf litter. Vegetated channels need to connect waterbodies to allow for safe passage (Queensland Government 2016, Forest Practice Authority of Tasmania 2011).

Food Requirements

- Has a variable diet and will consume most things that will fit in its mouth including: aquatic invertebrates, terrestrial insects, beetles, crickets, moths and even other frogs (Australian Reptile Park 2016, Climate Watch 2016, Society of Frogs and Reptiles 2016).

Threats

- Threats associated with climate change and land clearing for agriculture and or urban development have the ability to fragment the Striped Marsh Frogs habitats. They may also drain or completely dry out dependent water bodies.
- Water pollution, and wetland degradation from stock disturbance as well as changes to flow regimes (increased heavy flows) impact the Striped Marsh Frog’s niche habitat requirements.

- Predation on spawn by *Gambusia holbrooki* (mosquito fish) is a possible contributing factor in disturbed streams however water quality degradation from stormwater pollution and urban runoff are more likely to influence frog populations (Webb and Joss, 1997).
- Chytrid fungus is reported to be an emerging problem for the Striped Marsh Frog along with many other frog species. (NSW OEH 2016 and Forest Practice Authority of Tasmania 2011). It affects the frog's skin causing issues with respiration and nervous system function resulting in lethargy, immobility and malnutrition (NSW OEH 2016 and Forest Practice Authority of Tasmania 2011)

Habitat Management

Schematic diagrams summarizing the ecological requirements, threats and link to swimmability for the Long–necked Turtle and Striped Marsh Frog are illustrated in **Figures 27** and **28**. The primary recommendations to maintain the presence of these species are outlined below. Implementing the following recommendations will also provide beneficial outcomes for other aquatic species which rely on similar habitat characteristics such as the native fish, macroinvertebrates, reptiles, microbats and frogs.

Figures 27 and 28 can be used to trace trophic, synergistic and antagonistic links, and relationship to human values provided by iconic species (refer to legend at **Figure 10**). For example, the Striped Marsh Frog prefers slow moving water with shallow pools for egg-laying, and wetlands or moist aquatic or terrestrial vegetation for foraging, shelter and dispersal. This in-stream habitat supports the frog's specific foods: fish larvae, aquatic and terrestrial insects and smaller frogs. The same wetland areas provide the link to a swimmable river, regulating flows and providing oxygen improve water quality.

Similarly, the Long-necked Turtle needs soft sandy creek banks for egg-laying, and slow moving water with deep pools, large woody debris and in-stream rocks for foraging. This in-stream habitat supports the turtle's specific foods: small fresh-water fish, aquatic insects and yabbies. The same waterway complexity provides the link to a swimmable river, moderating flows and protecting creek channels from erosion to improve water quality.

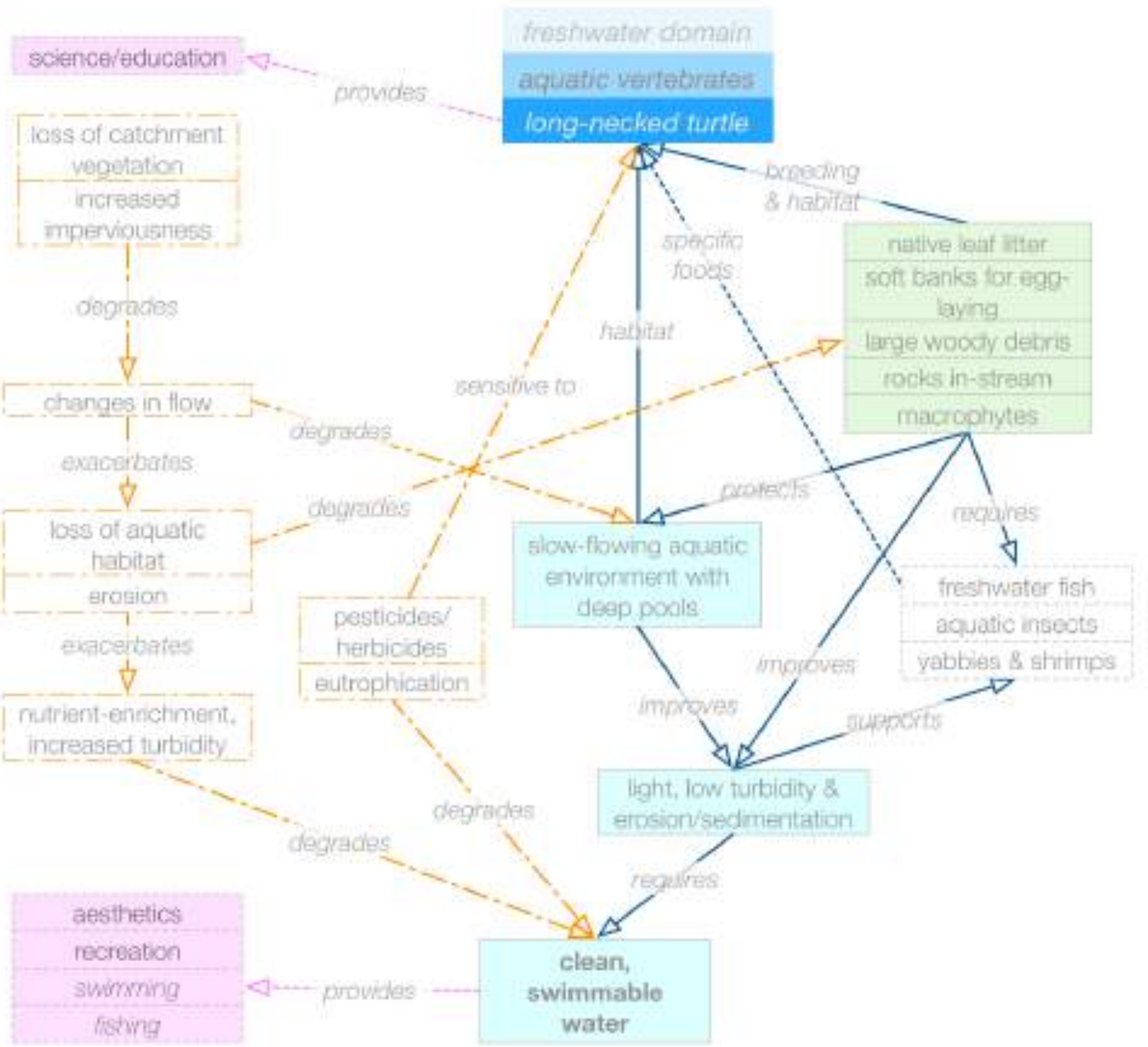


Figure 27: Schematic ecological requirements and threats for Eastern Long-necked Turtle (*Cheladina longiocollis*) and links to swimmability.

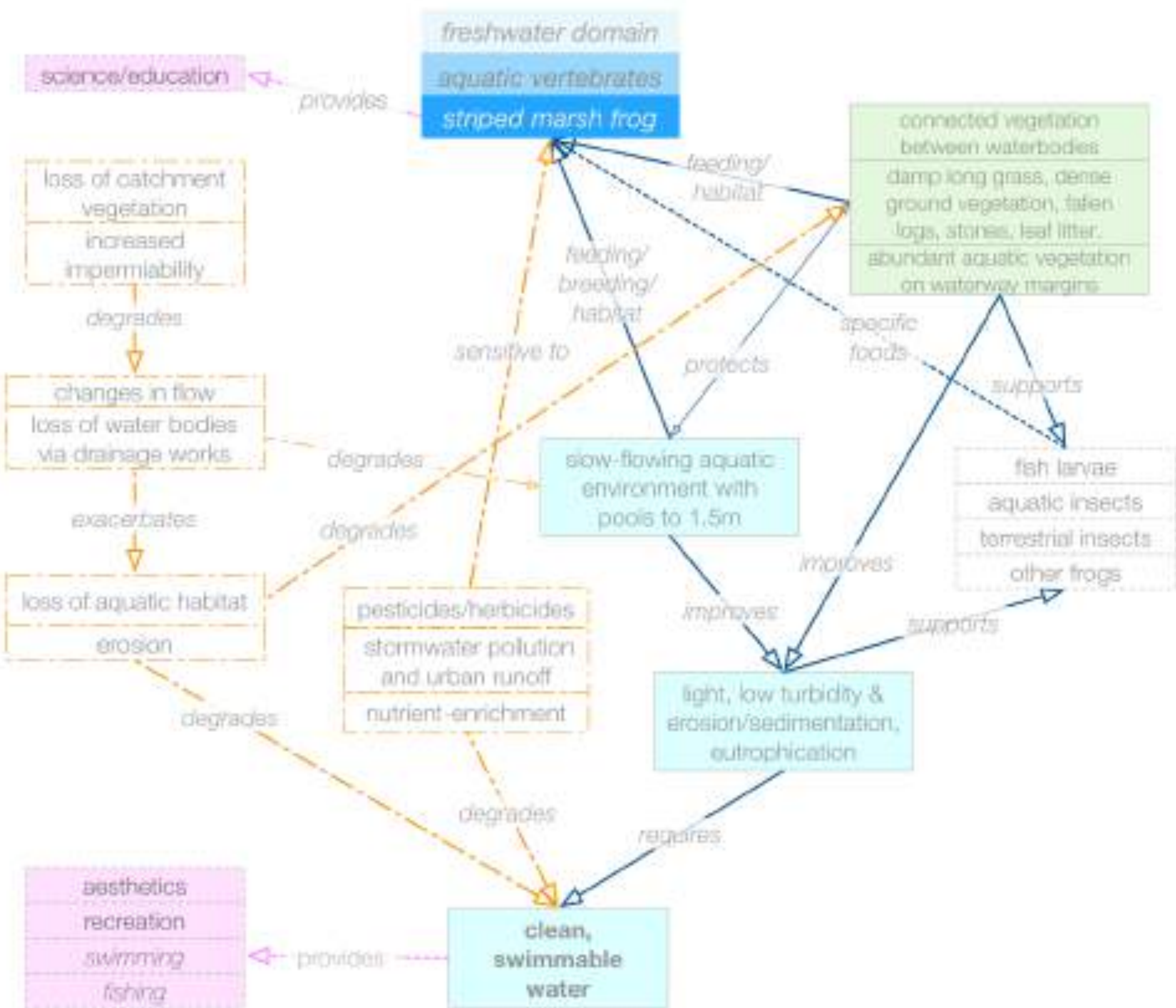


Figure 28: Schematic diagram of ecological requirements and threats for Striped Marsh Frog (*Limnodynastes peronii*) and links to swimmability.

Recommendations

Habitat Protection

1. ***Protect patches of native vegetation with dense riparian and gully vegetation***. This habitat provides refuge and basking opportunities for both Striped Marsh Frogs and Long Necked Turtle. Both the Striped Marsh Frog and Eastern Long-necked Turtle are common across the catchment and due to their mobile nature are likely to colonise any suitable habitat (**Figure 29**).
2. ***Protect frog and turtle nesting sites from fox predation.*** Implementation of a fox control/eradication program across the catchment or in core habitat zones (as identified in previous sections) would provide the benefit of reducing turtle nest and frog predation. Fox control will also benefit many other native animals such as small mammals, reptiles, crustaceans (yabbies), terrestrial beetles and birds, all of which are known prey of urban foxes (DAF 2016).

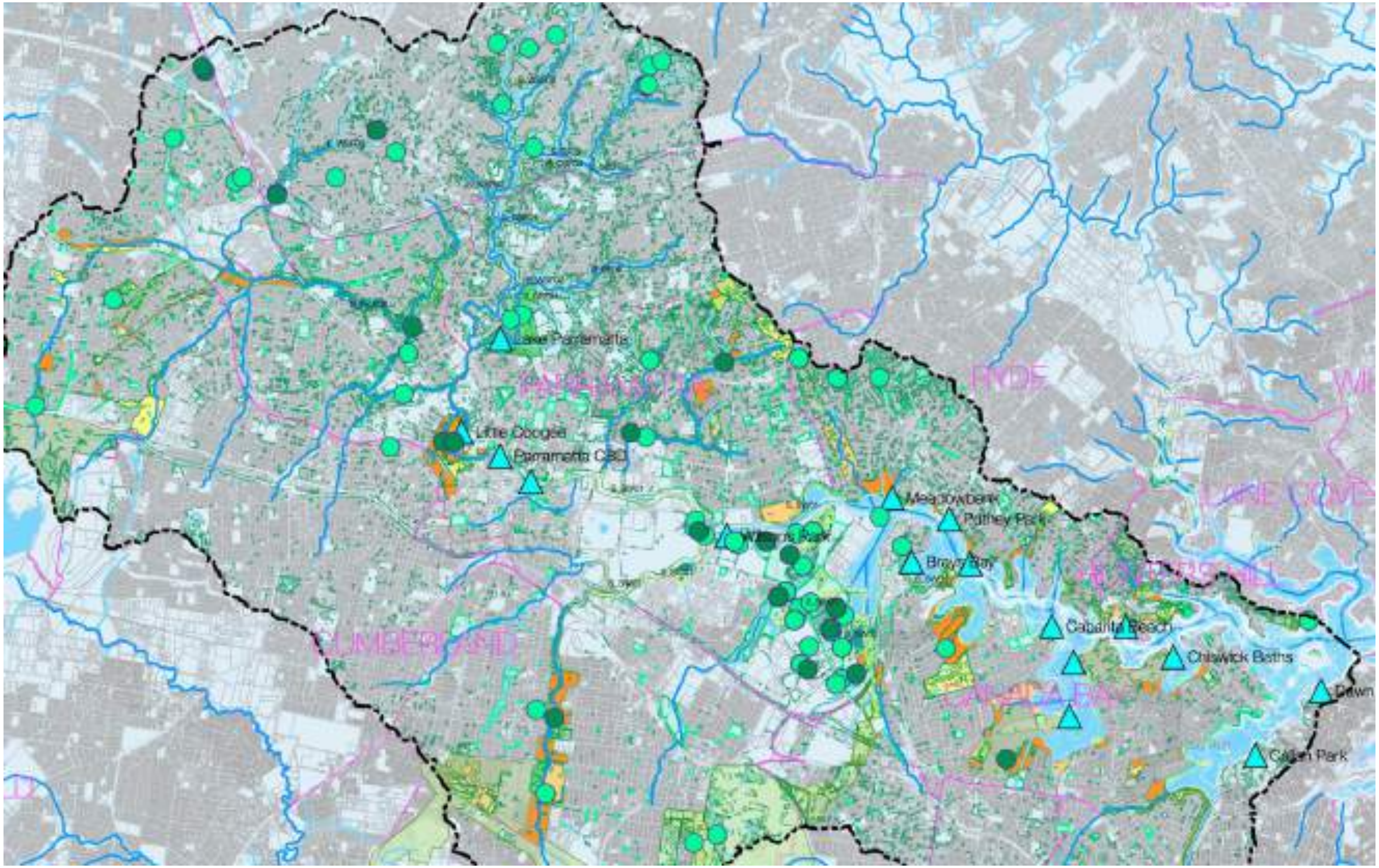


Figure 29: Recorded observations of Eastern Long-necked Turtle (dark green circles) and Striped Marsh Frog (light green) across the central catchment area: Records are relatively common and widespread along waterways. Blue triangles denote location of potential swimming sites.

Habitat Creation

1. ***Create submerged and emergent habitat by construction of fish crates.*** These instream features provide basking habitat for the Eastern Long-necked Turtle. Baskets are constructed from hard wood logs salvaged from land clearing activities and lowered into a low energy waterbody such as a pond or lake (**Figure 30**). Fish crate structures also provides habitat for other frog species, fish and water birds. Fish creates have been implemented in Deep Water Regional Park by Bankstown Council (GSLLS 2015). Where possible maintain or reinstate large woody debris to creek channels and wetlands where this will not impact on flooding developed areas. In addition, installation of large woody debris to creek channel and wetlands will provide aquaitic and emergent habitat for many species.

Figure 30: Construction of fish crates before being submerged into low velocity water body (GSLLS 2015).

2. ***Create off-line wetlands to provide habitat and improve water quality.*** The preferred habitat for the Eastern Long-necked Turtle and Striped Marsh Frog and are within aquatic environments with instream, fringing and emergent vegetation and deep expanses of still/slow flowing water. These characteristics are compromised because of the pressures associated with the urban stream syndrome (Walsh *et al* 2005) including flashy, high volume, high velocity flows. These altered stream conditions degrade the habitat of these species and are likely to limit expansion of them across the catchment.

   Off-line wetlands are also beneficial to other species including the Southern Myotis. Wetlands should be designed to bypass high flows and to balance water quality improvements with the community's desire for healthy and productive wetlands that support wildlife. An example of this design can be seen at Cup and Saucer wetland in the Cooks River catchment (**Figure 24**). Construction of off-line wetlands which incorporate dense fringing and riparian vegetation, fish crates and artificial hollows and re-standing dead stage trees provides an optimal combination of habitat niches for multiple species.

Domain/System	Species	Ecological Requirements	Threats	Recommendations	Link to swimmable River
Freshwater *Urban freshwater creeks and rivers*	**Eastern Long-necked Turtle**	**Habitat** – rivers, lakes, swamps and ponds, including farm dams. **Food** – invertebrates such as worms, snails and insect larvae.	Susceptible to decline in water quality, entanglement in rubbish, loss of habitat. Predation by dogs, cats and foxes.	**Protect** patches of native vegetation with dense riparian and gully vegetation. Construct fish crates to **create** submerged and emergent habitat. Construct off-line wetlands to **create** habitat and improve water quality. **Protect** frog and turtle nesting sites from fox predation.	Native vegetation corridors act as filters to overland flow, cleansing water before it enters waterways. Native vegetation stabilises creek banks which limits erosion and sedimentation therefore suppressing further water quality decline. The construction of off line wetlands will assist to mitigate against altered hydrology which is typical of urban streams. Increased flow in urban streams, exacerbates erosion of creek bed and banks and results in sedimentation and elevated turbidity. Increased flows remove in-stream habitat by washing away leaf litter, woody debris, natural sand and gravel beds and often results in a homogeneous creek channel devoid of niche habitats which would otherwise support a diverse aquatic ecosystem.
	Striped Marsh Frog	**Habitat** – a variety of natural and artificial wetlands, permanent fresh water bodies, lagoons, ponds, swamps, marshes, agricultural dams, quarries, garden ponds, roadside ditches and even dog's drinking bowls. Prefers shallow waterbodies with abundant marginal, submarginal and submerged vegetation for cover from predation Vegetated areas outside breeding season for hibernation and juvenile dispersal: damp long grass, dense ground vegetation, fallen logs, stones and leaf litter. Vegetated channels need to connect waterbodies to allow for safe passage. **Food** – Variable diet: consumes most things that will fit in its mouth including aquatic invertebrates, terrestrial insects, beetles, crickets, moths and other frogs.	Climate change and land clearing for agriculture and or urban development have the ability to fragment the Striped Marsh Frogs habitats. Water pollution, and wetland degradation from stock disturbance as well as changes to flow regimes (increased heavy flows) impact the Striped Marsh Frogs niche habitat requirements. Gambusia (also known as mosquito fish) are a possible contributing factor in disturbed streams however water quality degradation from stormwater pollution and urban runoff are more likely to influence frog populations. Chytrid fungus is an emerging problem for the Striped Marsh Frog.		

Table 7: Management recommendations for the Eastern Long-necked Turtle and Striped Marsh Frog and link to swimmable river

12. Estuarine Domain

Bar-tailed Godwit (*Limosa lapponica*)

Domain – Estuary, Community – Shore birds

Conservation Status

Commonwealth: Bar-tailed Godwit (*Limosa lapponica baueri*) - Vulnerable. NSW: Not listed.

Commonwealth: Bar-tailed Godwit (*Limosa lapponica menzbieri*) - Critically Endangered NSW: Not listed.

Distribution

The Bar-tailed Godwit is a migratory shore bird species which breeds throughout the Arctic from Northern Europe to Alaska. It then winters throughout Western Europe, Africa, the Middle East, South East Asia, New Zealand and Australia (Australian Government Department of the Environment 2016).

Australia plays a vital role in the Godwits survival as these birds use Australia for roosting and foraging to prepare themselves for the long migration back to their northern hemisphere breeding grounds (DEWHA 2009). Across the Parramatta River catchment, the distribution of the Bar-tailed Godwit is restricted to the Sydney Olympic Park and Homebush Bay area and areas in the immediate vicinity (**Figure 31**).

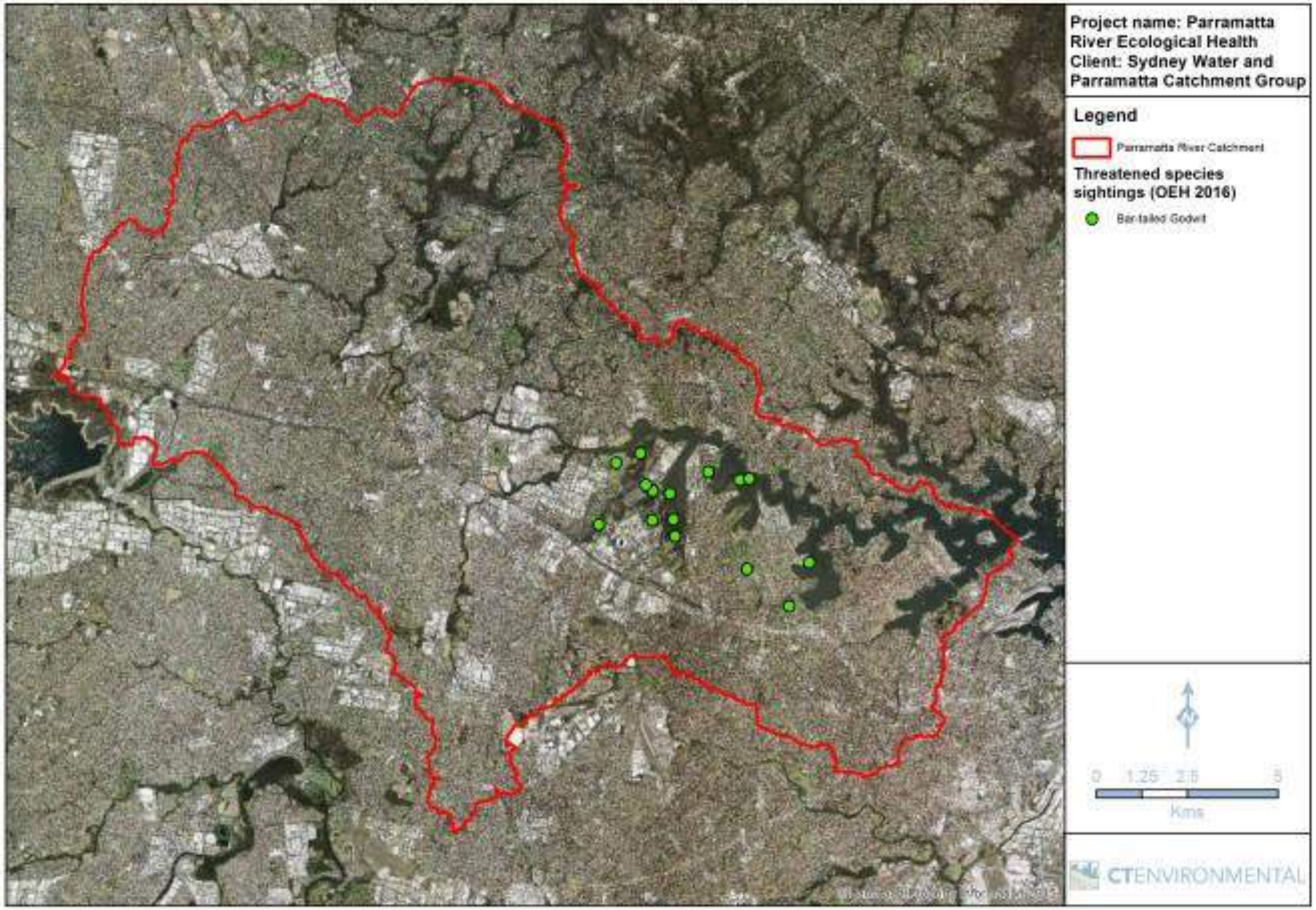


Figure 31: Recorded occurrences of Bar-tailed Godwit (*Limosa lapponica*) within Parramatta River catchment

Migration

Three sub-species are recorded to migrate to Australia;

- *menzbieri* breeds in northern Siberia between the Lena Delta and Chaunskaya Bay, wintering from south-east Asia to north-west Australia.
- *baueri* breeds from north-east Siberia (east of Chaunskaya Bay) to west and north Alaska, wintering from China to Australia, New Zealand and some south-west Pacific islands.
- *anadyrensis* breeds in east Siberia (Chukotka and Anadyr lowlands), wintering in Australia and possibly New Zealand (Van Gils and Wiersma 1996).

Two of these sub-species use the East Asian-Australasian Flyway to roost and forage throughout Eastern Australia. They compose nearly 90% of the East Asian-Australasian Flyway population making Australia a vital landmass for the survival of this migratory bird (Bamford et al 2008).

Reproduction

Adults breed during their summer migration period (Northern Hemisphere) and do not use Australia as a breeding ground. However, habitat requirements such as sufficient roosting for rest and food for energy storage within Australia play a vital role in their successful return to their northern hemisphere breeding grounds (DEWHA 2009).

Habitat Requirements

- Most commonly found in coastal habitats such as sandflats, mudflats, inlets, harbours, estuaries, lagoons, lakes and bays.
- Feeding habitat is generally along the edge of waterways or in the shallows of sandflats and mudflats for foraging at low tide.
- Prefer soft mud; often with beds of eelgrass *Zostera* or other seagrasses though have been observed foraging mangroves, rock platforms and insect larvae among the roots of *casuarina* species.
- Adults prefer roosting on sandy beaches, sandbars and near saltmarshes, however have been recorded to move to shelter and inland to avoid harsh weather events such as cyclones and heavy storms (Thompson 1990b, Marchant and Higgins 1993 and Jessop & Collins 2000).

Food Requirements

- Described as mostly carnivorous feeding on insects, molluscs, crustaceans, worms, tadpoles, fish and some fruit and vegetation.
- A study of Parramatta River communities of Bar-tailed Godwits found that polychaetes (worms) represented nearly 90% of their diet. Polychaetes are known to positively respond to elevated levels of organic pollution (Marchant and Higgins 1993 and Taylor et al. 1996).
- Godwits feed mainly during sunlight hours but have also been observed to feed under moonlight.

Threats

International

- Direct and indirect habitat loss of staging areas (resting) used during migration due to urban and industrial development and land reclamation, especially across the northern Asia flyway (Melville 1997, Barter 2002).
- Pollution of both breeding and roosting sites (Round 2006; Wei et al. 2006).
- Global warming and sea level impacting on breeding, staging and non-breeding grounds through intertidal habitat loss (Harding *et al*. 2007).

Australia

- Habitat loss, especially foraging and roosting sites, affects the ability of the Godwit to rest and build energy stores for the return migration to their northern hemisphere breeding grounds (DEWHA 2009).
- Habitat degradation from changes to silt or sediment loads, water pollution, aquatic weed invasion, changes to flow and hydrological regimes to loss of native estuarine vegetation. These all impact the Godwit and other shorebirds that are specialised feeders (DEWHA 2009).
- Disturbance from residential and recreational human activities and direct mortality during migration through Australian pathways from motor vehicles, planes and or malnutrition, dogs, noise and shoreline lighting (DEWHA 2009).
- Godwits have been observed leaving a foraging ground during feeding due to human disturbance and many will disperse when people approach closer than 70m in some instances (Marchant and Higgins 1993, Taylor and Bester 1999).

A schematic diagram summarizing ecological requirements, threats and links to swimmability is displayed in **Figure 32** below.

Habitat Management

A schematic diagram summarizing ecological requirements, threats and link to swimmability is displayed in **Figure 32**. The primary recommendations to maintain the presence of the Bar-tailed Godwit are outlined below. Implementing the following recommendations will also provide beneficial outcomes for estuarine species which rely on similar habitat characteristics such as fish, invertebrates and wading and water birds.

The schematic can be used to trace trophic, synergistic and antagonistic links, and relationship to human values provided by iconic species (refer to legend at **Figure 10**). For example, the Godwit requires exposed seagrass beds and tidal mudflats for foraging, and these habitats also supports the Godwit's specific foods: intertidal invertebrates. The same habitats provide the link to a swimmable river, supporting nutrient cycling and a low-energy environment for sedimentation, to help provide clean swimmable water.

The Godwit is distinct from other iconic species as it depends on breeding sites and habitat well outside the management areas directly controlled or influenced by PRCG stakeholders.

While this is a unique challenge, it also provides opportunity for international cooperation in education, management and scientific research.

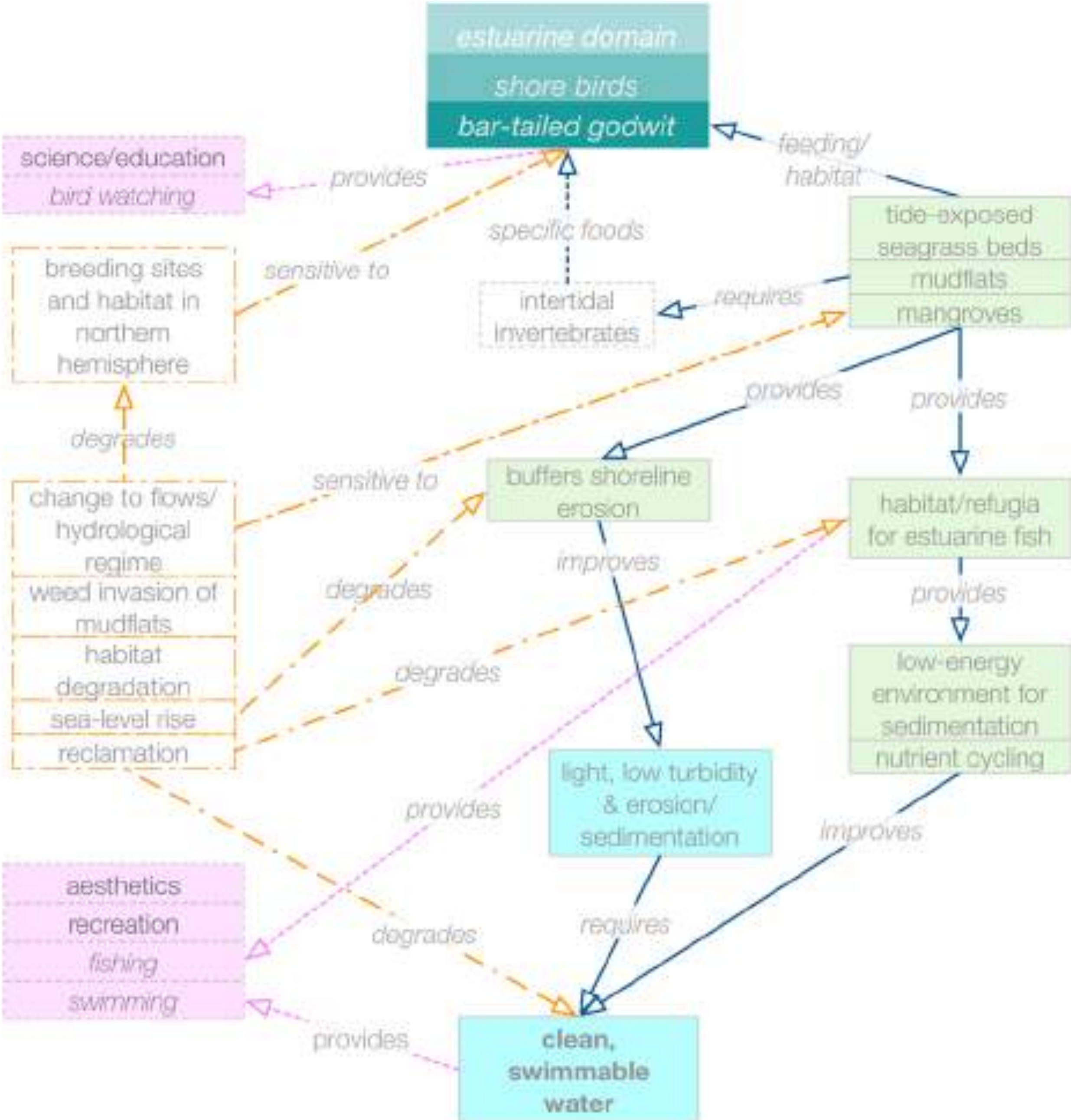


Figure 32: Schematic diagram of ecological requirements and threats for Bartailed Godwit (*Limosa lapponica*) and links to swimmability.

Recommendations

Habitat Protection

1. ***Protect areas of intertidal mudflat, saltmarsh and mangrove***. Where possible conduct strategic weed management to ensure these habitats remain weed free and conduct management activities in winter months when Bar-tailed Godwit and other migratory birds are not present. Distribution of Bar-tailed Godwits across the catchment is restricted to intertidal areas near Sydney Olympic Park, therefore any on-grounds works focusing on improving habitat for this species should be centred on this area (**Figure 33**).

Figure 33: Recorded observations of Bar-tailed Godwit (teal circles) and other migratory waterbird species (grey circles) along the Olympic Park foreshore. Estuarine vegetation (teal) and terrestrial vegetation patches (lighter teal/green) along with potential corridors (yellow indicates fair condition, orange represents poor condition, both lack well-structured native vegetation or groundcovers): Godwit records include a 70-metre buffer indicating their preferred distance from humans when foraging.

Habitat Management

1. **Manage Godwit feeding and roosting sites by developing detailed species population and habitat maps to better understand and support management and protection of these areas**. A comprehensive, detailed spatial layer based on existing survey (augmented if necessary) will support management efforts including those described above and provide a scientific and educational resource.

Habitat Creation

1. ***Create artificial oyster reefs to delineate ecological zones and protect habitats***. Disturbance of mudflats foraging grounds via land and water access, dogs and erosion represent a threat to the foraging habitat of the Godwit and other shore and wading bird species. Mudflats can be delineated and protected by artificial oyster reefs providing providing a barrier to human foraging within the roosting areas and protection impact from boat wake. Reefs also provide roosting sites at low tide, protected from dogs and people.

   The development of an artificial oyster reef program can be modelled on the Billion Oyster Project (BOP) which is an ecosystem restoration program aimed at restoring one billion live oysters to New York Harbor and engaging hundreds of thousands of school children through restoration based education programs. To date BOP has grown 19.5 million oysters and restored 0.5 ha of oyster reef. The BOP engages with local restaurants which provide used oyster shells that are recycled to artificial oyster reefs. **Figure 34** outlines the various stages of the process applied by the BOP to reinstate oyster reefs across New York Harbour.

   Implementation of a program such as the BOP will provide opportunity for PRCG and stakeholders to engage with community and encourage participation in community based monitoring programs.

2. ***Conduct a feasibility study to determine the viability of reef building***. To ensure the viability of a project such as the BOP it is recommended a feasibility study be undertaken to determine the viability of the project. The Sydney Rock Oyster (*Saccostrea glomerata*) is the native oyster species to the Parramatta River catchment and recent studies have shown this species is present as far upstream as Silverwater and Homebush Bay (Birch *et al* 2006, Scanes *et al* 2016). This upstream range coincides with most Bar-tailed Godwit records.

   The Sydney Rock Oyster is likely to be a suitable species to employ to artificial reef building as it is a reef forming species with the ability to tolerate urban estuarine conditions such as elevated nutrient levels (Paterson et al 2003). In addition, the Sydney Rock Oyster has been shown, under controlled conditions, to filter 49% of total suspended solids, 58% of bacteria and up to 80% of nutrients from the water column (Nell and Holliday 1988). This ability makes the species an effective filtration device to strip nutrients, sediment and organic particles from the water column.

   Although the Sydney Rock Oyster can tolerate urbanized catchments, the growth of the species is compromised by prolonged periods of salinity < 15 ppt (Rubio 2008). Birch et al (2006), Scanes et al (2016) and Rubio (2008) report the optimal salinity levels for the Sydney Rock Oyster is from approximately 23-39 ppt. Therefore, it is of importance that salinity ranges of potential locations for reef placement be understood to avoid failure.

Additional to the investigation of various environmental tolerances of the Sydney Rock Oyster a feasabilty study should also include investigation to determine which substrates are best suited to the building of artificial reef systems within the Parramatta River.

3. **Create a dog beach at Canada Bay to draw this recreation activity away from sensitive (feeding) areas at Hen and Chicken Bay**. Delineate the off-leash area from Godwit areas to 'protect and activate'. An example of an existing dog beach is at Federal Park. These facilities help protect biodiversity values while providing human-valued recreation opportunities. They can be developed as an interpretive/education and scientific resource with community engagement including before & after monitoring of bird activity.

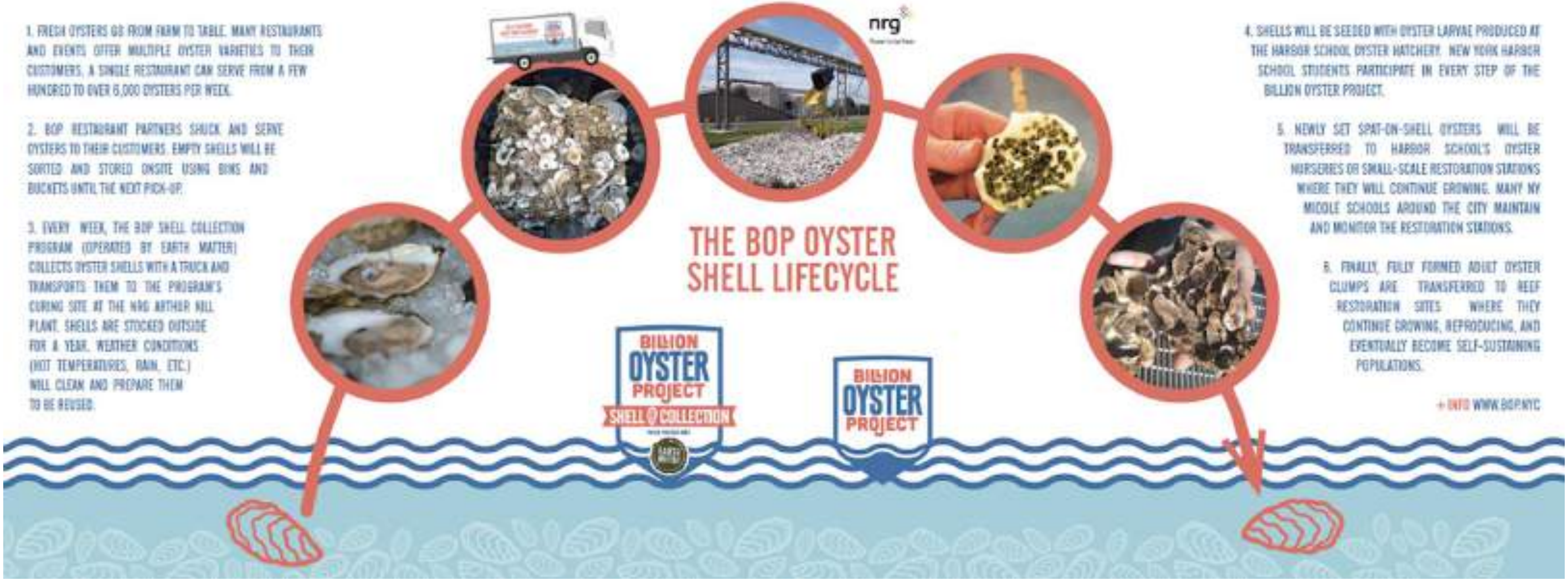


Figure 34: Stages of the process applied by the BOP to reinstate oyster reefs across New York Harbour.

Domain/System	Species	Ecological Requirements	Threats	Recommendation	Link to swimmable River
Estuary *Estuaries, Bays and Lagoons*	**Bar-tailed Godwit** *Limosa lapponica*	**Environment** Coastal habitats such as sandflats, mudflats, inlets, harbours, estuaries, lagoons, lakes and bays. Feeding habitat is generally along the edge of waterways or in the shallows of sandflats and mudflats for foraging at low tide. Prefer soft mud; often with beds of seagrasses though have been observed foraging mangroves, rock platforms and insect larvae among the roots of casuarina species. Adults prefer roosting on sandy beaches, sandbars and near saltmarshes, however have been recorded to move to shelter and inland to avoid harsh weather events such as cyclones and heavy storms. **Food** Insects, molluscs, crustaceans, worms, tadpoles, fish and some fruit and vegetation. A study of Parramatta River communities of Bar-tailed Godwits found that polychaetes (worms) represented nearly 90% of their diet. Godwits feed mainly during sunlight hours but have also been observed to feed under moonlight.	**International** Direct and indirect habitat loss affects staging/resting used during migration. Pollution affects both breeding and non-breeding areas. Global warming and sea level rise impacts breeding, staging and non-breeding grounds through intertidal habitat loss. **Australia** Habitat loss especially foraging and roosting sites affects the ability of the Godwit to rest and build energy stores for the return migration to their northern hemisphere breeding grounds. Habitat degradation from silt or sediment loads, water pollution, aquatic weed invasion, changes to flow and hydrological regimes and loss of native estuarine vegetation. Disturbance from residential and recreational human activities. Direct mortality during migration through Australian pathways from motor vehicles, planes and or malnutrition.	**Protect** areas of intertidal mudflat, saltmarsh and mangrove. **Create** artificial oyster reefs to protect habitats. Conduct a feasibility study to determine the viability of the **creation** of artificial oyster reefs. Create a dog beach at Canada Bay to draw this recreation activity away and **protect** sensitive (feeding) areas. Detailed survey and mapping of Godwit feeding and roosting sites to support efforts to **manage** these critical areas.	Increased awareness of sensitivity of migratory species and foreshore environments supports programs to enable a swimmable river. Sydney Rock Oysters have been shown to filter 49% of suspended solids, 58% of bacteria and up to 80% of nutrients from the water column, thus providing direct water quality benefits. Oyster reefs will also provide additional habitat to estuarine species, supporting fish and provide benefits to secondary recreation users in and on the river including anglers.

Table 9: Management recommendations for the Bar-tailed Godwit and link to a swimmable river.

13. Ecosystem Services, Iconic Species and the Challenges to Implementation

The key concept of a social-ecological system model is the relationship between the ecosystem services provided by natural systems and the human activities and social value they enable and support (Holling 2001, Gunderson et al 2002, SMCMA 2012). To provide ecosystem services, natural systems are not required to be in pristine condition. Within the Parramatta River catchment there exist a few natural areas that are remnant but most are modified and moderately to highly degraded. The range of ecosystem services provided by these systems all have value although clearly some more than others.

Appendix H provides a detailed explanation of the link between the ecosystem services, human activities, iconic species and their environmental requirements and detailed parameters for monitoring across the Parramatta River catchment identified by this project. Detailed parameters are then distilled to a simplified version and presented in Figure 40.

The primary indicators identified in **Appendix H** reflect the key aspects of water quality and flow, catchment vegetation (which protects water quality and regulates flow) and valued human activities. The latter may relate to interacting with the iconic species and their communities, or may simply depend on or benefit from a healthy catchment and river, including water quality and aesthetics.

Across the aquatic and terrestrial environments, actions required to achieve the swimmability goal for the Parramatta River and support the habitat and needs of the five iconic species can be categorised into three areas: habitat protection, habitat management and habitat creation. Each of these management approaches will impact on how the community use and relate to the catchment and waterways that is the life-fulfilling activities.

As discussed in previous sections most the catchment is highly modified and the iconic species nominated by way of community vote are not necessarily indicators of 'clean' or 'good' conditions. The Striped Marsh Frog, Eastern Long-necked Turtle, Southern Myotis and Bar-tailed Godwit are well adapted to living or foraging in waterways that are highly modified and if compared to undisturbed, non-urban and naturally vegetated catchment would be considered highly degraded. While they may prefer a less modified habitat it is not known if this may result in additional competition between these iconic species and others living in the catchment. However, the communities nomination of these as iconic species or 'mascots' reveals their popularity and how they relate within the socio-ecological system and thus activities that sustain their presence are supported, noting that unintended consequences or antagonistic links may arise (relate back to **Figure 11).**

The linking of ecosystem services with iconic species and swimmability sets up a detailed and and multi-aspect management system for the Parramatta River catchment. Across terrestrial and riparian environments, a hierarchy of controls are required to support the ecosystem services provided by natural areas to improving water quality which ultimately will lead to swimmability. These include the preservation, management and creation of habitats that not only benefit the five-iconic species but also provide life fulfilling functions for the community.

Within the aquatic environment, there are many life fulfilling activities that rely on water quality to meet recreational standards of contact. The greater the level of contact to the water the more important it is to have a treatment-train approach to the management of stormwater pollution throughout the catchment as well as strategies to address designed sewer overflows, leaks within the sewerage system and to address illegal discharges (pollution). A treatment train approach to urban water management is a well-established principle and requires a combination of technical, policy, legal and behavioural changes.

In addition, changes in the hydrology of urban streams presents significant issues for three iconic species. The changes to stream flow because of urban drainage systems has a detrimental impact on habitat and food resources. The treatment of urban water in a catchment such as Parramatta River will rely on the commitment and coordination of many agencies given the extensive network of pipes and stormwater outlets discharging into the Parramatta River and its tributaries.

14. Monitoring Requirements of Iconic Species and Communities

The five iconic species have specific ecological and environmental requirements to support their current populations and to maintain viable communities into the future. Common requirements across all icons of the Parramatta River catchment relate to complex habitat features, reliable food resources and regulated stream hydrology. Therefore, the recommendations made for each iconic species are based around the approach of habitat protection, management and creation.

Of note is the non-reliance of the iconic species on what would be considered 'good' water quality. As shown in the species profiles (**Sections 9-12**) the Striped Marsh Frog, Eastern Long-necked Turtle, Southern Myotis and Bar-tailed Godwit are well adapted to living or foraging in waterways that could be considered degraded. However, water quality is the primary driver of making the Parramatta River swimmable and as such monitoring and assessment of water quality parameters directly related to swimming, coupled with measures of habitat and the distribution of the iconic species across the catchment, is recommended. When combined, these common elements will form the basis of a robust monitoring program designed to assess the state of habitat and distribution of iconic species across the catchment which should have a feedback loop to the PCRG Master Plan and associated plans, policies and work practices of those who own and manage land in the catchment.

Given the complexity of ecological systems, multiple indices are recommended to provide greater understanding of the effects of waterway and catchment management throughout the Parramatta River catchment.

We note that the iconic species are distinct from and not intended as indicator species. This is because they have been selected by a process that capitalizes on community recognition, and not because of specific sensitivity to water quality or other environmental parameters. They do however provide focal points for community engagement in environmental monitoring programs, and thus provide support for community involvement in understanding and promoting the health of the river.

Parameters and indices for assessment are presented in **Table 8**. Several monitoring activities are included which encourage community participation to undertake surveys and work along side environmental scientists.

Figure 35 presents a schematic summary diagram outlining the ecological and environmental indicators and monitoring parameters linked to the iconic species. This diagram is a simplification of those shown in **Appendix F** which detail the valued community activities, iconic species and their environments, primary indicators and detailed parameters for monitoring.

Many of the parameters shown in **Table 8** and **Figure 35** are a simple measure of condition at the time of monitoring and standard methods exist for the process of sample collection and analysis (e.g. water quality parameters). However, some parameters have both qualitative and quantitative methods of survey (e.g. vegetation communities), and therefore the complexity of the methods and time constraints will be a major consideration as to how these parameters are measured.

An additional aspect of any monitoring program to consider is where and how data collected is stored and used. Some of the metrics recommended in **Figure 35** will require specialist personal to undertake survey and therefore as part of the NSW OEH scientific licensing protocol, data collected is required to be uploaded to BIONET (fauna and threatened species data) or VIS database (Biometric vegetation data). To compliment this requirement, it is recommended that PRCG develop a database to collect and store fauna and flora data to ensure information is stored in a central repository which can be easily queried and analysed.

To compliment the recommended monitoring requirements, **Figure 36** details a hierarchical approach to implementation of a monitoring program. **Figure 36** outlines steps required to achieve this approach to not only monitor iconic species across the catchment but ialso assess water quality and habitat and provide feedback loops to management plans, program reviews and the overarching ‘protect, manage, create’ strategy outlined in the habitat management sections for each iconic species.

Table 8: Summary table of monitoring methods to determine iconic species presence/absence and abundance and condition of suitable habitat.

Iconic Species	Type Of Index	Method	Data Collection	Professional Staff	Community Engagement
Powerful Owl	Presence/Absence/ Abundance/Distibution	1. Play call back. 2. Stag watch. 3. Direct observation. Guidelines on Powerful Owl survey methods can be found at: Department of Environment and Conservation (2004) Threatened Biodiversity Survey and Assessment: Guidelines for Developments and Activities. Lake Macquarie Council (2013) Flora and Fauna Survey Guidelines v4.2 Birdlife Australia (no date) Powerful Owl Survey Method. Note: collaboration with the Powerful Owl Project currently run by Birdlife Australia would be beneficial.	Record location of calls/sightings. Data to be uploaded to server and distribution of Powerful Owls mapped across the catchment. Recording of GPS location will support field validation / quality assurance of data collected. Existing apps (eg BirdLife Australia) could be promoted, or a focused field data collection app. could be developed to enable community members to easily record locations of sightings/calls.	Ecologist GIS Professional Database Developer	Yes
Powerful Owl	Habitat Assessment	Mapping of hollow bearing and stag trees to identify potential habitat/roost/nest trees for Powerful Owl. Note: Hollows for Habitat promoted by SOPA, GSLLS, Councils and Royal Botanic Gardens (John Martin https://twitter.com/Wingtags) Hollows as Homes partnership with Royal Botanic Gardens, Australian Museum and Sydney University http://www.holowsashomes.com/	Record location of hollows/stags. Data to be uploaded to server and distribution of habitat trees can be mapped across the catchment. Recording of GPS location will support field validation/quality assurance of data collected. A field data collection app. could be developed to support community members recording habitat assessment sites and data.	Ecologist GIS Professional Database Developer	Yes
Southern Myotis	Presence/Absence/Abundance/Distibution	1. ANABAT deployment 2. Stag/culvert watch – to be followed up by ANABAT survey if microbat species present.	Record location of confirmed records of the species or potential habitat. Data to be uploaded to server and distribution of species and habitat can be mapped across	Ecologist GIS Professional Database Developer	Yes (only as observers)

		3. Harp trapping Guidelines on Microbat survey methods can be found at: Department of Environment and Conservation (2004) Threatened Biodiversity Survey and Assessment: Guidelines for Developments and Activities. Lake Macquarie Council (2013) Flora and Fauna Survey Guidelines v4.2	the catchment. Recording of GPS location will support field validation /quality assurance of data collected. Identifying and mapping roost /maternity sites to enable site-specific management controls.		
Southern Myotis	Habitat Assessment	Assessment of riparian vegetation condition by application of a suitable method such as the Rapid Riparian Assessment (Findlay et al 2011, Dean and Tippler 2016). This method provides a semi-quantitative assessment of riparian and creek channel condition. Results can be used to strategically target on-ground work for habitat improvement.	Field based site assessments which record condition attributes, assessment location and photographic records. A field data collection app. has been developed by CTEnvironmental and can be modified to enable community members to easily assess habitat attributes and upload data to a central database or server.	Ecologist GIS Professional Database Developer	Yes (with appropriate training)
Striped Marsh Frog	Presence/Absence/Abundance/Distibution	Nocturnal survey on wet nights using call play back and call listening to determine presence/absence of species. Striped Marsh Frog calls all year round (Robinson (1998). Frog calls for playback are available on CD from Griffiths (2006) or on the Australian Museum Frogs Field Guide app. During survey other frog species encountered should be recorded which will build an inventory of the distribution of frog species across the catchment. Guidelines for amphibian survey methods can be found at: Department of Environment and Conservation (2004) Threatened Biodiversity Survey and Assessment: Guidelines for Developments and Activities.	Record location of calls/sightings. Data to be uploaded to server and distribution of frog species mapped across the catchment. Recording of GPS location will support field validation/quality assurance of data collected. Survey can be undertaken using the Australian Museum Frogs Field Guide app which allows the user to record sightings/calls of frog species, record a location and upload information to social media	Ecologist GIS Professional Database Developer	Yes

		Lake Macquarie Council (2013) Flora and Fauna Survey Guidelines v4.2			
Striped Marsh Frog	Habitat Assessment	Assessment of riparian vegetation condition by application of a suitable method such as the Rapid Riparian Assessment (Findlay et al 2011, Dean and Tippler 2016). This method provides a semi-quantitative assessment of riparian and creek channel condition. Results can be used to strategically target onground works for habitat improvement.	Field based site assessments which record condition attributes, assessment location and photographic records. Assessment can be undertaken on app and data uploaded to database. Paper based assessment can also be applied	Ecologist GIS Professional Database Developer	Yes (with appropriate training)
Eastern Long necked Turtle	Presence/Absence/Abundance/Distibution	Direct observation of the species to determine presence/absence and count to determine abundance across the catchment.	Record location of confirmed records of the species or potential habitat. Data to be uploaded to server and distribution of species and habitat can be mapped across the catchment. Recording of GPS location will support field validation /quality assurance of data collected.	Ecologist GIS Professional Database Developer	Yes
Eastern Long necked Turtle	Habitat Assessment	Assessment of riparian vegetation condition by application of a suitable method such as the Rapid Riparian Assessment (Findlay et al 2011, Dean and Tippler 2016). This method provides a semi-quantitative assessment of riparian and creek channel condition. Results can be used to strategically target onground works for habitat improvement.	Field based site assessments which record condition attributes, assessment location and photographic records A field data collection app. has been developed by CTEnvironmental and can be modified to enable community members to easily assess habitat attributes and upload data to a central database or server.	Ecologist GIS Professional Database Developer	Yes (with appropriate training)
Bar-tailed Godwit	Presence/Absence/Abundance/Distibution	Direct observation of species to determine presence/absence and abundance. Targeted survey to be conducted from August – November when species are in Australia.	Record location of confirmed records of the species or potential habitat. Data to be uploaded to server and distribution of species and habitat can be mapped across the catchment. Recording of GPS location will support field validation /quality assurance of data collected.	Ecologist GIS Professional Database Developer	Yes (with appropriate training)

			Birds of Australia app (Pizzey and Knight 2014) has capability to log records and upload data to itunes, however data cannot be sent to a central database.		
Water Quality	Water Quality Parameters	Direct measure of water quality parameters which relate specifically to primary (eg. swimming) and secondary (eg. kayaking) ie turbidity, heavy metals and dioxins, blue green algae and human derived bacteria PRCG has already developed a business case for a Riverwatch Monitoring Program that outlines the recommended methodology for this.	Record location of monitoing sites and upload monitoing data to server/database which allows appropriate data interrogation.	Environmental Scientist	Possibly (with appropriate training)

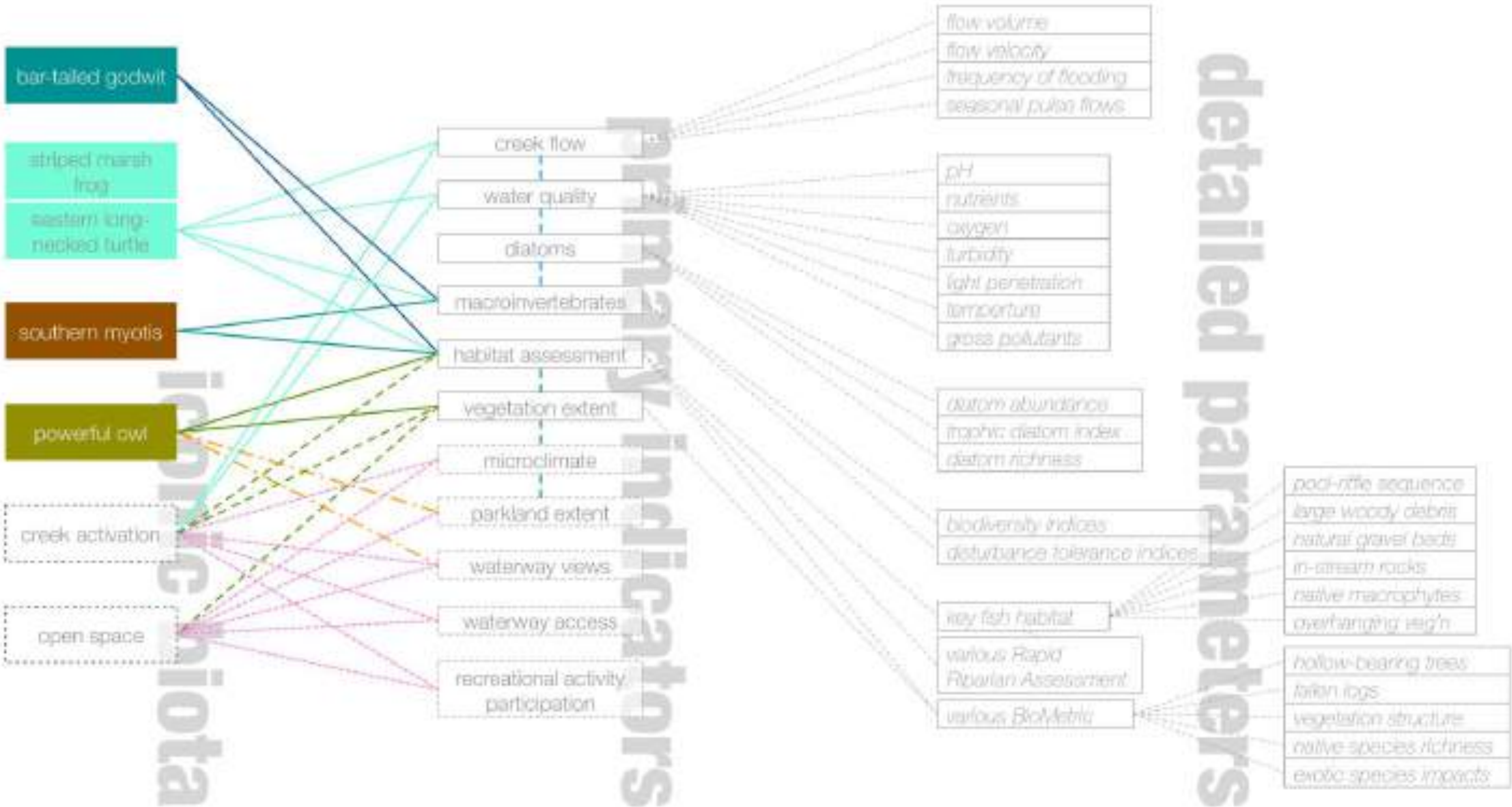


Figure 35: Indicators and parameters associated with monitoring iconic species of Parramatta River catchment.

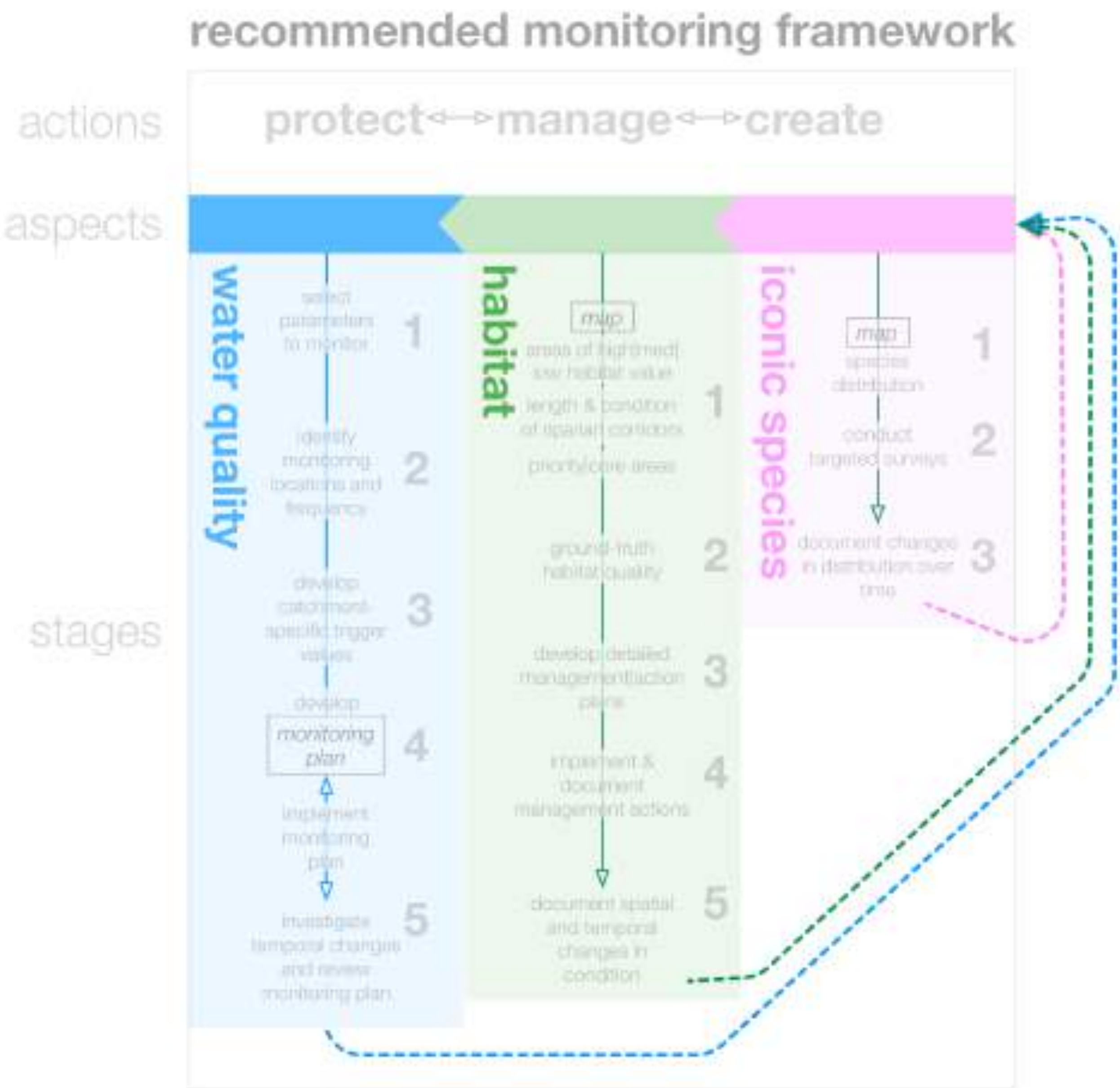


Figure 36: Schematic summary diagram of stages for implementation and review of ecological monitoring program.

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15. Appendix

Appendix A – Threatened Species of the Parramatta River Catchment

Class	Scientific Name	Common Name
Amphibia	*Crinia tinnula*	Wallum Froglet
Amphibia	*Heleioporus australiacus*	Giant Burrowing Frog
Amphibia	*Litoria aurea*	Green and Golden Bell Frog
Amphibia	*Pseudophryne australis*	Red-crowned Toadlet
Aves	*Anthochaera phrygia*	Regent Honeyeater
Aves	*Botaurus poiciloptilus*	Australasian Bittern
Aves	*Burhinus grallarius*	Bush Stone-curlew
Aves	*Calidris alba*	Sanderling
Aves	*Calidris ferruginea*	Curlew Sandpiper
Aves	*Calidris tenuirostris*	Great Knot
Aves	*Callocephalon fimbriatum*	Gang-gang Cockatoo
Aves	*Calyptorhynchus lathami*	Glossy Black-Cockatoo
Aves	*Charadrius leschenaultii*	Greater Sand-plover
Aves	*Charadrius mongolus*	Lesser Sand-plover
Aves	*Chthonicola sagittata*	Speckled Warbler
Aves	*Circus assimilis*	Spotted Harrier
Aves	*Climacteris picumnus victoriae*	Brown Treecreeper (eastern subspecies)
Aves	*Daphoenositta chrysoptera*	Varied Sittella
Aves	*Ephippiorhynchus asiaticus*	Black-necked Stork
Aves	*Epthianura albifrons*	White-fronted Chat population in the SMCMA
Aves	*Falco subniger*	Black Falcon
Aves	*Glossopsitta pusilla*	Little Lorikeet
Aves	*Haematopus fuliginosus*	Sooty Oystercatcher
Aves	*Haematopus longirostris*	Pied Oystercatcher
Aves	*Hieraaetus morphnoides*	Little Eagle
Aves	*Ixobrychus flavicollis*	Black Bittern
Aves	*Lathamus discolor*	Swift Parrot
Aves	*Limicola falcinellus*	Broad-billed Sandpiper
Aves	*Limosa limosa*	Black-tailed Godwit
Aves	*Lophochroa leadbeateri*	Major Mitchell's Cockatoo
Aves	*Lophoictinia isura*	Square-tailed Kite
Aves	*Melithreptus gularis gularis*	Black-chinned Honeyeater (eastern subspecies)
Aves	*Neophema pulchella*	Turquoise Parrot
Aves	*Nettapus coromandelianus*	Cotton Pygmy-Goose
Aves	*Ninox connivens*	Barking Owl
Aves	*Ninox strenua*	Powerful Owl
Aves	*Numenius madagascariensis*	Eastern Curlew
Aves	*Pandion cristatus*	Eastern Osprey
Aves	*Petroica boodang*	Scarlet Robin
Aves	*Petroica phoenicea*	Flame Robin

Aves	*Ptilinopus superbus*	Superb Fruit-Dove
Aves	*Rostratula australis*	Australian Painted Snipe
Aves	*Stagonopleura guttata*	Diamond Firetail
Aves	*Sternula albifrons*	Little Tern
Aves	*Stictonetta naevosa*	Freckled Duck
Aves	*Tyto novaehollandiae*	Masked Owl
Aves	*Tyto tenebricosa*	Sooty Owl
Aves	*Xenus cinereus*	Terek Sandpiper
Flora	*Acacia bynoeana*	Bynoe's Wattle
Flora	*Acacia clunies-rossiae*	Kanangra Wattle
Flora	*Acacia gordonii*	
Flora	*Acacia prominens*	Gosford Wattle, Hurstville and Kogarah Local Government Areas
Flora	*Acacia pubescens*	Downy Wattle
Flora	*Acacia terminalis subsp. terminalis*	Sunshine Wattle
Flora	*Allocasuarina glareicola*	
Flora	*Caesia parviflora var. minor*	Small Pale Grass-lily
Flora	*Caladenia tessellata*	Thick Lip Spider Orchid
Flora	*Callistemon linearifolius*	Netted Bottle Brush
Flora	*Camarophyllopsis kearneyi*	
Flora	*Cynanchum elegans*	White-flowered Wax Plant
Flora	*Darwinia biflora*	
Flora	*Darwinia peduncularis*	
Flora	*Deyeuxia appressa*	
Flora	*Dillwynia tenuifolia*	
Flora	*Diuris bracteata*	
Flora	*Epacris purpurascens var. purpurascens*	
Flora	*Eucalyptus camfieldii*	Camfield's Stringybark
Flora	*Eucalyptus nicholii*	Narrow-leaved Black Peppermint
Flora	*Eucalyptus scoparia*	Wallangarra White Gum
Flora	*Eucalyptus sp. Cattai*	
Flora	*Galium australe*	Tangled Bedstraw
Flora	*Genoplesium baueri*	Bauer's Midge Orchid
Flora	*Grammitis stenophylla*	Narrow-leaf Finger Fern
Flora	*Grevillea beadleana*	Beadle's Grevillea
Flora	*Grevillea caleyi*	Caley's Grevillea
Flora	*Grevillea juniperina subsp. juniperina*	Juniper-leaved Grevillea
Flora	*Grevillea parviflora subsp. parviflora*	Small-flower Grevillea
Flora	*Grevillea parviflora subsp. supplicans*	
Flora	*Haloragodendron lucasii*	
Flora	*Hibbertia sp. Bankstown*	
Flora	*Hibbertia sp. Turramurra*	Julian's Hibbertia
Flora	*Hibbertia stricta subsp. furcatula*	
Flora	*Hibbertia superans*	
Flora	*Hygrocybe anomala var. ianthinomarginata*	
Flora	*Hygrocybe aurantipes*	

Flora	*Hygrocybe austropratensis*	
Flora	*Hygrocybe collucera*	
Flora	*Hygrocybe griseoramosa*	
Flora	*Hygrocybe lanecovensis*	
Flora	*Hygrocybe reesiae*	
Flora	*Hygrocybe rubronivea*	
Flora	*Hypsela sessiliflora*	
Flora	*Kunzea rupestris*	
Flora	*Lasiopetalum joyceae*	
Flora	*Leptospermum deanei*	
Flora	*Leucopogon exolasius*	Woronora Beard-heath
Flora	*Leucopogon fletcheri subsp. fletcheri*	
Flora	*Marsdenia viridiflora subsp. viridiflora*	Marsdenia viridiflora R. Br. subsp. viridiflora population in the Bankstown, Blacktown, Camden, Campbelltown, Fairfield, Holroyd, Liverpool and Penrith local government areas
Flora	*Melaleuca deanei*	Deane's Paperbark
Flora	*Micromyrtus minutiflora*	
Flora	*Microtis angusii*	Angus's Onion Orchid
Flora	*Olearia cordata*	
Flora	*Persoonia hirsuta*	Hairy Geebung
Flora	*Persoonia mollis subsp. maxima*	
Flora	*Persoonia nutans*	Nodding Geebung
Flora	*Pilularia novae-hollandiae*	Austral Pillwort
Flora	*Pimelea curviflora var. curviflora*	
Flora	*Pimelea spicata*	Spiked Rice-flower
Flora	*Pomaderris brunnea*	Brown Pomaderris
Flora	*Pomaderris prunifolia*	P. prunifolia in the Parramatta, Auburn, Strathfield and Bankstown Local Government Areas
Flora	*Prostanthera junonis*	Somersby Mintbush
Flora	*Pterostylis saxicola*	Sydney Plains Greenhood
Flora	*Pultenaea parviflora*	
Flora	*Pultenaea pedunculata*	Matted Bush-pea
Flora	*Senecio spathulatus*	Coast Groundsel
Flora	*Syzygium paniculatum*	Magenta Lilly Pilly
Flora	*Tetratheca glandulosa*	
Flora	*Wahlenbergia multicaulis*	Tadgell's Bluebell in the local government areas of Auburn, Bankstown, Baulkham Hills, Canterbury, Hornsby, Parramatta and Strathfield
Flora	*Wilsonia backhousei*	Narrow-leafed Wilsonia
Flora	*Zannichellia palustris*	
Flora	*Zieria involucrata*	
Gastropoda	*Meridolum corneovirens*	Cumberland Plain Land Snail
Gastropoda	*Pommerhelix duralensis*	Dural Woodland Snail
Mammalia	*Arctocephalus forsteri*	New Zealand Fur-seal
Mammalia	*Arctocephalus pusillus doriferus*	Australian Fur-seal
Mammalia	*Cercartetus nanus*	Eastern Pygmy-possum

Mammalia	*Chalinolobus dwyeri*	Large-eared Pied Bat
Mammalia	*Dasyurus maculatus*	Spotted-tailed Quoll
Mammalia	*Dugong dugon*	Dugong
Mammalia	*Eubalaena australis*	Southern Right Whale
Mammalia	*Falsistrellus tasmaniensis*	Eastern False Pipistrelle
Mammalia	*Isoodon obesulus obesulus*	Southern Brown Bandicoot (eastern)
Mammalia	*Miniopterus australis*	Little Bentwing-bat
Mammalia	*Miniopterus schreibersii oceanensis*	Eastern Bentwing-bat
Mammalia	*Mormopterus norfolkensis*	Eastern Freetail-bat
Mammalia	*Myotis macropus*	Southern Myotis
Mammalia	*Perameles nasuta*	Long-nosed Bandicoot population in inner western Sydney
Mammalia	*Petaurus australis*	Yellow-bellied Glider
Mammalia	*Petaurus norfolcensis*	Squirrel Glider
Mammalia	*Petrogale penicillata*	Brush-tailed Rock-wallaby
Mammalia	*Phascolarctos cinereus*	Koala
Mammalia	*Pseudomys novaehollandiae*	New Holland Mouse
Mammalia	*Pteropus poliocephalus*	Grey-headed Flying-fox
Mammalia	*Saccolaimus flaviventris*	Yellow-bellied Sheathtail-bat
Mammalia	*Scoteanax rueppellii*	Greater Broad-nosed Bat
Mammalia	*Vespadelus troughtoni*	Eastern Cave Bat
Reptilia	*Dermochelys coriacea*	Leatherback Turtle
Reptilia	*Varanus rosenbergi*	Rosenberg's Goanna

Appendix B – Detail of Candidate Iconic Species of the Parramatta River Catchment

Domain	Also Found In	Community	Species	Requirements	Threats	Link to Swimmable River	Explaining the Link
Terrestrial	Riparian	Woodland/Forest Birds	**Powerful Owl**	Habitat – forest and woodland, dense riparian vegetation, tree hollows Food – possums, gliders, flying fox	Susceptible to loss of habitat in particular loss of large hollow bearing trees	Native vegetation corridors	Native vegetation corridors act as filters to overland flow, cleansing water before it enters the creek. Native vegetation stabilises creek banks which limits erosion and sedimentation therefore suppressing further water quality decline.
	Riparian	Woodland/Forest Birds	Eastern Yellow Robin	Habitat – forest and woodland with thick understory Food – insects and small invertebrates	Susceptible to loss of habitat and predation by feral animals especially cats	Native vegetation corridors Water quality	Native vegetation corridors act as filters to overland flow, cleansing water before it enters the creek. Native vegetation stabilises creek banks which limits erosion and sedimentation therefore suppressing further water quality decline.
	Riparian	Butterflies and Moths	Butterflies and Moths	Habitat – mosaic of vegetated habitats Food – nectar	Susceptible to loss of habitat by land clearing	Native vegetation corridors Water quality	Native vegetation corridors act as filters to overland flow, cleansing water before it enters the creek. Native vegetation stabilises creek banks which limits erosion and sedimentation therefore suppressing further water quality decline.
	Riparian	Cumberland Plain Vegetation	Forest Red Gum	Habitat – grassy, wet or dry forest or woodland on soils of medium to high fertility	Susceptible to clearing and weed invasion	Native vegetation corridors Water quality Flow regime	Native vegetation corridors act as filters to overland flow, cleansing water before it enters the creek. Native vegetation stabilises creek banks which limits erosion and sedimentation therefore suppressing further water quality decline. Increased flow, typical of urban streams exacerbates erosion of creek bed and banks and results in sedimentation and elevated turbidity. Increased flows also removes in-stream habitat by washing away leaf litter, woody debris, natural sand and gravel beds and often results in a homogeneous creek channel devoid of niche habitats which would otherwise support a diverse aquatic ecosystem.

Riparian

Riparian	Sandstone Vegetation	Sydney Blue Gum	Habitat – gound on deep clay based soils derived from either shale, volcanic rock or deep alluvium	Susceptible to clearing and weed invasion	Native vegetation corridors Water quality Flow regime	Native vegetation corridors act as filters to overland flow, cleansing water before it enters the creek. Native vegetation stabilises creek banks which limits erosion and sedimentation therefore suppressing further water quality decline. Increased flow, typical of urban streams exacerbates erosion of creek bed and banks and results in sedimentation and elevated turbidity. Increased flows also removes in-stream habitat by washing away leaf litter, woody debris, natural sand and gravel beds and often results in a homogeneous creek channel devoid of niche habitats which would otherwise support a diverse aquatic ecosystem.
Terrestrial Freshwater	Microbats	**Southern Myotis**	Habitat – tree Hollows, slow flowing water, dense riparian vegetation, Food – aquatic macroinvertebrates	Susceptible to loss of habitat in particular loss of large hollow bearing trees and loss of macroinvertebrate food resources due to altered water quality and flows	Native vegetation corridors Water quality Flow regime	Native vegetation corridors act as filters to overland flow, cleansing water before it enters the creek. Native vegetation stabilises creek banks which limits erosion and sedimentation therefore suppressing further water quality decline. Increased flow, typical of urban streams exacerbates erosion of creek bed and banks and results in sedimentation and elevated turbidity. Increased flows also removes in-stream habitat by washing away leaf litter, woody debris, natural sand and gravel beds and often results in a homogeneous creek channel devoid of niche habitats which would otherwise support a diverse aquatic ecosystem.
Terrestrial Freshwater	Frogs	**Striped Marsh Frog**	Habitat – wetlands, floodplains, flooded grassland, woodlands, slow moving creeks, pools and ponds Food – will eat anything smaller than it.	Susceptible to degraded water quality, herbicides and pesticides	Native vegetation corridors Water quality	Native vegetation corridors act as filters to overland flow, cleansing water before it enters the creek. Native vegetation stabilises creek banks which limits erosion and sedimentation therefore suppressing further water quality decline. Species that thrive in clean water can be a good indication of aesthetic, recreational and (often) primary contact water quality.

	Freshwater Estuarine		Rakali (Water Rat)	Habitat – permanent bodies of fresh or brackish water with dense riparian vegetation and clay banks used for burrows. Food – large insects, crustaceans, mussels, fish, frogs, lizards, small mammals and water birds	Susceptible to changes in flow and loss of riparian habitats and loss of prey due to decline in water quality. Susceptible to predation by cats and foxes.	Native vegetation corridors Water quality Flow regime Instream habitat	Native vegetation corridors act as filters to overland flow, cleansing water before it enters the creek. Native vegetation stabilises creek banks which limits erosion and sedimentation therefore suppressing further water quality decline. Species that thrive in clean water can be a good indication of aesthetic, recreational and (often) primary contact water quality. Increased flow, typical of urban streams exacerbates erosion of creek bed and banks and results in sedimentation and elevated turbidity. Increased flows also removes in-stream habitat by washing away leaf litter, woody debris, natural sand and gravel beds and often results in a homogeneous creek channel devoid of niche habitats which would otherwise support a diverse aquatic ecosystem.
Freshwater		Reptiles	**Long Neck Turtle**	Habitat – rivers, lakes, swamps and ponds, including farm dams Food – invertebrates such as worms, snails and insect larvae	Susceptible to decline in water quality, entanglement in rubbish, loss of habitat	Water quality Flow regime Instream habitat	Species that thrive in clean water can be a good indication of aesthetic, recreational and (often) primary contact water quality. Increased flow, typical of urban streams exacerbates erosion of creek bed and banks and results in sedimentation and elevated turbidity. Increased flows also removes in-stream habitat by washing away leaf litter, woody debris, natural sand and gravel beds and often results in a homogeneous creek channel devoid of niche habitats which would otherwise support a diverse aquatic ecosystem.
	Estuarine	Fish	Eel	Habitat – wetlands, dams and creeks with habitat such as logs and rocks and undercut banks to provide refuge in daylight hours Food – insect larvae, worms, snails, fish, yabbies, and even small birds	Susceptible loss of aquatic habitat, blockage of migration passage by road culverts and dams and declines in water quality	Water quality Flow regime Instream habitat	Species that thrive in clean water can be a good indication of aesthetic, recreational and (often) primary contact water quality. Increased flow, typical of urban streams exacerbates erosion of creek bed and banks and results in sedimentation and elevated turbidity. Increased flows also removes in-stream habitat by washing away leaf litter, woody debris, natural sand and gravel beds and often results in a homogeneous creek

						channel devoid of niche habitats which would otherwise support a diverse aquatic ecosystem.
Estuarine	Fish	Australian Bass	Habitat – freshwater and estuarine habitats with varied structures such as large woody debris, overhanging riparian vegetation, macrophyte beds and undercut banks Food – voracious predator that will eat almost anything including aquatic and terrestrial macroinvertebrates, fish and small waterbirds	Susceptible to changes in flows, water temperature and blockages to migration pathways to estuarine spawning grounds	Native vegetation corridors Water quality Flow regime Instream habitat	Native vegetation corridors act as filters to overland flow, cleansing water before it enters the creek. Native vegetation stabilises creek banks which limits erosion and sedimentation therefore suppressing further water quality decline. Species that thrive in clean water can be a good indication of aesthetic, recreational and (often) primary contact water quality. Increased flow, typical of urban streams exacerbates erosion of creek bed and banks and results in sedimentation and elevated turbidity. Increased flows also removes in-stream habitat by washing away leaf litter, woody debris, natural sand and gravel beds and often results in a homogeneous creek channel devoid of niche habitats which would otherwise support a diverse aquatic ecosystem.
	Saltmarsh	*Wilsonia backhousei*	Habitat – intertidal saltmarsh	Susceptible to habitat loss, changed salinity regimes resulting from modified drainage or discharge of stormwater and invasion of weeds such as *Juncus acutus*.	Water quality Native vegetation corridors	Species that thrive in clean water can be a good indication of aesthetic, recreational and (often) primary contact water quality. Native vegetation corridors act as filters to overland flow, cleansing water before it enters the creek. Native vegetation stabilises creek banks which limits erosion and sedimentation therefore suppressing further water quality decline.
	Mangrove	Mangroves	Habitat – occurs in fringing to intermediate tidal zone	Susceptible to changes in salinity regime, reclamation of habitat for foreshore development, off-road vehicles, dumping of rubbish/waste oil spills and toxic chemicals, tramp ling by humans and	Water quality	Species that thrive in clean water can be a good indication of aesthetic, recreational and (often) primary contact water quality. Mangroves, saltmarsh and seagrass recycle significant quantities of nutrients with the littoral/aquatic ecosystem.

Estuarine

			climate change and sea level rise		
Mangrove/Saltmarsh	Burrowing Crabs	Habitat – lives within the intertidal mangrove community Food – organic detritus such as algae and leaf litter	Susceptible to loss of mangrove habitat and siltation due to increased sediment from urban run-off	Water quality Sediment	Species that thrive in clean water can be a good indication of aesthetic, recreational and (often) primary contact water quality. Burrowing Crabs recycle significant quantities of nutrients with the littoral/aquatic ecosystem.
Intertidal	Sydney Rock Oyster	Habitat – sheltered estuaries and bays with relatively clear water and salinity, pH and temperature within optimal ranges	Susceptible to changes to water quality decline due to stormwater run-off and industrial pollution	Water quality	Species that thrive in clean water can be a good indication of aesthetic, recreational and (often) primary contact water quality. Oysters are filter feeders and actively sieve microorganisms and other particles from the water column.
Seagrass	Seagrass	Habitat – sheltered bays with shallow waters and soft sediments such as sand or mud	A significant factor in declining seagrass is a decline in water quality due to urban and agricultural run-off	Water quality	Species that thrive in clean water can be a good indication of aesthetic, recreational and (often) primary contact water quality.
Wading Bird	**Bar Tailed Godwit**	Habitat – Intertidal sandflats, banks, mudflats, estuaries, inlets, harbours, coastal lagoons and bays. It is found often around beds of seagrass and, sometimes, in nearby saltmarsh. Food – molluscs, worms and aquatic insects	Major threats to species includes habitat loss such as land clearing, reclamation and drainage of intertidal areas. Habitat degradation due to weed invasion, altered flows and water pollution.	Water quality Flow regime Native vegetation corridors	Species that thrive in clean water can be a good indication of aesthetic, recreational and (often) primary contact water quality. Increased flow, typical of urban streams exacerbates erosion of creek bed and banks and results in sedimentation and elevated turbidity. Increased flows also removes in-stream habitat by washing away leaf litter, woody debris, natural sand and gravel beds and often results in a homogeneous creek channel devoid of niche habitats which would otherwise support a diverse aquatic ecosystem. Native vegetation corridors act as filters to overland flow, cleansing water before it enters the creek. Native vegetation stabilises creek banks which limits erosion and sedimentation therefore suppressing further water quality decline.

Fish-eating Water Birds	Cormorants	Habitat – freshwater, estuarine and marine waterways Food – fish, crustaceans, amphibians and occasionally small birds	Susceptible to habitat loss and declines in food resources due to declines in water quality, overfishing and habitat loss.	Water quality	Species that thrive in clean water can be a good indication of aesthetic, recreational and (often) primary contact water quality.
Estuarine Fish	Black Bream	Habitat – brackish and fresh waters of estuaries and rivers wioth structures such as fallen trees, jettys and oyster beds Food – opportunistic feeder which will eat invertebrates, fish and crustaceans	Susceptible to loss of habitat, degraded water quality and altered flow in upstream freshwater water reaches	Native vegetation corridors Water quality Flow regime Estuarine habitat	Native vegetation corridors act as filters to overland flow, cleansing water before it enters the creek. Native vegetation stabilises creek banks which limits erosion and sedimentation therefore suppressing further water quality decline. Species that thrive in clean water can be a good indication of aesthetic, recreational and (often) primary contact water quality. Increased flow, typical of urban streams exacerbates erosion of creek bed and banks and results in sedimentation and elevated turbidity. Increased flows also removes in-stream habitat by washing away leaf litter, woody debris, natural sand and gravel beds and often results in a homogeneous creek channel devoid of niche habitats which would otherwise support a diverse aquatic ecosystem.

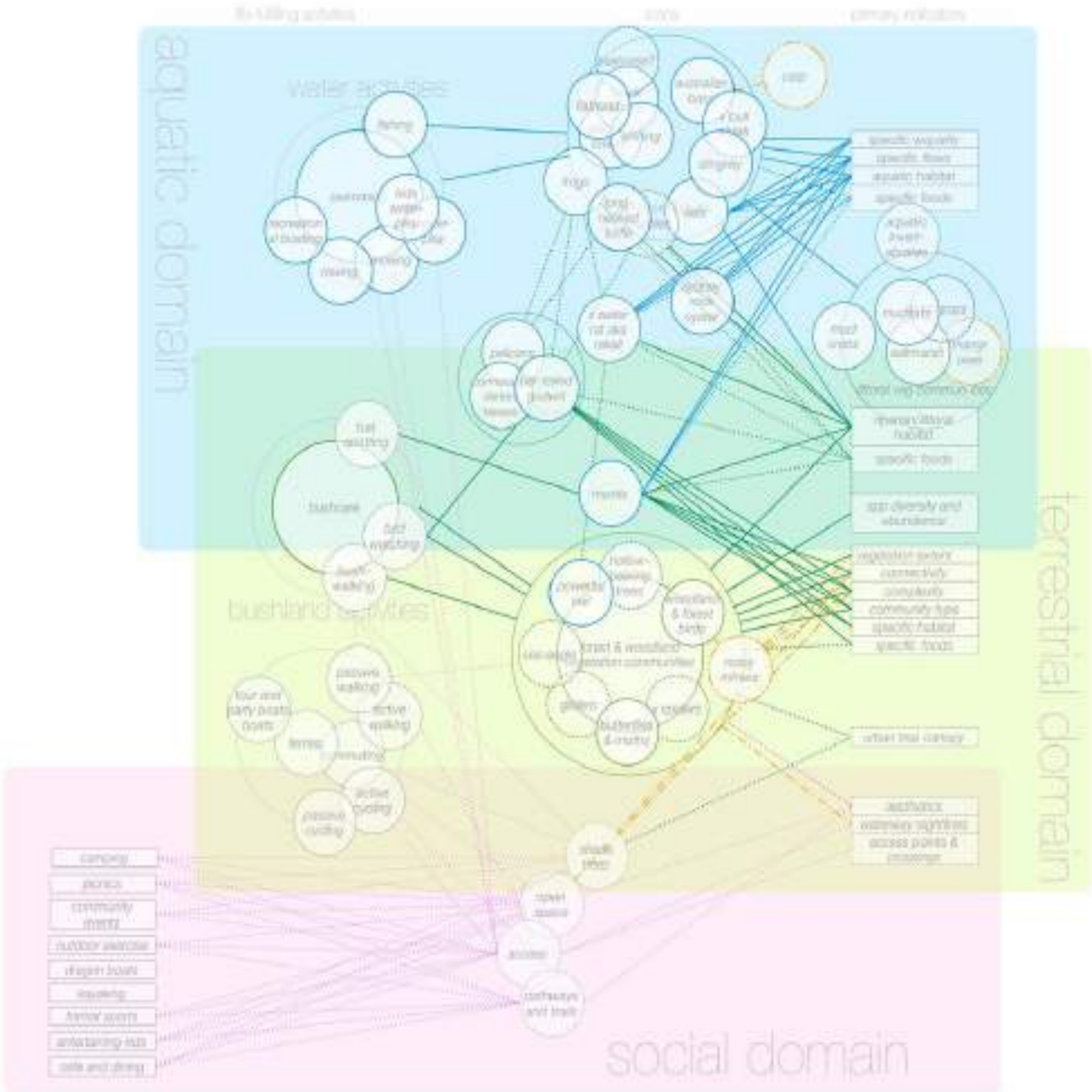
Appendix C- Environment Focused Community Groups in Parramatta River Catchment

Name	Local Council Area	Specific Location of Interest	Specific Field of Interest
Parramatta River Catchment Group	Multiple	Parramatta River Catchment	**Parramatta River catchment environment improvement**
Clean Up Australia Day	Multiple	Parramatta River Catchment	**Annual litter clean-up**
Streamwatch	Multiple	Parramatta River	**Water Quality**
Ashfield Council Greenway Bushcare Group	Cumberland	Inner West Council - Ashfield council area	**Bushcare**
Ashfield Park Community Garden	Cumberland	Ashfield	**Local community gardens and education**
Eora Garden Summer Hill	Cumberland	Summer Hill	**Local community gardens and education**
Haberfield Community Garden	Cumberland	Haberfield	**Local community gardens and education**
De-Vine Auburn Bushcare Program	Cumberland	Chiswick Road	**Duck River restoration and rehabilitation works**
Bankstown Bushcare Program	Canterbury-Bankstown	Multiple locations and Bushcare groups	**Bushcare**
Bushland Conservation Committee	The Hills	Multiple	**Multiple environmental issues within the Hills Shire**
Banksia Creek Bushcare Group	The Hills	Excelsior Reserve, North Rocks	**Bushcare**
Bass Sydney Fishing Club	Parramatta	Northmead	**Angling**
Camcor Bushcare Group	The Hills	Carlingford and North Rocks	**Bushcare**
Excelsior Park Bushland Society Bushcare Group	The Hills	Northmead	**Bushcare of Sydney Turpentine Ironbark Forest and Sydney Sandstone Gully Forest**
Mill Drive Bushcare Group	The Hills	Northmead	**Bushcare**
Northmead Reserve Bushcare Group	The Hills	Watsons place, Northmead	**Bushcare within Sydney Turpentine Ironbark Forests**
O'regan Reserve Bushcare Group	The Hills	Darling Mills Creek Catchment area.	**Bushcare within Sydney Sandstone Gully forest**
Powerful Owl Restoration Team	The Hills	Excelsior Reserve Mill Drive, North Rocks	**Powerful Owl protection**
Pye Ave Bushcare Group	The Hills	Excelsior Reserve Mill Drive, North Rocks	**Bushcare within Sandstone Gully Forest and Sydney Turpentine Ironbark Forest**
Randal Crescent Bushcare Group	The Hills	Randal Crescent walking trail, North Rocks	**Bushcare within Shale Sandstone Transition Forest and Sydney Sandstone Gully Forest**
Seville Reserve Bushcare Group	The Hills	Hunts Creek catchment, North Rocks	**Bushcare within Sydney Turpentine Ironbark Forest, Shale Sandstone Transition Forest and Sydney Sandstone Gully Forest**
Blacktown And Districts Environment Group	Blacktown	Remnant Cumberland Plains, Western Sydney	**Cumberland Plain Woodland protection**
Banks Reserve Bushcare Group	Blacktown	Sparman Crescent, Kings Langley	**Bushcare**

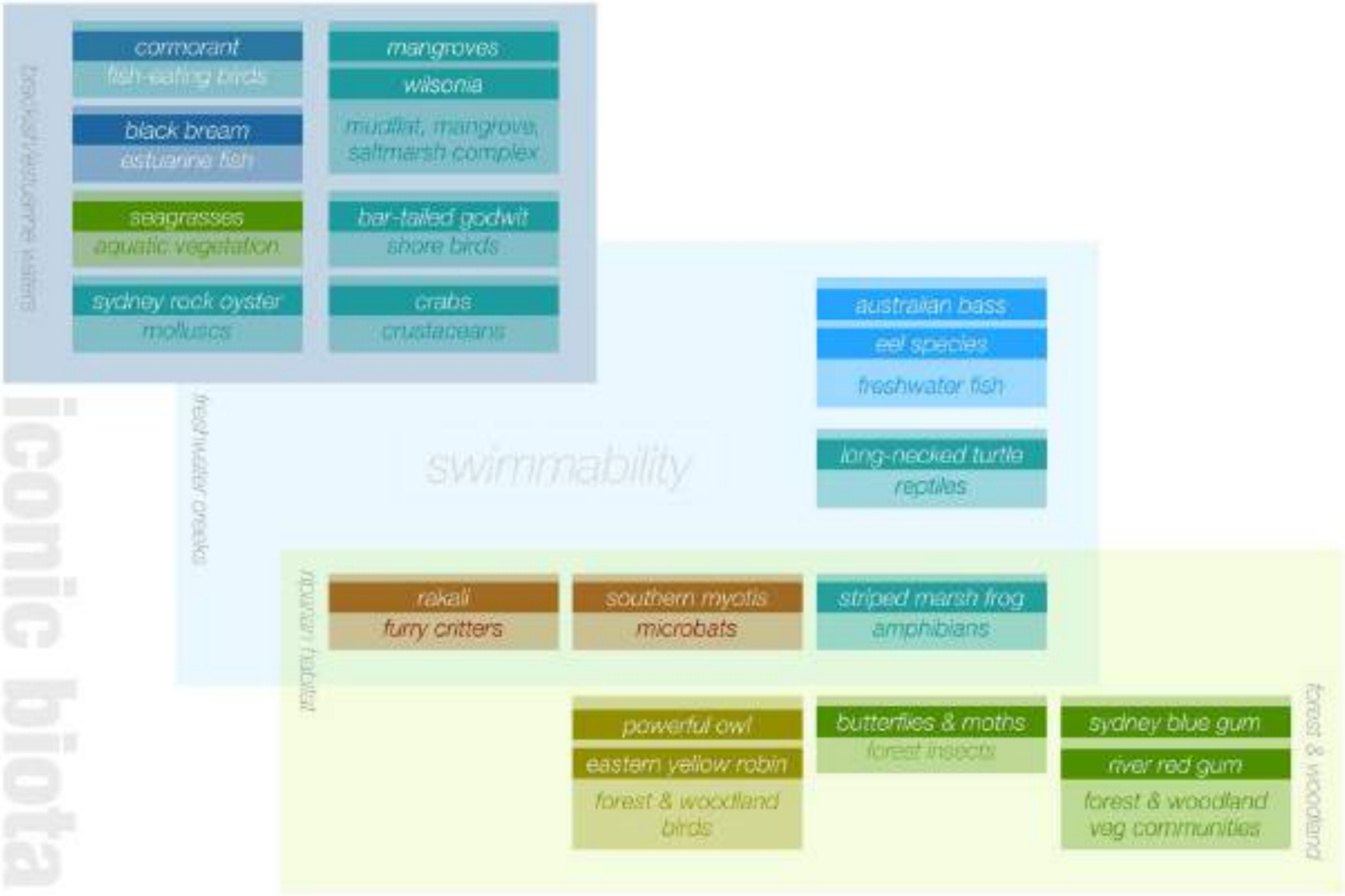
Duncan Park Bushcare Group	Blacktown	Superior Avenue, Seven Hills	**Bushcare**
Faulkland Crescent Reserve, Bushcare Group	Blacktown	Faulkland Crescent, Kings Park	**Bushcare**
Pied Piper Playground Bushcare Group	Blacktown	Beethoven Street, Seven Hills	**Bushcare**
Timbertops Reserve Bushcare Group	Blacktown	Norman Street, Prospect	**Bushcare**
Snowy Reserve, Bushcare Group	Blacktown	Tuross Street, Seven Hills	**Bushcare**
Amateur Fishermen's Association of Nsw	Canada Bay	Concord community centre, Concord	**Angling**
Sisters Bay Bushcare	Canada Bay	Sisters Bay and Half Moon Bay and Brett Park, Canada Bay	**Bushcare within Sisters Bay and Half Moon Bay and Brett Park**
Concord Bushcare	Canada Bay	Queen Elizabeth II Park, Concord, Lovedale Place, Concord West and Quarantine Reserve, Abbotsford	**Bushcare**
Cabarita Bushcare	Canada Bay	Prince Edward Park, Cabarita	**Bushcare**
Chiswick Bushcare	Canada Bay	Figtree Bay Reserve, Chiswick and Montrose Lane, Abbotsford	**Bushcare**
Yaralla Bushcare	Canada Bay	Concord West	**Bushcare**
Lower Prospect Canal Reserve Bushcare Group	Cumberland	Lower Prospect Canal Reserve, Prospect	**Bushcare**
Collingwood Street Reserve Bushcare Group	Hunters Hill	Woolwich baths, Hunters Hill	**Bushcare**
Friends of Betts Park and Gladesville Reserve	Hunters Hill	Gladesville Reserve and Betts Park, Hunters Hill	**Bushcare**
Friends of Boronia Park Bushcare Group	Hunters Hill	Boronia Park, Hunters Hill	**Bushcare within Sydney Turpentine Ironbark Forest, Estuarine Swamp Oak Forest and Estuarine Saltmarsh**
Friends of Buffalo Creek and The Great North Walk	Hunters Hill	Buffalo Creek Reserve, Hunters Hill	**Bushcare**
Friends of Ferdinand Street Reserve	Hunters Hill	Ferdinand Street Reserve, Hunters Hill	**Bushcare within Swamp Oak Floodplain Forest and Coastal Saltmarsh**
Friends of Kelly's Bush	Hunters Hill	Kelly’s Bush Reserve, Hunters Hill	**Bushcare**
Riverglade Bushcare	Hunters Hill	Riverglade Reserve, Gladesville/Hunters Hill	**Bushcare**
Tarban Creek Action Group	Hunters Hill	Tarban Creek, Gladesville/Hill	**Bushcare**
Tarban Creek Bridge Bushcare Group	Hunters Hill	Riverglade Reserve and Betts Park, Gladesville/Hunters Hill	**Bushcare**
The Priory Bushcare Group	Hunters Hill	The Priory	**Bushcare within the grounds or “The Priory”**
Balmain High Bushcare	Inner West	Bayville Street, Balmain	**Bushcare**
Callan Park Bushcare	Inner West	King George Oval	**Bushcare**
Elkington Park Bushcare	Inner West	Fitzroy Street, Balmain	**Bushcare**
Mort Bay Park Bushcare	Inner West	Mort Bay Community Garden, Bay Street, Birchgrove	**Bushcare**

Rozelle Bay Community Native Nursery	Inner West	Wisdom Street, Annandale	**Native plant propagation**
White's Creek Bushcare	Inner West	Rozelle Bay Community Native Nursery, Wisdom Street, Annandale	**Bushcare**
Wetland Education Programs	Inner West	Whites Creek, Annandale	**Wetland educational programs at Whites Creek Wetland Annandale.**
Inner West Environment Group Inc	Inner West	Dulwich Hill	**Bushcare and native corridor protection**
Marrickville Microbat Monitors	Inner West	Inner West Council - Marrickville Council area	**Microbat surveying**
Tempe Birdos	Inner West	Inner West Council - Marrickville Council area	**Bird watching and surveying**
Baludarri Bushcare	Parramatta	Corner of Broughton and Pemberton Streets, North Parramatta	**Bushcare**
Daranggara Corridor Bushcare	Parramatta	Third Settlement Reserve and Oakes Reserve, Winston Hills	**Bushcare**
Edna Hunt Sanctuary Bushcare	Parramatta	Hillside Crescent, Epping	**Bushcare**
Friends of Duck River Bushland	Parramatta	Wategora Reserve, Granville	**Bushcare**
Lake Parramatta Reserve Bushcare	Parramatta	Bourke Street, Parramatta	**Bushcare**
Sea Bees Boating Club Inc	Parramatta	Carlingford	**Angling**
Brush Farm Park Preservation Group	Ryde	Earlwood	**Dedicated to the preservation and regeneration of Brush Farm Park**
City of Ryde Bushcare	Ryde	City of Ryde	**Preserving urban Bushland within the City of Ryde**
Ryde Hunters Hill Flora and Fauna Preservation Society	Ryde/Hunters Hill	Field of Mars Reserve	**Bush care in the Field of Mars Reserve**
Strathfield Council Bushcare Groups	Strathfield	Multiple locations within Homebush and Strathfield	**Bushcare within saltmarsh, mangrove forest and Green and Golden Bell-Frog protection**
Strathfield Council Community Garden	Strathfield	Laker Reserve, Elva Street, Strathfield	**Community gardens and education**

Appendix D – Candidate Iconic Species and Links to Ecosytem Services

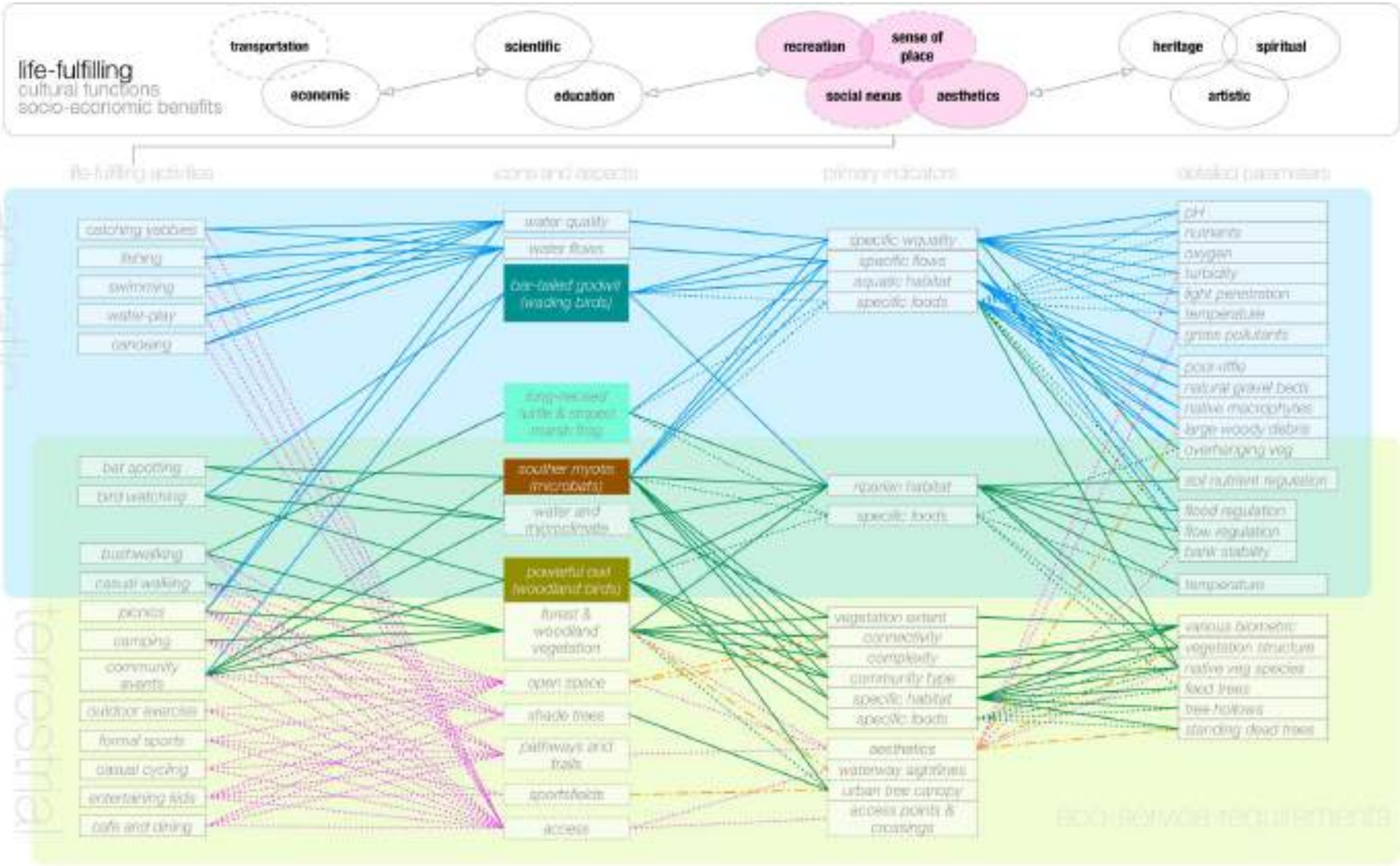


Appendix E – 19 Short Listed Candidate Iconic Species and Community Vote Count



Mascot Name	Total Votes
Southern Myotis	907
Eastern Long-necked Turtle	491
Powerful Owl	448
Striped Marsh Frog	234
Eastern Yellow Robin	203
Bar-tailed Godwit	195
Eel	170
Rakali	166
Cormorants	160
Wilsonia Backhousei	158
Mangroves	157
Australian Bass	151
Sydney Blue Gum	147
Sydney Rock Oyster	139
Semaphore Crab	132
Forest Red Gum	114
Seagrass	102
Black Bream	94
Butterflies and Moths	83

Appendix F - Schematic Summary Diagram Outlining the Ecosyetem Services, Ecological and Environmental Indicators and Monitoring Parameters Linked to Iconic Species.



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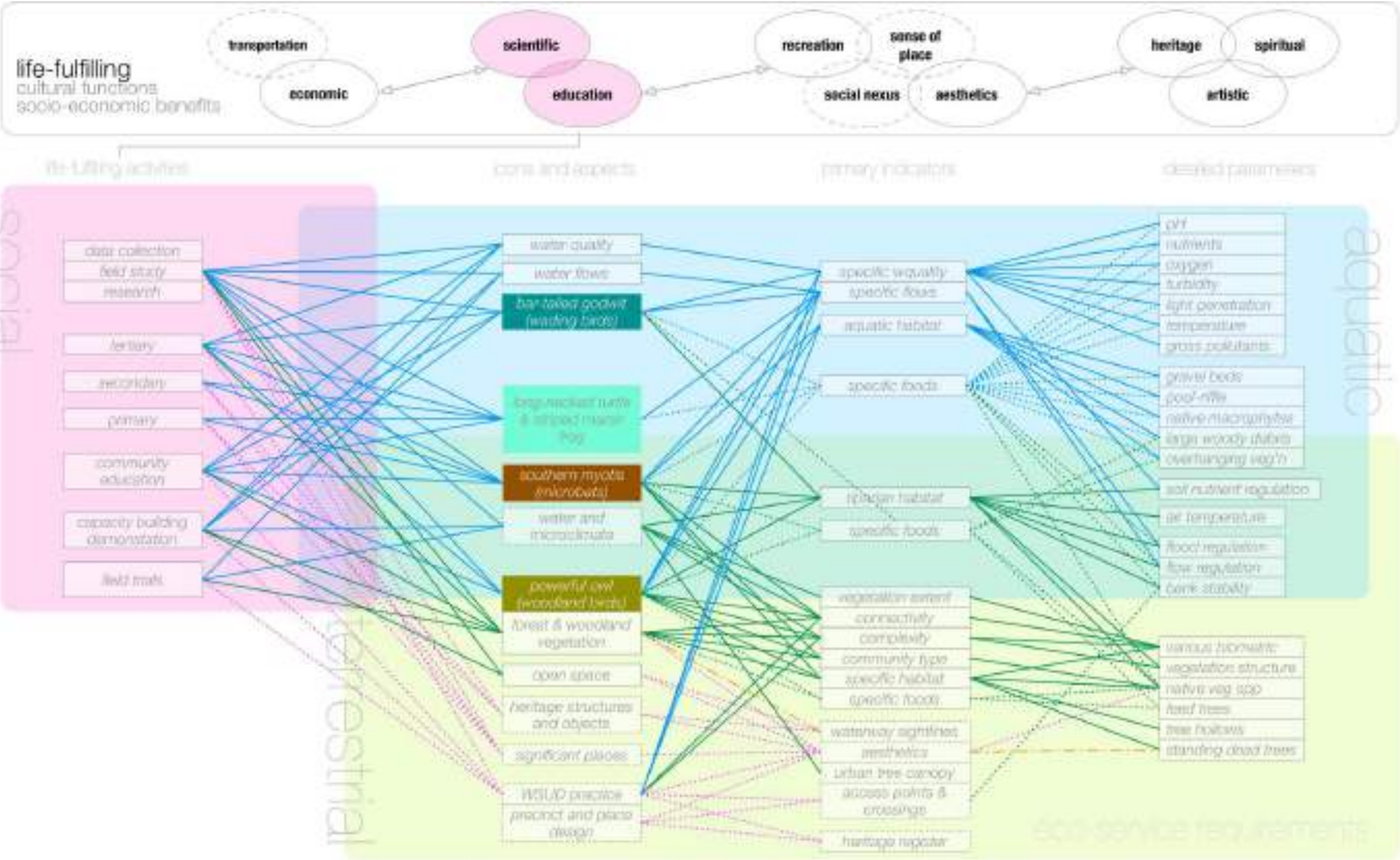

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primary indicators
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aquatic
terrestrial
data collection
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secondary
primary
community education
capacity building demonstration
field trails
water quality
water flows
bar-tailed godwit (wading birds)
long-necked turtle & striped marsh frog
southern myotis (microbats)
water and microclimate
powerful owl (woodland birds)
forest & woodland vegetation
open space
heritage structures and objects
significant places
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community type
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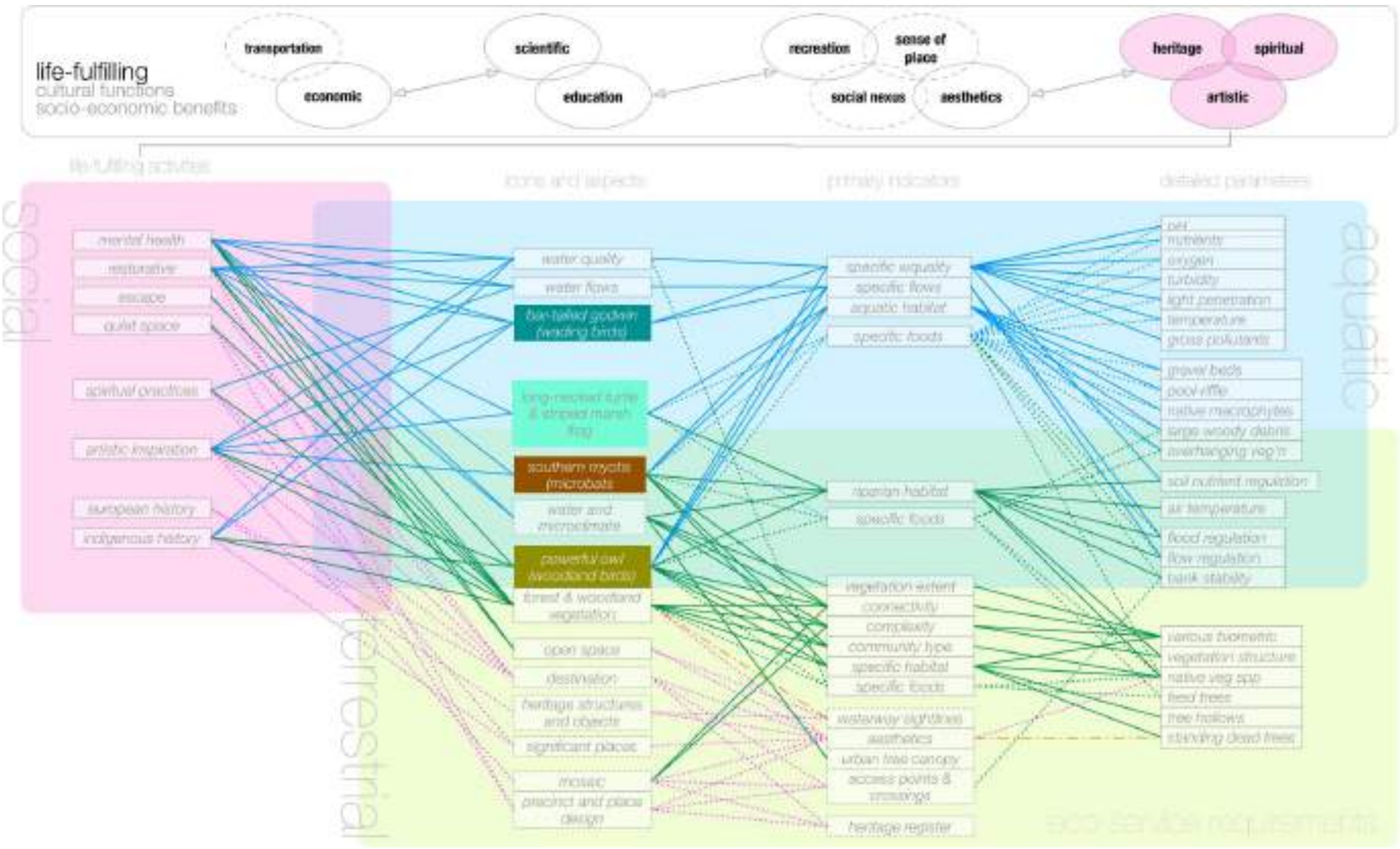
waterway sightlines
aesthetics
urban tree canopy
access points & crossings
heritage register
pH
nutrients
oxygen
turbidity
light penetration
temperature
gross pollutants
gravel beds
pool-riffle
native macrophytes
large woody debris
overhanging veg'n
soil nutrient regulation
air temperature
flood regulation
flow regulation
bank stability
various biometric
vegetation structure
native veg spp
feed trees
tree hollows
standing dead trees
eco service requirements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heritage register
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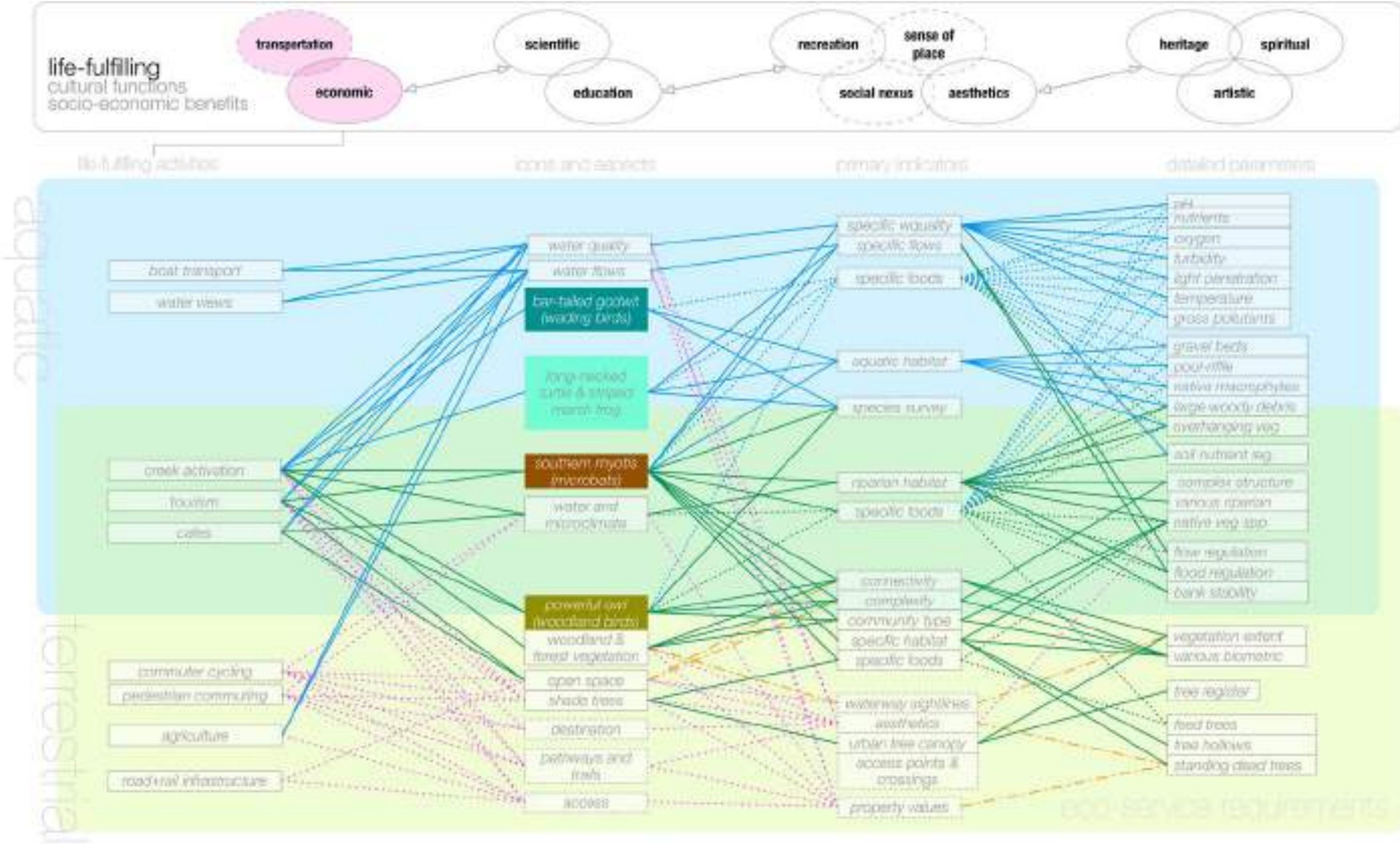
gross pollutants
gravel beds
pool-riffle
native macrophytes
large woody debris
overhanging veg'n
soil nutrient regulation
air temperature
flood regulation
flow regulation
bank stability
various biometric
vegetation structure
native veg spp
feed trees
tree hollows
standing dead trees
aquatic



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icons and aspects
primary indicators
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terrestrial
boat transport
water views
creek activation
tourism
cafes
commuter cycling
pedestrian commuting
agriculture
road+rail infrastructure
water quality
water flows
bar-tailed godwit (wading birds)
long-necked turtle & striped marsh frog
southern myotis (microbats)
water and microclimate
powerful owl (woodland birds)
woodland & forest vegetation
open space
shade trees
destination
pathways and trails
access
specific water quality
specific flows
specific foods
aquatic habitat
species survey
riparian habitat
specific foods
connectivity
complexity
community type
specific habitat
specific foods
waterway sightlines
aesthetics
urban tree canopy
access points & crossings
property values
pH
nutrients
oxygen
turbidity
light penetration
temperature
gross pollutants
gravel beds
pool-riffle
native macrophytes
large woody debris
overhanging veg
soil nutrient reg
complex structure
various riparian
native veg spp
flow regulation
flood regulation
bank stability
vegetation extent
various biometric
tree register
food trees
tree hollows
standing dead trees
eco-service requirements