Economic values of ACT urban lakes

Final report

September 2023

Natural Capital Economics

Alluvium recognises and acknowledges the unique relationship and deep connection to Country shared by Aboriginal and Torres Strait Islander people, as First Peoples and Traditional Owners of Australia. We pay our respects to their Cultures, Country and Elders past and present.

Artwork by Melissa Barton. This piece was commissioned by Alluvium and tells our story of caring for Country, through different forms of waterbodies, from creeklines to coastlines. The artwork depicts people linked by journey lines, sharing stories, understanding and learning to care for country and the waterways within.

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Acronyms

ABS	Australian Bureau of Statistics
ACT	Australian Capital Territory
AIC	Akaike's Information Criterion
DCE	Discrete Choice Experiments
EPSDD	Environment Planning and Sustainable Development Directorate
IIA	Independence of irrelevant alternatives
MNL	Multinomial logit
NCA	National Capital Authority
NCEconomics	Natural Capital Economics
PV	Present Value
PWI	Personal Wellbeing Index
RCP	Representative Concentration Pathway
SA3	Statistical Area Level 3
TN	Total Nitrogen
TP	Total Phosphorus
TSS	Total Suspended Solids
WIA	Wellbeing Impact Assessment
WSUD	Water Sensitive Urban Design

Executive summary

Urban lakes provide a range of diverse and sometimes competing benefits to the ACT community and the environment. The Environment Planning and Sustainable Development Directorate (EPSDD) and the National Capital Authority (NCA) face significant challenges in reconciling the outcomes of different lake management activities and determining an appropriate level of investment and expenditure in water quality management to maximise the total benefit to the community and environment, having regard to the tradeoffs associated with different benefit streams. While policy that informs lake management (i.e., ACT Planning and Development Act 2007, Water Use and Catchment General Code) alludes to a prioritisation of water quality management benefits, more recent research identified the strong links between community values and the lakes, which could outweigh other benefit streams.

Decision-making frameworks that can aide managers typically require outcomes to be expressed in quantifiable and comparable metrics, such as monetary values. However, there was a material gap in the understanding of economic values for ACT's urban lakes—particularly community values—that are not explicitly traded in markets.

The purpose of this project was to quantify the economic values across different benefit streams for three ACT urban lakes—Lake Burley Griffin, Lake Ginninderra and Lake Tuggeranong. Given the range and complexity of benefit streams from these lakes, it was determined that the focus of the project would be to investigate, quantify, and compare (1) the community value and wellbeing from the lakes—requiring good water quality—and (2) using the lakes as a water quality management asset—which results in declines in water quality at the lake.

This project involved four separate studies:

1. an economic valuation for the community values of the urban lakes
2. a preliminary assessment of the links between urban lakes and wellbeing
3. qualitative case studies for users of Lake Burley Griffin and Lake Tuggeranong
4. an economic valuation of water quality management from the three lakes.

The findings across these studies were synthesized to provide recommendations for EPSDD and NCA in considering applications for their lake management initiatives, and opportunities for future research.

Community values of ACT urban lakes

The key community values of interest for this project—specifically environmental amenity and access to lakes for primary and secondary contact recreation—were non-market in nature. Typical economic indicators like market prices could not readily be used to represent the value of these benefits. Thus, a discrete choice experiment (DCE) was developed to estimate these values. This involved developing an economic experiment-based survey for a representative sample of the ACT population (see Figure E 1 for an example of the experiment). The approach allowed analysis of the tradeoffs and consequently, estimation of the willingness to pay (WTP) values between lake attributes. The survey also collected information on lake usage, water quality perceptions, and socio-demographics of participants to determine if any of these have a bearing on community values. Key findings from the analysis were:

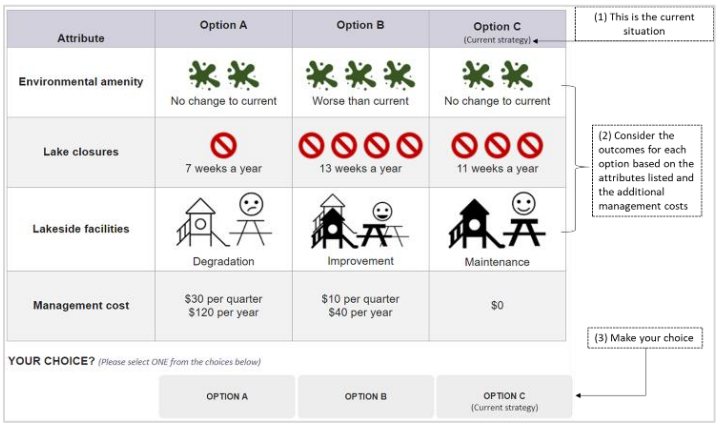

Figure E 1. Example of a choice task

- the majority of the sample, being representative of the ACT community, were likely to be infrequent, casual visitors who draw more value from the amenity and facilities of the lake as opposed to primary and secondary contact recreation (e.g., swimming and boating)
- in a similar vein, a material proportion of the participants did not consider impacts from increased annual closures as important in preferences for attributes of the lakes
- there were substantial values associated with lake attributes at each lake, particularly improvements in environmental amenity (between $35–70 per person per quarter depending on lake) and avoiding degradation of lakeside facilities (approximately $45 per person per quarter)
- the values for avoided lake closures at each lake were much lower than other attributes at approximately $12–19 per person per quarter. Across the lakes, the difference in values for avoided lake closures were almost 90% less for participants who did not consider access to the water as important
- the WTP values for environmental amenity at Lake Burley Griffin were the lowest among the three lakes at $35 per person per quarter and highest at Lake Tuggeranong at around $70 per person per quarter despite the size, location and visitation at Lake Burley Griffin (see Figure E 2).

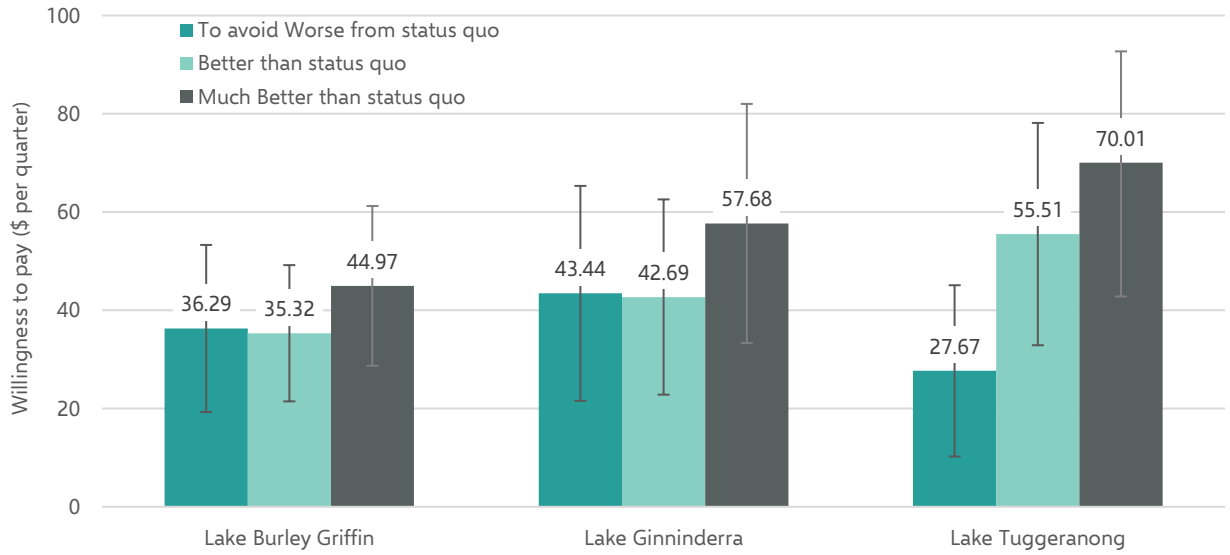

Figure E 2. Willingness to pay per person for changes to environmental amenity ($ per quarter)

Importance of urban lakes to wellbeing

A review of the ACT Wellbeing Framework and broader literature on wellbeing identified several causal pathways between wellbeing and access to the urban lakes, particularly through the domains of *access and connectivity*, *environment and climate*, *health*, and *social connectedness*. Preliminary quantitative analysis on the relationship between lake exposure and wellbeing found a positive but minimal effect. This was consistent with the broader literature that suggests access to nature and blue infrastructure may not demonstrate a strong causal pathway to wellbeing, particularly when analysed in isolation, given the complexity of other influences on wellbeing. Instead, causal pathways may be linked to specific indicators, similar to those identified for the domains of the ACT Wellbeing Framework. The results were also generally aligned with the study of community values, which indicated that frequency of lake access and usage did not have a significant impact on preferences and values. However, there are material knowledge gaps in the understanding of exposure to urban lakes and wellbeing that could be explored in the future.

Qualitative case studies of lake users

Two case studies were conducted, with lake user groups at Lake Burley Griffin and Lake Tuggeranong. This involved a qualitative survey of the respective lake users. Despite the different locations and sample sizes across both surveys, common themes emerged reflecting key attributes and concerns among users—which also aligned with the key attributes valued in the DCE study. Specifically, these themes were:

- the importance of the lakes for undertaking a range of activities,
- concerns around the incidence of algal blooms and loss of amenity
- a desire for improved condition of lakeside facilities.

These were generally in line with findings from the DCE study, except for the importance of lake access for on-water recreation among the user group members. This was expectedly higher than the broader ACT community surveyed for the DCE, the majority of whom did not partake in primary and secondary contact recreation.

Valuation of water quality management

An avoided abatement cost approach was utilised to estimate the values from water quality management by the lakes. Based on water quality modelling across different climate scenarios and a range of avoided abatement unit costs, the present value of water quality management by the lakes was estimated between $1.1–1.2 billion. The analysis also indicated that Lake Tuggeranong had the highest load abatement value by area ($2.3–2.5 million per hectare) despite having the lowest total benefit value ($133–144 million), which was the opposite to Lake Burley Griffin ($1.2–1.3 million per hectare but $816–865 million total) (Table E 1).

Table E 1. Present value of water quality management across study lakes

Lake (size)	PV ($ million) [range]		PV ($ million) per hectare [range]	
	RCP 4.5	RCP 8.5	RCP 4.5	RCP 8.5
Burley Griffin (664 ha)	$865.08 [628.14–1,201.24]	$815.54 [591.32–1,132.52]	$1.30 [0.95–1.81]	$1.23 [0.89–1.71]
Ginninderra (105 ha)	$170.07 [119.88–236.78]	$158.65 [112.10–220.45]	$1.62 [1.14–2.26]	$1.51 [1.07–2.10]
Tuggeranong (57 ha)	$143.92 [101.08–200.44]	$132.90 [93.58–184.80]	$2.52 [1.77–3.52]	$2.33 [1.64–3.24]
Total	$1,179.07 [849.10–1,638.46]	$1,107.09 [797.01–1,537.77]		

Synthesis and recommendations

The total annual non-market economic value of the lakes based on these two key benefit streams was estimated at approximately $216 million a year across all of ACT's urban lakes.

However, the competing nature of these benefit streams creates challenges for EPSDD and the NCA to determine an appropriate tradeoff between community use and water quality management to maximise these economic values going forward. A high-level comparison utilising results from the two valuation studies demonstrated that the community values for improved environmental amenity provide over double the economic value of water quality management. Although the actual outcomes from policy and interventions are likely to be somewhere in between the total theoretical values for each benefit stream, the findings provide consideration for future management interventions that have greater regard to the community values for the lakes.

It is recommended that EPSDD and the NCA:

- utilise the estimated valued, particularly the community values, in its decision-making frameworks to maximise economic benefits for the ACT
- consider addressing other research gaps to improve their decision-making not addressed in this project, which may include:
  - further economic studies to estimate values specifically for lake users (using a travel cost method) and property owners (using a hedonic pricing approach) in the ACT
  - exploring the links between urban lakes and wellbeing through a dedicated study that utilises the domains and indicators from the ACT Wellbeing Framework

– considering further approaches to refining the value of the water quality management benefits of the urban lakes.

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1 Introduction

1.1 Context

Water Sensitive Urban Design (WSUD) has been a critical component of stormwater management in the ACT since the 1960s, with a key asset category being urban lakes. These urban lakes provide a range of diverse and sometimes competing benefits to the community and environment. The ACT Planning and Development Act 2007 (ACT Government, 2007) and the Water Use and Catchment General Code (ACT Planning & Land Authority, 2009) outline key objectives for management of the urban lakes that allude to these multiple benefits, specifically:

- to prevent and control floods by providing a reservoir to receive flows from rivers, creeks and urban run-offs such as open space and rural drainage
- to prevent and control the pollution of waterways, ensuring discharges are consistent with the protection of downstream environment values
- to protect and conserve the water quality of highly valued lakes and provide aquatic habitat for fauna and flora
- ensure that water and catchment land use are consistent with maintaining ecological sustainability, the conservation values of the catchments, and as a drainage function
- protect and conserve the water quality of groundwater resources of the Territory
- make provision for a range of water uses and environment values that are compatible with the conservation values and drainage function of the catchments
- to provide for public use of the lake for recreation.

The objectives outlined in the relevant planning and policy for ACT's urban lakes focus primarily on water quality management, flood mitigation, and ecological catchment health, with objectives relating to urban use and recreation appearing less frequently. This contradicts previous work that identified the need to investigate the community value for these landmark lakes for active and passive recreation to understand the net values for management activities (NCEconomics, 2019). More recently, links have been identified between the existence of the urban lakes and elements of community wellbeing under the 12 domains of the ACT Wellbeing Framework (NCEconomics, 2023).

Analysis of monitoring data for the last 10 years reveal that the lakes receive large spikes in bacteria and algae levels (Figure 1), breaching thresholds that trigger lake closures for primary contact recreation (as defined in the ACT Guidelines for Recreational Water Quality). Data also indicate a variation in closures year on year, with Lake Burley Griffin experiencing a general increase in recent years (Figure 2). Reasons for these spikes are varied but include changes in rainfall, temperature, and contaminated inflows from stormwater (NCEconomics, 2023). Importantly, the impacts from contaminated inflows are outcomes from a key intended environmental benefit from the lakes in managing downstream water quality.

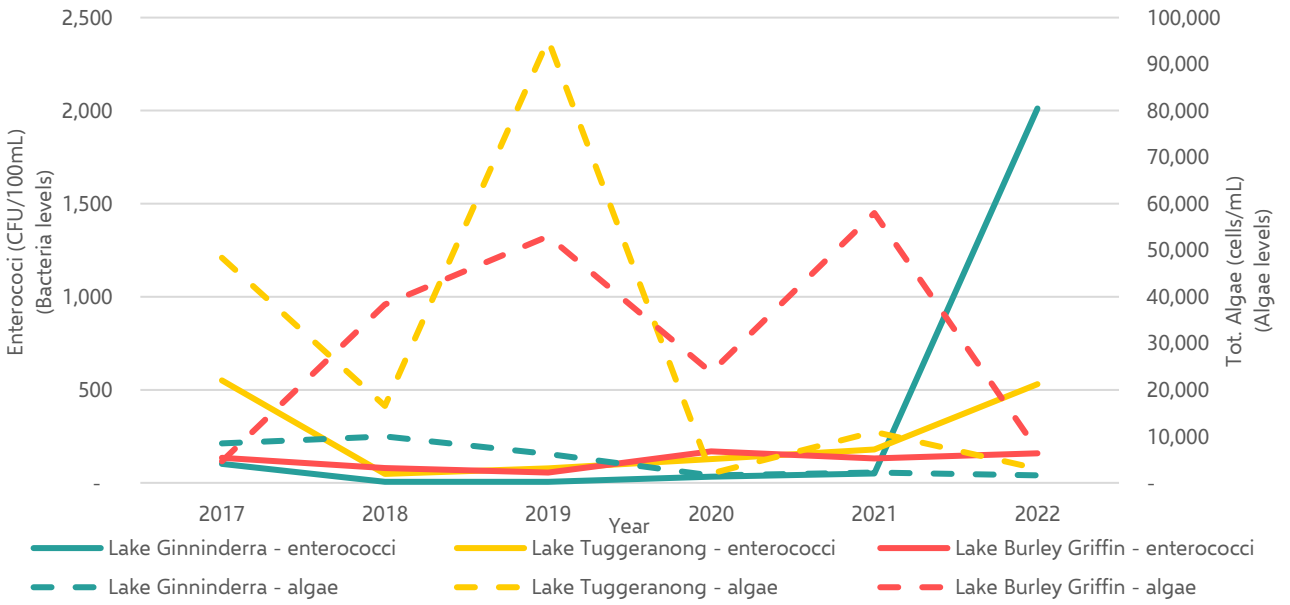


Figure 1. Lake Ginninderra, Tuggeranong and Lake Burley Griffin water bacteria and algae monitoring (2017–2022)

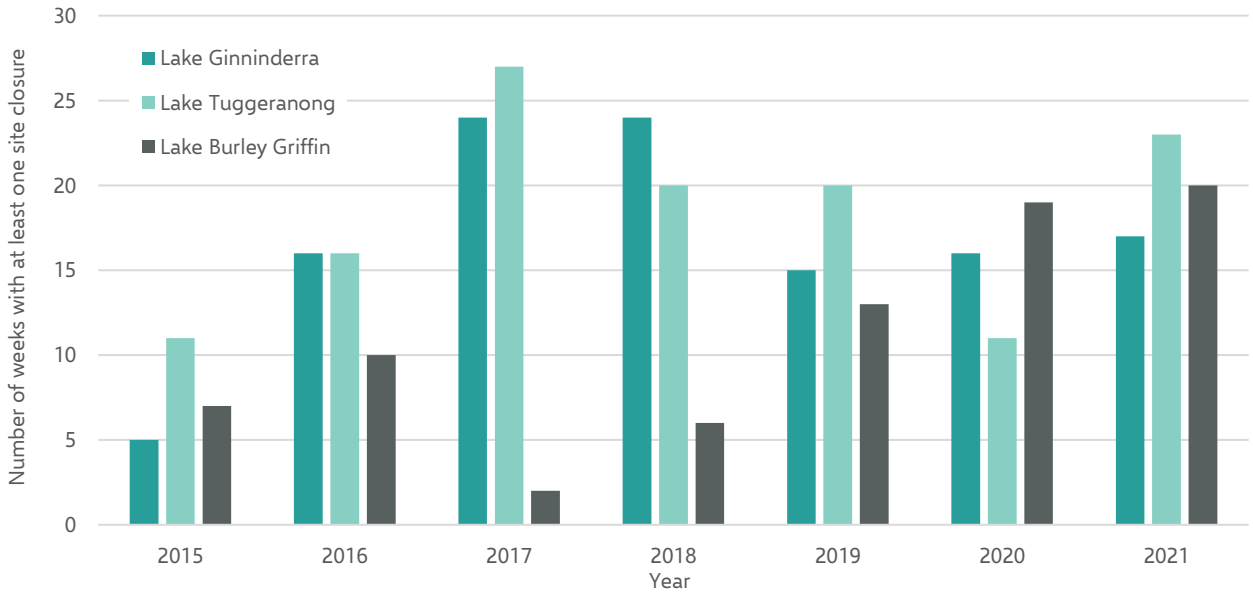


Figure 2. Number of closures to recreational sites within Lake Burley Griffin, Lake Ginninderra, and Lake Tuggeranong

Note: Lake Tuggeranong = 3 recreational sites. Lake Ginninderra = 4 recreational sites. Lake Burley Griffin (2015) = 8 sites. Lake Burley Griffin (2016 – April 2018) = 9 sites. Lake Burley Griffin (October 2018 - 2021) = 10 sites.

Poor water quality at the lakes is likely to have a significant impact on the economic and socio-cultural benefits and values for the community. Visitors have a less attractive experience when accessing the lakes for primary and secondary contact recreation due to health concerns from contact with the water (Breen, et al., 2018). Furthermore, the resulting lake closures result in tangible economic costs through the losses of membership fees for recreation and social groups, and similar flow-on impacts to revenues for lakeside clubs, businesses, and commercial operators (Lawrence, 2011). Finally, high concentration of pollutants—particularly algal blooms—also impact the experience for the wider community, even those who do not partake in primary

or secondary contact recreation. This is due to odour and loss of visual amenity. This loss could manifest in declines in property values but also decreases in non-market, welfare values for the community.[1]

The Environment Planning and Sustainable Development Directorate (EPSDD) administers the ACT Healthy Waterways Program, which has in its objectives to monitor and manage water quality in most of ACT's urban lakes. In a similar vein, the National Capital Authority (NCA) administers various community use and water quality matters associated with Lake Burley Griffin. The EPSDD and NCA face the challenge of determining an appropriate level of investment and expenditure in water quality management in urban lakes to maximise the total benefit for the community and environment, having regard to the tradeoffs between the competing benefit streams.

1.2 Project objectives and approach

The overarching objective of this project was to quantify the multiple benefits of specific ACT's urban lakes and determine the impacts of poor water quality on these values.

This project was delivered through a two-stage approach where in:

Stage 1: appropriate valuation approaches would be identified and recommended, based on the key benefit streams

Stage 2: the agreed approaches from Stage 1 would be implemented to quantify the corresponding benefit values for the lakes.

In Stage 1, it was determined that the key benefits to investigate and quantify are the community value from the use and non-use[2] of the lakes—requiring good water quality—and water quality management from the lakes, which results in declines in water quality. The outcomes from the analysis would not only provide values for the individual benefits but also insight into the tradeoffs associated with these critical competing benefit streams. Furthermore, it was agreed that in Stage 2:

- the lakes to be studied would be Lakes Burley Griffin, Ginninderra and Tuggeranong,
- the key analysis and valuation approaches would include:
  - using a discrete choice experiment to determine the community values for lake attributes
  - exploring links from the ACT Wellbeing Framework to the urban lakes and investigating any direct correlations between lake access and wellbeing
  - undertaking a qualitative case study analysis of users across Lake Burley Griffin and Lake Tuggeranong
  - utilising a benefit transfer of avoided abatement costs to value water quality management through the lakes (NCEconomics, 2023).

The findings from Stage 2 outlined in this report will support EPSDD in its administration of the ACT Healthy Waterways Program and inform future funding requests and proposals.

1.3 Structure of report

The subsequent sections of this report are structured as follows:

[1] See Appendix A for a high-level description of the types of values being discussed.
[2] See Appendix A on the description and differences between use and non-use values.

Chapter 2: Community values of urban lake attributes

Chapter 3: Linkages between lake usage and wellbeing

Chapter 4: Qualitative case studies of lake users

Chapter 5: Valuation of water quality management

Chapter 6: Summary and synthesis of findings.

2 Community values for ACT urban lakes

2.1 Overview

Previous work on the ACT Healthy Waterways Program identified a gap in the knowledge of economic values for lakes among the ACT community, which was a source of uncertainty in assessments of outcomes for the program. This particularly related to the visitation of the lakes for active and passive recreation, which would not be typically quantified given the public good[3] nature of the lakes (NCEconomics, 2019). Further research in Stage 1 identified that much of the prevailing work focused on impacts of water quality on direct use of the lakes for primary and secondary contact recreation and community activities. However, there was a material gap in understanding the non-direct use of the lakes (e.g., benefits from visual amenity) and complementary attributes (e.g., public amenities, parking facilities) that create the visitor experience. This is largely due to the complexity of estimating values for benefit streams that are not explicitly traded in prevailing markets (i.e., these benefits are non-market in nature). Furthermore, there has been little research identified on the values for non-users (or non-frequent users) of the lakes, who:

- may have different perceptions and preferences for the water quality of the lakes
- may be a material proportion of the community compared to frequent lake users
- equally contribute to lake management through taxes and rates.

Therefore, a discrete choice experiment (DCE or choice modelling) approach was considered most appropriate as the primary economic valuation approach for this study. DCEs allow for estimation of individual economic values for specific characteristics or attributes of a good or service to determine the relative importance to the intended community. Critically, these can include attributes associated with both direct and non-direct use.

In this chapter, the approach for and results from administering the DCE for the community value of ACT urban lakes is presented. Detail is provided on the study underpinnings, design, and analysis methods. The results are then discussed in the context of potential use and further utilised as a basis to compare findings across other analysis methods in this report.

2.2 Review of valuation approaches

In determining the most appropriate approach for economic valuation of ACT urban lakes, several approaches were considered. This section provides a brief review of the literature on economic valuation relevant to the values investigated for this study.[4] This review should provide an introduction and explanatory context to economic valuation methods within welfare economics.

Non-market valuation

Non-market valuation is a common term used to describe approaches for estimating economic values for goods and services that are not traded explicitly in markets i.e., non-market good/services (Haab & McConnell, 2022). The resulting values can be then incorporated into social cost-benefit analysis—accounting for

[3] Public goods are characterized by being non-excludable—public access to the good or service cannot be restricted—and non-rivalrous—an individual's use of the good or services does not diminish access and value from the good or service for the next person. It is challenging to identify users and assign payments, so such goods are typically publicly funded.
[4] A general description of economic values and valuation methods is provided in Appendix A).

outcomes across society and not just market interactions—to ensure efficient allocation of resources. Non-market valuation is often used in environmental and natural resource contexts with the purpose of ensuring ongoing expenditure is in line with societal outcomes for long-term management of these resources. These valuation techniques can be subdivided into revealed preference and stated preference methods.

Revealed preferences

Revealed preference methods are used to estimate the non-market use values.[5] These methods are based on observable and actual choices an individual makes to maximise their benefits (or utility) (Parsons, 2003). These preferences and values are determined indirectly through the consumption of representative market goods and services (Freeman, 2003). The most common examples of revealed preference approaches are the travel cost method (TCM) (e.g., Doshi & Pascoe, 2013; Pascoe, et al., 2014) and hedonic pricing (HP) (Bin & Landry, 2013; Pryce, Chen, & Galster, 2011).

Although revealed preference approaches are preferred for estimating direct use values, these methods cannot be used to estimate non-direct use and non-use values such as option, bequest, and existence values. Non-direct use values are important to consider in this study as individuals may derive satisfaction without contact with the lakes. This may be particularly critical if regular visitation to some lakes may not be high, but the community may have significant non-direct use values for the lakes.

Key point

Revealed preference approaches were not considered the most appropriate methods for estimating the value of urban lakes across the ACT community. This was due to the inability to capture non-direct use values through these methods. Revealed preference approaches may be considered by EPSDD to determine the economic value specific to visitors or property owners through separate studies (as alluded to in section 6.3), but the resulting values should not be added to any values estimated for this project due to the possibility of double counting.

Stated preferences

Stated preference approaches determine the value of a non-market good or service through responses to (hypothetical) changes or scenarios (Bennett & Blamey, 2001). In these methods, individuals are assumed to value a good/service/option based on its attributes and made tradeoffs with these attributes. Essentially, individuals derive value from a bundle of these attributes rather than the good/service/option itself (Louviere, et al., 2000). The individual choices are modelled to determine the values of the good/service/option or individual attributes. This allows elicitation of values for non-direct use (e.g., non-use and option values), which is highly relevant to this study. The theory and assumptions are grounded on economic principals of rational choice and utility (benefit) maximisation (Louviere, et al., 2010). The most common stated preference approaches are contingent valuation method (CVM) and discrete choice experiments (DCE).

An overarching concern with stated preference methods is the likelihood of hypothetical bias due to the use of stated responses (Hensher, 2010). However, this can be reduced through appropriate method selection, study design, and econometric modelling of responses, which will be discussed later in this chapter.

Key point

Stated preference approaches were considered most appropriate for this study because of its ability to capture non-direct use values (including non-use and option values)

[5] See Appendix A for description on different types of economic values.

Contingent valuation method

CVM analyses how much respondents are willing to pay (WTP) for a change in the quality/attribute for a good or service through scenario-based surveys. The economic values are *contingent* on what is highlighted in each scenario (Carson, 2011). The questions employed in CVM are diverse from open-ended (e.g., how much are you willing to pay) (Alvarez-Farizo, 1999), referendum-styled (e.g., are you willing to pay $X) (Cameron & Huppert, 1991) or through bidding (listing progressively increasing values until the respondent rejects) (Yu & Abler, 2010).

CVM is impacted by several limitation which can result in responses being exposed to bias or being invalid due to participants distorting their preferences, *yea saying*, being indifferent to the scope of the contingency mechanism, influenced by a *warm glow* effect due to altruism, or not reflecting the accessibility of substitutes (Bennett & Blamey, 2001; Diamond and Hausman, 1994). Improper design also results in a risk of forcing—where a respondent is not given an option of reflecting a preference of a zero WTP. These flaws potentially results in an overstatement of WTP through CVMs (Whitehead & Haab, 2013).

Discrete choice experiments

DCEs are based on the theory that an individual's probability of choosing from a set of alternatives (i.e., a choice set) is based on the respective, differing attributes and levels. Thus, the individual makes trade-offs across multiple attributes simultaneously (e.g., accepting a lower level in Attribute A for a higher level in Attribute B) (Bennett & Blamey, 2001). DCE uses a series of multiple hypothetical choice scenarios with varying levels in attributes, together with the inclusion of a 'no choice' status quo option to avoid issues of forcing (Rolfe & Bennett, 2009). As with all non-market valuation, the responses are then modelled econometrically to determine WTP values; however, DCEs allow for elicitation of preferences across a population more robustly, rather than aggregate preferences for the specific sample, given its fundamentals have become rooted in economic theory (Louviere, et al., 2010).

The underlying theory of DCEs provide several benefits over other stated preference approaches. The ability to breakdown WTP values by attribute allow for a detailed account of trade-offs across a study population and thus, application of values to alternative scenarios such as through benefit transfer (e.g., using an estimated value for improved amenity on an alternative policy that delivers similar outcomes) (Morrison, Bennett, Blamey, & Louviere, 2002). DCEs also reduce the impact of potential bias such as scope/framing issues, *yea saying*, and to an extent, hypothetical bias (Bennett & Blamey, 2001; Hensher, 2010; Murphy, et al., 2005; Rolfe, Bennett & Louviere, 2002).

Key point

Discrete choice experiments were considered the most appropriate approach for estimating the economic value for ACT urban lakes. DCEs are less likely to be susceptible to overstated WTP given the bounds introduced through experiment design and links to a realistic payment vehicle and corresponding market (e.g., increased through rate payments).

2.3 Approach

This section provides a general description of the approach utilised to apply a DCE to estimate the community values for ACT urban lakes.

For this study, the survey-based experiment was developed for a sample of participants representative of the ACT population. Survey participants were presented with a hypothetical, but realistic, scenario for lake management policy and its impacts to key attributes associated with ACT urban lakes. Responses from this

experiment, and other socio-demographic and preference-based questions, were econometrically modelled to estimate values for key attributes of the lakes. Further detail to the theoretical underpinnings and general econometric specification utilised is provided in Box 1.

Box 1: Theoretical underpinnings and general econometric specification of discrete choice experiments

The theoretical underpinnings of DCEs are well-established in the literature (Hensher, et al., 2005; Train, 2009). It assumes that an individual derives value—or utility—based on not the good itself, but the individual components or attributes of each good. The individual will make and pay for a choice from a set of alternatives to maximise their overall utility, having consideration for their preferences, price of alternatives and income constraints. It essentially unpacks the factors influencing an individual's choices, to determine how people value each attribute of the options being presented.

As with all approaches that attempt to model human behaviour, certain concessionary assumptions are required such as assuming consistency in preferences, assumptions on prevailing or *a priori* preference for attributes. Some differences in preferences—or heterogeneity—can be accounted for through the inclusion of broad socio-demographic characteristics and general preference indicators.

The analysis of DCE responses is based on Random Utility Theory where individual utility functions comprise of deterministic components i.e., socio-demographic characteristics (**y**), price (p) and attributes of options (**A**) from the given choice set (S_f), and unobserved/stochastic components (ε), the latter including unobservable components and errors. The probability of an individual's choice (c_n) is modelled econometrically—using one or more variants of a logit model—against the attributes of the independent variables outlined above, including the error component, as shown below.

$$\begin{aligned} P_i\{c_n = 1|S_f\} &= P_i\{\mathrm{V}_n(\boldsymbol{y}_i, \mathbf{A}_{nf}, p_n, \varepsilon_n) > \mathrm{V}_o(\boldsymbol{y}_i, \mathbf{A}_{of}, p_o, \varepsilon_o);\ \forall\, n \in S_f\} \\ &= P_i\{\mathrm{V}_n(\ .\ ) + \varepsilon_n > \mathrm{V}_o(\ .\ ) + \varepsilon_o;\ \forall\, n \in S_f\} \\ &= P_i\{\mathrm{V}_n(\ .\ ) + \varepsilon_n - \mathrm{V}_o(\ .\ ) > \varepsilon_o;\ \forall\, n \in S_f\} \end{aligned}$$

DCE analysis typically utilise some variant of the logit model, often a multinomial logit (MNL) model, based on the probabilities of choice described above. Alternative specifications such as a nested logit, random parameter logit, or latent class model are also often considered in analysis as a means of capturing additional heterogeneity.

Relative model performance (i.e., which model performs better) is based on the theoretical understanding of the problem and a statistical indicator known as the Akaike Information Criterion (AIC). The AIC is relative measure to compare between models based on the goodness of fit and complexity, where a lower AIC value indicates better model performance.

The marginal WTP for an attribute an, is estimated from the coefficients of the logit regression according to the function:

$$MWTP_{a_n} = -\frac{\beta_{a_n}}{\beta_{p_n}}$$

where the numerator is the coefficient of the attribute of interest and the denominator is the coefficient of the price/cost of the alternative, n. The negative sign is necessary given the assumption that the cost coefficient will be negative (Alpizar et al., 2003; Hensher et al., 2005; Train, 2009).

Key considerations to study design

Based on initial review of the DCE literature, several key matters were considered in developing the study design to maximise success of results. These are:

- **minimising sources of hypothetical bias**—as with any stated preference method, DCEs are susceptible to hypothetical bias (Bergmann, Hanley, & Wright, 2006; Roe et al., 2001); in order to minimise its impacts, several measures were included in the study design including:
  - benchmarking attribute levels with real outcomes (Bergmann, Hanley, & Wright, 2006; Roe et al., 2001) through discussions with EPSDD and NCA staff during experiment design, and
  - including an introductory script to encourage participants to consider their household budgets to limit overestimation of values (Carlsson, Frykblom, & Johan Lagerkvist, 2005; Van Loo, et al., 2011).
- **minimising cognitive burden**— the use of complex behavioural experiments places cognitive burden on participants. This could result in confusion, fatigue or frustration, impacting the accuracy of trade-offs and preferences (Bennett & Blamey, 2001). Thus, the survey was designed and extensively tested (internally, with EPSDD staff and through a pilot) to ensure time spent is minimised and any sources of burden are mitigated; respondents were also able to stop the survey at any time and continue through a 'save' function of the online platform.
- **capturing sources of heterogeneity**—economic models provide a simplified representation of the real world and as such, may not sufficiently capture the differences that drive outcomes or choices; survey questions were included to capture possible observable sources of heterogeneity including preferences and prevailing use of lakes, political views and trust in the government, and socio-demographic characteristics.[6] Several model specifications were also attempted to account for unobservable heterogeneity, as described below.
- **investigating independence of irrelevant alternatives (IIA)**—another source of heterogeneity, the literature discussed how MNL models assume choices between two alternatives are independent of other options (Hensher, et al., 2005). This can be tested through a Hausman-Macfadden (1984) test and if present, alternative specifications could be run like the nested or mixed MNL (Hensher, et al., 2005).
- **dealing with scoping/framing concerns**—the literature identified a potential for over-informing respondents creating an upward bias in results (Rolfe et al., 2000) or likelihood of overcomplicating experiments to the point of diverging from reality (Bennett & Blamey, 2001). Consideration was given to how the DCE introduction was worded and this was tested extensively to minimise this likelihood; also, inclusion of a status quo or no choice option was important to ensure participants were not forced to pick alternative options that create inflated values.
- **understanding non-attendance to attributes**—the literature has identified the likelihood that respondents may only consider a subset of attributes, ignoring one or more—known as attribute non-attendance. This was investigated through the inclusion of supplementary questions (i.e., if participants consistently ignored any attributes), known as stated non-attendance.[7]

[6] Part of the survey was also designed to investigate the impact of lake access on wellbeing. The associated wellbeing questions were not investigated as part of the DCE analysis. The wellbeing analysis is provided in chapter 3.

[7] Non-attendance can also be investigated through the econometric modelling through inferred non-attendance approaches such as through a latent class modelling approach (e.g., Campbell, Aravena, & Hutchinson, 2011; Campbell et al., 2008; Hensher, Rose, & Greene, 2012; Scarpa, Gilbride, Campbell, & Hensher, 2009). This was not explored as part of this report but could be in the future.

- **ensuring a representative sample is obtained**—as the intended sample of participants was to be representative of the ACT population, prospective participants were screened to meet quotes for gender, age, and residential area based on census data.

Key point

In developing the study design, several key matters were given consideration to maintain theoretical and empirical robustness of results, consistent with best practice for DCEs.

Survey design

The survey consisted of an introduction to the study to provide participants a general understanding of the project and five main sections as described below. A text version of the survey is provided in Appendix B.

Screening questions

As mentioned above, the survey was intended to collect responses from a representative sample of the ACT population. Thus, in addition to only finding participants from survey panels based in the ACT, three screening questions were used to ensure the total sample would be comparable to corresponding breakdown across the Territory:

- residing region—participants would indicate if they were from one of the following:
  - Belconnen
  - Inner South, Inner North and City
  - Gungahlin
  - Tuggeranong
  - Woden, Weston Creek and Molonglo
  - not in Canberra—participant would be excluded from the survey
- age—participants would indicate their age in one of the following brackets:
  - 18 years and under—participant would be excluded from the survey for ethical reasons
  - 19–24 years
  - 25–35 years
  - 45–54 years
  - 55–64 years
  - 65–74 years
  - 75 and over
- gender—participant would indicate if they identified as the following gender:
  - male
  - female
  - non-binary
  - use another term
  - prefer not to say.

Wellbeing questions

Two questions were included to elicit participants wellbeing for use in a separate wellbeing analysis. The theory and drafting of those questions are provided in chapter 3. The responses to these questions were not used in the DCE modelling.

Lake visitation, usage and perceptions

This next section included questions on participants visitation, use and experience at the lakes. These were in the form of question on visitation at the three study lakes and other waterbodies over the past 12 months and four weeks, length of visits, types of activities, whether visitation was alone or with others, and perception of water quality at the three study lakes (with a 'don't know' option in case the participant had not visited the lake or had no opinion on the water quality).

Choice experiment

Defining the attributes and levels are a critical part of the DCE and it is important to ensure relevant attributes reflect actual perceptions individuals may have (Hensher, et al., 2005). The attributes would need to be defined objectively to ensure the value of levels were consistent across participants. Finally, the selection of attributes and levels should allow for sufficient variation but avoid over-complication (Adamowicz, et al., 1998), and not introduce bias.

For this study, participants were given a hypothetical scenario where the ACT or Commonwealth government (depending on the assigned lake) were considering enacting one of three management options for the lake and participants would be able to assign preferences for each choice task. These three options—unnamed options A and B for alternative management and option C as the prevailing status quo—would result in changes across three attributes over the subsequent five years. The attributes were selected in discussion with EPSDD and NCA staff. Care was taken to ensure the attribute levels would correspond to actual outcomes that a resident may experience. The attributes and levels selected are provided in Table 1.

Through discussions with EPSDD and NCA, and the experimental design software, it was determined that four levels for most attributes were sufficient, with the attribute for lakeside facilities being represented by three levels. Care was taken to avoid complex description of the levels, with pictures and icons used, where appropriate. Although two attributes—environmental amenity and lakeside facilities— were largely qualitative, appropriate descriptions and visual aids were used to provide objectivity and commensurability. When comparing absolute and relative changes in levels from the status quo, past research found no difference in the framing of the levels (Kragt & Bennett, 2012). In this study, all levels were presented as relative changes from the status quo as this would reduce inconsistencies between participants and across study lakes.

Table 1. Attributes and levels for DCE

Attribute	To capture impact of management options on…	Levels	Basis for levels	Presentation in experiment
Level of environmental amenity	Visual amenity and smell caused by the build-up and decomposition of blue-green algae	Worse than current state No change to current state Better compared to current state Much better compared to current state	Assumption that across all three lakes, lake surface is regularly covered for weeks with multiple streaks and blooms of blue-green algae.	Qualitative description of outcome on visual amenity and smell (with pictures to illustrate visual impacts) Icons to denote different levels
Lake closures for primary recreation	Recreational access to the water	More (+20%) annual closures No change to annual closures Slightly less (-20%) annual closures Much less (-40%) annual closures	Corresponding percentage changes in annual closure rates for each lake based on prevailing closure data provided by EPSDD and NCA.	Numerical values for changes in number of weeks at least one site at the lake is closed Icons to denote different levels
Condition of lakeside facilities	Cleaning, maintenance, and replacement programs for lakeside facilities, specifically public toilets, picnic and BBQ areas, and playgrounds	Degradation from current state No change to current state Improvement from current state	Given abundance, diversity and quality of facilities across all three study lakes, this attribute was intended as a catch-all for non-natural components of a visitors experience at the lakes.	Qualitative description of outcomes to lakeside facilities across three levels Icons to denote different levels
Cost	Hypothetical additional payments collected through rates/taxes	$0 per quarter/year $10 per quarter/$40 per year $20 per quarter/$80 per year $30 per quarter/$120 per year	High-level discussion on appropriate levels for changes to rates/taxes with EPSDD and NCA.	Numerical values for payment amounts

The experiment was designed using specialist software Ngene (Rose, et al., 2021). Multiple combinations of parameters attribute and the respective levels were tested to produce the most efficient choice experiment design, measured by D-error (Rose & Bliemer, 2013) with an estimated sample size of 700 across the three lakes. This avoided requiring a full factorial design where each respondent completes choice tasks for each possible option (Hensher, et al., 2005), which would result in a total of 144 (4x4x3x3) combinations. The status quo (Option C) for each choice set was 'no change' for each attribute, including maintenance of lakeside facilities and no additional management costs. A total of 24 choice sets were generated, grouped into three blocks of eight choice sets i.e., each participant would complete eight choice tasks. The same design was used for each lake, with the only difference being the marginal changes in levels for lake closures (i.e., number of weeks), which were based on actual lake closure data provided by EPSDD. A sample scenario is provided in Figure 3. The estimated sample required for each lake was approximately 200 (based on both estimates from Ngene and a rule of thumb proposed by de Bekker-Grob, et al. (2015)) but the target for the total sample across the three lakes was conservatively set at 700.

Key point

Each participant would be randomly allocated to undertake the DCE for one of the three lakes, regardless of whether they visited the lake before or not in the past 12 months. This was done to capture actual usage among the entire community and potential for non-direct use values i.e., would participants still value the lakes if they did not visit it.

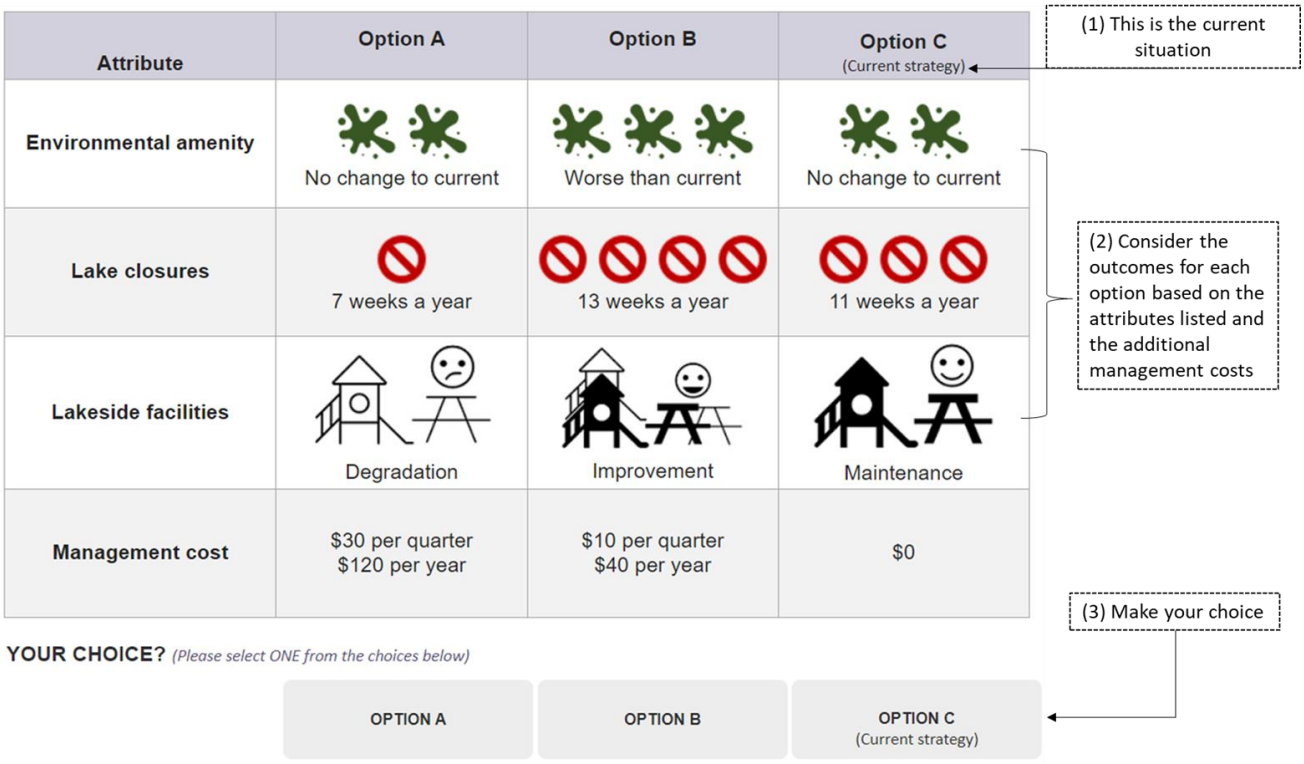


Figure 3. Example of the choice task used to instruct participants

After the choice experiment, participants were presented with a handful of debriefing questions to elicit how choices were made including scoring the importance of attributes to their decision making on a Likert-5 scale, reasons for choosing the same option (if they did so) and their perception of if the DCE would be used in decision-making (to determine if they took the experiment seriously). These debriefing questions were used to assess attribute non-attendance.

Socio-demographic characteristics

The final section of the survey involved collecting information on various socio-demographic characteristics and general views. This included household size and composition, income, education, political stance, and trust in the ACT government to 'do what is right'.

Survey administration

The survey was administered by Winton Research & Insights Pty ltd. As the survey passed through internal focus groups and testing, the final draft questionnaire was programmed using WebSurveyCreator (locally developed and hosted) and analysed using the Q tabulation software platform.

A pilot version of the survey was conducted in late April 2023 for 54 participants through the Pureprofile panel. The results were initially modelled, and it was determined that there was a likelihood of insufficient variation between levels. Thus, the experiment was redesigned through Ngene utilising the same attributes and levels, but different base parameters for the full launch; with pilot responses being discarded from further analysis.

The full launch of the survey was undertaken in early June 2023 using the Pureprofile and Octopus panels from the start, and adding a third panel, Research Profile, in the last week to ensure that the required sample of minimum of 700 was reached (i.e., the final sample was 710 participants).

The rate at which the panels released sample and the desired quotas for gender, location and age were closely controlled throughout the process, as well as close monitoring of the random location of lakes, blocks and sets for the DCEs. The representativeness of the sample was analysed and is presented in the next section.

2.4 Results

The summary and analysis of the data for the DCE is provided in this section. Firstly, a summary of key sample statistics is provided, including an assessment of the representativeness of the collected sample and other information that influenced the types of specifications and parameters used in the econometric analysis. Subsequently, detail is provided on the chosen econometric models and corresponding results. With each model, a high-level discussion is also provided to give context to the findings. These results are then used to develop a more in-depth discussion of the importance of various lake attributes and the implications on management in the subsequent section.

Key summary statistics

This section provides details of key summary statistics for the survey sample. Through this initial statistical analysis of the data, additional variables that could provide further explanation for participant choices—and thus included in the econometric analysis of DCE responses—were identified. The distribution of responses to other questions are provided in Appendix C.

Representativeness of sample

Residential area

Table 2 displays the number and percentage of survey respondents reported residing region in the ACT. This was compared with the 2021 census data for a similar breakdown of residing regions to assess representativeness of the sample according to this target, noting participants who did not live in the ACT were

excluded from the analysis. A chi-square ($\chi 2$) goodness of fit test[8] was also performed to test whether there are statistical differences between how survey respondents are distributed throughout the six ACT regions and Australian Bureau of Statistics (ABS) data in terms of where they live.

Table 2. Distribution of sample and population by ACT residential areas

Region	Sample (count)	Sample (%)	Population (%)†	$\chi 2$
Belconnen	174	24.5%	23.5%	0.3
Gungahlin	110	15.5%	19.5%	5.8
Inner South, Inner North & City	175	24.6%	20.6%	5.6
Tuggeranong	122	17.2%	19.8%	2.4
Weston Creek & Molonglo	46	6.5%	8.0%	2.0
Woden	83	11.7%	8.7%	7.4
Total	**710**	**100%**	**100%**	**23.48**

Source: ABS (2022a)

† The survey regions were compared with the corresponding SA3 data except for the 'Inner South, Inner North & City' region compared with the 'North Canberra' and 'South Canberra' SA3s, the 'Weston Creek & Molonglo' region compared with the 'Weston Creek' and the 'Molonglo' SA3s, and the 'Woden' region compared with the 'Woden Valley' SA3.

The chi-square test revealed a $\chi 2$ value of 23.48, and a p-value less than 0.01, meaning that there was a statistically significant difference between how survey respondents are distributed throughout the six ACT regions and 2021 census data in terms of where they live. This statistical difference is likely due to the regions presented to respondents representing arbitrary regions within the ACT—to reduce complexity for the survey—while census place of residence data for each region is based off Statistical Area Level 3 (SA3) data. While there was some general alignment in the two datasets, they were not perfect point of comparison for the goodness of fit test.

Age

Table 3 displays a distribution of survey respondents' reported age by count and percentage of sample. This distribution was compared against similar age distributions from the 2021 census data. A chi-square goodness of fit test was also performed to test whether there are statistical differences between the age distribution of survey respondents and 2021 census respondents (i.e., the distribution of the entire ACT population).

[8] A chi-square goodness of fit test is a statistical test to determine if the difference between the distribution of the sample and population is statistically significant, providing a quantitative metric for representativeness of the sample.

Table 3. Distribution of sample and population by age

Age bracket	Sample (count)	Sample (%)	Population (%)	χ2
18-24	100	-	-	-
25-34	146	23.9%	25.5%	0.0
35-44	110	18.0%	22.4%	0.0
45-54	79	12.9%	18.0%	0.0
55-64	126	20.6%	14.5%	0.0
65-74	106	17.3%	11.3%	0.0
75 and over	43	7.0%	8.3%	0.0
Total	**710**	**100%**	**100%**	**0.07**

Source: ABS (2022a)

Note: The 18–24 age bracket was excluded from the chi-square goodness of fit test as census data on age did not align with this age bracket from the 2021 census data. Hence, proportions used for the chi-square goodness of fit test were re-calculated to exclude the 18-24 age bracket.

The chi-square test revealed a χ2 value of 0.07, and a p-value of 0.99, meaning that there was no statistically significant difference between the age distribution of survey respondents and 2021 census respondents (i.e., the distribution of the ACT population whose age falls within the above age brackets).

Gender

Table 4 displays the distribution of the survey respondents by reported gender by count and proportion. The distribution across binary gender identities (i.e., male and female) was compared against the corresponding distribution from 2021 census data. A chi-square goodness of fit test was also performed to test whether there are statistical differences between gender survey responses and 2021 census data for binary gender identities.

Table 4. Distribution of sample and population by gender

Gender	Sample (count)	Sample (%)	Population (%)	χ2
Female	373	52.5%	50.6%	0.7
Male	333	46.9%	49.4%	0.7
Non-binary	3	0.4%		
Other term	1	0.1%		
Total	**710**	**100%**	**100%**	**1.36**

Source: ABS (2022b)

Note: 'Non-binary' and 'Í use another term' responses (4) were not included in the goodness of fit test as data on the 'non-binary' response was yet to be released at the time of this analysis, and an 'other term' response was not included as a response by the ABS in the 2021 census.

The chi-square test revealed a χ2 value of 1.36, and a p-value of 0.25, meaning that there was no statistically significant difference between the gender of survey respondents and 2021 census respondents.

Key point

Based on comparisons with the ABS 2021 census data and preliminary statistical analysis of the three sampling targets, it was concluded that the sample was generally representative of the ACT population.

Other key statistical findings

Lake visitation, frequency and activities

Figure 4 presents responses from participants regarding their average lake visitation over the last 12 months during leisure time. Across the lakes and other waterbodies, regular visitation—either daily or weekly—was considerably low. Lake Burley Griffin was the lake most visited by respondents during leisure time although in terms of frequency, most responses were less than once a month. The data also revealed that participants visited other waterbodies (not the three study lakes) more than Lakes Tuggeranong and Ginninderra. Also, it was interesting to note that many respondents reported never visiting Lakes Tuggeranong and Ginninderra in the preceding 12 months.

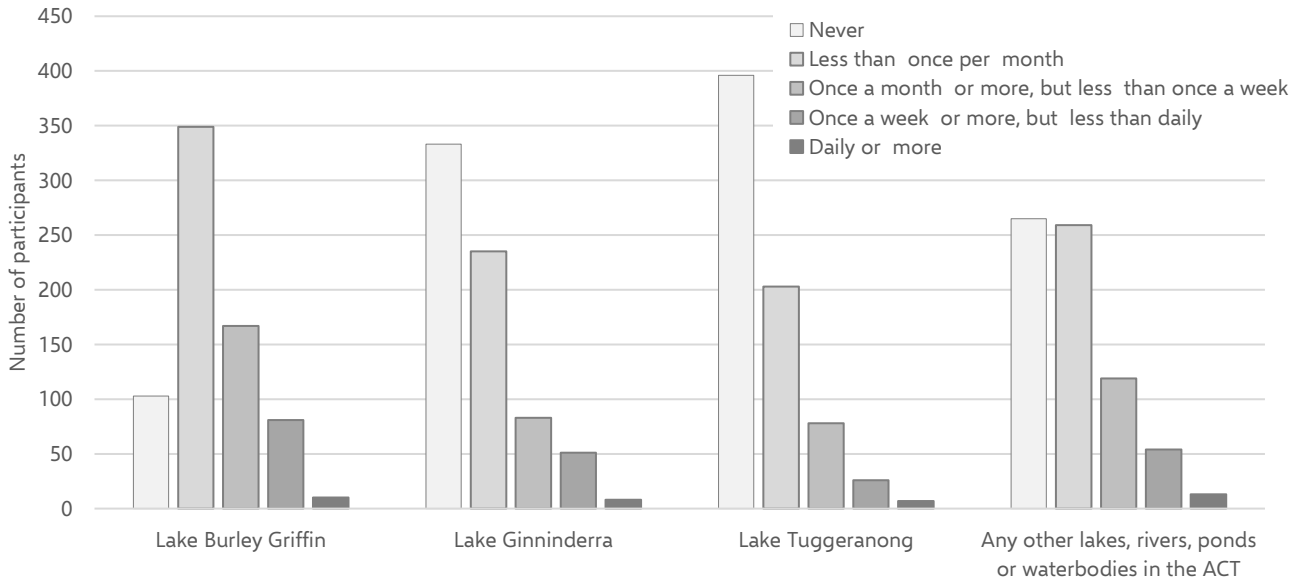


Figure 4. Average lake visitation over the last 12 months during leisure time

To understand visitation within a more recent timeframe, respondents who reported visitation to the lakes and waterbodies in the past 12 months were also asked about their visitation in the preceding four weeks (responses illustrated in Figure 5). The majority of respondents had either not visited any of the lakes during their leisure time or had visited a lake 1-2 times in the past four weeks. This suggests that in general, recent visitation generally align with average visitation across 12 months i.e., lake visitation may not necessarily be seasonal for this sample representing the ACT population.

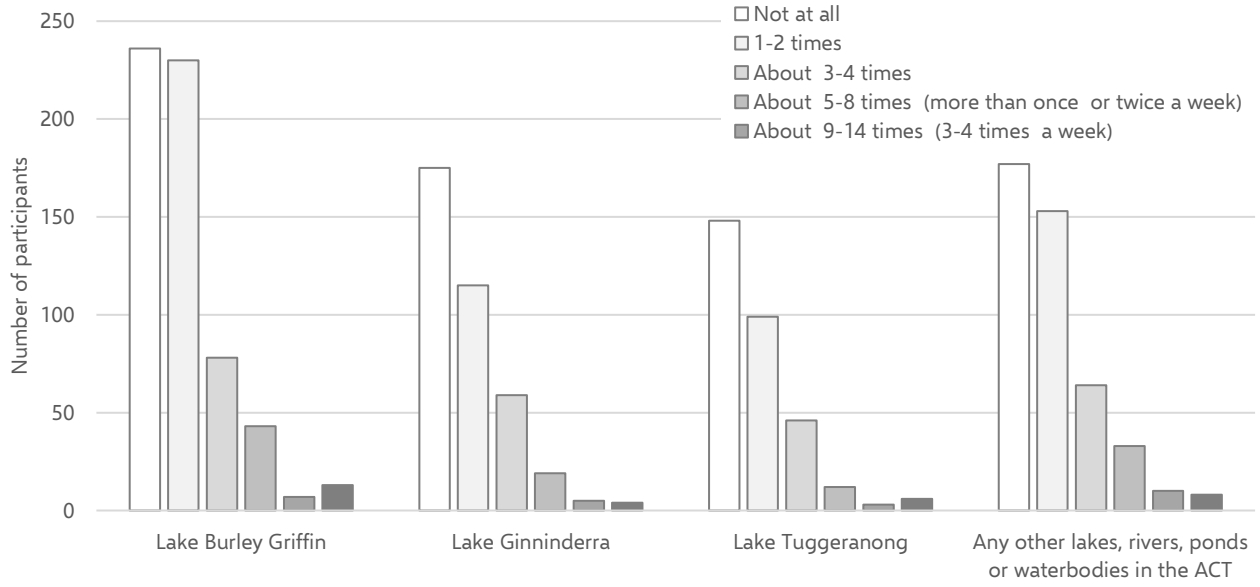


Figure 5. Average lake visitation over the last four weeks during leisure time (n=511)

Note: this question was only asked if the participant had visited the lake or waterbody in the past 12 months.

A preceding survey question asked respondents to compare their visitation within the past 12 months against the last four weeks. 62% of respondents indicated that they would typically visit the lakes about as often as they have in the last four weeks. However, a higher proportion of respondents (24.1%) indicated that they would normally visit the lakes much more than what they have in the last four weeks, compared to only 13.9% of respondents who stated that they would normally visit the lakes much less than what they have in the last four weeks.

Figure 6 displays what the average length of each visit was for respondents when visiting a lake over the last four weeks. The responses suggest that over 72% of participants who visited the lakes in the last four weeks spent between half an hour to two hours in each visit.

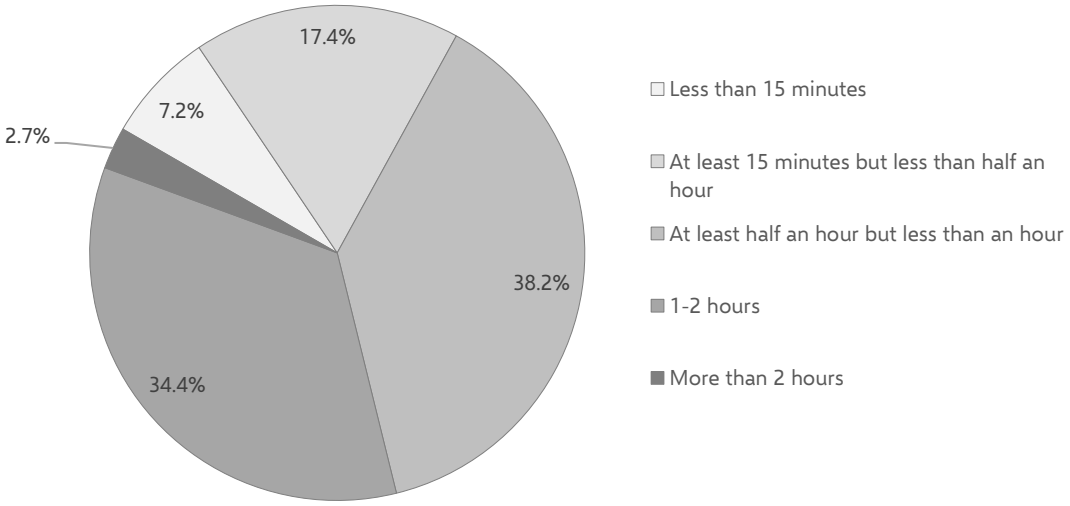


Figure 6. Average length of visitation over the last four weeks (n=511)

Note: this question was only asked if the participant had visited the lake or waterbody in the past 12 months.

Figure 7 displays what the primary activity undertaken was by respondents during lake visits. An overwhelming majority of visitors reported walking around the lakes as their primary activity, with primary and secondary contact recreation (e.g., swimming, boating, etc) being among the activities least represented across all visitors. It should also be noted that in the four weeks preceding the survey, only Lake Tuggeranong experienced closures to primary and secondary contact recreation and an 'extreme' alert levels for recreational water quality. Given the comparably low visitation to Lake Tuggeranong across the sample, it could be inferred that the lack of on-water recreation across the lakes is generally representative of typical community preferences and behaviour as opposed to material impact from closures.

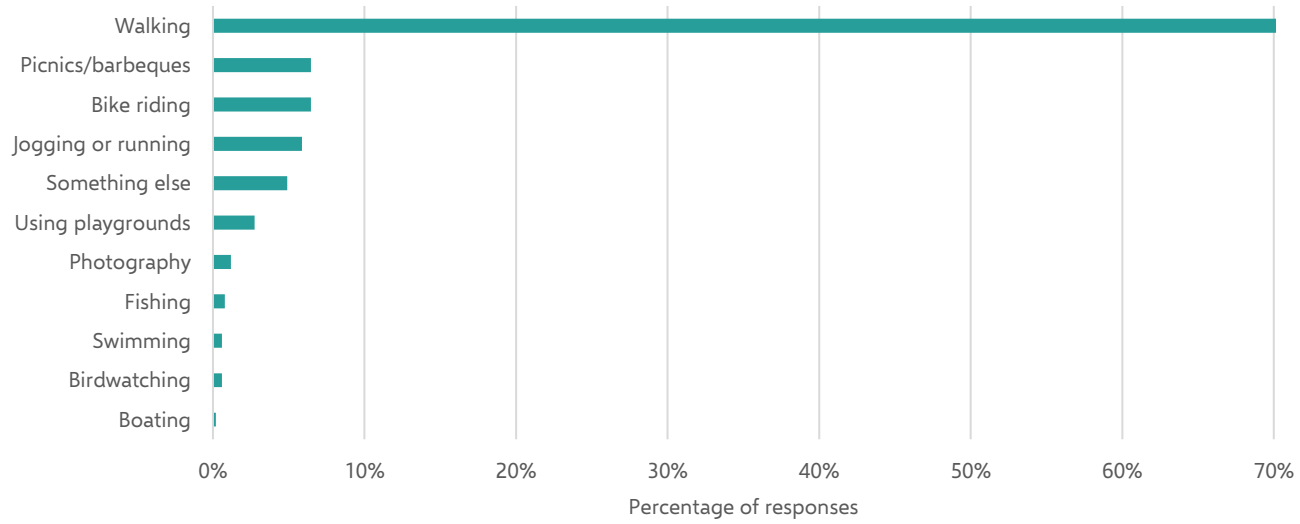


Figure 7. Primary activity undertaken during lake visits (n=511)

Furthermore, responses to a subsequent survey question indicate that the majority of respondents undertake these activities with others (66.5%), compared to by themselves (33.5%).

Key point

Based on the survey sample, general community use of the urban lakes in the ACT largely consisted of occasional, infrequent visits that did not involve primary or secondary contact recreation. Many participants also reported not having visited lakes and other waterbodies in the ACT. The dominant activity at the lakes is walking.

Perception of water quality

Respondents were also asked about their general perceptions of water quality at the three study lakes. Figure 8 displays that perceptions of water quality across the three lakes are generally mixed. Most participants reported that they did not know about the water quality at Lakes Ginninderra and Tuggeranong, which is a much higher proportion than Lake Burley Griffin. This may be due to Lake Burley Griffin representing the most frequently visited lake by respondents and as such, a higher likelihood of forming a perception about its water quality.

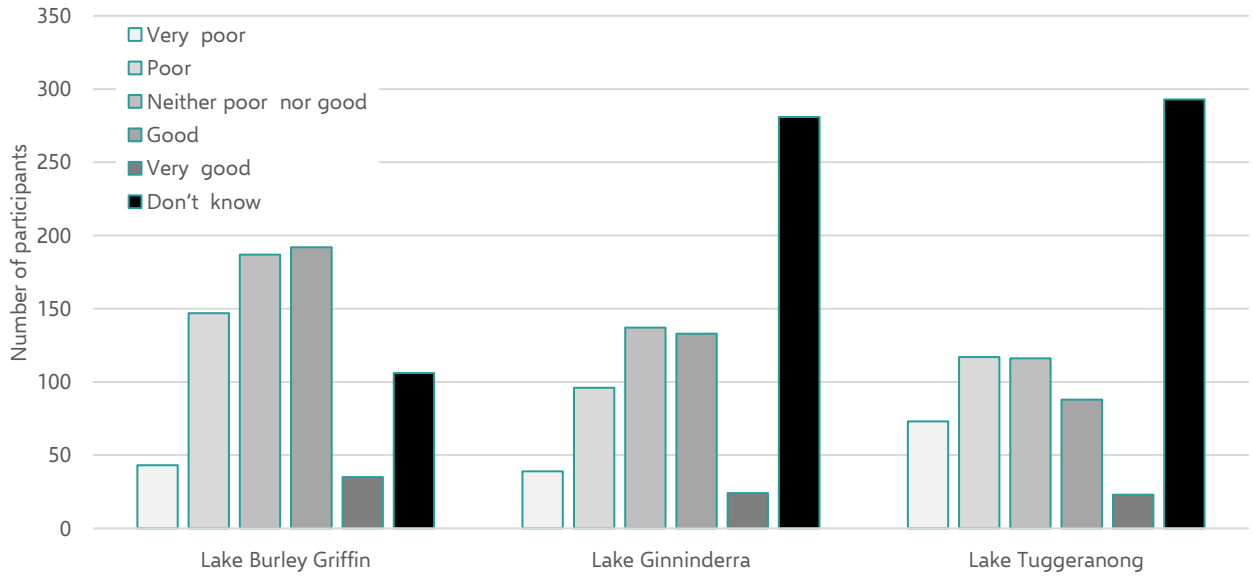


Figure 8. Respondents' perception of water quality at each of the lakes

Of those that had a view on water quality, more participants had a positive perception (i.e., good or very good) of water quality than a negative perception (i.e., poor or very poor) for Lakes Burley Griffin and Ginninderra; the perception of water quality at Lake Tuggeranong was more negative than positive. About a third of remaining participants did not state a perception of water quality being positive or negative at each lake.

This provides useful insight on perceived versus actual water quality at the lakes. As shown in section 1.1, Lakes Burley Griffin and Tuggeranong both had historically high levels of algae recorded, although these levels have decreased recently (Figure 1). However, the general perception of water quality was opposite for these lakes i.e., positive for Lake Burley Griffin and negative for Lake Tuggeranong. It is possible that perceptions of water quality may reflect temporal (e.g., historical views versus recent experiences) or location-specific perceptions (i.e., a visitor only visiting a section of the lake whereas the monitoring data is for samples taken across multiple sites at each lake). It should be recognised that this does not invalidate the results as the perception of water quality, rather than alignment with monitoring results, was the matter of interest in the subsequent analysis.

Key points

Current perceptions of water quality were generally in line with prevailing algae levels at the lakes. Where visitation was low, participants were expectedly not able to form a view on water quality.

Income

Figure 9 presents a distribution of the weekly household income that respondents usually receive. The data illustrates that over half of respondents (54.5%) receive a weekly household income between $1,250 and $3,499. Most respondents, who reported their income, indicated receiving between $2,000–2,499 per week in their household, which was also the median income bracket. This aligns with the median income for the ACT from the 2021 census ($2,373) (ABS, 2023a), as shown in Figure 9. It is also worth noting that 8.7% of respondents selected the 'Prefer not to answer' response, which is not uncommon in such surveys.

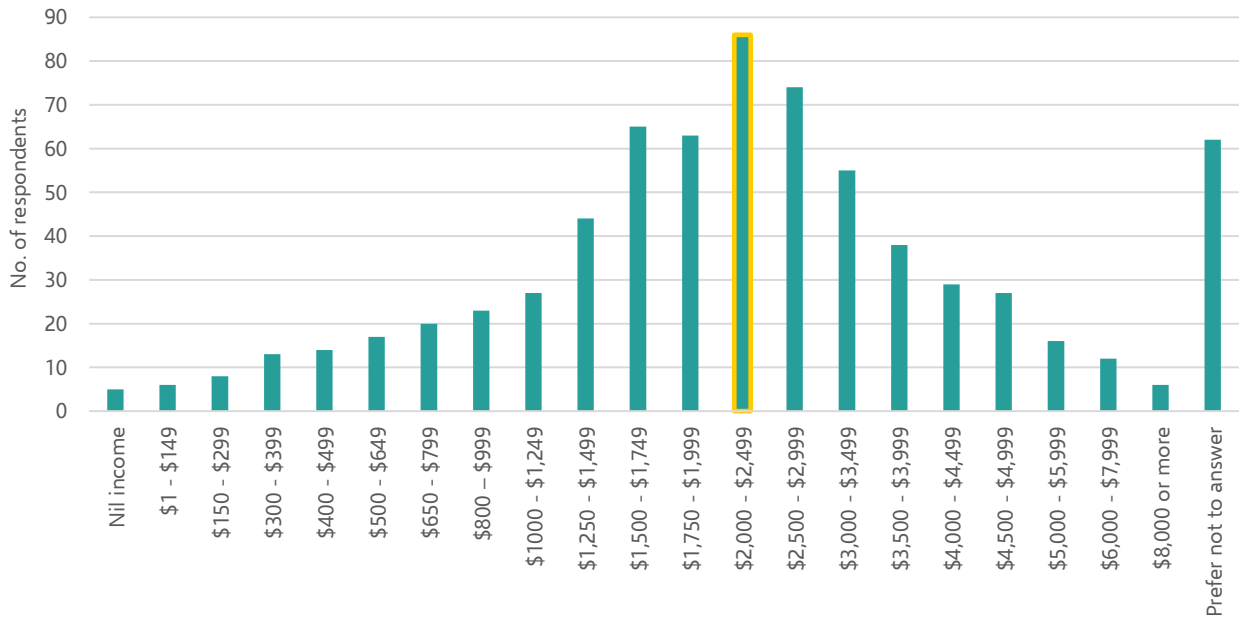


Figure 9. Respondents' total weekly household income

Note: the highlighted bracket corresponds to the median household income in the ACT as reported in the 2021 census (ABS, 2023a).

Several variants of an income parameter were attempted in the econometric modelling for the DCE responses including continuous variables and dummies to represent thresholds (e.g., if reported income was above the median household income). These parameters were not significant at a 10% level, which was a threshold criterion for inclusion in the final model (as discussed later). This was further complicated with the respondents who chose not to provide an answer to this question (approximately 8%); if these individuals were excluded from analysis, the model would suffer from a loss of information from the other more significant parameters. Models that excluded an income parameter tended to perform better and inclusion did not provide any discernible relationship for WTP. Thus, although the distribution of reported income for the sample was generally aligned with the ACT population, it was not included in the preferred models presented below.

Key point

While the distribution of the reported incomes of the sample generally was aligned with the ACT population, it was eventually excluded from the preferred models—after several iterations—due to lack of explanatory power on the WTP.

Education

Figure 10 presents respondents highest completed education qualification, alongside 2021 census data for highest completed education qualification of the ACT population (persons aged 15 years and over). The data suggests that the respondents were generally higher educated than the population; however, it is worth noting that the minimum age for this sample was 18 years compared to the data used from 2021 census at 15 years. Thus, while the actual percentages and some rankings of highest educational levels were slightly different between the two datasets, given the context of respondents, the sample was generally aligned with the ACT population in terms of highest educational qualification.

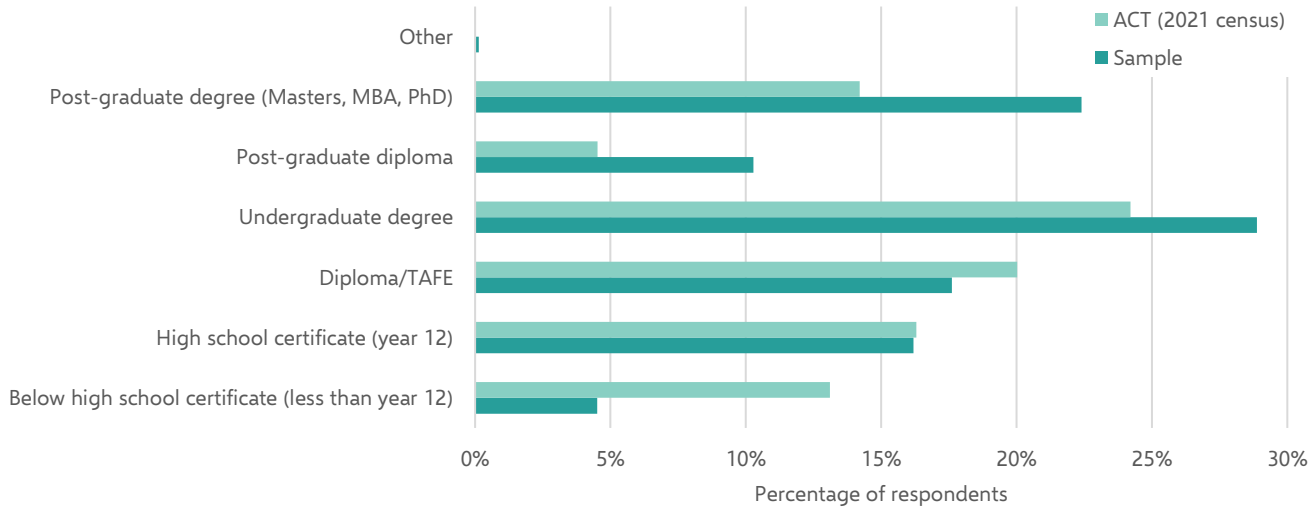


Figure 10. Highest completed educational qualification

Source: ABS (2022c)

Trust in Government

Figure 11 presents how well respondents agreed with the following statement: 'Í trust the ACT Government to do what is right'. The results indicate that the majority of respondents were found to trust the ACT government to do what is right, with the 'Agree' or 'Strongly Agree' responses selected by 46.5% of respondents, compared with the 29.1% who either disagreed or strongly disagreed.

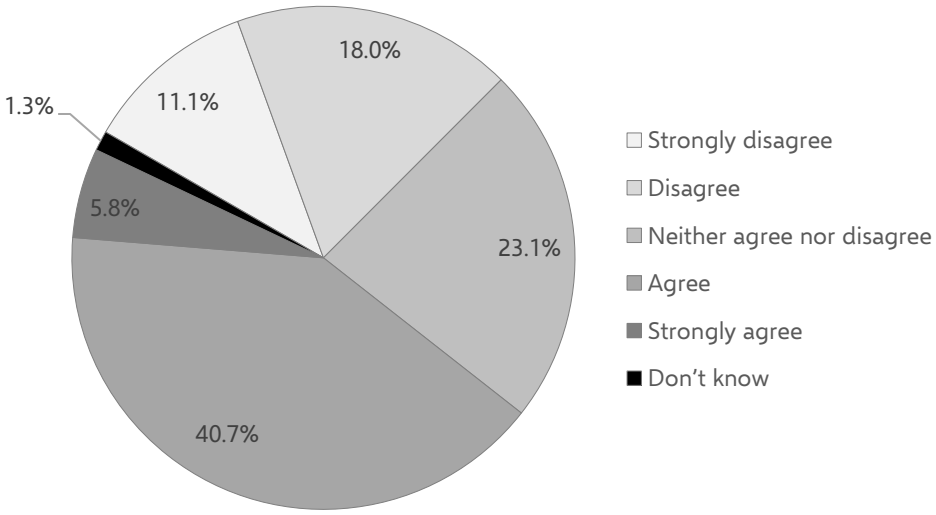


Figure 11. Respondents' trust in Government

Political stance

Figure 12 presents what respondents stated as their political stance between very conservative and not conservative at all. The majority of respondents were found to consider their political stance as 'Not conservative at all' (29.7%) and 'Slightly conservative' (29.4%). Only 1.8% of respondents stated their political stance as 'Very conservative'.

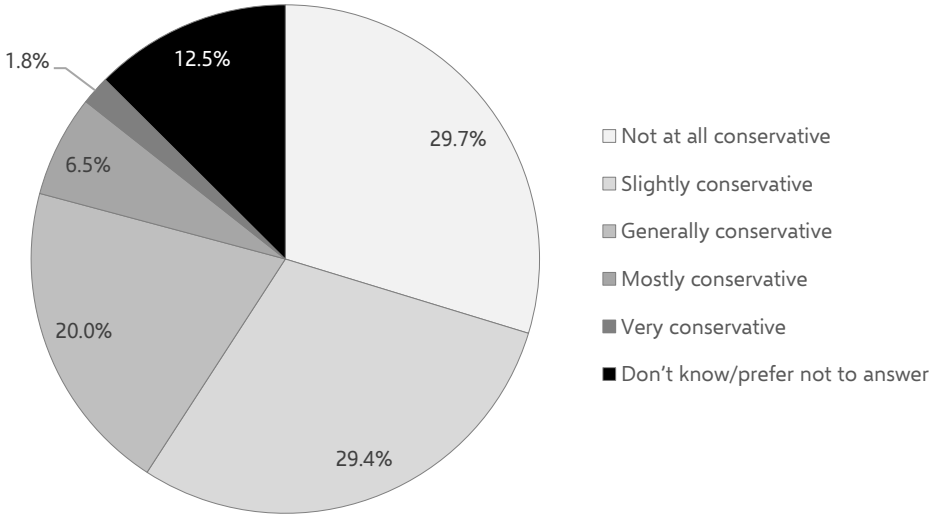


Figure 12. Respondents' political stance

Attribute importance

Figure 13 presents a summary of what the importance of each attribute was when making a choice. While the relative importance for most attributes were generally consistent (i.e., under 15% of respondents potentially not attending these attributes), a material percentage of respondents (i.e., more than double the percentage of other attributes at 32.7%) reported either completely ignoring or considering lake closures as unimportant to their choices. This suggests a likelihood of attribute non-attendance for lake closures, which may be due to these participants not considering access to the lakes for primary or secondary contact recreation as determinative in their preferences.

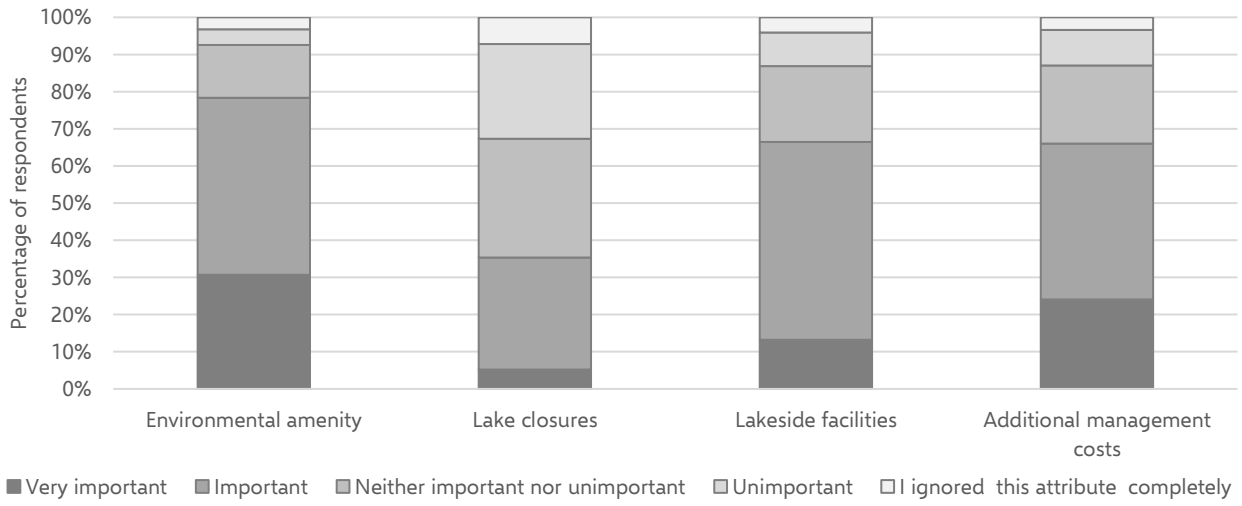


Figure 13. Stated attribute importance for respondents in choice experiment

Perception of information use

Figure 14 presents a summary of how likely respondents thought that the results of this study would be used by decision makers to inform future investment decisions about the management of the lakes. The data illustrates that 40.8% of respondents perceived that the study would be useful, and 34.8% reported otherwise.

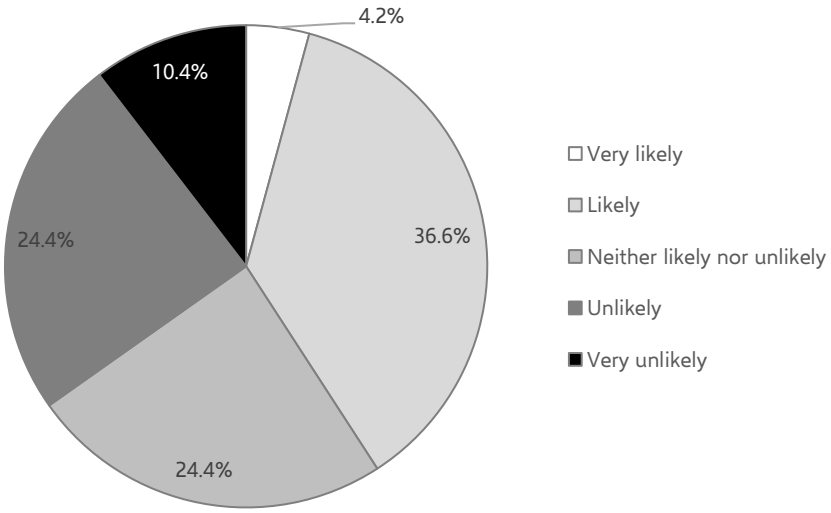


Figure 14. Perception of information use

Key point

Responses to several survey questions were considered to potentially inform participants' choices. These questions were converted to explanatory variables for the econometric modelling.

Choice experiment

There were 710 participants in the survey who made eight choices each, leading to a total of 5,680 choices for the DCE. Table 5 presents the number of participants that were allocated to each of the choice experiment blocks amongst each of the three lakes. The data illustrates that the intended sampling approach to allocate participants equally between each lake and for each block of choice sets was achieved.

Table 5. Number of respondents in each block and lake

	Lake Burley Griffin	Lake Tuggeranong	Lake Ginninderra	Total
Block 1	69 (31.8%)	77 (31.8%)	83 (33.1%)	229
Block 2	73 (33.6%)	81 (33.5%)	95 (37.8%)	249
Block 3	75 (34.6%)	84 (34.7%)	73 (29.1%)	232
Total	217	242	251	**710**

Figure 15 presents a summary of the choices made in the choice experiment between the status quo (Option C) and alternative scenarios (Option A and Option B) for experiments related to each lake. Overall, there was a slight preference for the status quo (Option C) compared to the alternative (Option A or B).

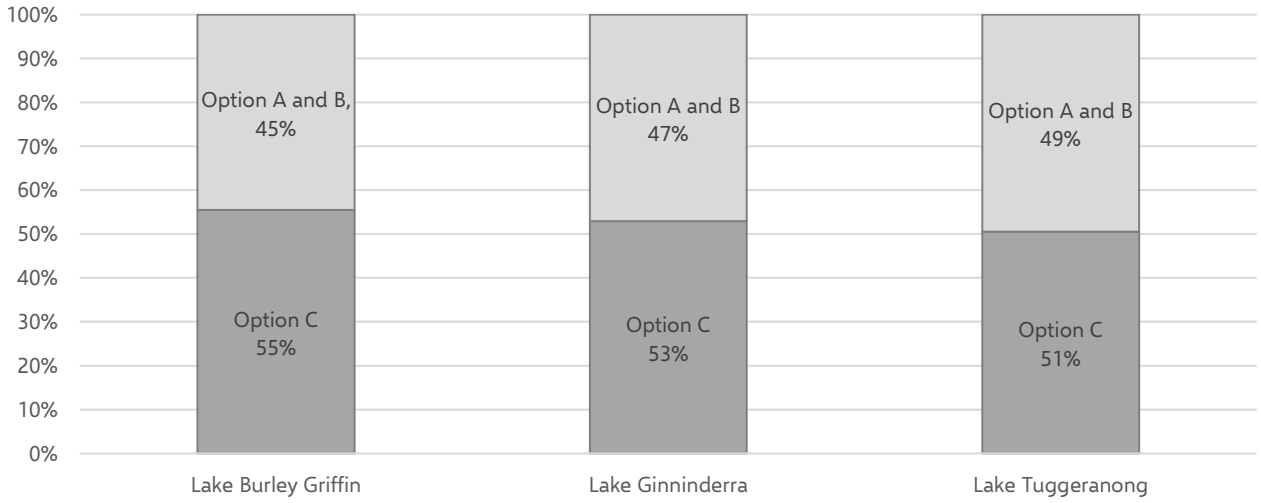


Figure 15. Summary of choices made in choice experiment

Furthermore, 166 respondents (23.4%) were found to have selected Option C for all eight of their choice cards. Among the most popular reasons mentioned by participants for these choices were that they did not think costs of new management initiatives should be passed onto residents through the levies suggested in the experiment, they genuinely preferred Option C and they could not afford the alternative options that required additional payments. Some of the DCE literature would suggest these could be considered 'protest' responses and should be excluded (Doshi, et al., 2023; Hensher, et al., 2005). However, the reasons for potentially 'protesting' appeared more reflective of realistic preferences than an actual protest of the experiment; it would be expected that actual protesting would involve explicitly stating 'I do not agree with the experiment' or 'I do not want to participate', which would presumably lead to a participant not completing the survey anyway. Dropping any of these respondents would result in a loss of critical information and not be appropriate. Thus, no responses were dropped on this basis.

Econometric modelling of responses

The econometric modelling for the DCE data is done using a limited dependent variable—limited by the number of alternatives for the respondents (i.e., three in this study). This variable is analysed based on underlying utility functions for each discrete choice, explained by the attributes of the alternative and characteristics of the individual. The functions are often estimated using variants of multinomial logit (MNL) models, using the probabilities of choosing each alternative option. Further technical explanation of the modelling assumptions is provided in Box 2.

Box 2: General econometric specification and models

The analysis was undertaken using the Apollo package, which is written in R for modelling of choice models by Hess and Palma (2019, 2023). As introduced in Section 2.3, modelling responses from DCEs are based on the assumption that individuals choose from a set of options based on the option that maximises their utility within their budgetary constraints. In the econometric modelling, two separate utility functions were used, a utility function for Option A and B, which have the same specification and a utility function for Option C. The utilities for the different options took the following form:

$$Utility = \begin{cases} V^{A,B}\left(ASC^{A,B}, \beta_k^{A,B}, X_k^{A,B} + \varepsilon^{A,B}\right) \\ V^{C}(ASC^{C}, \beta_l^{C}, X_l^{C}, + \varepsilon^{C}) \end{cases}$$

The first line represents an individual's utility function for Options A and B. The utility function consisted of the alternative specific constant (ASC) for the option, the coefficient (β) for lake attribute k multiplied by the corresponding levels (X_k), and the error term ε. The ASC captures any other unobserved factors of the individuals' choices (Hensher, et al., 2005).

The second line represents the utility function for Option C. The utility function for this option consisted of the ASC for Option C, the coefficient for the socio-demographic, usage or perception variable l multiplied by the corresponding information from the data for the individual (X_l), and the error term ε.

The utility functions were transformed into a non-linear WTP space to enable direct interpretation of the WTP values for the lake attributes from the model coefficients. The WTP specification for Options A and B was:

$$V^{A,B} = ASC^{A,B} + \Sigma_{k=1}^{K}\beta_{Cost} * \left(\beta_k^{A,B} * X_k^{A,B}\right)$$

The WTP specification for Option C was:

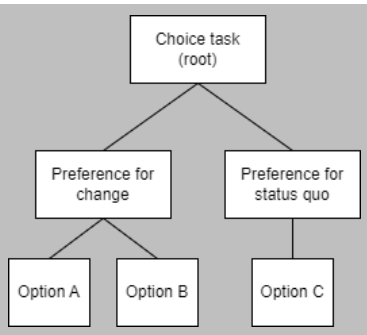
$$V^{C} = ASC^{C} + \Sigma_{l=1}^{L}(\beta_l^{C} * X_l^{C})$$

A positive coefficient for a socio-demographic, usage or perception variable meant that an individual with that characteristic derives utility from selection Option C instead of Option A or B and thus, was more likely to choose the former. If the sign of the coefficient is negative, then the person derives more utility from Option A and B compared to Option C and more likely to choose the alternative Options A or B.

Four different types of econometric specifications were attempted for each model:

- **multinomial logit (MNL)**—this is the base model and is the starting point of the analysis; it assumes that the error term of the utility is distributed independently and identically across the options and respondents, which has been noted to be a potential issue with this approach (Hensher, et al., 2005).

- **nested logit**—a nested model is run with two 'nests', which group Options A and B into one nest and Option C into the other to capture how respondents might consider Options A and B as a preference for a change and Option C as a preference for the status quo (see diagram on the right). In the context of modelling, this means that individuals may be more likely to substitute between Options A and B, as they are considered to be more similar compared to making a choice between Option A and C or Option B or C. The individual error terms are no longer distributed independently.



- **mixed multinomial logit**—a mixed logit model is another way for to capture heterogeneity by relaxing some assumptions around the error utility function being independent and identically distributed around the different options and respondents. This model adds additional complexity to the MNL models and specification decisions may have a big impact on model results.

- **latent class**—the latent class model is an alternative to the mixed logit model specification to accommodate heterogeneity in the model, but with an assumption that parameters are distributed discretely rather and continuously among individuals (Hensher et al., 2015).

The parameters used for the econometric analysis consisted of the choice attributes and parameters representing socio-demographic characteristics, perceptions, and usage of the lakes. The attributes for environmental amenity and lakeside facilities were converted to categorical parameters with numbers representing individual levels. Closure rates and costs were included as continuous parameters since in reality, these values could vary between each range, even to decimal points.

The socio-demographic, usage and perception variables were created from responses to corresponding questions. Different combinations and variations of 28 sociodemographic, usage and perception variables were tested along with the 10 lake attributes in different model configurations. The parameters that did not meet the threshold of being significant at the 10% level were dropped and replaced with other variables, as the inclusion of additional variables that have little explanatory power is penalised in the calculation of AIC–the measure of model fit (see Box 1). Among the variables that were found to not be significant were reported income, current employment status, relationship status, household composition, and users who partook in primary or secondary contact recreation activities (e.g., swimming and boating). The final list of parameters that meet the threshold for significance and used in the models presented in this report are provided in Table 6.

Table 6. Model parameter descriptions for discrete choice experiments

Group	Parameter name	Descriptions
Alternative Specific Constant (ASC)	ASC	Captured the unobserved factors of individual's choices that is derived from Option A or B. This ASC is a relative measure to the utility derived from Option C; thus, a positive ASC would indicate a general preference for the alternatives over the status quo. Unlike other parameters, the ASC is generated through the modelling as opposed to being an input. The ASC for Option C is not included in the modelling outputs as it was used as a basis for the relative measure (i.e., fixed to zero)
Environmental Amenity	Worse	A categorical[9] parameter that identified changes to environmental amenity relative to the status quo. This allowed estimation of separate WTP values for different levels of environmental amenity relative to keeping it the same.
	Better	
	Much Better	
Lake Closures	Closure	A continuous[10] variable that identified the percentage change in closures by converting the categorical levels outlined in Table 1 into a continuous parameter.
	Non-attendance shifter	A dummy[11] variable that identified if the respondent stated that closures were either ignored or unimportant in their choices i.e., respondent demonstrated stated non-attendance
Lakeside Facilities	Maintain	A categorial variable that identified changes to lakeside facilities relative to the status quo. in the model. This allowed estimation of separate WTPs for different levels of environmental amenity relative to keeping it the same.
	Degradation	
	Improvement	
Cost	Cost	A continuous variable for the quarterly management costs by converting the categorical levels outlined Table 1 into a continuous parameter.
Socio-demographics, lake usage and perceptions	Age	A continuous variable created by converting the stated responses to the age categories (see Q3 of the survey in Appendix B) to a numerical output based on the midpoint of the range. A positive coefficient means older respondents are more likely to choose the status quo (Option C).
	Undergraduate degree or above	A dummy variable for identifying if the respondent has an undergraduate degree or above by converting corresponding stated responses on the education levels (see Q22 of the survey in Appendix B). A positive

[9] A categorical variable can only take a limited, fixed number of values, typically integers (e.g., 1, 2, 3), to represent corresponding levels.
[10] A continuous variable has a value that can take any value within a range, including values with decimals.
[11] A dummy variable is a type of categorical variable that has only two values, 1 or 0, used to identify if a specific condition is met.

Group	Parameter name	Descriptions
		coefficient means respondents with higher educational attainment are more likely to choose the status quo (Option C).
	Lake User	A dummy variable that identified if the respondent had been to the Lake that they have been assigned to in the survey in the past 12 months (see Q6 of the survey in Appendix B). A negative coefficient means that lake users are less likely to choose the status quo (Option C) and are more likely to choose Option A or B.
	Positive perception of water quality	A dummy variable that identified if the respondent had a perception that the water quality at the lake that they are assigned to was either good or very good (see Q12 of the survey in Appendix B). A negative coefficient means that respondents that have good or better perception of lake water quality are less likely to choose the status quo (Option C) and are more likely to choose Option A or B.
	Retired	A dummy variable that identified if the respondent was retired (see Q21 of the survey in Appendix B). A positive coefficient means retired respondents are more likely to choose the status quo (Option C).
	Trust in Government	A dummy variable that identified if the respondent stated that they either agreed or strongly agreed with the statement 'I trust the ACT Government to do what is right' (see Q25 of the survey in Appendix B). A negative coefficient means that respondents that agree or strongly agree to the statement above are less likely to choose the status quo (Option C) and are more likely to choose Option A or B.
	Use of Information	A dummy variable that identified if the respondent thought that the results of the DCE would be very likely or likely be used by decision makers to inform future lake management decisions (see Q16 of the survey in Appendix B). A negative coefficient means that respondents who think that it is likely or very likely that the results of the DCE will be used are less likely to choose the status quo (Option C) and are more likely to choose Option A or B.

Results from DCE modelling

As outlined in Box 2, four separate model types were attempted for each specification. The preferred models were based on the MNL specification. This simpler specification was found to provide robust results that would be both easy to interpret with values that would be more easily applied by EPSDD and the NCA in their decision-making. More complex specifications (i.e., nested, mixed multinomial logit and latent class models), provided marginal improvements to model fit but created additional complexity in the interpretation of results that was considered to overcomplicate the estimation of WTP and practical application for EPSDD and the NCA's purposes. The outputs from other models provided in Appendix D.

Pooled models

The first set of results presented in Table 7 are for the pooled sample (combining all responses across all lakes into a single dataset); M1 is the MNL model for the pooled sample only capturing lake attribute parameters while M2 included the full specification of socio-demographic, lake usage and perception variables as outlined in Table 6. Across both pooled models, the coefficient for lake attributes from the DCE were highly significant at 1% with expected signs (i.e., respondents exhibited a positive WTP for improved environmental amenity, reduced lake closures, avoided degradation or improvement to lakeside facilities, but a preference for lower cost options, which is consistent with DCE theory).

Expectedly, inclusion of the full specification of parameters improved model fit, by AIC and by a separate likelihood ratio test. This indicates that M2 was a better model for the pooled sample.

Table 7. Pooled DCE modelling results

Group	Parameter	M1—pooled, lake attribute only		M2—pooled, full specification	
		Coefficient	95% confidence interval	Coefficient	95% confidence interval
ASC	Option	0.86 ***	0.72 to 1.00	0.62 ***	0.37 to 0.87
Environmental Amenity	Worse	-36.12 ***	-47.09 to -25.14	-36.12 ***	-47.06 to -25.18
	Better	44.35 ***	33.55 to 55.15	44.50 ***	33.69 to 55.31
	Much Better	57.78 ***	44.72 to 70.85	57.94 ***	44.88 to 71.00
Lake Closures	Closure	-0.55 ***	-0.69 to -0.40	-0.54 ***	-0.69 to -0.40
	Non-attendance shifter	0.49 ***	0.31 to 0.66	0.47 ***	0.30 to 0.65
Lakeside Facilities	Degradation	-45.39 ***	-56.29 to -34.48	-45.35 ***	-56.23 to -34.47
	Improvement	8.50 ***	3.50 to 13.49	8.52 ***	3.53 to 13.51
Cost	Cost	0.02 ***	0.02 to 0.03	0.02 ***	0.02 to 0.03
Socio-demographics, lake usage and perceptions	Age	NA	NA	0.01 ***	0.00 to 0.01
	Undergraduate degree or above	NA	NA	0.27 ***	0.15 to 0.38
	Lake User	NA	NA	-0.12	-0.25 to 0.02
	Positive perception of water quality	NA	NA	-0.22 ***	-0.36 to -0.08
	Retired	NA	NA	-0.34 ***	-0.51 to -0.16
	Trust in Government	NA	NA	-0.28 ***	-0.40 to -0.16
	Use of Information	NA	NA	-0.07 ***	-0.13 to -0.02
AIC		10,001.62		9,895.61	
Number of observations		710		710	

Note: shaded rows represent WTP for lake attributes. * denotes significance at the 10% level, ** denotes significance at the 5% level, and *** denotes significance at the 1% level.

The WTP estimated (in dollars per quarter) for different lake attributes—relative to the status quo—are provided in the shaded rows of Table 7 and summarised below.

The WTP per person to avoid a degradation (*Worse*) in **environmental amenity** was $36 per quarter but the WTP for improved amenity (*Better*) was $45 per quarter. This WTP for *Much Better* environmental amenity was $58 per quarter, thus the marginal WTP from *Better* to *Much Better* was approximately $13 per quarter (as illustrated in Figure 16).

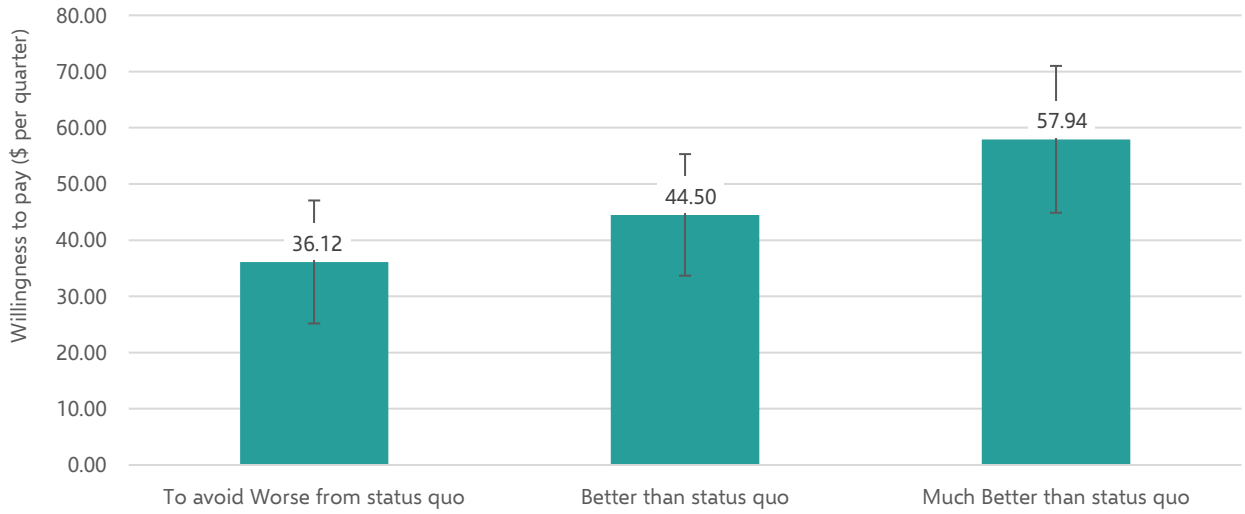


Figure 16. Willingness to pay per person for changes to environmental amenity from status quo ($ per quarter)

Note: For the *Worse* outcome, the WTP is to avoid a degradation to environmental amenity. Error bars represent the confidence intervals as reported in Table 10.

The WTP estimate to **avoid annual lake closures** increasing by 40%[12] for someone who reported attending attribute was $21.90 per quarter, whereas a person who reported not attending to Lake Closures had a WTP estimate of $2.43 per quarter ($0.54 less $0.47 multiplied by 40[13]), which is 89% less. Early model estimations that did not account for non-attendance yielded a WTP of $16.00 per quarter to avoid a 40% increase in lake closures, which suggest not capturing this effect could materially overestimate the actual WTP among the sample who were non-attendees.

A weighted WTP was calculated based on the proportion of respondents who stated the attribute was ignored or unimportant to their choices ($P_{Non-attenders}$) using the formula:

$$WTP^{Closure}_{Weighted} = (WTP^{Closure}_{Non-attenders} + WTP^{Shifter}_{Non-attenders}) * P_{Non-attenders} + WTP^{Closure}_{Attenders} * (1 - P_{Non-attenders})$$

As lake closure non-attendees comprise 32% of our sample data, the weighted WTP for avoiding a 40% increase in lake closures was $15.54 per quarter, which was not materially different to the WTP if attribute non-attendance was not modelled i.e., $16.00 as discussed above. This indicated that the approach to estimate WTP through consideration of attribute non-attendance is generally robust whilst also providing additional nuance to community preferences.

There was a considerable difference between the estimates for WTP per person for avoided degradation of **lakeside facilities** ($45 per quarter) from its current state, compared to the WTP for improvement of lakeside

[12] A 40% was used as a basis for comparison given the average change in annual closures across the three lakes was approximately 40% (NCEconomics, 2023).
[13] This accounts for the estimated coefficient for the Closure Shifter, which is a dummy identifying if a participant reported not attending the lake closure attribute.

facilities ($9 per quarter). This suggests a general satisfaction with the current state of lakeside facilities—which may include condition and maintenance/replacement activities—and respondents did not materially value further investment in improving these facilities.

Key point

The estimated quarterly WTP values per individual for the lake attributes across all three lakes were $36–58 for changes to **environmental amenity,** $15.54 for avoiding a 40% increase in **annual lake closures,** and $45 to avoid degradation of **lakeside facilities** but only $9 for improvement.

The positive coefficient for the ASC suggested that respondents generally derived a greater utility and therefore more likely to choose the alternatives Option A or B over the status quo Option C. Conversely, a positive coefficient for a variable for socio-demographics, lake usage and perceptions presented in Table 7 was associated with an increased likelihood of that respondent selection Option C instead of A or B. As discussed previously, this model only included parameters that were at least significant at a 10% level with other parameters dropped for improvement in model fit. The interpretation of these estimated parameters are as follows:

Of the modelled socio-demographic parameters, the ones that have the greatest magnitude of influence on preferences were *Retired*, *Trust in Government, Undergraduate degree or above, and Water Quality*. Interestingly, individuals who have a high level of educational attainment derive more utility from the status quo and are more likely to select Option C.

- *Age* had a small and positive coefficient—the older someone is, the more likely they were to select the status quo option instead of Option A or B; however, the coefficient for *Retired* had the largest marginal impact on preference and a retiree was more likely to choose Option A or B[14]
- if a respondent had an *Undergraduate degree or above*, they were more likely to choose Option C, with the marginal impact being among the top three for non-attribute variables
- the coefficients for being *Lake user* or having a *Positive perception of water quality* for the allocated lake expectedly demonstrated a preference for Options A or B instead of C; the *Lake user* coefficient had a level of significance of just outside the threshold at 10.8% but was included in further models given the potential importance of this parameters in lake-specific analysis and to compare against findings from the case studies (Chapter 4)
- the estimates for *Trust in Government* and *Use of information* both expectedly suggested a preference for Option A or B but the former had the second largest marginal impact on preference compared to the latter having the second lowest.

Key point

Among the other explanatory variables, having at least an undergraduate degree, a positive perception of water quality, being a retiree and stated trust in the ACT government were the largest drivers of preferences in the pooled model.

[14] Other measures of employment status were not found to be statistically significant such as if the respondent worked full time or were considered underemployed (i.e., non-retirees who were not working full time).

Lake-specific models

Further models were estimated for individual lakes to determine if there were material differences in results at each lake (Table 8). The coefficient signs and significance for the parameters were generally similar to the pooled model, with socio-demographic variables contributing to most of the variation between lakes.

Table 8. Results from lake-specific DCE modelling

Group	Parameter	M3—Burley Griffin		M4—Ginninderra		M5—Tuggeranong	
		Coefficient	95% confidence interval	Coefficient	95% confidence interval	Coefficient	95% confidence interval
ASC	Option	0.14	-0.32 to 0.60	0.81 ***	0.39 to 1.23	1.19 ***	0.75 to 1.64
Environmental Amenity	Worse	-36.29 ***	-53.31 to -19.28	-43.44 ***	-65.32 to -21.56	-27.67 ***	-45.11 to -10.24
	Better	35.32 ***	21.45 to 49.19	42.69 ***	22.82 to 62.57	55.51 ***	32.88 to 78.14
	Much Better	44.97 ***	28.71 to 61.22	57.68 ***	33.35 to 82.01	70.01 ***	42.82 to 97.20
Lake Closures	Closure	-0.27 ***	-0.43 to -0.11	-0.62 ***	-0.91 to -0.34	-0.74 ***	-1.06 to -0.43
	Non-attendance shifter	0.15	-0.08 to 0.37	0.54 ***	0.19 to 0.88	0.75 ***	0.39 to 1.12
Lakeside Facilities	Degradation	-46.59 ***	-63.55 to -29.62	-43.29 ***	-63.19 to -23.39	-45.21 ***	-64.10 to -26.31
	Improvement	5.42	-1.83 to 12.67	14.33 ***	4.19 to 24.47	5.12	-3.56 to 13.80
Cost	Cost	0.03 ***	0.02 to 0.03	0.02 ***	0.02 to 0.02	0.02 ***	0.01 to 0.03
Socio-demographics, lake usage and perceptions	Age	0.01 ***	0.01 to 0.02	0.01 *	0.00 to 0.01	0.00	0.00 to 0.01
	Undergraduate degree or above	0.62 ***	0.40 to 0.83	0.09	-0.10 to 0.28	0.16	-0.04 to 0.36
	Lake User	-0.08	-0.31 to 0.14	0.01	-0.22 to 0.25	-0.66 ***	-0.96 to -0.37
	Positive perception of water quality	-0.44 ***	-0.67 to -0.20	-0.23 *	-0.47 to 0.01	0.01	-0.28 to 0.30
	Retired	-0.56 ***	-0.90 to -0.22	-0.23	-0.52 to 0.07	-0.23	-0.53 to 0.07
	Trust in Government	-0.23 *	-0.46 to 0.00	-0.34 ***	-0.55 to -0.13	-0.29 ***	-0.50 to -0.09
	Use of Information	0.02	-0.21 to 0.25	0.00	-0.21 to 0.20	-0.68 ***	-0.89 to -0.47
AIC		2,942.66		3,557.01		3,329.62	
Number of Observations (% of sample)		217 (31%)		251 (35%)		242 (34%)	

Note: shaded rows represent WTP for lake attributes. * denotes significance at the 10% level, ** denotes significance at the 5% level, and *** denotes significance at the 1% level.

The WTP for improvements in **environmental amenity** at Lake Burley Griffin was generally lower to Lakes Ginninderra and Tuggeranong. This was contrary to expectations given the central location and larger size of the lake, and much higher visitation from participants in this study. The willingness to pay for improvements to environmental amenity was the highest for Lake Tuggeranong ($56–70 per quarter), followed by Lake Ginninderra ($43–58 per quarter). However, the WTP to avoid *Worse* environmental amenity was highest for Lake Ginninderra ($43 per quarter), followed by Lake Burley Griffin ($36 per quarter) and Lake Tuggeranong ($28 per quarter).

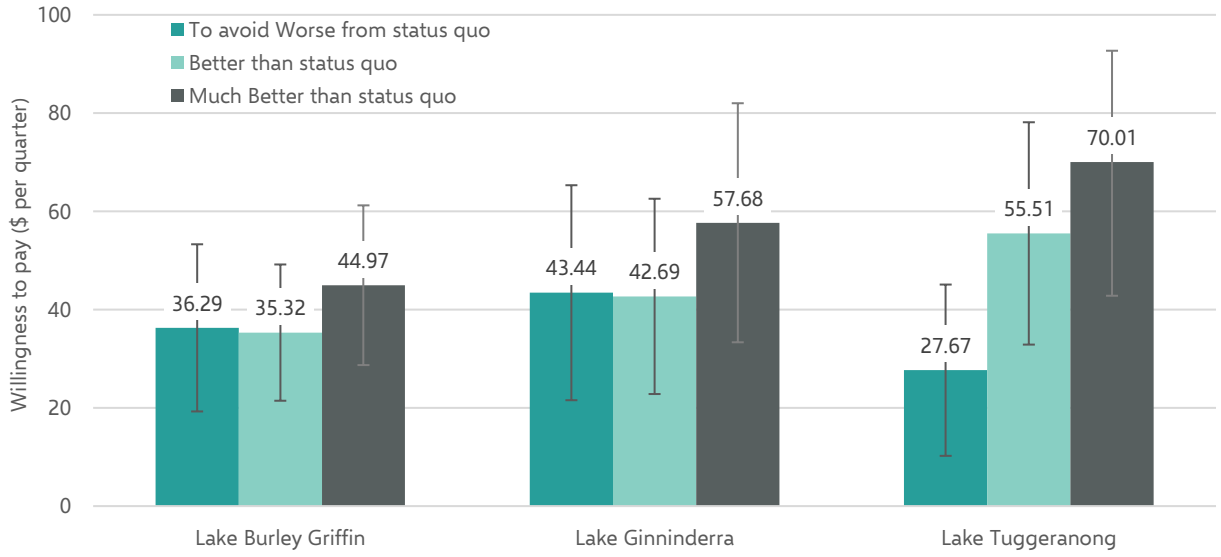


Figure 17. Willingness to pay per person for changes to environmental amenity from status quo ($ per quarter)

Note: For the Worse outcome, the WTP is to avoid a degradation to environmental amenity. Error bars represent the confidence intervals as reported in Table 10.

The WTP for **avoided lake closures** at Lake Tuggeranong was almost $0 if a person reported being a non-attendee to the attribute. However, the weighted WTP for this attribute was highest at Lake Tuggeranong, possibly due to the comparably lower proportion of non-attendees, at $4.80 per quarter to avoid a 10% increase in annual closures.[15] This was relatively similar to the weighted WTP for avoided closures at Lake Ginninderra at $4.60 per quarter.

In comparison, the WTP for avoided lake closures at Lake Burley Griffin for stated attendees to the attribute was estimated at $2.70 per quarter for an avoided 10% increase in closures, which is materially lower than the other two lakes. However, the non-attendance shifter was not significant for the Lake Burley Griffin model—indicating it did not provide significant explanatory power to participants' choices. This created difficulty in interpreting the preferences for those who stated non-attendance to lake closures at Lake Burley Griffin. Dropping reported non-attendees from the sample entirely was considered an unnecessary loss in information from the analysis. Instead, the WTP value for attendees was scaled by the proportion of attendees (67% of the sample for Lake Burley Griffin reported attending the attribute).[16] The resulting WTP of $1.82 for an avoided

[15] A 10% change in annual closure rate is used here purely to describe and compare the WTP at each lake. The actual WTP for avoided closures, having consideration for different changes to annual closures at each lake, is explored further in this section.
[16] A number of other approaches to estimate a weighted WTP was considered including not capturing the non-attendance effects—which would result in an under specified representation of the attribute—or using the marginal effect from the shifter—which would maintain the wide confidence intervals and reduce certainty of the estimate. These options were considered less appropriate for the purposes of this study, It should be noted this concern could be explored through more complex analysis as suggested in section 6.3.

10% increase in closures was a conservative estimate that ignored the preferences of non-attendees for lake closures only, given these preferences could not be inferred through the modelling.

However, when having consideration for the actual changes to annual closure rates, the WTP values are comparable between Lakes Burley Griffin and Tuggeranong (Table 9). This is due to the greater variability in annual closure rates for the former.

Table 9. Estimated WTP for avoided closures based on historical average changes in closures

Lake	Average lake closures (weeks per year) (2015–2021)†	Average annual change in lake closures‡	WTP per person for avoided closures ($ per quarter)	Range (low–high)
Lake Burley Griffin	11	58%	$10.46	$4.41–16.51
Lake Ginninderra	17	41%	$18.91	$11.45–26.38
Lake Tuggeranong	18	25%	$12.04	$7.41–16.67

† This average was used to define the status quo for the DCE.
‡ Based on six-year average of the year-on-year change in annual closures for each of the lakes.

The WTP to avoid degradation of **lakeside facilities** is relatively similar across all three lakes ($43–47 per quarter). However, the WTP for improvement to these facilities was greater in Lake Ginninderra ($14 per quarter) compared Lakes Burley Griffin and Tuggeranong (around $5 per quarter).

The socio-demographic variables that most notably differ between the three lakes were *Lake User, Positive perception of water quality, and Use of Information*. The *Lake User* variable had no effect on explaining the choices for visitors to Lake Burley Griffin and Lake Tuggeranong (i.e., the coefficients were not significant at 10% levels). Also, being a *Lake User* at Lake Tuggeranong indicated an increased probability of choosing the status quo, contradicting the pooled model; the marginal effect (explained by the magnitude of the coefficient) was also greater than the pooled model.

The *Positive perception of water quality* estimate for Lake Burley Griffin has the largest magnitude among the three lakes i.e., respondents that perceived water quality in Lake Burley Griffin as being good or better are less likely to stick to the status quo and are more likely to select Option A or B. The same conclusion is drawn for Lake Ginninderra. However, in the case of Lake Tuggeranong the magnitude of this variable is near zero and is insignificant. This means that perception of good water quality does not meaningfully explain choices for Lake Tuggeranong.

Use of Information coefficient is significant for Lake Tuggeranong and Lake Ginninderra; however, the magnitude of this effect is significantly larger for Lake Tuggeranong compared to Lake Ginninderra. This suggests that respondents are more likely to choose Option A or B if they believe that their responses will be used by authorities in developing management actions. This variable is not significant for Lake Burley Griffin.

Key point

There were material differences in WTP for attributes across the three study lakes, particularly for environmental amenity and avoided lake closures. This suggests that different values should be considered when assessing options and outcomes from management and interventions at each lake.

2.5 Summary of findings and discussion

The objective of this study was to derive estimates for the ACT community's value for urban lakes. Using DCEs, it was found that a sample of the ACT community had significant WTP values for the lake's attributes, particularly for non-direct use values (see Table 10). In summary:

- majority of the sample, being representative of the ACT community, stated not being regular visitors of the lakes and not partaking in primary or secondary contact recreation; most were likely to be casual visitors who draw value from the amenity and facilities of the lake
- a material proportion of the participants did not consider impacts from increased annual closures to on-water access as important in their decision-making when making tradeoffs on outcomes to lake attributes
- the WTP values per person for environmental amenity ranged from $36–57 per quarter; this included values for participants who stated not visiting the lakes regularly
- the WTP values per person for environmental amenity at Lake Burley Griffin were the lowest among the three lakes at $35 per quarter and highest at Lake Tuggeranong at around $70 per quarter; this was contrary to expectation given the size, locality, and visitation to Lake Burley Griffin
- the estimates for WTP per person to avoid a 40% increase to the number of annual lake closure days for on-water recreation ranged across $10–20 per quarter across the three lakes; the WTP value per person was substantially lower at Lake Burley Griffin but given closure rates are typically higher there, the net WTP is comparable to Lake Tuggeranong but still lower than Lake Ginninderra.
- the WTP per person to avoid the condition of lakeside facilities degrading of approximately $45 per quarter compared to a WTP per person of $5–8 per quarter for an improvement/upgrade to these facilities; only Lake Ginninderra was found to have a higher WTP per person for improvement to facilities but being about $14 per quarter compared to $43 per quarter to avoid degradation.

These results raise several implications for EPSDD's management. Firstly, the community values for the lakes are significant and possibly comparable with the value of its function to manage stormwater quality, which represents the critical trade-off for water quality management. This is further explored in chapter 6 but in short, EPSDD face a challenging task balancing water quality management upstream of the lakes to ensure community values for the lakes are maximised versus the intended purposes of the lakes being to contain nutrient and bacterial loads. The values from this study could be employed in prioritising management actions or in business cases to allow like-for-like comparisons across different lake management investments based on different benefit streams.

Secondly, when prioritising management options, EPSDD may have regard to the importance of lake access for primary and secondary contact recreation in the context of benefits for the wider community. For example, increase bacteria and pathogen loads in the lakes that restrict lake access for on-water recreation (i.e., lake closures) but do not restrict visitation is likely to have less impact to the community values compared to increased occurrences of algal blooms that negatively impact the environmental amenity of the lakes.

Thirdly, the value for environmental amenity at Lake Burley Griffin was the lowest among the three study lakes. This suggests that despite the size, locality and visitation to this lake, the community may have comparably less value for the amenity of the lake. This could be due to visits to Lake Burley Griffin being more linked to activities and proximity to the city centre (e.g., visiting sights, establishments, golf courses) as opposed to Lakes Tuggeranong and Ginninderra, where environmental amenity (both visual and smell) are more important to the community. However, it would be expected that the economic values for Lake Burley Griffin being higher in terms of revenues from events, tourism and lakeside businesses, and impacts to property prices.

Table 10. Summary of willingness to pay per individual for lake attributes

Attribute	Description	Willingness to pay per person ($ per quarter)			
		Lake Burley Griffin (range)	Lake Ginninderra (range)	Lake Tuggeranong (range)	All lakes (range)
Environmental amenity	WTP to avoid *worse* outcome from current status quo	$36.29 ($19.28–53.31)	$43.44 ($21.56–65.32)	$27.67 ($10.24–45.11)	$36.12 ($25.18–47.06)
	WTP for *better* outcome from current status quo	$35.32 ($21.45–49.19)	$42.69 ($22.82–62.57)	$55.51 ($32.88–78.14)	$44.50 ($33.69–55.31)
	WTP for *much better* outcome from current status quo	$44.97 ($28.71–61.22)	$57.68 ($33.35–82.01)	$70.01 ($42.82–97.20)	$57.94 ($44.88–71.00)
Avoided lake closures†	WTP to avoid increases to annual closures‡	$10.46 ($4.41–16.51)	$18.91 ($11.45–26.38)	$12.04 ($7.41–16.67)	$16.02 ($12.53–19.52)
Lakeside facilities	WTP to avoid degradation	$46.59 ($29.62–63.55)	$43.29 ($23.39–63.19)	$45.21 ($26.31–64.10)	$45.35 ($34.47–56.23)
	WTP for improvement	$5.42 (-$1.83–12.67)	$14.33 ($4.19–23.39)	$5.12 (-$3.56–13.80)	$8.52 ($3.53–13.51)

† WTP for weighted closure is calculated by using a weighted average of the WTP of closure attendees and non-attendees; except for Lake Burley Griffin where attribute non-attendance was not significant; instead, a scaled WTP was used that effectively ignored respondents preferences who stated non-attendance to lake closures. The resulting estimate for Lake Burley Griffin can be considered conservative.

‡ The WTP values for the individual lakes are calculated based on six-year average of the year-on-year change in annual closures for each of the lakes as reported in Table 9 and the average 41% increase for the pooled 'All lakes' results.

3 Importance of urban lakes to wellbeing

3.1 Overview and approach

The ACT Government introduced the ACT Wellbeing Framework to support decision-making in the context of improving the wellbeing of the ACT community. As part of this framework, policies and decisions are expected to include a Wellbeing Impact Assessment (WIA) to determine impacts on the 12 domains of the Wellbeing Framework, including who will be impacted, and the evidence base and data to demonstrate the scale of impacts.

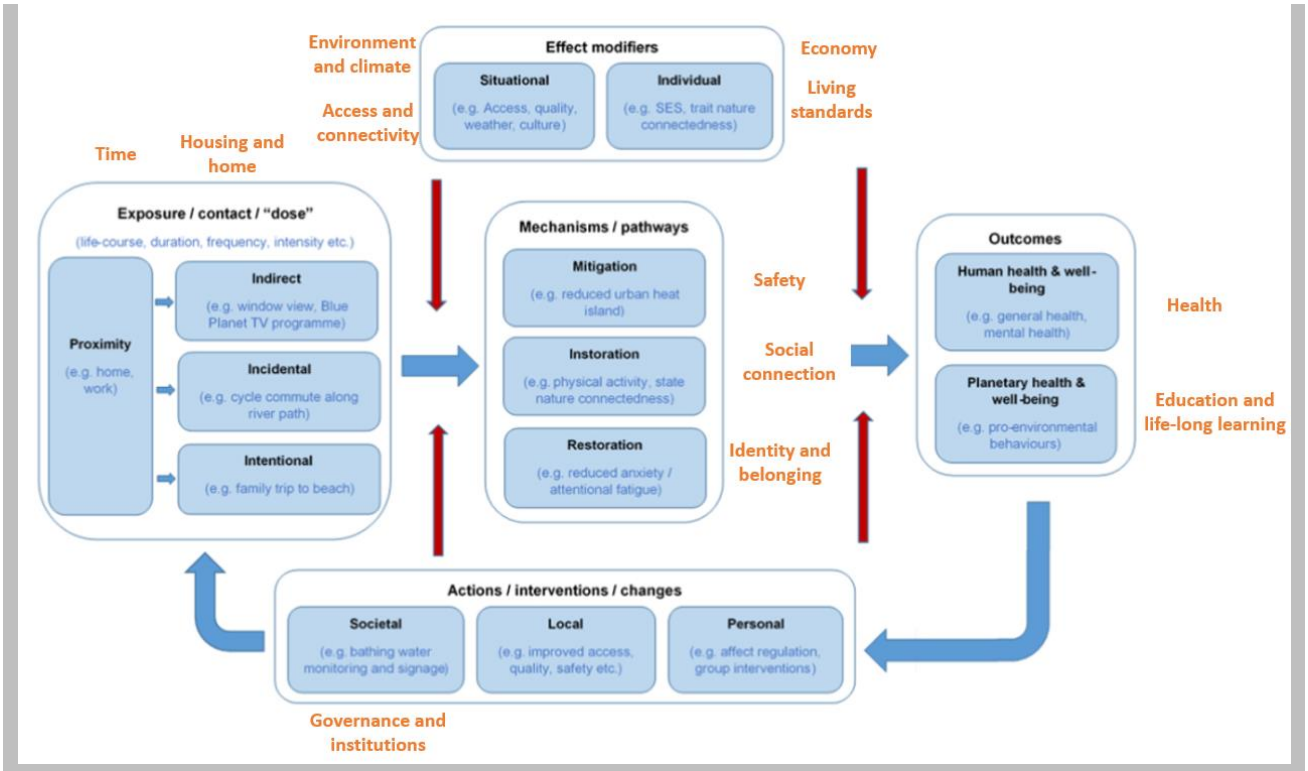
As part of this project, a preliminary assessment of the importance of urban lakes to community wellbeing was conducted. The objective of this study was to investigate the plausible pathways through which urban lakes support community wellbeing, and where possible, estimate the value of these links. This study utilised both qualitative—through a research-based review of the ACT Wellbeing Framework—and quantitative—through analysis of survey data—approaches. The results could then be assessed with the economic values estimated from the discrete choice experiment, to illustrate any alignments between the sciences.

3.2 Urban lakes, wellbeing, and the ACT Wellbeing Framework

There is a growing evidence base linking access to urban blue space (in this case lakes) and a range of positive outcomes to physical and mental health, and wellbeing. This includes access to a space to undertake physical activities, improve social cohesion, reduce stress, anxiety, and depression; and develop a sense of wellbeing and belonging. The prevailing literature provides a useful basis to aligning these links with the ACT Wellbeing Framework (as further explored in Box 3).

Box 3: Conceptual framework of health and wellbeing benefits from urban lakes

The figure below shows a conceptual framework explaining the relationships between contact with urban lakes, the associated health and wellbeing benefits, and the 12 domains of wellbeing as identified in the ACT Wellbeing Framework. This demonstrates the various roles that these domains of wellbeing play in shaping the relationship between urban lakes, and health and wellbeing benefits. For example, domains such as time, housing and home, and access and connectivity will determine the opportunities that people have to access and experience contact with urban lakes, and the associated health and wellbeing benefits. The domains of environment and climate, economy and living standards will act as modifiers of the relationship between urban lakes and health and wellbeing determining whether benefits or disbenefits are experienced. Urban lakes that are in poor environmental condition are likely to have a less positive effect on community health and wellbeing, and in some cases may even have a negative impact on community health (e.g., people coming into contact with or ingesting water of poor microbial water quality resulting in gastroenteritis). The domain of social connection is an important instoration pathway whereby urban lakes provide gathering spaces and opportunities for social interactions. Similarly, the domain of identity and belonging supports the restoration pathway whereby people can experience a sense of belonging through connecting with urban lakes. Finally, urban lakes even provide an opportunity to support the domain of education and life-long learning through building community environmental awareness, stewardship, and pro-environmental behaviours.



Adapted from: White, M. P., et al. (2020).

The ACT Wellbeing Framework consists of 12 domains of wellbeing, reflecting key factors that impact the quality of life for Canberrans. 56 indicators are used to measure progress across these 12 wellbeing domains. Table 11 outlines the 12 wellbeing domains and associated indicators alongside the known links between these domains and urban lakes. In addition to individual wellbeing domains, the Personal Wellbeing Index (International Wellbeing Group, 2013) includes seven key factors of life satisfaction, from across the domains, and summarises them into a single measure of how well life is going overall for people in the ACT.

Table 11. ACT Wellbeing Framework domains, indicators and links to urban lakes

Domain	Description	Indicators	Link to lakes
Economy	We share in our city's economy—A strong economy, business and innovation sector creates opportunities for all Canberrans to share in the wealth of our city.	• Business conditions and economic diversity • Economic performance • Employment • Income inequality	The first objective of this project will be directly assessing the economic values and contributions of lakes. Lakes can support economies through enhancing tourism, local business and providing jobs.
Access and connectivity	Getting around to places we value and accessing the services we need—Our planning, mobility and service systems allow us to move around our liveable city and access the types of places and services we need, when we need them. Those who require	• Access to services • Digital access • Liveable city • Transport use and access	Lakes contribute to liveable cities and are an important wellbeing resource that community should have equitable access to. A new indicator is currently under development, the 'Proximity to places that support wellbeing'

Domain	Description	Indicators	Link to lakes
	additional support to gain independence can access responsive, tailored services.		which has direct links to lake access.
Education and life-long learning	Gaining the skills and education needed at all stages of life—Canberrans have equitable access to education and learning opportunities, through all ages and stages of life, to develop and gain the skills needed to live life well.	• Early childhood education • Equity of educational outcomes • Learning for life • Learning growth • Student belonging	While there isn't a direct tangible link between lakes and education and life-long learning, lakes can provide important opportunities for outdoor learning and environmental education.
Environment and climate	The environment sustains all life now and into the future—Canberra's natural environment sustains all life, is accessible, climate resilient, and clean.	• Climate resilient environment and community • Connection to nature • Healthy and resilient natural environment	There is a strong link between our access to green spaces/ waterways and improvements in both physical and mental wellbeing. The connection to nature indicator and other indicators in the Access and Connectivity domain will measure access to waterways, as well as how much green space we have in the ACT in our parks, nature reserves and other places, whether we can access these spaces, and how often we use them.
Governance and institutions	Having a say, being heard, and working together for better outcomes—All Canberrans can have their say, connect with and be part of key government processes. Canberrans have a government and other institutions that respect human rights, are responsible, reliable, have integrity, are open, and are fair.	• Access to justice and restorative practice • Feeling that voice and perspective matter • Human rights • Trust in government • Trust in other institutions	While there isn't a direct tangible link between lakes and governance and institutions the management of lakes may be an important factor affecting community trust in government if community perceive the lakes as poorly managed by government.
Health	Being healthy and finding the right care—Canberrans have good physical and mental health and can access the services they need to lead healthier lives and manage illness. Individuals take steps to proactively maintain good health with the support of health-promoting environments.	• Overall health • Life expectancy • Mental health • Healthy lifestyle • Best start to life • Access to health services	There is a strong evidence base demonstrating the positive relationships between spending time at lakes and blue space and the associated overall health, mental health and life expectancy
Housing and home	Having a place to call home - Canberrans have access to secure, suitable and affordable housing throughout their lives.	• Homelessness • Housing affordability and availability	While there isn't a direct tangible link between lakes and housing and income, proximity to lakes can affect

Domain	Description	Indicators	Link to lakes
		• Housing suitability • Rental stress	housing and rental prices making them less affordable.
Identify and belonging	Being able to express identity, feel a sense of belonging, and participate fully in society—All Canberrans can participate on equal terms, regardless of age, gender, cultural background or disability. We recognise and value the First Nations residents of the ACT region and celebrate our Australian identity. We are proud to be Canberrans.	• Arts and culture • Connection to Canberra • Sense of belonging and inclusion • Support for multiculturalism • Valuing Aboriginal and Torres Strait Islander cultures and recognising our Traditional Custodians	The lakes are iconic and a core aspect of the Canberra identity. Lakes provide inclusive, public spaces for people to gather, connect and foster a sense of belonging.
Living standards	Having the financial resources to live life well—Canberrans can be economically secure and have the means to help manage their lives.	• Cost of living • Financial position • Income levels • Net worth	While there isn't a direct tangible link between lakes and living standards the economic value of lakes may affect this domain.
Safety	Feeling safe and being safe—Canberrans are and feel safe and secure around their families, homes, community and on-line.	• Community resilience to emergencies • Domestic and family violence • Emergency services • Feeling safe • Road safety • Victims of crime • Workplace safety	Lakes can provide spaces where people feel safe and welcomed, however if not managed properly they can also be a space where people don't feel safe.
Social connections	Being connected with family, friends and community—Canberrans are connected and supported within our community and come together in areas such as sport, culture, spirituality, religion and the arts.	• Levels of loneliness • Levels of volunteering • Participation in community events and activities • Sense of social connection	Lakes can be natural gathering spaces for friends, family and community providing valuable opportunities for social interactions and building a sense of social connection.
Time	Having time to live life well—Canberrans have the time to do things we want to as well as the things we are required to do.	• Quality of time • Time spent travelling within Canberra • Unpaid work including caring • Work-life balance	Being outdoors in one of the aspects considered with the quality of time scale. Lakes can provide engaging and restorative outdoor spaces enhancing quality of time.

3.3 Preliminary wellbeing impacts from lake visitation

Although the conceptual links between urban lakes and wellbeing appeared prevalent in the theoretical discussion above, this study attempted a preliminary investigation on the actual links between the two through the community survey. This section outlines how this analysis was conducted.

Approach

The approach utilised was based on a linear regression analysis, which assessed the relationship between wellbeing and different parameters, including access and usage of lakes. Several questions included as part of the community survey were used as explanatory variables including lake visitation, frequency of use, and socio-demographic indicators. Detailed description of these questions and distribution of responses are provided in chapter 2.

Wellbeing was measured using two additional questions in the community survey. First, the seven Personal Wellbeing Index (PWI) (International Wellbeing Group, 2013) statements were used to measure people's overall wellbeing, which is expressed as their satisfaction with their life, as a whole. Each statement referred to a theory-based quality of life domain: standard of living, health, achieving in life, relationships, safety, community-connectedness, and future security. The Personal Wellbeing Index has been tested, validated, and used widely across the globe, especially in Australia as part of wider health surveys for the general population. Second, a question to capture wellbeing under the Kessler Psychological Distress Scale (K6; Kessler et al., 2002) was included. The K6 scale uses six statements to assess a person's level of mental distress. This form of psychological distress has been found to have an inverse impact on Australian's subjective wellbeing, that is, higher levels of mental distress are associated with lower levels of wellbeing (Crowe et al., 2023). There was a likelihood that this average score could be subject to inconsistency based on participants' responses, rendering it unreliable. This scale reliability and consequently, appropriateness of the PWI score as a measure of wellbeing was tested using the Cronbach's alpha. Both the PWI and K6 Distress Scales were checked for reliability (Cronbach's α = .90 (PWI) and .90 (K6), indicating a high degree of internal consistency), and an average score for each scale was created to incorporate into the model.

A composite score based on the average of the responses to the PWI statements was then used as dependent variables to determine the relationships with other parameters, based on correlations. This included the K6 scale, which was expected to have a significant relationship with the PWI score.

The linear regressions were run using independent variables including the relevant demographic information, the psychological distress scale, and most importantly, a parameter capturing the lake exposure. A few different parameters were attempted to account for this lake exposure, including utilising the annual visitation to lakes and waterbodies (Q6 of the survey). However, given the recency associated with the PWI, it was considered more appropriate to use more recent measures of lake exposure. The final parameter that was used and presented below is a composite index of visitation in the last four weeks (Q7 of the survey) and average time spent with each visit (Q9 of the survey). The list of parameters used for this analysis are provided in Table 12.

Table 12. Model parameter descriptions for wellbeing correlation analysis

Parameter name	Description
Intercept	This parameter captures all other factors to explain the PWI score that are not captured within the estimates for the other coefficients below. Unlike other parameters, the intercept is generated through the modelling as opposed to being an input
Lake exposure	A continuous variable based on the total number of visits to lakes and other water bodies in the preceding four weeks (Q7) multiplied by the length of each visit (Q9).
Age	A continuous variable created by converting the stated responses to the age categories (see Q3) to a numerical output based on the midpoint of the range.
Gender	A dummy variable that identified if the respondent stated if their identified gender (Q3) was female.

Parameter name	Description
Income	A dummy variable that identified if the stated household income (Q17) was above the ACT average (as clarified in section 2.4).
Retired	A dummy variable that identified if the respondent was retired (Q21).
Trust in Government	A dummy variable that identified if the respondent stated that they either agreed or strongly agreed with the statement 'I trust the ACT Government to do what is right' (Q25).
Distress score	A continuous variable based on the aggregate score on responses of the K6 distress scale (Q5).
Household structure	A series of dummy variables to identify the household structure (Q20) being: • couple parent with children household • share or group household • single parent with children household • sole person household • other.

Results

Several model specifications to examine factors influencing wellbeing were attempted. The scale reliability was also tested through the regression analysis by including and excluding variables. The selected model (Table 13) performed the best in terms of overall model fit (as determined by the adjusted-R^2) and scale reliability. and diagnostics indicated the model did not violate assumptions for linear regressions. The key result from this analysis was that the coefficient for lake exposure was significant—it was a relevant explanatory variable for personal wellbeing—and positive—indicating the expectedly positive relationship between lake exposure and wellbeing. However, its marginal effect was very small. Conversely, other parameters like income, being retired, the K6 distress scale composite score, and household composition provided a much greater explanatory power to the PWI scores than lake exposure. This is generally consistent with the research and public policy literature that highlight the complexity of wellbeing and the inherent factors that contribute to it such as physical, social, and economic factors (Haapasalo et al., 2018; Hodgkin et al., 2018; Miranti, R., 2020). It is plausible that people may be accessing the Lakes as a protective measure to maintain or improve their wellbeing (Heinsch et a., 2022), however this study was not designed to investigate this possibility. The results were also reflective of the limitations of the study design, which was secondary to the estimation of community values (as outlined in chapter 2). A tradeoff was made to prioritise the robustness of the economic valuation. Attempting to study wellbeing to a similar degree through the same community survey would require a greater time commitment and cognitive burden from participants, with potential impacts on robustness on both studies.

Key point

Lake exposure only provided a small contribution to determining an individual's overall personal wellbeing compared to other socio-demographic indicators.

Table 13. Wellbeing correlation analysis results

Parameter	Coefficient	Std. Error
Intercept	9.55***	0.26
Lake exposure	0.04***	0.01
Age (mid-point of range)	-0.01***	0.00
Gender	-0.03	-0.10
Income	0.36***	0.11
Retired	0.70***	0.15
Trust in Government	-0.18***	0.04
Distress score	-1.09***	0.06
Household structure		
Couple parent with children household	-0.28**	0.13
Share or group household	-0.37**	0.18
Single parent with children household	-1.09***	0.21
Sole person household	-0.35***	0.13
Other	-1.37***	0.33
Adjusted R^2	0.47	

Note: * denotes significance at the 10% level, ** denotes significance at the 5% level, and *** denotes significance at the 1% level.

3.4 Summary of findings and discussion

This study identified the theoretical links between access to urban lakes and wellbeing, which generally aligns the ACT Wellbeing Framework, and the broader literature on positive impacts between blue infrastructure and wellbeing. Causal pathways were identified for several of the 12 domains of the ACT Wellbeing Framework, with key indicators being linked to *access and connectivity*, *environment and climate*, *health*, *and social connectedness*.

In view of this, a preliminary analysis was undertaken to determine the links between access to the urban lakes and wellbeing using a linear regression analysis. The results indicated that while lake exposure could have a positive relationship on wellbeing, the marginal impact is small; particularly, when comparing to other socio-demographic indicators that expectedly have a higher correlation with wellbeing (e.g., income and psychological distress). This is reflective of the limitations of this study design but are also generally consistent with the broader literature. Also, these results somewhat align with findings from the DCE study in chapter 2 where lake usage and access did not have a significant impact on preferences and WTP. Thus, it was not possible to determine the wellbeing value from the lakes in this study.

The causal links identified through the review of the ACT Wellbeing Framework suggest that exposure to nature can have a positive outcome to individuals' mental and physical health; however, when assessed in isolation, the marginal impacts may not be sufficient to override other factors that influence individual wellbeing. Cognisant of the limitations of this study, future research approaches are explored in chapter 6.

4 Qualitative case studies of lake users

4.1 Overview and approach

The DCE presented in the previous chapter demonstrated community values for various lake attributes, with environmental amenity—driven by water quality—being a key component of the community's experience at the lakes. To further supplement the importance of the lakes and the impacts of water quality, two case studies were undertaken: one at Lake Burley Griffin and one at Lake Tuggeranong. The purpose of these case studies was to provide more qualitative, personal views of the lakes from lake users and compare these with the quantitative results from the DCE.

The case study analysis involved surveying a targeted group of users through a short online survey of the importance of the two urban lakes, experiences, and impacts from changing outcomes, including water quality.[17] For Lake Burley Griffin, members of the Lake User Group, managed by the NCA, were invited to participate. This user group was comprised of representatives from a range of user organisations including rowing clubs, triathlon, land care, Scouts and commercial users. For Lake Tuggeranong, members of the local fishing club, the Tuggeranong Arts Centre, the Sea Scouts and Tuggeranong Catchment Carers were invited to participate. Participants completed the questionnaire as individuals and not as representatives of their respective groups. No identifiable information (e.g., names, addresses) was collected.

4.2 Case study results

Lake Burley Griffin

Respondent demographics

There were 23 respondents to the Lake Burley Griffin case study survey (but two chose not to disclose their gender and age). Of these respondents, 12 identified as male and nine identified as female. The majority of respondents (12 of the 21) indicated they were aged over 50, five were aged between 30 and 49, and two were younger than 30.

It should be noted that the purpose of this study was to gain a qualitative understanding of lake users so the demographics of the respondents were not intended to provide representation of lake users.

Importance of the lake

The importance of the lake was assessed by asking respondents to indicate the length of time they had been visiting the lake, the frequency of their lake visits, activities they do at the lake, and asking if they had a positive memory from the lake.

Most respondents (17 of the 21, two respondents did not answer) stated having visited Lake Burley Griffin for 10 years or more, with the majority (11 out of 17) visiting weekly. Of the four respondents who had been visiting the lake for less than 10 years, three reported visiting daily (Table 14).

[17] Text versions of the survey have been provided in Appendix E.

Table 14. Years and frequency of lake visitation for Lake Burley Griffin case study

Years visiting the lake	Frequency of visits			
	Daily	Weekly	Monthly	Less than monthly
Under 10 years	3	0	0	1
10–30 years	1	10	2	0
Over 30 years	2	1	1	0
Total	**6**	**11**	**3**	**1**

Survey respondents indicated they did a broad range of different activities on Lake Burley Griffin. These activities included:

- water sports – swimming, kayaking, canoeing, rowing, coaching, stand-up paddle boarding
- boating and sailing—including dragon boats
- exercise – walking, jogging/running, cycling
- recreation – fishing, picnics, coffee, event attendance (incl. markets), lake cruises
- work related – including surveillance, water extraction.

Over 82% (19 of the 23) of respondents mentioned activities that involved primary or secondary contract recreation.

Figure 18 illustrates where respondents indicated they do their various activities on the lake. There is an obvious cluster in the banks near Yarralumla, where various clubs (i.e., YMCA Sailing Club, Lake Burley Griffin Sea Scout Group, Rowing Australia), and boat ramps and storages are located.

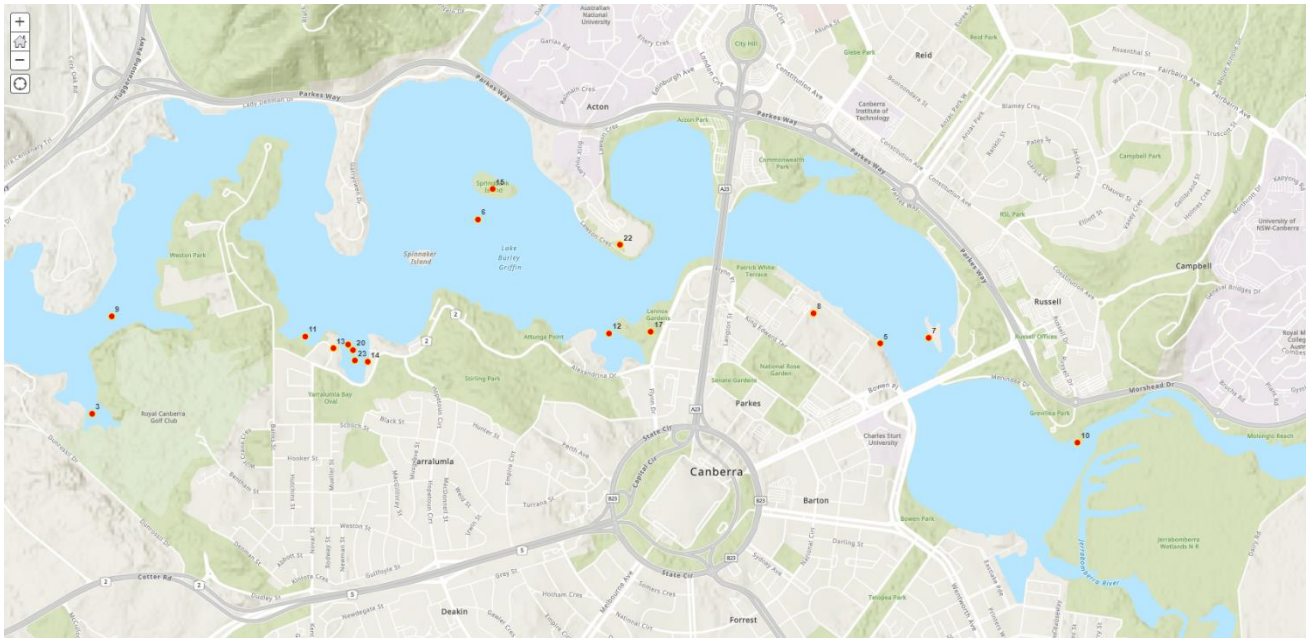


Figure 18: Map of user activity locations at Lake Burley Griffin

Respondents also provided detail around their favourite or positive memories they have from using the lake. These included:

- seeing sunrises and sunsets over the lake and Carillion,
- learning to sail and participating in sailing regattas,
- relaxing and enjoying picnics and other activities on the foreshore, and
- seeing fireworks and hot air balloons over the water.

Descriptive comments and pictures on these memories are provided in Box 4.

Box 4. Descriptive responses for memories at Lake Burey Griffin

"*Sunsets across the water shared with friends*" –male, aged 67, cruises on the lake.

"This is a quiet place to have a picnic surrounded by the lake" – male, aged 70, visits the lake each month boating and walking.

"*Sailing as a kid, fish and chips, watching fireworks*" – female, aged 50, visits the lake each week to walk, and have a coffee or drink.

"*I first learnt to sail with friends and family in this bay when I was 4*" – female, aged 21, visits the lake each week for sailing, canoeing and swimming.

Source: Anonymous respondents to 2023 NCE 'Importance of Urban Lakes, Lake Burley Griffin' survey 2023.

The importance of Lake Burley Griffin to respondents was also ascertained by asking the respondents to indicate their agreement or disagreement with different statements, as shown in Figure 19. From the results, there was a clear majority of respondents who saw Lake Burley Griffin as important to them. This could be expected given the survey respondents were members of the Lake User Group, and likely based many of their leisure, recreation and social activities on or around the lake.

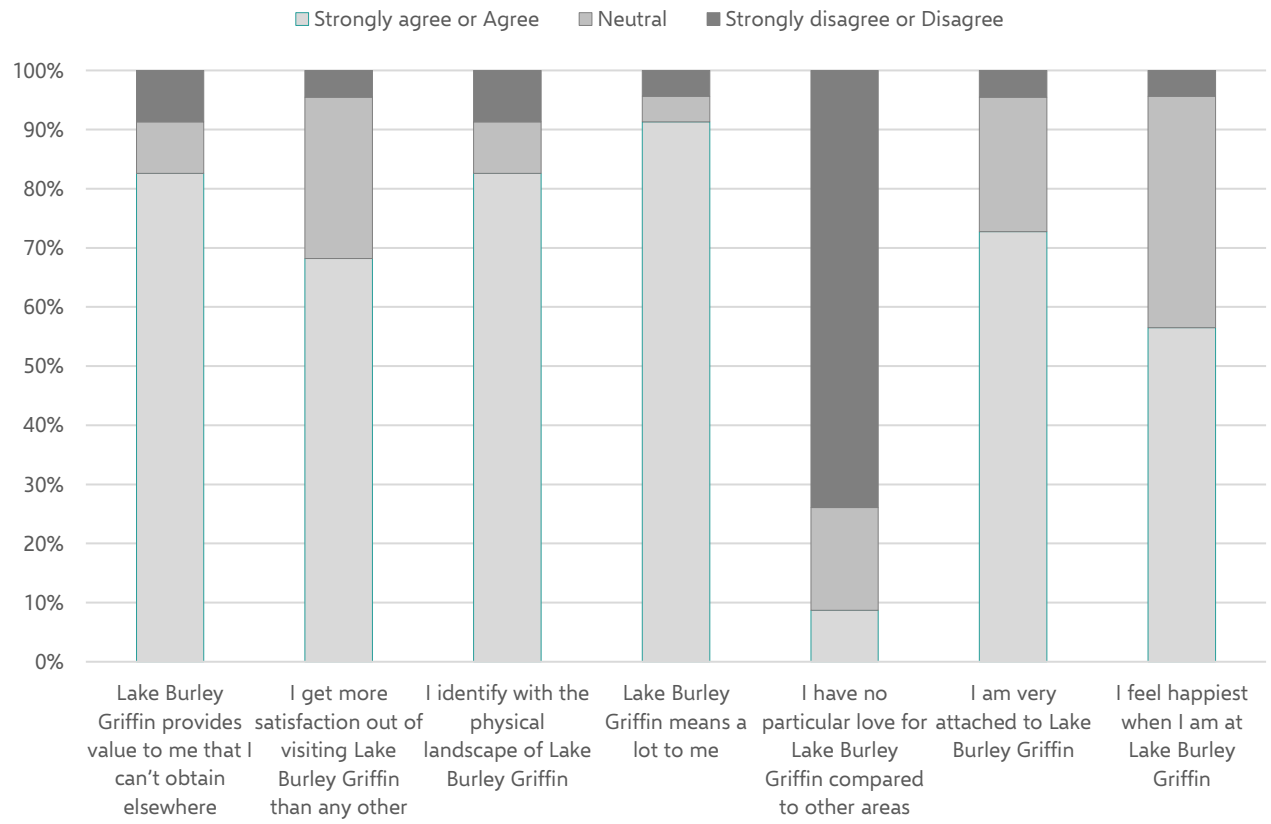


Figure 19. Importance of Lake Burley Griffin to case study respondents

The lake environment

Respondents were also asked about their experience with changes to the lake environment, lake closures and algal blooms, and what would improve their experience at Lake Burley Griffin in the future.

Some of the positive responses that were supplied included:

- improvement to the facilities around the lake (e.g., paths, coffee outlets)
- planting of trees on Springbank Island to replace unsuitable trees, which had been removed
- use of goats to control weeds, and
- improvements in boat berthing (e.g., cleats, soft edges).

However, respondents also indicated a number of negative changes to the lake environment, specifically:

- poor water quality and increased presence of algal blooms
- increase in weeds around shorelines of the lake, and
- inadequate separation between cyclists and walkers on footpaths.

Most importantly, 13 respondents commented on the water quality of Lake Burley Griffin, particularly in relation to the presence of algae, sediment and bacteria, particularly during summer. Further comments indicated that the poor water quality and presence of algae:

- prevented swimming and boating (owing to the risk from capsizing)

- negatively impacted the rowing course, leading to lost sailing opportunities, and
- negatively affected the general enjoyment and experience at the lake.

One respondent also commented on the negative health impacts they had experienced after exposure to the algae.

Respondents provided several suggestions that would improve their experience of using Lake Burley Griffin:

- improved water quality
  - more frequent water quality assessments and uploads to the swim guide application
  - undertake a comprehensive fauna and flora audit of the lake, and monitor ecosystem changes
  - prevent the use of fertiliser on golf courses and public amenities near the lake
  - installation of underwater electric fans to aerate and move the water
  - provide a catchment for logs and trees before they enter the lake
  - improve leaf litter collection in autumn
- improvements to footpaths
  - upgrade, widen and resurface the pathway around the lake
  - reduce the speed of cyclists on the Central Basin Bridge to Bridge loop
  - path separation for walkers and users on bikes and scooters
- more infrastructure around the lake including public toilets (and regular cleaning), boating facilities, and improvements to the rowing course facilities (e.g., additional lanes and improved distance markers)
- improvements to existing boating facilities including wharves, jetties, launch ramps, boat trailer parking, short term tie ups, and public berthing in Kingston Harbour
- encourage cross-activities on the lake between various user groups
- look into the ideas for improving and changing the Carillion area
- less development around the lake, including buildings and public access—maintain some areas for lower public activity levels.

Lake Tuggeranong

Respondent demographics

There were five respondents to the Lake Tuggeranong survey: four identified as female and one identified as male. Three of the respondents indicated they were aged 50 and over, and one was age 37 (one chose not to disclose their age).

It should be noted that the purpose of this study was to gain a qualitative understanding of lake users so the demographics of the respondents were not intended to provide representation of lake users.

Importance of the lake

Like the Lake Burley Griffin case study, the importance of the lake was assessed by asking respondents to indicate the length of time they had been visiting the lake, the frequency of their lake visits, activities they do at the lake, and asking if they had a positive memory from the lake.

All respondents indicated they had been visiting Lake Tuggeranong for 15 years or more. Frequency of visitation to the lake was weekly for three respondents, and monthly for the other (one respondent chose not to respond to these questions) (Table 15).

Table 15. Years and frequency of lake visitation for Lake Tuggeranong case study

Years visiting the lake	Frequency of visits	
	Weekly	Monthly
15 years	2	0
25 years	1	0
40 years	0	1
Total	**3**	**1**

Respondents indicated that they did a range of activities at the lake including walking/running, cycling, canoeing, boating, sailing, general exercise, and water quality monitoring. Figure 20 indicates where respondents showed that they do their lake activities.

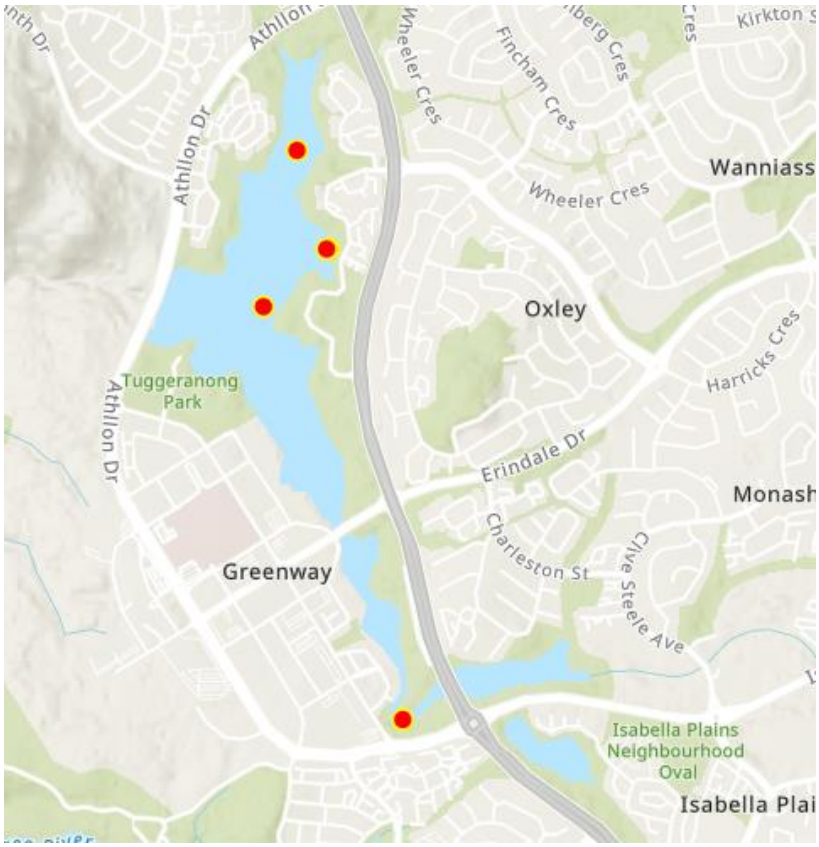


Figure 20: Map of user activity locations at Lake Tuggeranong

Respondents also provided detail around their favourite or positive memories from using the lake. Seeing sunrises and sunsets over the lake was a notable memory of three respondents, as well as sailing and canoeing, and seeing wildlife (a rakali or water-rat).

In responding to statements on the importance of the lake (Figure 21), there was strong agreement that Lake Tuggeranong held meaning to the respondents, as well as identification with the physical landscape. In the same vein, a majority of respondents disagreed with the statement that they have 'no particular love for Lake Tuggeranong compared to other areas'. However, given the low number of responses, clear inferences across a number of other statements were difficult to make.

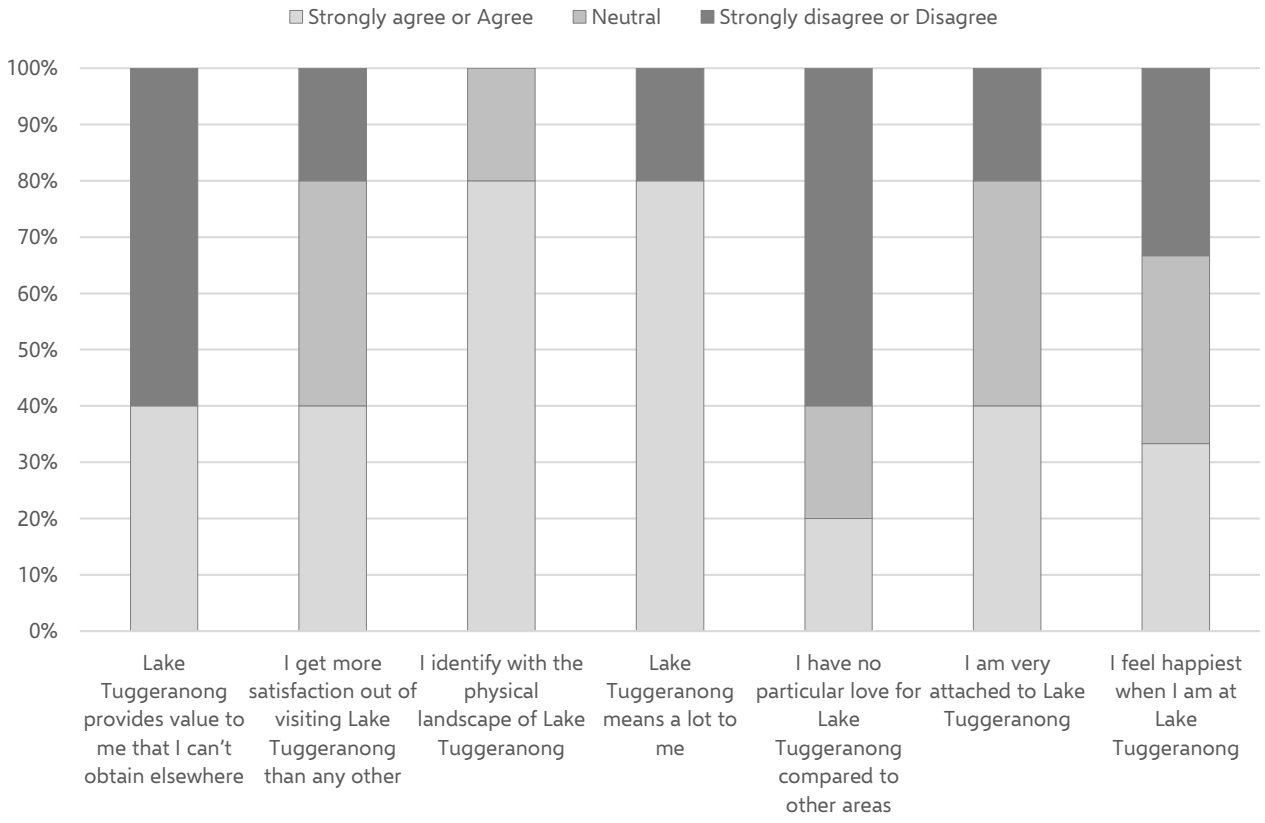


Figure 21. Importance of Lake Tuggeranong to case study respondents

The lake environment

Respondents were also asked about their experience with changes to the lake environment, lake closures and algal blooms, and what would improve their experience at Lake Tuggeranong in the future.

Some of the positive changes to the lake which were indicated by the respondents included:

- removal of the flock of white ibis in the northern end of the lake,
- general cleanliness and users keeping the lake tidy, and
- improvements in the lake facilities including new lights in the carparks near the Scout Hall.

However, respondents also indicated a number of negative changes to the lake environment:

- water quality issues including algal blooms—water quality is very poor for much of the year and it has impacted on the ability to swim or safely capsize boats,
- high rise buildings, and
- litter and medical waste (e.g., needles and syringes)

Further, four of the five respondents indicated that they had been personally impacted by lake closures or algal blooms on the lake. Respondents also commented that the algal blooms resulted in horrible smells on the lake, and the scout group could not take sailboats out as they did not want to risk capsizing.

Respondents provided that their experience of Lake Tuggeranong could be improved if there were:

- improvements and maintenance of water quality and reductions to algal blooms,
- wider paths for multi-use purposes,
- reduced litter,
- the establishment of a food service or restaurant overlooking the lake, and
- town planning changes related to development and building on the lake edge.

4.3 Discussion of results

There were some clear themes that emerged from the user group case studies at Lake Burley Griffin and Lake Tuggeranong:

- respondents undertook a range of activities on the lakes, including water sports, boating and sailing, exercise, and recreation
- respondents saw the lakes as important and identified with the physical landscape of the lakes
- the high frequency of poor water quality and algal blooms negatively impacted respondents' activities and experiences of the lakes
- respondents had many enjoyable memories and experiences from using the lakes, and
- respondents desired improved infrastructure, lake facilities, footpaths, and less development around the immediate vicinity of both lakes; improvements in facilities appeared to largely involve management and replacement of existing facilities as opposed to significant expansion.

Respondents for both lakes also agreed that changes were needed to reduce algal blooms and improve water quality.

These findings are generally in line with the broader community values for the lakes with amenity (impacted by algal blooms) and lakeside facilities being found to have material WTP values. The key distinction from the DCE study was that users clearly indicated high visitation and usage of the lakes for primary and secondary contact recreation, relative to the broader community findings. While such users may highlight the importance of ensuring safety for lake access and management to minimise lake closures to on-water recreation, the broader community (as sampled) indicated much lower preferences and priorities for lake closures.

5 Valuation of water quality management

5.1 Overview

One of the primary functions of Canberra's urban lakes—from initial conception to current objectives under the Urban Lakes and Ponds Land Management Plan—is the management of downstream water quality by acting as sediment ponds to intercept urban stormwater pollutants (ACT Government, 2022). Furthermore, the ACT Planning and Development Act 2007 and the Water Use and Catchment General Code both prioritise key objectives for ACT's lakes as preventing and controlling the pollution of waterways, ensuring that discharges are consistent with the protection of downstream environment values (ACT Government, 2007; ACT Planning & Land Authority, 2009). This can have significant benefits for the natural environment and downstream users. This chapter describes the approach and findings from valuing the water quality management benefits at the three study lakes.

5.2 Valuation approach

The benefits from water quality management at the three lakes are not traded explicitly in market terms. Thus, a non-market valuation technique of avoided abatement cost was utilised to determine the value from water quality management.[18] This is based on a hypothetical comparison of water quality outcomes with and without lakes by measuring the sediment and nutrient (nitrogen and phosphorus) loads upstream of the lake—a proxy for water quality 'without' lakes—against downstream—representing water quality 'with' lakes.

Modelling of water quality

The modelling of water quality outcomes was undertaken by EPSDD. The load of pollutants—total suspended solids (TSS), total phosphorus (TP) and total nitrogen (TN)—entering and exiting each lake was modelled in the software system Source (eWater Ltd). The ACT Source model was built to predict stream flows and water quality across the upper Murrumbidgee River catchment, and to fulfil its requirements of the ACT Water Resource Plan. The catchment model employs rainfall-runoff models, calibrated to observed streamflow to predict streamflow. Water quality constituents are modelled using a dry weather concentration/event mean concentration (DWC/EMC) approach to model pollutant loads (kg/day). The Source model runs on a daily timestep.

For this analysis, the ACT Source model was run over a period of 1980–2016, providing 36 years of simulated data. This was used as the 'baseline'. For modelling the uncertainty from different climate change scenarios, regional climate change projections drawn from NARCLIM 1.5 were used. NARCLIM 1.5 provides a wide range of climate change projections for NSW and ACT. Two climate change projections were chosen were used RCP 4.5 and 8.5. Firstly, an RCP 4.5 projection was chosen to represent a very likely future climate. A second, relatively extreme scenario from RCP 8.5 was chosen to represent a significant worse future outlook. A future time horizon of 2050 was chosen. Both scenarios reflect warmer and drier climate outlooks. Monthly scaling factors for rainfall and evapotranspiration were derived from the NARCLIM 1.5 data, and the Source model input data of historic rainfall and evapotranspiration were re-scaled using the NARCLIM 1.5 scaling factors. In addition to the climate scaling factors, anticipated changes to water resource development were included as well. For the RCP4.5 scenario, a moderate level of population growth incorporated (which is reflected in water

[18] See Appendix A for a description of valuation theory.

take and sewage treatment plant outflows, and non-potable water take). The RCP 8.5 scenario reflects a high degree of water resource development, including a high level of population growth, and water use.

The modelling of pollutant load capture in each of the urban lakes is based on modelled inflow of pollution (based on inflows and DWC/EMC values), and a level of pollutant capture within the lakes. This is defined by specifying the outflow concentration for each nutrient source.

Due to the warmer and drier climate outlooks for the RCP4.5 and RCP8.5 climate projections, annual inflows to the lakes are projected to decrease. This in turn leads to a decrease in pollutant loads. To what extent this will hold into the future is unknown. The modelling approach used (e.g., scaling factors on rainfall and evapotranspiration) does not provide any insight into how rainfall intensity may change, or secondary effects (such as changes to soil properties, groundcover, pollutant generation rates) may change. Furthermore, no consideration was given to potential changes in populations, development or land uses over time. Any changes in these will impact upon pollutant load in the future. For example, increased soil impermeability, reduced groundcover, or increased populations will increase pollutant runoff, potentially increasing pollutant loads, in addition to climate change.

Economic valuation approach

The economic value of water quality management—using the avoided abatement cost method—utilised the annual abatement unit costs estimated in a previous study by NCEconomics (2019). This previous work drew upon prevailing research on efficacy and annualised costs of different water sensitive urban design (WSUD) assets in the ACT such as raingardens, street trees, grass swales and artificial wetlands, which would deliver equivalent annual load reductions. The costs of these assets were indexed to 2023-dollars using Australian Bureau of Statistics (ABS) data consumer price indices.[19] The unit rates are provided in Table 16. The range of avoided costs were used to illustrate the uncertainty in value of the benefit, using Monte Carlo simulations (see Box 5).

Table 16. Annual unit abatement cost by pollutant ($/kg), adjusted to 2023-dollar values

Pollutant	Low	Most likely	High
TN	808	998	1,664
TP	2,671	3,301	5,502
TSS	5	6	10

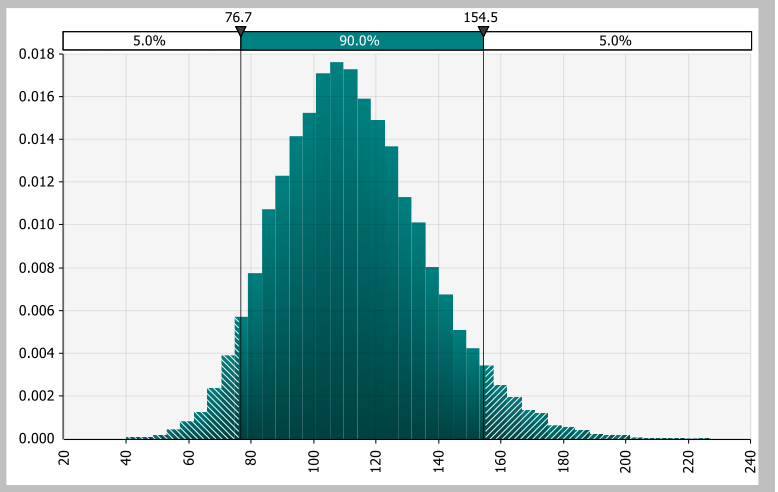
Source: NCEconomics (2019) indexed to 2023 dollars.

[19] https://www.abs.gov.au/statistics/economy/price-indexes-and-inflation/consumer-price-index-australia/mar-2022/640101.xlsx

Box 5: Capturing uncertainty through Monte Carlo simulations

Given the limitations (availability, variability and quality) of secondary data, sensitivity analysis was critical to the valuation of water quality management. If this uncertainty is not acknowledged and incorporated into the analysis, there is a risk that users of the report would place an over-reliance on the accuracy of the findings.

The key approach to addressing risk and uncertainty in the analysis was through the use of Monte Carlo simulations. This was undertaken by using multiple iterations (i.e., 20,000) of the valuation to investigate the impact of variability for avoided abatement costs (as provided in Table 16). This enabled the establishment of confidence intervals around the findings of the analysis (see figure on the right).



For this valuation, the simulations were used to establish:

- low value—based on the P10, which is the value that 90% of simulated estimations are higher than
- high value—based on the P90, which is the value that 90% of the simulated estimations are lower than.

This provides useful insight to the uncertainty in the value and can inform future research, data gathering and quality, and ongoing targeting for monitoring and evaluation of water quality outcomes. An example of this approach is shown in the figure below. Using this approach, indicative probability estimates of a range of values can be established.

The benefits of water quality management for each lake were estimated based on a present value (PV) of annualised avoided abatement costs for a 30-year period using a 7% discount rate. This approach consistent with the NCEconomics (2019) and relevant environmental valuation guidelines (OIA, 2023).

The unit abatement costs were multiplied by the modelled water quality outcomes as described above. The final forecast loads for each climate scenario (RCP 4.5 and RCP 8.5) were assumed as the final loads forecast at the end of the assessment period as shown in Table 17.

Table 17. Annual load abatement volumes under present day and future climate scenarios

Lake	Present day (kg/year)			2052 (kg/year)					
				RCP 4.5			RCP 8.5		
	TN	TP	TSS	TN	TP	TSS	TN	TP	TSS
Burley Griffin	112,951	11,895	12,415,828	98,897	9,945	9,469,751	82,034	7,592	6,871,177
Ginninderra	22,531	3,375	1,938,693	19,042	2,805	1,582,018	15,028	2,170	1,193,162
Tuggeranong	18,537	2,890	1,496,044	17,051	2,622	1,321,095	13,210	1,966	939,427

Source: Modelling by EPSDD.

Using the current load estimates, a consistent annual rate of change was estimated for the water quality benefits as shown in Table 18. The data demonstrated that by 2052, there will be a decline in abatement value for all three lakes.

Table 18. Annual rate of change for pollutant abated (yearly percentage change)

Lake	RCP 4.5			RCP 8.5		
	TN	TP	TSS	TN	TP	TSS
Burley Griffin	-0.44%	-0.59%	-0.90%	-1.06%	-1.49%	-1.95%
Ginninderra	-0.56%	-0.61%	-0.68%	-1.34%	-1.46%	-1.61%
Tuggeranong	-0.28%	-0.32%	-0.41%	-1.12%	-1.28%	-1.54%

Source: NCEconomics estimate based on EPSDD modelling.

The economic value of water quality management was estimated by multiplying the estimated value of pollution abated in a given year (as described above) by the unit value of abatement cost (Table 16).

Key assumptions

Given pollution abatement assets can typically achieve reductions in multiple different pollutants concurrently, there would a risk of double counting if benefits of multiple load reduction types were quantified for each lake. To manage this risk, only the highest-cost pollutant for each lake (in this case TN) was used to estimate the avoided abatement costs. This is consistent with the previous work by NCEconomics (2019).

The valuation did not factor the costs of managing the nutrient loads within the lakes i.e., removing or treating the loads within the lakes during the assessment period. It was assumed that the volumes of loads are not sufficiently material to trigger large-scale management (e.g., removing built up sediment or active treatment of nutrient loads) and the lakes have sufficient biophysical capacity to contend with the annual loads given their sizes. Furthermore, any prevailing costs for monitoring would be difficult to disentangle to attribute to specifically to managing nutrient and sediment loads and assumed to be immaterial in the context of valuation of the benefits (outlined below). However, the uncertainty of monitoring and management activities, particularly beyond the 30-year assessment period, should be acknowledged and provide nuance to the estimated values.

In addition, the benefits from water quality management will continue to accrue past the 30-year assessment period given the lakes are expected to exist going forward. However, a forecast of benefit values past the 30 years was not quantified given the increasing uncertainty associated with the efficacy of load reductions past that period. A 'residual value'—typically estimated for hard infrastructure assets that undergo quantifiable depreciation—was also not quantified given the lakes are a natural asset. Thus, it should be recognised that the value of water quality management through the lakes is likely an underestimate of the potential benefit.

5.3 Results

The estimated PVs of water quality management are presented in Table 19, including the range of values (i.e., low–high) determined through Monte Carlo simulations (see Box 5). Lake Burley Griffin provides the greatest value for water quality management among the three lakes for both climate scenarios—at approximately $816–865 million—followed by Lake Ginninderra ($156–170 million), and Lake Tuggeranong ($133–144 million). When comparing the PV by hectare, the results showed that Lake Tuggeranong provided the greatest abatement value despite being the smallest lake at $2.33–2.52 million per hectare compared to Lake Ginninderra ($1.51–1.62 million per hectare) and Lake Burley Griffin ($1.23–1.30 million per hectare).

Table 19. Present value of water quality management benefits across study lakes

Lake (size)	PV ($ million)		PV ($ million) per hectare	
	RCP 4.5	RCP 8.5	RCP 4.5	RCP 8.5
Burley Griffin (664 ha)	$865.08 ($628.14–1,201.24)	$815.54 ($591.32–1,132.52)	$1.30 ($0.95–1.81)	$1.23 ($0.89–1.71)
Ginninderra (105 ha)	$170.07 ($119.88–236.78)	$158.65 ($112.10–220.45)	$1.62 ($1.14–2.26)	$1.51 ($1.07–2.10)
Tuggeranong (57 ha)	$143.92 ($101.08–200.44)	$132.90 ($93.58–184.80)	$2.52 ($1.77–3.52)	$2.33 ($1.64–3.24)
Total	$1,179.07 ($849.10–1,638.46)	$1,107.09 ($797.01–1,537.77)		

Note: abatement of TN had the greatest economic benefit across all three lakes, so the values presented are associated with the treatment of this pollutant to avoid double counting.

Expectedly, the value for water quality management was generally higher in the RCP 4.5 climate scenario compared to the worse-case climate scenario of RCP 8.5. This is attributable to the higher nutrient loads estimated in the former, as described in section 0.

5.4 Summary of results and discussion

Among the three lakes studied, Lake Burley Griffin demonstrated the greatest total value in water quality management under both climate scenarios. Conversely, Lake Tuggeranong exhibited the lowest value for water quality management. Notably, Lake Tuggeranong – the smallest lake of the three, had the highest abatement capacity by area and thus, the greatest water quality management value.

When comparing the two climate scenarios, the analysis demonstrated that benefits were generally higher for the RCP 4.5 climate scenario. This is because under the hotter and drier conditions for the worse case RCP 8.5 scenario, there is reduced nutrient runoff entering the waterways and thus, a lower benefit for the lakes in terms of water quality management. This should be considered as a caveat of the modelling approach, which does not take into effect changes in rainfall intensity, or secondary effects such as changes in groundcover, runoff relationships or pollutant generation processes.

It should be recognised that the benefits from prioritising water quality management within the lakes may directly conflict with other social and community benefits related to direct and indirect use of the lakes, particularly due to dissolved nutrients resulting in increased aquatic weeds and algae levels. The consideration of these tradeoffs and implications for decision-making is further explored in chapter 6 of this report.

6 Summary and synthesis of findings

The objective of this project was to quantify the multiple benefits of Lake Burley Griffin, Lake Ginninderra, and Lake Tuggeranong, and determine the impact of poor water quality on those values. This chapter briefly summarises the key findings across the individual components of the project, outlining implications for lake management. Several recommendations are also provided on opportunities for future studies to improve understanding of the values from urban lakes, and the impact of changing water quality on lake management for EPSDD and the NCA.

6.1 Summary of results

Community values of urban lakes

DCEs were utilised to derive estimates of the ACT community's value for urban lakes, based on individual lake attributes. This approach allowed values to be estimated across a sample of the ACT population, regardless of access and usage of the lakes for primary or secondary contact recreation. The approach involved a survey that collected information on lake usage, perceptions, and socio-demographics of participants and, importantly, presented an economic experiment to derive values based on environmental amenity, annual closures, and the lakeside facilities of the three study lakes.

Key findings from the survey and DCE were:

- the majority of the sample, being representative of the ACT community, were likely to be infrequent, casual visitors who draw more value from the amenity and facilities of the lake as opposed to primary and secondary contact recreation
- in a similar vein, a material proportion of the participants did not consider impacts from increased annual closures as important in their preferences for attributes of the lakes, likely due to the majority of participants not partaking in on-water recreation (e.g., swimming, boating, etc)
- there was substantial value associated with lake attributes, particularly improvements in environmental amenity (between $35–70 per person per quarter depending on lake) and avoiding degradation of lakeside facilities (approximately $45 per person per quarter)
- the values per person for avoided lake closures were much lower than other attributes at approximately $12–19 per quarter; across the lakes, the difference in values for avoided lake closures were almost 90% less for participants who did not consider access to the water as important
- the WTP values per person for environmental amenity at Lake Burley Griffin were the lowest among the three lakes at $35 per quarter and highest at Lake Tuggeranong at around $70 per quarter, despite the size, location and visitation at Lake Burley Griffin; this was possibly reflective of the economic values at Lake Burley Griffin being attributable, to a greater degree, to other benefit streams like revenues from events, tourism, and lakeside businesses.[20]

A summary of values across the different model specifications have been provided in Table 10. Assuming the WTP for avoided degradation in amenity and public facilities, and increases to closure rates correspond to

[20] The monetary values from revenues were not investigated as part of this project.

current values, it could be inferred that the total community value for these lakes based on these attributes at current levels are approximately

Importance of urban lakes to wellbeing

A review of the ACT Wellbeing Framework and broader literature on wellbeing identified several causal pathways between wellbeing and access to the urban lakes, particularly through the domains of *access and connectivity*, *environment and climate*, *health*, and *social connectedness*. Preliminary quantitative analysis on the relationship between lake exposure and wellbeing found a positive but minimal effect. This was consistent with the broader literature that suggests access to nature and blue infrastructure may not demonstrate a strong causal pathway to wellbeing, particularly when analysed in isolation, given the complexity of other influences on wellbeing. Instead, causal pathways may be linked to specific indicators, which would be consistent with the domains of the ACT Wellbeing Framework. The results were also generally aligned with the study of community values, which indicated that frequency of lake access and usage did not have a significant impact on preferences and values.

While there are clear theoretical links between access to blue infrastructure and wellbeing, such as mental and physical health, there is also a material knowledge gap in understanding the relationship between urban lakes and wellbeing, given the unique nature of constructed lakes and their multiple uses. Opportunities to investigate and address this gap are further explored in the recommendations for future research below.

Qualitative case studies for lake users of Lakes Burley Griffin and Tuggeranong

The responses from the user group case study surveys indicated some common themes among users, specifically:

- the importance of the lakes for undertaking a range of activities,
- concerns around the incidence of algal blooms and loss of amenity
- a desire for improved condition of lakeside facilities—in line with the WTP for avoided degradation of these facilities.

These were generally in line with findings from the DCE study, except for the importance of lake access for primary and secondary contact recreation among users, which was expectedly higher than the broader ACT community.

Valuation of water quality management

An avoided abatement cost approach was utilised to estimate the value of water quality management from the lakes. Based on water quality modelling across different climate scenarios and a range of avoided abatement unit costs, the present value of water quality management by the lakes was estimated between $1.1–1.2 billion. The analysis also indicated that Lake Tuggeranong had the highest load abatement value by area ($2.3–2.5 million per hectare) despite having the lowest total benefit value ($133–144 million), which was the opposite to Lake Burley Griffin ($1.2–1.3 million per hectare but $816–865 million total). A summary of the values has been provided in Table 19.

6.2 Tradeoffs in lake management

The total annual non-market value the urban lakes, based on the two key benefit streams quantified in this project, was approximately $216 million a year (Figure 22). This was based on the assumptions that:

- the community values for the lakes were represented by the WTP values for avoiding degradation in amenity and lakeside facilities, and avoiding corresponding increases in lake closures as outlined in Table 10
- the value for water quality management were based on the annualised PV for water quality management outlined in Table 19.

The results demonstrate the significant non-market values that are derived from the lakes, despite only considering a limited subset of benefit streams as quantified in this project. More importantly, the results demonstrate the economic value from benefits to the community significantly outweigh the benefits attributable to water quality management through the lakes.

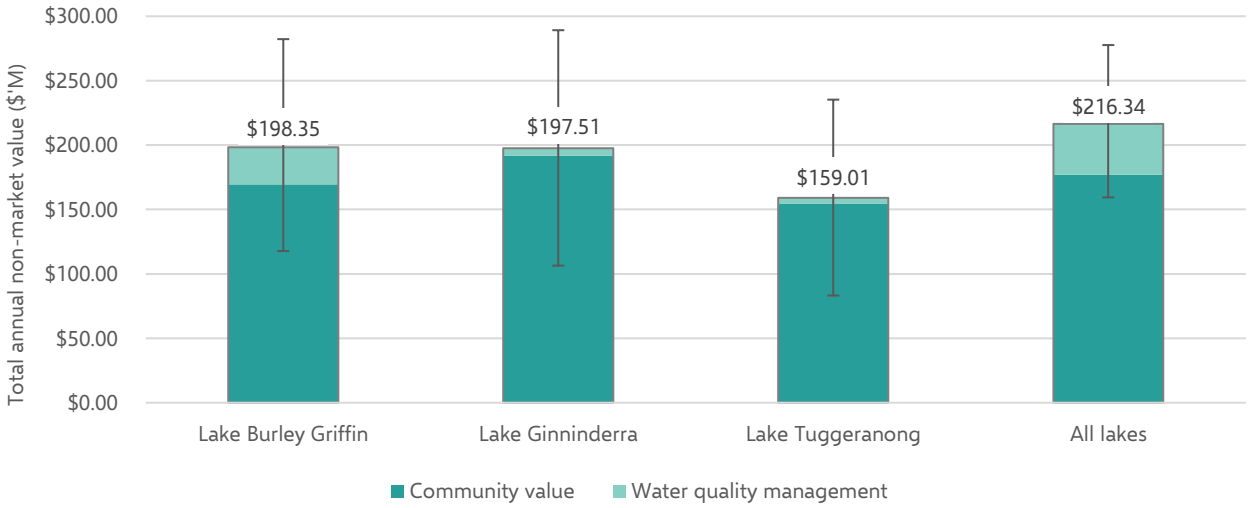


Figure 22. Total annual non-market economic value of ACT urban lakes

Note: Error bars represent the sum of confidence intervals between the two benefit streams. The aggregate community values are estimated by multiplying the WTP values by the estimated population of 454,000 (source: https://www.abs.gov.au/articles/snapshot-act-2021). These total values are based only on two benefit streams and values for individual lakes should not be aggregated to find the total value of the three lakes

As canvassed above, water quality management, flood mitigation, and ecological catchment health appear to be prioritised over community use and recreation as objectives of key policy documents (e.g., the ACT Planning and Development Act 2007, Water Use and Catchment General Code). However, there is a clear tradeoff in values associated with water quality management by ACT's urban lakes (as valued in chapter 5) and the community values for the lakes through access, usage and amenity (as explored in chapters 2–4). Where the study of community values clearly demonstrated a high WTP for pristine urban lakes, delivering these beneficial outcomes would require water quality management upstream of the lakes (e.g., increasing stormwater treatment or investment in upstream catchment protection[21]). This decreases the load reductions achieved by the lakes, decreasing water quality management value. Conversely, prioritisation of water quality management by the lakes—such as decreasing upstream load management and treatment, or reducing catchment management investments—could increase corresponding annual benefits values from water quality management, which would also leverage the cost-effective nature of the lakes as WSUD assets. However, these will directly result in declines in amenity and, potentially, increases in lake closures, impacting

[21] It should be noted that these are meant only to provide examples of upstream load management in the context of urban lakes. In reality, some upstream water quality management activities can deliver additional benefits, particularly management of catchment condition through natural assets that can deliver ecological and carbon sequestration benefits.

community values. This may be further exacerbated by the losses in revenues from lake-related events, tourism, and businesses.

EPSDD and the NCA face a significant challenge in determining an appropriate approach to water quality management that maximises total economic values from the lakes, in addition to broader values achieved across the water quality management train. This ideal approach will likely lie between targeting the community and water quality management values of the lakes, where the marginal[22] cost of increasing upstream management is equal to the marginal benefit for local communities that draw value from the lakes. This can be explored in cost-benefit analyses and business cases for investment in upstream treatment or catchment protection investment, where the community values in particular could be applied to robustly demonstrate outcomes across multiple benefit streams.

A high-level comparison between the two values (i.e., community and water quality management) may provide useful information for EPSDD and NCA on this trade-off. Using the annualised avoided abatement costs from chapter 5 as a proxy value for upstream water quality management—that would deliver higher water quality at the lakes—and the WTP values for the highest level (i.e., much better) of environmental amenity, the results demonstrate the latter providing over 2.5 times the economic value compared to the former across all the lakes (Table 20). Although there are significant caveats associated with this simple comparison[23], this still provides a reflection of the sizeable community values for water quality in ACT's urban lakes, and the net benefits generated by improvements in upstream water quality. This also provides context where the objectives prioritised for lake management under the relevant regulations and policy appear to contradict the value of benefit streams from the lakes.

Table 20. Indicative comparison between improved environmental amenity values and costs to improve water quality

Economic value	Value ($ M) (range)			
	Lake Burley Griffin	Lake Ginninderra	Lake Tuggeranong	All lakes
Annual aggregate WTP for a better environmental amenity	$64.14 ($38.96–89.33)	$77.53 ($41.44–113.62)	$100.81 ($59.70–141.91)	$80.80 ($61.17–100.44)
Annual aggregate WTP for a much better environmental amenity	$81.67 ($52.14–111.17)	$104.75 ($60.56–148.92)	$127.14 ($77.76–176.52)	$105.22 ($81.49–128.94)
Annual value for water quality management	$28.84 ($20.94–40.04)	$5.67 ($4.00–7.89)	$4.80 ($3.37–6.68)	$39.30 ($28.30–54.61)

Note: the aggregate WTP values for an improvement in environmental amenity are calculated by taking the estimates in Table 7 and multiplying them by the estimated population of 454,000 (source: https://www.abs.gov.au/articles/snapshot-act-2021). As such, these values should not be aggregated to find the total value across all three lakes. The annual cost for water quality improvement is calculated by taking the PV estimates presented in Table 19 and dividing it over 30 years.

6.3 Recommendations for decision-making and future research

Several recommendations have been identified for EPSDD and NCA to consider, both in the application of findings from this study and addressing knowledge gaps in the future.

[22] Marginal cost and benefit refer to the cost and benefit of each additional unit increase e.g., the marginal cost versus marginal benefit of each additional tonne of nitrogen load entering the urban lakes.

[23] For example, the direct biophysical relationship between the proxy abatement measures and actual water quality outcomes, and the avoided cost of ongoing lake management were not considered.

Application of findings in decision-making

Firstly, the estimation of economic values for ACT urban lakes is a significant contribution to the science of non-market values for constructed lakes but, more importantly, the understanding of outcomes in lake management. Lake managers can now consider these values in decision-making, such as in developing investment or business cases for management initiatives such as WSUD, upstream revegetation, and treatment options based on hard infrastructure, provided there has been or will be further analysis on the biophysical outcomes from interventions (e.g., the reduction in algal blooms, impact on closure rates, outcomes for amenity). The values can also be used more broadly in benefit transfer applications across other lakes and waterbodies in the ACT, provided appropriate adjustments are made to reflect individual waterbodies' attributes.

In addition, the links identified between urban lakes and wellbeing outcomes will also provide a basis for consideration of lake management initiatives under the ACT Wellbeing Framework, with a clear line of sight for WIAs. These findings also provide a basis for further wellbeing-focused studies in the future (as canvassed below).

Further research on total economic values of ACT urban lakes

The research undertaken in this project addressed a critical information gap in understanding the economic value from ACT's urban lakes by providing robust and interpretable values from the lakes to the ACT community. However, these estimates only account for a subset of the total economic value[24] of the lakes.

Firstly, EPSDD and the NCA could consider estimating the direct monetary values attributable to the lakes. These include revenues from events, tourism and lakeside businesses. Furthermore, the non-market values for users above monetary expenditure (known as consumer surplus) could be estimated using approaches like a travel cost method.[25] In fact, it was identified during survey design and analysis that a travel cost method could be attempted with the DCE survey data. This would allow estimation of non-market values for visitation to the lakes based on travel distances. Although the survey was not specifically designed for the travel cost method, variants of this approach (e.g., a zonal travel cost method) could be explored using postcodes or residing locations. This can provide EPSDD and NCA with values specific to lake users, which could then be compared against the broader economic values estimated through the DCE.

In the same vein, EPSDD and NCA could consider application of a hedonic pricing approach to determine the value of amenity from the urban lakes on property values in the ACT. This approach was considered as part of this study but not attempted due to data constraints—specifically, the difficulties in funding for data from commercial vendors or sourcing relevant data on property sales from the ACT Revenue Office. A key benefit from hedonic pricing would be the possibility of monetising these non-market values through duties on property sales, which could provide a direct line of sight to funding lake management.

Considerations for future DCE studies

The robust results estimated in this project allow for application of the values in the longer term, provided there are no material changes to ACT's urban lakes or population demographics or preferences for the lake attributes. This would also be generally consistent with best practice in publicly funded research. However, it should be noted that the approach undertaken for this project prioritised realistic attribute levels to negate hypothetical bias. This could have inadvertently resulted in a loss of information on participants' tradeoffs between levels. If DCEs are attempted in the future, consideration could be given to increasing the magnitude

[24] See Appendix A for a description of this concept.
[25] See Appendix A for a brief description of the approach and distinction between DCEs.

of difference between levels of attributes—including the payment mechanism or cost—to capture preferences across a wider range of outcomes. This would allow a greater distinction between, and analysis of, tradeoffs in lake attributes.

Further analysis of links between urban lakes and wellbeing

As noted in chapter 3, considering the value of access to urban lakes on wellbeing is a complex exercise. Where the community survey (in which economic values were prioritised) attempted to assess these links through specific questions, the results demonstrated minimal influence of lake access on individuals' wellbeing, which was consistent with the literature on drivers of wellbeing. If EPSDD and NCA consider value in exploring the relationship between the two—particularly where the ACT Wellbeing Framework is utilised in demonstrating the importance of urban lakes or for WIAs—a dedicated wellbeing study could be considered for future research. This could include exploring the relationship between lake access and wellbeing under relevant domains and indicators (as fleshed out in Table 11).

Further assessment of water quality management

Finally, the valuation of water quality management utilised an avoided cost approach. Another metric that could be considered is a cost-effectiveness analysis to compare water quality management through the lakes against other WSUD assets or upstream water quality options, similar to previous study (NCEconomics, 2019). This would require data on ongoing lake management costs and similar ongoing reductions to downstream nutrient loads of other assets/options. The information from such analysis would provide EPSDD and NCA a basis to assess the economic viability of upstream water quality management compared with the urban lakes, informing prioritisation of the multiple purposes of the lakes.

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Appendices

Appendix A

Description of economic values and valuation methods

Types of economic values

Like most disciplines, economics has several concepts of 'value' and different approaches to measure economic value. Therefore, it is very important to be transparent and consistent in the approaches used for the quantitative analysis. Relatively common approaches used include:

- total economic value (TEV)
- economic impact assessment
- environmental or natural capital accounting.

There are many common concepts and elements to each approach. In this report, a TEV approach is used to value benefits. This enables a broader scope of benefits to be included (benefits that have monetary and non-monetary values), the benefits attributable to the ACT's urban lakes to be isolated (avoiding overstating benefits), and results to be included directly into cost-benefit analysis and business cases for future initiatives proposed by the ACT Government.

TEV provides an all-encompassing measure of the economic value of any environmental asset. It distinguishes between value derived from use and from non-use. The components of TEV are shown in Figure 23.

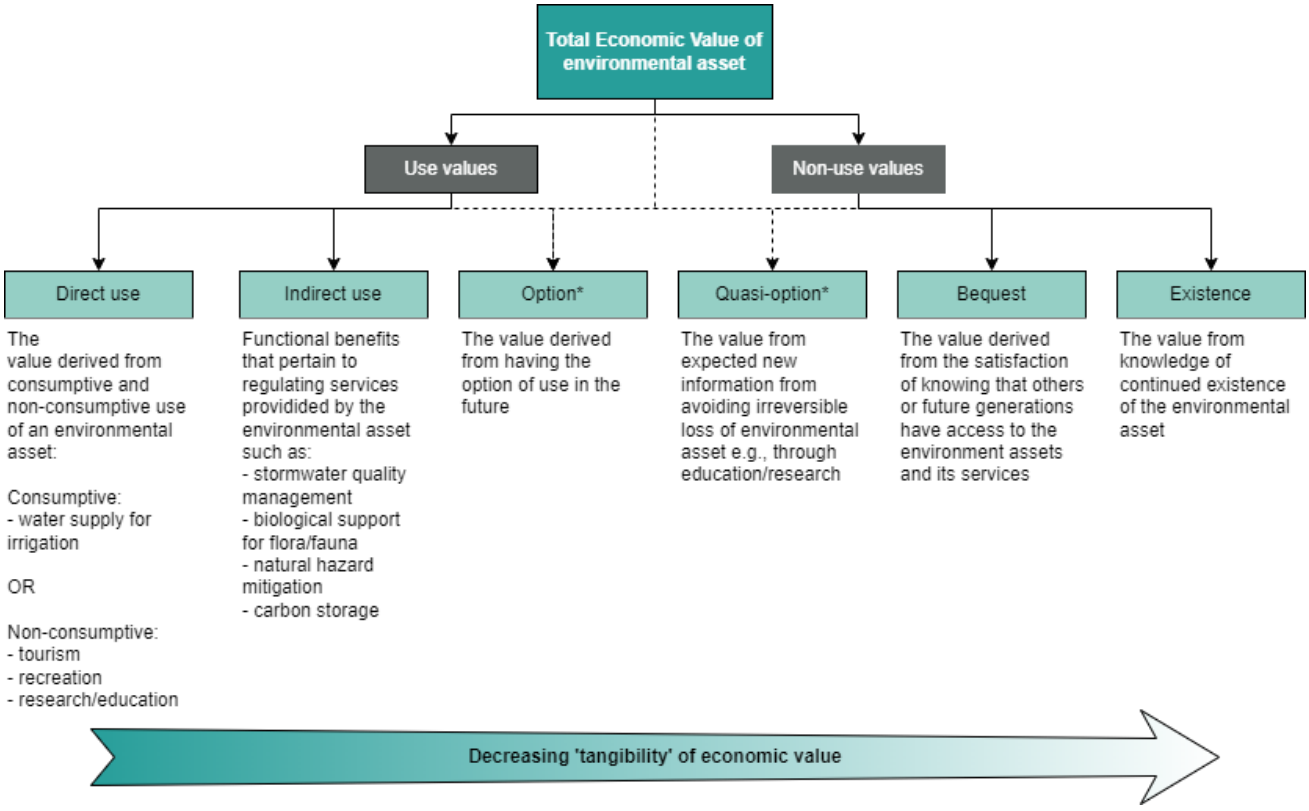


Figure 23. Components of total economic value

Adapted from: Tapsuwan, et al. (2009). *There is a lack of consensus in the literature on whether option and quasi-option values are use or non-use values (or neither).

Classifying the different types of value derived from an environmental asset can be useful for ensuring that the complete range of values is being captured in an analysis. It also assists with avoiding the double counting of benefits.

Economic valuation methods

The most commonly known approach to economic valuation is linked to expenditure on a good or service—market valuation based on corresponding prices. Such approaches provide a very basic representation of economic value and may provide a substantial proportion of economic value for an environmental asset. However, expenditure alone may not always provide a useful illustration of economic value given it only captures the direct use value. Furthermore, several economic values are not explicitly traded in markets rendering a dependence on expenditure-based approaches insufficient to provide an understanding of the total economic value from an ecosystem service.

Various approaches have been developed to quantify the total economic value of an environmental asset. Economic valuation approaches generally fall within two categories: revealed preference and stated preference methods. The former is based on observable behaviour in existing markets while the latter utilises consumer survey-based techniques to elicit values through hypothetical markets (Figure 24). Where there are constraints (time or resource) in understanding a dedicated revealed or stated preference study into an economic value, a benefit transfer approach could be applied. This approach involved transferring values from an existing study, in a comparable context, to a new study. Several matters need to be considered in order to perform benefit transfer robustly (Morrison, 2001).

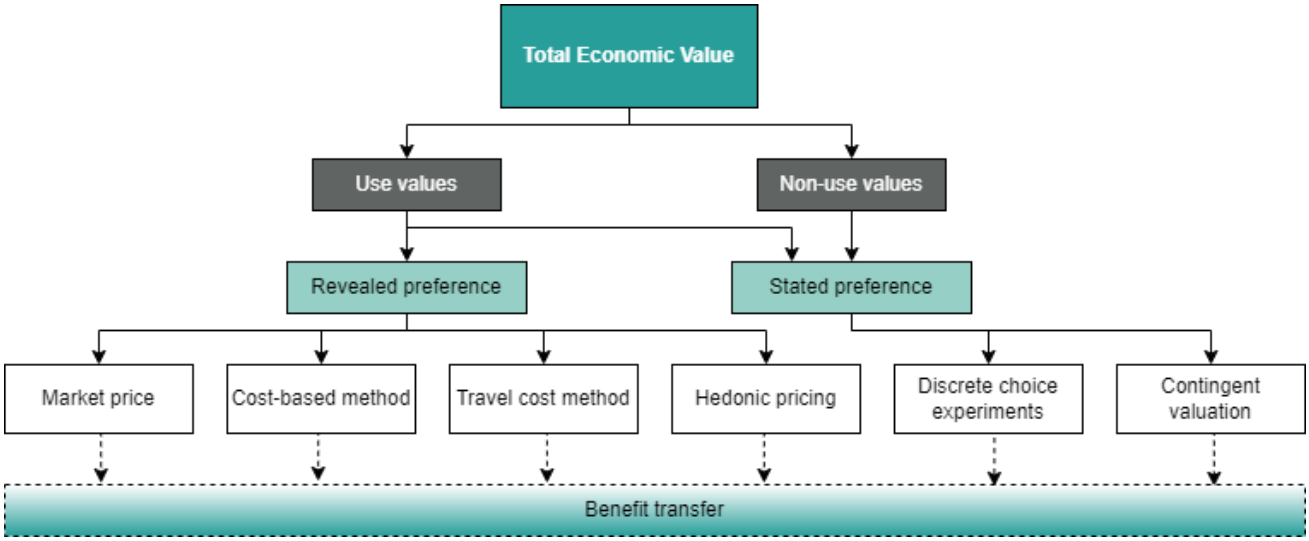


Figure 24. Economic valuation methods

Adapted from: Tapsuwan, Ranjan, MacFarlane & Elmahdi (2009). Only the market price approach is considered a market valuation approach. All other methods are considered non-market valuation techniques.

Table 21 provides a summary of the key economic valuation methods to estimate use and non-use values from ecosystem services. This includes the underlying basis, examples of uses and corresponding strengths and weaknesses of each approach. Each approach is limited in its scope and typically focused on one component of the total economic value for an ecosystem service and thus, using a single approach for each service would likely underestimate the total economic value. It is not uncommon for a variety of values and approaches to be utilised to provide a complete understanding of the total economic value for ecosystem services. These values can be aggregated as the total economic value from an ecosystem service or asset, although consideration should be given to avoid overestimation through double counting.

Table 21. Summary of economic valuation approaches

Method	Based on…	Examples	Strengths	Weaknesses
Revealed preference methods—using observed behaviour in existing markets				
Market price[26]	Market transactions	Market value of access	• Well-defined representation of direct use value • Methodologies are easy to implement and data relatively easy to obtain	• Market data is available for limited set of goods and services • Impacted by seasonality and other price factors • Difficult to measure the value of larger scale changes that are likely to affect supply or demand
Cost-based methods (e.g., avoided costs)	Market value as a proxy	Value of urban heat management through avoided cooling costs Value of flood protection through avoided replacement costs from damage	• Adequate representation of physical protection values • Consistent with some industry approaches (e.g., insurance) • Moderately data/resource-intensive	• May not represent actual benefit from protection • Does not capture for social values of service that may be above costs
Travel cost method	Non-market values from analysis of cost/expenditure for visiting a site or participating in an activity	Value of recreational activities like recreational fishing, swimming, or general visitation	• Based on actual behaviour and thus, defined value of service • Approach is established and generally well-understood	• Added costs from data collection and user participation • Only captures value for a point in time, not accounting for temporal or condition changes • Method requires specific expertise • Debate on assumptions used in methodology • May not reflect true value for all visitors (e.g., value may be underestimated if travel expenditure is low)
Hedonic pricing method	Non-market values from analysis of market prices for differentiated goods,	Amenity values based on residential prices	• Based on actual behaviour and thus, defined value of service	• Scope for services is limited to related market goods

[26] Direct expenditure on ecosystem services also has indirect and flow-on benefits for the local and wider economies. However, the approaches to estimate these flow-on values (e.g., using multipliers in input-output modelling) can be overly simplistic and not provide an accurate reflection of the total economic value from expenditure. For example, these approaches can overestimate the effects from direct expenditure and not consider constraints or substitution effects. Given these limitations, these values are discussed but not reported in this review.

Method	Based on...	Examples	Strengths	Weaknesses
	based on characteristics of corresponding services		• Some market values (e.g., property values) are efficient in responding to information on value of services • The method is versatile and can be adapted to consider several possible interactions between market goods and environmental quality • Data is typically reliable and relatively easy to obtain	• Only captures value for perceived benefits and not actual benefits/consequences • Assumes services drive value rather than income • Method requires specific expertise • Resource intensive and costly
Stated Preference Methods—using survey-based methods in hypothetical markets				
Discrete choice experiments	Consumer values for changes to attributes of an environmental asset	Value of amenity provided by environmental asset (use and non-use)	• Can be used to estimate use and non-use values • Considers individual socio-demographics and preference factors in values • Allow estimation of hypothetical or ex-ante changes	• Survey-design and analysis is resource intensive, costly and requires specific expertise • High risk of biases including hypothetical bias • Estimation of non-use values may not be robust
Contingent valuation	Consumer values for changes to an environmental asset	Value of changes to biodiversity within a natural asset		
Other techniques				
Benefit transfer	Corresponding values estimated in similar locations using other techniques	Transfer of use values for a natural asset or non-market values for changes to attributes of natural asset	• Less resource intensive and costly • Requires less expertise to implement • Can provide a basis to suggest primary study	• May not provide accurate reflection of values, given original studies tend to be policy, user or site-specific • Reference study may be difficult to find • Relevant studies for the policy or issue in question may not be available

Appendix B

Survey of ACT community

This section provides a text version of the community survey used to collect primary data. There were slight differences between the layout and visual experience for participants due to minor edits being made for programming.

The importance of urban lakes in Canberra

This survey is investigating how you value certain urban lakes in Canberra. It has been commissioned by Natural Capital Economics on behalf of the Environment, Planning and Sustainable Development Directorate, ACT Government.

Introduction

The ACT urban lakes provide a range of uses and benefits to the ACT community. This includes providing:

- a place to participate in various water-based activities
- access to various facilities (e.g., walking and cycling paths, BBQ and picnic areas, and playgrounds)
- a natural environment within an urban setting that provides visual aesthetics and a habitat for flora and fauna.

Over time, your ability to use and benefit from the lakes may be impacted due to various stressors from the environment and increasing population and visitors.

The ACT Government currently invests in ongoing monitoring and management activities to maintain the urban lakes to continue delivering benefits to the community. This includes programs to monitor ecological indicators and manage current and future impacts. Examples of the Government's activities include in water sensitive urban design, undertaking blue-green algae and bacteria treatment, and ongoing cleaning and maintenance of the lakes, natural surroundings, and facilities.

The ACT Government wants to understand the values that ACT residents have for these urban lakes. This information will help the Government improve its investment in management of the lakes based on providing the greatest overall benefit for the community.

You are invited to participate in this survey as a resident of the ACT who can provide insight into the value derived from these lakes.

Your participation in this study will involve completing a survey questionnaire anonymously, which consists of 26 questions that will take approximately 20 minutes. The questionnaire is structured to ask the following questions:

- Section 1: your current wellbeing
- Section 2: your visitation of lakes and activities undertaken
- Section 3: a hypothetical experiment consisting of a series of eight(8) scenarios to make choices
- Section 4: your socio-demography including income, education, and household makeup.

If you are unable to complete the survey, you can stop at any point and save your answers as long as you complete it within the same day. If you do not complete the survey in the same day, the information you provided up to the point you stopped are not able to be recorded or used for the study.

Some questions in the survey relate to your sense of wellbeing. If these questions cause you distress please select 'prefer not to say'. If you are feeling distressed or need assistance, you can contact the following services for assistance 24 hours a day:

Beyond Blue - 1300 224 636 or Lifeline - 13 11 14

Your participation in the survey is completely voluntary. You do not have to answer all questions in the survey, although your complete responses will be beneficial to the study. Your decision to participate will not affect any current or future relationship you may have with the ACT Government. If you do not wish to participate, you can withdraw at any time. However, as this survey is anonymous, it will not be possible to withdraw once the survey has been submitted.

All comments and responses are anonymous and will be treated confidentially. Your name is not required and you will not be identifiable based on the information you provide.

Submitting the completed online questionnaire is accepted as indication of your consent to participate in this study.

If you have any questions or require further information please contact one of the following researchers:

Sophie Rolls

Natural Capital Economics

Sophie.rolls@nceconomics.com

Danswell Starrs

ACT Environment, Planning and Sustainable Development Directorate

danswell.starrs@act.gov.au

Screening questions - socio-demographic

1. Where in the ACT region do you live?

Belconnen	Inner South, Inner North & City	Gungahlin	Tuggeranong	Woden, Weston Creek & Molonglo	I do not live in Canberra

2. How old are you?

18 years and under	19-24	25-34	35-44	45-54	55-64	65-74	75 and over

3. What gender do you identify as?

Male	Female	Non-binary	I use another term	Prefer not to say

Wellbeing

This section will ask a few questions about your life and mental health, to help us understand the different factors that influence your overall well-being. If these questions would cause you distress please tick 'prefer not to say'.

4. Thinking about your own life and personal circumstances, how satisfied are you with the following at the moment?

	Completely dissatisfied					Neither/nor					Completely satisfied	Prefer not to say
	0	1	2	3	4	5	6	7	8	9	10	
Your life as a whole												
Your standard of living												
Your health												
What you are currently achieving in life												
Your personal relationships												
How safe you feel												
Your future security												

5. In the last four weeks, how often have you felt…

	None of the time	A little of the time	Some of the time	Most of the time	All of the time	Prefer not to say
Nervous?						
Hopeless?						
Restless or fidgety?						
So sad that nothing could cheer you up?						
That everything was an effort?						
Worthless?						

Lake visitation, usage and perceptions

This section will ask a few questions about your visits and experience at the lakes.

6. During the last 12 months, how often on average have you visited the following lakes during your leisure time (select one per lake):

	Never	Less than once per month	Once a month or more, but less than once a week	Once a week or more, but less than daily	Daily or more
Lake Burley Griffin					
Lake Ginninderra					
Lake Tuggeranong					
Any other lakes, rivers, ponds or waterbodies in the ACT					

7. In the last four weeks, how often have you visited the following lakes during your leisure time (select one per lake) [only if did not respond 'never' to previous question]

	Not at all	1-2 times	About 3-4 times	About 5 – 8 times (more than once or twice a week)	About 9 – 14 times (3-4 times a week)
Lake Burley Griffin					
Lake Ginninderra					
Lake Tuggeranong					
Any other lakes, rivers, ponds or waterbodies in the ACT					

8. Thinking about your visits to the lakes in the past year, which of the following statements is correct?

- I would normally visit the lakes much more than what I have in the past four weeks
- I would normally visit the lakes much less than what I have in the past four weeks
- I would normally visit the lakes about as often throughout the year

9. On average how long was each visit within the last 4 weeks?

Less than 15 min	At least 15 min but less than half an hour	At least half an hour but less than an hour	1 -2 hours	More than 2 hours

10. What was the primary activity undertaken during these visits?

- Walking
- Picnics/barbeques
- Bike riding
- Photography
- Jogging or running
- Swimming
- Fishing
- Using playgrounds
- Birdwatching
- Boating
- Observing/catching seaplanes
- Other (please specify)

11. Did you normally do this activity with other people or by yourself?

- With others
- By myself

12. How would you rate the quality of the water at the lakes?

	Very poor	Poor	Neither poor nor good	Good	Very good	Don't know
	1	2	3	4	5	6
Lake Burley Griffin						
Lake Ginninderra						
Lake Tuggeranong						

Choice experiment – random allocation to one of the three lakes

Context setting

In the next section of the survey, we want to understand what characteristics or attributes of Lake X you value more using a hypothetical experiment. Even if you have not visited the lake before, we're still interested in understanding if and how much you value Lake X.

Consider a scenario where the ACT/Commonwealth government are deciding either to:

- Option A and B: undertake alternative management strategies for Lake X that will be funded through a separate levy or
- Options C: continue its existing management strategy for Lake X.

The management strategies for each Option will result in the following impacts to you over the next 5 years based on the options:

Environmental amenity

Lake X is impacted by blue-green algal blooms that result in:

- foul odours caused by the death and breakdown of algae
- unpleasant views of the lake and surrounding rocks and wildlife covered with the algal scum.

The Government may change its approach to monitoring and maintenance of the algal blooms of the lake, resulting in changes to the likely impacts to smell and visual amenity.

For this each option, there will be one of the following changes to environmental amenity/condition in the next 5 years:

Level of environmental amenity	Description
Worse compared to the current state 	The lake surface is **almost always covered for extended periods (months)** with major blooms of blue-green algae.  Lake visits have a **very high likelihood** of being plagued with bad smells.
No change from the current state 	The lake surface is **regularly covered for weeks with multiple streaks and blooms** of blue-green algae.  **High likelihood** of experiencing a bad smell during visit
Better compared to the current state 	**Infrequent and short duration of streaks** of blue-green algae on an otherwise clear lake surface 

	Low likelihood of experiencing a bad smell during visit
Much better compared to current state 	**No or almost no** visible algae on a clear lake surface  **Very low likelihood** of experiencing a bad smell during visit

Lake closures for primary recreation

The Government may change its approach to monitoring and maintenance of water quality, which would result in corresponding increases or decreases in dangerous algae and bacteria levels that trigger closures of Lake X for primary recreation. This would mean swimming and other direct contact recreation would not be allowed.

For each option, there will be one of the following changes to recreational access to water in the next 5 years:

Lake cosures for primary recreation	Description
More annual closures 	Lake Burley Griffin - 13 Lake Ginninderra - 20 Lake Tuggeranong - 21 weeks per year that at least one site in the lake is closed
No change to current annual closure rate 	Lake Burley Griffin - 11 Lake Ginninderra - 17 Lake Tuggeranong - 18 weeks per year that at least one site in the lake is closed
Slightly less annual closures 	Lake Burley Griffin - 9 Lake Ginninderra - 14 Lake Tuggeranong - 15 weeks per year that at least one site in the lake is closed
Much less annual closures 	Lake Burley Griffin - 7 Lake Ginninderra - 10 Lake Tuggeranong - 11 weeks per year that at least one site in the lake is closed

Lakeside facilities

The Government may change the cleaning, maintenance, and replacement programs of lakeside facilities, specifically public toilets, picnic and BBQ areas and playgrounds.

For each option, there will be one of the following changes to lakeside facilities in the next 5 years:

Level of lakeside facilities	Description
Degredation 	A decrease in investment on cleaning, maintenance and replacement of facilities, resulting in a general decline in quality for visitors.
Maintenance 	There will not be any change to current cleaning, maintenance and replacement, resulting in facilities being in existing quality and availability for visitors.
Improvement 	The Government will invest to improve the quality and availability of facilities e.g., cleaning more often, more timely maintenance and replacement of facilities such that visitors do not experience downtime.

Additional management cost

The Government currently funds its management activities through a portion of payment from rates/tax. Any new management strategy will incur an additional cost on top of current rates/taxes.

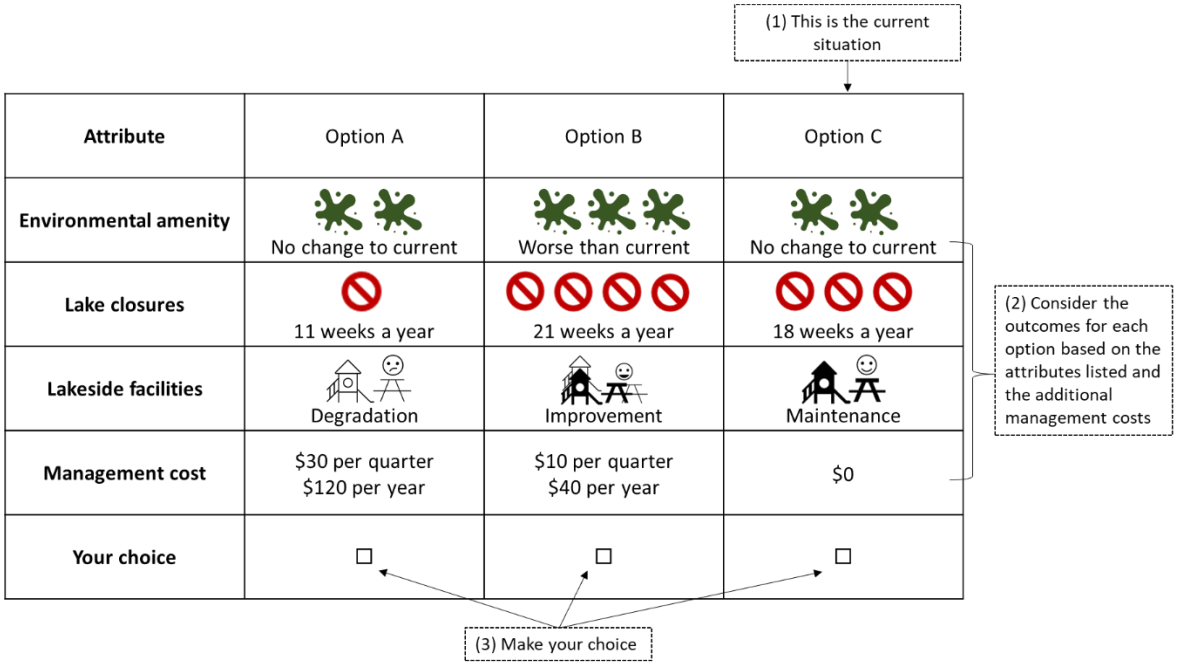
For each option, the cost to you for the next 5 years will be one of the following:

Management cost	Description
No change from current	$0 per year/quarter
$40 more per year	$10 per quarter
$80 more per year	$20 per quarter
$120 more per year	$30 per quarter

Residents who rent in the ACT will see the cost passed on directly through their rental payments.

Assume that all the money will only be used for management of Lake X and not be used for other activities and investments.

You will be presented eight(8) scenarios with outcomes based on different management activities undertaken at the lake and different rate payment amounts. Choose the option you would most support based only on the outcomes and levy amounts presented. An example of a choice scenario is shown below.



When choosing, please keep in mind that we would like to understand your honest choices and your choices should also reflect your personal situation and constraints, such as the impact any cost may have on your household budget.

13. Choice tasks (8 choice tasks per respondent, randomly but equally allocate to 1 of 3 blocks)

Attribute	Option A	Option B	Option C
Environmental amenity	No change to current	Worse than current	No change to current
Lake closures	11 weeks a year	21 weeks a year	18 weeks a year
Lakeside facilities	Degradation	Improvement	Maintenance
Management cost	$30 per quarter $120 per year	$10 per quarter $40 per year	$0
Your choice	☐	☐	☐

Debriefing questions

14. If you selected Option C (the situation in 5 years time with no management change) for all 8 management scenarios, please provide your reason why:

- I preferred this option to all others
- I could not afford the other options

- I believe funding to manage the lakes should come from somewhere other than my own pocket
- I believe funding to manage the lakes should be collected by some other means than a levy applied to rates
- I don't think the lakes need further investment to manage water quality
- I don't trust that the funds would be used to manage the lakes
- I don't believe there will be impacts during this time period
- I don't believe I should have to make these choices
- Other (please specify)

15. How important was each of the attributes when making your choice?

I ignored this attribute completely=1

Unimportant=2

Neither/nor=3

Important=4

Very important=5

- Environmental amenity
- Lake closures
- Lakeside facilities
- Additional management costs

16. How likely do you think it is that the results of this study will be used by decision makers to inform future investment decisions about the management of the lakes?

Very unlikely=1

Unlikely=2

Neither/nor=3

Likely=4

Very likely=5

Other socio-demographic characteristics

This final section will ask for information on you. As for all your answers, the information you provide here is strictly confidential.

17. What is the total of all income your household usually receives?

Do not include flatmates or people who you do not share finances with.

Do not deduct: tax, superannuation contributions, amounts salary sacrificed, or any other automatic deductions.

Include: wages and salaries, government pensions, benefits and allowances, profit and loss from business/rental properties, and other income.

- Negative income

- Nil income
- $1 - $149 per week ($1 - $7,799 per year)
- $150 - $299 ($7800 - $15,599)
- $300 - $399 ($15,600 - $20,799)
- $400 - $499 ($20,800 - $25,999)
- $500 - $649 ($26,000 - $33,799)
- $650 - $799 ($33,800 - $41,599)
- $800 – $999 ($41,600 - $51,999)
- $1000 - $1,249 ($52,000 - $64,999)
- $1,250 - $1,499 ($65,000 - $77,999)
- $1,500 - $1,749 ($78,000 - $90,999)
- $1,750 - $1,999 ($91,000 - $103,999)
- $2,000 - $2,499 ($$104,000 - $129,999)
- $2,500 - $2,999 ($130,000 - $155,999)
- $3,000 - $3,499 ($156,000 - $181,999)
- $3,500 - $3,999 ($182,000 - $207,999)
- $4,000 - $4,499 ($208,000 - $233,999)
- $4,500 - $4,999 ($234,000 – $259,999)
- $5,000 - $5,999 ($260,000 - $311,999)
- $6,000 - $7,999 ($312,000 - $415,999)
- $8,000 or more ($416,000 or more)
- Prefer not to answer

As for all your answers, the information you provide here is strictly confidential.

18. Are you of Aboriginal or Torres Strait Islander origin?

- No
- Yes, Aboriginal
- Yes, Torres Strait Islander
- Yes, both Aboriginal and Torres Strait Islander
- Prefer not to say

19. Which best describes you at the moment? Select one

- Never married
- Married or de facto
- Divorced or separated
- Widowed

20. Which best describes your household? Select one

- Sole person household
- Couple only household
- Single parent with children household
- Couple parent with children household
- Share or group household
- Other (please specify)

21. Which of the following describes your situation right now? Select all that apply

- Business owner/ co-owner
- Self-employed
- Work for an employer
- I have full-time work
- I have part-time paid work
- I have casual paid work
- Unemployed and looking for work
- Unemployed and not looking for work (e.g., unable to work)
- Care for dependent child/children
- Care for person/people with disability, physical or mental illness or frailty, drug or alcohol dependency, or other chronic condition
- Retired
- Studying part-time or full-time
- Other (please describe)

22. What is your highest completed educational qualification?

- Below high school certificate (year 12)
- High school certificate (year 12)
- Diploma/TAFE
- Undergraduate degree
- Post-graduate diploma
- Post-graduate degree (Masters, MBA, PhD)
- Other: please specify

23. Were you born in Australia (Y/N). If yes, what state or Territory?

24. What is your postcode?

Enter or don't know

Political stance

25. How well do you agree with the following statement:

I trust the ACT Government to do what is right.

1 = strongly disagree,

2= disagree,

3 = Neither/nor,

4 = Agree,

5 = strongly agree

6 = don't know)

26. What would you consider as your political stance between very conservative and not conservative at all?

Not conservative at all=1

Slightly conservative=2

Generally conservative=3

Mostly conservative=4

Very conservative=5

Don't know/prefer not to answer=6

Completion page

Thankyou for completing the survey!

If you have any feedback or comments please provide in the box below

Appendix C

Distribution of responses to community survey questions

This section provides distribution of responses for questions not described in section 2.4.

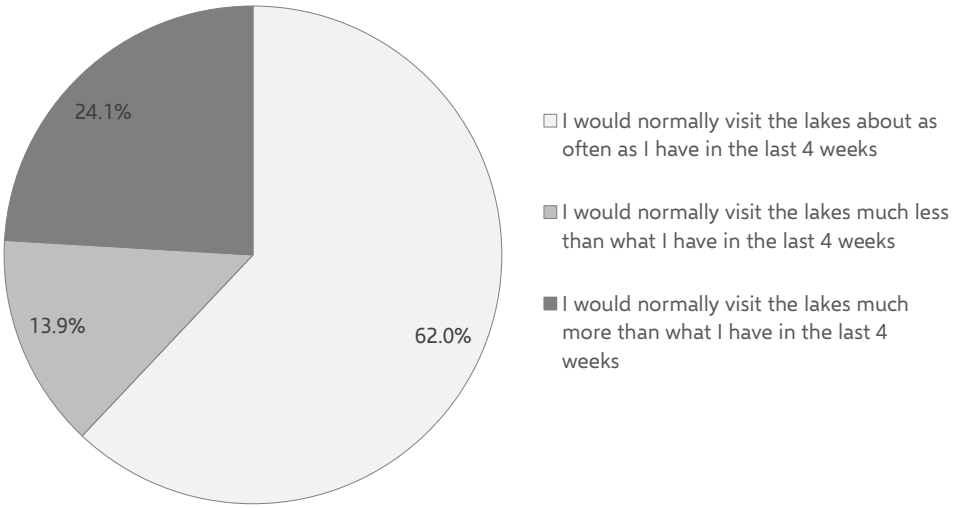


Figure 25. Results of 'Q8. Thinking about your visits to the lakes in the last 4 weeks, which of the following statements is correct?' (n=511)

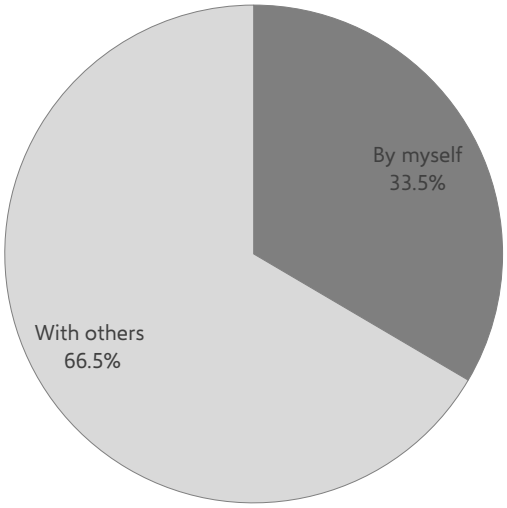


Figure 26. Results of 'Q11. Do you normally do these activities with other people or by yourself?' (n=511)

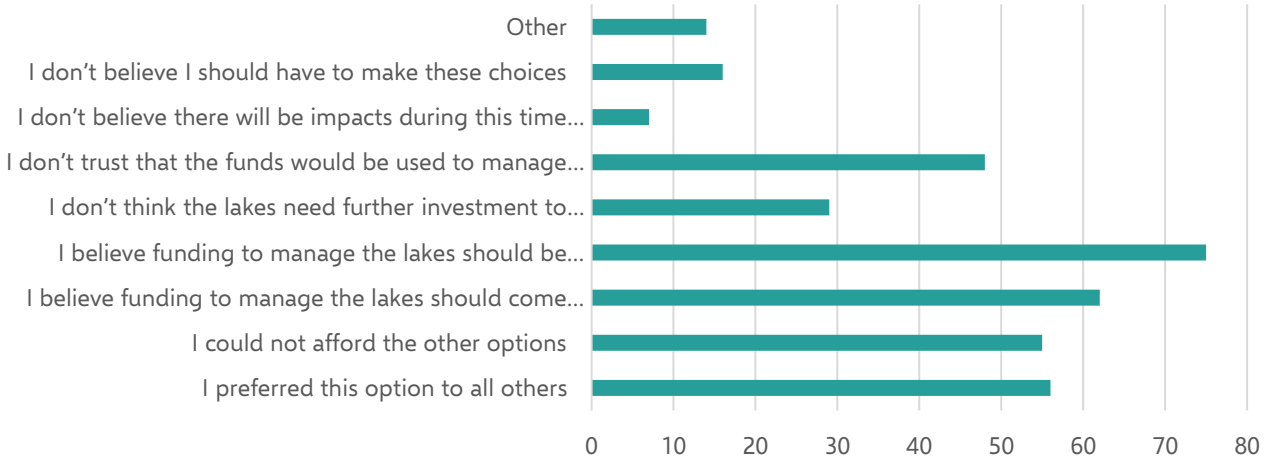


Figure 27. Results of 'Q14 - You selected Option C (the situation in 5 years time with no management change) for all 8 management scenarios, please provide your reason/s why:' (n=166)

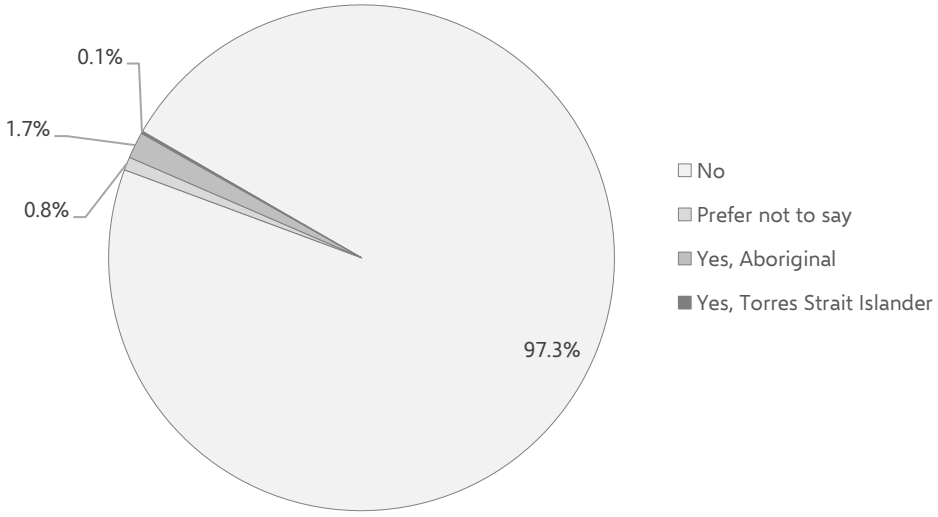


Figure 28. Results of 'Q18. Are you of Aboriginal or Torres Strait Islander origin'

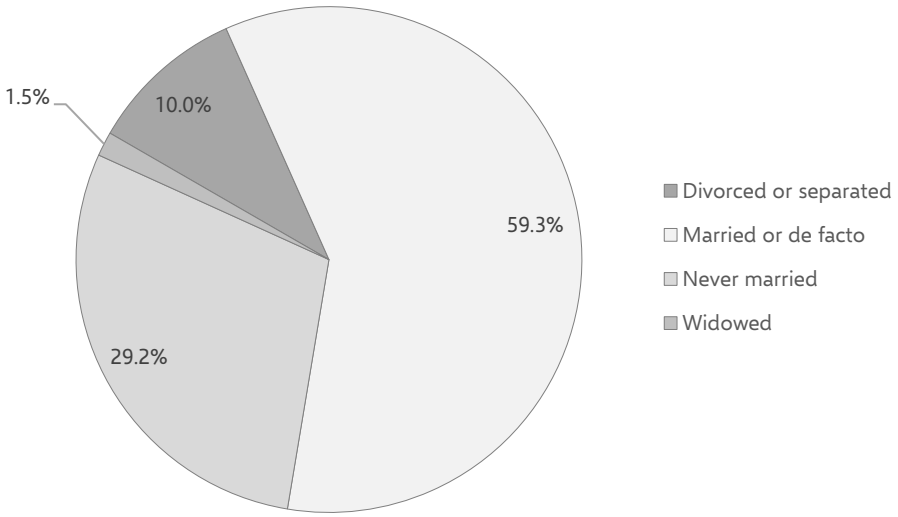


Figure 29. Results of 'Q19. Which best describes you at the moment? Select one'

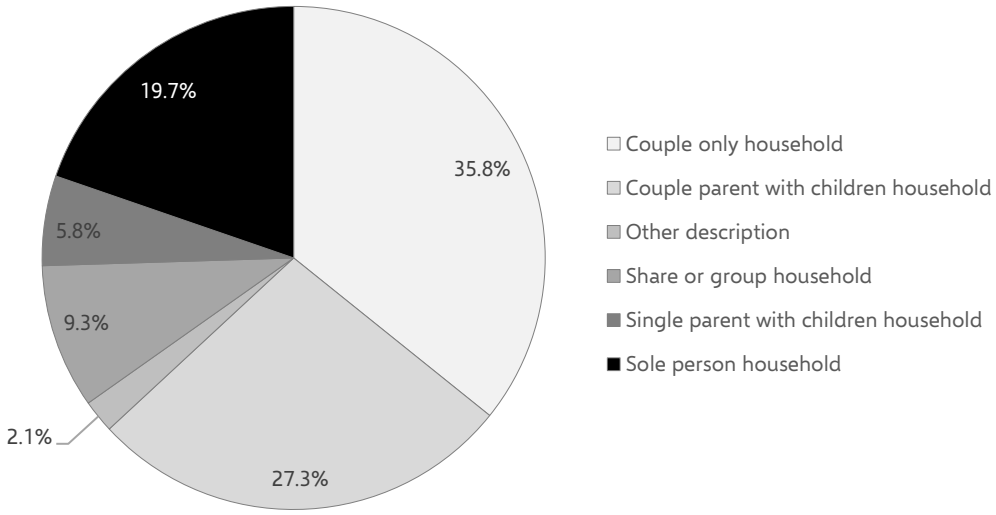


Figure 30. Results of 'Q20. Which best describes your household? Select one'

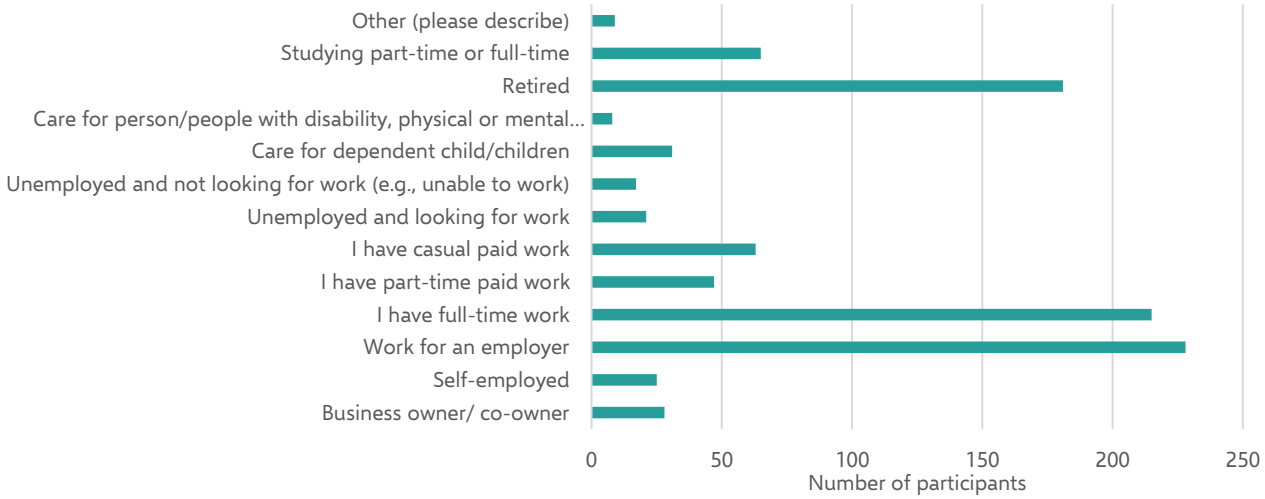


Figure 31. Results of 'Q21. Which of the following describes your situation right now? Select all that apply'

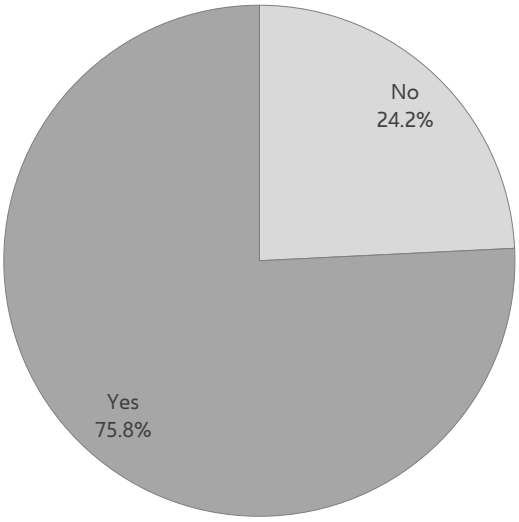


Figure 32. Results of 'Q23A. Were you born in Australia (Y/N).'

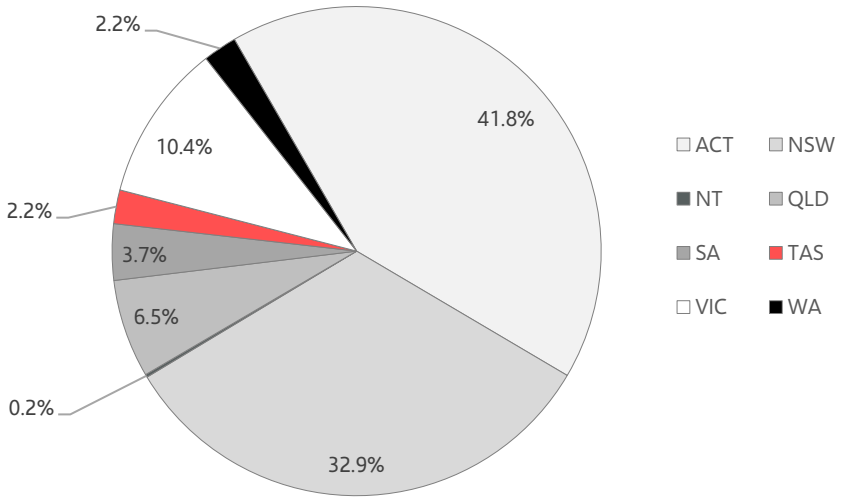


Figure 33. Results of 'Q23B. If yes, what State or Territory'

Appendix D

Further econometric specifications and models

This section provides modelling outputs from undertaking more complex modelling of the DCE data. Further analysis would be required to understand the validity of these results and interpret the additional complexity.

Nested Logit

```
Estimates:
                  Estimate        s.e.   t.rat.(0)  p(2-sided)    Rob.s.e. Rob.t.rat.(0)
asc_NoChange      0.000000          NA          NA          NA          NA          NA
asc_Option       -0.850942    0.140316      -6.064    1.324e-09    0.221045     -3.8496
b_EnvWorse       34.693315    5.341140       6.495    8.276e-11    6.031114      5.7524
b_EnvSame         0.000000          NA          NA          NA          NA          NA
b_EnvBetter     -41.992017    5.013427      -8.376    0.000000    5.904427     -7.1120
b_EnvMuchBetter -54.328424    6.112947      -8.887    0.000000    7.232869     -7.5113
b_Closure         0.514936    0.067582       7.619    2.554e-14    0.079441      6.4820
b_ClosureShift   -0.455376    0.082951      -5.490    4.026e-08    0.095612     -4.7628
b_FacSame         0.000000          NA          NA          NA          NA          NA
b_FacWorse       44.329272    5.210836       8.507    0.000000    5.753495      7.7048
b_FacBetter      -8.146026    2.333767      -3.491   4.8211e-04    2.324473     -3.5045
b_Age             0.008513    0.002268       3.754   1.7397e-04    0.004220      2.0173
b_EduUGrad        0.268756    0.058009       4.633    3.604e-06    0.118254      2.2727
b_LakeUser       -0.111620    0.070677      -1.579     0.114267    0.140109     -0.7967
b_LakeWQ         -0.211793    0.072015      -2.941     0.003272    0.147489     -1.4360
b_Retired        -0.339687    0.090725      -3.744   1.8101e-04    0.187623     -1.8105
b_TrustGov       -0.263977    0.062435      -4.228    2.357e-05    0.122463     -2.1556
b_InfoUse        -0.252277    0.062327      -4.048    5.174e-05    0.120364     -2.0960
b_Cost           -0.026425    0.003100      -8.523     0.000000    0.003754     -7.0390
lambda_A_B        1.288525    0.079444      16.219     0.000000    0.081852      15.7421

Nesting structure for model component :
Nest: root (1)
|----Alternative: No Change
'-Nest: A_B (1.2885)
   |-Alternative: OPTION A
   '-Alternative: OPTION B

WARNING: The nesting parameter for nest "A_B" should be between 0 and 1 (the
  nesting parameter for nest "root"), yet its value is 1.2885.
```

Mixed Multinomial Logit

Estimates:

	Estimate	s.e.	t.rat.(0)	p(2-sided)	Rob.s.e.	Rob.t.rat.(0)
asc_NoChange	0.000000	NA	NA	NA	NA	NA
asc_Option	-1.945638	0.235212	-8.2719	2.220e-16	0.394989	-4.9258
b_EnvWorse_mu	-454.980509	370.056459	-1.2295	0.218888	426.679018	-1.0663
b_EnvWorse_sig	992.628295	792.334756	1.2528	0.210282	902.046661	1.1004
b_EnvSame	0.000000	NA	NA	NA	NA	NA
b_EnvBetter_mu	866.483581	681.280771	1.2718	0.203428	733.807491	1.1808
b_EnvBetter_sig	317.833911	249.049624	1.2762	0.201889	253.153234	1.2555
b_EnvMuchBetter_mu	1056.068323	830.943666	1.2709	0.203755	885.316244	1.1929
b_EnvMuchBetter_sig	236.388690	201.936046	1.1706	0.241755	253.252583	0.9334
b_Closure_mu	-5.994411	4.763480	-1.2584	0.208244	5.213331	-1.1498
b_Closure_sig	-8.595164	6.744222	-1.2744	0.202504	7.295861	-1.1781
b_FacSame	0.000000	NA	NA	NA	NA	NA
b_FacWorse_mu	-580.932389	455.668554	-1.2749	0.202344	500.143012	-1.1615
b_FacWorse_sig	758.095468	595.767005	1.2725	0.203206	644.040120	1.1771
b_FacBetter_mu	291.548255	234.845155	1.2414	0.214440	244.339894	1.1932
b_FacBetter_sig	-320.461029	257.388900	-1.2450	0.213115	281.417324	-1.1387
b_Age	0.015182	0.004821	3.1491	0.001638	0.007964	1.9062
b_EduUGrad	0.456314	0.116228	3.9260	8.637e-05	0.197411	2.3115
b_LakeUser	-0.101050	0.139347	-0.7252	0.468349	0.229755	-0.4398
b_LakeWQ	-0.671747	0.138632	-4.8455	1.263e-06	0.252765	-2.6576
b_Retired	-0.525585	0.188157	-2.7933	0.005217	0.310834	-1.6909
b_TrustGov	-0.365872	0.127878	-2.8611	0.004222	0.210918	-1.7347
b_InfoUse	-0.312980	0.125544	-2.4930	0.012667	0.198849	-1.5740
b_Cost_a	0.002178	0.001690	1.2890	0.197401	0.001820	1.1970
b_Cost_b	-0.001551	0.001212	-1.2794	0.200757	0.001331	-1.1646

Latent Class

Estimates:

	Estimate	s.e.	t.rat.(0)	p(2-sided)	Rob.s.e.	Rob.t.rat.(0)
asc_NoChange	0.00000	NA	NA	NA	NA	NA
asc_Option	0.75087	0.053896	13.9320	0.000000	0.062173	12.0772
b_EnvWorse	78.55437	10.713756	7.3321	2.265e-13	14.314642	5.4877
b_EnvSame	0.00000	NA	NA	NA	NA	NA
b_EnvBetter	-6.36582	0.587844	-10.8291	0.000000	0.905357	-7.0313
b_EnvMuchBetter	-6.62823	0.568684	-11.6554	0.000000	0.829389	-7.9917
b_Closure_a	0.02704	0.009654	2.8014	0.005088	0.009235	2.9284
b_Closure_b	0.44499	0.068433	6.5026	7.897e-11	0.085899	5.1804
b_FacSame	0.00000	NA	NA	NA	NA	NA
b_FacWorse	53.85716	7.051236	7.6380	2.198e-14	9.317727	5.7801
b_FacBetter	0.53091	0.492336	1.0784	0.280873	0.439600	1.2077
b_Cost_a	-0.53373	0.077605	-6.8776	6.088e-12	0.147931	-3.6080
b_Cost_b	-0.01941	0.002457	-7.8984	2.887e-15	0.003430	-5.6584
delta_a	-0.77902	0.366563	-2.1252	0.033570	0.361138	-2.1571
gamma_Age_a	0.01131	0.004865	2.3255	0.020048	0.004697	2.4087
gamma_Age_b	0.00000	NA	NA	NA	NA	NA
gamma_LakeWQ_a	-0.16563	0.221719	-0.7470	0.455052	0.224711	-0.7371
gamma_LakeWQ_b	0.00000	NA	NA	NA	NA	NA
gamma_LakeUser_a	-0.32219	0.219894	-1.4652	0.142864	0.221024	-1.4577
gamma_LakeUser_b	0.00000	NA	NA	NA	NA	NA
gamma_EduUgrad_a	0.24381	0.174420	1.3978	0.162171	0.176956	1.3778
gamma_EduUgrad_b	0.00000	NA	NA	NA	NA	NA
gamma_TrustGov_a	-0.32974	0.190609	-1.7299	0.083639	0.193566	-1.7035
gamma_TrustGov_b	0.00000	NA	NA	NA	NA	NA
gamma_InfoUse_a	-0.13748	0.084313	-1.6306	0.102974	0.088538	-1.5528
gamma_InfoUse_b	0.00000	NA	NA	NA	NA	NA

Summary of class allocation for model component :

	Mean prob.
Class_1	0.3202
Class_2	0.6798

Appendix E

Case study surveys

This section provides a text version of the surveys used in the two case studies. The questions were slightly different between the two lakes, to reflect comments from the two agencies, EPSDD and NCA, managing the individual lakes. There were also slight differences between the layout and visual experience for participants due to minor edits being made for programming.

Lake Burley Griffin case study survey

This survey is investigating what you think about Lake Burley Griffin. It is being undertaken by Natural Capital Economics on behalf of the Environment, Planning and Sustainable Development Directorate, ACT Government and the NCA. The survey is to help the ACT Government and NCA understand the significance of certain ACT Lakes and waterways to different users.

You are invited to participate in this survey as a user of Lake Burley Griffin. You must be over 18 to participate.

Your participation in this study is voluntary and involves completing a survey that will take approximately 5-10 minutes.

All comments and responses are anonymous and will be treated confidentially. Your name is not required, and you will not be identifiable based on the information you provide.

Submitting the completed survey is accepted as indication of your consent to participate in this study and confirmation that you are over 18 years old.

You may like to submit photos in your responses to some of the questions, however, please note we may include your images in published project reports and other outputs. Due to the anonymous nature of this survey, these will not be credited to you. Photos with identifiable people in them will not be included.

If you have any questions or require further information, please contact one of the following researchers:

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Questions:

1. What is your gender?
2. What is your age (in years)?
3. How many years have you been visiting/using the lake?
4. How often do you visit/use the lake?
5. What activities do you do there?

6. Where is your favourite place on/around the lake?
7. Please tell us of a memory you have about this place
8. Have you experienced changes (positive and/or negative) in the lake and its surrounds (including water quality and environment)? Can you provide any detail?

   If you wish to include or take a photo of change
9. To what extent is your lake visits/use/activity impacted by lake closures or algal blooms on the lake?
10. Do you have any suggestions that are likely to improve your experience of using the lake?
11. Thinking about the Lake, can you please indicate how much you agree or disagree with the following statements (strongly agree to strongly disagree):

    - Lake Burley Griffin provides value to me that I can't obtain elsewhere
    - I get more satisfaction out of visiting Lake Burley Griffin than any other recreation place
    - I identify with the physical landscape of Lake Burley Griffin
    - Lake Burley Griffin means a lot to me
    - I have no particular love for Lake Burley Griffin compared to other areas
    - I am very attached to Lake Burley Griffin
    - I feel happiest when I am at Lake Burley Griffin
12. Any other comments or feedback?

Lake Tuggeranong case study survey

This survey is investigating what you think about Lake Burley Griffin/Lake Tuggeranong. It is being undertaken by Natural Capital Economics on behalf of the Environment, Planning and Sustainable Development Directorate, ACT Government.

You are invited to participate in this survey as a user of Lake Burley Griffin/Lake Tuggeranong. You must be over 18 to participate. Your participation in this study is voluntary and involves completing a survey which consists of 7 questions that will take approximately 10 minutes.

All comments and responses are anonymous and will be treated confidentially. Your name is not required and you will not be identifiable based on the information you provide.

Submitting the completed survey is accepted as indication of your consent to participate in this study and confirmation that you are over 18 years old.

You may like to submit photos in your responses to some of the questions, however, please note we may include your images in published project reports and other outputs. Due to the anonymous nature of this survey, these will not be credited to you. Photos with identifiable people in them will not be included.

If you have any questions or require further information please contact one of the following researchers:

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1. What is your gender?
2. What is your age (in years)?
3. How many years have you been visiting the lake?
4. How often do you visit the lake?
5. What activities do you do there?
6. Please tell us a positive memory you have about this place.
7. Where have you seen positive changes in the lake environment? Can you provide any detail?

   If you wish to include or take a photo of change (for positive)
8. Where have you seen negative changes in the lake environment? Can you provide any detail?

   If you wish to include or take a photo of change (for negative)
9. Have you been impacted by lake closures or alga blooms on the lake?
10. How have you been impacted by lake closures or algal blooms on the lake?
11. What would improve your experience of using the lake

12. Do you have any suggestions that are likely to improve your experience of using the lake?

13. Thinking about the Lake, can you please indicate how much you agree or disagree with the following statements (strongly agree to strongly disagree):

    - Lake Tuggeranong provides value to me that I can't obtain elsewhere
    - I get more satisfaction out of visiting Lake Tuggeranong than any other recreation place
    - I identify with the physical landscape of Lake Tuggeranong
    - Lake Tuggeranong means a lot to me
    - I have no particular love for Lake Tuggeranong compared to other areas
    - I am very attached to Lake Tuggeranong
    - I feel happiest when I am at Lake Tuggeranong

14. Any other comments or feedback?