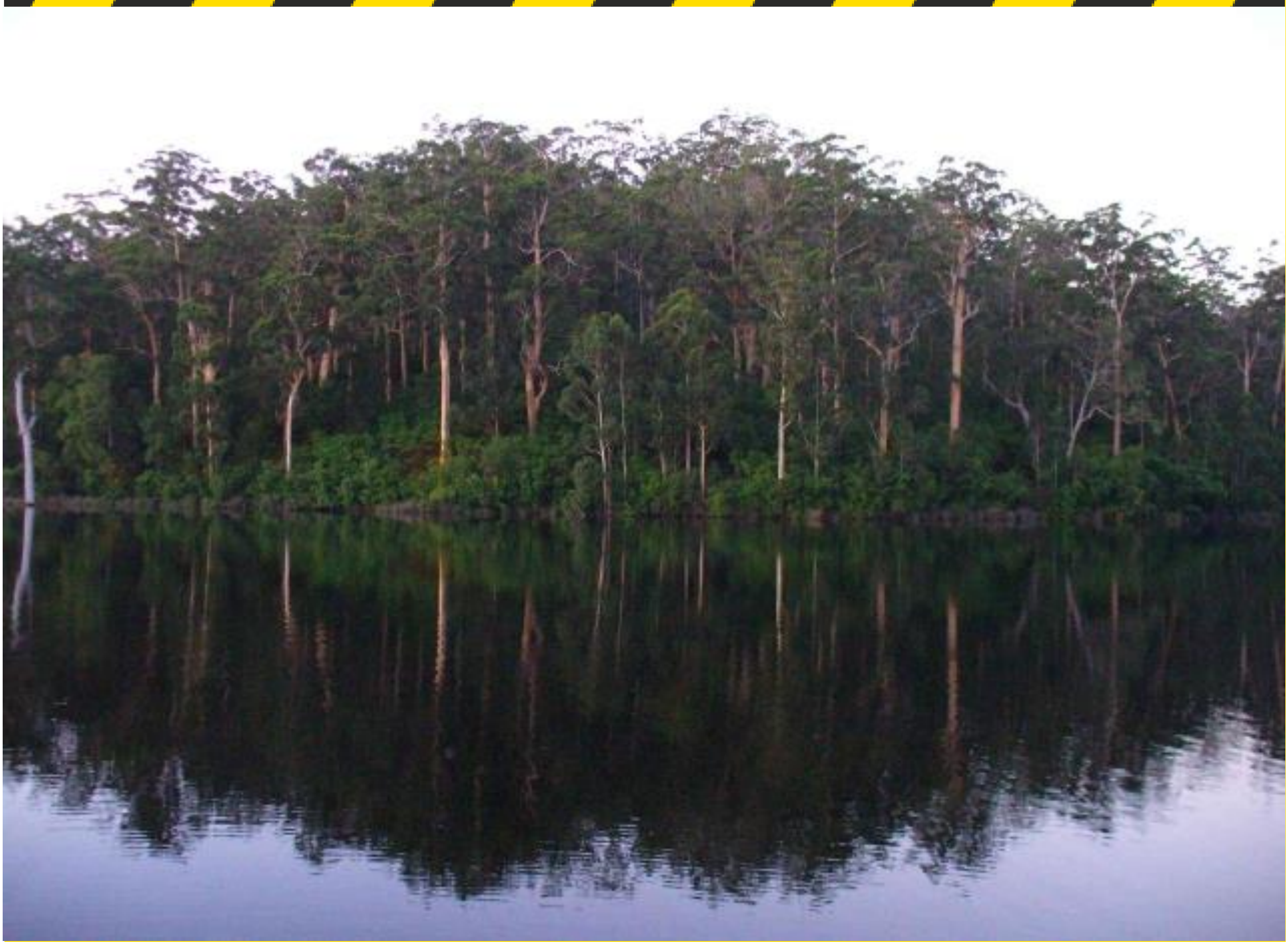
bnhcrc.com.au

# INCLUDING THE INTANGIBLE BENEFITS OF BUSHFIRE MITIGATION IN ECONOMIC ANALYSES: A ‘VALUE TOOL’ FOR INFORMED DECISION MAKING

**Peer reviewed research proceedings from the Bushfire and Natural Hazards CRC & AFAC conference**
**Sydney, 4 – 6 September 2017**

**Abbie A Rogers, Fiona L Gibson, Veronique Florec, Atakelty Hailu, David J Pannell**
The University of Western Australia
Bushfire and Natural Hazards CRC
Corresponding author: abbie.rogers@uwa.edu.au



| Version | Release history | Date |
|---|---|---|
| 1.0 | Initial release of document | 04/09/2017 |



**Publisher:**
Bushfire and Natural Hazards CRC

September 2017

Citation: Rogers, A. A., Gibson, F. L., Florec, V., Hailu, A. & Pannell, D. J. (2017). Including the intangible benefits of bushfire mitigation in economic analyses: a 'value tool' for informed decision making. In M. Rumsewicz (Ed.), *Research Forum 2017: proceedings from the Research Forum at the Bushfire and Natural Hazards CRC & AFAC Conference*. Melbourne: Bushfire and Natural Hazards CRC.

Cover: Karri forest, Pemberton WA

# TABLE OF CONTENTS

# ABSTRACT

Understanding the costs and benefits of bushfire mitigation is imperative for governments to be able to prioritise the strategies that provide the best value for money. The economic damages caused by bushfires and the costs of mitigation are relatively well documented and can be large. But the social and environmental benefits of bushfire mitigation, which can potentially be even larger, have not been well documented. As a result, these types of intangible benefits are often neglected in decision making. We have created a 'value tool' that makes information about these intangible benefits accessible to decision makers for use in economic studies such as benefit-cost analyses.

The value tool identifies the types of intangible values that might be affected by bushfires or their mitigation, in terms of health, environmental and social effects. We have compiled a database of different studies that have measured these values in dollar terms reflecting how much they are worth to the community. This means they can be directly compared with other monetary estimates of costs and benefits related to bushfire mitigation. The database comes with a set of user-friendly guidelines that illustrate how the intangible values can be used to make decisions and prioritise bushfire mitigation strategies. For example, a bushfire manager will be able to use the value tool to identify the types of intangible values that might be affected by a prescribed burning plan, such as protecting wildlife and minimising distress to local communities, and find dollar estimates for each of these values. The value tool also provides estimates of intangible values relevant to other types of natural hazards.

# INTRODUCTION

Bushfires and other natural hazards can cause large economic damages and governments recognise the importance of mitigation to avoid these costs (Penman et al. 2011). Limited financial resources makes it critical to be able to prioritise mitigation actions efficiently. The use of economic frameworks such as benefit-cost analyses enables the efficient allocation of funds by weighing up the financial benefits and costs of different mitigation programs (Ganewatta and Handmer 2006). Milne et al. (2015) point out that economic studies of bushfire risk mitigation tend to focus on financial costs, as opposed to the intangible benefits and costs associated with mitigation which includes the effects on social values, the environment and human health. These types of intangible or non-market values are relatively more difficult to quantify than other financial costs and benefits because they are not traded in markets. However, the intangible impacts of bushfire events and mitigation efforts can be significant. For example, in two of Australia's high impact fires the environmental losses accounted for 9% (1983 Ash Wednesday Fires) and 71% (2005/06 Grampians Fires) of the total losses resulting from the fires (Stephenson et al. 2012).

Non-market values can be used in policy and decision making instrumentally by directly influencing decisions, for example, through inclusion in benefit-cost analyses, or conceptually by improving the understanding of policy issues (Pandit et al. 2015). Benefit-cost analyses are able to incorporate intangible, non-market values provided they are quantified in financial-equivalent terms to other market costs and benefits. Non-market valuation is an economic approach that enables non-market values to be measured in this manner. Specifically, non-market valuation estimates how much people are willing to pay for a change in the quantity or quality of a non-market good, service or benefit (Bateman et al. 2002).

Original (new) studies applying non-market valuation are generally the preferred approach for providing non-market values for use in policy and decision making, as they offer the most accurate representation of values in a specific context. However, for various reasons, an original study is sometimes not justified or feasible (Rogers et al. 2015). For example, the project or policy timeframe might not allow for the collection of new data, the budget for analysis may be too small, or the decision to be made may be a relatively minor one. In such cases, benefit transfer offers an alternative to conducting an original study.

Benefit transfer is, put simply, the "transfer" or application of data collected from one location to a new location of policy interest. As such benefit transfer relies on the use of non-market valuation results from pre-existing studies at one or more sites or policy contexts (often called study sites) to predict willingness to pay (WTP) estimates or related information for other, typically unstudied sites or policy contexts (Rolfe et al. 2015). Benefit transfer is advocated for use in policy making, particularly for non-market values, because usually it is cheaper, takes less time and is more straightforward than conducting original studies.

We have created a look-up database, hereafter called the 'Value Tool', that provides a compilation of intangible values from existing studies that are suitable for use in benefit transfer for bushfire mitigation decision making, as well as for other natural hazards. The tool has been created in order to improve the capacity of bushfire managers to consider and include non-market benefits and costs in prioritising decisions. This paper provides a concise introduction to the economic approaches of non-market valuation and benefit transfer, before describing the design of the Value Tool. An example of how to apply the Value Tool is then provided before discussing its advantages and limitations.

# NON-MARKET VALUATION AND BENEFIT TRANSFER

Non-market valuation includes a set of economic methodologies that are based on the concept that people make choices to maximise their utility (or well-being), and in doing so they make trade-offs between the attributes of different goods and services, including the costs involved in purchasing those goods and services (Hanley and Barbier 2009). That is, it is assumed that consumers purchase products to maximise their utility subject to their individual budget constraint.

There are two main forms of non-market valuation: revealed and stated preference techniques. Revealed preference techniques use information about behaviour and data from markets related to non-market goods to infer WTP for those goods. For example, the travel costs of a trip can be used to infer the minimum that an individual is willing to pay to visit a particular recreational location, or we could analyse how housing prices change in proximity to a recreation facility to determine the premium people would pay to live nearby. These approaches can estimate lower bound estimates of WTP for the use of non-market resources (see Hanley and Barbier 2009 for more information on revealed preference techniques). Stated preference techniques are able to estimate maximum WTP for both the use and non-use (e.g. existence values that people might hold for protecting the environment) of non-market resources. Surveys are used to define a hypothetical scenario where the respondent makes a trade-off between how much they are willing to pay for some improvement, or set of improvements, in the non-market good that is being valued (see Bateman et al. 2002 for more information on stated preference techniques).

Benefit transfer uses the WTP estimates that are derived from original non-market valuation studies and applies them to new policy or decision contexts. There are a number of ways to conduct a benefit transfer, which vary according to the accuracy and expertise required. The main approaches include unit-value transfer and benefit-function transfer.

Unit-value transfers involve the transfer of a single number or a set of numbers from study sites to the policy sites (Johnston et al. 2015). The number(s) can be adjusted to account for differences in, for example, currency value across different time periods and differences in average income of the sampled population in the study and the population affected at the policy site. These adjustments are imposed *ex post* by the practitioner based on their knowledge of the policy site's characteristics, such as the sociodemographic profile of the population.

Benefit-function transfers use a "transfer function" to estimate and transfer values from study sites to policy sites (Johnston et al. 2015). The transfer function includes variables from the original study such as socio-demographic characteristics or the number of substitute sites available. That is, the transfer function can account for observable differences between the study and policy sites using adjustments based on information provided by the original study. The approach could be a parametric function, a meta-analysis (typically meta-regression analysis), or a preference calibration based on a structural utility model.

In cases where the study and policy sites are dissimilar in some respects, benefit-function transfers are generally more accurate than unit-value transfers (Bateman et al. 2011). Any mismatch between the study and policy sites will generate errors in the transferred values (Johnston et al. 2015). The ability to account for differences between the sites in the benefit-function transfers means that there is less error associated with the transferred value. However, a degree of error is likely to be present in any transfer approach and function-based approaches are more difficult to implement than unit-value approaches, generally requiring an experienced analyst to conduct the transfer. Thus, there is a trade-off between accuracy and practicality. The Value Tool relies on the simpler unit-value transfer approach given its focus on making non-market values more accessible for use in decision making, though the tool emphasises the importance of transparency in the assumptions that are made for each decision and informs users about the degree of accuracy in the transfers they might make.

# VALUE TOOL DESIGN

The first step in generating a database of WTP estimates for use in natural hazard decision making was to determine what types of intangible values could possibly be affected by natural hazard events or their mitigation. We identified 11 different value types via consultation with natural hazard decision makers and through reviews of the natural hazard management literature and the outcomes from risk assessment workshops run by the WA State Emergency Management Committee. The value types were divided into three categories (Table 1):

- Health – physical and mental health;
- Environment – ecosystems and water quality;
- Social – recreation, amenity, safety, cultural heritage, social disruption, memorabilia and animal welfare.

We identified a set of measurable processes and outcomes associated with each value type, as examples of the ways in which a value might be affected by a natural hazard event or its mitigation. The changes in final outcomes are typically what is 'valued', and where these changes can be measured they can be used to establish the marginal or physical change that people are willing to pay for (or require compensation for, in the case of a negative change) (see column 3, Table 1). However, it can sometimes be easier to quantitatively measure the physical changes related to intermediate processes, which subsequently produce a desired outcome (see column 2, Table 1). As such, the Value Tool database provides estimates related to changes in the processes and outcomes of the different value types. To avoid double counting it is important to be clear in the distinction between values for processes and outcomes, and not to combine WTP estimates for both in relation to the same value type. For example, for ecosystems, you would not use a WTP estimate for reducing the number of invasive species in an area – which is a process that leads to adverse impacts on native flora – along with a WTP estimate for improving the health of native flora – the desired outcome (Table 1).

With the value types and descriptions of likely processes and outcomes identified, we conducted a review of the non-market valuation literature to identify studies with appropriate WTP estimates for inclusion in the Value Tool database. There is a vast literature on non-market values related to the health, environmental and social categories; however, few studies have been conducted in a natural hazard decision making context. The policy or decision context in which a WTP study is conducted has implications for how appropriate it is to use in benefit transfer (Carlsson et al. 2010): while different decision contexts might lead to the same outcome (e.g. destruction of native forest), the cause of the change (e.g. clearing for a mining project versus an intense wildfire) can affect the magnitude of how much people are willing to pay for that particular outcome. Accordingly, we followed a search protocol where we selected the most relevant studies that were available for natural hazard decision making for each value type. In some cases, certain value types are not well represented in the literature, and the studies included in the database require caution when using for benefit transfer. We were able to identify studies to include in the database for all value types except memorabilia.

The search protocol prioritised studies for inclusion in the database as follows:

1) Studies measuring the value type in a natural hazard context, in Australia
2) Studies measuring the value type in a different context, in Australia

3) Studies measuring the value type in a natural hazard context, internationally
4) Studies measuring the value type in a different context, internationally
5) Studies measuring costs associated with a value type, where WTP studies can't be identified

The database includes over 40 studies, some of which have multiple WTP estimates reported for the various marginal changes measured within the study. For each study, the database records:

- which value type is being measured;
- which types of natural hazards the study provides suitable WTP estimates for;
- what specific marginal (physical) change is being measured;
- the WTP estimate(s) for the change, converted to Australian $ where relevant;
- information about study location, sample demographics, study methodology and supporting statistics (e.g. confidence intervals for WTP estimates) where provided; and
- recommendations on appropriateness for benefit transfer.

In addition to the database, the Value Tool also includes a set of guidelines on how to use WTP estimates listed in the database for the purpose of benefit transfer. The guidelines present a review of existing non-market valuation literature for each value type to establish how well the available literature, and corresponding WTP estimates, match natural hazard decision contexts. This provides an understanding of the accuracy with which values can be transferred from the database to a new decision. With this understanding in mind, the guidelines provide recommendations on how to undertake the benefit transfer, including suggested adjustments (e.g. income adjustments between study samples and the relevant population affected by the present decision) that can be made to transferred values and sensitivity testing.

# VALUE TOOL APPLICATION

Here we demonstrate a hypothetical example of how to apply the Value Tool. The first requirement is to follow instruction in the guidelines on defining the policy context. A checklist of questions must be answered to establish what type of value(s) the decision maker is looking for in the database. The checklist should be applied separately for each value type being considered.

We provide an example in the context of managing bushfire risk. The geographical area and mitigation strategy will help to determine exactly which value types from Table 1 are relevant in this context, but values that are likely to be relevant include physical health, mental health, ecosystems, recreation, amenity, safety and animal welfare. Focusing on the value type 'physical health', we show how to work through the checklist below:

1) What is the natural hazard type?
   *Bushfire*

2) Which value type is affected by the hazard or its mitigation?
   *Physical health*

3) How is this value affected, in terms of the physical changes that are likely to occur?
   *A prescribed burning regime is expected to prevent loss of life due to wildfire*

4) What is the scale of the proposed change?
   *5 lives saved*

5) Who is the affected population?
   *Victorian population*

We acknowledge that answering the checklist of questions is not always a straightforward task, particularly in relation to clearly establishing the physical change and the scale of that change. Answering these questions will often depend on the availability of information such as bio-physical data. In the absence of such data, expert judgement can play a valuable role.

With the policy context defined, decision makers are then advised to consult the literature review provided in the guidelines relevant to the value type they are measuring. The review provides a summary about the state of the existing literature and how relevant it is for decision making in a natural hazard context. In the case of physical health, the review concludes that:

- There is a large literature on value of statistical life which includes Australian studies, meta-analyses and study contexts relevant to natural hazards.
- Physical health values are well documented and readily applicable to benefit transfer.

With this contextual understanding in mind, the database can be consulted to extract relevant values. The database can be searched by hazard type, value type, and the specific marginal or physical change that is being measured (Figure 1). For our prescribed burning example, a study exists that provides a review of the international literature on the 'value of a statistical life', with the objective of identifying an appropriate value for Australia (Abelson 2008). The value of a statistical life can be measured through a range of revealed and stated preference techniques. It is generally a measurement of the trade-off an individual is willing to make between their income and the probability of death, or their WTP to reduce the risk of death.

Relative to our example, this study is not conducted specifically within the context of a natural hazard decision, but is based on a meta-analysis of studies providing a dollar estimate averaged over a variety of different contexts which means that it is broadly applicable to most situations. It does provide an estimate specifically relevant to the Australian population which means that the cultural and socio-demographic differences between the study site and our decision context are minimised. Accordingly, income and other population-based adjustments are not essential.

The database provides an estimate of $3,500,000 per Australian life saved, in 2007 AUS$ (Figure 2).

To make the estimate applicable to the prescribed burning plan, some adjustments are required:

1) The number must account for price changes or inflation over time using an index like the CPI (see http://www.rba.gov.au/calculator/):

   CPI adjusted AUS$ from 2007 to 2016 = $4,340,915.55

2) The number must then be aggregated over the number of lives saved:

   $4,340,915.55 x 5 lives saved = $21,704,578

This number can then be inserted into a benefit-cost analysis comparing the full range of benefits and costs associated with the prescribed burning plan over a specified time period.

# DISCUSSION

The Value Tool provides a practical means of finding non-market values for inclusion in natural hazard decision making, through the use of benefit transfer. The Value Tool can be used to improve decision making through a number of ways. First, it can provide quantitative, financial estimates of intangible values that can be used instrumentally in benefit-cost analyses or other prioritisation metrics, to ensure that the effects of non-market values are directly accounted for along with the market costs and benefits of proposed mitigation actions. Second, it can provide specific WTP estimates that can be used conceptually or qualitatively to make judgements about decisions, for example, by supporting or justifying an existing policy. Third, in addition to providing specific WTP estimates, it can provide information about the relative magnitudes of people's preferences for different types of values that can be used to judge how people might behave under a proposed decision. Finally, it provides a platform to improve understanding about the importance of including non-market values in decision making, as well as where the knowledge gaps and uncertainty exists in relation to these values, and different approaches for dealing with uncertainty.

A limitation of the Value Tool is the uncertainty of how accurate the information within the tool is given its reliance on benefit transfer and the probable errors that occur when using this approach to transfer WTP estimates between different decision contexts. This is particularly the case given the limited literature available to provide non-market values in the context of natural hazard decision making. Many of the WTP estimates in the Value Tool database are set in a different decision context to the specific types of decisions made by natural hazard managers. In addition, valuation of non-market benefits in quantitative terms is difficult and economists are well aware that non-market valuation and its associated techniques, such as benefit transfer, are not perfect (Hausman 2012; Kling et al. 2012). However, these techniques offer a structured and transparent framework by which policy makers can include non-market values in decisions. We are of the view that it is preferable to include some information about non-market values in the decision process, than none at all. The error, and decision bias, resulting from the latter is likely to be far greater than the error from using an inaccurate number.

Indeed, Pannell and Gibson (2016) simulated millions of decisions about environmental project prioritisation, and used the results to test whether it was preferable to omit poor-quality information or to include it despite its shortcomings. They evaluated the long-term environmental outcomes from the two approaches and found that it is clearly better to include information about a particular variable, such as a non-market value, than to ignore it, even if there is high uncertainty about the accuracy of the information.

Reinforcing our view that 'some number is better than no number', it should be recognised that omitting information about non-market values does constitute making an implicit assumption – that there are no differences in non-market values between the decision options – and this implicit assumption is highly likely to be wrong.

Provided the policy maker is aware of the potential for transfer errors when applying the Value Tool, and they use a conservative and transparent approach for transferring values, including appropriate sensitivity testing in analyses that use those values, then the values can provide useful, quantitative information for decision making. In some cases, where a value transfer is too unreliable, we do not recommend using the values in a quantitative analysis, but suggest using them in a qualitative manner to inform thinking about particular policies. Further, for major projects or decisions where time and budget permits, we recommend original non-market valuation studies are conducted to provide the most robust non-market value estimates for sound decision making.

The Value Tool will be publicly available for decision makers to utilise by the end of 2017. A custodian will maintain the tool to ensure its currency for decision making in the future. The Value Tool guidelines identify key gaps in the non-market valuation literature with respect to provision of WTP estimates suited for natural hazard decision making, particularly for the value types of mental health, ecosystems, cultural heritage and memorabilia (see Table 1). A future research focus will be to address these gaps by conducting original non-market valuation studies to provide suitable estimates for inclusion in the database. Further research is also recommended on the benefit transfer approach to establish the magnitude of transfer errors that occur under different natural hazard decision scenarios. This could enable rules-of-thumb to be established in setting the bounds of sensitivity tests for transfers made between well-matched study and policy sites, and those that are poorly matched.

# REFERENCES


Abelson, P. 2008. Establishing a Monetary Value for Lives Saved: Issues and Controversies. Working papers in cost-benefit analysis. Office of Best Practice Regulation, Department of Finance and Deregulation.

Bateman, IJ, Brouwer, R, Ferrini, S, Schaafsma, M, Barton, DN, Dubgaard, A, Hasler, B, Hime, S, Liekens, I, Navrud, S, De Nocker, L, Ščeponavičiūtė, R, and Semėnienė, D 2011. Making Benefit Transfers Work: Deriving and Testing Principles for Value Transfers for Similar and Dissimilar Sites Using a Case Study of the Non-Market Benefits of Water Quality Improvements Across Europe. *Environmental and Resource Economics*, 50: 365-387.

Bateman, I.J., Carson, R.T., Day, B., Hanemann, M., Hanley, N., Hett, T., Jones-Lee, M., Loomes, G., Mourato, S., Özdemiroglu, E., 2002. Economic valuation with stated preference techniques: a manual. Economic valuation with stated preference techniques: a manual. Edward Elgar, Cheltenham.

Carlsson, et al. 2010. Value of Statistical Life and Cause of Accident: A Choice Experiment. *Risk Analysis*, Vol. 30, No. 6, 975-986.

Ganewatta, GJ, Handmer, J (2006) Bushfire management: why, where and how economics matter? Contributed Paper for the Australasian Bushfire Conference. Brisbane, 6 – 9 June, 2006. http://www.griffith.edu.au/conference/bushfire2006/pdf/bushfire-management.pdf [accessed 20/12/15]

Hanley, N., Barbier, E.B., 2009. Pricing nature: cost-benefit analysis and environmental policy. Edward Elgar, Cheltenham.

Hausman, J 2012. Contingent Valuation: from Dubious to Hopeless, *Journal of Economic Perspectives* 26(4), 43–56.

Johnston, RJ, Rolfe, J, Rosenberger, RS and Brouwer, R 2015. Introduction to Benefit Transfer Methods. In RJ Johnston, J Rolfe, RS Rosenberger & R Brouwer (Eds). *Benefit Transfer of Environmental and Resource Values A Guide for Researchers and Practitioners* (pp 19-59). Springer, Dordrecht.

Kling, CL, Phaneuf, DJ and Zhao, J 2012. From Exxon to BP – Has Some Number Become Better than No Number?, *Journal of Economic Perspectives,* 26(4), 3–26.

Milne, M, Clayton, H, Dovers, S, Cary, GJ (2015) Evaluating benefits and costs of wildland fires: critical review and future applications. *Environmental Hazards* **13**(2), 114-132

Pandit, R., Subroy, V., Garnett, S.T., Zander, K.K., Pannell, D. 2015. A review of non-market valuation studies of threatened species and ecological communities. Report to the National Environmental Science Programme, Department of the Environment, Canberra.

Pannell, DJ and Gibson, FL 2016. Environmental cost of using poor decision metrics to prioritize environmental projects, *Conservation Biology,* 30(2): 382-391.

Penman, TD, Price, O, Bradstock, RA, 2011, Bayes Nets as a method for analysing the influence of management actions in fire planning, *International Journal of Wildland Fire*, *20*, 909–920

Rogers, AA, Kragt, ME, Gibson, FL, Burton, MP, Petersen, EH, Pannell, DJ (2015) Non-market valuation: usage and impacts in environmental policy and management in Australia. *Australian Journal of Agricultural and Resource Economics* **59** (1), 1-15

Rolfe, J, Johnston, RJ, Rosenberger, RS and Brouwer, R 2015. Introduction: Benefit Transfer of Environmental and Resource Values. In RJ Johnston, J Rolfe, RS Rosenberger & R Brouwer (Eds). *Benefit Transfer of Environmental and Resource Values A Guide for Researchers and Practitioners* (pp 3-17). Springer, Dordrecht.

Stephenson, C, Handmer, J, Betts, R (2012) Estimating the economic, social and environmental impacts of wildfires in Australia. *Environmental Hazards* **12**(2), 93-111

Table 1. Value types affected by natural hazard events and their mitigation.

| **Value type** | **Intermediate processes** | **Final outcomes** | **Availability of literature & recommendations** |
|---|---|---|---|
| *Health values* | | | |
| Physical health | Cause emergency/ health services to be overwhelmed, resulting in further deaths directly attributable to the hazard event. | Change in number of deaths<br><br>Change in number of injuries, serious illness and/or pain | There is a large literature on VSL which includes Australian studies, meta-analyses, and study contexts relevant to natural hazards.<br>Physical health values are well documented and readily applicable to benefit transfer. |
| Mental health | | Change in reported cases of grief, stress and anxiety | The approaches used in the literature to measure changes in mental health do not capture WTP with respect to the non-market *benefits* of avoiding/improving mental health problems.<br><br>New, original stated preference studies would be required to measure WTP for mental health changes, in the context of natural hazards, to provide estimates appropriate for use in benefit transfer.<br><br>The available literature can be used to assess the *costs* of mental health related treatment, which provide a partial indication of the benefits of avoiding mental health problems. |
| *Environmental values* | | | |
| Ecosystems | Change in spread of invasive species<br><br>Change in amount of debris and pollutants to enter marine or estuarine/riverine environments<br><br>Change in carbon stored in vegetation and soils<br><br>Change in occurrence of algal blooms in rivers and estuaries | Change in the number of flora and fauna species<br><br>Change in the status of vulnerable environmental ecosystems and/or identified critically endangered species.<br><br>Change in ocean surges and wave activity resulting in marine inundation and erosion of sandy coastlines/dune systems. | There are very few cases where non-market valuation studies have estimated the value of protecting ecosystems directly. These are typically not in the context of natural hazards, nor directly relevant to Australian policy.<br><br>More stated-preference studies are required to provide better estimates of these values for benefit transfer.<br><br>Use of available estimates of ecosystem values for benefit transfer in the natural hazard context is limited. |

| Value type | Intermediate processes | Final outcomes | Availability of literature & recommendations |
|---|---|---|---|
| Water quality | Change in turbidity in water bodies<br><br>Change in occurrence of algal blooms in rivers and estuaries<br><br>Change in debris and pollutants to enter marine or estuarine/riverine environments | Change in vulnerable environmental ecosystems and/or identified critically endangered species.<br><br>Change in ocean surges and wave activity resulting in marine inundation and erosion of sandy coastlines/dune systems.<br><br>Change in the aesthetics in the area. | There are few cases where non-market valuation efforts have estimated the value of water quality improvements in the context of natural hazards. However, there are numerous studies available for more general contexts.<br><br>Use of available estimates of water quality values for benefit transfer in the natural hazard context is limited, but possible due to the availability meta-analyses which provide average WTP estimates for water quality improvements over a range of policy contexts. |
| *Social values* | | | |
| Recreation | Change in turbidity in water bodies<br><br>Change in occurrence of algal blooms in rivers and estuaries<br><br>Change in debris and pollutants to enter marine or estuarine/riverine environments<br><br>Impact heritage buildings and cultural significant facilities<br><br>Change in aesthetics in the area.<br><br>Change in native vegetation communities | Change in recreation activity within the area | WTP estimates exist in the context of recreational values related to bushfires. There are numerous studies available for more general contexts.<br><br>Use of available estimates for benefit transfer is possible but should be undertaken with caution, as these values are not in an Australian policy context, and do not encompass all natural hazard types. |
| Amenity | Change in turbidity in water bodies<br><br>Change in algal blooms in rivers and estuaries<br><br>Change in debris and pollutants to enter marine or estuarine/riverine environments<br><br>Change in native vegetation communities | Change in aesthetics in the area.<br><br>Change in amenity related recreation | There is a large literature on WTP estimates for amenity and safety values which includes Australian studies and study contexts relevant to natural hazards.<br><br>Amenity and safety values are well documented and readily applicable to benefit transfer. |
| Safety | Impact to residential dwellings | Change in dwelling location<br><br>Change in dwelling construction | |

| Value type | Intermediate processes | Final outcomes | Availability of literature & recommendations |
|---|---|---|---|
| Cultural heritage | Impact to heritage buildings and cultural significant facilities | Change in cultural significance<br>Change in heritage related recreation<br>Impact sense of place | There are no cases where non-market valuation studies have estimated the value of protecting cultural heritage in the context of natural hazards.<br>Use of available estimates of cultural heritage values for benefit transfer is limited: with so much uncertainty and many variables affecting the valuation of cultural heritage in general, determining the specific valuation of the impact of natural hazards on these resources may not be feasible.<br>Available estimates can be used conceptually (qualitatively) to make judgements about decisions. |
| Social disruption | Evacuation to safe accommodation away from people's homes and work places<br>Evacuation of indigenous communities away from their country, as well as being housed together in groups not aligned to their culture<br>Change in existing social service providers (NGOs, Lions, Rotary, Salvation Army, CWA, other volunteer organisations), impacting community wellbeing.<br>Change in day to day functionality of facilities for vulnerable people (aged, childcare, disability)<br>Change in day to day functionality of facilities | Breakdown of existing family and support networks (including social community networks)<br>Change in community services and wellbeing<br>Change in availability of basic commercial products and services | There are very few cases where non-market valuation studies have estimated the value of avoiding social disruption. These are either not in the context of natural hazards, or are not Australian studies.<br>Use of available estimates of social disruption for benefit transfer in the natural hazard context is limited. |
| Memorabilia | | Impact to residential dwellings and contents | There are no estimates available to use for benefit transfer of memorabilia values.<br>New, original stated-preference studies would be required to measure WTP for memorabilia values, in the context of natural hazards, to provide estimates appropriate for use in benefit transfer. |

| Value type | Intermediate processes | Final outcomes | Availability of literature & recommendations |
|---|---|---|---|
| Animal welfare | | Displacement, death or injury to animals | There are no cases where non-market valuation studies have estimated animal welfare values in the context of natural hazards.<br><br>Use of available estimates of animal welfare values for benefit transfer is limited: the estimates are primarily in an agricultural and food-safety context, meaning there is difficulty in discerning the values for animal welfare separately from the intertwined values of food safety and environmental protection.<br><br>Available estimates can be used conceptually (qualitatively) to make judgements about decisions. |

| | A | B | C | D | E | F | G | H | I | J |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | STUDY IDENTIFICATION AND RELEVANCE | | | | | | | | | WILLINGNESS TO PAY |
| 3 | Observation ID *(Identification number for ...ry unique WTP* | Citation | Hazard types applicable | Value type applicabl | Brief summary of study objective(s) | Study conducted in the context of a natural hazard? *... or No)* | Study quality *(1=poor, 2=average, 3=high)* | Benefits transfer applicability *(1=rarely, 2=moderately, ...ighly)* | Recommendations *(Applicability for benefit transfer in natural hazard context)* | Definition of marginal change *(This is what is being measured - e.g. WTP for reduced loss of life)* |
| 4 | 18 | Vlaev, et al. 2009 | Fire, Flood, Storm, Earthquake, Tsunami | Physical health | WTP to relieve or avoid pain | No | 1 | 1 | Limited application; not NH specific, and be aware of/adjust for population differences | WTP to end a series of painful electrical shocks |
| 5 | 19 | Abelson 2008 | Fire, Flood, Storm, Earthquake, Tsunami | Physical health | VSL for death by any means | No | 2 | 3 | Useful for BT in Australia; be aware of generalised context - not NH specific | Value of a statistical life |
| 6 | 20 | Abelson 2008 | Fire, Flood, Storm, Earthquake, Tsunami | Physical health | VSL for death by any means | No | 2 | 3 | Useful for BT in Australia; be aware of generalised context - not NH specific | Value of a statistical life year |
| 7 | 21 | Knowlton, et al. 2011 | Storm | Mental health | Quantify mental health costs associated hurricanes | Yes | 3 | 2 | Very limited application; provides partial assessment of benefits by assessing the costs of treatment. | Mental health cost per person per event |
| 8 | | | | | | | | | | |

Value types | Health values | Environmental values | Social values | Notes

Figure 1. Screenshot of the Value Tool database showing study entries searchable by the 'Hazard types applicable', 'Value type applicable' and 'Definition of marginal change'.

| | A | B | J | K | L | M | P | Q | R | S | T |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | **STUDY IDENTIFICATION AND RELEVANCE** | | **WILLINGNESS TO PAY** | | | | | | | | |
| 3 | Observation ID *(Identification number for ry unique WTP* | **Citation** | **Definition of marginal change** *(This is what is being measured - e.g. WTP for reduced loss of life)* | **Hazard types identified** | **Specific value type measured** | **WTP estimate** | **WTP estimate** *(2016 $AU)* | **Unit measurement** *(Quantitative units - e.g. life saved* | **Model variables** | **Currency year** | **Currency** |
| 4 | 18 | Vlaev, et al. 2009 | WTP to end a series of painful electrical shocks | Physical pain | Physical Health | n/a | | Quantity of shocks | price, quantity, pain level | 2009 | GBP |
| 5 | 19 | Abelson 2008 | Value of a statistical life | Not specified | Physical Health | $3,500,000 | $4,159,946 | Life | n/a | 2008 | AUD |
| 6 | 20 | Abelson 2008 | Value of a statistical life year | Not specified | Physical Health | $151,000 | $179,472 | Life | n/a | 2008 | AUD |
| 7 | 21 | Knowlton, et al. 2011 | Mental health cost per person per event | Storm | Mental Health | $17.38 per person per hurricane event | $29.82 | Hurricane event | Ethnicity, present for hurricane winds, property damage, amount of incurred damage, time displaced from home, social support | 2008 | USD |
| 8 | | | | | | | | | | | |
| 9 | | | | | | | | | | | |

Value types | **Health values** | Environmental values | Social values | Notes

Figure 2. Screenshot of the Value Tool database showing the willingness to pay (WTP) data recorded for each study, including Abelson (2008) (highlighted) used in the Value Tool application example.