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Benefit-cost analysis of the Windara shellfish reef restoration project

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Project B1: Road testing decision support tools via case study applications

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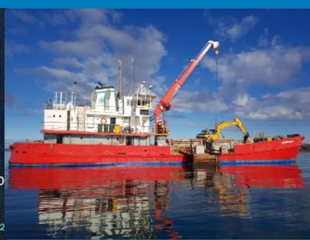

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Important Disclaimer

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EXECUTIVE SUMMARY

Windara Reef is the largest underwater marine habitat restoration attempt made in Australia to construct a native oyster reef. There has been wide-scale loss of shellfish habitats globally, and they are functionally extinct in many parts of Australia including South Australia where the Windara construction is located. Restoration is therefore important for the survival of these habitats, but requires significant financial investment. To justify investments of this nature, it is important to identify the economic benefits and costs of restoration projects, and wherever possible to ensure that these assessments include as many of the non-market values as possible.

Using benefit-cost analysis, we have undertaken an integrated economic assessment of the viability of the Stage Two 16ha restoration project led by The Nature Conservancy. This analysis was inclusive of the tangible, market-based outcomes of the project and also the intangible, non-market social and environmental outcomes. Specifically, the following costs and benefits were included in the analysis:

- Construction costs;
- Operating costs;
- Environmental benefits, related to improvements in biodiversity and ecosystem functioning;
- Intrastate recreational fishing benefits;
- Interstate recreational fishing benefits;
- Educational tourism;
- Profit to oyster suppliers;
- Profit to charter operators;
- Potential benefit to commercial fishers if the area remains open to fishing, or equivalently the costs if the area is closed.

A number of project scenarios were modelled that considered:

- Duration of operating costs, in terms of ongoing monitoring and maintenance over either a 2 or 10 year period;
- Alternative social discount rates used for the calculation of net present value, at either 3%, 7% or 10%;
- Sensitivity of the decision outcomes from the benefit-cost analysis dependent on the estimated values used, with lower and upper bounds identified for the benefits included in the analysis.

Using the estimated values for the benefits, the project demonstrated between a two and four return on investment and generated net benefits of between $4million to $10million depending on the discount rate applied and duration of operating costs. Across the modelled scenarios that allowed for sensitivity in the values of the estimated benefits, the net present value of the project ranged from -$2million to $50million, and the benefit: cost ratio from 0.4 to 15.7. Only the project scenarios that assumed the lower bound values for all benefits at a discount rate of either 7% or 10% resulted in a negative outcome. In all other instances, the project was viable, and demonstrated substantial capacity to absorb the risk of total project failure.

The key benefits driving project viability were the non-market environmental benefits and the additional spend that could be generated for the tourism sector by interstate recreational fishers. The extension of monitoring costs from 2 to 10 years into the life of the project did not alter the viability of the project and suggests that the ongoing monitoring of the reef to collect baseline data to inform future restoration investments is worthwhile.

As an emerging area of conservation investment, further economic assessments would be useful to establish whether the positive returns for Windara Reef are likely to extend to other marine and coastal habitat restoration projects.

1. INTRODUCTION

Shellfish reefs are important and productive marine ecosystems. They provide ecosystem services such as providing food and habitat for targeted fish and crustacean species, water quality improvement through their filter feeding and protection of shorelines from erosion in low energy systems (reviewed in Grabowski 2012). The economic value of the full suite of ecosystem services derived from natural oyster reefs in North America was recently estimated to be as high as US$99,000 ha^{-1} $year^{-1}$ (Grabowski et al. 2012), which is higher than estimates for other habitats such as mangroves (Balmford et al. 2002), seagrass (Grabowski et al. 2012) and permanent wetlands (Sutton and Costanza 2002). Unfortunately, human activities such as overfishing, dredging and other destructive fishing practices, water pollution, and the spread of disease have led to the loss or degradation of shellfish reefs – for example over 85% of oyster reefs have been lost globally (Beck et al. 2011). Acknowledging the importance of these reefs, attempts are now being made to restore them, with many international examples, including successful system-wide restoration projects (e.g. La Peyre et al. 2014; Shulte et al. 2009; McLeod et al. *In Press*)

Shellfish reefs in Australia have followed the global pattern with wide-scale loss (Gillies et al. 2018). *Ostrea angasi* (Australian flat oyster) reefs once extended across more than 1,500 km of coastline in South Australia: the reefs supported an important commercial wild harvest fishery from 1886 to 1944, and were a source of food for Aboriginal communities (Alleway and Connell 2015, Nell 2001). These reefs are now functionally extinct throughout their former range in all states except Tasmania, where the single reference site is located (Gillies et al.2017; 2018).

Interest in active restoration of marine and coastal habitats such as macroalgae forests, seagrass meadows, coastal saltmarshes and coral and shellfish reefs is increasing in Australia (McLeod et al. 2018; *In Review*). This interest follows an increasing understanding of the value of these habitats and wide-spread declines that are often not being reversed by current management practices (McLeod et al. *In Review*). Given that active restoration is a relatively new initiative in Australia, decision makers need quantified information about the costs and benefits of proposed restoration projects so they can make better informed decisions.

The Nature Conservancy is implementing Australia's largest scale attempt to restore a native flat oyster reef in Gulf St Vincent, South Australia, known as Windara Reef. The 20 ha reef restoration – which has been undertaken in two stages, with the first stage establishing a 4ha reef, and Stage Two a 16ha reef – is delivered through a public-private partnership which includes the Commonwealth, South Australian and Yorke Peninsula Governments, The Nature Conservancy and several community groups (Primary Industries and Regions SA 2017).

A restoration project of this scale requires significant investment. The total cost of the project is estimated at $3.4 million, with approximately 50% of funding provided by The Nature Conservancy and 50% from across three tiers of Government. To help enable further conservation investments in the future, it is important to establish the financial viability and return on investment provided by large-scale marine ecosystem restoration, including intangible non-market benefits.

Here, we present the results of a benefit-cost analysis (BCA) of Stage Two (16ha) of Windara Reef to determine the economic value of the project. A BCA is an economic assessment tool that is commonly used to compare the economic, social and environmental outcomes of undertaking a project, relative to the counterfactual case of having not implemented the project (Hanley and Barbier 2009). Importantly, it is able to embed intangible or non-market values into the assessment, such as the recreational and environmental benefits generated by a shellfish ecosystem.

2. METHODS

2.1 Defining the BCA scenarios

A BCA measures the net change between the benefits and costs over a specified timeframe of undertaking the project (the 'with-project' scenario), relative to what would have occurred if the project did not go ahead (the 'without-project' scenario) (Figure 1).

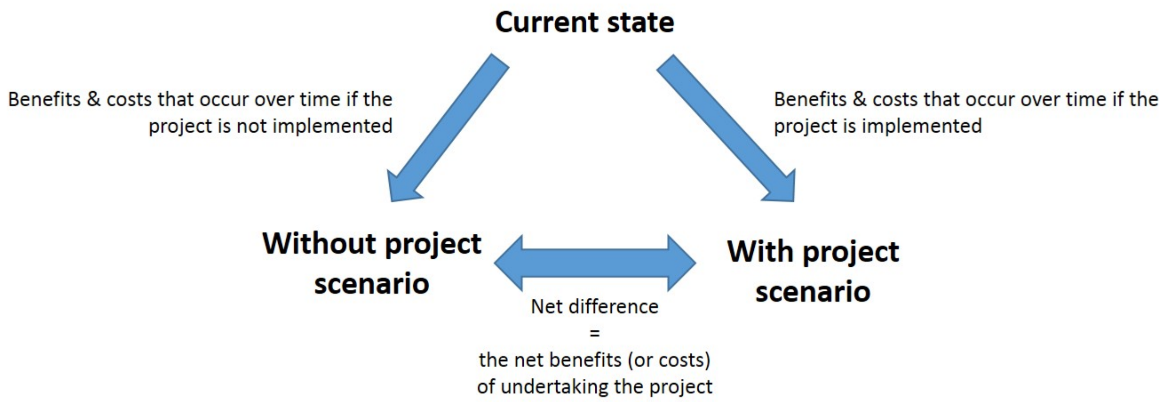

Figure 1. Calculation of net benefits between the with- and without-project scenarios in a BCA.

To undertake the analysis, the with- and without-project scenarios must be clearly defined. A workshop was held with oyster reef restoration experts, including the managers of the Windara Reef project, in February 2018 to determine the following factors for the BCA (see Rogers et al. 2018 for a complete summary):

- The 'with-project' scenario was defined as the Stage Two (16ha) component of the restoration project, implemented by TNC.
- The 'without-project' scenario was defined as the pre-construction habitat (predominantly sand/sediment, some pinna beds, and 25% seagrass beds), that existed prior to the 16ha reef construction project.
- A suitable timeframe for analysing the benefits and costs of the project was 30 years, which allows for the restored reef to be fully functioning as a natural reef.
- A number of benefits and costs were identified as being important to consider for the analysis, which are described in Section 3, along with the timing of when those benefits and costs would occur.
- Project risks that might lead to failure of the project or an over-estimation of the benefits it could deliver were identified, including:
    - Potential for oyster deaths from predation or disease
    - Engineering risks associated with the rock structure
    - Availability of accurate data to predict magnitudes of social and environmental changes

A timeframe for the progression of changes that would occur over the 30 years for the with- and without-project scenarios was developed in the workshop (Rogers et al. 2018), which is important for understanding when certain benefits and costs may occur. Figure 2 shows the expected process for the with-project scenario, beginning with the construction works in Year 1, leading to a fully functioning reef by Year 30. For the without-project scenario, it is anticipated that there would be a marginal decline in environmental quality over the 30 year period as some habitat degradation would result from continued presence of environmental stressors such as nutrient runoff.

Year 1	Year 3	Year 5	Year 7	Year 30
Reef construction Oyster seeding Reef acts as a Fish Aggregating Device	Oysters reach sexual maturity	Majority (80%) of recreational fishing benefit is established	Ecosystem begins to function properly – majority (80%) of environmental benefit is established	Fully functioning 'natural' reef – 100% of benefits are established

Figure 2. Timeline of anticipated changes following reef construction for the 'with-project' scenario (developed via consultation with reef restoration experts, see Rogers et al. 2018, and supported by current understanding of oyster reef restoration in Australia, see Gillies et al. 2017).

2.2 Data collation

The benefits and costs included in the BCA can be market-based (i.e. tangible, economic, monetary) or non-market based (i.e. intangible, non-monetary).

For market-based benefits and costs, TNC provided the relevant dollar values from their project budget, including information about when they expect particular expenditures to occur (see Section 3.2).

For non-market benefits and costs, it is necessary to first estimate what the anticipated biophysical or social changes might be, and then assign a monetary-equivalent value to those changes. The biophysical (e.g. changes in fish biomass) and social (e.g. changes in visitation) changes were estimated via literature review of the types of changes experienced in similar reef restoration projects internationally (e.g. Carlton et al. 2016) and based on expert judgement. The experts consulted included the TNC project managers, reef and fisheries ecologists, and South Australian government representatives from Department for Environment and Water (DEW), Department of Primary Industries and Regions (PIRSA) and Yorke Peninsula Tourism.

Once the anticipated biophysical and social changes were identified, monetary values were estimated for the benefits and costs. In particular, a process known as benefit transfer was used to estimate the non-market value of intangible benefits. Non-market valuation is an economic approach that measures people's willingness to pay (WTP) for changes in environmental or social outcomes, allowing a monetary-equivalent measure of value to be applied to the intangible benefits or costs of a project (Bateman et al. 2002; Hanley and Barbier 2009). Where sufficient time and resources are available, the collection of primary data via original non-market valuation studies is recommended for improved accuracy; however, when that is not feasible secondary data can be used. Benefit transfer involves the identification of existing non-market valuation case studies that have measured similar types of benefits, ideally in a similar type of decision or policy context and for a similar cultural and geographical population (Johnston et al. 2015). The values estimated in the original study are then applied to the new case study, with adjustments made to improve the accuracy of the value for the new decision context, for example, by adjusting for inflation and wage differences between populations (see Section 3.1).

2.3 BCA

The calculation of benefits and costs in the BCA is represented as the difference in benefits or costs between the with- and without-project scenarios. For example, a benefit related to increased fish biomass should be calculated as the anticipated increase in biomass derived from the with-project scenario, less any anticipated increase in biomass that would have occurred without the project (see Figure 1).

All values in a BCA must be represented as present values by using a discount rate on future benefits and costs (Hanley and Barbier 2009). The Office of Best Practice Regulation (2016) recommends using a social discount rate of 7%, and to test sensitivity to the discount rate by repeating the analysis with rates of 3% and 10%. The discount rate reflects the opportunity cost of the investment, in other words, the return you could expect if you had invested the money in some other way.

Future benefits and costs are converted to present values as follows (Boardman et al. 2017; Commonwealth of Australia 2006; Hanley and Barbier 2009):

$$Present\ value = \sum_{t=0}^{T} \frac{X_t}{(1+r)^t} \qquad \text{Equation 1}$$

Where *X* is the value of the future benefit (or cost) and *r* is the discount rate at time *t*. Benefits that occur in each year *t* are summed over the life of the project, *T* years.

Sometimes the source providing the measure of benefits is not aligned with the timeframe of the project being assessed. This is commonly the case when using WTP estimates from non-market valuation studies, where the payment for the management action may be defined over a set number of payment years (e.g. 5 years, with payments starting in Year 1) but the benefits that are accruing might occur for a longer period of time, and that period may differ between the original study and the new application (i.e. the original may have evaluated the WTP for an infinite stream of benefits, while a project may be evaluated over a fixed time period). In this case, it is necessary to infer what the value would be for the new time horizon. To do that, first we calculate the net present value, *NPV*, of the WTP amount over the payment timeframe specified in the valuation study using Equation 1. Then this value can be converted to an annualised benefit for a shorter time horizon as follows (Commonwealth of Australia 2006):

$$Annualised\ benefit = \frac{r\ (NPV)}{1-(1+r)^{-T}}$$ Equation 2

This annualised benefit can then be used to sum a stream of benefits over timeframe *T*.

In some cases, the benefit that we get is not constant from year to year, and the benefit stream needs to be apportioned on a gradual basis. For example, we may not reach the maximum benefit (equivalent to the annualised benefit) until a number of years into the project. We can calculate benefits on a linear trajectory to allow for the gradual building of the stream of benefits, according to the following equation:

$$Benefit\ (year\ t) = \frac{(Annualised\ benefit)\ t}{T}$$ Equation 3

Once all benefits and costs have been converted to present values the NPV of undertaking the project can be calculated as:

$$NPV = \sum present\ benefits - \sum present\ costs$$ Equation 4

If the NPV is positive, then the project benefits outweigh the costs and indicate the project is a worthwhile investment. When comparing projects, the larger the NPV, the greater the benefits. This measure is useful to compare projects when there are unlimited budgets to invest with as it shows which project will deliver the greatest absolute benefit.

The benefit: cost ratio (*BCR*) is calculated as:

$$BCR = \frac{\sum present\ benefits}{\sum present\ costs}$$ Equation 5

If the BCR is greater than one, then the project generates benefits that outweigh the costs and indicate the project is a worthwhile investment. The larger the ratio, the greater the benefit generated per dollar invested. This measure is more useful for prioritising projects when budgets are limited.

Risk of project failure should be accounted for in the BCA. In this instance, risk has been built into the operating budget for the construction of Windara: a 95% overstocking rate was applied in the oyster seeding to mitigate any loss of oyster stock in the first few years of the project due to disease, invasive species or other threats. The project was also properly engineered to reduce structural risks. The potential for risk in later years of the project still exists: for example, a disease could strike in Year 15, destroying the majority of the oyster stock, and reducing or delaying the stream of benefits associated with reef. There is substantial uncertainty in what risks exist, when they may occur, and the impact they could have on the reef and its benefits. With this in mind, rather than modelling risk of project failure in the BCA, we have identified the capacity of alternative project scenarios to absorb risk, in terms of the proportion of benefit that could be forgone while maintaining a viable or break-even NPV and BCR.

Finally, it is important to consider uncertainty in the variables used to estimate the NPV and BCR. Identification of a range around the estimated values of the benefits and costs – a lower and upper bound – can be used to test the sensitivity of each variable with respect to changes in the decision outcomes of the calculation of NPV and the BCR (Pannell 1997).

3. COSTS OF WINDARA REEF

The cost data include all tangible costs of construction and operating expenses over the life of the project for the with-project scenario. The without-project scenario has zero cost.

Construction costs all occur in the first year of the project, and are therefore already shown in present value terms and do not change dependent on alternative discount rates (Table 1). The operating expenses are shown according the year in which they occur (Table 2), and in terms of their present value (Table 3).

Note that two scenarios are presented (Tables 2,3): (1) a ‘2 year monitoring scenario’, which includes the essential monitoring and maintenance costs that are budgeted for years 1 and 2 of the project; and, (2) a ’10 year monitoring scenario’, which includes an ongoing monitoring and maintenance budget for years 3 to 10 of the project. The first scenario reflects the direct costs of the project; that is, the benefits cannot be achieved without this cost. The second scenario reflects costs that may be relevant to this project, as the first large-scale attempt at shellfish reef restoration in Australia, but that may not be relevant to future projects of this nature. That is, they are primarily associated with monitoring the condition of the reef to establish baseline data and understand how the ecosystem productivity is progressing. Building in a monitoring budget allows for adaptive management of the reef, for example, to identify threats to the oyster stock and to manage the risk of project failure in future years.

Table 1: Construction costs included in the BCA, provided by The Nature Conservancy.

Construction costs: Year 1	
Labour – TNC personnel	$640,242
Labour – PIRSA in-kind support	$510,000
Limestone substrate	$70,000
Oyster seeding supply, including shell preparation, transport & hatchery costs	$183,000
Barge delivery	$200,000
Engineering	$48,720
Construction contracting costs	$1,617,200
Total (present value)	**$3,269,162**

Table 2: Operating costs included in the BCA, provided by The Nature Conservancy.

Operating costs	**Year 1**	**Year 2**	**Years 3-10**
Monitoring & maintenance costs	$40,000	$40,000	$16,000/year
Travel	$18,750	$18,750	
Media & community engagement	$7,500	$7,500	

Table 3: Present value of operating costs under alternate discount rates, for scenarios allowing for a 2 year and 10 year monitoring and maintenance budget.

Discount rate	**3%**	**7%**	**10%**
Present value of 2yr monitoring scenario	$126,767	$119,781	$114,979
Present value of 10yr monitoring scenario	$232,635	$203,230	$185,524

4. BENEFITS OF WINDARA REEF

The key benefits that were identified as being of potential importance for Windara Reef include:

- Environmental benefits, related to improvements in biodiversity and ecosystem functioning;
- Recreational fishing benefits, both for intrastate recreational fishers (including locals and visitors to Yorke Peninsula from within South Australia) and for interstate recreational fishers;
- Educational or research-based tourism;
- Profit to oyster suppliers;
- Profit to charter operators;
- Potential benefit to commercial fishers if the area remains open to fishing.

The estimation of each benefit is discussed below, including the sources of information used to calculate the economic value, assumptions made in the estimation, and the timeframe over which these benefits occur during the life of the project.

4.1 Environmental benefits

The environmental benefits of the reef relate to the improvements in biodiversity, ecosystem functioning and productivity. With respect to these benefits, it is important to consider the with-project and without-project impacts. It is also important to acknowledge that the ecological values of the reef will not appear instantly once the reef is created: ecological systems take time to develop and mature, and the benefits that arise will likewise start low, and increase in line with the ecological development. It is therefore important to identify the timeline over which benefits will evolve. It is anticipated that with the project, the environmental status of Windara Reef will predominantly become established within the first seven years of the project, by which time the majority of the ecosystem services will be functioning. It is assumed that the environmental benefit stream will have reached about 80% of its maximal capacity by this time. It is assumed that the residual environmental benefit will be achieved by Year 30, when the reef will be fully-functioning as a natural, sustainable oyster reef.

Without the project, it is anticipated that there would be a gradual decline in the quality of the productive ecosystems that were located at the site prior to construction of the oyster reef: the area comprised approximately 25% seagrass habitat[1]. It is likely that up to 20% of the remaining seagrass habitat would have been lost over the 30 year time period without the project, due to existing threats

[1] Note that the with-project scenario implicitly requires the removal of this seagrass habitat, which could be viewed as an environmental cost during the first few months of the project when the habitat is being disrupted. However, given that (a) this 25% area of seagrass habitat is being replaced with a more productive oyster reef habitat, (b) the reef habitat will begin to have an environmental benefit during the first year, and (c) the non-market value estimated for the reef habitat is considered to be extremely conservative (see footnote 3), this cost is considered to be negligible and was omitted from the analysis.

and pressures on the environment. Figure 3 illustrates how the change in non-market environmental benefits for the with- and without-project scenarios would occur over the 30 year timeframe of the project.

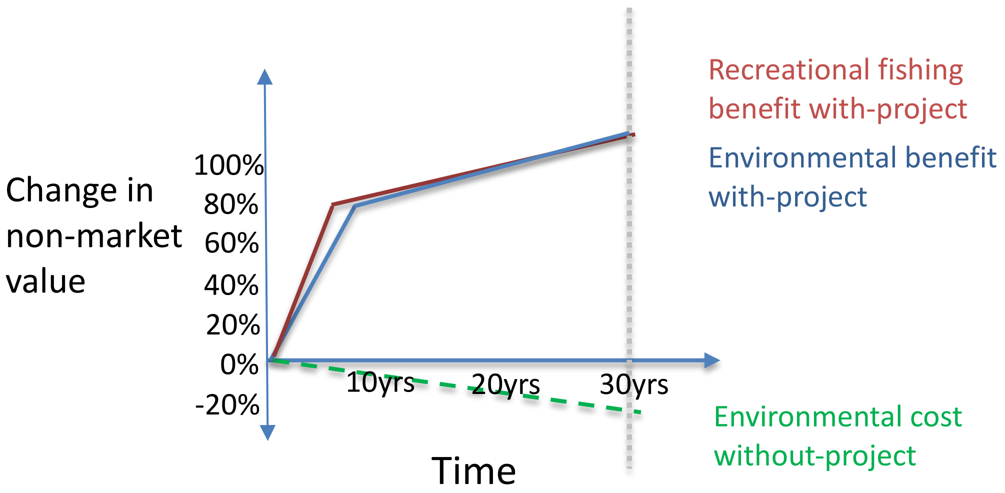

Figure 3. Occurrence of environmental and intrastate recreational fishing non-market benefits over the life of the project.

4.1.1 Environmental benefits – with the project

Individuals value the existence of marine habitats for their biodiversity, ecosystem functioning and productivity, and this can be expressed in terms of their WTP to protect them. Hatton MacDonald et al. (2015) conducted a non-market valuation of people's WTP for healthy reefs in Gulf St Vincent. They found that South Australian households were willing to pay $7.38 per year for a five year payment period for one additional healthy reef, in 2014AUD.

To estimate the present value of environmental benefits for Windara, a number of calculations were performed:

1. CPI adjustment: the study value of $7.38 was measured in 2014 AUD. In 2017 AUD this equates to a WTP of $7.73 per household per year for 5 years[2].

2. Adjustment to a per hectare value of reef in good condition: Hatton MacDonald et al. (2015) included 19 reefs from the Gulf St Vincent area in their study, and WTP is calculated per reef in good condition. To equate this to Windara, we needed to account for the size of the reefs that were included in the study and establish a per hectare value of reef, which can then be applied to the 16ha Stage Two Windara site.

[2] CPI adjustments here and elsewhere have been made using the RBA Inflation calculator, available at: https://www.rba.gov.au/calculator/

   a. DEW provided data on the approximate size for eight of the reefs (Table 4). We used this information to identify the median size of the reefs included in the study (51ha), and translated this to a per hectare WTP amount ($0.15/ha, Table 5).

   b. To test sensitivity of the WTP per hectare, we used the reef sizes either side of the median, 86ha (Semaphore reef) and 16ha (Seacliff reef), to inform the range for the lower and upper bound estimate of WTP/ha used in the BCA, respectively (Table 5)[3].

3. The WTP/hectare/household value was multiplied over the 16ha of the Windara Reef ($2.43/household, Table 5).

4. Aggregation by number of households: as the environmental benefits relate to existence (passive use) values, the relevant population who could hold these values for the reef is inclusive of the South Australian population. The 2016 Census[4] data states that there are 765,786 households in South Australia. The WTP/household for a 16ha reef was multiplied by the number of households to provide the aggregate WTP/year for the reef (Table 5). This amount applies each year for the 5 year payment period.

5. The NPV of WTP for environmental benefits of the reef was calculated over the 5 year payment period, using Equation 1, for discount rates of 3%, 7% and 10% (Table 6).

6. The annualised benefit was calculated using Equation 2 (Table 6).

7. The benefit stream was apportioned using Equation 3. It was assumed that 80% of maximal benefit would be reached by Year 7 (on a linear trajectory from Year 1 to 7), with the remaining 20% of the benefit achieved over the next 23 years (on a linear trajectory from Year 8 to 30, in addition to the benefit already achieved by Year 7) to reach the maximum benefit (equivalent to the annualised benefit) in Year 30 (see Figures 2 and 3).

8. The discounted benefits over the 30 years were summed, shown in Table 7.

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[3] We note that even the upper bound estimate of the values used is likely to a conservative estimate of the environmental value of Windara Reef: the original study focussed on restoring *existing* reefs back to a healthy condition, rather than constructing an entirely new reef (i.e. the net change is likely to be larger for the new reef). In addition, Windara Reef represents an ecosystem that no longer exists in the region which means it is likely to have a higher marginal value (i.e. the law of diminishing marginal utility, see Hanley and Barbier 2009 p.25). However, due to lack of available information about values for this type of ecosystem, we are unable to reliably extrapolate beyond the estimates used in Hatton MacDonald et al. (2015).

[4] Available at: http://quickstats.censusdata.abs.gov.au/census_services/getproduct/census/2016/quickstat/4

Table 4. Gulf St Vincent reefs included in Hatton MacDonald et al. 2015 (Area data provided by DEW).

Reef name	Approximate area (ha)
Glenelg blocks	0.6
Noarlunga Sth	2.6
Noarlunga Nth	7
Seacliff	16
Semaphore	86
Moana	164
Broken Bottom	190
Aldinga	688

Table 5. Transformation of WTP (reported in 2017AUD) per hectare of reef in good condition to aggregate value for Windara Stage Two reef.

	Lower bound	Estimated value	Upper bound
Median reef area from Hatton MacDonald et al. (2015)	86	51	16
WTP/household/ha of reef in good condition	$0.09	$0.15	$0.48
WTP/household for a 16ha reef in good condition	$1.44	$2.43	$7.73
Aggregate WTP for a 16ha reef in good condition	$1,101,307	$1,857,106	$5,919,526

Table 6. NPV of aggregate WTP for environmental benefits of the with-project scenario over the 5 year payment period from Hatton MacDonald et al. (2015), and annualised benefit of the NPV.

Discount rate	3%	7%	10%
NPV of aggregate WTP			
Lower bound	$5,043,664	$4,515,577	$4,174,820
Estimated value	$8,505,002	$7,614,502	$7,039,893
Upper bound	$27,109,695	$24,271,224	$22,439,660
Annualised benefit			
Lower bound	$257,324	$230,381	$212,996
Estimated value	$433,919	$613,625	$746,787
Upper bound	$1,383,117	$1,955,931	$2,380,382

Table 7. Sum of the NPV of environmental benefits, including the with- and without-project benefits.

	Lower bound	Estimated value	Upper bound
		3% Discount rate	
NPV with-project	$3,784,007	$6,380,874	$20,339,036
NPV without-project (avoided loss)	$0	$25,401	$124,516
SUM of NPV	$3,784,007	$6,406,275	$20,463,552
		7% Discount rate	
NPV with-project	$1,951,594	$5,198,109	$16,568,974
NPV without-project (avoided loss)	$0	$18,360	$89,999
SUM of NPV	$1,951,594	$5,216,469	$16,658,973
		10% Discount rate	
NPV with-project	$1,274,408	$4,468,205	$14,242,404
NPV without-project (avoided loss)	$0	$14,491	$71,035
SUM of NPV	$1,274,408	$4,482,696	$14,313,439

4.1.2 Environmental benefits – without the project

To account for the 20% marginal decline in environmental benefit of the seagrass habitat that would have occurred over the 30 years without the Windara Reef being constructed, WTP data was again drawn from Hatton MacDonald et al. (2015). The study also measured people's WTP for protection of seagrass beds in Gulf St Vincent. In this instance, the protection of the seagrass was linked to the provision of habitat for species targeted by recreational fishers. Therefore, this value implicitly accounts for any loss in recreational fishing benefit that may have occurred without the project, in addition to the loss of environmental benefit.

Hatton MacDonald et al. (2015) estimated that South Australian households were willing to pay $1.95/year for five years for a 1% increase in area of seagrass habitat, which equated to a 100ha area. To estimate the present value of the environmental loss without the project, a number of calculations were performed:

1. CPI adjustment: the study value of $1.95 was measured in 2014 AUD. In 2017 AUD this equates to a WTP of $2.04 per household per year for 5 years for a 100ha area of seagrass, or $0.02/ha.
2. The WTP value was equated to a 20% loss (0.8ha) of the remaining 4ha area of seagrass at the Windara site, which provided an estimated value of $0.02/household/year for five years (in 2017AUD).
3. To test the sensitivity of the impact on seagrass habitat for the without-project scenario the WTP value was also equated to:
    a. A lower bound estimate of no seagrass being lost (0ha), which is equivalent to $0 in value lost;

   b. An upper bound estimate of all seagrass being lost (4ha), which is equivalent to $0.08/household/year for five years.

4. The values in steps 2 and 3 were aggregated by number of South Australian households, NPV of WTP was calculated over the 5 year payment period, and the annualised benefit was calculated as for steps 4-6 in Section 4.1.1 above (Table 8).

5. The benefit stream was apportioned assuming that the benefits were distributed on a linear trajectory from Year 1 to 30, as per Equation 3 (see Figure 3).

6. The discounted benefits over the 30 years were summed, shown in Table 7.

Table 8. NPV of aggregate WTP for environmental benefits (avoided loss) of the without-project scenario over the 5 year payment period from Hatton MacDonald et al. (2015), and annualised benefit of the NPV.

Discount rate	**3%**	**7%**	**10%**
NPV of aggregate WTP			
Lower bound	\$0	\$0	\$0
Estimated value	\$57,235	\$51,243	\$47,376
Upper bound	\$280,566	\$251,190	\$232,235
Annualised benefit			
Lower bound	\$0	\$0	\$0
Estimated value	\$2,920	\$4,129	\$5,026
Upper bound	\$14,314	\$20,242	\$24,635

4.2 Intrastate recreational fishing benefits

The recreational benefits associated with reef construction depend critically on assumptions about whether the new reef will create additional fishing trips, or whether there will be substitution of effort from elsewhere, but with increased satisfaction for those trips. For intrastate recreational fishers, we assume the latter. There is an abundance of recreational fishing sites along the South Australian coast, particularly around the Gulf St Vincent and Yorke Peninsula region. Therefore, it is assumed that only those fishers who are in close proximity to the Windara Reef site and likely to consider shifting fishing locations.

Note that the benefits of the without-project scenario are assumed to be zero: the number of substitute sites available for recreational fishing in South Australia mean that any decline in environmental quality at the reef site are unlikely to have an impact on recreational fishing ability. In addition, the valuation of lost environmental benefit of the without-project scenario implicitly includes loss of recreational fishing value (see Section 4.1.2).

Data on recreational fishing effort was drawn from Giri and Hall (2015), and 2016 Census[5] data was used to refine the scale of fishing effort to households in the three nearby townsites of Port Victoria, Port Vincent and Stansbury.

In the Yorke Peninsula and Lower North regions (Giri and Hall 2015):

- There are 19,183 households;
- There are 14,935 individuals who go fishing;
- 4.9 days are spent fishing on average per fisher.

The towns of Port Victoria, Port Vincent and Stansbury account for approximately 9% of households in the region. Assuming the spatial distribution of recreational fishers across the region is uniform, this translates to a population of approximately 1,323 recreational fishers who might consider fishing at Windara Reef as a substitute to their local fishing spot.

Pascoe et al. (2014) estimated the WTP for improved satisfaction of a recreational fishing trip, based on increased catch, in Moreton Bay, Queensland, with data collected in 2011. They report that individual (marginal) WTP for a 50% increase in catch rate (related to improved satisfaction) is $3.80 per trip[6].

To estimate the present value of intrastate recreational fishing benefits, the following adjustments and calculations were made:

1. CPI adjustment: the study value of $3.80 was measured in 2011 AUD. In 2017 AUD this equates to a WTP of $4.60 per fisher per trip.
2. Income adjustment: median weekly earnings of households in the Yorke Peninsula region in the 2016 Census[7] were 66% of the weekly earnings reported for the sample in Pascoe et al. (2014)

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[5] Available at:
Stansbury:
http://quickstats.censusdata.abs.gov.au/census_services/getproduct/census/2016/quickstat/SSC41365?opendocument
Port Victoria:
http://quickstats.censusdata.abs.gov.au/census_services/getproduct/census/2016/quickstat/SSC41199?opendocument
Port Vincent
http://quickstats.censusdata.abs.gov.au/census_services/getproduct/census/2016/quickstat/SSC41200?opendocument

[6] Pascoe et al. (2014) also report WTP estimates for improved satisfaction from doubling the catch rate on a fishing trip. Given the fishing conditions in the broader Gulf St Vincent area, the WTP for the more conservative 50% increase in catch rate was considered to be a more appropriate measure: while Windara Reef will provide reliable aggregations of fish, there are other substitute sites in the Gulf that would provide a similar experience with respect to catch rates.

[7] Available at:
http://quickstats.censusdata.abs.gov.au/census_services/getproduct/census/2016/quickstat/40504?opendocument

(when the sample earnings are converted to equivalent 2016AUD). Accordingly, the WTP was adjusted to $2.81 per fisher per trip (2017AUD).

3. We assumed that every individual fisher will make 1 of their 5 fishing trips to Windara. To test sensitivity to this assumption, a lower bound is set to 1 in every 2 fishers making 1 trip to Windara, and an upper bound where every fisher makes 3 of their 5 trips to Windara (Table 9).

4. The annual benefit was calculated by multiplying the number of trips by the WTP value of $2.81 (Table 9).

5. The benefit stream was apportioned in two stages:

    a. 80% of maximal benefit was achieved by Year 5, calculated on a linear trajectory across the first 5 years (see Figures 2 and 3 and Equation 3);

    b. The residual 20% of the benefit was distributed on a linear trajectory across years 6 to 30, in addition to the benefit already achieved by Year 5, with the maximum benefit (equivalent to the annualised benefit) reached in Year 30.

6. Benefits were calculated for discount rates of 3%, 7% and 10% for the estimated value and the lower and upper bound values.

7. The benefits over the 30 years were summed, shown in Table 10.

Table 9. Estimated number and annual benefit of intrastate recreational fishing trips to Windara Reef.

	Lower bound	Estimated value	Upper bound
Number of fishing trips	661	1323	3968
Annual benefit (WTP)	$1,860	$3,719	$11,157

Table 10. Present value of intrastate recreational fishing benefits.

Discount rate	3%	7%	10%
Lower bound	$28,917	$17,047	$12,263
Estimated value	$57,834	$34,094	$24,526
Upper bound	$173,502	$102,282	$73,578

4.3 Interstate recreational fishing benefits

Windara Reef presents an opportunity to draw interstate visitation from recreational fishers through marketing of the reef for this purpose and the potential to host recreational fishing events or competitions at the site. The without-project scenario equates to zero benefits.

The Regional Tourism Profile for Yorke Peninsula (South Australian Tourism Commission 2017) provides the following profile of current levels of visitation:

- Interstate visitors who stay overnight: 61,000
- Average length of stay for visitors to the region: 4 nights
- Proportion of domestic visitors who go fishing: 35%

This equates to 21,350 recreational fishers among the interstate visitors, and 85,400 nights spent in the region by these visitors.

Tourism Research Australia (2015) indicate that the average spend per night of visitors to Yorke Peninsula during 2015 was $92.

To estimate the present value of interstate recreational fishing benefits, the following adjustments and calculations were made:

1. CPI adjustment: the average spend per night of $92 was measured in 2015AUD. In 2017 AUD this equates to a spend of $94.99 per night.

8. We estimated that the increase in visitation would be 5% of the current number of interstate recreational fishers[8] (i.e. 5% of 21,350 current visitors = 1,068). To test sensitivity to this assumption, a lower bound is set to a 0% increase in visitation, and an upper bound of a 25% increase in visitation (Table 11).

2. The annual benefit was calculated by multiplying the number of trips by the average length of stay (4 nights), and then by the average spend per night ($94.99) (Table 11).

3. The benefits were anticipated to begin in Year 6, after the majority of recreational fishing opportunity is established (see Figure 2), and to occur on an annual basis until Year 30.

4. Benefits were calculated for discount rates of 3%, 7% and 10% for the estimated value and the lower and upper bound values.

5. The benefits over the 30 years were summed, shown in Table 12.

[8] This figure is based on consultation with Yorke Peninsular Tourism, The Nature Conservancy, and unpublished data from EconSearch for a terrestrial eco-tourism project in the Yorke Peninsular region where a pull factor of 4% is estimated.

Table 11. Estimated increase in visitation by interstate recreational fishers and annual benefit generated.

	Increase in visitation	Number of visits	Number of nights	Aggregate spend (annual benefit)
Lower bound	0%	0	0	$0
Estimated value	5%	1068	4270	$405,607
Upper bound	25%	5338	21350	$2,028,037

Table 12. Present value of recreational fishing benefits from increased interstate visitation.

Discount rate	3%	7%	10%
Lower bound	$0	$0	$0
Estimated value	$6,092,519	$3,370,128	$2,286,055
Upper bound	$30,462,597	$16,850,638	$11,430,273

4.4 Educational tourism benefits

In addition to recreational fisher visitation, Windara Reef also offers a market for educational tourism. The novelty, in terms of scale, of the shellfish reef restoration effort means that it will be an important research site. The without-project scenario equates to zero benefits.

We envisage that restoration experts will travel to the region and research meetings will be held (e.g. conferences, workshops, symposia), with the following assumptions:

1. The average spend per night is $94.99 (see Section 4.3).
2. Approximately 50 researchers, experts, Government or NGO representatives, or similar will visit the region to attend such an event, staying for 2 nights. To test sensitivity to this estimate, we set a lower bound of 25 visitors for 2 nights, and an upper bound of 100 visitors for 2 nights (Table 13).
3. At least one major education/research event will be held each year for the first 10 years of the project; a major event will subsequently be held on each five year anniversary of the reef's construction (Years 15, 20, 25, 30).
4. Benefits were calculated for discount rates of 3%, 7% and 10% for the estimated value and the lower and upper bound values.
5. The benefits over the 30 years were summed, shown in Table 14.

Table 13. Estimated increase in visitation from educational tourism and annual benefit generated.

	Number of visits	Number of nights	Aggregate spend (annual benefit)
Lower bound	25	50	$4,750
Estimated value	50	100	$9,499
Upper bound	100	200	$18,998

Table 14. Present value of educational tourism benefits.

Discount rate	3%	7%	10%
Lower bound	$50,418	$37,806	$31,737
Estimated value	$100,835	$75,613	$63,474
Upper bound	$201,670	$151,225	$126,949

4.5 Oyster supplier benefits

The commercial company supplying the oyster seeding products will make a profit from the revenue generated from the Windara Reef project. The without-project scenario has no benefit.

Data on the proportion of profit generated from revenue is not readily available, with the exception of one South Australian source[9]. Of annual revenue generated ($900,000) for the commercial oyster farm approximately 44% was considered profit ($400,000 annually), though it was unclear whether personnel costs were removed. The farm required two full time employees to operate, which would approximately halve the stated profits.

To estimate the profit to the oyster supplier, we made the following assumptions:

1. Revenue equates to the cost of oyster supply to the project of $183,000 (see Table 1).
2. Profit is 22% of the revenue generated ($40,667). To test sensitivity of this assumption:
    a. A lower bound estimate of profit was set to 0% ($0), on the basis that a supplier may provide oyster seed for a restoration project at cost-price.
    b. An upper bound estimate of profit was set to 44% ($81,333), on the basis that personnel costs were already removed from the profits stated by the source.

As these benefits occur in Year 1 of the project discounting of values is not necessary.

[9] Commercial proprietors will generally keep this information in confidence. However, we were able to locate a statement regarding revenue and profit for a South Australian oyster farm advertising an expansion partnership (see: http://chinaconnections.com.au/2017/05/oyster-farming-expansion-export-public-listing/)

4.6 Charter operator benefits

The construction of Windara Reef creates opportunity for a commercial charter operator to begin eco-tours or recreational fishing charters to the reef. The without-project scenario has zero benefit for charter operators.

An understanding of current demand for charter tours was provided by Yorke Peninsular Tourism, leading to the following assumptions of the benefits that would be generated:

1. One charter boat would operate on the reef, with capacity for 20 passengers (10 adults, 10 children).

2. The boat would make trips to the reef on an average of 2 days per week (e.g. on weekends). To test sensitivity to this assumption, we assumed a lower bound frequency of 0 trips per week, and an upper bound frequency of 7 days per week (Table 15).

3. Ticket prices would be $40 per adult, $20 per child[10]. Profit from ticket prices would be 50% (Table 15).

4. Operation would begin in Year 2 of the project after construction is complete, and continue through to year 30.

5. Benefits were calculated for discount rates of 3%, 7% and 10% for the estimated value and the lower and upper bound values, and summed over the 30 years (Table 16).

Table 15. Estimated trip frequency of charter operator and annual benefit generated.

	Trips per week	Trips per year	Profit per year (annual benefit)
Lower bound	0	0	$0
Estimated value	2	104	$31,200
Upper bound	7	364	$109,200

Table 16. Present value of charter operation benefits.

Discount rate	3%	7%	10%
Lower bound	$0	$0	$0
Estimated value	$581,243	$358,003	$265,756
Upper bound	$2,034,349	$1,253,011	$930,146

[10] Ticket prices are based off similar tours operating in the region (e.g. see: http://www.thebigduck.com.au/)

4.7 Commercial fishing benefits

Impacts on commercial fisheries as a result of the Windara Reef construction are unclear. Given the water depth at Windara and current spatial effort of the various fisheries operating in the Gulf St Vincent area, the marine scalefish fishery (particularly the snapper fishery) is the only fishery operating in the area that is likely to be affected. On consultation with PIRSA and DEW, it is likely that the reef area – when considered in isolation – will have no impact on catch rate or effort, given the size of the snapper fishery (State wide). However, when cumulative impacts of other marine park and spatial fisheries management closures are considered, an impact is possible. The without-project scenario has zero impact.

The estimated value for commercial fishing impact is zero. However, in testing the sensitivity of this assumption, the lower and upper bounds consider that there may be a negative or positive impact on the snapper fishery, respectively. If Windara Reef remains closed to commercial fishing (the most likely policy scenario), and snapper aggregate at the reef (particularly during spawning season), this may reduce the available catch for fishers. Alternatively, if the Reef was to be opened to commercial fishing, and snapper aggregate at the reef during seasons where biomass is low, the known aggregation of the fish could enable fishers to maintain their catch rate.

Morison et al. (2013) examined the economic impact of temporal spatial closures on commercial catch of snapper in Gulf St Vincent, over a proposed closure area of 1,030km^2. The value of output (less the cost of goods and services to produce the output) lost due to the proposed spatial closure over 45 days was estimated to be $1,160,000 (2013AUD).

Estimates of the benefit (or cost) to commercial fishers utilised this data with the following assumptions:

1. CPI adjustment: the output value of $1,160,000 was measured in 2013AUD. In 2017 AUD this equates to $1,246,019.
2. Assuming a uniform spatial impact of the closure, the output value is $1,209/km^2.
3. For a 16ha area, or 0.16km^2, the value would be $193.47.
4. For a 12 month closure, the value would be $1,547.79. This provides the cost of closure of the reef to commercial fishing in the lower bound, and the benefit of opening the reef to commercial fishing in the upper bound.
5. The output value would apply every year over the life of the project.
6. Benefits (or costs) were calculated for discount rates of 3%, 7% and 10% for the estimated value and the lower and upper bound values, and summed over the 30 years (Table 17).

Table 17. Present value of commercial fishing costs (lower bound value) or benefits (upper bound value).

Discount rate	3%	7%	10%
Lower bound	-$30,337	-$19,207	-$14,591
Estimated value	$0	$0	$0
Upper bound	$30,337	$19,207	$14,591

5. BENEFIT COST ANALYSIS RESULTS

The present values of the benefits and costs defined in sections 3 and 4 are summarised in Table 18. These were used to calculate the NPV and BCR according to equations 4 and 5, respectively (Table 19), as well as the capacity of the alternative scenarios to absorb risk.

The results show that for the estimated values, the Windara Reef investment provides a positive NPV and a BCR greater than 1, indicating the investment has a positive return on dollars spent (Table 19). The benefits are almost four times the costs when the discount rate is low (3%), and are still double the costs when the discount rate is high (10%).

The impact of including the additional monitoring and maintenance costs for the 10 year scenario relative to the 2 year scenario is minimal: the decision outcome regarding the viability of the investment does not hinge on this factor as the difference in costs is small.

The capacity of the alternative project scenarios to absorb risk is also noted. With the exception of cases where lower bound values are used, the project has the capacity to absorb over a 50% risk of failure. That is, over 50% of the benefit stream could be lost – or there could be a 50% expected rate of total failure – and the project investment would still be viable.

Table 18. Summary of the present values of costs and benefits for alternative project scenarios for the Windara Stage Two reef: with values presented for discount rates of 3, 7 and 10%; for the estimated values and the lower and upper bound ranges of these values; and for the 2 year and 10 year operating cost scenarios.

	Lower bound			Estimated value			Upper bound		
Discount rate	**3%**	**7%**	**10%**	**3%**	**7%**	**10%**	**3%**	**7%**	**10%**
COSTS									
Capital costs	$3,269,162	$3,269,162	$3,269,162	$3,269,162	$3,269,162	$3,269,162	$3,269,162	$3,269,162	$3,269,162
2yr operating costs	$126,767	$119,781	$114,979	$126,767	$119,781	$114,979	$126,767	$119,781	$114,979
10yr operating costs	$232,635	$203,230	$185,524	$232,635	$203,230	$185,524	$232,635	$203,230	$185,524
Commercial fishing*	$30,337	$19,207	$14,591	$0	$0	$0	$0	$0	$0
TOTAL NPV COSTS									
2yr scenario	**$3,426,267**	**$3,408,150**	**$3,398,732**	**$3,395,929**	**$3,388,943**	**$3,384,141**	**$3,395,929**	**$3,388,943**	**$3,384,141**
10yr scenario	**$3,532,134**	**$3,491,599**	**$3,469,277**	**$3,501,797**	**$3,472,392**	**$3,454,686**	**$3,501,797**	**$3,472,392**	**$3,454,686**
BENEFITS									
Environmental	$3,784,007	$1,951,594	$1,274,408	$6,406,275	$5,216,469	$4,482,696	$20,463,552	$16,658,973	$14,313,439
Rec fish - intrastate	$28,917	$17,047	$12,263	$57,834	$34,094	$24,526	$173,502	$102,282	$73,578
Rec fish - interstate	$0	$0	$0	$6,092,519	$3,370,128	$2,286,055	$30,462,597	$16,850,638	$11,430,273
Education tourism	$50,418	$37,806	$31,737	$100,835	$75,613	$63,474	$201,670	$151,225	$126,949
Oyster supplier	$0	$0	$0	$40,667	$40,667	$40,667	$81,333	$81,333	$81,333
Charter operator	$0	$0	$0	$581,243	$358,003	$265,756	$2,034,349	$1,253,011	$930,146
Commercial fishing*	$0	$0	$0	$0	$0	$0	$30,337	$19,207	$14,591
TOTAL NPV BENEFITS	**$3,863,341**	**$2,006,447**	**$1,318,408**	**$13,279,373**	**$9,094,973**	**$7,163,174**	**$53,447,341**	**$35,116,669**	**$26,970,309**

*Note: The impact on commercial fishing is represented as a cost where it is assumed that the reef is closed to commercial fishing activity, and a benefit where it is open.

Table 19. NPV, BCR and risk capacity for the alternative project scenarios for the Windara Stage Two reef: with scenarios representing outcomes calculated at discount rates of 3, 7 and 10%; for the estimated values and the lower and upper bound ranges of these values; and for the 2 year and 10 year operating cost scenarios.

	Lower bound			Estimated value			Upper bound		
Discount rate	**3%**	**7%**	**10%**	**3%**	**7%**	**10%**	**3%**	**7%**	**10%**
NPV OF PROJECT									
2yr scenario	$437,075	-$1,401,702	-$2,080,324	$9,883,444	$5,706,030	$3,779,033	$50,051,412	$31,727,726	$23,586,168
10yr scenario	$331,207	-$1,485,151	-$2,150,868	$9,777,576	$5,622,581	$3,708,488	$49,945,544	$31,644,277	$23,515,623
BCR OF PROJECT									
2yr scenario	1.128	0.589	0.388	3.910	2.684	2.117	15.739	10.362	7.970
10yr scenario	1.094	0.575	0.380	3.792	2.619	2.073	15.263	10.113	7.807
RISK CAPACITY									
2yr scenario	11%	-70%	-158%	74%	63%	53%	94%	90%	87%
10yr scenario	9%	-74%	-163%	74%	62%	52%	93%	90%	87%

In testing the sensitivity of the estimated values with respect to the decision outcomes of the BCA, we note that when the upper bound estimates are used, the project becomes increasingly more worthwhile as the discount rate reduces, with benefits as great as 15 times the costs for a 3% discount rate (Table 19).

However, if the lower bound estimates are assumed across all benefits, the project is sensitive to the choice of discount rate and is only viable when the rate is 3%. With this in mind, we investigated which variables are most important for changing the viability of the project at the lower bound.

By maintaining the lower bound estimates for all benefits with the exception of either the environmental benefits (Table 20) *or* the interstate recreational fishing tourism benefits (Table 21), and setting either of these back to the estimated values, the project becomes viable again across all discount rates. The interstate tourism appears to have a larger impact on project viability at the 3% discount rate, but is more sensitive to the choice of discount rate than the environmental benefit.

Table 20. NPV and BCR when environmental benefits are set to the estimated values, all other benefits at lower bound values.

		3%	7%	10%
NPV OF PROJECT				
2yr		$3,059,343	$1,863,173	$1,127,964
10yr		$2,953,475	$1,779,724	$1,057,420
BCR OF PROJECT				
2yr		1.893	1.547	1.332
10yr		1.836	1.510	1.305

Table 21. NPV and BCR when interstate recreational fishing benefits are set to the estimated values, all other benefits at lower bound values.

		3%	7%	10%
NPV OF PROJECT				
2yr		$6,529,594	$1,968,425	$205,731
10yr		$6,423,726	$1,884,976	$135,186
BCR OF PROJECT				
2yr		2.906	1.578	1.061
10yr		2.819	1.540	1.039

6. SUMMARY

The outcomes from the BCA are generally supportive of the Windara Reef Stage Two investment. The only exception to this is when we assume a lower range of benefits in testing sensitivity of the estimated values, for higher discount rates. The key factors that are driving this outcome are the environmental and the interstate recreational fishing benefits. Provided at least one of these two benefits meets or exceeds our estimated values for them, the project is viable even when all other benefits are set to a lower range value and when discount rates are high. This is true even if we assume an ongoing monitoring and maintenance cost for the first 10 years of the project.

The environmental and interstate recreational fishing benefits are critical to the viability of the project given their magnitude. The importance of these benefits in influencing the outcomes of the BCA for Windara will have implications for establishing the viability of future investments in shellfish reef restoration. With this in mind, it will be important to capture baseline data on the actual environmental and recreational fishing benefits that Windara Reef generates over the longer term. Having more confidence in the estimated biophysical and social outcomes that can be achieved through a restoration project will enable a more accurate economic valuation of these benefits[11].

The magnitude of these benefits make them important considerations for future management of Windara Reef, particularly in relation to recreational fishery policy. Provided the environmental benefits accrue to the predicted values, the project can still generate a net benefit even if recreational fishing access to the reef is removed. However, if the environmental benefits are smaller than predicted, it may be necessary to balance this by maintaining some level of recreational fishing access (without further compromising the environmental benefit) to ensure the project remains a positive investment. For example, if recreational fishing pressure becomes a threat to the environmental benefits of the reef, options could be considered to have a seasonal event on the reef to attract interstate visitation, where the majority of the recreational fishing benefit is generated, and otherwise close the reef from fishing. Community engagement to promote Windara Reef will be important in helping to secure the predicted environmental and recreational fishing benefits.

The outcomes of the BCA are quite robust to the risk of project failure, which provides further confidence in the viability of the project. However, an issue identified in modelling project risk is that of when risks may occur, and what magnitude of impact they may have on the future stream of benefits. The lack of baseline data on shellfish reefs generally, and in relation to predicting project risks in particular, reinforces the need for the ongoing monitoring of Windara over the longer term. Given the monitoring costs included in our 10 year scenario do not alter the positive outcomes of the BCA, we

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[11] While the primary source of the uncertainty in our analysis stems from the need to have more confidence in non-economic data, there can also be uncertainty introduced through the approaches used to estimate the economic value of the assumed biophysical and social outcomes. One of the most important limitations is the lack of accurate primary data on the non-market values of environmental and social outcomes associated with marine habitat restoration in Australia. This leads to a reliance on secondary data, through benefit transfer. Johnston et al. (2015) provide an overview of best practice benefit transfer for environmental valuation, and note the importance of being able to closely match the valuation context from the study source with the project being assessed: where there is a poor match, there is a higher likelihood of large transfer errors being made, leading to over- or under-estimation of actual values.

recommend that this activity is undertaken to improve our future understanding of the benefits, costs and risks of shellfish reef restoration.

Due to lack of available data and understanding about the benefits of shellfish reef restoration projects, some potential benefits were not captured in the BCA. For example, as the first large-scale project attempted in Australia, this project is likely to generate substantial research benefits in terms of improved scientific knowledge. The project is also likely to be used as leverage to initiate a Sea Ranger program that will generate benefits for the Indigenous community in terms of skills that can be adapted for future employment. Further, it is envisaged that Windara will contribute to the promotion of eco-tourism and brand awareness for the Yorke Peninsular region more broadly, in conjunction with other environmental initiatives, which could generate an overall increase in tourist visitation to the region, beyond that expected from interstate recreational fisher and educational tourism. Each of these potential benefits will also generate costs, for example in terms of labour and marketing. A smaller scale benefit not captured is the amenity value for local divers. The reef presents a new dive location, although the number of divers visiting the site is anticipated to be small.

Finally, it is worth reiterating that Australian flat oyster reefs used to be a dominant habitat-forming ecosystem in many areas in southern Australia, and these habitats are now functionally extinct. The added value of returning a functionally extinct ecosystem, over and above the value of restoring a habitat that is not extinct, has not be quantified but is likely to be an important component of the overall value. Had it been possible to quantify all of these additional benefits (and their associated costs) and include them in the BCA, it is possible that all project scenarios, including those at the lower bound with high discount rates, may have generated a positive outcome in terms of the NPV and BCR.

Overall, the analysis of benefits and costs for the Windara Reef State Two restoration project show that the project is viable and robust to the inclusion of additional monitoring costs, to uncertainty in the estimated benefits, to project risks and to a range of social discount rates. This integrated economic assessment, inclusive of market (tangible) and non-market (intangible) values associated with reef restoration, provides justification for undertaking the Windara Reef Stage Two extension, and support for further investment in ongoing monitoring of the reef to gather baseline data. The collection of baseline data over the next 10 years will be particularly important: it would enable a retrospective assessment of whether the assumed environmental and social outcomes of the restoration project are being met, and the BCA could be updated with more accurate information. The translation of the findings from this BCA to inform other restoration investments must be approached with caution, as the benefits and costs of particular projects can be unique. As more case studies on BCA for marine and coastal habitat restoration develop, it may be possible to draw inferences from this modelling to inform decision making for restoration investment more broadly.

REFERENCES

Alleway, H.K., and Connell S.D., 2015. Loss of an ecological baseline through the eradication of oyster reefs from coastal ecosystems and human memory. Conservation Biology 29, 795-804

Balmford, A., Bruner, A., Cooper, P., Costanza, R., Farber, S., Green, R.E., Jenkins, M., Jefferiss, P., Jessamy, V., Madden, J., Munro, K., Myers, N., Naeem, S., Paavola, J., Rayment, M., Rosendo, S., Roughgarden, J., Trumper, K. and Turner, R. K. 2002. Economic Reasons for Conserving Wild Nature. Science, 297(5583): 950-953.

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

Beck, M.W., Brumbaugh, R.D., Airoldi, L., Carranza, A., Coen, L.D., Crawford, C., Defeo, O., Edgar, G.J., Hancock, B., Kay, M.C. and Lenihan, H.S., 2011. Oyster reefs at risk and recommendations for conservation, restoration, and management. *Bioscience*, 61 (2), 107-116.

Boardman, A.E., Greenberg, D.H., Vining, A.R. and Weimer, D.L. 2017. Cost-Benefit Analysis: Concepts and Practice 4th Edition, Cambridge University Press.

Carlton, J. S., Ropicki, A., and Balboa, B. 2016. The Half Moon Reef Restoration: A Socioeconomic Evaluation. Texas Sea Grant Publication TAMU-SG-16-211. Texas Sea Grant College Program, College Station Texas.

Commonwealth of Australia 2006. Handbook of Cost Benefit Analysis. Financial Management Reference Material No. 6, Department of Finance and Administration, Canberra.

Gillies, C.L., Crawford, C. and Hancock, B. 2017. Restoring Angasi oyster reefs: What is the endpoint ecosystem we are aiming for and how do we get there? Ecological Management & Restoration, 18(3): 214-222.

Gillies, C.L., McLeod, I.M., Alleway, H.K., Cook, P., Crawford, C., Creighton, C., Diggles, B., Ford, J., Hamer, P., Heller-Wagner, G., Lebrault, E., Le Port, A., Russell, K., Sheaves, M. and Warnock, B. 2018. Australian shellfish ecosystems: past distribution, current status and future direction. PLoS ONE, 13(2): e0190914 (available at: https://doi.org/10.1371/journal.pone.0190914).

Giri K and Hall K (2015) South Australian Recreational Fishing Survey. Fisheries Victoria Internal Report Series No. 62.

Grabowski, J.H., Brumbaugh, R.D., Conrad, R.F., Keeler, A.G., Opaluch, J.J., Peterson, C.H., Piehler, M.F., Powers, S.P. and Smyth, A.R., 2012. Economic valuation of ecosystem services provided by oyster reefs. BioScience, 62 (10), 900-909.

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

Hatton MacDonald, D., Ardeshiri, A., Rose, J.M., Russell, B.D. and Connell, S.D. 2015. Valuing coastal water quality: Adelaide, South Australia metropolitan area. Marine Policy, 52: 116-124.

Johnston, R.J., Rolfe, J., Rosenberger, R.S. and Brouwer, R. (Eds) 2015. Benefit Transfer of Environmental and Resource Values A Guide for Researchers and Practitioners. Springer, Dordrecht.

La Peyre, M., Furlong, J., Brown, L.A., Piazza, B.P. and Brown, K. 2014. Oyster reef restoration in the northern Gulf of Mexico: Extent, methods and outcomes. Ocean and Coastal Management, 89: 20-28.

Morison, J., Schirmer, J. and Rippin, L., 2013. Regional Economic and Social Impact of Snapper Spawning Spatial Closure Options 2012-2013. Report prepared for PIRSA Fisheries & Aquaculture by EconSearch, Marryatville SA.

Nell, J.A. 2001. The history of oyster farming in Australia. Marine Fisheries Review, 63(3): 14-25.

Office of Best Practice Regulation 2016. Cost-Benefit Analysis. Guidance Note. Australian Government, Department of the Prime Minister and Cabinet, Canberra.

Pannell, D.J. 1997. Sensitivity analysis of normative economic models: theoretical framework and practical strategies. Agricultural Economics, 16: 139-152.

Pascoe, S., Doshi, A., Dell, Q., Tonks, M. and Kenyon, R. 2014. Economic value of recreational fishing in Moreton Bay and the potential impact of the marine park rezoning. Tourism Management, 41: 53-63.

Primary Industries and Regions SA 2017. Windara Reef. South Australian Government, available at: http://pir.sa.gov.au/fishing/recreational_fishing/windara_reef

Rogers, A.A., Gillies, C., Hancock, B., McLeod, I., Nedosyko, A., Reeves, S., Soloranzo, L. and Burton, M.P. 2018. Benefit-cost analysis for marine habitat restoration: a framework for estimating the viability of shellfish reef repair projects. Report to the National Environmental Science Program, Marine Biodiversity Hub. The University of Western Australia, Crawley.

Schulte, D.M., Burke, R.P. and Lipicus, R.N. 2009. Unprecedented Restoration of a Native Oyster Metapopulation. Science, 325: 1124-1128.

McLeod I.M., Bostrom-Einarsson L., Johnson C., Kendrick G., Layton C., Rogers A.A., Statton J. (2018). The role of restoration for conserving Matters of National Environmental Significance. Report to the National Environmental Science Program, Marine Biodiversity Hub. 159 pages.

McLeod I.M., zu Ermgassen P.S.E., Gillies C., Hancock B., Humphries A.T. (in press) Can bivalve habitat restoration improve degraded estuaries? Wolanski E., Day J., Elliott E., and Ramachandran R. (Eds.) Coasts and Estuaries – The Future. Elsevier, Amsterdam.

South Australian Tourism Commission, 2017. Yorke Peninsula Regional Profile. Government of South Australia.

Sutton P.C., and Costanza R., 2002. Global estimates of market and non-market values derived from nighttime satellite imagery, land cover, and ecosystem service valuation. Ecological Economics. 41, 509-527.

Tourism Research Australia, 2015. Tourism Region Profiles 2015, Yorke Peninsula, South Australia. Australian Government, Austrade.

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