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Benefits and costs of alternate seagrass restoration approaches

Abbie A. Rogers, Michael P. Burton, John Statton, Matthew W. Fraser, Gary Kendrick, Elizabeth Sinclair, Daniel Gorman, Mat Vanderklift, Jennifer Verduin and Ian M. McLeod

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THE UNIVERSITY OF WESTERN AUSTRALIA

JAMES COOK UNIVERSITY AUSTRALIA

Enquiries should be addressed to:

Dr Abbie Rogers
abbie.rogers@uwa.edu.au

Project Leader's Distribution List

NESP Tropical Water Quality Hub	Damien Burrows
The Nature Conservancy`	Chris Gillies
The Nature Conservancy`	James Fitzsimons
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Important Disclaimer

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EXECUTIVE SUMMARY

The continued degradation and decline of marine habitats globally, including in Australia, has led to increased interest in marine habitat restoration. However, marine habitat restoration can be expensive, and there is significant competition for resources between practitioners restoring different habitat types, and locations where restoration may be suitable. Seagrass meadows are among the habitats competing for these limited resources.

Integrated economic frameworks can be used to understand the trade-offs between different restoration projects, and establish which restoration configurations will deliver the largest benefits (including intangible or non-financial benefits) relative to costs. To the knowledge of the authors of this report this is the first time such analyses have been conducted for seagrass restoration globally.

We conducted a benefit-cost analysis (BCA) to explore how key factors influence the viability of seagrass restoration projects in Western Australia. Different scenarios were analysed, including:

- Replanting and reseeding methods;
- Professional and volunteer-based methods;
- Urban (Cockburn Sound) and remote (Shark Bay) locations;
- Different spatial extents, with 1ha, 10ha and 100ha plot sizes.

Economic benefits were estimated for the carbon sequestration capabilities of restored meadows, and for the non-market (intangible) values that seagrass habitats generate. Costs were estimated based on recent seagrass restoration trials in Cockburn Sound and Shark Bay.

The key results from the BCA were:

- Replanting methods relying on professional staff were not economically viable;
- Reseeding methods were always economically viable, and had a greater capacity to manage the risks of project failure than replanting methods;
- Projects using volunteer-based labour sources delivered larger net benefits than those using professional labour only;
- Remoteness did not significantly affect the BCA outcomes;
- Net benefits were largest for projects with larger spatial extents.

With the exclusion of the professional-labour replanting scenarios, where costs exceeded benefits, all scenarios had positive net present values. The net benefits ranged from roughly $40,000 for a 1ha replanted, volunteer-based plot to over $7.8million for a 100ha reseeded volunteer-based plot (in 2018AUD).

Viable scenarios could accommodate a risk of total project failure (i.e. where none of the expected benefits eventuate) ranging from 42%-86%. The payback period, or year at which the benefits meant project costs were recovered, for these scenarios ranged from 6 to 17 years. This payback period can be compared to the probable frequency of catastrophic events, enabling restoration managers to assess whether a project is likely to be maintained long enough to generate a net benefit.

The BCA results suggest that, contingent on the assumptions made in the BCA, the most worthwhile investments are larger-scale, volunteer-based restoration projects that employ the reseeding method.

1. INTRODUCTION

Healthy marine and intertidal habitats such as mangrove forests, saltmarshes, coral and shellfish reefs, kelp forests and seagrass meadows provide a wide range of benefits to coastal communities. These can include boosting coastal productivity and fisheries, improving water quality, sequestering carbon, and supporting high levels of biodiversity (Barbier *et al*. 2011). These habitats and the benefits they provide have been greatly reduced through coastal development, destructive fishing, pollution, invasive species and climate change.

Seagrass meadows have been declining around the world, with one quarter of seagrass meadows lost globally since records began, and a trend of accelerating decline over time (Waycott *et al*. 2009). A broad spectrum of anthropogenic and natural causes including disease outbreaks, destructive fishing practices, vessel damage, coastal development, extreme weather events, water quality reductions from increased nutrient additions and sediment runoff in human-altered watershed, and global climate change (Waycott *et al*. 2009). Australia has an estimated 51 000 km^2 of seagrass meadows within its waters (McLeod et al. 2018). Losses of seagrasses have been reported across Australia (Statton et al. 2018) with the majority occurring along the heavily populated eastern region of Queensland and New South Wales, and mid-western region of Western Australia. The largest loss of seagrass recorded in Australia was in the subtropical region of Shark Bay, Western Australia, where an extreme marine heat wave event (summer of 2011) combined with cyclonic flooding (Fraser et al. 2014; Thomson et al. 2015) caused up to 86 000 ha loss of the temperate seagrass *Amphibolis antarctica* (Arias-Ortiz et al. 2018).

There are two broad strategies for stopping or reducing habitat loss: habitat that is still intact can be protected, and habitats that are degraded can be restored (Possingham et al. 2015). Interest in restoration has increased in recent years and this has been highlighted by the United Nations General Assembly declaring the decade from 2021-30 as the UN Decade on Ecosystem Restoration. Ecological restoration can be active or passive. Passive restoration focuses on removing the impact of environmental stressors such as pollution or poor water quality, which prevent natural recovery of the ecosystems occurring. Active restoration is where management techniques such as transplantation, planting seeds or seedlings, or the construction of artificial habitats are implemented within an ecosystem's natural range (Perrow and Davy 2002).

Traditionally, marine management in Australia has focused on protecting habitats from damage, for example through the implementation of marine protected areas, and passive restoration techniques such as improving water quality. Recently there has been increasing interest in active restoration to promote the recovery or resilience of marine ecosystems (e.g. Aronson and Alexander 2013; Gillies et al. 2015; Possingham et al. 2015; Anthony et al. 2017). There were at least 118 seagrass restoration attempts in Australia from the 1970s to 2016 (McLeod et al. 2016). The main metric used to assess the success of these projects is survivorship of seagrass plants, and this has varied greatly amongst projects. Forty three percent of projects reported less than 10% survival and only 13% of projects reported greater than 90% survival or showed expansion of surviving plants to form meadows (reviewed in McLeod et al. 2018). Most restoration trials were less than 100m^2, and the largest were a few hectares (McLeod et al. 2018). Replanting techniques were used in most restoration trials, with projects using different planting unit types and sizes, anchorage approaches, sediment stabilisation techniques, fertilisation, growth hormones and mechanical planting systems. The introduction of biodegradable hessian bags, strips or mats has been used to target the recruitment of wireweed (*Amphibolis spp*.) seedlings, which have comb-like grappling apparatus allowing them to attach to hessian fibres. This technique has shown mixed results. However, Tanner et al. (2014) suggested this was a non-destructive, cost-effective (around AU$10,000 per hectare) method of seagrass restoration that could be scaled-up to large spatial extents. Seed-based restoration is a relatively new concept in marine conservation, despite being a common approach in terrestrial environments. The advantages to using seeds for seagrass restoration are predicted to include savings in time, effort and costs required to collect adult plant material, less damage to existing meadows, and potentially higher levels of genetic variation (outcrossed seeds will have many different genotypes as compared with plant material potentially collected from a few clones).

However, restoration can be costly and the benefits of restoration are rarely quantified in relative terms to understand whether these costs are justified. Approaches are needed to make the investment value of restoration clear, potentially unlocking access to new financial resources for these activities. Restoration will also need to be prioritised between multiple habitats and geographical locations to maximise the benefits from these activities. Rogers et al. (2018a, 2018b) set out an integrated economic framework to begin conceptualising how funding agencies might prioritise habitat restoration efforts in order to allocate resources efficiently. Using benefit-cost analysis (BCA) they considered a range of tangible (market-based) and intangible (non-market) benefits and costs for restoring the Windara Reef, a shellfish reef in South Australia. Inclusive of a range of financial, social and environmental outcomes, the BCA demonstrated that the benefits of the reef far-outweighed the costs of the restoration effort. Here, we adapt this framework to apply BCA to seagrass restoration. Rather than evaluating a specific project as in Rogers et al. (2018b), the focus of this analysis is to broadly consider a range of restoration project design factors that may affect the outcomes of the BCA. This includes the restoration method, the labour source, remoteness of the location and the spatial extent of the restoration plot. Through building the BCA framework in this way, we can begin to establish an evidence-base to inform prioritisation of seagrass habitat restoration.

2. METHODS

2.1 Workshops

In June 2018, a Seagrass Restoration Network workshop was convened in Canberra, the day after the Marine and Coastal Habitat Restoration Workshop (McLeod et al. 2018). Ten members of the Seagrass Restoration Network were in attendance along with representatives from the Department of the Environment and Energy, The Nature Conservancy, OceanWatch and the National Environmental Science Program 'The role of restoration for the conservation of matters of national significance' project team. The most important next steps for the Seagrass Restoration Network were discussed. This workshop led to the following three outcomes.

1. The Seagrass Restoration Network has been supported by the NESP Marine Biodiversity Hub through an extension of project E5 'The role of restoration for the conservation of matters of national significance'. This support includes website and social media support, and secretariat services for the network until the end of 2020.

2. The importance of trialling seed-based and shoot-based seagrass restoration in Shark Bay was discussed leading to Project E6 'Assisting restoration of ecosystem engineers through seed-based and shoot-based programs in the Shark Bay World Heritage Site' being developed and funded through the Marine Biodiversity Hub.

3. The importance of benefit-cost analysis comparing different restoration techniques was discussed leading to the workshop in November discussed below.

In November 2018, a workshop was convened with nine of the ten co-authors of this report to establish the scenarios to be evaluated in the BCA. The framing of the case study locations, restoration methods, benefits and costs for inclusion were determined through the workshop and subsequent discussions among co-authors.

2.2 Case studies

2.2.1 Cockburn Sound

Cockburn Sound is a 124km^2 embayment located in the Perth metropolitan region of Western Australia. It has a historical legacy of heavy industrial activity that has developed since the 1950's (Cockburn Sound Management Council, 2018). This has included refineries, chemical plants, a bulk handling port, a desalination plant, and a wastewater treatment plant. Residential estates are now being developed in the area, and the Sound is a popular recreational site for fishers and a multitude of other uses. Prior to the industrial development, it was estimated that there were approximately 4,200ha of seagrass cover in the Sound. This subsequently reduced to an area of around 690ha by 1994 (Cockburn Sound Management Council, 2018). Notably, in the 20 years that followed, total seagrass cover in Cockburn Sound increased by over 200 ha, coinciding with improved water quality (Mohring and Rule, 2013) from long term management responses (Cockburn Sound Management Council, 2018) and with restoration trials (Verduin et al 2012). Some remaining stressors have been identified in particular locations in Cockburn Sound, for example with sediment stressors such as sulphide intrusion linked to seagrass shoot declines (Fraser and Kendrick 2017). However, seagrass coverage has remained relatively stable over the 5 year period from 2012: in 2017, the spatial extent of seagrass in the Sound was 965ha, an increase from 925ha in 2012 (Cockburn Sound Management Council, 2018) (Figure 1).

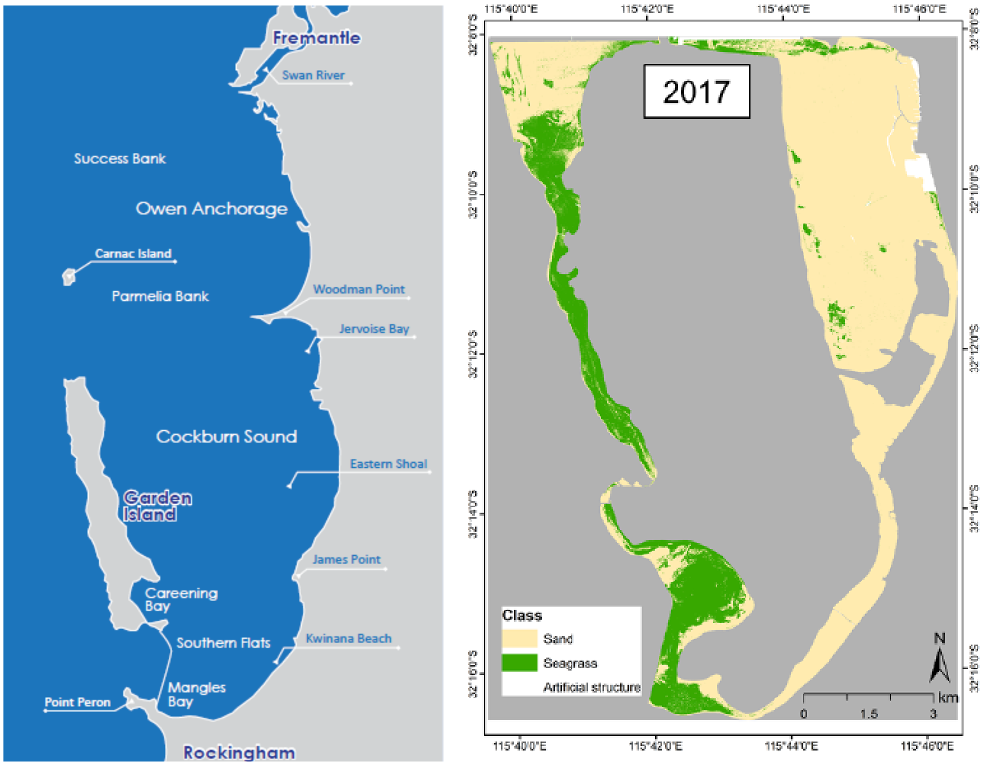

Figure 1. (a) Cockburn Sound, Western Australia (from Cockburn Sound Management Council, 2018, p3); (b) spatial extent of seagrass coverage in Cockburn Sound (from Hovey and Fraser, 2018, p14)

2.2.2 Shark Bay

Shark Bay is located in the remote Pilbara region in the northwest of Western Australia. It is a World Heritage area, and activities in the Bay include eco-tourism, recreational and commercial fishing and salt mining. The region experienced a marine heatwave event in 2010/11 which degraded a significant proportion of its extensive seagrass meadows (Arias-Ortiz et al. 2018). Prior to the heatwave event, it was estimated that there were 4,300km^2 of seagrass in the Bay. Around 900km^2 were lost during the heatwave, and almost 200km^2 damaged (Figure 2). It is likely that heatwaves will become more frequent and intense in the future, and will impact temperate seagrasses in Shark Bay given they already exist near their upper thermal tolerances (Kendrick et al. 2019). However, it is currently difficult to predict the frequency, severity, or precise locations that will be impacted. For many marine environments, including Shark Bay, it will be important to understand the relationship between frequency of extreme climatic events, and the time required for a restored seagrass meadow to generate a net benefit.

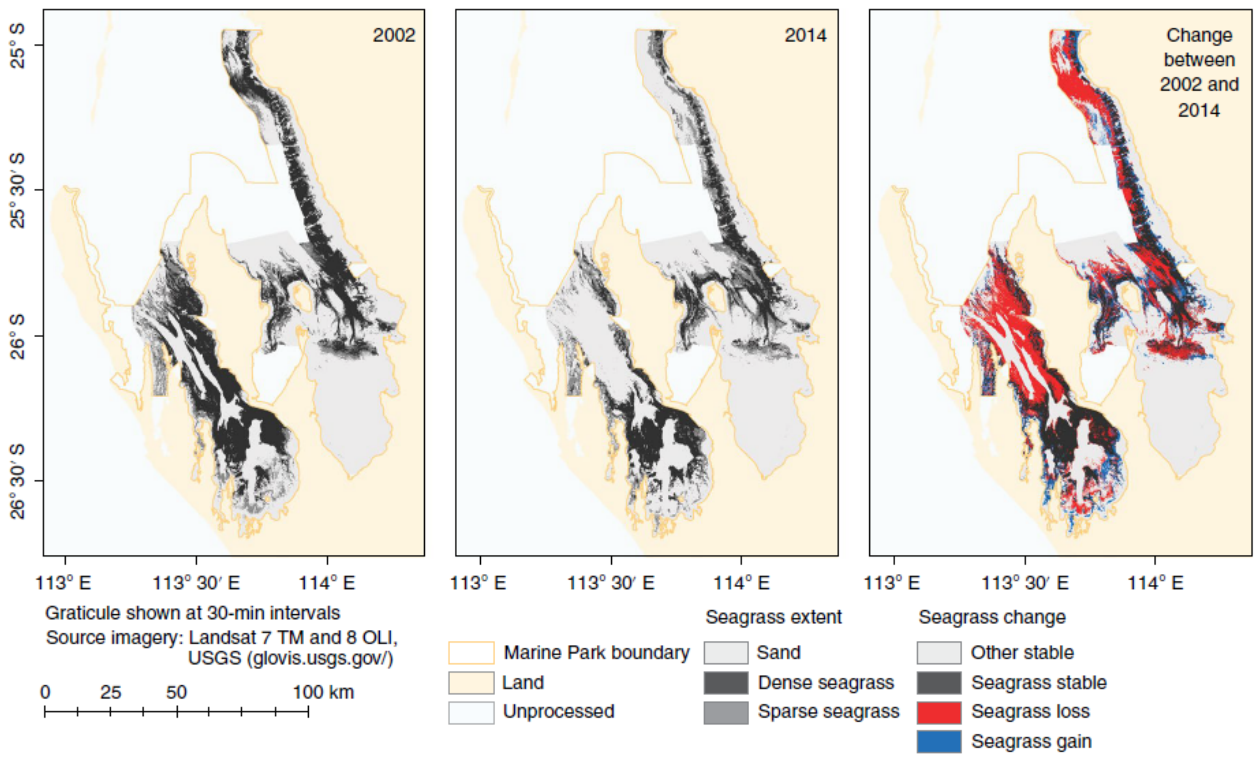

Figure 2. Spatial extent of seagrass in Shark Bay, Western Australia before and after the 2010/11 heatwave (from Arias-Ortiz et al. 2018, p342).

2.3 Scenarios

In the BCA, multiple scenarios are evaluated to compare the effect of locations, restoration methods, plot size and labour sources on project viability.

2.3.1 Restoration scenarios

The following scenarios are evaluated (Figure 3):

	Replanting	Reseeding
Cockburn Sound	Professional labour	Professional labour
	Volunteer-based	Volunteer-based
Shark Bay	Professional labour	Professional labour
	Volunteer-based	Volunteer-based

Figure 3. BCA restoration scenarios

In addition to the variations in Figure 2, three plot sizes are also evaluated:

- 1 hectare
- 10 hectares
- 100 hectares

Both the 10 and 100 hectare plots are substantially larger than restoration trials currently attempted in Cockburn Sound and Shark Bay. It is unlikely that a plot size larger than 100ha could be feasibly implemented, at least as a single project: a multi-year program would be needed to implement something of this size, with 100ha restored each year for example.

2.3.2 Counterfactual

For each restoration scenario, we need to consider what happens if the project is implemented ('with-project') and what happens if it is not ('without-project'). In this analysis, we assume that the without-project case is defined as a zero-marginal-cost and zero-marginal-benefit; that is, a continuation of current conditions into the future. This should not be taken to mean that there are zero costs and benefits associated with existing seagrass, and its management, but that these costs and benefits are unaffected by whether the project under consideration proceeds or not.

2.3.3 Timeframe for scenario evaluation

We estimate the benefits and costs of the restoration scenarios over a 100 year timeframe. A long time horizon is used to acknowledge that some of the benefits take time to establish, and are long-term in nature. While it is possible to use even longer time horizons, the benefits become negligible due to the effects of the discount rate.

2.3.4 Project risks

It is important to consider project risks, in terms of whether a scenario will deliver the anticipated benefits that are estimated in the BCA. As noted above, general stressors are either not a significant issue, or are being managed, for both Cockburn Sound and Shark Bay. However, there exists the potential for future events that could reduce the success of a restoration project or cause it to fail entirely. In Cockburn Sound, there is a planning process currently underway to consider the future expansion of port facilities in the metropolitan area[1]. The activities associated with a harbour expansion, and ongoing harbour maintenance, could adversely affect restored seagrass meadows in the Sound. In Shark Bay, there is a general consensus that extreme weather events are likely to occur again in the future, which could lead to similar effects as the 2010/11 heatwave, and a resulting loss of restored meadows (Arias-Ortiz et al. 2018). There are different approaches for accommodating risk in a BCA, discussed further in Section 2.4 below.

2.4 Benefit-cost analysis

2.4.1 Calculation of net present values

All benefits and costs in a BCA must be represented as present values. This requires the practice of discounting which reflects that there are opportunity costs associated with investing dollars in a particular project, relative to other projects, and that people have a preference to enjoy benefits now, rather than having to wait to enjoy them in the future (Boardman et al. 2017; OECD 2018). Discount rates can also be used to address project risk, as discussed further below. To convert future benefits and costs to present value equivalents, we have used a discount rate of 7%.

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

Occasionally benefits that need to be compared across projects are measured over different timeframes. In this case, annualised benefits are useful to calculate non-market value over time. For example, willingness to pay estimates from stated preference studies are often used to estimate the non-market (intangible) benefits of a project. Often in these studies, the hypothetical willingness to pay amount is ‘collected’ from survey respondents over a brief timeframe, for example an annual payment collected over a few years. But the environmental benefit that the willingness to pay amount is to be applied to might occur over a much longer time horizon. For example, environmental benefits could be in perpetuity. In such a case these respondents are expressing their willingness to pay for a perpetual stream of benefits through a shorter-term set of payments. One can obviously not directly apply the short-term annual payments as representative of the amount that they would

[1] https://www.transport.wa.gov.au/projects/westport-port-and-environs-strategy.asp

pay every year of the life of the environmental benefits. By annualising the benefits calculated through the willingness to pay study, we can attribute that benefit to each future year that it is relevant. This involves a two-step process. First the short payment schedule is converted to a net present value (i.e. an equivalent single sum in the first year, using Equation 1). Then one annualises this net present value over the lifetime of the benefit stream, to identify the annual benefit that the environmental change generates, that is (Boardman et al. 2017):

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

This annualised benefit is also useful in dealing with cases where the ecological outcomes are uneven over the lifetime of the project. A proportion of the annualised benefit can be applied to match the proportion of the environmental change that will occur in any year.

In the evaluation of benefits from restoration projects, we anticipate that not all benefits will be immediately available. For example, it will take some time for a restored seagrass meadow to establish itself, and function equivalently to a healthy, natural meadow. To accommodate this gradual increase in benefits, we can calculate benefits on a linear trajectory, where the stream of annual benefits increases until the maximal benefit (the annualised benefit) is reached at year T^m. When year $t = T^m$, and for all years beyond T^m until the end of the project (T), the proportion of the annualised benefit is equal to 1.

$$Benefit\ (year\ t) = Annualised\ benefit\ x\ \max\left(1, \frac{t}{T^m}\right) \qquad \text{Equation 3}$$

The net present value (NPV) of all benefits and costs for undertaking a project is then calculated as:

$$NPV = \sum present\ benefits - \sum present\ costs \qquad \text{Equation 4}$$

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. If we had the luxury of an unlimited budget to invest in restoration projects, we would implement all projects that have a positive NPV. In reality, where budgets are limited, we would identify which projects we can afford, given the present value of costs, and of those select the one (or combination of projects) with the highest NPV.

Other measures that can be calculated from a BCA include the benefit: cost ratio (*BCR*):

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

A BCR greater than one indicates that a project generates benefits that outweigh the costs. The larger the ratio, the greater the benefit generated per dollar invested.

2.4.2 Management of project risk

A BCA can account for project risk through different approaches. The discount rate accommodates project risks. The type of risk that discounting deals with is the systematic project risk; that is, the risk that the value of the project outputs will not be as high as anticipated due to unforeseen macro-economic conditions (OECD 2018). The Australian Government currently recommends using a discount rate of 7% (Office of Best Practice Regulation 2016). However, there is growing debate that this rate is too high, in general, based on the current cost of money[2]. There are recommendations the discount rate should be as low as 3.5%, for example for low-risk infrastructure projects, but that it should be higher for projects that carry higher levels of risk (Terrill and Batrouney 2018). Restoration projects are likely to fall into the latter category due to their sensitivity to general stressors on the environment, and noting that environmental conditions can influence the economy at a regional (macro) scale. In the following analysis , we have maintained the use of the 7% discount rate, on the basis that: (1) the risk-free discount rate should probably be lower than 7%, but (2) this type of environmental project will carry significant risk, and hence a risk premium should be added to account for a degree of riskiness in the project[3].

There are also some methods to explicitly incorporate risk in the analysis, for example, the likelihood of a benefit (or cost) failing to eventuate can be weighted by a probability. Or, a sensitivity analysis can be used to model probabilistic distributions of costs and benefits across all aspects of the operation (Pannell 2018). However, in this particular BCA application, project risks are difficult to quantify using these approaches given the need for better scientific understanding of restoration practices, and the uncertainty associated with extreme events that might result in project failure.

An alternative approach for dealing with possible catastrophic risks where the project as a whole fails (e.g. from an adverse climate event) is to evaluate the capacity of the project to absorb risk of failure, or to evaluate the payback period of the project (i.e. how many years of benefits are required to justify the initial costs). These approaches do not require an *a priori* assumption about what the probability of failure will be, and as such can provide an understanding of how the project will perform that can continue to be interpreted as our understanding of risk evolves.

Capacity of a project to absorb risk of failure can be calculated as:

$$Capacity\ to\ absorb\ risk = \left(1 - \frac{1}{BCR}\right) x\ 100 \qquad \text{Equation 6}$$

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[2] For a summary of the debate, see https://www.aph.gov.au/About_Parliament/Parliamentary_Departments/Parliamentary_Library/FlagPost/2018/October/Discount-rates

[3] An alternative is to estimate the internal rate of return of the project (i.e. the discount rate at which the project just breaks even) and then make an assessment of whether that adequately reflects the degree of risk, e.g. if the risk free rate of return in an economy is 4% and the internal rate of return on the restoration project is 5% then one might anticipate that this does not provide sufficient coverage for risk.

This calculation identifies the percentage of the benefit stream that could be lost while still maintaining a viable project, or in other words, the expected rate of total failure that a project could absorb and still be viable. For example, if the project has a 40% capacity to absorb risk, and we predict that there is a 70% probability that the project will be successful in obtaining all of its benefits (a 30% chance it will completely fail), then the investment would still be worthwhile. If we think there is a 50% chance the project will fail, we would not invest in it.

The payback period is an estimation of how many years the project would have to be maintained to cover establishment costs; that is, at what point the benefit stream exceeds the project costs. If the payback period is short relative to the probability of a catastrophic risk then this gives re-assurance that the project is appropriate. If for example, a heatwave event is predicted to occur every 30 years in a specific location, and a seagrass meadow generates an expected net benefit after 15 years, one may come to the view that the restoration attempt is worthwhile.

3. RESTORATION BENEFITS

3.1 Carbon sequestration

'Blue Carbon' sources are not currently accepted as a form of tradeable carbon in Australia, but are being investigated for their potential to be used as carbon offsets[4]. Seagrass meadows are an important source of blue carbon, and Shark Bay in particular contains one of the largest global stores of carbon (Fourqurean *et al.* 2012). We estimated the potential value of restored meadows to offset carbon emissions. Note that here we are considering only the benefits of restoration. Benefits associated with preventing loss may be much higher, as loss releases stored carbon from the sediment.

Marba et al. (2015) measured the burial rate of organic carbon in replanted seagrass plots in Oyster Bay, Albany, Australia. The plots ranged in age from 6 to 18 years, enabling a function to be derived showing the rate of carbon burial:

$$y = 28.70 - 69.01/x \qquad \text{Equation 7}$$

Where the rate of burial, *y*, is measured as grams of organic carbon per square metre per year, and *x* is the year since planting.

We applied this function to estimate the grams of organic carbon that would be buried per hectare over a 100-year timeframe, with the burial rate set to 26.4g/m^2/yr from Year 31, when the rate reached the burial capacity of a natural meadow. The grams of organic carbon were converted to tonnes of organic carbon per square metre (/1,000,000), and then to tonnes of atmospheric CO_2 (× 3.67). The per hectare amounts of CO_2 were extrapolated to the 10ha (×10) and 100ha (×100) restoration plot sizes.

It is assumed that, if blue-carbon becomes an acceptable form of carbon for trading in the Australian market, it would be subject to the same market conditions as terrestrial forms of carbon. A price of $15 per tonne of CO_2 was used to estimate the benefits, based on a recent report that predicted the long-term carbon offset price in Western Australia (RepuTex Energy 2018). This is in line with the average price awarded of $14.17 per tonne of CO_2 in the Australian Government's ninth Emissions Reduction Fund auction[5]. The benefits were calculated over the 100-year timeframe, for each plot size, and summed to estimate the NPV using a 7% discount rate (Table 3).

Note that $15/t was the low-price scenario based on conservative assumptions, and the report also considered a range of prices up to $100/t (RepuTex Energy 2018). Given the small size of the benefits of carbon sequestration estimated in this analysis, even using a value of $100/t would not have altered the general outcomes of the benefit-cost analysis (replanting with professional labour would still not be viable).

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[4] E.g. see https://www.environment.gov.au/climate-change/government/australia-work-on-blue-carbon

[5] See http://www.cleanenergyregulator.gov.au/ERF/Auctions-results/july-2019

3.2 Non-market benefits

People value seagrass habitats for their environmental benefits, including the presence of seagrass meadows themselves (i.e. their existence and recreational value), and also the importance of these habitats as a nursery and foraging area for other marine species (Connolly et al. 2005). Seagrass habitats are particularly important for juvenile fish and invertebrates, including recreationally and commercially targeted fish species (Heck *et al.* 1997; Butler and Jernakoff 2000).

To quantify the environmental benefits of restored seagrass habitat, we used the benefit transfer method (Johnston et al. 2015). Two relevant studies on willingness to pay for increases in seagrass habitat were considered: Hatton MacDonald et al. (2015), and Rogers (2013). The first of those estimated how much people were willing to pay for increases in seagrass habitat in the Gulf of St Vincent, South Australia, describing the seagrass habitat as being an important nursery area for fish species, particularly recreationally targeted species. The second study similarly estimated willingness to pay for increases in seagrass habitat in the Ngari Capes Marine Park in Western Australia, noting that seagrass habitats provide food and shelter for many marine species. Implied in both of these studies is that the valuation is inclusive of both the direct values people hold for the seagrass meadows themselves, but also for the benefits they provide to other marine fauna. The stated-preference approaches used in both studies encompass non-use (e.g. existence) and use-related (e.g. recreational) values.

The Hatton MacDonald et al. (2015) study was considered the most appropriate for the benefit transfer because it specifically referenced the ability to restore seagrass beds as a mechanism for increasing the area of habitat. The Rogers (2013) study referred to other management approaches, including better protection measures through marine park zoning. While the estimates calculated from Hatton MacDonald et al. (2015) are used in the BCA, for the purposes of validating the estimates, the net present benefits were estimated using both studies as follows (Table 1).

In Hatton MacDonald et al. (2015), South Australian households were willing to pay $1.95/year in 2014AUD for five years for a perpetual 100ha increase in the area of seagrass. To transfer this estimate to our scenarios the following calculations were made:

1. A CPI adjustment was made: 6.8% inflation over the period 2014 to 2018[6]. This equates to a willingness to pay of $2.08/100ha, or $0.02/ha per household per year, for 5 years, in 2018 dollars.

2. The willingness to pay was aggregated by the number of households in Western Australia (1,070,962)[7], totalling $22,304/ha per year, for 5 years.

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[6] https://www.rba.gov.au/calculator/annualDecimal.html

[7] 2016 Census Quickstats average number of households and median weekly earnings for Western Australia, available at: http://quickstats.censusdata.abs.gov.au/census_services/getproduct/census/2016/quickstat/5?opendocument

3. The willingness to pay was adjusted for difference in earnings, with median Western Australian household income approximately 132% of median South Australian household income[8]. The adjusted total was $29,498/ha per year, for 5 years.

4. The adjusted total per ha was aggregated over the 5-year payment period, and the present value calculated using a 7% discount rate ($120,948/ha, see Equation 1).

5. The present value willingness to pay estimate was annualised over a 100-year timeframe, to equate the benefits on a per year basis ($8,476/ha/yr, see Equation 2).

6. The benefit stream was apportioned using Equation 3. It was assumed that 100% of the non-market benefits would not be reached until Year 10, when a dense, fully functional meadow would be in place[9]. Benefits were distributed on a linear trajectory from years 1 to 10, with 100% of the benefits ($8,476/ha/yr) occurring from years 10 to 100.

7. The discounted benefits were summed over the 100 years, and were estimated for a 1ha, 10ha and 100ha plot, shown in Table 1.

Table 1. Comparison of the net present value of benefits calculated via benefit transfer from two willingness to pay studies.

Seagrass restoration plot size	1ha	10ha	100ha
WTP estimated from Hatton MacDonald et al. (2015)	$90,860	$908,604	$9,086,043
WTP estimated from Rogers (2013)	$117,365	$1,173,647	$11,736,475

In Rogers (2013), West Australian households were willing to pay $47/year (2008AUD) for ten years for a 5% increase in seagrass habitat, equating to $0.02/ha. Similar steps were taken to transfer this estimate for our scenarios:

1. A CPI adjustment was made: 23.5% inflation over the period 2008 to 2018[10]. This equates to a willingness to pay of $0.02/ha per household per year, for 10 years, in 2018 dollars.

[8] 2016 Census Quickstats median weekly earnings for South Australia, available at: http://quickstats.censusdata.abs.gov.au/census_services/getproduct/census/2016/quickstat/4?opendocument

[9] Note that the 10 year timeframe to reach the maximum non-market benefit (which is primarily related to seagrass growth being sufficient to provide habitat for fauna) is different to the 30 year timeframe for maximum carbon benefit (which is dependent on carbon burial rates).

[10] https://www.rba.gov.au/calculator/annualDecimal.html

2. The number of Western Australian households (1,070,962 households in total) used for aggregation was adjusted to acknowledge that in this study only 87% of the sample were willing to pay[11] (931,737 households willing to pay).

3. The willingness to pay was aggregated by the number of paying households, totalling $22,243/ha per year, for 10 years.

4. The total per ha was aggregated over the 10 year payment period, and the present value calculated using a 7% discount rate ($156,229/ha, see Equation 1).

5. The present value willingness to pay estimate was annualised over a 100 year timeframe, to equate the benefits on a per year basis ($10,949/ha/yr, see Equation 2).

6. The benefit stream was apportioned as per Step 6 above, and summed as per Step 7 above (Table 1).

We note that the estimates from both studies are very similar, with the per hectare values prior to adjustments being almost equivalent at $0.02/ha per household per year, providing validity to these results. It is also worth noting that both studies considered large areas for increases in seagrass, meaning that our 100ha plot size scenarios are within the bounds of the spatial extents for which the values were estimated. This is particularly important for benefit transfer processes, where extrapolation to spatial extents beyond that considered in the original valuation study introduces a risk of over-estimating values due to the theory of diminishing marginal utility (Hanley and Barbier 2009)[12].

3.3 Other benefits

Several benefits have not been explicitly included in the BCA.

- Recreational fishing benefits are captured through the non-market benefits estimated above, as recreational fish species are specifically referred to in the Hatton MacDonald et al. (2015) valuation scenario.

- Recreational use values and non-use (existence) values associated with other marine fauna that utilise seagrass habitats are assumed to be implicitly included in the non-market benefits estimated above. While benefits of seagrass habitats to megafauna were not

[11] See Rogers (2013): a proportion of the sample did not attend to the cost attribute in the survey.

[12] The theory of diminishing marginal utility recognises that each additional unit of a commodity will be valued slightly lower than the unit before it – so the 1000th hectare of seagrass is worth slightly less than the 999th hectare, and probably much less than the 100th hectare.

explicitly referenced in the Hatton MacDonald et al. (2015) valuation scenario, we cannot be certain that they were excluded from respondent decisions in the survey. As such, including an additional estimate of these values presents a risk of double-counting the benefits. This assumption is appropriate noting that Rogers (2013) refers to the broader benefits for marine fauna in their valuation scenario, and the benefits calculated from both studies are similar.

- Tourism revenue may be a relevant factor for Shark Bay, where the tourism industry is highly dependent on recreational fishing opportunities and eco-tourism (particularly the dolphin interactions at Monkey Mia). While there is scientific evidence linking the availability of seagrass habitat to the abundance and health of fish stocks and megafauna (Thomson et al. 2015), it is not yet apparent whether the tourism industry has been directly affected by changes in seagrass cover in Shark Bay. Tourism growth in the region has not met projected levels since the 2010/11 heatwave, but it is unlikely that loss of seagrass is the sole factor driving this. Similarly, eco-tourism is a feature in Cockburn Sound, particularly in relation to the Little Penguin population, but a complete linkage of understanding about changes in seagrass habitat, causal impacts on penguin populations and subsequent changes in tourist behaviour are unknown.

- Commercial fishing revenues may also benefit from increases in seagrass habitat. Key fisheries include snapper in both Shark Bay and Cockburn Sound, and the prawn and scallop fishery in Shark Bay. While studies have linked economic benefits of commercial fish species to increasing seagrass habitat in Australia (e.g. Blandon and zu Ermgassen 2014), there is a high degree of variability in the relationship between particular species and their economic enhancement, with some values being substantial and others negligible. Blandon and zu Ermgassen (2014) do not provide an estimate for snapper species, making it difficult to extrapolate the effect of seagrass area for snapper given the relationships are species-specific. Anecdotally, the impact of the marine heatwave on the prawn and scallop fishery in Shark Bay was highly varied, and appeared to affect stock negatively and positively depending on the particular species and life-cycle stage. As such, while we acknowledge that there are likely to be commercial fishing benefits from seagrass restoration, the variability and uncertainty in establishing those benefits makes it difficult to include in the analysis.

- Seagrass meadows are known to stabilise the sea floor through their extensive root and rhizome system (McLeod et al. 2018). The stabilisation of the seabed can help to combat the impacts of coastal erosion. There are currently no suitable studies available for benefit transfer to estimate how much people are willing to pay to protect the West Australian coast from coastal hazards such as erosion (Rogers and Burton 2018).

- Large losses of seagrass in Shark Bay could influence conditions in Hamelin Pool where the stromatolites are located by altering hydrodynamic flow, nutrient transfer and salinity. The stromatolites are one of the key factors that influenced the World Heritage listing of Shark Bay, and legislation demands that they should be protected. We were unable to incorporate potential effects on the stromatolites in this analysis, due to both uncertainty about how they may be impacted, and uncertainty about their quantitative value. Existence values are likely to be significant for stromatolites, but we are not aware of any stated preference studies that measure willingness to pay for them, or similar studies that are suitable for benefit transfer.

The implicit inclusion of some of these benefits, and the omission of others, suggests that the total benefits calculated in this analysis provide a conservative, lower-bound estimate of net benefits for seagrass restoration in Cockburn Sound and Shark Bay.

4. COST DATA

Costs were provided by co-authors based on actual costs of seagrass restoration trials over 1ha in both Cockburn Sound and Shark Bay, using both replanting and reseeding methods. Costs were extrapolated to the 10ha and 100ha plot sizes. These were typically extrapolated linearly, with the exception of some costs where efficiencies gained through scale were obvious (see the assumptions below).

We note that in some cases costs may be over-estimated for larger plot sizes as there may be different technologies available at that scale, or purchase (rather than hire) of equipment may be feasible. However, we also note that in some cases costs may increase for larger plot sizes as it may be difficult to source all of the necessary materials, equipment and labour during the timeframes (particularly for reseeding, which is limited to a 1-month annual window). This could lead to premiums being paid on some items[13]. Accordingly, the costs outlined are reasonable estimates given our understanding of current restoration practice in Australia.

The full costings estimated are outlined in Appendix A for each scenario. Unit costs per item are provided in Table 2 below. A number of assumptions made in relation to costs for different methods and locations are subsequently described.

Table 2. Unit values for restoration item costs.

Item	Unit cost
Labour (professional staff)	$272/day
Boat hire (for 6 person crew, including 4 divers)[a]	$300/day
Car hire (for 6 person crew, commute to dive location)	$70/day
Car hire (up to 12 people, round trip Perth to Shark Bay)	$140/trip
Tank system for seed processing (capacity for 1ha)	$4000/system
Staples for replanting	$5,265/ha
Cable ties for replanting	$2,025/ha
SCUBA hire & refill[b]	$27/diver/day
Accommodation (Shark Bay, housing up to 12 people)	$2000/week

[a]Larger boats could be hired for larger plots, however the cost of multiple smaller boats is a suitable proxy for the increased hire cost of a large boat.

[b]In practice in Shark Bay, tanks would be hired (approx. $20/diver/day) along with a compressor ($100/day) for refills, but differences in cost for the equipment variation are considered negligible.

[13] We do not have readily available estimates of current limits of supply (including for equipment and volunteer bases), as large-scale seagrass restoration projects are yet to be attempted in Australia.

Assumptions:

- There are 6 people to a boat crew: 1 skipper, 1 operation manager on deck, and 4 divers.
- There must be a minimum of 1 professional crew member to every 3 boat crews (maximum ratio 1 professional staff: 17 volunteers).
- It is assumed all crew bring their own food on board the boat and other required amenities, and no per diem rate is included for these expenses.
- Professional staff are paid at a rate equivalent to rates paid by UWA for level 4 step 03 professional staff ($34 per hour = $272/day).
- Volunteers are zero cost: it is assumed that the benefits they gain from participating in the activity balance out the opportunity costs of their time and other expenses.
- Volunteers are only used for boat-based activities, and not seed processing.
- Professional staff are assumed to be based in Perth, and travel to Shark Bay.
- All volunteer staff are assumed to be based locally to the dive location, and will commute there in their own vehicle, at their own expense. It is assumed there is sufficient access to volunteers in both locations.
- A 1 month (30 day) window of time is available for the reseeding activities to be carried out.
- Non-linear extrapolations for larger scale plots:
  - For reseeding projects, plot preparation costs reduce with increasing size of plot, due to different technologies employed at different spatial extents (e.g. posts and floats for 1ha, floats and GPS for 100ha).
  - For reseeding projects, remote costs (accommodation and car-hire) reduce with size of plot due to the reduction in labour required for plot preparation as above.
  - For volunteer-based projects, labour costs reduce with size of plot due to the ability to increase the ratio of volunteers: professional staff (by saturating boat crews with volunteers).
  - For volunteer-based projects, accommodation and car-hire costs reduce with size of plot due to reduced ratio of professional staff as above.

All costs occur in Year 1 of the project and therefore are not discounted. Total costs for each scenario are reported in Table 3.

5. BENEFIT-COST ANALYSIS

5.1 Net present values

The results of the BCA are reported below. Table 3 reports the present values of benefits and costs for the different restoration scenarios included in the analysis. The present value of carbon sequestration and non-market benefits are shown, noting that the non-market benefits are much larger than the carbon benefits[14]. It is the non-market benefit that is driving the outcomes of the BCA, with respect to cases where benefits exceed costs (i.e. the general outcomes would be the same even if carbon benefits were omitted). The summary figures for present value costs are reported in the table for each scenario, and shown in detail in Appendix A.

Note that the majority of benefits and costs are effectively scaled up proportionally with the plot size; that is, the benefits and the costs are roughly ten times larger for a 100ha plot than a 10ha plot, and for a 10ha plot relative to a 1ha plot. This result reflects the assumption that the benefits of the hundredth hectare will be the same as the first hectare, and that the same is true for the majority of the costs. In some cases, there were efficiencies gained in costs at larger spatial extents for scenarios that used volunteers and/or the reseeding method, reflecting the minor differences in proportions of costs as plot size increases.

Table 4 reports the net present value of benefits for each restoration scenario. Note that for all scenarios involving replanting as the restoration method with professional labour, the costs exceed the benefits. All other scenarios, including replanting methods with volunteer labour, have positive net benefits.

Table 5 shows the benefit: cost ratios for the different scenarios. The ratios for the professional-labour based replanting scenarios are below one, reflecting that benefits are smaller than costs. The ratios are relatively consistent across different the plot sizes reflecting the roughly linear increases in benefits and costs over different spatial extents. Volunteer-based reseeding scenarios offer the largest return of benefits per dollar invested.

[14] It is worth noting that while in the Australian context the potential to trade carbon offsets has a negligible impact on the BCA outcomes as the carbon value is small relative to the costs of the restoration exercise, this may be different for developing countries where the costs of restoration are lower (labour is cheaper).

Table 3. Present values of benefits and costs included in the BCA.

			1ha	10ha	100ha
Benefits					
	Carbon benefits		$121	$1,212	$12,120
	Non-market benefits		$90,860	$908,604	$9,086,043
	TOTAL PV BENEFITS		$90,982	$909,816	$9,098,162
Costs					
REPLANTING	Professional labour	Cockburn Sound	$178,570	$1,785,700	$17,857,000
		Shark Bay	$190,951	$1,909,514	$19,095,143
	Volunteer-based	Cockburn Sound	$50,214	$500,088	$4,998,828
		Shark Bay	$52,354	$507,068	$5,068,480
RESEEDING	Professional labour	Cockburn Sound	$31,932	$302,440	$2,988,530
		Shark Bay	$42,072	$332,860	$3,211,610
	Volunteer-based	Cockburn Sound	$13,560	$125,154	$1,237,422
		Shark Bay	$23,700	$135,294	$1,277,982

Table 4. Net present value of benefits for the restoration scenarios.

			1ha	10ha	100ha
REPLANTING	Professional labour	Cockburn Sound	-$87,588	-$875,884	-$8,758,838
		Shark Bay	-$99,970	-$999,698	-$9,996,981
	Volunteer-based	Cockburn Sound	$40,768	$409,728	$4,099,334
		Shark Bay	$38,628	$402,748	$4,029,682
RESEEDING	Professional labour	Cockburn Sound	$59,050	$607,376	$6,109,632
		Shark Bay	$48,910	$576,956	$5,886,552
	Volunteer-based	Cockburn Sound	$77,422	$784,662	$7,860,740
		Shark Bay	$67,282	$774,522	$7,820,180

Table 5. Benefit: cost ratios for the restoration scenarios.

			1ha	10ha	100ha
REPLANTING	Professional labour	Cockburn Sound	0.51	0.51	0.51
		Shark Bay	0.48	0.48	0.48
	Volunteer-based	Cockburn Sound	1.81	1.82	1.82
		Shark Bay	1.74	1.79	1.80
RESEEDING	Professional labour	Cockburn Sound	2.85	3.01	3.04
		Shark Bay	2.16	2.73	2.83
	Volunteer-based	Cockburn Sound	6.71	7.27	7.35
		Shark Bay	3.84	6.72	7.12

5.2 Risk analysis

The capacity of the restoration scenarios to manage the risks of project failure is reported in Table 6. The replanting, professional-labour based scenarios are obviously unable to absorb risk, as the projects are not viable even at zero-risk. All other scenarios remain viable in circumstances where the predicted risk of project failure is up to 42%. The volunteer-based reseeding projects are still worthwhile investing in even when the risk of failure is quite high at around 80%.

Table 6. Capacity of the restoration scenarios to absorb risk.

			1ha	10ha	100ha
REPLANTING	Professional labour	Cockburn Sound	-96%	-96%	-96%
		Shark Bay	-110%	-110%	-110%
	Volunteer-based	Cockburn Sound	45%	45%	45%
		Shark Bay	42%	44%	44%
RESEEDING	Professional labour	Cockburn Sound	65%	67%	67%
		Shark Bay	54%	63%	65%
	Volunteer-based	Cockburn Sound	85%	86%	86%
		Shark Bay	74%	85%	86%

Another way of interpreting the viability of the scenarios with respect to risk is in terms of the payback period, or the point at which costs are fully recovered. This is effectively the number of years that the restored seagrass plot would need to remain 'healthy' for, following the trajectories for the expected benefits as outlined in Section 3. If the project was to fail at any time after this point, it would have recovered its costs and hence would be seen as viable (from an economic perspective: although if one is allocating a fixed budget between competing alternatives, breaking even is not a sufficient criteria for selection). Table 7 reports the payback periods. For the viable projects, costs are recovered as early as Year 6, and can take up to 17 years.

Table 7. Payback periods for the restoration scenarios.

			1ha	10ha	100ha
REPLANTING	Professional labour	Cockburn Sound	Not viable	Not viable	Not viable
		Shark Bay	Not viable	Not viable	Not viable
	Volunteer-based	Cockburn Sound	Year 17	Year 16	Year 16
		Shark Bay	Year 17	Year 17	Year 17
RESEEDING	Professional labour	Cockburn Sound	Year 11	Year 11	Year 11
		Shark Bay	Year 14	Year 11	Year 11
	Volunteer-based	Cockburn Sound	Year 7	Year 6	Year 6
		Shark Bay	Year 9	Year 7	Year 6

6. DISCUSSION

The results of the BCA provide a clear distinction between the characteristics that lead to a viable seagrass restoration project and those that don't, given the assumptions made in our analysis. The key conclusions are discussed below.

Replanting methods in conjunction with professional labour sources were not viable. The replanting process is labour-intensive, such that the costs of supporting a professional staff base for these projects exceeds the benefits they stand to deliver, in both urban and remote locations.

Reseeding methods were viable under all permutations tested, including the use of either professional or volunteer-based labour sources. The reseeding scenarios also had a much higher capacity to absorb the risks of project failure, relative to the replanting scenarios. This was particularly evident when using volunteer-labour sources, with the largest 100ha plot sizes remaining a viable investment even when the risk of project failure was as high as 86%, for both Cockburn Sound and Shark Bay. This result needs to be interpreted with an understanding of whether replanting or reseeding projects are more likely to be successful. We assumed in our analysis that, with the level of replanting and reseeding applied in each scenario, there would be an equivalent success rate between the two methods. Under this condition, reseeding is clearly a better method to implement to manage risk.

Remoteness did not substantially alter the viability of undertaking the restoration project. While the costs of the activity were marginally higher for working in Shark Bay than in Cockburn Sound, the benefits were still sufficient to generate a net positive value for the projects analysed, with the exception of the replanting/professional-labour scenario, as above.

Both benefits and costs increased roughly in proportion to the scale of the restoration activity over the 1ha, 10ha and 100ha plot sizes analysed. This suggests that investments should be targeted towards the largest spatial extents possible[15], as these will deliver the largest net benefits. In many cases scaling up will become restricted by budgets, as the costs become prohibitive. In such cases, small projects (not including replanting/professional-labour) are still worthwhile investing in.

The scenarios that are viable appear to be quite robust to risk of failure. Reseeding methods in particular are worth investing in even if it is predicted that they could fail over half of the time, and have payback periods that would suggest they are likely to generate benefits in timeframes that are suitably balanced against the risks of extreme climatic events.

It is important to note that this study has focussed on identifying a number of factors that may influence the viability of a restoration project, under a set of assumed conditions. Some benefits were included in the analysis although they are not currently applicable in an Australian market: blue-carbon is not yet an accepted form of tradeable offset in Australia (acknowledging this had little

[15] This statement is made with the caveat that benefits and costs may be substantially different at far greater scales, and these results should not be extrapolated substantially beyond 100ha plot sizes. In particular, the value of benefits tend to diminish with larger quantities, so a 1000ha project may not be 10 times more valuable than a 100ha project.

impact on the BCA outcomes). On the other hand, some complex elements have not been included in the present analysis. For example, some benefits were omitted due to a lack of information about how they would affected by restoration activities and certainty about the magnitude of the associated values. This means that, overall, the benefits estimated in this analysis are relatively conservative.

Also, the assumptions made about costs are based on current experience with seagrass restoration activities in Western Australia. This experience is based on smaller-scale research trials; it is difficult to extrapolate costs as large-scale seagrass restoration has not been attempted in an Australian market setting. It is possible that not all of the economies of scale were captured in our cost estimations, as larger restoration projects may be able to take advantage of using different equipment, technologies and capital purchases that are not viable at small scales. Alternatively, limits on the supply of equipment and volunteers at larger scales may drive costs upwards. These elements could alter the outcomes of the BCA. If this type of analysis was to be used to support a specific decision about restoration in Shark Bay, Cockburn Sound or another location, it would need to consider a wider set of benefits, costs and risks that accommodate the omissions noted throughout this study. Primary data collection to provide clarity on some of these benefits and costs would be required to support such an analysis.

To our knowledge there has been no other study that has undertaken a formal BCA of seagrass restoration. There are some studies that look at the cost-side of restoration (e.g. Bayraktarov et al. 2016) but much fewer that consider the benefits. The latter is an issue that seems to be common in the marine restoration literature as illustrated by the review of coral restoration by Bayraktarov et al. (2019). van Katwijk et al. (2016) provide a major review of the factors that influence success in seagrass restoration, but this does not consider costs at all. Narayan et al (2016) excluded seagrass from their evaluation of coastal protection due to lack of data. Duarte et al (2013) make a claim that the value of carbon sequestration may exceed costs of restoration for seagrass, but they do not appear to apply any social discount rate to the benefit stream from sequestration. Blandon and zu Ermgassen (2014) provide estimates of the benefits of seagrass restoration based on the value of the increased total fish stock rather than the net value to the fishers from the increase in stock caught, which may be less.

In order to draw conclusive recommendations about how to prioritise seagrass restoration efforts, further work is required to test response to the assumptions made in this BCA. However, within the context of our assumptions, we can summarise that reseeding methods are a less-risky investment than replanting methods, and deliver larger benefits, especially through volunteer-based approaches. Restoration efforts are worthwhile in both urban and remote locations, and larger projects deliver greater benefits than smaller ones. Finally, the viable projects are expected to recoup their costs within 6 to 17 years, depending on restoration method, labour source, and location.

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APPENDIX A – COST DATA

The estimated costs for each restoration method, location and labour-source are set out in the tables below.

Table A1. REPLANTING: COCKBURN SOUND with professional labour							
		1ha Quan-tity	cost	10ha Quan-tity	cost	100ha Quan-tity	cost
materials	staples	1	$5,265	10	$52,650	100	$526,500
	cable ties	1	$2,025	10	$20,250	100	$202,500
Collect / replant	boat days	80	$24,000	800	$240,000	8000	$2,400,000
	days labour	480	$130,560	4800	$1,305,600	48000	$13,056,000
	SCUBA hire	320	$8,640	3200	$86,400	32000	$864,000
	car hire	80	$5,600	800	$56,000	8000	$560,000
plot preparation	boat days	2	$600	20	$6,000	200	$60,000
	days labour	6	$1,632	60	$16,320	600	$163,200
	SCUBA hire	4	$108	40	$1,080	400	$10,800
	car hire	2	$140	20	$1,400	200	$14,000
COSTS			**$178,570**		**$1,785,700**		**$17,857,000**

Table A2. REPLANTING: SHARK BAY with professional labour							
		1ha		10ha		100ha	
		quantity	cost	quantity	cost	quantity	cost
materials	staples	1	$5,265	10	$52,650	100	$526,500
	cable ties	1	$2,025	10	$20,250	100	$202,500
Collect / replant	boat days	80	$24,000	800	$240,000	8000	$2,400,000
	days labour	480	$130,560	4800	$1,305,600	48000	$13,056,000
	SCUBA hire	320	$8,640	3200	$86,400	32000	$864,000
	car hire	80	$5,600	800	$56,000	8000	$560,000
plot prepar-ation	boat days	2	$600	20	$6,000	200	$60,000
	days labour	6	$1,632	60	$16,320	600	$163,200
	SCUBA hire	4	$108	40	$1,080	400	$10,800
	car hire	2	$140	20	$1,400	200	$14,000
remote costs*	Accommodation	6	$11,571	58	$115,714	579	$1,157,143
	car hire P-SB-P	6	$810	58	$8,100	579	$81,000
COSTS			**$190,951**		**$1,909,514**		**$19,095,143**

*Quantity shown for accommodation and car hire (Perth-Shark Bay- Perth) is the number of houses or vehicles required to rent, based on each house/vehicle having a capacity of 6-12 people.

Table A3. REPLANTING: COCKBURN SOUND with volunteer labour							
		1ha		10ha		100ha	
		quantity	cost	quantity	cost	quantity	cost
materials	staples	1	$5,265	10	$52,650	100	$526,500
	cable ties	1	$2,025	10	$20,250	100	$202,500
Collect / replant	boat days	80	$24,000	800	$240,000	8000	$2,400,000
	days labour	27	$7,344	267	$72,624	2667	$725,424
	SCUBA hire	320	$8,640	3200	$86,400	32000	$864,000
	car hire	27	$1,890	267	$18,690	2667	$186,690
plot preparation	boat days	2	$600	20	$6,000	200	$60,000
	days labour	1	$272	7	$1,904	67	$18,224
	SCUBA hire	4	$108	40	$1,080	400	$10,800
	car hire	1	$70	7	$490	67	$4,690
COSTS			**$50,214**		**$500,088**		**$4,998,828**

Table A4. REPLANTING: SHARK BAY with volunteer labour							
		1ha Quan-tity	cost	10ha Quan-tity	cost	100ha Quan-tity	cost
materials	staples	1	$5,265	10	$52,650	100	$526,500
	cable ties	1	$2,025	10	$20,250	100	$202,500
Collect / replant	boat days	80	$24,000	800	$240,000	8000	$2,400,000
	days labour	27	$7,344	267	$72,624	2667	$725,424
	SCUBA hire	320	$8,640	3200	$86,400	32000	$864,000
	car hire	27	$1,890	267	$18,690	2667	$186,690
plot preparation	boat days	2	$600	20	$6,000	200	$60,000
	days labour	1	$272	7	$1,904	67	$18,224
	SCUBA hire	4	$108	40	$1,080	400	$10,800
	car hire	1	$70	7	$490	67	$4,690
remote costs	Accommodation*	1	$2,000	3	$6,524	33	$65,095
	car hire P-SB-P*	1	$140	3	$457	33	$4,557
COSTS			**$52,354**		**$507,068**		**$5,068,480**

*Quantity shown for accommodation and car hire (Perth-Shark Bay- Perth) is the number of houses or vehicles required to rent, based on each house/vehicle having a capacity of 6-12 people.

Table A5. RESEEDING: COCKBURN SOUND with professional labour							
		1ha Quan-tity	cost	10ha Quan-tity	cost	100ha Quan-tity	cost
setup	tank systems	1	$4,000	10	$40,000	100	$400,000
	labour	9	$2,448	90	$24,480	900	$244,800
collection	boat days	10	$3,000	100	$30,000	1000	$300,000
	days labour	60	$16,320	600	$163,200	6000	$1,632,000
	SCUBA refills	40	$1,080	400	$10,800	4000	$108,000
	car hire days	10	$700	100	$7,000	1000	$70,000
processing	days labour	1	$272	10	$2,720	100	$27,200
plot preparation	boat days	1	$300	2	$600	3	$900
	days labour	6	$1,632	12	$3,264	18	$4,896
	car hire days	1	$70	2	$140	3	$210
	SCUBA refill	4	$108	8	$216	12	$324
seed dispersal	boat days	1	$300	10	$3,000	100	$30,000
	days labour	6	$1,632	60	$16,320	600	$163,200
	car hire days	1	$70	10	$700	100	$7,000
COSTS			**$31,932**		**$302,440**		**$2,988,530**

Table A6. RESEEDING: SHARK BAY with professional labour							
		1ha Quan-tity	cost	10ha Quan -tity	cost	100ha Quan -tity	cost
setup	tank systems	1	$4,000	10	$40,000	100	$400,000
	labour	9	$2,448	90	$24,480	900	$244,800
collection	boat days	10	$3,000	100	$30,000	1000	$300,000
	days labour	60	$16,320	600	$163,200	6000	$1,632,000
	SCUBA hire	40	$1,080	400	$10,800	4000	$108,000
	car hire days	10	$700	100	$7,000	1000	$70,000
processing	days labour	1	$272	10	$2,720	100	$27,200
plot preparation	boat days	1	$300	2	$600	3	$900
	days labour	6	$1,632	12	$3,264	18	$4,896
	car hire days	1	$70	2	$140	3	$210
	SCUBA hire	4	$108	8	$216	12	$324
seed dispersal	boat days	1	$300	10	$3,000	100	$30,000
	days labour	6	$1,632	60	$16,320	600	$163,200
	car hire days	1	$70	10	$700	100	$7,000
remote costs	Accommodation*	6	$10,000	26	$30,000	254	$220,000
	car hire P-SB-P*	6	$140	26	$420	254	$3,080
COSTS			**$42,072**		**$332,860**		**$3,211,610**

*Quantity shown for accommodation and car hire (Perth-Shark Bay- Perth) is the number of people requiring accommodation or a car; accommodation costs are calculated over the 30 day (5 weeks rent) timeframe for seed collection, assuming 1 house can accommodate up to 12 people; car hire costs assumes up to 12 people can be accommodated in a vehicle.

Table A7. RESEEDING: COCKBURN SOUND with volunteer labour							
		1ha Quan-tity	cost	10ha Quan-tity	cost	100ha Quan-tity	cost
setup	tank systems	1	$4,000	10	$40,000	100	$400,000
	labour	9	$2,448	90	$24,480	900	$244,800
collection	boat days	10	$3,000	100	$30,000	1000	$300,000
	days labour	4	$1,088	34	$9,248	334	$90,848
	SCUBA hire	40	$1,080	400	$10,800	4000	$108,000
	car hire days	4	$280	34	$2,380	334	$23,380
processing	labour	1	$272	10	$2,720	100	$27,200
plot preparation	boat days	1	$300	2	$600	3	$900
	days labour	1	$272	1	$272	1	$272
	car hire days	1	$70	1	$70	1	$70
	SCUBA hire	4	$108	8	$216	12	$324
seed dispersal	boat days	1	$300	10	$3,000	100	$30,000
	days labour	1	$272	4	$1,088	34	$9,248
	car hire days	1	$70	4	$280	34	$2,380
COSTS			**$13,560**		**$125,154**		**$1,237,422**

Table A8. RESEEDING: SHARK BAY with volunteer labour							
		1ha		10ha		100ha	
		quantity	cost	quantity	cost	quantity	cost
setup	tank systems	1	$4,000	10	$40,000	100	$400,000
	labour	9	$2,448	90	$24,480	900	$244,800
collection	boat days	10	$3,000	100	$30,000	1000	$300,000
	days labour	4	$1,088	34	$9,248	334	$90,848
	SCUBA hire	40	$1,080	400	$10,800	4000	$108,000
	car hire days	4	$280	34	$2,380	334	$23,380
processing	labour	1	$272	10	$2,720	100	$27,200
plot preparation	boat days	1	$300	2	$600	3	$900
	days labour	1	$272	1	$272	1	$272
	car hire days	1	$70	1	$70	1	$70
	SCUBA hire	4	$108	8	$216	12	$324
seed dispersal	boat days	1	$300	10	$3,000	100	$30,000
	days labour	1	$272	4	$1,088	34	$9,248
	car hire days	1	$70	4	$280	34	$2,380
remote costs	Accommodation*	1	$10,000	5	$10,000	46	$40,000
	car hire P-SB-P*	1	$140	5	$140	46	$560
COSTS			**$23,700**		**$135,294**		**$1,277,982**

*Quantity shown for accommodation and car hire (Perth-Shark Bay- Perth) is the number of people requiring accommodation or a car; accommodation costs are calculated over the 30 day (5 weeks rent) timeframe for seed collection, assuming 1 house can accommodate up to 12 people; car hire costs assumes up to 12 people can be accommodated in a vehicle.

www.nespmarine.edu.au

Contact:

Dr Abbie Rogers
The University of Western Australia

Address | 35 Stirling Hwy | Crawley, WA, 6009

email | abbie.rogers@uwa.edu.au

tel | +61 8 6488 5506