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Benefit-cost analysis for marine habitat restoration: a framework for estimating the viability of shellfish reef repair projects

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Contents

1. Introduction 1

2. Shellfish reef restoration project 2

3. Benefit-cost analysis for the Gulf St Vincent restoration project 2

3.1 With versus without scenarios 3

3.1.1 The 'with project' scenario 3

3.1.2 The 'without project' scenario 4

3.2 Causal processes 4

3.2.1 'With project' causal processes 5

3.2.2 'Without project' causal processes 5

3.3 BCA timeframe 6

3.4 Project risks 6

3.5 Benefits and costs 7

3.5.1 Market benefits 7

3.5.2 Non-market benefits 7

3.5.3 Market costs 7

3.5.4 Non-market costs 7

4. Alternative scenarios to consider in the benefit-cost analysis 8

4.1 Alternative management configurations 8

4.2 Alternative spatial scales 8

4.3 Alternative habitat types 8

REFERENCES 9

1. INTRODUCTION

Coastal habitat loss is a global problem, including degradation of shellfish reefs, coral reefs, seagrass meadows, salt marshes, and kelp and mangrove forests. A growing interest has developed in the ability to restore these habitats as a means to replace lost habitat, restore ecosystem productivity and reduce the impacts of coastal hazards such as erosion and inundation (McLeod et al. 2018). A delegation of experts at the Australian Coastal Restoration Symposium identified numerous key factors affecting the advancement of restoration projects in Australia. A selection of these are as follows (McLeod et al. 2018, pE3):

> “Legislative approval is a major barrier for restoration projects, and funding is difficult to secure in Australia”;
>
> “Choosing the right location for restoration to maximise ecosystem benefits, cost-effectiveness and community support”;
>
> “Restoration costs need to be estimated for the area of habitat restoration and reported to help support management and planning through mechanisms such as benefit-cost analysis”;
>
> “A decision framework needs to be established to enable calculated risks to be taken”;
>
> “It would be beneficial to develop a list of what materials and approaches work for coastal restoration and in which setting”.

Underlying these factors is the need to be able to weigh up the benefits and costs of a restoration project, to be able to do this relative to alternative projects, and to incorporate the risks and probabilities of project success. This in turn identifies a need for frameworks that have the ability to integrate the environmental, social and economic outcomes of a restoration project and provide quantitative decision metrics that can be used in evidence-based decision making, including justification for funding support. Benefit-cost analysis (BCA) is an economic approach that provides a platform to do this (Hanley and Barbier 2009).

BCAs are a framework for bringing together the tangible, market-based or monetary elements of a project (the economic benefits and costs), as well as the intangible, non-market or non-monetary elements (the environmental and social benefits and costs) of the project. These benefits and costs can all be equated in the same metric, often monetary, enabling direct trade-offs between both the market and non-market benefits and costs. The BCA provides different measures of project viability that can be used to demonstrate whether a project is worthwhile undertaking (i.e. the benefits outweigh the costs), how multiple projects should be prioritised (i.e. which has the greatest benefits relative to costs), or at what thresholds a project becomes unviable under different project assumptions (i.e. when changing the probabilities that certain benefits and costs occur).

The objective of this report is to identify a preliminary framework for a BCA of a shellfish reef restoration project. This includes identification of the reef case study and focus of the BCA (Section 2), scoping of the BCA framework (Section 3), and potential extensions to the BCA that could be considered in future to help address the key factors affecting advancement of coastal restoration projects in Australia (Section 4).

2. SHELLFISH REEF RESTORATION PROJECT

It is estimated that over 85% of the world's shellfish ecosystems have been lost or degraded through human activities such as overfishing, dredging and other destructive fishing practices, water pollution and the spread of disease (Gillies et al. 2018). For example, in Australia, it is estimated that only 1% and 8% of the ecosystems formed by once common species *Ostrea angasi* and *Saccostrea glomerata* remain, respectively.

The Nature Conservancy are undertaking Australia's largest scale attempt to restore a shellfish reef in Gulf St Vincent, South Australia. A four hectare trial site was restored in the area by the South Australian Government, and funding was acquired by The Nature Conservancy from the Australian Government's National Stronger Regions Fund to restore an additional 16 hectares of shellfish reef. The preliminary BCA framework that will be developed will focus on this 16ha project.

The BCA will compare two scenarios: one where the 16ha restoration project exists, and one where it does not. Outputs from the BCA will include:

- Assigning monetary-equivalent values to changes in the intangible environmental and social outcomes of the project. Non-market valuation (specifically, benefit transfer) will be used to provide dollar estimates for these non-market values (Bateman et al. 2002; Johnston et al. 2015).
- Discounting of all future project costs and benefits into their equivalent present values. This is to recognise that people place more value on having something now, rather than having to wait for it in the future.
- Calculation of the net present value of the project, where a positive value would indicate that the project's benefits exceed the costs. Net present value is used to show which projects have the greatest benefits overall, if prioritising between multiple project alternatives.
- Calculation of the benefit: cost ratio of the project, where benefits outweigh the costs if the ratio is greater than one. The benefit: cost ratio is used to measure the return on investment, and is more useful than the net present value to select projects that deliver the 'best bang for your buck' in cases where funding resources are limited.

3. BENEFIT-COST ANALYSIS FOR THE GULF ST VINCENT RESTORATION PROJECT

To establish a framework for the BCA, it is necessary to have an understanding of the different scenarios with and without the 16ha restoration project. It is important to capture the causal processes that occur between project commencement and the realisation of the project's benefits, and to capture any equivalent processes that may occur in the same time horizon in the scenario with no restoration project. The different benefits and costs that occur along this chain of causal processes must be identified, along with the timing of each and the probabilities that they will actually occur. That is, project risks and uncertainties must be accounted for in the framework. Finally, the specific benefits and costs that are important to include in the BCA need to be identified.

In February 2018, we convened a workshop with the Gulf St Vincent project managers and shellfish reef restoration experts from The Nature Conservancy and James Cook University to provide input into the structure of the BCA framework based on the elements discussed below.

3.1 With versus without scenarios

The benefits and costs of the 16ha restoration project scenario (the ‘with project’ scenario) must be compared with the benefits and costs of a base case scenario (the ‘without project’ scenario) to identify the net difference between the two cases, and subsequently establish the viability of undertaking the restoration project (Figure 1). A brief description of these scenarios are provided below.

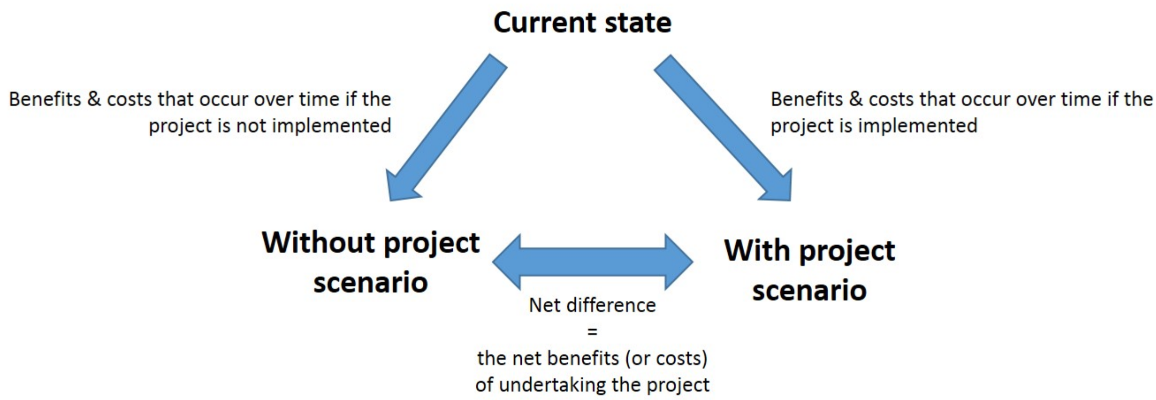

Figure 1. Comparison of with versus without project scenarios in BCA.

3.1.1 The ‘with project’ scenario

- 16ha shellfish reef restoration project in Gulf St Vincent, South Australia. The footprint of this scenario will also encompass any adjacent areas that are identified as being likely to experience an increase in ecosystem productivity as a direct result of the reef.
- Objective of the restoration activity is to improve environmental quality, particularly finfish habitat.
- Anticipated that environmental benefits to the area will be in terms of increased ecosystem productivity.
- Associated social benefits for recreational fishers and divers, and flow on benefits to the regional community in terms of increased visitor numbers, as well as increased finfish stock for commercial catch.
- The site is located offshore meaning that other benefits often associated with reef restoration projects such as improved coastal amenity and coastal hazard protection are not relevant.

3.1.2 The ‘without project’ scenario

- Habitat at the site as per pre-restoration conditions: up to 25% seagrass beds (including *Halophila sp.* and *Heterozostera sp.*), some pinna beds, and predominantly bare sand/sediment.
- Relatively stable geographic location means that climate change and other anthropogenic pressures are not major threats.
- Anticipated that there could be a small, gradual decline in environmental quality over the next few decades.
- Current recreational uses of the area will be relatively stable.

3.2 Causal processes

The processes that occur between project commencement and realisation of the full costs and benefits of the project is important to understand in developing the BCA framework. Having these processes mapped out enables subsequent identification of when particular benefits and costs of the project are realised (for appropriate discounting to present values), and how risks and uncertainties may manifest themselves in the sequence of events.

3.2.1 'With project' causal processes

Project commencement & stakeholder engagement	• Change in management/monitoring of the surrounding area and in government behaviour: implementation of an aquatic reserve adjacent to the reef • Change in stewardship for local & user communities: 'our reef'
On-ground works: laying substrate	• Within first 12 months: change in environmental condition – small decline in environmental productivity due to removal/damage/disturbance of existing seagrass and Pinna beds
On-ground works: oyster seeding	• In first 12 months: change in recreational fisher behaviour: initial decrease from construction disturbance, followed by net increase as fish stocks from other sites move into the area and aggregate (reef is effectively acting as a fish aggregative device (FAD) at this point)
Self-sustaining reef	After approximately 7 years: • Finfish stocks increase, rather than just aggregate • Habitat becomes 250-300% more productive than the original habitat • Recreational fishing opportunities have increased substantially • Other recreational uses are realised: diving/snorkelling on the reef • Coastal business precinct begins to benefit from increased recreational activity (cafes, charters, tackle & dive shops, etc.) • Change in community and government behaviour – further support and advocacy for more restoration projects

3.2.2 'Without project' causal processes

Continuation of pre-restoration management	• Continuation of existing low levels of recreational fishing activity • No diving/snorkelling activity
Gradual degradation	• Minor decline in environmental quality over next ~20 years due to climate change and other anthropogenic threats • Associated minor decline in recreational fishing activity

3.3 BCA timeframe

The time horizon used in the BCA framework needs to be sufficient to allow all project benefits and costs to be realised. Important timeframes that should be considered for this BCA include:

- At least 7 years is required to realise the full environmental benefits of the reef, under assumed (ideal) project conditions;
- Approximately 20 years is required to realise the minor decline in environmental productivity for the 'without project' scenario;
- Between 20-30 years is required to allow for potential delays in realising the environmental benefits of the reef if disease or predation events occur;
- Associated policy timeframes (e.g. EPBC Recovery Plans) are often based around management and monitoring of three generations, which for shellfish is approximately 30 years (10 years per generation; lifespan of *O.Angasi* predicted to be up to 20 years in the wild).

With these timeframes in mind, a time horizon of 30 years is suitable for the BCA.

3.4 Project risks

The outcomes of environmental restoration projects can be affected by multiple risks, including:

- Scientific uncertainties or lack of credible data
- Technical risks
- Socio-political risks
- Financial risks
- Managerial and human-resourcing risks

This project in particular must consider the following risks:

- The potential for oyster deaths to occur, leaving behind a less productive rocky reef.
  - Oyster deaths may results from predation (e.g. starfish, stingrays) and disease, and related biosecurity risks.
  - Management options may be to remove predators, reseed the oyster stocks, or use disease-tolerant stock to replenish the reef over time.
  - Biosecurity protocols are in place to manage these risks with respect to transfer of oyster stock.
- Engineering risks associated with the rock structure.
  - Having a well-engineered project means some risks are lowered relating to the rock structure.
- Availability of data to predict magnitudes of social and environmental changes.
  - Given the lack of shellfish reef habitats in Australia, international literature will be required to help predict the anticipated increase in ecosystem productivity.
  - Magnitudes of increased visitation to the area by recreational fishers and divers/snorkelers may be difficult to predict.

BCA frameworks are well equipped to manage risks and uncertainties, by capturing the probability that particular benefits and costs will be realised. Probabilities can be altered in sensitivity analyses to determine how uncertainty regarding a particular benefit or cost might change the decision outcomes of the BCA (Pannell 1997). Thresholds at which point the project becomes unviable can be identified in this way.

3.5 Benefits and costs

A non-exhaustive list of the most important benefits and costs to be included in the BCA framework are identified below. Other important or large benefits and costs will be identified and included in the framework as it develops.

3.5.1 Market benefits

- Profits to the shellfish aquaculture sector (hatcheries and growers) from supply of oyster stock
- Profits to the tourism sector from increased visitor numbers, including cafes, diving and fishing charters, tackle and dive businesses.
- Commercial fishing benefits generated by increased finfish stock
- Profits to local council from boat ramp user fees

3.5.2 Non-market benefits

- Environmental benefits in terms of increased ecosystem productivity and creation of finfish habitat
- Recreational fishing benefits (for finfish)
- Recreational diver benefits
- Creation of social capital from community engagement and volunteering
- Cultural benefits for indigenous communities
- Contribution to knowledge from research and monitoring of a large scale restoration site

3.5.3 Market costs

- Labour for construction, monitoring and management of the project
- Limestone substrate
- Oyster seeding supply
- Transportation costs for construction materials

3.5.4 Non-market costs

- Not yet identified, anticipated to be minimal.

4. ALTERNATIVE SCENARIOS TO CONSIDER IN THE BENEFIT-COST ANALYSIS

Section 3 describes the scope of the BCA framework for the 16ha Gulf St Vincent shellfish reef restoration project. In future work, it will be possible to extend the framework to consider alternative habitat restoration projects. These alternative analyses will be aimed at providing an understanding as to how restoration projects might be prioritised over a range of management configurations, spatial scales and habitat types. Examples of the alternative project scenarios that could be considered are as follows.

4.1 Alternative management configurations

For the Gulf St Vincent project, there are hypothetical variations that could be tested to compare which management approaches are most efficient, for example:

- Government, NGO, and private sector-lead projects.
  Different types of project managers could alter the benefit: cost ratio. For example, NGOs can often attract cheaper pricing for some of the capital costs of the project, relative to other sectors. Different sectors also have different levels of experience in managing restoration projects, which can lead to different efficiencies and project risks.
- Fisheries management policies.
  The governance of the restoration site will have implications for the social and environmental benefits. Comparisons of (finfish) fishing restrictions could include cases where no fishing is allowed, where only recreational fishing is allowed, or where both recreational and commercial fisheries are allowed to operate at the site.

4.2 Alternative spatial scales

The 16ha Gulf St Vincent project, in combination with the existing 4ha trial site, is the largest attempt at shellfish reef restoration in Australia. In allocating funding, it could be possible to have many small-scale projects, or fewer large-scale projects. Smaller scale projects might be associated with community grants and volunteer-driven efforts which could have greater social benefits, but smaller environmental benefits, than a large scale government or NGO-driven project. Different construction materials might be used in different scales of projects, which will be associated with different project risks, and different magnitudes of environmental benefits. To prioritise resources it will be important to understand whether many small-scale or fewer large-scape projects provides the greatest benefits, and what types of benefits each approach will generate.

4.3 Alternative habitat types

There are many degraded marine habitat types in Australia worthy of consideration for restoration projects. The limited resources available for restoration will mean it is important not just to prioritise which shellfish restoration projects are worthwhile, but which habitat types more broadly should be prioritised for restoration. Extending the BCA framework to consider the benefits and costs of coral reef, seagrass, saltmarsh, mangrove and kelp habitat restoration projects will be useful in this regard.

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