Australian Government
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# COST-BENEFIT ANALYSIS OF MARY RIVER WETLANDS SALINITY MITIGATION

## An Overview

Northern Territory Government
Department of Infrastructure, Planning and Environment

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This booklet gives an overview of a study undertaken to evaluate the cost and benefits of options to prevent the intrusion of salt water upon the Mary River Wetlands in the Northern Territory, Australia. Since the 1940s, this highly significant freshwater wetland has been subject to approximately 240 km$^2$ of salt water inundation, resulting in the loss of salt-sensitive vegetation and significant impacts on the area's environmental and economic values.

Under enhanced greenhouse conditions sea-level is projected to rise. In Australia, CSIRO research projects an increase in mean sea-level of between 9 cm to 88 cm by 2100. The associated coastal recession, of between 4.5 m to 88 m by 2100, means salt water inundation of freshwater wetlands is a likely impact.

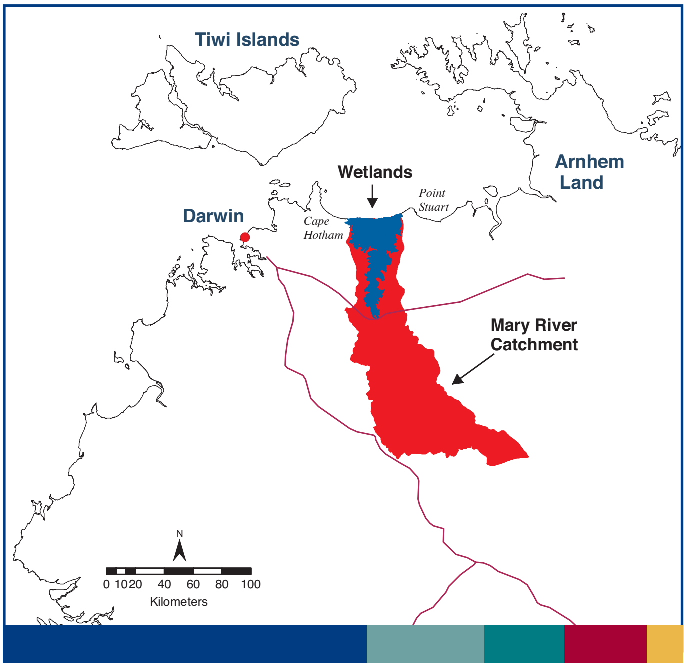
Whilst the salt water inundation in the Mary River is not a result of climate change, it provides an opportunity to undertake research in circumstances similar to those projected to occur due to global warming.

The study demonstrated an economic methodology which could be used to assess options to adapt to greenhouse induced sea-level rise.

## BACKGROUND

The Mary River Catchment covers an area of 8,062 km$^2$ and is part of a network of over 10,000 km$^2$ of coastal floodplains (see Figure 1). The wetlands have high biodiversity and are also highly productive, making a large contribution to the Northern Territory's barramundi, threadfin salmon, magpie geese and crocodile yields, as well as providing a unique opportunity for cattle grazing late into the dry season. The area also attracts a growing number of tourists.

*Figure 1: Location of the Mary River Wetlands and Catchment*




*Source: Bach and Hosking (2002)*[1]

[1] Bach, C. & Hosking, E.J. 2002, *Wetland Monitoring for the Mary River Catchment, Northern Territory*. Natural Heritage Trust Project No. 97152. NT Department of Infrastructure, Planning and Environment, Darwin.

Up to the 1940s the floodplains were entirely freshwater, with rows of low level 'chenier' ridges along the coast forming a barrier between the sea and the wetland system (see Figure 2). During the 1940s the chenier ridges were breached, and while the reasons remain uncertain, potential causes include feral buffalo, dynamiting to create boat channels and coastal erosion.

Over time, tidal flushing resulted in increases in salt water in the wetlands and created deeper, wider outlets which allowed more rapid transmission of freshwater to the sea. By the 1980s the process of saline intrusion had accelerated despite mitigation efforts by local landholders.

In 1987 the Northern Territory government commenced a major barrage building program. The unstable substrate, based on many metres of marine mud, resulted in considerable experimentation, constant maintenance and ongoing adaptation to the changing courses of the waterways. Because of this, the barrage construction program resulted in considerable expense, but continued on the basis of the perceived but unquantified benefits of the freshwater system.

To assist with future decision making, there was a need to more accurately identify the costs and benefits of the options available to address the salt water intrusion. This formed the basis for the study.

*Figure 2: Chenier ridges in the wet season*

*Source: Jonauskas, P. NT Department of Infrastructure, Planning and Environment.*

## THE STUDY

Cost-benefit analysis is defined as a technique to *"assess the relative desirability of competing alternatives in terms of economic worth to society"*[2]. Importantly, it allows for an assessment in economic terms of intangible values. Intangible values are those for which no market exists, such as the value of conserving the ecology of the Mary River Wetlands.

The following steps were undertaken in the study:

- Identifying the salinity mitigation options and their likely impacts
- Estimating the costs associated with each option
- Determining the likely benefits of each option
- Using a mathematical model to calculate the present value of the net benefits for each option.

## THE OPTIONS AND THEIR LIKELY IMPACTS

Four options to address the salinity intrusion were identified for assessment:

### Option 1 – The Base Case - Let nature take its course

Under this option no further mitigation action would be taken. Whilst this is a potential course of action, it is also the relative basis against which all other mitigation options are assessed (the 'base case' scenario). Under this option there would be a rapid increase in salinised land, with a reduction in agricultural, wild harvest and tourism activity. Based on historical rates of intrusion, and allowing for the existing mitigation works, the study estimated that complete inundation of the wetlands (112,600 hectares) would occur by 2050. The only cost associated with this option is basic monitoring.

### Option 2 – Band Aid

This option involves completing the basic network of small barrages, stabilising these with spillways to deal with their vulnerability to wet season flows, and maintaining these over time. This option, to be implemented over 2-3 years, would most likely result in maintenance of the existing area of freshwater wetlands but no retrieval of previously lost areas.

### Option 3 - Two Chokes

This option involves reducing the strength of tidal flows, and therefore limiting salinisation, by gradually choking two main channels with submerged weirs constructed from geotextile bags filled with mud. The existing small barrages would be maintained. Retrieval of some lost freshwater wetlands is likely with this approach. The total program would be completed over 10 years.

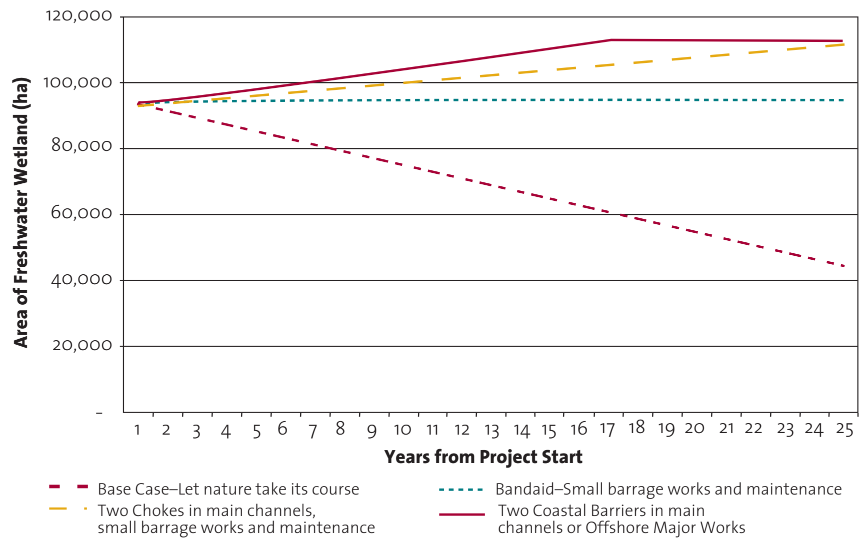
[2] Sinden, J.A. & Thampapillai, D.J. 1995, *Introduction to Cost-Benefit Analysis.* Longman, Sydney. pg ix

## **Option 4 – Two Coastal Barriers**

This option is conceptual and based on previous research suggesting that there may be options to use barriers at the creek mouths or offshore to reduce tidal flows and slow the salinisation process. Although this option was considered unlikely due to its high costs, it was included in the study to ensure an option that addressed the intrusion at the source was considered. While the impacts of this option are the most uncertain, because the effectiveness of the approach is largely unknown, it is anticipated that the likely outcome would be retrieval of the same area of freshwater wetlands as in Option 3, but within a shorter timeframe.

Figure 3 illustrates the area of freshwater wetland likely under each option.

*Figure 3: Area of freshwater wetland under each option*




## THE COSTS

The costs for Option 2 – Band Aid and Option 3 – Two Chokes were estimated through examination of work to date and discussions with technical experts. Costs included direct costs such as materials (e.g. geotextile bags), engineering services (e.g. design, planning), equipment hire and labour. Allowances for breakdowns and rainfall were also included. The costs for Option 4 – Two Coastal Barriers were taken directly from the previous research on this option.

The costs were extrapolated over a 25 year planning period. Both capital and operating costs were identified and expressed as 2003 values so as to exclude the effects of inflation and standardise the value over time. A 7% social discount rate was used to calculate the present value of the costs. Where externalities were identified in respect of existing or proposed mitigation works, the costs for any remedial measures were calculated. Externalities are costs or benefits caused by the activities of one person or business spilling over onto another. For example, because barrages are a deterrent to fish migration, the cost of the fish ladders was also included.

*Table 1: The costs of each option*

| Option | Description | Capital cost | Maintenance per annum | Monitoring per annum | Present value (7%) |
|---|---|---|---|---|---|
| 1 | The Base Case | $0 | $0 | $6,888 | |
| 2 | Band Aid | $840,000 | $100,000 | $6,888 | $1,620,000 |
| 3 | Two Chokes | $725,822 | $150,000 | $6,888 | $2,165,000 |
| 4 | Two Coastal Barriers | $2,395,980 | $119,799 | $6,888 | $3,899,000 |

## THE BENEFITS

The benefits were identified for each option and presented as a comparison to Option 1 – The Base Case. These benefits were separated into tangible benefits, those which could be valued confidently using market prices, and intangible benefits, those that required more indirect valuation techniques and consequently resulted in more uncertain valuations.

In determining benefits the study makes a clear distinction between a producer surplus and consumer surplus. The producer surplus is the amount in excess of the actual supply costs that some producers receive for their products at the market price. Consumer surplus is the amount in excess of actual market price that consumers would be willing to pay for a product or service, and is akin to customer satisfaction.

### Tangible Benefits

The tangible benefits of several industries were measured by the producer surplus attributable to the Mary River. In all instances a conservative 20% producer margin was assumed in line with typical industry returns.

#### Cattle Grazing

Livestock prices were estimated from discussions with producers and from industry reports. Costs of cattle production were determined by the use of adjusted interstate gross margins for cattle as none were available for the Northern Territory.

*Table 2: Local cattle industry estimates*

| | |
|---|---|
| No. of head exported from Mary River each year | 35,000 |
| Estimated income from Mary River cattle | $17,500,000 |

*Table 3: Cattle grazing calculation*

| | | Total Price |
|---|---|---|
| **Trading Margin** | | |
| Buy | August (206 kg @ 115c/kg) | $237 |
| Sell | January (256 kg @ 146c/kg) | $374 |
| Trading margin | $374-$237 | $137 |
| **Value Added** | | |
| Estimated carrying cost per beast | | $26.26 |
| Gross margin per beast | $137 - $26.26 | $110.74 |
| Fixed costs and labour (from literature) | | $78.00 |
| Total costs | $237 + $26.26 + $78 | $341.26 |
| Profit per beast | $374 - $341.26 | $32.74 |
| **Risk Margin** | | |
| After 1 year in 5 loss risk adjustment for weather and production losses | 81% | $26.26 |
| Average stocking rate (beasts/ha) | | 0.31 |
| Value added per ha per annum | $26.26 x 0.31 | $8.16 |
| Estimated land value (from amortised value added at 10%) | | $74.10 |

Using this information, and adding adjustments for seasonal and price risks, it was estimated that the land value associated with cattle enterprises in the Mary River Wetlands is approximately $75 per hectare. However, the Northern Territory Valuer General estimates local land values at $50 per hectare. Due to the wide disparity of the estimates, the more conservative value of $50 was used in the study.

### Commercial and Recreational Fishing

In the study it was assumed the combined commercial and recreational fishing harvest was equivalent to the estimated sustainable fishery yield of the Mary River. The estimate of sustainable yield was determined through discussions with Northern Territory fisheries officers. The proportion of recreational yield was determined through analysing recent surveys.

Because commercial fishing catch data was unavailable due to privacy controls, average prices for barramundi and threadfin salmon from the Northern Territory were obtained from Sydney fish market records.

It was assumed the productivity of the fishery is likely to be proportional to the area of freshwater nursery habitat. Based on this assumption, an annual fishery production value of $1.61 per hectare of wetland was estimated.

*Table 4: Producer surplus for fishing*

| Species | Long term sustainable yield | Average wholesale price | Annual value | Producer surplus per annum (20%) |
|---|---|---|---|---|
| Barramundi | 64 tonnes | $10.01/kg | $640,640 | $128,128 |
| Threadfin salmon | 47 tonnes | $5.64/kg | $265,080 | $53,016 |
| Total | 111 tonnes | | $905,720 | $181,144 |

Because the salinised land will gradually be colonised by salt-tolerant mangroves, the likely mud crab catch from a mangrove based Mary River system was also estimated. The estimate was based on the catch per hectare of mangrove around Darwin. Known average prices were used to determine the producer surplus likely to arise from a mangrove system. The annual production value was estimated as $0.80 per hectare.

*Table 5: Producer surplus for mangrove environment*

| Species | Yield | Average wholesale price | Annual average | Producer surplus per annum (20%) |
|---|---|---|---|---|
| Mud Crabs | 34 tonnes | $13/kg | $448,000 | $89,000 |

## Intangible Benefits

Any producer or consumer benefits that could not be quantified using market information were classed as intangible. These included benefits relating to the use of the Mary River environment, either directly (through viewing it or being there), or indirectly (through hunting Magpie Geese elsewhere in the Northern Territory that were produced in the Mary). The intrinsic value placed on the wetlands by people who never visit them ("non-use") was also determined.

### Wild Harvest

The two most significant wild harvest species in the Mary River are magpie geese and crocodiles.

#### Magpie Geese

Previous research estimated that 10% of magpie geese hunted throughout the Northern Territory are sourced from the Mary River. This percentage was applied to the annual yield of the Mary system to estimate annual harvest rates. The value of magpie geese was estimated using informal market prices and data from a survey of the willingness of consumers to pay for magpie geese.

*Table 6: Producer surplus for magpie geese*

| Value per bird | Annual yield (10%) | Producer margin | Producer surplus per annum (20%) |
|---|---|---|---|
| $20 | 39,422 | 20% | $158,000 |

### Crocodiles

A license limits the number of crocodiles taken in the Mary River to 25. It was assumed this number would not change throughout the study period of 25 years. The value of each crocodile was determined using published skin values of $5.85 per centimetre and assuming crocodiles taken had skin lengths in excess of 4 m.

*Table 7: Producer surplus for crocodile skins*

| Total value | Producer margin | Producer surplus per annum (20%) |
|---|---|---|
| $11,600 | 20% | $2,320 |

Photo by Robert Thorn, DEH Collection.

Some property owners also harvest crocodile eggs from the Mary River system. These eggs are then hatched for crocodile farming operations. In the study, the ongoing harvesting of wild eggs was assumed.

Egg yields for the Mary were assumed to be 12% of the Northern Territory's total sustainable yield, in line with Mary's share of problem crocodile harvest (i.e. 25 problem crocodiles each year, compared to a total problem crocodile harvest in the Northern Territory of 200 per year). The value of crocodile eggs was estimated based on reported United States prices for alligator eggs, allowing for a slight premium for Australian crocodiles.

*Table 8: Producer surplus for crocodile eggs*

| Value per crocodile egg | Number taken in Mary | Producer margin | Producer surplus per annum (20%) |
|---|---|---|---|
| $12 | 1,320 | 20% | $3,168 |

### Tourism

Tourism activities on the Mary River Wetlands include recreational fishing, hunting and sightseeing.

The number of visitors anticipated over the study period was determined by linking Northern Territory Tourist Commission forecasts (5% growth to 2008) with nearby Kakadu National Park forecasts and then conservatively inferring a spillover effect to the Mary River. This was based on evidence of a relationship between the growth of Kakadu visitor numbers and Mary River visitation in the 1990s.

The proportion of tourists undertaking recreational fishing, hunting and sightseeing was estimated. The benefit to each of these visitors was determined by estimating what proportion of their expenditure or travel costs was associated with visits to the Mary River through examination of representative travel cost surveys in other studies. Adjustments were made to account for the high proportion of tourists that fish on the Mary River, based on data from a Northern Territory recreational fishing survey.

*Table 9: Consumer surplus per visitor*

| Assumed long term breakdown | % | Number | Travel cost surplus estimate per visitor day | Consumer surplus | Consumer surplus per ha |
|---|---|---|---|---|---|
| Recreational fishing expenditure | 40 | 4,687 | $100 | $468,701 | $4.16 |
| Hunting | 15 | 1,758 | $90 | $158,187 | $1.40 |
| Sightseeing | 45 | 5,273 | $20 | $105,458 | $0.94 |
| | 100 | 11,718 | $63 | $732,346 | $6.50 |

### Non-Use Value

People who do not use the Mary River Wetlands are also likely to attribute some value to them and may be willing to pay something to ensure they are preserved. Because 'willingness to pay' surveys were beyond the scope of the study, estimates from other studies on the non-use value of wetlands with similar attributes and in similar socioeconomic circumstances were used. This technique is known as benefit transfer.

A study of wetlands in southern Australia found non-users were willing to pay (WTP) a minimum value of $1.15 per 1,000 ha of healthy freshwater wetland. In the Mary River study, this conservative figure was multiplied by the number of people estimated to be willing to pay. This is typically the population of the nearest major city, being Darwin City's population of 68,378 people.

*Table 10: Non-use value (Option 3, Year 1)*

| WTP for 1,000 ha of wetland per person | Non-use benefit of 2,771 ha of wetland | Total non-use benefit per ha |
|---|---|---|
| $1.15 one off payment<br>OR<br>Approximately $0.14 per annum over project life | $27,002 | $9.75 |

*Table 11: Summary of benefits*

| Current benefits per hectare based on 112,600 ha | Producer Surplus | Consumer Surplus | Initial Total Benefit (1 year) | Mean Benefit Over Project Life (Option 3) | % of Benefit | Assumptions |
|---|---|---|---|---|---|---|
| Agriculture | $8.16 | | $8.16 | $8.16 | 22% | Agriculture prices and productivity assumed static in the long term |
| Fishery | | | | | | Fish prices and fisheries productivity per ha assumed static in the long term, but because freshwater wetlands expand under Option 3, the mean per hectare value is higher in the long term than initially |
| Commercial Barramundi & Threadfin (est. at 10% of total yield) | $0.16 | | $0.16 | | | |
| Recreational fishery (est. at 90% of total yield) | $1.45 | | $1.45 | | | |
| Crab (per ha of mangrove, therefore currently negative) | -$0.80 | | -$0.80 | | | |
| Total | $0.81 | | $0.81 | $0.97 | 3% | |
| Wild Harvest | | | | | | Wild harvest prices and productivity per ha assumed static in the long term |
| Crocodiles | $0.02 | | $0.02 | | | |
| Crocodile eggs | $0.03 | | $0.03 | | | |
| Magpie geese | $1.40 | | $1.40 | | | |
| Total | $1.45 | | $1.45 | $1.45 | 4% | |
| Tourism | | | | | | Tourism yield from the Mary assumed to grow in line with NT Tourism Commission forecasts |
| Hunting | | $1.40 | $1.40 | | | |
| Fishing | | $4.16 | $4.16 | | | |
| Sightseeing | | $0.94 | $0.94 | | | |
| Total | | $6.50 | $6.50 | $15.86 | 43% | |
| Non-use value | | $9.75 | $9.75 | $9.75 | 27% | It was assumed there is no increase in non-use willingness to pay per person or population |
| Residual value of capital investment | $0.16 | | $0.16 | $0.16 | 0% | Depreciated value of capital works is not significant |
| Total Benefit | $10.58 | $16.25 | $26.83 | $36.35 | 100% | |

Photo by Merran Williams, DEH Collection.

## CALCULATING NET BENEFIT

A mathematical model was used to calculate the present value of the costs and benefits under each mitigation option. The present value of the costs were then deducted from the present value of the benefits to determine the net benefit. Table 12 shows the results for the various salinity mitigation options. All options are assessed against Option 1 – The Base Case.

Option 3 – Two Chokes had the highest Net Present Value (NPV), meaning it had the highest value in absolute terms of each option. This option offered significantly higher benefits than Option 2 – Band Aid for only a slightly higher cost. Option 4 – Two Coastal Barriers had a higher benefit than Option 3 – Two Chokes, but at a significantly higher cost. Figure 4 compares the total costs and benefits of each option.

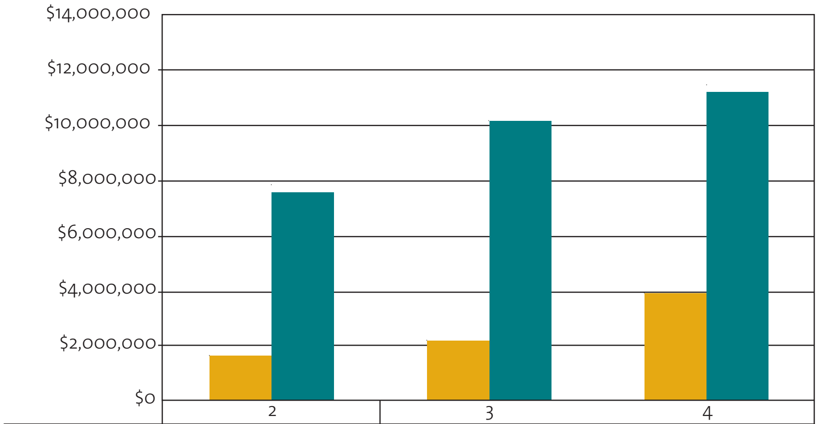
*Table 12: Evaluation results*

| Present value @ 7% in ($) | Mitigation Options | | |
|---|---|---|---|
| | 2 | 3 | 4 |
| | Band Aid | Two Chokes | Two Coastal Barriers |
| Capital | $735,000 | $1,060,000 | $3,366,000 |
| Annual Costs | $885,000 | $1,105,000 | $533,000 |
| Total Cost | $1,620,000 | $2,165,000 | $3,899,000 |
| Revenue/Benefit | $7,778,000 | $10,105,000 | $11,403,000 |
| Benefit/Cost Ratio | 4.80 | 4.67 | 2.92 |
| Total Cost per ha ($) | $10 | $10 | $16 |
| Gross Revenue/Benefits per ha | $47 | $47 | $46 |
| Gross Benefit Net of Cost per ha | $37 | $37 | $30 |
| Net Present Value | $6,158,000 | $7,939,000 | $7,505,000 |
| NPV per ha p.a. ($) | $37 | $37 | $30 |

All the mitigation options had positive NPVs compared to Option 1 – The Base Case. This means each option would be more beneficial than letting nature take its course. Avoiding the loss of wetlands provides the majority of the benefits for each option. Because Option 3 - Two Chokes and Option 4 - Two Coastal Barriers both provide increases in wetland area, they had higher NPVs than Option 2 – Band Aid. However, the extra benefits from Option 4 - Two Coastal Barriers over Option 3 - Two Chokes are cancelled out by this option's significantly higher costs.

Option 2 – Band Aid had the highest Benefit/Cost Ratio, meaning it delivers the highest value in proportion to its costs. This is because of the lower cost of this option. However, an option with a higher Benefit/Cost Ratio than NPV would only be considered where the budget for the project is severely limited and there was a need to get the greatest proportionate benefit from a fixed budget.

*Figure 4: Total costs and benefits*




| | 2 | 3 | 4 |
|---|---|---|---|
| Total Cost | $1,620,000 | $2,165,000 | $3,899,000 |
| Revenue/Benefit | $7,778,000 | $10,105,000 | $11,403,000 |

## Sensitivity Testing

Many of the parameters in the analysis were subject to considerable uncertainty. The wide confidence intervals of the values required that the results be tested for their sensitivity to changes in the parameters.

The results were tested for a 20% increase in costs, a 20% decrease in benefits and a combination of both (see Table 13). They were also tested for their sensitivity to variations in the other inputs including the discount rate setting, capital cost driver (bag placing rate per day), non-use willingness to pay per person, non-use population willing to pay, fishery margin, land value, sustainable magpie goose yield, willingness to pay for magpie geese consumption and tourism expenditure margin.

The results showed that all options had a positive NPV irrespective of parameter values, however the preferred option varied. The options are not sensitive to the discount rates, but the parameter values can have a significant impact on the size of the benefits.

Changes in the non-use value or the size of the population used to calculate the non-use value had the most significant effect on the NPV. This could mean that, because the study used conservative values for the willingness-to-pay for wetland conservation, the NPV of options that deliver increases in wetland area (such as Option 4 – Two Coastal Barriers) could have been underestimated. However, the uncertainty of both the costs and effectiveness of Option 4 – Two Coastal Barriers must also be taken into account.

When all the intangible benefits were excluded from the analysis, Option 2 – Band Aid and Option 3 – Two Chokes remained viable, but Option 4 – Two Coastal Barriers was considered less favourable than Option 1 – The Base Case – Let nature take its course.

*Table 13: Sensitivity testing of total costs and benefits*

| | Mitigation Options | | |
|---|---|---|---|
| | 2 | 3 | 4 |
| Variation in benefit and/or cost | Band Aid | Two Chokes | Two Coastal Barriers |
| +20% Cost | | | |
| Benefit/Cost Ratio | 4.02 | 3.91 | 2.45 |
| Net Present Value | $5,869,000 | $7,553,000 | $6,776,200 |
| -20% Benefit | | | |
| Benefit/Cost Ratio | 3.86 | 3.75 | 2.35 |
| Net Present Value | $4,630,400 | $5,955,800 | $5,265,000 |
| +20% Cost and -20% Benefit | | | |
| Benefit/Cost Ratio | 3.22 | 3.13 | 1.96 |
| Net Present Value | $4,306,400 | $5,522,800 | $4,485,200 |

## RESULTS

The study demonstrated that:

- there are significant net benefits from preventing the salinisation of the Mary River Wetlands
- the majority of the benefits are from avoiding the loss of agricultural, fishery and tourism output that would occur if the Mary River Wetlands became salinised
- there are also significant benefits in reclaiming land that has been salinised, with the options that increased the area of freshwater wetlands (Options 3 and 4) having significantly higher net benefits than the option that does not (Option 2)
- the net benefits of delivering this reclamation of salinised land more rapidly via Option 4 – Two Coastal Barriers are not significantly different than those for Option 3 – Two Chokes

## CONCLUSIONS

Cost-benefit analysis has significant value for assessing projects to adapt to climate change because it provides a logical process for determining the cost-effectiveness of a project. Along with allowing comparison of various options, it also identifies the critical economic elements required to maximise the effectiveness of a project.

The cost-benefit analysis of salinity mitigation options in the Mary River was undertaken with an understanding of the scientific uncertainties and risks associated with valuing intangibles. However the use of conservative values in the calculation of the benefits demonstrates that, at the very least, salinity mitigation in the Mary River is economically sensible. Additionally, best available evidence suggests that the mitigation action will deliver significant net benefits that will not be reduced by sea-level rise due to climate change over the project life.

Whilst the results did not clearly demonstrate one mitigation option was better than the other, the process of determining the net benefit for each option illustrates critical economic elements from which more informed decisions can be made. Because the results were so close, any decision to choose one option over another is likely to be based on factors outside the scope of the study, such as the proven effectiveness of each option.

This study contributes to Australia's knowledge base for evaluating the costs and benefits of actions to adapt to the impacts of climate change on natural and human systems. Further development and application of the methods presented in the study will be important to ensuring sustainable solutions to the challenges of climate change.

Photo by John Baker, DEH Collection.

## FURTHER INFORMATION

The full study – *Cost-Benefit Analysis of Mary River Salinity Mitigation* – is available on the internet at www.greenhouse.gov.au.

The study was undertaken in partnership between the Northern Territory Department of Infrastructure, Planning and Environment and the Australian Greenhouse Office and was based on research by:

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