A bio-economic model of wetland protection on private lands*

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A bio-economic model of wetland protection on private lands

Abstract

Wetland ecosystems on privately owned farms – such as those on the Murrumbidgee River Floodplain in the state of New South Wales, Australia – provide a mix of potentially valuable outputs to their owners and the wider community. The mix of values generated is dependent on the biophysical status of the wetlands, which in-turn, is dependent on the land management in and around these multiple-output ecosystems. Despite the range of private and public values generated, management decisions are based primarily on the private values that landowners receive. These private land management decisions also affect social values. Hence, there is potentially a demand for public policy to influence decisions based on the social values wetlands generate. This paper is predicated on the principle that good policy is reliant on information about wetland values. We present an integrated bio-economic model of wetland management that incorporates the biological and economic impacts at a landscape scale. The model reflects the multiple private and social values generated by wetlands and the dynamic nature of the trade-offs between these values. A number of broad policy conclusions for wetland management in Australia are generated from the outputs of the bio-economic model.

1 Introduction

Many wetlands across Australia are located on private land. These wetlands generate private values to wetland owners and social values that extend to the wider community. Wetland owners capture the values generated by some wetland outputs, such as the cattle and sheep that graze the wetlands. Both wetland owners and other community members enjoy the social values generated by wetlands. Some of the multiple values generated may be potentially conflicting (grazing and biodiversity conservation), while others may be complementary, at least to some extent (biodiversity conservation and recreational amenity). However, in all cases, management decisions by wetland owners alone can alter both the private and social values generated by these wetlands. Hence, society may wish to develop public policy options that would influence private wetland management decisions. Such policy should take into account the net benefits and the distribution of the mixes of values generated by alternative wetland management strategies.

The net benefit to society of alternative courses of action can only be determined if the biophysical and consequential economic outcomes of these courses of action can be estimated. Information about such values can be delivered, in part, via an integrated bio-economic model that examines changes in the net benefits to society as a result of changes in the biological status of either a geographic area or an ecosystem. A bio-economic model comprises three key stages:

prediction of the mix of biophysical outputs and management resources required under alternative management scenarios;

prediction of the changes to private and social values associated with alternative bundles of wetland outputs; and,

integration of biophysical and economic information to estimate the mix of values generated under alternative wetland management scenarios.

The ability to predict the likely change to the benefits enjoyed by society provides a basis for deciding whether changes to wetland policy are desirable. If changes are desired, the relationship between wetland owner actions and the costs and benefits incorporated into the bio-economic modeling process provides guidance to the issues that effective wetland protection policies would need to address.

Thus the goals of this paper are twofold: first, to identify whether there is a net demand for changes to wetland policy in the case of privately owned wetlands on the Murrumbidgee River floodplain (MRF), New South Wales, Australia; and, if so, to provide guidance as to what attributes a new policy mix would exhibit. These goals are addressed in the following seven sections. In the next section, the theoretical framework to key elements of a bio-economic is described. The third section provides an introduction to the MRF case study area. The development of the biophysical and economic components of the model is discussed in the fourth and fifth sections respectively before being integrated into a bio-economic model in section six. A brief discussion identifying the policy conclusions arising from the bio-economic model and drawing out some implications for designing effective wetland protection policy is presented before the paper closes by summarizing the key findings and noting several future research directions.

2 Theoretical framework

2.1 Bio-economic modeling and wetland management

Bio-economic modeling integrates economic and biophysical processes to assist in determining natural resource management goals. Bio-economic models are used in the process of setting appropriate stock and catch levels in fisheries (for example Eggert 1998) and modeling the impacts of tree planting to control dryland salinity (see for example, Cacho, Greiner and Fulloon 2001). Many, if not most, bio-economic models are focused on guiding management with respect to the private values generated by alternative resource management strategies (see for example Eggert's 1998 survey). Others are focused on the trade-offs between development and consumptive resource use (see for example van Vuuren and Roy 1993 with respect to wetlands and

Mallawaarachchi and Quiggin 2001 with respect to sugarcane production). Such models explicitly estimate and incorporate non-market environmental values.

The structure of bio-economic models ranges from simplistic linear models to complex dynamic models that may include non-linearities, discontinuities and critical thresholds.[1] Model structure may be either explicit, where models are used to derive continuous relationships for optimization as in Mallawaarachchi and Quiggin (2001), or implicit, where mental models are used to identify 'best-guess' social, economic or ecological outcomes under specific resource allocation scenarios as is the case for elements of van Vuuren and Roy (1993).

Most bio-economic models directed towards the analysis of development trade-offs focus on an *ex ante* examination of an essentially irreversible, and therefore one-off, allocation of resources between a single consumptive use and conservation (for example Mallawaarachchi and Quiggin 2001). However, the goal of this paper is to contribute to the design of policy relating to the ongoing production of multiple environment protection outputs from privately owned wetlands that are impacted by a range of consumptive uses. Furthermore, the range of social values produced by a recreated wetland substantially resembles that produced by the original wetland ecosystem in many cases. Thus, wetland management decisions may be considered substantially 'reversible' (see for example National Research Council 1992). This is distinct from the type of debate about the optimal level of development involving an irreversible change that is presented in van Vuuren and Roy (1993) or Mallawaarachchi and Quiggin (2001).

2.2 Structure of bio-economic modeling

Bio-economic modeling can be viewed as complementary to the concept of cost-benefit analysis. Bio-economic models contribute to policy development by assisting with the task of comparing the net social benefits of alternative courses of action. Such models incorporate similar elements to a cost benefit analysis including (Department of Finance 1991):

the benefits and costs evaluated relate to society as a whole, including non-market transactions, rather than to particular individuals;

since costs are subtracted from benefits to assess the net benefit to society they must be comparable. Hence all costs and benefits are converted to monetary amounts. Where conversion is not possible the benefits or costs are defined and described in non-monetary terms for assessment by decision-makers; and,

costs and benefits occurring at different points in time are compared via discounting to a present value.

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[1] For example, Knowler (2002) surveys fisheries bio-economic models with environmental influences some of which incorporate these attributes.

Hence, a bio-economic model will effectively compare the net present value of alternative management scenarios. Specifically, the management scenarios generate a stream of costs and benefits that are, in part, a function of the biophysical environment. The net present value of these benefit and cost streams is compared to continuing business as usual (BAU) in order to determine which course of action generates greater benefits to the community. This relationship is summarized in equation (1):

$$NPV_i = \sum_{t=0}^{T} \frac{(B_t - C_t - BAU_t)}{(1+r)^t} \quad (1)$$

Where: NPV_i is the net present value of strategy 'i' compared to business as usual

B_t , C_t and BAU_t are the benefits and costs of changing management and of continuing BAU respectively in any future year and are at least an implicit function of the biophysical environment.

t is time

r is the discount rate

Hence, bio-economic models differ from standard cost benefit analysis in that they specifically incorporate biophysical models into the analysis.

The process involved in constructing a bio-economic model can be summarized into nine distinct steps as shown in Figure 1.[2] Figure 1 also shows which steps comprise each of the three stages of bio-economic modeling that were noted in the introduction and used as the structure for this paper.

Figure 1: Structure of bio-economic modeling process.

Bio-Economic modeling								
Biophysical modeling			Economic modeling			Bio-economic integration		
Step 1	Step 2	Step 3	Step 4	Step 5	Step 6	Step 7	Step 8	Step 9
Project definition	Identify biophysical impacts	Quantify biophysical impacts	Identify relevant economic	Monetary valuation of impacts	Discount values of future	Aggregate values of impacts	Analyze distribution of impacts	Sensitivity analysis of impacts

[2] These steps are adapted from processes described for cost benefit analysis by Hanley and Spash (1993) and Sinden and Thampapillai (1995).

			impacts		impacts			

2.3 Biophysical modeling

Biophysical modeling comprises project definition, identification of biophysical impacts and quantification of these impacts. A number of theoretical constructs in ecology underlie the estimation of the biophysical model. The overarching science is restoration ecology (Cairns and Heckman 1996; New 2000). Restoration ecology is in turn underpinned by a number of concepts including the theory of island biogeography (MacArthur and Wilson 1967; Cox and Moore 2000), the theory of conservation reserve design and selection (Diamond 1975; New 2000), the flood pulse concept (Junk, Bailey and Sparks 1989; Walker, Sheldon and Puckridge 1995; Kingsford 2000), and, the serial discontinuity concept (Ward and Stanford 1995). These constructs provide the theoretical framework for considering the biophysical impacts of reallocating resources in wetlands and providing 'best estimates' of the changes to biophysical factors.

Project definition involves identifying packages of resources that are reallocated within a defined boundary or case study area. Analysis is based on the concept of the 'margin' because these resource allocations involve a relatively small proportion of total resource use within the case study area. Despite the relatively small reallocation of resources, the changes are posited to impact significantly on the biophysical outcomes within and potentially beyond the system being modeled via the underlying ecological assumptions.

The practical application of bio-economic modeling requires the development of an appropriate spatial and temporal context. The definition of the impacts of changes (and therefore spatial and temporal scales) is linked to the concept of the margin. The scale is chosen so as to encompass the area for which management changes are considered. At the same time, any impacts beyond the study area (externalities) must also be included within the model. The temporal context is determined by the time required to reallocate resources and for the resultant changes in the biophysical outcomes to take place.

The proposed resource reallocations and consequent biophysical impacts must then be estimated for each scenario that is considered. The biophysical impacts must also be estimated for the BAU resource allocation. That is, the impact of no changes to management but continued changes to outcomes must also be quantified. Underpinning this process is the estimation of the resource reallocation time-path and future biophysical changes. Wetlands, like all ecosystems, are in a continual state of change and flux and outcomes will continue to change over time with and without changes to management. Therefore, these predictions are subject to substantial error. Adaptations of both management and policy will therefore be required as economic, social and biophysical circumstances change.

2.4 Economic modeling

Whereas biophysical modeling is the compilation and analysis of the changes to biophysical conditions in wetlands caused by the reallocation of resources, economic modeling is the compilation and analysis of the changes to private and social values that result. Economic modeling involves estimating the value of the costs and benefits of each of the marginal changes to resource allocation and the consequent biophysical impacts that were identified and quantified in the biophysical model.

The concept of economic modeling is based on the concept of total economic value[3]. It is applied via the estimation of changes to the economic surpluses generated from alternative wetland uses along with the capital and ongoing costs associated with changing wetland use. A change to economic surpluses will occur when wetland management changes impact on one or more individuals. A pragmatic approach to the estimation of changes to economic surpluses is adopted following Willig (1976).[4]

Estimation of these changes is complicated by the existence of monetary and non-monetary values for wetland outputs and benefits and costs that arise at different points in time. Despite the debate about the appropriate approach to discounting of investments in natural resource management, the standard approach is adopted in this paper as shown in Equation 1.[5] Estimation of non-monetary values is an altogether different issue that cannot be avoided in an analysis of the private and social values of wetlands. In some cases, suitable benefit estimates may be ‘transferred’ from other suitable studies in order to incorporate non-market values. Where suitable candidates are not available a decision about the appropriate non-market valuation technique to be applied must be made.

Techniques for estimating non-market consumer surpluses can be divided between those that rely on revealed preferences (the travel cost and hedonic price methods) and those that rely on stated preferences (contingent valuation and choice modeling). Revealed preference methods are not suitable for many non-market wetland outputs (such as biodiversity conservation) because they are reliant on data about actions in a related market. In turn contingent valuation is eliminated as technique because of the complexity and expense of undertaking multiple surveys to estimate values for multiple wetland management scenarios and consequent outcomes. Finally, choice modeling is a robust proven methodology in the context in which it would be applied (see for example Bennett

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[3] See for example Hanley and Spash (1993) or Hodge (1995).

[4] Hanley and Spash (1993) and Johansson (1993) provide a good summary of the debate over the estimation and aggregation of alternative measures of economic surpluses.

[5] Hanley and Spash (1993) provide an extended discussion of the debate.

and Blamey 2001).[6] Hence, choice modeling is the preferred non-market valuation technique for estimating the non-market values reported in this paper.

2.5 Integration into a bio-economic model

Integrating the biophysical and economic models is the foundation of the bio-economic model. It facilitates the comparison of alternative biological states in terms of the net benefits they generate to society. This stage consists of the aggregation of the costs and benefits of changing wetland management, analysis of the distribution of the population of gainers and losers, and, sensitivity analysis of the underlying assumptions. The outputs from the bio-economic model can be used to achieve the two goals set out in this paper. First, to identify whether there is a net demand for changes to wetland policy via an assessment of whether changing wetland management could deliver net benefits to the wider community. Second, to provide some guidance as to the necessary attributes of effective policy via an examination of the scale and distribution of the costs and benefits of changing wetland management.

Generating these conclusions is reliant on two broad assumptions about the values that are estimated within the economic model. First, income elasticities are assumed to be similar for all individuals and that actual changes to incomes and income distributions from changing wetland management are small (Hanley and Spash 1993). The second assumption is related to the first and requires that the income distribution on which estimates are based be regarded as a sufficiently fair base for making comparisons.

3 Setting the scene – wetlands on the Murrumbidgee River Floodplain in NSW

More than 470 km^2 of wetlands are located on the Murrumbidgee River Floodplain between Wagga Wagga and Hay Weir. Over 70 percent of these wetlands are located on private land (360 km^2). Several of the wetlands in the study area are listed in 'A Directory of Important Wetlands in Australia' (Environment Australia 2001). The location of the MRF is shown in Figure 2.

Few wetlands in the MRF have been drained but most wetlands on the floodplain are now too dry due to reduced flooding caused by water storage for irrigation. Other MRF wetlands closely linked with the river have become too wet due to water releases for irrigated cropping and pasture production. Wetlands in the MRF have also been degraded by red gum logging and firewood collection, grazing, and to a lesser extent, drainage from irrigated areas. Current land and water management practices are largely motivated by the private values generated from irrigation, grazing and timber production.

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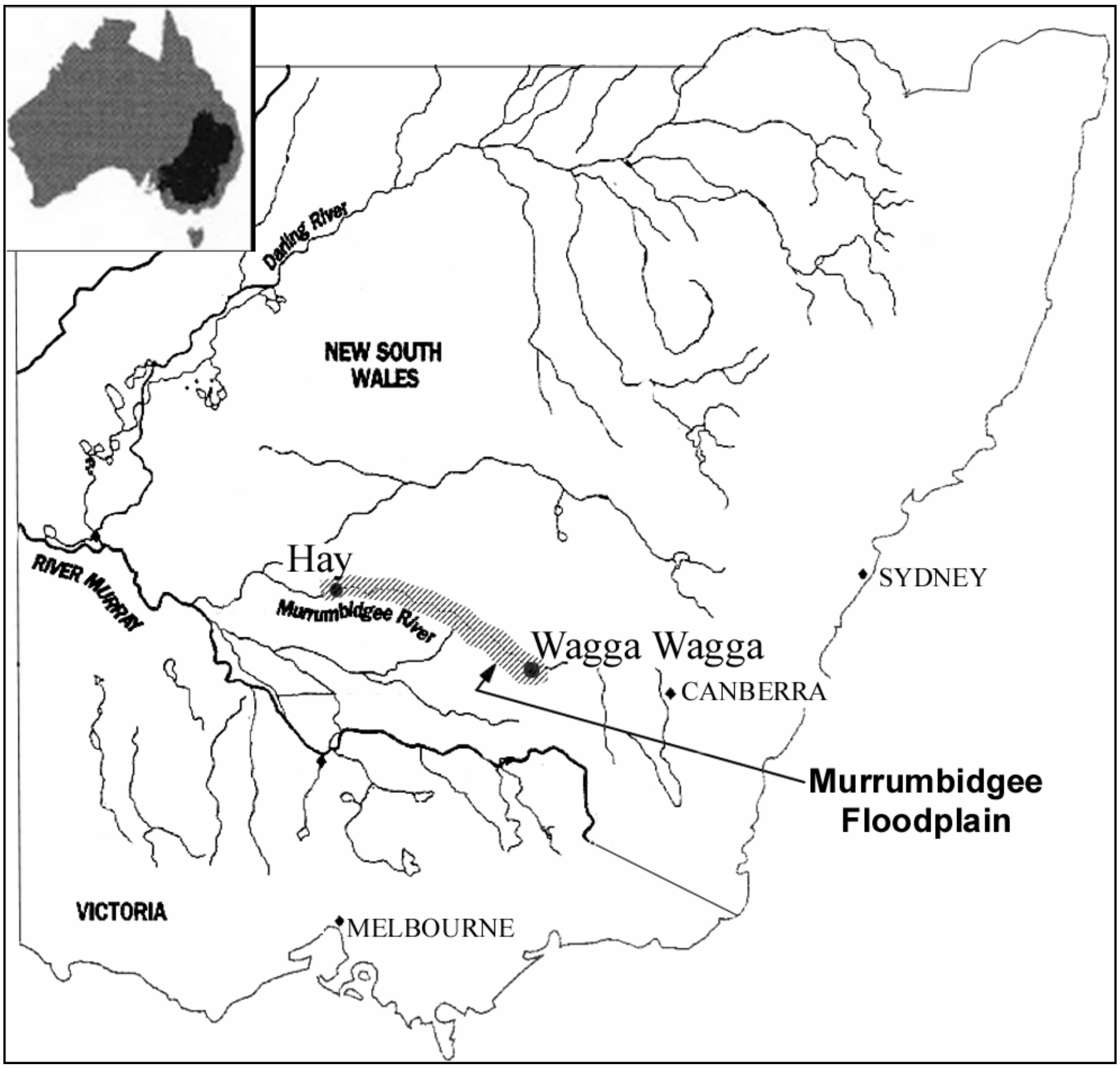
[6] While the CM method is robust and proven in the context, further development may be warranted to increase response rates and confidence in research outputs.

The private values derived from the current management of wetlands in the region are divided between wetland owners (benefits resulting from the sale of stock that graze wetlands, logging and some irrigated crops) and irrigators downstream (benefits derived from the sale of irrigated crops). The consequences of accessing these private values include reduced social (and private) values caused by reduced bird and fish populations, reductions in water quality, and, fewer healthy wetlands.

Figure 1: Location of MRF case study area.



4 Biophysical modeling

The biophysical boundaries of the MRF case study are defined as the northern and southern limits of the largest mapped flood on record, which occurred in 1973. The eastern limit of the MRF case study area is near where the floodplain broadens significantly and the type of costs and benefits experienced by wetland owners' change significantly compared to upstream wetland owners. The western limit is close to where the nature of floodplain wetlands changes again with larger floodplain lakes and depressions becoming common and generated a different set of values and management strategies in this region.

As a precursor to constructing a biophysical model, and to help identify biological drivers and impacted values, an extensive literature review of the information available relating to wetlands in the MRF region and the values drawn from wetlands more generally was undertaken (see Whitten and Bennett 1999). The literature review was supplemented by extensive consultation with scientists with expertise either in the region and/or in the types of biophysical relationships in the MRF.

The biophysical modeling boundaries draw on the literature review of biophysical relationships in the region and extend up-stream and down-stream of the case study wetlands. Management of upstream irrigation dams impact on hydrology above, within and below the case study region. Changing wetland management within the region impacts downstream flood behavior and water quality and may impact on fish populations within and beyond the MRF. The array of potential values drawn from MRF wetlands is shown in Table 1. In practice not all of the potential values shown in Table 1 are of importance in the biophysical modeling process. In many cases, the scale of change to wetland management will not be sufficient to impact on the benefits.

The key management factors driving MRF wetland values can be summarized as:

the number, timing and size of flood-pulses in conjunction with irrigation storage dam management;

the interaction between floodplain wetlands and the Murrumbidgee River through flood linkages;

pressures on wetland vegetation caused by grazing, timber harvesting and weed competition; and,

pressures on native fauna from feral animals and competition by domestic livestock.

Table 1: Array of potential values drawn from wetlands in the MRF region.

Pure private values	Private and social values
Benefits	
Grazing production	Flora and fauna values
Firewood and timber production	Ecosystem values
Water supply	Beautify the farm and regional landscape
Drainage storage/basin	Attract birds that help reduce pests
Tourism	Existence values

Recreation	Flood mitigation and groundwater recharge
Hunting	Water quality benefits
	Natural fire break
	Fishing
	Public tourism and recreation
Costs	
Source of pest animals and weeds	Nuisance insects and disease vectors
Reduced agricultural productivity	Fire danger when dry
Access difficulty	

These management factors were refined into four distinct wetland management scenarios:

improved hydrological management of water (termed ‘water management’);

improved grazing management practices in wetlands and buffer areas (termed ‘grazing management’);

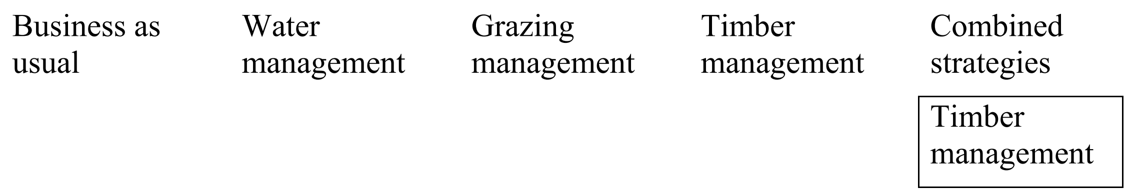
improved management of timber harvesting practices in wetlands (termed ‘timber management’); and,

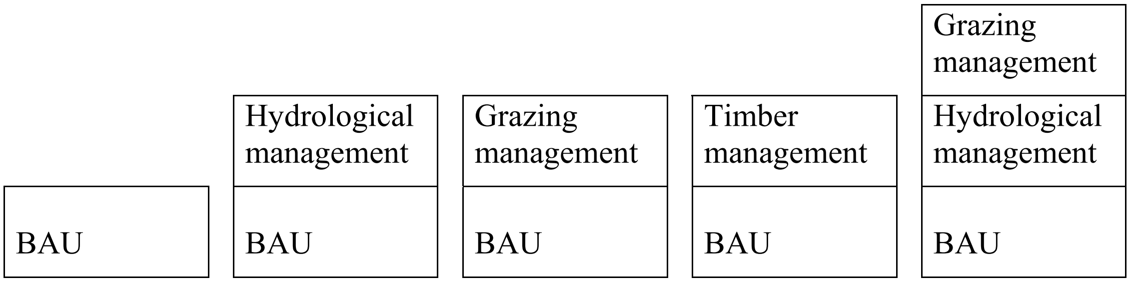
combining the three different options into a single strategy creates a fourth option (termed ‘combined strategies’).

All scenarios are superimposed on the fifth option of continuing BAU. The relationship between these scenarios is shown graphically in Figure 3.

The core of the biophysical model is the quantification of the biophysical outcomes generated by continuing BAU or changing wetland management along with the shifts in resource use required to achieve these changes. These impacts were defined as those that would occur over a 30-year period. This is the most complex segment of the biophysical model and was undertaken in two stages. First, the set of reallocated resources was identified for each scenario including changes in grazing and timber harvesting landuse intensity, shifts in water use from irrigation to flooding wetlands, other capital works to achieve land or water use changes (such as fencing, levee removal and revegetation works), and, those needed for ongoing wetland management.

Figure 3: Structure of MRF modeling scenarios.





The changes to resource use when compared to BAU are summarized in Table 2. For example, under the 'timber management' scenario a total of 27,500 fewer cubic meters of timber would be harvested from MRF wetlands compared to BAU (comprising 9000 m^3 saw logs, 18,100 m^3 residue and 400 m^3 firewood). The five MRF wetland management scenarios were then presented to a panel of expert scientists. The consensus ecological outcomes of these resource allocations returned by the scientists are shown in the lower part of Table 2. For example, adopting the 'water management' strategy would increase the area of wetlands by 27 km^2 compared to BAU. While the resource allocations in Table 2 are summed to give the 'combined strategies' outcome, the ecological outcome exhibits some synergistic impacts from changing a combination of drivers. As a result, the cumulative area of healthy wetlands under all strategies is 94 km^2 compared to 112 km^2 under 'combined strategies'. A considerable amount of uncertainty as to the biological outcomes remains and the potential impact needs to be assessed within a sensitivity analysis.

Table 2: MRF wetland outcomes under alternative wetland management scenarios.

Descriptive attributes	Unit	BAU	Water management	Grazing management	Timber management	Combined strategies
Aggregate MRF resource allocations						
Water reallocated	Gl	0	50	0	0	50
Grazing productivity	dse[a]	55,000	55,000	40,000	55,000	40,000
Timber – saw logs	m^3	20,600	20,600	20,600	11,600	11,600
Timber – residue	m^3	41,200	41,200	41,200	23,100	23,100
Timber – firewood	m^3	2,000	2,000	2,000	1,600	1,600
Fencing required	km	0	0	2,406	0	2,406
Alternate stock water	km^2	0	0	120	0	120
Rehabilitation	km^2	0	6	5	0	11

Descriptive attributes	Unit	BAU	Water management	Grazing management	Timber management	Combined strategies
works						
Ongoing management	km^2	0	27	67	0	112
Recreation trips	No.	500,000	503,000	507,500	500,000	512,500
Best information ecological outcomes						
Healthy wetlands	km^2	23	50	90	23	135
Native bird population	% 1800	40	60	60	50	70
Native fish population	% 1800	20	30	25	25	40
Marginal change to resource allocations compared to BAU						
Water reallocated	Gl	n.a.	50	0	0	50
Grazing productivity	dse*	n.a.	0	-15,000	0	-15,000
Timber – saw logs	m^3	n.a.	0	0	9,000	9,000
Timber – residue	m^3	n.a.	0	0	18,100	18,100
Timber – firewood	m^3	n.a.	0	0	400	400
Fencing required	km	n.a.	0	2,406	0	2,406
Alternate stock water	km^2	n.a.	0	120	0	120
Rehabilitation works	km^2	n.a.	6	5	0	11
Ongoing management	km^2	n.a.	27	67	0	112
Recreation trips	No.	n.a.	3,000	7,500	0	12,500
Marginal change to ecological outcomes						
Healthy wetlands	km^2	n.a.	27	67	0	112
Native bird population	% 1800	n.a.	33	20	20	75
Native fish	%	n.a.	50	25	25	100

Descriptive attributes	Unit	BAU	Water management	Grazing management	Timber management	Combined strategies
population	1800					

[a] dse are dry sheep equivalents, the standard unit of measuring pasture productivity for grazing.

5. Economic modeling

The economic modeling phase comprises identifying and estimating the present value of the relevant biophysical 'margins' quantified in the biophysical model. This step in the bio-economic modeling process is explicitly anthropocentric as only biophysical impacts that impact on humans are considered. The concept of total economic value (Hodge 1995) is employed to identify the nature of the values of the biophysical changes. The economically relevant biophysical impacts of the management options can be divided between use and non-use values. Use values can be divided between direct use values and ecological function values. Direct use values can be further divided between marketed and non-marketed benefits. Market based techniques facilitate the estimation of changes to economic values from data generated in markets. Some other direct use values can also be estimated using market data. The estimation of ecological function and non-use values requires the use of non-monetary valuation techniques. Care must be exercised to ensure that ecological function values in particular are not double counted in their contribution to a marketed, unpriced or non-use value.

The resultant changes to values that need to be estimated are shown in Table 3 along with the estimation methodology employed.[7] In each case, the methodology was chosen based on the trade-offs between the theoretical requirements for adequate estimation accuracy, and the costs and difficulty of achieving estimates within the budget and time constraints of the project.[8] This is an important point given the pragmatic nature of the study since the majority of public policy inputs will be generated within such an environment.

The estimation of the monetary costs associated with reduced grazing production, reduced timber harvesting, the costs of water acquisition, and, changing wetland management are relatively straightforward. The only major consideration is whether the appropriate measure of producers' surplus or cost is employed in the process. This is particularly the case for the cost to irrigated agriculture of flooding wetlands, which is the

[7] Note that some values were ignored (that is assumed zero or an insignificant value change) on the grounds that the physical marginal change was insufficient to impact on community well being. This assumption involves an element of judgement and may be regarded as a potential weakness of this research.

[8] Careful application of sensitivity analysis minimizes the risk of poor or inaccurate estimates leading to invalid conclusions.

opportunity cost of acquiring water for this purpose. Reallocation of water is not expected to cause any significant structural adjustment issues and consequent costs. However, a question arises as to whether the current uncertainties due to ongoing water reforms (both actual and perceived) mean that water prices do not accurately reflect the true opportunity cost of reallocation. The larger degree of uncertainty helps guide the sensitivity analysis in the bio-economic modeling phase.

Table 3: MRF value changes and estimation methodology.

Net cost or benefit	Type of value	Estimation method
Reduced grazing production	Monetary	Producer surplus estimated via enterprise gross margins less labor costs (assuming sunk capital costs).
Reduced timber harvests	Monetary	Producer surplus estimated via lost net payments to landholders.
Reduced irrigated agriculture / cost of water acquisition	Monetary	Current water prices assumed to equal the capitalized benefits of future water usage and hence the cost of lost producer surpluses.
Changed wetland management:		
• rehabilitation (earthworks and revegetation)	Monetary	Benefit transfer from similar actions in the USE of SA (see Whitten and Bennett 2004).
• ongoing management;	Monetary	Costs of existing programs and projects in the MRF.
• fencing for stock control;	Monetary	Costs of existing programs and projects in the MRF.
• alternative stock water source	Monetary	Benefit transfer from Forest Creek proposal (Forest Creek Management Plan Committee).
• alternative irrigation buffer storage	Monetary	Expert estimate of costs. [a]
Tourism and recreation	Non-monetary	Benefit transfer from King River, a similar riverine and wetland environment (see Sinden 1989).
Healthy wetlands including biodiversity, existence, scenic amenity etc.	Non-monetary	Choice modeling survey of MRF, Adelaide and Canberra residents.

Note: Some private values may accrue to public sector organizations such as the returns from timber harvesting in publicly owned wetlands.

[a] Mr. Steve McKay (Scanbail Pty. Ltd.) provided an estimate of costs for suitable buffer storage systems.

The estimation of non-monetary costs is altogether more complex as was noted in Section 2.4. Moreover, these estimates are critical to generating an accurate result from the bio-economic model. Therefore, it is worthwhile focusing on the issues associated with benefit transfer of recreation values and choice modeling in some detail.

5.1 Benefit transfer and estimates of tourism and recreation

'Benefit transfer' refers to 'the transposition of monetary environmental values estimated at one site (study site) through market-based or non-market-based economic valuation techniques to another site (policy instrument site)' (Brouwer 2000, p. 138). The cost-effectiveness of benefit transfer makes it an attractive way of including non-use values and non-marketed use values within a bio-economic model. However, benefit transfer is subject to a number of criticisms based on specificity and contextual influences on the original estimates and their impacts on the accuracy or possibility of employing benefit transfer (see for example Brouwer 2000).

These concerns, along with the results of tests of benefit transfer indicate that caution should be exercised in using benefit transfer as a method of including non-marketed values within a bio-economic model (see for example Brouwer 2000, Ruijgrok 2001 or Morrison 2001). A set of protocol to address these concerns was developed by Desvousges, Naughton and Parsons (1992). Their criteria would limit benefit transfer to situations where:

the valuation study from which benefit estimates are transferred is carried out properly;

the type and quantity of the environmental goods produced is similar; and,

the populations and market characteristics are similar for both locations.

Brouwer (2000) refines these criteria and suggests that stakeholder consultation is important in ensuring that transferred values are appropriate for decision-making.

Over a quarter of a million people visit MRF wetlands each year for recreational activities including fishing, swimming, picnicking and nature watching (Forestry Commission of NSW 1986). The majority of visits to MRF wetlands are day visits to beaches and picnic areas within the NSW State Forest managed areas. These visits generate benefits in the form of a consumers' surplus. In addition, 73 percent of wetland owners in the MRF also use their wetlands for pleasure or recreation.[9]

Sinden (1989) reports estimates of the willingness to pay (WTP) for recreation in the Ovens and King Basin in Victoria, a geographically and environmentally similar area (comprising billabong and river beach recreation areas). The recreational activities valued in the Ovens and King Basin are relatively similar to those in the MRF study area

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[9] Data from a survey of MRF wetland owners conducted in 1999 and reported in Whitten and Bennett (2000).

(fishing, swimming and general recreation). The source of visitors in the two regions differs because less than half of all visitors are attributed to the local area in the Ovens and Kings Basin while most MRF visitors are likely to be local. The significant difference in beneficiaries between the two regions may signify that the Ovens and King Basin generates larger values to potential users than the MRF. The impacts of this possibility are considered as part of the sensitivity analysis.

Sinden (1989) estimates the WTP at $27.80 per trip to the Ovens and King Basin ($22.00 1989 converted to 2001 dollars using ABS 2001). The change in consumers' surplus is estimated by multiplying an estimated increase in visitor numbers by the WTP.[10] The change to visitor numbers under potential resource allocations in the MRF and the consequent estimate of consumers' surplus generated is reported in Table 4. For example, adopting the 'grazing management' strategy is estimated to stimulate 7500 additional visits that generate $1.8m in present value consumers' surplus.

Table 4: Recreation consumers' surplus compared to the 'BAU' strategy.

	Unit	Water management	Grazing management	Timber management	Combined strategies
Extra visitors to MRF wetlands	No.	3000	7500	0	12500
	(%)	1.2%	3.0%	0.0%	5.0%
Visitor consumers' surplus (PV over 30 years)	$	$742,000	$1,842,000	$0	$3,078,000

5.2 Choice modeling estimates of non-monetary, non-use wetland values

Choice modeling offers technical (estimation of consumers surplus) and practical (single survey) advantages over related techniques for the estimation of the non-monetary, non-use values of MRF wetlands. In a CM survey, a sample of people is asked to choose their preferred options for future wetland management from a number of scenarios. All alternatives are described using a common set of outcome 'attributes'. These are shown for the MRF in Table 5. In the CM questionnaire, respondents were presented with three alternatives per choice question: A BAU management strategy, and two different wetland protection strategies that required respondents to pay a one-off

[10] Existing visitors are also likely to receive an increased consumer's surplus as a result of the change to management. While the possible increase to existing visitor consumers' surplus was not estimated sensitivity tests of the impact of an increase were conducted.

environmental levy in return for environmental improvement that could be realized within a period of 30 years and continue indefinitely into the future.

Respondents were told that the wetland protection scenarios would generate positive environmental impacts including increases to the area of healthy wetlands, the population of water and woodland birds and the population of native fish. A ‘farmers leaving’ attribute was also included due to a perception identified amongst community members that these changes must cause significant negative impact on farm viability thus causing farmers to leave the region. This perception was identified in focus groups undertaken to improve the choice modeling questionnaire design. A fifth attribute – a levy to pay for the implementation of the alternative strategies – was included to provide the monetary numeraire. Use of focus groups also led to the innovative use of pictogram-based choice sets in the questionnaire rather than the standard numeric framework. A sample choice set and accompanying fold out symbol key is shown in Appendix 1.

Table 5: Choice model survey attributes.

Attribute	Variable name	Unit of measurement	Levels used in questionnaire			
			BAU	Level 1	Level 2	Level 3
Area of healthy wetlands	Wetlands	Hectares	2500	5000	7500	12500
Population of water and woodland birds	Birds	Percentage of pre-1800 bird numbers	40	60	70	80
Population of native fish	Fish	Percentage of pre-1800 fish numbers	20	30	40	60
Social impact	Farmers leaving	Number	0	5	10	15
Levy on income tax	Cost	One-off dollar cost per household in 2000-01	0	20	50	200

By analyzing the choices respondents make in response to the attribute trade-offs presented in a questionnaire, it is possible to observe how much of one attribute they are willing to give up in order to get more of another. Because one of the attributes is monetary, the CM results can be used to estimate the 'willingness to pay', or value, respondents hold for environmental improvements in wetlands.

A total of 2,800 surveys about the future management of MRF wetlands were sent to households in the Murrumbidgee region of New South Wales, the Australian Capital Territory and Adelaide in South Australia. A response rate of just over 30 percent was achieved. Respondents tended to self-select, being older, more highly educated, more likely to be male and wealthier than the Australian average (ABS 1997). Full details are shown in Appendix 1.

Model specification

After initial tests, a nested logit model was used to describe the data relationships (for more information on choice modeling including nested logit models see Louviere, Henscher and Swait 2000).[11] The model of respondents' choices was estimated using

[11] Tests of this initial model indicated that the critical 'assumption of independence of irrelevant alternatives' (IIA) was violated. IIA is a requirement for the statistical validity of multinomial logit

pooled survey data from the four sub-samples. The computer package LIMDEP was used to estimate the model parameters. Within the nested logit model respondents initially make a decision as to whether or not to support an environmental levy to fund wetland protection. Conditional on supporting a levy, the respondent makes a lower level decision about the particular protection strategy to support. The upper level decision was assumed to be influenced by a range of socioeconomic variables, attitudinal variables, and an inclusive value (IV) that represents the sum of expected utility from the choice alternatives nested below the 'support' or 'non-support' options. The lower level utility associated with each alternative was specified as a function of the attributes. The model was specified as follows in equations 2a, 2b and 3, where V_j is the utility associated with alternative j:[12]

Upper Level choice:	$V_{support} = ASC1 + \Sigma \beta_i$ (socioeconomic and attitudinal variables) $+ \alpha_1 IV_{support}$	(2a)
	$V_{no\ support} = \alpha_2 IV_{no\ support}$	(2b)
Lower level choice:	$V_j = ASC2 + \beta_1\ Cost + \beta_2 * 1 / Wetlands + \beta_3 * 1 / Birds + \beta_4 * 1 / Fish + \beta_5 * Farmers\ leaving$	(3)

Where $V_{support}$ is the utility associated with the levy options and $V_{no\ support}$ is the utility obtained from selecting the status quo option. An alternative specific constant (ASC1) was specified for the levy option, and the socioeconomic and attitudinal characteristics were incorporated into the model as interactions with this ASC. The coefficient on the inclusive value for the *no support* option (α_2) was fixed to one because only one alternative exists in the lower level nest for this option. V_j is the utility function for management strategy j, where the set of J strategies includes BAU, or no change, as one option.

Note that the model structure uses a 1/*x* form for the *wetlands*, *birds* and *fish* attribute parameter coefficients. This structure performed better than a standard linear model. The innovative 1/x form allows for diminishing marginal values for increases in attribute levels. The *farmers leaving* and *cost* attributes are assumed to be linear due to the inclusion of zero as the BAU level of those attributes.

Results

The key results of interest are the implicit prices derived from the attribute coefficients estimated in the model that are shown in Table 6. These estimates are measures of the

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models. In this application, testing of the best performing multinomial logit model showed IIA violations at the 1 and 5 percent level.

[12] Definitions of the variables used are provided in Appendix 1.

amount of money respondent households are willing to pay (on average) to trade-off a unit improvement in an environmental attribute or the amount they are willing to pay (on average) to prevent a farmer leaving the MRF region. The equation for calculating implicit prices (IP) for the environmental attributes is:

$$IP_{wetlands, birds, fish} = (ß_{wetlands, birds, fish} / \text{attribute level}^2) / ß_{cost} \quad (4)$$

and for *farmers leaving* the IP formula is:

$$IP_{farmers\ leaving} = ß_{farmers\ leaving} / ß_{cost} \quad (5)$$

Note that the IP for *farmers leaving* is a constant, while that for *wetland area*, *birds* and *fish* varies according to the level of the attribute (due to the functional form). On average, at the attribute mid-point level, respondents were willing to pay (per household as a one-off payment) $11.39 for an extra 1000 hectares of healthy wetlands, $0.55 for a one percent increase in the population of native wetland and woodland birds and $0.34 for a one percent increase in the population of native fish. A result of the CM survey with important policy implications is the high willingness to pay respondents' had to avoid farmers having to leave the land as a result of changes to wetland management ($5.73 per farmer). Full model results and performance statistics are shown in Appendix Table A2.

Table 6: Estimates of MRF attribute values.

Attributes[a]	Unit price
Wetland area (/ 1000 ha)	$11.39
Native birds (/ 1% pre 1800 pop.)	$0.55
Native fish (/ 1% pre 1800 pop.)	$0.34
Farmers leaving (/ farmer)	-$5.73

[a] One-off average willingness to pay per household.

Compensating surpluses are calculated using equation 6:[13]

$$CS = -1 / ß_{cost} * (V_{BAU} – V_{ALT}) \quad (6)$$

V_{BAU} and V_{ALT} are estimated by substituting the coefficients and attribute levels (except cost) for the current situation into equations 7 and 8 respectively:[14]

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[13] Estimation of consumers' surplus from CM results is based on the assumption that the cost coefficient ($ß_{cost}$) equals the marginal utility of income.

[14] The socio-economic and attitudinal values are corrected for sample bias by inclusion at population levels or average respondent measures where population measures are not available. Because measures of respondent confusion and protest against the payment vehicle are included in the model an estimate of the

V_{BAU} = ASC1 + ($ß_{wetland\ area}$ / Wetlands + $ß_{birds}$ / Birds + $ß_{fish}$ / Fish + $ß_{farmers\ leaving}$ * Farmers leaving) + Σ ($ß_{socioeconomic\ \&\ attitudinal}$ * Socio-economic and attitudinal) (7)

V_{ALT} = IV parameter * (ASC2 / 2 + $ß_{wetland\ area}$ / Wetlands + $ß_{birds}$ / Birds + $ß_{fish}$ / Fish + $ß_{farmers\ leaving}$ * Farmers leaving) (8)

The average per-individual compensating surplus estimate calculated must then be extrapolated across the population. The assumptions used to calculate the aggregate MRF estimates reported in Table 7 are:

only 29.6 percent of the population of the Murrumbidgee Catchment (including the ACT) hold values for wetlands in the MRF (that is, values are only extrapolated across the response rate of the survey *within* the region);

no values are held by non-Murrumbidgee Catchment residents; and,

no growth in the Murrumbidgee Catchment population over the next 30 years.

The environmental values are not discounted to a present value because respondents were asked to place their current value on an outcome that would occur in 30 years time. Hence, individuals implicitly discounted their future values by providing single payment present values for a future outcome.

Table 7: Environmental value consumers' surplus compared to the 'BAU' strategy.

Attributes and values	Water management	Grazing management	Timber management	Combined strategies
Individual CS estimate	$132	$143	$47	$184
Confidence interval – lower 95%	$114	$124	$20	$160
Confidence interval – upper 95%	$148	$164	$80	$210
Extrapolated population	64,300	64,300	64,300	64,300
Aggregate CS estimate	$8,459,000	$9,212,000	$3,016,000	$11,832,000

Note: Confidence intervals are calculated using Krinsky and Robb (1986).

true willingness to pay if there was no confusion or protest at the payment vehicle can also be made. This estimate was included as part of the sensitivity tests.

6 Bio-economic modeling

The CM estimates for wetland attributes comprise just one of several costs and benefits from changing wetland management in the MRF. For a judgment to be made about the net benefits from changing wetland management these estimates need to be integrated with the biophysical modeling and other costs and benefits of changing wetland management to form a bio-economic model. That is, the change in total community benefits that would result from adoption of each potential management strategy must be evaluated.

An integrated cost-benefit analysis of the net difference between each of the four alternative MRF wetland management scenarios relative to the BAU outcome is shown in Table 8. Only the ‘grazing management’ strategy yields a positive net present value (NPV) to society ($5.1m). Adoption of the ‘water management’, ‘timber management’ or ‘combined strategies’ would each generate a negative value to society.

The conclusion that changing wetland management under the grazing management policy could generate a net benefit to society indicates that changing wetland policy may generate net benefits. However, the biophysical and economic modeling components are subject to risk and uncertainty due to incomplete scientific information, assumptions made in value estimation processes, and the difficulty of forecasting future events. A key component of bio-economic modeling is the assessment of potential impacts of risk and uncertainty on the conclusions drawn from the bio-economic model.

Sensitivity analysis was undertaken for all assumptions underlying the estimates shown in Table 8. The initial conclusion that the grazing management options would generate a net benefit if adopted proved extremely robust. The conclusions regarding the remaining strategies were sensitive to a number of assumptions. The rules used to extrapolate the environmental non-use values reported in Table 7 have the highest leverage of the bio-economic model components shown in Table 8. Relaxing the assumptions minimally (for example, assuming thirty percent of non-respondents hold similar values per Morrison 2000) leads to a positive NPV for the ‘water management’ option. Alternatively, extrapolation to the remainder of the NSW population at 25 percent of the value of respondents within the Murrumbidgee catchment leads to all options generating a positive NPV, as does extrapolation to the population of Adelaide.[15]

There is a relatively large amount of uncertainty surrounding the opportunity costs of water used to create an artificial flood on the MRF. This uncertainty arises from the incomplete water reform process in NSW and hence uncertain future returns from irrigation enterprises. The degree of this uncertainty leads to a large range in the possible

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[15] Adelaide residents exhibited significantly higher willingness to pay for environmental outcomes than other respondents. These values are possibly due to a perceived impact on the downstream water quality from improved MRF wetland management.

NPV outcomes (from $4.6m to -$22.6m) for the 'water management' option but does not change the conclusion for the 'combined strategies' option. The benefits to recreational users of the MRF are also potentially large enough to generate a positive NPV from the 'combined strategies' option. Their degree of leverage is large enough to suggest that it would be cost effective to gather additional data on recreational visits in the region to facilitate a more accurate estimate.

Table 8: Aggregate cost-benefit analysis of MRF management strategies.

Cost or benefit	Water management	Grazing management	Timber management	Combined strategies
Changes to agricultural activities				
Lost agricultural production	$ 0	-$3,137,000	$ 0	-$ 3,137,000
Cost of providing watering points	$ 0	-$ 198,000	$ 0	-$ 198,000
Lost timber production	$ 0	$ 0	-$4,678,000	-$ 4,678,000
Sub-total	$ 0	-$3,335,000	-$4,678,000	-$ 8,013,000
Management costs of wetlands				
Capital costs of water acquisition	-$18,161,000	$ 0	$ 0	-$18,161,000
Capital costs of wetland rehabilitation	-$ 1,151,000	$ 0	$ 0	-$ 1,151,000
Capital costs of fencing	$ 0	-$1,261,000	$ 0	-$ 1,261,000
Capital costs of wetland revegetation	$ 0	-$ 209,000	$ 0	-$ 209,000
Ongoing costs of wetland management	-$ 566,000	-$1,187,000	$ 0	-$ 2,072,000
Income from future water sales	$ 6,246,000	$ 0	$ 0	$ 6,246,000
Sub-total	-$13,633,000	-$2,657,000	$ 0	-$16,609,000
Environmental values generated – consumers' surpluses				
Recreation	$ 742,000	$ 1,842,000	$ 0	$ 3,078,000
Non-use values	$ 8,459,000	$ 9,212,000	$3,016,000	$11,832,000
Sub-total	$ 9,201,000	$11,053,000	$3,016,000	$14,911,000
Wetland owner use values	not estimated			

Total changes valued	-$ 4,432,000	$ 5,061,000	-$1,661,000	-$ 9,711,000

Note: Values are net present values of benefit and cost streams over 30 years using a 7% discount rate except non-use values for which a one-off value was estimated implicitly incorporating an unknown discount rate.

7 Discussion and policy implications

Bio-economic modeling involves identifying the biophysical management strategies that lead to the highest community net benefits. The question of what public policies may realize the potential net benefits to the community then arises. In this section several broad policy conclusions as well as specific information for policy design are drawn from the outputs from the bio-economic model. The implications of these policy conclusions are discussed for the MRF and other Australian wetlands.

The analysis presented in Section 6 generates two initial policy conclusions. First, the results of the bio-economic model suggest that changing wetland policy to facilitate the 'grazing management' scenario could generate a net benefit to the MRF community and beyond. However, this conclusion is subject to the caveat that development and implementation of wetland policies is a costly process. Indeed the costs of undertaking a study such as that presented in this paper should be considered against the likelihood that the findings would deliver a net policy payoff (although these become 'sunk costs' once the study is completed). Second, the considerable economic and biophysical uncertainty presented in the sensitivity analysis reveals that there exists significant quasi-option values associated with the collection of additional information to inform the decision making process. For example, sensitivity tests of the opportunity cost of acquiring water to flood wetlands and the benefits from recreation activities in and around MRF wetlands indicate that uncertainty is sufficient to alter the conclusions from the bio-economic model. These quasi-option values are likely to exist with respect to many wetland systems across Australia.

More detailed policy conclusions for the MRF and similar wetland ecosystems can be drawn from a detailed distributional analysis of the bio-economic modeling results. The costs of changing wetland management can be divided between those confined to wetland owners, those impacting on other elements of the community (such as downstream irrigators) and those that are more broadly distributed (but which may also include wetland owners). Such a distributional analysis for the MRF is shown in the upper half of Table 9. For example, the largest costs direct to wetland owners are loss of timber and grazing outputs and the capital costs of wetland rehabilitation and fencing. Conversely the majority of benefits in the MRF are accrued by individuals who do not manage the wetlands. They are the non-use benefits that were valued using the CM technique. In this case there will likely be a need to transfer some of the benefits received by non-wetland owners to owners of wetlands and irrigators in order to achieve the proposed change to wetland management. A second conclusion is that if benefits extend beyond the MRF region (as indicated by the CM findings) then policy mechanisms that are able to draw on these values may be necessary to ensure that a net benefit is generated to the community.

Table 9: Distribution of adoption costs and benefits of MRF strategies.

Distribution assessment	Water management	Grazing management	Timber management	Combined strategies
Monetary costs to wetland owners	-$ 1,717,000	-$ 5,992,000	-$4,678,000	-$12,706,000
Monetary costs to irrigators	-$18,161,000	$ 0	$ 0	-$18,161,000
Monetary benefits from future water sales	$ 6,246,000	$ 0	$ 0	$ 6,246,000
Net monetary benefits	-$13,633,000	-$ 5,992,000	-$4,678,000	-$25,622,000
Non-monetary benefits	$ 9,201,000	$11,053,000	$3,016,000	$14,911,000
Total net benefits	-$ 4,432,000	$ 5,061,000	-$1,661,000	-$ 9,711,000

Nature of costs and benefits of changing wetland management				
Costs imposed on wetland owners				
Capital investment/repair costs	-$ 1,151,000	-$ 1,661,000	$ 0	-$ 2,813,000
Ongoing maintenance costs	-$ 566,000	-$ 1,194,000	$ 0	-$ 2,079,000
Loss of income	$ 0	-$ 3,137,000	-$4,678,000	-$ 7,814,000
Costs imposed on other community members				
Capital investment in water acquisition	-$18,161,000	$ 0	$ 0	-$18,161,000

Ongoing water management costs	$ 6,246,000	$ 0	$ 0	$ 6,246,000
Non-monetary benefits (includes CS)	$ 9,201,000	$11,053,000	$3,016,000	$14,911,000
Total net benefits	-$ 4,432,000	$ 5,061,000	-$1,661,000	-$ 9,711,000

The costs imposed on wetland owners can also be divided between one-off investments in changing wetland management, ongoing wetland maintenance costs and the opportunity costs of changing wetland management. This division is shown in the lower half of Table 9. This analysis suggests that, for example, a wetland stewardship payment scheme that does not address the one-off cost of changing wetland management is unlikely to be effective. Similarly, policies that do not provide an ongoing, performance based, incentive for wetland management (either through markets or some other mechanism) covering wetland maintenance costs will not effectively protect healthy wetlands into the future.

8 Conclusions and future research directions

The development of a bio-economic model of wetland protection on private lands offers guidance for designing appropriate policy for the management of wetlands on private lands. Bio-economic modeling assists in determining whether wetland policy should be altered, and in determining appropriate goals for wetland management that will increase community well being. It offers the community a rigorous tool to compare alternative future outcomes. The detail within the bio-economic model also offers guidance to policy makers about the attributes that an effective wetland policy would exhibit.

While bio-economic modeling offers a useful policy tool as applied in this study, a number of future research directions have emerged from this research that could improve the confidence in the results from such bio-economic models and environmental valuation techniques more generally. These opportunities can be divided between those emerging from the biophysical modeling conclusions and those relating to policy development.

Sensitivity analyses within the bio-economic modeling procedure show that conclusions are most sensitive to biophysical predictions and extrapolation of non-market choice modeling values. Hence, there is considerable scope for research directed towards improving the accuracy of the information input into the biophysical model in terms of the range and probability distribution of potential outcomes. The exploration of the possibility and consequences of including measures of biophysical uncertainty as a descriptive attribute within the choice modeling non-market valuation technique is a related opportunity. Further CM research could be directed to identifying the appropriate geographic extent and percentage of the population for extrapolation of non-market, non-use values. CM research could also fruitfully be devoted to exploring the appropriate functional form following the successful incorporation of a diminishing marginal returns functional form in this paper.

Broader policy research should address the issue of transaction costs of alternative policy mechanisms and its implication for policy design. A related area of research concerns the degree to which wetland owner heterogeneity may impact on the generalized conclusions generated from the MRF bio-economic model.

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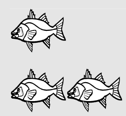
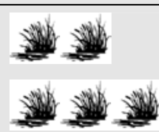
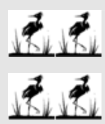
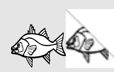
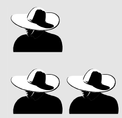
Appendix 1: Choice modeling survey results

Figure A1: Sample choice set and symbol key from CM questionnaire

6. Suppose options A, B and C are the **ONLY** ones available, which would you choose?	I Pay Levy	What I get Healthy wetlands	Bird numbers	Native fish numbers	Farmers leaving	**I would choose** Tick one box only
Option A No Change	NIL				NIL	☐1
Option B						☐2
Option C						☐3

Foldout symbol key used in questionnaire

Symbol key

(use for questions 6 to 10)

Area of healthy wetlands		= 2500 Hectares (6000 acres)
Water and woodland birds		= 20% pre 1800 bird numbers
Native fish		= 20% pre 1800 fish numbers
Farmers leaving		= 5 farmers

A summary of the situation

Healthy wetlands	2500 Hectares (6000 acres)
Water and woodland birds	40% pre 1800 numbers
Native fish	20% pre 1800 numbers

Farmers leaving	No farmers leaving

Table A1: Sample sizes and respondent characteristics - MRF study

Sample	Sample size	Undelivered [a]	Response [b] (%)	
Griffith	800	113	22.0	
Wagga Wagga	800	96	33.0	
Canberra	800	121	33.7	
Adelaide	400	48	34.1	
Total	2,800	378	30.2	

Sample characteristics	ACT	Adelaid e	Wagga Wagga	Griffith	Overall
Median age	48	52	49	52	50
Sex (% male)	61.8	60.2	55.8	66.2	60.9
Median annual h/hold income (A$)	52,000 - 77,999	36,400 - 51,999	36,400 - 51,999	36,400 - 51,999	36,400 - 51,999
Proportion with tertiary education (%)	52.3	42.5	28.4	26.0	37.9
Population characteristics [c]					
Median age	39	43	39	41	42
Sex (% male)	48.7	47.8	48.5	50.3	48.9
Median annual h/hold income (A$)	48,699	30,971	32,850	33,163	34,322
Proportion with tertiary education (%)	23.9	10.4	8.9	6.1	11.0

[a] Undelivered surveys were those returned to sender.

[b] Response rate expressed as a percentage of delivered questionnaires

[c] For all samples, the sample is significantly different from the population age at the 95 percent level of confidence. Population means sourced from Australian Bureau of Statistics 1996 census.

Table A2: Model results – MRF study [a]

Model statistics		
N (choice sets)	3148	
Log Likelihood	-2400.30	
Adjusted rho-square (%)	33.58	
Lower level choice equations		
ASC2	1.20E-01	***
Cost	-0.12E-01	***
1 / Wetlands	-7.83E+03	***
1 / Birds	-5.10E-01	***
1 / Fish	-3.28E-01	***
Farmers leaving	-0.70E-01	***
Upper level choice equations		
ASC1	5.81E+00	**
Income	-3.45E-01	***
Intended visit	-4.44E-01	***
Age	1.01E-01	***
Tertiary	-2.16E-01	*
NDT	1.55E+00	***
Levy	2.11E+00	***
Griffith	5.39E-01	***
Adelaide	-2.28E01	
Inclusive value parameters		
IV No support	1.00	
IV Support	4.65E-01	***

[a] Model estimates are based on pooled data from the four respondent samples.

* Denotes significance at the 10% level

** Denotes significance at the 5% level

*** Denotes significance at the 1% level.