

What are the benefits to landholders of adopting riparian works?



A summary of evidence and technical information



October 2016

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Part 1 Background and Summary

1.1 Project scope and purpose

This summary of evidence was undertaken as part of a pilot study between the Department of Environment, Land, Water and Planning (DELWP), Arthur Rylah Institute (ARI) and Evidentiary. The purpose of the pilot study was to investigate how an evidence based approach could be used to assist policy development and decision making regarding program investments in riparian management. The results of this pilot will be used to assess the suitability of the process for future use within the Department.

It is important that any investment in an evidence based approach has a clear decision making objective to assist in justifying and evaluating the cost of resource inputs. Two questions of high policy relevance formed the basis of the pilot project, the question of relevance for this particular summary of evidence being *“What are the benefits to landholders of adopting riparian works?”*

In summarising evidence to answer this question the following types of riparian works were focussed on:

- Re-vegetation
- Off-stream water
- Weed control (specified species)

NB: It was assumed that riparian fencing was a component of each of these works.

As specialists in evidence based approaches in the environmental sector, Evidentiary has undertaken the search and synthesis of evidence using a transparent and systematic approach. A search protocol was first agreed upon between the parties, then used to guide how the search was undertaken and how the located evidence items were assessed for relevance and quality.

The purpose of this summary of evidence is to present the relevant evidence items found in the search, in order for DELWP staff and/or content experts to synthesise the relevant evidence into further products relevant to decision making. The findings contained in this report and the associated Policy Brief developed aim to inform decision making.

1.2 The issue

The Victorian Government has provided the state’s catchment management authorities (CMAs) with substantial funds to encourage the uptake of riparian works on private land or licensed Crown frontage. While some landholders have embraced the opportunities provided by these investments, others remain resistant to undertaking riparian works for a variety of reasons. One identified barrier to adoption is that while the ecological and broader societal benefits of riparian works are well understood, many landholders want to know ‘what’s in it for me?’ On a personal and property scale, some landholders are primarily interested in production gains, cost savings or lifestyle and amenity benefits in order to be convinced to participate in a government funded riparian works program. How riparian works benefit landholders is outlined in many CMA, government agency and agricultural organisation’s fact sheets, although the evidence underpinning this information is often not

referenced or anecdotal rather than being based on studies with transparent methodologies. Unless this experiential or opinion based information can be validated against settled science, there are risks in using this information to inform decision making. At worst, landholders will become disillusioned and disengaged by a lack of results based on unsubstantiated recommendations.

It is important to note however that science based evidence is only one input to the policy or program development process and often does not fulfil all of the information needs of the complex space that policy making occurs (Bennett, 2016). To this end gaining an understanding of the **context of the evidence review question** is important. This is discussed further below.

This summary of evidence is an opportunity to determine whether some of the assumed benefits of riparian works are supported by sound evidence, and whether there are any other benefits that are not being communicated to landholders. It would be extremely useful to collect a set of experiential evidence from landholders who have been involved with the implementation of riparian works as a way of validating or corroborating both the settled science and the claims made in the plethora of government Extension Notes, Fact Sheets and the like.

The search protocol (see Appendix 3) outlines the parameters of this project and the search inclusion and exclusion criteria in detail. In short, the riparian works to be investigated are limited to:

- Re-vegetation
- Fencing off riparian land
- Installing off-stream water supplies
- Weed and pest animal control

The project focused primarily on the private benefits to landholders involved in dairy, grazing (sheep and cattle) and cropping. Some of the assumed benefits of riparian works to landholders that were searched for included production benefits, ecosystem services, property prices and amenity or aesthetic values. The project did not include evidence regarding longer term environmental benefits that may pass on derived benefits to landholders –the benefits needed to be capable of being seen or experienced by landholders in the short term.

There is a substantial body of evidence of mainly scientific studies around the ecological benefits and broader societal benefits of riparian works. These include:

- Changes in water quality as a result of riparian works (Belsky et al., 1999; Miller et al., 2011; Orzetti et al., 2010; Wilcock et al., 2013)
- Changes to biodiversity levels (particularly bird life) after undertaking riparian works (Popotnik and Giuliano, 2000; Hale et al., 2015; Argent and Zwier, 2007; Giuliano and Homyack, 2004)
- Changes in streambank erosion as a result of undertaking riparian works (McKergow et al., 2003a)

This body of evidence was largely excluded because it did not consider direct landholder benefits and therefore did not directly answer the project question.

1.3 Context of the review

As discussed above, the focus of this review is on the evidence for the private productivity gain benefits to landholders of adopting riparian works. The rationale being that landholders are more

likely to adopt riparian works if individual, on-farm benefits can be demonstrated. The goal is therefore to increase adoption of riparian works. This will ultimately lead to catchment scale community benefits derived from the ecosystem services that rivers and riparian lands provide. It must be realised however that the evidence plays only one part in the full picture of a) the reasoning and motivations for landholders to adopt riparian works and b) the information needed by program or policy makers to deliver a successful intervention that increases adoption of riparian works.

For the landholder there are multiple reasons, motivations and barriers for adopting riparian works ranging from personal circumstances to business needs and industry and community expectations. It is difficult to determine the influence of any single exposure to information, education or incentive in shaping the decision. The delivery of information products derived from this review of evidence should be tailored to the local context of the target landholders in order to maximise its penetration. This local contextual information is best gathered through targeted social research.

Appendix 1 attempts to describe some of the context of landholder decision making and the alternative pathways that can be used to increase landholder adoption of riparian works. Whilst the provision of evidence based information is one of these, other pathways such as the use of market based instruments, voluntary mechanisms, training and education or compliance and enforcement are all important to consider according to the context of the target landholders.

Appendix 1 however does not cover the broader context of factors that must be considered in the development of policy or program. These other important contextual factors include:

- community perceptions and attitudes of the need and value of riparian lands
- the political environment of the Victorian Government regarding current policies and imperatives for management of riparian lands
- the views of influential stakeholder groups in the management of riparian lands such as CMAs and peak industry bodies such as the Victorian Farmer Federation and Environment Victoria.

1.4 The DELWP decision need

It is imperative that any investment of additional resources in an evidence based approach is driven by a **defined decision need**. Not only is this efficient use of resources, but also a well defined decision need assists in the process for the collection of the evidence and evaluation of the benefits of collection and use of the evidence.

This pilot review was commissioned to assess the validity of information available to Victorian Catchment Management Authorities, Government workers and landholders in making decisions regarding the adoption of riparian works for on-farm production benefits. Evidence of these benefits will be used to encourage landholders to adopt riparian works in partnership with the Victorian Government.

It is intended that this summary of evidence will be used to influence policy and operational decisions made by the Department of Environment, Land, Water and Planning (DELWP). A Policy Brief summarising the summary of evidence findings has been developed to assist the Catchments Branch in preparing funding bids for Treasury. In addition it is intended that the summary of evidence is used to influence the following:

1. Decisions regarding cost sharing between landholders and the Catchment Management Authorities (CMAs).
2. In developing key, fact based messages for landholders. Where there is clear evidence of production benefits to landholders strong messages can be developed, where there is weak, no or negative evidence of production benefits then there is less reason to peruse these messages.
3. To assist in engaging particular agricultural industry groups such as dairy, cattle producers or croppers. Messages based on key findings can be tailored to particular industry groups.
4. To target particular characteristics of landholders or properties for example if the property is mixed grazing/cropping then pollination services from the riparian zone could be considered
5. To assess the likely benefits to landholders and environmental benefits – this may result in a “go/no go” decision process.
6. To enable a better assessment of the types of works, how much and what quality is needed to derive the desired benefits over individual or multiple properties including consideration of the ‘additionality’ of benefits.

There are currently high levels of uncertainty regarding the effectiveness of riparian works (fencing, off stream water, weed control and revegetation) in delivering individual landholder benefits, hence the need for this review of evidence. **It is desired that the level of uncertainty surrounding the effectiveness of these interventions is reduced to enable Catchment Management Authorities and other organisations to be confident in promoting the benefits of particular riparian works to landholders.**

1.5 Uncertainty in the evidence

For the purposes of communicating uncertainty in this review a traffic light style colour coding approach has been used in a summary table within the Key Findings section below. Rather than presenting or interpreting the findings in terms of uncertainty, it is more useful in a decision making context to describe the level of confidence in the findings. The level of confidence for any given relationship is directly related to:

- a) The quality and quantity of the evidence. Evidence quality includes relevance of the evidence to the stated relationship.
- b) Consistency in the body of evidence in supporting the given relationship

The summary table below has therefore uses a traffic light indicator to provide some measure of the confidence in the evidence (the quantity and quality) and the consistency of the evidence in confirming that the cause and effect relationship is true. For example there may be only a few good quality items of evidence but these may provide a high level of consistency in supporting the cause and effect relationship i.e. confirming that it is true. In other cases there may be a higher number of good quality evidence items but there may be inconsistency or little support for the stated cause and effect relationship.

Confidence in evidence quality/quantity is denoted as:

- green = a high level of confidence
- yellow = some caution should be exercised for the reasons provided
- red = a low level of confidence

Consistency in the body of evidence in supporting the relationship is denoted as:

- green = a high level of consistency in supporting the relationship
- yellow = some inconsistency but overall support for the relationship
- red = little consistency and little support for the relationship

Some general points in determining the level of confidence are:

- A lot of poor quality studies do not provide high confidence, whereas a few high quality studies can provide a higher level of confidence
- A good quality study will include a description the method that has been used, how the conclusions were drawn, the use of appropriate synthesis method, appropriately referenced and the use of an appropriate experimental design
- In some cases surveys based on observational data may be appropriate evidence. For example if the cause and effect relationship is quite self-evident (i.e. stock are easier to find in non-heavily vegetated areas) then greater confidence can be placed in observational data. The confidence that can be placed in survey data relating to more complex cause and effect relationships such as the provision of fresh water leading to an increase in weight gain or milk production is however much lower.

Most commonly evidence quality or consistency was rated as poor due to the lack of referenced statements or any form of independent agreement (corroboration) to substantiate statements of claim. Many “Fact Sheet” style documents were typical of this. In some cases there were too few good quality studies to be able to have high confidence in the conclusions i.e. there are remaining high levels of uncertainty.

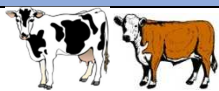
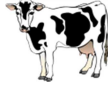
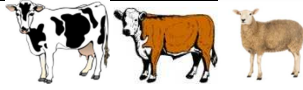
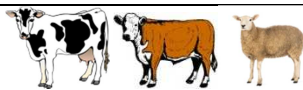
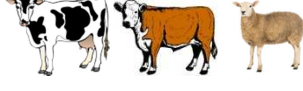
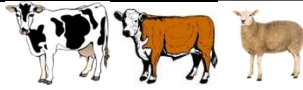
It is possible, given greater scope in the project, to increase the level of confidence placed in the evidence used for some relationships by conducting more targeted searches and using a process of corroboration (independent validation) with other forms of evidence including the collection of experiential evidence from practitioners.




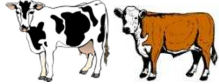


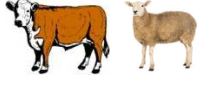

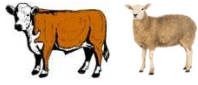

With the exception of the three areas where a more comprehensive search strategy was used (see page 79-82) a very generic search strategy was employed given the scope of the project. The result is that there were often few relevant evidence items found by the search hence it was difficult to measure consistency.




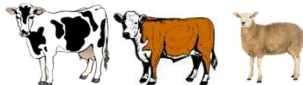

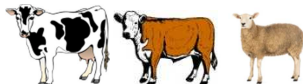



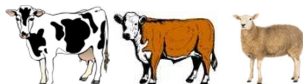

2.0 Summary of key findings

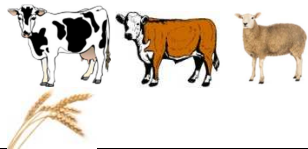
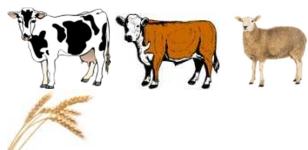
A summary of the key causal relationships and the confidence for the evidence and each of the relationships is shown in Table 1 below. Further details, including all relationships can be found in the evidence tables found in Part 2. A Summary Report is available from the authors.

Table 1. Summary of confidence in the evidence (quality and quantity) and consistency of evidence for key causal relationships between riparian works and productivity benefits/disbenefits.

Riparian works	Production type to which benefit applies	Causal impact pathway	Confidence in evidence	Consistency of evidence to support relationship
<i>Production benefits</i>				
Off stream water and fencing		Stock not standing in water >> reduced risk of disease	Few relevant studies found	Too few relevant comparable studies to assess consistency
Off stream water		Increased accessibility of water >> reduced heat stress leading to increased milk production	Only one study of questionable relevance found.	Too few relevant comparable studies to assess consistency
Riparian fencing		Stock excluded from heavily vegetated or weedy riparian zone >> increased ease of mustering >> reduced costs	Few studies found with search strategy used but the study designs used are reliable	Highly consistent
Off stream water		Increased accessibility of high quality water >> increased water and forage intake >> increased milk production (dairy) or weight gain (grazing)	Numerous high quality studies	Highly consistent
Off stream water		Increased accessibility of high quality water (impact of inorganic compounds) >> >> increased milk production (dairy) or weight gain (grazing)	Numerous studies found but few of high quality	Although there is consistency relating to adverse impacts from breaching thresholds, there is some inconsistency regarding other effects at lower levels
Off stream water		Increased accessibility of high quality water >> decreased	Numerous studies found but few reliable studies. Evidence is largely	High, although there is not complete consensus in all studies of the





		consumption of pathogens >> reduced risk to health and performance	from non-primary experiments	negative impact of pathogens.
Riparian fencing		Increased use of natural fertilizer >> Reduced fertilizer costs	One study using multiple sources was found	Too few relevant comparable studies to assess consistency
Riparian fencing			A small number of good quality studies for dairy	High consistency for dairy
		Fencing off riparian land >> less pasture available >> lower production	Few reliable studies for non-dairy production types	Some inconsistency for non-dairy production
Off stream water and fencing		Improved grazing distribution and pasture utilization >> Increased production	Few reliable studies	Some inconsistency in findings
Off stream watering, fencing and revegetation		Riparian works and/or farm system changes >> increased farm productivity	Few studies. Survey data only	High consistency
Riparian fencing and /or off stream water		Stock not standing in water >> reduced risk of bogging or drowning	Few studies found	Too few relevant comparable studies to assess consistency
Revegetation		Riparian revegetation >> riparian stock shelter >> improved stock health and productivity	Few studies found with relevance to riparian vegetation	High consistency of generalised findings
Weed control		Riparian revegetation, weed control and fencing >> change in invasive plant species	A small number of good quality studies.	High consistency
Weed control		Blackberry control >> increased carrying capacity of pasture >> increased production	Only one good quality study found for blackberries	Too few relevant comparable studies to assess consistency
Revegetation or retention		Healthy riparian vegetation >>	Few reliable studies found: area for	Too few relevant comparable studies

		Increased pollination services >> increased crop production	future research	to assess consistency
Natural biological control of pest animals		Provision of native vegetation >> biological control of pests >> increased crop productivity	Few reliable studies: area for future research	Too few relevant comparable studies to assess consistency
Revegetation		Riparian shelterbelt >> crops protected from wind and erosion >> reduced soil moisture loss >> increased crop productivity Shelter >> Increased water filtration >> more productive crops	Very few reliable studies found by search. More specific search strategy required.	Highly consistent
Maintain a healthy riparian buffer		Reduced soil erosion >> more productive crops	Few relevant studies were revealed by the search strategy. More specific search strategy required.	Highly consistent.
Revegetation / maintenance of riparian vegetation	 	Reduced risk of soil salinisation and acidification >> increased land value	Few studies looking at local effects only More specific search strategy required	Consistent within the general relationship
Revegetation / maintenance of riparian vegetation	 	Reduced risk of soil salinisation and acidification >> protect property value and maintain or increase production	Very few studies that are scale dependent (time and space) so little evidence of direct benefit	Too few relevant comparable studies to assess consistency
Weed control (gorse and willow)	 	Weed control >> reduced production losses	Few relevant studies found	Too few relevant comparable studies to assess consistency
Land value benefits				
Maintenance of or revegetation of riparian vegetation	 	Presence of on-farm riparian vegetation >> increased land value	The evidence used is indirect i.e. it is not specified if it relates to riparian vegetation.	There is high consistency of support for the relationship for rural and residential

			There is a need for more studies that assess the influences of the many contextual variables of the relationships between specifically riparian vegetation and property values.	properties. NB: studies suggest that a threshold proportion of native vegetation exists
Aesthetic, amenity and landholder wellbeing benefits				
Revegetation		Biodiverse riparian zone >> enhanced visual amenity and wellbeing	A small number of good quality social survey reports.	High consistency
Revegetation		Healthy and attractive riparian zone >> landholder sense of stewardship and contribution to nature conservation	A very small number of good quality social survey reports.	High consistency

Note: Farm operations are assumed for the “Aesthetic, amenity and landholders wellbeing benefits” as the studies used did not specify the type of operation.

Key for table interpretation

Production type	 Dairy  Beef  Sheep  Cropping
Confidence in evidence quality/quantity	<ul style="list-style-type: none"> ● green = a high level of confidence ● yellow = some caution should be exercised for the reasons provided ● red = a low level of confidence
Consistency in the body of evidence in supporting the relationship	<ul style="list-style-type: none"> ● green = a high level of consistency in supporting the relationship ● yellow = some inconsistency but overall support for the relationship ● red = little consistency and little support for the relationship

2.01 Summary of relationships by confidence level

The following section aims to provide a summary of the overall confidence that can be assigned to relationships shown in Table 1. The author's judgement has been used to assign relationships to the three confidence levels shown. This is based on an assessment of a) the quality/quantity of evidence and b) the consistency of evidence in supporting the stated relationship. This has been done to assist with the development of future information products.

High confidence causal relationships

Stock excluded from heavily vegetated or weedy riparian zone >> increased ease of mustering >> reduced costs

Four independent studies of suitable quality from Australia (Aither, 2014, Sillar Associates, 1998 Queensland Government, 2013) and the USA (Chamberlain and Doverspike, 2001) on dairy and beef cattle using mixed methods, including cost benefit analysis, provide adequate evidence for a high level of confidence for this low complexity cause and effect relationship.

For more information on the evidence used in this relationship, refer to the evidence tables in Part 2 on page 30.

Increased accessibility of high quality water >> increased water and forage intake >> increased milk production or weight gain

There are two primary effects here that are evidenced in the literature. The first is direct relationship of high quality water and palatability, hence greater consumption. Evidence suggests that the more water stock consume, the more they eat and hence the more weight gain or milk production. The other effect is the more direct influence of high concentrations of inorganic compounds on the health of stock hence adversely impacting on weight gain or production.

There is strong evidence (more than ten independent studies of suitable quality from Australia and the USA provided high confidence for these relationships) to support both of these effects but the evidence is less clear (less of it and more inconsistent) regarding the influence of lower levels of inorganic compounds on stock production.

It is important to note that the direction and magnitude of the effect varies according to the concentration or combination of specific organic, inorganic, microbiological or other water quality parameters. There are numerous studies and commentary on the affect of the **amount of water consumption** on milk production in dairy cattle (Beede, 2005; Ensley, 2000; Landefeld and Bettinger, 2002; Little et al., 1984; Looper and Waldner, 2007). Similarly there are multiple studies on the affect of feed type and amount on water consumption and milk production.

Numerous authors recognise the impact of these thresholds of water quality on productivity including total dissolved solids (Beede, 2008; Morgan, 2011), salinity and sodium chloride (Looper and Waldner, 2007; Morgan, 2011; Saul and Flinn, 1978; Solomon et al., 1995), sulphate (Loneragan et al., 2001; Looper and Waldner, 2007; Morgan, 2011), nitrates and nitrites (Ensley, 2000; Morgan, 2011), blue green algae (Galey et al., 1987; Looper and Waldner, 2007; Morgan, 2011), microbiological agents (Collins et al., 2007; LeJeune et al., 2001; Looper and Waldner, 2007; Morgan, 2011) and temperature (Milam et al., 1986; Morgan, 2011; Stockdale and King, 1983).

The relationship between water quality and cattle productivity gains (in the form of weight gain) is widely cited in the literature. As discussed above however, this relationship is primarily through the amount of water consumed and this relationship with the type and quantity of forage eaten

NB: The search strategy employed did not aim to look at the influence of riparian fencing on reducing stock effluent entering the waterway as this only has a effect on production when water is transported back to the farm for consumption by stock.

For more information on the evidence used in this relationship, refer to the evidence tables in Part 2 on page 32 and 37.

Fencing off riparian land >> less pasture available >> lower production/higher costs

Two Australian **dairy** studies of high quality showed that fencing off riparian land resulted in less pasture available for stock consumption, which in turn increased costs to landholders due to the necessity of purchasing fodder (Aarons 2009, 2011).

A case study involving beef cattle from the Burdekin rangelands in northern Australia however, showed a herd reduction of 2% with no changes in cattle weight gains due to the construction of 90 km of riparian fencing. It should be noted that the fencing excluded approximately only 1.5% of the property (Department of Agriculture, Fisheries and Forests, 2014).

A social survey of landholders in Victorian CMAs found that 76% of respondents indicated that there had been no loss of productivity as a result of the riparian works which included fencing (Ede, 2011).

A study in California in the USA showed that the cost of installing vegetative buffer strips (VBS) in erosion prone watersheds, was outweighed by the production benefits in intensive row crop agricultural system (Rein, 1999).

It is difficult to draw any conclusion from these studies in non-dairy enterprises as there are many contextual variables that influence the outcome including the percentage of land affected by the fencing, the type of agricultural production (high value crops for example) and the susceptibility to processes that negatively influence production such as erosion that can be ameliorated by riparian protection.

For more information on the evidence used in this relationship, refer to the evidence tables in Part 2 on page 35.

Presence of on-farm riparian vegetation >> increased land value

Four reliable studies from Australia (Polyakov et al., 2014, 2013, 2012 Walpole et al., 1998) and one study from the USA (Bastian et al., 2002) have examined the influence of the presence of vegetation including riparian vegetation land on property value. It is assumed that riparian vegetation is included within the assessment of on-farm vegetation in these studies.

The literature reveals that there are many contextual variables that influence the relationship of the presence of riparian land and property value. These include the property size and proportion of native vegetation, the land use (lifestyle or agricultural production), the recreational opportunities of the riparian land (and adjacent water body) and the distance to these recreational opportunities and quality of the riparian habitat.

Of greatest relevance to application in Victoria are several recent studies that have been conducted in central Victoria (Polyakov et al., 2014, 2013, 2012 Walpole et al., 1998). These studies found that there is an optimal proportion of native vegetation influencing positive property values. Polyakov and colleagues suggest that this is about 40% and that a ratio of native vegetation that exceeds 80% reduces the value of the property to less than the value associated with no native vegetation and that the optimal proportion of native vegetation changes with the size of the property (Polyakov et al., 2013, 2012). A further study by Polyakov et al. revealed that private benefits of native vegetation are greater per unit area on small and medium-sized properties and smaller on large production-oriented farms. In other words native vegetation has a diminishing marginal benefit as its proportion of a property increases (Polyakov et al., 2014).

A similar conclusion was drawn by in a willingness to pay (WTP) study by Walpole where it is suggested that WTP for remnant native vegetation may increase (but in decreasing margins) up to a point where the proportion of native vegetation may begin to have a negative impact upon agricultural production (Walpole et al., 1999). A related study by Walpole et al. using sales information for 2,480 properties in the north-east Victoria reported on the influence of remnant native vegetation (RNV) on property sale price for two study areas (one in Victoria and one in NSW). In agreement with the Polyakov findings, the study showed that the existence of RNV at a proportion greater than 50% had a negative influence on property price. The study showed however that below this threshold however, the area of RNV appears to have little influence on property price (Walpole et al., 1998).

Discussion of use of indirect evidence

Conclusions for the relationship between riparian vegetation and property value are drawn from several areas of evidence found in the literature. While there are no studies (not specified in the studies used) that consider directly, the relationship between riparian vegetation and property values, there is however evidence from several areas that are closely related to this relationship as shown in Figure 1 below. This evidence included studies that have considered the influence of riparian land on urban and peri-urban land values, the influence of proximity to riparian lands on property value and several willingness to pay studies. It is unclear whether studies that have measured willingness to pay for riparian vegetation could be used as a market proxy for enhanced property values.

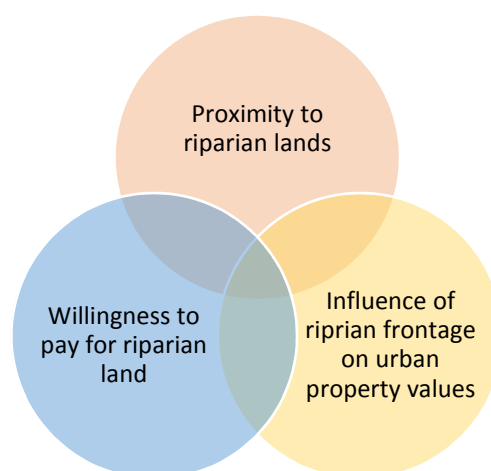


Figure 1. Related fields of evidence for the influence of riparian vegetation on property value

Polyakov's central Victorian studies showed that the extent of native vegetation in the surrounding landscape affects the property price and exhibits a diminishing marginal return. The study results indicate that location characteristics are also important determinants of property values. These include greater accessibility of recreational opportunities measured by nearer proximity to lakes, rivers, and parks increases property values (Polyakov et al., 2013, 2012).

The literature indicates that generally people have a willingness to pay (WTP) for new or improved riparian vegetation within proximity of their house (Kragt et al., 2007, 2009; Qiu et al., 2006). Results from a study in the George catchment in north-eastern Tasmania, for example, show that respondents are, on average, willing to pay between \$2.47 and \$4.46 for a km increase in native riverside vegetation (Kragt et al., 2009). Two quality Australian studies have examined the willingness to pay (WTP) for the amenities offered by riparian lands. A 2008 study of Victorian Rivers showed that the WTP for improvements in riparian vegetation ranged between \$3 and \$6 for an additional one per cent of the river's length with healthy vegetation on both banks (Bennett et al., 2008) and in a similar study of five NSW rivers it was found that for an increase of one per cent in the length of the river with healthy native vegetation and wetlands survey respondents were willing to pay in the order of one to two dollars (Bennett and Morrison, 2001).

Numerous studies have been conducted on the influence of proximity to riparian areas on urban residential house values. These studies have shown that riparian land has a positive influence on house values when houses have close proximity to rivers, lakes or wetlands (Colby and Wishart, 2002; Hodgkinson and Valadkhani, 2009; Mooney and Eisgruber, 2001), the riparian vegetation is of high habitat quality (Bark et al., 2009), there are associated wildlife benefits (Netusil, 2006; Qiu et al., 2006) or when there are associated recreational opportunities such as fishing or hunting (Bastian et al., 2002; Wasson et al., 2013) .

A study in Dijon, France showed that when in the line of sight, trees and farmland in the immediate vicinity of houses influenced positive prices and that urban houses with riparian frontages commanded higher prices (Cavailhès et al., 2009).

Several studies have shown that that property values are positively influenced when urban houses have riparian frontage (Bin et al., 2009), when remote agricultural lands include wildlife habitat, fishing opportunities and scenic views (Bastian et al., 2002), through increasing the overall percentage of riparian corridors and upland wildlife habitat (Netusil, 2006).

Interestingly a study involving over 700 properties in Oregon USA found that although stream frontage increased property values by seven percent, that each additional foot of riparian buffer decreased property value, on average by .06 percent and that this effect is greater for buffers less than 30 feet. The authors speculate that wider riparian buffers may obscure residents' view of the stream, thus reducing property value (Mooney and Eisgruber, 2001).

For more information on the evidence used in this relationship, refer to the evidence tables in Part 2 on pages 51-53.

Riparian revegetation, weed control and fencing >> change in invasive plant species

Five independent studies of suitable quality from Australia (Aither, 2014, Ede, 2011, Walpole, 1999) and the USA (Hafner and Brittingham, 1993, Sonoma, 2007) provided high confidence for this relationship. Weed management of fenced riparian land is an issue that is reported often through landholder surveys such as those conducted by Walpole, 1999 and Aither, 2014.

Further evidence could be found by using a more targeted search strategy. For more information on the evidence used in this relationship, refer to the evidence tables in Part 2 on pages 42-43.

Reduced soil erosion >> more productive crops

It is the author's opinion that this cause and effect relationship is quite self-evident and there is a large volume of experimental studies that are consistent in confirming this relationship but these were not revealed by the generic search strategy. A comprehensive assessment of the economic production benefits of reducing soils erosion through the maintenance or introduction of vegetation is beyond the scope of this project.

Three high quality studies (Nakao and Sohngen, 2000, Lynch and Donnelly, 1980, Williams et al 2004) showed that reduced soil erosion led to more productive pastures. Effect modifiers played an important role, with Williams et al. (2004) noting the importance of government cost share programs if landholders are to have a net economic gain due to high capital works costs. Furthermore, the cost of a tonne of soil erosion reduction varies across site characteristics in a watershed, including field shape and size, tillage method, and soil type (Nakao and Sohngen, 2000).

For more information on the evidence used in this relationship, refer to the evidence tables in Part 2 on page 47.

Biodiverse riparian zone >> enhanced visual amenity and wellbeing

Six evidence items (predominantly from landholder surveys) outlined that landholders undertook riparian works because they wanted to improve environmental outcomes (Ede, 2011), create an attractive and aesthetic frontage (Aither, 2014; Graymore and Schwarz, 2012), and increase wellbeing benefits to their families (Land and Water Australia, 2006). Two surveys found that landholders were motivated to be involved in riparian works because of personal pride and a 'feel good factor' for their work (Auckland Regional Council, 2001; Aither, 2014). One evidence item of low quality discussed the enhanced social capital of weed control if undertaken in a model that was cooperative and community led manner such as that used by the Victorian Blackberry Taskforce (Furze et al., 2008).

For more information on the evidence used in this relationship, refer to the evidence tables in Part 2 on page 54.

Healthy and attractive riparian zone >> landholder sense of stewardship and contribution to nature conservation

Four independent studies of suitable quality from Australia (Aither, 2014, Januchowski-Hartley et al 2012, Smith, 2008) and New Zealand (Auckland regional Council, 2001) provide high confidence for this relationship. The studies are based on landholder surveys or interviews. It may be argued that a landholder "sense of stewardship" does not contribute to increased farm productivity but this is an area for potential new research.

For more information on the evidence used in this relationship, refer to the evidence tables in Part 2 on page 55.

Medium confidence causal relationships

Increased accessibility of high quality water (impact of inorganic compounds) >> increased milk production (dairy) or weight gain (grazing)

There are fewer reliable studies examining the **direct influence of water quality on cattle** (Looper and Waldner, 2007), aside from those studies examining the impact organic or inorganic compounds and water temperature at levels that cause disease or physiological issues.

On the positive side for production, Ensley (2000) showed some relationship between sulphate concentrations up to 1500 parts per million (ppm) having a positive effect on dairy cattle milk production (Ensley, 2000). Generally the literature suggests that the influence of water quality on milk production, weight gain and breeding success is indirectly related to both the amount of water and forage consumption. As discussed above, both the amount of water and forage consumed is more directly related to production than water quality. The quality of water however can influence the palatability of water and hence the amount consumed.

In a literature review on the topic, Schutz (2012) noted that “although there seem to be general consensus that the water quality affects the palatability and water consumption of animals, there have been surprisingly few studies investigating the effects of water quality on livestock health and production” (Schutz, 2012). This is supported by earlier research by Waldner and Looper, 2007 who state “Research on water contaminants and their effects on cattle performance are sparse”. This appeared to remain so in 2015, with only three studies of sufficient quality (i.e. with a methods section) located in the search for this evidence.

Water quality is often assessed in terms of its total dissolved solids (TDS), water microbiology (especially coliform bacteria), total soluble salts (TSS) and salinity, hardness, nitrates, sulfates, pH, iron and manganese (Linn and Raeth-Knight, 2010; Patterson et al., 2002; Schutz, 2012; Umar et al., 2014). Not all of these factor of water quality are influenced by fencing and off-stream watering, although TDS and water microbiology often are.

The majority of evidence located was in the form of government fact sheets, or literature reviews that cited other literature reviews and government fact sheets (Bohnert, n.d.; Higgins et al., 2005). Other evidence items, while referred to as studies, were excluded because they either relied on observation only and did not account for confounding variables (Zeckoski et al., 2007) or they were a summary of findings with no methods section or study design apparent (Buchanan, 1996; Tanaka et al., 2007).

For more information on the evidence used in this relationship, refer to the evidence tables in Part 2 on pages 32-34 (dairy) and 37-39 (beef and sheep)

Increased accessibility of high quality water >> decreased consumption of pathogens >> reduced risk to health and performance

Firstly it is important to note that research on water contaminants and their effects on cattle performance are sparse (Umar et al., 2014). There is however, much non-primary research evidence available in the form of Government Extension Notes and expert opinion pieces. Twelve such items are shown in the Part 2 Evidence tables.

A good example of this is the following quote from a non-peer reviewed article by Zeckoski based on interviews with cattle producers.

“Many producers commented on general herd health improvements that resulted from implementing their stream exclusion systems. Most producers who provided an alternative source of water for their livestock saw a decrease in incidence of disease. Common diseases that declined after stream exclusion included foot rot, pink eye, scours, and mastitis. Producers noted that the reason for the decline in scours and mastitis in particular was the fact that the cows’ udders were no longer immersed in dirty water as they had been when the cows were allowed to stand in the stream.” (Zeckoski et al., 2007).

Five criteria can be considered when evaluating drinking water quality: organoleptic (odor and taste), physio-chemical, substances present in excess, toxic compounds, and microorganisms (primarily bacteria) (Beede, 1993). Organic compounds can influence these factors and hence influence the amount of consumption. Some organic agents may directly impact animal health by causing disease and infection whereas others have a more indirect effect particularly in causing cattle to decrease their water intake. When water intake is suppressed, feed intake normally also decreases, resulting in animals gaining less weight (Brew et al., 2009).

For more information on the evidence used in this relationship, refer to the evidence tables in Part 2 on pages 31-32 (dairy) and 39-40 (beef and sheep).

Fencing off riparian land >> less pasture available >> lower production/higher costs

A case study involving beef cattle from the Burdekin rangelands in northern Australia however, showed a herd reduction of 2% with no changes in cattle weight gains due to the construction of 90 km of riparian fencing. It should be noted that the fencing excluded approximately only 1.5% of the property (Department of Agriculture, Fisheries and Forests, 2014).

A social survey of landholders in Victorian CMAs found that 76% of respondents indicated that there had been no loss of productivity as a result of the riparian works which included fencing (Ede, 2011).

A study in California in the USA showed that the cost of installing vegetative buffer strips (VBS) in erosion prone watersheds, was outweighed by the production benefits in intensive row crop agricultural system (Rein, 1999).

It is difficult to draw any conclusion from these studies in non-dairy enterprises as there are many contextual variables that influence the outcome including the percentage of land affected by the fencing, the type of agricultural production (high value crops for example) and the susceptibility to processes that negatively influence production such as erosion that can be ameliorated by riparian protection.

For more information on the evidence used in this relationship, refer to the evidence tables in Part 2 on page 35.

Stock not standing in water >> reduced risk of disease

Caution should be held in the statement that “stock not standing in water reduces the risk of mastitis” as there were few good quality studies to support the oft-cited benefit that excluding dairy cows from waterways through fencing and off-stream watering reduces the incidence of mastitis. **While there is**

a large body of research on the causes and recommended treatment of mastitis, no studies were found that isolated the management practice of excluding dairy cows from streams and tested its validity as a preventative measure. More research needs to be conducted in this area if reduction of mastitis is to be promoted as a benefit of stock exclusion from riparian land. Two studies gave support for an association between high Somatic Cell Count (SCC) and a number of dairy management practices, including allowing stock to access streams. SCC is an indicator of milk quality and SCC increases when certain bacteria are present, including bacteria that cause mastitis (Barnouin et al., 2004; Schukken et al., 1990). A further study in North Carolina found that samples of mastitis-causing *Prototheca spp* were taken from water, sludge, mud, and vegetation from a creek in the stock lounging area (Anderson and Walker, 1988).

When searching for evidence regarding stock standing in water and stock illnesses due to waterborne disease, the majority of the studies focused on water borne diseases that affect humans caused by stock access to waterways, rather than diseases that affect stock only. Given that the focus of this project was benefits to landholders (particularly production benefits) of riparian works, the body of literature regarding down-stream human health risks was not included. A general search for waterborne diseases that affect stock health as a result of stock access to waterways did not yield many relevant results. The diseases associated with *Cryptosporidium*, Dermatophilosis and foot rot were searched for (Kragt et al., 2007, 2009; Qiu et al., 2006) individually. While there was a large body of research conducted around these diseases, few scientific studies were found that demonstrated an association between stock standing in flowing water and the onset of these diseases in stock.

For more information on the evidence used in this relationship, refer to the evidence tables in Part 2 on pages 29-30.

Increased use of natural fertilizer >> Reduced fertilizer costs

One good quality Australian study (Sillar Associates, 1998) based on multiple sources of evidence undertook a costs benefits study concluding that there was a reduction in farm gate fertilizer cost based on a substitution with natural animal waste. Further quality studies are needed to increase the confidence in this relationship.

Further evidence could be found by using a more targeted search strategy. For more information on the evidence used in this relationship, refer to the evidence tables in Part 2 on pages 34 (dairy) and 41 (beef and sheep).

Improved grazing distribution and pasture utilization >> Increased production

Two independent Australian studies (Aither, 2014, Sillar Associates, 1998) of suitable quality provided medium confidence for this relationship. It is important to note however that the studies both involved the use of a higher management input grazing system such as a rotational grazing regime. It is unclear if there are production benefits (from better pasture utilization) from only the provision of off-stream water and/or riparian fencing.

Further evidence could be found by using a more targeted search strategy. For more information on the evidence used in this relationship, refer to the evidence tables in Part 2 on page 41.

Riparian works and/or farm system changes >> increased farm productivity

Three independent studies (Aither, 2014, Dodd et al 2008, Graymore and Schwarz, 2012) of suitable quality provide medium confidence for this relationship. The studies indicate that landholders recognise that riparian lands are an integral part of total farm operations and productivity. Depending on how riparian lands are used and managed they can result in positive or negative production benefits.

Further evidence could be found by using a more targeted search strategy. For more information on the evidence used in this relationship, refer to the evidence tables in Part 2 on page 42.

Stock not standing in water >> reduced risk of bogging or drowning

One study (Sillar Associates, 1998) undertook a cost benefit analysis of riparian restoration in Queensland and found that the loss of stock would account for zero to 0.5% of overall herd mortality in dairy herds and to be negligible in beef herds.

For more information on the evidence used in this relationship, refer to the evidence tables in Part 2 on page 36.

Revegetation >> stock shelter >> improved stock health and productivity

The evidence of the benefits of shelter belts to stock wellbeing and production appears to be quite well settled science. A report titled '*The economic benefits of native shelter belts*' prepared for the Basalt to Bay Landcare Network provides summaries of numerous studies demonstrating many different ways in which shelter belts provide landholders with economic benefit (Austin, 2014). While this report and associated evidence is a useful inclusion in this summary of evidence, some caution needs to be exercised in directly applying the evidence to other contexts such as benefits of riparian vegetation.

While an assessment of the external validity of the evidence used in the Basalt to Bay report has not been undertaken, there are a number of considerations in adopting the evidence of the reported benefits to landholders. These include:

- The orientation of the riparian zone with respect to protection of harmful winds (cold and hot) and extreme temperatures on stock and crops.
- The height, density and configuration of vegetation to be able to provide the benefits of protection from drying winds and solar radiation to stock and crops
- The location of the riparian zone to be effective in ameliorating soil erosion or salinity

While the evidence of the benefits of shelter belts to stock wellbeing and production appears to be quite well agreed science, the application of these studies to the benefits from riparian areas (where stock are excluded) need to be considered.

The Basalt to Bay report contains numerous sources of evidence and although a little dated, reliable studies such as Lynch and Donnelly (1980) showed that sheep with access to shelter had a 31% increase in wool production and a 21% increase in live-weight, and landholder survey data in NSW

found that the most important economic benefits from remnant native vegetation was to provide shelter for stock and crops (Walpole, 1999).

For more information on the evidence used in this relationship, refer to the evidence tables in Part 2 on pages 36-37.

Blackberry control >> increased carrying capacity of pasture >> increased production

One good quality study costed the wool production losses caused by blackberry infestations in central NSW between 1982 and 1983. It found that the overall economic cost of blackberry to central western NSW during 1982-1983 was estimated at \$4.737 million (Vere et al., 1984). It noted that blackberry infestations mainly occur in non-crop areas, so livestock enterprises are the most affected. It outlined the types of economic cost caused by blackberry, the most important being loss of potential livestock production (which can be up to 50% with dense blackberry cover). Additionally, effective chemical control and re-sowing with improved pasture is expensive, along with the time and effort involved in keeping pastures blackberry free. Studies of similar quality but of a more recent date would be helpful in order to gain a more contemporary insight into blackberry control and production costs. The search strategy did not reveal any evidence of the effect of blackberries harbouring pest herbivores such as rabbits and hares. This is an area for future research.

Further evidence could be found by using a more targeted search strategy. For more information on the evidence used in this relationship, refer to the evidence tables in Part 2 on page 44.

Healthy riparian vegetation >> Increased pollination services >> increased crop production

Two studies (De Marco and Coelho, 2014, Winfree et al., 2011) looked at production benefits due to increased pollination, however they were not directly related to Victorian climates and crops, or to riparian zones. Nevertheless, Cole et al. (2015) found that buffer strips should be a least 5 metres wide if they are to benefit pollinators, and because many species of insect pollinators and flowering plants are adversely influenced by shading, large-scale afforestation of riparian field margins should be discouraged. Further research is required in this area.

Further evidence could be found by using a more targeted search strategy. For more information on the evidence used in this relationship, refer to the evidence tables in Part 2 on page 45.

Provision of native vegetation >> biological control of pests >> increased crop productivity

Three independent studies (Miles et al., 1998, Ward et al., 2003, Wood et al., 2011) of suitable quality provided medium confidence for this relationship. Two of the three studies were based on qualitative data and the third study had limited relevance to Victorian agriculture. There is potential however for further investigation of evidence for this relationship and an area for future research.

Further evidence could be found by using a more targeted search strategy. For more information on the evidence used in this relationship, refer to the evidence tables in Part 2 on page 45.

Shelterbelt >> crops protected from wind and erosion >> reduced soil moisture loss >> increased crop productivity AND Shelter >> Increased water filtration >> more productive crops

This evidence is of average quality, with one paper (Bird et al., 1992) citing numerous sources in a literature review, where the primary evidence was not available online. There does not appear to be many new recent (last ten years) studies on the benefits of shelterbelts on crop production. Several older studies have been cited repeatedly in the literature such as Anderson and Anderson, 1986; Bird et al., 1993; Bird, 1991; Sturrock, 1981; Sun and Dickinson, 1994. There is a need for more recent research into this area.

Bullman (1998) notes some effect modifiers as the location of the shelterbelt, the width of shelterbelt, the value of displaced agriculture, shelterbelt establishment cost and production gains (including crop increases and/or timber production).

For more information on the evidence used in this relationship, refer to the evidence tables in Part 2 on pages 46-47.

Weed control (gorse and willows) >> reduced production losses

Most evidence around gorse was related to the most effective way to control it, rather than the production benefits to landholders of controlling it. There were, however, studies regarding the high fire risk of gorse (Anderson and Anderson, 2010; De Luis et al., 2004) and gorse's impact on soil composition (Leary et al., 2006). The search revealed a cost benefit analysis demonstrating the economic benefit to landholders of controlling gorse in Victoria, given gorse's impact on a property's productivity (Miller et al., 2010). Studies have also been conducted demonstrating that goats are a more profitable way to control gorse than using chemicals, because they can be fed on gorse for most of the year and their wool and milk can be used as an alternative source of income (Howe et al., 1988; Krause et al., 1984).

Most evidence regarding willows discussed their utility for biochar, biomass and biofuel. In regards to willow removal for asset protection, a survey of landholders conducted in the Goulburn Broken catchment in Victoria showed that a substantial minority of respondents disagreed with the statement that '*Removing willows is an important part of work to improve the condition of native vegetation on river frontages*'. The author reports that this is consistent with the views of many interviewees who felt that the high cost of willow removal and replacement with native vegetation was not justified in terms of providing better erosion control (Curtis et al., 2008). One study examined the utility of willow control for irrigators by looking at their water evapotranspiration and the increased water available for irrigation on their removal. Doody et al. (n.d.) found that the amount of water taken up by willows from the stream system varies considerably depending on their location, thus the simulated net water saving from willow removal was in the range -5 to +9 ML ha⁻¹ year⁻¹ of willow projected crown area.

Further evidence could be found by using a more targeted search strategy. For more information on the evidence used in this relationship, refer to the evidence tables in Part 2 on pages 49-50.

Reduced risk of soil salinisation and acidification >> protect property value and maintain or increase production

A spreadsheet model was developed to show the benefits and costs of various planting configurations and methods over a 30-year time span (Hill 2004). While the long term economic benefits to landholders of revegetation in terms of salinisation is supported by evidence, it will depend on many contextual variables. Research in Western Australia conducted by Read et al. (2001) indicated that where the groundwater system is local, planting trees can affect watertables within economically viable timeframes. However, where groundwater systems are not local and lag effects between planting and watertable levels are much longer, the economic benefits of native vegetation are only realised in the longer term while costs are incurred in the short term. Biophysical modelling studies have indicated that very extensive areas of tree planting are necessary in a catchment to significantly affect the rate of spread of salinised land, reduce the loss of productivity and reduce salt loads in rivers (Heaney et al (2001), Herron et al (2001), Walpole and Lockwood (1999), Hill (1997)). In the case of salinity control by revegetation, it is common that not all the benefits flow directly to the landholder.

For more information on the evidence used in this relationship, refer to the evidence tables in Part 2 on page 49.

Low confidence causal relationships

Increased accessibility of water >> reduced heat stress leading to increased milk production

One Queensland Government study (Queensland Government, 2013) of margin relevance provided low confidence in this relationship. Other factors of water quality are perhaps more important in considering the production benefits of the provision of off-stream water.

For more information on the evidence used in this relationship, refer to the evidence tables in Part 2 on page 30.

2.02 Economic appraisals of riparian works

Some studies showed an overall economic benefit to landholders, or at least no perceived loss of income. For example, Rein (1999) found that the costs to strawberry growers of installation of Vegetative Buffer Strips are outweighed by the benefits of minimizing erosion-related costs, resulting in a net benefit to farmers of \$1,488 in the first year and \$6,171 over five years, for a 36-acre system. In Ede (2011)'s survey 76% of respondents indicated that there had been no loss of productivity across the property as a result of the riparian works (Ede, 2011). Other studies showed a net economic loss to landholders for undertaking riparian works. Results from a study by Aither (2015) into Victorian landholders with crown frontages showed that for an 'average' frontage, annual landholder expenses to operate and maintain the riparian works are estimated at \$2,100 per licence while the benefits of the frontage (including the provision of shelter, improved water quality, better stock control, and more sophisticated grazing regimes) were estimated to average \$1,250 per licence.

There is evidence suggesting that riparian works brought about some disadvantages to graziers. The most notable disadvantage of riparian fencing and/or revegetation was an increase in weeds, with five studies of medium to high quality consisting of landholder surveys, economic analysis and a site survey all highlighting weeds as an issue. The study conducted by the **University of California Cooperative Extension (2007)** concluded that there is a need to improve project design, implementation, and maintenance in order to address this issue. The reduced property carrying capacity and production due to fencing off riparian land was also mentioned as a cost to landholders in two costed studies and some landholder surveys.

2.1 Using the key findings to meet the defined decision needs

It is important to consider how the key findings from this summary of evidence can be used to meet the original desired decision needs of DELWP as stated in Section 1.4 above.

Stated DELWP desired decision need	Use of findings
Inform DELWP policy development in the area of increasing landholder adoption of riparian works	A Policy Brief was developed providing a high level summary of the evidence summary findings. The Brief was written in a style suitable for non-science based policy makers to understand. The Policy Brief was used as a supporting document for a Department of Treasury and Finance funding bid. The document described the areas of evidence of high confidence and the areas with lower confidence including those for potential future research.
Decisions regarding cost sharing between landholders and the Catchment Management Authorities (CMAs).	The findings revealed that there are numerous contextual variables relevant to each landholder/property that should be considered in reaching cost sharing arrangements with landholders. These include factors such as the amount of frontage area, the extent of existing degradation (works needed to ameliorate degradation), the private versus public benefit and the type of farming operation (cropping, dairy or grazing)
In developing key, fact based messages for landholders. Where there is clear evidence of production benefits to landholders strong messages can be developed, where there is weak, no or negative evidence of production benefits then there is less reason to peruse these messages.	The findings revealed that the level of confidence in the evidence for specific relationships tested varied from high to low. For relationships with a high level of confidence, these findings can be communicated to landholders and relevant stakeholders in DELWP information products. For relationships with medium levels of confidence, caution and caveats should be placed on the information communicated. For relationships with low levels of confidence, these should not be communicated to stakeholders. Section 2.1.1 below summarises the confidence in the conclusions from the evidence for each key relationship.
To assist in engaging particular agricultural industry groups such as dairy, cattle producers or croppers. Messages based on key findings can be tailored to particular industry groups. AND To target particular characteristics of landholders or properties for example if the property is mixed grazing/cropping then pollination services from the riparian zone could be considered	The findings showed that there are significant differences in the potential benefits of undertaking riparian works across the different industry groups. For example the provision of high quality off stream water has multiple benefits for dairy cattle relating to milk production and cattle health and wellbeing, more so than for beef cattle. The benefits of riparian revegetation however may be greater for croppers (i.e. crop protection and pollination services) than for grazing enterprises.
To assess the likely benefits to landholders and environmental benefits – this may result in a “go/no go” decision process.	While the review did look at the benefits of undertaking riparian works to landholders it did not consider the broader (catchment or community) environmental benefits.
To enable a better assessment of the types of works, how much and what	While some economic analysis was included in the evidence found, there was insufficient scope within the review to

<p>quality is needed to derive the desired benefits over individual or multiple properties including consideration of the 'additionality' of benefits.</p>	<p>consider any quantification of amount of works needed to derive individual or multiple property benefits.</p>
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2.1.1 Applying confidence levels to decision making

High confidence: Government authorities can feel confident communicating these benefits to landholders, although it is important that landholders understand the contextual variables that make these interventions beneficial.

Medium confidence: While it may be appropriate to continue to communicate these benefits to landholders in certain circumstances, government authorities should do so with caution and be clear that more research is required to understand if and when these interventions are beneficial.

Low confidence: It is advisable that either more research be undertaken before communicating these benefits to landholders, or that the lack of supporting evidence for them be clearly disclosed.

Part 2 - Evidence of the benefits to landholders of riparian works

Evidence tables

A. Production benefits

Dairy

Benefits – Stock health and wellbeing	Interventions	Evidence and reliability
Stock not standing in water >> reduced risk of disease	Off stream water and fencing	<p>A 2004 French study examined dairy herds (n = 534) enrolled in the National ‘Zero Mastitis Objective’ Program in order to understand what management practices were associated with herds that had a very low somatic cell score. Somatic cell count (SCC) is an indicator of milk quality. SCC increases when certain bacteria are present, including bacteria that cause mastitis. The herds studied were stratified into 2 groups, those with low SCC and those with a medium SCC. Management practices that could explain the difference in SCC between herds were collected through questionnaire surveys, and the final analysis identified 18 that were considered as primary factors for very low SCC. One of these 18 management practices was ‘heifers at pasture not drinking water from a river.’ (Barnouin et al., 2004)</p> <p>A study conducted in North Carolina in 1988 investigated the source of <i>Prototheca spp</i> causing mastitis in a herd of 263 milking cows. Of 38 samples from the dairy environment, 18 contained <i>Prototheca spp</i> and these samples were taken from sites that included cattle drinking water; sludge, mud, vegetation from a creek in the cattle lounging area, a feed trough, a dirt lounging area and the floor of a freestall barn. Sites characterized by wetness and the presence of organic matter most commonly yielded <i>Prototheca spp</i> (Anderson and Walker, 1988).</p> <p>In a study undertaken in 1990, the incidence rate of clinical mastitis in 125 herds with a low annual bulk milk SCC was modelled using a Poisson regression model. The rate of clinical mastitis was significantly associated with some variables that increased the exposure to environmental microorganisms. One of these variables was herds drinking from streams or wells instead of public water sources. Although no obvious explanation is present,</p>

		<p>the cow consuming stream or well water may have an increased exposure to dirt (Schukken et al., 1990).</p> <p>A Queensland case study aimed at assessing the benefits of wetlands in improving farm management and incomes, and the practices that contribute to wetland health found that with restricted access to the river, mastitis cases dropped from around 10% to 1% of the herd. This has saved the landholder \$2800.00 in veterinary costs and discarded milk (Queensland Government, 2013)</p> <p>The Merck Veterinary Manual is a possible source of information in landholder fact sheets regarding mastitis and stock access to streams. It says that “Mastitis due to <i>T. pyogenes</i> is common among dry cows and heifers that are pastured during the summer months on fields and that have access to ponds or wet areas. The vector for animal-to-animal spread is the fly <i>Hydrotaea irritans</i>. Control of infections is by limiting the ability to stand udder-deep in water and by controlling flies.” The Merck Veterinary Manual contained no references in support of this information. Two studies were located that examined the relationship between the fly <i>Hydrotaea irritans</i> (the European headfly) and the occurrence of summer mastitis in herds in Europe (Chirico et al., 1997; Hillerton et al., 1990). These studies did not, however, discuss the immersion of udders in streams as being a factor in attracting flies and therefore increasing any infection risk. It is unclear how applicable these European studies regarding the European headfly and summer mastitis are in an Australian context.</p>
Increased accessibility of water >> less heat stress >> increased milk production	Off stream water	A Queensland case study aimed at assessing the benefits of wetlands in improving farm management and incomes, and the practices that contribute to wetland health found that off stream watering reduced heat stress and increased milk production by 140 litres per day (across the milking herd of 500–600 Friesian cows including heifers, dry cows and calves) providing an extra \$18,000 year (Queensland Government, 2013).

Benefits – Easier stock management	Interventions	Evidence and reliability
Cows excluded from heavily vegetated or weedy riparian zone >> increased ease of mustering >> reduced costs	Riparian fencing	<p>A Queensland case study aimed at assessing the benefits of wetlands in improving farm management and incomes, and the practices that contribute to wetland health found that the time taken to muster cattle from the river was reduced by about 60 minutes per day; this saves the landholder around \$2,800.00 per year in labour costs (Queensland Government, 2013).</p> <p>A 1998 cost benefits study of riparian restoration on the Mary River, Queensland reported on the benefits</p>

		<p>(derived from interviews with landholder, experts, literature searches and experiences reported from a farmer survey) that the amount of time saved in mustering time is quite variable but is most likely to be more important on dairy farms because cows are mustered twice a day. The time saved was been estimated at between zero and 20 minutes per day on dairy farms depending upon such things as the completeness of the riparian zone fencing and whether the cattle are still given access to the riparian zone after fencing. Where a time saving was expressed by a farmer, the annual incremental benefit is priced on the basis of farm labour at \$12.50 per hour (Sillar Associates, 1998).</p> <p>A case-study in Oregon considered a solar powered livestock water pumping system combined with a mobile electric fence, which cost \$3000 to assemble (in 2001) and worked to divert problematic cattle congregation and use of riparian zones. Cost savings from reduced riding to muster stock was estimated at roughly \$2000 per season (Chamberlain and Doverspike, 2001).</p> <p>In a survey respondents noted better stock control (i.e. less lost stock) as a productivity benefit of fencing and off-stream watering (Aither, 2014).</p>
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Benefits – Increased weight gain or milk production	Interventions	Evidence and reliability
<p>Increased accessibility to high quality water >> fewer pathogens/biological agents in water >> increased health/production</p> <p>Effect modifiers:</p> <ul style="list-style-type: none"> • Influence on water intake due to taste • Cleanliness of troughs • Trough design • Season (temperature and sunlight exposure) • Proximity to the feedbunk <p>(LeJeune et al., 2001)</p>	<p>Fencing and off stream water</p>	<p>A report from Oklahoma State University states that <i>Leptospira</i> spp. are common contaminants of water sources such as ponds and can cause late-term abortions and decreased milk production. The report also states that <i>Fusobacterium</i> from contaminated water has resulted in chronic lameness and possible sepsis. Tuberculosis (<i>Mycobacterium bovis</i>) has been transmitted by communal drinking water, but a large infective dose is required. The author reports that a running stream has not spread the disease to animals downstream, but stagnant water has caused infection up to 18 days after its last use by an infected animal (Morgan, 2011).</p> <p>A University of Florida Extension Notes states that there is a demonstrated positive relationship between access to clean drinking water and performance factors such as growth, reproduction, and milk production. The author states that “animals that drink clean, contaminant-free water are generally less prone to illness and disease, gain more weight, and produce more milk.” (Brew et al., 2009).</p> <p>A 2001 University of Missouri Extension document states that stagnant water contaminated with manure or other nutrients may develop blue-green algae, which can poison livestock, causing muscle</p>

		<p>tremors, liver damage, and death. The paper also makes comments that the bacterial contaminants <i>Leptospirosis</i> and <i>Fusobacterium</i> often use water and mud, as modes of transportation from animal to animal. <i>Leptospirosis</i> is spread through urine of carrier animals and often manifests itself as reproductive problems. These may range from infertility, to low milk production, to widespread late-term abortion (Brew et al., 2009; Pfof et al., 2001).</p> <p>For dairy cattle, ingesting greater quantities of cleaner water can improve both milk and butterfat production (Landefeld and Bettinger, 2002).</p> <p>Drinking water contaminated with urine contains leptospira that causes reproductive loss including infertility and late term abortion and decreased milk production in cattle by leptospirosis (Pfof et al., 2001).</p> <p>In a study conducted in Illinois, water containing blue-green algae was shown to kill cattle (Galey et al., 1987). Similarly anecdotal evidence suggests that one cause of low water intake is due to poor water quality caused from microbial or bacterial contamination (Maynard, 1992).</p> <p>Despite extremely elevated coliform bacteria levels in the drinking water of certain study sites, there was no relationship observed between the coliform count and stock weight gain or milk production (Ensley, 2000).</p>
<p>Increased accessibility of high quality water (inorganic compounds) >> increased water and forage intake >> increased milk production or weight gain</p> <p>Water consumption by cattle is influenced by age, weight, breed, species, ambient temperature, humidity, lactation status, diet and level of production (Morgan, 2011), the concentrations of organic and inorganic compounds (Crowley et al., 1974; Ensley, 2000; Jaster et al., 1978; Linn and Raeth-Knight, 2010; Looper and Waldner, 2007; Looper, 2007; Morgan, 2011; Raisbeck et al., n.d.) and water temperature (Jaster et al., 1978; Milam et al., 1986)</p>	<p>Off stream water</p>	<p>It is no surprise that water is a vital component of dairy production given that typically a livestock's animal body is comprised of between 60-70% water (Looper and Waldner, 2007) and milk is comprised of 87% water (Beede, 2005). The primary anti-quality factors known to affect dairy cattle include total dissolved solids, sulfur, sulfate and chloride, nitrates, iron, and fluoride (Beede, 2005).</p> <p>A study conducted for a thesis in Iowa, USA, found that sulfate concentrations up to 1500 ppm may have a positive effect on dairy cattle milk production. The study also found that an elevation in the nitrate concentration of drinking water increased length of calving intervals. There was also a negative relationship between nitrate concentration of drinking water and Rolling Herd Average for Milk Production and Rolling Herd Average for Protein Production (Ensley, 2000). The findings in this study substantiate the observation by Crowley, 1974 of a negative impact of elevated nitrate content of drinking water on reproduction.</p> <p>Willms et al., (2002) found no significant difference between the weight or back fat thickness of the cows themselves that were subject to clean and direct water (while there were significant differences for their calves). It is proposed that the reason for this is that the cows consuming clean water produced more milk, and this was the cause of the increased weight gain in their calves, however this assumption was not tested in the study.</p>

		<p>A study from Israel showed that daily production of milk was higher for the cows receiving desalinated water than for the cows receiving salty water. The percentage of protein in milk and the daily protein production were higher for the cows receiving desalinated water than for the cows receiving salty water: 2.89% and 1.01 kg versus 2.84% and 0.93 kg, respectively. The study also showed that the percentage of milk fat and the daily fat production were higher for the cows receiving desalinated water. The results from this study indicate that water salinity negatively affects milk production (Solomon et al., 1995)</p> <p>Young dairy heifers had reduced water intake at salinity levels greater than 3,500 ppm. This indirectly affects forage consumption and production (Morgan, 2011).</p> <p>A study undertaken in Hamilton, Victoria used nine groups of four Hereford heifers with a control group provided with low levels of total suspended solids (TSS) and an exposed group to high levels of TSS showed that a TSS level of 5,000 ppm caused a large but non-significant reduction in live weight gain (36.3v. 25.9 kg) over the 79-day period while a level of 11,000 ppm reduced live weight by 49% (36.3 V. 18.5 kg, P<0.05) (Saul and Flinn, 1978).</p> <p>A study from Colorado showed that high water sulfate concentrations had a significant and deleterious effect on performance and carcass characteristics of feedlot steers. The study showed that, averaged over time, a water sulfate concentration of greater than 583 mg/L, equivalent to 0.22% of the diet, decreased feedlot performance. (Loneragan et al., 2001).</p> <p>Research in the U.S has shown feedlot cattle drinking saline water (TDS = 6,000 parts per million, ppm) had lower weight gains than cattle drinking normal water (TDS= 1,300 ppm), when the ration's energy content was low and during heat stress. High-energy rations and cold environmental temperatures negated the detrimental effects of high-saline water consumption (Looper and Waldner, 2007).</p> <p>Elevated total dissolved solids (TDS) adversely affect the palatability of water hence consumption and indirectly feed consumption and performance. Salinity at moderate to high levels (> 3,000 ppm) can cause diarrhoea, and issues for pregnant, lactating, stressed or young animals. Concentrations above 12,500 ppm can cause sodium ion toxicoses in cattle. Blue-green algae can also cause death in cattle. Disease in cattle resulting in poor performance can also be derived from bacterial, viral and protozoan microbiological agents (Morgan, 2011).</p> <p>Sulfate has been shown to reduce feed and water intake resulting in a reduction of growth and performance. It is recommended to keep concentrations below 1000 mg/L. Nitrate and nitrites can cause death and/or abortion in ruminants but concentrations less than 400 mg/L are acceptable (Raisbeck et al., n.d.)</p>
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Removal of pest herbivore harbor >> reduced pasture competition from pest herbivores >> increased production	Weed control	No studies or surveys of suitable quality found.

Benefits – Reduced fertilizer cost	Interventions	Evidence and reliability
Increased use of natural fertilizer >> Reduced fertilizer costs	Riparian fencing	A cost benefits study of riparian restoration on the Mary River, Queensland reported on the benefits (derived from interviews with landholders, experts, literature searches and experiences) reported that excluding cattle by fencing off the riparian zone ensures that dung and urine are deposited on land and not in the stream hence could be expected to increase soil fertility and pasture production. If it is assumed that 5% of animal manure and urine which was previously deposited directly in the stream is deposited on rye grass pasture after fencing the riparian zone then at farm gate fertilizer substitution prices for nitrogen, potassium and phosphorus, the long term annual value of nutrient recycling via animal waste amounts to \$616 for a 100 cow herd (Sillar Associates, 1998).

Disadvantage – less pasture available – increased fodder costs	Interventions	Evidence and reliability
<p>Fencing off riparian land >> less pasture available >> landholders need to purchase fodder >> increased cost</p> <p>Contextual variables: (Aarons, 2011)</p> <p>Botanical composition of grasses, soil moisture and fertility, seasonal factors.</p>	<p>Riparian Fencing</p>	<p>The potential impact on farm productivity of pasture production excluded by riparian fencing was assessed for 3 dairy farms. By fencing their riparian areas to 20 m, between 2.2% and 9.8% of their milking area would be out of production amounting to about \$16,000 in additional purchased fodder costs (Aarons, 2011).</p> <p>Pasture production, botanical composition and soil moisture and fertility were measured in riparian and elevated areas on three case study farms Gippsland, Victoria from September 2006 until November 2007. Riparian and flat areas produced significantly more pasture, with on average approximately 25% greater dry matter grown in these areas than hill paddocks for all farms. Based on pasture dry matter data, milk income would have been 0.2% to 1.7% (i.e. \$2000 - \$8000) greater in the 2006 / 2007 lactation, if riparian areas were not fenced to current widths (an average of 3 to 7 m from the waterway). If farmers fence their riparian areas to 20 metres to improve biodiversity conservation, the impact on income increases to 1.3% to 4.9% or \$9000 to \$12000 (Aarons, 2009).</p>

Research gaps

- Further evidence on the claimed benefits around reduced fertiliser costs, weed control resulting in less pest herbivores and increased pasture production and increased milk production due to the accessibility of off stream watering and reduced heat stress.
- The search strategy did not specifically search for studies costing the beneficial effects of retaining dairy cow fertiliser on pastures rather than effluent being deposited in riparian areas or in streams
- The search strategy did not specifically search for the impact of feral herbivores such as rabbits and hares on pasture availability from being harboured in riparian weeds such as blackberries and gorse
- More high quality studies examining the various benefits at a property scale to dairy landholders of riparian works.
- Corroboration of unsubstantiated claims commonly found in Extension Notes and Fact Sheets with experiential evidence from landholders

Sheep and cattle dry land grazing

Benefits – Stock health and wellbeing	Interventions	Evidence and reliability
Stock not standing in water >> reduced risk of disease	Riparian fencing	<p>Risk factors for herd and animal level Bovine Johne’s infection are also of considerable interest, although no clear pattern of identifiable risk factors have emerged, other than herd size and numbers of introductions (Sergeant, 2005)</p> <p>In one study in beef cattle herds in Texas, USA (Roussel et al., 2005), risk factors for seropositive animals included the water source (seroprevalence was higher for cattle watered on a running stream or river) but it was unclear if serum results were false positives.</p>
Stock not standing in water >> reduced risk of bogging or drowning	Riparian fencing and/or off stream water	<p>A 1998 cost benefits study of riparian restoration on the Mary River, Queensland reported on the benefits (derived from interviews with landholder, experts, literature searches and experiences reported from a farmer survey) that the loss of stock would account for zero to 0.5% of overall herd mortality in dairy herds and to be negligible in beef herds. This loss is avoided by fencing-off the watercourse. This loss is valued at the farm gate replacement cost of a dry dairy cow with district average production potential is estimated to be \$800. For a herd comprising 100 head for example, the average loss avoided would therefore be \$400/year (Sillar Associates, 1998).</p>
Revegetation >> stock shelter >> improved stock health and productivity	Native vegetation retention, fencing	<p>A 5 year trial showed that sheep with access to shelter (in this study, the shelter was a fence) had a 31% increase in wool production and a 21% increase in live-weight (Lynch and Donnelly, 1980) .</p> <p>A recent publication by the Basalt to Bay Landscape Network (Austin, 2014) cites several studies showing benefits to stock production:</p> <ul style="list-style-type: none"> • In shorn sheep, shelter that reduces wind speed by 50% can reduce energy losses by 20%, increase live-weight by 30% (Black and Bottomley, 1980). • Cold stress reduces live-weight gain by 6kg in sheep and depresses wool growth by 25%, while heat stress reduces wool growth by reducing feed intake (Anderson, 1986).

		<ul style="list-style-type: none"> • Sheltered lambs exhibit a 50% reduction in losses (SW Victoria) and 28% increase in survival rates (Bird, 1981). • In cattle – efficiency of production (live-weight gain or milk output per unit of feed) is improved by shelter; shading and protection from high-humidity alleviates stress, and improves milk production and weight gain (Reid and Bird, 1990) . • Protected areas of farms have a 20% to 30% higher yield than unprotected areas, with annual benefits of \$38-\$66 per hectare (Fitzpatrick, 1994). • Cold stress reduces live-weight gain in cattle by 31% over several weeks (Anderson, 1986). <p>A study measured the on-farm benefits and costs associated with remnant native vegetation (RNV) in the two study areas, the northeast Victorian catchment and the Murray catchment of NSW. Data were collected using landholder surveys. The most important economic benefits from RNV under current management regimes in the Victorian study area were productivity effects associated with prevention of land degradation, firewood production, and for the NSW study area, stock and crop shelter (Walpole, 1999).</p>
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Benefits – Increased weight gain	Interventions	Evidence and reliability
<p>Increased accessibility of high quality water >> increased water and forage intake >> increased weight gain</p> <p>Contextual variables:</p> <p>Water consumption by cattle is influenced by age, weight, breed, species,</p>	<p>Off stream water</p>	<p>A study in Saskatchewan, Canada aimed to measure weight gains from cows, calves and steers using three treatments to water - aeration, coagulation and just pumped to a trough. Cows and calves were observed to show the biggest weight gains from the pumping to a trough treatment whereas steers gained more weight (9%) from the coagulated and aerated treatments rather than the just pumped treatment (Lardner et al., 2005).</p> <p>A study in Oregon, Canada showed that cows and calves that were provided with off stream water and trace-mineral salt gained 11.5 kg and 0.14 kg/d more, respectively, than cows and calves without off stream water, averaged across years (P < 0.05) (Porath et al., 2002)</p> <p>Elevated total dissolved solids (TDS) adversely affect the palatability of water hence consumption and indirectly feed consumption and performance. Salinity at moderate to high levels (> 3,000 ppm) can cause diarrhoea, and issues for pregnant, lactating, stressed or young animals. Concentrations above 12,500 ppm can cause sodium</p>

<p>ambient temperature, humidity, lactation status, diet and level of production (Morgan, 2011)</p> <p>Factors influencing the quality of off stream water such as the nutrition content of the water, exposure to sunlight, cleaning management, trough design, and air temperature are all important for stock consumption (Schutz, 2012)</p> <p>Climate variability and its impact on precipitation, forage production, and forage quality (Lardner et al., 2005)</p> <p>Dry matter intake and palatability (Lardner et al., 2005)</p> <p>Porath et al., (2002) were unsure why stock that consumed off stream water gained more weight than stock that consumed water directly from the source. However in the study, stock distribution patterns indicated that more uniform grazing and less patch grazing may have occurred in offstream pastures, which might have influenced the weight gain of stock in the study (Porath et al., 2002).</p> <p>The use of a rotational grazing system in combination with the provision of off stream water is reported in several studies to enhance stock pasture utilisation and hence weight gain.</p>		<p>ion toxicoses in cattle. Blue-green algae can also cause death in cattle. Disease in cattle resulting in poor performance can also be derived from bacterial, viral and protozoan microbiological agents (Morgan, 2011).</p> <p>Sulfate has been shown to reduce feed and water intake resulting in a reduction of growth and performance. It is recommended to keep concentrations below 1000 mg/L. Nitrate and nitrites can cause death and/or abortion in ruminants but concentrations less than 400 mg/L are acceptable (Raisbeck et al., n.d.)</p> <p>A 1997 study in north east Oregon, Canada involving 300 cows found that cattle with access to off stream water were distributed more evenly across pastures and consumed more upland forage before desired riparian levels were reached. Consumption of more upland forage allowed the long run equilibrium herd size to remain at traditional numbers. This result combined with improved animal performance yielded positive net returns for the project (Stillings, 1997).</p> <p>A Canadian study examined the effects of water source on cattle production and behaviour, to determine the relationship of selected chemical and biological constituents on the observed response and to test the effect of faecal contamination on water consumption. Calves, with cows drinking clean water, gained 9% more < 0.10) weight than those with cows on pond direct but cow weight and back fat thickness were not affected. Yearling heifers having access to clean water gained 23% (P = 0.045) and 20% (P 0.076) more weight than those on pond direct and pond trough, respectively. Cattle avoided water that was contaminated with 0.005 % fresh manure by weight when given a choice of clean water. Cattle that had access to clean water spent more time grazing and less time resting than those that were offered pond trough or pond direct (Willms et al., 2002).</p> <p>A study conducted for a thesis in Iowa, USA, found that (1) there was no relationship observed between total dissolved solids (TDS) and stock weight gain or milk production (2) There was a negative correlation between calving intervals and elevate nitrate levels in drinking water (3) Sulfate concentrations up to 1500 ppm may have a positive effect on dairy cattle milk production (4) There was also a negative relationship between elevated nitrate levels and Rolling Herd Average (RHA) milk and RHA protein (Ensley, 2000).</p> <p>There was no relationship observed between total dissolved solids (TDS) and stock weight gain or milk production (Ensley, 2000).</p> <p>In a review of literature Zeckoski reports the on the following studies showing increases in cattle weight gain as a result of providing cleaner water to cattle:</p> <ul style="list-style-type: none"> • 0.2 lb/day - 0.4 lb/day for cows (Buchanan, 1996, Willms et al 1994)
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<p>Increased accessibility of high quality water >> decreased consumption of pathogens >> reduced risk to health and performance</p> <p>Effect modifiers:</p> <ul style="list-style-type: none"> • Influence on water intake hence production • Cleanliness of troughs • Trough design • Season (temperature and sunlight exposure) • Proximity to the feedbunk (LeJeune et al., 2001) 		<p>A University of Florida Extension Notes states that there is a demonstrated positive relationship between access to clean drinking water and performance factors such as growth, reproduction, and milk production. The author states that “animals that drink clean, contaminant-free water are generally less prone to illness and disease, gain more weight, and produce more milk.” (Brew et al., 2009).</p> <p>High levels of bacteria have been found in cattle watering ponds where they may contribute to outbreaks of coliform related illnesses caused by <i>E.coli</i>, <i>E. aerogenes</i>, and <i>Klebsiella</i> species. These can lead to mastitis, urinary tract infections, diarrhea and numerous other unsavory and often lethal infections (Brew et al., 2009).</p> <p>Drinking water contaminated with urine contains leptospira that causes reproductive loss including infertility and late term abortion and decreased milk production in cattle by leptospirosis (Pfof et al., 2001).</p> <p>Eggs, larvae and adult parasites if present in drinking water can infest the animal, affecting the health status, growth and performance. Also, cattle are commonly hosts to <i>Giardia</i> spp., <i>Cryptosporidium</i> spp, nematodes and other parasites that affect their health (Umar et al., 2014).</p> <p>Many harmful organisms are present in the stream, including those that cause foot rot, environmental mastitis, jaundice, fever, red nose, bovine virus diarrhea, and tuberculosis (Bendfeldt, 2004; Pfof et al., 2000; Adams, 1994). Removing cattle from the stream and providing an alternative source of water limits contact with these pathogens (Zeckoski et al., 2007)</p> <p>Manure levels don't affect consumption until it is more than 0.25% in water. Studies have shown that livestock offered manure contaminated water don't grow well as compare to those having free access to clean water (Umar et al., 2014).</p> <p><i>E.coli</i>, <i>Campylobacter jejuni</i>, <i>Klebsiella</i>, <i>E.aerogenes</i>, <i>Salmonella</i> spp., <i>Shigellae</i> spp. and <i>Vibrio cholera</i> are the</p>

		<p>common causes of coliform illness outbreaks; these can lead to a range of unappealing and usually deadly infections (Brew et al., 2009; LeJeune et al., 2001).</p> <p>Both Willms et al., (2002) and Lardner et al., (2005) found negligible differences between the rate of infection by <i>Giardia</i>, <i>Cryptosporidium</i>, <i>Trichostrongylus</i>, or <i>Nematodirus</i> spp among stock that drank clean water from a trough and stock that drank water of lower quality directly from the water source.</p> <p>A study conducted for a thesis in Iowa, USA, found that Despite extremely elevated coliform bacteria levels in the drinking water of certain study sites, there was no relationship observed between the coliform count and stock weight gain or milk production (Ensley, 2000).</p> <p>Water quality problems affecting livestock are more commonly seen with high concentrations of minerals (excess salinity); high nitrogen content; bacterial contamination; heavy growths of toxic blue-green algae (Landefeld and Bettinger, 2002).</p>
<p>Stock exclusion >> reduced carrying capacity and production</p>	<p>Fencing off riparian zone</p>	<p>A project involving a social survey in Victorian CMAs found that 76% of respondents indicated that there had been no loss of productivity as a result of the riparian works which included fencing (Ede, 2011).</p> <p>A study in the USA showed that the cost of installing vegetative buffer strips (VBS) in erosion prone watersheds, was outweighed by the production benefits in intensive row crop agricultural system (Rein, 1999).</p> <p>A case study from the Burdekin rangelands in northern Australia showed that the construction of 90km of fencing on a 300,000 ha property (1.5% of the area) resulted in herd reduction of 2% with no changes in cattle weight gains. The study reports the trade-off was improved ecological health which includes improved runoff quality, minimised sediment loss, pasture improvement, and weed reduction (Department of Agriculture, Fisheries and Forests, 2014)</p>

Benefits – Pasture and water quality and abundance	Interventions	Evidence and reliability
<p>Increased use of natural fertilizer >> Reduced fertilizer costs</p> <p>Contextual factors: A number of other critical factors are likely to affect the beneficial impact on soil fertility and pasture productivity, including (a) the base line soil fertility and type of the pasture and its ability to respond to added nutrition (e.g. added nutrient may be surplus to requirements for optimum growth), (b) the use of pasture management procedures to optimise nutrient recycling (e.g. use of pasture harrows), (c) the proportion of beneficial defecation actually falling on productive pasture land (and not, for example, in laneways, milking sheds & cattle camps etc), and (d) the amount of animal waste unproductively deposited in the riparian zone before fence construction and thus, the incremental benefit (Sillar Associates, 1998).</p>	<p>Fencing and off stream water</p>	<p>A cost benefits study of riparian restoration on the Mary River, Queensland reported on the benefits (derived from interviews with landholder, experts, literature searches and experiences) reported that excluding cattle by fencing off the riparian zone ensures that dung and urine are deposited on land and not in the stream hence could be expected to increase soil fertility and pasture production. If it is assumed that 5% of animal manure and urine which was previously deposited directly in the stream is deposited on rye grass pasture after fencing the riparian zone then at farm gate fertilizer substitution prices for nitrogen, potassium and phosphorus, the long term annual value of nutrient recycling via animal waste amounts to \$616 for a 100 cow herd (Sillar Associates, 1998).</p>
<p>Improved grazing distribution and pasture utilization >> Increased production</p>	<p>Fencing and off stream water</p>	<p>A cost benefits study of riparian restoration on the Mary River, Queensland reported on the benefits (derived from interviews with landholder, experts, literature searches and experiences) reported that a positive economic return can be gained from better forage utilisation as a result of the provision of additional off stream watering points. The study reports that better feed management, and production can occur on both dairy and beef farms because a more efficient rotational grazing system can be implemented as a results of having more stock watering points available. Two costed case studies show Annual Incremental Gross Margins of \$50,140 and \$69,200 for a dairy farmer and beef producer respectively (Sillar Associates, 1998).</p> <p>Survey respondents noted improved and more sophisticated grazing regimes as a productivity benefit of fencing and off-stream watering (Aither, 2014)</p>

Benefits – Increased farm productivity	Interventions	Evidence and reliability
<p>Riparian works and/or farm system changes >> increased farm productivity</p>	<p>Fencing, off stream watering and revegetation</p> <p>Revegetation (native and pine plantation) and fencing (combined with pastoral intensification)</p>	<p>Eight landholders from Glenelg Hopkins and Corangamite CMA regions were interviewed. For six of the landholders, carrying out riparian restoration works had enhanced their production values. For example, fencing off and planting trees along waterways increased birdlife which assisted in pest control of grubs and bugs on pastures. Other production benefits described by farmers were shelter and shade for stock (including warmer paddocks), pastoral improvement and maintenance, energy retention by livestock, increased livestock production (by up to 30%) in terms of lambing percentages, lamb survival and livestock weight, and once trees are established use of riparian areas for grazing and firewood collection (Graymore and Schwarz, 2012).</p> <p>In a Victorian crown frontage landholder survey respondents were asked whether the productivity of livestock grazing the frontage and/or the paddocks next to the fenced frontage had changed during their ownership/leasehold of the property as a result of fencing and off-stream watering. 29% said there had been changes. The positive changes were: Reduction in erosion remediation works, Better water quality, Better stock control (i.e. less lost stock), Improved and more sophisticated grazing regimes, Increase in stock shelter. Reductions in productivity that respondents pointed to included: Loss of water access, Loss of productive land areas, Loss of stock wind and weather shelter belt, increased pest problems, Increased management costs (i.e. checking off-stream watering infrastructure) (Aither, 2014)</p> <p>Land use and management changes were implemented to improve economic and environmental performance of the Mangaotama case study catchment farm. The major changes included: afforestation of 160 of the 296 ha catchment farm with pine and native trees, riparian management of the entire 20 km of stream network via fencing and/or forestry, restoration of 5 ha of existing native forest, and intensification of the remaining pastoral component to a high fecundity ewe flock and bull beef finishing. Marked improvements were observed in the key environmental and economic performance indicators. In particular, declines in sediment (76%) and phosphorus (62%) loads and faecal coliform (43%) levels were observed, native forest fragments showed early signs of recovery in terms of sapling numbers and vegetative cover, and the pastoral enterprise recorded increased per hectare production of lamb (87%) and beef (170%). There were implementation challenges with the better matching of land use to land capability, but this study demonstrated that significant progress can be made in the short-term (Dodd et al., 2008).</p>

Other factors – presence of pest plants and animals	Interventions	Evidence and reliability
Riparian revegetation and/ fencing >> change in invasive plant species	Revegetation	<p>A retrospective, cross-sectional survey of riparian revegetation projects on north coastal California working ranches was conducted. 102 sites were surveyed, totalling 19.4 kilometres, along streams in Marin, Mendocino, and Sonoma Counties from 2002 to 2005. The study goal was to determine the efficacy of riparian restoration within the working landscape of California’s rangelands. The project documented plant community succession and structure, and aquatic habitat response to restoration over time. The results point to an unintended outcome resulting from such projects - increases in invasive plant species. This highlights the need to improve project design, implementation, and maintenance (University of California Cooperative Extension, County of Sonoma, 2007).</p> <p>In a Victorian crown frontage landholder survey the results show that for crown frontage the total costs with respect to time and money for managing pest plant and animals are higher on fenced frontage compared with unfenced frontage; however, it was unclear whether the difference was due to differences in the area of fenced and unfenced frontage, so this result is inconclusive. The survey did provide evidence to show that landholder costs on freehold are approximately double those on crown frontage with respect to both time and materials. Respondents were asked whether or not the time and expense of controlling pest plants and animals within the fenced area had changed since fencing. For the majority of respondents, the costs associated with pest plant and animal control remained the same or increased (less than two times) after fencing. 15% of respondents claimed that costs had decreased since fencing (Aither 2014).</p> <p>Weed management after works was the most frequently mentioned issue for survey respondents, with some respondents being concerned at the extent of resources required to manage weeds after works (Ede, 2011a)</p> <p>Reducing stream-bank erosion, improving water quality, and the belief that fencing would become mandatory in the future were the primary reasons landowners gave for participating in a riparian land fencing program in Pennsylvania. After joining the program, the major concerns or complaints landowners had about fencing involved weeds, fence maintenance, and loss of pasture (Hafner and Brittingham, 1993)</p> <p>A landholder survey that measured the on-farm benefits and costs associated with retained native vegetation (RNV) in a northeast Victorian catchment and the Murray catchment of NSW showed that the most significant cost in both study areas was weed management. A proposed conservation management scenario that included fencing of the RNV, and limitations on grazing and firewood and post removal would negatively affect most of the survey participants. In both study areas, the incremental economic costs of the scenario outweighed the incremental economic benefits for at least 89% of participants (Walpole, 1999).</p>

Benefits – increased productivity	Interventions	Evidence and reliability
Blackberry control >> increased carrying capacity of pasture >> increased production	Weed control	Blackberry was estimated to cause aggregate wool production losses valued at \$4.251 million in central western NSW between 1982 and 1983. Blackberry significantly reduced the sheep carrying potential of both improved and natural pastures. A further \$0.486 million was spent by councils and landholders in the area during that time on chemical control. The overall economic cost of blackberry to central western NSW during 1982-1983 was estimated at \$4.737 million (Vere et al., 1984).

Benefits – aligns with farm management goals	Interventions	Evidence and reliability
Riparian works >> assists farm management goals	Fencing, off stream watering, revegetation	Eight landholders from Glenelg Hopkins and Corangamite CMA regions were interviewed. Six landholders who had adopted restoration works on their properties had done so because it matched their farm management goals which included the need to realign fences to accommodate floodways; the need to fix/re-fence areas of the farm, and therefore, made sense to realign fences with creeks; erosion control in gullies and along drains and creeks; excluding stock from waterways for livestock management and health; protection of water resource and water quality due to stream-side degradation (erosion, pugging, loss of vegetation) (Graymore and Schwarz, 2012).

Research gaps

- Corroboration of unsubstantiated claims commonly found in Extension Notes and Fact Sheets with experiential evidence from landholders
- A greater understanding of the circumstance in which riparian vegetation provides shelter benefits to stock
- A greater understanding of the economic benefits to landholders of riparian works at the property scale to show in what circumstances fencing and off-stream watering can:
 - improve grazing distribution and increase production
 - increase the use of natural fertiliser and reduce fertiliser costs
 - improve animal wellbeing and reduce bogging and drowning

Cropping

Benefits –	Interventions	Evidence and reliability
<p>Healthy riparian vegetation >> Increased pollination services</p> <p>Effect modifiers (Cole et al., 2015)</p> <ul style="list-style-type: none"> To benefit insect pollinators buffer strips should be a minimum width of 5m. As many species of insect pollinators and flowering plants are adversely influenced by shading, large-scale afforestation of riparian field margins should be discouraged 		<p>Riparian margins had richer plant assemblages and supported more pollinators than grassland fields. Fenced riparian buffer strips supported more even and diverse assemblages of bumblebees and a greater number of butterflies than unfenced riparian margin (Cole et al., 2015).</p>
<p>Increased pollination services >> increased crop production</p> <p>Effect modifiers (Winfree et al., 2011)</p> <ul style="list-style-type: none"> If a crop requires pollination and landholders are paying to rent bees to conduct the pollination, costs can be saved if this pollination is undertaken by wild pollinators. Wild pollinators will require appropriate habitat. 	Revegetation	<p>Coffee farms in Brazil near forest fragments had an increase of 14.6% in production that can be related to pollinating services (De Marco and Coelho, 2004).</p> <p>This study does not examine pollination services as a result of riparian or on-farm vegetation. It examines 3 different methods by which to measure the economic value of pollination generally, through a case study of the pollination of watermelons in New Jersey (Winfree et al., 2011).</p>
<p>Provision of native vegetation >> biological control of pests >> increased crop productivity</p>	Weed control, revegetation	<p>Macadamia orchards removed exotic weeds from an adjacent non-crop riparian habitat, which harboured a high density of a native rodent. Endangered rainforest ecosystem species were planted. Over a 3-yr period, orchard trees adjacent to the restored habitat received 50% less rodent damage than trees adjacent to non-manipulated habitats. A cost–benefit analysis of the damage reduction indicated a break-even point of 3.4 yr. After break-even, this represents an economic benefit to growers that will result in an additional return of approximately \$4500 per annum per km of orchard frontage (Ward et al., 2003).</p> <p>A Rural Industries Research and Development Corporation (RIRDC) report provides further evidence that planting of select native plant species near horticultural production facilities may have potential for improving economics and sustainability of pest-management, in addition to providing a range of other</p>

		<p>biodiversity and public benefits (Wood, G. et al., 2011).</p> <p>The presence of a diversity of native vegetation types can assist biological control of non-beneficial insects by birds and other animals. For example, about two thirds of respondents in a survey of north-eastern Victorian and southern NSW landholders identified the provision of habitat for animals that control pests as a benefit from native vegetation secondary research (Miles et al. (1998), as cited in Agtrans Research, (2007)).</p>
Increased vegetation >> reduced salinity problems	Revegetation	The science for the relationships between native vegetation and salinity management is vast and reasonably well understood. A review of this evidence is beyond the scope of this project.
<p>Shelterbelt >> crops protected from wind and erosion >> increased crop productivity</p> <p>Effect modifiers: (Bulman, 1998) Location of shelterbelt Width of shelterbelt The value of displaced agriculture</p> <p>Shelterbelt establishment cost Production gains (crop increases and/or timber production)</p>	Revegetation	<p>In the cropping and higher rainfall grazing areas, the systematic planting of 10% of the land in a net of shelterbelts/timber belts/clusters could achieve a 50% wind speed reduction; this would substantially improve livestock and pasture production in the short and long-term. Wind erosion could be dramatically reduced and crop production probably increased by the use of windbreaks, Wheat and oat yield at Rutherglen (Victoria), and lupin yield at Esperance (Western Australia), were increased in the sheltered zone by 22% and 47%, and 30%, respectively. In semi-arid and dry temperate areas, planting of 5% of the land to shelter could reduce wind speed by 30–50% and soil loss by up to 80% (Bird et al., 1992).</p> <p>An experimental study conducted on the Atherton Tablelands to quantify the shelterbelt benefit on potato production found potato yield was increased by 6.7% due to the shelterbelt (Sun and Dickinson, 1994)</p> <p>Australian studies of increased crop yields include: 22% for oats, 47% for wheat in areas of above 600mm annual rainfall (Sturrock, 1981 as cited in Austin 2015).</p>

<p>Reduced soil erosion >> more productive crops</p> <p>Shelter from wind >> reduced soil moisture loss >> increased productivity</p> <p>Effect modifiers: (Williams et al., 2004) Cost share payments are important for the landowner to benefit from the projects. Only two of the projects studied will have a positive net present value without cost share payments specifically targeted for streambank stabilization. This is because construction costs (revegetation and bank stabilisation) averaged \$16,143 per site, and cost share programs paid on average 90% of these construction costs.</p> <p>(Nakao and Sohngen, 2000) The cost of a ton of soil erosion reduction varies across site characteristics in a watershed, including field shape and size, tillage method, and soil type.</p>	<p>Riparian buffer, other</p>	<p>13 severely eroded sites along a river in Kansas were the subject of restoration works, including revegetation (38 m. wide buffer zone) and bank stabilisation (re-shaping streambanks, installing weirs and rock veins). Over a 15 year period, economic analysis shows that each project has a positive net present value to the landowner. Annualized net present values (ANPV) over the 15-year life of the projects range from \$126 to \$1,760 with an average of \$781. Gains are also realized from the value of hectares not lost to erosion, income from being able to crop the preserved hectares not in the stabilization project, and payments received for the hectares enrolled in Continuous Conservation Reserve Program (CRP) as part of the project. The net present value (NPV) increases in proportion to the annual erosion rate relative to the number of hectares required in the stabilization project (Williams et al., 2004).</p> <p>A study estimated the cost of reducing soil erosion with riparian buffers. The methods are used to show how watershed managers may target funds to high and low cost sites and regions within a watershed. The results suggest that the costs of reducing soil erosion with riparian buffers are lower when buffers are applied to conventionally tilled fields, and that the costs of buffers are comparable to the costs of no-till. The relationship between buffer size, drainage area size, and effectiveness is explored. The paper shows how riparian buffers with low effectiveness can be cheaper to install than riparian buffers with high effectiveness (Nakao and Sohngen, 2000).</p> <p>A study by Lynch and Donnelly showed that shelter improved plant growth and increased pasture and crop production, by reducing moisture loss from soils and transpiration in crops and pastures; shelter reduced the loss of water from soil in late spring by 10-12mm (Lynch and Donnelly, 1980).</p>
<p>Shelter >> Increased water filtration >> more productive pasture</p>	<p>Revegetation</p>	<p>In a study to observe infiltration rates, tree shelterbelts were established in selected pastures of land used for sheep grazing. Water infiltration rates were up to 60 times higher in areas planted with young trees than in adjacent grazed pastures (Carroll et al., 2004).</p>
<p>Increased carbon sequestration >> alternative income stream (with a carbon market)</p> <p>Effect modifiers: (Crossman et al., 2011) The price of carbon The vegetation planted (less carbon is sequestered by mixed native tree and shrub plantings)</p>	<p>Revegetation</p>	<p>A study quantified the economic returns from agriculture and from carbon plantings (monoculture and mixed tree and shrubs) under six carbon-price scenarios. We also identified high-priority locations for restoration of cleared landscapes with mixed tree and shrub carbon plantings. Depending on the price of carbon, direct annual payments to landowners of AU\$7/ha/year to \$125/ha/year (US\$6–120/ha/year) may be sufficient to augment economic returns from a carbon market and encourage tree plantings that contribute more to the restoration of natural systems and endangered species habitats than monocultures. Thus, areas of high priority for conservation and restoration may be restored relatively cheaply in the presence of a carbon market (Crossman et al., 2011).</p>

		Using a combination of methodologies, carbon farming was a viable land use in over 2.3% of our study extent with a low \$5 t CO ₂ e ⁻¹ carbon price, and up to 10.5 million hectares (34%) with a carbon price of \$50 t CO ₂ e ⁻¹ . Our study highlights the potential utility of assisted natural regeneration as a reforestation approach which can cost-effectively deliver both carbon and biodiversity benefits (Evans et al., 2015) .
Fencing and revegetation >> Reduced degradation of stream banks and the riparian zone >> Reduce erosion and water sedimentation	Fencing and revegetation	<p>This study demonstrates the benefits of riparian management (fencing and re-vegetation) in reducing stream bank erosion (McKergow et al., 2003b).</p> <p>After riparian treatments (buffer strips, stream bank stabilization, and rock-lined stream crossings) on 2 streams with livestock grazing, stream bank vegetation increased from 50% or less to 100% in nearly all formerly grazed riparian buffers and goals of the riparian restoration to minimize erosion and sedimentation were met. (Carline and Walsh, 2007).</p> <p>(The science for the relationships between native vegetation and reduced erosion is reasonably well understood. A review of all of this evidence is beyond the scope of this project.)</p>

Research gaps

- More research specific to riparian land is required to demonstrate that riparian revegetation leads to increased crop productivity through pollination services, protecting crops from wind and erosion, reduced pest herbivores and a reduction in salinity.
- More research specific to the provision of native vegetation >> biological control of pests >> increased crop productivity would be very beneficial in encouraging cropping based enterprises to adopt riparian works.
- Most of the well quoted studies regarding the benefits of shelterbelts and pasture and crop production are greater than 20 years old. While this may not be a concern it would be useful to have some more recent studies. Some of the literature is not available.

Other benefits

Benefits – other	Interventions	Evidence and reliability
<p>Reduced risk of soil salinisation and acidification >> protect property value and maintain or increase production</p>	<p>Revegetation</p>	<p>This study addressed the economic feasibility of managing native vegetation to reduce the impacts of salinity. A spreadsheet model was developed to show the benefits and costs of various planting configurations and methods over a 30-year time span. The study found that specific native tree planting configurations of block and alley planting in the study area of the Murrumbidgee Region were economically feasible where electric fencing was used. Salinity benefits, measured as reduced land salinisation and reduced salt loads, were a small component of overall benefits. The modelling can be applied to other native vegetation management techniques and in a variety of geographical areas by changing the input data (Hill, 2004).</p> <p>Research in Western Australia (Read et al (2001) indicated that where the groundwater system is local, planting trees can affect watertables within economically viable timeframes. However, where groundwater systems are not local and lag effects between planting and watertable levels are much longer, the economic benefits of native vegetation are only realised in the longer term while costs are incurred in the short term (Hill, 2004)</p> <p>Biophysical modelling studies have indicated that very extensive areas of tree planting are necessary in a catchment to significantly affect the rate of spread of salinised land, reduce the loss of productivity and reduce salt loads in rivers (Heaney et al (2001), Herron et al (2001), Walpole and Lockwood (1999), Hill (1997)). Not all the benefits flow directly to the landholder.</p>
<p>Fencing of riparian zone >> increased groundcover >> increased ground water recharge >> increased availability of groundwater for production</p>	<p>Fencing</p>	<p>A book on riparian management in Alberta states that a healthy riparian zone can increase ground water recharge through processes such as by slowing the movement of water over the soil surface (Fitch et al., 2003)</p>
<p>Gorse weed control >> reduced fire risk</p> <p>Effect modifiers:</p> <ul style="list-style-type: none"> The results indicate that the major variable influencing both fire ignition and fire spread development in gorse is the moisture content of the elevated dead fine fuel layer. (Anderson and Anderson, 2010) 	<p>Gorse weed control</p>	<p>Field experiments were carried out in stands of gorse (<i>Ulex europaeus</i> L.) in New Zealand to determine the conditions under which fires would both ignite and spread. Fires were observed to spread successfully in this elevated fuel layer only, independently of the surface fuels and the near-surface fuels. Elevated dead fuels failed to ignite at a moisture content of greater than 36%, and ignition only resulted in a spreading fire at moisture contents below 19% (Anderson and Anderson, 2010).</p> <p>A study analysed fire behaviour using indicators obtained at different scales. Both the fire-line intensity values and the fire severity values observed can be considered high with respect to those observed in other Mediterranean communities, thus confirming Mediterranean gorse as a high-risk community (De Luis et al., 2004).</p>

<p>Weed control >> reduced production losses</p>	<p>Gorse weed control</p>	<p>The Gorse Control Strategy was developed for the Ballarat Region Gorse Task Force Area (GTFA) in consultation with a wide cross section of the community. It includes a cost benefit analysis. The costs of gorse to GTFA are significant, with the cost of lost production in the area being calculated at \$389 per hectare if gorse takes over the land. An ongoing 'do nothing' strategy will result in approximately \$7 million in tangible and intangible costs over five years. The implementation of the recommended control option will be approximately \$7.2 million over 5 years, but result in a total economic benefit of approximately \$2.1 million over the five year period (Miller et al., 2010).</p>
<p>Gorse control using goats >> cost saving alternative to chemical control and also alternative income stream</p>	<p>Gorse weed control</p>	<p>Goats were superior to sheep in their ability to break down highly lignified diets such as gorse, as demonstrated in this study. Cashmere fibre production from goats grazing on gorse for 7 months of the year was proposed as a cost effective alternative to managing gorse with chemicals (Howe et al., 1988). Controlling gorse with goats is more profitable than using chemical control. The capital input is not lost since the goats can be sold once gorse control has been achieved. Secondly, goat enterprises generate income during the process of gorse control. The amount of income is dependent on the particular goat enterprise. Even if no income was generated from goats, this method would still remain the most attractive alternative (Krause et al., 1984).</p>
<p>Willow control >> decreased water evapotranspiration >> increased water available for irrigation</p> <p>Effect modifiers: (Doody, Tanya M. et al., n.d.) The amount of water taken up by willows from the stream system varies considerably depending on their location.</p>	<p>Willow weed control</p>	<p>Water for Rivers commissioned a two stage project to quantify the net impact on evapotranspiration of removing willow trees from creeks used to transport irrigation water. In stage one of the project, evapotranspiration from the stream bed and banks with and without willows was modelled over a 12 year period (1986 to 1997) using the Penman-Monteith equation. Willow water use was only simulated within broad confidence limits. Rainfall interception, and soil and surface water evaporation were also modelled. The simulated net water saving from willow removal was in the range -5 to +9 ML ha⁻¹ year⁻¹ of willow projected crown area, depending on stomatal behaviour and the proportion of willow crown area shading water compared to dry creek bank (Doody, Tanya M. et al., n.d.).</p>

B. Land Value benefits

Benefits – Asset protection and value	Interventions	Evidence and reliability
<p>Presence of on-farm riparian vegetation >> increased land value</p> <p>Effect modifiers:</p> <ul style="list-style-type: none"> • Property size • Proportion of native vegetation • Land use – commercial or lifestyle • Personal preferences • Soil type – sandy soils have a positive influence whereas clay soils have a negative influence. 	<p>Maintenance of or revegetation of riparian vegetation</p>	<p>Recent studies by Polyakov et al. in central Victoria found that there is an optimal proportion of native vegetation influencing positive property values. The authors suggest that this is about 40 percent, a ratio that increases property value by approximately AU\$7,400 per hectare or 10.5 percent of the 2012 median property price per hectare. The study also suggests that, a ratio of native vegetation that exceeds 80 percent reduces the value of the property to less than the value associated with no native vegetation and that the optimal proportion of native vegetation changes with the size of the lifestyle property. This ranges from 45 percent for a 1-hectare property to 30 percent for a 20-hectare property (Polyakov et al., 2013, 2012).</p> <p>A further study by Polyakov et al. revealed that private benefits of native vegetation are greater per unit area on small and medium-sized properties and smaller on large production-oriented farms. In other words native vegetation has a diminishing marginal benefit as its proportion of a property increases. The optimal proportions of native woody vegetation for a 10 ha, 100 ha, and 1,000 ha property are estimated to be 37%, 29%, and 20%, respectively. The study showed that these proportions would increase property values by 16%, 9%, and 5% in comparison to the values of similar properties without any native vegetation (Polyakov et al., 2014).</p> <p>A GIS based hedonic pricing model was use to assess the value of agricultural lands in Wyoming in the USA, that include wildlife habitat (including vegetation), angling opportunities, and scenic vista compared with lands dominated by agricultural production. It was found that the lands with these multiple values commanded higher prices per acre than the lands dominated by agricultural landscapes (Bastian et al., 2002).</p> <p>A study using sales information for 2480 properties in the north-east Victoria reported on the influence of remnant native vegetation (RNV) on property sale price for two study areas (one in Victoria and one in NSW). The study showed that the existence of RNV at a proportion greater than 50% had a negative influence. On property price, below this threshold however, the area of RNV appears to have little influence on property price (Walpole et al., 1998).</p> <p>Anecdotal evidence from real estate agents suggests that well managed riparian frontage can add up to 10% of the market value of a rural property (Price et al., 2005).</p>

<p>Presence of riparian land (urban and peri-urban) >> increased land value</p> <p>Effect modifiers:</p> <ul style="list-style-type: none"> • Quality of riparian habitat • Water quality – influencing recreational activity types 	<p>Presence of riparian land</p>	<p>A well cited study in south-western Michigan, USA found that ecosystem services are largely capitalized through lakes, rivers, wetlands, forests and conservation lands. Ecosystem services that support direct use values, such as recreational and aesthetic services, are likely to be perceived by land owners and thus realized in land prices. The study found that nearby rivers increase land values by 5.8% per 1000 m closer to a river (Ma and Swinton, 2011). Interestingly the study also concluded that on-site rivers reduce land values by 8.8% per 100 m of river on the site. The authors suggest that although water bodies provide recreational and scenic values their negative effects, such as erosion along waterways, reduction of arable areas or flood risk threatening crop production may outweigh the benefits (Ma and Swinton, 2011).</p> <p>A study conducted in rural Wexford County in Michigan, USA found that proximity to lakes and subdivision open areas positively affected the values of some parcel types, while proximity to forested land, publicly owned land, streams, and a National Scenic River did not have a positive influence (White and Leefers, 2007).</p> <p>A study in Portland, Oregon in the USA found that streams on urban properties are found to increase a property's sale price and that increasing the overall percentage of riparian corridors and upland wildlife habitat has a positive but declining effect on sale price. The study concluded that this effect however depends on the type and quality of resources (Netusil, 2005).</p>
<p>Willingness to pay for riparian land including riparian vegetation</p> <p>Effect modifiers:</p> <ul style="list-style-type: none"> • Quality of riparian habitat • Proportion of native vegetation 	<p>Presence of riparian land</p>	<p>A 2008 study of Victorian Rivers showed that the WTP for improvements in riparian vegetation ranged between \$3 and \$6 for an additional one per cent of the river's length with healthy vegetation on both banks (Bennett et al., 2008). Another study of five NSW rivers in 2001 found that for an increase of one per cent in the length of the river with healthy native vegetation and wetlands survey respondents were willing to pay in the order of one to two dollars (Bennett and Morrison, 2001).</p> <p>A study conducted in central Victoria using a willingness to pay method (WTP) suggested that WTP for remnant native vegetation may increase (but in decreasing margins) up to a point where the proportion of native vegetation may begin to have a negative impact upon agricultural production (Walpole et al., 1999).</p> <p>Results from a study in the George catchment in north-eastern Tasmania show that respondents are, on average, willing to pay between \$2.47 and \$4.46 for a km increase in native riverside vegetation (Kragt et al., 2009).</p>
<p>Proximity to riparian areas and associated recreational opportunities >> increased land value</p> <p>Effect modifiers:</p>	<p>Proximity to riparian land</p>	<p>A study in central Victoria showed that the extent of native vegetation in the surrounding landscape was shown to affect the property price and exhibits a diminishing marginal return. The study results indicate that location characteristics are also important determinants of lifestyle property values. These include greater accessibility of recreational opportunities measured by nearer proximity to lakes, rivers, and parks increases property values.</p>

<ul style="list-style-type: none"> • Distance to recreational amenities • Distance to State parks or reserves – variable effect across studies • Distance to town • Quality of riparian habitat • Water quality – influencing recreational activity types 		<p>The study showed that being located 1 km closer to one of these recreational amenities increases the value of the median lifestyle property by AU\$5,452 per hectare for a river, AU\$1,886 per hectare for a lake, and AU\$3,535 per hectare for a park (Polyakov et al., 2013, 2012).</p> <p>A hedonic property price model applied within the Murray Darling Basin showed that for a property in the study area that is 1 km away from the River Murray, moving half a kilometre closer increases the property price by \$245,000 (holding every other variable constant at the mean). Further to this the study shows that this value is increased by \$27,000 if the house is in an area where there is high river recreational attractiveness and drops by \$14,000 if river recreational attractiveness is low (Tapsuwan et al., 2012).</p>
<p>Riparian restoration >> greater willingness to pay (including increased sales tax)</p>	<p>Riparian revegetation</p>	<p>A study was undertaken to estimate the benefits and costs of riparian restoration projects along the Little Tennessee River. The study showed that local residents had a willingness to pay (WTP) increased county sales taxes for differing amounts of riparian restoration. There was a greater WTP for more riparian restoration along a watercourse (Holmes et al., 2004).</p>

Research gaps

- There is a lack of robust economic analysis of the impact of well managed riparian areas on the real estate value of rural properties focused on primary production.
- While there is a large body of research around the different biological and other methods of controlling gorse, blackberries and willow, there is a research gap regarding the direct benefits to landholders of controlling these weeds. This may be because the economic benefit of weed control is highly dependent on characteristics of the property and its production. This may also be due to the bigger picture – that weed control by one single landowner may be ineffective, and re-infestation is likely to occur if adjoining properties do not also initiate weed control (Ireson et al., 2007).
- More economic studies of the direct landholder financial benefits of streambank erosion control and soil salinity control as a result of riparian revegetation is required.

C. Aesthetic, amenity and landholder wellbeing

Benefits – Enhanced visual and recreational amenity and landholder wellbeing	Interventions	Evidence and reliability
<p>Biodiverse riparian zone >> enhanced visual amenity and wellbeing</p>	<p>Revegetation</p>	<p>Improving the aesthetic value of the riparian zone was one of the top 3 responses given by landholders surveyed (n=218) in response to why they undertook riparian works. Other top reasons were to improve the health of the waterway and to improve overall environmental outcomes across the property (Ede, 2011b).</p> <p>A study of 268 farmers of the mid-western watershed of Michigan, USA revealed that farmers are intrinsically motivated to practice riparian conservation practices by such factors as the attachment to their land and the desire to conserve land for future generations rather than motivations for receiving economic compensation (Ryan et al., 2003)</p> <p>Survey respondents indicated that those benefits of most importance to them of riparian works were non-commercial in nature i.e. Creation of habitat where native birds, Attractive and aesthetic nature of the frontage (Aither, 2014).</p> <p>Increased bird numbers as a result of riparian works such as fencing, off-stream watering and re-vegetation (Jansen and Robertson, 2001; Popotnik and Giuliano, 2000).</p> <p>A set of case studies conducted by Land and Water Australia provided statements from landholders regarding their perceptions of the value of riparian areas including wellbeing benefits to their families (Land and Water Australia, 2006)</p> <p>Eight landholders from Glenelg Hopkins and Corangamite CMA regions were interviewed. Many of the landholders were motivated to carry out works for aesthetic or conservation reasons, including the peace and beauty of having native vegetation and wildlife on the farm with some recreational benefits, such as fishing, boating, relaxing and meditation. Farmers used visual references in their expression of these goals – “it looks better” “Beautification – it’s more pleasing to the eye, it looks like someone cares”. Aesthetic values were seen to enhance these intrinsic values (i.e. values important to landholder but “not necessarily worth anything to the</p>

		farm” and, for four landholders, increase the economic value of the farm (Graymore and Schwarz, 2012).
Healthy and attractive riparian zone >> landholder sense of stewardship and contribution to nature conservation		<p>Anecdotal information suggests that there is a “feel good” factor of being a good environmental citizen for landholders who care for their riparian zones (Auckland Regional Council, 2001).</p> <p>Survey respondents indicated that those benefits of most importance to them of riparian works were non-commercial in nature i.e. Personal pride in land improvement and good management (Aither, 2014).</p> <p>Interviews with 21 landholders in Queensland involved in riverine restoration projects found that a sense of stewardship and improved landscape aesthetics' (an internal factor) was the most commonly reported private benefit (Januchowski-Hartley et al., 2012).</p> <p>Landholders in the neighbouring Wallatin and O’Brien Creek catchments of the central wheat belt of Western Australia planted 1750 ha of woody perennial vegetation in the catchments from the 1920s to 2006, adding 4.6% further cover to the 9.4% cover of uncleared remnant native vegetation. Landholders attribute most plantings to two or more motives with salinity mitigation and nature conservation the largest drivers of revegetation (27% and 22% by area, respectively), but soil erosion and aesthetics are also important (Smith, 2008).</p>
Community based weed control >> Enhanced social capital	Weed control	Weed control undertaken in a manner promoted by the Cooperative Model for Invasive Plants can not only effectively control weeds in a locally appropriate and sensitive way, but can also enhance social capital, cohesion and knowledge. The Victorian Blackberry Taskforce is an example of this model (Furze et al., 2008) .

Research gaps

- No studies were found examining the relationship between a healthy riparian zone and recreational amenity.
- More research is required into the direct recreational benefit to landholders of a health riparian zone, as well as the direct and indirect benefits to landholders of increased health due to reduced pathogens in their water supply.
- Surveys in this area could be more robust and measure changes in landholders’ health as a result of a healthier riparian zone, for example measuring changes in stress and depression levels.

Useful Case Studies

Dairy and Grazing

Reference	Location	Type of production and intervention	Landholder benefit	Contextual variables/other information
Aarons 2009	Victoria, Australia	Dairy, fencing	Pasture production, botanical composition and soil moisture and fertility were measured in riparian and elevated areas on three case study farms Gippsland, Victoria from September 2006 until November 2007. Riparian and flat areas produced significantly more pasture, with on average approximately 25% greater dry matter grown in these areas than hill paddocks for all farms. Based on pasture dry matter data, milk income would have been 0.2% to 1.7% (ie \$2000 - \$8000) greater in the 2006 / 2007 lactation, if riparian areas were not fenced to current widths (an average of 3 to 7 m from the waterway). If farmers fence their riparian areas to 20 metres to improve biodiversity conservation, the impact on income increases to 1.3% to 4.9% or \$9000 to \$12000.	Trends towards improvements in vegetation and trappable small mammal biodiversity were observed in rehabilitated riparian areas on Farm S, although these were not statistically greater four years after revegetation of the site. Bird abundance and diversity have not recovered to that observed before fencing, most likely due to the absence of habitat, food and nesting requirements. In contrast, biological water quality appeared to improve with in-stream macro-invertebrate species meeting or exceeding minimum species requirements, although SIGNAL scores still indicated poor water quality.
Bohnert, n.d.	Oregon, Canada	Grazing, off stream watering	Initial data reported in 1996 suggested that pumping water from a dugout to a trough increased performance of cows, calves, and steers (Figure 1). Briefly, pumping water from a dugout to a trough increased average daily gain by approximately 0.5 pounds. In a later study, cow performance was not affected by water source; however, weight gain of yearlings and calves was increased by approximately 20% with non-pond water. When comparing the clean and dirty pond water, there was about a 5% increase in yearling and calf weight gain with the clean water. The increased performance was attributed to greater water consumption and forage intake because cattle avoided water that was contaminated with as little as one-half of 1% fresh manure by weight. Also, cattle with access to fresh water spent	Before deciding on off stream watering tanks: the percent of the pasture is unused because of poor grazing distribution, what is the value of the additional pasture that would become available to you (increased days grazing for your cow herd) if additional feed resources had to be purchased/leased, is calf and/or cow performance suffering because of poor grazing distribution or water quality; are your cattle spending a significant amount of time in riparian areas and degrading the site; and could water developments, such as developing a spring or well, reduce the amount of time and

			<p>more time grazing and less time resting than cows offered both types of pond water. The researchers noted that, when given the choice, cattle preferred water from a trough 92% of time compared with the time spent drinking from a stream. More importantly, stream bank erosion was reduced by almost 80%, while faecal coliform and streptococci were reduced by 51 and 77%, respectively. Off-stream watering can be effective in improving water quality and maintaining a properly functioning riparian zone by reducing the time cattle spend in or near a stream. Economists and animal scientists from Oregon State University and the University of Idaho used available data and plugged it into a bio-economic model based on an average 300 cow/calf operation that relies on both public and private lands. The result was an increase in annual net return ranging from \$4,500 to \$11,000, depending on the position in the cattle cycle and amount of annual precipitation.</p>	<p>money spent hauling water.</p>
Lardner et al. 2005	Canada	Grazing, fencing	<p>A study was conducted to determine the effects of improvements in water quality on cattle performance. The effect of pasture water quality on weight gain of beef cattle was assessed with 44 Hereford yearling steers over 5 years and 40 Angus cow-calf pairs over 3 years. From 1999 to 2003, cattle were allocated to 1 of 4 treatments, which comprised untreated dugout water pumped to a trough, aerated water pumped to a trough, and coagulated and chlorinated water pumped to a trough, all compared with direct access by livestock to the water source. Data were collected on livestock weight gains, water consumption, faecal parasites, environmental conditions, water chemistry, biological constituents, and forage production and quality.</p>	<p>Daily weight gains tended to be improved slightly by simply pumping water to a trough without treatment. Water aerated and pumped to a trough in early summer tended to produce greater ($P < 0.05$) weight gains in calves than those drinking directly from the dugout. The effect of treatment on improving cattle weight gains appeared to be related to improved water palatability, which increased water and feed consumption. Water chemistry and biological constituents analysed did not identify significant differences among treatments. These results suggest that improving water quality with aeration and pumping to a trough will improve weight gain 9–10% over a 90-day grazing period in most years</p>
Lynch and Donnelly 1980	Australia	Grazing, windbreaks	<p>The effect of windbreaks was studied in an experiment in which sheep were grazed continuously at 15, 30 and 37.5 ha⁻¹ for five years. The paddocks were either square or rectangular in shape with fences of sheet iron or wire. In the square paddocks the</p>	<p>A 5 year trial showed that sheep with access to shelter had a 31% increase in wool production and a 21% increase in live-weight. Shelter also improved plant growth and increased pasture</p>

			<p>sheet iron fences acted as a windbreak providing protection for plants and animals. In the first two years when rainfall was well below average, sheep in sheltered paddocks at 37.5 sheep ha-1 had marginally higher production than sheep in the other treatments, while at 15 sheep ha-1 the productivity of the sheltered sheep was markedly higher. During the remaining three years, there were no large differences between treatments in herbage or animal production at the lowest stocking rate, while at the highest stocking rate sheep in sheltered paddocks had substantially higher production than those in unsheltered treatments. At 30 sheep ha-1 there was also increased plant and animal productivity from sheltered paddocks during the last two years of the experiment. This experiment is one of the first to show the effect of a windbreak on grazed pastures. The results indicate that shelter may have an important place in increasing pasture and animal production in the temperate areas of Australia.</p>	<p>and crop production, by reducing moisture loss from soils and transpiration in crops and pastures; shelter reduced the loss of water from soil in late spring by 10-12mm.</p>
Miller et al., n.d.	Victoria, Australia	Cropping and grazing, gorse control	<p>The Gorse Control Strategy was developed for the Ballarat Region Gorse Task Force Area (GTFA) in consultation with a wide cross section of the community. It includes a cost benefit analysis. The costs of gorse to GTFA are significant, with the cost of lost production in the area being calculated at \$389 per hectare if gorse takes over the land. An ongoing 'do nothing' strategy will result in approximately \$7 million in tangible and intangible costs over five years. The implementation of the recommended control option will be approximately \$7.2 million over 5 years, but result in a total economic benefit of approximately \$2.1 million over the five year period.</p>	
Platts and Wagstaff 1984	USA rangelands	Cattle (beef), fencing	<p>To the fencing costs, managers must add the costs of lost grazing, and this could equal one animal-unit month per acre in the highly productive riparian zone. A 100- foot-wide corridor would contain about 12 acres per mile, or the equivalent of 12 animal-unit months. Fencing all riparian habitat rather than just a corridor along the banks would become very expensive in terms of lost grazing and, in many situations, could prove to be</p>	

			economically unsound. Other alternatives to fencing need to be found. Few known grazing strategies, other than rest, have been demonstrated to improve or maintain riparian and fisheries habitat. Therefore, more emphasis needs to be placed on analyzing the positive benefits in promising grazing strategies and the effects that different classes of livestock have on the various habitat types if alternatives are going to be found for fencing.	
Porath et al., 2002	Oregon Canada	Cattle, off stream watering	The objective of this study was to test the combined effect of offstream water and trace mineral salt on cattle distribution in a riparian meadow and its adjacent uplands. From July 15 to August 26, 1996 and 1997, three treatments were each randomly assigned to one pasture in each of three blocks. Sixty cow/calf pairs were then randomly allotted to the grazed pastures. The treatments included 1) stream access and access to offstream water and trace-mineral salt (offstream), 2) stream access and no access to offstream water or trace-mineral salt (no-offstream), and 3) un-grazed control. The response of cattle was measured through visual observations of cattle distribution, grazing activity and travel distance, cow/calf performance, and faecal deposit distribution.	Grazing activity, faecal deposit distribution, and travel distance of cattle were not affected by the presence of offstream water and trace-mineral salt. Cows and calves with offstream water and trace-mineral salt gained 11.5 kg and 0.14 kg/d more, respectively, than no-offstream cows and calves averaged across years ($P < 0.05$). Overall, cattle distribution patterns and cow/calf performance were influenced by the presence of offstream water and trace-mineral salt. Changes in distribution were most pronounced early in the grazing season.
Schutz, 2012	New Zealand	Cattle, off stream watering	A comprehensive New Zealand report prepared for MAF Sustainable Farming Fund (MAF SFF Project 03/001 2004) investigated the impact of water quality on livestock productivity and it was concluded that issues of microbial contamination and contamination with high concentrations of particular minerals or other contaminants of water were the primary concern from an animal health perspective. However, the potential positive effects of providing a clean water supply on animal productivity have not been extensively studied.	Many of the factors that influence the survival and proliferation of bacteria in natural aquatic ecosystems have parallels in cattle water troughs. Factors, such as the nutrition content of the water, exposure to sunlight, cleaning management, trough design, and air temperature are all likely to influence the quality of the water. Further research regarding cattle utilization of riparian areas, the effects of providing off-stream water sources, and the effects of clean, palatable water in New Zealand conditions is warranted.
Sillar Associates,	Mary River	Cattle - beef and	A long list of potential benefits (both 'on-farm' and 'externalities'	3) Cattle death by misadventure. A farmer

1998	catchment Qld	dairy, horticulture, sugar	arising from different types of riparian works funded by under the RRGs has been generated. These potential benefits are described, their significance evaluated and, where possible, quantified. The evaluation is based on interviews with, and questionnaire response from, riparian landowners, consultation with technical experts in various fields, literature search and our own experience in other catchments. These include: 1) nutrient recycling. To ascribe economic benefit, it is assumed that 5% of animal manure and urine which was previously deposited directly in the stream is, post stream-fencing, deposited on rye grass pasture. At farm gate fertilizer substitution prices for nitrogen, potassium and phosphorus the long term annual value of nutrient recycling via animal waste amounts to \$616 for a 100 cow herd. 2) Better forage utilisation. Better feed management, and production there from, can occur on both dairy and beef farms because a more efficient rotational grazing system can be implemented as a results of having more stock watering points available. Two costed case studies show Annual Incremental Gross Margins of \$50,140 and \$69,200 for a dairy farmer and beef producer respectively	survey shows this factor to account for zero to 0.5% of overall herd mortality in dairy herds and to be negligible in beef herds. This loss is avoided by fencing-off the watercourse. This loss is valued at the farm gate replacement cost of a dry dairy cow with district average production potential, estimated to be \$800. For a herd comprising 100 head, the average loss avoided would therefore be \$400/year 4) Reduced mustering time. The amount of time saved is quite variable but is most likely to be a factor on dairy farms because the cow herd is mustered twice a day. Time saved has been estimated at between zero and 20 minutes per day on dairy farms depending upon such things as the completeness of the riparian zone fencing and whether the cattle are still given access to the riparian zone after fencing. Where a time saving was expressed by a farmer, the annual incremental benefit is priced on the basis of farm labour at \$12.50 per hour.
Vere et al., 1984	NSW Australia	Sheep grazing, blackberry control	Blackberry was estimated to cause aggregate wool production losses valued at \$4.251 million in central western NSW between 1982 and 1983. Blackberry significantly reduced the sheep carrying potential of both improved and natural pastures. A further \$0.486 million was spent by councils and landholders in the area during that time on chemical control. The overall economic cost of blackberry to central western NSW during 1982-1983 was estimated at \$4.737 million.	Blackberry mainly occurs in non-crop areas, so livestock enterprises are most affected. There are 3 types of economic cost caused by blackberry - The most important is loss of potential livestock production (which can be up to 50% with dense blackberry cover). Second, effective chemical control and re-sowing with improved pasture is expensive. Third expense and effort involved in keeping pastures blackberry free.
Walpole et al., 1999	Victoria and NSW	Grazing and cropping, revegetation	This study measured the on-farm benefits and costs associated with remnant native vegetation (RNV) in the two study areas, the northeast Victorian catchment and the Murray catchment of	A proposed conservation management scenario that included fencing of the RNV, and limitations on grazing and firewood and post

			<p>NSW. Data were collected using landholder surveys. The most important economic benefits from RNV under current management regimes in the Victorian study area were productivity effects associated with prevention of land degradation, firewood production, and for the NSW study area, stock and crop shelter. The most significant cost in both study areas was weed management.</p>	<p>removal would negatively affect most of the survey participants. The differences between the net present value (NPV) of the current management regime maintained over a 40 year period, and the NPV of the proposed scenario were large and negative. For Victorian participants, the marginal effect of the conservation proposal was - \$2 million, and for NSW participants -\$15 million. In both study areas, the incremental economic costs of the scenario outweighed the incremental economic benefits for at least 89% of participants. This study confirmed that one of the major barriers to protecting RNV is the economic costs associated with conservation management</p>
<p>Zeckoski et al., 2007</p>	<p>Virginia USA</p>	<p>Cattle, off stream watering and fencing</p>	<p>The study interviewed twenty dairy and cattle producers while conducting this investigation. The economic benefits realized by the interviewed producers fall into three general categories: increased productivity, decreased incidence of disease, and improved management. Most of the producers who fenced their livestock from the stream and provided an alternate source of water experienced increases in beef cattle weight gain and dairy cattle milk production and quality. One producer reported increased weight gains of 5-10% over a 9-10 month growth period for the beef he raises. Most producers cited the better grass available from their rotational grazing systems and the cleaner water available from alternative water sources as the reasons for the increased weight gains and better milk production. Neither of these is a direct result of streamside fencing (for instance, several farmers who put in streamside fencing but did not implement rotational grazing and still allowed access to the stream as the sole water source via a hardened crossing did not see these improvements), but both internal fencing for rotational grazing and wells and troughs for alternative waterers are included in the typical stream exclusion cost-share package in Virginia (SL-6) (Virginia Department of</p>	<p>). In addition to the weight gains on a per-cattle basis, most farmers who implemented rotational grazing saw increased beef production on a weight-per-acre basis. Many producers commented on general herd health improvements that resulted from implementing their stream exclusion systems. Most producers who provided an alternative source of water for their livestock saw a decrease in incidence of disease. Common diseases that declined after stream exclusion included footrot, pink eye, scours, and mastitis. Producers noted that the reason for the decline in scours and mastitis in particular was the fact that the cows' udders were no longer immersed in dirty water as they had been when the cows were allowed to stand in the stream. Additionally, one producer noted that his cows no longer drown in the stream as a result of getting caught in tree roots on the stream bank, and another reported a decrease in</p>

			Conservation and Recreation, 2005	injuries once his cows no longer bunched close together to fit in the stream.
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Cropping

Reference	Location	Type of production and intervention	Landholder benefit	Contextual variables/other information
Nakao and Sohngen, 2000	USA	Cropping, revegetation and erosion control	This paper estimates the cost of reducing soil erosion with Riparian buffers. The paper explores how the cost of a ton of soil erosion reduction varies across site characteristics in a watershed, including field shape and size, tillage method, and soil type. The methods are used to show how watershed managers may target funds to high and low cost sites and regions within a watershed. The results suggest that the costs of reducing soil erosion with Riparian buffers are lower when buffers are applied to conventionally tilled fields, and that the costs of buffers are comparable to the costs of no-till. The relationship between buffer size, drainage area size, and effectiveness is explored. The paper shows how Riparian buffers with low effectiveness can be cheaper to install than Riparian buffers with high effectiveness.	The paper explores how the cost of a ton of soil erosion reduction varies across site characteristics in a watershed, including field shape and size, tillage method, and soil type.
Rein, 2010	California, USA	Strawberry growers, revegetation and buffer strips	It was found that the costs to strawberry growers of installation of Vegetative Buffer Strips are outweighed by the benefits of minimizing erosion-related costs, resulting in a net benefit to farmers of \$1,488 in the first year and \$6,171 over five years, for a 36-acre system. Costs were direct agricultural benefit of land converted to vegetative buffer strip, seeds, land preparation and planting, first year maintenance costs. Benefits were elimination of herbicide use at buffer strip border, farm damage due to erosion, road maintenance costs (landholders are responsible for erosion damage to county roads). This was calculated by based on average farm size in the watershed and assumptions regarding Vegetative Buffer Strip efficiency the ratio for the system in this	In addition to the costs and benefits outlined above, there are a number of additional potential benefits to farmers from vegetative buffer strips that either are difficult to quantify or for which there is insufficient data, including beneficial insect habitat, increased groundwater recharge (which decreases long-term groundwater extraction costs), and soil replacement.

			study consists of 1 acre of VBS-planted land for every 35 acres of strawberry production, or a 36-acre system. In the first part of the study, costs were divided either by watershed acreage of total land in production (10,300 acres) or by acreage in strawberry crops (3,600 acres).	
Ward et al., 2003	Queensland Australia	Cropping (Macadamia nuts), weed control	The cost-effectiveness of habitat manipulation as a management strategy for the control of rodent pests in Australian macadamia (<i>Macadamia integrifolia</i>) orchards was investigated in a 3-yr study that combines a pest management strategy with a conservation outcome. The manipulation involved the total removal of exotic weeds from an adjacent non-crop riparian habitat, which harboured a high density of the native rodent, <i>Uromys caudimaculatus</i> , and the planting of species common to an endangered rainforest ecosystem. Over a 3-yr period, orchard trees adjacent to the restored habitat received 50% less rodent damage than trees adjacent to non-manipulated habitats.	A cost-benefit analysis (based on both contractor and farm rates) of the damage reduction obtained after the initial manipulation indicated a break-even point (based on farm rates and a nut in shell price of \$2.80/kg) of 3.4 yr. After break-even, this represents an economic benefit to growers that will result in an additional return of approximately \$4500 per annum per km of orchard frontage.
Williams et al., 2004	Kansas, USA	Cropping, streambank stabilisation projects	13 severely eroded sites along the river were the subject of restoration works, including revegetation (38 m. wide buffer zone) and bank stabilisation (re-shaping stream banks, installing weirs and rock veins). Over a 15 year period, economic analysis shows that each project has a positive net present value to the landowner. Annualized net present values (ANPV) over the 15-year life of the projects range from \$126 to \$1,760 with an average of \$781. Gains are also realized from the value of hectares not lost to erosion, income from being able to crop the preserved hectares not in the stabilization project, and payments received for the hectares enrolled in Continuous Conservation Reserve Program (CRP) as part of the project. The net present value (NPV) increases in proportion to the annual erosion rate relative to the number of hectares required in the stabilization project.	Cost share payments are important for the landowner to benefit from the projects. Only two of the projects studied will have a positive net present value without cost share payments specifically targeted for stream bank stabilization. This is because construction costs (revegetation and bank stabilisation) averaged \$16,143 per site, and cost share programs paid on average 90% of these construction costs. Cost share programs are important.

Other

Reference	Location	Type of production and intervention	Landholder benefit	Contextual variables/other information
Aither, 2015	Victoria, Australia	Costs and benefits of managing Crown frontages under licence	This report investigates the economic and financial costs and benefits to landholders, the Victorian Government, and the community of managing Crown frontages under licence. The total average annual expenditure on the capital costs of riparian works on riparian management licenses averages \$3,000 per licence on 'average' frontages. The average government contribution to this cost is 72%, with the remaining cost contributed by landholders (28%). The largest expenditure is for fencing, followed by off-stream watering and revegetation. The capital costs for riparian works are most sensitive to the dimensions of the frontage, although some regional differences in unit costs do occur.	The overall findings of the financial analysis of costs and benefits show that: For unlicensed frontages, there is a substantial cost to landholders where the landholder is assumed to fence the frontage, install off-stream watering and obtain a take-and-use licence to access water. For grazing licenses there is minimal net financial impact for both government and landholders. Landholder costs for pest plant and animal approximate the benefits provided from direct grazing. For riparian management licence's there is net expense for both government and landholders that is approximately equal in magnitude.
Dodd et al., 2008	New Zealand	Grazing, revegetation and fencing	The third phase of a multi-stakeholder, integrated catchment management project at the Whatawhata Research Centre is described. Land use and management changes were implemented to improve economic and environmental performance of the Mangaotama case study catchment farm. The major changes included: afforestation of 160 of the 296 ha catchment farm with pine and native trees, riparian management of the entire 20 km of stream network via fencing and/or forestry, restoration of 5 ha of existing native forest, and intensification of the remaining pastoral component to a high fecundity ewe flock and bull beef finishing. Marked improvements were observed in the key environmental and economic performance indicators. In particular, declines in sediment (76%) and phosphorus (62%) loads and faecal coliform (43%) levels were observed, native forest fragments showed early signs of recovery in terms of sapling numbers and vegetative cover, and the pastoral enterprise recorded increased per hectare production of lamb (87%) and beef (170%). There were implementation challenges	In terms of long term changes, The feasibility of this plan depended on significant capital investment in land use and enterprise change, and the full outcomes were likely to take up to 30 years to manifest themselves in the key performance indicators.

			with the better matching of land use to land capability, but this study demonstrated that significant progress can be made in the short-term.	
Ede, 2011	Victoria, Australia	Dairy and grazing, fencing	The reasons most frequently cited by survey respondents as to why they did the riparian works were (1) to improve the health of the waterway (2) to improve overall environmental outcomes across the property (3) to improve the aesthetic value of the riparian zone. Other reasons were enhancing enjoyment of the riparian zone, improving the value of the property, stock management and shelter for stock. Responses varied throughout the different CMA's (with landholders from some CMA's valuing aesthetic reasons more than others).	76% of respondents indicated that there had been no loss of productivity across the property as a result of the riparian works. Common species of woody weeds included blackberry, gorse, sweet briar and willows; Weed management formed part of the riparian works activities at 54% of sites as well as being undertaken at sites both prior to and after works; Weed management after works was the most frequently mentioned issue for survey respondents.
Polyakov et al., 2012	Victoria, Australia	Revegetation, Property prices	This paper presents a hedonic pricing model that quantifies the value of the remnant native vegetation captured by owners of rural lifestyle properties in rural Victoria, Australia. Remnant native vegetation has a positive but diminishing marginal implicit price. The value of lifestyle properties is maximized when their proportion of area occupied by native vegetation is about 40%. Most lifestyle landowners would receive benefits from increasing the area of native vegetation on their land. Findings from this study will be used to support decisions about ecological restoration on private lands in fragmented agriculture-dominated landscapes.	
Wilson et al., 2003	Goulburn Broken catchment	Mixed, Landholder perceptions of benefits	A large proportion of landholders identified environmental rather than economic reasons for adopting these land management practices. For example, improving stock management was a less important reason for fencing than increasing biodiversity. There is an even distribution across both economic and environmental reasons amongst landholders who derive the bulk of their income from on-farm enterprises and those who do not. 'Other' reasons cited for undertaking fencing included salinity management and vegetation connectivity, as well as issues unrelated to riparian management, such as	

			preventing young children from accessing creeks. Landholders that had undertaken riparian improvements on their properties, such as fencing, were also asked whether they believed such practices were cost effective. Results from these questions showed that many landholders believed management options aimed at improving riparian condition could produce economic gains.	
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Appendix 1. Evidence review context

There are multiple ‘pathways’ for achieving increased landholder adoption using different mechanisms such as voluntary mechanisms, enforcement and regulation, market based instruments and education and training. These are shown in the theory of change model in Figure 1 below. The provision of evidence for the benefits of riparian works (this project) falls under the education and training pathway. Realistically, the practical implementation to increase adoption of riparian works by landholders would involve one or more of these pathways.

It is recognised that landholders having knowledge of the personal benefits of undertaking riparian works alone will not necessarily lead to increased adoption levels if other barriers continue to remain. Understanding what some of these other barriers are, along with motivators to adoption has been recognised as a further, higher level question of relevance to CMA’s and policy makers, in which the question regarding the benefits of riparian works is nested. This is demonstrated in the model in Figure 1, below. The green boxes represent the ‘pathway’ that is of interest to this summary of evidence of evidence and that is ‘what are the benefits of riparian works and how can this evidence be used to increase the adoption of riparian works by landholders’. The heavy blue lines represent the proposed theory of change in using the evidence to increase adoption by landholders. As can be seen, there are uncertainties that exist within this pathway but this summary of evidence does not intend to assess these uncertainties involved with the transfer of information from DELWP to the organisations (i.e. Victorian Farmers Federation or Catchment Management Authorities) who will provide the information to landholders.

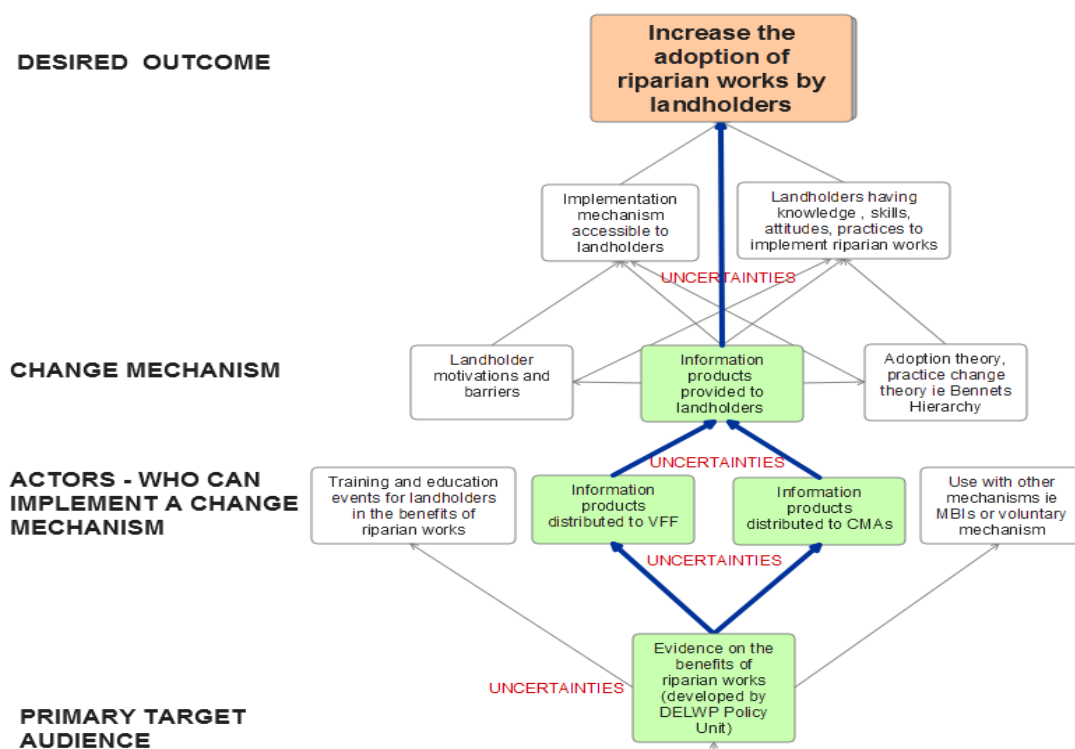


Figure 1. Theory of change model for using evidence of the benefits of riparian works to increase landholder adoption of riparian works

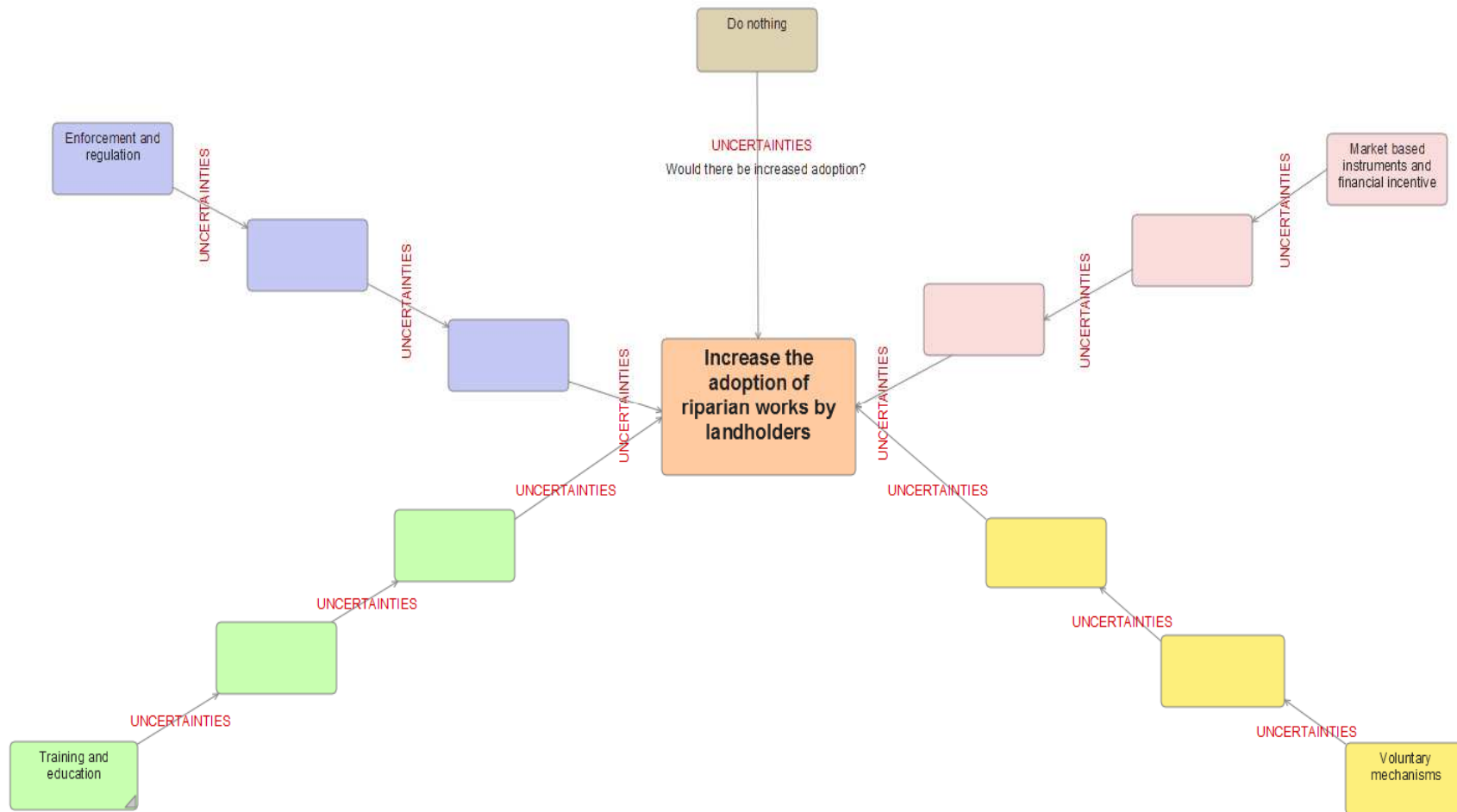


Figure 2. Theory of change model highlighting pathways to increased landholder adoption of riparian works and their uncertainties

Appendix 2 Review limitations and evidence relevance and quality assessment

Review limitations

There are a number of limitations that are important to make transparent in considering the summary of evidence:

- The scope and resources available to conduct the search for evidence in this pilot study was not comparable to those normally available in a full systematic style review which would commonly take approximately 12 months to conduct **for each relationship**. The project looked at over forty different relationships.
- The project was concerned with the benefits to landholders on the property where riparian works are undertaken as opposed to catchment scale, downstream or regional scale benefits. Many benefits of riparian works occur at scales larger than the property scale, and there is a large body of high quality evidence available regarding these broader benefits. This body of evidence has been largely excluded because it was not relevant to the project question.
- Cause and effect relationships that were part of causal chains but not **directly** relevant to on-farm production were not specifically searched. For example the relationship between riparian buffers and sediment or nutrient inputs to waterways was not searched.
- In searching for the evidence to answer this question, broad search strings were derived around the three different riparian works interventions (off stream water, revegetation and weed control). This search found minimal or no evidence to support some of the relationships in the conceptual models. One reason for this could be that the search was not specific enough to find evidence for that particular relationship.

Quality assessment

One of the key points of difference between a traditionally narrative literature review and undertaking a systematic style review is the reduction of potential bias in the conclusions that are drawn from the review. This is achieved through:

1. The development of an *a priori* search protocol documenting the search terms and phrases, search sources, the inclusion and exclusion criteria and any conflicts of interest
2. Transparent documentation of the assessment of relevance of information returned from the search process
3. An assessment of the quality of evidence items
4. The transparent documentation of the extraction the relevant evidence from studies using a Data Extraction spreadsheet
5. A transparent process of evidence synthesis

All of these processes have been undertaken in this summary of evidence and all associated documentation will be provided to DELWP. The assessment of the quality of evidence items found during the search is important to ensure that the conclusions drawn by the final synthesised review are credible, transparent and reliable. One of the benefits of undertaking an evidence based approach is to be able to rigorously and critically appraise commonly held beliefs or opinions. In the case of this summary of evidence there is abundance of literature claiming the benefits to

landholders of undertaking riparian works but little of it appears to be based on transparent, repeatable and rigorous methodology.

All items of evidence that have been assessed as being relevant to the project topic have been assessed for quality in consideration of the following:

- The study design used
- Transparency of the process used to draw the conclusions of the study
- Any apparent conflicts of interest

Most commonly evidence quality was rated as poor due to the lack of referenced statements or any form of independent agreement to substantiate statements of claim. Many “Fact Sheet” style documents were typical of this.

There is a large body of information in Government and NRM body fact sheets and similar information products that is topically relevant to the summary of evidence question, but was excluded because of quality assessment issues. These publications had either no study design, consisted of either anecdotal evidence or case study stories of individual landholder’s opinions.

This left a smaller than expected number of robust studies and surveys that directly considered landholder benefits of riparian works on a property scale. Amongst this body of evidence were numerous surveys assessing the attitudes of landholders to the value of riparian works (Armstrong and Stedman, 2012; Curtis and Robertson, 2003; Fielding et al., 2005; Graymore and Schwartz, 2012; Januchowski-Hartley et al., 2012; Klapproth and Johnson, 2009; Land and Water Australia, 2006; Lankester et al., 2009; Thomson and Pepperdine, 2003). One such study involved a survey of landholders that had undertaken riparian works in Victoria, and they were asked whether they believed these practices were cost effective. The interview responses showed that many landholders believed management options aimed at improving riparian condition could produce economic gains (Wilson et al., 2003).

These surveys suggest that landholders often perceive numerous productive and non-productive benefits from riparian works. While an understanding of these perceptions is useful, in many circumstances it was often difficult to find high quality scientific or economic studies that could support these perceptions. There is an evidence gap here and many of the relationships in the conceptual models included in this summary of evidence would benefit from further specific research.

This summary of evidence has found that for many of the purported landholder benefits of riparian works, there is no large, consistent, high quality body of evidence in support of claims. There are however some areas of more reliable evidence to support conclusions such as the benefits of shelter belts to stock production, the benefits of stock not standing in water and the benefits of the provision of freshwater to increase stock production.

The reason why some evidence rated as poor quality has been retained in the summary of evidence is because it is the only evidence that exists for some cause and effect relationships that the authors consider are important to include in the summary of evidence despite their being little or poor quality evidence.

Relevance

The review found a number of economic studies considering the financial benefits to landholders of utilising riparian land for forestry (Barbieri and Valdivia, 2010; Stewart et al., 2011) and surveys

regarding landholders reasons for participating or not participating in government riparian works programs, and their experiences in these programs (Curtis et al., 2010; Hafner and Brittingham, 1993; Parminter, T.G. et al., 1998). Most of these studies were also excluded, either because they did not directly answer the project question or, in the case of the agro-forestry literature, it was not a benefit which we were asked to explore in this summary of evidence.

Appendix 3: Search Protocol

OBJECTIVE OF THE REVIEW

This review will answer the question “What are the benefits to landholders of adopting riparian works?” The end user of the report is landholders, production landholders in particular – with information from the review potentially being used by extension officers and outlined in fact sheets.

The primary audience of the review is DELWP policy makers and CMA staff. Other stakeholders or organisations who can use the information to implement change are other government agencies, the VFF, Dairy Australia, Agricultural Representative groups, Industry groups, Landcare, Greening Australia and Trust for Nature.

Benefits

This review will focus on the private benefits to production-oriented landholders. Some of the assumed benefits to landholders that we will investigate in this review are benefits to:

- Production
- Ecosystem services
- Property prices
- Recreation opportunities
- Amenity or aesthetic quality
- Biodiversity
- Health and well-being
- Social capital

The review will not be limited to these benefits – if there are bodies of evidence that highlight other benefits to landholders these will also be discussed in the review.

Landholders

The review will primarily focus on the benefits to production landholders, as these landholders represent the most relevant group in order to increase uptake, given the large amount of land under their management.

Riparian works

The riparian works to be investigated in this review were limited to:

- Re-vegetation
- Fencing off riparian land
- Installing off-stream water supplies
- Weed and pest animal control*

The review identified which ‘riparian works’ intervention lead to which benefits.

*Given that finding evidence to support the benefits of controlling all Victorian pests and weeds to all types of producers would be beyond the scope of this pilot review, we restricted the search to focus primarily on examples of woody weed control, particularly willow, gorse and blackberry. While not being topics of a specific search, any evidence found regarding noxious ground weeds and rabbit pest control was also included.

METHODS

The search method aims to capture an unbiased representative sample of the literature as comprehensively as the available resources of the study will enable. Published and unpublished literature was used. Search sources were broad including web based grey literature, universities, and government and non-government organisations.

The approach used the “best available evidence” for each relationship of interest. This means that the quality of evidence varies between relationships. For some relationships we were able to draw on good quality experimental design papers (for example the influence of increased accessibility of high quality water on increased water and forage intake and increased weight gain). In other cases the best available evidence was from non-peer reviewed or non-experimental design reports (for example the influence of pathogens on stock health/performance). In other cases the best available evidence has been indirect. For example the evidence found on the influence of riparian vegetation on property values related to vegetation that was not specific (or not specified) to the riparian zone.

Where possible, only primary source literature was used and not secondary source items such as Annual reports, Summary Reports, existing synthesis or reviews. Popular press or media sources was not used.

References provided in studies assessed were also used to search for further relevant studies.

Search strategy for initial search

Databases

The search aims to include the following databases:

1. *Science Direct*
2. *Wiley Online*
3. *Web of Science*
4. *TROVE*
5. *CSIRO Publishing*
6. *AGRICOLA (agricultural databases)*
7. [ANR Index Archive \(Agriculture and Natural Resources Index Archive\)](#)
8. [ANR Research \(Agriculture and Natural Resources Research\)](#)

Web sites

An internet search will be performed using the following web sites:

1. www.google.com
2. www.googlescholar.com

The first 150 (in some cases 100) hits from each search were assessed for relevance. If there are sufficient numbers of relevant search return appearing after the first 150 then further searches were conducted until there were less than 2 returns per 50 items.

ARI and DELWP unpublished reports

Any relevant, unpublished reports that are in the possession of Arthur Rylah Institute and DELWP were sourced and included.

Search terms

The search phrases used were derived from the following search terms from the key elements defining the question subject, intervention and outcomes elements. Search phrases were constructed using Boolean operators.

Elements:

Landholders

Landholder, landowner, farmer, land manager, rancher, grazier, private land, private property, primary producer

Riparian

Riparian, riparian buffer, conservation buffers, riparian zones, works, green belts, watershed restoration, streamside, river frontage, stream frontage, streamside zone, riverbank

Riparian Works Interventions

Off-stream watering, off-stream stock watering, off-site water, , water trough, remote watering, farm dams, stock ponds, farm ponds, farm tanks, stock tanks

Revegetation, tree planting, windbreaks, replanting

Fencing off, fencing, streamside livestock exclusion, riparian livestock exclusion

Weed control, pest animal control, pest plant control, noxious weed management, weed management, pest management, willow management, willow control,

Benefits

Motivation, advantage, benefit, productivity

Biodiversity, erosion, bank stability, wind belt, pollination, flood, salinity, shade, stock health, water, stock management, livestock health, livestock management, ecosystem services, property values, health and well-being, social capital, increased amenity, recreational opportunities.

The following search phrases will be used for initial searches with more specific search phrases being developed during the search process. Search phrases have been developed around the four specific riparian work interventions. A search results statistics table was used to record all search phrases, sources and results.

1. ("off-stream water*" OR "off-site water*" OR "streamside livestock exclusion" OR "water trough" OR "remote water*") AND (riparian OR "conservation buffer*" OR "green belt*" OR "watershed restoration" OR "river frontage" OR "streamside zone*")
2. fenc* AND (riparian OR "conservation buffer*" OR "green belt*" OR "watershed restoration" OR "river frontage" OR "streamside zone*")
3. (control OR management) AND (weed OR pest) AND (riparian OR "conservation buffer*" OR "watershed restoration" OR "river frontage" OR "streamside zone*")
4. (revegetation OR "tree planting") AND (farm OR "private land") AND (production OR economic OR financial)
5. (revegetation OR "tree planting") AND (farm OR "private land") AND (social OR mental OR psychological OR "well being")

Further detailed searches

Several subsequent, more detailed searches were conducted for the following relationships:

1. Stock standing in streams >> increased risk of disease
2. Improved water quality >> stock weight gain / milk production
3. Existence of native riparian vegetation >> Increased property value

Study Inclusion criteria

It is necessary to apply study inclusion criteria in order to ensure that only the most relevant items of evidence are used hence increasing the efficiency of the search process. The inclusion criteria used was related to the key syntax elements of the primary and secondary questions. These elements are the subject, types of interventions, types of comparator and types of outcomes.

Search returns were initially screened on title for relevance and then screened on abstract after viewing the item. Finally articles were screened based on reading the full text.

All relevant search returns are stored in an electronic bibliographic management library – Zotero (<http://www.zotero.org/>).

Inclusion criteria:

- ✓ Rural location
- ✓ Riparian land along rivers, wetlands and estuaries
- ✓ Evidence of the benefits of native and non-native vegetation to landholders (not only restricted to riparian vegetation for the re-vegetation and weed and pest control riparian works)
- ✓ Evidence of the impacts of water quality on production
- ✓ Broader societal benefits of riparian works (where there is a corresponding private benefit such as building social capital)

Exclusion criteria:

- ✗ The disadvantages of riparian works to landholders unless:
 - They are disadvantages that CMA's are not aware of. Disadvantages that CMA's are aware of are the initial costs involved, that revegetated and fenced riparian land is perceived as a fire risk, is seen as a long term weed and fence management issue with resulting costs, causes loss of access to water and takes some land out of production)
 - They are disadvantages in direct opposition to the notional benefits
- ✗ Urban or peri-urban location
- ✗ Benefits to the broader society

Types of article: Only articles published in English will be used. No date restrictions will apply to the year of publication.

Both quantitative and qualitative literature will be used.

Types of study: Studies will be included that compare the effect of the exposure and intervention on the outcomes. This will include positive or negative outcomes.

Study types will not be constrained by experimental design. Qualitative and quantitative data will be used

Data extraction

Data extraction spreadsheets were developed for each search. These spreadsheets contain the key relevant text extracted from each evidence item referenced in the evidence summary report.

Meta data for all evidence items has been stored in an electronic evidence library that has been developed using the free software Zotero. This library has been made accessible to several DELWP staff members. Access can be provided to any interested DELWP or CMA staff members.

Search strategy for additional searches

Stock disease

This search strategy was undertaken to locate evidence items for the relationship between fencing and off stream watering preventing stock from standing in water, and the reduction in water borne disease that impacts upon productivity and stock health. Government fact sheets mentioned that keeping stock out of water can lead to a reduction in mastitis, cryptosporidiosis, dermatophilosis and foot-rot, therefore these diseases were searched for specifically.

Databases

The search included the following databases:

1. *Science Direct*
2. *Wiley Online*
3. *Google Scholar*

The first 150 (in some cases 100) hits from each search were assessed for relevance. If there are sufficient numbers of relevant search return appearing after the first 150 then further searches were conducted until there are less than 2 returns per 50 items.

If there are literature reviews relevant to the topic area, relevant citations were searched for and included in the evidence summary.

Inclusion and exclusion criteria

Inclusion:

Diseases mastitis, cryptosporidiosis, dermatophilosis and foot-rot.
Cattle, dairy cows, sheep and goats

Exclusion:

Evidence items that were not a scientific study
Studies regarding diseases of animals other than cattle, dairy cows and sheep

Search terms

General search terms

1. (cattle OR dairy OR sheep OR stock) AND "waterborne disease"
2. (cattle OR dairy OR sheep OR stock) AND water AND (mastitis OR cryptosporidiosis OR dermatophilosis OR "foot rot")
3. (stream OR river) AND impact AND disease AROUND(3) (cattle OR dairy OR sheep OR stock)

Mastitis – specific search

4. Riparian AND mastitis
5. (dairy OR cow) AND "standing in water" AND mastitis
6. Mastitis AND "T pyogenes" AND "Hydrotaea irritans"
7. "environmental mastitis" AND (water OR stream OR river)
8. (dairy or cow) AND mastitis AND (river OR stream OR water)

Cryptosporidiosis – specific search

9. Cryptosporidiosis AND (stock OR cattle OR dairy OR sheep) AND (water OR stream or river)
10. Cryptosporidiosis AND (stock OR cattle OR dairy OR sheep) AND (prevention OR control) AND (water OR stream or river)
11. Cryptosporidiosis AND calves AND (prevention OR control) AND (water OR stream or river)
12. riparian AND Cryptosporidium

Dermatophilosis – specific search

13. (cattle OR dairy OR sheep OR stock) AND dermatophilosis AND (river OR stream OR water)
14. Sheep AND “standing in water” AND dermatophilosis

Foot rot – specific search

15. (cattle OR dairy OR sheep) AND "foot rot" AND (river OR stream OR water)
16. Sheep AND “standing in water” AND “foot rot”

Water quality and livestock production

This search strategy was undertaken to locate evidence items for the relationship between improved water quality due to fencing and off stream watering, and any increase in stock production (such as weight gain or increased milk production). It aimed to answer the question “*What influence does drinking water quality have on stock health and production?*”

Two areas of search were conducted: general search including inorganic compounds and organic compounds including pathogens, bacteria and algae.

Subject: stock (cattle and sheep)

Intervention: consuming good water quality

Comparator: not consuming good water quality – inorganic and organic compounds including bacteria, pathogens and algae

Outcome: stock condition, weight gain, health, milk production, mortality

Databases

The search included the following databases:

1. AGRIS (<http://agris.fao.org/agris-search/index.do>)
2. CSIRO Publishing
3. Google Scholar

Inclusion and exclusion criteria

Inclusion: cattle, sheep

Exclusion: Water Buffalo, lama, goats, alpacas, deer, undeveloped countries (Africa, India, South America), Non-English written studies, groundwater

Search terms and results

Unless otherwise stated, a title and abstract search was conducted in the following databases or search engines.

Search string	Science Direct	JSTOR	TROVE	Wiley	Google Scholar
"water quality" AND ("cattle performance" OR "sheep performance") OR ("cattle health" OR "sheep health")	2/33	2/27 (3)	2/8 (1)		33/723 (first 150)
"water quality" AND sheep	0/26				
"water quality" AND cattle OR sheep OR livestock				1/196 (Abstract)	
(pathogen* OR bacteria OR microbial*) AND "water quality" AND ("dairy production" OR "milk production")					4/4,530 (first 100)
(pathogen OR bacteria OR microbial) AND "water quality" AND sheep OR cattle					3/36,400 (first 100)

Property value

This search strategy was undertaken to locate evidence items for the relationship between the existence of native riparian vegetation and property value. It aimed to answer the question *"What is the relationship between rural property value (economic value) and the existence of native vegetation?"*

Subject: riparian native vegetation

Intervention: existing riparian vegetation, on-farm native vegetation

Comparator: no riparian vegetation

Outcome: increased property value from sales, increased willingness to pay, increased property valuation

Databases and search engines

The search included the following databases:

1. Science Direct
2. Google Scholar

In addition to searching these two data sources, a snowballing method was used whereby references from existing sources were searched and included where relevant.

Inclusion and exclusion criteria

Inclusion: rural property, semi-rural property, riparian buffer, riparian vegetation, riparian native vegetation, native vegetation.

Exclusion: proximity (as opposed to the riparian vegetation actually being on the property) to riparian areas or wetlands, urban property, residential property, peri-urban property, recreational value of riparian areas, other non market based values, non-native or commercially harvested vegetation, improvements to water quality (and value) resulting from riparian vegetation.

Search terms and results

Title and abstract searches were conducted in the following databases or search engines.

Search string	Science Direct	Google Scholar
rural AND (property OR real estate) AND value AND riparian	NA	11,600 (36) first 200 results
("property value" OR "real estate") AND riparian	467 (1) first 100 results	15,500 (12) first 100 results

POTENTIAL CONFLICTS OF INTEREST AND SOURCES OF SUPPORT

There are no known conflicts of interest at the time of writing this protocol. Funding to undertake the study has been provided by the Department of Environment, Land, Water and Planning.