Braided River Research and Management Priorities:

Terrestrial invertebrates, lizards, terrestrial native plants, terrestrial weed invasions, and geomorphology, wetlands, river mouths and estuaries.

Report prepared by the Department of Conservation for Environment Canterbury, 2019

Department of Conservation
Te Papa Atawhai

New Zealand Government

Cover: "Braided River, Canterbury. *Photo: Bernard Spragg*

DOC-5928684

Contents

1 Purpose

The objective of this report is to advise targeted braided river biodiversity and ecosystem programs across the Canterbury region, by identifying knowledge gaps and providing research and management priorities. The scope of this project includes braided river systems within Environment Canterbury (ECan) boundaries, from the Waitaki to the Clarence Rivers inclusive. It is limited to terrestrial species and weed control work within these systems, and the wetlands, lagoons, estuaries and river mouths associated with these rivers. This report provides guidance on knowledge gaps, and key priorities for management and future work. This report was compiled by the Department of Conservation (DOC) (D. Lewis and R. Maloney) for ECan, in consultation with ECan, the National Institute of Water and Atmospheric Research (NIWA), the University of Canterbury, Wildlands Consultants and other independent consultants.

2 Introduction

New Zealand's braided river systems are regarded as being exceptional on a global scale for the number of rivers that remain relatively unmodified, and the high level of endemism of both plants and animals (O'Donnell *et al* 2016). The highly dynamic, changing physical environment of braided rivers systems support a diverse range of indigenous wetland birds, freshwater fish, bats, lizards, invertebrates and plants that are either unique to braided rivers, depend on them for a critical part of their life history, or form community assemblages which are best represented in braided river ecosystems (O'Donnell *et al* 2016).

New Zealand contains over 300 braided rivers, 64% of which are in Canterbury. Despite being an iconic feature of the Canterbury landscape, braided rivers are a naturally rare ecosystem (Williams *et al* 2007), occurring in only a few places in the world. Braided rivers are also ranked as an 'endangered' ecosystem (Holdaway *et al* 2012), meeting the criteria of 'severe decline in ecological function in >80% of extant distribution internationally'.

Despite the high values braided rivers contain, and their endangered ecosystem status, New Zealand's braided rivers are rapidly being degraded (Gray *et al* 2018, Grove *et al* 2015), and are at risk from land use change, weed invasion, and competing demands for recreation, gravel extraction, irrigation and hydro-electricity (Young *et al* 2003). The impacts of these, and other human activities, on these braided river ecosystems is not well understood. Although specialised bird populations and native freshwater fish within braided river ecosystems are relatively well understood, much remains unknown about the ecology of lizards, invertebrates, bats and indigenous plants (O'Donnell *et al* 2016).

The objective of this report is to identify the gaps in ecological knowledge of braided rivers and provide clear priorities to inform project funding decisions across braided river systems. Therefore, this report focuses on areas that have historically had less 'attention', namely lizards, terrestrial invertebrates, native terrestrial vascular plants, geomorphology, and wetland, river mouth, lagoon and estuarine habitats, as well as terrestrial weed invasion.

This evaluation was carried out by a process of multi-agency consultation with experts from the Department of Conservation, Environment Canterbury, the National Institute of Water and Atmospheric Research, the University of Canterbury, Wildlands Consultancy, and other individual consultants. Recommendations provided in O'Donnell *et al* (2016) are also incorporated into this report. This report is structured by presenting the consultation outcomes by the following topics:

- Invertebrates

- Lizards
- Native terrestrial vascular plants
- Geomorphology, estuaries, lagoons, river mouths and wetlands
- Terrestrial weeds

A summary of common recommendations across topics and a table collating the research priorities across the full range of categories is also provided. Recommendations provided within this report are not assigned priority order, with the exception of the lizard research recommendations which are presented in suggested order for implementation in section 4.6.

Contributors are recognised at the beginning of each relevant section. A full list of experts contacted for consultation is included in Appendix 1.

3 Research and Management Priorities for Terrestrial Invertebrates on Canterbury Braided Rivers

Terrestrial invertebrate research priorities were identified in consultation with Dr. Tara Murray from the University of Canterbury, Warren Chinn from the Department of Conservation, and Dr. Brian Patrick from Wildlands Consultancy.

3.1 High priority and key terrestrial invertebrate biodiversity values

Canterbury braided river systems are known to support hundreds of invertebrate species, with the unique vegetation and substrate characteristics present indicating that many of these are likely to be endemic to the region (see Peat *et al* 2016). Key species identified for braided river systems include, but are not limited to, the Tekapo ground wētā (*Hemiandrus 'furovarius'*) and mirid bug (*Pimeleocoris roseus*) (Nationally Critical), robust grasshopper (*Brachaspis robustus*) (Nationally Endangered) and numerous at risk or data deficient species (see Appendix 2). Additionally, non-threatened species are identified as being of value, such as the southern blue butterfly (also called the New Zealand blue) (*Zizina oxleyi*), New Zealand's only endemic blue butterfly.

3.2 Key threats to terrestrial invertebrate biodiversity values in Canterbury braided river systems

Despite the high numbers of invertebrate species, and the likelihood of a high degree of endemism within these species, Canterbury braided river invertebrate biodiversity is poorly understood. Species mostly likely to be specific to braided rivers are the less mobile species, such as flightless species and herbivores that have close associations with host plants (e.g. *Muehlenbeckia* and associated moths, *Roulia* etc.), and species adapted to specific substrate properties such as the Tekapo ground wētā. These, along with some of the smaller invertebrate species, are less able to respond to pressures, and therefore most at risk from ecosystem level threats such as host plant decline via competition, weed invasion, and changes in hydrology and vegetation resulting from climate change (e.g. rainfall gradients, reduced numbers of frost days etc.).

Weeds potentially pose the most significant immediate threat to total invertebrate biodiversity on braided rivers, having the potential to cause population decline or extinction from population fragmentation, loss of suitable habitat, or loss of host-plants. Woody and herbaceous weed species associated with open early-succession habitats that are resilient to natural disturbance present the greatest threat to terrestrial invertebrates. This is because their impacts are multifaceted, being both direct and indirect. For example, weeds can change the substrate structure and river hydrology by binding gravels, suppress native plants important to host-specific herbivores, harbour predators, and smother open gravels to which endemic invertebrates have adapted. Smothering gravels impacts some invertebrate species ecologically and behaviorally, disrupting normal behaviors such as basking and mate finding.

Obligate braided river species, such as robust grasshopper, are at particular risk from habitat loss. This can be driven by a number of threats, including adjacent land use changes, weed encroachment and climate change. Cattle also pose a threat to invertebrates by damaging the quality of riverbed habitat and water quality, mechanical disturbance of surfaces, weed spread and local extinction of host plants (by grazing).

Predation of terrestrial invertebrates is a significant threat in braided river ecosystems. Hedgehogs (*Erinaceus europaeus*) are likely to be the major insect-predator in these areas, threatening all terrestrial invertebrates. Mice pose significant potential for meso-predator release following suppression of larger predators for the protection of native birds. Rats may also be a significant threat in lower catchments.

Competition pressure can directly impact invertebrate species as well as their habitats. The endemic southern blue butterfly uses river terraces as a key habitat, and is under threat from an Australian invading blue butterfly *Z. labradus*. The southern blue has already been displaced through hybridization by the invasive Australian blue butterfly species throughout most of New Zealand, with only the populations in the south-east of the South Island still unaffected.

Hydroelectric schemes, flood mitigation plantings and climate change all pose threats due to their impacts on natural disturbances that maintain key characteristics of braided river ecosystems and the species adapted to these environments. Climate change can have both direct and indirect impacts, including change of habitat and directly impacting cold adapted species, through increased flood magnitude and frequency, reduced frost days etc. which may result in population decline or extinction.

3.3 Known terrestrial invertebrate projects currently underway

Three existing projects on invertebrates in braided river ecosystems were identified during this project: 1) The Tasman River invertebrate survey by DOC, which is in the final write up stage. The objective of this project is to identify species composition and diversity in the Tasman River and inform future monitoring strategies. 2) The robust grasshopper project, which is assessing methods for species management and monitoring techniques. This project includes a University of Canterbury PhD thesis due for completion mid-2019, and 3) an MSc project to identify whether robust grasshoppers increase in population size following exclusion of predators, due to be completed 2020.

3.4 Knowledge gaps for terrestrial invertebrates in Canterbury's braided river environments

There have been a series of invertebrate surveys on braided riverbeds, however these surveys are incomplete and demonstrate how little is known about invertebrate abundance and composition in these areas. In the most extensive study to date (Tasman River) 919 recognisable taxonomic units (RTUs) were identified but only 56 (6% of RTUs identified to named species and 14% of total RTUs) were found to have been assessed under the New Zealand threat Classification System (NZTCS). This indicates that the terrestrial invertebrate values of the braided river habitats remain largely unknown. As well as not knowing the full range of invertebrate species on braided rivers, there are knowledge gaps with understanding speciation across, and along, the large braided rivers of Canterbury.

Invasive introduced species pose significant ongoing threats which need research to both understand and mitigate. There is an incomplete understanding of the impact of weed encroachment and braid constraint on terrestrial invertebrate habitats, as well as limited understanding of the ability of invertebrates to recover following weed suppression. The impacts of different weed suppression methods on invertebrates is also poorly understood (e.g. the active ingredients of herbicides should not harm insects, but many of the surfactants and other ingredients do have the potential to cause harm, and mechanical weed removal and island building could cause direct invertebrate mortality). The impacts of these methods need to be compared and assessed.

There is also a lack of understanding of the impact of predatory mammals on invertebrate populations, in particular the potential for meso-predator releases following suppression of larger predators for the protection of native birds.

There is a lack of understanding of the mechanism for the southern blue butterfly displacement on the ground, and how complete any displacement of southern blue butterflies may potentially be, i.e. is there a possibility of extinction of the southern blue butterfly?

The impacts of climate change on invertebrates needs to be studied and the implications for management of threatened species identified e.g. the location and number of populations to protect considering predicted changes in rainfall gradients and frost days.

3.5 Areas where there is scope to expand existing management projects and potential new projects

Invertebrate biodiversity assessment could be added to existing or upcoming programmes including predator control (e.g. Cass-Godley, Tasman, upper Rangatata, Ashley etc.), weed removal and island building for the protection of bird nesting colonies (e.g. Ashley, Hurunui, lower Waitaki etc.). This could also be added in areas where pest removal is being conducted as part of the Te Manahuna Aoraki programme. Ideally these assessments would include several seasons of pre-treatment data, so their establishment should be a priority.

3.6 List of monitoring recommendations for terrestrial invertebrates

1. Measure presence or abundance of indicator species.
2. Characterise community structure by functional groups and noting change over time.
3. Alps to ocean series of transects to understand the composition of invertebrates relative to human activity and the relative proportions of native to exotic. Work has been started but is incomplete.
4. Monitor the 'migration front' for exotic riverbed communities in valleys for changes caused by intensive agriculture, land use change, and climate change.
5. Conduct pre-treatment monitoring of invertebrates in locations subject to upcoming predator and weed management programmes.
6. Build on Tasman study focusing on gaps in the design of that study that will answer key questions about diversity and monitoring methods. This includes assessing the biodiversity across vegetation types and across rivers, and developing biodiversity health indices for terrestrial braided river invertebrates focusing on recognizable taxonomic units (RTUs) or morpho-species and functional diversity.
7. Continue and refine recently established methods and improve ability to detect population change over time for the robust grasshopper. Ensure these methods become integrated into the management programme as best practice guidelines. Establish intervention thresholds.
8. Establish best practice monitoring method, appropriate frequency and intervention thresholds for Tekapo wētā.
9. Develop survey methods to monitor health of invertebrate populations (probably based on RTUs and functional diversity).

3.7 Key recommendations and priorities for future terrestrial invertebrate projects.

1. A terrestrial invertebrate biodiversity index needs to be established. Indices for estimating stream health based on tolerances of key aquatic invertebrates exist, but there is no similar index for terrestrial riverbed habitats. Biodiversity values across a range of rivers need to be determined, and an index needs to be developed to monitor habitat and invertebrate community health over the long-term which will be used to set priorities and assess future management actions.
2. The invertebrate community has only been assessed for one of 11 identified vegetation communities on the Tasman River. Assessment of the invertebrate biodiversity values associated with braided river vegetation types would help in prioritising management and monitoring over large areas.
3. Species specific to dynamic environments created by natural disturbance are likely to be at the greatest risk from riverbed stabilization resulting from hydroelectric schemes, willow planting, and weed invasion. The biodiversity associated with these habitats and Canterbury Plains rivers where weeds are a significant feature, need to be identified.
4. There has been some work on an alps to ocean series of transects along braided rivers which should be completed. The aim of this work is to understand the composition of invertebrates relative to human activity, and the relative proportions of native to exotic species.
5. Existing or future predator, weed and island building projects focused on other taxa should include monitoring of invertebrates to gather information on impacts of activities.
6. A new predator removal study to specifically assess impacts on biodiversity and key species, and invertebrate monitoring where predators are being removed as part of existing projects, needs to be designed and implemented. Priorities for this work are hedgehogs in upper catchments, rats (*Rattus, R. norvegicus* and *R. exulans*) in lower catchments, and mice (*Mus musculus*) wherever larger mammals are being removed.
7. The impacts of woody and herbaceous weeds on terrestrial invertebrate species and communities need to be identified, and the potential for invertebrate recovery following weed removal should be investigated.
8. The effects of weed control strategies, specifically herbicide and mechanical weed removal, on invertebrate communities needs to be tested.
9. The predicted impact of future changes in rainfall gradients and temperature in the Mackenzie, with focus on implications for management of robust grasshopper populations (some data has already been collected) needs to be modelled. The findings of this work will have application across a wide range of taxa.
10. Research and management are required to arrest the replacement of New Zealand/southern blue butterflies by Australian blue butterflies. A suggested site for this work is the Dagnum Reserve on the north-side terrace of the Waimakariri River.
11. Develop best practice management for improving populations of, and mitigating threats to, all threatened or at risk invertebrate species (e.g. Tekapo ground wētā, mirid bug and robust grasshopper).

4 Research and Project Priorities for Canterbury Braided River Lizards

Research priorities for lizards in the wider braided river system were identified in consultation with Lynn Adams, Dr Jo Monks and Dr Marieke Lettink from the Department of Conservation.

4.1 High priority and key lizard biodiversity values

Canterbury has a unique and diverse lizard fauna, but very little is known about any of the species. Nineteen of the 24 known species in the Canterbury region are ranked as 'threatened' or 'at risk' (one Nationally Critical, nine Nationally Vulnerable, eight Declining and one Naturally Uncommon). Surveys have established the mid-Canterbury uplands as a hot spot of lizard diversity in New Zealand. The Ashburton Lakes basin has the highest diversity of lizard species on mainland New Zealand, providing habitat to nine species. Within this area there is a single hotspot with eight species within the same habitat. This knowledge facilitates the establishment of better management programmes and protection of important populations. It is entirely feasible that new species will be discovered with further surveying (e.g. recent surveys in north Otago have identified three previously unknown, but likely new, threatened species).

4.2 Key threats to lizard biodiversity values in Canterbury braided river systems

Lizards throughout Canterbury are suffering continual decline in range, number of viable populations and abundance. Predation and habitat loss are significant causes of this decline. Predation on lizards is primarily from rodents (including mice), mustelids, hedgehog, cats (*Felis catus*), possums (*Trichosurus Vulpecula*) and pigs (*Sus scrofa*) (Spitzen - van der Sluijs *et al* 2009). Habitat loss and degradation is the result of several different influences including both animal and plant pests, livestock, land use change and climate change. Animal pests and livestock modify and degrade habitat by trampling and grazing on plants which provide habitat. Plant pests can displace native plants used as habitat and reduce carrying capacity. Land use changes such as intensification, vegetation clearance, cultivation, increased water input (irrigation) and recreational activities can cause both habitat degradation and loss, reducing carrying capacity. Afforestation also can cause loss of habitat, reduced carrying capacity and degradation of existing habitat for most ecosystems used by lizards, but in particular low stature vegetation such as scrubland and tussock subalpine (Norbury *et al* 2009). A known threat, with largely unknown impacts on lizards, is climate change. Likely impacts include a shift in predator guild and loss of habitat from flooding or erosion.

There is an added threat to threatened lizard fauna as an unintended consequence of the objectives of the various Predator Free New Zealand initiatives. Predator Free strategies have overlooked the predator guild shift that may occur, where mice and weasels will likely flourish and replace the biomass of stoats and rats, should the latter two be eradicated at the landscape scale. Mice (and weasels) are potentially more damaging predators than rats and stoats for lizards because they can access small interstitial spaces inhabited by lizards. Thus, releasing them from competition and predation by rats might worsen the outcomes for New Zealand's most threatened lizard taxa (Norbury 2001).

4.3 Known lizard projects currently underway

There are very few lizard projects currently being undertaken in Canterbury braided river ecosystems, however, the projects being carried out in other areas will contribute to the overall understanding of Canterbury lizard species. There are no current projects directly addressing the cause of lizard decline. The current Canterbury projects include: 1) A study on Banks Peninsula measuring pest control and population response of jewelled gecko (*Naultinus gemmeus*) (private project). 2) The Christchurch City Council has site management work at Cavendish Reserve, particularly for spotted skink. 3) Translocation of Canterbury gecko (*Woodworthia cf. brunnea*) to Riccarton Bush. 4) Rough gecko surveys in Kaikoura. 5) Predator management at Kaitorete Spit. 6) White- bellied skink surveys. 7) Lakes skink monitoring programme in a predator control site in the Upper Ohau, to determine changes in lake skink populations in predator-controlled areas. This is an ongoing study until at least 2023. 8) Scree skink monitoring at O Tu Wharekai. The O Tu Wharekai project has done the most comprehensive survey work in recent years. Targeted surveys such as those undertaken as part of O Tu Wharekai wetland funding has allowed a far greater understanding of the range and extent of many lizard species and has provided better understanding of the importance of particular habitat types (e.g. wetlands and riverbeds). Additionally, there are a range of development driven mitigation projects, but these may have limited conservation value.

4.4 Knowledge gaps for lizards in Canterbury's braided river environments

The distribution and life history of many of New Zealand's lizards is not well known, and this is particularly so over most of Canterbury. The areas where there is sound distributional information are primarily near roads or places people frequent, so lizard distribution knowledge is patchy. This patchy knowledge limits the ability to make informed management decisions. Over half of Canterbury's lizard species are undescribed, and there is limited information available on the species boundaries. Information on some species is so limited that genetic techniques are required for positive identification.

The management tools available to facilitate recovery in lizard populations are limited to predator eradication or exclusion (i.e. predator free islands or exclusion fences). There is limited evidence that pest control tools used successfully for other species (e.g. braided river birds) has enabled recovery of lizard populations, so there is an urgent need to develop pest control tools to protect lizard species, and to monitor lizards at existing braided river pest control sites.

4.5 Areas where there is scope to expand existing management projects and potential new projects

There is more than four decades of quantitative evidence for the continued impact of mice on species such as lizards (Newman 1994; Norbury *et al* 2014; Wilson *et al* 2018). Despite this knowledge, there is a lack of sustainable management tools to address this need beyond the use of eradication on off-shore islands, or the construction and costly maintenance of mammal proof fences on the mainland. Whilst brodifacoum is extremely effective for the control of mice, it's environmental persistence and bio-accumulation makes it untenable for sustained use.

Predator-proof fencing is expensive, and large-scale predator trapping targeting the full range of predators works in a low-rodent environment. However, it's expensive and untested where rodent control is required. Cost-effective predator control for lizards, usually where predator control is being done at lower intensity for other species needs to be explored.

4.6 Key recommendations and priorities for future lizard projects

The work needed for Canterbury's lizard species focuses on two themes, understanding the distribution and abundance of lizards in Canterbury, and developing pest control methods to protect lizards in a variety of ecotypes. This mahi will allow for informed management decisions to protect our most threatened species. The initial section identifies priority work required to address knowledge gaps for a range lizard species in different ecotypes.

1. Understand the impacts of pest control for braided river birds on lizard populations. Landscape scale pest control may be detrimental to lizards if it results in meso-predator release.
2. Understand the distribution and abundance of lizards occupying the main rivers on the floor of the Mackenzie Basin. This would include the rocky terraces flanking the Tekapo and Pukaki Rivers, and may include important tributaries where there is suitable habitat. This project fits with the objectives of Project River Recovery, which acknowledge that lizards are a knowledge gap. Several threatened lizard species (e.g. Mackenzie, lakes & scree skinks) are found it this area, but there is poor understanding of their distribution. This area is also under significant pressure for land-use changes that will impact lizards.
3. Understand the distribution and abundance of lizards occupying river margins, and estuary margins and adjoining wetland habitats in lowland Canterbury. These areas provide relatively unmodified refuges and can support abundant lizard populations if the habitat is right (e.g. cobble strand adjoining Wainono Lagoon near Waimate).
4. Understand the distribution and abundance of lizards occupying the Waimakariri Basin braided rivers, and other poorly understood areas. Very little is known about lizard biodiversity in these areas, but they are likely to support significant lizard populations. A focus would be on areas that may be affected by future land use change, climate change, or where habitat indicates highly threatened species could be present.

The five priorities presented below are recommended as a five-step programme for the development and testing of pest mammal control for lizards:

1. Evaluating existing registered rodent toxins for intensive ground control efficacy.
2. Determining the drivers of mouse populations and how these impact on their predatory behaviour through monitoring of environmental characteristics, productivity and population parameters of mice and lizards for the development of a predictive management model.
3. Investigating non-target impacts of bait deployment of baits where there is no previous experience in using it at the quantities identified for mouse control.
4. Providing a management plan and operational tools to field operations staff to employ for localised recovery of threatened taxa.
5. Developing a robust analysis model for field trials that will generate a predictive model and inform management triggers and responses for operational decision making.

5 Research and Project Priorities for River Geomorphology, Estuaries, Lagoons, Wetlands and River Mouths Associated with Canterbury Braided Rivers

River geomorphology, estuary, wetland, lagoon and river mouth research priorities were identified in consultation with Dr Jo Hoyle from NIWA, Dr Collin O'Donnell and Helen Kettles from the Department of Conservation, and Dr Duncan Gray from ECan.

5.1 High priority and key terrestrial biodiversity values in estuaries, lagoons, wetlands and river mouths associated with Canterbury braided rivers

Wetlands in New Zealand are a highly threatened ecosystem, with only an estimated 10% of natural wetlands remaining (Johnson and Gerbeaux 2004, Maglone 2009, Myers *et al* 2013). Nationally, wetlands contain high proportions of threatened species, including 13% of New Zealand's nationally threatened plant species (Holdaway *et al* 2012, de Lange *et al* 2009, Myers *et al* 2013). River mouths provide bird habitat both in the breeding season, and as roosting habitat in the nonbreeding/winter for substantial local migratory species, e.g. black-fronted tern (*Chlidonias albostriatus* Nationally Endangered), banded dotterel (*Charadrius bicinctus* Nationally Vulnerable) and South Island pied oystercatcher *Haematopus finschi* Declining). Estuaries are ranked as a 'vulnerable' ecosystem (Holdaway *et al* 2012).

5.2 Key threats to geomorphology, wetlands, estuaries, lagoons or river mouth values connected with braided river systems

Threatened lowland habitats and ecosystems are increasingly vulnerable to ongoing pressures from surrounding land use, invasive plants and animals (Myers *et al* 2013), climate change, and risks that cannot be managed, such as earthquakes which pose a risk of potentially elevating land and causing liquefaction. Some of New Zealand's most threatened wetlands are those in the lowland zone, which has undergone extensive agricultural transformation in the last 150 years. Many of these lowland wetlands occur on private land and within environments classified as acutely or chronically threatened (Myers *et al* 2013).

Land use, including agriculture, urban development, and industrial and infrastructure development can impact wetland and estuarine environments in a number of ways. Draining of land for agriculture or agriculture expansion can lead to the loss of entire ecosystems and species. Agricultural runoff has been identified as one of, if not the most significant sources of water contamination in wetlands and other aquatic ecosystems in New Zealand (Ministry for the Environment, 1997; Parliamentary Commissioner for the Environment, 2004). Eutrophication is a common problem for wetlands downstream from agricultural and urban landscapes, because the nutrients allow invasive plants to establish, spread, and displace native species. Coastal wetlands in particular are fragile and prone to trampling/browsing damage from livestock. Trampling damage can also be caused or exacerbated by human activity, due to both increases in foot and vehicle traffic (i.e. four-wheel driving).

Climate change is causing the sea level around New Zealand to rise, altering the shape of estuaries and causing them to slowly move inland. Plants will follow this movement, with the salt tolerant species establishing further inland. If infrastructure is present 'coastal squeeze' can occur and the extent of coastal wetlands reduced. Climate change is also increasing disturbance to estuaries with more intense storms, causing direct and indirect impacts, including increased sedimentation and decreased salinity.

Gravel extraction poses a risk to these ecosystems, both from direct impacts during the extraction, and the indirect impacts on geomorphology and habitats due to over extraction, compaction and alteration of bed substrate composition. Geomorphic changes in a river will often have flow on effects downstream to their estuaries and river mouths.

Invasive exotic vegetation, including existing and potential future woody shrubs and herbaceous species, each impact habitats to varying degrees. Invasive weeds have the ability to change the character of these ecosystems, as well as threatening the indigenous flora and fauna. Mammalian and avian predators present risks to the threatened indigenous fauna in wetland, estuary and river mouth areas.

Some braided river mouths may be periodically blocked to the sea. Connection to the ocean, freshwater flow and productivity indices have been identified to underlie the environmental differences between the permanently open and intermittently closed estuaries (Lill *et al* 2013). The timing and duration of these closures can have impacts in the upstream system resulting in flooding and restriction of access between the sea and river for numerous species. These blockages can become more frequent or last for longer periods of time with lower flows, increasing the negative impacts of blocked hāpua/lagoons to the braided river system.

Modification of flow regimes (dams, flood harvesting, cumulative effects of water takes etc.) which can include alteration of low flows, seasonality of flows, flow intermittence, flood flows, can alter the naturally dynamic nature of braided rivers (e.g. resulting in stabilisation of riverbeds).

A large magnitude earthquake on the alpine fault could cause loss of/changes to habitat in all braided river ecosystems through increased sediment inputs into the braided river system flows.

5.3 Known geomorphology, wetland, estuary, lagoon or river mouth projects currently underway

Ten current projects were identified during consultation (see Appendix 3). The only project specific to wetlands or estuaries is a NIWA/University of Canterbury PhD project aiming to understand the hāpua response to changing flow regimens, sediment supply, waves, climate change and sea-level. This work is due for completion 2020. The remaining projects are on the wider braided river area including ECan's BRIDGE project to define braided riverbeds, habitat monitoring mapping braidplain constraint and habitat change over time, various investigations relating to Waitaki Power Scheme reconsenting by Meridian, development of a new theory of sediment transport in braided rivers which is a NIWA led Marsden funded project, a NIWA lead Ministry of Business Innovation and Employment (MBIE) Smart Idea project investigating measurement of flows in rivers by drones, a NIWA study on the effects of flood harvesting on fine sediment deposition in the Rangitata River, and NIWA funded research aimed at establishing relationships between flows, geomorphic change and braided river weeds.

5.4 Knowledge gaps for geomorphology, wetlands, estuaries, lagoons or river mouths in Canterbury's braided river environments

There is limited information available on the ecology of hāpua/lagoons in general. The ecology of these areas needs to be studied.

There is no list of threatened or at risk species for estuarine ecosystems.

There is little known about the morphological impacts of woody weeds on braided river wetlands, estuaries, hāpua or river mouths, or how to manage the impacts that are known. Additionally, vegetation dynamics and feedbacks have not been quantified (i.e. how do rates of weed growth vary under different conditions and what are the thresholds for removal by flows), and vegetation dynamics and water needs will likely vary for different invasive exotic plant species in braided rivers e.g. if willows get replaced by gorse what are the impacts on surface water/hyporheic water/ground water.

Research needs to be done to gain a quantitative understanding of the role of landscape configuration, dispersal and succession on heterogeneity-biodiversity relationships.

How landscape drivers (flow regime, sediment supply, vegetation cover, river width) alter the physical characteristics of the river, and subsequently impact on ecological values needs to be studied to gain a quantitative understanding of the mechanisms. Globally, there is no morphological model capable of quantitatively predicting how river drivers alter the physical characteristics of braided rivers over temporal and spatial scales appropriate to management. This is needed to help river managers weigh alternative management strategies and assess the effects of these strategies on ecological values.

Research needs to be done to provide an understanding of how controls on braidplain width alter physical river processes such as braid avulsion and sediment transport, and the subsequent impacts of changes in these processes on the functioning of braided river ecosystems.

The hydrological and ecological effects of flow intermittence (natural and anthropogenic) needs to be studied.

Understanding surface water/hyporheic flow/groundwater dynamics in braided rivers (e.g. how do changes in active braidplain width alter groundwater recharge? This is the focus of an MBIE Endeavour research programme application currently under assessment (2019 funding round). This proposed project has been led by Lincoln Agritech (with significant involvement from NIWA).

5.5 Areas where there is scope to expand existing management projects and potential new projects

Strategic woody weed control is required throughout Canterbury's braided river systems. The infrastructure for existing management currently exists but it requires a funding mechanism.

5.6 List of monitoring recommendations for geomorphology, estuaries, lagoons, wetlands and river mouths.

1. Land use, woody weed invasion and flood control works can cause braid plain constraint, which needs to be carefully monitored.
2. The impacts of changes in water allocation and sediment supply on estuaries, wetlands, river mouths and the ecosystems these landscapes support, needs to be monitored.

3. Long-term monitoring of a range of sites e.g. engineered bird islands for threatened species is required to develop quantitative understanding of habitat needs.
4. Long-term monitoring of coastal vegetation communities needs to be established to aid in predicting climate driven retreat of these systems.
5. Invasive woody weeds are known to outcompete native plant species, alter hydrology and reduce habitat for indigenous fauna in all braided river habitats, including wetlands (Boffa Miskell 2019). The invasion rates of woody weeds into new areas needs to be monitored.

5.7 Key recommendations and priorities for future geomorphology, wetland, estuary, lagoon or river mouths projects.

1. Restoration of estuarine and wetland riparian vegetation
2. Identify the extent of the plant communities in each habitat type.
3. A study on the morphological impacts of woody weeds on wetland ecosystems.
4. The complex and dynamic nature of braided river systems means a large scale, coordinated, strategic approach to research is necessary. Ideally, this would include widening the focus of any monitoring, so that we can quantify relationships between river processes and river values. This will likely require different groups collaborating and monitoring at the same locations. E.g., when collecting species observation data, also collecting a wider range of environmental data (precise GPS locations, substrate size, vegetation cover (height, distance to), flow at the time of observation, antecedent flows etc.).
5. Establish a study, or series of studies, to identify and better understand hāpua/lagoon functioning and ecology.
6. Gain a quantitative understanding of the role of landscape configuration, dispersal and succession on heterogeneity-biodiversity relationships.
7. Develop morphological model capable of quantitatively predicting how river drivers alter the physical characteristics of braided rivers over temporal and spatial scales appropriate to management.
8. Identify how controls on braidplain width alter physical river processes such as braid avulsion and sediment transport, and the subsequent impacts of changes in these processes on the functioning of braided river ecosystems.
9. Gain an understanding the hydrological and ecological effects of flow intermittence (natural and anthropogenic).
10. Compile a list of threatened and at risk species for braided river estuarine ecosystems.
11. Establish a best practice for incorporating ecosystem values in erosion protection work.

6 Research and Project Priorities for Canterbury Braided River Terrestrial Native Plants

Terrestrial native plant research priorities were identified in consultation with Jane Gosden and Richard Clayton from the Department of Conservation.

6.1 High priority and key terrestrial native plant values

Braided river system contains five threatened ecosystems that provide important plant habitat, including ephemeral wetlands (Critically Endangered), seepages and flushes, lagoons and braided river beds (both Endangered) and estuaries (Vulnerable) (Holdaway *et al* 2012). These dynamic and rare ecosystems allow braided river systems to support a distinctive flora, with one survey in the upper Waitaki River system identifying 265 native terrestrial vascular plants (18 threatened) (Woolmore 2011). There are at least 24 threatened, at risk or data deficient native terrestrial plants in Canterbury braided riverbeds and nearby alluvial fans, including two Nationally Critical species, two Nationally Endangered and five Nationally Vulnerable species, as well as *Carmichaelia juncea*, which is possibly already extinct (Appendix 4).

6.2 Key threats to native terrestrial native plant values in Canterbury braided river systems

The key threats to the terrestrial native plants of braided river systems include resource competition, loss of ecosystems, loss or change of habitat, and lack of space to retreat from environmental changes. Native plants can be outcompeted by weedy plants for essential resources such as pollinators, seed dispersers, space and light.

Loss of ecosystems can be caused by encroachment of agricultural land into the riverbed area, land use changes or climate change. Plants that rely on ephemeral wetlands in particular, are at risk of habitat loss from drainage of land for agriculture, which can result in both ecosystem and threatened species loss. Loss of open riverbed habitat can occur through several mechanisms, including encroachment of pastoral land onto riverbeds and weed invasion. Loss of habitat for native plants could affect a number of plant species, with Nationally Critical species at risk of extinction.

Climate change can have both inland and coastal impacts on native terrestrial plants in braided river systems. Inland systems may suffer from loss of habitat or change in distribution, and lack of space to retreat along environmental gradients. In coastal areas, climate change induced sea level rise can reduce estuarine and other coastal areas, restricting space for natural retreat from the changing climate for coastal ecosystems, and ultimately resulting in the loss of those ecosystems.

6.3 Known terrestrial native plant projects currently underway

Two current projects on native terrestrial plants in braided river systems were identified. Both are by the Department of Conservation. Project River Recovery have carried out a survey of the upper Waitaki River systems and are currently analysing the data, and there are several Ō Tū Wharekai community projects including riparian planting.

6.4 Knowledge gaps for terrestrial native plants in Canterbury's braided river environments

There are number of data deficient terrestrial plant species in braided river ecosystems that need further information collected for. Additionally, some of the threatened species in these areas require taxonomic resolution as well as information on distribution, life histories, recruitment etc. This information is necessary for any recovery program for highly threatened braided riverbed plants. Interactions between braided river bed plant communities and native birds (especially nesting birds) needs to be better understood. For example, is there an association between braided river plant and bird species similar to the nutrient input colonies of breeding birds in the coastal region. The impact of introduced mammals on riverbed plant communities needs to be identified, including disturbance through trampling/burrowing, browsing and seed dispersal.

Overflow of nutrients from farms is known to impact dryland plant communities, but the information is not available on impacts of nutrient accumulation or overflow on braided river terrestrial plant communities. Any impact of nutrient accumulation and overflow on braided riverbed plant communities needs to be identified, along with the degree of that impact.

There is not enough understanding of the impacts of climate change impacts on the plant values in braided river ecosystems, including any inland or altitudinal climate driven retreat.

6.5 Areas where there is scope to expand existing management projects and potential new projects

Survey for *Carex decurtata* along riverbeds and associated tarns where there are known location of the species, or known suitable habitat in the Mackenzie Basin and Central Otago. This work would cost an estimated $5000 and may fit within the work already being done at Manaaki Whenua Landcare Research by Kerry Ford.

Taxonomic resolution for tag named species within braided river ecosystems. This would require surveying and collecting species from known locations and would cost approximately $20,000 per species. This work could potentially be led by the Allan Herbarium at Manaaki Whenua Landcare Research.

6.6 List of monitoring recommendations for terrestrial native plants

1. Survey weedy areas prior to large scale weed removal in case populations of threatened plants are persisting in the environment, then monitor vegetation dynamics in the area post large scale weed removal.
2. Long-term monitoring of braided riverbed vegetation communities needs to be established. This would include riparian edges and any associated terrestrial ecosystems.
3. Establish long-term monitoring of coastal vegetation communities to aid in predicting climate driven retreat of these systems.
4. Data deficient and tag names species require monitoring to be further understood. Specifically, their distributions and impacts on other threatened plants and their life histories if they are to be included in any form of restoration or translocation work.
5. Long-term monitoring of braided river system plant communities would be useful to show patterns like: Predator control impacts on plant communities, changes to water flow or nutrient inputs on plant communities, climate change impacts on braided river bed and estuarine ecosystems, and to quantify the impacts of gravel extraction on flora and fauna, including breeding and spawning success.

6.7 Key recommendations and priorities for future terrestrial native plant projects.

Four high priority projects were recommended for native terrestrial plants:

1. Research individual threatened and data deficient terrestrial plants in braided river environments. This will require one to three years of research per species, possibly more if additional monitoring is required.
2. Long-term monitoring of native braided riverbed plants. This would involve monitoring being done every one to two years, then potentially reducing to every five years depending on findings of earlier monitoring.
3. Climate change research towards understanding the retreat of ecosystems both inland and altitudinally. This would need to be ongoing work.
4. Restoration of riverbeds following large-scale weed removal.

Five projects were considered to be of medium priority to native terrestrial plants in braided river systems:

5. A study on the impacts of nutrient accumulation on braided riverbed plant communities, including determining if the increased nutrient and water loads into buffering or transitional areas is a problem? If so, how much and why? This would be expected to be at least a three-year study.
6. Study of the distribution, life histories, recruitment of threatened plant taxa. i.e. the information required for any recovery program for highly threatened braided river bed plants is recommended. This study would need to be carried out over one to three years per plant/ecosystem.
7. A project examining the interactions between birds (especially nesting birds) and riverbed plant communities (e.g. nutrient input colonies of breeding birds provide and whether there is an association with any plants) is also recommended. This work would take a minimum of three years.
8. Study the impacts of mammals on riverbed plant communities e.g. disturbance through trampling/burrowing, browsing and seed dispersal. This would be at least a three-year study.
9. Trials exploring the use of seed 'bombing' and underplanting trials as a means of restoring woody vegetation in braided river margins where those areas had been infested with gorse and broom were also suggested. This is as an alternative to the weed control methods currently used in braided river ecosystems.

7 Research and Project Priorities for Canterbury Braided River Weed Control

Weed control priorities were identified in consultation with Peter Raal and Dean Nelson from the Department of Conservation, and Dr Frances Schmechel from Environment Canterbury.

7.1 Identification of key braided river ecosystem values threatened by weed invasion

To varying degrees, all of Canterbury's braided river systems are of value to wildlife and plants. They provide habitat for a unique array of species and communities, many of which are threatened or at risk, e.g. kakī (*Himantopus novaezelandiae*), black fronted tern (*Chlidonias albostriatus*), scree skink (*Oligosoma waimatense*), robust grasshopper (*Brachaspis robustus*) and jeweled gecko (*Naultinus gemmeus*). Over most of the extent of braided rivers, all of these values are becoming increasingly restricted as weeds invade habitat and predator and disturbance pressures continue unmanaged. Generally, the upper reaches of Canterbury's braided rivers have relatively less weeds than the heavily weed invaded lower reaches, although weed encroachment is occurring in some upper catchments (e.g. Rakaia and Rangitata). This means that although high value species are present in the lower reaches (e.g. black-billed gulls and white-fronted terns), much of the current exceptional biodiversity value is in the upper reaches, including significant populations of braided river birds and other fauna, and extensive unmodified flora. Remnant populations in the warmer and potentially more food rich lower reaches are recoverable and provide buffers against other threats, such as future climate change. All reaches are at risk from weed encroachment from the invasive weed species currently abundant in the lower reaches.

Invasive weed species, such as false tamarisk (*Myricaria germanica*), Russell lupin (*Lupinus polyphyllus*), yellow tree lupin (*L. arboreus*), broom (*Cytisus scoparius*), gorse (*Ulex europaeus*), and grey and crack willow (*Salix cinerea* and *S. fragilis*) threaten the habitat values of braided rivers by establishing on the sparsely vegetated open gravels, outcompeting indigenous plant species and increasing cover for predators (O'Donnell *et al* 2016, Peat *et al* 2016). Invasive weeds also threaten the general integrity of Canterbury's river systems as 'braided' rivers. Weeds pose the risk of stabilising rivers, preventing them from freely adjusting and thus losing their braided characteristic. Woody weeds also invade wetlands in the wider river floodplain, outcompeting native plant species, altering wetland hydrology and reducing habitat for indigenous fauna (O'Donnell *et al* 2016).

7.2 List of existing weed control programmes

Eighteen currently active weed control programmes throughout Canterbury braided river areas were identified (Appendix 5). These programmes include trials to find effective herbicide control methods for false tamarisk (*Myricaria germanica*), Russell lupin (*Lupinus polyphyllus*), Monkey musk (*Erythranthe guttata), Salix* species and other large woody weeds.

Annual control work is being carried out on ten rivers and one lake bed. Additional woody weed control, primarily in plains rivers, to prevent blockages and flooding is being carried out by ECan on an approximate 5-year cycle. There is also a Hurunui vegetation surveillance project being carried out, monitoring relationships between flows, geomorphic change and braided river weeds.

7.3 List of highest priority areas for braided river weed control programmes in the Canterbury region

Prioritisation of weed control in Canterbury braided rivers should consider current levels of invasive weeds and high biodiversity values. For example, upper basins of the rivers above the foothill gorges have been identified as being of highest priority because, in general, they are relatively weed free and have high riverbed values. Any priorities set need to be flexible, so that any new weed incursions that are identified in areas of high biodiversity value, which are otherwise clear of weeds, can be prioritised.

Any portion of a river system that is relatively clear of weeds and has high existing biodiversity values is also of high priority. The Te Manahuna Aoraki project includes the Tasman River, Murchison River, Godley River, Cass River, Fork Stream and Ahuriri Rivers, which should be prioritised (in that order) for highest biodiversity values, number and distribution of weeds and investment over time.

Other key areas based on ecosystem values or other priorities (wetlands, breeding islands, rivercare groups) include:

- Clarence River (strategy complete after this year)
- Waiau River (needs a strategy/ action plan)
- Upper Waimakariri River (has strategy/ action plan 2016)
- Upper Rakaia River
- Ashburton River (has shorebird action plan 2016)
- Upper Rangitata River (strategy after this year 2019)
- Mackenzie basin rivers (Project River Recovery)

7.4 Recommendations on key factors for successful implementation of weed control programmes

There are a number of key factors identified for successful implementation of weed control programmes. These are primarily based on sound understanding of threats and values, planning, communication and resource availability.

A strategic approach with clear goals and priorities, coordination, reporting and communication, reviews and monitoring is necessary for invasive weed management. Establishing clear goals and priorities requires having an understanding of the values and threats present in an area. This includes knowledge of the extent of weed species and the impact, or potential impact, of these species on the area's values. Biodiversity values may be negatively impacted by the process of removing or controlling weeds. Identification of the values present and the potential risks from weed control methods will help prevent unnecessary collateral damage.

Dedicated resources need to be available to manage programs, including multi-year funding, staff and contractors. A number of the weed species have very hard coated seeds which means they can remain viable in the substrate for a long period of time (Russell lupin, gorse, broom). Therefore, it is critical that adequate levels of funding are maintained so control work can be carried out annually. Additionally, false tamarisk is relatively new to the Mackenzie Basin, upper Rakaia River and the Rangitata River, and it has very light wind-blown seeds, so it is critical to control annually to ensure that it doesn't get established. With the Ministry for Primary Industries funded wilding conifer programme expected to progress, adequate numbers of skilled ground and aerial contractors may

become hard to find. Recruitment needs to be well planned to be prepared for this to ensure suitable contractors are available.

Planning is essential for weed control in down-country sites. Weed control in braided riverbeds is dependent on good weather for spraying. Spring and early summer, which is the key time for control of Russell lupin, is often windy and/or wet.

Communication between landowners and agencies engaging in weed control is important to ensure co-ordination of projects and efficient effective control. Knowledge of weed control plans on private property would allow for agencies to best plan for seed sourcing control. An integrated approach will be more effective for most species and is needed for Russell lupin control now that wild Russell lupins are pests under the Regional Pest Management Plan. This requires the cooperation (and funding) of DOC, ECan, LINZ, Councils, NZTA (seeds from lupins on roadsides are carried in to waterways) and private landowners.

A biosecurity type approach to new weed species either establishing in Canterbury and/or establishing in new parts of Canterbury (i.e. false tamarisk in the Mackenzie Basin) would allow for prioritisation and response to new incursions of weeds in previously clear areas.

7.5 Priorities for developing new techniques, methods and approaches

Project River Recovery funded research is taking place to evaluate the ability of high-resolution aerial photos to identify areas of weeds and the species present. Continuation of this work was recommended as being essential because this technique could make control more efficient over the extensive areas involved in weed control when they are scattered over large riverbeds or islands in large braided rivers.

There is a need to resolve perceived conflict between willow control and issues around river engineering/riverbank erosion.

There is some evidence to suggest that where lower riverbeds are becoming weed infested, the use of heavy machinery to clear weeds off islands (for riverbed bird nesting) and/or root raking to loosen up the substrate and promote more mobile riverbeds, can be beneficial, but it requires ongoing follow-up control. Experimental control and monitoring of this practice are required to determine its efficacy and viability.

An assessment of the species not included in current weed control (e.g. sweet briar (*Rosa rubiginosa*) and stonecrop (*Sedum acre*)) and identification of best practice management should be completed. Sweet briar is spreading in some riverbeds and provides cover for rabbits and predators. The impacts of stone crop on threatened plants need to be identified. The most effective method of control, without impacting on non-target species, needs to be identified and potentially implemented for these species.

An effective method of communication between agencies needs to be established to allow for transfer knowledge between agencies and prevent doubling-up of work efforts. For example, monkey musk (*Erythranthe guttata*), sweet briar and stone crop were provided as examples of weed species that require further research, however, DOC have already completed some of the recommended work and are able to advise on herbicide use for each of these weed species.

Assessment of the potential for recent developments in herbicides and control techniques for wildling conifer to be transferred to the control of other species, such as willow, alders and poplars.

Development of effective weed control prescriptions that enhance key ecosystem components (where to do it, how much, cost-effectiveness).

Improve mapping resources and systems across all stakeholders to see and understand which are the priority weeds, where these weeds are, timing of control work, and the control effort and effectiveness.

NIWA has plans (but funding is yet to be confirmed) to develop new remote sensing techniques aimed at identifying different species and quantifying changes in cover and biomass over time, thereby establishing rates of growth/spread of invasive braided river weeds. Understanding how growth rates vary for different species is aimed at better understanding the required frequency of weed control measures.

Further development of weed sighting databases and maps and mobile applications that are specific, e.g. a site-specific surveillance project on a phone app (e.g. Find-A-Pest specifically for the Rangitata and one for the Rakaia).

How to manage wind dispersed species like grey willow and false tamarisk?

Review and identify the best way to report and evaluate the success of control operations.

Better understanding of the 'soft' program elements. What are the key ingredients for successful programs over time:

- What are the more difficult bits that we struggle with e.g. pathway management, surveillance, low density, control timing (before seeding), contractor capacity and solutions, contractor skills, long term funding, key messages.
- What are the key tradeoffs being made (i.e. area versus more frequent returns) and model the results (are they initiative or not so much)?
- Where are the most potential benefits of added resource and effort?
- Can we ever 'win some of the wars' (specific species e.g. Forbes Russell lupin) or is the best we can hope for sustained control?
- Is the weather going to prevent long-term success (unable to prevent seeding)?
- Are there better ways to run resources (contracts vs dedicated teams, contracting systems, etc.)?

7.6 Areas where there is scope to expand existing management projects and potential new projects

1. Recommendations for the expansion of existing management should be provided on a river by river basis, with the exception of Russell lupin control. It is recommended to increase existing projects, or establish new ones, anywhere that Russell lupins are present in braided rivers.
2. In addition to the Russell lupin control, follow-up willow control has been recommended for the Ahuriri River because willow is reestablishing following Project River Recovery control in the main riverbed a number of years ago.
3. Landscape scale expansion is recommended for the Upper Rangitata. This would require additional funding, resources and capacity for prevention, pathway management, annual aerial assessment and surveillance or support for surveillance (having others reporting key species). This work is currently $140,000 per year and would require $60,000 per year for control work. Contacts would be Pete Caldwell, Frances Schmechel, Liz Gunning. There is probably existing management capacity for the control work, but not the rest. This work could be managed by a weed control coordinator if appointed.

4. Landscape scale expansion for the Upper Rakaia. This would require additional funding, resources and capacity for prevention, pathway management, annual aerial assessment and surveillance or support for surveillance (having others reporting key species). This would cost an additional $100,000 (approximately). Contacts would be Pete Caldwell, Frances Schmechel, Liz Gunning.
5. Additional weed surveillance in the upper Ashburton catchment, and for weed work down to gorge. This would have an approximate cost of $15,000 – $50,000 per year.
6. The Clarence River requires program management capacity to ensure the action plan is implemented.
7. Removal of woody weeds and Russell lupins from the top of the Waimakariri River system down to the lower reaches.

7.7 List of monitoring recommendations and identification of projects that might be developing new management methods for invasive weed species

1. Available high-quality habitat in upper catchments, are we holding the line or making progress. Model what it would be without control.
2. Surveys to monitor native species (determine how much collateral damage is occurring, ways to reduce if necessary).
3. Changing climatic conditions may affect weed species' ability to invade new territory. Well-established weed species may be able to spread more vigorously, or new weed species may be able to survive in environments they previously could not. It is important to monitor trends in weed progression to understand if a weed species is becoming more invasive.
4. Result monitoring on target weeds following operations to ensure the methods are effective, particularly following a new herbicide or technique.

7.8 Recommendation of the value or need for weed coordinators

Appointment of a Canterbury braided river weed coordinator was recommended for coordination of control across properties, agencies and resources, implementation of smart interventions and for long-term sustainability of weed control projects. The three key reasons presented are:

1. Coordination (across property types/ agencies/ etc.) and resources, e.g. funding bids, communications, collation of information. Making sure key parties and key resources are connected and all are moving in agreed direction and that the resources are secured to do that. Work with landowners if actions like planting are needed prior to control. Ensure consistency and maintain good relationships between program and key stakeholders.
2. Smart interventions including surveillance (by users/landowners/run holders), awareness, pathway management (cleaning stations and behavior change, stock management, etc.)
3. Sustainability of weed control work. Weed control requires long-term action. These roles could help provide that by outlasting individual staff and/or care group chairs. Could advocate and make case for ongoing work and provide outside perspective.

7.9 Key recommendations and priorities for future invasive weed projects.

Six priorities were identified for invasive weed control in braided rivers. These include appointment of staff, surveillance, workshops and development of control strategies.

1. Develop a sites-specific surveillance project application. An initial application has already been developed so this is expected to be within the next two years.
2. Research on the effectiveness and further development of existing weed control programmes. This would require new resources and direction.
3. A seminar or workshop on weed control. This would be for landscape scale programmes and have a biodiversity focus. This could potentially be delivered by the BRaid coordinator and involve ECan, DOC and the advisory group.
4. Identify regional weed control priorities and develop a strategy for braided rivers. This would include clear goals, coordination, reporting and communication, reviews and monitoring.
5. Develop a Waiau River weed action plan.
6. Develop a more effective mapping system. Some work has already been done by ECan and Boffa Miskell for LINZ.

8 Research and Project Priorities for Canterbury Braided River Management

This section summarises management recommendations, values, threats and priorities for all of the categories reviewed for this report. The management recommendations, threats and values summarises those that were identified either for multiple topics within the report or that impacted multiple topics but did not strictly fit into any of the reviewed categories. The priorities presented are all of the priorities presented throughout this report.

8.1 Management recommendations common to all braided rivers

A need for a strategic and collaborative approach to braided river management and research was identified by the majority of the contributors. Ideally, this would include widening the focus of any monitoring so that relationships between river processes and river values, across all value types, are quantified (e.g. integrated monitoring plans for terrestrial work that measure numerous outcomes including impacts on freshwater and coastal systems, or the impacts of weed control on invertebrate and lizard species). This will likely require different groups collaborating and monitoring at the same locations, e.g., when collecting species observation data, also collecting a wider range of environmental data and considering other values e.g. survey for invertebrates, lizards and plants before weed removal.

Management issues across the braided river ecosystem were identified by several contributors, specifically the need to legally define and better protect braided river ecosystems. There is no legal definition to define the extent of a braidplain. This lack of clear legal definition means that management framework is lacking and uncertain. A clear definition and legislative protection of braided river ecosystems is required to understand what area of braidplain has been lost to agricultural encroachment, weed invasion and flood management engineering (stopbanks and willow plantings), as each of these 'controls' on river adjustment needs to be managed differently and it will help understand how to protect what is remaining.

	Recommended Management Action
1	Establish a strategic and collaborative approach to braided river management
2	Establish a strategic and collaborative approach to braided river research
3	Legally define braided river braidplains
4	Review and strengthen legal protection of braidplains

8.2 Values and threats identified across most or all braided rivers

Morphologically intact braidplains were identified as a key value within braided river systems. Braidplain constraint by land use and woody weeds were identified as the primary threats to braidplain structure and function. Understanding how controls on braidplain width alter physical river processes such as braid avulsion and sediment transport, and the subsequent impacts of changes in these processes on the functioning of braided river ecosystems was identified as a being of priority.

Several identified threats were common across most or all areas of the braided river system including animal pests, weeds and climate change. Climate change was identified as a threat to all areas of the braided river ecosystems. Climate change can have both direct and indirect impacts, including change of habitat and directly impacting cold adapted species, through increased flood magnitude and frequency, reduced frost days etc. which may result in population decline or extinction. Likely

impacts on smaller fauna include a shift in predator guild and loss of habitat from flooding or erosions.

Threat		Values threatened	Impact
1	Braidplain constraints by land use	Morphologically intact braidplain	Change in braidplain structure and function.
2	Braidplain constraints by woody weeds	Morphologically intact braidplain	Change in braidplain structure and function
2	Climate change, Animal pests, weeds.	Species, habitats, river function, natural character of river	Direct and indirect decline or loss of species and habitats. Increased flood magnitude altering river function
3	Animal pests	Species and habitats	Direct and indirect decline or loss of species and habitats.
4	Weeds	Species and habitats, natural character of river	Direct and indirect decline or loss of species and habitats.

8.3 Management and research priorities for braided river ecosystems

Priorities presented in this section are not listed in ranked order (with the exception of lizard priorities which are detailed in section 4.6). Research questions or priorities that were suggested for more than one of the topics reviewed during the process of this project are listed first with the relevant categories.

Relevant Topics		Recommended Research or Project
All flora and fauna	1	Quantify the impacts of gravel extraction on geomorphology, flora and fauna e.g. breeding success.
	2	Quantify impacts of different (increasing) recreational activities on behaviour and breeding success of threatened species.
	3	Develop more robust monitoring methods to record outcomes of management for threatened species, and assess whether the indicator species concept is useful for monitoring responses of braided river species to management and for reporting on those trends.
	4	Increase understanding of the drivers of productivity and survival of threatened species and, particularly, the interactions among threats, including: Determining interactions between predation risk, flow management and weed encroachment, and gathering accurate data on productivity and survival of threatened species populations at a range of sites to develop population viability models.
Weeds, lizards, invertebrates	1	Research the costs and benefits of weed removal and control techniques on invertebrates and lizards.
Invertebrates, native terrestrial plants	1	Assess the invertebrate values associated with native braided river vegetation types.
Invertebrates and lizards	1	Predator removal study to assess impacts of predator removal on other species (lizards and invertebrates). Prioritise hedgehogs in upper catchments, rats in lower catchments and mice anywhere that larger mammals are being removed.
Invertebrates, weeds	1	Determine the impacts of woody and herbaceous weeds on invertebrates, and the potential for recovery following weed removal.
Weeds	1	Appoint a Canterbury braided river biodiversity weed coordinator.
	2	Site specific surveillance project mobile/computer application.
	3	Effectiveness, research and development for weed control programmes.

	4	Weed control workshop or seminar. Biodiversity focus and landscape scale programs.
	5	Create regional weed control priorities and strategy for braided rivers.
	6	Create Waiau River weed action plan.
	7	Develop a better mapping system. Some work already done by ECan and Boffa-Miskell (for LINZ).
Invertebrates	1	Survey/identify the invertebrate species present in areas most susceptible to stabilisation from weeds and flow restrictions.
	2	Study the potential of southern blue butterflies to be displaced by Australian blue butterflies and identify management/mitigation strategies.
	3	Establish terrestrial invertebrate biodiversity index.
	4	Model predicted impact of future changes in rainfall gradients and temperature in the Mackenzie with focus on implications for management of robust grasshopper populations.
	5	Complete alps to ocean series of transects to understand the composition of invertebrates relative to human activity and the relative proportions of native to exotic.
	6	Existing or future predator, weed and island building projects focused on other taxa should include invertebrates to gather information on threats/mitigation methods.
	7	Develop best practice management for improving populations of, and mitigating threats to, all threatened or at risk invertebrate species (e.g. Tekapo ground wētā, mirid bug and robust grasshopper).
Lizards	1	Understand the distribution and abundance of lizards occupying the main rivers on the floor of the Mackenzie Basin.
	2	Understand the distribution and abundance of lizards occupying river margins, river mouths and adjoining wetland habitats in lowland Canterbury.
	3	Understand the distribution and abundance of lizards occupying the Waimakariri Basin braided rivers, and other poorly understood areas. A focus would be on in areas that may be affected by future land use change, climate change, or where habitat indicates highly threatened species could be present.
	4	Evaluating existing registered rodent toxins for intensive ground control efficacy for protecting lizards.
	5	Determining the drivers of mouse populations and how these impact on their predatory behaviour through monitoring of environmental characteristics, productivity and population parameters of mice and lizards for the development of a predictive management model.
	6	Investigating non-target impacts of bait deployment of baits where there is no previous experience in using it at the quantities identified for mouse control.
	7	Providing a management plan and operational tools to field operations staff to employ for localised recovery of threatened taxa.
	8	Developing a robust analysis model for field trials that will generate a predictive model and inform management triggers and responses for operational decision making.
Wetlands, river mouths, estuaries and geomorphology	1	Restoration of riparian vegetation in key sites.
	2	Determine the extent of plant communities in each habitat type.
	3	Establish a study, or series of studies, to identify and better understand hāpua/lagoon ecology.
	4	Gain a quantitative understanding of the role of landscape configuration, dispersal and succession on heterogeneity-biodiversity relationships.
	5	Develop morphological model capable of quantitatively predicting how river drivers alter the physical characteristics of braided rivers over temporal and spatial scales appropriate to management.
	6	Identify how controls on braidplain width alter physical river processes such as braid avulsion and sediment transport, and the subsequent impacts of changes in these processes on the functioning of braided river ecosystem.

	7	Gain an understanding the hydrological and ecological effects of flow intermittence (natural and anthropogenic).
	8	Create a list of all threatened and at risk species in braided river estuarine environments.
	9	Establish a best practice for incorporating ecosystem values in erosion protection work.
Native terrestrial plants	1	Threatened plant research (including data deficient species).
	2	Long-term monitoring of native riverbed plants.
	3	Impacts of nutrient accumulation/ intensive agriculture on braided riverbed plant communities.
	4	Restoration of riverbeds following large scale weed removal.
	5	Distribution, life histories, recruitment of threatened plant taxa. i.e. the information required for any recovery program for highly threatened braided riverbed plants.
	6	Interactions between birds (especially nesting birds) and riverbed plant communities. E.g. nutrient input colonies of breeding birds provide and whether there is an association with any plants as observed in the coastal region.
	7	Impacts of mammals on riverbed plant communities e.g. disturbance through trampling/burrowing, browsing and seed dispersal.
	8	Climate change research towards understanding the retreat of ecosystems.

9 References

Boffa Miskell Limited. 2019. Upper Rangitata River Ten Year Weed Plan. Report prepared by Boffa Miskell Limited for Environment Canterbury.

Chinn, W. 2011. Terrestrial invertebrate composition of the Havelock and Clyde valley floor, upper Rangitata River. *Department of Conservation Survey*. 13pp.

Forest and Bird. 2016. New Zealand Seabirds: Sites on Land, Rivers, estuaries, coastal lagoons & harbours. The Royal Forest & Bird Protection Society of New Zealand, Wellington, New Zealand.

Gray, D., Grove, P., Surman, M. and Keeling, C. 2018. Braided Rivers: natural characteristics, threats and approaches to more effective management. Environment Canterbury Technical Report No. R17/13.

Grove, P., Parker, M., Gray, D. and Behrens, F. 2015. Land use change on the margins of lowland Canterbury braided rivers, 1990-2012. Environment Canterbury Technical Report No. R15/49.

Harding, M. 2018. Rakaia riverbed Weed control Strategy. Five Year Review. Report prepared for Environment Canterbury.

Holdaway, R.J.; Wiser, S.K.; Williams, P.A. 2012: Status assessment of New Zealand's naturally uncommon ecosystems. *Conservation Biology 26*: 619–629.

Johnson, P. and Gerbeaux, P. 2004. Wetland types in New Zealand. Department of Conservation. Wellington, New Zealand.

Lill, A.W.T., Schallenberg, M., Lal, A., Savage, C., and Closs, G.P. 2012. Isolation and connectivity: Relationships between periodic connection to the ocean and environmental variables in intermittently closed estuaries. *Estuarine, Coastal and Shelf Science* 128: 76-83

McArthur, N. and Bell, M. 2016. Ashburton River/Hakatere shorebird habitat management strategy. Client report prepared for Environment Canterbury. Wildlife Management International Ltd, Blenheim.

Ministry for the Environment 1997. The State of New Zealand's Environment. Wellington, New Zealand.

Myers, S., Clarkson, B., Reeves, P., Clarkson, B. 2013. Wetland management in New Zealand: are current approaches and policies sustaining wetland ecosystems in agricultural landscapes? *Ecological Engineering* 56: 107–120.

Norbury, G. 2001. Conserving dryland lizards by reducing predator-mediated apparent competition and direct competition with introduced rabbits. *Journal of Applied Ecology* 38: 1350-1361

Norbury, G., Heyward, R. and Parkes, J. 2009. Skink and invertebrate abundance in relation to vegetation, rabbits and predators in a New Zealand dryland ecosystem. *New Zealand Journal of Ecology* 33(1): 24-31

Norbury, G, van den Munckhof, M., Neitzel, S., Hutcheon, A., Reardon, J. and Ludwig, K. 2014. Impacts of invasive house mice on post-release survival of translocated lizards. *New Zealand Journal of Ecology* 38: 2

O'Donnell, C., Sanders, M., Woolmore, C., and Maloney, R. 2016. Management and research priorities for conserving biodiversity on New Zealand's braided rivers. Department of Conservation. Wellington, New Zealand.

Peat, N., Patrick, B., and Rebergen, A. 2016. Rivers Rare: The first 25 years of Project River Recover 191-2016. Department of Conservation, Wellington.

Spitzen - van der Sluijs AM, Spitzen J, Houston D, Stumpel, AHP 2009. Skink predation by hedgehogs at Macraes Flat, Otago, *New Zealand. New Zealand Journal of Ecology* 33: 205–207.

Williams, P.A., Wiser, S., Clarkson, B., Stanley, M.C. 2007. New Zealand's historically rare terrestrial ecosystems set in a physical and physiognomic framework. *New Zealand Journal of Ecology* 31: 119-128.

Wilson, D., Innes, J. G., Fitzgerald, N.B., Bartlam, S., Watts, C. and Smale, M.C. 2018. Population dynamics of house mice without mammalian predators and competitors. *New Zealand Journal of Ecology*. 42(2): 192-203

Woolmore, C. B. 2011. The vegetation of braided rivers in the upper Waitaki basin South Canterbury, New Zealand. *Department of conservation, Canterbury Series* 0211.

Young R, Smart G, Harding J. 2004. Impacts of hydrodams, irrigation schemes and river control works In: Harding JS, Mosley P, Pearson C, Sorrell B ed. Freshwaters of New Zealand. *New Zealand Hydrological Society and New Zealand Limnological Society, Christchurch.* Pp. 37-43.

10 Appendices

Appendix 1 List of contributors and contacts for each topic.

Topic	Name	Organisation	Outcome
Terrestrial Invertebrates	Tara Murray	University of Canterbury	Contributed
	Warren Chinn	Department of Conservation	Contributed
	Brian Patrick	Wildlands Consultants	Contributed
Native Terrestrial Plants	Jane Gosden	Department of Conservation	Contributed
	Mike Harding	Consultant	Unavailable
	Kate Wardle	Consultant	Unavailable
	Dean Nelson	Department of Conservation	Unavailable Recommended John Barkla
	John Barkla	Department of Conservation	Unavailable Recommended Jane Gosden and Mike Harding
	Chris Woolmore	Department of Conservation	Unavailable Recommended Dean Nelson
	Richard Clayton	Department of Conservation	Contributed
Lizards	Lynn Adams	Department of Conservation	Contributed
	Jo Monks	Department of Conservation	Co-contributed
	Marieke Lettink	Department of Conservation	Co-contributed
Wetlands/Estuaries/River mouths/Geomorphology	Jo Hoyle	NIWA	Contributed
	Colin O'Donnell	Department of Conservation	Consulted
	Duncan Gray	Environment Canterbury	Contributed
	Hugh Robertson	Department of Conservation	Unavailable Recommended Natasha Grainger
	Helen Kettles	Department of Conservation	Contributed
	Natasha Grainger	Department of Conservation	Recommended Philippe Gerbeaux and Helen Kettles
	Philippe Gerbeaux	Department of Conservation	Unavailable
	Jason Butt	Environment Canterbury	No reply
	Andrew Crossland	Christchurch City Council	Unavailable. Recommended Colin O'Donnell, Andy Grant Frances Schmechel (all contacted), and Anita Spencer and Mike Bell (too late to contact).
Terrestrial Weed Invasion	Frances Schmechel	Environment Canterbury	Contributed
	Dean Nelson	Department of Conservation	Contributed
	Peter Raal	Department of Conservation	Contributed
	Laurence Smith	Environment Canterbury	Contacted but no form received

Appendix 2 Threatened, at risk or significant invertebrate species of Canterbury braided rivers.

Common Name	Species	Threat Status
Tekapo ground wētā	*Hemiandrus 'furoviarius'*	Nationally Critical
Ground Beetle	*Holcaspis bidentella*	Nationally Critical
Mirid bug	*Pimeleocoris roseus*	Nationally Critical
Robust grasshopper	*Brachaspis robustus*	Nationally Endangered
Small flightless moth	*Kiwaia 'plains jumper'*	Nationally Vulnerable
Moth	*Orocrambus 'Mackenzie Basin'*	Nationally Vulnerable
Moth	*Theoxena scissaria*	Nationally Vulnerable
Ground beetle	*Holcaspis falcis*	Declining
Alpine grasshopper	*Sigaus minutus*	Declining
Ground Beetle	*Megadromus Omaramae*	Relict
Lycosid spider	*Anoteropsis arenivaga*	Naturally Uncommon
Darkling beetle	*Artystona lata*	Naturally Uncommon
Grasshopper	*Brachaspis 'lowland'*	Naturally Uncommon
Tortricid moth	*Eurythecta robusta*	Naturally Uncommon
Moth	*Gadira 'black/brown' EGW*	Naturally Uncommon
Inland common robber fly	*Neoitamus smithii*	Naturally Uncommon
Hemiptera: Lygaeidae	*Nysius liliputanus*	Naturally Uncommon
Scarab beetle	*Prodontria minuta*	Naturally Uncommon
Stiletto fly	*Anabarhynchus albipennis*	Data Deficient
Wolf spider	*Anoteropsis alpina*	Data Deficient
Sheet web spider	*Cambridgea elegans*	Data Deficient
Ground weta	*Hemiandrus furcifer*	Data Deficient
Tunnelweb spider	*Hexathele cantuaria*	Data Deficient
Ground spider	*Matua festiva*	Data Deficient
Ground beetle	*Megadromus sp. 11 'Benmore'*	Data Deficient
Moth	*Orocrambus sophronellus*	Data Deficient
Scarab beetle	*Prodontria 'Ben Ohau'*	Data Deficient
Hemiptera: Lygaeidae	*Rhypodes triangulus*	Data Deficient
New Zealand/southern blue butterfly	*Zizina labradus oxleyi*	Not Threatened

Appendix 3 Current projects identified by contributors for geomorphology, wetlands, estuaries and river mouths.

Project Title	Objective	Organisation	Timeframe
BRIDGE	Define all braided river riverbeds.	ECan	Uncertain
BRAG ownership on braided rivers	Determine and rationalize land.	ECan/DOC/LINZ	
ECan habitat monitoring	Mapping braidplain constraints and habitat change over time.	ECan	Ongoing
Hapua morphology: River-mouth lagoon response to changing river flow regime, sediment supply, wave climate and sea-level	Understanding hāpua dynamics.	NIWA/UC– Richard Measures PhD	2017-2020

Appendix 3 continued

Project Title	Objective	Organisation	Timeframe
Managing bed levels and flood risk in braided rivers: does conventional channel confinement theory fail by neglecting key sediment transport processes?	To develop a new theory of sediment transport in braided rivers that includes the contribution of transient morphological events and associated bedload "bursts".	NIWA – Gu Stecca Marsden Fast Start project	2019-2021
Various investigations relating to Waitaki Power Scheme reconsenting		Meridian Contact Jeff Page	2017-2023
Hurunui vegetation surveillance	Monitoring relationships between flows, geomorphic change and braided river weeds.	NIWA Strategic Science Investment Funding	2018-2019
Drone flow	Measuring flow in rivers remotely using drones.	NIWA – MBIE Smart Idea project	2019-2021
Effects of flood harvesting on fine sediment deposition in the Rangitata River	Understanding the impacts of changes in flow regime on fine sediment deposition in braided rivers.	NIWA project	2018-2020

Appendix 4 Threatened or at risk native terrestrial plants in braided river systems.

Value Type (e.g. species/habitat)	Common Name/Description	Species Name	Threat Ranking
Habitat	Ephemeral wetlands	Threatened ecosystem	Critically Endangered
Habitat	Seepages & flushes	Threatened ecosystem	Endangered
Habitat	Estuaries	Threatened ecosystem	Vulnerable
Habitat	Lagoons	Threatened ecosystem	Endangered
Habitat	Braided River beds	Threatened ecosystem	Endangered
Species		*Olearia adenocarpa*	Nationally Critical
Species		*Raoulia* (a) (CHR 79537; "K")	Nationally Critical
Species		*Craspedia* (p) (CHR 469073; Havelock River)	Nationally Endangered
Species		*Helichrysum dimorphum*	Nationally Endangered
Species		*Carmichaelia juncea*	Nationally Vulnerable
Species		*Convolvulus verecundus*	Nationally Vulnerable
Species		*Myosurus minimus subsp. novae-zelandiae*	Nationally Vulnerable
Species		*Pimelea sericeovillosa subsp. pulvinaris*	Nationally Vulnerable
Species		*Raoulia monroi*	Nationally Vulnerable
Species		*Myosotis uniflora*	Naturally Uncommon
Species		*Stenostachys deceptorix*	Naturally Uncommon
Species		*Stellaria elatioides*	Extinct

Appendix 5 Existing weed control programmes on Canterbury braided rivers.

Location	Target Weed Species	Frequency	Organisation
Rakaia River	False tamarisk (*Myricaria germanica*)	Trial to find and effective herbicide control method	DOC
Twizel	Russell lupin (*Lupinus polyphyllus*)	Trial to find herbicide control method with residuality properties to suppress seed germination	DOC
Ohau River Twizel	All weed (and native) species	Trial and operational to control weeds and prevent them from re-establishing to benefit native animal species.	DOC (and Clutha Fisheries Trust)
Twizel	*Salix* species and other large woody weeds, e.g. alders and poplars	Trial to find effective herbicide for drilling and filling willows and other large woody weeds	DOC
Twizel River	*Erythranthe guttata* Monkey musk	Trial to find and effective herbicide control method of monkey musk for galaxias fish	DOC
Godley/Macaulay Rivers	Russell lupin, broom, gorse, willow, wilding conifer and false Tamarisk	Annually	Project River Recovery (PRR) (DOC)
Cass River	Russell lupin, broom, gorse, willow, wilding conifer and false Tamarisk	Annually	Project River Recovery (DOC)
Fork Stream	Russell lupin, broom and willow in the lower reaches	Annually	Project River Recovery (DOC)
Tekapo River	Russell lupin, broom, gorse, willow, wilding conifer in upper reaches	Annually	LINZ, ECan and Project River Recovery (DOC)
Tasman River	Russell lupin but some willow, broom, false Tamarisk and wilding conifer	Annually	Project River Recovery (DOC)
Lake Tekapo shoreline	Russell lupin, willow	Partially started, will become annual	Project River Recovery (DOC)
Ahuriri River	Russell lupin, willow	Annually in the upper reaches	Project River Recovery (DOC)
Ohau River	Russell lupin, willow, broom, wilding conifer	Annually	Project River Recovery (DOC)
Lower Waitaki River cleared islands	Gorse and broom plus any other weeds	Annually	DOC Geraldine
Upper Rangitata/Ashburton basin	Various weed species including gorse and broom	Annually	O Tu Wharekai, ECan, LINZ, Tas and the Landcare group funding.
Clarence River Catchment	Various woody weeds and Russell lupin	Annually (approx.)	Kaikoura Zone Committee, ECan
Upper Rakaia	Various woody weed species and Russell lupin	Annually	ECan, LINZ, DOC
Approx. 60 rivers and drains, primarily on the Canterbury plains	Woody weeds on larger rivers, and any weeds that obstruct flow in smaller streams	Approx. 5 years on larger rivers, smaller streams vary with conditions	ECan River Engineering