# Management and research priorities for conserving biodiversity on New Zealand's braided rivers

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New Zealand Government

Department of Conservation
*Te Papa Atawhai*

Cover: Rangitata River, Canterbury. *Photo: Colin O'Donnell.*

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# Summary

The distinguishing feature of braided rivers is that they have, over at least some part of their length, multiple, mobile channels that flow across a gravel floodplain. Braided rivers occur widely in New Zealand, but particularly in the South Island. Features characteristic of braided rivers include flowing channels, backwaters, seepages and associated spring creeks as well as terrestrial islands, shingle bars, lake deltas and adjacent flood plain terraces.

Braided rivers in New Zealand support unique communities of plants and animals and many threatened species. However, these communities are subject to a number of threats, particularly predation, weed invasion, water abstraction, dams, modified flow regimes for electricity generation, flood protection works and human recreational activities on rivers. The result of these activities is that biodiversity values in braided rivers are in decline. However, in recent years, public awareness of the biodiversity values of braided rivers and threats to these values has increased. The number of initiatives to undertake conservation work within braided rivers has likewise increased. At the same time, greater demands are being placed on braided rivers, particularly as sources of water for irrigation and hydro development, but also for gravel extraction and recreational purposes such as jet-boating, four-wheel driving and fishing.

The vision for biodiversity recovery is that New Zealanders will value and enjoy braided river ecosystems as a unique and integral part of their natural heritage. People with an interest in conservation, management or use of braided rivers will support ongoing, sustainable local conservation programmes, and these will be demonstrably successful in maintaining and improving indigenous biodiversity of braided rivers. This document emphasises ecosystem and multi-species approaches to addressing the decline in biodiversity values, with a focus on conserving indigenous species that specifically depend on braided rivers (including a range of threatened species).

Current knowledge of the biodiversity values of braided rivers and the conservation management of these values is extensive. However, there is a clear need to improve conservation outcomes for braided river ecosystems and species through the development of a better understanding of the ecology of braided rivers and the development of more-effective management tools. This document aims to assist this process by providing guidance on current 'good practice' for managing biodiversity on and in braided rivers, priorities for management and future research, and by promoting co-operation among a range of stakeholders (including all levels of government, institutions, iwi, community groups, and local people and businesses) to conserve braided river ecosystems and species.

Specifically, this document:

- Describes a vision for the conservation of biodiversity on braided rivers.
- Provides an overview of the biodiversity values of braided rivers and the factors that influence them, in the context of conservation of indigenous biodiversity, and particularly threatened species.
- Summarises current 'good practice' for managing biodiversity on braided rivers and uses a range of case studies as examples.
- Identifies and prioritises specific management and future research actions in relation to the main threats that directly impact braided river biodiversity.

# 1. Introduction

## 1.1 Purpose and scope of this document

The overall purpose of this document is to improve conservation outcomes for braided river species and ecosystems by providing high-level guidance on research and management priorities, by promoting active management initiatives, and by fostering co-operation and collaboration amongst the range of people and organisations with interests in braided rivers, including all levels of government, universities and other research agencies, iwi, community groups, local people and businesses.

This document is not a recreation guide, integrated management plan, specific planning resource, bibliography or review of everything that is known about the biodiversity of braided rivers or the threatened species that occur on them, although it does provide references to key braided river information sources. Neither does it include individual species action plans or plans of what should be done on specific river reaches (site-specific management plans).

Rather, this document is intended to provide assistance in the future development of site or species management plans. It is also intended to complement the growing number of other documents focussed on braided river biodiversity management, such as those developed by regional councils and other organisations. It seeks to encourage a holistic approach to the conservation of braided river biodiversity, because management actions are highly likely to affect the various biotic and abiotic components of these systems in complex, interacting ways.

This document:

- Describes a vision for the conservation of biodiversity on braided rivers (Section 1).
- Provides an overview of our current state of knowledge of the biodiversity and conservation of braided rivers including threatened species, the threats biodiversity faces, and people's interests in braided river conservation (Section 2).
- Summarises current 'good practice' for managing biodiversity on braided rivers (Section 3) and uses a range of case studies as examples.
- Identifies and sets priorities for specific management and research actions in relation to the main threats and other factors that directly influence braided river species and ecosystems (Section 4).

## 1.2 Vision

The vision promoted in this document is that:

> New Zealanders will enjoy and care for braided river ecosystems as a distinctive a valued part of their natural heritage. Stakeholders will support ongoing, sustainable conservation programmes, and these will be demonstrably successful in maintaining and improving the indigenous biodiversity of braided rivers.

# 2. Overview of braided river biodiversity conservation

## 2.1 General context

A braided river can be defined as one that, over some part of its length, flows in multiple, mobile channels across a gravel floodplain (Gray & Harding 2007) (Figs. 1 & 2). River channels are diverse in size and flow characteristics, ranging from fast-flowing rapids and torrents to broken water (riffles) in rocky or shallow channels of the river to quiet runs and backwaters where the water is slow flowing and calm and seepage zones where subterranean water re-enters river channels (Fig. 3). The number of rivers that remain relatively unmodified and the high level of endemism in the plants and animals that inhabit them mean our braided river ecosystems are regarded as being exceptional on a global scale (O'Donnell & Moore 1983; Gray & Harding 2007). Braided rivers 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 rivers (Fig. 4).

Figure 1. Image of typical braided river habitat: The upper Rangitata River, Canterbury. *Photo: Peter Langlands ©Wild Capture.*

Figure 2. An oblique view of the Cass River, Mackenzie Basin, showing the active gravel river bed and multiple channels and a spring creek meandering through herbfield-dominated terraces along the river margins. *Photo: Colin O'Donnell.*






Figure 3. Close ups of A. a large channel rapid where it enters the quieter waters of a run (Wairau River), B. small channel shallow riffles of broken water forming complex channel patterns (Rangitata River), C. unbroken water in a major channel run (Wairau River), D. backwater of still water off a main channel (Wairau River), E. seepage zone where subterranean water reaches the surface on the edge of a channel (Wairau River). *Photos: Colin O'Donnell*


Figure 4. Image of DOC's braided river poster showing the range of species that use braided river habitats. *Artwork by Simone End.*

In New Zealand, more than 300 rivers are braided on at least some of their sections (D. Brown pers. comm.). Despite their number, braided rivers of the type found in New Zealand are considered naturally rare ecosystems (Williams et al. 2007). Collectively, areas of braided river in New Zealand cover > 250 000 ha (Table 1), although this total represents only c. 0.9% of the country's total land area. While such rivers can be found through much of the country, most are in the South Island, particularly Canterbury (64%), as well as the West Coast (15%), Marlborough (8%), Southland (4%) and Otago (7%) (Table 1). The remainder are in the North Island on rivers in the Manawatu and Hawkes Bay regions (and they tend to be smaller than those in the South Island (Table 1; Wilson 2001)). Further, they are internationally rare, with only the North American continent and parts of the Arctic and Asia having similar river systems (Miall 1977; O'Donnell & Moore 1983; Gray & Harding 2007).

Table 1. Extent of terrestrial braided river habitats in New Zealand (From Department of Conservation Draft Rare Ecosystems Database). Note: these data are indicative only because mapping the precise extent of braided rivers depends on the precision of base data and spatial definition of habitat types. This mapping was based on examination of NZMG 260 topovectors (Land Information New Zealand), Wilson (2001), digitisation from air photography and expert advice.

| REGION | ACTIVE RIVERBED[1] (ha) | RECENT FLOODPLAIN[2] (ha) | TOTAL AREA (ha) | % |
|---|---|---|---|---|
| Canterbury | 103103 | 61067 | 164170 | 63.9 |
| Nelson-Marlborough | 16614 | 4265 | 20879 | 8.1 |
| North Island | 5511 | 152 | 5663 | 2.2 |
| Otago | 13181 | 4327 | 17508 | 6.8 |
| Southland | 4926 | 5097 | 10023 | 3.9 |
| West Coast | 28127 | 10736 | 38863 | 15.1 |
| Total | 171462 | 85644 | 257106 | 100.0 |

1 'Active riverbed': areas of unstable gravels and flowing channels.

2 'Recent floodplain': flat land either side of the active riverbed. Floodplains may be reactivated if rivers change their course or may be flooded in the highest floods.

Braided rivers are highly unstable, with mobile beds (Fig. 5). They are characterised by high spring to early summer flows, frequent flooding and rapid substrate deposition that control the establishment and survival of plants across extensive floodplains (sometimes many kilometres wide). Braided river floodplains develop mosaics of different-aged vegetation, spring-fed tributaries and wetlands (Fig. 6) on the river margins, which are progressively reworked by active channels, forming new networks of bare shingle bars, sparsely vegetated recent flood channels and flowing braids (Miall 1977; Gray & Harding 2007) (Fig. 7). They have numerous islands and multiple and dynamic channels of different sizes that frequently change their location and characteristics. The constantly changing channels result in braided river systems having highly diverse aquatic habitats and invertebrate species (Gray et al. 2006).

Figure 5. Active river bed surfaces after a recent flood, illustrating small silt deposits and bare shingle islands (upper Ashburton River). *Photo: Colin O'Donnell*

Figure 6. Mt Sunday wetland, an example of a wetland fed by springs and linked to the upper Rangitata River. *Photo: Jane Sedgeley*





Figure 7. A. semi-stable islands and low terraces with scattered vegetation adjacent to active channels on the Ashburton River and B. old, stable terraces with lichen, herbfield and scattered indigenous shrubs on the north side of the upper Ashburton River provide nesting sites for banded dotterels and South Island pied oystercatchers. *Photos: Colin O'Donnell*

Braided rivers are under threat from multiple sources, including introduced predators, weed invasion, water abstraction, nitrification, dams, modified flow regimes associated with electricity generation, river protection works, gravel extraction and human disturbance. In recent years, public awareness of the biodiversity values of braided rivers and the threats they face has increased dramatically, particularly with respect to rivers east of the Southern Alps in the South Island. At the same time, human demands on braided rivers have been increasing, particularly as sources of water for irrigation and hydroelectric power development, but also for development of arable land, gravel extraction, and recreational purposes such as jet-boating, four-wheel driving and fishing. In addition, changes in adjacent land use may be having impacts on rivers.

In response to concerns about the growing threats faced by braided rivers, a number of conservation programmes have been initiated by community groups in recent years (e.g. the Ashley/Rakahuri Rivercare Group, the Rangitata Gorge Landcare Group and the Orari River Protection Group). Several of these programmes are jointly managed with regional councils (e.g. Canterbury Water Management Strategy 'Immediate Steps' Braided River flagship programme; see Box 1). Conservation programmes have also arisen as a result of mitigation in

## BOX 1: Environment Canterbury's Immediate Steps programme

Environment Canterbury's (ECan's) Immediate Steps funding programme, which is part of the Canterbury Water Management Strategy, aims to protect and restore freshwater-influenced ecosystems.

The Regional Committee (Canterbury Water Management Strategy—CWMS) has used this programme to allocate $540,000 over 5 years for the upper Rakaia and Rangitata Rivers. These catchments were chosen in part because of their importance for breeding wrybills and other braided river bird species.

Community members at an Ecan workshop discuss options and priorities for biodiversity conservation in their area. *Photo: Frances Schmechel*

This weed control work is funded jointly by DOC, Land Information New Zealand (LINZ) and local runholders as part of Landcare Groups they have formed, and the Immediate Steps funding (Braided River Regional Flagship).

For further information: [http://ecan.govt.nz/advice/biodiversity/funding/pages/immediate-steps.aspx](http://ecan.govt.nz/advice/biodiversity/funding/pages/immediate-steps.aspx)

The key outcomes sought from the programme are to maintain and enhance the open braided river landscape, enhance bird nesting opportunities and protect and enhance wetlands and tributaries.

ECan worked with local community and stakeholders to develop priorities for the programme. One of the key priority actions agreed to was weed control. Immediate Steps is contributing approximately $70,000 per year towards weed control across the two catchments over the next 5 to 10 years.

Inspection of management area decided on for weed control in the upper Rangitata catchment 2011–12. *Photo: Francis Schmechel*

response to Resource Management Act decisions, such as gravel extraction companies working with Environment Canterbury and the Department of Conservation (DOC) to develop codes of practice to minimise the impacts of their activities on breeding birds.

The increased awareness, desire and resources to undertake conservation work on braided rivers are presenting good opportunities to achieve conservation gains. However, research and management activities since the late 1970s have revealed that understanding and managing the problems facing braided river communities is complex and challenging (Keedwell et al. 2002a; Cameron et al. 2005; O'Donnell & Hoare 2011; Woolmore 2011). It is clear that there is still much we don't know about the composition of, and relationships among, all the component parts within braided river ecosystems, and that there are no easy solutions to many of the problems that have been identified.

It is therefore essential that both ongoing and new research and management are well-directed and informed by the work undertaken to date. Braided river management is more likely to be beneficial and cost-effective, and less likely to cause unintended harm, if the people commissioning or undertaking research work or management actions understand the current state of knowledge about braided rivers, and the key threats and management issues facing them.

## 2.2 Biodiversity of braided rivers

Biodiversity describes the richness of plant and animal life in an environment. Braided rivers provide habitat for more than 80 bird species, some of which are threatened (e.g. kakī/black stilt *Himantopus novaezelandiae*, black-fronted tern *Chlidonias albostriatus*, black-billed gull *Larus bulleri*, wrybill plover *Anarhynchus frontalis*, banded dotterel *Charadrius bicinctus*) (Fig. 8, Table 2). About 20 wetland bird species are characteristic of braided rivers and are found widely on them (O'Donnell & Moore 1983). These birds have specialised adaptations for living on rivers, including specialised morphological features (e.g. the side-ways bend on the wrybill's bill), foraging behaviours, breeding behaviours and migration patterns (Lalas 1977; Pierce 1979; O'Donnell & Moore 1983; Robertson et al. 1983; Hughey 1985; O'Donnell 2000a, 2004). Many birds and some fish are migratory, not spending their whole lives on or in braided rivers.




Figure 8. Examples of threatened bird species of braided rivers. A. black-billed gull *Larus bulleri* – Nationally Critical; B. black-fronted tern *Chlidonias albostriatus* – Nationally Endangered; C. wrybill plover *Anarhynchus frontalis* – Nationally Vulnerable. *Photos: Peter Langlands ©Wild Capture*

Table 2. Examples of threatened species on braided rivers. This is not an exhaustive list, but demonstrates the range of threatened taxa and their dependence on braided river habitats.

| THREAT STATUS[1] | COMMON NAME | SCIENTIFIC NAME | TYPE | DEPENDENCE ON BRAIDED RIVERS[2] | USE[3] | MAIN THREATS | BREEDING DISTRIBUTION ON BRAIDED RIVERS |
|---|---|---|---|---|---|---|---|
| Nationally Critical | Kakī/black stilt | *Himantopus novaezelandiae* | Bird | Primary | F,B,S | Predation<br>Habitat loss | Mackenzie Basin (remnant range) |
| Nationally Critical | Black-billed gull | *Larus bulleri* | Bird | Obligate | F,B,S | Predation<br>Habitat loss<br>Human disturbance | Throughout South Island |
| Nationally Critical | Grey duck | *Anas superciliosa* | Bird | Facultative | F,B,S | Hybridisation | Throughout South Island |
| Nationally Critical | Long-tailed bat | *Chalinolobus tuberculatus* | Bat | Facultative | F | Predation | South Canterbury, Otago, Southland |
| Nationally Critical | Lowland longjaw galaxias (Kakanui River) | *Galaxias cobitinis* | Fish | Obligate | F, B, S | Habitat loss<br>Predation | Kakanui River |
| Nationally Critical | Waitaki lowland longjaw galaxias | *Galaxias* aff. *cobitinis* "Waitaki" | Fish | Primary | F,B,S | Habitat loss | Waitaki River |
| Nationally Critical | Olearia | *Olearia adenocarpa* | Plant | Obligate | | Habitat loss | Two rivers in Canterbury |
| Nationally Endangered | Black-fronted tern/ tarapiroe | *Chlidonias albostriatus* | Bird | Obligate | F,B,S | Predation<br>Habitat loss<br>Human disturbance | Eastern South Island |
| Nationally Endangered | Australasian bittern/ matuku | *Botaurus poiciloptilus* | Bird | Facultative | F | Predation<br>Habitat loss | Throughout |
| Nationally Endangered | Robust grasshopper | *Brachaspis robustus* | Invertebrate | Primary | F,B,S | Predation<br>Habitat loss | Mackenzie Basin |
| Nationally Endangered | Central Otago roundhead galaxias | *Galaxias anomalus* | Fish | Faculative | F, B, S | Predation<br>Habitat loss | Clutha and Taieri Rivers |
| Nationally Endangered | Alpine galaxias (Manuherikia River) | Galaxias aff. *paucispondylus* "Manuherikia" | Fish | Obligate | F, B, S | Predation<br>Habitat loss | Manuherikia River |
| Nationally Endangered | Hector's tree daisy | *Olearia hectori* | Plant | Facultative | | | South Island |
| Nationally Vulnerable | Wrybill plover/ ngutuparore | *Anarhynchus frontalis* | Bird | Obligate | F,B,S | Predation<br>Habitat loss | Eastern South Island |
| Nationally Vulnerable | Banded dotterel/ tuturiwhatu | *Charadrius bicinctus* | Bird | Primary | F,B,S | Predation<br>Habitat loss | Eastern South Island |
| Nationally Vulnerable | Blue duck/whio | *Hymenolaimus malachorhynchos* | Bird | Facultative | F,B,S | Predation | South Island |

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*Table 2 continued*

| THREAT STATUS[1] | COMMON NAME | SCIENTIFIC NAME | TYPE | DEPENDENCE ON BRAIDED RIVERS[2] | USE[3] | MAIN THREATS | BREEDING DISTRIBUTION ON BRAIDED RIVERS |
|---|---|---|---|---|---|---|---|
| Nationally Vulnerable | Pied shag/karuhiruhi | *Phalacrocorax varius* | Bird | Facultative | F,S | Coastal habitat loss | South Island |
| Nationally Vulnerable | Red-billed gull/ tarapunga | *Larus novaehollandiae* | Bird | Facultative | B,S | Coastal habitat loss | Eastern South Island |
| Nationally Vulnerable | Caspian tern/taranui | *Hydroprogne caspia* | Bird | Facultative | F,B,S | Coastal habitat loss | Eastern South Island |
| Nationally Vulnerable | Taieri flathead galaxias | *Galaxias depressiceps* | Fish | Faculative | F,B,S | Predation<br>Habitat loss | Taieri River |
| Nationally Vulnerable | Gollum galaxias | *Galaxias gollumoides* | Fish | Faculative | F,B,S | Predation<br>Habitat loss | Southland and southern Otago |
| Nationally Vulnerable | Bignose galaxias | *Galaxias macronasus* | Fish | Primary | F,B,S | Habitat loss | Waitaki River |
| Nationally Vulnerable | Upland longjaw galaxias (Canterbury, West Coast) | *Galaxias prognathus* | Fish | Obligate | F,B,S | Habitat loss | Rakaia, Rangitata, Hurunui, Maruia |
| Nationally Vulnerable | Shortjaw kokopu | *Galaxias postvectis* | Fish | Facultative | F,B,S | Habitat loss | Throughout |
| Nationally Vulnerable | Lamprey | *Geotria australis* | Fish | Facultative | F,B,S | Habitat loss | Throughout |
| Nationally Vulnerable | Alpine galaxias (Southland) | *Galaxias* aff. *paucispondylus* "Southland" | Fish | Obligate | F,B,S | Predation<br>Habitat loss | Waiau, Oreti, Mataura, Clutha |
| Nationally Vulnerable | Upland longjaw galaxias (Waitaki) | *Galaxias* aff. *prognathus* (Waitaki) | Fish | Obligate | F,B,S | Habitat loss<br>Predation | Waitaki River |
| Nationally Vulnerable | Northern flathead galaxias (Marlborough, Nelson, West Coast) | *Galaxias* "northern" | Fish | Obligate | F,B,S | Habitat loss<br>Predation | Marlborough, Nelson, West Coast |
| Nationally Vulnerable | Scree skink | *Oligosoma waimatense* | Lizard | Primary | F,B,S | Predation<br>Habitat loss | Canterbury |
| Nationally Vulnerable | Wire broom | *Carmichaelia juncea* | Plant | Primary | | Habitat loss | South Westland, Canterbury, NW Nelson |
| Declining | South Island pied oystercatcher/torea | *Haematopus finschi* | Bird | Primary | F,B,S | Predation | Eastern South Island |
| Declining | Pied stilt/poaka | *Himantopus leucocephalus* | Bird | Facultative | F,B,S | Predation | Eastern South Island |
| Declining | White-fronted tern/tara | *Sterna striata* | Bird | Facultative | F,B,S | Predation<br>Coastal habitat loss | Eastern South Island |
| Declining | NZ pipit/pihoihoi | *Anthus novaeseelandiae* | Bird | Facultative | F,B,S | Predation<br>Habitat loss | Throughout |

*Continued on next page*

*Table 2 continued*

| THREAT STATUS[1] | COMMON NAME | SCIENTIFIC NAME | TYPE | DEPENDENCE ON BRAIDED RIVERS[2] | USE[3] | MAIN THREATS | BREEDING DISTRIBUTION ON BRAIDED RIVERS |
|---|---|---|---|---|---|---|---|
| Declining | Longfin eel | *Anguilla dieffenbachii* | Fish | Facultative | F,B,S | Habitat loss | Throughout |
| Declining | Torrentfish | *Cheimarrichthys fosteri* | Fish | Facultative | F,B,S | Habitat loss | Throughout |
| Declining | Dwarf galaxias (West Coast) | *Galaxias divergens* | Fish | Primary | F,B,S | Habitat loss | East Coast + North Island |
| Declining | Giant kokopu | *Galaxias argenteus* | Fish | Facultative | F,B,S | Habitat loss | Throughout |
| Declining | Koaro | *Galaxias brevipinnis* | Fish | Facultative | F,B,S | Habitat loss | Throughout |
| Declining | Inanga | *Galaxias maculatus* | Fish | Facultative | F,B,S | Habitat loss | Throughout |
| Declining | Bluegill bully | *Gobiomorphus hubbsi* | Fish | Primary | F,B,S | Habitat loss | Throughout |
| Declining | Redfin bully | *Gobiomorphus huttoni* | Fish | Facultative | F,B,S | Habitat loss | Throughout |
| Declining | Dwarf galaxias (Nelson, Marlborough, and North Island) | *Galaxias* aff. *divergens* "northern" | Fish | Obligate | F, B, S | Predation<br>Habitat loss | Nelson, Marlborough, and North Island |
| Declining | Southern flathead galaxias (Southland) | *Galaxias* "southern" | Fish | Obligate | F, B, S | Predation<br>Habitat loss | Southland |
| Declining | | *Luzula celata* | Plant | Facultative | | Habitat loss | South Marlborough, Canterbury, Otago |
| Declining | Canterbury gecko | *Woodworthia* cf. *brunnea* | Lizard | Facultative | F,B,S | Predation<br>Habitat loss | Canterbury |
| Declining | Jewelled gecko | *Naultinus gemmeus* | Lizard | Facultative | F,B,S | Predation<br>Habitat loss | Canterbury |
| Declining | Southern long-toed skink | *Oligosoma* aff. *longipes* "southern" | Lizard | Primary | F,B,S | Predation<br>Habitat loss | Canterbury |
| Declining | Common skink (Clades 4 & 5) | *Oligosoma* aff. *polychroma* | Lizard | Facultative | F,B,S | Predation<br>Habitat loss | South Island |
| Declining | Green skink | *Oligosoma chloronoton* | Lizard | Facultative | F,B,S | Predation<br>Habitat loss | Otago, Southland |
| Declining | Spotted skink (3 taxa) | *Oligosoma* aff. *lineoocellatum* | Lizard | Facultative | F,B,S | Predation<br>Habitat loss | Canterbury, Marlborogh |
| Declining | | *Pimelea sericeovillosa* subsp. *pulvinaris* | Plant | Facultative | | Habitat loss | South Canterbury<br>Central Otago |
| Declining | | *Raoulia monroi* | Plant | Facultative | | Habitat loss | South Marlborough, Canterbury, Otago |

*Continued on next page*

*Table 2 continued*

| THREAT STATUS[1] | COMMON NAME | SCIENTIFIC NAME | TYPE | DEPENDENCE ON BRAIDED RIVERS[2] | USE[3] | MAIN THREATS | BREEDING DISTRIBUTION ON BRAIDED RIVERS |
|---|---|---|---|---|---|---|---|
| Declining | Wolf spider | *Anoteropsis arescens* | Invertebrate | Primary | | Habitat loss | Eastern South Island |
| Naturally Uncommon | Alpine galaxias | *Galaxias paucispondylus* | Fish | Obligate | F, B, S | Predation<br>Habitat loss | Canterbury, Marlborough, West Coast |
| Naturally Uncommon | Stokell's smelt | *Stokellia anisodon* | Fish | Faculative | B, S | Predation<br>Habitat loss | Canterbury |
| Naturally Uncommon | | *Craspedia* "Havelock River" | Plant | Obligate | | Habitat loss | South Canterbury - Rangitata River |
| Naturally Uncommon | | *Myosotis uniflora* | Plant | Obligate | | Habitat loss | South Canterbury |
| Naturally Uncommon | | *Leptinella serrulata* | Plant | Facultative | | Habitat loss | Eastern South Island |
| Naturally Uncommon | Grasshopper | *Sigaus minutus* | Invertebrate | Primary | F,B,S | Habitat loss | Otago, Mackenzie Basin |
| Naturally Uncommon | Wolf spider | *Anoteropsis arenivaga* | Invertebrate | Primary | F,B,S | Habitat loss | Eastern South Island |

1 Sources of threat classifications: de Lange et al. 2013; Robertson et al. 2013; O'Donnell et al. 2010; Goodman et al. 2010, Hitchmough et al. 2013, W. Chinn pers. comm.

2 Dependence on braided rivers: Obligate = and specialist user of braided rivers, dependent on the habitat for at least part of its life cycle and a key focal species of this strategy. Primary = Lives in a range of habitats but braided rivers are an important habitat; Facultative = Can occur incidentally in braided rivers but is not dependent on it.

3 Use code: F = Feed, B = Breed, S = Shelter

Figure 9. The threatened upland longjaw galaxias *Galaxias prognathus* – Nationally Vulnerable. *Photo: Simon Elkington*

Figure 10. Robust grasshopper *Brachaspis robustus* – Nationally Endangered. *Photo: Warren Chinn*

The occurrence of indigenous freshwater fish in braided rivers is also relatively well known (McDowell 1990, 2000), including the distribution of 31 threatened species (Fig. 9, Table 2; Goodman et al. 2014). In fact, the majority of threatened fish in New Zealand occur in braided rivers, and new genetic lineages continue to be recognised (e.g. Waters & Wallis 2001; Waters & Craw 2008).

How indigenous plants, bats, reptiles and terrestrial and freshwater invertebrates (Figs 10 & 11) use braided rivers is less well known, largely because there have been few comprehensive studies carried out (O'Donnell 2000b; Woolmore 2011; Grainger et al. 2014). Studies of animals and plants in and on braided rivers invariably identify previously undescribed species, new locations of threatened species, new nationally important populations as well as contributing to a better understanding of community assemblages and relationships (e.g. braided river springs; Gray 2006). For example, a recent survey of terrestrial invertebrates on islands and floodplain terraces on the Tasman River recorded 20 new taxa (1 beetle, 18 flies, 1 bee). This result is not surprising when so little invertebrate research has been carried out in terrestrial braided river ecosystems (S. Anderson pers. comm.).

Figure 11. Examples of threatened plants – A. *Luzula celata*, B. *Myosotis uniflora*. *Photos: Chris Woolmore*

## 2.3 Conservation status of braided river flora and fauna

Many of the endemic plant and animal species present in braided river ecosystems are declining and more than 30 species are classified under the New Zealand Threat Classification System (Townsend et al. 2008) as Threatened or At Risk (Table 2; Goodman et al. 2013; O'Donnell et al. 2010; de Lange et al. 2013; Robertson et al. 2013). However, this number will be an underestimate given the poor state of our knowledge of the population status and distribution of terrestrial and

aquatic invertebrates, lizards and plants on braided rivers. Of particular concern are obligate or primary species (see Table 2) that depend on braided rivers for their continued survival (e.g. robust grasshopper *Brachaspis robustus* (Fig. 10), upland longjaw galaxias *Galaxias prognathus* (Waitaki River), lowland longjaw galaxias *Galaxias cobitinis* (Kakanui River), alpine galaxias *Galaxias paucispondylus*, kakī/black stilt, wrybill, black-fronted tern, black-billed gull and banded dotterel; Table 2; Pierce 1979; Rebergen et al. 1998; Maloney 1999; O'Donnell 2000a; Keedwell et al. 2002b; Sanders & Maloney 2002; Keedwell 2005; McClellan 2009; McDowall 2010).

Some recent freshwater bird colonists appear to be stable or expanding in abundance and distribution on braided rivers, notably black-fronted dotterels *Elseyornis melanops* and spur-winged plovers *Vanellus miles*. Pied stilts *Himantopus leucocephalus* have been highly successful colonists since the mid-1800s (Pierce 1986), although they are now considered to be declining (Robertson et al. 2013).

## 2.4 Significance and protection of braided river ecosystems

Braided rivers are classified as endangered ecosystems (Holdaway et al. 2012) and all are considered ecologically significant to varying degrees, being locally, regionally or nationally significant (O'Donnell & Moore 1983; O'Donnell 2000a). While the values of braided rivers are being increasingly recognised in statutory planning and regulatory processes; overall, they are very poorly represented in protected natural areas. Few braided rivers have been formally protected, except where high-altitude reaches are included in national parks (e.g. Murchison, upper Tasman, Godley and Waimakariri Rivers) or through local amenity reserves where protection is piecemeal and ad hoc. The waters of some nationally significant rivers are protected by National Water Conservation Orders (e.g. Rakaia, Rangitata and Ahuriri Rivers), which place controls on the damming and abstraction of water, while others have similar restrictions on water use placed on them via Environment Court planning decisions (e.g. Hurunui River).

## 2.5 Human-related factors that threaten braided rivers

Braided rivers have been, and continue to be, influenced by a number of human-related factors, many of which pose threats to braided river species and ecosystems. In many cases these threats are key drivers of decline in threatened species populations and ecosystem integrity. In particular:

- Predation and disturbance by introduced mammalian predators and native avian predators (numbers of the latter appear to be high as a result of recent land use changes)
- Predation of native fish by introduced fish species leading to population fragmentation and loss of diversity
- Invasive terrestrial and aquatic species, which threaten habitat integrity and food webs, and displace species
- Altered flow regimes and creation of impoundments which change flow patterns and, in some cases, destroy preferred habitats and threaten food availability
- Water abstraction (leads to increased dewatering affecting instream habitat as well as groundwater, floodplain springs and wetlands)
- River control works (stop banks, willow planting, channelisation, bridge abutments, gravel extraction) that channel, stabilise and modify habitats
- Recreational activities (e.g. 4WD vehicle use, fishing, dog walking), which disturb or kill wildlife and reduce habitat quality
- Water quality – elevated nutrient levels from increased nutrient inputs from surrounding catchments causing excessive algal growths, which can alter aquatic invertebrate and fish communities. Under certain conditions, algal species that produce toxins may dominate, affecting recreational use of waterways

The flow regime of a river has a strong direct influence on its physical structure (Glova & Duncan 1985; Resh et al. 1988; Jowett & Duncan 1990; Mosley 2004) and vegetation (indigenous and introduced), which provide habitat for river birds, lizards, fish and aquatic and terrestrial invertebrates. Flowing water transports sediment, and shapes channels (and islands). Floods are important in clearing vegetation and maintaining areas of bare or sparsely-vegetated substrate that provide habitat for characteristic early-succession indigenous plant communities, and are the preferred nesting habitats of many river birds (Robertson et al. 1983; Hughey & Warren 1997; O'Donnell 2000a,). Floods also act to redistribute substratum and, dependant on magnitude, slough periphyton from river-bed stones (Biggs 2000). Dams and water abstraction commonly result in reductions in the magnitude or frequency of floods, which can reduce their weed-clearing effects, exacerbating invasion by weeds that can out-compete indigenous plants and reduce the amount of sparsely-vegetated substrates available for river birds.

As well as reductions in flood magnitudes and frequency, changes in river flow regimes may affect both terrestrial and aquatic braided river biota, although these effects are still poorly understood. If flows are reduced so much that channels dry up, there will be an almost complete loss of water-dependent fauna in affected reaches (see the extreme example of the Pukaki River, which was diverted into a canal as part of the Upper Waitaki Power Scheme; Maloney 1999). However, the effects of smaller reductions in flow are less clear but appear to be complex (Table 3). Glova & Duncan (1985) showed that flow is positively correlated with the amount of food producing habitat and O'Donnell & Hoare (2011) showed that declines in black-fronted tern numbers have been greatest on rivers that had much reduced flows, suggesting water abstraction may be detrimental to wildlife.

Raising the levels of natural lakes or creating new lakes results in a direct loss of terrestrial habitat through inundation (e.g. upper Waitaki Lakes; Wilson 2001). Impoundments can also alter downstream flow regimes and interrupt sediment transport, resulting in a range of complex interacting effects. Controlling waterways with dams can result in flooding of bird nesting sites by untimely discharges and ameliorate natural floods thereby exacerbating weed invasions (as has happened in the river channels affected by the Upper Waitaki Dams).

Structural modifications of riverbeds (e.g. stop banks, willow planting, bridge abutments, gravel extraction) can alter the quantity and biological diversity of braided river habitats. Construction of river protection works and encroachment by associated introduced vegetation and

Table 3. Potential effects and consequences of reduced flow on braided river flora and fauna during the breeding season.

| PREDICTION | POTENTIAL EFFECTS | POTENTIAL CONSEQUENCES |
|---|---|---|
| 1. Lower flows | • Lower food availability | • Greater competition for food |
| | • Increased weed encroachment | • Less breeding and feeding habitat |
| | • Less food-producing habitat | • Increased cover for mammalian predators and their prey |
| | • Increased access to islands by mammalian predators | • Lower productivity and survival |
| 2. Fewer channels (braids) | • Reduced area of feeding habitat | • Fewer habitat choices – greater competition for food |
| | • Increased access to islands by mammalian predators | • Less-optimal breeding habitat |
| | | • Lower productivity and survival |
| 3. Fewer islands | • Fewer islands safe from predators | • Lower productivity and survival |
| 4. Increased channel stability | • Reduced accessibility to preferred foods | • Less breeding and feeding habitat |
| | • Increased weed encroachment | • Increased cover for mammalian predators |

development of riparian habitats for farming can constrain a floodplain to its actively flowing channels, effectively displacing other natural features associated with the wider floodplain and contributing to changes in river geomorphology such as channelisation or reduction in the number of river braids. These types of structural works can have large-scale and possibly irreversible impacts.

Wetlands, springs, oxbows and advanced successional surfaces are important repositories of biodiversity and major fish-spawning habitats in braided river floodplains (Fig. 6). These features often lie outside the active channels in a riverbed and are vulnerable to activities which affect groundwater flows (e.g. water abstraction, drainage), surface water infiltration (e.g. compaction), water quality (elevated nutrient or pollutant concentrations) and overtopping by flood protection plantings.

In addition, a range of human-related factors beyond the immediate river beds, either in the surrounding catchment (e.g. land use changes and encroachment of development activities onto river floodplains) or at more distant locations (such as the wintering sites used by migratory bird species) can have impacts on braided river species. Also, human settlements are often located close to rivers, leading to a plethora of disturbance-related threats.

These human-related factors interact with each other and braided river ecosystems in complex ways (Fig. 12). Although their affects on the biodiversity values of braided rivers are generally adverse, some factors can also have some positive effects. For example, hydroelectric impoundments can reduce the frequency and magnitude of floods, resulting in lower losses of nests to floods, but also greater invasion by exotic weeds, loss of ecosystem components through inundation and reduced island and bank erosion. Such complex interactions need to be taken into account in managing braided rivers.

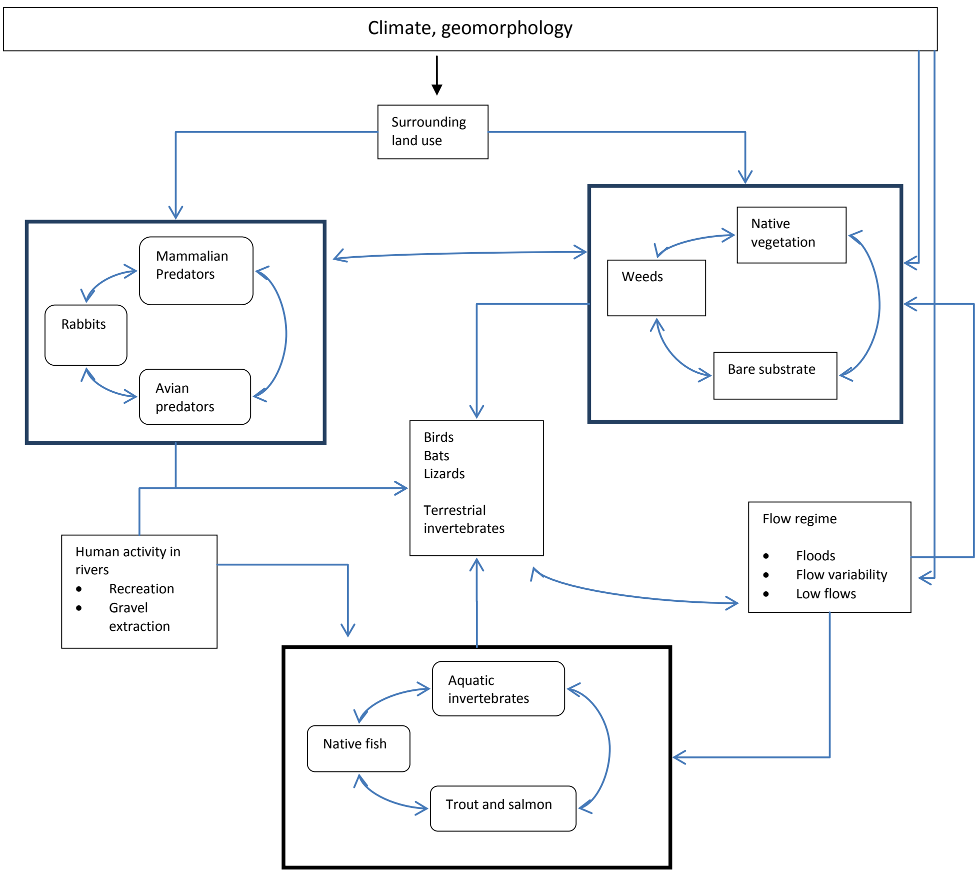



Figure 12. Simplified conceptual model of major ecological components and processes of braided river ecosystems.

## 2.6 What interests in braided rivers do people have?

There is a broad base of people and institutions with an interest in braided rivers. Land tenure, statutory management responsibilities and recreational and community interests in braided rivers are complex. The Department of Conservation is responsible for conserving New Zealand's natural heritage and has special responsibilities for indigenous wildlife, but directly administers only relatively small areas of braided rivers, mainly within National Parks and reserves. The active beds of most braided rivers are crown land administered by the Commissioner of Crown Lands, and are managed by Land Information New Zealand (LINZ) on behalf of the Commissioner. Among other roles, LINZ undertakes some weed and animal pest control on crown land, including along braided rivers. Regional and district councils manage local reserves on riverbed lands (river protection reserves, regional parks) as well as having regulatory responsibilities for the use of water from rivers. Councils also have river control responsibilities (e.g. stop banks, flood management, land use, water quality, ecosystem health) and manage most gravel extraction. Many landowners occupy the recent floodplains of braided rivers and various organisations, community groups and individuals are also interested in braided rivers for water abstraction, hydroelectric power development, gravel and mineral extraction, recreation and conservation purposes. Some landowners have special land titles, which confer limited property rights to adjoining riverbeds (ad medium filium or AMF rights).

Iwi have a strong interest in the guardianship of braided rivers, their sacred sites (wahi tapu) and the species present that are taonga to them. Natural resources are treasures of the people that are handed down by the ancestors to present and future generations. Thus iwi have formulated a wide range of policies and plans to support and encourage good catchment management and conservation (e.g. Te Rūnanga o Kaikōura 2007).

Central and local government, when carrying out their riverbed and waterway regulatory and consenting functions, are required to take into account a range of legislative responsibilities, consider natural and cultural values, and consult widely. In the context of the Resource Management Act 1991 (RMA), they are required to recognise and provide for the protection of areas of significant vegetation and significant habitats of indigenous fauna from inappropriate subdivision, use and development (s 6(c)), and the relationship of Māori and their culture with taonga (6(e)). There is also a duty to have a particular regard to the intrinsic values of ecosystems (7(d)). As the Government implements its national biodiversity strategy, local authorities are playing an active role in safeguarding indigenous biodiversity, including that of braided rivers.

Managing the biodiversity of braided rivers takes place within the context of these multiple interacting stakeholder relationships. Balancing the many human-use demands made on braided rivers against sustaining biodiversity values and ecosystem processes in the rivers is challenging. An important aim of these guidelines is to inform and assist those making key strategic decisions relating to braided rivers and their future management, including:

1. Senior managers in DOC
2. Resource Management Act (RMA) decision makers
3. Iwi
4. Businesses that want to use water or other resources from braided rivers
5. Regional and district councils with responsibilities for land and water management
6. Universities and other research agencies
7. Adjoining and nearby land owners and riverbed administrators
8. The community of river users (e.g. zone committees (Canterbury), river care groups and other community-based organisations and individuals involved in restoration activities)
9. Fish and Game managers

# 3. Current 'good practice' for managing threats to braided river biodiversity

People have been trialling management methods for reducing threats to braided river biodiversity and restoring braided rivers for many years. This section summarises current 'good practice' for managing biodiversity based on research and management trials and uses a range of case studies as examples.

## 3.1 Managing predation

Strong evidence indicates that predation by introduced mammals and native avian predators is one of the most important threats to the viability of bird populations that live on braided rivers (e.g. Hay 1984; Pierce 1986, 1987; Rebergen et al. 1998; Dowding & Murphy 2001; Keedwell 2002; Sanders & Maloney 2002; Keedwell et al. 2002a; Steffens et al. 2012; Fig. 13). Studies to date demonstrate that the most important predators are cats *Felis catus*, stoats *Mustela erminea*, ferrets *Mustela putorius*, hedgehogs *Erinaceus europaeus*, harriers *Circus approximans* and southern black-backed gulls *Larus dominicanus*, although one study also showed that Norway rats *Rattus norvegicus* were an issue. However, the relative impacts of these and other predator species are not well-understood, although it is clear that the relative impacts vary from river to river, and over time. Native fish are known to be preyed upon by introduced sports fish (McDowall 1990, 2003, 2006). Barriers preventing upstream movement of introduced fish in small streams have been installed in several locations to protect threatened fish populations. Lizards and terrestrial invertebrates are also likely to be adversely affected by predation (Reardon et al. 2012), although the processes involved are not well understood.

Many predator trapping and poisoning operations have been undertaken over the past 30 years with the aim of protecting braided river birds, but only three of these have yielded clear benefits for the birds (O'Donnell & Hoare 2011; Cruz et al. 2013; Monks et al. 2013; S. Anderson pers. comm.). Most predator control programmes for braided river birds have had equivocal results or




Figure 13. Examples of predation of threatened bird species including A. predation of an adult wrybill by a feral cat, B. banded dotterel eggs eaten by a hedgehog (*Photos: Peter Langlands ©Wild Capture*) and C. black-fronted terns preyed on by a feral cat. (*Photo: Colin O'Donnell*)

have failed to demonstrate benefits, largely because they were not implemented at a landscape scale at sufficient intensity and failed to target the full range of potential predators responsible for wildlife deaths.

In the absence of more detailed knowledge, best management practice for predator control needs to:

1. Target the entire predator guild mentioned above, including native avian predators.
2. Be implemented at an extensive landscape scale (thousands of hectares and preferably over whole catchments, especially those with barriers to reinvasion, see Box 2).
3. Use very high densities of capture devices if small, high-value sites need protection, (e.g. Ohau River black-fronted tern protection, see Box 3).
4. Use all available predator control methods (different trap types for cats, mustelids and possums, shooting, appropriate toxins), following the model provided by the Tasman River predator control programme (see Box 2);
5. Apply trap devices at high densities to maximise the chances of lowering predator densities (i.e. start intensively and potentially reduce intensity over time if predator densities drop sufficiently);
6. Monitor predator capture rates regularly and monitor outcomes for species so that management can be adapted and improved;
7. Consider indirect ways of controlling predators by:
    a. Reducing other prey (e.g. associated rabbit populations, which are known to enhance predator numbers, although sporadic control can result in increased predation through 'prey-switching'; Norbury & McGlinchy 1996; Norbury & Heyward 2007)
    b. Maintaining safe islands with high water flows around them to limit predator access. We now have good evidence that islands are safer, on average, from mammalian predators than mainland sites, almost certainly because flow limits the ability of some predators to reach islands (i.e. the 'moat effect'; Hay 1984; Rebergen et al. 1998; Boffa Miskell 2007; McClellan 2009; Sanders 2009).
8. Note that predator control is expensive, and any benefits will cease soon after control stops because predators rapidly reinvade and/or increase in numbers.
9. Build weirs or barriers to prevent predatory salmonids entering native fish habitats.

Actions that aim to benefit indigenous fauna by killing predators or reducing predator pressure should be viewed as management experiments and should be carefully monitored to evaluate their effectiveness. Small-scale, short-term control has not worked in the past, and resources should not be directed to this (Keedwell et al. 2002a).

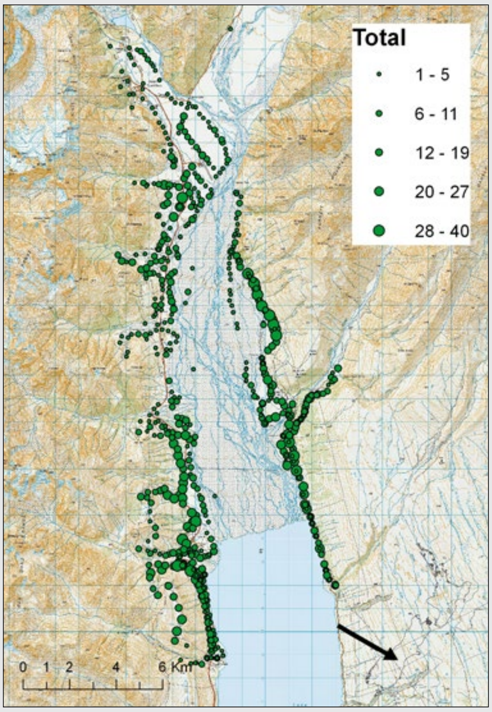
Maintaining or creating suitable island habitat (e.g. Jobin & Picman 1997; Nordstrom & Korpimaki 2004; Zoellick et al. 2004) may help improve breeding success of fauna, especially if combined with other predator management, although the size of the 'moat effect' is weak and highly variable (mammalian predation is still common on river islands; G. Pickerell pers. comm.).

## 3.2 Managing weeds

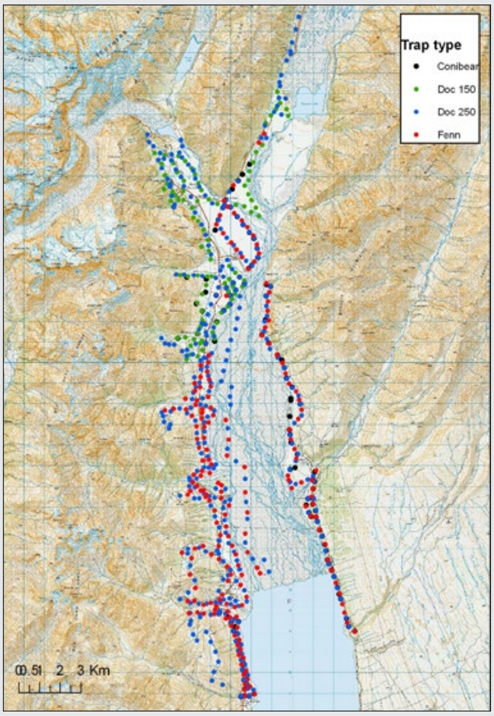
Introduced weeds (particularly, but not limited to, willows *Salix fragilis*, *S. cinerea*, broom *Cytisus scoparius*, yellow tree lupin *Lupinus arboreus*, Russell lupin *L. polyphyllus* and gorse *Ulex europaeus*) can be highly invasive in braided river systems with long-lasting, possibly irreversible impacts on river braid geomorphology, ecosystem processes and competitive displacement of many indigenous plants and animals. In particular, weed invasions are a serious threat to populations of braided river birds (e.g. Stead 1932; O'Donnell & Moore 1983; O'Donnell 1992; Maloney 1993; Brown 1999a, 1999b).

## BOX 2: Predator control at a landscape scale in the Tasman River Valley

The Tasman Valley predator control project aims to test methods of large-scale predator control for the benefit of braided river birds. Specifically, the project is testing whether management of predators can be achieved over a large area (approx. 23,000 ha) to a level that benefits birds that use the riverbed for breeding within a core area of approx. 9000 ha.




Map 1. All hedgehog captures in the Tasman Valley, 2005–13, scaled by number of captures per trap.




Map 2. Locations of predator traps in the Tasman River catchment.

Predator control targets all small mammalian predators found at over the 23,000 ha (feral cats, ferrets, stoats, possums, weasels, Norway rats and hedgehogs (Map 1)), and catches harriers. The control programme mainly uses four types of kill traps (DOC150, DOC250, modified coni-bear, timms), and two types of catch and kill traps (Victor 1.5 leg-hold, and Havahart cage traps). Kill traps are set 250 m apart in lines along the valley sides, valley floor, riverbed edge and mid-riverbed (Map 2), are alternated between types and checked monthly. Leg-hold traps are set in blocks of approximately 100 traps, set at 100 m spacings along the valley floor and on the edge of the river bed. Blocks of leg-hold traps are run over a 10 day period several times per year. Cage traps are set in locations within 1 km of one landowner's residence to prevent injury to domestic cats.

The project began in 2005 and by 2013 there had been a total of 1,932,145 trap nights, capturing 12,108 animals of the target species. Those captures comprised 1553 feral cats, 656 ferrets, 772 harriers, 5884 hedgehogs, 28 rats (identified rats were Norway rats), 514 possums, 2616 stoats and 82 weasels. Capture rates for most species show seasonal trends (higher in autumn, lowest in late winter and spring), and spatial differences (higher capture rates in buffer areas than in the core zone). However, for some species, such as hedgehogs, capture distributions are generally even throughout the trapping grid.

Four braided river bird species (banded dotterels, wrybills, black-fronted terns and kakī) have been monitored through the duration of the project. Aspects monitored for these species have included hatching success, fledging success, population trends and adult survival. Monitoring results have varied among years, with the values recorded related to changes in predator control and river flows. In general, hatching success of dotterels and wrybills was high. For dotterels, hatching was adversely affected both by low minimum river flows, which increased predator risk on islands and by high flood flows. Wrybill chick survival was reduced by predation, and by high minimum and low maximum river flows. Tern chick survival was mostly low, and localised predation of terns may be due to specialisation by individual predators. Survival of adult kakī increased with predator control and with lower kakī abundance, and predator control is important for kakī persistence at this site.

## BOX 3: Intensive predator control around black-fronted tern colonies

Project River Recovery's upper Ohau black-fronted tern predator-control project aims to protect a colony of black-fronted terns on an island in the Mackenzie Basin's upper Ohau River. This small-scale but intensive control operation is being trialled to develop effective predator protection for birds that nest in colonies. It involves both direct predator control (using kill traps and, where necessary, applications of toxic baits) and indirect predator control (by controlling rabbits, the primary prey of several of the introduced mammalian predator species).

Predator trapping is carried out in a 1 km radius area around the island on which the black-fronted terns nest. Several different types of kill traps and trap baits are used to target the full suite of mammalian species that have been identified as predators of black-fronted terns in the Mackenzie Basin—stoats, ferrets, rats, hedgehogs, cats and possums. Two types of possum trap are placed in areas of known possum activity and along the river margins. The remaining predator traps are positioned on a grid layout, with three types of cat trap placed at 200 m intervals along the grid lines and two trap types targeting the other smaller predator species placed at 100 m intervals along the grid lines (Map 1). The trap types alternate along their respective lines; the bait types alternate along the lines and between trap check sessions. The traps are run continuously all year round. They are checked, re-set and re-baited fortnightly during the winter months and weekly for the remainder of the year.

Toxic baits are used to assist with controlling Norway rats and possums because traps alone have proven insufficient for these two species. Bait stations are run continuously from 2 months before nesting commences through until the last chicks have fledged. The rat bait stations are placed at 50 m intervals along the waterway margins, with a double line of bait stations near the island; the possum bait stations are placed at 50 m intervals in areas of known possum activity and at 100 m intervals in other areas of suitable possum habitat and along the river margins near the island (Map 2).

The rabbit-control zone extends for a further 200 m radius beyond the trapping zone, to provide a buffer area with reducing rabbit densities. Rabbit numbers were sufficiently high at the start of the predator-control project that a toxic bait operation was carried out to reduce rabbit numbers to a level that could subsequently be maintained by a regular regime of night shooting.

Map 1. Upper Ohau predator-control project boundaries and predator trap layout. Solid black line represents the boundary of the predator-trapping zone; dashed black line represents the boundary of the rabbit-control zone (the southern boundary is formed by a rabbit-barrier fence so the rabbit-control zone does not overlap the trapping zone entirely). White circles indicate positions of traps targeting mustelids, rats and hedgehogs; white squares indicate positions of traps targeting cats; white triangles indicate positions of traps targeting possums. Additional traps (not shown) are set on the island in the centre of the trapping area. Scale 1:12,000.

Map 2. Upper Ohau predator-control project bait station layout. Solid black line represents the boundary of the predator-trapping area. White circles indicate positions of rat bait stations; white triangles indicate positions of possum bait stations. Scale 1:12,000.



Figure 14. The effects of weed encroachment can be dramatic: A. healthy natural open herb field on the Godley River (*Photo: Chris Woolmore*) compared with B. Complete loss of open bird nesting habitat through weed encroachment on the Ashburton River. *Photo: Colin O'Donnell*

Exotic weeds cover areas of riverbed that were formerly bare shingle or covered in low-stature indigenous plants (e.g. *Raoulia* spp. *Muehlenbeckia axillaris, Epilobium* spp.) (Fig. 14). Areas clear of emergent plants are key breeding and foraging habitats for many birds. By mapping the extent of weeds from aerial photographs it is possible to gain an idea of the large amount of habitat lost to specialist river species. Weed encroachment reaches up to 75% in some rivers (Wilson 2001) and as such reflects the extent of habitat loss. Weeds often establish on the higher, more stable, areas of islands and force breeding birds to nest closer to water—raising the risk of nests flooding.

Apart from these direct impacts, exotic weeds are thought to stabilise shingle islands, deepen river channels, decrease the availability of shallow water foraging areas and increase risk of predation (by providing predator habitat), although further work is needed to test these ideas (e.g. O'Donnell & Moore 1983; Robertson et al. 1983; Balneaves & Hughey 1990; O'Donnell 1992; Pascoe 1995; Hughey & Warren 1997; Rebergen et al. 1998).

In braided rivers, weed diversity and abundance is generally lower in river headwaters and highest in lower reaches closer to the sea (Williams & Wiser 2004; Woolmore 2011). These distributions are generally correlated with the amount of human occupation and related activities at sites ((Sullivan et al. 2004, 2009). There is also evidence of correlations between riverbed weed distributions and climatic gradients (e.g. water balance ratio, water deficits, winter solar radiation, minimum annual temperature; Williams & Wiser 2004; Woolmore 2011).

Figure 15. The invasive algae didymo encroaching instream habitat on the Mararoa River. *Photo: Colin O'Donnell*

Not all invasive weeds are terrestrial. The invasive algae *Didymosphenia* ('didymo') has become widely spread throughout braided rivers (Fig. 15). Some research on didymo has focussed on in-stream effects and has shown shifts in invertebrate community composition and a reduction in drift of certain invertebrate species, both of which potentially affect food supplies for fish and birds (Arscott et al. 2009; Whitton et al. 2009).

Specific best management practice for weed control operations includes:

1. Give priority to preventing or removing new incursions of weed species known to have severe impacts in braided river systems (e.g. false tamarisk *Myricaria germanica*).
2. Target weed species with highly invasive characteristics (e.g. high numbers of seed produced, seed bank persistence, very effective seed dispersal mechanisms, ability to reproduce from fragments, rapid regrowth from roost stocks after floods) and which have serious impacts on braided river ecosystem function (e.g. disruption of successional pathways, changes to geomorphic processes or perturbation of key ecosystem components).
3. Make weed control decisions based on informed assessments of the range of biodiversity values being protected, appropriate target weeds, the impact of target weeds and proposed control methods on values to be protected, achievability of controlling target weeds and resources required to achieve desired outcomes. For example, if using herbicides, selection of products and formulations that are least persistent and have lowest impacts in aquatic environments should be selected.
4. Ensure long-term commitment of resources, where necessary. Many riverbed weeds produce large quantities of seed each year, which can last decades in soil seed banks. A lapse in control for just 1 year can negate many previous years of investment.

The tools available for weed control include:

- Hand weeding (hand pulling, use of hand tools, scrub bars etc.); e.g. hand-pulling of weeds to improve black-fronted tern habitat in the Eglinton Valley – see Box 4
- Mechanical methods (heavy earthmoving machinery); e.g. experimental clearing of islands with bulldozers on the Waitaki River – see Box 5
- Hand application of herbicide (knapsack, low-pressure basal stem treatment)
- Mechanised application of herbicide (vehicle-mounted handgun, mist blowers, vehicle-mounted boom)
- Aerial application of herbicide (helicopter with boom, handheld wand).

## BOX 4: Hand pulling of weeds on islands in the Eglinton River to improve conditions for black-fronted terns



Controlling local infestations of weeds around breeding colonies using hand pulling or mechanical means can make a difference to bird breeding success. In the Eglinton Valley, four islands traditionally used for breeding by black-fronted tern colonies were cleared by hand-pulling and grubbing of Russell lupins over 2 days in 2009. Within a week, a colony of c. 50 black-fronted terns and several pairs of banded dotterels had established on one of the islands. The weed clearing involved hand pulling and grubbing by five energetic people. Repeat visits to the area for several hours each spring have enabled weeds to be kept down for the last 4 years and birds continue to nest on the islands.

Island in the middle of the Eglinton River
A. before and B. after weed clearance.
*Photos: Colin O'Donnell*

## BOX 5: Weed control using machinery to provide island habitat

At sites with very dense weed infestations, especially by woody shrubs and trees, physical removal of weeds using earthmoving machinery may be the only viable option for recreating suitable bird habitat.

Typical dense weed growth on the island prior to weed-removal. *Photo: Mark Sanders*

In 2007, Meridian Energy and ECan conducted a habitat enhancement trial on an 8 ha densely weed-infested island on the Waitaki River, employing mechanical removal of weeds followed by weed control using herbicides. The trial site was transformed, in a few days, from a silty, weed-infested island to a 'clean' site dominated by relatively coarse substrates. The island was surrounded by wide, deep channels (total mean flow of 350 cumecs).

Monitoring during the breeding season following weed clearance showed that the cleared island provided highly suitable river bird habitat. River birds were essentially absent from the site prior to weed control, whereas after weed clearance the island was used as nesting and/or roosting habitat by a range of braided river birds including black-fronted terns (37 minimum), wrybills (3), banded dotterels (21), pied stilts (18), black-billed gulls (6) and a pied oystercatcher (1). An adjacent non-treatment site continued to be little-used by birds. Higher parts of the island also provided refuge for chicks during a fairly large (920 cumecs) flood in January 2008.

However, although the site provided suitable bird habitat, breeding success in the first year appeared to be low, almost certainly because eggs and/or chicks on the island were preyed upon (by unknown predators). This reinforces the need for a reduction in predation pressure, in addition to the provision of suitable habitat, if threatened river bird populations are to persist or recover.

Two other large-scale mechanical weed-clearance operations in the Waitaki catchment have also successfully restored bare substrates, which birds have subsequently used for nesting and roosting (Maloney et al. 1999; Sanders & Maloney 2000). Whilst successful in restoring suitable habitat for birds, mechanical clearance is expensive, and requires ongoing weed control to prevent re-invasion. At flood-prone sites the new habitat may eventually be lost through natural channel erosion and deposition (in 2013 the Waitaki island is no longer discernible in aerial photographs). Thus, this technique may only be justified where there is an extreme lack of suitable bird habitat. Potential impacts of this technique to indigenous plants, lizards and invertebrates also need to be considered.

A low-lying part of the cleared island, after mechanical weed removal and after a 900-cumec flood that has removed machinery tracks and debris that remained following weed removal. *Photo: Mark Sanders*

- Regional pest management strategies
- Advocacy and development of 'codes of practice'

Clearance of weeds to benefit riverbed fauna can sometimes be integrated into other management activities. If managed carefully to avoid having impacts on nesting birds, fish spawning and downstream geomorphology, gravel extraction operations can be used to clear infested riverbeds and create suitable habitat for wading birds (islands and shallow, sheltered water edges for foraging). Various mechanical weed clearance operations have demonstrated that birds (and their aquatic prey) colonise newly-cleared sites immediately (Maloney et al. 1999; Sanders & Maloney 2000; Boffa Miskell 2009).

## 3.3 Ensuring statutory processes achieve the best outcomes for braided river ecosystems and biodiversity

Changes to natural river flows, raising or altering the variation in levels of natural lakes, damming rivers to create new impoundments, altering the physical structure of the landscape, invasion by introduced weeds and other forms of disturbance resulting from human activities can all threaten braided river species and habitats. Advocacy using legal statutory and other indirect tools can be useful in maintaining, enhancing or protecting river biodiversity and habitats (e.g. setting flow regimes; see Box 6).

Existing activities and proposals for new developments that affect braided river biodiversity are mainly addressed in the context of consultation and resource consent hearings under the RMA (at Regional and District Council, Environment Court, or Board of Inquiry levels), or Water Conservation Order Tribunals. Other contexts include submissions on National Policy Statements or National Environmental Standards. Brake & Peart (2013) provide a detailed discussion of relevant legislation and planning processes.

Generally, opportunities to improve development proposals occur during consultation, at hearings and during implementation. Actual or potential concerns are more likely to be given due consideration during consultation and hearings when the following good advocacy practices are applied:

1. Engage early. Proponents of significant development projects typically want to resolve as many issues as possible as early as possible, and actively seek to engage with other stakeholders. The earlier those proponents and guardians, community, and governments stakeholders are involved in discussing proposals together that have potentially adverse effects on biodiversity, the more likely it is that potentially controversial issues can be identified and addressed or resolved. For example, identifying whether specific surveys are needed that may require lead-in time, or identifying ecologically significant, possibly contentious sites may be able to be avoided at the design stage.
2. Proponents should build and maintain positive relationships with other key stakeholders. Positive respectful engagement is more likely to achieve good outcomes than an adversarial approach.
3. Both proponents and other stakeholders should consider asking for assistance. Addressing major consent applications can be very time consuming and expensive. Assistance with costs/resources/expertise may be available from DOC, Councils, applicants, or conservation organisations such as Forest & Bird or the Environmental Defence Society.
4. Both proponents and other stakeholders should consider early on-site meetings to discuss potential adverse effects and ways of avoiding and mitigating them. Site visits can by highly useful; understanding of the proposals and the individuals involved is most effectively gained on site, and written material will make more sense if the site has been visited. This also helps build relationships among stakeholders.

## BOX 6: Setting flow regimes beyond minimum flows within statutory planning

River flow-setting regimes in New Zealand have often focussed on setting minimum flows, even though it has long been understood that other aspects of flow such as flow variability and the frequency and duration of mid-range and large floods strongly influence river ecosystems (Biggs et al. 2008). Increasingly, however, improved knowledge from scientific studies is informing flow allocation decisions (e.g. being applied in Regional Plans and in major resource consent allocations), and contributing towards the design of flow regimes that should achieve better environmental outcomes than can be achieved by simply setting minimum flows.

In 2008-2009, the consultation and resource consent hearings for Meridian Energy's North Bank Tunnel Project provide a good example of how scientific input (freshwater and terrestrial ecology, hydrology, hydraulic modelling, river geomorphology) can contribute to setting a flow regime that balances the wishes of numerous stakeholders, including river conservation interests, irrigators, Meridian Energy, anglers and jet boaters, local communities and iwi. In designing the flow regime, detailed consideration was given to how different flows affect river geomorphology (e.g. sediment transport and braiding patterns), instream biological processes (periphyton, aquatic invertebrates, indigenous and introduced salmonid fish) and terrestrial processes (weed invasion/removal).

The key elements of the proposed flow regime of particular relevance to river birds are:

- Channel maintenance flows. When large floods (>900 $m^3/s$) occur, abstraction for hydro generation will cease in order to allow the entire flood to pass unimpeded down the Waitaki River. The objective is to restore the channel-forming and weed-clearing processes associated with these floods which, among other things and along with weed control, will help restore bird nesting and foraging habitat.
- Flushing flows. Each year, at least seven 'flushing flows' (at least 450 cumecs over 24 hours) must be provided. These are designed to clear nuisance periphyton and fine sediment. They are timed to avoid the bird nesting and indigenous fish spawning seasons.
- Reduce artificially high flow variability. Cessation of the current highly variable flow regime, which results in a barren 'varial zone' (i.e. the zone periodically inundated by water along channel edges), to allow development of productive aquatic invertebrate habitat in shallow channel edges, which should improve bird foraging habitat.
- Adaptive management. Monitoring is required, with specific, quantitative triggers and outcome-based performance measures to test whether these measures are effective. If not, the consents require that flow regimes are adjusted to achieve the specified ecological outcomes.

However, the project did not proceed because of the current reduced demand for electricity nationally. If or when the North Bank Tunnel is constructed, the extensive monitoring required in the resource consents will allow a thorough evaluation of the success or otherwise of this designed flow regime.

5. Read and understand the relevant material – ask for assistance and clarification if necessary. As with on-site meetings, presentations by technical experts followed by questions and answer sessions can be very helpful in identifying and resolving issues early in the process.
6. All stakeholders need to understand that project development is an iterative process – engaging early creates scope for positive influence, but requires a recognition that, at the early stage of proposals, investigations and design may be incomplete, and will likely change (potentially for the better as a result of input from the full range of stakeholders).
7. Identify the key issues and desired outcomes as specifically as possible. It is helpful to suggest solutions or alternatives to achieve those outcomes. Because of the complex

interactions between threats, the focus should be on outcomes for biodiversity sought (e.g. advocating for a particular flow regime and/or weed control that will achieve the outcome of maintaining a specified quantity and quality of habitat, in specific reaches of the river).

8. Obtain guidance on how to make submissions from council websites or directly from council staff, and ensure that submissions comply with legal requirements of particular cases.
9. Acknowledge uncertainty. Understanding of braided river ecosystems is limited and it is important that uncertainties are acknowledged. For example, the specific flow requirements of individual riverbed plants and animals are not well-understood.
10. Ensure that submissions on proposed developments are, as far as possible, evidence-based, rather than mere assertions. Where resources are limited, and strong evidence-based submissions cannot be made, it can be reasonable and helpful to ask identify areas of uncertainty and ask specific key questions to clarify issues.
11. Make use of technical experts. Technical experts have an over-riding duty in law to provide impartial advice to decision makers (hearing committees or Environment Court). Ideally, issues are resolved during consultation but, if not, it is helpful during the hearing process if specific questions are put to submitting parties (in submissions or at hearings).

## 3.4 Minimising human disturbance

Most riverbed birds have well-camouflaged nests that are difficult to see and therefore highly vulnerable to being trampled or run over by vehicles. Physical disturbance from vehicles driving on riverbeds and on the shores of coastal lagoons is a major concern (O'Donnell & Moore 1983; Robertson et al. 1983) (Fig. 16). Drivers of 4WD vehicles often use braided rivers for recreation. When this coincides with the breeding season of indigenous birds the activity can have direct impacts on birds resulting from vehicles crushing nests. Gravel extraction is a common commercial activity on riverbeds. If extraction occurs during the breeding season of terrestrial birds, nests can be disturbed or crushed and instream biodiversity may be affected by machinery crossing channels or diverting their flows. For fish, if extraction occurs during the spawning season, eggs could be directly damaged or destroyed.  Larval fish are typically pelagic, meaning they swim in the water column. Thus, poorly designed water abstraction systems entraining small fish can also impact on populations.

Figure 16. 4WD vehicle tracks within 2 m of a wrybill nest on the Rangitata River. *Photo: Peter Langlands ©Wild capture*

Vehicles can also damage fragile plant communities, such as cushion plants and, in particular, the wetland turf communities that are often found within and adjacent to braided river beds. Impacts on lizards and terrestrial invertebrates are unknown, but it seems likely that adverse effects on plant communities will also adversely affect associated fauna.

In addition to these direct impacts, increasing levels of disturbance on rivers from humans and their pets, in vehicles or on foot, and from jet boats, may cause birds to vacate feeding areas or abandon nests. Wave action from boats can cause low-lying nests to be flooded. Direct disturbance by humans or their pets is also a concern. This can be in the form of recreationalists walking through nesting areas or colonies (causing birds to abandon nests), collection of eggs,

vandalism, and inadvertent deaths resulting from fishing and shooting activities carried out near nesting birds. Even where birds do not abandon nests, nesting success can be significantly lower because they leave nests or chicks for longer than normal. As a result predation rates and egg mortality from cooling or overheating increase. Similarly, chicks are more susceptible to predation and weather (heat, cold, rain) when separated from their parents.

Current management methods that can be used to reduce human disturbance impacts include:

1. Fencing or other physical barriers (e.g. rocks) to exclude vehicles from nest sites.
2. Provision of specific, clearly identified parking areas with signs to educate river users about flora and fauna – in particular, helping users to recognise and move away from disturbed breeding birds (many outdoor enthusiasts are receptive to understanding the behaviour of the animals around them).
3. Identifying (and/or creating) alternative areas where recreational activities will have minimal impact.
4. Marking a clear track and fording locations to limit impacts where river crossings by vehicles are necessary.
5. Education through articles (e.g. in fishing and 4WD magazines and newspaper columns), signs (e.g. Fig. 17) and non-threatening direct contact with river users in the field.
6. Widespread circulation of the 'Braided River Care Code' to known riverbed users.
7. Working with commercial operators on rivers such as jet boat operators and gravel extraction companies. Setting conditions on gravel extraction consents such pre-extraction biodiversity surveys, minimum distances between nests and extraction activities, rules about timing of extraction and zones of activity is now relatively common.


Figure 17. Example of a sign placed at a braided river access point to highlight river values to recreational users. *Photo: Project River Recovery, DOC*

## 3.5 Monitoring the responses of species to management and using this information to adapt and improve management

The distribution and relative abundance of freshwater fish and birds on most braided rivers is fairly well-described (e.g. O'Donnell & Moore 1983; Maloney 1999; O'Donnell 2000a; McDowall 2010). In contrast, the distribution of lizards (Fig. 18), aquatic invertebrates and plants on braided rivers is relatively poorly-known (but see Gray & Harding 2007; Woolmore 2011). Even less is known of the terrestrial invertebrate fauna of braided rivers, and it is likely that many new species remain to be discovered. Thus, there is a clear need for surveys to describe the identity and distribution of flora and fauna of braided rivers.

There is also a need for ongoing monitoring in order to understand long-term population trends and responses to both hydrological and physical modifications to rivers and active conservation management. It is unrealistic to monitor all river species in all rivers (although most birds can be monitored relatively easily) so efforts will need to focus on indicator species and key locations. Identifying which species and sites to monitor is an important issue.

Measuring the response of species and communities to conservation management actions is essential for both improving future management and for reporting outcomes of management. For birds, considerable information (from standardised counts) is available on the relative importance of particular braided rivers for different bird species, although the data are piecemeal in time and space (e.g. O'Donnell & Hoare 2011). Formal monitoring programmes need to be set up. Ongoing monitoring need not include all braided river bird sites, but should include a range of representative habitats of significance.

Figure 18. The threatened scree skink – Nationally Vulnerable ; only recently discovered to have important populations on braided riverbeds, and techniques are only now being developed to survey and monitor these cryptic species. *Photo: Marieke Lettink*

Strict standardisation of survey methods is needed to ensure that results can be compared over time. All braided rivers should be surveyed over their full length at least once for all indigenous species (see O'Donnell & Moore 1983 for techniques for birds). The importance and value of sites vary seasonally: some sites may only be used at a particular time of year (e.g. breeding, over-wintering, or as a staging site for migration). Therefore, surveys and monitoring programmes should include different seasons (e.g. spring, summer, autumn, winter). For sites that currently have no data, it is essential that baseline surveys are carried out before any monitoring is done to assess the impacts of developments or weed or pest control.

National population counts (e.g. of black-billed gull) and compilation and analysis of existing datasets would assist in understanding trends; for example, a recent analysis of all known survey data on black-fronted terns has provided a more comprehensive picture of the status of this species, and has shed light on how river flow may affect population trends (O'Donnell & Hoare 2011).

The current best practice for monitoring includes:

1. Standardised index counts for braided river birds (see Box 7 for examples).
2. Standardised sampling for aquatic invertebrates (see river macro-invertebrate sampling; Stark et al. 2001).
3. Standardised methods for sampling fish using electro fishing are available for single-channel rivers (Joy et al. 2013), but these techniques have not been adapted fully for use on braided rivers. Despite this, electrofishing and other methods can still be used in braided river systems.
4. Standardised methods for sampling terrestrial invertebrates such as malaise, light and pitfall trapping (see, for example, Moeed & Meads 1985; Harris et al. 2004).
5. Plant monitoring techniques (see Woolmore 2011).

## 3.6 Integrating management through good planning, partnerships, community involvement and education

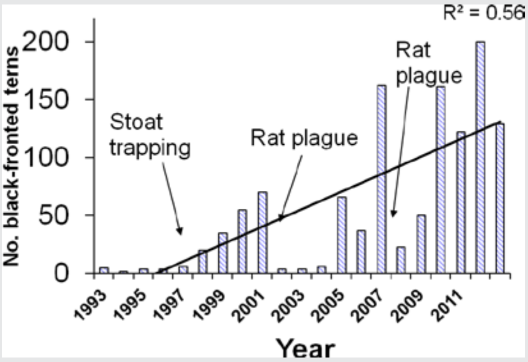
Effective management involves not only implementing the techniques described above, but doing so in a co-ordinated manner that involves iwi, the community of river users and local, regional and national government officials as much as possible. As mentioned above, braided rivers are used and managed by many different stakeholders, some of which have direct statutory

## BOX 7: Using standard index counts of braided river birds to monitor their response to management

Surveying for birds on the Rangitata River. *Photo: Peter Langlands*

Standardised bird counts regularly carried out on a large number of braided rivers since the 1960s provide valuable data on the importance to the birds of particular rivers and trends in their numbers (O'Donnell & Moore 1983; Maloney 1999; O'Donnell & Hoare 2011).

For example, on the Eglinton River in Fiordland National Park, the number of black-fronted terns present in the middle of the breeding season has been counted once annually since 1992. Numbers were very low until a valley-wide stoat trapping programme commenced in late 1997. The numbers of terns counted increased each summer until an irruption of ship rats occurred in 2000. Numbers of terns dropped to their former levels, before recovering 4 years later, following continued valley-wide predator control focused on rats and stoats. Increases in tern numbers have continued to the present day. However, it is important to note that this area has lower predation pressures than many others, as several major black-fronted tern predators (hedgehogs, ferrets and feral cats) occur only rarely (O'Donnell & Hoare 2011).




Example of braided river index counts for birds – Black-fronted terns on the Eglinton River since the commencement of stoat trapping in 1998 (based on O'Donnell & Hoare 2011).

Other examples of monitoring include surveys of the Waitaki River in 2001, 2005, and 2010 involving 5 replicated surveys each year, and recent surveys of Canterbury Rivers. Helicopter surveys of black-fronted terns, black-billed gulls and other prominent species, using experienced observers and high resolution photography of key species, has yielded promising results on a number of rivers (Waitaki, Wairau, Waiau), and may offer a safe, rapid, and cost-effective alternative to on-river surveys (K. Steffens, pers. comm.).

responsibilities for management, while others have direct interests as users. In addition, braided rivers are nationally significant habitats and iconic landscapes that are appreciated by and of concern to New Zealanders and international visitors.

Communication, education and participation are all critical to increasing awareness amongst stakeholders and the general public and vital to achieving the aims of this strategy. The continued development and provision of advocacy tools (training, factual material etc.) is needed to raise public awareness of the importance of braided river ecosystems and their biodiversity. The aim of advocacy is to increase the numbers of people who participate in activities that contribute towards the conservation of braided river ecosystems and sustainable development.

The conservation needs of braided river ecosystems extend beyond the immediate bounds of braided rivers. Many indigenous birds migrate from braided river breeding grounds to local coastal sites, northern wintering grounds at harbours such as Manukau and the Firth of Thames, and even to sites in eastern Australia (Pierce 1999). These needs must be incorporated into the

management of estuarine habitats and the processing of development proposals (e.g. for wind farms) that might affect migration routes or wintering grounds. Similarly, migratory species of native fish in braided rivers spend parts of their life cycle in the sea or in lakes.

Practices that enhance outcomes of management include:

1. Identifying opportunities for all people with an interest in conservation of braided rivers to foster communication, education and engagement aimed at enhancing awareness of the values of braided river ecosystems and their key species.

- Recognising and encouraging the role of tangata whenua as key partners in braided river conservation.
- Setting up networks to enhance communication and information flow (e.g. BRaid – the Braided River Aid Network – see Box 8).
- Organising local community groups interested in restoring braided river ecosystems (e.g. Ashley-Rakahuri Rivercare Group – see Box 9).
- Developing specific relationships (e.g. Project River Recovery, see Box 10).
- Providing sources of ongoing strategic guidance to those who affect or seek to manage braided river ecosystems. For example, the National Braided River Technical Advisory Group (TAG) currently provides support and strategic advice for management of braided river biodiversity. The TAG comprises a small group of experts (science, technical and operational capabilities and key stakeholders) with a national focus, and the ability to ask for additional expertise when required.
- Undertaking specific management planning such as species recovery plans or strategies with clear objectives (e.g. kakī /black stilt recovery plan – see Box 11).
- Developing education opportunities to help improve understanding of the significance and plight of biodiversity on braided rivers. Education can focus at multiple levels with products such as posters and pamphlets (http://braid.org.nz/publications/conservation/native-animals/birds/life-on-a-braided-river/) and teacher classroom resources (http://braid.org.nz/getting-involved/for-teachers/conservation-education-resources/river-life-braided-rivers-in-the-mackenzie-basin/).
- Identifying opportunities to integrate management initiatives in braided rivers with research opportunities and coordinating these at a regional or national scale.

## BOX 8: BRaid – The Braided River Aid Network

BRaid, a group which promotes protection of all braided river ecosystems in Canterbury, was the brainchild of the Ashley-Rakahuri rivercare group and came into existence in 2007. BRaid was formed to bring together the various parties involved in braided river management and conservation. Current partners are Ngai Tahu, Department of Conservation, Canterbury Regional Council, Ornithological Society of New Zealand, Land Information New Zealand and Landcare Research. A major aim is to assist in the formation of other community-driven rivercare groups. To this end, BRaid regularly organises training courses for the management of birds in braided rivers and to disseminate information on advances in our understanding of braided river ecosystems.

Children from North Loburn School learning about braided river birds on the Ashley River. *Photo: Nick Ledgard*

The vision of BRaid is *To promote protection, enhancement and awareness of braided river ecosystems by liaising with and promoting co-operation between stakeholders, encouraging community groups, and facilitating the collection and storage of information.* The group's website provides a repository for data from bird counts, monitoring protocols, advice on management of rivers, news releases and other topical issues.

For more information see the BRaid website and facebook page:

http://braid.org.nz/

https://www.facebook.com/braidedriveraid

## BOX 9: Activities of the Ashley-Rakahuri Rivercare Group

The Ashley-Rakahuri Rivercare Group is a community group formed in 1999 to assist with the management of shorebirds and their habitat in the lower reaches of the Ashley River/Rakahuri. This river has small but stable breeding populations of wrybills, and provides good breeding habitat for all the other indigenous braided river birds. In 2005, the Group became an incorporated society. Meetings are held 4–5 times per year and there are 64 people on a membership email list at the time of writing. Major activities involve bird monitoring (one annual survey, plus a number of riverbed visits every week from September to January), predator control (up to 5000 trap-nights annually), habitat enhancement (weed control) and advocacy (increasing awareness and minimising human disturbance), all of which are covered in annual reports – which also contain recommendations for future management. A professional ornithologist is employed part-time to assist with monitoring (particularly wrybill banding) and report writing. After 8 years of regular riverbed-related activities by the group, resident bird numbers are relatively stable or increasing. Major funding has come from the Pacific Development and Conservation Trust, the New Zealand National Parks and Development Foundation, the Habitat and Protection Fund of World Wildlife Fund (New Zealand), and the Lotteries Environment and Heritage Fund, plus local sponsorship.

Ashley-Rakahuri Rivercare Group member checking predator traps on the Ashley River. *Photo: Nick Ledgard*

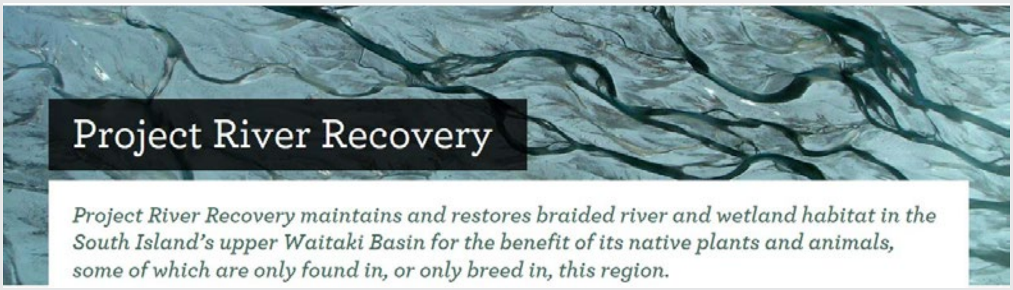
For further information see: http://www.naturespace.org.nz/groups/ashley-rakahuri-rivercare-group-inc

## BOX 10: Project River Recovery

Project River Recovery (PRR) was established in 1990 to deliver programmes of braided river and wetland ecosystem restoration and enhancement which are jointly agreed between Meridian Energy Ltd, Genesis Energy Ltd and the Department of Conservation. The programme is funded by the power generation companies through a mitigation agreement explicitly recognising the impacts of hydro-electric power generation on braided rivers and wetlands in the upper Waitaki River system and is tied to the term of the power scheme resource consents which expire in 2025. PRR currently uses these funds to:

1. **Maintain indigenous vegetation and enhance habitat by removing weeds**
   - Targeted removal of problem weeds in priority locations before they become widespread.
   - Preventing problem riverbed weeds which aren't established in upper Waitaki catchment rivers from becoming naturalised (e.g. yellow tree lupin *Lupinus arboreus*, false tamarisk *Myricaria germanica*).
   - Undertaking research and field trials to improve effectiveness and reduce possible adverse impacts of PRR weed control programmes.
2. **Continue to build knowledge of natural heritage in braided river ecosystems**
   - Ongoing riverbed surveys to assess long-term bird population trends throughout upper Waitaki Rivers.
   - Demonstrating the creation and successful management of wetland habitat for specialised wading birds.
   - Large-scale survey and description of threatened plants and wider plant communities in upper Waitaki braided rivers.
3. **Test and develop more-effective methods of predator control in braided rivers**
   - Catchment-scale trapping of predators in the Tasman River in conjunction with the Kakī Recovery Programme to improve breeding success of a wide range of river birds and other fauna.
   - Intensive trapping of predators as a technique to benefit colonial-nesting birds.
4. **Increase public awareness of braided rivers and wetlands**
   - Preparing and distributing a wide range of attractive braided river resource materials including braided river posters, a field guide, information pamphlets and a river-care code.
   - Development of a student/teacher resource which examines values, human impacts and management of braided river ecosystems and fits into the senior high school curricula.

For further information:




www.doc.govt.nz/our-work/project-river-recovery/

www.doc.govt.nz/upload/documents/science-and-technical/casn298.pdf

# BOX 11: The Kakī/black stilt Recovery Programme

Kakī (black stilt) are wading birds that were once widespread in rivers and wetlands throughout the North and South Islands. However, because of the impact of introduced predators and changes to their habitat, they are now one of New Zealand's most critically threatened birds, and one of the world's most endangered wading species.

The Department of Conservation have put in place a Recovery Plan aimed at securing kakī from extinction and increasing their numbers throughout their range. The Recovery Plan is a planning document designed to summarise the priority actions needed to help ensure the species recovers and persists. The plan is in two phases, with the first phase designed to maximise the number of young kakī in the population. It involves finding pairs in the wild and collecting as many eggs as possible. Eggs are then incubated in captivity and the chicks hand-raised until they are fully grown, when they are released back to the wild. Captive-rearing and release techniques are used because they ensure a much better survival rate for young birds than letting the chicks be raised by their wild parents. Most eggs and chicks in the wild are either killed by predators or have their nests destroyed by floods. Hand-raising avoids these losses and gives the population a much-needed boost.

This first phase of population recovery is working well and, in a good season, 160+ eggs are collected from both wild and captive kakī pairs, over 100 chicks are successfully hand-raised for release and the wild population has increased from a low of 33 birds in 1999 to more than 70 birds in 2014.

The second recovery phase is designed to discover the best method of keeping kakī alive in the wild in mainland New Zealand. This has involved some research using radio transmitters on released birds to try to ascertain where and why they die. Also, a large-scale (23,000 ha) predator control programme in the Tasman River Valley (see Box 2) has been established since 2005. Analysis of the first 5 years of results indicates that this form of predator control enhances adult survival and population viability of kakī. The challenge now is to ensure that this predator programme can also be effective in improving fledging success, which is essential if kakī populations are to survive in the long term.




Images of aviaries and winter release. A. Pair of adult kakī protecting a chick in the nest, breeding aviary, Twizel (*Photo: Liz Brown*), B. Local school children releasing captive-bred juvenile kakī into the wild at Lake Tekapo (*Photo: Dean Nelson*), C. Captive-bred kakī in the wild (*Photo: Phil Guilford*)

# 4. Future research needs and knowledge gaps

Despite a range of good management practices now being available for conservation of braided river species and habitats, there is still a need to develop new practices and for others to be improved. This section identifies the research needed to improve understanding of the factors that influence braided river biodiversity and to increase effectiveness of management. The highest-priority research needs are summarised in Box 12.

### BOX 12: Priority research objectives

1. To develop effective predator control prescriptions for threatened species on braided rivers that focus on (a) optimising predator control, (b) developing new tools (e.g. toxins), and (c) determining the importance of predator-safe habitat refugia (islands and flows).
2. To develop flow prescriptions for the benefit of birds and fish to maintain or restore their populations and habitats.
3. To develop effective weed control prescriptions that enhance key ecosystem components (where to do it, how much, cost-effectiveness).
4. To determine the relative importance of aquatic microhabitats within rivers for threatened species to help build predictive flow models.
5. To increase understanding of the drivers of productivity and survival of threatened species and, particularly, the interactions among threats, including:
   a. Determining interactions between predation risk, flow management and weed encroachment
   b. Gathering accurate data on productivity and survival of threatened species populations at a range of sites to develop population viability models (and thereby generalise predictions about the impacts of threats and to describe outcomes of management.
6. To develop more robust monitoring methods to record outcomes of management for threatened species (e.g. breeding success, survival, quantitative survey and monitoring methods for fish and rapid methods) and assess whether the indicator species concept is useful for monitoring responses of braided river species to management and for reporting on those trends.
7. To quantify impacts of different (increasing) recreational activities on behaviour and breeding success of threatened species.
8. To quantify the impacts of gravel extraction on flora and fauna, including breeding and spawning success.
9. To learn more about factors influencing survival of braided river species on non-breeding (wintering grounds).
10. To develop salmonid control methods to benefit threatened native galaxids.

## 4.1 Control of predators

Given the profound effect that predation by introduced mammals has on New Zealand's indigenous fauna, a very high priority for braided river conservation is to develop cost-effective and efficient strategies to maintain and restore populations of threatened species by reducing the impacts of predators on river birds, lizards and (probably) terrestrial invertebrates, as well as salmonid predation on native freshwater species. Although we know how to kill the predators in question there have been few broad-scale successes in riverbed predator control and these

have benefited only a few species (Keedwell et al. 2002a; Pham et al. 2003; O'Donnell & Hoare 2011; Cruz et al, 2013). The improvements required centre on increasing effectiveness of predator control to ensure predation rates are reduced to levels that provide sustained biodiversity benefits.

Problems with our current understanding include the long timeframes needed to see results across a range of indigenous species, the large number of predator species and the variability in their abundance in space and time, the large scale of the control required to protect indigenous species at the population level, and that broad-scale control methods may not succeed with all animals (i.e. the need to deal with 'rogue-type' individuals that avoid traps or baits).

Specific priorities are:

**A. Develop cost-effective methods of killing predators to levels sufficient to benefit indigenous fauna, and measure those benefits.**

A range of methods need to be tested and more-efficient and cost-effective techniques need to be developed to, for example:

1. Control mustelids, cats, hedgehogs, harriers and rats using kill traps and a range of toxic baits and lures.
2. Control black-backed gulls to low levels using ground application of toxic baits (alphachloralose).
3. Utilise new technology such as self-resetting traps and new toxins and delivery methods (such as PAPP and the 'spitfire' delivery system).

**B. Test whether indirect methods such as habitat, land-use management or manipulating predator behaviour can reduce predation risk.**

Alternative approaches to direct control of predators need to be investigated; particularly the possibility that controlling populations of primary prey (particularly rabbits *Oryctolagus cuniculus*) could suppress predator numbers. Options include:

4. Sustained rabbit and hare *Lepus europaeus* control to low levels by ground hunting and ground application of toxic baits to reduce food supplies for predators.
5. Physical manipulation of islands and channels in rivers to maintain a protective moat around bird breeding sites (and potentially reduce their vulnerability to floods).
6. Reducing predation rates by manipulating predator behaviours. For example, experimenting with conditioning predators using taste aversion or scent camouflage (where predators are habituated to ignore the scents of braided river birds).

**C. Understand predator ecology to better-inform predator management.**

Our ability to develop effective predator management strategies is restricted by a limited understanding of predator ecology. There is a strong need to address fundamental ecological questions relating to predator behaviour and ecology in braided river landscapes, including how predator numbers and their impacts vary in time and space and how predator use of the landscape is influenced by river 'flow' parameters (e.g. channel width, depth and velocity, number of channels, turbulence, etc.). Understanding predator ecology should help improve control techniques and lead to efficiencies. Key research questions are:

7. What is the relative importance of different predator species and predator guilds (i.e. the particular suite of all predator species present at a site) among rivers and over time?
8. Which ecological factors drive variation in predator numbers and predation risk for indigenous fauna?
   i. How are predator behaviour and predation impacts affected by variation in flow regimes, weed encroachment and their interactions?

ii. What is driving stoat population irruptions in river headwaters? Stoat populations periodically explode in forests as a result of periodic heavy seeding of beech trees that in turn drive rodent population irruptions (O'Donnell & Phillipson 1996). Tussock (*Chionochloa* spp.) seeding in grasslands may have the same effect.

iii. How important are the effects of interactions between causes of fauna mortality (e.g. predation and flow or vegetation encroachment and nest/river flooding interactions).

9. What are the longer-term impacts of predation on population viability both for individual populations and species as a whole? Good population models are needed so it is possible to identify when predator control targets are achieved (i.e. threatened species recover in numbers).
10. What are the impacts of herbivores (especially rabbits, hares and stock) on native plant populations?

## 4.2 Weeds

Whilst there is a need to improve understanding of how weeds affect flora and fauna in braided riverbeds, this should not impede weed management; it is clear that weeds are detrimental, and well-established principles and methods of weed control can be employed to control weeds at many sites. However, sustaining resources to apply such techniques cost-effectively at a landscape scale and over decades remains a challenge and needs further research. Priorities for weed research are:

**A. Improve understanding of optimal environmental weed control in braided rivers.**

Key research questions include:

1. What is the optimal mix of planned weed control and reliance on natural processes to sustain sufficient habitat for braided river species (e.g. is it better in some cases to wait for a flood than to maintain cleared substrate between floods)?
2. How should weed control be prioritised? Are weeds in some rivers so widespread or dense that they can't be controlled cost-effectively?
3. How much weed control do we need to do, how often, and in which sites (spatial and temporal scales) to increase breeding success, particularly for threatened riverbed species?
4. What more-effective weed control methods are available or could be developed?
5. To what extent is the availability of bare gravel a limiting factor for threatened species?
6. How important are introduced grasses and herbs as weeds of braided river habitats?
7. How does weed invasion alter the community composition of terrestrial invertebrates, lizards and native plants?
8. How do weeds influence predation risk (e.g. by providing habitat or supporting prey such as rabbits)?
9. What is the impact of didymo on food supplies of threatened species and can we manage it?

## 4.3 Altered flow regimes

Currently, our understanding of the relationship between braided river flow regimes and riverbed flora and fauna is not sufficient to accurately assess the effects of altered flow regimes or to prescribe optimal flow regimes. We can hypothesise about potential effects and their consequences on flora and fauna (Table 3), but data need to be collected to verify these hypotheses. In a resource management context, the present lack of data presents a major limitation to addressing and setting minimum flows for regional plans, or assessing projects that

propose to abstract water from rivers. Thus the main recommendations here relate to improving understanding of river flows and how they influence the flora and fauna of braided rivers. Flows influence:

1. Bed movement and island creation or destruction. Reduction in flows can stabilise channels and reduce the size and number of small channels as well as the overall useable area of aquatic habitat. Increased stabilisation of flows reduces the ability of the river to form new channels and the natural processes of erosion and deposition.
2. The ability of weeds to establish and spread. While flood flows appear to contribute to periodically clearing low shingle islands of weeds, weeds and flows also interact in a number of other ways. For example, weeds stabilise shingle islands, leading to an increase in deep channelisation and thus decreasing the availability of shallow water foraging areas. Weeds force indigenous birds to nest closer to the river channels as higher terraces less-affected by floods become covered in vegetation, which subjects nests to an increased frequency of flooding from both small (freshes) and large (floods) increases in flow.
3. The ability of predators to cross channels to islands and then survive on them. Anecdotal information points to a higher breeding success of braided river birds and a lower abundance of mammalian predators on braided river islands compared with the main riverbed; therefore it is assumed that by breeding on islands birds are afforded some level of protection from predation: the 'safe island' concept. Although it is well known that predators can swim across river channels, it appears that the frequency with which they do so is limited considerably by flows (e.g. Pierce 1987; Pascoe 1995; Pickerell et al. 2014).
4. The abundance and composition of aquatic invertebrate communities which, in turn, influence food availability for freshwater fish, braided river birds and other wildlife. It is common for the breeding densities of birds to be limited by resources such as food, including braided river species (Lalas 1977), although the extent to which New Zealand river fauna are limited by food is unknown. While there is a reasonable knowledge of general foraging behaviours and diet of some braided river birds and fish, detailed knowledge of feeding habitat use patterns is essential to be able to make predictions about the potential impacts of modifying river flows on those patterns. It is important to understand the use of specific aquatic microhabitats for feeding and how flow modification influences food abundance and availability in them.

Specific priorities are:

**A. Improve understanding of how flow regimes influence indigenous plant and animal communities on braided rivers.**

Key research questions are:

1. How important is variation in flows to sustaining habitat (substrates and vegetation) and what are optimal flow regimes for different braided river plant and animal species at all life stages?
2. What flow regimes (volume, spatial and temporal variation in velocity and volume etc.) would sustain the habitats of the threatened plant and animal species at all life stages?
3. What are the effects of flow regimes (including altered flows) on weed encroachment?

**B. Develop accurate models and predictions about consequences of altering flow regimes on indigenous plant and animal communities on braided rivers.**

Although several modelling systems are available to make predictions about flow modification on aquatic invertebrates and freshwater fish (RHYHABSIM for instream habitat flow assessments and CHES – Cumulative Hydrological Effects Simulator), models are needed for birds, terrestrial invertebrates and plants and their interactions with aquatic elements of the braided river ecosystem.

## 4.4 Human disturbance

The impacts of human disturbance on river flora and fauna are difficult to measure and are not well-understood. Human use of riverbeds (e.g. fishing, 4WD vehicles) has increased dramatically in many braided rivers and specific research is needed to assess the impact of these factors on the ecology of braided river flora and fauna, and particularly on the long-term viability of populations. Specific priorities are listed below, although many of these issues also need to be dealt with through education and advocacy as set out in Section 3.6. Specific priorities are to:

**A. Identify important nesting, breeding and spawning areas and locations of populations of birds, lizards, invertebrates, fish and plants and determine methods to discourage driving and other recreational activities in those areas.**

**B. Undertake research to better understand the impacts of recreational use on braided river plant and animal communities.**

Key questions are:

1. What are the impacts of recreation disturbance on the viability of populations of threatened species specifically and braided river ecology more generally?
2. How do changes in flow regimes – particularly reductions in flow – affect recreational use of rivers, and how does this affect river birds? (e.g. do lower flows lead to more use of riverbeds by people?)
3. Does education and advocacy result in changes in behaviour?
4. What are appropriate buffer distances between gravel extraction and bird nesting sites, as these are often specified in consents?
5. Can the presence of humans confer benefits such as deterring predators?
6. What effects do structures on rivers (e.g. bridges, stop banks, plantings) have on the physical habitat of braided river fauna? Do they have an impact on food supplies and available breeding sites?

## 4.5 Surveys and monitoring

Work needed to improve survey and monitoring includes the following priorities:

**A. Undertake baseline surveys of flora nad fauna of braided rivers to improve knowledge of the significance of braided rivers.**

Skills available to undertake surveys are limited, so development of training programmes for people carrying out surveys is essential, as are the skills and capacity to implement management actions resulting from survey findings.

**B. Identify key species that should be monitored.**

**C. Monitor the abundance and distribution of key species in order to describe population population trends and to assess effects of mnagement and human-induced changes to rivers.**

**D. Develop standard methods for monitoring and surveying key components of braided river ecosystems.** For example, optimising monitoring in relation to time of day, time of year, observer biases and replication. Particular gaps are:

1. Freshwater fish
2. Terrestrial invertebrates
3. Birds

**E. Continue developing tools to improve monitoring and identification of harmful new weed invasions.**

It is critically important to identify new incursions of weeds and prevent their spread before they become a major problem. This requires robust systems of monitoring and reporting by field staff, a good spatial weed database, ongoing follow-up by control agencies and legislative support from regulatory authorities.

## 4.6 Prioritisation of sites

Over 300 rivers in New Zealand are braided or contain braided sections. These are distributed throughout much of the South Island and parts of the North Island (Table 1). Each braided river, while superficially similar to the other rivers in the region, is sufficiently distinctive in its habitat characteristics to provide for distinctive assemblages of birds (O'Donnell & Moore 1983) and, probably, distinctive assemblages of other fauna and flora.

The habitat provided by braided rivers is used at different scales by different animals. With birds and migratory freshwater fish, for example, individual river systems complement each other to provide a network of habitats spanning many hundreds of kilometres. In addition, it appears (for some species at least) that patterns of usage change from one river to another, and from year to year as conditions change. In contrast, terrestrial invertebrates, lizards, and non-migratory fish are less mobile, and populations and sub-populations are likely to be restricted to smaller distributions (e.g. apparently isolated populations of robust grasshopper in Tekapo, Ohau and Pukaki Rivers). Similarly, indigenous plant distributions can be restricted to particular rivers or sites within rivers (Woolmore 2011).

Thus habitat degradation in braided rivers has the cumulative effect of reducing habitat availability across a range of scales, increasing risk for species dependent on these ecosystems. For example, when large alpine-fed rivers such as the Rakaia are in flood, the small hill-fed rivers of the plains such as the Selwyn now offer poor alternative habitat for birds because of lack of flow and weed invasion. Within rivers, stop banks and other protection works prevent populations of birds using spring-fed creeks and backwaters during large floods.

Considerable information is available about the relative importance of braided rivers for different bird species from bird counts (albeit, the data are piecemeal in time and space). However, little information is available regarding lizards, terrestrial invertebrates, and fish. If baseline surveys for all these groups are incomplete or greater than five years old, it may be difficult to assess sites for their ecological significance or detect population trends and thus apply management effectively. As a result, caution should be exercised when prioritising sites for management, or assessing their significance in terms of the RMA – the quality of available information needs to be taken into account, and information gaps need to be recognised.

Selection of priority sites for conservation management is widely undertaken in New Zealand, and presents a number of challenges – at least partly because different people value ecological components differently, but also because of the need to work with 'patchy' information, as described above. Thus, there is a need to develop methods of selecting areas for management that cope with these challenges. In addition, braided river birds, particularly colonial nesting species, appear to be highly mobile. Annual variability in counts of some species on single rivers suggests that they may use a network of rivers during their life cycles; perhaps moving among rivers as conditions vary over time (e.g. McClellan 2009). Thus, management or protection of single rivers may not provide long-term security for a population.

O'Donnell's (2000) evaluation of rivers in Canterbury as habitat for birds provides an example of how to use a comprehensive range of detailed data about 'microhabitat' and bird communities present. O'Donnell ranked sites for habitat values and for threatened species presence. Such approaches, which incorporate information on historic and current plant, invertebrate, fish and lizard communities, are needed, and should be applied nationally.

Priorities for research include:

**A. Develop and use a robust system for selecting priority sites for research and for applying conservation management actions.**

**B. Determine where the key populations of threatened species are.**

## 4.7 Decision support tools

Effective management of threats will be aided by having effective techniques for investigating and mitigating them. A range of decision-support tools and analytical methods require further development. Recent examples include the use of DNA analysis to identify potential predators of birds (Steffens et al. 2012) and infrared digital video to aid understanding of breeding success at bird nest sites (Sanders & Maloney  2002).

In order to develop effective decision-support tools there is an urgent need to gather accurate data on populations and input these parameters into population viability models so that we can generalise predictions about impacts of threats and outcomes of management. This need includes getting more precise population parameters across a range of representative sites. The priority is to:

**A. Promote the development of tools and build the capacity of natural resource managers, decision makers and local stakeholders to manage braided river ecosystems for biodiversity.** For example:

1. Decision-support tools to assist in deciding when and where to manage threats.
2. Methods for identifying and ranking priority rivers for management.
3. Modelling methods to predict benefits of management on population viability and predict flow regimes for management.
4. More-robust monitoring methods to record outcomes (e.g. fledgling success and survival).
5. Genetic studies to improve knowledge on population structures across species' ranges.

## 4.8 Braided river ecology

In addition to the various research priorities identified above, the following research needs apply across braided rivers as a whole.

Land use in the catchments of braided rivers potentially impacts on habitats of threatened species, especially as intensification of farming and other land uses increase. Clearance of vegetation in the wider catchment can increase or change runoff patterns and cause erosion and increased sedimentation down-stream. Deposited fine sediment can smother habitat, or impacts may be more subtle, affecting, for example, invertebrate food supplies. Drainage of backwaters and associated wetlands on the margins of braided rivers causes direct loss of seasonal feeding and breeding habitat. Neighbouring land use changes may also alter predator-prey cycles and influence impacts on adjacent braided rivers. For example, black-backed gull populations largely depend on adjacent farmland for food and unnaturally large populations may be sustained, which result in higher than normal predation rates on threatened bird species.

Changes in water quality occur as a result of runoff from agricultural chemicals used in surrounding catchments (e.g. McColl et al. 1975; PCE 2013). Inorganic fertilisers and pesticide residues enter waterways via runoff. Changes in water quality may influence aquatic food supplies available to wetland birds and organochlorides have been recorded accumulating in tissues of wetland birds and eels (e.g. O'Donnell & Fjeldsa 1997). However, there has been no research conducted in New Zealand to determine what the precise impacts of such changes would be on the viability of threatened species populations.

Similarly, discharges of pollutants and sewage into waterways come from a wide variety of sources and cause loss of invertebrates and eutrophication (Hughes et al. 1974). Discharges of irrigation water following abstraction elsewhere within a catchment, or from elsewhere, may change the flow characteristics of a particular river. Such changes could be detrimental if discharged waters carry additional nutrient loads from farmland. Thresholds at which such discharges impact on indigenous birds have not been studied in New Zealand.

In addition, many bird species migrate from riverbed breeding grounds to local coastal sites (Pierce 1999), northern wintering grounds (Section 3.6) or move among rivers from year to year (McClellan 2009). Therefore, factors well beyond the boundaries of the immediate riverbed may influence their survival. Key questions that need to be addressed through research to improve understanding of how braided river ecosystems function include:

**A. Importance of adjacent land use practices.**

1. How does run off (nutrients) effect quality of braided river habitat?
2. What are the consequences of continued intensification in land use (e.g. dairy farms) adjacent to significant rivers and groundwater connected catchments?
3. How does abstraction from groundwater aquifers adjacent to rivers effect aquatic habitats within rivers?
4. What is the importance of riparian areas for river bird species (moving on and off river)?

**B. Importance of habitat networks.**

1. What threats face braided river bird species on their non-breeding grounds and how do we manage them?
2. How do threatened species use habitat at a macro scale? That is, are rivers 'networks' for populations of some species (fish and birds)? Do birds nest on the same river each year or move between rivers?
3. How can we best manage populations that span multiple rivers?

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# 6. References


Arscott, D.B.; Shearer, K.; Kilroy, C. 2009: Benthic and drifting macroinvertebrate community response to the incursion of Didymosphenia geminata in the Opuha River (2006–2008). *NIWA Client Report: CHC2009-177*, NIWA, Wellington.

Balneaves, J.M.; Hughey, K.F.D. 1990: The need for control of exotic weeds in braided river beds for conservation of wildlife. Pp. 103–108 in: Proceedings of the 9th Australian Weeds Conference, Adelaide, South Australia.

Biggs, B.J.F. 2000: New Zealand periphyton guideline: detecting, monitoring and managing enrichment of streams. Ministry for the Environment, Wellington, New Zealand.

Biggs, B.J.F.; Ibbitt, R.P.; Jowett, I.G. 2008: Determination of flow regimes for protection of in-river values in New Zealand: an overview. *Ecohydrolology and Hydrobiology 8*: 17–29.

Boffa Miskell 2007: Black-fronted tern trial: effects of flow and predator control on breeding success. Unpublished report prepared for Meridian Energy by Boffa Miskell Limited in conjunction with Urtica Consulting, April 2007.

Boffa Miskell 2009: Waitaki Braided River Bird Habitat Enhancement Trial. Report prepared for Meridian Energy Ltd by Boffa Miskell Ltd, June 2009.

Brake, L.; Peart, R. 2013: Treasuring our Biodiversity: An EDS Guide to the protection of New Zealand's indigenous habitats and species. Environmental Defense Society. Auckland.

Brown, K.P. 1999a: Ahuriri weed control resource consent monitoring 1993–1999. *Unpublished Project River Recovery Report No. 99/19*, Department of Conservation, Twizel.

Brown, K.P. 1999b: Project River Recovery weed control plan 1999–2004. *Unpublished Project River Recovery Report No. 99/11*, Department of Conservation, Twizel.

Cameron, B.G.; van Heezik, Y.; Maloney, R.F.; Seddon, P.J.; Harraway, J.A. 2005. Improving predator capture rates: analysis of river margin trap site data in the Waitaki Basin, New Zealand. *New Zealand Journal of Ecology 29*: 117–128.

Cruz, J.; Pech, R.; Seddon, P.; Cleland, S.; Nelson, D.; Sanders, M.; Maloney, R. 2013: Species-specific responses by ground-nesting Charadriiformes to invasive predators and river flows in the braided Tasman River of New Zealand. *Biological Conservation 167*: 363–370.

de Lange, P.; Rolfe, J.; Champion, P.; Courtney, S.; Heenan, P.; Barkla, J.; Cameron, E.; Norton, D.; Hitchmough, R. 2013: Conservation status of New Zealand indigenous vascular plants, 2012. *New Zealand Threat Classification Series 3*. Department of Conservation, Wellington. 70 p.

Dowding, J.E.; Murphy, E.C. 2001: The impact of predation by introduced mammals on endemic shorebirds in New Zealand: a conservation perspective. *Biological Conservation 99*: 47–64.

Glova, G.J.; Duncan, M.J. 1985: Potential effects of reduced flows on fish habitats in a large braided river, New Zealand. *Transactions of the American Fisheries Society 114*: 165–181.

Goodman, J.M.; Dunn, N.R.; Ravenscroft, P.J.; Allibone, R.M.; Boubee, J.A.T.; David, B.O.; Griffiths, M.; Ling, N.; Hitchmough, R.A.; Rolfe, J.R. 2014: Conservation status of New Zealand freshwater fish, 2013. *New Zealand Threat Classification Series 7*. Department of Conservation, Wellington. 12 p.

Grainger, N.; Collier, K.; Hitchmough, R.; Harding, J.; Smith, B.; Sutherland, D. 2014: Conservation status of New Zealand freshwater invertebrates, 2013. *New Zealand Threat Classification Series 8*. Department of Conservation, Wellington. 28 p.

Gray, D. 2006: Spatial biodiversity patterns in a large New Zealand braided river. *New Zealand Journal of Marine and Freshwater Research 40*: 631–642.

Gray, D.; Harding, J.S. 2007: Braided river ecology: a literature review of physical habitats and aquatic invertebrate communities. Science for Conservation 279. Department of Conservation, Wellington.

Gray, D.; Scarsbrook, M.R.; Harding, J.S. 2006: Spatial biodiversity patterns in a large New Zealand braided river. *New Zealand Journal of Marine and Freshwater Research 40*: 631–642.

Harris, R.J.; Toft, R.J.; Dugdale, J.S.; Williams, P.A.; Rees, S.J. 2004: Insect assemblages in a native (kanuka – *Kunzea ericoides*) and an invasive (gorse – *Ulex europaeus*) shrubland. *New Zealand Journal of Ecology 28*: 35–47.

Hay, J.R. 1984: The behavioural ecology of the wrybill plover. Unpublished PhD thesis. University of Auckland, Auckland.

Hitchmough, R.; Anderson, P.; Barr, B.; Monks, J.; Lettink, M.; Reardon, J.; Tocher, M. Whitaker, T. 2013: Conservation status of New Zealand reptiles, 2012. *New Zealand Threat Classification Series 2*. Department of Conservation, Wellington. 16 p.

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

Hughey, K.F.D. 1985: Hydrological factors influencing the ecology of riverbed breeding birds on the plain's reaches of Canterbury's braided rivers. Unpublished PhD thesis, Lincoln College, University of Canterbury, Christchurch.

Hughey, K.F.D.; Warren, A. 1997: Habitat restoration for wildlife nesting on degraded braided riverbeds in New Zealand. In Hale, P.; Lamb, D. (Eds): Conservation Outside Nature Reserves. Centre for Conservation Biology, University of Queensland, Brisbane.

Jobin, B.; Picman, J. 1997: Factors affecting predation on artificial nests in marshes. *Journal of Wildlife Management 61*: 792–800.

Jowett, I.G.; Duncan, M.J. 1990: Flow variability in New Zealand rivers and its relationship to in-stream habitat and biota. *New Zealand Journal of Marine and Freshwater Research 24*: 305–317.

Joy, M.; David, B.; Lake M. 2013: New Zealand freshwater fish sampling protocols – Part 1 wadeable rivers and streams. Massey University, Palmerston North.

Keedwell, R.J. 2002: Black-fronted terns and banded dotterels: causes of mortality and comparisons of survival. PhD thesis (unpublished), Massey University, Palmerston North, New Zealand.

Keedwell, R.J. 2005: Breeding biology of Black-fronted Terns (*Sterna albostriata*) and the effects of predation. *Emu 105*: 39–47.

Keedwell, R.J.; Maloney, R.F.; Murray, D.P. 2002a: Predator control for protecting kaki (*Himantopus novaezelandiae*): lessons from 20 years of management. *Biological Conservation 105*: 369–374.

Keedwell, R.J.; Sanders, M.D.; Alley, M.; Twentyman, C. 2002b: Causes of mortality of black-fronted terns *Sterna albostriata* on the Ohau River, South Island, New Zealand. *Pacific Conservation Biology 8*: 170–176.

Lalas, C. 1977: Food and feeding behaviour of the black-fronted tern, *Chlidonias hybrida albostriatus*. Unpublished MSc thesis, University of Otago, Dunedin.

Maloney, R.F. 1993: Riverbeds and weeds – how do we keep them apart and keep the wildlife? *Ecological Society Newsletter 69*: 6–7.

Maloney R.F. 1999: Bird populations in nine braided rivers of the Upper Waitaki Basin, south Island, New Zealand: changes after 30 years. *Notornis 46*: 243–256.

Maloney, R.F.; Keedwell, R.; Wells, N.J.; Rebergen, A.L.; Nilsson, R.J. 1999: Effect of willow removal on habitat use by five birds of braided rivers, Mackenzie Basin, New Zealand. *New Zealand Journal of Ecology 23*: 53–60.

McClellan, R.K. 2009: The ecology and management of Southland's black-billed gulls. Unpublished PhD thesis, University of Otago.

McColl, R.H.S.; White, E.; Waugh, J.R. 1975: Chemical runoff in catchments converted to agricultural use. *New Zealand Journal of Science 18*: 67–84.

McDowall, R.M. 1990: When galaxiid and salmonid fishes meet - a family reunion in New Zealand. *Journal of Fish Biology 37* (Supplement A): 35–43.

McDowall, R.M. 2003: Impacts of introduced salmonids on native galaxiids in New Zealand upland streams: a new look at an old problem. *Transactions of the American Fisheries Society 132*: 229–238.

McDowall, R.M. 2006: Crying wolf, crying foul, or crying shame: alien salmonids and a biodiversity crisis in the southern cool-temperate galaxioid fishes? *Reviews in Fish Biology and Fisheries 16*: 233–422.

McDowall, R.M. 2010: New Zealand freshwater fishes an historical and ecological biogeography. *Fish & Fisheries Series 32*: 449.

Miall, A.D. 1977: A review of the braided river depositional environment. *Earth Sciences Review* 13: 1–62.

Moeed, A.; Meads, M.J. 1985: Seasonality of pitfall trapped invertebrates in three types of native forest, Orongorongo Valley, New Zealand. New Zealand Journal of Zoology 12: 17–53.

Monks, J.M.; O'Donnell, C.F.J.; Spurr, E.B. 2013: Population trends in black-fronted terns (*Chlidonias albostriatus*) on the Ashley River, North Canterbury. *Notornis 60*: 171–172.

Mosley, M.P. 2004: Rivers and the riverscape. Chapter 8 in Harding, J. (Ed.): Freshwaters of New Zealand. New Zealand Hydrological Society and New Zealand Limnological Society, Wellington.

Norbury G.; Heyward R. 2007: Predictors of clutch predation of a globally significant avifauna in New Zealand's braided river ecosystems. *Animal Conservation 11*: 17–25.

Norbury, G.; McGlinchy, A. 1996: The impact of rabbit control on predator sightings in the semi-arid high country of the South Island, New Zealand. *Wildlife Research 23*: 93–97.

Nordstrom, M.; Korpimaki, E. 2004: Effects of island isolation and feral mink removal on bird communities on small islands in the Baltic Sea. *Journal of Animal Ecology 73*: 424–433.

O'Donnell, C.F.J. 1992: Birdlife of the Ashburton River, Canterbury, New Zealand. Canterbury Conservancy Technical Report No. 1. Department of Conservation, Christchurch.

O'Donnell, C.F.J. 2000a: The significance of river and open water habitats for indigenous birds in Canterbury, New Zealand. Environment Canterbury Unpublished Report U00/37. Environment Canterbury, Christchurch.

O'Donnell, C.F.J. 2000b: Distribution, status and conservation of long-tailed bat (*Chalinolobus tuberculatus*) communities in Canterbury, New Zealand. Environment Canterbury Report U00/38. Christchurch, Environment Canterbury.

O'Donnell, C. 2004: River bird communities. Pp. 18.1–18.19 in Harding, J.S.; Mosley, M.P.; Pearson, C.P.; Sorrel, B.K. (Eds): Freshwaters of New Zealand. New Zealand Hydrological Society Inc. and New Zealand Limnological Society Inc. Christchurch.

O'Donnell, C.F.J.; Phillipson, S.M. 1996: Predicting the occurrence of mohua predation from the seedfall, mouse and predator fluctuations in beech forests. *New Zealand Journal of Zoology 23*: 287–294.

O'Donnell, C.F.J.; Christie, J.E.; Hitchmough, R.A.; Lloyd, B.; Parsons, S., 2010. The conservation status of New Zealand bats, 2009. *New Zealand Journal of Zoology 37*: 297–311.

O'Donnell, C.F.J.; Hoare, J.M. 2011. Meta-analysis of status and trends in breeding populations of black-fronted terns *Chlidonias albostriatus*, 1962–2008. *New Zealand Journal of Ecology 35*: 30–43.

O'Donnell, C.F.J.; Moore, S.M, 1983. The wildlife and conservation of braided river systems in Canterbury. Fauna Survey Unit Report No. 33. NZ Wildlife Service, Wellington.

Pascoe, A. 1995. The effects of vegetation removal on rabbits (*Oryctolagus cuniculus*) and small mammalian predators in braided riverbeds in the Mackenzie Basin. Unpublished M.Sc. thesis, University of Otago, Dunedin.

PCE (Parliamentary Commissioner for the Environment) 2013. Water quality in New Zealand: land use and nutrient pollution. Parliamentary Commissioner for the Environment, Wellington, New Zealand. 82 p.

Pham, L.; West, D. Closs, G.P. 2013. Reintroduction of a native galaxiid (*Galaxias fasciatus*) following piscicide treatment in two streams: response and recovery of the fish population. *Ecology of Freshwater Fish 22*: 361–373.

Pickerell, G.A.; O'Donnell, C.F.J.; Wilson, D.J.; Seddon, P.J. 2014. How can we detect introduced mammalian predators in non-forest habitats? A comparison of techniques. *New Zealand Journal of Ecology 38*: 86–102.

Pierce, R.J. 1979. Foods and feeding of the wrybill (*Anarynchus frontalis*) on its riverbed breeding grounds. *Notornis 26*: 1–21.

Pierce, R.J. 1986. Difference s in the susceptibility to predation during nesting between pied and black stilts (*Himantopus* spp.). *Auk 103*: 273–280.

Pierce, R.J. 1987. Predators in the Mackenzie Basin: their diet, population dynamics and impact on birds in relation to the abundance and availability of their main prey (rabbits). Unpublished Wildlife Service Report, Wellington, New Zealand.

Pierce, R.J. 1999. Regional patterns of migration in the banded dotterel (*Charadrius bicinctus bicinctus*). *Notornis 46*: 101–122.

Reardon, J.T.; Whitmore, N.; Holmes, K.M.; Judd, L.M.; Hutcheon, A.D.; Norbury, G.; Mackenzie, D.I. 2012. Predator control allows critically endangered lizards to recover on mainland New Zealand. *New Zealand Journal of Ecology 36*: 141–150.

Rebergen, A.; Keedwell, R.; Moller, H.; Maloney, R. 1998. Breeding success and predation at nests of banded dotterel (*Charadrius bicinctus*) on braided riverbeds in the central South Island, New Zealand. *New Zealand Journal of Ecology 22*: 33–41.

Resh, V.H.; Brown, A.V.; Covich, A.P.; Gurtz, M.E.; Li, H.W.; Minshall, G.W.; Reice, S.R.; Sheldon, A.L.; Wallace, J.B.; Wissmar, R.C. 1988. The role of disturbance in stream ecology. *Journal of the North American Benthological Society 7*: 433-455.

Robertson, C.J.R.; O'Donnell, C.F.J.; Overmars, F.B. 1983. Habitat requirements of wetland birds in the Ahuriri River catchment, New Zealand. *NZ Wildlife Service Occasional Publication No. 3*. Department of Internal Affairs, Wellington.

Robertson, H.A.; Dowding, J.E.; Elliott, G.P.; Hitchmough, R.A.; Miskelly, C.M.; O'Donnell, C.F.J.; Powlesland, R.G.; Sagar, P.M.; Scofield, R.P.; Taylor, G.A. 2013. Conservation status of New Zealand birds, 2012. *New Zealand Threat Classification Series 4*. 22 pp.

Sanders, M.D. 2009. Statement of evidence presented to the Environment Court, 20 August 2009, in relation to TrustPower Ltd's proposed Wairau Hydroelectric Power Scheme.

Sanders, M.D.; Maloney, R.F. 2000. Effect of weed control on nesting success and nest density of braided river birds on the Ahuriri River. Unpublished Project River Recovery Report No. 99/08. Department of Conservation, Twizel, New Zealand.

Sanders, M.D.; Maloney, R.F. 2002. Video monitoring of nesting banded dotterels, black stilts, and black-fronted terns in braided rivers of the Upper Waitaki Basin. *Biological Conservation 106*: 225–36.

Stark, J.D.; Boothroyd, I.K.G.; Harding, J.S.; Maxted, J.R.; Scarsbrook, M.R. 2001. Protocols for sampling macroinvertebrates in wadeable streams. Prepared for the Ministry for the Environment, Sustainable Management Fund Project No. 5103. http://www.cawthron.org.nz/coastal-freshwater-resources/downloads/protocols-full-manual.pdf and www.doc.govt.nz/get-involved/run-a-project/our-procedures-and-sops/biodiversity-inventory-and-monitoring/freshwater-ecology/

Stead, E. F. 1932. The life histories of New Zealand birds. Search Publishing Co., London.

Steffens, K.E.; Sanders M.D.; Gleeson D.M.; Pullen K.M.; Stowe C.J. 2012. Identification of predators at black-fronted tern *Chlidonias albostriatus* nests using DNA analysis and digital video recorders. *New Zealand Journal of Ecology 36*: 48–55.

Sullivan, J.J.; Williams, P.A.; Cameron, E.K.; Timmins, S.M. 2004. People and time explain the distribution of naturalized plants in New Zealand. *Weed Technology 18*: 1330–1333.

Sullivan, J.J.; Williams, P.A.; Timmins, S.M.; Smale, M.C. 2009. Distribution and spread of environmental weeds along New Zealand roadsides. *New Zealand Journal of Ecology 33*: 190–204.

Te Rūnanga o Kaikōura 2007. Te Mahere Whakahaere Taiao o Te Rūnanga o Kaikōura Te Rūnanga o Kaikōura Environmental Management Plan. 2$^{nd}$ Editiion. Te Rūnanga o Kaikōura, Kaikōura.

Waters, J.M.; Craw, D. 2008. Evolution and biogeography of New Zealand's longjaw galaxiids (Osmeriformes: Galaxiidae): the genetic effects of glaciation and mountain building. *Freshwater Biology 53*: 521–534.

Waters, J.M.; Wallis, G.P. 2001. Mitochondrial DNA phylogenetics of the *Galaxias vulgaris* complex from South Island, New Zealand: rapid radiation of a species flock. *Journal of Fish Biology 58*: 1166–1180.

Whitton, B.A.; Ellwood, N.T.W.; Kawecka, B. 2009. Biology of the freshwater diatom Didymosphenia: a review. *Hydrobiologia 630*: 1–37.

Williams, P.A.; Wiser, S. 2004. Determinants of regional and local patterns in the floras of braided riverbeds in New Zealand. *Journal of Biogeography 31*: 1355–1372.

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, G. 2001. National Distribution of Braided Rivers and the Extent of Vegetation Colonisation. Landcare Research Contract Report: LC0001/068. Prepared for Department of Conservation, Twizel.

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

Zoellick, B.W.; Ulmschneider, H.M.; Cade, B.S.; Stanley, A.W. 2004. Isolation of Snake River islands and mammalian predation of waterfowl nests. *Journal of Wildlife Management 68*: 650–662.