

IN THE MATTER of the Resource Management Act 1991

AND

IN THE MATTER of applications for resource consent by the Central Plains Water Trust and a notice of requirement for the designation of land by Central Plains Water Limited associated with the construction and operation of the Central Plains Water Scheme

**STATEMENT OF EVIDENCE OF KENNETH FREDERICK DAVID HUGHEY ON BEHALF
OF THE DIRECTOR GENERAL OF CONSERVATION**

1. INTRODUCTION

Qualifications and experience

- 1.1 My full name is Kenneth Frederick David Hughey. I am Professor of Environmental Management in the Environment, Society and Design Division at Lincoln University. I have been working at Lincoln University since 1995. Prior to then I worked for the Department of Conservation in a variety of research and management positions. Between 1984 and 1987 I worked for the New Zealand Wildlife Service. My principal qualifications are MSc (Resource Management) and PhD (Resource Management).
- 1.2 I have considerable experience with wetland research and management, primarily concerning the use by and habitat requirements of wetland birds on braided rivers. My PhD concerned the habitat requirements of wetland birds on braided rivers – in particular it involved field work on the Lower Rakaia and Ashley rivers. I have been involved in surveying most braided rivers along the eastern South Island and with some on the West Coast, and the Clutha River in South Otago. This work was complemented by a major study of the invertebrate food supplies in both the lower Waimakariri and Ashley rivers. In addition, for several years I was chair of the Department of Conservation's black stilt recovery group and I was one of the key designers of the Project River Recovery programme in the Mackenzie Basin. I am one of only a few people to have had published in peer reviewed journals and books articles on quantitative habitat needs and modelling work related to riverbed nesting birds.
- 1.3 I have previously given evidence to hearings on wildlife (mostly birdlife but also concerning aquatic and terrestrial invertebrates and sometimes fish) issues relating to the rivers and wetlands of the Mackenzie Basin, the Rakaia River and Rangitata River (on Water Conservation Order applications), the Ashley and Wairau rivers (on resource consent applications), the Waitaki River Water Allocation Board (established under the Resource Management (Waitaki Catchment) Amendment Act), and on the Waimakariri Regional River Plan.
- 1.4 I am familiar with the applications by Central Plains Water (CPW) for resource consents for on the irrigation scheme taking water from the Waimakariri and Rakaia rivers, the AEE report (dated June 2006) and the more detailed supporting assessments relevant to my area of expertise. I am also familiar with the further

information circulated by CPW and dated August 2006 and relevant evidence provided since then, including that presented in the councils' officers' reports, that in the evidence of CPW witnesses received on 8 February 2008, and others witnesses for Fish and Game, and DoC.

- 1.5 I confirm that I have read and agree to comply with the Code of Conduct for Expert Witnesses (Environment Court Consolidated Practice Note 2006). This evidence is within my area of expertise, except where I state that I am relying on what I have been told by another person. I have not omitted to consider material facts known to me that might alter or detract from the opinions that I express.

Scope of evidence

- 1.6 I have been asked by the Department of Conservation to describe the overall ecology of the Waimakariri and Rakaia rivers, as braided river systems, and the essential characteristics that sustain their native fisheries and its birdlife communities. There will be a particular focus on the habitat requirements of river-bed 'dependant' bird species and, more specifically, two species of major conservation concern, the black-fronted tern *Sterna albostrigata* and wrybill *Anarhynchus frontalis*. Both species are significant because of this conservation concern and because both rivers represent important remaining strongholds for these species. Consequently, the CPW scheme needs to be carefully considered in relation to whether or not it will affect the habitat requirements of these species. In addition I have been asked to describe the wildlife and general conservation features of Te Waihora/Lake Ellesmere (from hereon 'the lake') and to identify the potential impacts of the CPW scheme on birdlife in particular.
- 1.7 My evidence is divided into four parts and I cover the following:

PART A: OVERALL ECOLOGY OF BRAIDED RIVER SYSTEMS AND THE CHARACTERISTICS THAT SUSTAIN BIRDLIFE

- a. Broad description of gravel-bed braided rivers in NZ, including physical features affected by changing flows that are important to birdlife
- b. International and National significance of braided rivers
- c. Bird communities of braided rivers and seasonality
- d. Essential characteristics that sustain birdlife

- e. Aquatic invertebrate food resources – key controlling factors
- f. Description of existing and potential threats to braided river ecology and birdlife

PART B: SIGNIFICANCE OF THE WAIMAKARIRI AND RAKAIA RIVERS

- g. General description of the overall ecology of the rivers
- h. Description of the birdlife communities of the rivers, including species distribution and relative abundance
- i. Assessment of the national and international significance of the rivers and their birdlife communities
- j. Summary of the range of habitat types and essential characteristics needed to sustain the birdlife communities on the two rivers

PART C: POTENTIAL IMPACTS OF THE CPW SCHEME ON BIRDLIFE

- k. Identification of how the CPW scheme may adversely affect the capacity of the rivers to continue to sustain overall ecological functioning and birdlife communities
- l. Critique of the relevant bird components of the key councils' officers' reports and CPW witnesses' evidence

PART D: CONCLUSIONS RELATED TO BIRDLIFE OF THE WAIMAKARIRI AND RAKAIA RIVERS

PART E: DESCRIPTION OF THE ECOLOGY OF TE WAIHORA/LAKE ELLESMERE WITH AN EMPHASIS ON BIRDLIFE

- m. General description of the overall ecology of the lake
- n. Description of the birdlife communities of the lake, including species distribution and relative abundance
- o. Assessment of the national and international significance of the lake and its birdlife communities
- p. Summary of the range of habitat types and essential characteristics needed to sustain the birdlife communities of the lake

PART F: KEY QUESTIONS RELATED TO POTENTIAL IMPACTS ON BIRDLIFE OF TE WAIHORA/LAKE ELLESMERE

PART G: CONCLUSIONS RELATED TO BIRDLIFE OF TE WAIHORA/LAKE ELLESMERE

- 1.8 My evidence has two broad purposes: it attempts to deal with key aspects of birdlife and their ecology on the affected rivers and on the lake; and, it provides the context for the more detailed evidence of other witnesses on behalf of the Director-General and North Canterbury Fish and Game Council on the potential impacts of the CPW Scheme on the instream ecology and riverbed birdlife communities of the Waimakariri and Rakaia rivers.

Summary of findings

PART A: OVERALL ECOLOGY OF BRAIDED RIVER SYSTEMS AND THE CHARACTERISTICS THAT SUSTAIN BIRDLIFE

- 1.9 The multi-channelled, unstable, and mostly mountain-catchment braided rivers found on the eastern South Island are rare internationally. Their combination of physical features provide habitat for a range of endemic bird species. While superficially many of the braided rivers appear similar, in fact there are often subtle differences which make some better for birdlife than others. In this regard the lower sections of the Waimakariri and Rakaia are generally more gently sloping, wider and much more braided than lower sections of other Canterbury braided rivers including the Rangitata River, thus making them more suitable to some key braided river bird species.
- 1.10 A large and diverse range of bird species, in seven guilds ('communities of like birds'), use these rivers: open water divers (e.g., cormorants), deep water waders (e.g., stilts), shallow water waders (e.g., wrybill), dabbling waterfowl (e.g., ducks), aerial hunting gulls and terns (e.g., black-fronted tern and black-billed gull), swamp specialists (e.g., pukeko), and riparian wetland species (e.g., kingfishers). While particular species, e.g., black-fronted tern, are of conservation concern, it is important to provide appropriate habitat conditions for the range of guilds, and therefore species present.
- 1.11 There is a high degree of seasonality to bird use of these rivers. The waders (two guilds) and aerial hunting gulls and terns in particular use the river mainly for breeding and feeding during the period late August to January. Outside of these times members of these guilds typically migrate to other areas where they over-winter. When these birds are not present, river flows remain important in terms of foods for the breeding

season and for maintaining nesting habitat clear of exotic vegetation growth (flood flows).

- 1.12 Broadly speaking the guilds and key species require very diverse habitat types. Many species are ground nesters and require bare areas of shingle protected from predation for breeding, and a range of aquatic (e.g., shallow riffles for short legged waders) and terrestrial habitats for feeding. These habitats are maintained in braided rivers by: natural flow instability/variation underpinned by a definable (and seasonally appropriate) minimum flow, maintenance of a sediment supply for an active riverbed, maintenance of overall riverbed width to provide a natural braiding pattern, and a balance of non-vegetated and only lightly-vegetated terrestrial riverbed environments.
- 1.13 Invertebrates, primarily of aquatic origin, are the main foods of key species and guilds. Provision of these foods relies on appropriate flows. While birds are mainly on the rivers in the spring and early summer it is important that flows are maintained at suitable levels in winter to provide conditions conducive for food production for when the birds arrive for breeding.
- 1.14 There are five main threats, either potential or existing, to the birds on these rivers: predators, both mammalian (e.g., stoats) and aerial (black-backed gulls), weed encroachment, water use, flood control works and channelisation, and recreational activities. There are relationships between the causes and effects of all of these threats so changes in one can lead to changes elsewhere.

PART B: SIGNIFICANCE OF THE WAIMAKARIRI AND RAKAIA RIVERS

- 1.15 The Waimakariri and Rakaia rivers support bird species from all seven guilds expected for these types of braided rivers. In addition both the invertebrate and native fish faunas are typical of these types of rivers. When considered together the overall ecology of these rivers reflects the characteristics of the braided river environment.
- 1.16 Both rivers are nationally and internationally important for the large number and high proportion of the 'nationally endangered' black-fronted tern and the 'nationally vulnerable' wrybill populations they support. While both rivers are very important, the former supports around 6% of the endangered tern population and the latter around 5% of the wrybill population in those parts of the rivers surveyed for both species. These species rely on particular combinations of microhabitats for their ongoing conservation.

- 1.17 It is particularly hard to reliably determine trends in numbers of the key species on these rivers, without major and ongoing investment in repeat surveys. This means that any significant impact predicted to detrimentally impact on birds, and required mitigation measures, will be very difficult to monitor. The existing surveys may even be inappropriate as baselines for ongoing decision monitoring.
- 1.18 Part of the reason the rivers are so important for birds is because of the relatively large area and high degree of naturalness and intactness of their braided river wildlife habitats, including river flows. Particularly notable are relatively natural river flows, the extent of braiding and the high percentage of substantially bare terrestrial riverbed habitat needed for secure nesting.
- 1.19 Related to the above there are three key principles/factors affecting birdlife on the Waimakariri and Rakaia, all of which have relationships both direct and indirect with river flows, and each of which has synergistic and potentially cumulative effect considerations:
- a. The provision of suitable potential nesting habitat, substantially free of standing exotic vegetation;
 - b. Protection of nests and nesting birds from the effects of predators; and
 - c. The provision of suitable food supplies at the right time and at the right location.

PART C: POTENTIAL IMPACTS OF THE CPW SCHEME ON BIRDLIFE and
PART D: CONCLUSIONS RELATED TO BIRDLIFE OF THE WAIMAKARIRI AND
RAKAIA RIVERS

- 1.20 I have provided a general-level introduction to the three key principles/factors and then specifically critiqued each against the applicant's evidence.
- 1.21 Overall, I find that while the CPW scheme has potential to impact birdlife in a number of ways there is insufficient information provided by the applicant to enable a fully informed assessment to be made.
- 1.22 Nevertheless, I conclude that synergistic affects and interactions between the key ecological principles/factors, identified in 1.19, as a result of the proposed irrigation scheme are likely to diminish the conservation prospects of key birdlife on the Waimakariri River. I am especially concerned about the lowering of flows in the bird breeding season which research suggests will lead to increased rates of predation of

already endangered species. My own recent research suggests the optimal range for bird nesting habitat appears to be 60-90 m³s⁻¹ which is typical of flows occurring in the peak of the spring-early summer breeding season: Oct-Dec.

- 1.23 Mitigation and monitoring measures proposed by the applicant, in respect of the Waimakariri River, e.g., exotic weed control and mammalian predator control, face major challenges. Monitoring changes in bird numbers is very difficult to reliably undertake. Weed control is expensive and ongoing and mammalian predator control is costly, ongoing and of unproven benefit. The best known form of mammalian predator control is, in my opinion, maintaining the natural river flows.
- 1.24 With regard to the Rakaia I am of the view that the provisions of the National Water Conservation Order, plus the relatively minor size of the take, will have an overall 'less than minor effect' on the birdlife of this river. There might be some local effects, e.g., intake structure management, but there are relatively straight forward mitigation opportunities in these circumstances.

PART E: DESCRIPTION OF THE ECOLOGY OF TE WAIHORA/LAKE ELLESMERE WITH AN EMPHASIS ON BIRDLIFE

- 1.25 Te Waihora/Lake Ellesmere has long been recognised for its wetland wildlife values, and these values exist today – overall the lake is of national and international importance for birdlife. The lake contains a diverse range of habitat types used by many guilds of birds including threatened and endangered species. The biggest controlling influences over these values and the habitats is lake level management, itself strongly influenced by tributary inflows, and water quality.

PART F: POTENTIAL IMPACTS ON WILDLIFE OF TE WAIHORA/LAKE ELLESMERE

- 1.26 The CPW scheme will have major effects on water quantity and quality of the lake, as identified in the evidence of key CPW witnesses and others. It seems highly likely that inflows will increase and the annual average number of lake openings will increase. Impacts of water quality changes may be severe for some wildlife but there is insufficient information provided by the applicant to enable a fully informed assessment to be made.

PART G: CONCLUSIONS RELATED TO BIRDLIFE OF TE WAIHORA/LAKE ELLESMERE

- 1.27 Some changes associated with water quantity should be positive for the lake by leading to increases in tributary inflows. Changes to water quality, however, are much more problematic and require further urgent research and consideration before any firm conclusions about impact on wildlife can be drawn. I am nevertheless of the view that they will on the whole be detrimental for wildlife.

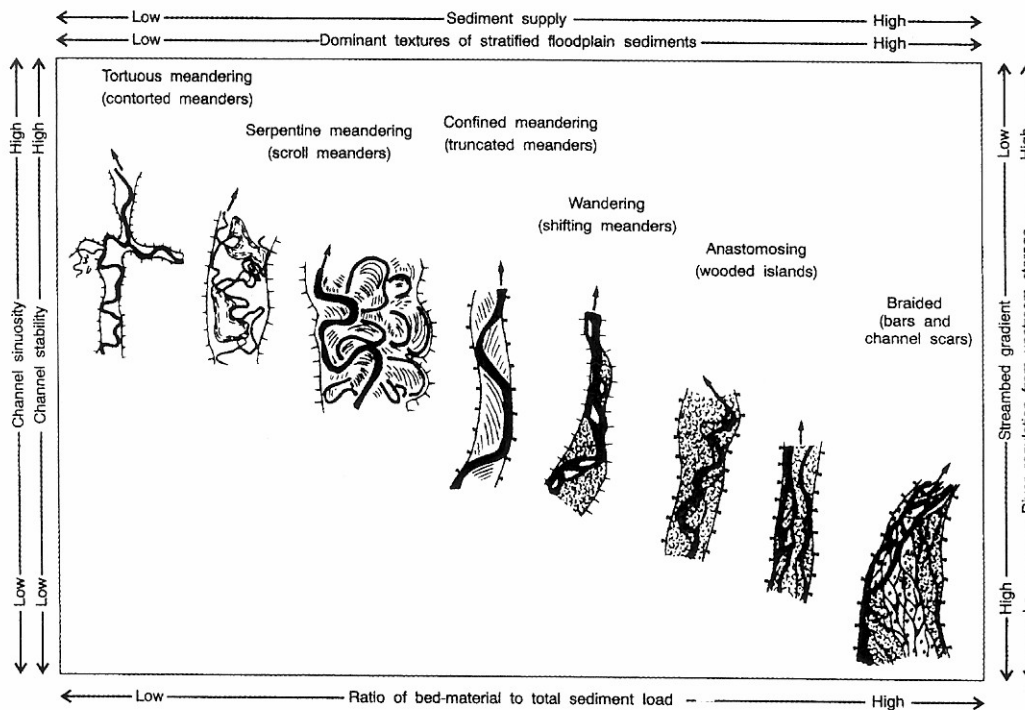
2. EVIDENCE

PART A: OVERALL ECOLOGY OF BRAIDED RIVERS AND CHARACTERISTICS THAT SUSTAIN BIRDLIFE

(a) Broad description of gravel-bed braided rivers in NZ

- 2.1 Braided rivers are most simply and typically defined as rivers with comparatively high levels of instability and multiple channels – in New Zealand these rivers sit at the extreme end of instability continua, as shown in Figure 1 below (after Mollard 1973, cited in Mosley 2004: 8.17). As can be seen from this diagram these rivers are characterised by having:
- high ratios of bed-material to total sediment load;
 - high streambed gradients;
 - low levels of river regulation from upstream storage;
 - high levels of sediment supply; and
 - low levels of channel sinuosity and stability.
- 2.2 There are important implications for management from this understanding, e.g., assuming it is important to maintain an unstable braided river (say for birdlife), then river regulation issues need to be carefully managed. For example, in relation to the Waitaki some of these issues (with the benefit of considerable hindsight) were not fully considered and there has been a progressive increase in vegetation cover and the river is becoming narrower, more stable and less inclined to braid (Hicks *et al.* 2003) – all factors which over time could reduce the river's value as a habitat for some key bird species.

Figure 1: The continuum of river types and controlling variables (after Mollard 1973, cited in Mosley 2004)



2.3 In New Zealand the multiple braided rivers identified by Wilson (2001) can be classified into several types, including:

- a. large, very unstable, wide, gravel-bedded (and largely uncontrolled) rivers with catchments in the main divide of the Southern Alps, either on the east or west coasts, with multiple braids, e.g., often 3-7 in any one cross-section; and
- b. smaller, largely, foothill catchment braided rivers along the east coasts of both the North and South Islands typically with only a few braids, and more stable than type 'i' rivers.

2.4 While both these types of braided rivers are significant for native fisheries and birdlife it is type (a) that most typifies conditions within much of the lower Waimakariri and almost all of the lower Rakaia and which will therefore be the focus of the remainder of this evidence. Both the Rakaia and Waimakariri systems differ from the lower sections of other braided rivers in Canterbury, including large parts of the lower Rangitata which is steeper, is composed of a much larger substrate, and tends to be less highly braided. The lower Rakaia and Waimakariri rivers, i.e., the sections below the gorges, therefore provide more suitable habitat for many key braided river bird species, e.g., wrybill and banded dotterel, than does the equivalent part of the Rangitata.

(b) International and National significance of braided rivers

2.5 Braided rivers with the physical characteristics of those found in New Zealand are rare internationally – this is largely because the New Zealand physical environment is comparatively young and highly dynamic (see Mosley and Schumm 2000). While superficially similar systems occur in parts of South America and North America they are mostly characterised by seasonally different flow regimes, they often occur in dramatically different climatic environments and often have different substrate characteristics – in combination these characteristics mean they do not provide the same potential to be inhabited by the type of diverse birdlife community found on the braided rivers of New Zealand.

2.6 Nationally braided rivers occur around much of New Zealand (see for example Wilson 2001). While only a few occur in the North Island there are many in the South. However, of these many rivers only a few are significant for the ecological values they support for wide ranging native fisheries and birdlife values, and mostly these rivers occur along the eastern South Island. Furthermore, and apart from a few smaller rivers in the Mackenzie Basin and in Canterbury, most of the really important braided rivers are sourced from catchments in the Southern Alps.

(c) Bird communities of braided rivers, generally, including seasonality

2.7 In this section of evidence I discuss the bird species that generally occupy braided riverbeds, then about seasonality of use, and then draw some conclusions related to seasonality and general habitat provision principles. The discussion covers braided rivers generally, and not just the lower reaches – this is because much of the key research has been undertaken in upper river reaches.

Bird Guilds

2.8 Guilds, or communities of bird species with similar requirements (Verner 1984), have primarily been identified by characterising the main microhabitats and the depth of water that species used for feeding on braided rivers and then grouping the species with similar characteristics together. Generally, species within guilds also have similar nesting and roosting habitats.

2.9 While O'Donnell (2000) identified eight bird guilds occurring on rivers generally, I consider only seven to be of relevance to braided rivers:

- i. **Open water divers.** Cormorants, e.g., black shag, and diving waterfowl that usually forage in open, deep waters on both lakes and rivers. Most hunt by diving for fish, though some consume invertebrates and waterweed from lake or river pool or backwater bottoms. Diving waterfowl nest in vegetation overhanging the waters edge at water level. Cormorants usually nest high in overhanging trees (especially willows) and overhanging rock outcrops.
- ii. **Deep water waders.** Waders with medium-long legs that allow them to forage in water depths of >200 mm as well as shallow water (e.g., stilts, herons, oystercatchers). They breed on the ground in open areas, especially shingle or sand, free of emergent vegetation. They usually roost in flocks in similar habitats. This guild includes species that breed in New Zealand and arctic migrant waders. Arctic migrants (e.g., godwits) do not breed in New Zealand but use habitats here as their wintering ground. Most of Canterbury's Arctic migrants are present only in summer and are concentrated on coastal water bodies. However, they use microhabitats and water depths similar to those of resident waders.
- iii. **Shallow water waders.** Waders with short legs that restrict them to feeding in water <80 mm, and most use is of water <40 mm deep (e.g. plovers, sandpipers). They breed on the ground in open areas, especially shingle, wetland turf, or sand, free of emergent vegetation. They usually roost in flocks in similar habitats. This guild includes species that breed in New Zealand, e.g., wrybill plover and banded dotterel, and arctic migrant waders.
- iv. **Dabbling waterfowl.** Ducks and swans (e.g., NZ shoveler, paradise shelduck) that predominately feed by dabbling while floating on open water or graze on wetland turf, saltmarsh and pasture. Most species nest within dense cover in swamps or riparian vegetation and roost by floating on open water.

- v. **Aerial hunting gulls and terns.** Generally aerial hunters, flying over open water or river channels and diving for invertebrates and small fish (e.g., black-fronted tern, black-billed gull). They nest on open shingle bars and islands.
- vi. **Swamp specialists.** Rails, such as marsh crake and pukeko, and bittern that dwell in dense swamp vegetation associated with wetlands. Their diet consists of seeds and invertebrates gleaned from swamp vegetation or surface water with good vegetative cover. They also consume vegetation itself, and, in the case of bittern, fish and amphibians. They generally nest within *Carex secta* or *Typha orientalis* and other rushes (e.g., O'Donnell 1994).
- vii. **Riparian wetland species.** Species that do not exclusively depend on either terrestrial or aquatic habitats (e.g., swallows, pipits, kingfishers). They do not depend on wetlands though are often associated with them as much as any other habitat for either breeding and feeding.

2.10 Threats to water birds often vary among guilds. For example, construction of dams would potentially favour dabbling waterfowl and open-water divers, but be detrimental to wading birds that forage primarily in shallow water. Abstraction of small amounts of water from rivers would also likely be detrimental to the shallow water wading species if the amount of shallow water habitat declined, but other guilds might not be affected.

Seasonality

2.11 Most braided river birds are not present on the rivers for the whole year (See Table 1). They have a set annual cycle, and so their requirements change throughout the year. Most birds are migratory. They arrive on the rivers in late winter and early spring, then breed on the rivers and migrate again to their wintering sites (usually coastal estuaries in New Zealand, although some migrate to Australia) in mid-summer. Note there is a close connection between some key species on the Rakaia with habitat, seasonal use, and river flood flows, with Te Waihora/Lake Ellesmere, e.g., when the Rakaia is in large flood many wrybills often temporarily flock to the lake (pers. obs.).

2.12 The arrival of breeding birds coincides with the typical onset of increased flows in the river in spring and the associated rapid increase in the availability of aquatic

invertebrates – higher flows at this time are therefore important for feeding. The birds use this increase in food availability to recover/improve their body condition after migration, and to sustain themselves during periods when energy demand (associated with establishing territories, producing eggs, and then raising chicks).is high. If this period of increased flow and the associated higher levels of food production and availability is threatened, then many bird species (particularly waders and terns) would not have sufficient food supplies to sustain themselves through the breeding season.

Guild	Example species (Common name)	Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec		
Open water divers	black shag	←→													
Deep water waders	SIPO	←→							→					→	
Shallow water waders	Wrybill	←→							→					→	
Dabbling waterfowl	Paradise shelduck	←→													
Aerial hunting gulls and terns	black-fronted tern	←→								→					→
Swamp specialists	pukeko	←→													
Riparian wetland species	kingfisher	←→													

Table 1. Examples of seasonal use of rivers by bird species guild (←→), and the core breeding seasons (yellow) for deep water and shallow water wading bird guilds and aerial hunting gulls and terns.

- 2.13 The arrival of birds varies by several weeks depending on the species and the location of the river. The first birds to arrive are South Island pied oystercatchers in late June and early July. Wrybill and banded dotterel typically arrive around mid-late August although dotterels begin nesting earlier. Black-fronted terns appear to nest about a month later than wrybill. For example, on the Ohau River, the earliest nest for black-fronted terns was 26 September and the peak laying began in the second week of October. Black-fronted terns were present and courting at potential colony sites from early September (Lalas 1977; Keedwell 2002). On the Rakaia they were reported by Hughey (1985) as nesting in the first week of October.
- 2.14 The earliest banded dotterel nests on the Ohau were in the first week of September or last few days of August and peak laying began in the second week of September. Near the coast, banded dotterels start breeding in late July and peak in September, then are finished by the end of December.
- 2.15 Thus, appropriate breeding season river flows are required from August to January to cover the key nesting periods for the key species, but especially from September to December inclusive. Flows at other times, in particular the late winter/early spring, are also important for birds as they are linked to the production and availability of aquatic food resources, and to the provision of nesting habitat. More detail about the timing and departure of breeding birds can be found in the following references: Pierce (1982), Robertson *et al.* (1983, 1984), Hay (1984), and Hughey (1985).

(d) Essential characteristics that sustain birdlife

- 2.16 In this section I first deal with the broad principles of habitat related to birdlife. I then address specific habitat types and their use by birds. Where possible I address this latter work with specific application to the Waimakariri and Rakaia rivers. Unfortunately for some guilds and some key species there has been little to no work done on these rivers. Nevertheless I am of the general view that scientifically robust information gathered from other braided rivers will be relevant also in this context.

The broad principles

- 2.17 There are multiple physical characteristics which in combination act to provide habitat for the wide ranging native fisheries and birdlife that occupy braided rivers. The single most essential of these are water and the nature of the sediment supply

regime within catchments (see also the evidence of Dr Tim Davies). The roles played by water, sediment and catchment shape amongst a range of variables are well reviewed by Mosley and Schumm (2000), while some of the factors contributing to food chain development in gravel-bed rivers are outlined and discussed by Power (2000). The essential characteristic, however, which both confounds and best helps explain fisheries and birdlife presence, is variability.

2.18 Variability, within the New Zealand braided river environment, can be defined as being the range of physical and biotic conditions which interact in dynamic and frequently non-linear ways to provide habitat that is suitable to ongoing but unstable occupation by fisheries and birdlife. Key natural components that contribute to this variability, summarised largely from Mosley and Schumm (2000), are:

- climate, especially rainfall (and where appropriate snow accumulation and snowmelt);
- sediment supply, which in turn is related to historic baseline (e.g., glaciation events) and contemporary disturbance (e.g., earthquakes and other ongoing tectonic movements) events; and
- native riverbed vegetation.

Key human-induced components include:

- flow regime change, i.e., damming and abstraction;
- riverbed management, i.e., channel control;
- catchment land use (e.g., forestry);
- exotic, terrestrial (e.g., willows) and aquatic (e.g., didymo) vegetation (see Miller 2000) and animals (e.g., trout and mammalian predators); and
- direct human interactions, e.g., recreational activities such as the uncontrolled use of off-road vehicles.

2.19 Together the natural components interact to provide for, or at times limit, use of the river by native fish, birdlife and other biotic components of the gravel-bed river food chain (as described by Power 2000), e.g., major floods substantially, but temporarily reduce the biomass of the river while at the same time sometimes rejuvenating habitat, e.g., the provision of non-vegetated areas used by key bird species for nesting. The human-induced components typically interact with the natural components to, in general, limit or negatively impact on the native biotic values, i.e., they act to exacerbate negative effects that are sometimes associated with the

natural variability. For example naturally water flows can drop to low levels which can impact on bird nesting success, but lower river flows caused by water abstraction would worsen this effect. In extreme cases the additional human-induced changes can lead to loss of key ecosystem/biotic components including localised species loss and extinctions, e.g., the almost complete loss of braided river birdlife on the Opihi River as a result of water resource development.

2.20 Given the above, the essential components are the appropriate combination of the core natural components, modified by human-induced changes only to the extent that these changes do not significantly reduce the essential habitat requirements of the key species and communities on these riverbeds. In summary, and broadly speaking, for birdlife these key characteristics are:

- natural flow instability/variation underpinned by a definable minimum flow, i.e., both the longer term lower to medium flows and the periodic flood and fresh events;
- maintenance of riverbed sediment supply which helps maintain an active and mobile riverbed;
- maintenance of overall active riverbed width to provide for the natural braiding patterns; and
- a balance of non-vegetated and only lightly-vegetated terrestrial environments within the active riverbed area.

2.21 Specifically, it is important to note that the channels in braided rivers vary enormously from those that are primarily fed from through-flow in gravels (i.e., seepage channels), to small tertiary or minor channels connected at both ends to others braids, to intermediate or secondary channels, and to major or primary channels which might carry in excess of 30% of the river's flow. Each of these channel forms has characteristics that affect their ability to be utilised or otherwise at various times, e.g., during relatively small freshes or floods seepage channels often remain stable and can provide a significant food resource possibly not available in other channels at these times; major channels can act as barriers against egress by mammalian predators onto riverbed islands; etc. And within each of these channel forms there are the pools, runs, riffles and backwaters which provide a range of varying habitat opportunities for both fish and birdlife. What now follows is a detailed description of the habitat types required by the riverbed bird community.

Particular habitat types required by riverbed dependent birds

- 2.22 In this section of evidence I will highlight the fact that each guild of birds requires quite different habitat and flow conditions to sustain their breeding and feeding habitat. If one or a number of these habitats are altered or disappear then the ability of the system to sustain the full range of the birdlife community will be reduced and future opportunities for restoration will be limited. It is important to note that there is little published (or even unpublished) habitat related research regarding birdlife on the Waimakariri River. There is work for the Rakaia (Hughey 1985) but even this is now dated. Thus, throughout the course of what follows I will be referring to what I consider is the best and most recently available applicable work from elsewhere, mostly from the Mackenzie Basin, lower Waitaki River, and the Wairau River. While there are differences between some of these rivers I consider the overall general findings to still be applicable.
- 2.23 All habitats can be subdivided into smaller habitat components that members of each bird guild generally use for foraging, breeding or roosting. For example, on a braided river, the habitat can be divided into terrestrial or aquatic habitats, into zones with different substrates, or levels with different flooding frequency. Channels can be divided into different types with different flow characteristics. In reality, individual species have very complex habitat requirements that vary seasonally.
- 2.24 I have been involved in studies that characterised habitat use profiles of key wetland species that occur in Canterbury and Otago using multivariate criteria (habitat descriptions, substrates, water depth and velocity) (e.g., Hughey 1985, Hughey *et al.* 1986). I am also very aware of the other principal work in this area undertaken by Robertson *et al.* (1983, 1984) and specifically for black-fronted terns on the Wairau by O'Donnell *et al.* (2006).
- 2.25 The remainder of this section of evidence will highlight the different microhabitats that need to be maintained across a typical river profile in a mountain catchment braided river.
- 2.26 In the first instance it is important to note that key species on the Waimakariri and Rakaia, including black-fronted tern (see O'Donnell *et al.* 2006: 5) and wrybill (Hughey 1985) do not use habitats randomly. For instance on the Rakaia wrybills

selectively chose seepage and other minor channels for feeding and establishing breeding home ranges near (Hughey 1985, 1998).

- 2.27 Pond and backwater microhabitats are important for waders, shags and waterfowl. For example, on the Ahuriri River, 5-20% of feeding observations of black shags were in this habitat type (depending on the season), 10% of paradise duck feeding and 15-30% of grey duck feeding. On the Waitaki River, 5% of feeding observations of black shags, and 5-10% of paradise duck feeding were in this habitat type. There is no significant research for the Waimakariri or Rakaia that deals with these microhabitats for key guilds that I am aware of.
- 2.28 Where the backwaters are out in the open, and not overhung with vegetation they provide habitat for both short and long-legged waders. For example, on the Ahuriri River 10-35% of white-faced heron feeding (depending on season of the year), 5-20% of feeding by stilt species and 10% of South Island pied oystercatcher feeding is in this habitat type. Black-fronted terns hawked for 5-15% of their time over backwaters (Robertson *et al.* 1983). On the Waitaki River 5-10% of white-faced heron feeding, 5% of oystercatcher feeding and 15-20% of pied stilt feeding was in backwaters (Robertson *et al.* 1984). Comprehensive data illustrating these points can be found in Robertson *et al.* (1983, 1984) and Hughey *et al.* (1986).
- 2.29 Very shallow channels with riffles, runs and seepage zones often occur relatively high on the river profile. These channels, being very shallow are prone to dry up if flows are reduced.
- 2.30 Shallow riffles, runs and seepage zones are particularly important for short-legged wading birds such as wrybill and banded dotterel, and to a lesser extent, long-legged waders. A large number of published scientific studies have also emphasised the importance of this microhabitat type for waders on a variety of braided rivers in Canterbury (e.g. Lalas 1977; Pierce 1976, 1979, 1982; Bomford 1978, Hughey 1985, 1997). For example, on the Ahuriri River, up to 40% of feeding observations of banded dotterel, 30% of wrybill, 35% of pied stilt, and 15% of oystercatcher feeding were in minor channels (Robertson *et al.* 1983). Black-fronted terns and black-billed gulls hawked over small channels for up to 30% of the time, whereas on the Wairau it seems comparatively more feeding was undertaken in small to medium sized channels in water <30 cm deep flowing at <0.2 m sec⁻¹ (see O'Donnell *et al.* 2006: 6).

On the lower Rakaia over 80% of wrybill feeding and 50% of banded dotterel feeding was in these minor channels (Hughey 1985).

- 2.31 Bars, flats and spits comprising shingle, cobbles or wet sand comprise much of the terrestrial habitat within the riverbed. These are the main habitats used for breeding in the majority of braided river birds but also for foraging of several species. For example, on the Ahuriri River, up to 30% of foraging time of pied oystercatchers is spent on saturated or wet sand flats in summer. Banded dotterels spend up to 45% of their time feeding on wet sand in winter and 20% in summer. They are often more terrestrial in spring, with 50% of feeding on shingle and cobble bars. There is a risk of these areas drying out if river flows are reduced.
- 2.32 Major channels (both riffles and runs) with large flows have been recorded on other rivers as being very important for black-fronted terns including the recent findings from O'Donnell *et al.* (2006: 6) reported comparatively more feeding in small to medium sized channels. On the Ahuriri River, 50% of spring-time feeding, 35% of late summer feeding, and 70% of autumn feeding were in major channels (both riffles and runs) with large flows (Robertson *et al.* 1983). On the Waitaki River, 55% of black-fronted tern spring-time feeding, 35% of late summer feeding, and 45% of autumn feeding was on major channels (Robertson *et al.* 1984). L alas (1977) did a detailed study of black-fronted tern foraging behaviour on the Tasman, Ahuriri, Ohau and Waitaki Rivers. He found that black-fronted terns were specialists at feeding in major channels. They are mainly insectivorous and feed swallow-like on emerging aquatic insects on or above the water surface or on drifting insects below the water surface by dipping their beaks under water while in flight. When feeding young, they seem to spend more time in minor channels capturing small fish. The black-fronted tern is possibly the largest diurnal non-soaring bird that feeds solely while flying (L alas 1977), therefore energetic costs of feeding are relatively high compared with other braided river birds. When the availability of aquatic insects was reduced in major channels (e.g., during freshes or inclement weather) black-fronted terns were able to find alternative prey along river banks. However, handling and search times, and thus the energetic costs of hunting and competition for food, increased significantly.
- 2.33 Major channels are also important for black-billed gulls (Ahuriri River 15% of feeding, Waitaki River 10%), Caspian tern (Ahuriri River 80% of feeding, Waitaki River 90% of feeding) and white-fronted tern (Waitaki River 90% of feeding). On the lower Rakaia

River 40% of pied stilt foraging and 15% of oystercatcher feeding was in this habitat (Hughey 1985).

2.34 Some braided river bird species also feed on farmland adjacent to rivers. However, use by all (except oystercatchers, spur-winged plover, black-backed and black-billed gulls) is generally very low. Activity by black-fronted terns over farmland is much debated but appears to be almost exclusively limited to the non-breeding season or when rivers are in flood (Lalas 1977; Robertson *et al.* 1983, 1984; Hughey *et al.* 1986; Hughey 1985; Jolly 2003). Having said this, recent observations from O'Donnell *et al.* (2006) indicate such feeding can occur at any time but is a very small proportion of total feeding, i.e., only 7% of feeding occurred over farmland and shrublands.

2.35 To summarise, I want to make two points. First, microhabitat requirements of braided river birds appear to be generally consistent across different rivers in Canterbury, largely because foraging behaviour of most species is relatively fixed and different wading birds are limited to specific water depths by their different leg lengths. Second, the different requirements of the full range of bird guilds all need to be taken into account when trying to understand their habitat requirements. One specific flow regime is not going to be optimal for all bird species. For example, short-legged waders need very shallow water for feeding, but medium-legged waders need moderately shallow waters and aerial feeders like black-fronted terns feed over both deep and shallow channels, with also intra-seasonal importance reported for these channels on the Waimakariri (Duncan *et al.* 2003). Most species require bare shingle areas for nesting and roosting. The diversity of bird guilds, which is a feature of the braided river ecosystem, is maintained by the diversity of habitat provided by the natural flow characteristics and variability of flows. Any reduction in the available variety of microhabitats including channel forms, depths and velocities by reduction in flow or the stabilisation of that flow will potentially affect that diversity.

(e) Aquatic invertebrate food resources – key controlling factors

2.36 Aquatic invertebrates are critical food resources for many braided river bird species. While other witnesses, especially Dr Olsen, deal in much more detail with this issue it is nevertheless important to set the scene, and draw some conclusions from a birdlife perspective.

- 2.37 Aquatic invertebrates are the major food items of several key bird species, i.e., wrybill and banded dotterel using the Rakaia River (see Hughey 1997) and black-fronted tern. Their abundance in the braided rivers of Canterbury is strongly influenced by flow instability and by the flood flows that mobilise the substrates. Sagar (1983 and 1986) has undertaken the most detailed studies of invertebrates in the Rakaia. He showed that flood events are a major modifying influence by causing bed load movement and by increasing suspended sediment load. Such factors cause catastrophic drift of invertebrates, physical damage to some individuals, and a reduction in the food supply available to invertebrates by abrading algal populations from the substrate. Hughey *et al.* (1989) has undertaken the only detailed study of invertebrate composition and biomass in different channels of a highly braided section of the lower Waimakariri (and Ashley) rivers. They found seepage fed channels had significantly greater diversity and abundance than larger channels, but that nevertheless larger channels were important food producing areas. Within this context I have read the evidence of both Dr Dean Olsen and Mr John Hayes and concur fully with their analyses.
- 2.38 Sagar (2003) concluded that given the similarity in species composition among the aquatic invertebrate communities of the braided rivers in Canterbury, the factors governing their abundance are also similar (including aspects of seasonality) (see also the evidence of Dr Olsen). Consequently, he concluded flood flows are likely to be the overriding factor determining species composition and abundance of aquatic invertebrates. However, should low or stable flows persist longer than about a month, then the numbers and densities of aquatic invertebrates will be determined by the extent of suitable habitat available to them. This is discussed below.
- 2.39 Studies completed in the Rakaia, Cass and Ashley Rivers indicate that aquatic invertebrate populations recover rapidly from the effects of floods. In the Rakaia River, Sagar (1986) recorded increases in the densities of aquatic invertebrates within a month of the last flood that mobilised the riverbed, irrespective of whether the flood occurred in summer or winter.
- 2.40 Studies by Scrimgeour *et al.* (1988) concluded that the results of their study and that of Sagar (1986) indicated that the larvae of *Deleatidium* in particular are well adapted to surviving frequent, unpredictable floods in braided rivers. They also concluded that the presence of larvae in a wide range of size classes throughout the year, and long flight and emergence periods may be important factors contributing to the

persistence and resilience of benthic invertebrate populations in unstable New Zealand rivers. Such life history features ensure that larvae in a mature stage of development will be present throughout the year, and so have the potential to produce a new generation rapidly should a period of stable flow occur.

- 2.41 That aquatic invertebrates in braided rivers can colonise even previously dry channels rapidly was shown by Sagar (1983) in the Rakaia River. The results of this study showed that in August-September during a period of stable flows recolonisation was complete (i.e. densities of invertebrates in the previously dry channel exceeded or were similar to those in the feeder channel) after 33 days. Having said this, changes in flows that lead to loss of preferred habitat have been shown by Dr Olsen to lead to 'more than minor' effects on the productivity of the invertebrate community in the Waimakariri River. Thus in my opinion, the losses of production may be of such magnitude as to be detrimental to birdlife.
- 2.42 Flow fluctuations were the main factor affecting recolonisation rates, and drift of aquatic invertebrates was assumed to be the main source of colonising animals.
- 2.43 Given the rapidity with which aquatic invertebrate populations both recover from floods and recolonise previously dry braids, then it might be assumed that the greater the wetted area of the river the greater the aquatic invertebrate populations. However, each species is best adapted to a particular habitat which, in rivers, is usually determined by water depth and water velocity. In New Zealand, habitat suitability curves that define the suitability of habitat in terms of substrate, water depth and water velocity have been developed for *Delatidium* spp. of mayfly (Jowett *et al.* 1991, subsequently modified by I. Jowett as used in RHYHABSIM.. Modelling based on these curves and others has been undertaken for the Waimakariri River and is reported in the evidence of Dr Burrell, Dr Olsen and Mr John Hayes. As noted by Mr Hayes the area of suitable habitat (WUA (m^2/m)) for food production increases with flow.
- 2.44 In general and based on the full range of the above research, as flood flows recede and the river declines to more-or-less natural seasonal (i.e., on average higher in spring and early summer than at any other time of the year) base flows, then aquatic invertebrates will re-establish, densities will increase and food will become increasingly available for fish and birds. However, this situation can then be altered in two main ways:

- a. If the loss of flow leads to braids becoming dewatered, aquatic invertebrates will either drift out with the receding water and re-establish themselves in braids with continuous flow, or seek refuge in the substrate of the dewatered braid, or become stranded and eventually desiccate and die. In such cases while some areas may have increased densities it is likely that overall production and availability will decline, i.e., there is less overall habitat available for both the invertebrates and ultimately for the birds (and/or the fish).
- b. Flood or other high flow events will occur and temporarily reduce invertebrate production and availability, thus also limiting food resources for fish and birds, albeit for relatively short periods of time.

2.45 Combinations of both of the above are likely to negatively impact on both the food and feeding of birds, but the impact of this combination of events, especially for birds is poorly understood as there has been little to no quantitative research into the energetics of braided river birds related to changes in food production related to river flow. It has however, been postulated that increased periods of low flow, e.g., caused by abstraction, might detrimentally impact on the energetics and thus the breeding potential of birds, through reductions in food supplies.

(f) Description of existing and potential threats to braided river ecology and birdlife

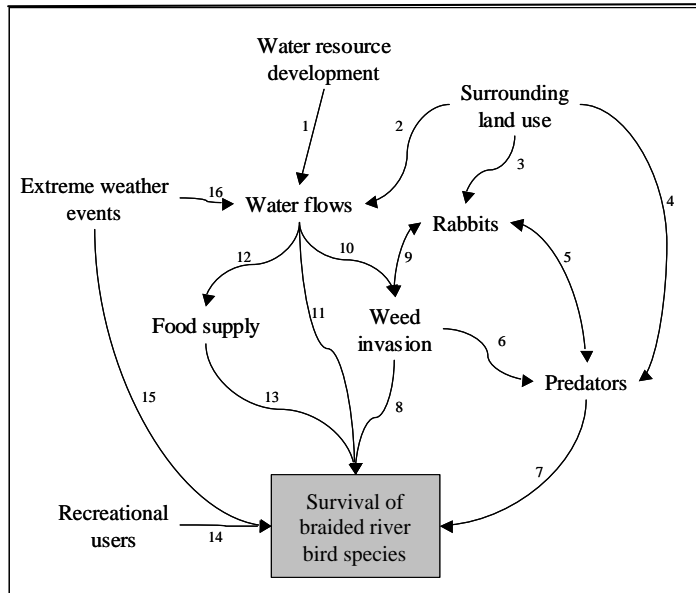
2.46 I will briefly describe the main threats to the viability of these aquatic bird communities. The key threats to birdlife on braided rivers are often caused by the interrelated/interactive disruption of ecosystem services by:

- 1) water resource development (channelisation, reduced or changed flows as a result of irrigation and hydro power generation),
- 2) invasion of habitat by exotic plant pests (willows, lupins, etc),
- 3) invasion of habitat by exotic predators (hedgehogs, stoats, cats, etc) and,
- 4) disturbance (anglers, off-road vehicle users, etc).

There has been little or no integrated research into these threats, and especially into how the underlying habitat requirements relate to river flow. A conceptual model of some of these key relationships provides a basis for visualising the threat-species

relationships. It also demonstrates the connection between some of these issues (Figure 2).

Figure 2. Relationships of some of the key factors impacting on survival of braided river birds (Adapted from Keedwell 2004)



Examples of hypothesised interactions between the different factors include:

- 1 – river flow is modified by abstraction, damming or a combination of the two, changing river flows and flood frequencies and magnitudes;
- 2 – surrounding land use directly impacts on water quality and river management including flood protection schemes which reduce the area of active riverbed;
- 3 – rabbit control on farmland lowers rabbit abundance;
- 4 – differing land use practices changes habitat availability for predators;
- 5 – predator abundance is altered by changes to rabbit abundance but also helps control rabbit abundance;
- 6 – vegetation on riverbeds provide cover for predators;
- 7 – predators prey on eggs, chicks and adults;
- 8 – weeds, clog up breeding habitat (e.g., lupins) and alter feeding habitat (e.g., the invasive aquatic weed didymo);
- 9 – vegetation provides cover and food for rabbits, but some weed species are controlled by rabbit grazing;
- 10 – lowered water flows and floods allow vegetation to establish on riverbed or in the river (e.g., didymo);
- 11 – floods destroy nests, but with freshes also act as controls on terrestrial and aquatic weeds (e.g., didymo);
- 12 – lowered water flows can alter abundance of aquatic insects and feeding areas;
- 13 – food abundance can influence survival of young or condition of breeding adults;
- 14 – fishers, campers and four-wheel drivers can destroy nests or disturb breeding birds;
- 15 – extreme cold spells can kill eggs and chicks;
- 16 – high rainfalls can cause floods.

(i) Introduced predators:

2.47 It is well established that predators have a major impact on the productivity and survival of birds on braided rivers. Since the Rangitata River Water Conservation Order hearings however, there has been considerably more work undertaken on a range of braided river systems. The Department of Conservation (C. Woolmore pers. comm.) has continued management and research into predators and river birds on the Tasman and other rivers in the Mackenzie Basin, and on the Wairau River in Marlborough (C. O'Donnell pers. comm.), Boffa Miskell Ltd and Urtica Consulting (2007) looked at the relationship between predation and river flows on the lower Waitaki River, and McEntee (2007) studied egg predation by avian predators on the Waimakariri River. Based on relevant 'older', and findings from the new research, the following key points can be made about predators:

- On most braided rivers the key predators are introduced mammals, mainly stoats, ferrets, cats and hedgehogs;
- Avian predators, mostly southern black-backed gulls (*Larus dominicanus*), have been identified as also being important on some parts of some braided rivers (e.g., McEntee 2007 found them to be a very significant predator of banded dotterel eggs on lower reaches of the Waimakariri River);
- Wrybills and banded dotterels, and black-billed gulls and black-fronted terns are especially vulnerable to mammalian predation as they are ground nesting birds with nest sites on mostly bare shingle islands;
- In my opinion:
 - Wrybills will be least affected by aerial predators because the adults, their nests and eggs are almost impossible to see from the air;
 - Black-fronted terns and black-billed gulls are very observable. Despite their colonial nesting behaviour meaning they are able to mount some defence of their nests from avian predators – these species are probably very prone to both avian and mammalian predators;
 - All these species will be prone to mammalian predators;
- Although the best data on predator densities come from the upper reaches of braided rivers we know that introduced predators are very common in lowland Canterbury and Otago (e.g., Fitzgerald 1964, Hughey 1985; Alterio & Moller 1994, Ragg *et al.* 1994; Alterio *et al.* 1998; O'Donnell 2000; Gillies 2001; Moss & Sanders 2001; Landcare Research 2003; Boffa Miskell Ltd and Urtica Consulting 2007).

- The Department of Conservation is undertaking considerable research (both in the Mackenzie Basin, and more recently on the Wairau River in Marlborough) on the predation issue so that integrated predator control programmes can be designed and implemented, assuming of course they are ecologically beneficial and cost effective compared to natural barriers such as flowing river channels.

2.48 The impacts of predation depend not only on numbers of predators and their prey present (Keedwell and Brown 2001), but for mammalian predators also on the relative abundance and species of predators present, the flow characteristics of the river (number of channels, velocity and width of flowing water)(see Boffa Miskell and Urtica Consulting 2007) and density of exotic weeds (Hughey 1985; Pierce 1987; Pascoe 1995; Rebergen *et al.* 1998). Unfortunately these relationships are at best only poorly understood. Generally, I remain concerned that any reduction in river flows would reduce channel depths, widths or velocities and/or the number of channels, and thus reduce the availability of relatively predator free islands for birds to nest on safely even further.

2.49 I raise the concern about mammalian predators because the lowered flows resulting from water abstraction facilitate easier access for predators (and four-wheel drive vehicles) onto riverbed islands that under higher flow conditions were relatively more secure for nesting birds. I have previously observed (e.g., Hughey 2003, 2006), and must comment also now, that much more research is required about flows and predators. However, some recent material reported in the Project Aqua AEE is helpful here, as is some long-standing research reported in Mosley (1983). Regarding the former, Hicks *et al.* (2003: 75) shows that for several braided rivers, where reliable information is available (including the Waimakariri), there is a relationship between increasing flow and the number of braids (see Figure 3) Mosley (1983) demonstrated a similar relationship, albeit in a 'fuzzy' way, with a different set of rivers (see Figure 4). Ian Jowett's evidence to the 2001 Rangitata River Special Tribunal concluded (Para 4.12; p17) that:

“As the flow increases in a braided river, the number of braids and total width of the wetted area increase to accommodate the increase in flow”.

2.50 I have little doubt, based on the above and from my own work on the Ashley and Waimakariri rivers (Hughey 1987), that this relationship does apply for the most

heavily braided cross-sections of the Waimakariri and I will comment in Part C of my evidence as to whether there has been any relevant new work undertaken on behalf of the applicants in this case. I also hypothesise there is a relationship between changing flow and the number and area of 'secure' islands for nesting birds, and report on my own recent study on this later in my evidence.

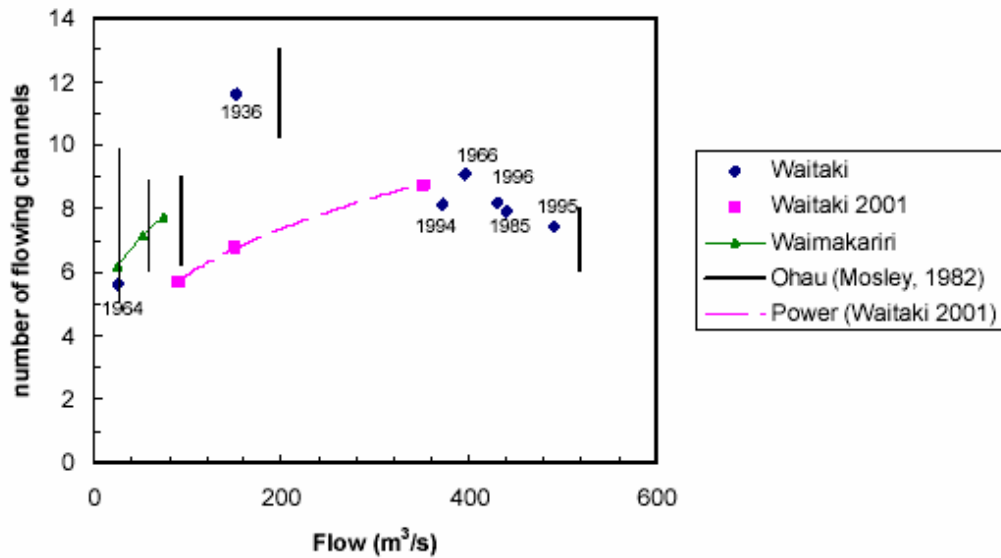


Figure 3: Relationship between number of flowing channels and water discharge. Data shown for the coastal reach of this study and for the Waimakariri River at Crossbank (Hicks, NIWA, pers. comm.). Vertical bars show the range of number-of-channels measured by Mosley (1982) in the Ohau River at various discharges.

Source: Hicks *et al.* (2003: 75)

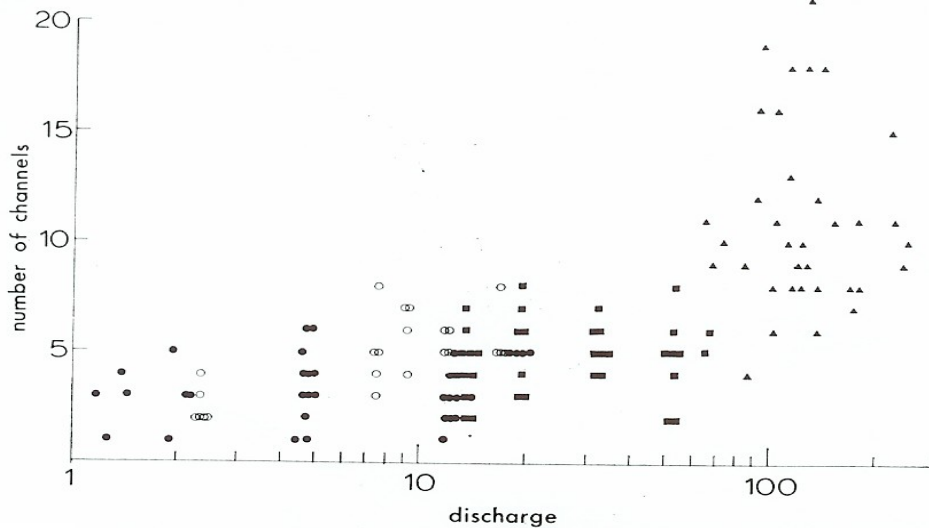


Figure 4: 2—Number of branch channels at selected cross-section as a function of discharge (m^3/s) for the Ashley (●), Ahuriri (○), Hurunui (■) and Rakaia (▲) Rivers
(Source: Mosley 1983: 52)

2.51 Although it is well known that some mammalian predators can and do swim across river channels, it appears that the frequency with which they do so is limited considerably by flows. Keedwell (2006), with respect to the Wairau River, summarised and evaluated the best available information regarding predators and riverflows. More recent work by Boffa Miskell Ltd and Urtica Consulting (2007) for the Waitaki indicates channel flows measured as low as 0.059 cumecs appeared to provide strong protection against some predation. I am aware of this information and in summary make the following five points:

- There are no long term comprehensive studies that properly examine the relationships between river flows and predation on braided rivers - despite this point it appears that:
- Flows of almost any level in braids surrounding islands provide a level of protection for nesting birds, against mammalian predators – the key point is of course that there has to be some flow and there is likely to be some sort of correlation between size of flow and level of protection;
- From the little evidence available it seems clear each mammalian predator varies in its ability/willingness to cross water, e.g., hedgehogs seem to be stopped by virtually any flow, ferrets and cats seem to be slowed or stopped by higher flows, and stoats are probably not restricted at all;

- The predator threat will of course vary from river to river depending on the density of each predator present and their food supplies, both on- and off-river; and
- Moreover, and following logically from a range of studies, relatively higher flows provide relatively higher levels of protection for birds nesting on islands in braided rivers.

2.52 My own research on the lower Rakaia River showed that 95% of wrybill nests and 90% of banded dotterel nests were on islands separated from the riverbanks by flowing channels generally of $>10 \text{ m}^3\text{s}^{-1}$ of water. There, flooding caused most of the failures in breeding and only 10% of wrybill nests and 12% of dotterel nests were lost to predators. However, on the much smaller Ashley River, where nests were on banks or islands separated by flows of only 1 or $2 \text{ m}^3\text{s}^{-1}$ at most, predation was more likely to affect breeding success (33% of nests lost to predators, Hughey 1985). A similar result was recorded on the Cass River (Bomford 1978). Thus it is quite possible that species such as black-fronted terns and black-billed gulls have not declined at all or to the same extent (but see paragraph 5.9 re assessing trends in numbers) in recent years on the Waimakariri and Rakaia rivers compared to those populations on much smaller rivers such as the Ashburton and Ashley (O'Donnell 1992; Ornithological Society Unpubl. data). This might be because their nest sites are on islands within the river, surrounded by large channels which are relatively better protected from mammalian predators. Any reduction in the low to medium flows is thus likely, in my opinion to increase vulnerability to predation. If flow reduction leads to drying out of channels (Mosley 2001), then there would likely be even greater access by predators to nesting colonies.

(ii) Exotic weed encroachment on riverbeds:

2.53 Areas clear of upright emergent plants are key breeding and foraging habitats for many birds. Introduced terrestrial weeds, particularly standing/upright species like broom, yellow lupin, Russell lupin and gorse are particularly invasive and serious threats to habitats of braided river birds (Stead 1932; O'Donnell & Moore 1983; O'Donnell 1992; Maloney 1993; Brown 1999a, 1999b). These exotic weeds cover areas of the Waimakariri and Rakaia riverbed that were formerly bare shingle or covered in indigenous mat plants. The exotic weeds can stand from 1-3 m tall and cover all potentially secure nesting areas – in particular this leads to:

- Birds nesting on lower parts of islands where they are more exposed to smaller freshes and floods than if they were nesting higher on the islands (see Hughey 1985);
- The areas of exotic plants becoming home to introduced herbivores (mainly rabbits) and their predators (ferrets, stoats and cats) – the latter also opportunistically or targeting nesting birds and thus increasing predation.

Native prostrate mat plants do not pose the same level of threats in these respects compared to exotic weeds. Apart from direct impacts, exotic weeds are thought to stabilise shingle islands, and decrease the availability of shallow water foraging areas (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). Natural patterns of floods and freshes are the main way that weeds are removed from river beds, although not all vegetation is ever cleared this way.

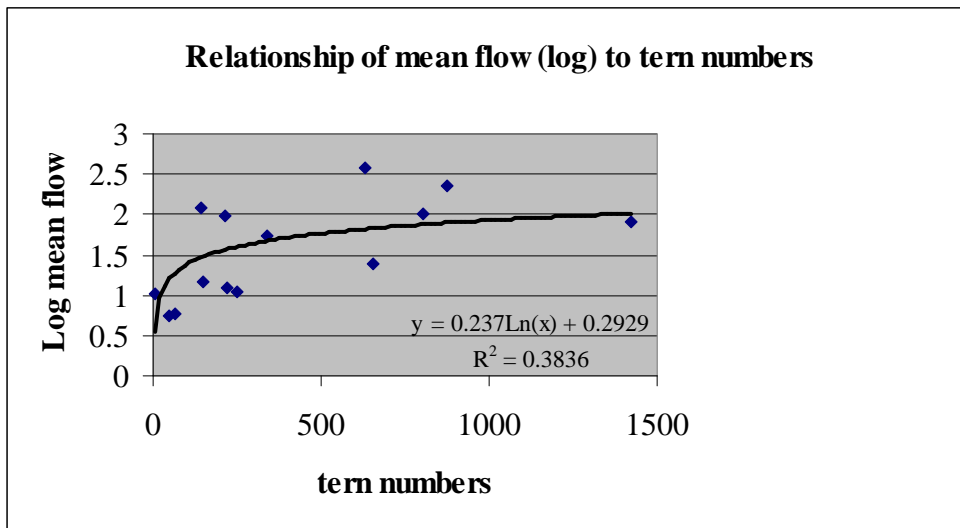
2.54 There is increasing research interest in the potential for the invasive aquatic algal weed, didymo, currently absent from the Waimakariri River to invade and pose a threat to the foods and feeding of key birds, especially wrybill and black-fronted tern. While unstable braided rivers are unlikely to provide an idea didymo 'home' a stabilised 'Waimakariri' low-medium flow regime may well be conducive to the weed. As far as I am aware no work has been done on didymo and birds but it must be factored into flow management considerations.

(iii) Abstraction and diversion of water for irrigation and other uses:

2.55 Braided river bird communities are highly tuned to the natural flow regime patterns and instability of braided rivers (O'Donnell & Moore 1983; Robertson *et al.* 1983). Maintenance of natural flow regimes on braided rivers is essential for maintaining feeding and nesting habitat of river birds, particularly threatened species (Hughey 1985b, 1997, 1998; Hughey *et al.* 1989). Figure 5 (based on an analysis of black-fronted tern bird count and river flow data in Table 2) indicates a reasonably strong positive correlation for the relationships between mean river flow and black-fronted tern numbers. That is, the higher the flows the greater the number of terns still surviving on these rivers. Caution is necessary with interpreting correlations (for example while the R^2 value of 0.3836 is reasonable from an ecological context it nevertheless indicates that only around 38% of the variation is explained by the correlation) but nevertheless both ecologically and statistically we do know that terns,

gulls and the key wading bird species require both aquatic and terrestrial habitats in riverbeds and that both of these requirements are highly related to river flow.

Figure 5: Relationship of mean flow (log) to tern numbers



- 2.56 The precise impacts of water abstraction will of course depend on how much water is extracted or diverted from the main stem of the river. Impacts are likely to be incremental. Data on specific microhabitats indicates that a diversity of shallow and deep-water habitats is needed to maintain the variety of bird guilds present on the river, but abstraction will affect different species in different ways. Taking very small amounts of water (by say one irrigation scheme) might not have a significant impact in itself, but when combined with other abstractions and diversions over time would significantly reduce habitat for some species and increase it for others.

Table 2. Key summary bird, vegetation and hydrological data for Canterbury and Marlborough braided rivers containing more than 100 black-fronted terns

River	Recorder Site	Mean flow ¹	7 day low flow		Floods		Most recent tern count (Source: R. Keedwell, unpubl. collated data, and A. Grant, DoC 2008)	Riverbed area and vegetation (Source: Wilson 2001)		
			Mean annual	10 year return period	Mean annual	10 year return period		Riverbed area (ha)	Open riverbed area (ha)	% vegetation cover
Wairau	at scheme discharge	82.1		9	535	1500	1423	6837	5825	14.8
Clarence	Jollies	14.9	3.3	2.2	195.7	317	147	4169	3004	28
Waiau	Marble Pt	98	32.2	21.9	1059	1413	217	7412	5389	27
Hurunui	Mandamus	52.9	16.6	11.4	531	831	338	5138	2546	49
Ashley	Gorge	12.3	2.2	1.2	298	539	218	3610	1783	48
Waimakariri	Old Highway Bridge	122	40.2	27.4	1495	2344	312	14342	10487	27
Rakaia	Fighting Hill	221	92	76	2514	3701	877	32102	21853	32
Sth Ashburton	Mt Somers	11.2	4.8	3.5	103	181	251	2441	942	75
Rangitata	Klondyke	100	41.7	35	1085	2324	804	18091	11249	38
Tasman							120	6897	4927	28
Tekapo							501	3178	1063	66
Ohau - Upper							137	111	37	71
Ohau - Lower							295	322	246	24
Ahuriri	South Diadem	23.8	9	7.1	255	434	656	4353	1661	60
Waitaki	Kurow	373					632	8104	3509	57

¹ Data sources: ECan web site and the Wairau HEP AEE. Note – flow data for the Tasman, Tekapo and Ohau was sought from ECan in March 08. I have received some Ohau data and some very unsatisfactory information for the Tekapo, but nothing is available for the Tasman. As a result trying to understand relationships between flow and bird numbers can only be done on rivers with reliable flow information.

2.57 Abstraction of water on rivers has the potential impact of reducing feeding habitat. Reduction in flows firstly reduces the size and number of small channels as well as the overall useable area of aquatic habitat to the bird community (see details in references cited by Dr Paul Mosley 2001 and O'Donnell 2000, but also the evidence of Dr Olsen and Mr Hayes). Shallow-water waders are dependent on small channels, seepage zones and backwaters, so would be directly affected by their reduction if the water table on the river were lowered. However, the aerial feeders will typically be affected more by reductions in larger channels. There are indirect impacts of abstraction on breeding habitats as well. For example, there may be greater magnitudes of fluctuations in river flow. This means that birds like black-fronted terns that like to nest close to water will nest lower down the river profile, and be subject to increased flooding because freshes would still be of normal size. Flooding is a major cause of nest failure on some braided rivers (Hughey 1985).

2.58 Other potential impacts include greater accumulation of sediment during periods of prolonged low flow, consequential detrimental effects of reduced availability of invertebrate food sources, increased algal growth, lower oxygen concentrations causing invertebrate deaths, decreased velocity (affecting composition of invertebrates, particularly invertebrate drift), and disturbance of birds by on-going river works. For example, any flow modifications that would reduce drift of mayflies in larger channels may reduce food availability to black-fronted terns (see the evidence of Dr Olsen).

(iv) Flood control works and channelisation:

2.59 A variety of flood control and other in-river works (construction of stop banks, channelisation, clearing floodways with bulldozers, managing intake structures, spraying exotic weeds) can disturb birds directly, reduce breeding success and modify riverbed habitat. Machinery used can immediately destroy feeding areas and nest sites, and river control works can be potentially catastrophic if undertaken during the spring-summer breeding season. Stopbanking and channelisation leads to confinement of river channels, reduction in the number of active channels, decreased area of habitat, and a reduction in the ability of channels to change direction and renew areas of bare shingle.

(v) Recreation:

2.60 Smith, Hughey and Booth (1997) studied the potential impacts of off-road vehicle use on birds of the Tekapo River. They found that unmanaged recreational vehicle access had a high probability of destroying nests and disturbing birds. I have observed large numbers of people and vehicles on parts of the lower Waimakariri during the bird breeding season, including in colonies of black-fronted terns adjacent to McLeans Island (around Christmas 2008, pers. obs.). Significantly lower flows would likely increase access by people and their vehicles – both of which, in my view, can trample or crush nests.

2.61 The impacts of these five related threats on the continued viability of threatened species on the Waimakariri and Rakaia, in particular the interactions between the impacts of introduced predators and habitat reduction through flow reduction or weed encroachment cannot be viewed in isolation from each other. Synergistic and cumulative effects are important and will be considered in the evaluation of the applicant's evidence.

PART B: SIGNIFICANCE OF THE WAIMAKARIRI AND RAKAIA RIVERS**(g) General description of the overall ecology of the Waimakariri and Rakaia Rivers**

2.62 Overall, the ecology of the Waimakariri and Rakaia rivers appears to be similar to that of other medium-large mountain catchment braided rivers, e.g., the same broad assemblages of aquatic invertebrates (i.e., *Deleatidium* species dominant), native fish and birdlife. However, there are differences and these can be summarised as:

- The Waimakariri River has a substantial lagoon and wetland system associated with its river mouth and is highly tidal and channelised in its lower reaches;
- The Rakaia, apart from its central gorge, is essentially highly braided from source to sea.

2.63 Both rivers fall into what I define as the middle category of rivers in terms of percent vegetation cover (Table 3), i.e., around 1/4-1/3 cover – these are typically highly unstable Southern Alps catchment braided rivers.

Table 3. Main braided rivers ranked by % vegetation cover (data source: Wilson 2001)

River	Area (ha)	Non-vegetated (ha)	% vegetated
Wairau	6837	5825	14.8
Waiau	7412	5389	27
Waimakariri	14342	10487	27
Clarence	4169	3004	28
Tasman	6897	4927	28
Rakaia	32102	21853	32
Rangitata	18091	11249	38
Ashley	3610	1783	48
Hurunui	5138	2546	49
Waitaki	8104	3509	57
Ahuriri	4353	1661	60
Tekapo	3178	1063	66
South Ashburton	2441	942	75

(h) Description of the birdlife communities of the Waimakariri and Rakaia rivers, including species distribution and relative abundance

Species richness

2.64 From the surveys I have reviewed the native species present on the Waimakariri and Rakaia rivers (excluding their lagoons) is presented in Table 4.

Table 4. Species richness, foraging guild and conservation status of native riverbed bird species on the Rakaia (R) and Waimakariri (W) rivers (Source: O'Donnell and Moore 1983, pers. obs.).

Species	Scientific name	Conservation status (Source: Hitchmough <i>et al.</i> 2007)	Foraging guild						
			Open water divers	Deep water wadlers	Shallow water wadlers	Dabbling waterfowl	Aerial hunting gulls and terns	Swamp specialists	Riparian wetland species
black shag	<i>Phalacrocorax carbo</i>	Sparse	R W						
little shag	<i>P. melanoleucos</i>		R						
white-faced heron	<i>Ardea navaehollandiae</i>			R W					
pieb stilt	<i>H. himantopus</i>			R W					
spur-winged plover	<i>Vanellus miles</i>			R W					
South Island pied oystercatcher	<i>Haematopus ostralegus finschi</i>			R W					
wrybill	<i>Anarhynchus frontalis</i>	Nationally vulnerable			R W				
banded dotterel	<i>Charadrius bicinctus</i>	Gradual decline			R W				
black-fronted dotterel	<i>Charadrius melanops</i>				R? W?				
black swan	<i>Cygnus atratus</i>					W			
paradise shelduck	<i>Tadorna variegata</i>					R W			
grey duck	<i>Anas superciliosa</i>	Nationally endangered				R W			
black-fronted tern	<i>Sterna albobriata</i>	Nationally endangered ²					R W		
white-fronted tern	<i>S. striata</i>	Gradual decline					R		
Caspian tern	<i>S. caspis</i>	Nationally vulnerable					R W		
black-billed gull	<i>Larus bulleri</i>	Serious decline					R W		
southern black-backed gull	<i>L. dominicanus</i>						R W		
NZ pipit	<i>Anthus novaeseelandiae</i>								R W
welcome swallow	<i>Hirundo tahitica</i>								R W
NZ kingfisher	<i>Halcyon sancta</i>								R W
harrier hawk	<i>Circus approximans</i>								R W

² This species has been reclassified from Serious Decline to Nationally Endangered. This change in listing was due to both improved knowledge and continuing decline. The species is very susceptible to predation and disturbance. The Ashburton River/Hakatere population decreased from 750 birds in 1981 to 200 birds in 1990 (see Hitchmough *et al.* 2007).

2.65 Totals of 18 and 19 native ‘wetland’ bird species have been recorded respectively on the braided sections of the Waimakariri and Rakaia rivers. Based on the Department of Conservation NZ threat classification lists (Hitchmough *et al.* 2007) eight of these species are of conservation concern.

Foraging guilds

2.66 Table 4 above also indicates which species are in each guild. On both rivers, six of the seven bird guilds, characteristic of braided river wetlands, have been recorded:

- Open water divers: 2 species;
- Deep water waders: 4 species;
- Shallow water waders: 3 species;
- Dabbling waterfowl: 3 species;
- Aerial hunting gulls and terns: 6 species;
- Swamp specialists: none recorded but very likely that marsh crake at least is present in some areas; and
- Riparian wetland species: 5 species.

For both rivers the most notable guilds for which we have data are:

2.67 **Shallow water waders** such as wrybill and banded dotterel with short legs that restrict them to feeding in water <80 mm, and most use is of water <40 mm deep (see Hughey 1985). They also breed on the ground in open areas, especially shingle, wetland turf, or sand, largely free of emergent vegetation. There are very high numbers of both species on the Rakaia River on the upper and middle sections of the Waimakariri.

2.68 **Aerial hunting gulls and terns** (e.g., black-fronted tern and black-billed gull). They are generally aerial hunters, flying over open water or river channels and diving for invertebrates and small fish. They nest on open shingle bars and islands in large numbers (in the case of black-fronted terns) on both rivers.

Surveys of distribution and abundance

2.69 There is need for caution when interpreting bird counts and bird monitoring data for key species on braided rivers, because for example:

- There has been huge variability in survey method, number and expertise of surveyors, geographic coverage, timing of survey, weather conditions, etc;
- Some bird species are extremely cryptic and difficult to find (esp. wrybill) while others are extremely observable but also highly mobile and therefore prone to repeat counting (e.g., black-fronted tern); and
- There can be unexplained intra- and inter-seasonal shifts in bird distributions both within and between rivers.

In combination these factors lead to high levels of uncertainty about the inferences that can be drawn from survey and monitoring data.

2.70 Resulting from the above there has been considerable debate about how best to interpret the sorts of historic and contemporary information collected about bird numbers on all braided rivers. In 2007 the Department of Conservation (in a brief prepared jointly by Drs O'Donnell and Hughey and Mr A. Grant) commissioned Dr Jennifer Brown, Mathematics Department of the University of Canterbury, to undertake an analysis of the different contexts within which data are gathered and the different analyses undertaken, with a view to providing explanatory guidance for expert witnesses, lawyers and tribunal members (see Brown and Robinson 2008 in prep.).

2.71 Brown and Robinson (2008 in prep.) evaluated six survey scenarios:

1. Annual surveys for 10 years, with one section visited once only during one day. This is called scenario 'a'. Surveys similar to this have been undertaken on the Ashburton River.
2. Annual surveys for 10 years, with four sections visited 3 times a day for 3 days, scenario 'b'. Some surveys like this have been undertaken on selected rivers in the Mackenzie Basin.
3. Surveys in years 1, 5 and 9, with one section visited once only during one day, scenario 'c'. There is survey work from the Waitaki that roughly fits this scenario.
4. Surveys in years 1, 3, and 10, with one section visited once only during one day, scenario 'd'.

5. Surveys in years 1 and 10, with one section visited once only during one day, scenario 'e'. This is the situation that best matches both the Waimakariri and Rakaia data.
6. Surveys in years 1 and 10, with one section visited once a day, for 3 days, scenario 'f'.

For each scenario they simulated trends of 2, 5, and 10% increase and decrease per annum, for wrybill and black-fronted tern, subject to various detection parameters, e.g., relative observability.

Results were presented as a series of graphs. The graphs, for each species, show the range of likely estimated trends from the simulations for the six data-collection scenarios. In what follows I have selected one graph for explanatory purposes, and then abstracted, almost word for word, key parts of the Brown and Robinson (2008, in prep.) report – where my own interpretation is included I try and make this clear (e.g., the text boxes in Figure 5).

Now consider Figure 5 below - assume there is a real decline in wrybill population size of 2% per year for 10 years. Taking the first box plot, the river is surveyed by visiting once a year, in one section on one day (scenario 'a'). There is a 50% chance that the annual change estimated from such a survey would be somewhere between -8.2% and +4.6%. This is what the "box" of the box plot is describing – where the middle 50% of the (simulated) estimated annual changes lay. In other words, there is a 50% chance that with such a survey design, and with a real 2% annual decline, the trend estimated from the survey results would be even more negative than -8.2%, or even more positive than 4.6%. The "whiskers" on the box plot extend out to the observation within 1.5 times the interquartile range (IQR). The IQR is simply the width of the box. The box plot is a well-used method to display spread of a large number of observations (1000 in this application).

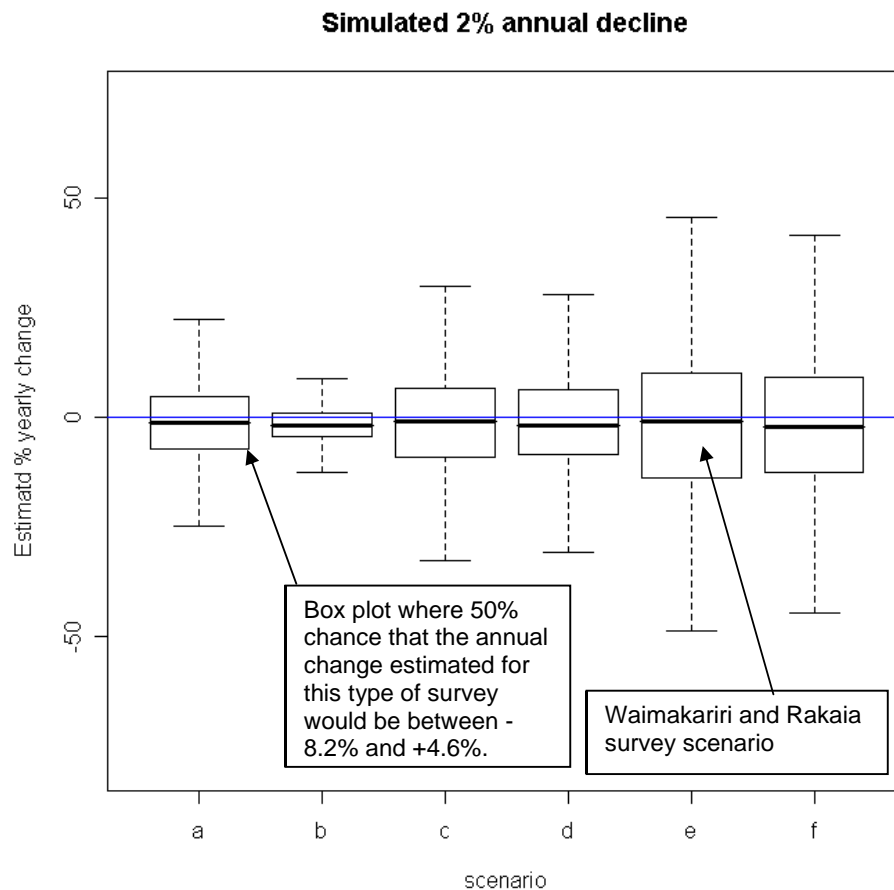


Figure 5. Wrybill - distribution of estimated trends from Monte Carlo simulations. The y-axis is the estimated change in the population per year (%), with a reference line for 0 (no change). For each survey design, 1000 estimates of change per year were produced. The box plot shows the distribution of these 1000 estimates. A perfect survey design would have all 1000 estimates equalling the simulated change (Source: Brown and Robinson 2008, in prep.).

Continuing with Figure 5, the effect of implementing and analysing different survey scenarios can be seen. Scenario 'b', annual surveys to three sections of the river for three days, gives a far narrower box. The uncertainty associated with the trend estimated from the survey data has declined, now there is a 50% chance that the estimated trend will be between -4.8% and +0.7%. Reading across the box plots, within the graph, from left to right, the effect on uncertainty of differing scenarios can be clearly visualised. I note that scenario 'e', the one closest to the current survey data situation for both rivers, has the greatest level of uncertainty.

Analyses for both wrybill and black-fronted tern have been undertaken. Some general observations are:

1. Larger annual changes have less uncertainty than smaller annual changes. When a 10% annual decline for wrybill was simulated almost always (84% of the Monte Carlo simulations) a decline in the population size was detected using scenario 'a' survey design. In comparison when a 2% annual decline was simulated only 57% of the Monte Carlo simulations detected a decline.
2. Scenarios 'a' and 'b' allow comparison of surveys with annual visits for 10 years, visiting on one day once a year, with surveys with three visits three times a day. The additional survey effort (scenario 'b') results in less uncertainty.
3. Scenarios 'c' and 'd' allow comparison of surveys with three annual visits and even spacing among years, with surveys with uneven spacing (two visits in early years and one in year ten). Scenario 'd', the latter scenario, has less uncertainty because more effort is concentrated where there is greatest model-variation (i.e., the beginning, or end, of the model line). This assumes the trend is linear and surveys conducted over wide time intervals, e.g., years 1, 3 and then 10 (scenario 'd'), or years 1 and 10 only (scenarios 'e' and 'f') would not provide information to detect a non-linear trend. Examples of non-linear trends are where the population increases and then decreases, or where the population decreases rapidly and then later, at a slower rate.

2.72 The overall implication from the Brown and Robinson (2008 in prep.) work is that great care is needed in interpreting data collected often spasmodically for riverbed birds. The ability of such surveys to detect 'actual' change if only small annual incremental changes are occurring is highly problematic. Thus, only the following data are referred to further:

- the O'Donnell and Moore (1983) survey data (as this is the only reasonably full data set for both rivers), and
- the DoC partial river survey data gathered for both rivers in 2006 and 2007, and planned to continue annually from hereon (A. Grant, pers. comm.) .

The latter allow limited comparisons with the 1970s and 1980s work for the mid-lower section of the Rakaia and for the lower Waimakariri. And, also as a result of the Brown and Robinson (2008 in prep.) findings I will not be commenting on any

'apparent' trends in numbers, but rather on the relativities against known or estimated total population estimates. With help from staff at the Department of Conservation I have calculated the annual ongoing costs of this new monitoring work, instigated largely as a result of water resource development proposals. The ongoing annual monitoring programme for both the Waimakariri and Rakaia rivers is estimated to cost around \$30,000 per annum:

- 15 people for 3 days for each of two rivers
- An hourly cost of around \$25 per person for 8 hour days
- About \$5000 for jetboat fuel
- Around \$2000 in other overheads.

2.73 Details of the limited survey data for both rivers are:

- The Rakaia has never been subject to a full riverbed survey, with the most complete surveys occurring over parts of the river in the breeding seasons of 1975 and 1978-79;
- In 2006 and 2007 repeat surveys were undertaken of one (mid-lower) section of the Rakaia (Additional detailed work has been undertaken by Hughey (1985, principally over two seasons) for a 10km stretch of the lower Rakaia for a range of bird species);
- The Waimakariri has had only one full riverbed survey and that occurred over the breeding seasons of 1980 and 1981; data from 2006 and 2007 repeat surveys were undertaken of one (mid-lower) section of river, (and parts of the river were surveyed multiple times over the same 2006-07 period by an external party but are not available.)

In my view a condition of any consent granted should include a requirement to undertake monitoring that meets key decision criteria, and that the monitoring data is publicly available to further our knowledge of these species.

Distribution of birds

2.74 In presenting the survey data I therefore concentrate on the significance of the Waimakariri and Rakaia for riverbed dependent species and by survey section for both rivers. I have used the river section classification used by O'Donnell and Moore (1983).

2.75 Riverbed dependent birds were distributed along the whole of both rivers (Table 5 and Figure 6 below).

Relative species abundance and distributions on the Waimakariri and Rakaia rivers

2.76 The initial surveys can be used for two main comparative purposes:

- To determine variations, at that time, in the relative distribution of species along the river;
- To examine differences in key species' presence or absence between the two rivers.

Table 5. Summary counts of key riverbed bird species on parts of the lower Waimakariri (a) and Rakaia (b) rivers, for the most reliable bird surveys.

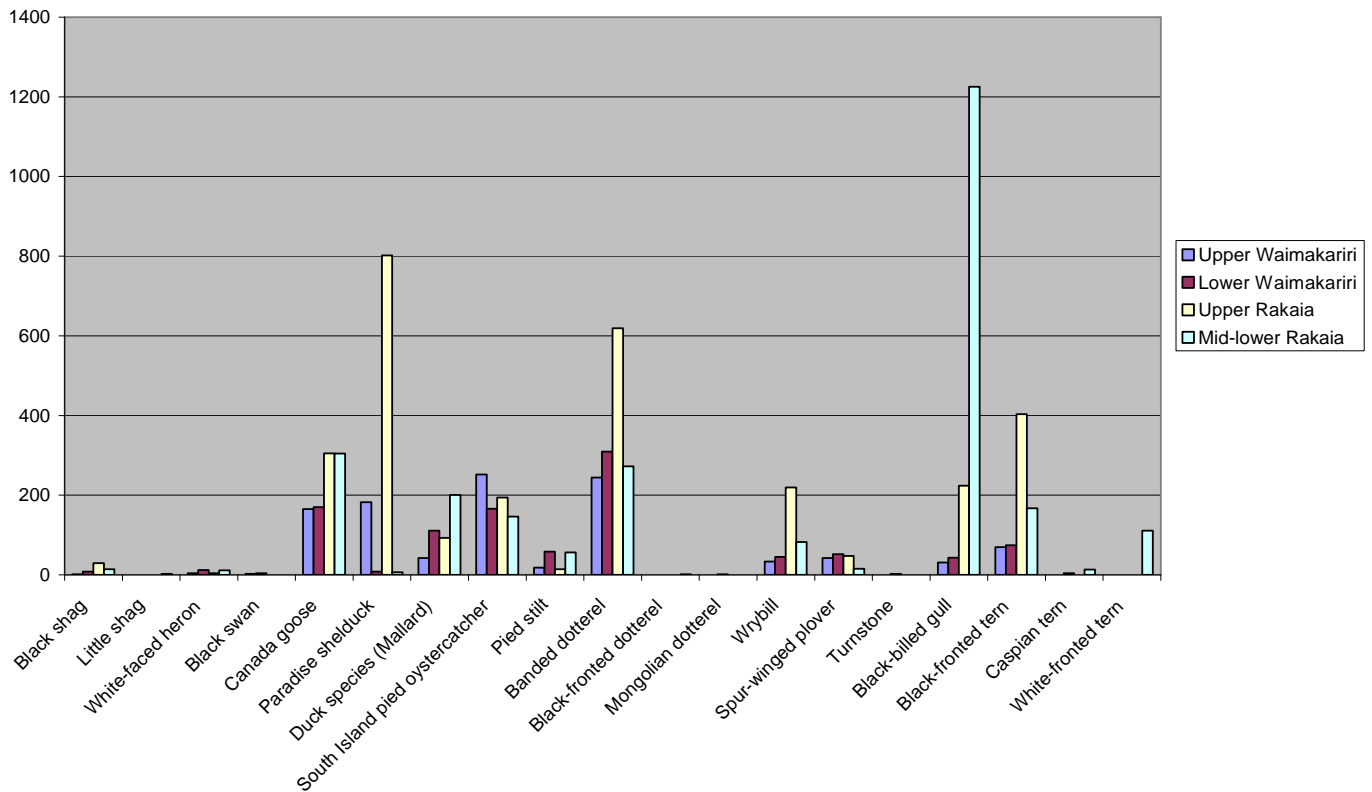
a. Waimakariri River (Gorge to Harewood Crossbank – 40.6km)

Species	1980	2006	2007	Estimated total population (and year of estimate)	% of national population at maximum of 2006-07
Black-fronted tern	74	247	312	5000 (1995)	6.2%
Caspian Tern	4	0	0		
White-fronted tern		0	28		
Black-billed gull	42	201	18	<50000 (2007)	0.04%
Banded dotterel	309	116	419	50000 (1995)	0.08%
Wrybill	45	26	73	4500 (2004)	1.6%
Southern black-backed gull	NC	4019	4801		
SIPO	166	27	48		
Pied stilt	58	0	26		
Spur-winged plover	52	22	343		
Black shag	8	17	4		
pied shag		0	7		
Paradise shelduck	8	0	19		
Duck species	111	157	85		
Canada goose	170	13	537		
Welcome swallow		10	0		
White-faced heron	12	0	11		

b. Rakaia River (Barhill to River mouth – 36km)

Species	1975	2006	2007	Estimated total population (and year of estimate)	% of national population at maximum of 2006-07
pied shag	0	3	1		
Paradise shelduck	6	0	0		
Duck species	200	237	190		
Canada goose	304	16	256		
White-faced heron	0	3	0		
Black-fronted tern	167	160	170	5000 (1995)	3.4%
Caspian Tern	13	14	3		
White-fronted tern	111	396	328		
Common tern	0	1	2		
White-winged black tern	0	2	2		
Black-billed gull	1225	921	2830	<50000 (2007)	5.7%
Red-billed gull	0	12	123		
Banded dotterel	272	138	172	50000 (1995)	0.3%
Black-fronted dotterel	1	0	0		
Wrybill	82	45	105	4500 (2004)	2.3%
Turnstone	0	19	32		
Southern black-backed gull	4753	7362	5525		
SIPO	146	70	62		
Pied stilt	56	49	98		
Spur-winged plover	15	409	150		
Black shag	14	77	29		
Little shag	2	3	0		

Figure 6: Distribution of riverbed dependent bird species (except black-backed gull) on 'roughly' comparable sections of the Waimakariri and Rakaia rivers in the mid-late 1970s early 1980s.



2.77 Subsequent, smaller scale surveys over the last 2 years must be treated with extreme care because:

- a. They are not censuses and thus are indexes of relative abundance;
- b. They are only for smaller sections of each river and we do not know how distributional patterns have varied over time or space.

2.78 Given the above what is perhaps most interesting from the surveys is that:

- i. black-fronted terns occurred in very large numbers on the Waimakariri River;
- ii. black-billed gulls were also present in substantial numbers, especially on the Rakaia;
- iii. large numbers of wrybills are present on both rivers and in the largest numbers for any lowland river sections recorded (e.g., compared for example to the lower Rangitata or the Waitaki).

2.79 Although previous surveys give a reasonable picture of species present on both rivers and their distributions, given the inconsistencies within and between some of these it would be unwise to use these data for determining trends in numbers and changes in distribution. Even using the results of only two surveys, it would be dangerous to draw any conclusions about changes in status of particular species on the river, especially mobile and difficult to count colonial species like black-fronted tern.

2.80 Nevertheless, regular monitoring of 11 rivers in the Mackenzie Basin, and on the Ashburton River in mid-Canterbury (Maloney *et al.* 1997; Maloney *et al.* 1999; O'Donnell 1992; Unpublished DOC Databases) indicates that overall numbers of aquatic birds have not changed dramatically over the last 40 years. Nationally, some species have declined, particularly black-fronted tern, wrybill and black-billed gull. However, their decline only serves to increase the importance of the habitats where they remain. This is because as species decline, sites where they occur become even more critical.

(i) Assessment of the national and international significance of the Waimakariri and Rakaia rivers and their birdlife communities

2.81 The Waimakariri and Rakaia rivers are of national and international significance, given the composition of birds, diversity of bird guilds present, and apparent population sizes present described in the previous section.

2.82 The Waimakariri and Rakaia are of national and international significance because of their outstanding value to birdlife according to the assessments made based on 'old' NZ Wildlife Service criteria, international Ramsar criteria, and RMA-related criteria for determining significance. The findings I present below are consistent, I believe, with limited CPW assessments.

2.83 During the late 1970s and early 1980s the New Zealand Wildlife Service undertook the first national inventory of habitats of significance to wildlife, termed Sites of Special Wildlife Interest (SSWIs). I assisted with some of these inventories on braided rivers between 1980 and 1985. Habitats were rated as being of "Outstanding", "High", "Moderate-high", "Moderate", or "Potential" value for species

protected by the Wildlife Act 1953. Sites were assessed according to 16 criteria. The criteria used were based on criteria used by the International Ramsar Convention for identifying Wetlands of International Importance at the time, for which New Zealand has been a contracting party since 1976. The Convention on Wetlands, signed in Ramsar, Iran, in 1971, is an inter-governmental treaty which provides the framework for national action and international co-operation for the conservation and wise use of wetlands and their resources.

- 2.84 Once the surveys of key reaches of key rivers were completed in the mid-1980s, the Waimakariri and Rakaia rivers were ranked overall as being of “Outstanding” value to aquatic birds. This ranking was based on the presence of breeding populations of rare and endangered endemic species and their associated habitat. The rivers appeared to be of vital importance to wrybills and black-fronted terns - the former has a small population size and restricted range while the latter have a reasonably broad breeding distribution, but a limited population size which is now declining. The rivers provided extensive habitat type not well represented elsewhere in the country. The habitats are of large size and contained viable populations of many of the species, which were typical of the habitat type and a diverse range of microhabitats for breeding, feeding and roosting.
- 2.85 The Ramsar Convention has used a new set of criteria since 1999 (see www.ramsar.org). I have assessed both rivers in respect of these criteria and consider that the Waimakariri and Rakaia meet the latest criteria for designation as a Wetland of International Importance. This includes Group A of the Criteria pertaining to sites containing representative, rare or unique wetland types. Criterion 1 states that a wetland should be considered internationally important if it contains a representative, rare, or unique example of a natural or near-natural wetland type found within the appropriate biogeographic region.
- 2.86 Group B of the Criteria is based on species and ecological communities and pertains to sites of international importance for conserving biological diversity. A wetland should be considered internationally important if it supports vulnerable, endangered, or critically endangered species or threatened ecological communities (Criterion 2). The Waimakariri and Rakaia support populations of several rare bird species. Why braided rivers of this type are a rare wetland type is described in O'Donnell & Moore (1983).

- 2.87 Criterion 3 states that a wetland should be considered internationally important if it supports populations of plant and/or animal species important for maintaining the biological diversity of a particular biogeographic region. Criterion 4 states that a wetland should be considered internationally important if it supports plant and/or animal species at a critical stage in their life cycles, or provides refuge during adverse conditions. The presence of wrybills and black-fronted terns during the breeding season is a good example of this criterion.
- 2.88 Criterion 6 states that a wetland should be considered internationally important if it regularly supports 1% of the individuals in a population of one species or subspecies of waterbird. From Table 5 it is clear that the lower sections of both rivers meet this criterion for at least one of the key species.
- 2.89 Dr Colin O'Donnell (2000) wrote a report for Environment Canterbury and ranked all the rivers and lakes in Canterbury according to their significance in the context of the Resource Management Act. Rankings were based on widely accepted nature conservation principles relevant to sustaining wildlife (e.g., Soulé 1986; O'Connor *et al.* 1990; Norton & Roper-Lindsay 1999). At their highest level these criteria are embodied in the International Biodiversity Convention (Rio) to which the New Zealand Government is a signatory. He ranked the habitats separately for their overall bird community value and their value for threatened species. I have read that report and agree that the Waimakariri and Rakaia rivers rate very highly in the context of representativeness of the birdlife community type.
- 2.90 Both the Rakaia and Waimakariri rivers rate well in O'Donnell's scored 272 freshwater habitats in Canterbury for their significance under these criteria (i.e., representativeness, life supporting capacity, natural diversity, distinctiveness, intactness, and long-term viability).
- 2.91 I will now briefly discuss the principles behind this scoring procedure.

(i) Representativeness: This indicates how typical a habitat is of a particular ecological region and the quality of the site at representing the habitat type. Implicit in assessing representativeness in this exercise was determining the proportion of indigenous water bird guilds represented within a habitat, overall species diversity, and whether the habitat supports taxonomically distinct species. Both rivers score highly because of the diversity of bird guilds present, the presence of endemic

genera, and the fact that the habitat type is not well represented in other regions of New Zealand.

(ii) Life supporting capacity: Generally, size of habitat is considered a measure of its potential carrying capacity (total numbers of birds) and of the diversity of species, guilds, communities and microhabitats likely to be present. The Rakaia and Waimakariri score very highly because of the large area of bird habitat (respectively c.22,000 and 10,500 ha of bare shingle habitat) available for breeding, roosting and feeding and both having had large numbers of aquatic birds. They each represent some of the largest habitats for braided river aquatic birdlife in New Zealand (see Table 3). Landcare Research (Wilson 2001) mapped the extent of land classified as river from the New Zealand Land Cover Database and the New Zealand Land Resource Inventory. The size of habitat means that habitat is extensive enough to support viable populations of almost all braided river bird species.

(iii) Natural diversity: These criteria measure the diversity of a site in terms of species and microhabitat richness. Areas with greater diversity tend to have the greatest potential for maintaining all life support functions throughout much of the annual or lifetime cycle of a species. Both rivers score highly in terms of diversity of bird microhabitats, and moderately in terms of diversity of guilds present.

(iv) Distinctiveness: The Rakaia is distinctive because it is probably (along with the upper Rangitata) the largest single breeding site for wrybill. The rivers provide important habitat for species with specialist feeding, breeding and behavioural requirements. The mid and lower sections of the two rivers provide the only significant wrybill breeding and feeding habitat in low country areas.

(v) Intactness/naturalness: The upper sections of both rivers are substantially unmodified, and even lower sections compare well to similar rivers. Relative intactness compared to numerous other rivers occurs in terms of the composition and numbers of birdlife present, the range of foraging habitats available to them, and the continuity of the bird movement and migration flyway from upper to lower to rivermouth and the coast. The rivers are slightly modified in terms of some water resource developments but to date these are seen as insignificant in terms of birdlife. Perhaps the biggest impacts are those on the lower Waimakariri related to flood protection works, water pollution below State Highway 1, and the very large Southern black-backed gull colonies that may be threatening other more

conservation-important species. Overall, however, I am of the view that the rivers retain a high degree of naturalness and intactness in relation to the birdlife habitat.

- 2.92 In summarising these values I would consider the Rakaia and Waimakariri rivers to rank overall as being High 1 according to the criteria reported on in O'Donnell (2000). I consider the rivers easily fulfil criteria for national and international significance. International ranking systems like Ramsar generally call for a site to fulfil just one of the criteria to justify the ranking. The rivers fulfil most criteria, each in a number of different ways. The rivers, especially the Rakaia, are among the best examples of the habitat types present in New Zealand, are relatively unmodified, and not well represented elsewhere in the country. The rivers are of large size, with diverse microhabitats and water bird fauna, and support viable populations of many of the species and guilds which are typical of the habitat type.
- 2.93 Finally, with regard to the Government's Sustainable Development Programme of Action, freshwater, I have summarised the key values of the eastern South Island braided rivers (Table 6 below). You can see from this table that the Waimakariri and Rakaia rivers rank comparatively highly in terms of both their biodiversity and recreational values and are some of the least modified of the braided river ecosystems.

Table 6. Summary characteristics of eastern South Island braided rivers

River	Water Programme of Action national importance ³	Mountain catchment	Foothills catchment	Relative mean flow H=>125m ³ s ⁻¹ M=50-125m ³ s ⁻¹ L=<50m ³ s ⁻¹	Natural flows	Modified flows	Water resource development planned	Weed status: F= 'free' M= moderate L=large scale	Key bird species present ⁴	Key predators present
Wairau	a,c,d,e,h	✓		M	✓		✓	F/M	BFT, BBG, WB(? breeding)	All spp
Awatere	-	✓		L	✓		✓	M	?	All spp
Clarence	a,c,l	✓		M	✓		?	M	BFT	All spp
Conway	-		✓	L	✓		?	F/M	BFT	All spp
Waiau	c,d,h,l	✓		M		✓	?	L	BFT	All spp
Hurunui	a,c,d,e,h,l	✓		M		✓	✓	M	BFT	Most spp
Ashley	a,c		✓	L		✓	?	L	BFT, WB, BBG	All spp
Upper Waimakariri	a,c,l	✓		M	✓		?	F/M	BFT, WB	Most spp
Lower Waimakariri	a,c,d,e,l	✓		L		✓	✓	F/M	BFT, WB	All spp
Upper Rakaia	a,b,c,f,k,l	✓		H	✓		?	F/M	BFT, WB	Most spp
Lower Rakaia	a,b,c,d,e,f,l,j,k,l	✓		H	✓	✓	✓	L	BFT, WB, BBG	All spp
Ashburton	A		✓	L		✓	✓	L	BFT, BBG	All spp
Upper Rangitata	a,c,l	✓		M	✓		x	F	BFT, WB	Most spp
Lower Rangitata	a,c,d,e,f,l	✓		M		✓	✓	L	BFT, BBG	All spp
Orari	A		✓	L	✓		✓	L	BFT?	All spp
Opihi	a,c,d,e		✓	L		✓	✓	L	BFT?	All spp
Upper Waitaki	a,c,e,f,k,l	✓		L-M	✓	✓		F/M/L	BFT, WB, BS	Most spp
Lower Waitaki	a,c,d,e,f,h,k	✓		H		✓	✓	L	BFT, BBG	All spp

³ Adapted from MfE/MAF. 2004. *Potential Water bodies of National Importance*. Technical Working Paper, ME number 562, MfE, Wellington. Key: a=Potential water body of national importance for biodiversity; b= Water dependent geodiversity and geothermal features of national importance; c= Potential water body of national importance for recreation; d= Contribution to farmgate GDP from the supply of irrigation water [In 2003/04 dollars, only water bodies with an irrigation value of *greater than \$5 million* are included.]; e= Potential net contribution to gross domestic product at the farmgate from new irrigation development; f= Existing hydro generation by catchment; g= Potentially nationally important water bodies for existing energy generation; h= Potentially nationally important water bodies for potential energy generation with a medium probability of proceeding by 2025; i= Water bodies of highest economic value for existing domestic use; j= Water bodies identified for *potential* domestic use; k= Water bodies with highest economic value for existing industrial use; l= Potential water bodies of tourism/scenic value.

⁴ BFT = black-fronted tern; BS = black stilt; BBG = black-billed gull; WB = wrybill plover

(j) Summary of the range of habitat types and essential characteristics needed to sustain the birdlife communities on the Rakaia and Waimakariri rivers

2.94 Amongst a range of issues considered, the previous sections have identified the main characteristics of the Waimakariri and Rakaia rivers in terms of habitat and associated use by birdlife. These can be summarised in terms of habitat as:

- Terrestrial habitats in the form of islands and connected riparian areas that provide mainly nesting and roosting sites for bird species;
- Aquatic environments associated with major channels, minor channels and seepage channels that provide pools, runs, riffles and backwaters, used primarily for feeding purposes, mainly for aquatic invertebrates.

2.95 These habitats are used by representatives of seven guilds, the most notable of which are the aerial hunting gulls and terns and the shallow water waders. In terms of the former, three species namely the wrybill, black-fronted tern and black-gilled gull (except on the Waimakariri), and to a lesser extent banded dotterel, are of conservation concern and are present on the rivers in significant numbers. Because members of each guild use microhabitats in subtly different ways it is important that integrated river management provide not only for the species of conservation concern but also for other guilds and their members.

PART C: POTENTIAL IMPACTS OF THE CPW SCHEME ON BIRDLIFE

(k) Identification of how the CPW scheme may adversely affect the capacity of the Waimakariri and Rakaia rivers to continue to sustain overall ecological functioning and birdlife communities

2.96 In the preceding sections I have constructed a picture of the broad characteristics of braided rivers which then contribute in specific and inter-related ways to supporting a range of birdlife guilds including particular species of conservation concern. I have noted how the natural characteristics of these systems are often synergistic, and can be modified, normally in adverse and often cumulative ways, by human-induced actions.

- 2.97 In this section I first reiterate the fact that each guild of bird species requires quite different habitat and flow conditions to sustain their breeding and feeding habitat. If one or a number of these habitats are altered or disappear from the Rakaia or Waimakariri rivers then the ability of the system to sustain the full range of the birdlife community will be reduced and future opportunities for restoration will be limited.
- 2.98 Management of waters in the Waimakariri and Rakaia rivers should also seek to sustain the key threatened and endangered species. Sustainability, in the context of bird populations, is defined in terms of ensuring the persistence of sufficient amounts of high quality foraging, roosting and breeding sites for birdlife to maintain viable populations in perpetuity. There needs to be sufficient habitat available so that birds can disperse, and still thrive, if unfavourable conditions develop in particular parts of the habitat. There also needs to be sufficient habitat left for restoration of threatened species in the future.
- 2.99 In seeking to provide for this sustainability any proposed development should seek to avoid any individual or cumulative or synergistic impacts because of the parlous state of the wrybill population and the nationally endangered black-fronted tern population on the two rivers and because of the presence of other important species and the range of guilds that utilise the rivers.
- 2.100 The remainder of this section of evidence will highlight the importance of the principles presented in Part B for maintaining the braided riverbird community on the Waimakariri and Rakaia rivers. I will illustrate the different microhabitats that need to be maintained across a typical river profile.
- 2.101 Terrestrial habitats and their use by birds can be impacted by the following flow-related changes:
- Changes to the flow regime, e.g., by damming and harvesting of moderate to high flows, which increase bed stability and thus may lead to increased levels of vegetation cover which in turn is likely to impact on the predator-prey relationships resulting in higher levels of predation by terrestrial mammalian predators. An additional impact is that vegetation encroachment is most prolific on the high points of islands thus leading birds to nest in suboptimal lower level locations where they are more prone to having their nests destroyed by floods or freshes of higher frequency but lower magnitude.

In examining expert evidence from CPW and its consultants, and other relevant experts, I looked for modelling and other research to demonstrate whether the level of flood and/or fresh flow harvesting will have any significant effect on vegetation encroachment and related impacts on birdlife of the river.

2.102 Aquatic habitats, generally speaking, can be impacted by the following flow-related changes:

- Reductions to low-medium flows during the breeding season are thought to reduce the level of relative protection provided by channels and their flows against movement by mammalian predators onto islands. These impacts are most likely to affect the shallow and deep water wading bird guilds and aerial feeding gulls and terns which rely on the riverbed for nesting.
- Similar to the above, (possible) changes to the size and distribution of channels will likely change patterns of feeding behaviour for both colonial and territorial nesting birds. This in turn is likely to impact on both the feeding and subsequently the breeding success of birds on the river. From work I have undertaken or reviewed on other rivers and from other evidence I have examined I consider this a potential impact on the Waimakariri in particular. All three guilds identified above would likely be impacted by such changes in flow.

In examining expert evidence from CPW and its consultants in relation to these nesting and feeding related minimum flow issues, I will be looking for modelling and other research-based evidence to demonstrate whether the river flow regime remaining if the CPW proposals are approved will have any significant effect on these key requirements.

(I) Critique of the relevant bird components of the CPW evidence in light of the above considerations

2.103 As stated above, my evaluation seeks to identify any activity which by itself, synergistically, or cumulatively, negatively impacts on the key bird species' populations present on both rivers: specifically these are the black-fronted tern, wrybill and banded dotterel on the Waimakariri, and these three species and the

black-billed gull on the Rakaia. Employing this evaluation approach requires very careful consideration of terms/phrases such as 'less than minor', and 'significant' which are often used in the AEE, S92 responses and evidence of Drs' Bishop and Burrell. I concur with the evidence of Dr Hayes which concludes there is no rationale in any of the applicant's supporting evidence for what determines less than or more than minor. In my view, and given the national and international importance of these rivers for bird species of conservation concern, then any cumulative change above a 20% threshold (and individual change maybe as low as 10 or 15%) is a more than minor impact. The nature of many of the effects I describe are synergistic and without an adequate flow regime and careful design of, and major investment in other mitigation measures if this scheme proceeds, then it will likely lead to further conservation concerns about these species on these rivers.

2.104 Before beginning the evidential evaluation in earnest it is important to reiterate the importance of synergistic-interactive and cumulative effects. This has not been addressed in the evidence of CPW witnesses as far as I am aware. Essentially, for key riverbed nesting species and guilds the sorts of parameters that interact include the provision and use of nesting habitat, invasion and control of exotic weeds and predators, and food supplies (as demonstrated in Figure 2 following paragraph 2.46 of my evidence) – a change to one or more of these can have multiple and interactive effects on the bird guilds and individual species, e.g., changes in surrounding land use that results in higher predator numbers means more exposure to potential riverbed invasion by these predators and the likelihood of lower breeding success. This effect can be partially mitigated for if natural river flows are sustained, i.e., the 'moating' effect of flows provides some degree of nest site protection (although of course not to avian predators), but if flows are reduced significantly then this effect is diminished and predation likely increases, incrementally as conditions increasingly suit predators that find channels difficult to cross at higher flows. At the same time the diminished flows can reduce food production and may change the energetic balance required by the birds. Clearly these are synergistic and potentially cumulative effects. There is very little consideration of this complex situation by CPW's consultants even in the physical habitat modelling or overall ecological evaluation of these effects. The sort of question that needs to be researched by the applicant is: would a 'less than minor' effect on feeding habitat availability be exacerbated by another 'less than minor' reduction in the number of braids as flows decline thus resulting in reduced breeding success for key species which may cumulatively be much 'more than minor'? I cannot find any consideration of these

sorts of questions, yet they are fundamental to predictive ecology and assessments of adverse effects.

- 2.105 The applicant has not assessed whether cumulative “less than minor effects” could have major effects. Without such an assessment it is not possible to make a fully informed assessment.
- 2.106 Now moving to the key principles/factors, all of which have relationships both direct and indirect with river flows, which can be identified also from Figure 2 (following paragraph 2.46):
- a. The provision of suitable potential nesting habitat, substantially free of standing exotic vegetation (ie, terrestrial weed invasion);
 - b. Protection of nests and nesting birds from the effects of predators (i.e., predators); and
 - c. The provision of suitable food supplies at the right time and at the right location (i.e., food supply).

These principles and factors in turn are addressed in summary form, in relation to a critique of Dr Bishop’s evidence, in Table 7. The main points to be drawn from this table, based on an examination of the above principles and factors, follow.

- 2.107 In terms of (i) ‘The provision of suitable potential nesting habitat, substantially free of standing exotic vegetation (i.e., weed invasion)’, there are several important conclusions that can be drawn. First, while the Waimakariri has a relatively high proportion of bare riverbed there is no guarantee this will remain the situation, i.e., I am not aware of research to demonstrate trends in vegetation cover for this or for many other rivers. Furthermore, I am also aware that many key weed species are present on this river as they are on others, e.g., lupin and willow. Second, and importantly, while freshes may well play, individually, a very small role in vegetation clearance I suspect that cumulatively in some parts of the river they play a more than ‘minor’ role, but no quantitative research has been presented that I am aware of to demonstrate whether or not this is the situation. Finally, and as noted in Table 7, weed control as a responsibility of CPW, is a possibility, but is very costly – no cost estimates are presented for the thousands of hectares referred to in Dr Bishop’s supplementary evidence at paragraph 36. I have estimated, based on DoC ‘high’ and ‘low’ costs per ha of weed control in the Mackenzie Basin (C. Woolmore pers comm.

2006 figures) that for 2000ha costs would be in the range of \$38000 to \$120000pa (the latter being equivalent to the entire size of the applicant's Environment Enhancement Fund). It is unclear from evidence presented as to where this funding would come from.

Table 7. Summary evaluation of the principal and supplementary evidence of Dr Bishop against key birdlife ecological principles

Key principle/ factor (and see also Figure 2)	Key conclusions, summary and related issues/questions from the evidence	Paragraphs referred to	Problem(s)	My response
(i) The provision of suitable potential nesting habitat, substantially free of standing exotic vegetation (i.e., weed invasion) Also (ii) and (iii)	a). "There is ample scope for mitigation for any adverse effects ... in the many thousands of hectares of broom and gorse dominated scrub and shrubland along the Waimakariri River terraces"	Principal at: Supplem. at: 36	This is very costly and would need to be ongoing – are there resources committed to doing this? Also, what does the witness define as terraces as if out of river and on berm land then unlikely to be used by many key species.	The Waimakariri is one of the better braided rivers in terms of weed encroachment – I believe this is in part due to ECan's clear fairway policy which should continue to be supported. There are likely to be bigger issues on the Waimakariri than exotic weeds under such circumstances.
(ii) Protection of nests and nesting birds from the effects of predators (i.e., predators)	b). "... suggest that the CPW take will have no significant effect on feeding habitat, and by inference nesting habitat availability for riverine birds".	Principal at: 126 Supplem. at: 31-38	I agree with para 28 of his supplementary which acknowledges the need to assess against key drivers. However, there is little integrated analysis to support his fundamental conclusion (i.e., no significant effect), either in the principal or supplementary evidence. The latter refers to additional information but even this is analysed to a limited degree. Furthermore, none of the flow analysis is undertaken against the breeding season flow regime which is much higher than other times of year and greatly impacted by maximum takes, i.e., critical months Sept to Dec with August and January also important.	My quantitative analysis of the additional information (2-D modelling by NIWA) indicates there is a relationship between breeding habitat and flows on the Waimakariri and that 20 cumec flow reductions in the breeding season could be highly detrimental to critical bird species, especially I think wrybill.
	c). Says 'almost all river 'islands' that are present in the 60 cumec scenario are also present in the 40 cumec scenario...'	Principal at: 129, esp 130 Supplem. at: 33, 34	There are major problems with this conclusion given that flows during the breeding season are typically much higher than $40 \text{ m}^3\text{s}^{-1}$, and often around $60\text{-}90 \text{ m}^3\text{s}^{-1}$. Major flow reductions at this time could lead to significant increases in predation pressure.	My analysis indicates major reductions in habitat across the range of modelled flows between around $60\text{-}40\text{m}^3\text{s}^{-1}$: this sort of reduction would occur with a $20\text{m}^3\text{s}^{-1}$ abstraction and would almost certainly increase predation pressure on key bird species.
(iii) The provision of suitable food supplies at the right time and at the right location (i.e., food supply) Also (i) and (ii)	d). Concludes modelled changes in habitat/food resources in the Waimakariri relatively insensitive to changes in flows.	Principal at: 127 Supplem. at: 31-38	Does not acknowledge incrementalism or synergistic negative connections – this is a major problem here and should have been explored by the applicant. Assessment undertaken over the wrong time period – birds are not breeding during many of the summer period they have modelled.	Note the importance of synergistic and incremental impacts, including the ones he identifies and note that each on its own may have 'less than minor' impacts but together they may well be 'major' – the problem is we do not know as the applicants have not undertaken the research or the monitoring or modelling required. Flow modelling needed to be done over the bird breeding season: Sept to Dec inclusive.

- 2.108 From the above the key question, in my opinion, is ‘what incremental or cumulative role do freshes play in slowly contributing to erosional and depositional processes in areas with smaller and unconsolidated bank materials? While potentially ‘minor’, in the bigger scheme of erosional and depositional processes the resulting point bars can be important feeding and potential nesting areas for some species. This issue does not seem to have been addressed by the applicant (e.g., in the evidence of Dr Mabin) but it may be important for ongoing habitat provision for nesting on the Waimakariri River. Dr Davies cited Mr Duncan (NIWA, March 2008, pers. comm.) as suggesting some bed load could be transported in deeper and steeper parts of the river at quite low flows.
- 2.109 Regarding (ii) ‘Protection of nests and nesting birds from the effects of predators (i.e., predators)’ a range of important conclusions need to be drawn. First (see Table 7), and to reiterate, there is a lack of research in this area and virtually none of the evidence from Dr Bishop addresses this issue in a quantitative manner (see principal evidence para 129 at p24). In my opinion a quantitative analysis is required which would involve a proper experimental and quantitative research programme to assess the relationship between mammalian predation and river flows on the Waimakariri River. The most recent research undertaken (Boffa Miskell Ltd and Urtica Consulting 2007) for the Waitaki reinforces my long held view about the validity and importance of the ‘moat effect’ of braided river hydrology. That study indicates channel flows measured as low as $0.059 \text{ m}^3\text{s}^{-1}$ appeared to provide a measure of protection against predation, although in my view probably not against the more mobile species. Dr Bishop only refers to “... channels with very low flows (<3 cumecs) ...” as being beneficial. Adopting the principle that maintaining flows in as many channels as is possible with typical spring-early summer flows for the Waimakariri is beneficial for predator control, then even for some channels with flows as low as in the order of $0.059 \text{ m}^3\text{s}^{-1}$, has implications for management of flows around islands, i.e., maintaining flows of almost any size in braids is of some benefit. Without specific Waimakariri information I am left with no choice but to be precautionary and to reiterate the need for more research. There is a relationship between river flow changes and the numbers of braids in highly braided cross-sections. The work of Hicks *et al.* (2003) as well as my own work (e.g., Hughey 1985 – for the Ashley River, 1987 – for the Waimakariri River), shows such relationships, when evaluated carefully and against ecologically relevant criteria, do exist. I do, nevertheless, acknowledge the relationships are ‘fuzzy’ and thus difficult to base predictions on. The relationship, despite such difficulties, is important however because essentially it

means that at reduced flows there is a diminished level of protection for birds nesting on islands. Once again, and with recourse to only very limited, and dated, quantitative evidence on this matter I am left in a position of recommending a highly precautionary approach of maintaining the low to median 'spring-early summer' flow regime in order to help protect nesting birds.

2.110 In the absence of any new research from the applicants I have undertaken my own, very recent, research in this area. It is based on NIWA's 2-D modelling of a 3km reach of the Waimakariri at Crossbank (an area with a substantial number of wrybills) (Data source: M. Duncan, NIWA). In summary I have found:

- The recent Meridian funded work on the Waitaki (Boffa Miskell and Urtica Consulting, 2007) shows islands are beneficial for nesting success so long as there is some flow around them, i.e., the 'moat effect' principle works;
- I therefore asked NIWA to measure and provided me with raw data on the number and size of all islands in the 3km modelled section of river at flows ranging from 20-768 m³s⁻¹ and I have analysed in detail those ranging from 20-130 m³s⁻¹;
- I have then applied decision criteria based on my own research (see Hughey 1985, 1998) about the minimum sizes of islands key bird species typically nest on – as a result the statistical and graphical analysis presents data on islands >2ha in size;
- Findings show that both the number of islands and area of islands varies with flow (see Figure 7 below), with high correlations for each analysis;
- At flows below 60 m³s⁻¹ there is a substantial reduction in both the number and total area of available islands on the river and I conclude this will likely be bad for all of the key riverbed species because potentially secure nesting sites are more exposed to mammalian predation as channels dry up – Figure 8(a) and 8(b) show the modelling results for 40 m³s⁻¹ (8 islands >2ha) and 60 m³s⁻¹ (10 islands >2ha);
- The optimal range for bird nesting habitat appears to be 60-90 m³s⁻¹ which is typical of flows occurring in the peak spring breeding season: Oct-Dec.
- I have used data from Richard de Joux and undertaken a preliminary analysis of core breeding season monthly minimum flows. In two years that I have analysed, 1971 (Figure 9a) and 1995 (Figure 9b) it is clear that these flows are reduced greatly under the CPW proposal. Further, the desirable breeding season minimum of 60 m³s⁻¹ is heavily compromised, thus reducing numbers

and areas of suitable islands for nesting and thus leading to more predation from mammalian predators.

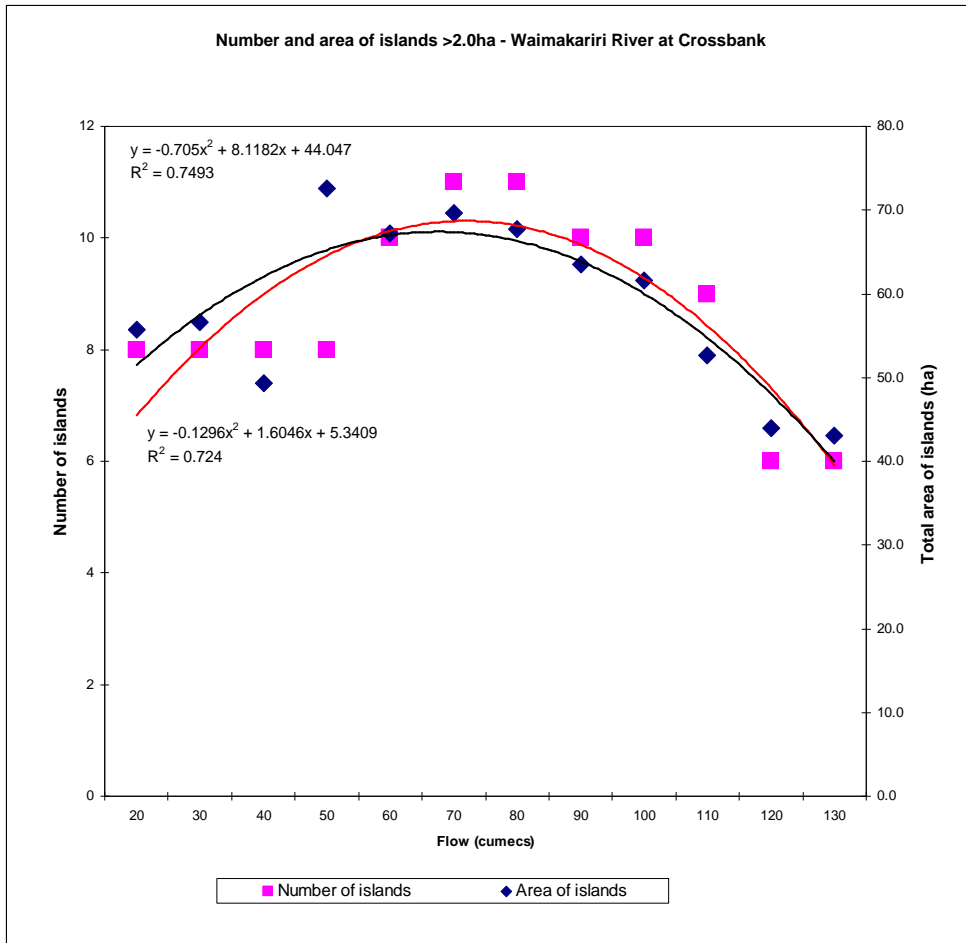


Figure 7. Relationship between number and area of islands >2ha – Waimakariri River at Crossbank.

Figure 8(a). 2-D model of the Waimakariri at Crossbank at 40m³s⁻¹

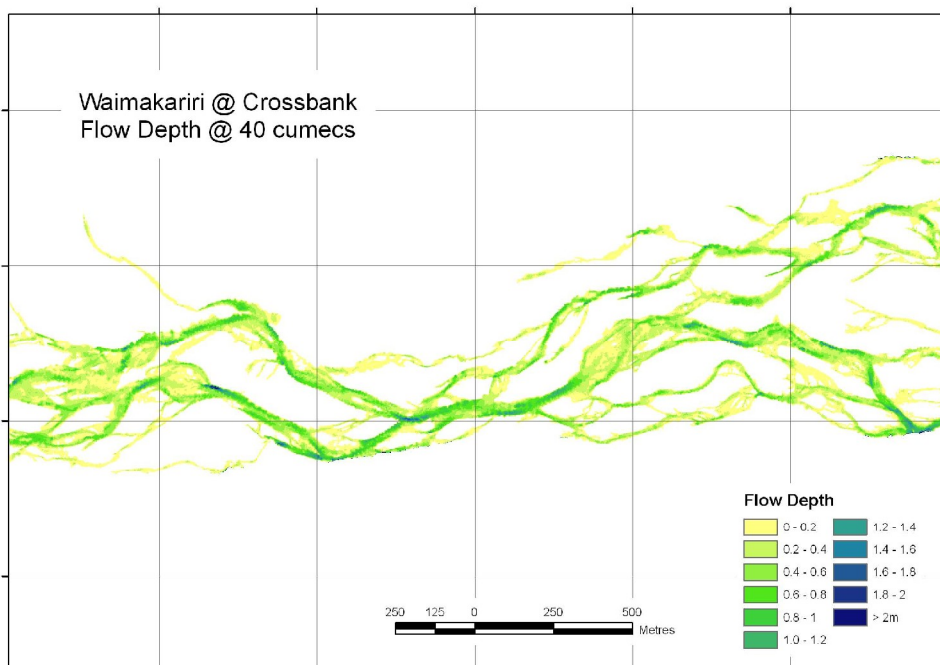


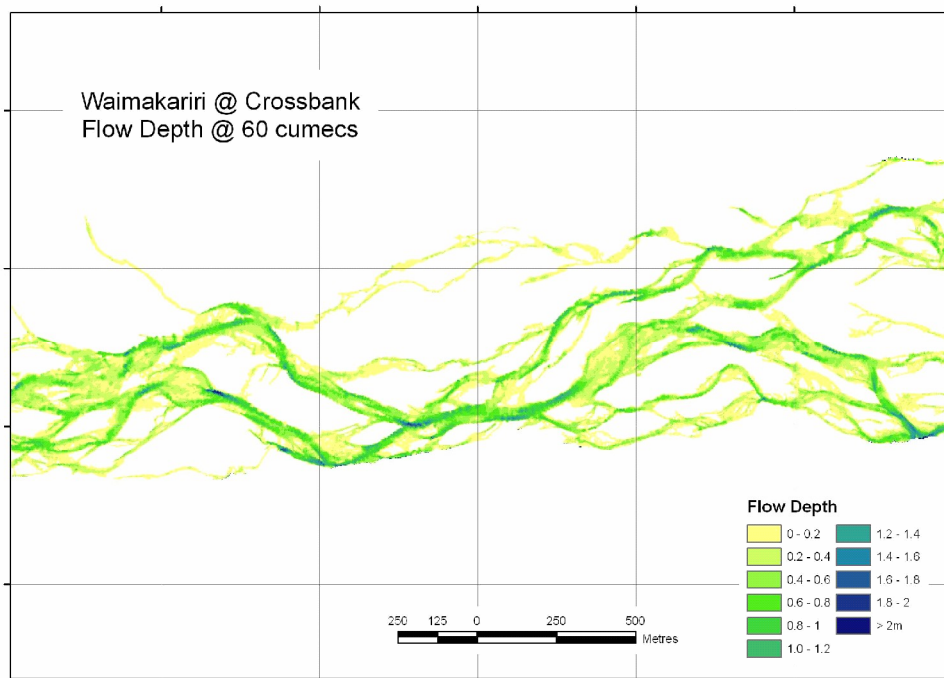
Figure 8(b). 2-D model of the Waimakariri at Crossbank at $60\text{m}^3\text{s}^{-1}$ 

Figure 9a. Waimakariri monthly minimum flows – 1971.

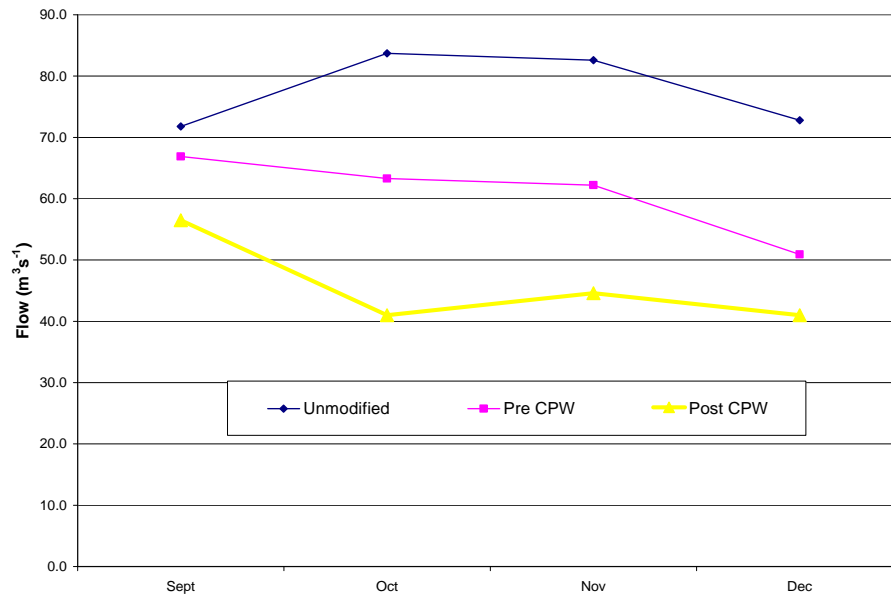
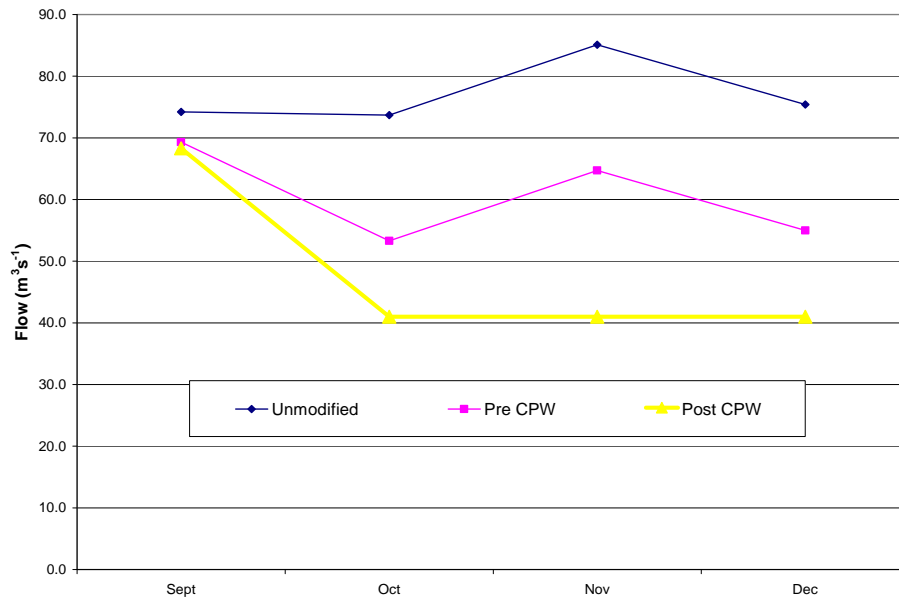


Figure 9b. Waimakariri monthly minimum flows – 1991.



- 2.111 At low to moderate flows access to islands for mammalian predators is a vital but problematic question. Apart from the work of Pascoe (1995) and some limited work by Pierce (1987), Boffa Miskell (2003), and more recently Boffa Miskell Ltd and Urtica Consulting (2007), there is little quantitative information about predator movements in braided rivers related to river flow. Unfortunately while this proposal was highly rated by the FRST, due to limited funding in 2005 it was not approved. CPW presents limited data related to the hydrological characteristics associated with flows around nesting islands but no quantitative information about potential movements across channels by mammalian predators, i.e., there are no estimates of probabilities associated with different flow conditions resulting in different likelihoods of birds being predated, etc. In my opinion CPW witnesses totally underestimate the potential adverse effects of this issue on riverbed nesting birds. This is in contrast to the North Bank proposal where such measures were proposed.
- 2.112 In regards to (iii) 'The provision of suitable food supplies at the right time and at the right location (i.e., food supply)', there are potential synergistic and cumulative issues related to the implications of (i) and (ii) above. For example, changes to braiding as a result of lowered flows (i.e., a reduction in the number of braids), which will likely increase the rate of predation, will also change the distribution and abundance of food supplies (see the principal evidence of Dr Burrell at 5.14, p14, Dr Olsen and Mr Hayes). Such changes will likely affect the energetics of wrybills and black-fronted terns and will almost certainly have cumulative adverse effects on the species and their conservation, i.e., more energy might be used as wrybills need to forage further a field and are more involved in territorial defence or in protecting nests from predators. These are potentially major effects on this species but there is no research to allow a proper evaluation to be undertaken,
- 2.113 Finally, and consistent with my earlier comments about the importance of food supply, I now wish to assess some key elements of benthic invertebrate productivity and availability for riverbed nesting birds, especially for both shallow water and deep water wading guilds and for the aerial feeding gull and tern guild. On p7 of Golder Kingett Mitchell (2007) and in Dr Burrell (in his principal evidence at 5.14-5.17), it is reported that WUA (m^2/m) reduced linearly with declining flow. I am concerned that these reductions will have a direct negative affect on the viability of habitat for the wading bird species and might well also detrimentally affect the gulls and terns. I am not aware of any peer reviewed and published which examines the significance of

such effects. In the absence of such information I support the conclusions drawn by Dr Olsen and Mr Hayes regarding the overall negative effect of likely reduced food production in the Waimakariri River. A further factor which might come into play here is that rapid changes in flow can lead to the onset of catastrophic invertebrate drift. Such drift can provide temporary foods for birds but can then exacerbate productivity limitations as the flows continue to fluctuate in these ways – again, I am unaware of any CPW work on this issue.

2.114 In terms of modelling the amount of physical habitat potentially available for feeding black-fronted terns I note that Golder Kingett Mitchell (2007: 11) use habitat preference curves for modelling generated from both the Waimakariri and Rangitata rivers. Dr Burrell at 5.17 of his principal evidence discusses the nature of the differences between the two curves - I generally agree with his views but also consider more work in this area is urgently required. I collected the data that generated the Rangitata curves – flow conditions were stable at medium to low flow levels and the birds were feeding primarily on aquatic invertebrates; the Waimakariri data were collected during relatively high and unstable conditions when the birds were feeding mainly on small fish. I therefore concur with Mr Hayes (at 6.18) where he suggests “...that the habitat suitability of feeding terns would overlap with aquatic macroinvertebrate habitat suitability (as represented by the “food producing” and *Deleatidium* suitability criteria) and that the latter perhaps are more relevant habitat measures for feeding terns”. Overall then I am concerned that CPW has not provided enough information to properly assess these effects.

PART D: CONCLUSIONS RELATED TO THE WAIMAKARIRI AND RAKAIA RIVERS

2.115 Braided rivers of the physical and ecological type found in New Zealand are rare. They are special geographic features which because of particular combinations of physical conditions provide habitat for wide ranging invertebrate, fish and birdlife communities. In my opinion, and in support of the applicant’s own reports, the Waimakariri and Rakaia River is clearly of outstanding national value to aquatic bird communities because it supports several threatened species, as well as representative fauna communities, high natural diversity, and rare and distinctive species. The rivers have very large potential carrying capacities, are relatively intact, and are well connected with other habitats. Ranking the rivers in terms of Wildlife

Service, International Ramsar, and RMA criteria reaches the same conclusions regarding outstanding values.

- 2.116 Given the above conclusions management of waters in the Waimakariri and Rakaia River should seek to sustain these outstanding (and for some species at severe conservation risk) birdlife communities. Sustainability, in the context of bird populations, is defined in terms of ensuring the maintenance of sufficient amounts of high quality foraging, roosting and breeding sites for birdlife to maintain viable populations in perpetuity. There needs to be sufficient habitat available so that birds can disperse, and still thrive, if unfavourable conditions develop in particular parts of the habitat. There also needs to be sufficient habitat left for restoration of threatened species in the future.
- 2.117 The different requirements of the full range of bird guilds all need to be taken into account when trying to understand their habitat requirements. One flow regime is not going to be optimal for all bird species. Maintenance of foraging habitat would be meaningless without protection of a viable amount of preferred nesting, roosting or breeding sites - and *vice versa*.
- 2.118 In my opinion maintenance of as close as possible to natural flow regime conditions on the Waimakariri and Rakaia rivers is essential for maintaining feeding and nesting habitat of river birds, particularly the conservation at risk species. Maintenance of these conditions during the critical breeding months (August to January, and more particularly September to December) will ensure that the full range of channel types required for birds are present (i.e., backwaters and pools, seepage zones, saturated sand banks, minor riffles and runs and major channel riffles and runs; shallow channels <40 mm deep for shallow water waders, channels up to 200 mm deep for moderate sized deep water waders. But, in addition to these requirements there needs to be provision of higher flows that maintain the ability to keep the riverbed substantially clear of weeds and woody vegetation and to maintain a relatively high degree of security against mainly mammalian predators.
- 2.119 Birds migrate to the Waimakariri and Rakaia in spring to breed and take advantage of flushes in the availability of aquatic insects. These increases in food and its availability are typically also associated with increases in average river flow over these months. Flows need to be higher in spring and early summer to ensure invertebrate food supplies are sufficient, but also to provide a measure of protection

against the mainly mammalian predators which threaten the ongoing conservation of some of these species. Thus, maintenance of flows will also reduce the risk of predators reaching islands in the middle of the river where much nesting occurs.

2.120 In ensuring the ongoing provision of these needs for birdlife I have assessed the applicant's AEE and supplementary material provided in response to the S92 requests and then finally in the evidence of two key witnesses, i.e., Dr Bishop (principally) and Dr Burrell. I have come to the conclusion that there are major concerns about flows and habitat in the Waimakariri and that critical questions remain unanswered, and without which I do not believe it is possible to make assessments that effects will be 'less than minor'. In particular I note an ongoing uncertainty about:

- how the applicant defines 'minor' and 'significant' in terms of their conclusions – these are important terms and without clear definition, in probability contexts, the reports and evidence remain ambiguous and difficult to interpret;
- the role of freshes and flows of less than $200 \text{ m}^3\text{s}^{-1}$ in providing for some ongoing role in vegetation clearance, but also in terms of the supply and replenishment of food resources;
- the role of ongoing substantial spring and early summer breeding season flows in maintaining islands relatively free of mammalian predators and thus reducing the predation potential – there is no probability based quantitative assessment of this critical risk; and
- the relationship between substantial daily variations in riverflow on invertebrate food productivity and availability for birdlife and also on access to predators.

2.121 Overall then I am left with much more than a 'minor' concern about the effects of these proposals on the ongoing viability of the key bird species' populations' on the Waimakariri River, and of the need to provide the flow conditions to support the full range of bird guilds present there..

2.122 Given this high level of concern and having read the evidence of Drs Olsen and Mr Hayes, I am of the opinion that the proposed scheme will change the flow regime and environmental characteristics of the Waimakariri to such an extent that the combination of changes will likely be highly detrimental to the key birdlife, especially

for wrybill plover and black-fronted tern. I have found little in the applicant's reports or expert witness evidence that is at all compelling with respect to the environmental aspects of the scheme related to birdlife on the Waimakariri River in particular. I consider the proposed mitigation measures to be entirely inadequate. Indeed from the new research I have conducted I consider only a significant increase in the river's minimum flow will provide the sort of habitat protection required in the face of this proposed scheme. These conclusions lead me to the final view that, as proposed, the scheme will lead to a substantial (but unquantified) overall loss of habitat quantity and quality which could have significant adverse effects on braided river birdlife conservation and black-fronted tern endangered species (and probably wrybill plover) management in New Zealand.

PART E: DESCRIPTION OF THE ECOLOGY OF TE WAIHORA/LAKE ELLESMERE

(m) General description of the overall ecology of the lake

2.123 Te Waihora/Lake Ellesmere is a complex system, in almost every way. The applicant's proposed irrigation scheme will impact in multiple direct and indirect ways on this system. The problem for me and this hearing is that the management response to these impacts is, as I understand the situation, the responsibility of others. I am not aware of any agreements between the applicant and these other parties covering such impacts. The purpose of this part of the evidence is therefore to describe the overall ecology and complexity of the lake system and note the complex links and interactions between many of the system components and drivers of change.

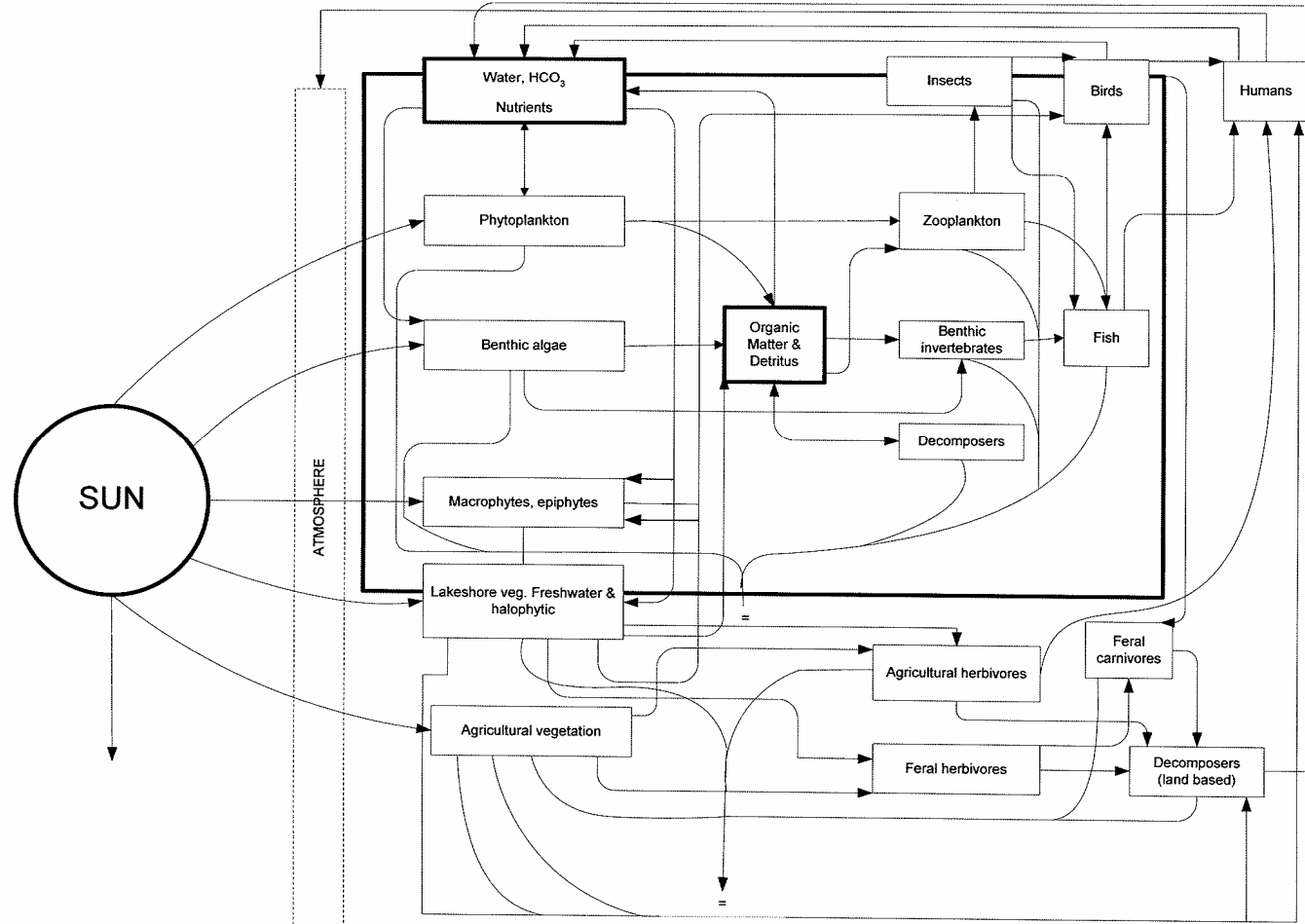
2.124 Hughey *et al.* (2007: 2) summarised the features of the lake by stating: "Te Waihora/Lake Ellesmere is New Zealand's 5th largest (by area) lake – it is a brackish "bar lagoon" type lake of around 20000 ha sitting at the foot of a largely agricultural catchment of 256000 ha. The lake is important culturally⁵ (Pauling and Arnold 2007), for its birdlife (Hughey and O'Donnell 2007), for its botanical features (Grove and Shanks 2007) and for its indigenous fisheries values (Jellyman 2007). While it retains recreational values (Booth 2007), in some areas these have been disastrously reduced (Millichamp 2007). Agriculture and commercial fishing are important activities (Butcher 2007) around and in the lake. The principal form of lake

⁵ In this context 'cultural' refers primarily to the Nga Uara Ngai Tahu/The Ngai Tahu Values – from hereon therefore 'cultural' will mostly be referred to as The Ngai Tahu Values.

management is via a managed lake opening regime – this management is one of the influences on water quality (Haywood 2007) and in turn is influenced by water quantity changes (Thorpe 2007). All of these values and related influencing variables or factors combine and interact in complex and often non linear ways. Adding to this complexity are the multiple agencies with statutory planning and other responsibilities for the lake (Rennie 2007)”.

- 2.125 Figure 10 is an ecosystem-based model of Te Waihora/Lake Ellesmere built around the energy flows and the food web for the lake and its environs. The model has been modified from Davis *et al.* (1996: 162). The main change is the insertion of an atmospheric link between the sun and primary producers to reflect increasing interest in climate change and the impact that is likely to have on the system, and other connections largely associated with agricultural interactions with the lake.
- 2.126 Although the model is a simplified one in that it only incorporates the major contributors, the energy flows and links to the food web do illustrate the complexity of the lake ecosystem. It indicates a large number of interactions between plant and animal groups, and implies levels of interdependency between these components; a change in the distribution or abundance of one has “flow-on” consequences for others.

Figure 10. Model of the Te Waihora/Lake Ellesmere energy flows (adapted from Davis et al. 1996)(Source: Hughey et al. in prep.)



2.127 However, such a view of the lake system has limitations. It does not, of itself, describe, let alone explain, the interactions between the biota and the physical and chemical environment of the lake, which are fundamental to system condition. Moreover, the energy flow and food web model tells us nothing about the dynamics of the system (how the biological elements vary spatially or over various time cycles such as seasons), its stability (whether any of those elements are in long-term decline or increase), or its optimality. It may also imply linearity in cause and effect – but this is clearly often not the case. Optimisation is a particularly important consideration for sustainable lake management; do some aspects of the physico-chemical environment favour some parts of the biological system over others, or are conditions the best possible with respect to the biota as a whole? If the former, are those that are advantaged the ones with the highest values? And how will interventions affect those relativities?

(n) Description of the birdlife communities of the lake, including species distribution and relative abundance

2.128 From the key literature (e.g., O'Donnell 1985, Taylor 1996) it is clear that the key scientific 'values' of the lake's birdlife are:

- A very high level of species diversity (N=110 indigenous bird species that use the lake and its riparian margins for feeding or breeding), represented within a range of guilds, including international migratory species. Sagar *et al.* (2004: 38) note that the total number of species recorded at the lake is 167 species – given a total number of extant bird species in New Zealand of 324 recorded in 1996 then at least 50% have been recorded from the lake. This proportion is far more than any other site in New Zealand;
- Very large numbers of birds (up to 98,000 recorded at one time), especially waterfowl (Figure 11);
- Comparatively large numbers of some species which rely on the lake for particular life stages (e.g., southern crested grebe, bittern, banded dotterel (Figure 12));
- Comparatively large proportions of the numbers of some species using New Zealand wetlands as over-wintering sites during migration (e.g., wrybill, pied stilt).

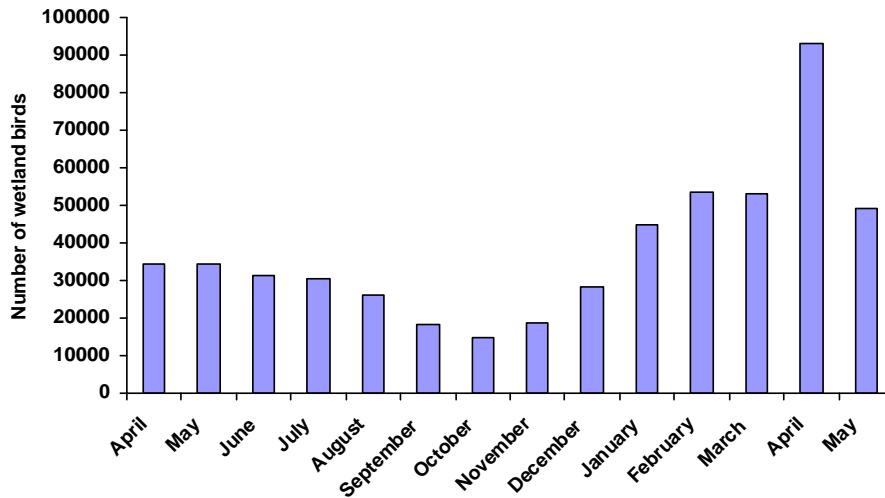


Figure 11. The total wetland bird cycle of numbers for Te Waihora/Lake Ellesmere: 1986-87.

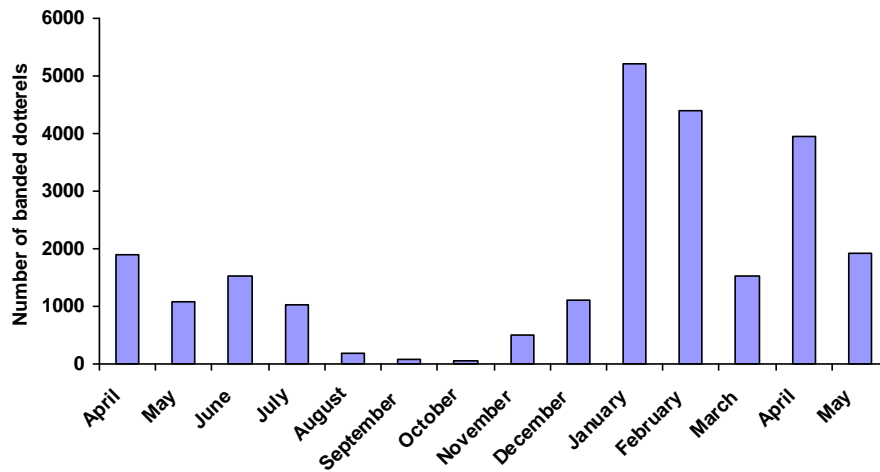


Figure 12. An annual cycle of banded dotterel at Te Waihora/Lake Ellesmere: 1986-87.

(o) **Assessment of the national and international significance of the lake and its birdlife communities**

2.129 The lake is considered nationally important (O'Donnell 1985) because:

- A very large number of birds occur there at all times;
- There is a very high species diversity across a wide range of guilds;
- There are significant proportions of New Zealand populations of around 20 bird species present;
 - Significant areas of habitat exists for birds with restricted distributions; and
 - Habitats for indigenous species that are migratory in New Zealand exist.

2.130 In addition the lake meets multiple criteria under the Ramsar Convention on Wetlands of International Importance. A summary of these and other forms of recognition is given in Te Rūnanga o Ngāi Tahu (2005: 69-71).

2.131 It is also very clear that the lake has high cultural and recreational values with respect to birdlife and that these have varied hugely over time, e.g., some bird species such as brown teal that were harvested by the tangata whenua in the past are now extinct from the lake, and while game shooting is very important so too now is bird watching. In relation to all of the above it is clear that a diverse range of habitats occur around the lake and these are strongly influenced by seasonal lake level management, by riparian management practices, and by other human induced pressures, e.g., mammalian predation.

(p) Summary of the range of habitat types and essential characteristics needed to sustain the birdlife communities of the lake

2.132 Underpinning these values is the diversity of different microhabitat types that provide a wide range of foraging and breeding opportunities (Figure 13). The list of indigenous species found on the lake, their guilds, conservation status and population characteristics, is provided in Appendix 1.

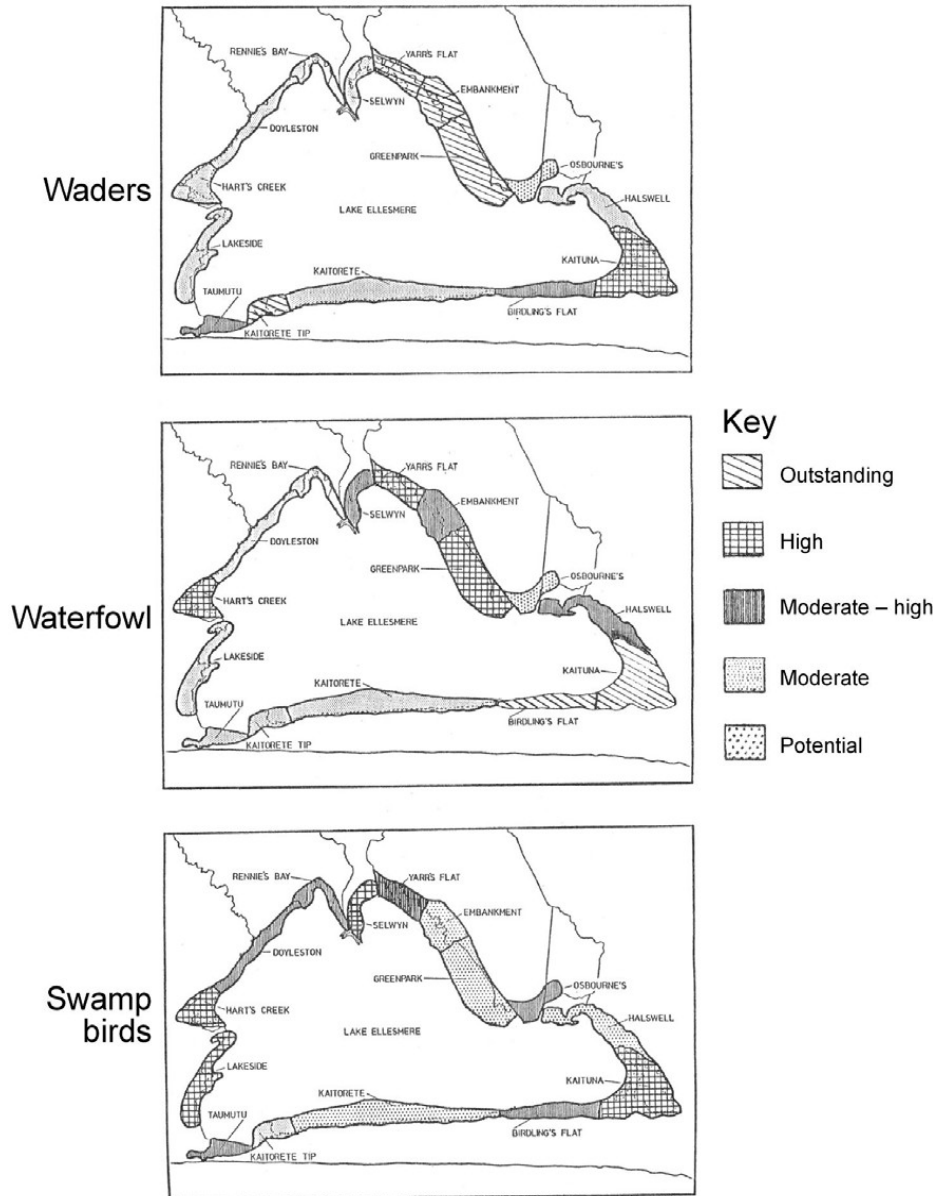


Figure 13. Birdlife values⁶ and key habitat areas around Te Waihora/Lake Ellesmere Source (O'Donnell 1985).

2.133 The human-related drivers of change that might be influenced by the proposed CPW irrigation scheme are important to understand and are identified in a general way below.

⁶ During the late 1970s and early 1980s the New Zealand Wildlife Service undertook the first national inventory of habitats of significance to wildlife, termed Sites of Special Wildlife Interest (SSWIs). Habitats were rated as being of "Outstanding", "High", "Moderate-high", "Moderate", or "Potential" value for species protected by the Wildlife Act 1953. Sites were assessed according to 16 criteria. The criteria employed were based on criteria used by the International Ramsar Convention for identifying Wetlands of International Importance at the time, for which New Zealand has been a contracting party since 1976. The Convention on Wetlands, signed in Ramsar, Iran, in 1971, is an inter-governmental treaty which provides the framework for national action and international co-operation for the conservation and wise use of wetlands and their resources.

- 2.134 Water level management - there is no one lake level management regime that if implemented would benefit all birdlife on Te Waihora/Lake Ellesmere – and, there has never been one. Rather, different regimes will suit different guilds of birds in different ways, sometimes at the expense of other guilds. These effects are most obviously related to the lake level management regime. Thus, recommending a lake level management regime for birdlife is about maximising average benefits to desirable birdlife, e.g., a more-or-less permanently high lake level would benefit many guilds but effectively destroy the exposed mud and turfland flats exploited by the deep and shallow water waders. An optimum (implying the obvious tradeoffs are considered and balanced by conservation managers) water regime will ensure that there is sufficient open water for species that prefer that zone, but will also ensure a general lowering of levels in spring so that saltmarshes become exposed and wind action ensures regular temporary re-watering of some of those saltmarshes and also some of the swampland areas.
- 2.135 Eutrophication - Impacts are largely unknown for the wildlife although if water quality degrades to a 'tipping point' level where there is a significant reduction in invertebrate food production, the impacts could be catastrophic. This situation is thought to be occurring now; it may have an impact but in which direction is unknown.
- 2.136 Weeds, e.g., grey willow - the proliferation of grey willow in Harts Creek needs to be reversed as it will likely lead to a long term reduction in bittern and other bird and fish habitat. Lake level changes and water quality changes (especially salinity) have close relationships to vegetation patterns including the spread of weeds.

PART F: POTENTIAL IMPACTS ON WILDLIFE OF TE WAIHORA/LAKE ELLESMERE

- 2.137 In the previous sections about Te Waihora/Lake Ellesmere I have outlined how the lake and environs need to be thought about in a systems way, and then I have described the birdlife values of the lake and how these values can be influenced by changes to water quantity and water quality. In this section I use this context and an evaluation of expert evidence to consider possible impacts of the CPW proposal on birdlife of the lake.

- 2.138 There is no disputing the importance of Te Waihora/Lake Ellesmere for its overall wetland values and for its birdlife. It is clear from the preceding descriptive material and from an understanding of the CPW proposal that the following are likely to be influenced by the scheme: lake water levels as a result of changes to inflows in streams and drains, and water quality. To date CPW has provided insufficient material to provide the basis for any proper evaluation of lake changes and possible impacts to wildlife. However, with respect to water quality in particular I concur with the evidence of Dr Scott Larned, especially at 4.5 and 4.6 (vegetation), 4.8-4.11 (nitrates), 4.15-4.17 (lake opening) and 4.18-4.33 (phosphorus). Notwithstanding these comments the following sections attempt to identify some likely effects of the proposed scheme on wildlife.
- 2.139 Assuming more water reaches the lake then it is likely that over time the average number of lake openings per annum will increase (from an average of 3.4 to 4.6; CPW evidence of Dr Mabin). In terms of providing the range of wetted habitats needed for the key bird guilds then so long as the existing 'reasonably' ecologically sensitive lake management regime continues to operate then this should not, overall, be detrimental to wildlife. Indeed, under appropriate management, it may be slightly beneficial. However, there is no analysis by the applicant of the effects of increased inputs on birdlife of the lake, nor on the underlying habitat conditions.
- 2.140 Inflowing drains and streams provide important habitat for several guilds of birds and for some species in particular, e.g., bittern feeding. These habitats have been identified by Hughey and O'Donnell (2007 and in press) as needing improved management. If, as a result of the scheme proceeding, additional work is required in terms of drain management (see evidence of Shirley Hayward at paragraph 31) then it is important it meets ecological criteria as well as economic – there is insufficient information to enable a proper assessment of this issue.
- 2.141 In my view the weight of evidence clearly indicates the quality of water downstream of the scheme command area will deteriorate, both in streams and in the lake, i.e., there will be higher nitrogen and phosphorus concentrations. The evidence of Dr Scott Larned in particular shows that at times both Nitrogen and Phosphorus are limiting in the lake – increases to either could therefore be highly detrimental to wildlife, including some bird species. In general, any increase in available phosphorus will likely lead to an increase in algal growth. This may be detrimental to

some components of the wildlife community of the lake, particularly if it contributes to disruptions in the key production cycles, as is suggested by the evidence of Dr Larned at 4.30.

2.142 Kelly and Jellyman (2007) showed there was a major switch in benthic invertebrate composition in the lake in the 1970s, post the loss of the macrophyte beds. This switching is a known phenomenon in shallow lakes like this (see for example, Folke *et al.* 2002), and is not necessarily bad so long as the relevant adaptive cycle retains its resilience capacity. There is some evidence that the loss of macrophyte beds has detrimentally affected trout (Millichamp 2007) and some guilds and species of birds (but not others). But what is potentially of concern here is that increased levels of nutrient input and changes to algal growth as a result may well lock the foreseeable future of the lake into its current state. This would be undesirable given that there are widely held views that overall the lake performs 'better' within a macrophyte-dominant system state.

2.143 Attempts to achieve this macrophyte-dominant state rely largely on improving lake level management (e.g., increasing average lake levels while at the same time reducing the exposure time during openings), and on reducing nutrient inputs hugely. This view appears to be reinforced by Dr Burrell (at paragraph 11.7 of his principal evidence) where he states: "Although we are lacking long-term water quality data from Lake Ellesmere to categorically state the cause of the current long period without macrophytes, I consider there is sufficient data from overseas studies to state that elevated nutrient concentrations are the cause (Scheffer 1998)". His further conclusion at 11.8 also supports my concern about the future of the lake: "For Lake Ellesmere, this suggests that extensive recolonisation of macrophyte beds is unlikely, given the existing high nutrient loading of the lake". He then states at paragraph 11.9: "In my opinion, increased nitrate loadings to Lake Ellesmere will not influence the likelihood of macrophyte beds recovering in the lake, because nutrient concentrations are already too high, and the lake is too turbid, for re-establishment to occur, irrespective of the CPW scheme. However, I do agree with submitters that greater macrophyte dominance in the lake is a desirable management goal for the lake, and therefore that nutrient management within the entire lake catchment should be a priority." This conclusion begs the question (as also alluded to by Dr Larned at 4.9): 'Has CPW undertaken an overall nutrient budget model for its entire scheme area that compares the present with the predicted under a range of intensification scenarios, with a view to only submitting proposals that will lead to a significant net

reduction of nutrients in the lake?’ From the evidence I have read, i.e., Dr Burrell, Mr Kennedy, Shirley Hayward and Dr Larned, it is clear to me that there will be a major increase in nutrients and in my view this will be detrimental for the lake and its birdlife.

2.144 Finally, there will of course be synergistic connections between lake level management and water quality management. There is insufficient information to enable a proper assessment of this issue.

PART G: CONCLUSIONS RELATED TO BIRDLIFE OF TE WAIHORA/LAKE ELLESMERE

2.145 Te Waihora/Lake Ellesmere, despite many largely detrimental changes over the last 100 or so years, remains a wetland of national and international importance for birdlife – specifically it contains very large numbers of birds representing a wide range of guilds and species living in a wide range of habitats. Despite these levels of importance some habitats associated with the lake are declining in value and so too are the species and guilds linked to these habitats. Overall then while the state of birdlife can be considered in ‘reasonable health’, the trend is probably a slow decline in value for birdlife. To reverse this trend, and secure the ‘health’ of the lake’s birdlife, a range of management actions need to be taken. These actions range from immediate work on willow control to improvements in lake level (linked in part to the water conservation order provisions), water quality and riparian management – some of these are urgent, some are more strategic, but all are necessary.

2.146 The extent to which the CPW proposals compromise the values or the necessary restoration and enhancement procedures is somewhat of an unknown. There is little or no evidence from CPW that assesses effects on lake birdlife, either directly or indirectly.

2.147 Despite the lack of adequate information from CPWI on changes to lake level and water quality and the relationships between these parameters it is possible from the information available to conclude that water levels in the lake will change, water quality will deteriorate further and there will be issues with riparian management of inflowing drains. I cannot be confident about the overall effects on wildlife of any of these changes until further information, including an overall water quality budget from

the scheme command area, is made available to allow me to undertake a properly informed assessment.

K Hughey

May 2008

REFERENCES

- Alterio, N.; Moller, H. 1997. Daily activity of stoats (*Mustela erminea*), feral ferrets (*Mustela furo*) and feral house cats (*Felis catus*) in coastal grassland, Otago Peninsula, New Zealand. *New Zealand Journal of Ecology* 21(1):89-95.
- Alterio, N.; Moller, H.; Ratz, H. 1998. Movements and habitat use of feral house cats *Felis catus*, stoats *Mustela erminea* and ferrets *Mustela furo*, in grassland surrounding yellow-eyed penguin *Megadyptes antipodes* breeding areas in spring. *Biological Conservation* 83(2):187-194.
- 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. Proceedings of the 9th Australian Weeds Conference, Adelaide, South Australia.
- Boffa Miskell. 2003. Terrestrial Ecology and Wetlands Assessment Report. Appendix L to Project Aqua: Assessment of Effects on the Environment. Meridian Energy Limited, Christchurch. Meridian Energy, Christchurch.
- Boffa Miskell and Urtica Consulting. 2007. Black-fronted tern trial: effects of flow and predator control on breeding success. Prepared for Meridian Energy Ltd, Boffa Miskell, Christchurch.
- Bomford, M. 1978. The behaviour of the banded dotterel. Unpubl. MSc thesis. University of Otago, Dunedin.
- Brown, J.B.; Robinson, T. 2008. In prep. Uncertainty in Braided River Bird Counts. Report to Department of Conservation. University of Canterbury, Christchurch.
- 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.
- Butcher, G. 2007 - *Economic Values Associated with Te Waihora*. In: K.F.D. Hughey and K.W. Taylor. The Current State and Future Management of Te Waihora/Lake Ellesmere. Based on the 2007 Te Waihora/Lake Ellesmere Living Lake Symposium. In prep. Waihora Ellesmere Trust, Christchurch.
- Davis, S.F.; Blackford, C.J.; Glennie, J.M.; Glova, G.T.; Hughey, K.F.D.; Partridge, T.R.; Taylor, K.J.W.; Ward, J.C. 1996. Chapter 11: *Lake Ecosystem....* in: The Natural Resources of Lake Ellesmere (Te Waihora) and its Catchment. Ed. By K.J.W. Taylor, Canterbury Regional Council, Christchurch.
- Duncan, M.; Sagar, P.; Kelly, G.; Wild, M. 2003. Habitat use of Waimakariri River Black-fronted Terns. *NIWA Client Report: CHC2003-013*, NIWA, Christchurch.
- Fitzgerald, B.M. 1964. Ecology of mustelids in New Zealand. Unpubl. MSc thesis. University of Canterbury, Christchurch.
- Folke, C.; Carpenter, S.; Elmquist, T.; Gunderson, L.; Holling, C.S; Walker, B. 2002. Resilience and Sustainable Development: Building Adaptive Capacity in a World of Transformations. *Ambio*, 32(5): 437-440.
- Grant, Andrew. Canterbury Conservancy Advisory Scientist, Department of Conservation. Personal communication.
- Gillies, C. 2001. Advances in New Zealand mammalogy 1990-2000: House cat. *Journal of the Royal Society of New Zealand* 31(1):205-218.
- Golder Kingett Mitchell. 2007. Waimakariri river flow, habitat availability and angling suitability: tow-dimensional modelling results. Golder Kingett Mitchell, Christchurch.
- Gough, J.D.; Ward J.C. 1996. Environmental Decision-Making and Lake Management. *Journal of Environmental Management*, 48(1): 1-15.
- Grove, P and Shanks, A. 2007. *Te Waihora Lakeshore Vegetation*. In: K.F.D. Hughey and K.W. Taylor. The Current State and Future Management of Te Waihora/Lake

- Ellesmere. Based on the 2007 Te Waihora/Lake Ellesmere Living Lake Symposium. In prep. Waihora Ellesmere Trust, Christchurch.
- Hay, J.R. 1984. The behavioural ecology of the wrybill plover. Unpublished PhD thesis. University of Auckland, Auckland.
- Hayward, S. 2007. Te Waihora Water Quality: Current State and Trends. In: K.F.D. Hughey and K.W. Taylor. The Current State and Future Management of Te Waihora/Lake Ellesmere. Based on the 2007 Te Waihora/Lake Ellesmere Living Lake Symposium. In prep. Waihora Ellesmere Trust, Christchurch.
- Hicks, D.M.; Duncan, M.J.; Shankar, U.; Wild, M.; Walsh, J.R. 2003. Project Aqua: Lower Waitaki River geomorphology and sediment transport. NIWA Client Report CHC01/115. Appendix Z to Project Aqua: Assessment of Effects on the Environment. Meridian Energy Limited, Christchurch.
- Hitchmough, R.; Bull, L.; Cromarty, P. (comps) 2007. *New Zealand Threat Classification System lists*. Department of Conservation, Wellington.
- 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. 1985b. The relationship between riverbed flooding and non-breeding wrybills on northern feeding grounds in summer. *Notornis* 32: 42-50.
- Hughey, K.F.D. 1987. Wetland birds. P264-275 in: Henriques, P.R. (ed.). Aquatic biology and hydroelectric power development in New Zealand. Oxford University Press, Auckland.
- Hughey, K.F.D. 1997. The diet of the wrybill (*Anarynchus frontalis*) and the banded dotterel (*Charadrius bicinctus*) on two braided rivers in Canterbury, New Zealand. *Notornis* 44: 185-193.
- Hughey, K.F.D. 1998. Nesting home range sizes of wrybill (*Anarynchus frontalis*) and banded dotterel (*Charadrius bicinctus*) in relation to braided riverbed characteristics. *Notornis* 45: 103-111.
- Hughey, K.F.D. 2003. Statement of evidence in the matter of an application for a water conservation order pursuant to section 201 of the act and in the matters of an inquiry into the draft National Water Conservation (Rangitata River) Order 2001. Environment Court, Christchurch RMA.
- Hughey, K.F.D. 2006. First Statement of Evidence of Kenneth Hughey on behalf of the Director-General of Conservation. Before the Marlborough District Council Hearing Committee in the Matter of the Resource Management Act 1991 (The Act) and in the Matter Trustpower Ltd's Proposed Wairau Valley Hydro Electric Scheme.
- Hughey, K.F.D.; Fraser, B.; Hudson, L.G. 1989. Aquatic invertebrates in two Canterbury rivers - related to bird feeding and water development impacts. *Science & Research Series* No. 12. Department of Conservation, Wellington.
- Hughey, K.F.D., O'Donnell, C.F.J. 2007. *The state of wildlife of Te Waihora/Lake Ellesmere and future management actions*. In: K.F.D. Hughey and K.W. Taylor. The Current State and Future Management of Te Waihora/Lake Ellesmere. Based on the 2007 Te Waihora/Lake Ellesmere Living Lake Symposium. In prep. Waihora Ellesmere Trust, Christchurch.
- Hughey, K.F.D. Smith, L.A.; Preston, D.C. 1986. Birds of the lower Clutha River, their distribution and habitat use. NZ Wildlife Service Occasional Publication No.11. Department of Internal Affairs, Wellington.
- Hughey, K.F.D., Taylor, K., Ward, J.C. Te Waihora/Lake Ellesmere: An integrated view of the current state and possible futures. In: K.F.D. Hughey and K.W. Taylor. The Current State and Future Management of Te Waihora/Lake Ellesmere. Based on the 2007 Te Waihora/Lake Ellesmere Living Lake Symposium. In prep. Waihora Ellesmere Trust, Christchurch. In prep.
- Hughey, K.F.D.; Warren, A. 1997. Habitat restoration for wildlife nesting on degraded braided riverbeds in New Zealand. In Hale, P. & Lamb, D. (ed.) Conservation Outside Nature Reserves. Brisbane, Centre for Conservation Biology, University of Queensland.

- Jellyman, D., Smith, C. 2007. Native Fish and Fisheries of Te Waihora. In: K.F.D. Hughey and K.W. Taylor. The Current State and Future Management of Te Waihora/Lake Ellesmere. Based on the 2007 Te Waihora/Lake Ellesmere Living Lake Symposium. In prep. Waihora Ellesmere Trust, Christchurch.
- Jolly, J.N. 2003. Statement of evidence, Resource consent applications, Rangitata Diversion Race Management Ltd and CPW Ltd the Canterbury Regional Council.
- Jowett, I.G. Rangitata River Special Tribunal. Statement of evidence in the matter of an application for a water conservation order pursuant to section 201 of the act. Timaru.
- Jowett, I.G.; Richardson, J.; Biggs, B.J.F.; Hickey, C.W. 1991. Microhabitat preferences of benthic invertebrates and the development of generalised *Deleatidium* spp. habitat suitability curves, applied to four New Zealand rivers. *New Zealand Journal of Marine and Freshwater Research* 25: 187-199.
- Keedwell, R.J. 2002. Black-fronted terns and banded dotterels: causes of mortality and comparisons of survival. PhD thesis. Massey University, Palmerston North.
- Keedwell, R.J. 2004. Use of population viability analysis in conservation management in New Zealand. 2. Feasibility of using population viability analysis for management of braided river species. *Science for Conservation* 243:39-60.
- Keedwell, R.J. 2006. First Statement of Evidence of Rachael Keedwell on behalf of the Director-General of Conservation. Before the Marlborough District Council Hearing Committee in the Matter of the Resource Management Act 1991 (The Act) and in the Matter Trustpower Ltd's Proposed Wairau Valley Hydro Electric Scheme.
- Keedwell, R.J.; Brown, K.P. 2001. Relative abundance of mammalian predators in the upper Waitaki Basin, South Island, New Zealand. *NZ Journal of Zoology* 28(1): 31-38.
- Kelly, D.J.; Jellyman, D.N. 2007. Changes in trophic linkages to shortfin eels (*Anguilla australis*) since the collapse of submerged macrophytes in Lake Ellesmere, New Zealand. *Hydrobiologia*, 579:161–173
- Lalas, C. 1977. Food and feeding behaviour of the black-fronted tern, *Chlidonias hybrida albostratus*. Unpublished MSc thesis, University of Otago, Dunedin.
- Landcare Research 2003. Kararehe Kino. Vertebrate pest Research. Issue 2. Landcare Research. Lincoln.
- Mosley, M.P. 1983. Response of braided rivers to changing discharge. *Journal of Hydrology (NZ)* 22: 18-66.
- McEntee, D. 2007. Wax eggs as a method to identify predators and record interference rates in real and artificial nests of banded dotterel (*Charadrius bicinctus*) in braided river systems. Unpublished MSc thesis, Lincoln University, Lincoln.
- 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.; 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.
- Maloney, R.F.; Rebergen, A.L.; Nilsson, R.J.; Wells, N.J. 1997. Bird density and diversity in braided river beds in the Upper Waitaki Basin, South Island, New Zealand. *Notornis* 44: 219-232.
- Miller, R.G. 2000. Influence of bank vegetation on alluvial channel patterns. *Water Resources Research* 36: 1109-1118.
- Millichamp, R. 2007. *The Demise of New Zealand's Greatest Brown Trout Fishery*. In: K.F.D. Hughey and K.W. Taylor. The Current State and Future Management of Te Waihora/Lake Ellesmere. Based on the 2007 Te Waihora/Lake Ellesmere Living Lake Symposium. In prep. Waihora Ellesmere Trust, Christchurch..
- Mosley, M.P. 1983. Response of braided rivers to changing discharge. *Journal of Hydrology (NZ)* 22: 18-66.
- Mosley, M.P. 2001. Rangitata River natural character, amenity value, and flow regime. *Report R01/8*. Environment Canterbury, Christchurch.

- Mosley, M.P. 2004. Rivers and the riverscape. Chapter 8, in: Harding, J. (ed). 2004. Freshwaters of New Zealand. New Zealand Hydrological Society and New Zealand Limnological Society, Wellington.
- Mosley, M.P.; Schuum, S.A. 2000. Gravel bed rivers – The view from the hills. Pp 479-506, in: Mosley, M. P. (ed). 2000. Gravel-bed rivers V. Proceedings of the 5th International Gravel-Bed Rivers Workshop, Christchurch and Franz Josef Glacier, New Zealand, 29 August-2 September 2000. NZ Hydrological Society, Wellington.
- Moss, K.; Sanders, M. 2001. Advances in New Zealand mammalogy: Hedgehog. *Journal of the Royal Society of New Zealand* 31(1):1-5.
- Norton, D.; Roper-Lindsay, J. 1999. Criteria for assessing ecological significance under Section 6(c) of the Resource Management Act 1991. Discussion Paper prepared for the Ministry for the Environment, Wellington.
- O'Donnell, C.F.J. 1985. Lake Ellesmere: a Wildlife Habitat of International Importance. *Fauna Survey Unit Report 40*. NZ Wildlife Service, Department of Internal Affairs, Christchurch.
- 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. 1994. Distribution and habitats of spotless crakes in Canterbury. *Notornis* 41: 211-213.
- O'Donnell, C.F.J. 2000. 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.; Moore, S.M. 1983. The wildlife and conservation of braided river systems in Canterbury. *Fauna Survey Unit Report* No. 33. NZ Wildlife Service, Wellington.
- O'Donnell, C.F.J.; Sedgeley, J.A.; Westbrooke, I. 2006. Habitat use by black-fronted terns (*Sterna albobriata*) on the Wairau River, New Zealand: Preliminary results May 2006. Research Development & Improvement Division, Department of Conservation, PO Box 13049, Christchurch,
- O'Connor, K.F.; Overmars, F.B.; Ralston, M.M. 1990. Land evaluation for nature conservation: A scientific review compiled for application in New Zealand. *Conservation Sciences Publication* No. 3. Department of Conservation, Wellington.
- Olsen, D. 2006. First Statement of Evidence of Dean Olsen on behalf of the Director-General of Conservation. Before the Marlborough District Council Hearing Committee in the Matter of the Resource Management Act 1991 (The Act) and in the Matter Trustpower Ltd's Proposed Wairau Valley Hydro Electric Scheme.
- 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, New Zealand.
- Pauling, C. and Arnold, J. 2007. *What is the cultural health of Te Waihora?* In: K.F.D. Hughey and K.W. Taylor. The Current State and Future Management of Te Waihora/Lake Ellesmere. Based on the 2007 Te Waihora/Lake Ellesmere Living Lake Symposium. In prep. Waihora Ellesmere Trust, Christchurch.
- Pierce, R.J. 1976. The feeding ecology of wrybills in Canterbury. Unpublished Dip. Sci. thesis, University of Otago, Dunedin.
- Pierce, R.J. 1979. Foods and feeding of the wrybill (*Anarynchus frontalis*) on its riverbed breeding grounds. *Notornis* 26: 1-21.
- Pierce, R.J. 1982. A comparative ecological study of pied and black stilts in South Canterbury. Unpubl. PhD thesis, University of Otago, Dunedin.
- 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). NZ Wildlife Service, Department of Internal Affairs, Wellington.
- Power, M.E. 2000. Controls on food webs in gravel-bedded rivers: the importance of the gravel-bed habitat in trophic dynamics. Pp. 405-422, in: Mosley, M. P. (ed). 2000. Gravel-bed rivers V. Proceedings of the 5th International Gravel-Bed Rivers Workshop, Christchurch

- and Franz Josef Glacier, New Zealand, 29 August-2 September 2000. NZ Hydrological Society, Wellington.
- Ragg, J.; Waldrup, K.; Moller, H. 1994. Bovine tuberculosis infections in ferrets, stoats and feral cats in Otago, New Zealand. *NZ Veterinary Association Deer Branch Course No. 11*: 114-126.
- Rebergen, A.; Keedwell, R.; Moller, H.; Maloney, R. 1998. Breeding success and predation at nests of banded dotterel (*Charadrius bicinctus*) on braided river beds in the Central South Island, New Zealand. *New Zealand Journal of Ecology* 22: 33-41.
- Rennie, H. 2007. *The Coroner's Report – Life after death for Te Waihora/Lake Ellesmere*. In: K.F.D. Hughey and K.W. Taylor. The Current State and Future Management of Te Waihora/Lake Ellesmere. Based on the 2007 Te Waihora/Lake Ellesmere Living Lake Symposium. In prep. Waihora Ellesmere Trust, Christchurch.
- 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, C.J.R.; Law, E.; de Hamel, R.J.B.; Wakelin, D.J.; Courtney, S.P. 1984. Habitat requirements of wetland birds in the lower Waitaki River catchment, New Zealand. *NZ Wildlife Service Occasional Publication No. 6*. Department of Internal Affairs, Wellington.
- Sagar, P.M. 1983. Invertebrate recolonisation of previously dry channels in the Rakaia River. *New Zealand Journal of Marine and Freshwater Research* 17: 377-386.
- Sagar, P.M. 1986. The effects of floods on the invertebrate fauna of a large, unstable braided river. *New Zealand Journal of Marine and Freshwater Research* 20: 37-46.
- Sagar, P.M. 2003. Statement of evidence in the matter of an application for a water conservation order pursuant to section 201 of the act and in the matters of an inquiry into the draft National Water Conservation (Rangitata River) Order 2001. Environment Court, Christchurch RMA.
- Sagar, P., Hawes, I., Stephens, S., Jellyman, D., Kelly, D. 2004. *Lake Ellesmere (Te Waihora): a review of water clarity and the potential for macrophyte growth, and the benthic invertebrates, fisheries and birds, and their feeding relationships*. NIWA Client Report No. U04/45. Environment Canterbury, Christchurch.
- Scrimgeour, G.J.; Davidson, R.J.; Davidson, J.M. 1988. Recovery of benthic macroinvertebrate and epilithic communities following a large flood in an unstable, braided New Zealand river. *New Zealand Journal of Marine and Freshwater Research* 22: 337-344.
- Smith, D.; Hughey, K.F.D.; Booth, K. 1997. Impacts of recreational users on the wildlife of braided rivers - a preliminary study on the Tekapo River. Report prepared for Department of Conservation, Christchurch. Department of Resource Management, Lincoln University.
- Soulé, M.E. (ed.). 1986. *Conservation Biology: the science of scarcity and diversity*. Sinauer Associates, Sunderland, Massachusetts.
- Stead, E.F. 1932. *The Life Histories of New Zealand Birds*. Search Publishing, London.
- Taylor, K.J.W. (ed). 1996. *The Natural Resources of Lake Ellesmere (Te Waihora) and its Catchment*. Canterbury Regional Council, Christchurch.
- Taylor, K.J.W. 1996. *The Wildlife Community*. Ch 13, in: *The Natural Resources of Lake Ellesmere (Te Waihora) and its Catchment*. Ed. By K.J.W. Taylor, Canterbury Regional Council, Christchurch.
- Te Rūnanga o Ngāi Tahu. 2005. *Te Waihora Joint Management Plan*. Te Rūnanga o Ngāi Tahu and Department of Conservation, Christchurch.
- Thorpe, H. 2007. *Hydrology of Te Waihora-Lake Ellesmere*. In: K.F.D. Hughey and K.W. Taylor. The Current State and Future Management of Te Waihora/Lake Ellesmere. Based on the 2007 Te Waihora/Lake Ellesmere Living Lake Symposium. In prep. Waihora Ellesmere Trust, Christchurch..
- Verner, J. 1984 The guild concept applied to management of bird populations *Environmental Management* 8: 1-14.

Wilson, G.H. 2001. National distribution of braided rivers and the extent of vegetation colonisation. *Landcare Research Contract Report*: LC0001/068.

Woolmore, Chris. Programme Manager, Project River Recovery. Twizel Area Office, Department of Conservation. Personal communication

Appendix 1. Indigenous bird species, guilds and estimated population sizes for all species recorded at Te Waihora/Lake Ellesmere from c.1900 - present

Nomenclature from Heather and Roberston (1996). Source: Hughey and O'Donnell (2007, in press).

The list includes species that use the lake and its wetland margins. It **excludes** oceanic species and vagrants that occur at sea off the Kaitorete Spit, penguins that may moult along the Kaitorete Spit, introduced species, and extinct species.

Key:

B = Breeding species,

F = Uses the lake for feeding only,

M = Regular international migrants that occur most years,

V = Vagrants, i.e., species that occur only very rarely on the lake

X = Locally extinct post European arrival (but still occur elsewhere in New Zealand)

Shaded rows = The 'core' 40 species for monitoring species diversity on an annual basis

Species common name, by guild	Maori name	Scientific name	Origin and breeding status	New Zealand wide conservation status - 2007	Typical numbers at one time 1985 and 1988 ^{7,8}	Typical numbers at one time 2000-2007	Max at one time (1980-present)	National population (year estimated in) and approx. proportion of national total present at lake at one time (%) ⁹
1. Open water divers								
Australasian crested grebe	Puteketeke	<i>Podiceps cristatus</i>	B	Acutely threatened	0-1	10-20	32	400 (2004) (8%)
NZ dabchick	Weweia	<i>Poliiocephalus rufopectus</i>	X	Chronically threatened	-	-	-	
Australasian gannet	Takapu	<i>Morus serrator</i>	V		0	0	1	

⁷ Bird data for this period was collated from O'Donnell (1985) and NWASCA (1988), as reported in Taylor (1996: 191).

⁸ Data from DoC unpubl reports, Ornithological Society of NZ unpubl. reports and A. Crossland, Christchurch City Council, from the February 2006 survey, and from the February 2007 survey.

⁹ Data from Heather and Robertson (1996) unless otherwise noted.

Species common name, by guild	Maori name	Scientific name	Origin and breeding status	New Zealand wide conservation status - 2007	Typical numbers at one time 1985 and 1988	Typical numbers at one time 2000-2007	Max at one time (1980-present)	National population (year estimated in) and approx. proportion of national total present at lake at one time (%)
Australian pelican		<i>Pelecanus conspicillatus</i>	V		0	0	1	
Black shag	Kawau	<i>Phalacrocorax carbo</i>	B	Chronically threatened	100-200	250	500	5-10000 pairs (3%)
Little shag	Kawaupaka	<i>P. melanoleucos</i>	B		400-500	500	500	5-10000 pairs (5%)
Pied shag	Karuhiruhi	<i>P. varius</i>	F		0	10-20	24	5-10000 pairs (<1%)
Little black shag		<i>P. sulcirostris</i>	V	Chronically threatened	0	0	6	
Spotted shag	Parekareka	<i>Stictocarbo punctatus</i>	F		1-100	<200	20	10-50000 pairs (<1%)
NZ scaup	Papango	<i>Aythya novaeseelandiae</i>	B		0	100-200	235	20000 (1990s) (<1%)
Australian coot		<i>Fulica atra</i>	V		0	0	3	
White-eyed duck		<i>A. australis</i>	V		0	0	0	
2. Deep water waders								
White heron	Kotuku	<i>Egretta alba</i>	F	Acutely threatened	1-15	1-15	19	100-120 (2000) (19%)
Intermediate egret		<i>E. intermedia</i>	V		0	0	1	
Little egret		<i>E. garzetta</i>	M		0-1	0-1	2	<50 (4%)
Reef heron	Matuku moana	<i>E. sacra</i>	V	Acutely threatened	0	0	0	
White-faced heron		<i>Ardea novaehollandiae</i>	B		100-200	100-200	421	Widespread & common
Royal spoonbill	Kotuku ngutu-papa	<i>Platalea regia</i>	F		0-2	70-120	199	610 (1995) (30%)
Nankeen night heron		<i>Nycticorax caledonicus</i>	V		0	0	0	
Glossy ibis		<i>Plgadis falcinellus</i>	M		0	0	2	Frequent vagrants

Species common name, by guild	Maori name	Scientific name	Origin and breeding status	New Zealand wide conservation status - 2007	Typical numbers at one time 1985 and 1988	Typical numbers at one time 2000-2007	Max at one time (1980-present)	National population (year estimated in) and approx. proportion of national total present at lake at one time (%)
Australian white ibis		<i>Threskiornis molucca</i>	V		0	0	0	
Finsch's oystercatcher ¹⁰	Torea	<i>Haematopus finschi</i>	F		80	20-75	143	85000 (1995) (<1%)
Variable oystercatcher	Toreapango	<i>H. unicolor</i>	F		0	<5	4	
Pied stilt	Poaka	<i>Himantopus himantopus</i>	B		1000-3000	Up to 2937	10000	30000 (1993) (33%)
Black stilt	Kaki	<i>Himantopus novaezelandiae</i>	B	Acutely threatened	1-4	2	4	89 (2007) (4%)
Australian red-necked avocet		<i>Recurvirostra novaehollandiae</i>	V		0	0	0	
Banded stilt ¹¹		<i>Cladorynchus leucocephalus</i>	V		0	0	0	
Eastern curlew		<i>Numenius madagascariensis</i>	V		0	0	1	
Whimbrel		<i>N. phaeopus</i>	V		0	0	0	
Bar-tailed godwit	Kuaka	<i>Limosa lapponica</i>	M		0-50	20-80	325	85-105000 (1995) (<1%)
Black-tailed godwit		<i>Limosa limosa</i>	V		0	0	13	
Hudsonian godwit		<i>L. haemastica</i>	V		0	0	1	
Siberian tattler		<i>Tringa brevipes</i>	V		0	0	1	
Greenshank		<i>T. nebularia</i>	V		0	0	1	
Lesser yellowlegs		<i>T. flavipes</i>	V		0	0	0	
Marsh sandpiper		<i>Tringa stagnatilis</i>	V		0	0	2	
Stilt sandpiper		<i>Micropalama himantipus</i>	V		0	0	1	

¹⁰ Also referred to as South Island pied oystercatcher (SIPO).

¹¹ Although not formerly recognised on the New Zealand bird species list, there is a specimen from Lake Ellesmere in the Canterbury Museum (Tunncliffe 1977), and Cayley (1961) cites this species as straggling to New Zealand.

Species common name, by guild	Maori name	Scientific name	Origin and breeding status	New Zealand wide conservation status - 2007	Typical numbers at one time 1985 and 1988	Typical numbers at one time 2000-2007	Max at one time (1980-present)	National population (year estimated in) and approx. proportion of national total present at lake at one time (%)
3. Shallow water waders								
NZ dotterel	Tuturiwhatu	<i>Charadrius obscurus</i>	V	Acutely threatened	0	0	0	
Banded dotterel	Tuturiwhatu	<i>C. bicinctus</i>	E, B	Chronically threatened	1000-3000	1000-2000	4846	50000 (1995) (10%)
Red-capped dotterel		<i>C. ruficapillus</i>	V		0	0	0	
Black-fronted dotterel		<i>C. melanops</i>	F		0	0	2	
Large sand dotterel		<i>C. leschenaultii</i>	V		0	0	1	
Mongolian dotterel		<i>C. mongololus</i>	V		0	0	1	
Oriental dotterel		<i>C. veredus</i>	V		0	0	1	
Wrybill	Ngutu parore	<i>Anarhynchus frontalis</i>	F	Acutely threatened	50-200	50-200	459	4500 (2004) (10%)
Pacific golden plover		<i>Pluvialis fulva</i>	M		50-70	122	122	600-1200 (1995) (10-20%)
Spur-winged plover		<i>Vanellus miles</i>	B		100-500	100-200	1052	Abundant & widespread
Turnstone		<i>Arenaria interpres</i>	M		0-10	0-10	34	5-7000 (1995) (<1%)
Lesser knot	Huahou	<i>Calidris canutus</i>	M		5-90	10-35	85	50-70000 (1995) (<1%)
Great knot		<i>C. tenuirostris</i>	V		0	0	1	
Sanderling		<i>C. alba</i>	V		0	0	3	
Curlew sandpiper		<i>C. ferruginea</i>	M		5-70	10-20	86	50-150 (1995) (60%)
Sharp-tailed sandpiper		<i>C. acuminata</i>	M		10-25	10-25	33	50-200 (1995) (17%)
Pectoral sandpiper		<i>C. melanotos</i>	M		1-3	0-6	10	<20 (1995) (50%)

Species common name, by guild	Maori name	Scientific name	Origin and breeding status	New Zealand wide conservation status - 2007	Typical numbers at one time 1985 and 1988	Typical numbers at one time 2000-2007	Max at one time (1980-present)	National population (year estimated in) and approx. proportion of national total present at lake at one time (%)
Red-necked stint		<i>C. ruficollis</i>	M		200	Up to 63	220	150-300 (1995) (70%)
Little stint		<i>Calidris minuta</i>	V		0	0	1	
Long-toed stint		<i>C. subminuta</i>	V		0	0	1	
Broad-billed sandpiper		<i>Limicola falcinellus</i>	V		0	0	1	
Ruff (Reeve)		<i>Philomachus pugnax</i>	V		0	0	2	
Little whimbrel		<i>Numenius minutus</i>	V		0	0	2	
Terek sandpiper		<i>Tringa terek</i>	V		0	0	4	
Grey phalarope		<i>Phalaropus fulicarius</i>	V		0	0	1	
Red-necked phalarope		<i>Phalaropus lobatus</i>	V		0	0	0	
Wilson's phalarope		<i>Phalaropus tricolor</i>	V		0	0	2	
4. Dabbling waterfowl								
Black swan ¹²	Wani	<i>Cygnus atratus</i>	B		6000-13000	Up to 10651	16000	63000 (1980) (25%)
Cape Barren goose*		<i>Cereopsis novaehollandiae</i>	V		0	2	2	
Paradise shelduck	Putangitangi	<i>Tadorna variegata</i>	B		10-400	100-500	1635	120000 (1981) (1%)
Chesnut-breasted shelduck		<i>T. tadornoides</i>	V		0	2	2	13 (2007) (15%)
Grey duck	Parera	<i>Anus superciliosa</i>	B	Acutely threatened	<100	?	?	<500000 (1995)

¹²* Black swans and Cape Barren geese are generally considered introduced species. However, Worthy (1998) found that bones of the 'extinct' New Zealand swan were identical to those of the introduced Australian species. The 'New Zealand goose' is in a similar position with the Cape Barren goose. Thus, it appears that these species are indigenous species that were inadvertently re-introduced to New Zealand.

Species common name, by guild	Maori name	Scientific name	Origin and breeding status	New Zealand wide conservation status - 2007	Typical numbers at one time 1985 and 1988	Typical numbers at one time 2000-2007	Max at one time (1980-present)	National population (year estimated in) and approx. proportion of national total present at lake at one time (%)
Australasian shoveler	Kuruwhengi, Pateke	<i>A. rhynchotis</i>	B		500-15000	Up to 3405	>15379	150000 (1980s) (10%)
Brown teal	Pateke	<i>A. aucklandica</i>	X	Acutely threatened	-	-	-	
Grey teal	Tete	<i>A. gracilis</i>	B		500-7000	Up to 10979	10979	>50000 (1995) (22%)
Mixed shoveler/ teal					5000-10000	Up to 1260	27166	
5. Torrent specialists								
None present								
6. Aerial hunting gulls & terns								
Brown skua	Hakoakoa	<i>Catharacta skua</i>	V	Acutely threatened	0	0	1	
Antarctic skua		<i>C. maccormicki</i>	V		0	0	0	
Arctic skua		<i>Stercorarius parasiticus</i>	M		0	0	6	
Pomarine skua		<i>S. pomarinus</i>	M		0	0	2	
Black-billed gull		<i>Larus bulleri</i>	F	Acutely threatened	500-3000	Up to 1592	5000	<50000 (2007) (10%)
Red-billed gull	Tarapunga	<i>L. scopulinus</i>	F	Chronically threatened	10-500	Up to 59	544	100000+ (2000) (<1%)
Black-backed gull	Karoro	<i>L. dominicanus</i>	B		500-1000	Up to 648	1561	Abundant & widespread
Caspian tern	Taranui	<i>Sterna caspia</i>	B	Acutely threatened	10-40	Up to 63	70	3000 (1995) (2%)

Species common name, by guild	Maori name	Scientific name	Origin and breeding status	New Zealand wide conservation status - 2007	Typical numbers at one time 1985 and 1988	Typical numbers at one time 2000-2007	Max at one time (1980-present)	National population (year estimated in) and approx. proportion of national total present at lake at one time (%)
White-fronted tern	Tara	<i>S. striata</i>	F	Chronically threatened	0-100	Up to 169	204	30000 (2000) (<1%)
Black-fronted tern	Tarapiroe	<i>S. albobristatus</i>	F	Acutely threatened	0-50	54	58	5000 (1995) (1%)
White-winged black tern		<i>Chlidonias leucopterus</i>	M		0	0	4	<10 (1995) (40%)
Arctic tern		<i>S. paradisaea</i>	V		0	0	1	
Fairy tern		<i>S. nereis</i>	X	Acutely threatened	-	-	-	
Little tern		<i>Sterna albifrons</i>	M		0-1	0	11	
7. Swamp specialists								
Banded rail	Moho-pereru	<i>Rallus philippensis</i>	X	Chronically threatened	-	-	-	
Spotless crake	Puweto	<i>Porzana tabuensis</i>	B	Chronically threatened	?	n.c.	5	?
Marsh crake	Koitareke	<i>Porzana pusilla</i>	B	Chronically threatened	?	n.c.	26	?
Pukeko	Pukeko	<i>Porphyrio porphyrio</i>	B		250-500	Up to 28	502	Abundant
Australasian bittern	Matuku	<i>Botaurus poiciloptilus</i>	B	Acutely threatened	20	n.c.	20	580-725 (3-5%)
Painted snipe		<i>Rostratula benghalensis</i>	V		0	0	1	
Japanese snipe		<i>Gallinago hardwickii</i>	V		0	0	1	
Fernbird	Matata	<i>Bowdleria punctata</i>	X	Chronically threatened	-	-	-	
8. Riparian wetland species								
Kingfisher	Kotare	<i>Halcyon sancta</i>	B		10-50	n.c.	20	
Welcome swallow		<i>Hirundo tahitica</i>	B		100+	n.c.	514	

Species common name, by guild	Maori name	Scientific name	Origin and breeding status	New Zealand wide conservation status - 2007	Typical numbers at one time 1985 and 1988	Typical numbers at one time 2000-2007	Max at one time (1980-present)	National population (year estimated in) and approx. proportion of national total present at lake at one time (%)
Cattle egret		<i>Bubulcus ibis</i>	M		10-30	<10	94	<1000 (10%)
Australasian harrier hawk	Kahu	<i>Circus approximans</i>	B		?	58+	58+	Widespread & common
NZ falcon	Karera	<i>Falco noveseelandiae</i>	V	Chronically threatened	0	0	1	
Weka	Weka	<i>Gallirallus australis</i>	X		-	-	-	
NZ pigeon	Kereru	<i>Hemiphaga novaeseelandiae</i>	F		0	0	1	
Kea	Kea	<i>Nestor notabilis</i>	V	Acutely threatened	0	0	1	
Shining cuckoo	Piwiwharauoa	<i>Chalcites lucidus</i>	F		?	?	?	
Long-tailed cuckoo	Koekoea	<i>Eudynamys taitensis</i>	V		0	0	1	
Black-faced cuckoo shrike		<i>Coracina novaehollandiae</i>	V		0	0	0	
Silvereye	Tauhou	<i>Zosterops lateralis</i>	B		?	?	?	
Grey warbler	Riroriro	<i>Gerygone igata</i>	F		?	?	?	
NZ pipit	Pihoihoi	<i>Anthus novaeseelandiae</i>	B		?	?	?	
Fantail	Piwakawaka	<i>Rhipidura fuliginosa</i>	F		?	?	?	
Bellbird	Korimako	<i>Anthornis melanura</i>	F		?	?	?	