Bird density and diversity in braided river beds in the Upper Waitaki Basin, South Island, New Zealand

R. F. MALONEY, A. L. REBERGEN, R. J. NILSSON, and N. J. WELLS*
Department of Conservation, Private Bag, Twizel, New Zealand

ABSTRACT

Wetland birds on 11 rivers of the Upper Waitaki Basin, South Island, New Zealand were surveyed annually between 1991 - 1994. Diversity, minimum abundance and density of birds were compared. In total 26 species of wetland birds were recorded. Minimum estimated river bird numbers were: 3566 Black-backed Gulls *(Larus dominicanus)*, 3302 Black-fronted Terns *(Sterna albostriata)*, 3260 Banded Dotterels *(Charadrius bicinctus)*, 793 Black-billed Gulls *(Larus bulleri)*, 789 Wrybills *(Anarhynchus frontalis)*, 788 South Island Pied Oystercatchers *(Haematopus ostralegus)*, 421 Pied Stilts *(Himantopus himantopus)*, 85 Black Stilts *(Himantopus novaezelandiae)*, 51 Caspian Terns *(Hydroprogne caspia)*, and 3680 waterfowl and cormorants. Densities of birds ranged from 0.17 birds ha^{-1} on the Pukaki River to 0.95 birds ha^{-1} on the Lower Ohau River. The Cass, Lower Ohau, Godley, Tekapo and Ahuriri Rivers had higher densities of one or more species than the Upper Ohau and/or Pukaki Rivers. Densities of Black-fronted Terns, Black Stilts, Pied Stilts and Caspian Terns were negatively correlated with altitude, and in general birds preferred river sections with low or moderate flows, and low or moderate vegetation cover. Eight of the 11 rivers surveyed had more than 1 % of estimated total populations of one or more of three globally vulnerable or endangered species, and in combination rivers of the Upper Waitaki Basin support almost all known Black Stilts, 15% of all Wrybills and 32 % of all Black-fronted Terns. We suggest that the Upper Waitaki Basin may now provide half of all remaining suitable braided river bird habitat in New Zealand.

KEYWORDS: braided river, survey, wetland birds, density, diversity, Upper Waitaki basin

INTRODUCTION

Braided rivers are uncommon worldwide, but are often found in areas of active mountain uplift and active erosion (Miall 1977). In New Zealand, braided rivers are a particularly common and characteristic feature of the eastern side of the South Island's Southern Alps. The formation of alluvial plains from outwash gravel carried by these braided rivers has been going on for millennia, and several species of birds have adapted to utilize this environment. Six endemic bird species; Wrybill (*Anarhynchus frontalis*), Black Stilt (*Himantopus novaezelandiae*), Banded Dotterel (*Charadrius bicinctus*), South Island Pied Oystercatcher (*Haematopus ostralegus finschi*), Black-fronted Tern (*Sterna albostriata*) and Black-billed Gull (*Larus bulleri*) breed primarily in braided river habitat, and the largest populations of these species are found in Canterbury and North Otago rivers. The Black Stilt is an endangered

*Present addresses: ALR: Department of Conservation, P.O. Box 191, Masterton, New Zealand; RJN: 166 Hills Rd., Shirley, Christchurch, New Zealand; NJW: 36 Glencairn Rd, Twizel, New Zealand.

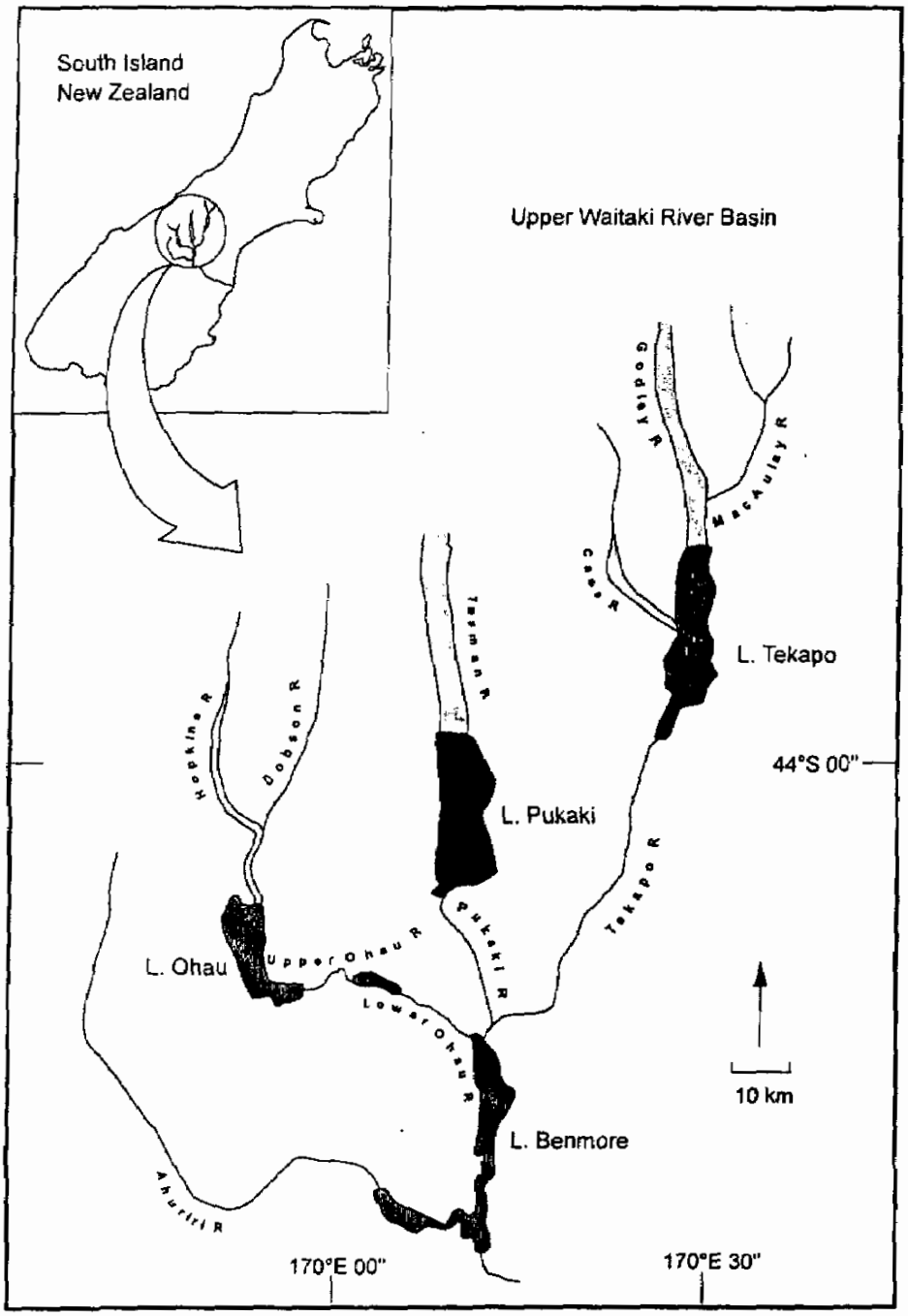

FIGURE 1 - Location of rivers surveyed for birds in the Upper Waitaki Basin, South Island, New Zealand.

species, while Black-fronted Terns and Wrybills are listed by the Department of Conservation as threatened species (Tisdall 1994).

Major causes of decline for these species are probably a combination of loss and degradation of habitat from predation by mammals, spread of introduced vegetation, hydro-electric development, constriction of river channels and river edge development. The inter-relationship between these factors and their impact on braided river bird species is complex and not fully understood, and few studies have attempted to measure them (Hughey 1985).

Studies of birds in braided river environments have usually focused on individual species in one part of their range (see Hay 1984, Pierce 1979 on Wrybill; Lalas 1977 on Black-fronted Tern), or exceptionally over their entire range (Black Stilt, Reed *et al.* 1993). Population trends or habitat use by birds has been studied on the Rakaia River (Hughey 1985), Ashburton River (C. O'Donnell, unpublished), Cass River (Pierce 1983), Ahuriri River (Robertson *et al.* 1983), and the Waitaki River (Robertson *et al.* 1984). Single surveys of sections of 14 rivers in Canterbury were completed between 1974 and 1981 (O'Donnell & Moore 1983), but few studies on all birds over wider spatial and temporal scales have occurred. In the Upper Waitaki River catchment sections of 10 rivers were surveyed three times between 1962 - 1968 (B. D. Bell unpublished), while C. O'Donnell (unpublished) systematically described populations of braided river birds in the Ashburton River annually for ten years.

In this paper we report on a survey of populations of braided river birds of the Upper Waitaki River catchment, where 11 rivers were surveyed for several consecutive years as part of an ongoing programme to monitor braided river birds.

We aimed to (1) compare the diversity, minimum abundance and density of birds between rivers, (2) test the hypothesis that bird population sizes and distributions differ because of large-scale differences in river altitude, topography, substrate, vegetation cover, water flow and water management regime, and (3) evaluate the status of populations of Black Stilts, Wrybills and Black-fronted Terns in the Upper Waitaki catchment relative to reported numbers elsewhere throughout their respective ranges.

MATERIAL AND METHODS

River surveys

Populations of river birds were surveyed between October and December from 1991 to 1994, on 11 rivers. The rivers were (in descending order by area) the Tasman, Godley, Hopkins, Ahuriri, Tekapo, Cass, Dobson, Macaulay, Lower Ohau, Pukaki and Upper Ohau (Fig. 1). All rivers were surveyed in each year, except for the Tasman, Dobson and MacAulay (not in 1991) and the Godley and Hopkins Rivers (1992 and 1993 only). Surveys of the Tekapo, Ahuriri, Upper and Lower Ohau, and Pukaki Rivers were completed first, to coincide with earlier river bird breeding in lower altitude rivers compared to later arrival and breeding times on rivers at higher altitudes (see Pierce 1983, Robertson *et al.* 1983). Each river was surveyed in one day, except the Ahuriri (two days), using the same number of observers and the same section boundaries each year. The survey method was similar to that of O'Donnell & Moore (1983) and Robertson *et al.* (1983). Observers spaced themselves evenly across the width of a river and walked downstream at a constant pace (about 3 km h^{-1}), recording birds only when they moved upstream of the observer. Birds were also recorded if they left the river system on either edge or if they flew downstream and were not seen again by the end of the survey (i.e., if the number of birds of one species seen flying downstream was greater than the total of that species recorded for the survey, then the difference between these

values would be added). Observers walking in a line communicated with predetermined hand-signals, two-way radios, or by shouting. Every effort was made to avoid double counting of birds. All observers were familiar with braided rivers and river birds, and it is unlikely that there were significant observer-related inconsistencies in the data collected among rivers or years (but see Sauer *et al.* 1994).

Each river was divided into sections of 4.8 km mean length (range 0.25 - 14.5 km). These sections were delimited by access and river crossing points, landscape features such as gorges, wide braided sections and river deltas. Section boundaries were consistent among years, and were readily identifiable to all team members. Section width was generally defined as the limits of the active riverbed (i.e., that area that was likely to be occasionally flooded). Descriptions of sections are held by the Department of Conservation, Twizel, and are available from the first author. Observers followed as much as possible areas of clean (unvegetated) gravel and cobble near to water, or vegetated islands, rather than the stable vegetated banks on either side. We considered that this increased the likelihood of observing Wrybills. In all rivers, except in the Upper Cass and Upper Ahuriri, the boundaries between grassland dominated "farmland" (not surveyed) and gravel dominated riverbed (surveyed) were clear. In the Upper Cass the stable river terraces on the true right bank were not included; whereas the Ben Avon and Birchwood wetland complexes associated with the Upper Ahuriri were included. Each survey member recorded sightings of birds per section directly onto a tally sheet, while all locations of Wrybills, Black Stilts, unusual species and large nesting colonies of gulls and terns were also recorded onto a photocopied topographical map (NZMS 260, 1:50 000 series). It is highly likely that some Wrybill (cryptic in nature) and Banded Dotterel (widespread on areas adjacent to the river and confusing when exhibiting mobbing behaviour) were overlooked in each river system.

Data analysis

Six species that are primarily dependent on braided river habitat (Wrybill, Banded Dotterel, South Island Pied Oystercatcher, Black-fronted Tern, Black-billed Gull, Black Stilt) as well as Caspian Tern (*Hydroprogne caspia*) and Pied Stilt (*Himantopus himantopus*) were included in all analyses. Only selected data on Black Stilts are presented here; all known individuals of this species have been closely monitored for more than a decade. Distribution, abundance and movements of Black Stilts are summarised in Reed *et al.* (1993). Data for waterfowl, cormorants, miscellaneous species and Southern Black-backed Gulls (*Larus dominicanus*) are presented in summarised form.

Minimum population estimates for each species per river were defined as the highest single total count of each species in any of the two to four survey years. Minimum densities of each species were calculated by dividing the mean number of individuals counted over all survey years by the area of riverbed in each of the 55 river sections, and for all 11 rivers. We used area rather than river length in our

calculations because this better represented the available river habitat, particularly as surveyed sections varied in width from 0.15 km (the Cass River) to 4.0 km (Tasman). The longest surveyed river (Ahuriri, 77.2 km) was five times (60.8 km) longer than the Tasman River (16.4 km), but, because of the width of the Tasman River, was 30 % (1155 ha) smaller in area. Section areas were calculated by placing a 1 ha scale grid over the survey map and counting the total number of squares inside the survey boundaries (rounded down to the nearest 5 ha), irrespective of vegetation cover, substrate and water areas. Therefore, area values will over-estimate habitat for species with specific requirements (e.g., Wrybill, Robertson *et al.*, 1983), but will allow consistent and repeatable estimation of bird densities between rivers and years. Total area for each river was calculated as the sum of the section areas within a river. No attempt is made to extrapolate density estimates beyond the area surveyed. Bird densities by species were averaged over the years of surveys. Minimum densities of birds were compared among the 11 rivers using Kruskal-Wallis non-parametric ANOVAs. Multiple comparison tests were used to determine differences between rivers when overall ANOVA values were significant (Siegel & Castellan 1988). All tests were two-tailed, with a rejection level of $P = 0.05$.

To evaluate habitat preference of each bird species, the following general riverbed attributes were recorded for each of the 55 river sections: (1) altitude, (2) topography, (3) substrate, (4) vegetation cover, (5) water flow, (6) river management regime. The density of each bird species per river section were compared to these six variables. Altitude of each river section was determined by averaging mean heights above sea level (to nearest 20 m interval line) recorded from NZMS 260, 1:50 000 topographical maps at 1 km intervals. Topography was assigned to one of four general landform categories: (1) highly braided river with more than four channels, (2) moderately braided river with two to four channels, (3) single channel river in open landscape or, (4) single channel river in enclosed hill area (gorge). Riverbed substrate categories were recorded as substrates dominated by (1) boulder (>100 mm diametre), (2) cobble (50-100 mm), (3) coarse gravel (10-49 mm) or, (4) a mix of fine gravel, sand and silt (<10 mm). Vegetation cover was categorized as none, low, moderate or dense. Approximate mean daily flows in spring were ranked as none (Pukaki), low (< 10 m^3s^{-1}, Lower Ohau, Cass, Macaulay, Tekapo), moderate (10 - 50 m^3s^{-1}, Ahuriri, Dobson, Upper Ohau) or high (>50 m^3s^{-1}, Tasman, Godley, Hopkins). Flow management of all river sections were rated as being (1) highly modified with no flow, side streams or seepage (Pukaki), (2) managed rivers with controlled flows and some seepage or side stream inputs (Lower Ohau, Upper Ohau, Tekapo) or, (3) unmanaged rivers with natural flows (Tasman, Godley, Hopkins, Dobson, Macaulay, Cass, Ahuriri).

River sections were assigned into categories by the first author. The intent was to examine broad scale differences in habitat by grouping sections on the basis of the most predominant habitat type present. Other sub-classes of habitat were not necessarily absent from a section, but they were less prevalent. As altitude was measured on a ratio scale we used Spearman Rank-order correlation to compare section altitudes with species density. All other habitat variables were measured on

TABLE 1 - Presence (+)/absence (-) of 26 wetland birds recorded during surveys of 11 rivers of the Upper Waitaki Basin, 1991 - 1994.

Species	River											Present on no. of rivers
	Tasman	Godley	Hopkins	Ahuriri	Tekapo	Cass	Dobson	Lower Ohau	Upper Ohau	Pukaki	Macaulay	
Black Shag	+	+	+	+	+	+	+	+	+	+	+	11
Little Shag	+	+	+	+	-	-	-	-	-	-	-	4
White-faced Heron	+	-	-	+	+	-	+	+	+	+	+	8
Black Swan	-	-	+	+	-	+	-	+	-	-	-	4
Canada Goose	+	+	+	+	+	+	+	+	+	+	+	11
Paradise Shelduck	+	+	+	+	+	+	+	+	+	+	+	11
Mallard	+	+	+	+	+	+	+	+	+	+	+	11
Grey Duck	+	+	+	+	+	+	+	+	+	+	-	10
Grey Teal	-	+	+	+	+	+	-	+	-	-	-	6
N.Z. Shovelor	-	-	-	+	+	+	+	+	-	+	-	6
N.Z Scaup	-	-	-	+	+	-	-	-	-	-	-	2
Pukeko	-	-	-	+	-	-	-	-	-	-	-	1
S. I. Pied Oystercatcher	+	+	+	+	+	+	+	+	+	+	+	11
Pied Stilt	+	+	+	+	+	+	+	+	+	+	+	11
Black Stilt	+	+	+	+	+	+	-	+	-	-	+	8
Banded Dotterel	+	+	+	+	+	+	+	+	+	+	+	11
Black-fronted Dotterel	-	-	-	+	-	-	-	-	-	-	-	1
Wrybill	+	+	+	+	+	+	+	+	+	+	+	11
Spur-wing Plover	+	+	+	+	+	+	+	+	+	+	+	11
Eastern Curlew	-	-	-	-	-	+	-	-	-	-	-	1
Black-backed Gull	+	+	+	+	+	+	+	+	+	+	+	11
Black-billed Gull	+	+	+	+	+	+	-	+	+	+	-	9
White-winged Black Tern	-	-	-	+	-	+	-	-	-	-	-	2
Black-fronted Tern	+	+	+	+	+	+	+	+	+	+	+	11
Caspian Tern	+	+	+	+	+	+	+	+	-	-	-	8
Arctic Tern	-	-	-	-	-	+	-	-	-	-	-	1
Number of species present	17	17	18	24	19	21	15	19	14	16	13	

an ordinal scale and comparisons with species densities were made using Kruskal-Wallis nonparametric ANOVAs. Where habitat variables were not independent among sections of the same river (i.e. water flow and river management regime variables) a single mean value for the density of each bird species per river was calculated and compared to habitat variable scores.

RESULTS

Patterns of species richness among rivers

In total, 26 wetland bird species were recorded during the surveys. Of these, 11 species were common to all rivers, and 13 species (50 %) were found on nine of the 11 rivers (Table 1). The average number of species per river was 17.5 (s. d. = 3.2 species). One river, the Ahuriri, had 24 of the 26 species, whereas the least number of species (13) was recorded on the Macaulay River. There were significantly more bird species on larger (Paired t-test, t = 4.16, d.f. = 10, P = 0.002), but not longer rivers (t = 1.22, d.f. = 10, P > 0.05).

Minimum population sizes of birds per river

Minimum population estimates for nine bird species, and for two species groups (waterfowl and cormorants, miscellaneous) are given in Table 2. Two species had combined river totals in excess of 3000 individuals (Banded Dotterels 3260, Black-fronted Terns 3302), three species had nearly 800 individuals (Black-billed Gulls 793, Wrybills 789, South Island Pied Oystercatchers 788), while total numbers of Pied Stilts, Black Stilts, Caspian Terns, Black-backed Gulls, and for all waterfowl and cormorants combined were 421, 85, 51, 3566 and 3680, respectively. Rivers with large riverbed areas (Tasman, Godley, Ahuriri, Tekapo but not Hopkins) held significantly more of one or more species than four of the five rivers with small riverbed areas (Pukaki, Upper Ohau, Macaulay, Dobson, but not Lower Ohau; Kruskal-Wallis tests for each species, all P < 0.003), indicating that each species either had an even spatial distribution or was clustered with an even distribution of clusters.

Density estimates of birds per river

Mean population densities of the eight key species combined varied from a low of 0.17 birds ha^{-1} on the Pukaki River to maximum densities of 0.95 birds ha^{-1} on the Lower Ohau River. Five species (Banded Dotterels 0.3 birds ha^{-1}, Black Stilts 0.01, Pied Stilts 0.09, Black-fronted Terns 0.8 and Caspian Terns 0.01; Table 3) were found at highest densities on the Lower Ohau River. Densities of two species (South Island Pied Oystercatchers and Black-billed Gulls, both 0.1 birds ha^{-1}) were highest on the Ahuriri River, while Wrybills (0.07 birds ha^{-1}) were found at highest densities on the Godley River. Lowest densities of Banded Dotterels occurred on the Upper Ohau River (0.05 birds ha^{-1}), of Wrybills on the Pukaki River (0.001), of South Island Pied Oystercatcher on the Upper Ohau and Pukaki Rivers (both 0.01), and of Black-fronted Terns on the Tasman River (0.03 birds ha^{-1}). Zero densities of

TABLE 2. - Minimum number of birds recorded during surveys of 11 Upper Waitaki Basin (UWB) rivers.

	River											
Species	Tasman	Godley	Hopkins	Ahuriri	Tekapo	Cass	Dobson	Macaulay	Lower Ohau	Pukaki	Upper Ohau	Minimum number in UWB
S.I. Pied Oystercatcher	76	65	99	278	106	62	37	22	34	4	5	788
Pied Stilt	21	3	24	154	97	30	3	4	74	11	6	427
Black Stilt	14	2	3	31	17	3	0	1	14	0	0	85
Banded Dotterel	599	496	281	445	496	371	114	138	242	60	18	3260
Wrybill	151	258	112	84	30	65	20	33	31	1	4	789
Black-backed Gull	609	85	201	701	1621	173	99	5	16	50	14	3574
Black-billed Gull	25	18	9	492	42	112	0	0	92	2	1	793
Black-fronted Tern	175	174	138	692	766	236	76	49	761	43	192	3302
Caspian Tern	2	4	7	10	15	4	2	0	7	0	0	51
Waterfowl and Shags	407	853	472	1109	374	127	141	33	118	26	20	3680
Miscellaneous spp	24	14	139	160	78	35	28	20	23	8	8	537
Total number of birds	2103	1970	1485	4156	3642	1218	521	305	1412	206	268	17286
River Area (ha)	3820	3470	2730	2665	1755	1095	800	765	455	450	190	18195
River length (km)	16.4	18.2	25.6	77.2	46.3	22.7	15.3	9	11.5	12.5	10.3	265

TABLE 3 - Estimated mean densities (number of birds 100 ha^{-1}, S.E. underneath) of eight key wetland bird species. Kruskal-Wallis test statistic (H) values, P values and significant pairwise comparisons as indicated by multiple comparison tests are given. Abbreviations: AH, UO, PK, CA, LO, TK, DB and GO are Ahuriri, Upper Ohau, Pukaki, Cass, Lower Ohau, Tekapo, Dobson and Godley Rivers, respectively.

	River													
Species	Tasman	Godley	Hopkins	Ahuriri	Tekapo	Cass	Dobson	Macaulay	Lower Ohau	Pukaki	Upper Ohau	H-value	P	Multiple comparison test
S.I.Pied Oystercatcher	1.6	1.7	3.0	9.4	4.0	4.5	3.4	2.0	4.2	0.8	0.8	29.3	0.001	AH > UO, PK,
	0.2	0.2	0.7	0.5	0.7	0.8	0.6	0.5	1.1	0.1	0.7			
Pied Stilt	0.4	0.1	0.7	4.6	3.3	1.5	0.2	0.2	8.7	1.4	1.1	26.7	0.003	-
	0.1	0	0.2	0.9	0.8	0.6	0.1	0.2	2.9	0.4	0.8			
Black Stilt	0.1	0	0.1	0.5	0.1	0.1	0	0.1	1.1	0	0	28.5	0.002	LO>PK,UO,DB,GO
	0	0	0	0.1	0.1	0.1	0	0.1	0.2	0	0			
Banded Dotterel	14.8	12.6	8.5	14.5	20.9	26.7	11.9	14.9	27.8	8.5	5.3	30.3	0.001	CA, LO, TK> UO
	0.6	1.7	1.8	0.8	2.6	2.9	3.1	2.5	8.5	1.7	1.5			
Wrybill	3.5	6.6	4.0	2.2	1.7	4.9	1.8	3.0	3.5	0.1	0.9	27.8	0.002	GO, CA, >PK
	0.2	0.8	0.1	0.4	0	0.6	0.4	0.8	1.2	0.1	0.4			
Black-billed Gull	0.3	0.4	0.2	9.4	1.2	6.1	0	0	5.7	0.1	0.1	23.9	0.008	-
	0.2	0.1	0.2	3.1	0.4	2.2	0	0	4.9	0.1	0.2			
Black-fronted Tern	3.2	3.6	3.6	22.3	28.6	8.3	06.8	4.7	78.1	4.2	55.0	24.1	0.007	-
	0.7	1.5	1.4	1.3	5.9	4.7	1.6	0.9	29.8	2.1	20.8			
Caspian Tern;	0.1	0.1	0.2	0.2	0.5	0.3	0.1	0	0.7	0	0	23.9	0.008	-
	0	0	0.001	0.1	0.1	0.1	0.1	0	0.4	0	0			
No. survey years	3	2	2	4	4	4	3	3	4	4	4			

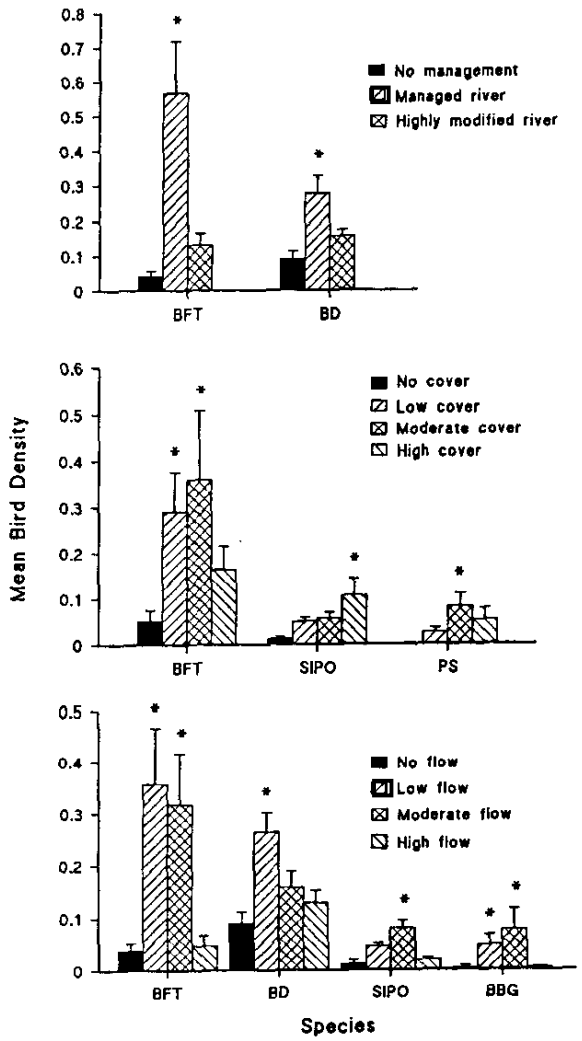

FIGURE 2 - Estimated mean densities (± S.E.) of river bird species for each of three habitat variables: flow, flow management and vegetation cover. Species and habitat variables are only shown where statistical comparisons were significant. * denotes habitat categories where densities were significantly greater. Species codes are as for Table 3.

four species occurred on five rivers: Black Stilts on the Pukaki, Upper Ohau and Dobson; Pied Stilts on the Godley; Black-billed Gulls on the Dobson and Macaulay; and Caspian Terns on the Upper Ohau and MacAulay Rivers. Densities of each of the eight species varied significantly among rivers (Kruskal-Wallis tests, Table 3), and where multiple comparison tests were significant it was because the Cass, Lower Ohau, Godley, Tekapo and/or Ahuriri Rivers had high densities of some species than did the Pukaki and/or Upper Ohau Rivers.

Comparison of bird densities with habitat variables

Densities of four bird species were negatively correlated with altitude (Spearman rank correlations; Black-fronted Terns r_s = -0.43, Black Stilts -0.32, Pied Stilts -0.56, Caspian Terns -0.29; all $P < 0.05$). In comparisons with other habitat features, bird densities were significantly higher in sections that had low or moderate vegetation cover, low or moderate water flow volumes, and controlled management regimes (Fig. 2). Banded Dotterel densities increased in sections with low (< 10 m^3s^{-1}, Kruskal-Wallis test, H = 11.8, d.f = 3, P = 0.008) and controlled flows (H = 10.8, d.f. = 2, P = 0.005), while Black-fronted Tern densities were greatest in rivers with

low or moderate (H = 21.8, d.f. = 3, P = 0.0001) controlled flows (H = 15.5, d.f. = 2, P = 0.004), and with low or moderate vegetation cover (H = 13.8, d.f. = 3, P = 0.003). Black-billed Gull densities were highest in rivers with low or moderate flows (H = 10.6, d.f. = 3, P = 0.014). Densities of South Island Pied Oystercatcher were highest in sections with greater vegetation cover (H = 12.4, d.f. = 3, P = 0.006), and in rivers with moderate flow volumes (H = 12.6, d.f. = 3, P = 0.006), while Pied Stilt densities were highest in sections with moderate vegetation cover (H = 10.3, d.f. = 3, P = 0.016). Wrybill densities were significantly higher in sections of river which were highly braided compared to moderately or unbraided sections (H = 16.1, d.f. = 3, P = 0.001).

Status of Wrybill, Black-fronted Tern and Black Stilt in the Upper Waitaki River Basin

The minimum numbers of Wrybills (789), Black-fronted Terns (3302) and Black Stilts (85) counted in our surveys represent 15 % of an estimated national Wrybill population of 5500 individuals (Davies 1997), 32 % of a national population of ~10 000 Black-fronted Terns (Robertson *et al.* 1983), and 85 % of 100 Black Stilts (Reed *et al.* 1993). On an individual river basis, eight of the 11 rivers surveyed had more than 1 % of world populations of one or more of these species. For Wrybills, the Godley (N = 258, 5.2 %), Tasman (151, 3.0 %), Hopkins (112, 2.2 %), Ahuriri (84, 1.7 %), and Cass (65, 1.3 %) Rivers had more than 1 % of total numbers. The Ahuriri (692, 6.9%), Tekapo (766, 7.7%), Lower Ohau (761, 7.6 %), Cass (236, 2.4 %), Upper Ohau (192, 1.9 %), Tasman (175, 1.8 %), Godley (174, 1.7 %) and Hopkins (138, 1.4 %) Rivers had more than 1 % of all Black-fronted Terns. Any river that had one or more Black Stilts had a minimum of 1 % of the world population. We recorded Black Stilts on eight of the 11 rivers surveyed, with largest numbers on the Ahuriri (N = 37), Tekapo (17), Tasman (14) and Lower Ohau (14).

DISCUSSION

Diversity and abundance of birds in the rivers of the Upper Waitaki Basin were high. The 26 bird species recorded here includes most of the 34 wetland bird species recorded by O'Donnell & Moore (1983) in other South Island rivers. Additional birds recorded by O'Donnell & Moore (1983) were either coastal species or winter migrants, and were unlikely to be present in the Upper Waitaki Basin (e.g., Red-billed Gull *Larus novaehollandiae*). One species, Black Stilt, was recorded from eight rivers in the Upper Waitaki basin but is rarely found in other braided rivers. Five species of river bird were particularly abundant; two of these (Banded Dotterel and Black-fronted Tern) numbered over 3000 individuals each. This confirms that the rivers of the Upper Waitaki Basin are nationally important for birds of braided riverbeds.

Densities of birds among rivers were variable, but generally rivers with small riverbed areas had fewer birds than larger rivers. In comparison to river area, the length of river surveyed was not a good predictor of bird densities, mainly because rivers differed greatly in bed width. Reporting only species densities can under-

represent the value of a river, particularly for species with low total populations. Often larger rivers had the highest minimum population counts (e.g. the Tasman and Godley Rivers), but these rivers frequently had low overall densities of birds, compared to smaller rivers (e.g. Lower Ohau River). Therefore, we recommend that all bird survey data for braided river systems should be expressed as a density (birds per unit area) not linear (birds per unit of river length) measure, and that both density and minimum number estimates should be reported.

River flow volumes, and human management of river flow periodicity and volume, were two important predictors of bird densities for four species (Banded Dotterel, Black-fronted Tern, Black-billed Gull and South Island Pied Oystercatcher), with densities increasing in rivers with low or moderate and controlled flows. These observed differences in densities may be related to the degree of instability within both the aquatic and terrestrial habitat used by river birds. Aquatic habitat instability, such as that caused by major flooding of naturally flowing rivers is likely to cause a rapid decline in the abundance of aquatic macro-invertebrates (Hughey 1985, Sagar 1986), the main food supply of most braided river birds (Lalas 1977, Pierce 1979, 1986). Thus, food supply may be limiting during periods of frequent flooding, but it should be more predictable in controlled rivers (which in the Upper Waitaki Basin have low or moderate flow volumes). Flood events may similarly make terrestrial habitat less suitable for breeding braided river birds in naturally flowing rivers, as frequent bank - flow floods in spring, during peak periods of river bird breeding may decrease the long-term probability of nesting and fledging success, compared to controlled rivers, where flooding is less frequent. The comparison of food availability and abundance with breeding success of birds in rivers with controlled and uncontrolled flows needs further testing.

Two species (Pied Stilt and South Island Pied Oystercatcher) were found at higher densities in river sections that had high plant cover scores. Of all river bird species, these two species use a wide range of habitats and thus are widely distributed throughout New Zealand (Robertson 1985). Other species, such as Wrybill, Black-fronted Tern, Black Stilt and Banded Dotterel had no apparent preference for either low or high vegetation cover, at least not at the level of resolution used in this study. The absence of significant differences indicated by these analyses need not imply that these species of river birds are not selective in their micro-habitat requirements. Rather, birds are exploiting suitable but small patches of habitat interspersed among larger less favoured areas. Clustered distributions of birds caused by patchiness of vegetation cover cannot explain why some rivers with low vegetation cover scores (e.g., Macaulay, Hopkins, Dobson) had fewer birds than others (e.g., Lower Ohau, Cass). A more detailed analyses of habitat use by river birds, such as that undertaken by Robertson *et.al.* (1983) on the Ahuriri River, is required to examine why densities of birds were different among the rivers of the Upper Waitaki Basin.

Differences in distributions and abundances of river birds may also be related to factors that were not measured in this study. For example, Pierce (1986) found that a major limiting factor in the distribution of Pied Stilts compared to Black

Stilts was the relative abilities of the two species to forage for aquatic prey during times of flood; Black Stilts used a scything tactile feeding motion, whereas Pied Stilts apparently lacked the ability to feed in this manner. Thus, the distribution of Pied Stilts may be restricted to areas where floods are rare, or to areas with alternative food supplies. What is clear from our study is that differences in habitat utilization by river birds (such as the role of flow volume and human management of rivers) can be detected by considering only broad scale habitat categories.

When compared to surveys of Canterbury braided rivers completed in the 1970s and 1980s, the Upper Waitaki rivers have populations of the endangered Black Stilt, and threatened Wrybill and Black-fronted Tern, that are equal to or greater than most other New Zealand braided rivers. O'Donnell & Moore (1983) surveyed 14 rivers throughout Canterbury (not the Waitaki Basin or Rangitata Rivers). Only the Waimakariri (N = 78) and the Rakaia (N = 301) had as many Wrybills as eight Upper Waitaki rivers (range 30 - 258 Wrybills per river). The number of Black-fronted Terns recorded in all Upper Waitaki rivers combined (N = 3302) was similar to the combined total for 14 Canterbury rivers (N = 2919, O'Donnell & Moore 1983), and populations of around 700 - 760 terns on the Ahuriri, Tekapo and Lower Ohau Rivers were equivalent to the highest numbers recorded for other braided rivers (560 birds on the Rakaia River and 760 on the Ashburton River). However, numbers of Black-fronted Terns have declined markedly on the Ashburton River, the only Canterbury river where surveys have been undertaken in recent times, and by 1990 less than 200 birds were recorded (C. O'Donnell unpublished).

Although Upper Waitaki rivers have relatively high numbers of these threatened species, the total New Zealand populations are still very low and are dispersed over a large area. The 5500 Wrybills over more than 25 rivers along the length of the South Island and the ~10 000 Black-fronted Terns in the same area makes management, such as predator and weed control, and estimates of population size and change very difficult. For most of their range, Black-fronted Tern populations were censused more than ten years ago, and if the three-fold decline in numbers recorded in the Ashburton River from 1981 to 1990 (C. O'Donnell unpublished) is typical, then the minimum number of terns recorded by O'Donnell & Moore (1983) of 2919 individuals in 14 Canterbury Rivers may now be considerably lower. The 11 rivers we surveyed represented less than one third of the total braided river area available in the South Island (286 km, of ~1000 km in combined total braided river length). However, most braided river habitat in lowland Canterbury is severely degraded (Balneaves & Hughey 1989), and supports only low numbers of both Wrybill and Black-fronted Tern. Most populations of these species are now restricted to the upper reaches (O'Donnell & Moore 1983), where densities may be further limited by altitude affects. By measuring approximate lengths of braided riverbeds above 500 m. a.s.l. from topographical maps, we estimate that all upland braided river areas are only about 400 - 500 km in length, suggesting that the Upper Waitaki catchment (250 km, Table 2) may now represent up to 50 % of the remaining suitable braided river habitat in New Zealand. Given that we could locate only 3300 Black-fronted Terns in the 11 rivers we surveyed (and only three large colonies of around 700 birds), the total Black-fronted Tern population may now be considerably

lower than previous estimates of around 10 000 individuals (e.g., Robertson *et al.* 1983). A study of the population status and dynamics of this species is urgently required.

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