

---

# MAKARORA BRAIDED RIVER BIRD SURVEY

---

November 2017



**ILLUMINATE ECOLOGY**

ASPIRING BIODIVERSITY TRUST - OTAGO REGIONAL COUNCIL

General Report Information 026.1

| <b>Version</b> | <b>Date</b> | <b>Author</b>              | <b>Description</b>                           |
|----------------|-------------|----------------------------|--|
| 1.0            | 26 Oct 2017 | RL Hufton - Lead Ecologist | Document created                             |
| 1.1            | 09 Nov 2017 | As above                   | First draft issued (DOC)                     |
| 1.2            | 16 Nov 2017 | “ “                        | Amended version to include 11 Nov site visit |

## Summary

Makarora braided river birds; black-fronted tern (*Chlidonias albostrigata*), black-billed gull (*Larus bulleri*), banded dotterel (*Charadrius bicinctus*) and South Island pied oystercatcher (*Haematopus finschi*) returned to breed during September 2017. Wrybill (*Anarhynchus frontalis*) was first recorded back on the Makarora River during October.

An update braided river bird walkover survey was undertaken for the length of the Makarora on the 16 October and completed on the 17 October (as per previous survey method) following previous reconnaissance site visit on the 15 October.

Additional site visits were undertaken during October and November to monitor nesting sites and to sample the lower Wilkin braid plain.

Nesting sites were recorded for black-billed gull (*Larus bulleri*) (Nationally Endangered), black-fronted tern (*Chlidonias albostrigata*) (Nationally Endangered), banded dotterel (*Charadrius bicinctus*) (Nationally vulnerable) and South Island pied oystercatcher (*Haematopus finschi*), (Nationally declining). Wrybill (*Anarhynchus frontalis*), (Nationally Vulnerable) was recorded mainly in pairs, one chick was observed. Southern black-backed gull (*Larus dominicanus*) and Canada goose (*Branta canadensis*) was also found to be breeding within the braided river habitat.

Southern black-backed gull (*Larus dominicanus*) was observed harassing a black-fronted tern (*Chlidonias albostrigata*) nesting colony. Black-fronted tern nesting defence response was observed.

Following collation of survey data, an initial ten DOC 200 mammal traps were installed (early November 2017) within the vicinity of identified nesting sites for black-billed gull, black-fronted tern, banded dotterel, South Island pied oystercatcher and within the location breeding wrybill's had been observed.

Following a period of precipitation, the Makarora River level rose during the 4 November. This resulted in displacement of a large breeding colony of black-billed gulls; including the loss of nests, eggs and six recently hatched chicks. Additionally, a number of black-fronted tern nest sites were lost.

Other observations during the survey work included the presence of livestock within the braided river both for the Makarora and the Wilkin Rivers. Hare (*Lepus europaeus*) was also regularly encountered moving through the braided habitat of the Makarora.

This survey and monitoring work highlights the cumulative pressures and threats upon endangered braided river birds such as; mammalian predators, opportunistic avian predators, livestock trampling and changes in river water levels.

**The Makarora River is an important site for endemic braided river birds, maintaining a diverse and complete braided river avifauna. Recommendations are provided to help promote, restore and safeguard indigenous braided river birdlife populations for the Makarora River catchment.**

## Recommendations

- Installation of cost effective catchment scale invasive mammal trapping regime for both sides of the Makarora River and around identified braided river bird nesting sites for black-billed gull, black-fronted tern, banded dotterel, South Island pied oystercatcher and wrybill during the breeding season (Oct-Feb). Trap locations may need to be adjusted throughout the season as colonies may change position according to river flow levels.

- Undertake annual braided river bird survey/ monitoring to guide future conservation management and determine effects on population growth of endemic birdlife. To include where possible; counts of nest sites, eggs hatched and pre-fledgling chicks at the end of breeding season, banding of adults and chicks.
- Investigate further predator guilds utilising the braided river habitat such as feral cat and devise trapping procedure for this.
- Devise population control method for Southern black-backed gull to include removal of eggs to assist fledging of endangered endemic braided river birds.
- Implement strategy for awareness raising, interpretation signage and advocacy of the importance of braided river habitat and the endemic species dependant on them for fecundity and survival.
- Develop a community and landowner engagement strategy in conjunction with Braided River Aid (BRAID).
- Promotion of educational groups within braided river monitoring activities where possible.
- Investigate aspirational braided river weed control measures in relation to future habitat management *i.e. crack willow*
- Explore possibility of raising favoured island areas of braided river habitat to promote successful fledging of indigenous braided river birds.

## Introduction

This survey work provides an update (initiated by lead ecologist Rachel Hufton of Illuminate Ecology in collaboration with the Department of Conservation and Forest and Bird) to previous Makarora braided river bird survey undertaken during 2012 by the Department of Conservation (DOC).

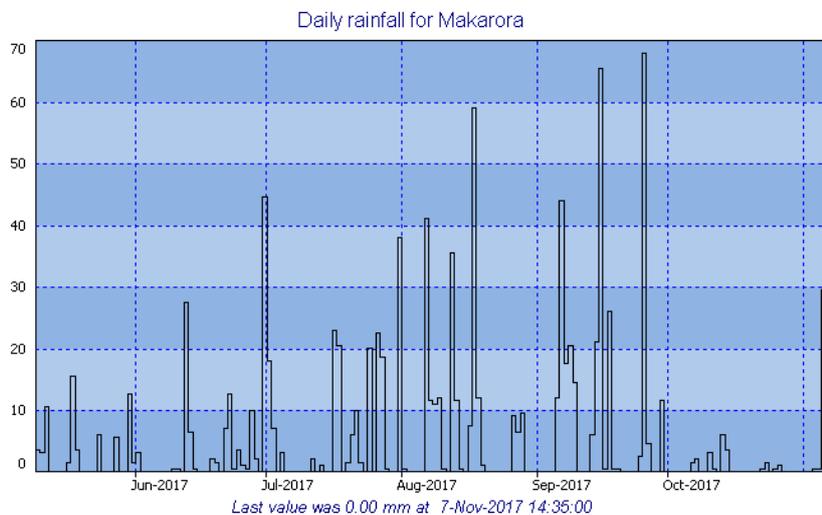
Following a reconnaissance site visit, safety and bird identification briefing with survey team on the 15 October a braided river bird walkover survey was undertaken on the 16 October and completed on the 17 October. Three competent braided river bird surveyors (Rachel Hufton, Taylor Hume, Anthony Coote) walked the length of the river from Boiler Flat (1,300,633 E 5,100,178 N) to below the final confluence of the Makarora River with the Wilkin River (1,295,809 E 5,090,431 N) where the waterway becomes a single channel once more. Both sides of the river were covered during the survey, crossing in tandem where safe river conditions allowed. A total of 9 river crossings were made during the survey.

Following the initial Makarora walkover survey a sample of the lower Wilkin braid plain was undertaken on 28 October 2017. Ensuing breeding status site visits for the Makarora River were also undertaken following the initial walkover survey during October up till 11 November 2017.

## Study area

The Makarora River originates off the Main Divide and flows south to Lake Wanaka at 300 m above sea level. Braiding of the river begins at Boiler Flat, approximately 304 m above sea level and flows south west joining the Blue and the Young Rivers, then extending its braid plain further meeting its confluence with the Wilkin River continuing to the delta before reaching Lake Wanaka. The riverbed is typical of braided rivers in the South Island, containing multiple channels with islands of gravel between them, on which bird's nest. Five threatened endemic braided river bird species; black-fronted tern (*Chlidonias albostrigata*), black-billed gull (*Larus bulleri*), banded dotterel (*Charadrius bicinctus*), Wrybill (*Anarhynchus frontalis*) and South Island pied oystercatcher (*Haematopus finschi*) are dependent on this braided river habitat to complete their life cycle. These species have unique adaptive survival strategies such as cryptic coloration and multiple brood production to allow survival and reproduction within this often-harsh environment.

Makarora has an annual average rainfall of 2500 mm, daily rainfall for the last 5 months is summarized below (Fig 1).



**Fig 1:** Daily rainfall for Makarora showing the last 180 days rainfall in mm/day (Otago Regional Council 2017).

## **Method**

The same area and distance (15km) of the Makarora River was surveyed as per previous DOC braided river bird surveys. Methods followed the Department of Conservation guidance on braided river walkover bird survey. River crossings undertaken according to recognised best practice and Health and Safety standards (New Zealand Mountain Safety Council). Surveys were undertaken between 08:00 – 17:00 (when river birds are active and conspicuous) with three competent bird surveyors.

Survey commenced from Boiler Flat to below the Makarora/Wilkin confluence. The river was walked downstream covering both sides of the river. Surveyors spread evenly across river bed, walking at a steady pace recording all observations. Surveyors co-ordinated so that they commence counting birds at the same time. Counting birds on either side, was taken not to double count birds. Surveyors walked slowly down river, keeping in line and in communication with each other, and counted birds as they passed them or as the birds flew upriver passing the observers. The observers counted all waders, gulls, terns and shags. Surveyors walked down stream, carefully crossing river channels (according to recognised river crossing methods). Keeping an eye on the line of observers to make sure everyone kept together.

Locations of significant bird species or breeding colonies were recorded on a map and GPS coordinates were taken. Numbers of nests/pairs for threatened or important bird species along the length of the river were recorded.

Results were tallied at the end of the river section and counts amalgamated with other observers on the section. Tallies of non-flying young etc were kept separate from the count of adult birds. The counts are indices of abundance, not censuses, because of factors such as imperfect detectability, observer variability, spatial and temporal variation, and sampling error (Brown & Robinson 2009) as summarised within limitations below.

## **Limitations**

The number of surveyors was sufficient on this survey occasion. However, previous Makarora braided river survey teams have involved four plus survey members which may influence bird count survey results.

Species such as wrybill are particularly cryptic and inconspicuous within their environment and therefore may easily be missed within the braided river habitat. Hence, this species may be under represented within the total bird count data. Similarly, species such as black-backed gull and South Island pied oyster catcher are likely to be under estimated as these birds often forage within surrounding pastoral habitat and may be absent on the river bed at the time of survey and therefore not added to total species counts.

It should be noted that the lower Wilkin confluence to the Makarora delta is yet to be fully surveyed this year and is not included within the bird counts as per previous historical surveys undertaken by the Department of Conservation (DOC).

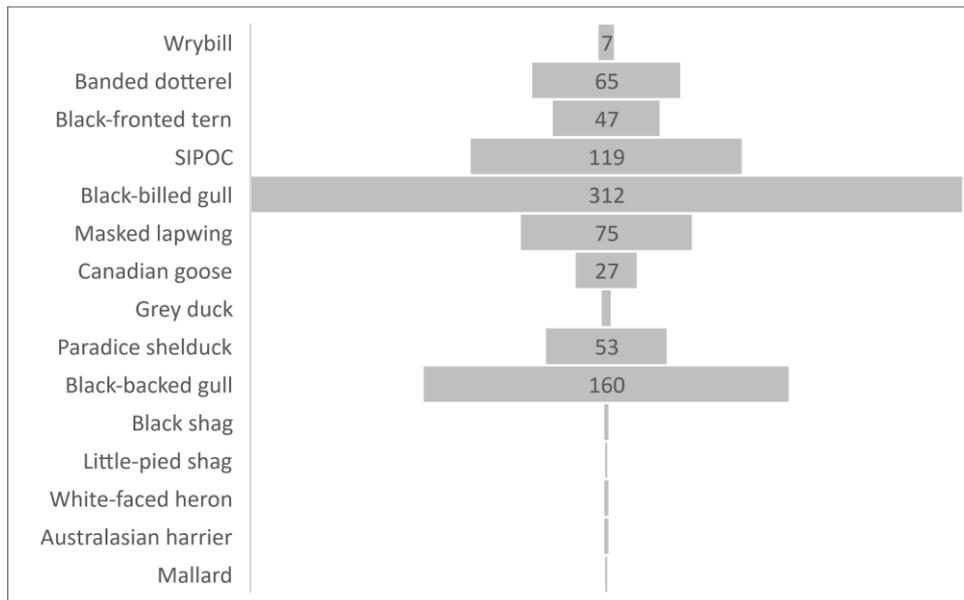
## Results

Table 1, summarises bird counts (not including passerines) on the Makarora River from Boilers Flat to the Lower Makarora/ Wilkin confluence. A total of 15 species comprising waders, gulls, terns, shag, waterfowl and one raptor. Of these; five species, wrybill, black-fronted tern, black-billed gull, banded dotterel and South Island pied oystercatcher are dependent on the braided river habitat to complete their life cycle.

**Table 1:** Makarora braided river total bird counts for 15 species during walkover survey 16 -17 October 2017. Conditions on both occasions; fine, dry, sunny with windy intervals, temp min 7°C max 18 °C.

| Braided river bird species | Total count |
|----------------------------|-------------|
| Wrybill                    | 7           |
| Black-fronted tern         | 47          |
| SI pied oystercatcher      | 119         |
| Black-billed gull          | 311         |
| Masked lapwing             | 75          |
| Black shag                 | 2           |
| Banded dotterel            | 65          |
| Canadian goose             | 27          |
| Grey duck                  | 4           |
| Mallard                    | 1           |
| Australasian harrier       | 2           |
| Paradise shelduck          | 53          |
| Southern-blackbacked gull  | 160         |
| Little pied shag           | 1           |
| White-faced heron          | 2           |
| <b>Total</b>               | <b>876</b>  |

**Fig 2:** funnel chart showing braided river bird species counts as proportions of total count.



**Wrybill (Ngutuparore) *Anarhynchus frontalis* - Nationally and Internationally Vulnerable**

Three pairs of wrybill were observed within the Wilkin/ Makarora River confluence area. Foraging behaviour was observed, and no nest site were found during the initial October walkover survey visit. A seventh wrybill, probable gravid female was observed feeding on aquatic invertebrates along the water's edge during the 28 October. A single wrybill chick (Fig 4) was recorded on 11 November with male and female parents.



**Fig 3:** Adult wrybill observed foraging on aquatic invertebrates along the water edge. Makarora 2017.



**Fig 4:** Wrybill chick recorded with male and female adults on 11 November 2017 at Makarora River. Fledging at 35 days. Note cryptic colouration against braided river alluvial material.

**Black-fronted tern (Tarapirohe) *Chlidonias albostrata* - Nationally and Internationally Endangered**

A total of 47 black-fronted terns were recorded during the walkover survey. Adult birds were recorded throughout the length of the river either in flight, commuting, foraging on surface insects along the river or roosting on the riverbed. Territorial defence behaviour was observed indicating that potential nesting sites were close by.



**Fig 5:** Thirty adult black-fronted terns observed roosting on braided river shingle bar during September 2017 marking their return to Makarora River.

Three black-fronted tern roosting locations were identified on the river, including a nesting colony of 25 birds. One of the shingle bar roosting habitats was observed during a September site visit. The terns no longer roost in this area and the water levels have risen reducing the size of this potential roost site. Black-fronted terns were also regularly observed feeding on invertebrates over pastural fields.



**Fig 6:** Evidence of black-fronted tern nest with olive/brown eggs laid in simple scrape within shingle (23 days to incubation, month to fledge), 1 November 2017 Makarora River. Nest site lost to flash flooding just days after.

**Banded dotterel (Tuturiwhatu) *Charadrius bicinctus* - Nationally Vulnerable**

Regularly observed (usually in pairs) along the length of the river during the walkover survey and additional survey monitoring visits. Highest density appeared to be located close to the Wilkin/ Makarora confluence. This species was noted on both braided river habitat material but also on more vegetated areas of the floodplain. Only two banded dotterels were observed within the lower Wilkin. Nesting behaviour was observed and nest distraction feigned wing-injury behaviour. Banded dotterel chicks were regularly observed from early November monitoring site visits.



**Fig 7:** Adult banded dotterel in alternate plumage. Makarora River 2017.



**Fig 8:** Makarora tiny banded dotterel chick (1 of 4); highlighting cryptic colouration against braided river material (November 2017). Fledging 5 – 6 weeks.

**Black-billed gull (Tarapuka) *Larus bulleri* Nationally and Internationally Endangered**

A nesting colony of 240 black-billed gulls was observed above the Wilkin/ Makarora confluence. Evidence of nest construction and nesting behaviour was clear along a raised strip of braided river gravels. Eighteen nest sites with 2-4 eggs were confirmed. This habitat had been recorded under water during September already, prior to egg laying.



**Fig 9:** On 1 November 2017 six black-billed gull chicks had hatched within the nesting colony.



**Fig 10:** Black-billed gull chicks (x 2) with unhatched pale olive egg (chicks fledge 25 days), 1 November 2017 Makarora River.

On 4 November following a period of precipitation (after a dry Oct) and rising river levels the nesting colony of black-billed gulls (Fig 17) had dispersed, and no eggs or chicks were found remaining. Consequently, adult gulls relocated upstream close to a black-fronted tern colony and a Southern black-backed gull nesting site. On the 11 Nov a new nesting sites was recorded further down-stream.



**Fig 11 & Fig 12:** Black-billed gull breeding colony during October and following river level rise in Nov 2017.



**South Island Pied Oystercatcher (SIPO) *Haematopus finschi* - Nationally at risk/ Declining**

South Island pied oystercatcher was frequently observed and heard calling, usually in pairs. Nesting distraction behaviour was observed by many pairs and individual birds. Three SIPO chicks were noted above the Wilkin/ Makarora confluence during 15 October. A flock of adult birds approx. 50 were also observed within adjacent pastureland; not included within the total count for this species.



**Fig 13:** Single brownish blotched egg and shallow nest scrape of South Island pied oystercatcher.

**Southern black-backed gull *Larus dominicanus* - Not threatened**

The largest gull, widespread and increasing in Makarora. Several colonies of black-backed gull were noted along the course of the river. One on the west side of the river and one at the far end below the Wilkin/ Makarora confluence. Large groups of this species were also observed within pastoral fields along the Haast to Wanaka highway. Nesting adults and eggs were confirmed on raised braided river habitat.



**Fig 14:** Part of the Southern black-backed gull colony up river from endangered nesting braided river birds.



**Fig 15:** Southern black-backed gull nest comprising three greenish grey eggs within a deep nest (27 days incubation).

**Mask-lapwing/ Spur-winged plover *Vanellus miles* - Not Threatened**

Low numbers of this species were recorded throughout the length of the Makarora River however a flock of 45 birds in flight was observed at the Wilkin/ Makarora confluence. This species has previously been thought to damage eggs of banded dotterel (OSNZ).

**Pied stilt *Himantopus himantopus* - Not Threatened**

This species was not recorded during the walkover survey however two individuals were recorded on the river during September 2017 and observed foraging in pastural land off School Road on 23 October 2017. This species may also be found within Makarora wetland which did not form part of this survey. Two pied stilt were later recorded on 11 Nov on the Makarora River with black-billed gulls.

**Grey Duck *Anas superciliosa* - Nationally Critical**

Four grey duck were observed in flight. A hybrid grey/mallard duck was also recorded.

**Paradise Shelduck *Tadorna variegata* - Not Threatened**

Frequent observations and calls of paradise shelduck were recorded and three young chicks were observed on the river.

**Canada Geese *Branta canadensis* – Introduced**

A large flock was observed, and frequent goose pellets encountered in concentrated areas of the Makarora riverbed. This species was confirmed nesting and breeding on the Makarora River (Fig 15).



**Fig 16:** Canadian goose down-lined nest with six large, light-coloured eggs.

***Other Species/ observations***

**Birds**

Additional bird species recorded during the survey included; Australasian harrier *Circus approximans*, white-faced heron (*Egretta novaehollandiae*), black shag (*Phalacrocorax carbo*), little pied shag (*Phalacrocorax melanoleucos*), goldfinch (*Carduelis carduelis*), Common starling (*Sturnus vulgaris*), New Zealand pipit (*Anthus novaeseelandiae*), welcome swallow (*Hirundo neoxena*), redpoll (*Carduelis flammea*), house sparrow (*Passer domesticus*).

**Lagomorphs**

Hare (*Lepus europaeus*) was regularly observed traversing about the Makarora braided river system.

**Livestock**

Cattle were often observed in the river channel or within the braided riverbed habitat. This was noted a concern due to possible trampling and disturbance of nesting birds such as black-fronted tern, a

species prone to abandon nest sites once disturbed (particularly at night). Additionally, livestock contribute to increased water nitrate levels within water bodies which may impact on water quality.

### **Jetboats**

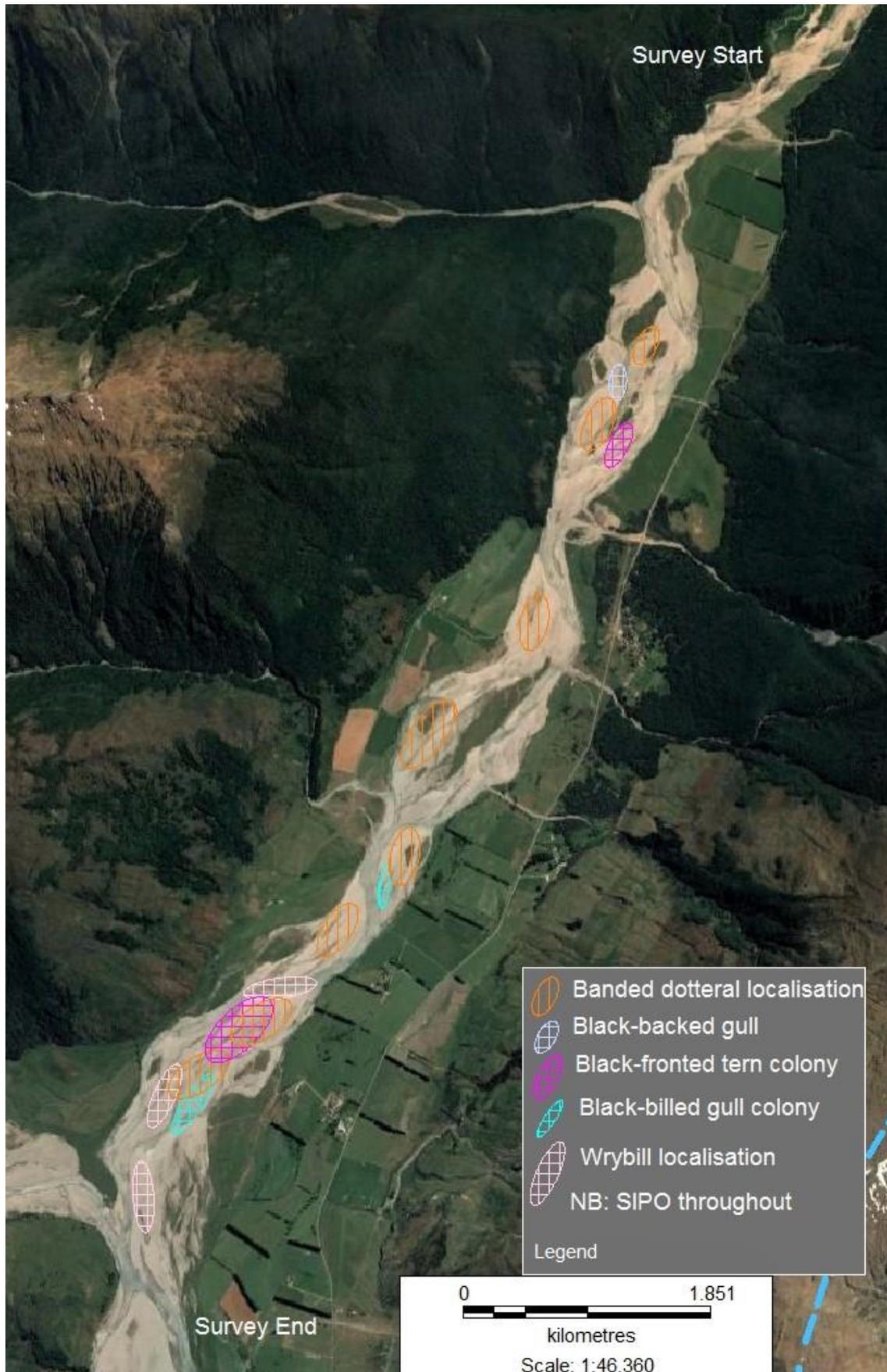
A jet boat was observed sailing directly past a black-billed gull nesting colony and no displacement behaviour was observed. However, other species may be less tolerant of such impacts (McKinlay 2001).

### **Lower Wilkin**

A sample walkover of the lower Wilkin was surveyed by two surveyors during late October 2017. Conditions were fine, sunny with windy intervals. A small number of birds were observed including two banded dotterel, four South Island pied oystercatcher, a white faced heron and a black shag. A herd of twelve livestock with calves was observed ranging freely throughout the valley and crossing the Wilkin. Braided river alluvial material was noted to be a lot finer within this area compared to the Makarora which appears to provide a wider range and gradient of braided river alluvial materials.

**Beyond the lower Makarora/Wilkin confluence to Lake Wanaka** - walkover to be completed Nov/Dec. Refer to Addendum to this report for the Lower Wilkin Confluence to Makarora delta.

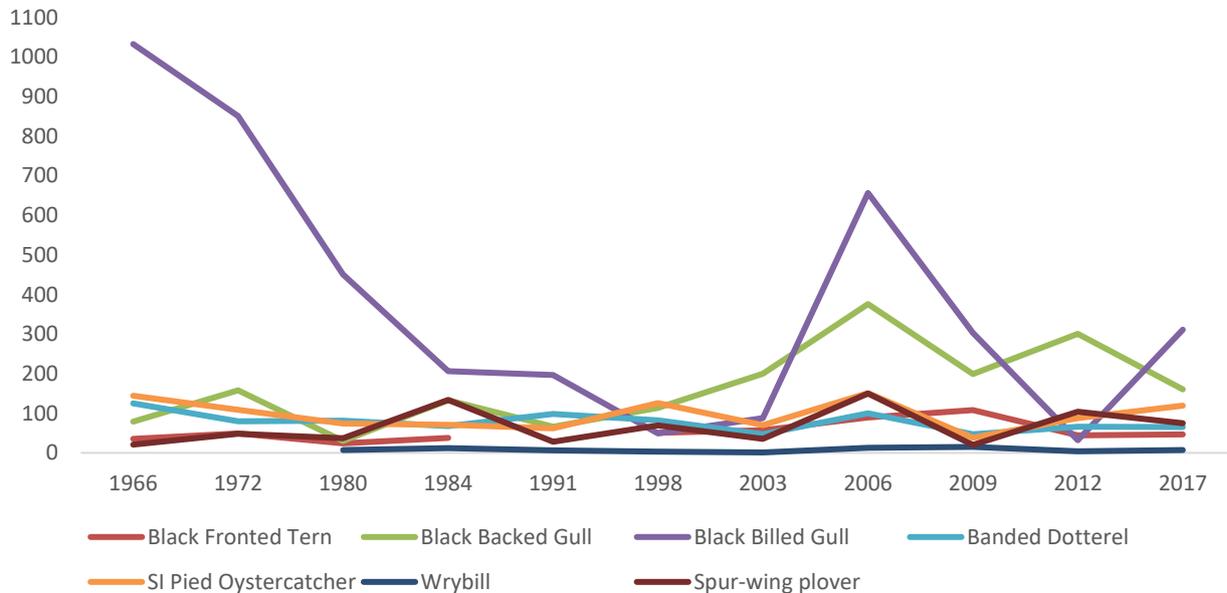
Fig 17: Makarora braided river bird nesting locations – October/ November 2017.



## Discussion

Comparisons for 2017 with previous years survey data 1966 – 2012 for Makarora River (data kindly supplied by DOC). The six indicator bird species for braided rivers are wrybill, banded dotterel, black-billed gull, black-fronted tern, South Island pied oystercatcher (SIPO) and Southern black-backed gull. Spur-wing plover has been included as known to potentially be a threat to endemic braided river birds.

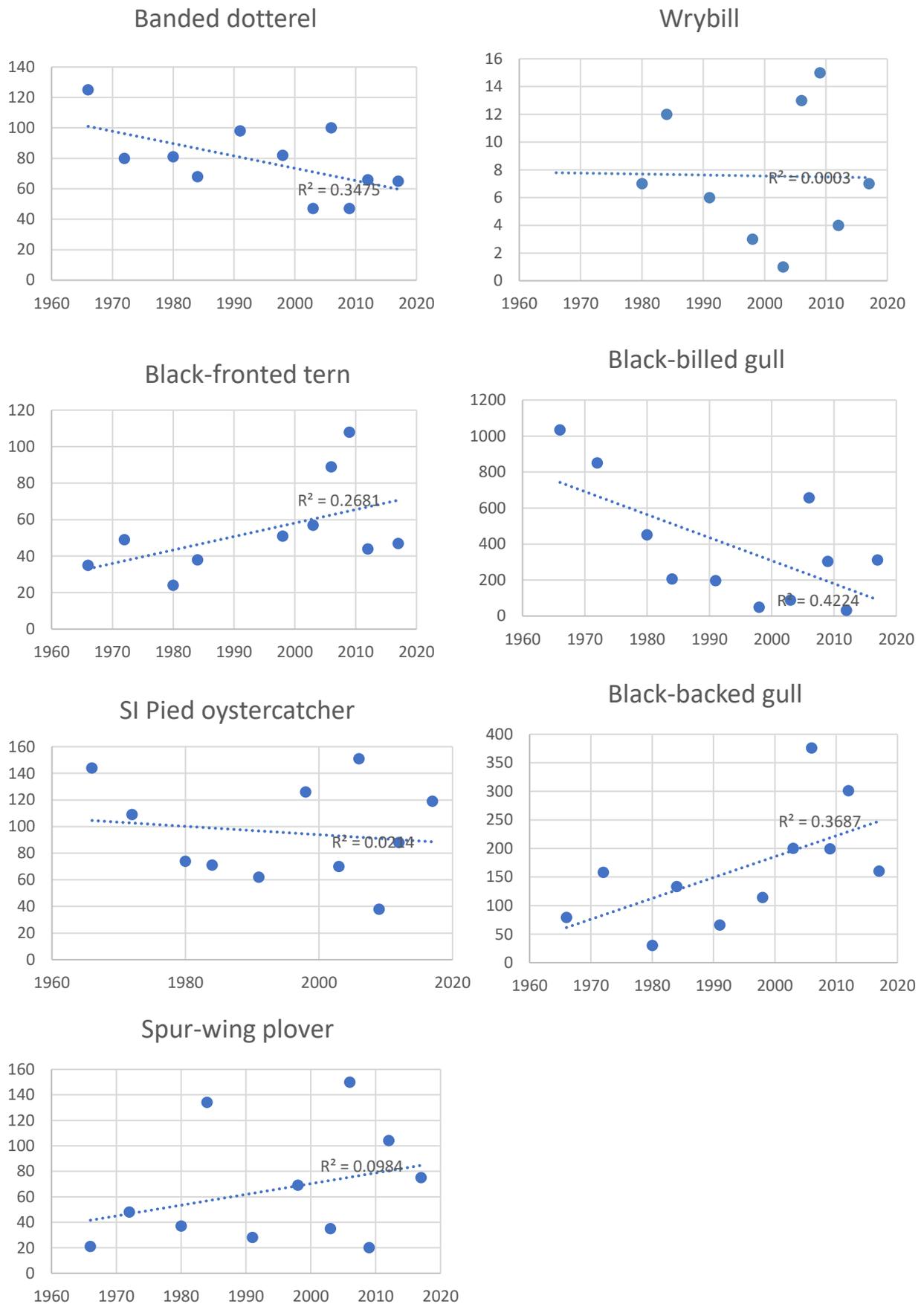
Fig 18: Braided river indicator bird species walkover survey counts 1966 - 2017



Previous survey data indicates that most braided river bird species have remained present with exception for wrybill, which wasn't recorded until 1980 and black-fronted tern which was recorded absent during 1991, returning during a 1998 survey. This species was also recorded breeding (40 individuals) on the Makarora during 2014 (Schlesselmann et al 2014). The largest fluctuation in bird count numbers over the survey time period has been for black-billed gull, with a peak in 2006 of 657 and a low of 32 birds in 2012. This correlates with a rise in black-backed gull and spur-winged plover. Both species known to be a threat to endemic braided river birds. Numbers of black-billed gull for this year appear to have increased since 2012. Wrybill has remained present since 1980 but at low counts of on average 7.5 birds with the highest count being 15 during 2009. Banded dotterel counts remain reasonably constant but with an overall decreasing trend. Black-fronted tern counts were highest in 2009 and this year are around average counts. Black-backed gull count of 160 for 2017 is within average of previous survey counts. However, not all birds within pastoral land were included within total counts. Although, a natural predator within New Zealand this species is now a considerable threat to endemic braided river birds particularly in relation to fledgling success.

Control measures for black-backed gull have been identified as necessary and are being undertaken on other braided river systems (Peat 2016) such as the Tasman. South Island pied oystercatcher appeared to be at a low in 2009 with counts showing an overall gradual decline. Recent studies have recorded SIPO showing minimal potential nest predation and banded dotterel pecking at abandoned tern eggs. Snowshoe hare have previously found to be predators of artificial eggs in Northern hardwood forests but are likely to only be occasional chance predator of ground nesting birds (Bell 2017). For most braided river birds, the main predation threat is from introduced mammals; stoat, ferret, rat, feral cat, hedgehog.

**Fig 19:** General overall trends for Indicator braided river bird species 1966 - 2017.



## Conclusion

The Makarora River is an important site for endemic braided river birds, maintaining a diverse and complete braided river avifauna. Evidence of breeding black-billed gull and black-fronted tern colonies have been identified and pairs of breeding SIPO, banded dotterel and wrybill are present. Further monitoring is required to determine braided river bird fledging success for this breeding season.

The survey highlights the cumulative threats encountered by braided river birds. Not only from mammalian and avian predators but also flash flooding. As in the case of the black-billed gull nesting colony and its recently washed away eggs and chicks. There is also the threat of native opportunistic avian predators such as black-backed gull also breeding near to endangered braided river birds such as black-fronted tern. Black-backed gull was observed harassing black-fronted terns during nesting and is known to take chicks.

Strong evidence indicates that predation by introduced mammals and native avian predators is one of the most important threats to the viability of bird populations that live on braided rivers (O'Donnell 2016).

Makarora braided river birds need help to successfully fledge their chicks this year without being subject to invasive mammalian predation from stoats, rats, ferret and hedgehogs. This requires an extended river trapping scheme to increase the number of mammal traps and to include feral cat control. Currently there are 15 DOC 200 traps along the eastern river bank and an additional 10 DOC 200's recently placed near to nesting birds within the braid plain (Fig 16). A method for controlling black-backed gull particularly during the breeding season is also required.



**Fig 20:** stoat and hedgehog caught by Makarora River trapline (15 traps), winter 2016 (Fen traps now upgraded with DOC 200's).

Where there is considerable predator control braided river bird chick survival rate has been proven to massively increase (Ledgard 2016) within braided river system such as the Tasman Delta and the Ashley River. Therefore, there is hope of helping to contribute to lowering the conservation status of these unique and iconic braided river specialists such as wrybill (estimated world population - 5000). Annual braided river bird monitoring is recommended to help determine if the effectiveness of future predator control management methods used are sufficient to suppress and maintain predators at low enough levels to achieve population growth.

## Acknowledgements

With thanks to Otago Regional Council (ORC) for funds contributing to Makarora braided river bird surveys for 2017.

Thanks to Florence Gaud and Kerie Uren (DOC Wanaka) in relation to supply of historical braided river survey data, logistics and use of radio's during survey. BRAID for production of drone video footage of the Makarora River to help guide future management. Taylor Hume and Anthony Coote for contribution to survey, monitoring and logistics. APSAR (local Wanaka business) for supply of 10 initial mammal predator traps (DOC 200's) now installed within braided river bird habitat extending existing river trapping network of 15 traps to 25 traps.

## References

- Bell, M. (2017). Population size, breeding success and predators of black-fronted tern (*Chlidonias albastraitatus*) in the upper Clarence River catchment, New Zealand. *Notornis*, 2017 Vol. 64 154-161.
- Brown, J.A.; Robinson, T.J. 2009. Addressing uncertainty in braided river bird counts. DOC Research & Development Series 311. Wellington: Department of Conservation.
- BRaid (July 2017) Drone footage screen shot (front page).  
<http://nzbirdsonline.org.nz>
- Gaud, F. (2009). Makarora Bird Survey. Department of Conservation. Wanaka, NZ.
- Hauer, RF. & Locke, H et al (2016). Gravel-bed river floodplains are the ecological nexus of glaciated mountain landscapes. *Applied Ecology*. Vol 2, No: 6.
- McKinlay, B, Smale, A. (2001). The effect of jetboat wake on braided riverbed birds on the Dart River. *Notornis* 48, 2, 72 – 75.
- O'Donnell, C.F.J.; Sanders, M.; Woolmore, C.; Maloney, R.F (2016). Management and Research Priorities for New Zealand Braided Rivers. Department of Conservation. Wellington, New Zealand.
- Peat, N. Patrick, B. Rebergen, A. (2016). Rivers Rare. The First 25 Years of Project River Recovery (1991 – 2016). Department of Conservation, Wellington, New Zealand.
- River Safety. New Zealand Mountain Safety Council [www.mountainsafety.org.nz](http://www.mountainsafety.org.nz)
- Schlesselmann, A-KV, Cooper, J, Maloney, RF (2017). Single season colony records of black-fronted terns (*Chlidonias albastraitatus*) spanning their entire breeding range. *Notornis* 64, 1, 38 – 43.
- Spur, E B and Ledgard, N J (2016). Population trends of braided river birds on the Ashley River (Rakahuri), Canterbury, New Zealand, 1963–2015. *Notornis*, 2016, Vol. 63: 73-86.
- Wittington, RJ. (2015). The foraging ecology of non-breeding Wrybills (*Anarhynchus frontalis*) in the Firth of Thames: a thesis presented in partial fulfilment of the requirements for the degree of Master of Science in Ecology at Massey University, Palmerston North, New Zealand.