Agenda For The Meeting of
Otago Fish & Game Council
25 July 2024

14.0 Items To Be Received Or Noted

Bendigo Wildlife Management Reserve Works 2022-24

Introduction

Bendigo Wildlife Reserve, spanning 158 hectares, is situated at the confluence of the Upper Clutha/Mata-au River and Lake Dunstan (Figure 1). This Crown Land reserve has been designated under the Government Purpose (Wildlife Management) Reserve classification, as per Gazette 2019 ln 585. The management and control of Bendigo Wildlife Reserve fall under the authority of the Otago Fish and Game Council, operating in accordance with the Reserves Act 1977.

Figure 1. Boundary of Bendigo Wildlife Management Reserve

Management Goals and Responsibilities

Fish & Game Otago, in collaboration with the Department of Conservation (DOC), has established management goals for Bendigo Wildlife Reserve, prioritised as follows:

Enhancing Waterfowl Populations: Managing habitats and public use to benefit waterfowl populations.

1. **Promoting Recreational Waterfowl Hunting**: Maximising opportunities for recreational hunting.
2. **Conservation of Protected Wildlife**: Managing habitats and public use to enhance values for protected wildlife species.

Current Challenges and Issues

Under the first priority, the encroachment of willow (Salix) species in island and channel areas poses a significant challenge. This encroachment has led to a notable reduction in open water areas crucial for waterfowl, which serve as loafing and feeding zones (Figure 1). Historical aerial photographs circa 1989 (Figure 2) depict extensive gravel beds for loafing and resting, as well as open channels and backwaters utilised for feeding and brood rearing purposes.

Addressing the proliferation of willows and restoring critical habitat areas for waterfowl are pivotal tasks for the ongoing management of Bendigo Wildlife Reserve.

Figure 2: Aerial photo of Bendigo Wildlife Reserve area, circa 1989.

Recommendations

1. Implement strategic willow management strategies to reclaim habitats.
2. Commence and monitor habitat restoration efforts, including planting.
3. Engage stakeholders and the public in conservation initiatives to enhance awareness and support.

This report is an update on the current work that has been conducted in the reserve since 2022, along with recommendations for future work.

All work that has been undertaken have been permitted activities. Otago Regional Council (ORC) receives notifications of this work, as required under section 55 of the NES-FW.

The current weed control that is undertaken is a permitted activity under 12.C.1.1 of ORC rules.

Weed Control Management

Weed control, particularly targeting willow trees (Salix species), is a critical management focus within Bendigo Wildlife Reserve. The proliferation of crack willow has significantly impacted biodiversity and recreational activities within the reserve area.

A priority of the work undertaken so far has been to combat invasive plant species within Bendigo Wildlife Reserve, aiming to preserve biodiversity and enhance recreational opportunities in the reserve area. (Figure 3)

Figure 3: Area of willow control showing initial stages of decay.

Impact of Willow Infestation

The spread of willow trees has led to several detrimental effects on the reserve ecosystem and recreational use:

- **Sedimentation**: Annual leaf fall creates a dense layer of sediment on the lakebed, reducing habitat for macroinvertebrates critical for sports fish and juvenile waterfowl like mallard ducks.
- **Shading and Habitat Loss**: Willow shading diminishes algae productivity in waterways, impacting invertebrate habitats.

- **Log Jams**: Accumulation of willow debris forms log jams that obstruct boat access and can alter river channels.
- **Access Restrictions**: Dense thickets of small willows limit foot access for anglers and waterfowl hunters.

Although willow trees in riparian areas, overhanging the water, provide some escape cover for mallard and grey teal, this single benefit is vastly outweighed by the negative impacts from the presence of these trees.

Willows have been controlled at the Gilmore Road access site since autumn 2022. Around 12ha of the reserve has had willows controlled since then, with a further 4ha of willows that have not received any treatment to be controlled over the 2024/25 season. (Figure 4)

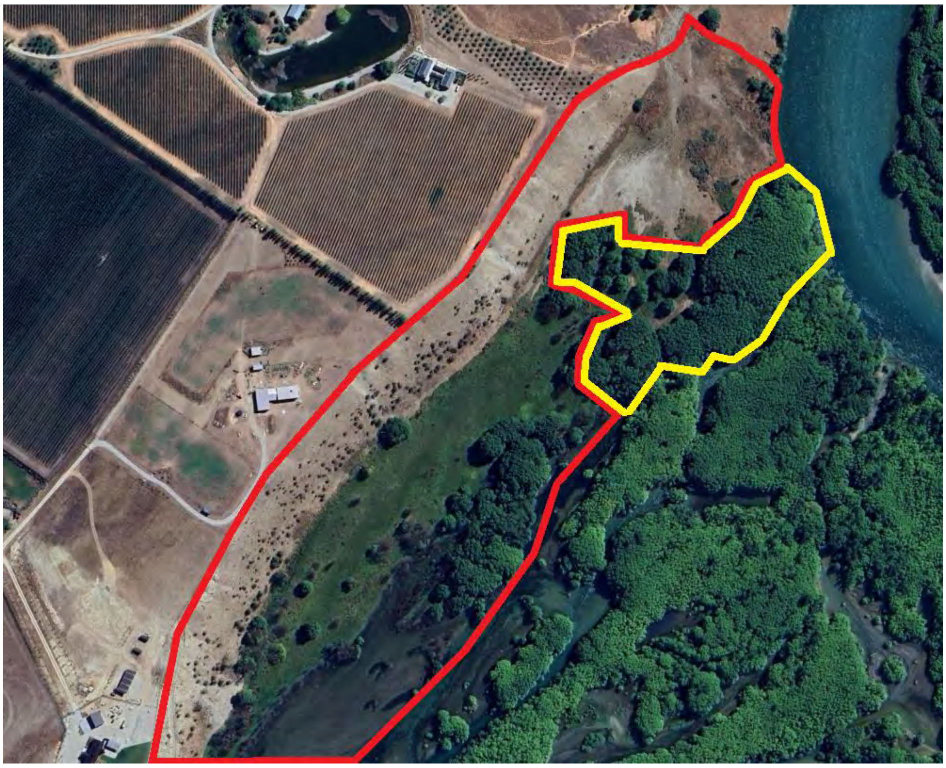

Figure 4: Area of willow and other weed control in red area. Yellow area for control over 2024/25 season.

Control Methods and Strategies
Efforts to control willows have been ongoing, primarily focusing on:

- **Large Trees**: These have been controlled by drilling the trunk of the trees and injecting Glyphosate into the hole. A two-stroke petrol drill is used for the task, using a 20mm drill bit. Holes are drilled around the circumference of the trunk, roughly 20-30cm spacing, at a depth of 80mm. The holes are angled downwards, to prevent the herbicide from running out of the hole once applied.
  A drench gun is used to apply the herbicide. Around 20 to 25ml of Glyphosate 360 has been used at an undiluted rate in each hole.
  The kill rate of this method has been varied. Overall, the kill rate has been quite high, however, many trees have had some branches unaffected by the herbicide, and others

will continue growing with obvious deformities, primarily curled leaves. Secondary treatment with basal spraying on these branches has been necessary for total kill of some individual trees.

- **Medium Trees**: Medium-sized trees have been controlled by basal spraying. Grazon herbicide (Picloram) is diluted with diesel at a rate of 1:4 and applied directly to the tree trunk with a knapsack sprayer under low pressure. The area covered is enough to surround the entire circumference of the tree, 30 to 50cm above the ground height. Trees with thinner bark and a trunk diameter of around 40cm or less have seen the most successful results. Mortality rates have been extremely high with this method, with few follow-up applications needed.

  Basal spraying has also proved effective on finishing trees not effectively killed with the drilling method alone.

  Basal spraying is more costly than the drill/drench method, with picloram over twice the price of glyphosate per litre.

- **Small Seedlings**: Controlled using knapsack spraying of foliage with diluted glyphosate.

Management of Other Weed Species
In addition to willows, other invasive species have been targeted:

- **Lupin and gorse**: Controlled with glyphosate spraying, requiring annual follow-up due to reemergence.
- **Wild Rose, Cape Hawthorn and Elder**: Managed through basal spraying during willow control operations.
- **Silver Birch**: Found on the northern boundary and effectively controlled with basal spraying.
- **Chinese Clematis**: Identified in two sites, treated with glyphosate knapsack spraying. Ongoing monitoring and treatment are essential to prevent reestablishment.

Conclusion
Effective weed control, particularly of willow species, is crucial for restoring and maintaining the ecological balance and recreational value of Bendigo Wildlife Reserve. The integrated approach of drilling, basal spraying, and knapsack spraying ensures targeted and efficient management of invasive species throughout the reserve.

Next steps
1. **Monitor and Evaluate**: Regular monitoring of treated areas to assess effectiveness and identify new infestations.
2. **Adaptive Management**: Adjust control strategies based on monitoring results to optimise resource allocation and effectiveness.

Planting Program

The plant species selected for Bendigo Wildlife Reserve are based on rigorous research from the pre-settlement woody vegetation of Central Otago (Walker, Lee & Rogers 2004). Other species selected for planting have been chosen from the Otago Regional Council's Riparian Planting Guide, Central Otago Region.

This selection ensures that only species adapted to the harsh local conditions are used, promoting their resilience and survival. It is recommended that ONLY these species that naturally occurred here are used for future planting of the area, as not only will they perform well under the harsh conditions experienced at this location, but it will also serve to promote Fish & Game NZ as a spearhead of conservation land management.

The planting will take place in the corner of the reserve accessed by Gilmore Road, bounded by the edge of the reserve and the first deep side channel of the Clutha River. This area is highlighted in red in Figure 5.

Figure 5: Area for planting 2022-25

Primary Plant Species and Proportions:

- Kanuka (*Kunzea serotina*): 60%
- Kowhai (*Sophora microphylla*): 20%
- Manuka (*Leptospermum scoparium*): 10%
- Totara (*Podocarpus laetus*)
- Silver Beech (*Lophozonia menziesii*)
- Cabbage Trees (*Cordyline australis*)

These species are strategically distributed across different areas of the reserve based on their tolerance to soil types, water levels, and exposure to environmental elements.

Other Species:

- *Coprosma rugosa*
- *Coprosma propinqua*
- *Phormium tenax*
- *Carex secta*
- *Carex virgata*
- Other small native species

These species complement the canopy plants by enhancing biodiversity and providing habitat structure for wildlife.

A particular effort will be placed on establishing areas of *Carex Secta* in shallow marginal areas, to allow escape cover for ducklings from aerial predators such as harriers.

Under management goal 1 (To manage the habitat and public use so as to enhance waterfowl populations) efforts will be placed on reducing predation of waterfowl chicks. By providing escape cover and nesting habitat through planting, the productivity of the area will increase the local waterfowl population. The main threat to nests and early-stage hatchlings will be from avian predators, namely harriers. This is best managed by strategic plantings.

Funding plantings

Plants were sourced primarily from Milton Correctional Facility, where eco-sourced seeds have been grown specifically for the project.

Two successful rounds of funding applications from the Otago Regional Council's EcoFund have purchased $10,000 worth of trees from Matukituki nursery. The trees purchased are either slow growing, or difficult to obtain or grow for the Correctional Facility to produce.

In autumn 2024, 700 trees were donated through an application to Trees That Count, and these were sourced from Matukituki Nursery also.

Planting Areas and Conditions

The reserve's planting areas are classified into four distinct zones, each with unique soil characteristics, groundwater levels, and environmental challenges (Figure 6):

1. **Area A (Dry and Exposed):** This area experiences extended periods of drought, extreme temperature fluctuations, and drying winds. Only the most drought-tolerant species are planted here to ensure survival.
2. **Area B (Wet and Flood-Prone):** Continuously wet with occasional flooding due to high water levels from rainfall and dam management. Plant species must withstand prolonged soil moisture and occasional submersion.
3. **Area C (Fine Alluvial Soils):** Predominantly silt-based soils with varied drainage patterns. This area receives high and low temperature fluctuations but is sheltered from drying winds by rank grasses.
4. **Area D (Former Willow Infestation):** Previously dominated by willows, now treated to prevent their re-establishment. This area offers moderate shade and protection, similar to Area C.

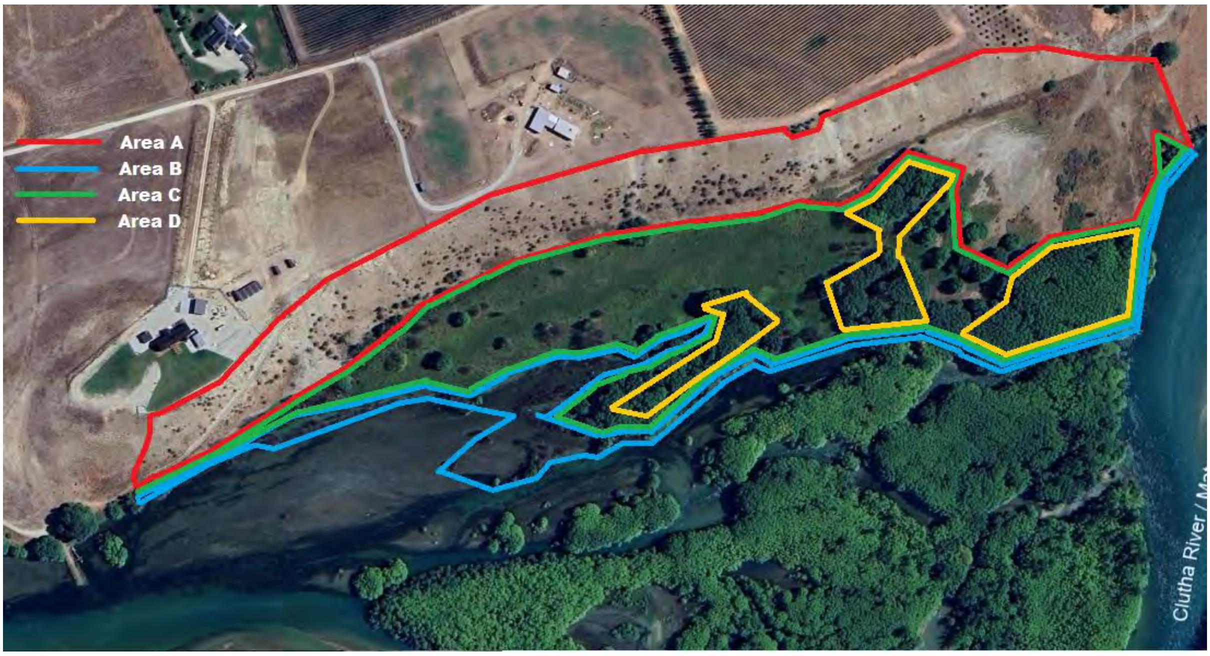

Figure 6: Map of planting area

Plant Species for each planting area.

Area A:
Kanuka (*Kunzea serotina*)
Matagouri (*Discaria toumatou)*
Kowhai (*Sophora microphylla*)
Halls totara (*Podocarpus laetus*)
Scented tree daisy (*Olearia odorata*)
Mountain akeake (*Olearia avicennifolia*)
Fierce Lancewood (*Pseudopanax ferox*)
Broadleaf (*Griselinia littoralis*)
Twiggy tree daisy (*Olearia lineata*)
Porcupine bush (*Melicytus alpinus*)
Cabbage tree (*Cordyline australis*)
Flax (*Phormium tenax)*
Toetoe (*Austroderia richardii*)

Area B:
Cabbage tree (*Cordyline australis*)
Flax (*Phormium tenax)*
Toetoe (*Austroderia richardii*)
Purei (*Carex secta*)
Swamp sedge (*Carex virgata*)

Area C:
Mingimingi (*Coprosma propinqua*)
Kanuka (*Kunzea serotina*)
Matagouri (*Discaria toumatou)*
Manuka (*Leptospermum scoparium*)

Twiggy tree daisy (*Olearia lineata*)
Needle leafed coprosma (*Coprosma rugosa*)
Korokia (*Corokia cotoneaster*)
Ribbonwood (*Plagianthus regius*)
Broadleaf (*Griselinia littoralis*)
Cabbage tree (*Cordyline australis*)
Flax (*Phormium tenax)*
Toetoe (*Austroderia richardii*)

Area D:

All species from Area C plus:
Marbleleaf (*Carpodetus serratus*)
Silver beech (*Lophozonia menziesii*)

Planting and Management Practices

Preparation and Maintenance:

- Prior to planting, vegetation is cleared using a scrub bar if necessary, and remaining grasses are treated with Glyphosate to reduce competition and facilitate successful establishment of new plants.

Protection Measures:

- Cardboard shelters are employed around young plants vulnerable to rabbit predation. Some of these cardboard protectors have been reused in the event of plant mortality to optimise cost-effectiveness.

Monitoring and Maintenance:

- Each plant is marked with the plant protector during planting. Regular audits assess and record plant survivability.

Planting commenced in August 2022, and planting preparation and maintenance has been a primary job during late autumn and early to mid-spring since. Each plant site was cleared of grasses and weeds with a scrub bar and grasses sprayed with Glyphosate prior to planting if it was deemed necessary. Mesh cages or alternative plant protectors were be placed around these to prevent rabbit predation. Plant protectors were recycled during the autumn 2024 planting season, where the protectors were removed from dead plants and reused on new plantings to cut costs.

Several community groups have been involved with planting, with around one hundred volunteer hours involved in planting plants and constructing rabbit protectors.

Over 3,000 plants have been planted by staff and volunteers in less than two years, with many of these early plantings thriving. (Table 1)

Species	# Planted	% Mortality (Dec 2023)
A. richardii	106	4
C. secta	475	0.63
C. virgata	80	0
C. serratus	58	0
C. propinqua	90	5.26
C. rugosa	113	1.51
C. australis	260	0
C. cotoneaster	0	0
G. littoralis	58	10.53
K. serotina	759	15.27
L. scoparium	155	18.56
L. menziesii	60	8.33
O. avicennifolia	91	6.67
O. lineata	212	1.89
O. odorata	75	0
P. tenax	477	0.42
P. regius	77	3.9
P. laetus	25	0
P. ferox	92	1.09
S. microphylla	183	5
Total:	3446	4.15%

Table 1: Plants planted August 2022 to June 2024, and mortality of plants from December 2023

Community Involvement and Support

Community engagement plays a pivotal role in the success of restoration efforts at Bendigo Wildlife Reserve:

- **Volunteer Participation:** Various community groups, including Cromwell Youth Trust, Cromwell High School, Scouts, Cromwell Homeschool group, and members of the public, contribute volunteer hours to planting and conservation activities.
- **Educational Events:** Community planting days, such as those held during Conservation Week, serve to raise awareness, and foster local stewardship.

Challenges and Mitigation Strategies

Plant Mortality:

- Plant survivability has been an issue. A mortality audit was conducted in December 2023, where each plant was visited and observed for survival status (Table 1). Although the overall mortality was low (4.15%) some species such as manuka was as high as 18.56%. Kanuka and manuka were the worst affected, however, this is to be expected from these two plants, as they are well known to be sensitive to root disturbance during planting.
- The main causes for plant mortality have been drought for the 2023-24 summer period and poor planting techniques. Rabbit predation was extremely low, and only affected a few individual plants where the rabbit protector had been blown off in high winds.

  Unfortunately, some of the earlier plantings with youth help has resulted in plants dying due to improper planting techniques, primarily placing the plant in the hole, and not filling in the rest of the hole with soil. This caused the affected plants to quickly dry out and die. Due to the weed suppressing mats and plant protectors placed onto the plants on planting, it has been difficult to audit each plant to access whether they were correctly planted. Subsequent plantings have involved a closer supervision of planting, and clear and repeated instruction on the correct techniques.

Weed Management:

- Rank grass growth has smothered plants in some areas of the reserve. Trimming with weed eaters and knapsack spraying with glyphosate has been effective to reduce the competition for planted species. Some grass has been useful, as it has prevented foliage damage from windburn and frost on some plants.
  Weed eating and spraying is best done in spring, to allow the plants reduced competition during the growing season but allow the grass to provide protection during summer and winter. Once yearly weed releasing with this technique should be adequate. During the weed releasing, plant mortality can be addressed and recorded. This also provides an opportunity to replace any damaged plant protectors and apply Nitrophoska fertiliser during the growing period.

Conclusion

The comprehensive planting strategy at Bendigo Wildlife Reserve exemplifies Fish & Game NZ's commitment to sustainable land management and biodiversity conservation. Next steps are to:

- **Continue Monitoring:** Regularly evaluate plant survivability and adapt management practices to enhance long-term success.
- **Expand Engagement:** Strengthen community partnerships and outreach initiatives to ensure ongoing support and participation in conservation efforts.
- **Sustainable Practice:** Maintain collaborations for eco-sourced plant supply and resource management, fostering resilience and diversity within the reserve.

Maimai Site Development for Novice Hunters

As part of the restoration project at Bendigo Wildlife Management Reserve, efforts have been made to create a safe and accessible area for gamebird hunters to harvest waterfowl. An area has been selected for a novice and junior hunter's maimai, to provide opportunities similar to what has been already conducted at coastal Fish & Game managed wetlands, such as Takitakitoa and Otokia.

Site Selection

A shallow backwater area within a former side channel of the Clutha River has been identified for the installation of the first hunting peg (Figure 7). Access to most of the reserve is challenging, primarily relying on boat access. The selected area offers shallow feeding margins and has been observed to host small numbers of game species such as mallard and shoveler ducks, alongside occasional feral geese.

To enhance bird populations at the site, feeding is recommended to be conducted prior to and during the hunting season, to attract and sustain game species in the area. This will not be done by Fish & Game, and only by hunters wishing to increase the hunting opportunities.

Figure 7: Site for hunting stand

Hunting Stand Placement

The maimai site was strategically positioned to ensure a clear shooting arc away from the reserve's boundary and any proposed cycle trails. Dense plantings of Carex secta, flax, and cabbage trees surround the site, serving as a natural visual barrier.

Maimai Installation Plan
Prefabricated maimais have been procured at cost from Southern Institute of Technology, and installation of one of these hides is scheduled after the 2024 gamebird season to minimise hunter disturbance. Native pohuehue vines (Muehlenbeckia australis) will be planted adjacent to the maimai to enhance camouflage and protect surrounding vegetation from damage from hunters 'brushing' the blind. These vines will be encouraged to grow over the structure, providing permanent coverage and eliminating the need for brushing.

Conclusion The development of the maimai site is integral to supporting sustainable game bird hunting access, while maintaining the ecological balance of the reserve. The strategic placement and environmental considerations outlined ensure minimal impact on wildlife and habitat, promoting a harmonious coexistence between conservation efforts and recreational activities.

Next steps:
1. Erect maimai at the location recommended, and plant pohuehue vines.
2. Conduct regular maintenance to ensure the sustainability and safety of the maimai site.
3. Evaluate the potential for boardwalks or other pathways to access the site.

Rabbit Management

Rabbits are the predominant browsing species in the Gilmore Road planting area. This report assesses their current population, management strategies employed, and recommendations for future control measures.

Population
Rabbit populations in the Gilmore Road area range between 1 to 3 on the Modified McLean Scale (Table 2). Cardboard plant protectors have effectively minimised browse-induced mortality among planted species. Interestingly, rabbits have been beneficial in some sections by controlling weed growth, thereby supporting the planted species.

Scale	Rabbit infestation
1	No sign found. No rabbits seen.
2	Very infrequent sign present. Unlikely to see rabbits.
3	Pellet heaps spaced 10m or more apart on average. Odd rabbits seen; sign and some pellet heaps showing up.
4	Pellet heaps spaced between 5m and 10m apart on average. Pockets of rabbits; sign and fresh burrows very noticeable.
5	Pellet heaps spaced 5m or less apart on average. Infestation spreading out from heavy pockets.
6	Sign very frequent with pellet heaps often less than 5m apart over the whole area. Rabbits may be seen over the whole area.
7	Sign very frequent with 2-3 pellet heaps often less than 5m apart over the whole area. Rabbits may be seen in large numbers over the whole area.
8	Sign very frequent with 3 or more pellet heaps often less than 5m apart over the whole area. Rabbits likely to be seen in large numbers over the whole area.

Table 2: Modified McLean Scale (Credit: National Pest Control Agencies).

Fencing and Control Measures

The area adjacent to the reserve at Gilmore Road is bordered by an ageing rabbit fence. While much of the fence was intact, the southern boundary had two cuts—one at the adjacent property border and another at the lake shore track, allowing free rabbit movement. In August 2023, Fish & Game staff repaired and reinforced the fence, installing mesh and filling burrow holes with large rocks to restrict rabbit access. A gate was also installed on the track to regulate rabbit ingress and egress (Figure 8).

Figure 8: Gate erected on rabbit proof fence.

Rabbit Management Within the Reserve
Inside the reserve, rabbit numbers remain relatively low. Regular presence of border collie dogs from neighbouring property deters rabbits, resulting in occasional predation, with a rabbit killed every day or two. Limited shooting has been conducted with minimal impact on rabbit populations.

Control Options
Toxin-based control, particularly Magtox in warrens post-observation of rabbit activity, is recommended. However, its efficacy might be hindered by current low rabbit density. Baits like pindone are considered less effective due to ample natural feed available, reducing bait uptake. Pindone should be reconsidered if rabbit populations rise above current carrying capacity.
Spotlight shooting is an option for controlling small numbers, however, long grass will limit areas where this will be effective.

Conclusion
Effective rabbit management in the Gilmore Road planting area involves a combination of physical barriers, such as repaired fencing and gate installations, alongside strategic use of toxins like Magtox for targeted control. Continued monitoring and adaptive strategies will be essential to maintain low rabbit populations.

Next steps:

1. Maintain and monitor repaired fencing to prevent rabbit incursions.
2. Consider periodic applications of Magtox in identified warrens for targeted control.
3. Assess Pindone baiting strategies if rabbit populations increase beyond current levels.

2024-25 Season Work Plan

Planting work is proposed for spring in 2024 and again in autumn 2025. Plants funded by ORC's EcoFund in May 2024 have been purchased and are currently being grown at Matukituki nursery until the planting season has commenced.

Fish & Game have already received interest from many volunteers to help with this work, including Cromwell High School, Cromwell Scout group, Mohiki Trust and others.

Weed releasing for the plants currently in the ground will be done around September and October 2024. This will involve trimming grasses with a weed eater and spraying a buffer around each plant with glyphosate from a knapsack sprayer to suppress weed growth during spring.

During this time, each plant will be assessed for mortality, and this will be recorded. Nitrophoska fertiliser (purchased through leftover funds from ORC's EcoFund) will be applied to the plants, to allow them an extra boost for the spring growing season.

When time and staffing allow, the maimai will be erected at the site proposed, as well as the planting of the pohuehue vines to help camouflage the hide.

Willow control will commence once the growing season starts, typically around early November, and it is hoped that the willows will have been controlled in the entire area by winter 2025, depending on mortality success. Further control of lupins, gorse and other weeds will be undertaken over summer.

Perimeter checks of the rabbit fence will be conducted every six months, to check for holes and rabbit burrowing under the fence.

References

Otago Regional Council. Riparian Planting Guide, Central Otago Region.

Walker, Lee & Rogers (2004). Pre-settlement woody vegetation of Central Otago, New Zealand Journal of Botany

Ben Sowry
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June 2024

14.2

Designated Waters Fishery and Controlled Fishery Report for the 2023/2024 Season

Introduction

The introduction of the Designated Waters Licence for the 2023/2024 season represents a significant shift in fisheries management, replacing the backcountry licence and setting limitations on the total number of angler days allowed for non-resident anglers on specified Designated Waters.

This change was driven by an increasing number of complaints over the past decade regarding overcrowding in fragile fisheries. These pressures have negatively impacted both the angling experience and trout behaviour, with residents feeling displaced by non-resident anglers.

Historically, certain fisheries experienced a roughly equal split between resident and non-resident anglers. However, by the early 2000s, this had shifted to an 80/20 usage split in favour of non-residents. To address these issues, the Designated Waters Licence aims to control crowding and disperse angling pressure, particularly in pressure-sensitive fisheries.

To evaluate the impact of the new licence on both resident and non-resident anglers, riverside surveys were conducted alongside regular compliance work. The findings from these surveys, including the Greenstone Controlled Fishery (GCF), for the 2023/2024 season are covered in this report.

Designated Waters Monitoring

Given the significance of the new Designated Waters Licence, the Otago Fish and Game Council implemented an extensive plan for ranging and surveying on all designated rivers, with the exception of the upper Lochy River. The upper Lochy River was excluded due to high accessibility costs and reports indicating a lack of fish and very limited angler use, making it not viable for inclusion in the survey.

A combination of staff and honorary rangers carried out the surveying and compliance trips. These efforts often required helicopters or jetboats to access remote rivers, followed by a walkout the next day to maximize interactions with anglers. Honorary rangers also performed ranging activities on Designated Waters without conducting surveys when they were in the area for recreational purposes.

Greenstone Controlled Fishery

The Controlled Fishery Period requires anglers to make a booking in order to fish the Upper Greenstone River and ensures anglers will have exclusive angling access to a determined stretch of river (a beat) for the period of their booking. A limited amount of data was collected from the online booking system. This data is presented in the results.

Compliance

Compliance monitoring was undertaken to enforce the sports fishing regulations. Additionally, Fish & Game rangers gathered information on guided fishing operators on behalf of the Department of Conservation. Pre-season Designated Waters information letters and/or presentations were given to a number of user groups including;

- Accommodation providers i.e. fishing lodges,
- Fishing guides (including NZPFGA members),
- New Zealand Deerstalkers Association (Southern Branch),
- New Zealand Jet Boat Association (Otago Branch),
- Central Otago aircraft operators,
- All successful hunting parties in the Wanaka roar ballot and the Greenstone / Caples ballot,
- Department of Conservation hut wardens based at Glenorchy with an emphasis on the wardens working in the Caples and Greenstone Valleys.

Timing of ranging

Designated Waters monitoring was undertaken throughout the 2023/2024 season (01 October – 30 April and 01 November - 31 May).

Results

Greenstone Controlled Fishery (GCF)

Table 1: GCF angler effort and demographics 2008-2023

Year	2008	2009	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
No. Of Anglers Total					40	43	55	66	55	38	38	21	22	41	25
Capacity allocated	51%	46%	46%	27%	27%	25%	26%	39%	29%	22%	29%	19%	21%	34%	21%
NZ res anglers	31%	36%	31%	37%	48%	42%	29%	38%	31%	45%	34%	90%	91%	56%	76%
Non res anglers	69%	64%	69%	63%	52%	58%	71%	62%	69%	55%	66%	10%	9%	44%	24%
Guided anglers	21%	20%	34%	43%	10%	16%	36%	33%	18%	6 %	*	*	*	*	*

NB: Following a review of past booking records some adjustments were made to these results for past seasons and this table varies from those previously reported. Due to inaccuracies and inconsistencies with angler details reported (particularly prior to the introduction of the non-resident licence) some judgements were required regarding the interpretation of results (Helen Trotter 2018)

** This figure could not be ascertained as an angler survey was not completed for the CF period in 2019, 2020, 2021, 2022 or 2023.*

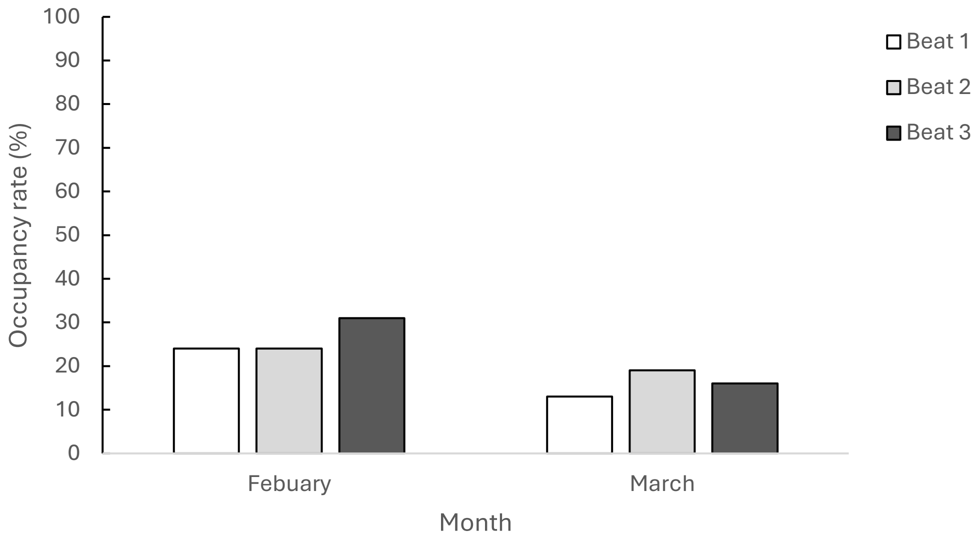

Figure 1: *Occupancy rates of the Greenstone Controlled Fishery for the 2023-2024 season*

The capacity in the Greenstone River Controlled Fishery (beats 1–3) decreased this season, with only 21% of the available beats being booked (Table 1). Resident anglers comprised 76% (n=19) of the angling effort, while non-resident anglers accounted for the remaining 24% (n=6) during the controlled period.

Over the past decade, the occupancy rate has been consistently low (20–30%), with the highest rates observed in 2016 and 2022. This season's occupancy rates are similar to those during the COVID-19 years (2020, 2021) (Table 1).

Beat 3 had the highest booking rate with an occupancy of 24%, while beat 1 had the lowest at 19% (Figure 1). February saw a significantly higher occupancy rate at 26% compared to March's 16% (Figure 1).

Designated Waters Survey results

Table 2: Designated Waters Survey Effort 2023 /2024

River	Number of days surveyed	Resident anglers surveyed	Non- resident Anglers surveyed	Total anglers surveyed	Non-resident angler percentage	Guides	Offences detected
Hunter River	3	16	3	19	16%	0	0
Dingle Burn	3	1	3	4	75%	1	0
Greenstone River	6	14(9*)	12 (2*)	26 (11*)	44%	1	0
Caples River	9	20	4	24	17%	0	2 x No DW licence
Nevis River	7	8	2	10	20%	4	0
Upper Pomahaka	2	5*	0	5*	0%	0	0
Wilkin River	6	3	0	3	0%	0	0
Young River	3	1	2	3	67%	1	1 x No DW licence

* = Direct email surveys were conducted targeting two specific groups of anglers: those who reported fishing the upper Pomahaka River in the 2023/24 Lower Clutha angler survey, and those who booked beats in the Greenstone River Controlled Fishery.

Overall, 94 riverside surveys were conducted on Otago's Designated Waters during 39 survey days throughout the 2023/24 fishing season. Resident anglers comprised 72% of the total surveyed anglers, while non-resident anglers accounted for the remaining 28%.

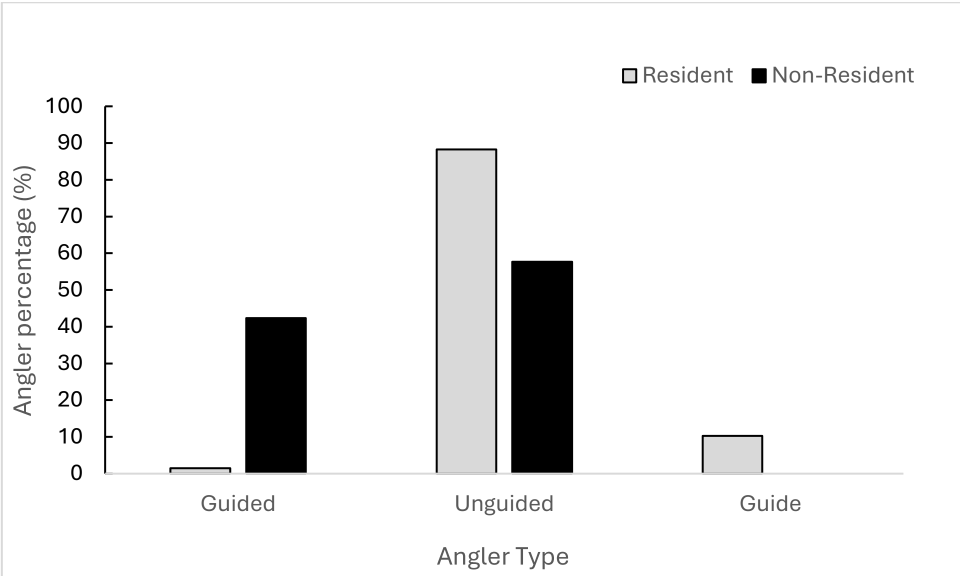

Figure 2: Angler composition (guided, unguided, guide) of anglers surveyed on Otago's Designated Waters for the 2023/24 season.

Unguided anglers were the most frequently encountered type throughout the survey, with over 88% of resident anglers and 57% of non-resident anglers fishing without a guide. Only 1.4% of all resident anglers surveyed were using a guide, in contrast to 42% of non-resident anglers. Additionally, seven fishing guides were encountered during the survey, all of whom were resident anglers, making up 10% of the resident anglers surveyed.

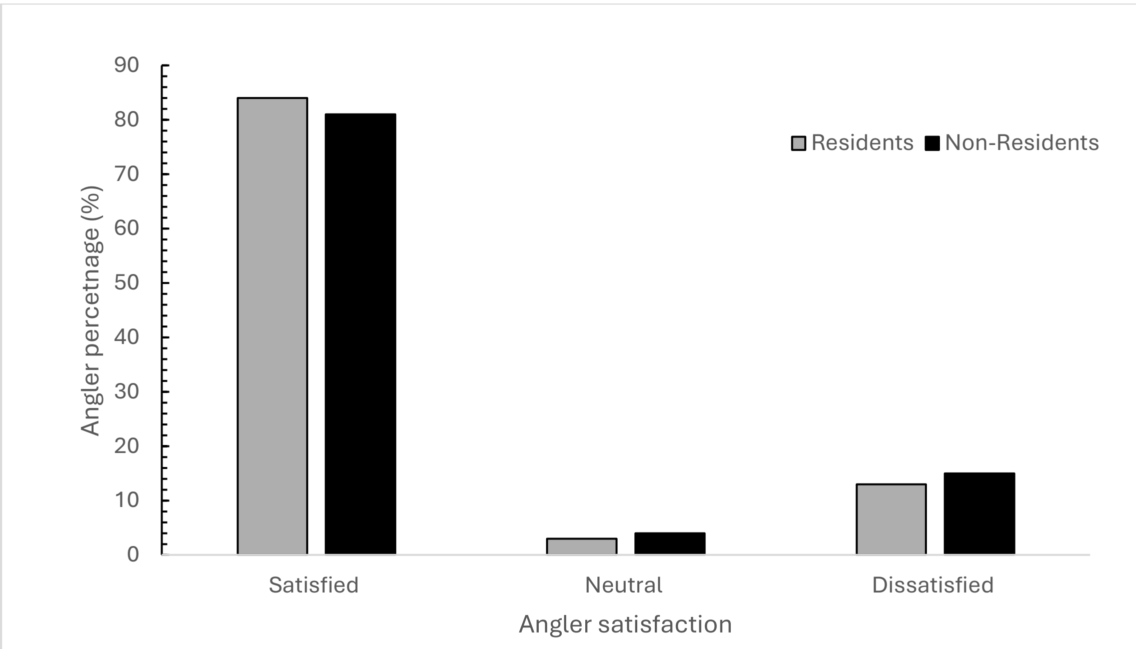

Figure 3: Satisfaction rate for anglers surveyed on Designated Waters during the 2023/24 season

Over 80% of both resident (84%) and non-resident (81%) anglers were satisfied with their fishing experience on the Designated Waters they were fishing that day when surveyed. Meanwhile, 15% of non-resident and 13% of resident anglers were dissatisfied with their experience. Additionally, 3% of resident and 4% of non-resident anglers were neutral, indicating they were neither satisfied nor dissatisfied.

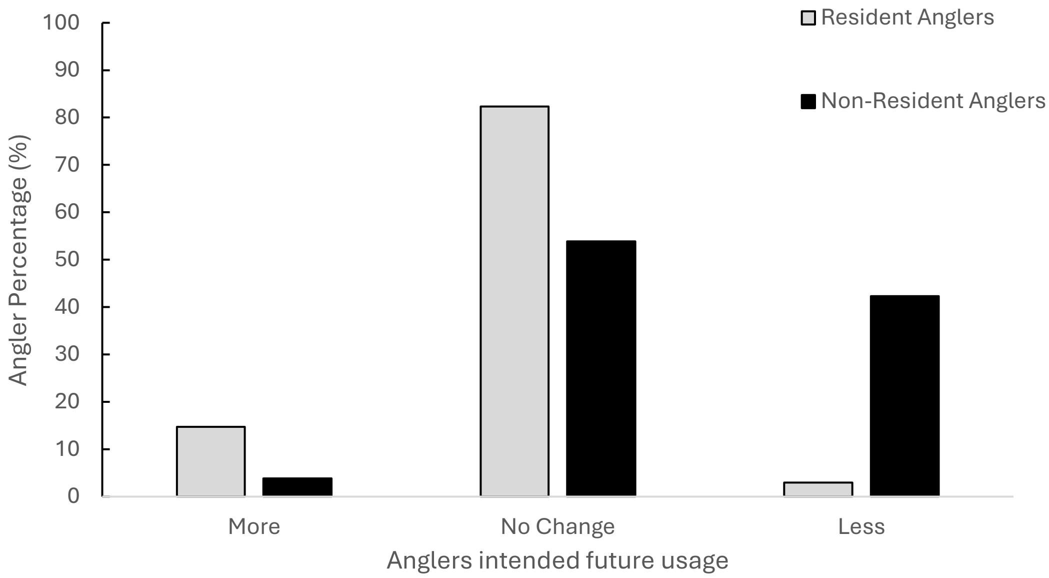

Figure 4: Angler intended usage in relation of the newly implemented Designated Water licence.

The survey revealed that 14% of resident anglers planned to fish the Designated Waters more frequently since the introduction of the Designated Waters Licence, while 4% of non-resident anglers indicated an increase in their usage. Conversely, only 3% of resident anglers stated they would fish these waters less, compared to 42% of non-resident anglers. The new licence made no change to the usage patterns for 82% of resident anglers and 53% of non-resident anglers.

When asked, "*Does the Designated Waters Licence make you more comfortable to make the trip to fish this river?*" 63% of resident anglers responded affirmatively, while 37% said it did not or that there was no change. Additionally, 71% of resident anglers said they would avoid certain rivers at certain times due to overcrowding, whereas 29% stated that overcrowding did not affect their river selection.

The rivers most frequently mentioned by anglers to avoid due to overcrowding were the Upper Oreti (17 mentions), Upper Mataura (15), Hunter River (8), Ahuriri River (6), and the Caples (4) (Table 3).

Table 3: Most frequently mentioned rivers that survey respondents said they avoid due to overcrowding.

River	Total mentions
Upper Oreti River (Southland)	*17*
Upper Mataura River (Southland)	*15*
Hunter River	*8*
Ahuriri River (CSI)	*6*
Caples River	*4*
Makarora River	*2*
Waikaia River (Southland)	*2*
Deans Bank (Clutha River)	*1*
Diamond Creek	*1*
Dingle Burn	*1*
Greenstone River	*1*
Moke Lake	*1*
Nevis River	*1*
Travers River (Nelson & Marlborough)	*1*
Upper Pomahaka River	*1*

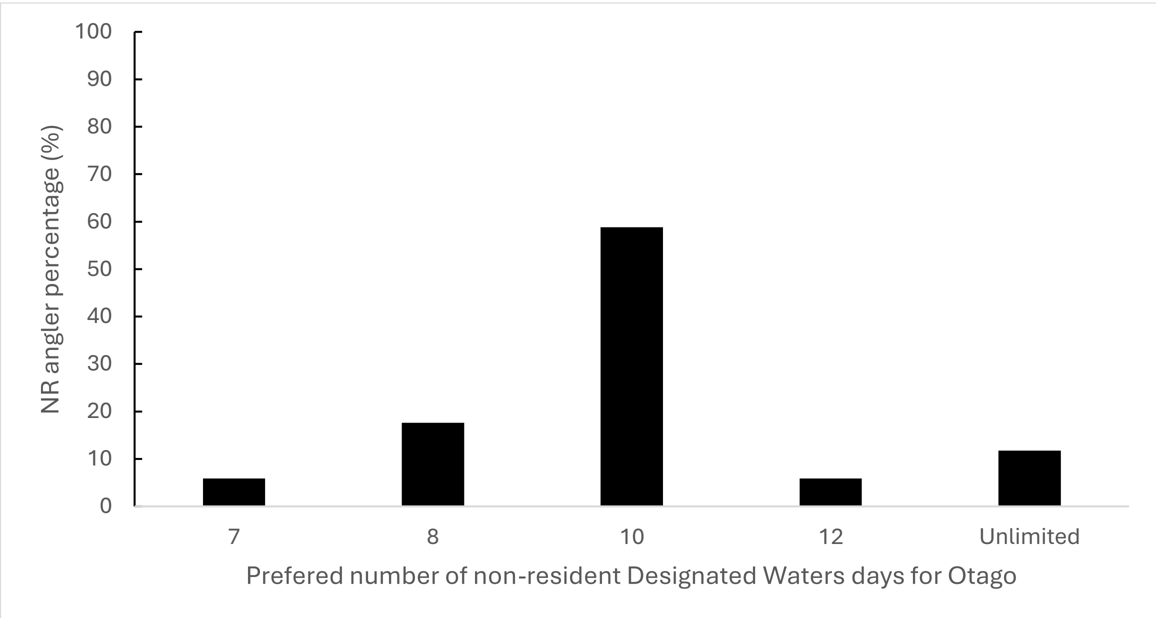

Figure 5: Preferred number of Designated Water days for the Otago region for non-resident anglers.

When surveyed, 65% of non-resident anglers expressed that five Designated Water days were insufficient for Otago's Designated Waters, while 35% indicated they were satisfied with 5 days. When asked about their preferred number of days, 58% of non-resident anglers preferred ten days, 17% preferred eight days, and 11% desired unlimited days similar to resident designated water licences. Additionally, smaller percentages suggested seven days (6%) and twelve days (6%) (Figure 5)

Sports Fishing Regulations Compliance
Rangers completed a total of 90 licence checks over 44 ranging days (Table 2), significantly more than the previous season's 35 licence checks over 20 ranging days. Of the anglers checked, 63 were residents (70%) and 27 were non-residents (30%). Five anglers were found to be without valid Designated Water licences, resulting in a compliance rate of 94% for the 2023/24 season.

Department of Conservation concessionaire compliance
Seven fishing guides were encountered during the 2023/24 season on Designated Fisheries. A total of 44 different fishing guides have been interviewed in Otago fisheries over the past nine seasons and all have had a valid concession.

Discussion
This season (2023/24) recorded the lowest beat occupancy for the Greenstone Controlled Fishery since 2020, with only 21% of available beats booked over the two months. The non-resident angler ratio also declined, dropping from 44% last season to 26%, marking the lowest year not affected by border closures or COVID-19 restrictions. During the COVID-19 years (2020/21), non-resident usage on the Greenstone Controlled Fishery did not exceed 10%.

Consistent with previous trends, beat 3 (6km stretch from Sly Burn confluence to beat sign upstream from Steele Creek confluence was the most booked, likely due to its accessibility). Reports of variable fishing conditions in the Greenstone may have made anglers hesitant to invest significant time and cost into accessing the upper beats.
The decrease in angler use of the Greenstone Controlled Fishery could be attributed to either the implementation of the Designated Waters Licence perceptions around the current state of the fishery. Anglers had mixed experiences, with some reporting excellent fishing in terms of size and quantity, while others noted low numbers and smaller fish sizes. To better assess the number and size of catchable fish, a proposed drift dive on the Greenstone River leading into the 2024/25 season could provide valuable insights.

The introduction of the Designated Waters Licence has influenced angler behaviour differently between residents and non-residents. Resident anglers increased their usage of Designated Waters by 14% and felt more comfortable making the often-extended trips to fish these rivers (63%). In contrast, 42% of non-resident anglers indicated they would fish the Designated Waters less, with only 3% of residents planning to decrease their usage. This trend is further illustrated by the percentage of non-resident anglers encountered throughout the season on Designated Waters, which was 27%. Only two rivers, the Dingle Burn and Young River, had a non-resident angler percentage higher than 50%, likely because the only anglers encountered on both rivers were guides with multiple non-resident clients (Table 2).

Overall, a high level of satisfaction was reported among both resident (84%) and non-resident (81%) anglers regarding their fishing experiences on Otago’s Designated Waters. Both resident and non-resident anglers were frequently happy to encounter staff and rangers on the riverside and were usually more than willing to answer survey questions, as they are often very invested in the management of these special rivers. The study conducted by Hayes and Lovelock (2019) found good levels of support for management mechanisms to control crowding from both resident and non-resident anglers. Non-resident anglers were more willing to pay for these management mechanisms, which likely explains why satisfaction levels remained high despite increases in licence prices and usage limitations.

Some of the dissatisfied anglers, both resident and non- resident, are likely those anglers that experienced overcrowding this season particularly opening day on the Hunter River and end of season on the Caples River. The total numbers of fish caught seemed to matter less than number of other anglers seen on the river when it came to anecdotal comments, many anglers were simply happy to be out in the back country.

A proposed post-season survey for Otago Designated Waters licence holders was cancelled to avoid survey fatigue, as four other Fish & Game regions had already sent out multiple surveys targeting Designated Water anglers. Additionally, the Otago Fish and Game Council was not considering any changes this year. Direct email surveys were however, conducted targeting two specific groups of anglers: those who reported fishing the upper Pomahaka River in the 2023/24 Lower Clutha angler survey and those who booked beats in the Greenstone River controlled fishery. This was done to gather more data for these specific rivers.

Angler compliance with the New Designated Waters regulations was 94% this season, with five anglers detected without valid Designated Waters licences. Three out of the five offenses were also only holding a day fishing licence, which would have also not been legal for the previous Backcountry regime. Compliance of fishing guides with valid concessions is also very high with no detection of illegal guiding occurring over the past nine seasons.

Planned work for 2024 – 2025

- Continue to monitor the Designated Waters and other pressure sensitive fisheries (subject to funding)
- Conduct a large-scale end of season survey for Otago's Designated Waters Licence holders
- Complete Sports Fishing Regulation training with Department of Conservation staff hut wardens (October 2024).
- Continue to liaise with Department of Conservation on concession monitoring and reporting.
- Drift dives on selected Designated Waters to assess fishery health and number of catchable fish (subject to funding)
- Increase public communications regarding Designated Waters and requirements needed to fish them.

Recommendation
That this report be received

Mason Court
Fish & Game Officer
July 2024

References

Hayes, S., & Lovelock, B. A. (2019). Angler displacement on and from pressure-sensitive rivers in Otago.

Trotter, H. 2016. COUNCIL REPORT AUGUST 2016. Backcountry Rivers Online Satisfaction Survey 2015-2016 Season. Fish & Game, Otago

Appendix

Table 4: Designated waters Ranging effort for 2023/2024 season

Dates	Location	Ranger	Days Ranging (incl access)	Total Anglers	Guides	Offences detected
9/01/2023	Nevis River	Mason	1	0	0	
23/10/2023	Nevis River	Mason	1	0	0	
1/11/2023	Dingle Burn	Mason	1	0	0	
1/11/2023	Wilkin River	Mason	1	0	0	
1/11/2023	Hunter River	Mason	1	12	0	
1/11/2023	Greenstone River	PVK	2	9	0	
1/11/2023	Caples River	Jakub	2	10	0	1x R no DW
3/11/2023	Nevis River	David	1	2	0	
10/11/2023	Nevis River	Ben	1	3	1	
19/11/2023	Young River	PVK	1	0	0	
20/11/2023	Caples River	Santillan	2	1	0	
20/11/2023	Greenstone River	Mason	2	4	0	
19/12/2023	Nevis River	Ben	1	4	1	
27/12/2023	Greenstone River	Fraser	2	3	0	2x NR no DW
01/01/2024	Caples River	Mark	1	1	0	
6/01/2024	Upper Pomahaka River	Jayde	2	0	0	
15/01/2024	Caples River	Mason	2	5	0	1x NR no DW
16/01/2024	Young River	David	1	3	1	1x R no DW
18/01/2024	Nevis River	Ben	1	1	0	
11/02/2024	Wilkin River	PVK	1	0	0	
14/02/2024	Nevis River	Ben	1	1	0	
27/02/2024	Wilkin River	PVK	1	0	0	
9/03/2024	Nevis River	Fraser	1	1	0	
5/05/2024	Wilkin River	PVK	1	2	0	
11/05/2024	Caples River	PVK	1	1	0	
24/02/2024	Nevis River	Ben	1	5	2	
26/05/2024	Greenstone River	Jason	2	3	0	
26/05/2024	Caples River	Jakub	2	7	0	
29/02/2024	Dingle Burn	Mason	1	4	1	
29/02/2024	Wilkin River	Mason	1	1	0	
29/02/2024	Hunter River	Mason	1	0	0	
29/05/2024	Hunter River	Ben	1	7	0	
29/05/2024	Dingle Burn	Ben	1	0	0	
30/05/2024	Young River	Ben	1	0	0	
30/05/2024	Wilkin River	Ben	1	0	0	

Sheet 1: Survey form for Designated Waters

DESIGNATED WATERS ANGLER QUESTIONNAIRE

Fish & Game New Zealand

ANGLER DETAILS

Name: ______________________ Date: ______________________

Fishing Licence Number: ______________ DW Licence Number: ______________

Designated Water: ______________ Licence Type: ________ Unguided/Guided/Guide

QUESTIONS

1. How many days have you spent fishing this river this season? How many more days do you intend to fish it?

____

2. How has the Designated Waters licence system influenced your usage of this river? (E.g., more, less)

____

3. Are you satisfied with your fishing experience on this river? Why/why not?

____

4. Have you fished/do you plan on fishing any of the other Designated Waters in this region? Which ones? How many days for?

____

____

5. NR only: For the Otago region, is Five DW licence days per season sufficient? Record preferred Number?

____

____

6. NR Only: What other waters have you been fishing or plan to fish?

____

____

7. Resident only: Does the DW licence make you feel more comfortable making the trip to fish this river?

____

____

8. Resident only: *Are there any rivers you won't fish, or avoid fishing at certain times, because they are too crowded?*

____

____

Project 1122 – Creel Surveys of Lake Hāwea

Executive Summary

Thirty-six randomised creel surveys were undertaken on Lake Hāwea over the months of September to May during the 2023 – 2024 fishing season to gather angler and fisheries information. One hundred and twenty anglers were interviewed totalling 189 hours of angling effort for a catch of sixty-three fish, which equates to one fish for approximately 2.9 hours fishing. Trolling, both deep and shallow, was the most popular method accounting for 47.5% of the overall angling effort and 42.9% of the total catch.

Spin fishing from the shore was more popular than last year, at 38.3%, with 42.9% of the total catch, the same numbers as caught by trolling. Fly fishing percentage has doubled since last year, with 14.2% of the angling effort, and fly anglers made up 14.3% of the total catch. No bait anglers were interviewed during the surveys. Rainbow trout were the main catch of most anglers, followed by brown trout and then salmon. Salmon catches were highest during November, with December having the highest salmon numbers last season.

1. Introduction

Lake Hāwea is located in the Otago region of New Zealand, at an altitude of 348 metres. Covering an area of 141 km^2 and reaching 392m deep, it is New Zealand's ninth largest lake. The lake holds populations of brown and rainbow trout and landlocked chinook salmon and is highly valued nationally and internationally for its sports fishing opportunities.

Creel surveys were undertaken on Lake Hāwea from 2014-2018 and summarised (Halford, 2018).

This report summarises the Lake Hāwea Creel survey results for the 2023 – 2024 season starting in September 2023 and finishing at the end of May 2024.

2. Survey Methodology

The survey was a randomised creel survey with a frequency of at least two surveys per week and two weekend days per month, with randomised starting times. The survey methodology meets the requirements of a randomised stratified roving creel survey (Pollock, et al. 1994).

Two weekdays and two weekend days were selected each month and morning and evening starting times were randomly selected.
Creel survey start times were either 0900 hours or 1200 hours.

A full schedule of survey days and start times was compiled. Surveys had to be completed within the four- or five-hour survey period. Volunteers were often used to support staff on the boat.

Creel survey sheets and a questionnaire were developed to document all the relevant information (Appendix 1).

Surveys were conducted using the Otago Fish and Game boat (OFG7), a 5.5-metre Kiwi Kraft with a 115hp four stroke Suzuki. Surveys circumnavigated the lake from a selected boat ramp. The direction of the trip was randomly selected. In windy conditions, the surveys were shore based, due to difficulty in approaching other vessels and safely mooring alongside. Staff would drive to popular land-based fishing areas and conduct angler surveys from the vehicle. Similarly, if boat trailers were not present at the two boat ramps (campground and the Neck) then the boat OFG7 was not launched, as no boats were present on the water.

On the lake all anglers were approached. Extra care and consideration were given when approaching shore anglers with the boat to ensure that they were not overly interrupted. This was achieved by beaching the boat a fair distance from their fishing position around the shoreline.

Some boat angler interviews were conducted while anglers continued to fish with the Fish & Game boat pulling alongside. Fenders were deployed from the Fish & Game boat, and boats were approached from our starboard side onto their port side to mitigate damage to either vessel.

Anglers were asked about their angling activity for the day along with a standard set of creel questions (Appendix 2). In addition, anglers were asked about their years of experience on the lake and how many days a year did they commonly fish the lake. Their fishing location was recorded (Appendix 1).

All fish harvested were weighed and measured (Appendix 3) and data collected was entered onto an Excel data base where it has been analysed for reporting.

3. Results and Discussion

A total of 120 angler interviews were obtained from thirty-six sampling periods. There were sixteen survey days during the duration of the creel programme for the 2023 – 2024 season in which no anglers were interviewed. Although not recorded, adverse weather conditions were noticeable this season compared to the previous. It is likely that of the sixteen days there were no anglers encountered, many of these would be due to high winds.

Most of the survey effort was in the lower third of the lake where our monitoring effort was focused. This was where most anglers were located.

The Neck and the western shoreline between the campground and the Neck were the most popular angling areas where fish were commonly caught. Some angling effort was focussed off the Timaru and Dingle Burn stream mouths when weather conditions allowed.

The total catch from the 120 anglers was sixty-three fish for an overall 189 hours of angling effort, significantly down on last year's (304.24). Anglers returned forty-eight fish, which was 76.2% of the total catch.

Eighty-eight (73.3%) anglers caught no fish during survey periods, almost identical to last year's survey (75.5%). Sixteen anglers had caught one fish when interviewed, eight anglers caught two fish each, and three anglers caught three fish. Five anglers had caught over three fish, with the highest catch from an angler trolling with a lead line, catching five fish.

4. Catch Rate

The Total Catch Rate (TCR) is calculated from the number of fish caught over the length of angling time. 189 divided by 63 fish = one fish for 3 hours angling effort or (.33) as fish per hour caught. This was fairly similar to last season, with one fish for 2.9 hours angling effort or (.35) as fish per hour caught.

Of the sixty-three fish caught, twenty-two were brown trout, twenty-five were rainbow trout, and sixteen salmon were recorded. The harvest rate (HR) is calculated from fish kept divided by total angling effort and shown as fish per hour.

Table 1. Total catch rates (TCR), return rates and harvest rate (HR) for each species.

Season	Species	Fish caught. (TCR)	Fish released (TCR) and % returned	Fish kept and (HR)
Sept 2022-May 2023 (inc)	Brown	15 (0.05)	12 (0.04) 80%	3 (0.009)
Sept 2023-May 2024 (inc)	Brown	22 (0.116)	17 (0.09) 77.3%	5 (0.03)
Sept 2022-May 2023 (inc)	Rainbow	65 (0.21)	31 (0.10) 47.7%	34 (0.11)
Sept 2023-May 2024 (inc)	Rainbow	25 (0.13)	19 (0.1) 76%	5 (0.03)
Sept 2022-May 2023 (inc)	Salmon	25 (0.08)	12 (0.04) 48%	13 (0.04)
Sept 2023-May 2024 (inc)	Salmon	16 (0.08)	11 (0.06) 68.8%	5 (0.03)

During the 1998-2001 seasons Scott & Wright (2007), recorded (TCR) for brown trout at 0.14, 0.14 and 0.10, respectively. For rainbow trout it was 0.10, 0.16 and 0.08 and for landlocked salmon TCR was 0.04, 0.01, and 0.04 for the respective years.

5. Catch Rate by Method

Table 2. Fish Caught and Catch Rate (CR) by method as fish per hour.

Year	Fish caught Fly (CR)	Fish caught Spin (CR)	Fish caught Surface Trolling (CR)	Fish caught Deep Trolling (CR)
Sept 2022-May 2023 (inc)	14 (0.05)	11 (0.04)	3 (0.01)	75 (0.25)
Sept 2023-May 2024 (inc)	9 (0.05)	27 (0.14)	13 (0.07)	15 (0.08)

Spin angling was the most productive method accounting for twenty-seven fish, and 42.9% of the total catch. Deep trolling including down rigger, lead line and paravane was next (23.8%) then surface trolling (20.6%). The remainder of catches was from fly anglers (14.3%).

Table 3. Total Angling effort for each Method

Year	Angler Numbers and (%) Time Fly fishing	Angler Numbers and (%) Time Spinning	Angler Numbers and (%) Time Surface Trolling	Angler Numbers and (%) Time Deep Trolling
Sept 2022-May 2023 (inc)	13 (7.1%)	60 (26%)	26 (16%)	92 (49.6%)
Sept 2023-May 2024 (inc)	17 (14.2%)	46 (38.3%)	18 (15%)	39 (32.5%)

Over the 2023-2024 season both spinning and trolling were the most popular methods (Table 3) and most productive (table 2) with spin fishing the standout method. Scott & Wright (2007) reported similar findings with trolling being the most popular method and between 57-68% of the angling effort for the three survey years from 1998 - 2001.

Fly fishing was only encountered in shallower areas of the Neck, and the delta of the Hunter River, making up 14.2% of angler effort.

Spinning around the shoreline was mostly concentrated near the dam and campground area at the bottom of the lake, and at the Neck. Spin angling was more popular this season than the previous. This is possibly due to windy conditions being more prevalent than last season.

6. Catch Details

Table 4. Provides the average length, weight and condition factor of each sports fish species recorded.

Year	Average Length (mm)			Average weight (Grams)			Average condition factor		
	Brown	Rainbow	Salmon	Brown	Rainbow	Salmon	Brown	Rainbow	Salmon
Sept 2022 -May 2023 (inc)	458	401.9	378	1290	920	764	47.9	51.9	50.3
Sept 2023 -May 2024 (inc)	418.6	412.7	339.3	860	816.7	518.2	41.9	42.8	47.6

In the 2023 – 2024 season six rainbow trout were weighed and measured. Five brown trout were measured but only four were weighed, as one of the fish had been gutted. Eleven salmon were measured, although nine of these were harvested by staff members outside of the survey days.
The length, weight and condition factors were all down from the previous season.

7. Summary

This was the second season out of three for surveying anglers on Lake Hāwea.

Half of the surveys were conducted by vehicle, and half by boat. This was either from adverse weather conditions making boating undesirable, or due to an absence of boat trailers at either of the two boat ramps.

Anglers overall seemed satisfied with angling on the lake, even though only 26.7% of anglers had caught fish when interviewed. Many anglers, however, had had told us of recent success on the lake during the interviews. A selection of anglers having poor results often were using poor techniques or fishing in unproductive areas, so staff would often redirect them to try and increase their angling success.

Catch rates varied over the season. Most noticeable was the catch rate of salmon, with nearly all salmon caught during the surveys occurring in November and December.
During mid-January to mid-March, trout catch rates plummeted, with successful anglers using downriggers and fishing in depths of up to forty metres.

Monitoring angling on Lake Hāwea provides current fisheries information over the three-year surveys. With next season, 2024-25, being the final year of the study, it will be valuable to compare the results from the 2022-25 studies with previous creel surveys on Lake Hawea (Halford, 2018). The 2024-25 Council report will compare this data to give a long-term insight into the fishing on the lake.

8. References

Halford, C. 2018. *Summer season angler surveys and compliance monitoring on Lakes Hawea, Wanaka, and Wakatipu*. Otago Fish and Game Council report

Pollock, K.H., Jones, C.M. and Brown, T.L. 1994. *Angler survey methods and their applications in fisheries management.* American Fisheries Society Special Publication 25.

Scott, D., Wright, M. 2007 *Thirty Years of Creel Surveys.* Otago Fish and Game Council.

Recommendation

The report be received.

Ben Sowry
July 2024

Appendix 1.

WATER : LAKE HAWEA **DATE:** **RANGERS:**

ANGLER DATA						SPORTS FISH DATA						Experience	
ZONE	LICENCE NUMBER	LICENCE CATEGORY	HOMETOWN	HOURS FISHED	METHOD	FISH KEPT			*FISH RETURNED*			# Seasons	Days / season
						B	RB	S	*B*	*RB*	*S*		

AS: Adult Season **AD**: Adult Day **FA**: Family Adult **FJ**: Family Junior **FC**: Family child **JS**: Junior season
CF: Child Free **LA**: Local Area **LS**: Loyal Senior **SB**: Short Break **LB**: Long break **NR**: Non-Resident

Appendix 2.

Lake Hāwea Survey - Angler Questionnaire

1. **How many hours have you fished today?**
2. **What fishing method are you using?**
3. **Have you caught any fish today?**
4. **Is this your first fishing trip on Lake Hāwea?**
5. **Or how many seasons have you fished Lake Hāwea?**
6. **How many days per season do you fish this lake?**

Appendix 3.

Lake Hāwea Fish Data Sheet

DATE	**Brown**		**Rainbow**		**Salmon**	
	Length	Weight	Length	Weight	Length	Weight

14.4

Development of a Salmonid Spawning Layer

Photo 1: Brown trout digging a redd in a previously un-surveyed Catlins tributary, identified by an early iteration of the spawning model.

Summary

A model of salmonid spawning habitat in the Otago Region has been created. The model was trained using the extensive Otago Fish & Game spawning database and records of juvenile salmonids from the New Zealand Freshwater fish database. The model has been ground tested over the summer of 2023-24, scrutinised by expert staff and found to perform well.

As the model is based on environmental datasets and predicts a biological activity, it is not perfect, however it appears to do an excellent job overall at predicting spawning habitat across a very large region. It is expected that the model will serve as a "living document", being improved over time as new data emerges.

The model can be explored here.

Defining Spawning water

Salmonid spawning occurs in flowing waterways throughout the Otago region but is concentrated in places with suitable gravel composition, flow profiles, and temperatures. Spawning requirements vary with the size of the fish, so there must be enough variability to accommodate different sizes.

The Otago region has four species of salmonids: brown trout, rainbow trout, brook char, and Chinook salmon. A fifth species, Atlantic salmon, is likely locally extinct. The spawning requirements of the four main species are likely to be similar although Chinook salmon are known to have stronger preference for spring or lake fed waterways and favour larger substrate sizes and faster flows. It's also likely that rainbows will be more affected by temperature and flow issues due to their later spawning period.

The need to identify spawning water

The need to produce a spatial database of spawning habitat has come from multiple work streams. Primarily, it is helpful to communicate the range of spawning habitat to stakeholders. An important aspect of this will be to support policy and planning work, such as the upcoming Otago Land and Water Plan process, the next sports fish and game management plan, and defining salmonid spawning areas under the Conservation Act.

Ideally, mapping spawning habitat would be conducted by ground survey alongside spawning surveys. However, spawning surveys are labour-intensive. Fish & Game staff can complete around 10 km of surveying in a day. Due to the size of the Otago Region and the small number of staff, ground surveying the whole region is unfeasible. Instead, models have been set up to extrapolate from publicly available records of juvenile salmonids and the extensive spawning database that Otago Fish & Game has built over many decades.

Alongside the Otago spawning modelling, there has been a National Fish & Game project to model spawning habitat nationally. As the timeframes of this project were unclear and relied on many external parties, Otago Fish & Game staff decided to push ahead with Otago-based modelling. The nationwide project is led by Dr Adam Canning of James Cook University. It is expected that Dr Canning's work will help to improve or supersede the model created by Otago Fish & Game staff.

Model design

Several methods to model spawning in the Otago region were trialled. The use of maximum entropy or Maxent (Phillips et al., 2006) based models fit our data the best. Maxent, based on machine learning principles, emphasises habitat variables that are good predictors and minimises those that aren't. This is important as habitat variables can contribute to species distributions in subtle and often non-intuitive ways. Maxent employs a technique that predicts species occurrences by finding the distribution that is most spread out or closest to uniform, while considering the limits of environmental variables at known locations (Baldwin, 2009). Another key requirement in choosing a model was our need for one which worked using “presence only” data. True absence data for spawning habitat is difficult to obtain, as even a spawning survey that didn’t find any evidence of spawning doesn’t mean an area is not potentially suitable for spawning, or that it won’t happen there in future.

Model Training

The model was trained using a list of waterway reaches defined as suitable for spawning (presence data). We confirmed whether a river reach was suitable for spawning in multiple ways:

- Salmonid redd (nest) presence recorded by Fish & Game staff (n=4,600).
- Presence of adult salmonids during spawning season (n=3,700). These salmonids were almost always present alongside redds. These records only added sections where redds could not be identified due to extremely low algal levels.
- Presence of juvenile salmonids the following spawning season (n=14,200 records). We defined this as salmonids 100mm or less, determined by communications with staff from around the larger organisation. There was consensus that this size class would be found close to their natal habitat. This data was sourced from the NIWA freshwater fish database.
- Fish and Game staff surveying a reach and providing a professional opinion on whether the site was suitable (n=76).

In practice, many of these observations occurred in the same reaches. Overall, 1,550 waterway segments were used as training presence data.

The model, trained with data from all salmonid species, can predict the spawning of these species due to their similar habitat preferences.

A limitation of the presence data is that the survey effort to obtain it was not randomised. The data is biased by location, as sites that are practical to access and closer to the organisations conducting electric fishing or spawning surveys are more likely to be sampled. There is also a further bias in that survey effort is more likely to be concentrated on areas assumed to be important, such as streams running into popular and prolific lake fisheries. There is no practical way to fix this bias, so it is recognised that models created from this dataset are likely to bias towards easy-to-access waterways and recognised fisheries.

Habitat data inputs

The key habitat dataset used to model salmonid spawning was the FENZ (Freshwater Ecosystems of New Zealand) river GIS database (J. R. Leathwick et al., 2010). This database consists of a line geometry with associated habitat variables, described in Appendix 1. The line geometry of FENZ matches that of RECv1 (River Environment Classification).
Several habitat variables were also taken directly from the RECv1 dataset (https://niwa.co.nz/freshwater/management-tools/environmental-flow-tools/river-environment-classification). The variables are defined in Appendix 2. These data were linked to the FENZ habitat models using the NZ river reach number.

There were limitations with these datasets, including:

- The habitat variables in these datasets are created by various ground-tested modelling techniques and are not entirely accurate.
- The data are stored at a relatively coarse level. Stream segments in Otago are 0.66 km on average, but can be as long as 7.6 km.
- Lines do not always follow waterways exactly, particularly in places where streams have been diverted.
- Some waterways are not present in the database, most apparent for spring-fed streams. A notable example is Bullock Creek in Wanaka, a recognised spawning habitat.
- Some waterways are not well depicted by the FENZ/REC GIS layer. Notably, the lower Kyeburn, Pig Burn, and the lower reaches of the upper Clutha which is sometimes inundated by Lake Dunstan.
- Braided river habitat is represented by a single line, meaning it is not well described by the models.

Model Testing

Initial modelling

The creation of the current iteration of the spawning layer consisted of multiple parts. The initial stages involved setting up a predictive model using only presence records from the national freshwater fish database (NZFFD (Stoffels, 2022)). This model was then informally tested by overlaying the Otago database of salmonid redds. We found that almost all recorded spawning occurred in areas the initial model predicted as suitable salmonid spawning habitat.

This result validated the method and showed that records of salmonids under 100 mm were a valid proxy for spawning habitat.

A key issue noted at this stage was that the modelling method, which uses presence-only data, can focus on variables that indicate survey effort rather than species presence. The main problem variable was the downstream distance to the coast ("DSDist2Coast", Appendix 1). This was an issue because previous electric fishing work tended to be clustered closer to the organisations that carried out the work (Fish & Game, Otago University, and DOC) and often targeted particular, mostly coastal species. This meant the initial models unreasonably penalised sites further from the coast despite other variables being suitable. The "DSDist2Coast" variable was removed in future models, which significantly improved them.

Second Stage

A second model was set up using data from both the NZFFD juvenile records and redd locations from the Otago spawning database. A small number of redds had their positions estimated by evenly placing the number of redds seen along the riverbed between the recorded start and end points. This was necessary for some older spawning surveys that only had start, end, and total number of redds, rather than GPS-marked individual redds. This method was only used when more recent spawning data was unavailable. Although not ideal, it appeared to be suitable for the scale at which the model operates.

Ideally, the model would have been finalised earlier, allowing the 2023/2024 summer programme to focus entirely on testing. Unfortunately, due to delays caused by the need to improve the model and enter historic spawning data, the summer work programme designed mainly to test the model also had to include work to fill out areas assumed to be spawning habitat but not identified by the model.

Second Stage – Testing

Figure 1 shows the Otago region and the Otago Fish & Game region, which are largely aligned except for north of the Waikouaiti catchment, which lies in the Central South Island Fish & Game Region. Overlaid on the maps are the 130 ground testing sites surveyed over the 2023-24 summer work programme. Data were entered directly into a phone application designed specifically for this project to allow for easier analysis. The data will be uploaded into the freshwater fish database in the future.

Sites were selected mainly by looking at areas without previous records of spawning or juvenile presence, with a slight priority given to sites likely to be spawning habitats. This selection was informed by staff knowledge and previous models.

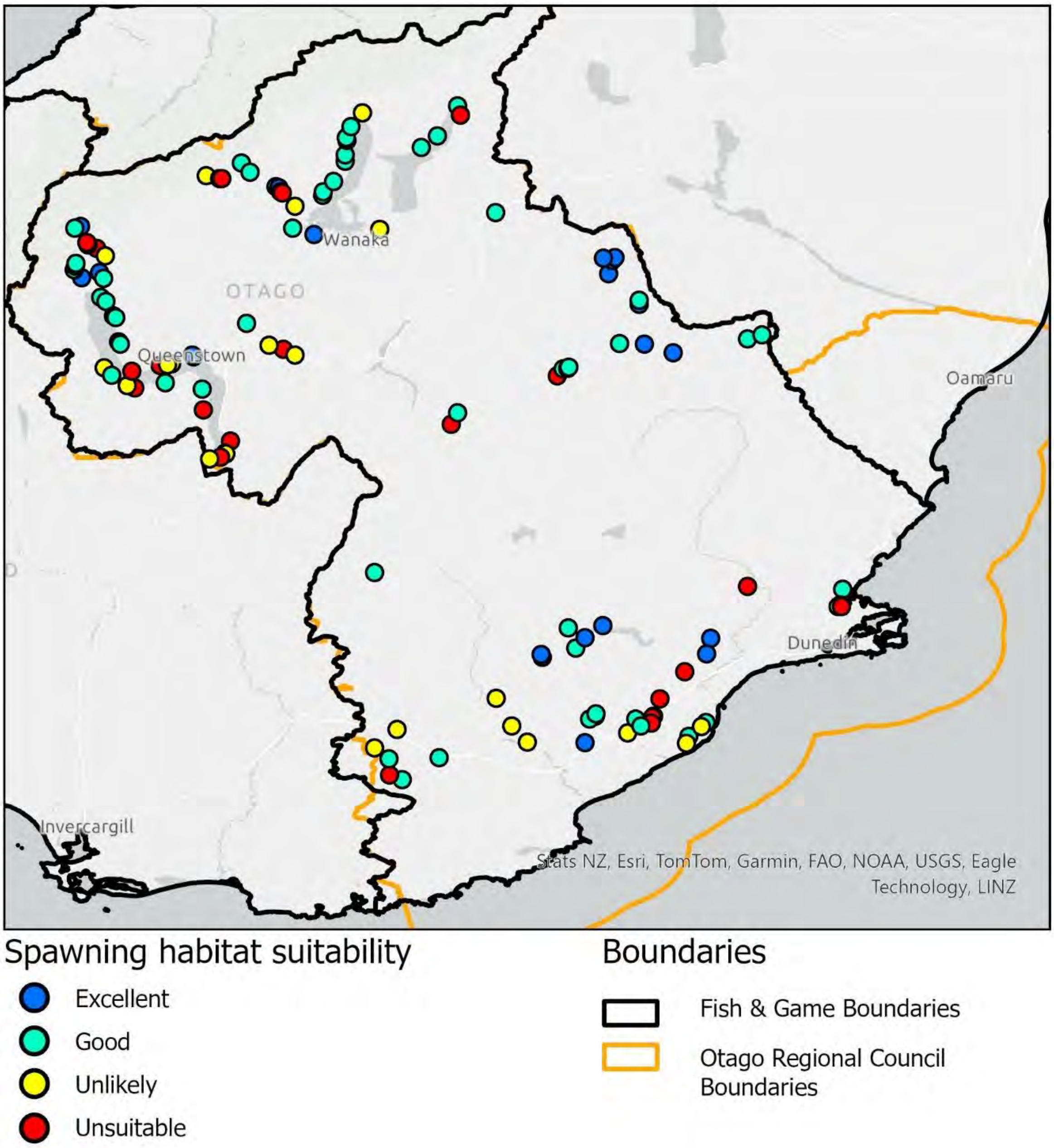

Figure 1: Map showing the sites that were assessed for spawning suitability (n=130) in the 2023-24 ground testing program

The coloured dots in Figure 1 show the staff assessment of how suitable each site was for spawning. The total number in each category is noted in the axis titles of Figure 2 below. Figure 2 also shows the average value and variation in model output for each spawning suitability band that staff categorised.

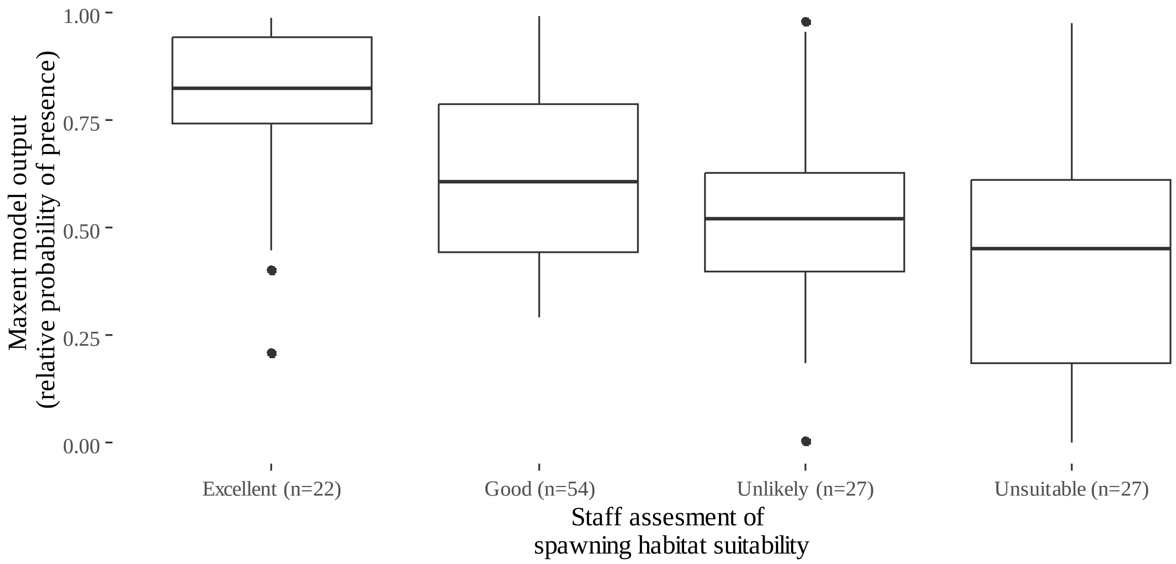

Figure 2: Staff assessment of a water ways suitability for spawning against the output of the second round of modelling.

The ground testing aligned well with the model, as the highest-rated spawning habitat categories had the highest median model outputs, and this pattern continued sensibly into the lower categories. This provided further evidence of the method's suitability for modelling spawning habitat in Otago.

Despite the overall fit of the staff assessments against the second-stage model, there was variability in outputs across each category. Lower model outputs in the higher categories could generally be attributed to issues with the modelling process, which were addressed in subsequent iterations. Conversely, higher model outputs in the lower categories were often due to staff identifying a reach as poor spawning habitat, typically because of a known downstream barrier—a factor not well-modelled by this process. Another contributing factor was low flow on the day of the survey; however, many of these sites are expected to have better flow during winter or spring, when most salmonid spawning occurs.

Of the 130 sites assessed for spawning habitat suitability, 95 were also electric fished. Reasons for not electric fishing a site varied, but generally included unsuitability due to low flow or inability to arrange access to the land in time. Table 1 shows the total number of sites where each juvenile species was detected.

Table 1: The number of sites that were electric fished in summer 2023-24 with the number that had salmonids present.

Variable	Number of Sites
No juvenile salmonids present	22
Juvenile brown trout present	56
Juvenile rainbow trout present	28
Juvenile brook char present	3
Juvenile Chinook salmon present	0
Any juvenile salmonid present	73
Total number of sites electric fished	**95**

Just over three-quarters of the sites that were fished contained juvenile salmonids, with brown trout being found at the majority. Unfortunately, no juvenile Chinook salmon were found across the summer.

The presence of salmonids was tested against the output from the second round of modelling, as shown in Figure 3.

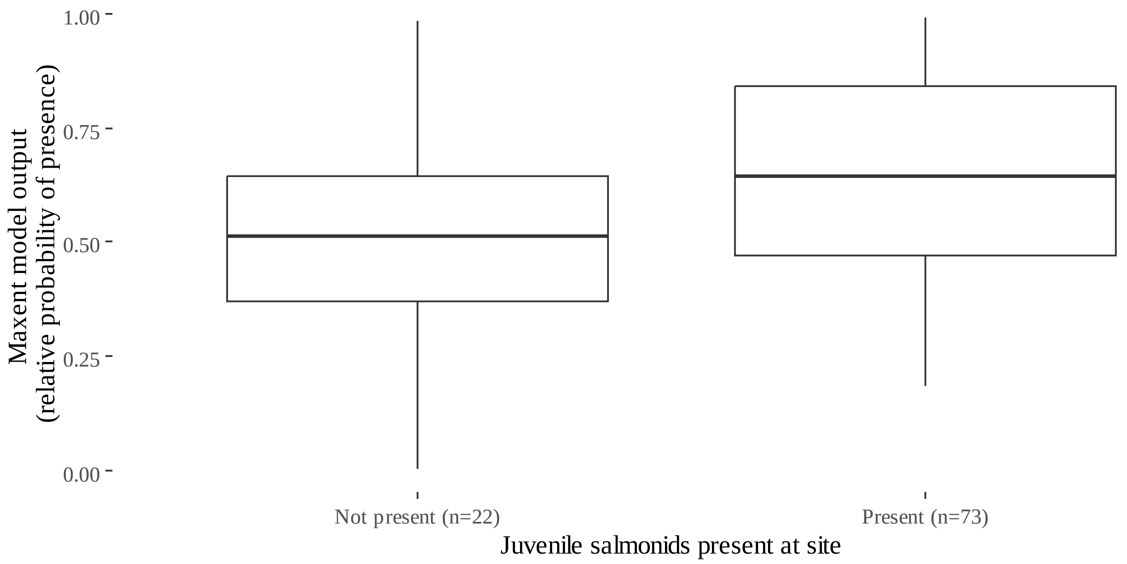

Figure 3: The presence of salmonids at ground testing sites against the output of the second round of modelling.

Comparing the model output to the presence of juvenile salmonids presented more challenges than the staff suitability assessments, as there were several reasons why juveniles were not found despite favourable habitat characteristics. One key factor was the scale of the ground testing project, which meant that some sites couldn't be electric fished until late in the season. During this time, juveniles may have moved downstream for growth or been displaced by floods.

Despite juvenile presence not being as suitable for model testing as staff assessments of habitat suitability, it provided additional evidence of the method's effectiveness, contributed to staff assessments, and enhanced understanding of salmonid presence across the region.

Final Model Creation

Key issues with previous models

Previous stages of model creation identified issues with juvenile and spawning records being incorrectly allocated to river sections. This was addressed in the final model by manually verifying records that corresponded to very low flows in the FENZ dataset and low outputs from previous models. The main issue often stemmed from GPS points being closer to nearby minor tributaries (see Figure 4), particularly notable during helicopter surveys.

Figure 4: Screenshot showing two redds marked in red, overlaid with waterway shapefiles labelled with their modelled flow. Note that the more southern redd would have been incorrectly allocated to the very small tributary below it in earlier models.

Models were tested by removing some variables, focusing on those likely to be highly correlated. However, removing variables did not improve the models, so the advice of Elith et al. (2011) was followed. This paper outlines that the machine learning process reduces the effect of correlated variables by amplifying important ones, suggesting no need to remove variables unless they are biologically irrelevant.

Model parameters

Feature classes (the types of relationships allowed: lineal, quadratic, product, threshold and hinge) were assessed in multiple iterations of the models. Restricting the number of feature classes didn't appear to significantly improve the models. As our number of presence sample reaches (n=1,549) is far higher than the minimum of 80 suggested in Merow et al. (2013),all feature classes were retained for the final model.

The modelling requires a prior assumption about the percentage of stream lengths that contain spawning. This relied on staff expertise based on multiple spawning surveys around the region. Adjusting this factor made very little difference to the model output. Various percentages were tested, with five percent selected for the final model as it provided the output that fit testing data the best.

The final crucial modelling variable is the regularisation parameter. Regularisation smooths the models, reducing the risk of overfitting to the training data and mitigating biases in the collection of presence data. Essentially, this means the model fits the data trends rather than the noise in the data. A regularisation parameter of four was chosen for the final model. This parameter balances the overall precision of the model (expressed as AUC, described below) with ensuring that individual habitat variables contribute sensibly to the model without fluctuating wildly.

Final Model Assessment

Figure 5 presents an ROC curve (receiver operating characteristic curve) illustrating the model's performance across different thresholds. Traditionally, an ROC curve assesses how well a model distinguishes between presence and absence points. However, since our model uses presence-only data, it distinguishes between presences and the background data, which could also be suitable for spawning. Therefore, the model is not expected to completely differentiate between these types even under optimal conditions.

The y-axis (sensitivity) indicates the model's ability to correctly identify a spawning reach at a specific threshold. The x-axis (1-specificity) shows how much of the background is identified as spawning at that same threshold. For instance, a green circle on the chart suggests that to correctly identify 90% of spawning grounds, approximately 30% of the total reaches in the region need to be identified.

The model was validated using a random 5% of sample and background points, with their classification shown in red, while the remaining 95% of training data is depicted in red. For comparison, the curve for a model that randomly guesses whether a reach contains spawning is shown in black.

The area under each curve (AUC) is also provided. As stated in Merow et al. (2013), "AUC is interpreted as the probability that a randomly chosen presence location is ranked higher than a randomly chosen background point."

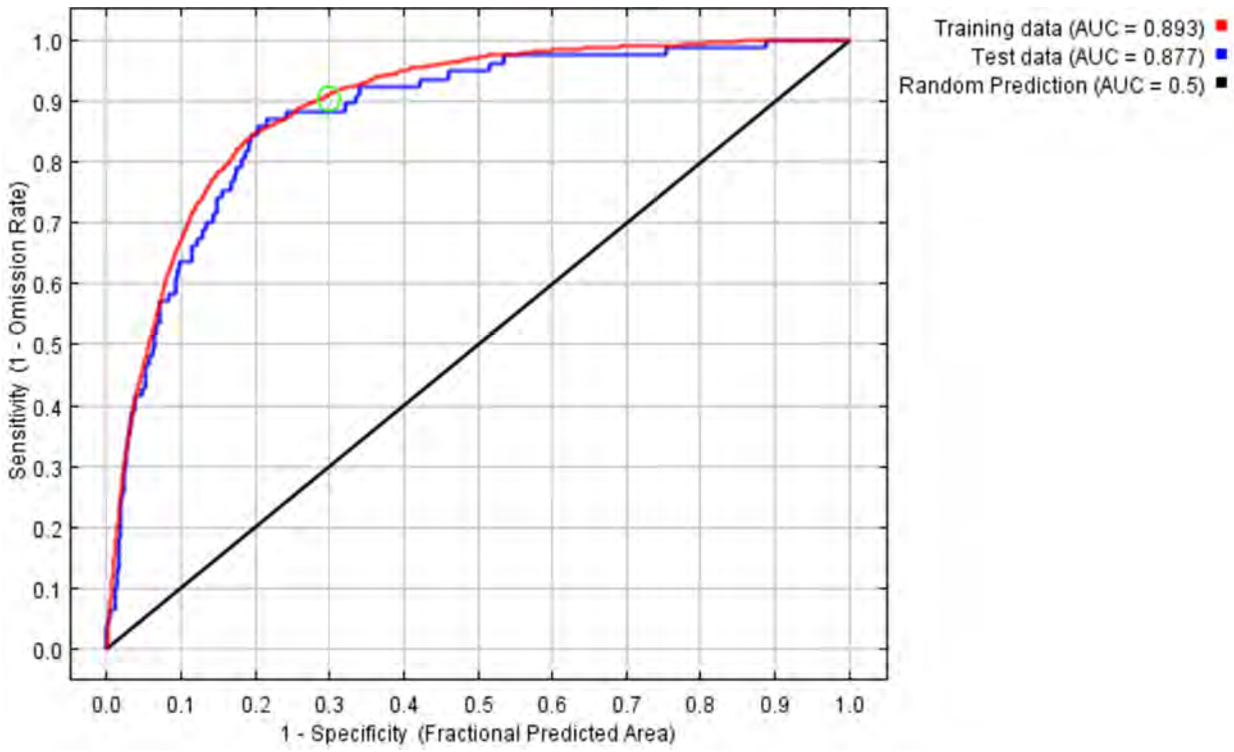

Figure 5: ROC curve for the finalised model.

The curve shows that overall the model performs exceptionally for a presence only based model. AUC reached as high as .904 in a similar model without a regularisation multiple (smoother), however this model was chosen as a good balance.

Figure 6 illustrates the relative importance of each environmental variable in the final model. The values, shown as "Regularized training gain," indicate how well each model can differentiate between the presence and background records. For example, seg flow has a regularized training gain of 0.7. As this is a logarithmic value, it converts to 2.01 ($e^{0.7}=2.01$), meaning the model based solely on flow is twice as likely to correctly allocate spawning reaches compared to random chance. The regularization factor, discussed earlier, is applied here to prevent the model from overfitting.

The most influential factor was the flow of the reach, followed by the stream order (as explained in Appendix 2). Since many flow variables scored highly, it suggests that the size, velocity, and stability of a waterway are crucial factors in determining its suitability for spawning, albeit complicated by correlations among flow variables.

Among the environmental variables, the maximum slope downstream of the section and the prevalence of pasture upstream of the section had the most significant impact on model gain when omitted. This reduction in gain indicates that these variables provide unique information not captured by other variables.

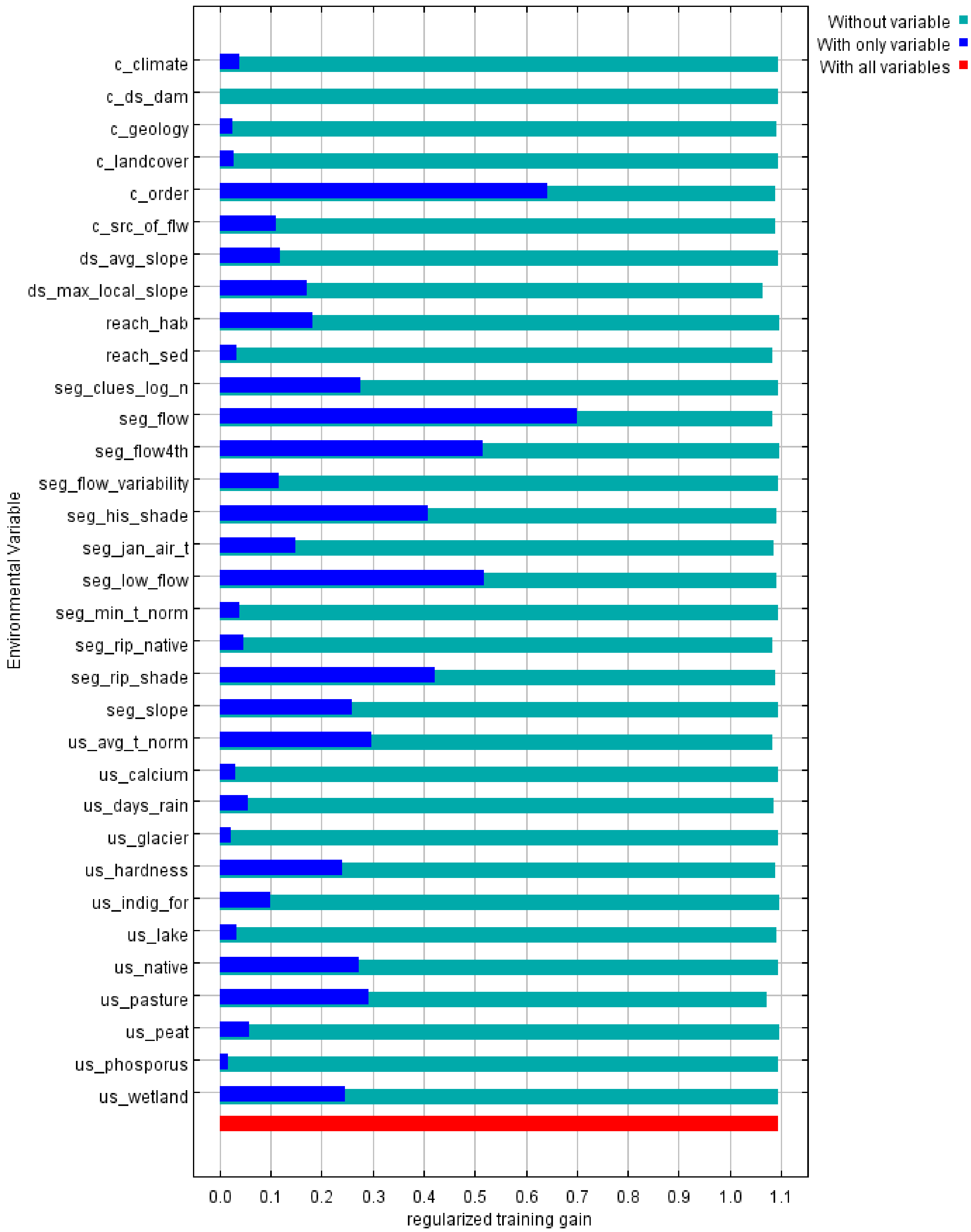

Figure 6: Jackknife chart illustrating the importance of each environmental variable. Teal bars indicate the model's performance when each factor is removed, while blue bars represent the effectiveness of a model created by adjusting only that variable. Note that some variables are prefixed with "c_" to denote they are categorical variables.

Figure 7 presents a series of charts, each showing a model set up with only one environmental variable. This setup provides insight into how each factor contributes to spawning habitat independently of other variables and their correlations. The high values near 1 on the Y-axis indicate the model predicts a higher probability of encountering conditions suitable for spawning, while low values near 0 suggest a lower probability of suitable conditions based on that specific environmental variable. The values are relative, so actual numbers are less important than the patterns shown in the charts (increasing, decreasing, peaking for example).

Overall, the results generally align with intuition. For instance, the model output from a low maximum downstream local slope starts at a moderate value, increases as the distance above swampy low-lying areas grows, and then decreases at higher values in very steep waterways that likely impede trout passage or lack suitable physical characteristics.

Some variables exhibit patterns that may seem counterintuitive, which can sometimes be explained by the characteristics of the main stem of the Clutha/Mata-Au. Despite not matching traditional spawning stream characteristics (shallow, stable, clear), the river between lakes Wanaka and Dunstan and below Roxburgh Dam are significant spawning locations.

Both Figure 6 and Figure 7 highlight an interesting finding: the presence of a dam downstream surprisingly had minimal influence on the model. Waterways without downstream dams received only slightly higher model outputs than those with dams present. This is likely due to a significant proportion of Otago's waterways lying upstream of dams, particularly upstream of Roxburgh Dam, and the presence of salmonid populations in dammed reservoirs that seek spawning locations.

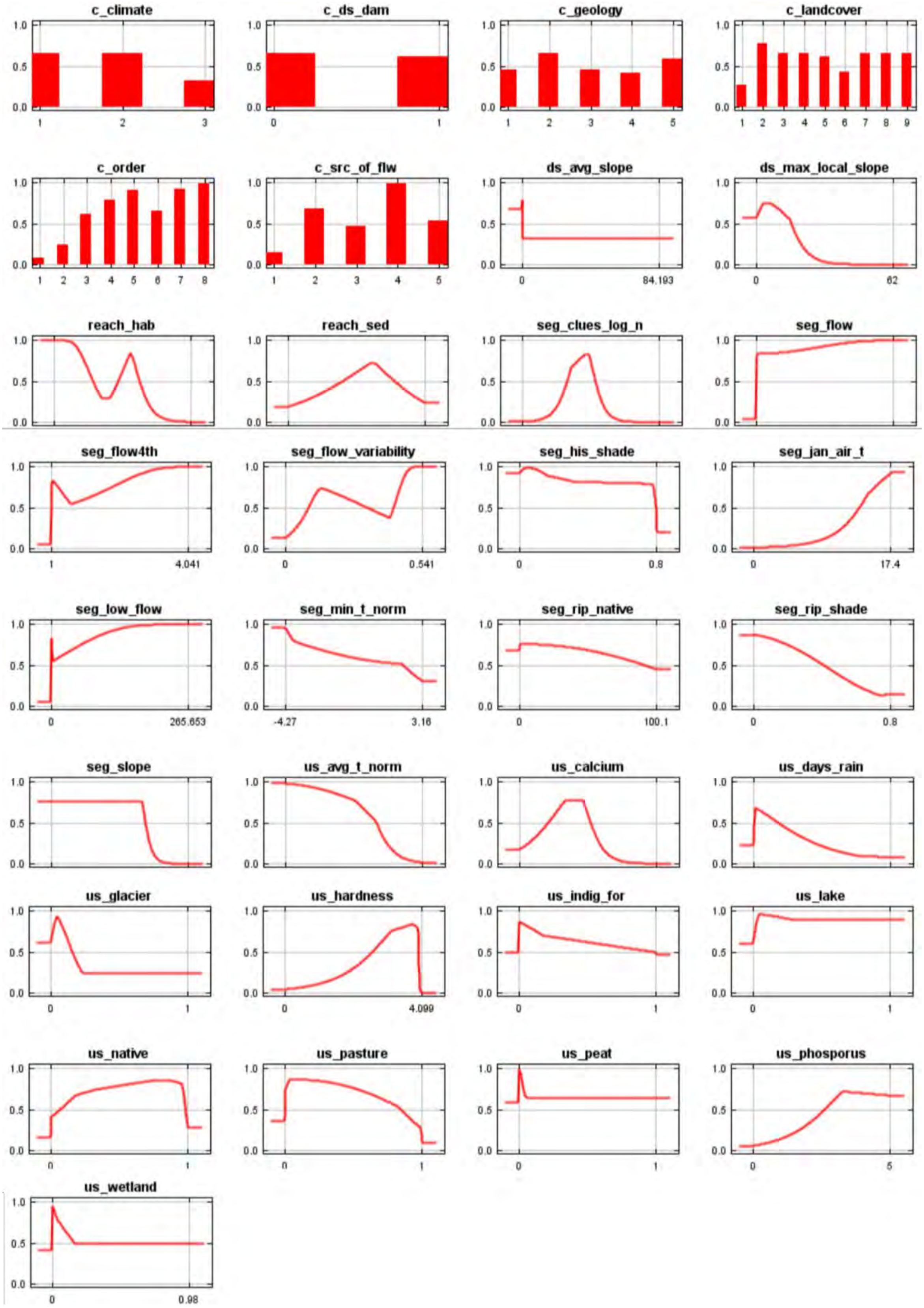

Figure 7: Charts showing how each variable contributes to model output.

Model Example

Suitability bands

The reaches have been color-coded: red indicates a high probability of being suitable spawning habitat, while yellow indicates a medium probability. It is estimated that the red sections will encompass approximately 60% of the suitable spawning reaches, with an additional 30% covered by the yellow sections. This calculation assumes unbiased habitat sampling for model creation and accurate underlying datasets.

The red reaches cover just under 10% of waterways in the region, and including the yellow sections extends this coverage to a further 15%.

Example of model

The model's detailed output is best viewed online due to the size of the Otago Region. You can access it via the following link (Link Here), however an example of the model output is shown in Figure 8.

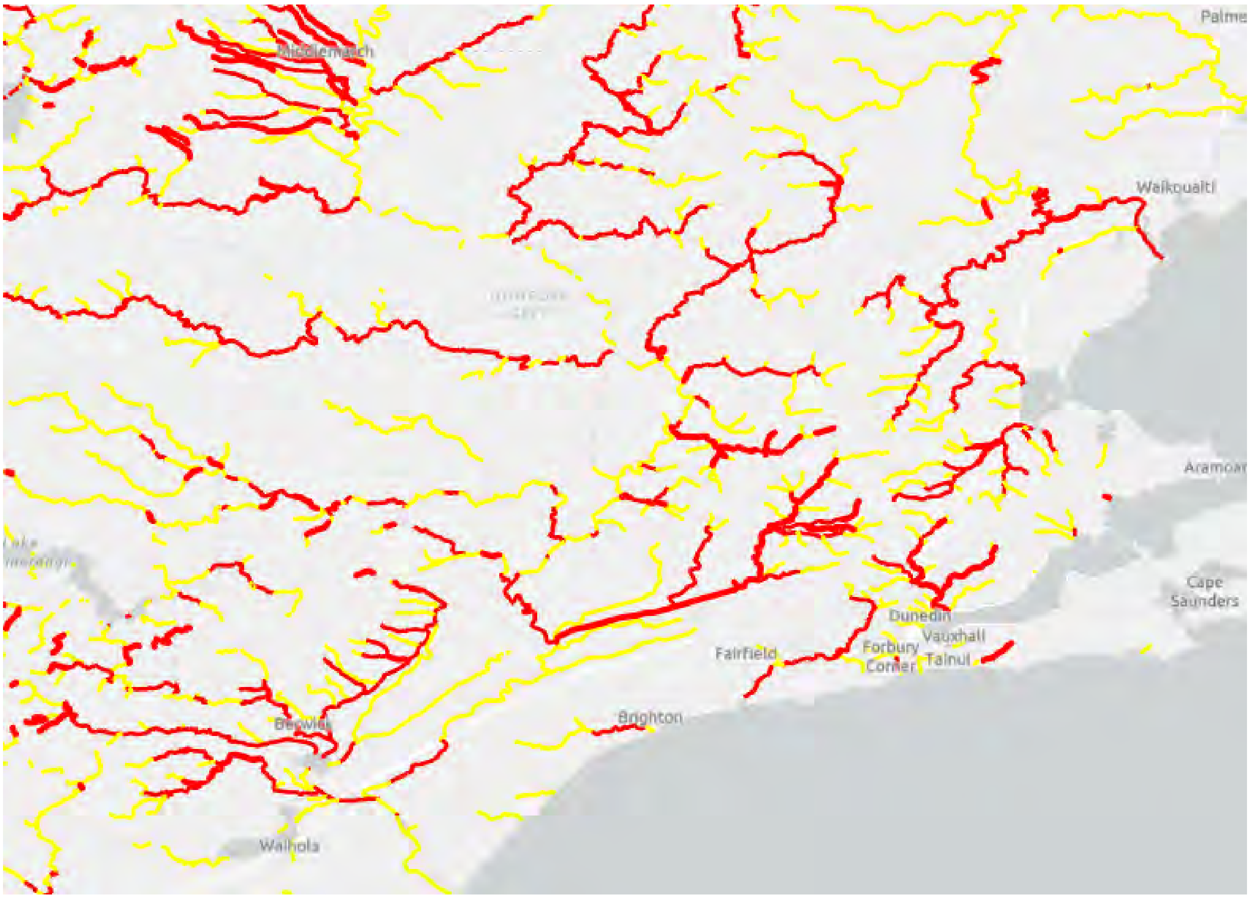

Figure 8: Example output of the spawning model. Dunedin to Middlemarch area.

Discussion / Summary

Overall, the modelling work effectively portrays the extent of spawning habitat in the Otago Region. This conclusion is supported by several validations: excluding portions of the training data, ground testing, subsequent spawning surveys, and statistical analyses have collectively affirmed the model's accuracy. Continued improvement is anticipated as more data becomes available. It is important to acknowledge several limitations of the final model, which have been addressed in various ways:

Salmonid Barriers

There are numerous salmonid barriers throughout the Otago Region, often crucial for protecting vulnerable and important galaxiid populations from salmonids. The model partially addresses this by using the maximum downstream slope value, which penalises waterways with steep sections below them. Some barriers may have suitable spawning habitat characteristics but remain free of salmonids. Conversely, some barriers do have salmonids above them due to various reasons. Deciding whether a reach above a barrier is suitable for spawning and whether barriers should be maintained, improved or removed requires collaboration with key stakeholders.

The influence of rearing habitat

As the model is trained on juvenile presence data as well as adult spawning data, it consequently models juvenile rearing habitat to some extent. Rearing habitat is similar to spawning habitat and generally occurs in similar areas. Only salmonids under 100mm have been used for training, so this is not likely to drastically affect the model, especially given the spatial scale of the underlying datasets.

Braided rivers

The dataset for braided rivers is not well-suited for our purposes because they are represented by single lines. Spawning in braided rivers primarily occurs in springs and stable braids that shift with floods, appearing and disappearing across the braid plain. To account for this dynamic, polygons representing the probable spawning range have been positioned around braid plains.

Spring Fed Creeks

On average, spring-fed creeks provide better spawning habitat than non-spring-fed creeks, primarily due to their stable flow conditions. Unfortunately, spring-fed creeks are *not well* represented in the underlying datasets and consequently do not score well in the model, largely due to their low stream order and lack of training data. To address this gap, manual additions of important spring-fed spawning streams have been included. These additions encompass streams like Welcome Stream (Waitaki tributary), Diamond Creek (Rees), and Bullock Creek (Lake Wanaka). However, this list does not encompass all significant spring-fed streams and will require ongoing updates.

As a result, users of the model should take a precautionary approach when considering spawning in spring-fed creeks, as the model is more likely to provide false negatives in that context.

Waterways poorly mapped by the datasets

Several waterways have discrepancies between their actual positions and the shapefiles used in the model. To rectify this, these discrepancies, such as those found in the lower Kyeburn, sections of the Pig Burn, and the Kakanui River near State Highway 1, have been manually adjusted to align with their true geographical locations.

Site with previously surveyed spawning or juvenile salmonids

Care has been taken to avoid setting the model threshold for defining spawning too low, as this would cause it to identify an excessive area as potentially suitable for spawning. While this is likely to be more accurate, it would also be uninformative. To prevent this, the thresholds for defining areas have been set conservatively. Consequently, some areas with confirmed juvenile or spawning presence have not met the model's thresholds. To remedy this, an overlay layer marks these locations as confirmed spawning sites despite not being recognised by the model. This layer can be toggled to see its extent.

Multiple species

As the model is trained on data from all species and their spawning habitat preferences are similar, its output can be used to predict the spawning area of all the species, this does however require a knowledge of whether the species are present.

The model was trained on Chinook salmon data but only to a limited extent, only 0.6% of juvenile records were for Chinook. Salmon spawning requirements are notably different to the other salmonids, having a stronger preference for spring or lake fed waterways and favouring larger substrate sizes and faster flows particularly for large sea run salmon. The salmon fishery is at historically low levels in the lower Waitaki, the lower Clutha River Catchment and the Southern Lakes, meaning that protection of spawning is crucial to the return of these species and potentially their long-term survival. Despite this, the understanding of the extent of salmonid spawning grounds is limited, although improving. Its assumed that the model does model salmon spawning habitat to an extent, but that a manual process would improve the dataset.

Acknowledgments

Thanks to the Otago staff particularly Steve Dixon, Ben Sowry and Mason Court, who put in a huge effort over the summer to ground test the modelling work. Thanks also to Dr Adam Canning, Matt Kavermann, Adam Daniel and Nigel Paragreen, who provided datasets, advice and expertise on spawning habitats, modelling and ground testing.

Recommendation

This report be received.

Jayde Couper
Fish & Game Officer
July 2024

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Appendices

Appendix 1: Description of FENZ database attributes, reproduced from (J. R. Leathwick et al., 2010)

Field	Description
NZREACH	The unique identifier associated with each REC segment
SegJanAirT	Summer (January) air temperature (degrees C) – used in the absence of robust estimates of water temperature
SegMinTNorm	Average minimum daily air temperature (degrees C) normalised with respect to SegJanAirT – negative values indicate strongly seasonal climates and positive values indicate weakly seasonal climates
SegFlow	Mean annual flow (m3/sec), derived from hydrological models, provided by Jochen Schmidt, NIWA, 2006
SegLowFlow	Mean annual 7-day low flow (m3/sec), derived from hydrological models, provided by Jochen Schmidt, NIWA, 2006 – see http://wrenz.niwa.co.nz/webmodel/ for details.
SegFlow4th	4th root transformed mean annual 7-day low flow, i.e., (low flow+1)0.25, accommodates the strong skew in distribution of values when fitting statistical models, values are approximately linearly related to flow velocity
SegFlowVariability	Ratio of annual low flow/annual mean flow – indicates long-term stability of flow through the year
SegSlope	Segment slope (degrees), derived from GIS calculation using length and difference between upstream and downstream elevation for each segment
SegSlopeSqrt	Square-root transformed segment slope (slope +1)0.5
SegRipShade	Riparian shading (proportion), the likely degree of riparian shading derived by using national, satellite image-based vegetation classification to identify riparian shading in each segment, with the degree of shading then estimated from river size and expected vegetation height
SegHisShade	Estimated shade assuming complete vegetation cover as could be expected during pre-human conditions

Field	Description
SegRipNative	Proportion of native riparian vegetation within a 100 m buffer of the river, calculated using landcover information contained in version one of the Landcover Database (LCDB)
SegCluesN	Nitrogen concentration (ppb) as estimated from CLUES, a leaching model combined with a regionally-based regression model, implemented within a catchment framework (Woods et al., 2006)
SegCluesLogN	Log_{10} transformed values of nitrogen concentration
DSDist2Coast	Distance to coast (km), from mid-point of each river segment, recomputed in Hamilton and differing from the original REC estimates of downstream distance that were computed from the upstream end; change made so values indicate average distance from a segment to the coast, rather than the maximum
DSAvgSlope	Average slope (degrees), from mid-point of each river segment to the coast, differing from the original REC estimates of downstream slope that were computed from the upstream end; change made so values indicate average slope from within a segment
DSAvgSlopeSqrt	Square root transformed values of DSAvgSlope , i.e. (slope+1)0.5.
DSMaxLocalSlope	Maximum downstream slope (degrees), local slopes at 100m intervals along each river segment where calculated and maximum value encountered recorded. Each segment was traversed downstream from its mid-point to the coast to identify the maximum downstream value encountered
DSDam	Presence of downstream obstruction (mostly dams) are indicated by a ‘1’, absence by a ‘0’.
USAvgTNorm	Average air temperature (degrees C) in the upstream catchment, normalised with respect to SegJanAirT, with negative values indicating colder (higher elevation) headwaters than average, given the segment temperature, and positive values indicating warmer temperatures

Field	Description
USDaysRain	Days/year with rainfall greater than 25 mm in the upstream catchment to indicate the likely frequency of elevated flows, rainday frequencies were provided by Brett Mullan (NIWA) and were derived by averaging across estimated daily rainfalls over the 10 year period from 1990 to 2000 – indicates short-term stability of flow through the year
USAvgSlope	Average slope in the upstream catchment (degrees), describes catchment-driven modification of flow variability
USCalcium	Calcium concentrations in surface rocks using values derived from the underlying LENZ layers – refer LENZ documentation for details
USHardness	Average hardness (induration) of surface rocks using values derived from the underlying LENZ layers – refer LENZ documentation for details
USPhosporus	Phosphorus concentrations in surface rocks using values derived from the underlying LENZ layers – refer LENZ documentation for details
USPeat	Flow-weighted area of peat in upstream catchment (proportion)
USLake	Lake buffering in the upstream catchment, computed as described in the original REC manual
USWetland	Flow-weighted area of wetland in upstream catchment (proportion)
USIndigFor	Flow-weighted area of indigenous forest in upstream catchment (proportion), computed using cover estimates from LCDB1
USNative	Flow-weighted area of indigenous vegetation in upstream catchment (proportion), computed using cover estimates from LCDB1
USPasture	Flow-weighted area of pasture in upstream catchment (proportion), computed using cover estimates from LCDB1
USGlacier	Flow-weighted area of glacial cover in upstream catchment (proportion), computed using cover estimates from LCDB1

Field	Description
ReachSed	Weighted average of proportional cover of bed sediment using categories of: 1– mud; 2–sand; 3–fine gravel; 4–coarse gravel; 5–cobble; 6–boulder; 7–bedrock, predicted from a boosted regression tree model – details of model fitting are provided in (J. Leathwick et al., 2008)
ReachHab	Weighted average of proportional cover of local habitat using categories of: 1– still; 2–backwater; 3–pool; 4–run; 5–riffle; 6–rapid; 7–cascade, predicted from a boosted regression tree model – details of model fitting are provided in Leathwick et al. (2008)
Shape_Length	Segment shape length in metres as computed by ArcGis

Appendix 2: Description of REC database attributes, reproduced from (Snelder et al., 2004)

Field	Description
Climate	The climate classification procedure is based on two pieces of information, Mean Annual Temperature and Effective Rainfall. 1: Cool- dry 2: Cool- wet 3: Cool- extremely wet
Geology	The classification procedure for the Geology factor was based on an assessment of catchment rock type using the New Zealand Land Resource Inventory (LRI) database. 1: Alluvium 2: Hard-Sedimentary 3: Miscellaneous 4: Soft-Sedimentary 5: Volcanic-Basic
Landcover	The Land-Cover classification was based on information derived from the New Zealand Land Cover Database (LCDB). 1: Bare-Ground 2: Exotic-Forest 3: Indigenous-Forest 4: Miscellaneous 5: Pastoral 6: Scrub 7: Tussock 8: Urban 9: Wetlands
Order	A measure of stream or river size defined by the degree of branching in a drainage system. For example, a first-order stream has no tributaries, while a second-order stream has at least two first-order tributaries. A third-order stream must have at least 2 second-order tributaries (LAWA).
Src_of_flow	The classification of the Source-of-Flow factor for each river section was based on two sets of information: an estimate of the distribution of rainfall within the upstream 100 New Zealand River Environment Classification User Guide catchment and an estimate of the influence of lakes. 1: Glacial/ mountain 2: Hill 3: Low elevation 4: Lake 5: Mountain

Acoustic Salmonid Monitoring in the Southern Lakes 2024

Photo 1: Acoustic monitoring of Lake Wakatipu in OFG1. Photo: B Quirey.

Executive Summary

The first Fish & Game-led acoustic survey of Lakes Wānaka, Hāwea, and Wakatipu was conducted over six days in early February 2024. The survey followed the methods established by four previous surveys conducted by NIWA in 2007, 2008, 2009, and 2023.

Total fish counts and densities were relatively consistent with previous surveys, with Hāwea and Wakatipu showing a decrease from last year's count, and Wānaka showing an increase. Fish were observed at similar depths and distances from the bottom, predominantly concentrated near the lake bottom.

Across all three lakes, there were two clear groupings of target strength, likely correlated to fish size, it is suggested that future studies should investigate this further.

A follow-up survey is planned for 2025 to determine annual fluctuations and to build the long-term dataset.

Introduction

Acoustic surveying is a well-established method used worldwide for both saltwater and freshwater. It has previously been used to index the Southern Lakes fisheries on four occasions between 2007 and 2023. This year's survey represents the first time Otago Fish & Game has run this programme following extensive training during the 2023 survey. Otago joins the Eastern Region as the only Fish & Game regions using this technology, although the Eastern Region uses the system to monitor smelt levels in their lakes rather than salmonids.

The upper three Southern Lakes represent a significant angling resource. The most recent National Angling Survey (Stoffels & Unwin, 2023) suggests that in the 2021-2022 season, they accounted for close to 57,000 angling days combined, almost a third of Otago's freshwater angling activity. The importance of these lakes in sustaining angling activity and licence sales is extremely high.

Monitoring of the Southern Lakes is extensive, comprising angler surveys, competition surveys and spawning counts and drift dives on the tributaries. However, due to the large size of the lakes, population data is limited. The acoustic monitoring programme designed by NIWA provides a repeatable, long-term index of salmonid populations in the lakes and fills gaps in knowledge on some of our most utilised and well-loved fisheries. The programme is spread across 25 transects over three lakes (Figure 1).

The methodology followed the practices outlined by NIWA, which are explored and explained in depth in the 2023 report (Escobar-Flores & O'Driscoll, 2023). A simplified summary of the method is provided in Appendix C.

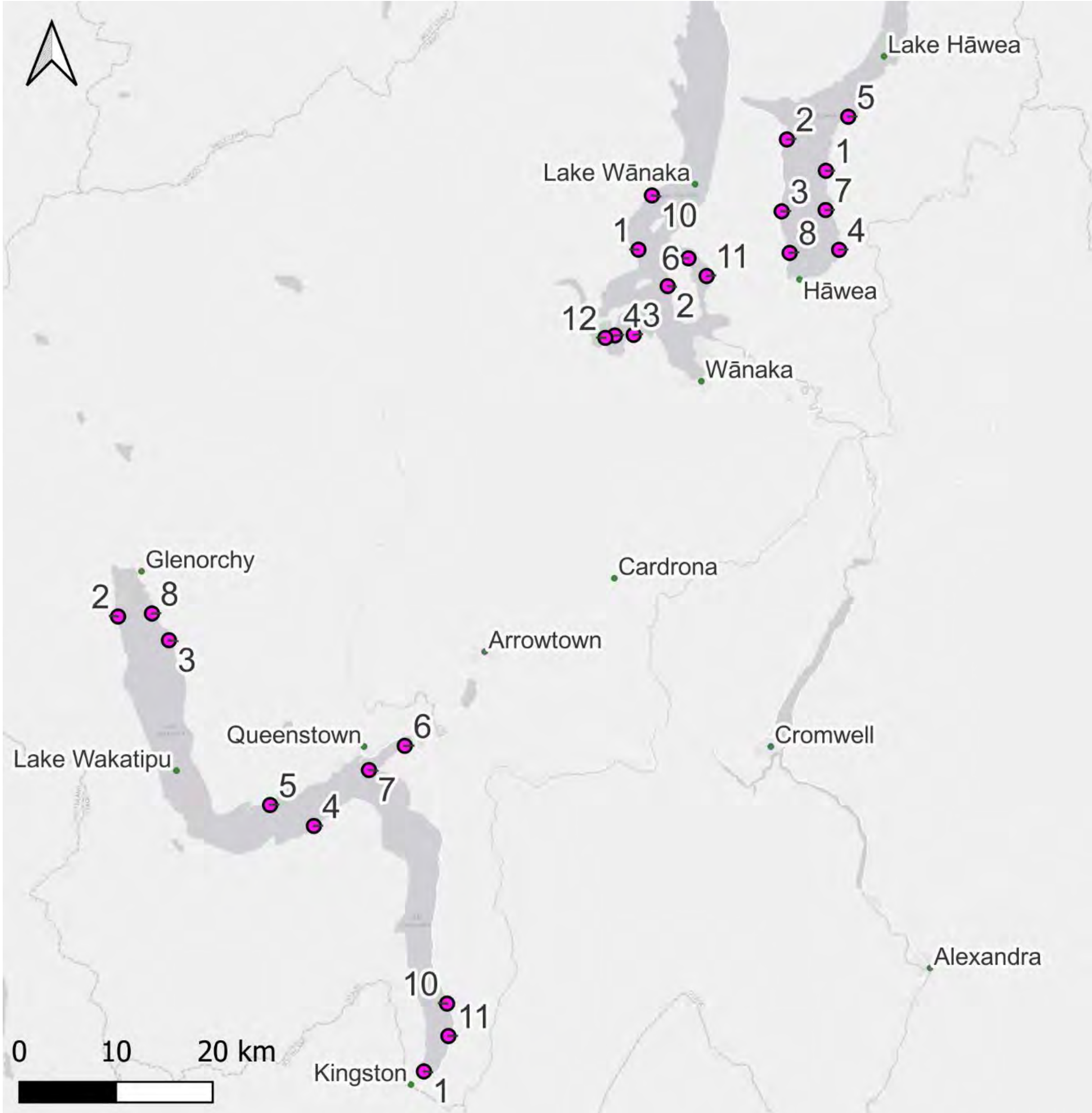

Figure 1: Map showing the surveyed lakes locations and the start point of each transect.

Results

Survey execution.
Dunstan:

The initial calibration run was conducted on February 12 at 1630 hrs on Lake Dunstan. There were multiple issues with the initial setup that were largely solved with the help of NIWA staff. Unfortunately, the results from this calibration were usable but of poor quality. Following the recommendations of Escobar-Flores & O'Driscoll (2023), no surveying was carried out in Lake Dunstan.

Wānaka:

A second calibration alongside an RBR cast was run at 1000 hrs on February 13, just outside Glendhu Bay. This calibration was adequate but not used due to poor coverage on the edges of the beam pattern. Surveying started at 1200 hrs; unfortunately, due to a settings error, transect 12 – Paddock Bay had to be repeated. The weather was hot with strong winds in the afternoon. Surveying concluded at 1900 hrs. Due to heavy winds, no surveying was conducted on February 14.

Wakatipu:

Surveying the Kingston area was carried out between 1135 hrs and 1330 hrs on February 15, followed by an RBR cast at 1350 hrs. There was heavy rain throughout the survey and issues with the sounder not maintaining the requested ping rate. The boat was then relaunched at Frankton Arm to carry out the Frankton transect (T6), which took place in heavy rain between 1540 hrs and 1700 hrs. The rest of the Frankton area transects were run between 1300 and 1540 hrs on February 16, followed by an RBR cast. Surveying in the Glenorchy area occurred on February 16 between 0800 and 1120 hrs, with an RBR cast performed at 0930 hrs. The weather was clear and calm.

Hāwea:

Lake Hāwea surveys occurred on February 17 between 0845 and 1445 hrs, followed by an RBR cast. The weather was clear and calm. One camera drop was conducted on transect 4 at 0945 hrs. The final calibration used for analysis was conducted near the Hāwea Township between 1515 and 1600 hrs.

Calibration

Calibration is a crucial step as it tests whether the equipment is operating correctly and provides adjustment values to ensure surveys are comparable across years. Calibration was performed following the procedure outlined in Escobar-Flores & O'Driscoll (2023). There were issues with early calibration settings, requiring three calibration runs, with only the results from the third one being utilised and reported on. The calibration occurred on Lake Hāwea near the township. The weather was hot and clear, with very little surface disturbance.

The RMS of the difference between the echoes and the Simrad beam model was 0.19, indicating a calibration of excellent quality (< 0.4 dB is acceptable, 0.3-0.4 dB is good, and < 0.2 dB is excellent (Escobar-Flores & O'Driscoll, 2023)). The low RMS value, as well as a symmetrical beam pattern centred on zero, suggested the equipment was operating correctly.

A full calibration report is available on request.

Environmental parameters and acoustic coefficients

As the survey environment affects the way waves travel through water, several variables were measured to calculate absorption and the speed of sound in each waterway (or area, in the case of Wakatipu). Calculating these correctly ensures that the distances from the sounder to both fish and the bottom are accurate, and that target strength is consistent between lakes and surveys. This consistency allows for comparisons between lakes and over time.

Table 1: Average water temperature and depths at RBR cast locations in the Southern Lakes. Estimates for sound speed and absorption were calculated in ESP3 using the formulas of Francois & Garrison (1982) and Fofonoff & Millard Jr (1983).

Lake	Temperature (°C)	Max. depth (m)	Sound speed (ms^{-1})	Absorption (dB km^2)
Lake Hāwea	15.48	44.88	1,468.34	3.67
Lake Wakatipu - Frankton	14.41	43.71	1,464.57	3.81
Lake Wakatipu - Glenorchy	14.20	33.11	1,463.65	3.84
Lake Wakatipu - Kingston	15.55	30.30	1,468.35	3.67
Lake Wānaka	15.64	26.55	1,468.98	3.66

Software output

Figure 2 displays a relatively typical output in the ESP3 software, showing several submerged trees and four targets that met the algorithm requirements and can be assumed to be salmonids. Three of these targets are in midwater to the left, while one is amongst the trees to the right. As the software is set to optimise the view of the fish rather than the bottom profile, the bottom profile in black appears inaccurate; however, with adjusted settings, it can accurately follow the bottom and submerged vegetation. This pattern of "mobbed" up fish was relatively uncommon, with most targets found away from others. There were no areas with more than three to four fish in a small area. Anglers often note that lake-resident salmon are found in groups, but it is unclear what this might look like on an echogram or whether this example represents such a grouping.

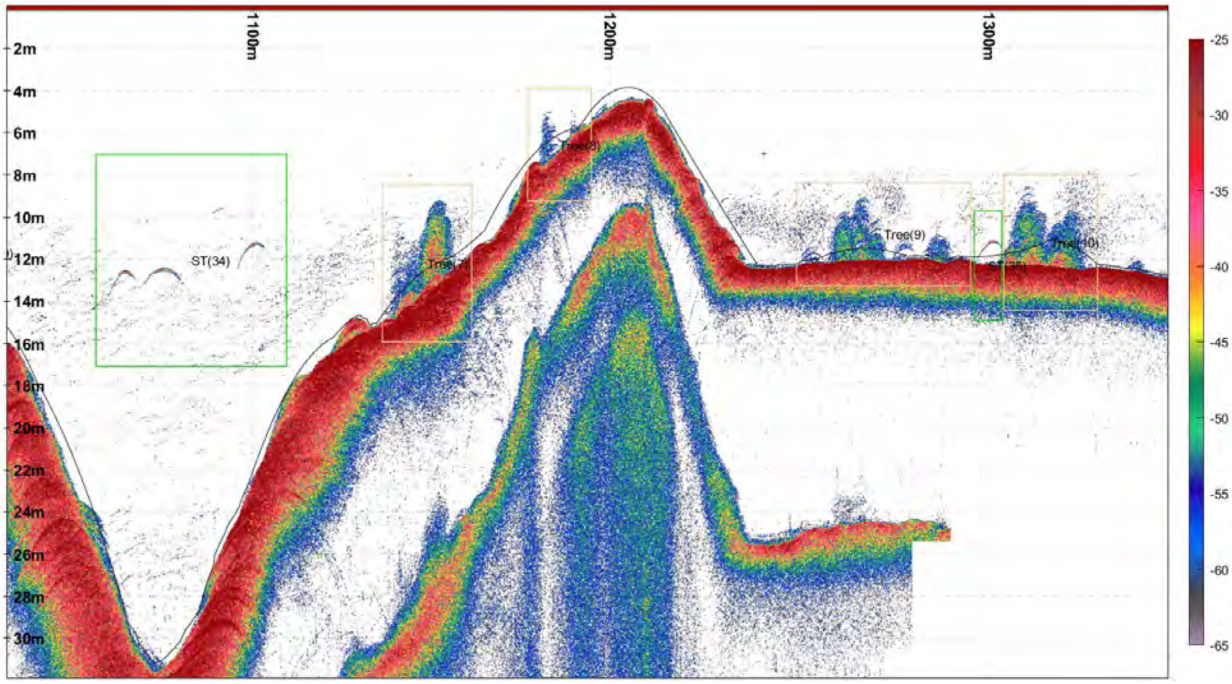

Figure 2: Echogram from Hāwea Transect 5 showing bottom profile in black, suspected trees in orange boxes and tracked targets, assumed to be salmonids in green boxes.

Camera drop

Due to time limitations, only one camera drop was conducted, which took place on transect 4 in Lake Hāwea. During the survey, a small group of targets was observed near the bottom at approximately 14 metres depth. At the end of the transect, we returned to deploy the camera over this area. Figure 3 displays the echogram from the initial surveying pass, while

Photo 2 shows the clearest shot obtained from the camera drop.

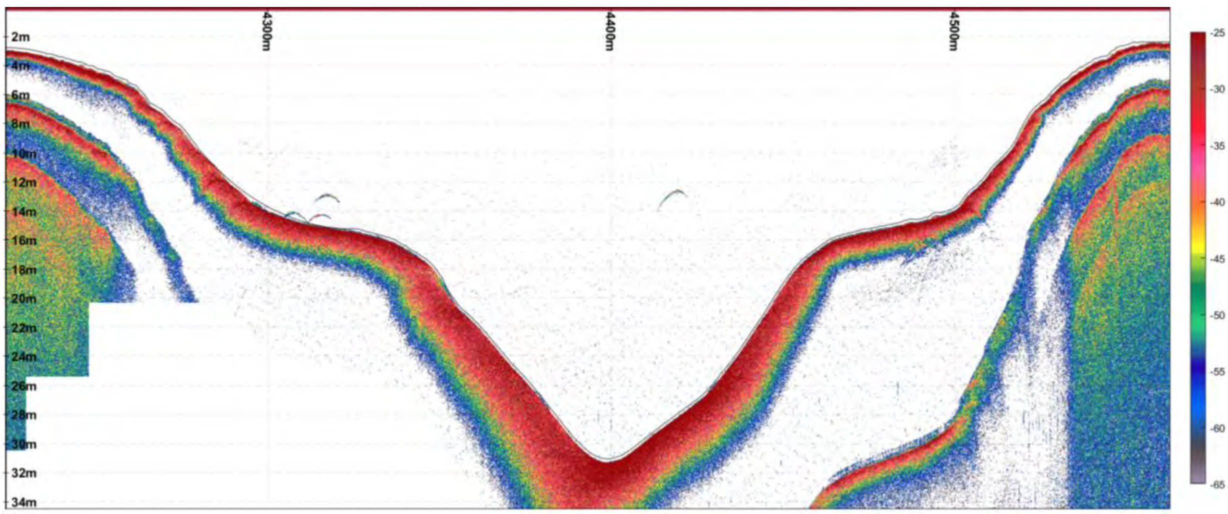

Figure 3: Echogram showing a set of three "thumbnail" shapes near the bottom left alongside another out in mid water.

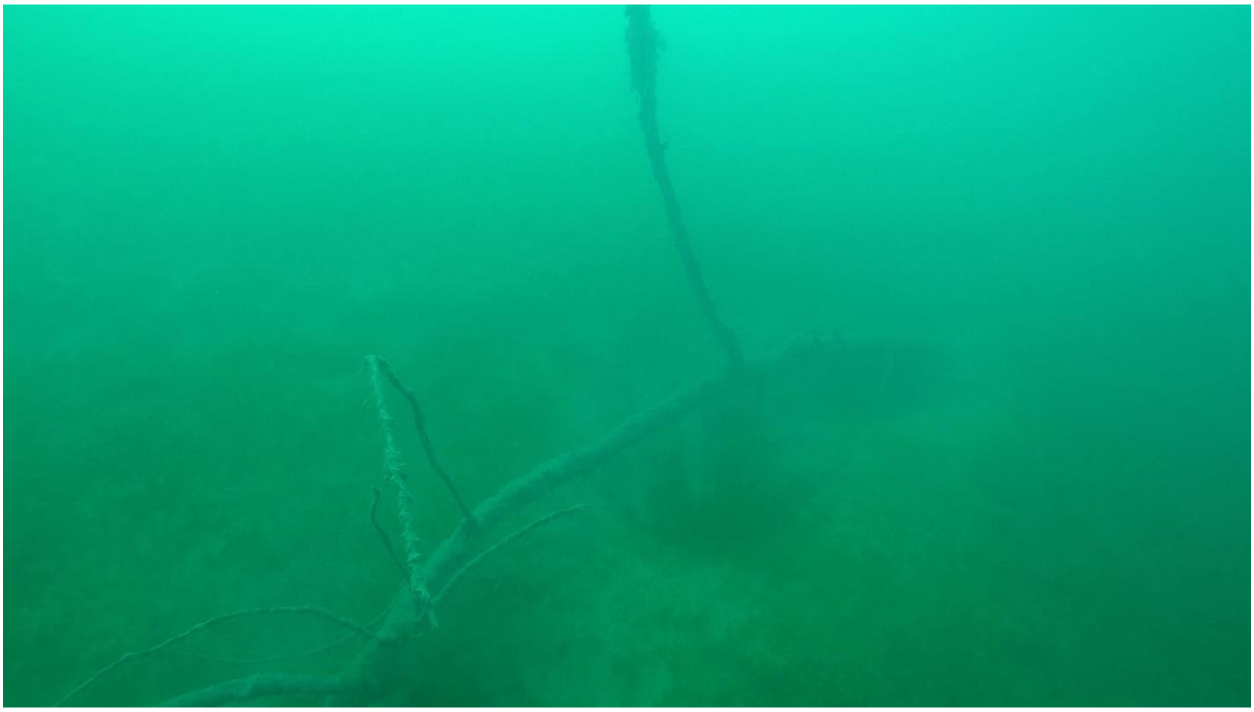

Photo 2: Footage from the drop camera on Hāwea transect 4, showing a submerged branch.

The camera drop did not reveal any fish and showed a relatively bare lake bottom, although a "thumbnail" shaped stick was present in the area. It is difficult to confirm if this was the exact location of the targets from the first pass due to the drifting boat, the camera being on a long line, and GPS inaccuracies. It is possible that the stick from the photo appears in the echogram as one of the three grouped thumbnail shapes; however, this is unlikely given the distinct shape and strong target strength of the echoes. More likely, the stick appears just below the bottom line to the left of the three shapes. In any case, the movement of the other shapes suggests they are almost certainly fish.

Tracked targets

Table 2 below presents the volume of water sampled by the program, along with the estimated number of fish and their densities.

Table 2: Number of targets identified as likely salmonids in each lake during the 2024 survey. Fish density is expressed in two ways: per unit volume (cubic hectometre, hm³, equivalent to a 100m x 100m x 100m cube) and per unit surface area (hectare, ha). Detailed data for each survey transect are available in Appendix A.

Lake	Volume sampled (m^3)	Tracked target count	Fish (hm^{-3})	Fish (ha^{-1})
Hāwea	2,764,700	115	41.6	6.1
Wakatipu	7,244,100	291	40.2	8.2
Wānaka	3,327,000	131	39.4	6.9

Lake Wakatipu recorded the highest number of fish and the highest density based on area, while Lake Hāwea exhibited the highest density based on volume. Figure 4 displays the number of tracked targets, assumed to be salmonids, found in each lake across the five surveys, whereas Figure 5 presents these results expressed as fish per hectare. The 2007 results should be interpreted with caution due to the lower number of transects surveyed; however, they are included for completeness.

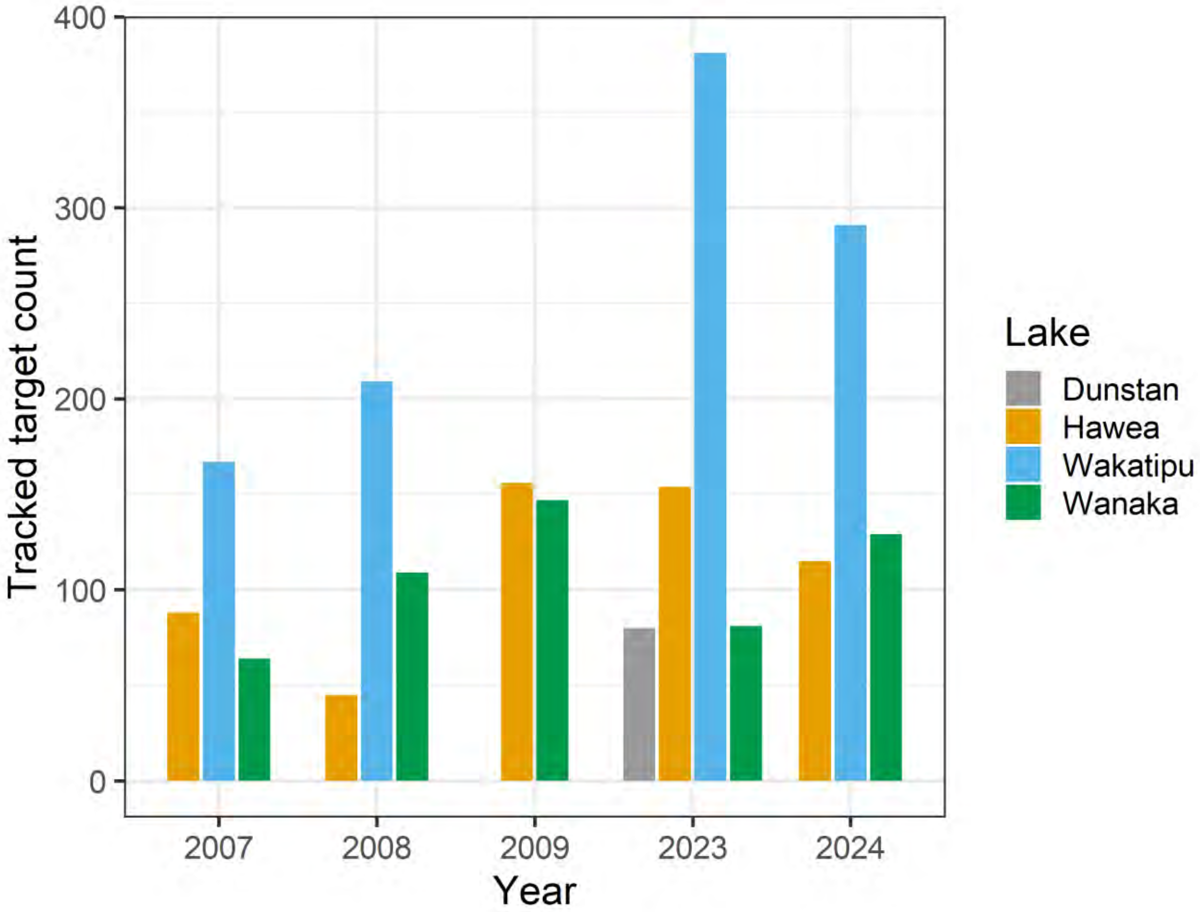

Figure 4: Number of tracked targets by lake and survey year. Please note that the number of transects surveyed in Lakes Hāwea, Wakatipu, and Wānaka increased from 4, 7, and 5 in 2007 to consistently 7, 10, and 8 transects, respectively, since 2008.

Lakes Wakatipu and Hāwea both saw a decrease in last year's tracked target count, although it's worth noting that last year's counts were relatively high compared to previous years. Conversely, the count for Wānaka increased from a particularly low count last year.

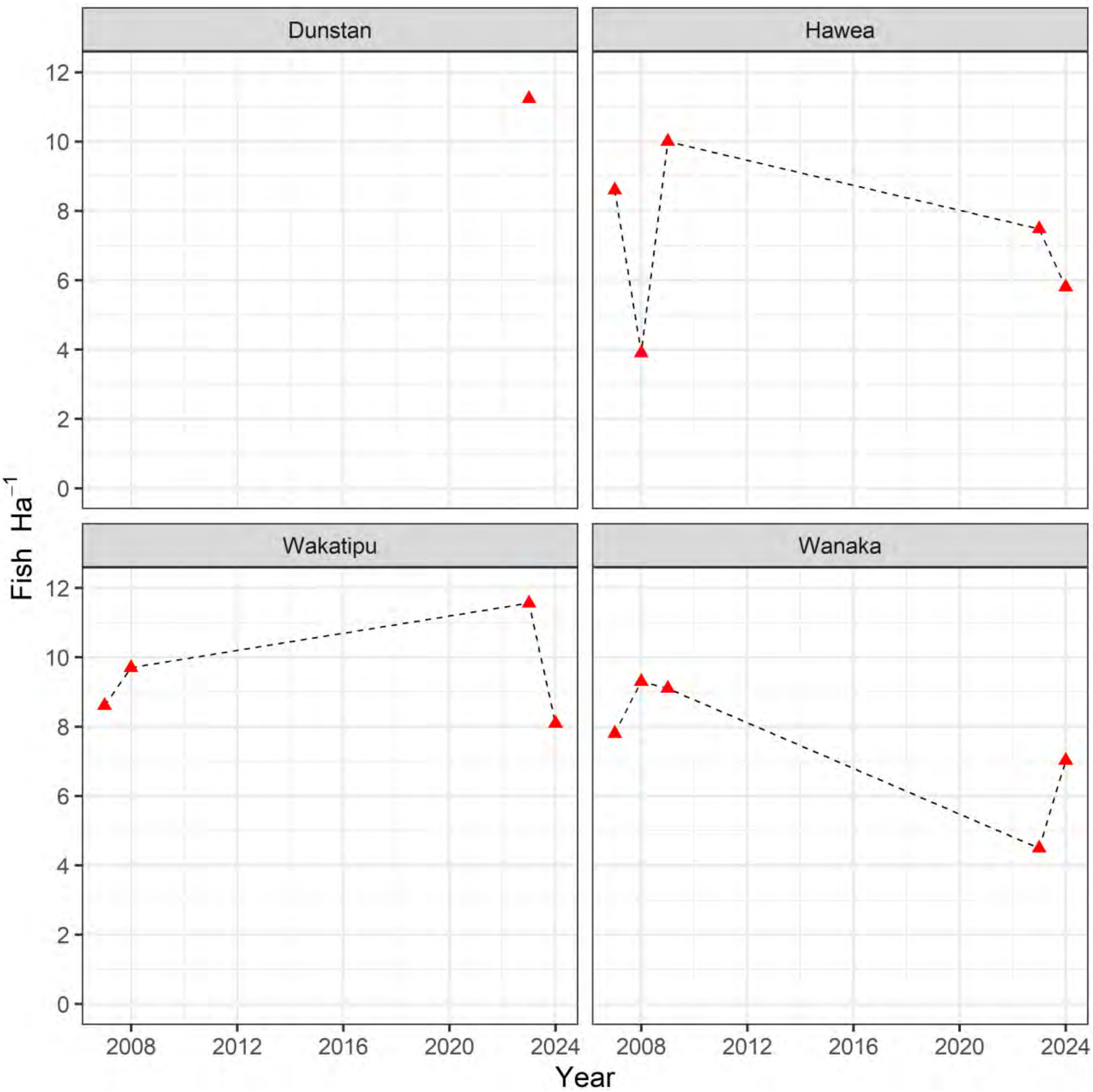

Figure 5: Target density (fish per hectare) estimate by lake and survey year. Please note that the number of transects surveyed in lakes Hāwea, Wakatipu, and Wānaka increased from 4, 7, and 5 in 2007 to consistently 7, 10, and 8 transects, respectively, since 2008.

Efforts have been made to run the same transects since 2008, resulting in relatively consistent sampling locations and areas. Consequently, the density of tracked targets reflects a pattern similar to the total number counted. Lakes Wakatipu and Hāwea saw a decrease in last year's count, while Wānaka experienced an increase.

Figure 6 displays the target strength distribution for each lake in the 2024 survey. Target strength is associated with fish size, although this relationship has not been well tested for salmonids at 120 kHz (Escobar-Flores & O'Driscoll, 2023). The charts appear similar to one another and align well with the data collected in 2023. Each lake exhibits a pronounced bi-modal pattern, with numerous targets concentrated around -45 dB and -30 dB. This pattern could indicate a separation in age classes. If the acoustic monitoring program continues long-term, testing should be conducted to confirm the relationship between target strength and fish size in Otago lake salmonids and to understand how this relates to the observed pattern.

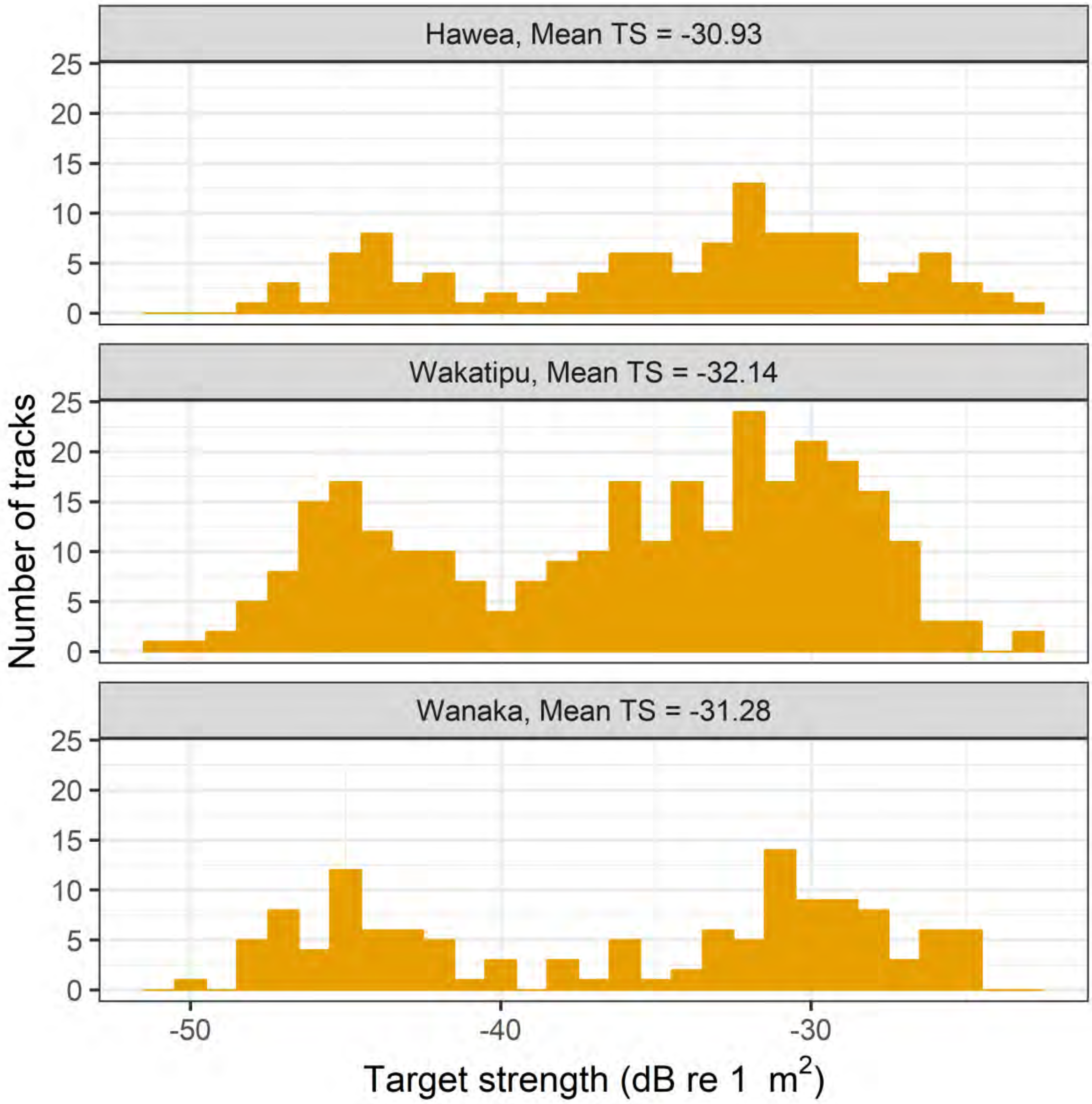

Figure 6: Acoustic target strength distribution by lake for the 2024 survey. Mean target strength is provided above each chart.

Given the clear bi-modal pattern in target strengths observed across the lakes (Figure 6), which aligned with last year's data, the vertical distribution of the two target strength bands was analysed separately to identify any patterns. Targets were defined as "strong" if their target strength was above -40 dB, or "weak" if it was below.

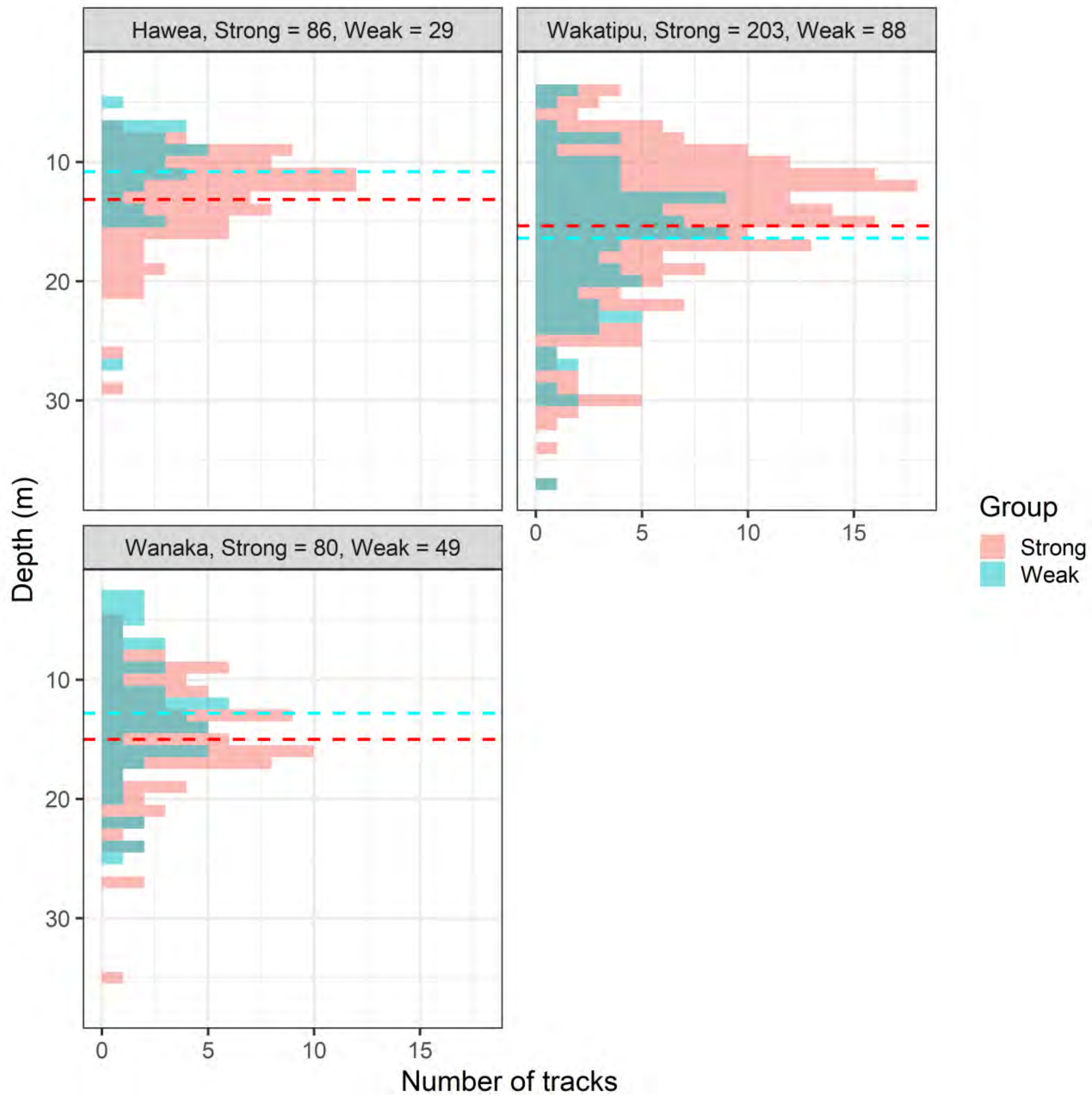

Figure 7: Depth distribution by target strength for the 2024 survey, with dashed lines denoting the average depth for each target strength group.

No consistent pattern was observed across the lakes: in Lake Hāwea and Wānaka, larger fish were generally found deeper than smaller fish. Conversely, in Lake Wakatipu, smaller fish were found deeper on average, although the depth difference between the two classes was minimal. This pattern aligns well with the data collected in 2023.

Figure 8 displays the depth at which targets were found below the transducer face.

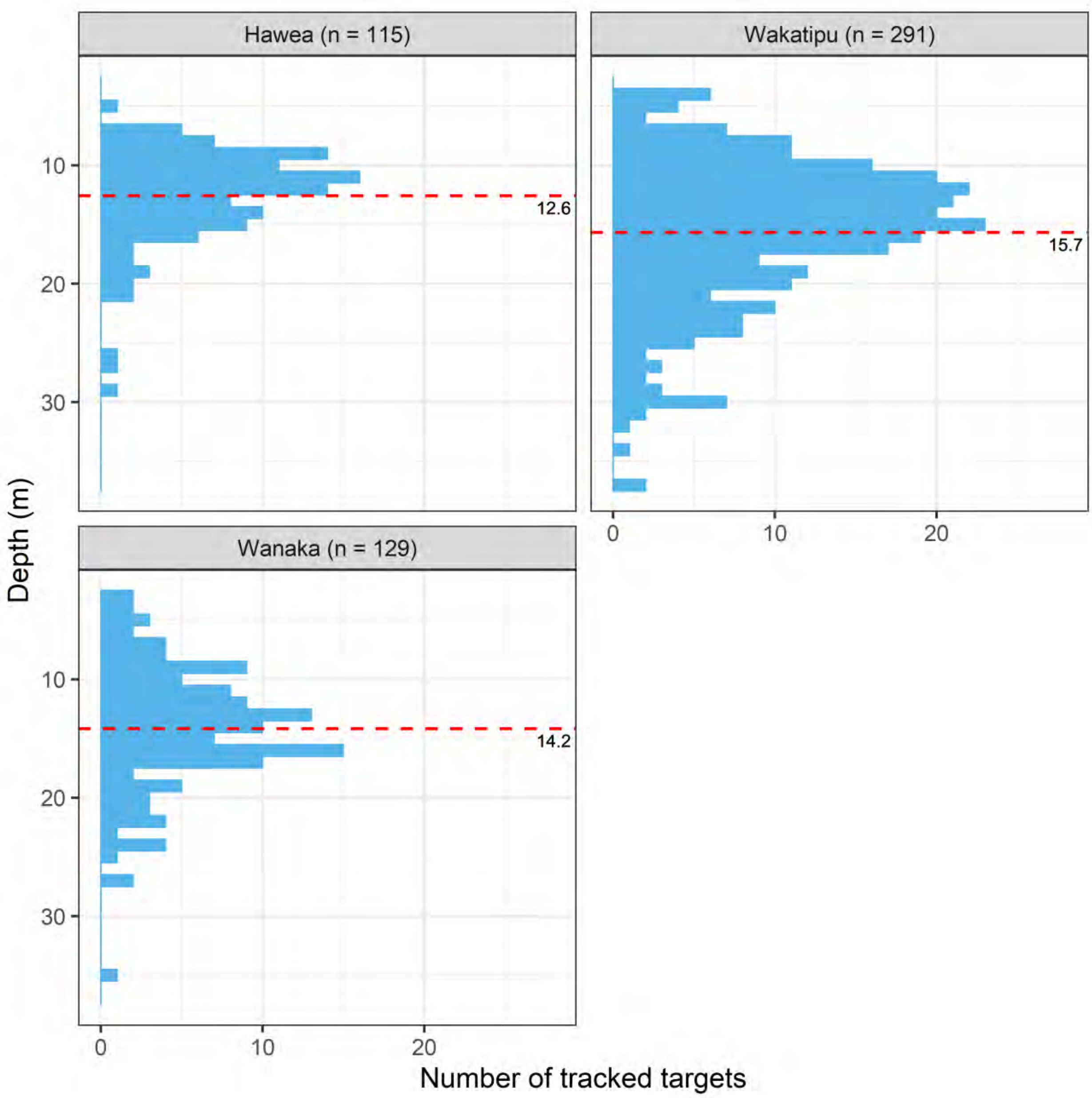

Figure 8: Depth distribution of tracked targets in the 2024 survey, with dashed lines indicating the average target depth.

All lakes exhibited a roughly Gaussian (bell-shaped) distribution, with only a few fish found at very deep or shallow depths. Fish were notably closer to the surface in Lake Hāwea by approximately 2 metres. The average depth at which tracked targets were found was significantly shallower compared to the respective lakes in the 2023 survey.

Figure 9 presents a metric similar to Figure 8, but instead of showing the distance of targets below the surface, it illustrates their position above the lake bottom.

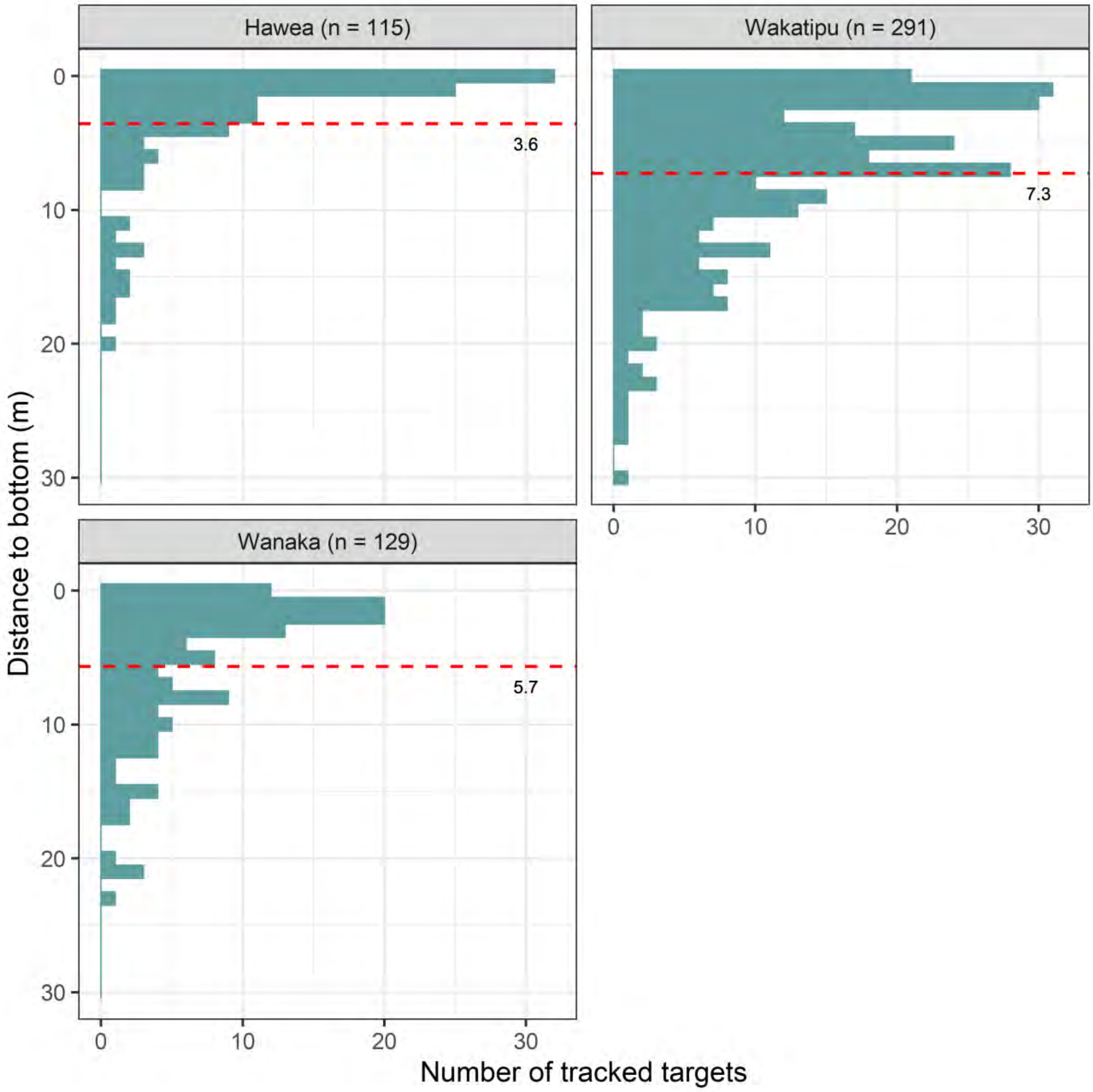

Figure 9: Distance from target to the lake bottom for the 2024 survey, with dashed lines indicating the average distance.

Generally, targets were most concentrated near the lake bottom, with their density decreasing as the distance from the bottom increased. In Lake Hāwea, targets were notably closer to the bottom, with almost 40 percent located within 1 metre of it. In contrast, fish in the other two lakes were more evenly distributed throughout the water column: nearly 20% were within 1 metre of the bottom in Lake Wānaka, and only 14 percent in Lake Wakatipu.

Discussion

The results from the 2024 survey are generally consistent with previous years, showing similar numbers of tracked targets and densities across most lakes, except for Lake Wakatipu which displayed lower densities than in previous surveys. This consistency is reassuring for the first year Fish & Game has led this project and suggests that despite some technical issues, staff have effectively learned the system from NIWA. Despite this consistency, Lake Wakatipu experienced notable declines in both fish counts and densities when compared to the 2023 survey.

It is expected that these large lake fisheries will exhibit fluctuations in year classes; however, drastic shifts in overall populations are expected to occur only during major environmental events, such as prolonged periods of turbid waters resulting from significant flooding. Continuing this monitoring program over the long term and correlating the data with other monitoring projects will help determine the significance of any changes in the count.

Otago plans to continue this survey through the 2025 season to compile a three-year data set. This will test the consistency over time and help establish a long-term database to track trends in the lake populations. The evolving database will allow for further exploration of target strengths and could enable tracking of rough age classes to make future predictions. The data also supports this with the presence of two distinct target size strength classes across all lakes over the last two years.

Future efforts, as discussed by Escobar-Flores & O'Driscoll (2023), should include work on developing the relationship between target strength from the acoustic sounder and the size of salmonids in the lakes. This relationship can be partially explored using gill nets to capture fish accumulations identified by the sounder. Increased use of drop cameras alongside this netting could also help determine species composition. Unfortunately, both activities require more field time than was available this year due to the learning curve involved. Next year, it is anticipated that Fish & Game staff will gather more information within the same timeframe.

The vertical distribution of fish remained consistent with previous surveys, with similar depths recorded across the lakes. Although there were differences among the lakes, the overall patterns were clear, and Fish & Game's typical advice to anglers should remain the same; fish in relatively shallow water (less than 10m) and ensure lures are near the bottom where the highest fish concentrations are found.

Appendices include transect totals and fish densities across 100m sections, which may be useful to anglers. However, no detailed analysis of year-to-year changes at this scale has been attempted, as it might be too granular for meaningful comparison. Future investigations should explore subdividing the lakes into sections, such as splitting Lake Wakatipu into Glenorchy, Kingston, and Central areas for more detail.

This project has underscored the benefits of Fish & Game collaborating with external research agencies to develop projects and receive training. This approach leverages the extensive knowledge base available, upskills staff, and keeps long-term costs down, while also enhancing the scientific reputation of Fish & Game.

Acknowledgements

Special thanks to Dr. Pablo Escobar-Flores and Dr. Richard O'Driscoll of NIWA Wellington, who provided training and guidance to staff throughout the 2023 and 2024 surveys, both in the field and during the analysis. Appreciation is also extended to David Priest, who managed logistics, and to Ben Sowry, who skilfully captained the boat through technical challenges and varying weather conditions. Additionally, gratitude is due to Helen Trotter and Ian Hadland for their pivotal roles in reviving this project after a significant hiatus.

Recommendation

This report be received.

Jayde Couper
Fish & Game Officer
July 2024

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Appendices

Appendix A – Summary tables

The following tables show the number of targets identified as likely salmonids in each lake/ transect during the 2024 survey. Fish density is expressed in two ways: per unit volume (cubic hectometre, hm^3 - equivalent to a 100m x 100m x 100m cube) and per unit area (hectare, ha).

Table 3: Lake Hāwea.

Transect number	Volume sampled (m^3)	Mean depth (m)	Tracked target count	Fish (hm^{-3})	Fish (ha^{-1})
1	353,300	14.0	21	59.4	8.3
2	607,800	16.0	16	26.3	4.2
3	317,100	12.7	8	25.2	3.2
4	447,400	13.9	17	38.0	5.3
5	701,200	18.6	35	49.9	9.3
7	148,400	9.3	13	87.6	8.2
8	189,500	13.2	5	26.4	3.5

Table 4: Lake Wānaka.

Transect number	Volume sampled (m^3)	Mean depth (m)	Tracked target count	Fish (hm^{-3})	Fish (ha^{-1})
1	723,800	17.6	11	15.2	2.7
2	384,800	18.0	7	18.2	3.3
3	336,300	17.6	4	11.9	2.1
4	757,900	18.0	13	17.2	3.1
6	330,500	19.0	13	39.3	7.5
10	110,900	16.4	5	45.1	7.4
11	328,400	15.5	56	170.5	26.5
12	354,400	17.9	22	62.1	11.1

Table 5: Lake Wakatipu.

Transect number	Volume sampled (m³)	Mean depth (m)	Tracked target count	Fish (hm^{-3})	Fish (ha^{-1})
1	742,900	18.9	39	52.5	9.9
2	1,163,700	18.8	54	46.4	8.7
3	973,600	21.2	44	45.2	9.6
4	625,400	21.4	15	24.0	5.1
5	544,000	21.7	12	22.1	4.8
6	1,161,900	22.6	52	44.8	10.1
7	318,900	19.6	4	12.5	2.5
8	646,900	19.4	41	63.4	12.3
10	547,100	20.6	18	32.9	6.8
11	519,700	19.8	12	23.1	4.6

Appendix B – Maps showing the spatial distribution of track targets.

The maps integrate the number of tracked targets within each 100-meter section of the surveyed transects. The starting point of each numbered transect is marked with a white dot. The 2024 tracklog is depicted in pink. For an overview of the entire area, refer to Figure 1.

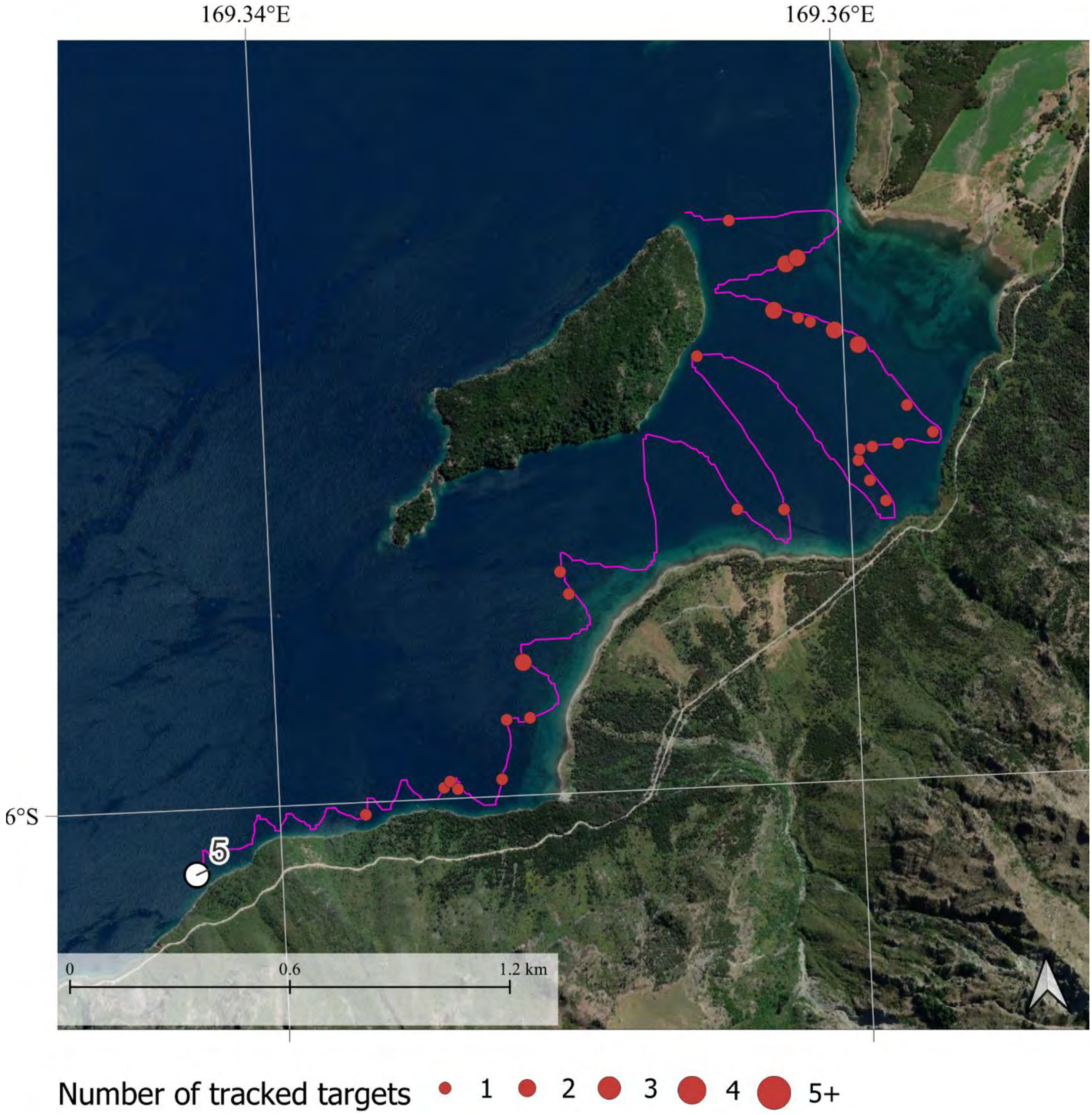


Figure 10: Northern Lake Hāwea.

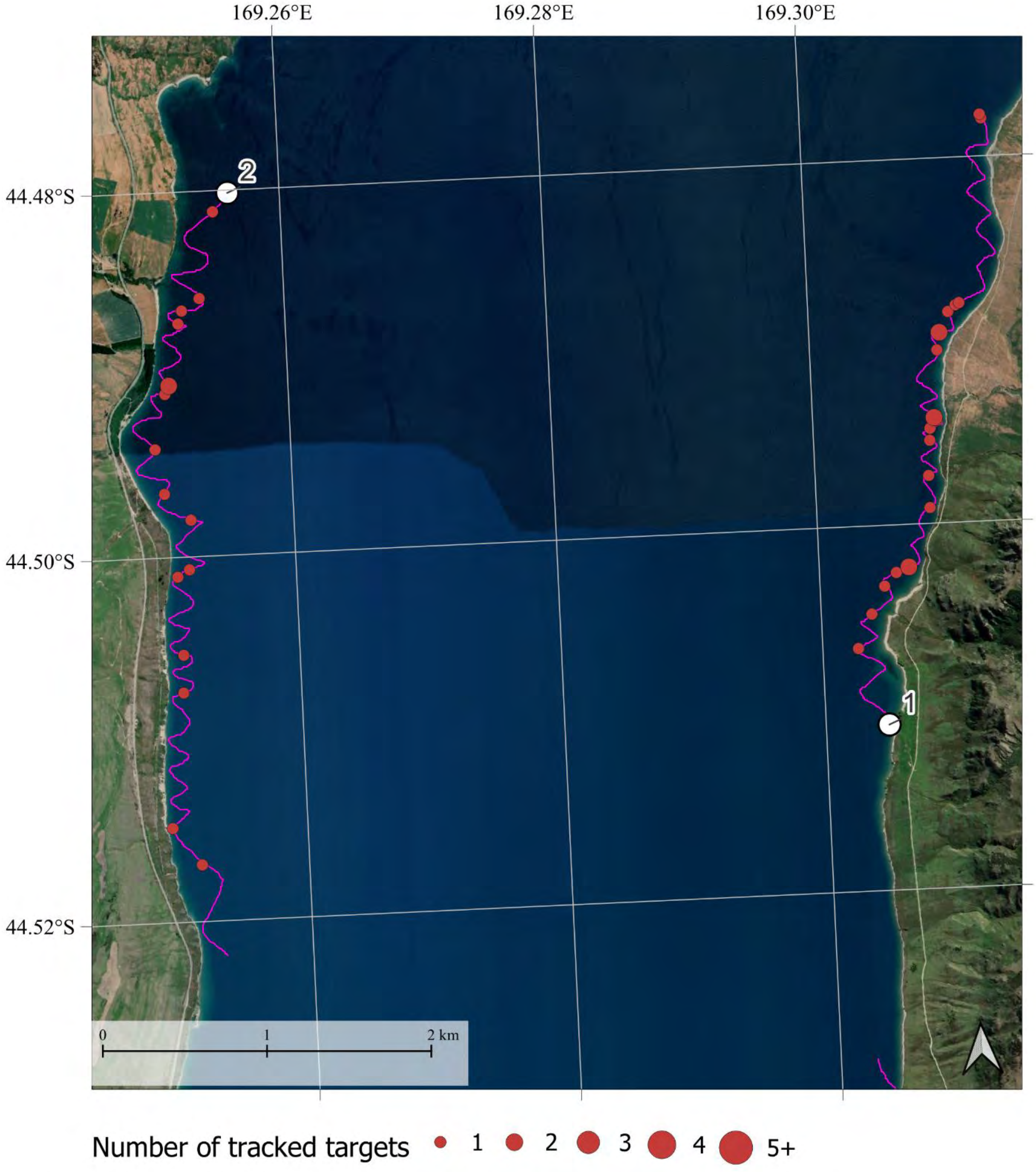


Figure 11: Central Lake Hāwea.

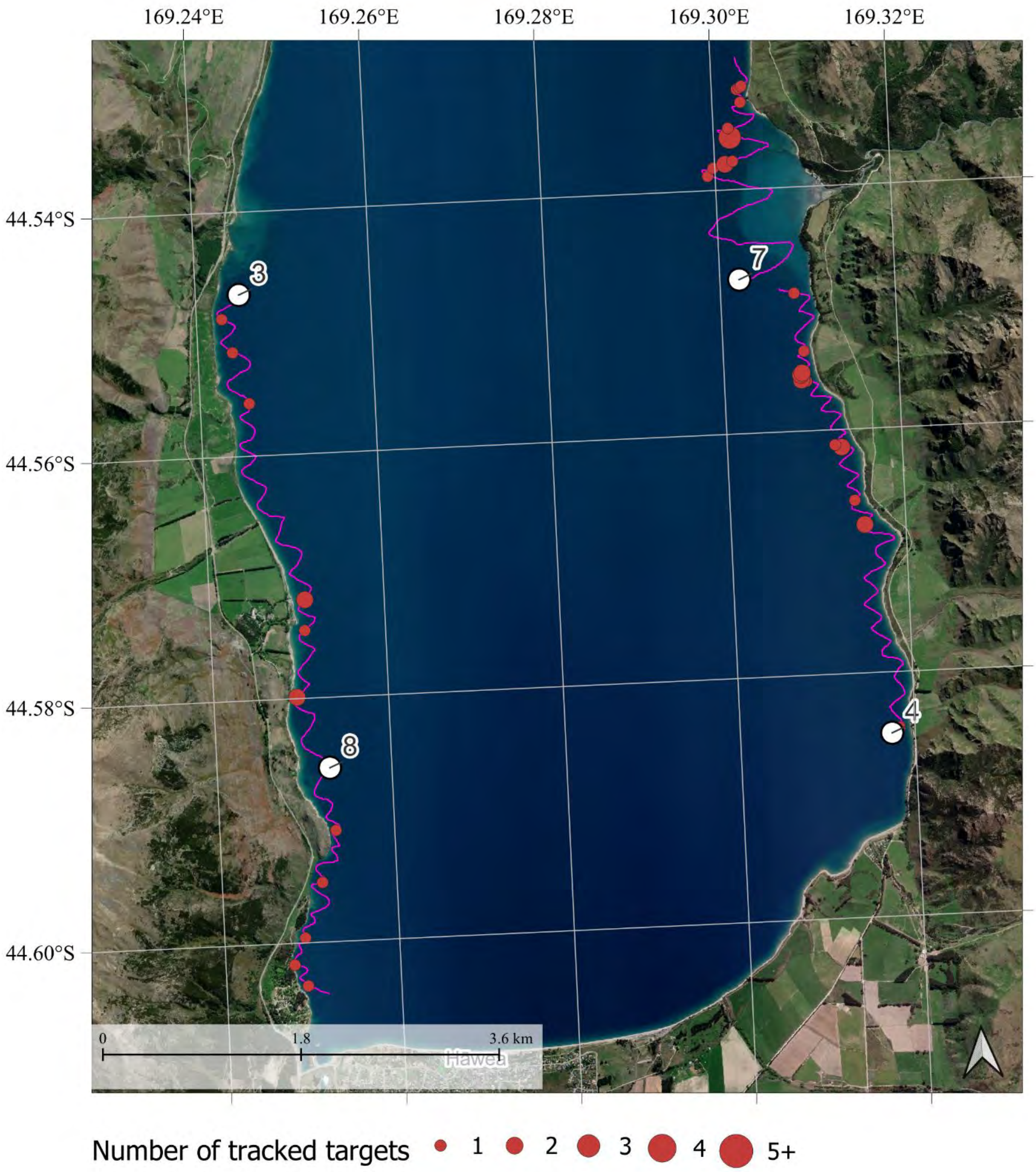


Figure 12: Southern Lake Hāwea.

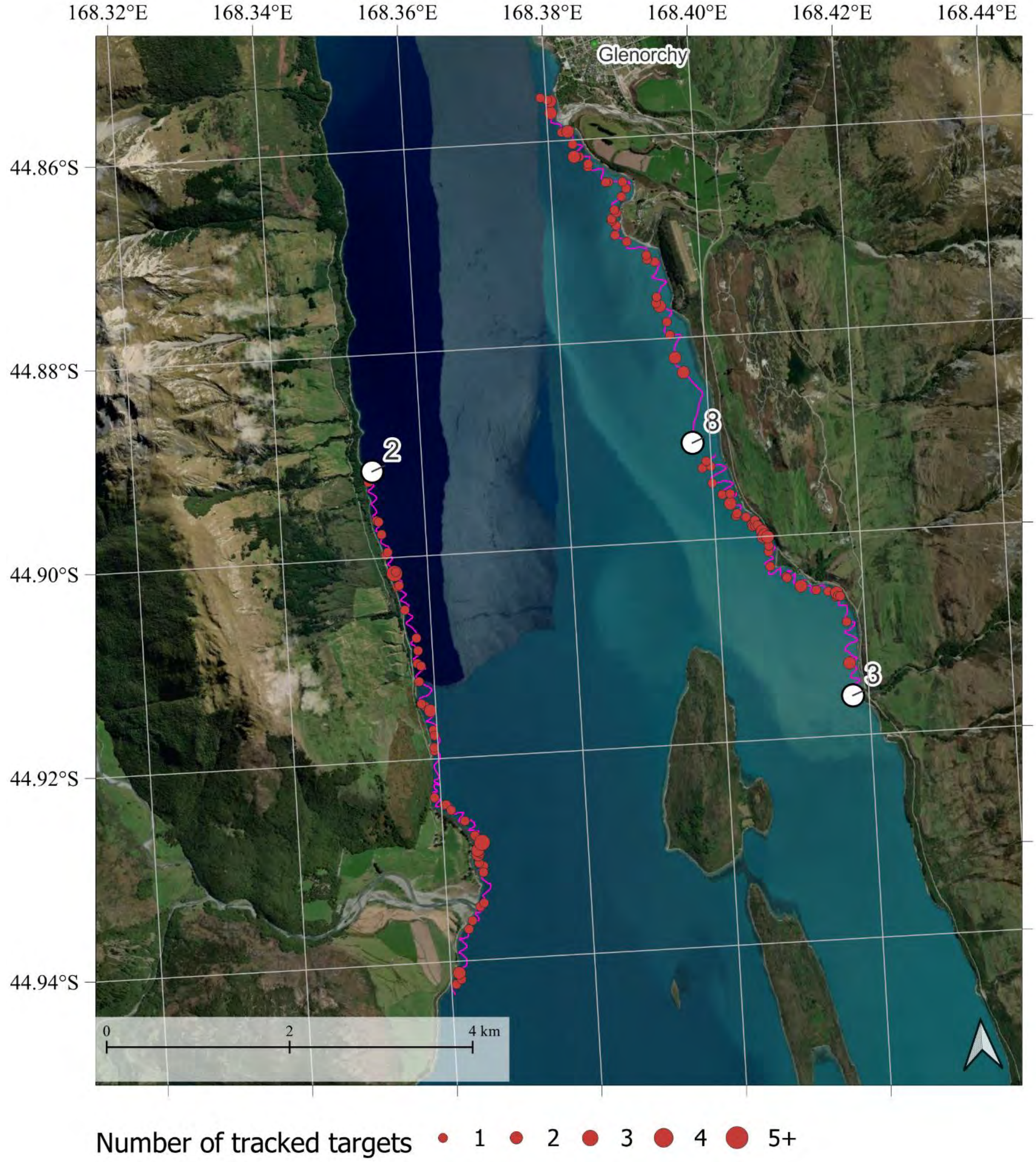


Figure 13: Wakatipu – Glenorchy area.

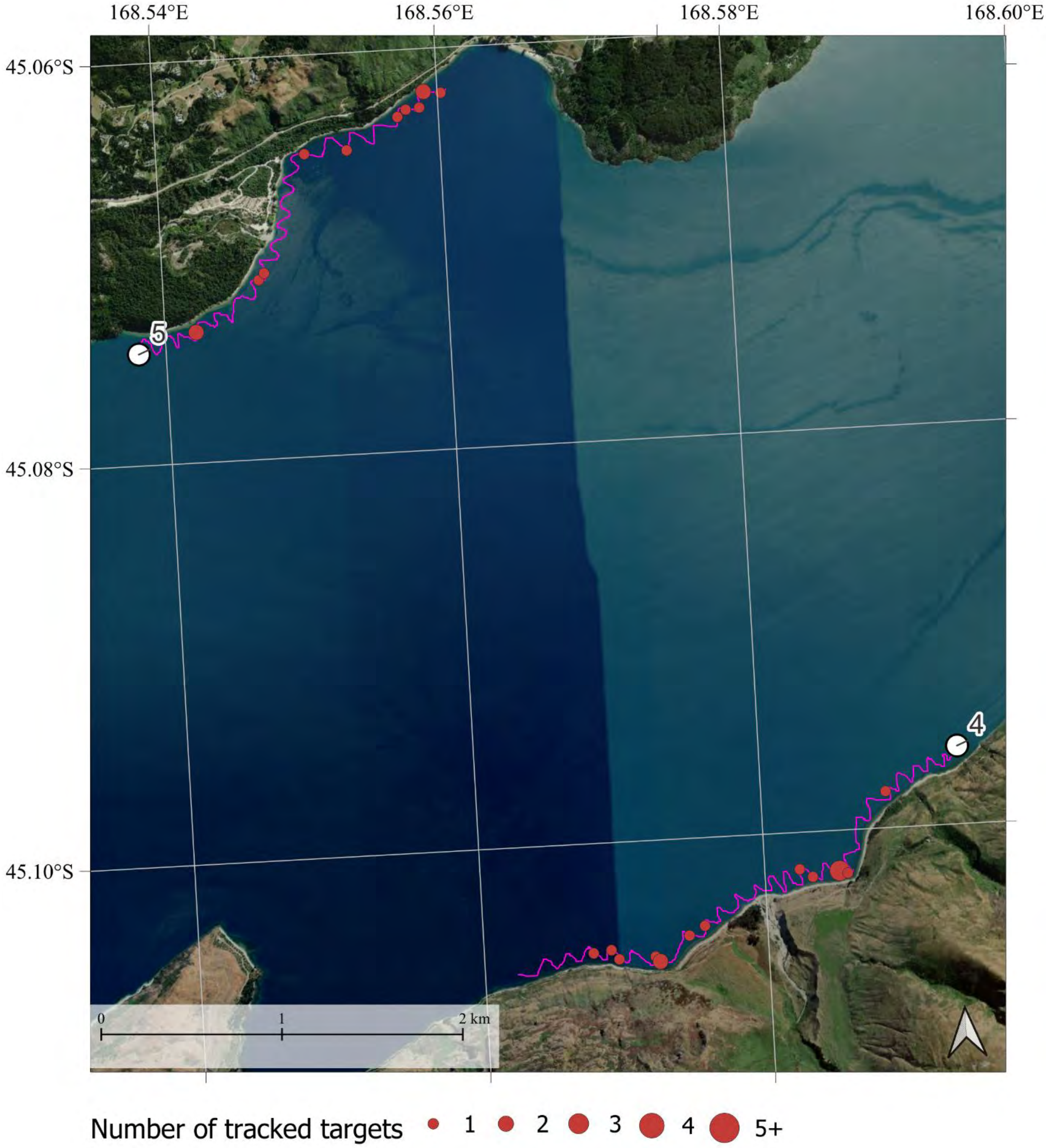


Figure 14: Wakatipu - Central.

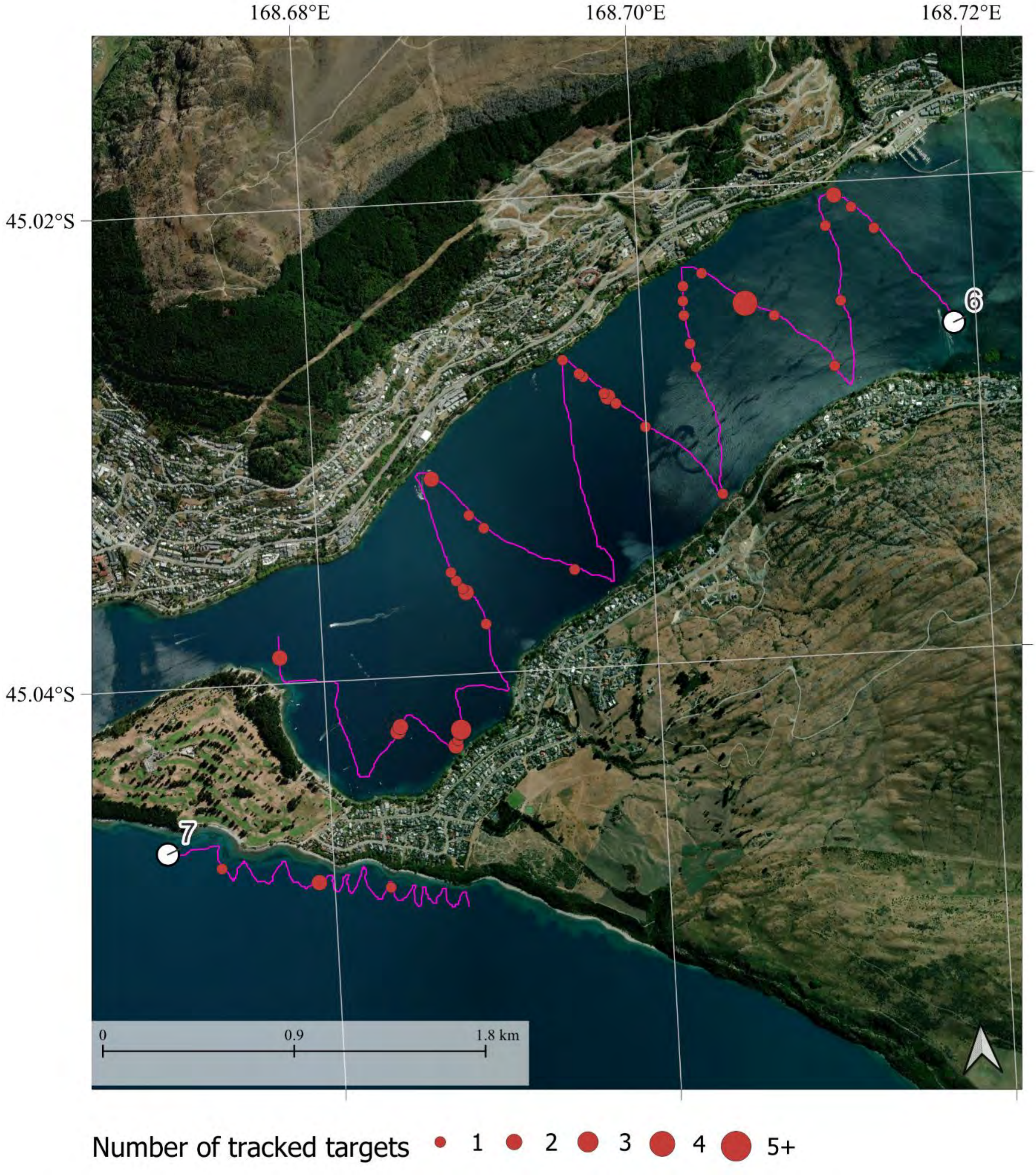


Figure 15: Wakatipu – Frankton area.

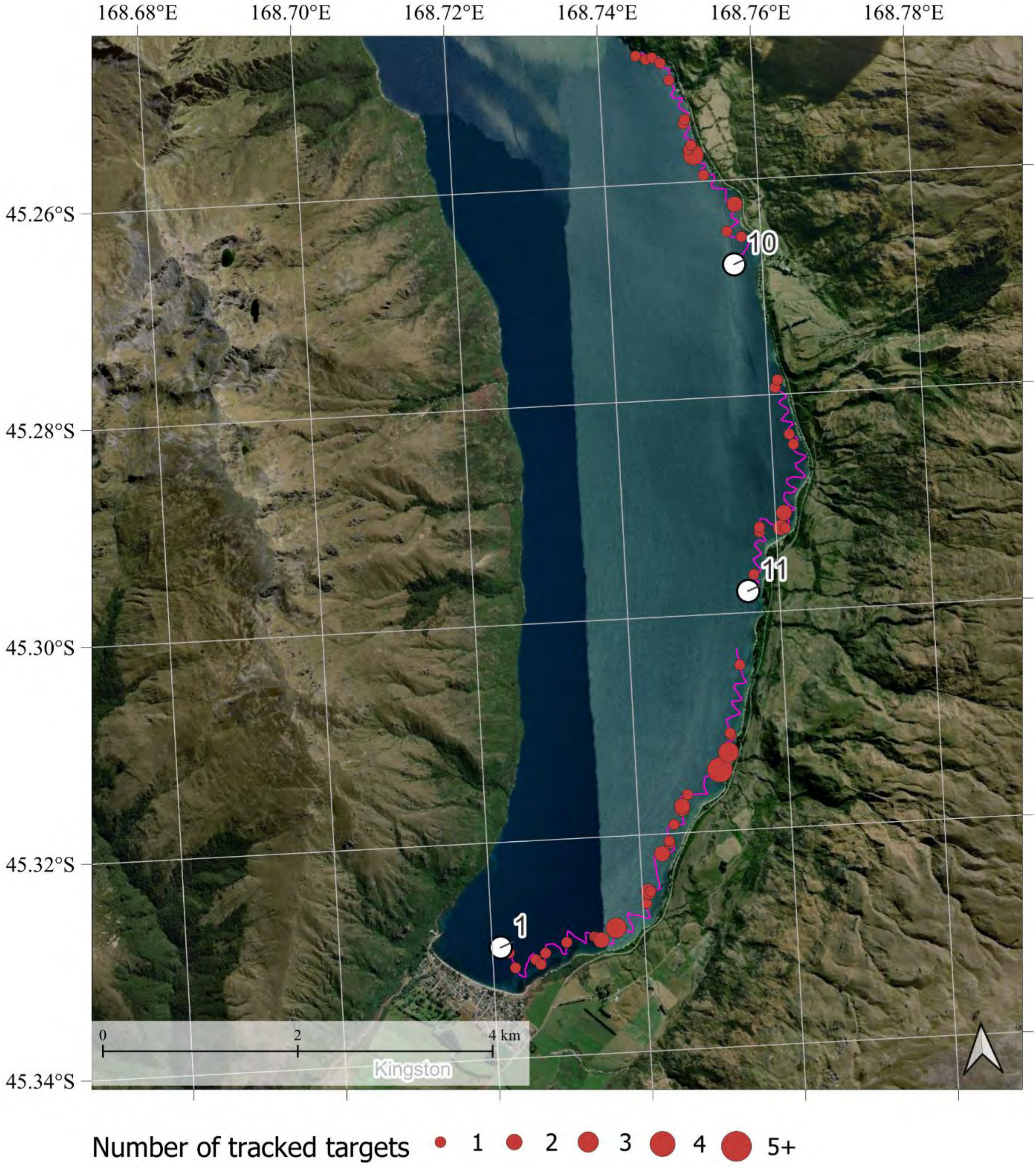


Figure 16: Wakatipu – Kingston area.

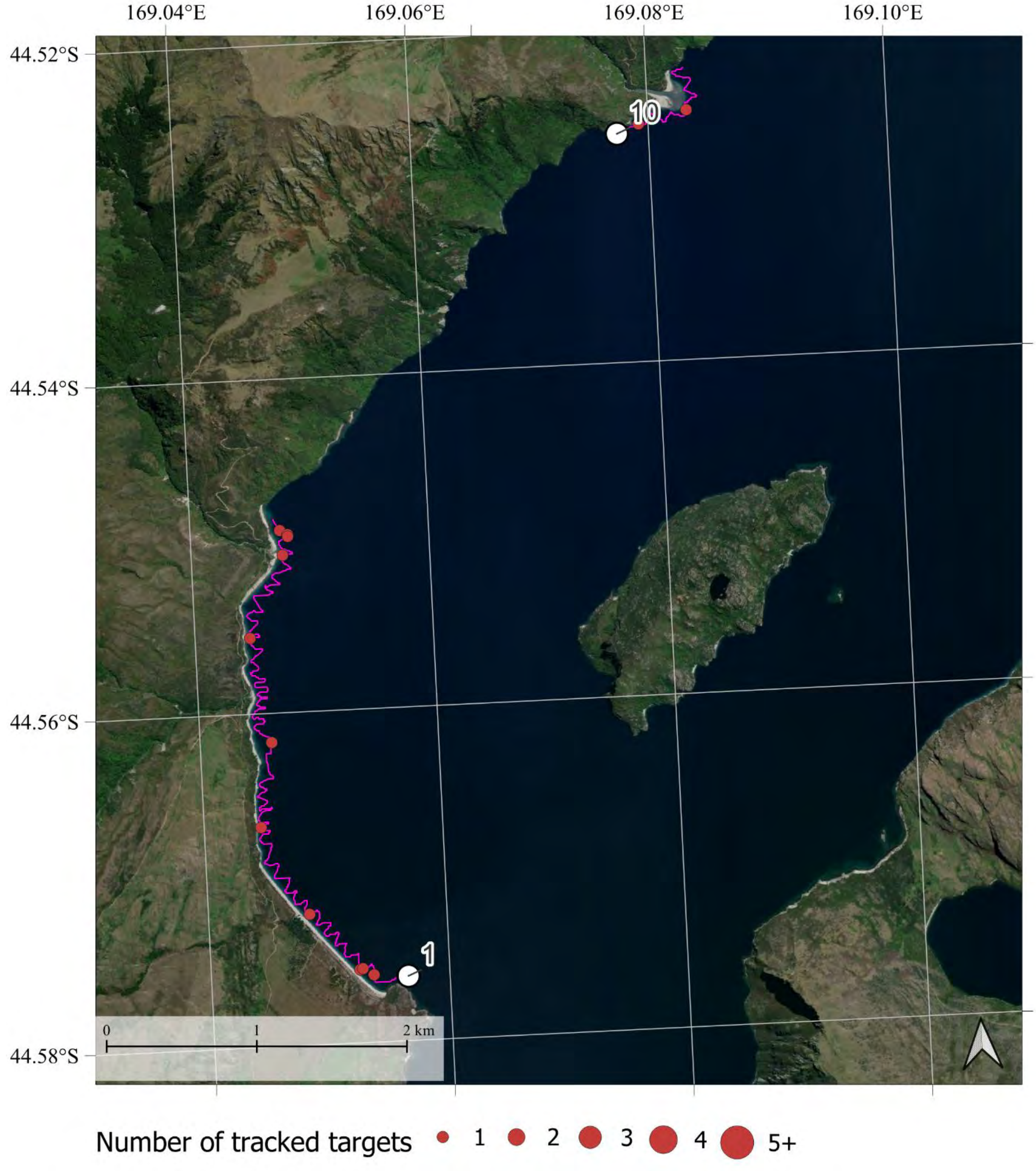


Figure 17: Wānaka – Northern.

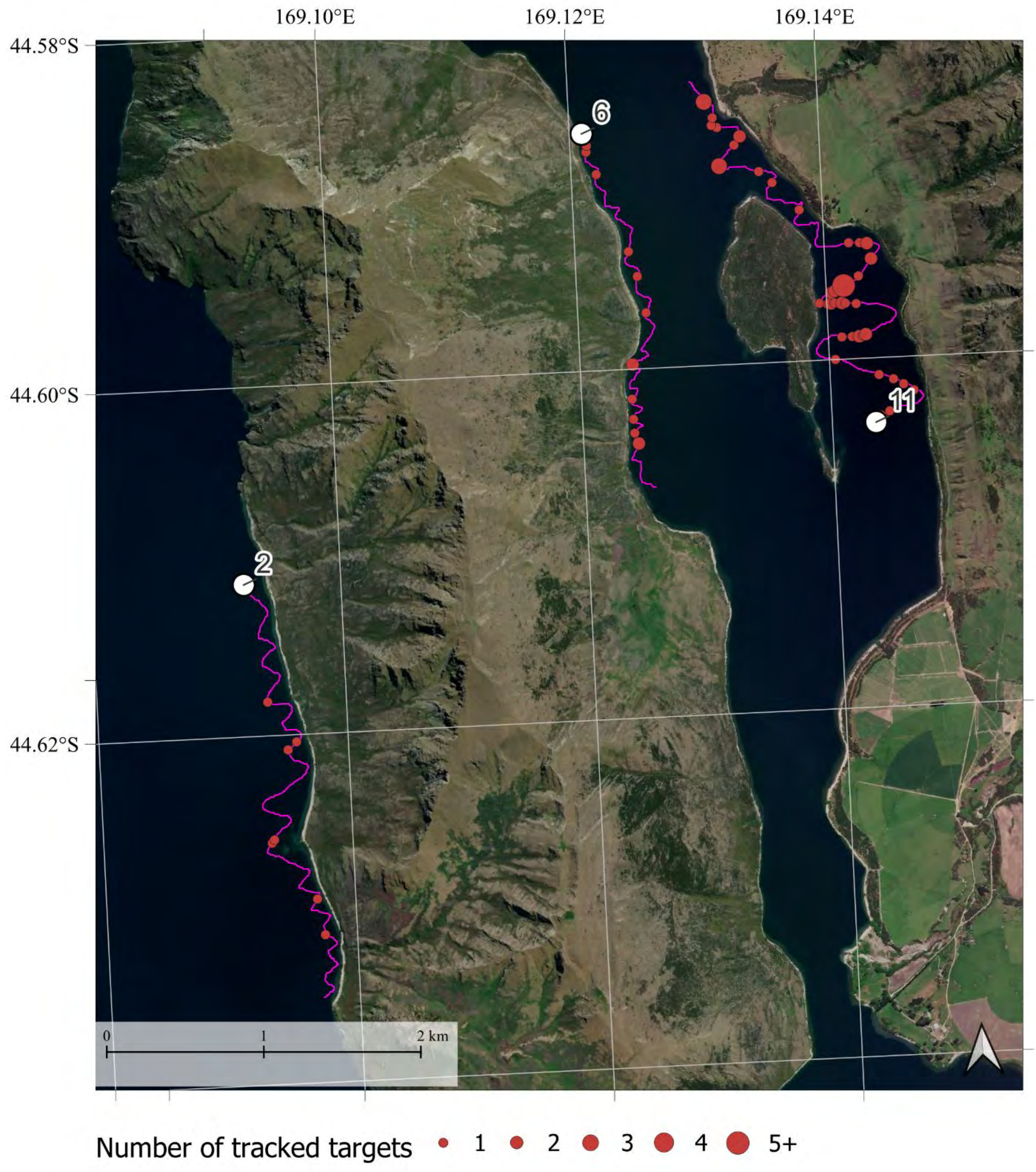


Figure 18: Wānaka- Eastern.

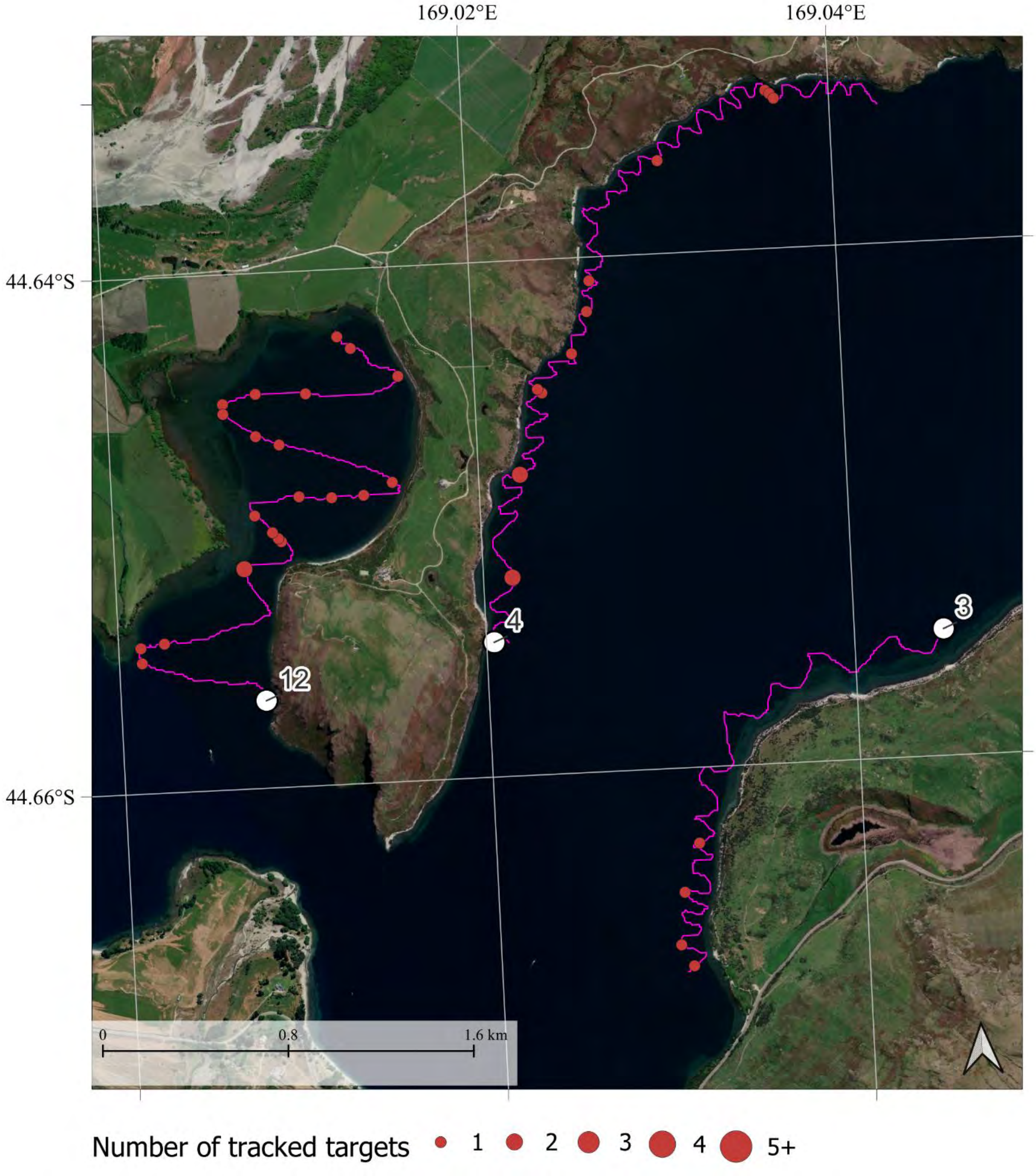


Figure 19: Wānaka- Western.

Appendix C - Methods

Field work

The survey fieldwork occurred from the 12th to the 17th of February 2024, with further details provided later in this report. The surveys were conducted using Otago Fish & Game's Central Otago boat, OFG7. The equipment was the same as the 2023 survey, namely a SIMRAD EK60 echosounder with a 22-degree, 120 kHz transducer. The GPT (general-purpose transceiver) was controlled using a Toughbook laptop with SIMRAD EL80 software, which also recorded the raw acoustic output. The acoustic output was continually geo-referenced using an external GPS chip. The transducer was mounted amidships on the starboard side on a pole mount designed specifically for Southern Lakes acoustic surveying.

The system was calibrated using NIWA protocols, which broadly follow Demer et al. (2015). Acoustic transducers vary and degrade over time, so calibration using an object with known physical characteristics is crucial to compare results between years. A full calibration report is available on request.

The estimates for sound speed and absorption needed to accurately calculate acoustic strengths were determined in ESP3 using the formulas of Francois & Garrison (1982) and Fofonoff & Millard Jr. (1983). These formulas require a temperature profile, which was obtained using an RBR Concerto logging thermometer. One RBR cast was conducted in both lakes Hāwea and Wānaka, while three were conducted in Lake Wakatipu due to its size and arm structure (Glenorchy, Frankton, and Kingston). The salinity was set to zero as the survey was in freshwater.

Surveys followed the transects and track logs from the 2009 surveys (Gauthier, 2009), which were largely based on earlier gillnetting surveys by James & Graynoth (2002). Surveys generally followed a zigzag pattern across the shallow zone, usually between 2 and 30 metres depth. Navigation was via a laptop with an external GIS chip, running QGIS software. Track logs were also added to the boat's plotter to assist navigation. The boat plotter had the transducer turned off to avoid interference.

To assist with target identification, gillnets and a GoPro set up with a dive torch were taken. Unfortunately, due to holdups while learning the process, only one camera drop and no gillnet sets were conducted.

Acoustic analyses

Acoustic data analysis employed "echo counting" methods (Kieser & Mulligan, 1984), implemented in version 1.52.0 of NIWA's custom ESP3 post-processing software (Ladroit et al., 2020). Calculating the depth, area and volume surveyed required constructing a bottom profile for each transect. The bottom detection v2 algorithm was used with settings refined by Dr Richard O'Driscoll following the 2023 survey. Bottom profiles were then manually scrutinised and edited where needed.

Potential fish targets in the echogram were manually identified using a 40 log R time-varied gain, as described in Escobar-Flores & O'Driscoll (2023), following the advice of Simmonds &

MacLennan (2007). Targets were required to show the distinctive "thumbnail" shape produced by a single fish. This manual process also allowed us to identify bad data regions, including trees, bubbles, and surface turbulence.

Targets identified by the above procedure then had a single target selection algorithm run. Table 6 shows the algorithm parameters used to identify whether targets met the target strength requirements to be considered salmonids.

Table 6: Single target detection parameters used in ESP3 software.

Parameter	Value
Minimum range (m)	3
Maximum range (m)	Infinite
Target strength minimum threshold (dB)	-55
Target strength maximum threshold (dB)	-20
Pulse length determination level (dB)	6
Minimum normalised pulse length	0.5
Maximum normalised pulse length	2.0
Maximum beam compensation (dB)	12.0
Maximum standard deviation of angles (degrees)	2.0

Targets that met the above requirements had a tracking algorithm applied to ensure individual fish were less likely to be counted multiple times. The tracking algorithm was run with the parameters in Table 7.

Table 7: Tracked target detection algorithm parameters used in ESP3 software.

Parameter	Value
Lower threshold for maximum TS within a track (dB)	-45.0
Alpha	0.7
Beta	0.5
Exclusion distance – major and minor axis (m)	2.0
Exclusion distance – depth (m)	0.4
Major axis weight (%)	20.0
Minor axis weight (%)	20.0
Range weight (%)	40.0
Target strength weight (%)	20.0
Minimum number of single targets in track	3.0
Maximum gap between single targets (pings)	3.0
Exclusion distance – major and minor axis (m)	2.0
Exclusion distance – depth (m)	0.4

Habitat Enhancement Fund Project Updates

This report was undertaken on selected projects approved for funding from the Council's habitat and research enhancement fund in the 2018-2020 years.

Robert Hewett. Manuka Gorge

In 2019, the Council granted $1,000 towards fencing costs. Mr. Hewett planned to flood an existing wet area, but due to the catchment's size, a resource consent was required for the proposed pond covering approximately 0.35 hectares. The project stalled due to insufficient funding, prompting a decision to allocate the grant towards supporting the resource consent application.

To date, Mr. Hewett has not repositioned the fence, built the dam, or initiated planting. However, 200 Carex secta plants allocated for the project were successfully planted as part of a riparian fencing initiative elsewhere on his property. Mr. Hewett remains committed to constructing the dam to enhance the wetland before the resource consent expires in 2029.

Photo 1. Area to be inundated.

Terry Broad. Lower Taieri

In May 2019, the Council approved a $2,000 grant for Mr Broad to enhance a wetland dominated by rank grasses by creating open a water area, located along the lower Taieri River. Mr Broad aimed to establish varying depths of open water to provide habitat for tuna and inanga. Additionally, the project aimed to offer suitable areas for waterfowl to loaf, feed, and breed.

During the site visit, no waterfowl were observed, although Mr Broad had previously seen shoveler and royal spoonbill using the pond. Currently, while the pond supports inanga spawning, its benefits to waterfowl appear limited. The dam, constructed from a drain, has resulted in steep banks, and the absence of overhead vegetation restricts cover essential for attracting waterfowl to utilise the pond.

Introducing overhanging and emergent vegetation will provide food sources such as seeds and invertebrates, as well as overhead cover, enhancing the pond's attractiveness to waterfowl and further supporting inanga productivity. Planting the surrounding areas with Carex secta and other suitable plants, along with modifying the banks to create shallow water zones, is likely to improve the overall habitat quality and productivity of the pond.

Mr Broad has expressed a desire to continue the open water development in this wetland.

Before

Photo 2. Before. An area of open water approximately 18m by 65m was created on the left-hand side of the drainage line in this photo

After

Photo 3. Shows the new pond after its formation, characterized by steep banks and a lack of cover. Inanga have been observed spawning on the pond's banks during leap tides, potentially providing a food source for shoveler/kuruwhengi.

Photo 4. After. Shallow end of pond inundated during high tides.

David Hill. Omakau

In November 2019, the Council approved a $2,000 grant to support earthworks, planting, and fencing for the creation of a new wetland spanning just under 1 hectare. Situated between two established wetlands, one on an adjacent property, these three areas collectively double the wetland coverage in the Manuherekia region, contributing significantly to wetland restoration efforts.

The design of the new wetland included a spring-fed source to maintain shallow water levels, strategically complemented by plantings aimed at providing food and cover specifically for dabbling ducks. Additionally, Mr. Hill has generously offered the site for use by junior or novice hunters for duck hunting purposes.

The establishment of this wetland, coupled with enhancements to the adjoining pond on the neighbouring property (as seen in Photo 6), has created a substantial wetland complex benefiting waterfowl. During observation, over 100 waterfowl were present, including a pair of black swan/kakīānau with signets alongside greylards and scaup/pāpango.

To further support habitat enhancement, major waterways on the property have been fenced, with stock crossings and plantings of carex secta and flax. However, the success rate of these plantings has been hindered by late timing of planting, impacting survival rates during summer, compounded by competition from rank grass. Mr Hill has expressed a desire to enhance a further three ponds on his property.

Before

Photo 5. Before. The area to be flooded by earthworks with fencing and planting.

Photo 6. Before. Neighbouring wetland located to the northwest on the boundary of the adjoining property

Photo 7. Depicts the small wetland area before development. It is located immediately northwest of the newly proposed wetland, with the neighbouring pond situated behind the willow trees in the background. This wetland was integrated into the developed area.

Photo 8. A panoramic photo that depicts the wetland comprising two ponds with shallow water, uneven edges, and an island. The willow and poplar trees are visible in previous photographs serving as reference points for the scale of this development.

Photo 9 The shallow water is bordered by rushes and sedges, creating edge cover and offering foraging opportunities for waterfowl. Beech trees have been planted to provide shelter, although their current height limits coverage along the edges. Mr. Hill intends to plant additional trees along the far edge to enhance wind shelter and predator cover as part of the ongoing development of this wetland.

Photo 10. Shows the wetland spring featured in Photo 7. This area includes an island that was utilized for nesting by black swans/kakīānau this year. Upon arrival, around 12 greylards flew off from this pond. The spring ensures that the water remains in motion, preventing freezing during this time of year.

Photo 11. After the development, sedges now line the edge of the pond. A few weeks ago, sheep broke through the fence, leading to uneven browsing across sections of the wetland. In the neighbouring pond, swans and their signets from the island can be seen, alongside approximately 70 greylards, 30-40 scaup, and a pair of paradise ducks. The neighbouring pond, visible in the background (Photo 6), has also been fenced off.

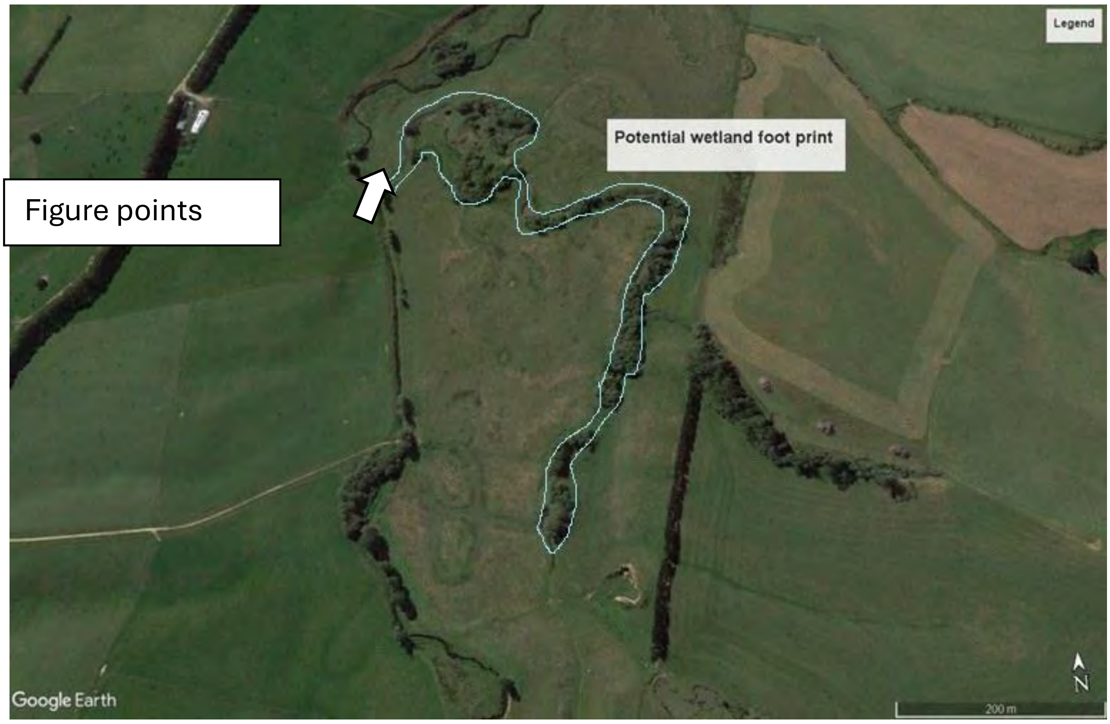
Pamu, formerly Landcorp. Dawson Downs dry stock farm. Kaihiku.

In April 2018, the Council approved $2,000 for stage one of a two-stage project aimed at flooding an ephemeral tributary of the Kaihiku River to create shallow water habitats for dabbling ducks. Stage one included fencing, willow control, and initial planting initiatives. Stage two was planned to involve installing a culvert or another method for water level management. The total flooded area is anticipated to potentially cover up to 2 hectares, depending on water level management.

Upon approaching the wetland area, 15-20 greylards were observed flying off. Since the grant approval, the project has faced challenges due to changes in farm management, resulting in delays. A larger area than originally planned has been fenced off to restrict stock access to the wetland and the Kaihiku river. Willow control has commenced recently, using herbicide drilling, with complete removal scheduled for November. No formal plantings have been undertaken; instead, native sedges are naturally revegetating the waterway margins from the existing seed bank.

Part two of the project, involving water level management through a culvert installation, has not yet been implemented, but plans are still in place to proceed with this phase soon. During the site visit, the area had already been flooded.

Before



Proposal to fence and flood. Estimated area likely to be flooded

Photo 12. Depicts the ephemeral wetland area before development, susceptible to seasonal flooding. It shows part of the area expected to be inundated.

After

In Photo 13. 15-20 greylards are seen flying off from the unfrozen water. The farm manager grazed the site to facilitate easier and safer work on drilling the willow

Photo 14. Shows native sedges regrowing along the bank edge. The area features diverse habitat, including an island providing shelter for waterfowl nesting

Photo 15. Captures the ephemeral section of the wetland holding water

John Mark. Heriot.

In May 2019, the Council approved a $2,000 grant for the development of a shallow water pond with sediment traps upstream. The pond, initially planned at 0.2 hectares (70m x 30m), was designed to provide nesting habitat for dabbling ducks, while the sediment traps were intended to enhance water quality in the Pomahaka River as part of a broader water quality improvement project within the catchment.

Upon inspection, 15-20 greylards were observed flying off from the wetland. The wetland area exceeded the original plan in size, with the dam wall being raised post-initial construction to create a larger open water area. It now serves as habitat for greylard loafing and brood rearing. The wetland integrates well with the farm's overall development strategy, with most waterways fenced and planted on the property. Upstream of the pond, there are two sediment traps (the top one recently emptied), and the area is surrounded by extensive plantings of native species, supplemented by pin oaks.

Additionally, approximately 0.5 hectare of land uphill has been fenced off to mitigate sediment runoff. This is grazed by young stock behind a wire in summer to keep a section of the pond bank with low grass for a loafing site. Gorse has started to emerge as a problematic weed at the lower end of the pond. Measures are being taken to manage it by cutting and applying gel to the stems to avoid harming native plants by weed spray.

Before

Photo 16. Depicts the area before flooding, illustrating the section intended to be inundated.

After

Photo 17. Shows the aftermath of wetland development, featuring two sediment traps that were constructed. The hillside in the background has been retired from grazing. The main pond is situated behind the dam wall to the left.

Photo 18. Shows the upper end of the pond after restoration, featuring shallow water adorned with a variety of native plantings. These include flax, toi toi, carex secta, mapau (black maple), and tarata (lemon wood). Pin oaks have also been planted at the far end of the dam, where summer grazing occurs behind a portable electric fence.

Photo 19. Depicts the edge of the pond after development, where Carex secta lines the edge of the wetland to provide cover and nesting habitat. This area represents the bottom end of the pond development. However, gorse has emerged as a threat, affecting access and the natural appearance of the wetland.

Scott Patterson. Makarora.

In 2019 the Council approved $4,050 to assist with the enhancement of the largest remaining wetland in Makarora. 450m of old fencing was removed and replaced with new fencing providing a larger buffer around the 4.3ha wetland for planting. Another 450m of new fencing was installed, while 250m of existing fencing was upgraded.

This is one of the largest grants made by Council. At the time of the inspection black swan, paradise ducks and pūkeko were all present on or immediately adjacent to the wetland area. The fencing and planting have enhanced and secured the large wetland area. Further plantings of carex secta and other native wetland species and willow control has the potential to improve the biodiversity at this significant wetland site.

Before

Photo 20. Shows a section of open water at the Mt Albert Station Pond Enhancement project before modifications. The cattle in the background are now excluded from this area due to the new perimeter fence.

Photo 21. Shows the area before modifications, with the fence in the foreground positioned close to the water's edge. The fence line running through the pond has yet to be removed.

Photo 22. Shows the western view of the wetland area, currently grazed, which is slated to be included in the 4.3-hectare pond enhancement project. The red line indicates the planned location for the new fence

After

Photo 23. Depicts the western view after completion, displaying patches of established native plantings along the edges of the wetland. A significant area of shallow open water has developed, creating habitat for waterfowl.

Photo 24. Depicts the scene after restoration, where sedges and rank grasses line the banks. Black swans (kakīānau) and paradise shelducks (pūtakitaki) are comfortably settled in their habitat

Photo 25. Depicts the area after restoration, displaying a large expanse of open water surrounded by rank grass, willows, and sedges. Enhancements such as planting Carex secta and adding more trees along the banks would further improve the breeding habitat and provide cover from predation for waterfowl.

Photo 26. Shows the area after restoration, where willow trees are starting to establish in some sections of the wetland, providing cover from predation. However, there is concern that over the long term, willows could dominate and encroach upon the open water areas. Native sedges, and rank grass form the edge cover around the water.

Summary

Except for Mr. Marks' wetland development, the common issue among these wetlands is the varying quality of planting and subsequent cover available to benefit waterfowl. Providing additional grants for plants grown at the Correction nursery would significantly enhance the breeding success of these wetlands by increasing cover and ensuring a continuous food source for waterfowl. Landowners have shown willingness to undertake further planting; supplying plants would bolster their motivation and complement the Council's current investment in these sites.

Tailoring the allocation to the specific needs of each site, between 100 to 200 plants, mainly carex secta, would markedly improve the habitat's suitability for waterfowl of some promising wetland development. This further enhancement directly supports license holders by boosting brood production.

Recommendation
That this report be received

David Priest
Operations manager
July 2024

References

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14.7

Compliance Summary Report

Purpose

This report provides a summary of compliance activity during the 2023/24 fishing and gamebird hunting seasons.

It also reports on achievement of internal regional compliance guidelines of:

- Checking 10% of Fish or Game Adult Full Season Licence holders annually.
- Maintaining 95% compliance with laws and regulations.

Licence Diversion levels

Direction on matters of prosecution, including diversion levels are guided by the "Offense Guidelines" adopted by the Council. These standard diversion fines were approved in September 2022 and are in line with Southland and Central South Island regions levels.

Fishing Season Compliance

Total Adult and Family Full Season Licence holders	11,766
Documented Interview with anglers	1,086
% Checked (Target >10% Adult licence holders)	**9.23%**
Number of Offenders (excluding Failure to Produce or "FTP's")	36
% Compliance (Target: 95%)	**96.69%**

Our total number of interviewed anglers decreased to 1,086 compared to 1,167 last year. The compliance team fell short of its target, achieving 9.23% of the total full season family and adult licence checks, below the 10% goal.

Thirty-four individuals were apprehended for offences under the Conservation Act 1987, which is three more than the previous season. Over the past five years, compliance levels during interviews have ranged from 95% to 98%, with this season's result falling within that range at 96.69%.

In addition to more serious offences, individuals who failed to produce a licence to a ranger in the field (FTPs) had their licence status checked in the database and were issued verbal warnings. This routine procedure ensures anglers do not falsely claim to possess a valid sports fishing licence.

Overview of Fishing Offences

Fishing without a valid sports fishing licence (FWL) continues to be the predominant offence in the Otago region, accounting for 91.66% of detected offences (excluding FTPs). No serious (obstruction type) offences required prosecution action during this period. Additionally, three individuals were found to be fishing with two rods, a violation of regulations.

Fishing Prosecution Summary

Fishing Without a Llicence Outcomes

- FWL offenders received warnings because they failed the public interest test for prosecutions.
- 22 FWL offenders accepted and completed diversion.
- Two FWL offenders did not respond to attempts to engage with them, so matters were dropped due to the cost of trying to locate them.

Two Rod Offence Outcomes

- Three offenders accepted and completed diversion

The region continues to utilise its diversion system, which entails lodging charges with the nearest Court and concurrently offering diversion opportunities. All charged offenders accepted the Council's offer of Diversion and contributed to the Otago Region's 'Habitat Enhancement and Research Fund.'

Of the two offenders who evaded prosecution, one was a non-resident who provided contact details for his residence in Australia but subsequently ignored repeated attempts at communication. The other was a resident who also failed to respond to phone calls and emails and did not answer the door to receive the summons, despite indications of someone being home.

A decision was made that the costs of further pursuing these individuals would outweigh the benefits of the prosecution. Details of their offences and case circumstances have been documented in the National Compliance database for future reference in case of any future encounters.

Game Season Compliance

Total documented game licences	3,854
Total game licences checked	106
% Checked (Target >10% Adult licence holders)	**2.75%**
Number of Offenders (excluding Failure to Produce or "FTP's")	4
% compliance (Target: 95%)	**96.23%**

Game Compliance Summary

Once again, we fell short of our target to interview 10% of gamebird licence holders this season. This target remains very challenging to achieve, particularly since much of our compliance efforts are concentrated on the opening weekend across our region, where we field the largest team of rangers for opening weekend nationally.

During this year's opening weekend, staff visited 107 ponds and ranged around Lake Dunstan, engaging with 106 hunters. In the Lake Mahinerangi-Lawrence area, we observed numerous empty maimai with ducks present, indicating significant unoccupied water.

Following the opening weekend, our game ranging efforts typically require substantial resources for limited hunter contacts. As a result, all 106 game licence checks for this season were conducted during the opening weekend, covering a mix of public and private lands.

Hunting Without a Licence Outcomes

- Two Hunting without licence offences accepted and completed diversion

Breach of Game Gazette conditions

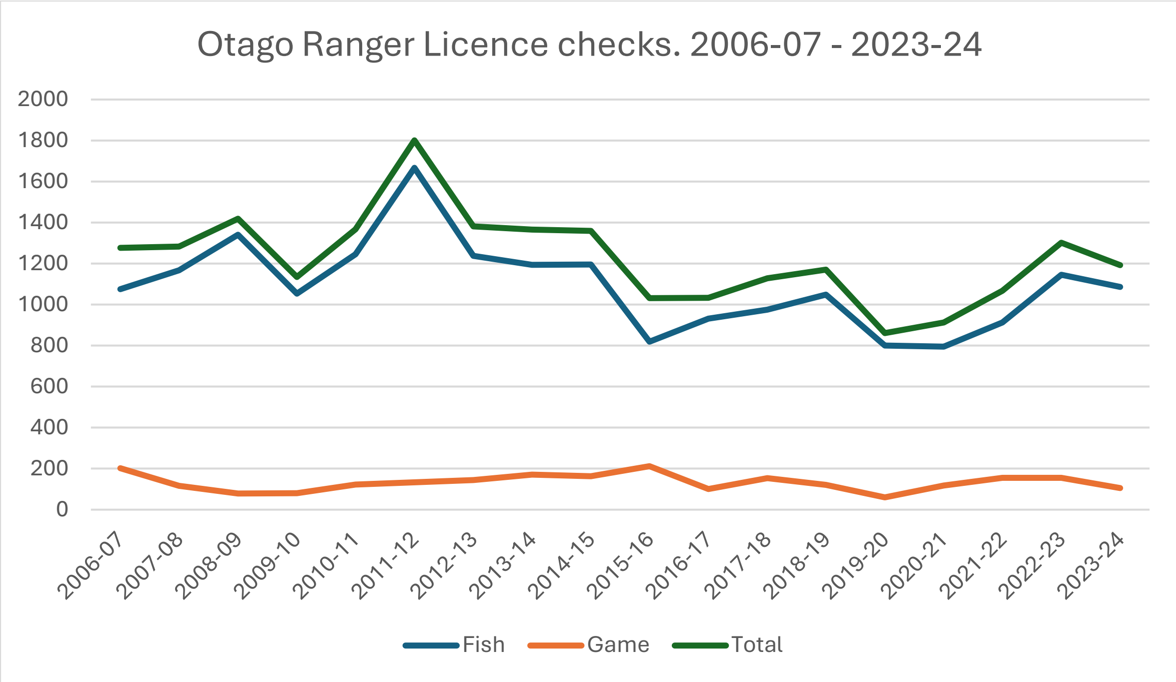
Lead Shot Possession Outcomes.

- One lead shot offender was issued a warning due to the amount of lead shot present.

Over bag limit

- One offender was issued a warning for being Over the Bag Limit (Shoveler Hen).

Trends in ranging activity



Fishing licence checks were down 84 interviews from the 2022/23 season.

Game bird licence checks were also down from the 2023 season, with a decrease of 49 interviews.

Recommendation
Council receives this report.

David Priest
Operations Manager
Cromwell
July 2024

Summary of Fishing Competitions for the 2023/24 Season

Introduction

Fishing competitions are approved annually in accordance with the Sports Fish and Game Management Plan (SFGMP) for the Otago Region, adhering to conditions outlined in the Freshwater Fisheries Regulations 1983.

This report summarises the competition activities for the 2023/24 work year (Project 1351 in the workplan) and provides detailed information (see Appendix 1) on larger commercial-type competitions that are required to pay a $40.00 administration fee and levies.

Overview

During the 2023/24 season, there were four main competitions in the Otago region that attracted levies. These events, publicly notified, emphasise family participation, with special attention given to junior anglers through prizes and giveaways.

Our approval conditions generally allow each contestant to weigh and measure one fish of each species at each event. The number of fish presented for weigh-in can vary significantly between seasons, largely influenced by weather conditions. On lakes Hāwea and Wakatipu, small salmon are frequently caught in abundance, with many being released.

Freshwater Fisheries Regulations 1983 Section 57F Rental

Under Section 57F of the Freshwater Fisheries Regulations 1983, a fishing competition approved by a Fish and Game Council that charges an entrance fee incurs a rental fee payable to the Council. For major competitions, we have been requesting only 50% of the levy, recognising their community-based nature, contribution to angling opportunities with family involvement, and support for local communities. Levy income varies based on entry grades, such as adults versus juniors.

Levy income supports the purchase of fishing equipment and merchandise for events hosted by schools and Take A Kid Fishing (TAKF) programmes. Major competitions receive a rod and reel set as a junior prize.

Refer to Appendix 1 for a comprehensive list of major competitions and supporting details for the 2023/24 season, noting that profits are sourced from entry fees, donations, sponsorship, fundraising, and BBQs.

In-house competitions by angling and hunting clubs regularly feature for club trophies, with some TAKF programmes incorporating competition components. We are involved in most events and provide financial support through our grants budget where applicable. Staff attendance at major events, particularly those where fisheries data collection is crucial, is prioritised.

Staff attended events in Glenorchy, Hāwea, and Cromwell to conduct fish measurements and weight assessments.

Collection of Fisheries Information

Catch data from major competitions is collected and stored in a database. We possess extensive fisheries information spanning over 40 years from competitions like the annual Glenorchy event at the head of Lake Wakatipu, enriching our understanding of lakes Dunstan, Hāwea, and Wakatipu.

Summary

Fishing competitions offer diverse fishing opportunities and enjoyment for clubs, organisations, families, and individuals. Major competitions subject to levies are well-organised and align with requirements under Otago's SFGMP. Staff participation is appreciated by organisers, and the fisheries data collected significantly contributes to monitoring population trends and fishery health.

Early season competitions serve as incentives for purchasing new season licenses.

Recommendation

The report is recommended for approval.

Ben Sowry
Fish and Game Officer
June 2024

Appendix 1. Major fishing completions which attracted an application fee and levies for the 2023/24 season

Date	Event and duration (years)	Organiser	Lake	No of entries	Fish measured and weighed	Application fee $40, and levies	Distribution of Profits
7th October 2023	Glenorchy Fishing Competition (42)	Glenorchy Playgroup	Wakatipu	199	127	$472.50	$3237.50 income raised for Glenorchy Early childhood education center.
12th Nov 2023	Lake Dunstan Fishing Competition (29)	Rotary of Cromwell	Dunstan	79	47	$170.50	$494 profit to the Cromwell College Breakfast Club, books for babies, and library books for primary school libraries
2nd January 2024	Lake Dunstan Fishing Competition (13)	Cromwell Town and Country Club	Dunstan	122	59	$262.50	All profits went into prizes
10th February 2024	Lake Hāwea Family Fishing Classic (27)	Family Fishing Classic Committee	Hāwea	330	210	$604	$8,700 in profits distributed to the following: $700 Upper Clutha Hockey $500 Friends of MAC $500 Hawea Kindergarten $500 Hugo Dale $500 Food for Love $500 Hawea Community Centre $500 Hawea Men's

							Shed $500 Hawea Flat Playgroup $500 Kahu Youth $250 Hawea Moggie Squad $250 Old Folks Tucker $500 St John Youth $500 Upper Clutha Childrens Medical Trust $500 Riding for the disabled $500 Hawea Thursday Group $500 Hawea Domain Trust $500 HCA – Hawea Anzac Committee $500 Hawea Fire Brigade Sky Tower Challenge 2025