Acoustic assessment of salmonids in large South Island lakes, February 2009

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Contents

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Executive Summary

This report documents results from the third successful acoustic survey of salmonids in large South Island lakes. Series of acoustic transects were carried out in February 2009 in Lakes Coleridge, Benmore, Hawea, Wanaka, and Te Anau following the same protocols developed for the 2007 and 2008 research programme. In addition to the acoustic survey, gillnetting experiments were conducted in Lake Coleridge and Lake Benmore to verify and determine the composition of targets and to compare catches to acoustic densities. Visual surveys were also conducted in Lake Te Anau to assess the density of salmonids in shallow water not accessible to the acoustic survey.

Data obtained from the acoustic survey were consistent with the 2007 and 2008 results. Lake Benmore had the highest density of targets and showed steady rise in density since 2007. Comparatively Lake Te Anau had the lowest recorded density and has been on a decline since 2007. Data from the gillnetting exercise in Lakes Coleridge and Benmore were consistent with observed acoustic densities, but mesh size and soak time differed among lakes. Only four fish were captured in Lake Coleridge compared to 96 in Lake Benmore, 40 of witch were sockeye salmon. Evidence also suggests that these salmon feed on extended layers of zooplankton (mysids), which are denser in this lake. Visual surveys were successful in Lake Te Anau and suggest that this may be an accurate method of assessing fish density in shallow waters. Data suggest that fish density in shallow water is comparable to that obtained from the acoustic transects in deeper water, and that the exclusion of this zone may have negligible effects on overall density results. It is suggested that more detailed experiments with gillnets and/or visual survey be carried out to further validate the acoustic method and improve the time series of salmonids density for these lakes.

1. Introduction

Fish and Game New Zealand has statutory responsibility for most of New Zealand's freshwater recreational fisheries. This includes the management of large lakes that support populations of rainbow trout (*Oncorhynchus mykiss*), brown trout (*Salmo trutta*), Chinook salmon (*Oncorhynchus tshawytscha*) and/or sockeye salmon (*Oncorhynchus nerka*).

In 2007 and 2008, NIWA was contracted to develop and test acoustic techniques to survey some of these lakes in the South Island in an effort to develop a monitoring system for salmonids. Following these successful trials, five of these lakes were surveyed again from February 10 – 19 2009 (Lakes Coleridge, Benmore, Hawea, Wanaka, and Te Anau). In association with the acoustic survey, gillnetting was carried out in Lake Coleridge and Lake Benmore to confirm and identify species present, and to compare catch rates to acoustic indices along a few transects. Furthermore, visual surveys at five sites were performed in Lake Te Anau to assess the presence and density of salmonids in shallow waters not accessible to the acoustic survey (areas less than 3 m depth).

This report presents the results from the 2009 survey with comparisons to the previous years. Results from the gillnetting and visual survey are discussed along with recommendation for future work.

2. Methods

2.1. Acoustic system

The echosounder used for these surveys was a SIMRAD EK60 with a 22° (at 3 dB half power points) split-beam transducer specifically developed for this work by Industrial Research Limited. Details of the system are given in Table 1. The echosounder comprises a transceiver unit (of similar dimensions to a small desktop computer), a transducer mounted on the side of the vessel, and a laptop running monitoring and data-collection software. The echosounder was powered by a 12V deep-cycle battery (to isolate electric noise), while other instruments (laptop, GPS) were powered off the boat's auxiliary outlet. A 200 kHz system was also available during the survey, but problems with the power supply from its transmitting unit prevented its use.

Table 1: Configuration of the acoustic system used to collect data. Refer to Section 7.1 for calibration results.

Parameter	Value
Echosounder	EK60
GPT model/serial	120 kHz S/N 511
GPT software version	not recorded
EK60 software version	2.1.2
Transducer model	IRL 120
Transducer serial number	SB032120022
Operating frequency (kHz)	120
Transducer draft setting (m)	0.0
Transmit power (W)	100
Pulse length (ms)	0.064
Transducer peak gain (dB)	13.3
Sa correction (dB)	-0.18
Bandwidth (Hz)	11800
Sample interval (m)	0.012
Two-way beam angle (dB)	-10
Absorption coefficient (dB/km)	3.7
Speed of sound (m/s)	1466
Angle sensitivity (dB) alongship/athwartship	6.10/6.10
3 dB beamwidth (º) alongship/athwartship	22.1/22.1
Angle offset (º) alongship/athwartship	0.0/0.0

2.2. Acoustic sampling procedures

The survey was conducted with the Fish and Game New Zealand Southland region vessel (Fig. 1). The physically small transducers (12 cm x 12 cm outer-shell) were mounted on the lower end of a pole (50 mm diameter stainless steel tube), which could be raised and lowered in a bracket that dropped into a hole made in the gunwale of the vessel at approximately amidships (Fig. 1). Transducer faces were submerged approximately 50 cm below the surface. The pole could be readily withdrawn by hand for transit and then reinserted to resume surveying.

Figure 1: The New Zealand Fish and Game Southland Region vessel used for the survey (a), with the pole mounted amidships on the starboard gunwhale (b), and the two transducers mounted at the end (c). The 200 kHz was not used in 2009.

Transects consisted of a series of zigzag patterns alongshore (see Sections 7.4–7.8 for transect maps), covering depths from as shallow as possible (usually about 2-3 m) out to 30 m (this being the depth beyond which few fish were found in the earlier set netting surveys; James & Graynoth 2002, and was confirmed by acoustic survey; Gauthier 2008). Survey speed was approximately 4 knots, and successful results (limited acoustic noise) were obtained in conditions up to about 10 knots of wind (small waves with occasional whitecaps), depending on fetch and exposure conditions. To maximize fish detection and minimize biases due to the acoustic dead-zone near the bottom (especially in steep contours), a ping interval of 0.13 sec was employed. Faster ping rates increase beam overlap and thus the probability of detecting targets on the edge of the beam, before their echo gets merged with the bottom. This is particularly useful in areas where bottom depth quickly changes along the transect path (Fig. 2). Faster ping rates can however generate significant reverberation due to multiple boundary scattering (e.g. multi-path echoes), so it had to be adjusted from time to time depending on bathymetry and bottom type (ping rate interval ranged from 0.10 to 0.20 sec during the 2009 survey).

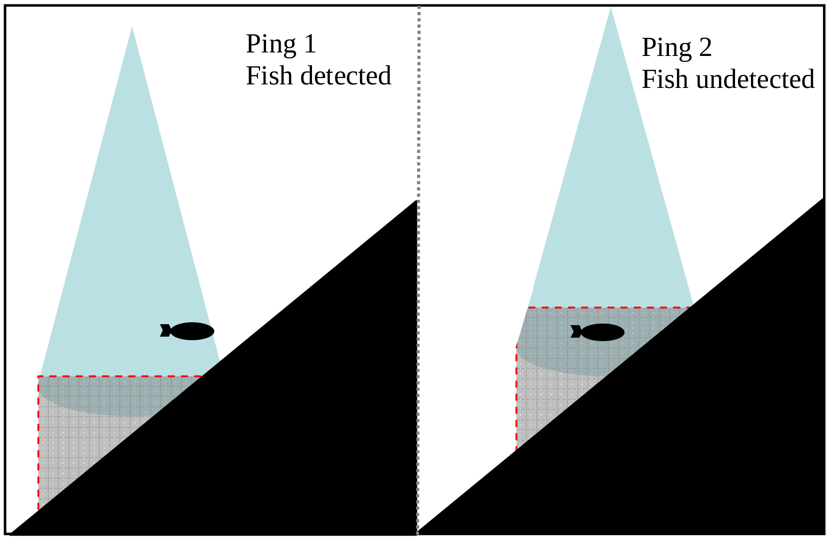


Figure 2: Example of echo transmission over a target that is close to the bottom on the edge of a steep slope. The shaded grey area represents the acoustic dead zone, where discrimination of fish from bottom echoes is impossible (as in ping 2). Faster ping rate increases beam overlap and the probability of detecting fish when they are on the edge of the beam (as in ping 1).

Navigation was provided by a laptop operating the FUGAWI© software linked to a GPS unit. A second GPS unit was also connected to the computer collecting the acoustic data for continuous geo-reference. All transects visited in 2008 were repeated in 2009 in Lakes Coleridge, Benmore, Hawea, Wanaka, and Te Anau.

2.3. Gillnet experiments

Experiments using gillnets were conducted with the assistance of Fish and Game officers on 2 transects in Lake Coleridge and 1 transect in Lake Benmore. For exact positions of the nets along the acoustic transects please refer to the maps in Section 7.9. All nets were laid out close to the bottom during the day (09:00 – 17:00) for a fixed period of time ranging approximately from 2 to 5 hrs (Table 2). Nets were installed after the acoustic sampling was completed on the transect. All fish collected in gillnets were identified to species and their length was measured with a precision of 5 mm. Stomachs from a few individuals were inspected for content in Lake Benmore.

Table 2: Parameters of gillnets used in Lakes Coleridge and Benmore. All nets were approximately 2 m in height. Set number 4 in Lake Coleridge (transect 1) used a thicker black nylon for meshes and was deemed inappropriate for comparisons.

Lake	Acoustic Transect	Set number	Depth (m)	Duration (minutes)	Section Length (m)	Mesh size (mm)
Coleridge	1	1	5	120	15	25
					15	37
		2	10	125	15	25
					15	37
		3	10	140	15	25
					15	37
	4	5	15	120	15	25
					15	37
		6	15	120	15	25
					15	37
		7	15	120	15	25
					15	37
Benmore	1	1	10	307	19	40
					20	65
					14	105
		2	10	276	19	50
					20	125
					29	100
		3	28	315	19	50
					20	125
					17	100
		4	20	323	19	40
					20	65
					15	105

2.4. Visual survey

Salmonids density in shallow waters that were not sampled by the acoustic method (water depth less than 3 m) was estimated by visual survey in Lake Te Anau. This method consisted of driving the boat at slow speed (1-3 knots) following the shoreline from a distance that varied between 5 to more than 50 m (depending on visibility, bathymetry, and presence of obstacles). The driver and observer(s) were positioned facing the shore (from the starboard side in the case of the Southland region boat) in a stand-up position (as high as possible) and verbally acknowledged the presence of fish when they were detected. Times of each detection were tabulated and the total distance travelled recorded by the GPS (noting start and end times). Success of this method requires suitable conditions for proper visual sampling. These conditions include:

1 – Fairly good water clarity (secchi depth of at least 5 m), with low turbidity.
2 – No wind, breeze, or rain, as small ripples on the water surface makes it impossible to detect fish.
3 – Good lighting angle (e.g. preferably with the sun in the back of the observer, with limited shadowing), as reflections can cause shimmering and gleaming. The use of polarized lens is also important to reduce reflections from the water surface.

Visual surveys were attempted at five locations where all these conditions were met (Fig. 3). For details please refer to Section 7.10.

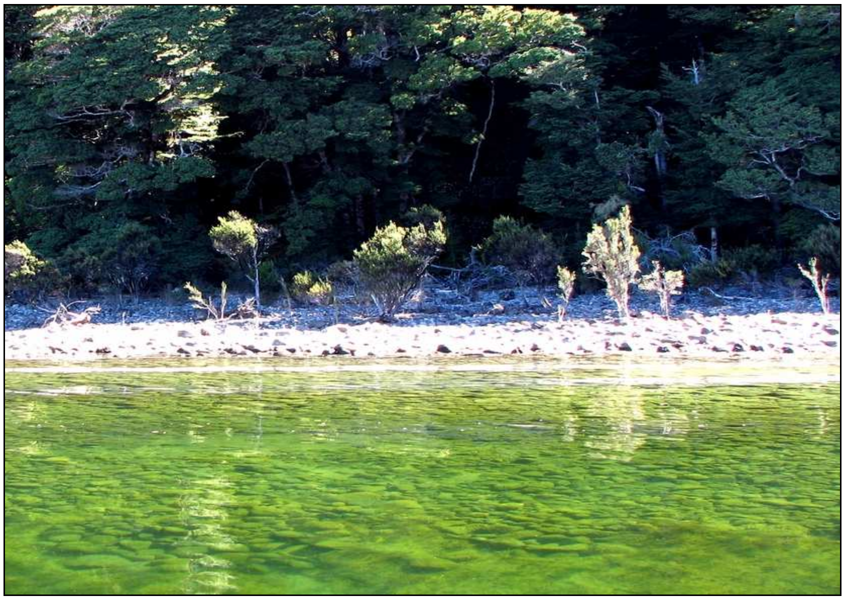


Figure 3: Example of suitable conditions for visual survey in Lake Te Anau. The bottom (cobbles and rocks in this instance) was clearly visible. Salmonids appeared as darker (and often moving) targets against the background. Use of polarized lens (not applied in this picture) removed most of the reflections visible in this photo.

2.5. Acoustic analyses

Analyses of acoustic data were performed using Myriax Echoview© post-processing software. Analyses consisted of a number of steps to identify and quantify targets. The first step involved using variable amplitude thresholds to scrutinise echograms and manually identify potential fish targets. The target strength amplitude threshold in the echogram was adjusted manually to determine whether the echo had the distinctive 'thumbnail' shape produced by a single target and was spatially separate from other echoes.

Using this approach it was possible to isolate fish targets close to the bottom, a technique most useful over steep slopes, where the acoustic dead zone (the superposition of fish and bottom echoes due to beam spreading) is substantial. The technique also enabled the detection of artefacts (such as submerged trees, and bubble plumes) that could otherwise be misconstrued as fish targets, or the detection of single targets within dense clouds of small organisms. For more information on the detection of single targets and examples of the use of multiple thresholds, see James et al. (2007b). All echograms were examined with a 40Log R time-varied gain, suitable to identify and measure dispersed single targets (MacLennan and Simmonds, 1992). Thresholds used to identify regions of potential fish targets and areas of artefacts ranged from -90 to -30 dB. Once all targets were identified, a region (box) was drawn around each potential fish target (or cluster of targets).

The second step of the analysis consisted of creating a well-defined boundary for the bottom echo. The total water depth was then used to estimate the total volume of water sampled based on the Kieser and Mulligan (1984) algorithm. For this we assume that the volume (in m^3) of water covered for 1 ping in the analysis domain is equal to:

$$V_p = \frac{l}{N} \sin\frac{\phi}{2} \delta_i \sum_{i=0}^{n-1} (R_{i+1}^2 - R_i^2)$$

Where l is the length (m) measured along the cruise track (assuming a constant speed and travel in a straight line), N the number of pings in the same analysis domain (to account for overlaps), ϕ the across track beam angle (see Gauthier (2008) for more details), R the range (m) measured along the beam axis, and δ has a value of 0 or 1 (0 for bad pings or bad data regions, 1 otherwise). We only included data where the bottom was 30 m or less. All data within 3 m of the transducer were also removed (where fish avoidance is likely). The total volume sampled for an entire transect was obtained by the summation of all the ping volumes.

The final step in the analysis consisted of applying the single target detection and tracking algorithms to the regions previously identified as containing fish echoes. The parameters for the algorithms are listed in table 3. The target strength threshold used in target tracking was based on the 2007 tank experiment results (James et al. 2007b) and was chosen to include targets that are large enough to likely represent salmonids.

Table 3: Configuration of the parameters for single target detection using the 120kHz wide-beam transducer.

Parameter (unit)	Value
Lower TS threshold (dB)	-55.0
Pulse length determination level (dB)	6.0
Minimum normalized pulse length	0.5
Maximum normalized pulse length	2.0
Beam compensation model	Simrad LOBE
Maximum beam compensation (dB)	12.0
Maximum standard deviation of angles (degrees)	2.00

Fish tracks were identified based on the results from the single target detection. Fish tracks consist of consecutive echoes from the same fish as it passes under the transducer. Single echoes were subjected to an Alpha-Beta tracking algorithm (Blackman, 1999) to determine acceptance or rejection of a target to a particular track. Details of the fish track detection algorithms are provided in Table 4.

Table 4: Target tracking detection parameter properties. The TS threshold represents the minimum value for the maximum TS within a track (i.e. if the maximum TS within a track is below -45.0 dB, the track is rejected).

Parameter (unit)	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
Minor axis weight (%)	20
Range weight (%)	40
Target strength weight (%)	20
Minimum number of single targets in track	3
Maximum gap between single targets (pings)	3

Because target strength is a logarithmic variable, the mean target strength (dB) of a track was calculated by taking the linear value of all the backscatter along the track. If σ_{bs} is the acoustic backscattering cross-section of a target (units of $m^2\ m^{-2}$) then 'target strength' (TS) is

$$TS = 10\mathrm{Log}_{10}(\sigma_{bs}) \text{ or equivalently } \sigma_{bs} = 10^{TS/10}$$

and the linear mean of a set of target strength values is obtained by converting from TS to σ_{bs}, taking the mean of these values and converting the result back into a TS value.

Volumetric densities of salmonids were obtained by dividing the number of detected tracks along a transect by its total volume sampled. Results were expressed as fish per cubic metre and as fish per cubic hectometre (hm^3). One hectometre is equal to 100 m. Area densities of fish (fish per m^2 or fish per hectare) were also calculated by multiplying the volumetric densities by the mean depth along a transect (Keiser and Mulligan 1984). These units are more commonly used and can be extrapolated to fish population for a given surface area.

2.6. Catch-Per-Unit-Effort analysis

Catches from gillnets were compared to acoustic density along the transects in which they were laid. The mesh size differed among nets, especially between the nets used in Lake Coleridge and Lake Benmore. For this reasons comparisons are only relative and should be interpreted with caution. Catch-per-unit-effort (CPUE) was expressed as the number of fish per net per hour (fish net^{-1} h^{-1}), where the total catch in a net was divided by the amount of time it was in the water (in hours).

2.7. Visual survey analysis

The area density of salmonids detected during the visual surveys was estimated by dividing the total number of fish observed by the area sampled. The area sampled was estimated by joining the track of the boat (geo-referenced by GPS) to the shoreline. Areas of the resulting polygons were calculated with a GIS mapping software (Quantum GIS version 0.8.1). This approach assumed that the probability of detecting a fish was constant and independent of the distance from the boat.

3. Results and discussion

3.1. Acoustic survey

All acoustic transects completed in 2008 were repeated in 2009 for the five South island lakes. Lake Wakatipu was not visited in 2009. Results were comparable to the ones obtained in 2008. Lake Benmore had the highest target count and density, while Te Anau had the lowest (Table 5).

Table 5: Number of salmonid targets counted by lake during the acoustic survey in February 2009, with corresponding densities. Densities are expressed by volume and by area. Detailed values for each transect are available in Section 7.2.

Lake	Target count	Volume sampled (m^3)	Fish (m^{-3})	Fish (hm^{-3})	Fish (m^{-2})	Fish (ha^{-1})
Coleridge	104	2360976	4.40E-05	44.0	7.84E-04	7.8
Benmore	493	2708234	1.82E-04	182.0	2.37E-03	23.7
Hawea	156	2882450	5.41E-05	54.1	1.00E-03	10.0
Wanaka	147	3008336	4.89E-05	48.9	9.12E-04	9.1
Te Anau	63	4623282	1.36E-05	13.6	2.58E-04	2.6

Figure 3 and 4 illustrates the number of tracked fish and area density for each lake.

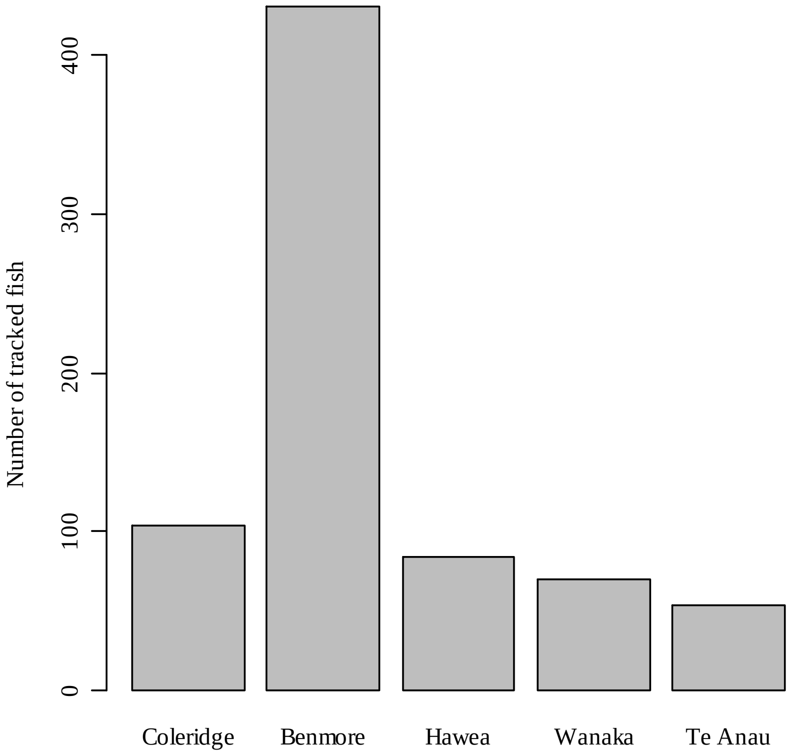


Figure 3: Number of target tracked in each lake surveyed during February 2009.

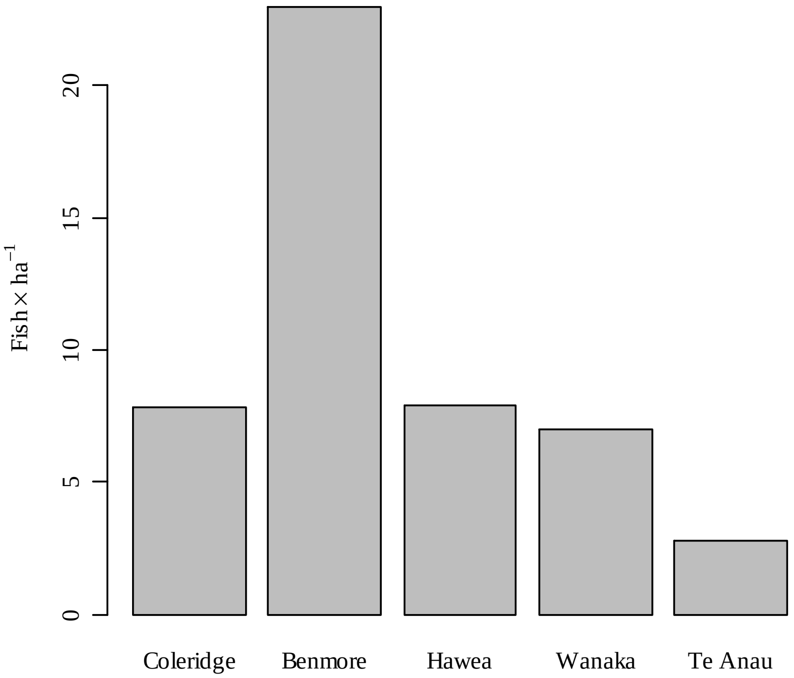


Figure 4: Area density for each lake surveyed during February 2009.

Time series of the surveys reveal various trends between 2007 and 2009 (Fig. 5). Lake Benmore density has been increasing steadily since 2007, while Lake Te Anau appears to be on a relatively steep decline. Density in Lake Coleridge dropped between 2007 and 2008, but results from 2009 have levelled. In Lake Hawea, densities in 2009 are at their highest, after a noticeable reduction between 2007 and 2008. Lake Wanaka had consistent and similar results between all three years.

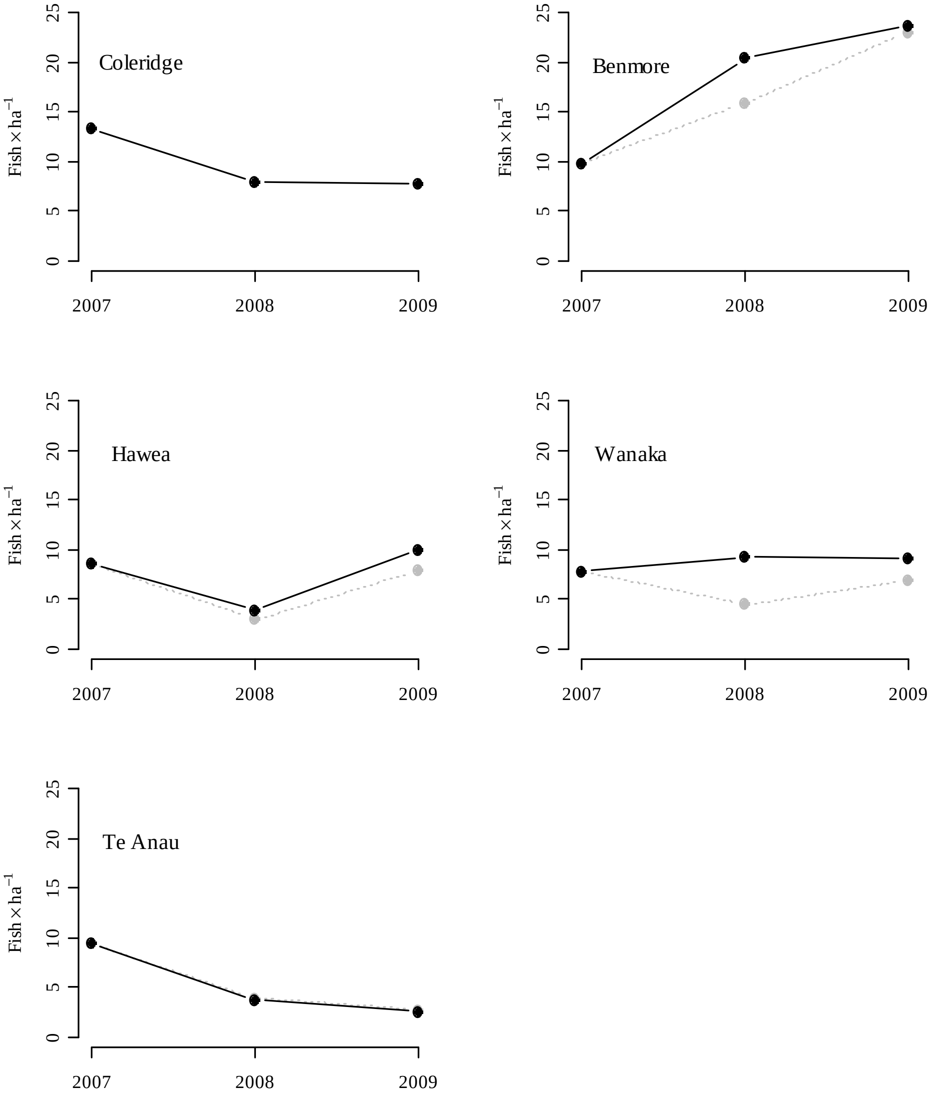
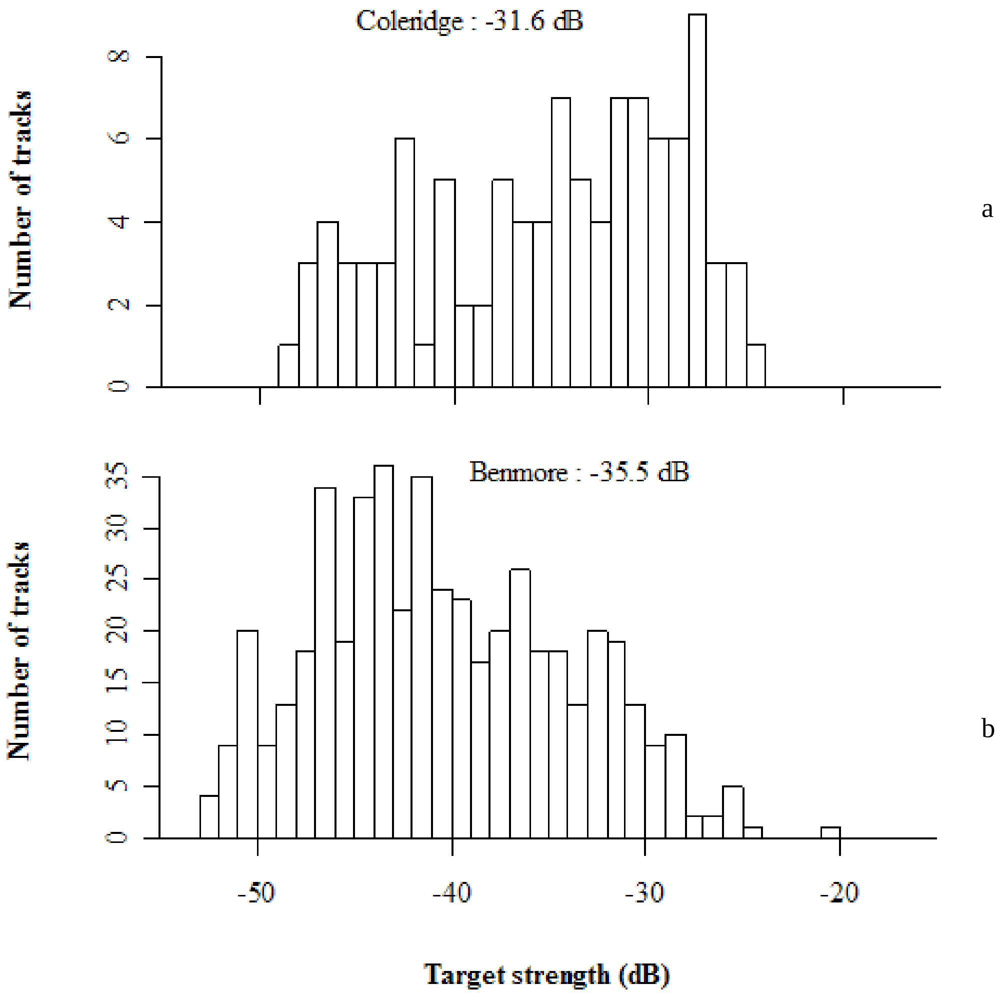


Figure 5: Area density in each lake for the three years surveyed. Grey points with dotted line represent the results for the initial set of transects surveyed in 2007 (e.g. not including the new transects surveyed in 2008 and 2009).

Target strength (TS) distributions (which correlate to fish size) are presented in Figure 6. All five lakes yielded relatively similar distributions, with a mean TS ranging from –31.6 to –35.5 dB. The lowest mean target strength was observed in Lake Benmore, with large numbers of fish with target strength less than –40 dB. Compared to the other lakes, this distribution was fairly unimodal. In contrast, target strength data from Lake Benmore in 2008 was distinctly bimodal, with a strong mode in the –45 dB range and another centred on –30 dB. Besides this notable difference, target strength distributions in 2009 was similar to those observed in 2008.



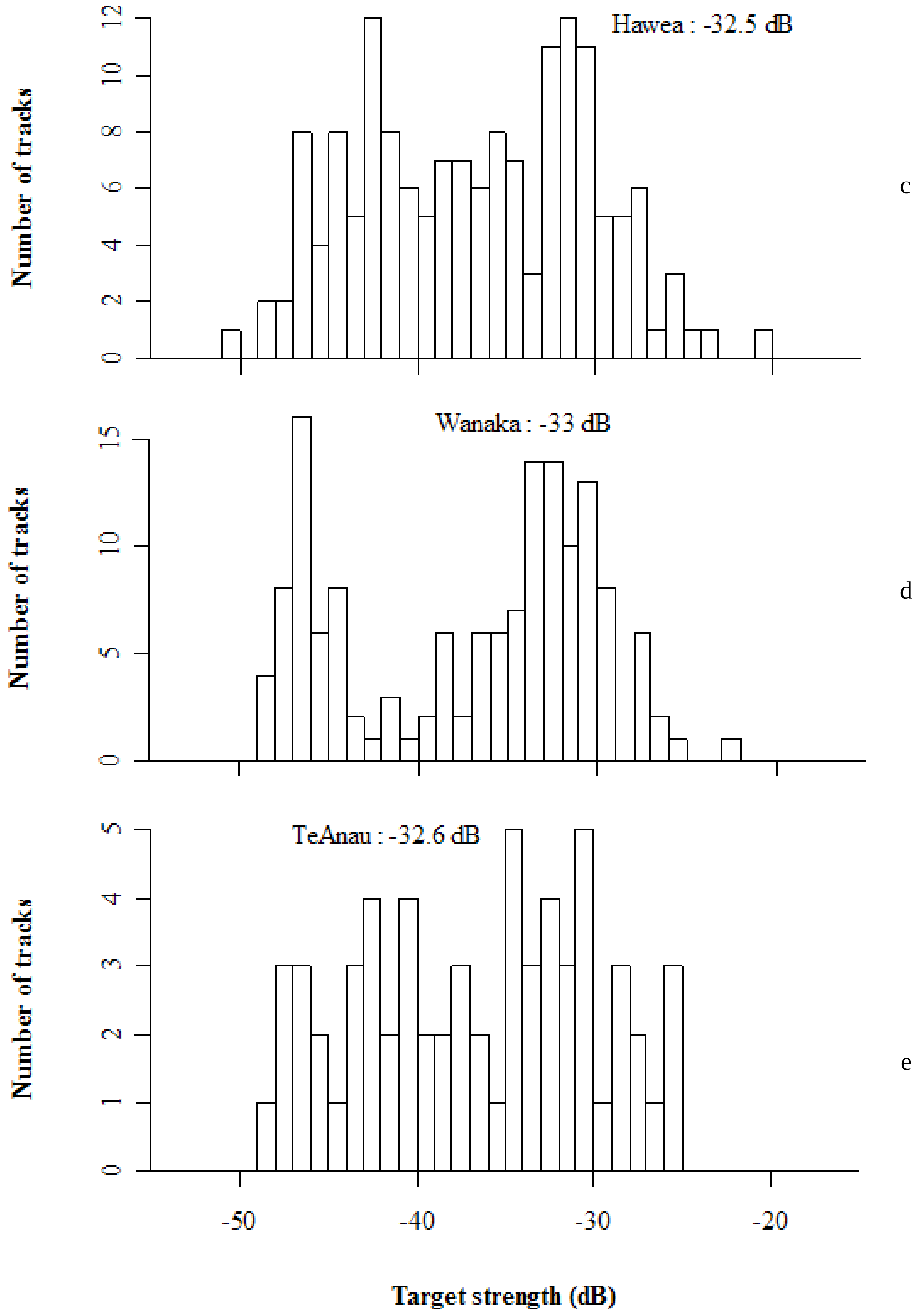
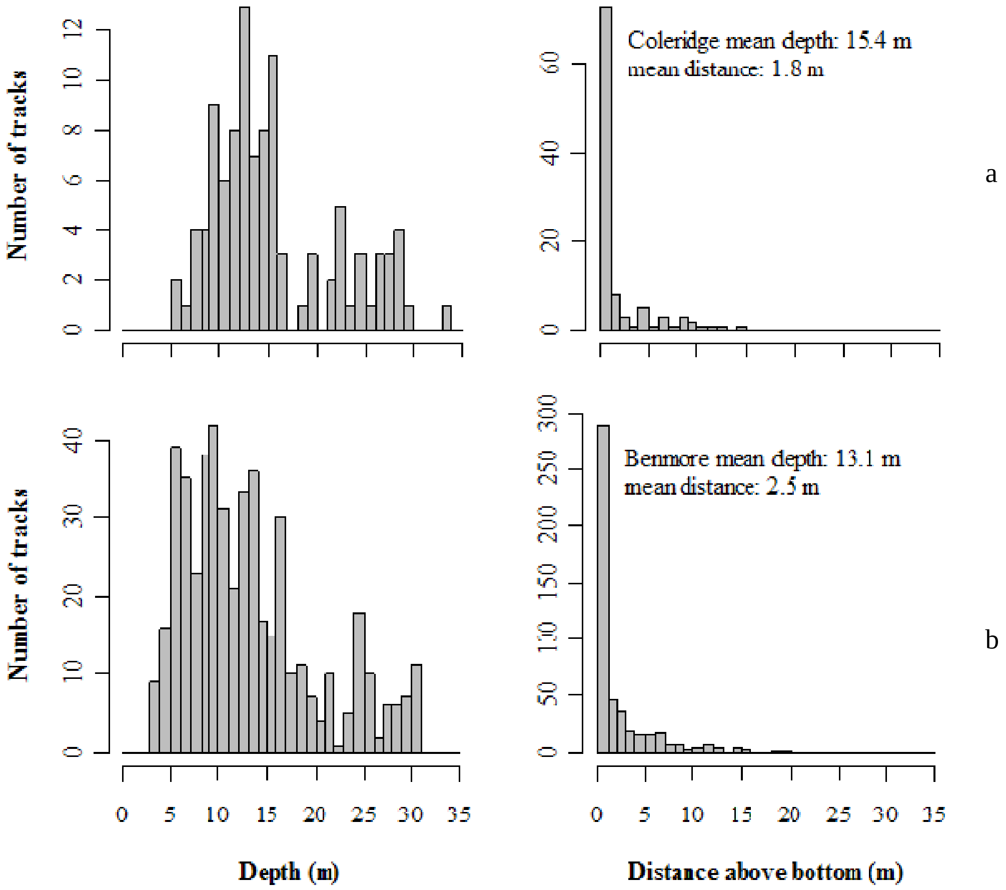


Figure 6: Distributions of acoustic target strength for each of the lakes surveyed during February 2009. Mean target strength for all tracks are given on top of each histogram.

Depth distributions of salmonid targets within the survey depth range were also broadly comparable to those obtained in 2008 (Figure 7). Fish were deeper on average in Lakes Hawea and Te Anau. Targets were shallower in Lakes Benmore and Wanaka, as the sites in these lakes cover relatively larger areas of shallow waters. In all lakes most targets were observed within the first metre off the detected bottom. However, in Lake Benmore a large number of targets were distributed at a greater distance off the bottom, a behaviour that may be related to the lower water clarity in this lake. This was also observed in Lake Wanaka this year, with a mean distance of targets above bottom of 4.7 m, the highest recorded value to date. Turbidity in Lake Wanaka was noticeably higher in 2009, but this was also true for Lake Hawea, where targets were recorded close to the bottom as in 2008.



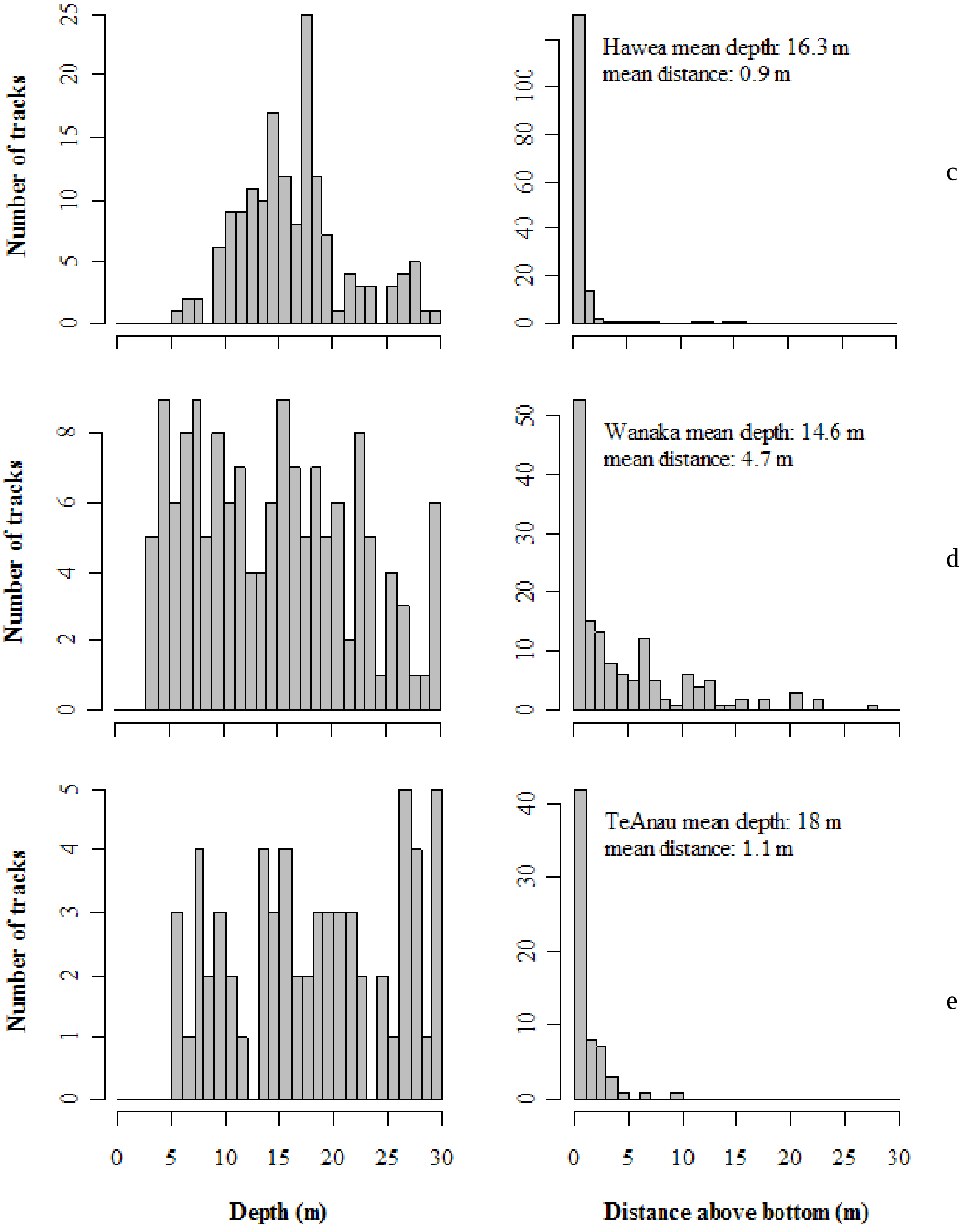


Figure 7: Fish depth distribution for each of the five lakes surveyed in February 2009. The left figure in each set shows the mean depth and the right figure the mean distance off the bottom for each fish target.

3.2. Gillnetting

In Lake Coleridge, only four (4) fish were caught using gillnets. In acoustic transect 1, a rainbow trout of 370 mm (FL) was caught in Twin Creek at 10 m depth (set #2), while a brown trout of 520 mm (FL) was caught in Scamander Bay in about 8 m depth (set #3). In acoustic transect 4, two brown trout (440-450 mm FL, set #5 and #6) were caught in approximately 15 m water depth. In contrast, 96 fish were caught in Lake Benmore. Table 6 details the catch in each set.

Table 6: Details of the catch for gillnet sets in Lake Benmore, with numbers caught (N), mean, minimum, maximum, and standard deviation (SD) of fork length in mm.

Set #1	N	Mean	Min	Max	SD
Rainbow trout	1	435	-	-	-
Brown trout	4	342	292	420	59
Sockeye salmon	1	340	-	-	-
Total	**6**	**357**	**292**	**435**	**60**

Set #2	N	Mean	Min	Max	SD
Rainbow trout	34	360	200	490	85
Brown trout	10	412	212	489	95
Sockeye salmon	0	-	-	-	-
Total	**44**	**372**	**200**	**490**	**89**

Set #3	N	Mean	Min	Max	SD
Rainbow trout	0	-	-	-	-
Brown trout	0	-	-	-	-
Sockeye salmon	39	424	360	475	23
Total	**39**	**424**	**360**	**475**	**23**

Set #4	N	Mean	Min	Max	SD
Rainbow trout	1	392	-	-	-
Brown trout	6	395	300	430	48
Sockeye salmon	0	-	-	-	-
Total	**7**	**395**	**300**	**430**	**44**

Thirty nine (39) of forty (40) sockeye salmon were caught in one net (set #3), which was laid at 28 m depth. Although this may indicate a preference for deeper water for this species, it may also just reflect the more gregarious nature of sockeye salmon, as small aggregations may have randomly fall into this net.

Specimens of sockeye salmon that were caught were noticeably fat (Figure 8). The stomachs content of two individuals were inspected, and contained exclusively large amounts of freshwater mysids. In contrast, two stomachs of rainbow trout were inspected and contained a mixture of chironomids pupae and gastropods. The condition of the salmon and the presence of mysids in their stomachs suggest that this prey must be present at high densities. This would explain the large aggregation and layers of zooplankton observed in this lake in recent surveys (James et al. 2007, Gauthier 2008).

Figure 8: Specimens of sockeye salmon caught in Lake Benmore using gillnets. Notice the large girth of these fish.

In the 2009 survey, large clouds of plankton (now thought to be mysids) were also observed all along the acoustic transects, particularly over deeper waters (Fig. 9). Echoes of salmonids were often observed above the bottom within these dense layers. Such layers have been observed in other lakes, but are much stronger in Lake Benmore. The apparent recent increase in densities of salmon observed in Lake Benmore may be closely linked to the availability and high density of plankton in this reservoir.

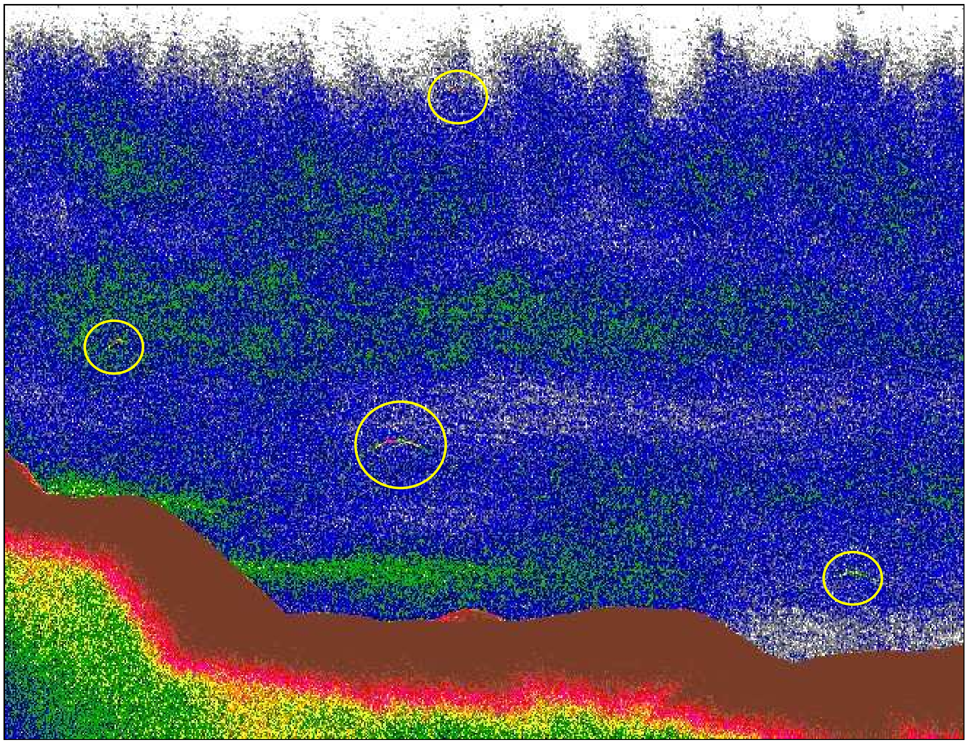


Figure 9: Examples of an echogram from Lake Benmore, showing strong layers of invertebrates (thought to be mysids). Echoes from salmonids are identified by yellow circles. Echogram threshold of -70 dB with a 40 log Time Varied Gain (TVG). Maximum bottom depth (strong red bottom line) is 30 m.

When expressed as Catch-Per-Unit-Effort, gillnet catches were strongly correlated to the number of targets detected acoustically along their respective transects (Fig 10 left panel). However, the relationship was not linear with acoustic density (fish ha^{-1}) (Fig. 10 right panel). With only three sample points (gillnets in three acoustic transects) it is not possible to draw conclusions. Furthermore, it is practically impossible to estimate the actual sampling volume of passive nets, as this is subject to many factors such as fish movements, net detectability, and selectivity. Nevertheless these experiments are encouraging and suggest that the acoustic technique develop for these lakes is suitable for detecting salmonids.

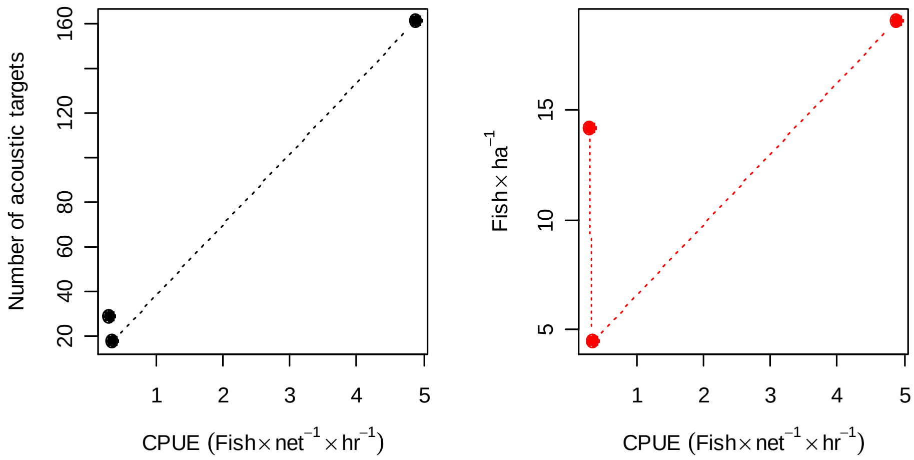


Figure 10: Relationship between the Catch-Per-Unit-Effort (expressed as the number of fish per net per hour) and the number of acoustic targets (left panel) detected along the transect in which they were laid. This target number is expressed as fish density (fish per hectares) along the transect in the right panel (a function of volume sampled and mean depth).

3.3. Visual survey

A total of 75 fish were detected during the visual surveys carried out in Lake Te Anau (table 7). The mean density of salmonids identified during this exercise was 3.9 fish per hectare. This is somewhat higher than the salmonids density estimated acoustically in 2009 (2.6 fish ha^{-1}) but nearly identical to the 2008 results for Lake Te Anau. All other lakes yielded higher acoustic densities (more than 7 fish ha^{-1}). This indicates that the densities of salmonids in shallow waters is in the same order as the ones estimated within the acoustic survey area (depth 3-30 m), and that the exclusion of this zone may have negligible effect on overall density results. How these results compare to salmonids density in shallow water for other lakes is questionable and hard to test, as water clarity and turbidity may differ between lakes, time of year, and years.

Table 7: Numbers and density of fish detected during visual surveys at five locations in Lake Te Anau in February 2009. The numbers in bracket indicate the number of eel detected.

Transect	N	Survey area (ha)	Density (fish ha^{-1})
V1	14	3.55	3.9
V2	17	3.13	5.4
V3	3	1.28	2.3
V4	14 (1)	4.74	3.0
V5	25 (1)	5.24	4.8

The species composition between shallow water and deeper areas also most likely differ, as brown trout are more likely to be found in the shallows than rainbow trout (James and Graynoth, 2002).

Most of the fish observed during this trial were active and swam away from the boat. Avoidance behaviours were observed at distances often greater than 10 m. This suggest that other visual sampling approach (e.g. by means of snorkel, as per Hamelin-Vivien *et al*. 1985 or Brind'Amour and Boisclair 2004; 2006) would probably not be suitable at determining densities of large predatory fish in these lakes, especially at low densities.

4. Conclusions and recommendations

Results from the 2009 survey are encouraging and further suggest that the acoustic technique developed by NIWA and Fish and Game would provide an accurate way of monitoring salmonids populations in large lakes. Gillnet experiments in lakes Coleridge and Benmore proved useful in confirming the presence and composition of salmonids targets, and catch rates appeared to be somewhat correlated to acoustic densities. However the sample size for such experiment was low (3 acoustic transects) and further experiments would be quite useful for accurately validating the acoustic method. The visual trials in Lake Te Anau were also successful and suggest that salmonids densities in shallow waters not accessible to acoustic survey are comparable to the ones obtained in deeper areas (3-30 m), although undoubtedly change in species composition may occur. Further visual surveys should be carried out to confirm these results and further validate the density estimates obtained acoustically. Exploration of ancillary information (for example catch rates at annual fishing competitions) may also prove to be useful at validating and interpreting acoustic results.

5. Acknowledgements

This work would not have been possible without the help and dedication of Bill Jarvie, Fish and Game New Zealand Southland Region. Many thanks also to Davor Bejakovich, Brian Ross, and Steve Terry (Fish and Game New Zealand) for their assistance with the gillnet experiment in Lake Coleridge, and to Graeme Hughes and Mark Webb (Fish and Game New Zealand) for the gillnet experiment in Lake Benmore.

6. References

Blackman, S.S. (1999). Design and analysis of modern tracking systems, Artech House, Massacheusetts.

Brind'Amour, A.; Boisclair, D. (2004). Comparisons between two sampling methods to evaluate the structure of fish communities in the littoral zone of a Laurentian lake. *Journal of Fish Biology 65*: 1372-1384.

Brind'Amour, A.; Boisclair, D. (2006). Effect of the spatial arrangement of habitat patches on the development of fish habitat models in the littoral zone of a Canadian Shield lake. *Canadian Journal of Fisheries and Aquatic Science* 63: 737-753.

Dawson J.; Mulligan T. (2000). Echo selection and trace formation: techniques, interactions, and advancements. *Proceedings of the Fifth European Conference on Underwater Acoustics,* ECUA 2000: 1455-1460.

Gauthier, S. (2008). Acoustic assessment of salmonids in large South Island lakes, New Zealand, February 2008. *NIWA Client Report WLG2008-64.* 47 p.

Harmelin-Vivien, M.L.; Harmelin, J.G.; Chauvet, C.; Duval, C. ; Galzin, R.; Lejeune, G. ; Barnabé, G. ; Blanc, F. ; Chevalier, R. ; Duclerc, J.; Lasserre, G. (1985). Évaluation visuelle des peuplements et populations de poissons: méthodes et problèmes. *Revue d'écologie (Terre et Vie)* 40: 466-539.

James, G.D.; Dunford, A.; Knol, W.; Hawke, L. (2007). Detection of trout in close proximity to benthic weed beds : acoustic target strength experiments in Lake Coleridge, March 2006. *NIWA Client Report CHC2007-047.* 28 p.

James, G.D.; Gauthier, S.; Dunford, A.; Knol, W. (2007). Acoustic assessment of salmonids in large South Island lakes, February 2007. *NIWA Client Report CRCH2007-115*. 39p.

James, G.D.; Graynoth, E. (2002). Influence of fluctuating lake levels and water clarity on trout populations in littoral zones of New Zealand lakes. *New Zealand Journal of Marine and Freshwater Research 36*: 39-52.

Kieser, R.; Mulligan, T.J. (1984). Analysis of Echo Counting data: A Model. *Canadian Journal of Fisheries and Aquatic Science 41*: 451-458.

Love, R.H. (1971). Dorsal aspect target strength of an individual fish. *Journal of the Acoustical Society of America* 46: 746-752.

Myriax echoview © help documentation, software version 4.3. Myriax PTY, Ltd. GPO Box 1387 Hobart, Tasmanian, Australia 7001.

MacLennan, D.N.; Simmonds, E.J. (1992). Fisheries Acoustics. Chapman and Hall, London.

7. Appendices

7.1. Calibration

7.1.1. Methods

The 120 kHz IRL wide-beam transducer was calibrated in Lake Te Anau on February 19, 2009. This calibration was done during the salmonid survey of South Island lakes. The boat used was owned by Fish and Game New Zealand Southland Region (based in Te Anau). The transducer was mounted amidships off the starboard side, using a mounting bracket through the gunwale. The transducer face was approximately 0.5 m below the surface. The calibration was conducted broadly as per the procedures in MacLennan & Simmonds (1992).

The calibration data were recorded in EK60 raw format files. These data are stored in the NIWA Fisheries Acoustics Database. The EK60 transceiver settings in effect during the calibration are given in Table 1.

A 38.1 mm diameter tungsten-carbide sphere was suspended directly under the transducer at a range of 13.3 m. Another monofilament line was attached to the sphere loop using a standard fishing rod that was used to pull and push the sphere within the acoustic beam. The weather during the calibration was very good and the boat was slightly drifting. A temperature/depth profile was taken using a RBR data logger. Estimates of acoustic absorption and sound speed were obtained from the Echoview© software v4.3 calculator.

7.1.2. Analysis

The data in the .raw EK60 files were extracted using custom-written software. The amplitude of the sphere echoes was obtained by filtering on range, and choosing the sample with the highest amplitude. Instances where the sphere echo was disturbed by fish echoes or excessive movement were manually discarded. The alongship and athwartship beam widths and offsets were calculated by fitting the sphere echo amplitudes to the theoretical beam pattern using 2nd order polynomial equations. The transducer peak gain was calculated by comparing the theoretical sphere target strength to the measured mean target strength for all sphere echoes within 0.5º of on-axis. The S_a correction was calculated by comparing the theoretical Sa value for the sphere against the measured Sa value for all sphere echoes within 0.5º of on-axis.

7.1.3. Results and discussion

The results from the temperature/depth cast are given in Table 8, along with estimates of the sphere target strength, sound speed, and acoustic absorption for 120 kHz.

The calibration parameters resulting from the calibration are given in Table 9. The estimated beam pattern as well as the coverage of the beam by the calibration sphere is given in Figure 11. The fit to the beam pattern is shown in figure 12. These indicate that the beam shape and correction are appropriate. The root mean square (RMS) of the difference between the Simrad beam model and the sphere echoes out to half the 3 dB beamwidth is 0.35 dB, which indicates an acceptable quality calibration.

Table 8: RBR data logger cast details and derived water properties. The values for sound speed and absorption are at a depth of 6 m.

Parameter	
Date/time (NZST, start)	19 February 2009, 12:30
Position	45 22.96 S 167 45.38 E
Mean sphere range (m)	13.3
Mean temperature (ºC)	14.6
Mean salinity (psu)	0 (freshwater)
Sound speed (m/s)	1464.5
Sound absorption (dB/km)	3.787
Sphere target strength (dB re 1m^2)	-39.63

Table 9. Calculated echosounder calibration parameters.

Parameter	
Frequency (kHz)	120
Transducer peak gain (dB)	13.05
Sa correction (dB)	–0.38
Beamwidth (º) alongship/athwarthship	23.7/24.7
Beam offset (º) alongship/athwarthship	0.00/0.00
RMS deviation	0.35

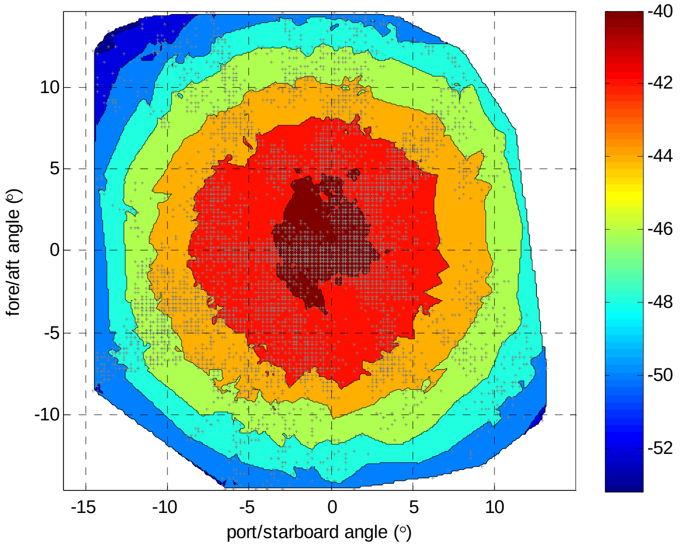


Figure 11. The 120 kHz estimated beam pattern from the sphere echo strength and position. The '+' symbols indicate where sphere echoes were received. The colours indicate the received sphere echo strength in dB re 1 m^2.

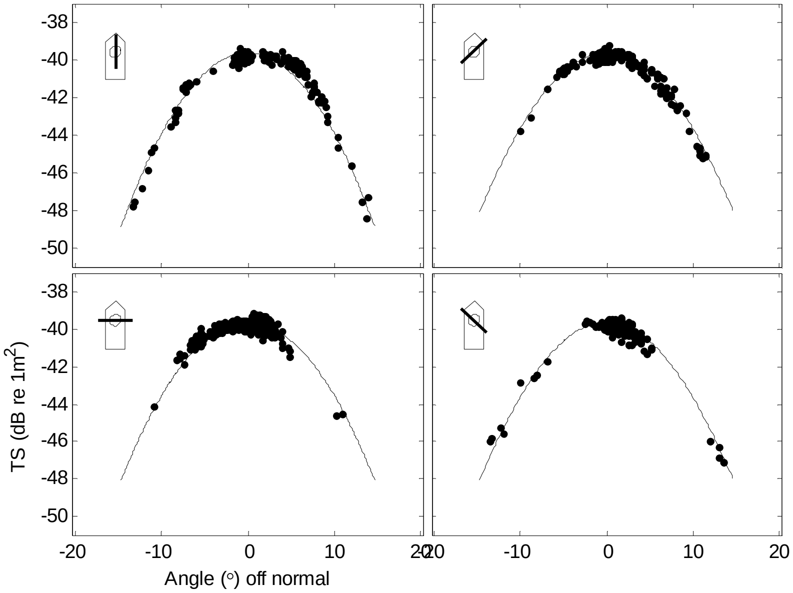


Figure 12. Beam pattern results from the 120 kHz analysis. The solid line is the ideal beam pattern fit to the sphere echoes for four slices through the beam.

7.2. Tables

Number of salmonid targets with corresponding densities by transect for all lakes sampled in 2009. Densities are expressed by volume and by area. Depth represents the mean bottom depth along each transects. Transect number/name are consistent with the 2007 and 2008 survey. An asterisk indicates new transects for 2008 and 2009.

Lake Coleridge

Transect	Target count	Volume sampled (m^3)	Fish (m^{-3})	Fish (hm^{-3})	Depth (m)	Fish (m^{-2})	Fish (ha^{-1})
1	29	318476	9.11E-05	91.1	15.6	1.42E-03	14.2
2	32	734962	4.35E-05	43.5	18.0	7.84E-04	7.8
3	25	576643	4.34E-05	43.4	18.0	7.82E-04	7.8
4	18	730895	2.46E-05	24.6	18.4	4.53E-04	4.5

Lake Benmore

Transect	Target count	Volume sampled (m^3)	Fish (m^{-3})	Fish (hm^{-3})	Depth (m)	Fish (m^{-2})	Fish (ha^{-1})
1	161	1510411	1.07E-04	106.6	17.8	1.90E-03	19.0
2	270	955722	2.83E-04	282.5	12.9	3.65E-03	36.5
3*	62	242101	2.56E-04	256.1	9.2	2.35E-03	23.5

Lake Hawea

Transect	Target count	Volume sampled (m^3)	Fish (m^{-3})	Fish (hm^{-3})	Depth (m)	Fish (m^{-2})	Fish (ha^{-1})
1	10	388225	2.58E-05	25.8	19.1	4.92E-04	4.9
2	29	685347	4.23E-05	42.3	21.0	8.89E-04	8.9
3	27	496863	5.43E-05	54.3	17.0	9.24E-04	9.2
4	18	447197	4.03E-05	40.3	18.2	7.31E-04	7.3
5*	40	370744	1.08E-04	107.9	18.1	1.95E-03	19.5
7*	24	231747	1.04E-04	103.6	16.0	1.66E-03	16.6
8*	8	262327	3.05E-05	30.5	20.2	6.15E-04	6.1

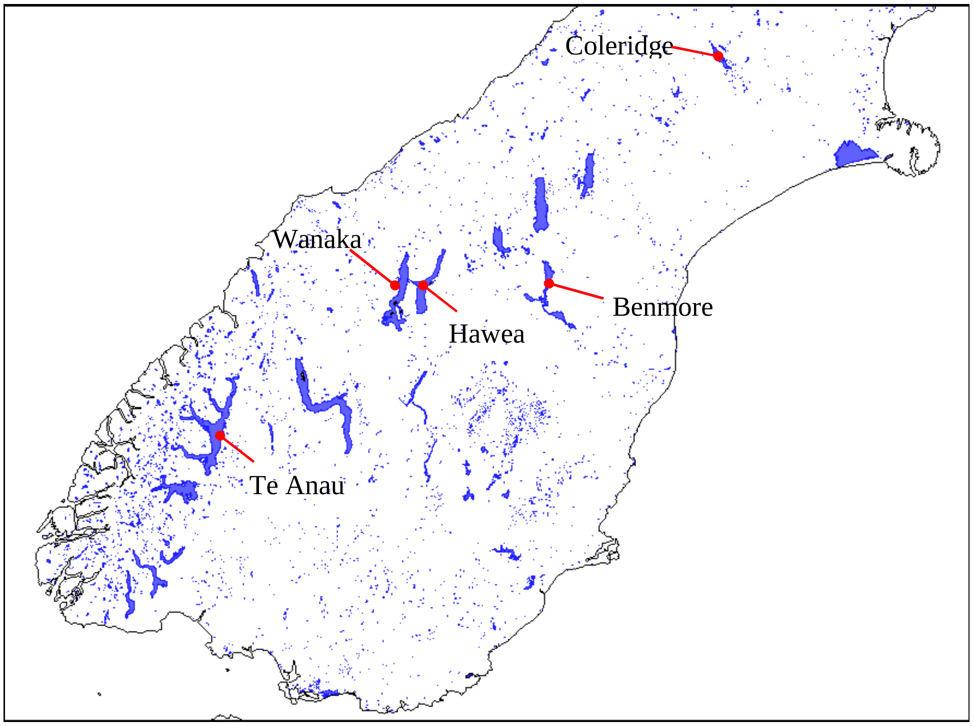
Lake Wanaka

Transect	Target count	Volume sampled (m^3)	Fish (m^{-3})	Fish (hm^{-3})	Depth (m)	Fish (m^{-2})	Fish (ha^{-1})
1	14	533312	2.63E-05	26.3	18.7	4.92E-04	4.9
2	13	418182	3.11E-05	31.1	17.2	5.35E-04	5.4
3	10	268426	3.73E-05	37.3	18.8	7.01E-04	7.0
4	15	383359	3.91E-05	39.1	21.7	8.49E-04	8.5
6	18	317998	5.66E-05	56.6	18.6	1.05E-03	10.5
10*	3	99150	3.03E-05	30.3	18.5	5.61E-04	5.6
11*	18	455122	3.95E-05	39.5	16.7	6.61E-04	6.6
12*	56	532787	1.05E-04	105.1	18.1	1.90E-03	19.0

Lake Te Anau

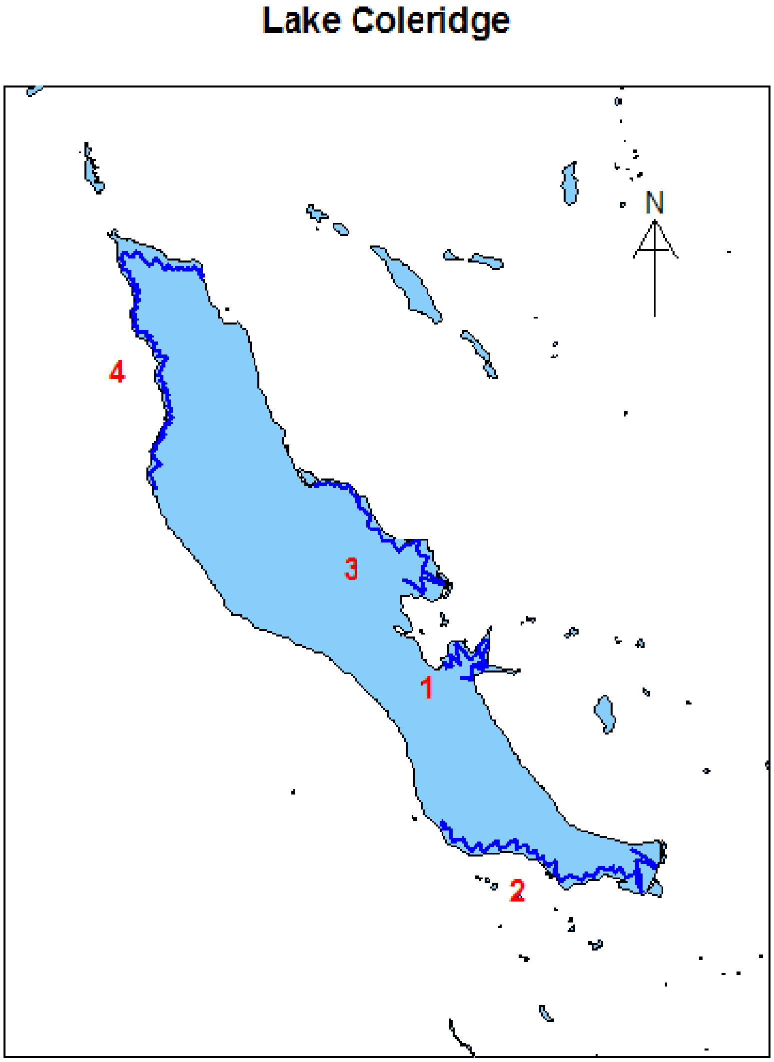
Transect	Target count	Volume sampled (m^3)	Fish (m^{-3})	Fish (hm^{-3})	Depth (m)	Fish (m^{-2})	Fish (ha^{-1})
1	21	879955	2.39E-05	23.9	19.4	4.64E-04	4.6
2	4	455275	8.79E-06	8.8	18.9	1.66E-04	1.7
3	0	286889	0.00E+00	0.0	18.9	0.00E+00	0.0
4a*	8	899197	8.90E-06	8.9	20.2	1.80E-04	1.8
4	1	356475	2.81E-06	2.8	17.4	4.87E-05	0.5
6	14	865342	1.62E-05	16.2	19.5	3.15E-04	3.1
7	6	371801	1.61E-05	16.1	21.4	3.45E-04	3.5
9*	9	508351	1.77E-05	17.7	15.8	2.79E-04	2.8

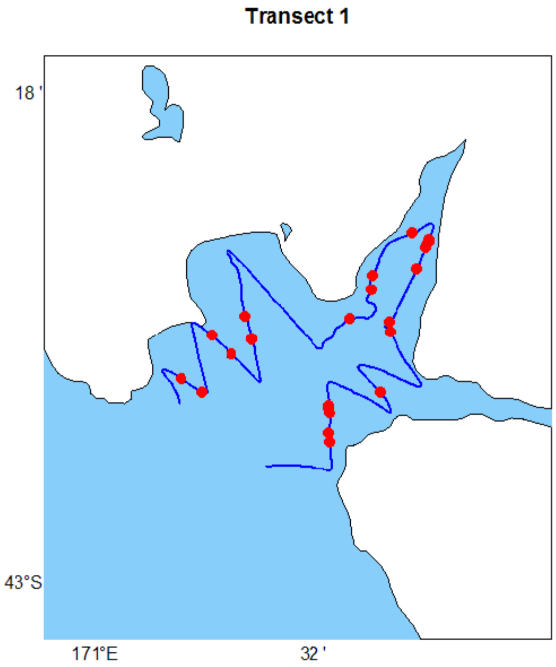
7.3. South Island lakes location map



7.4. Lake Coleridge transect maps

Location of transects within Lake Coleridge. The following detailed views of each transect show fish target locations (red dots).

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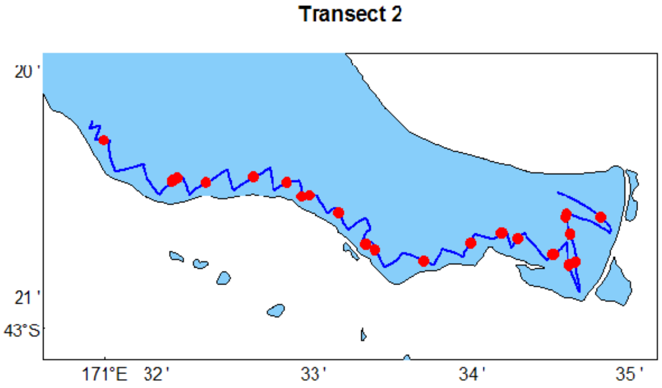
32 '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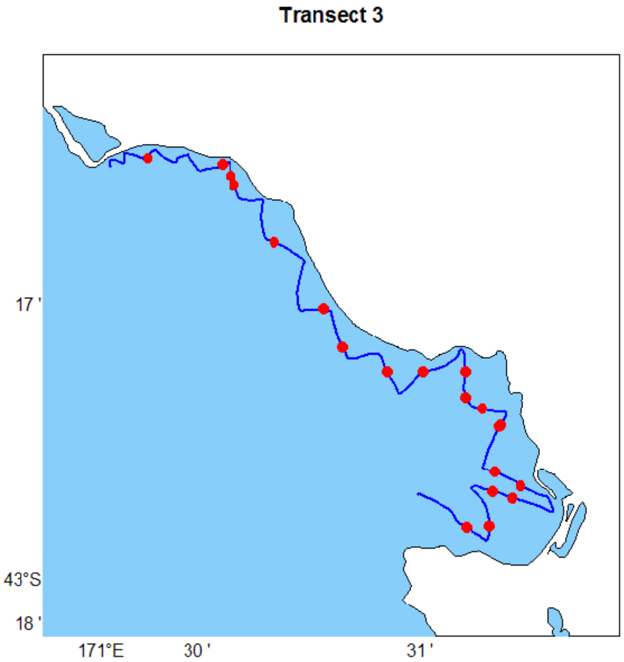
33 '
34 '
35 '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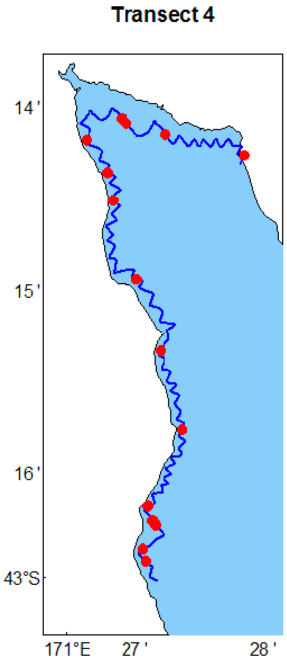
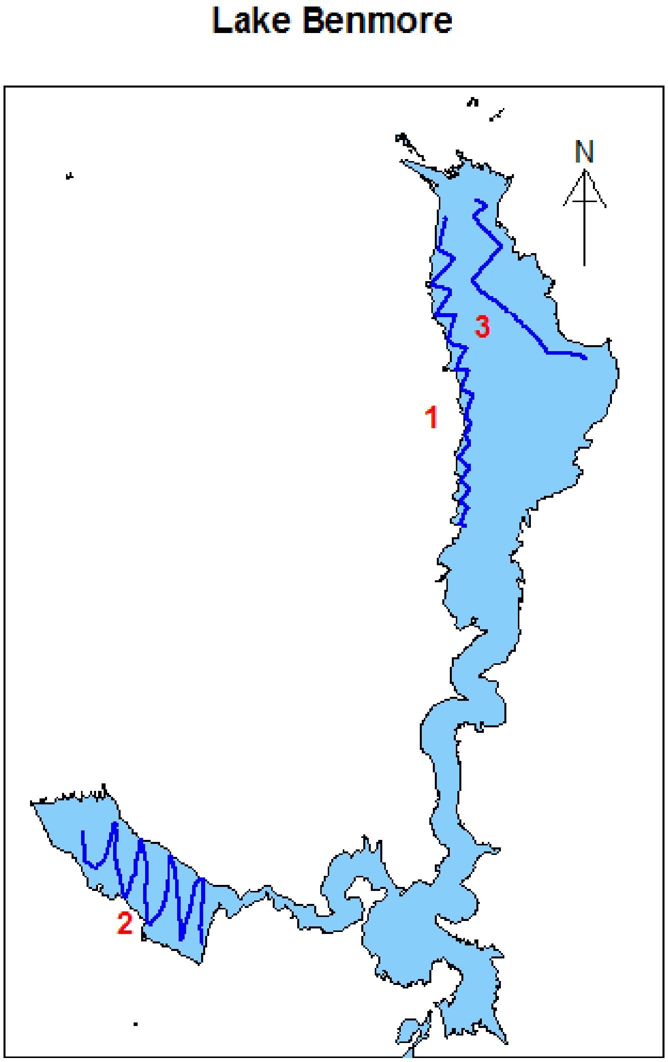
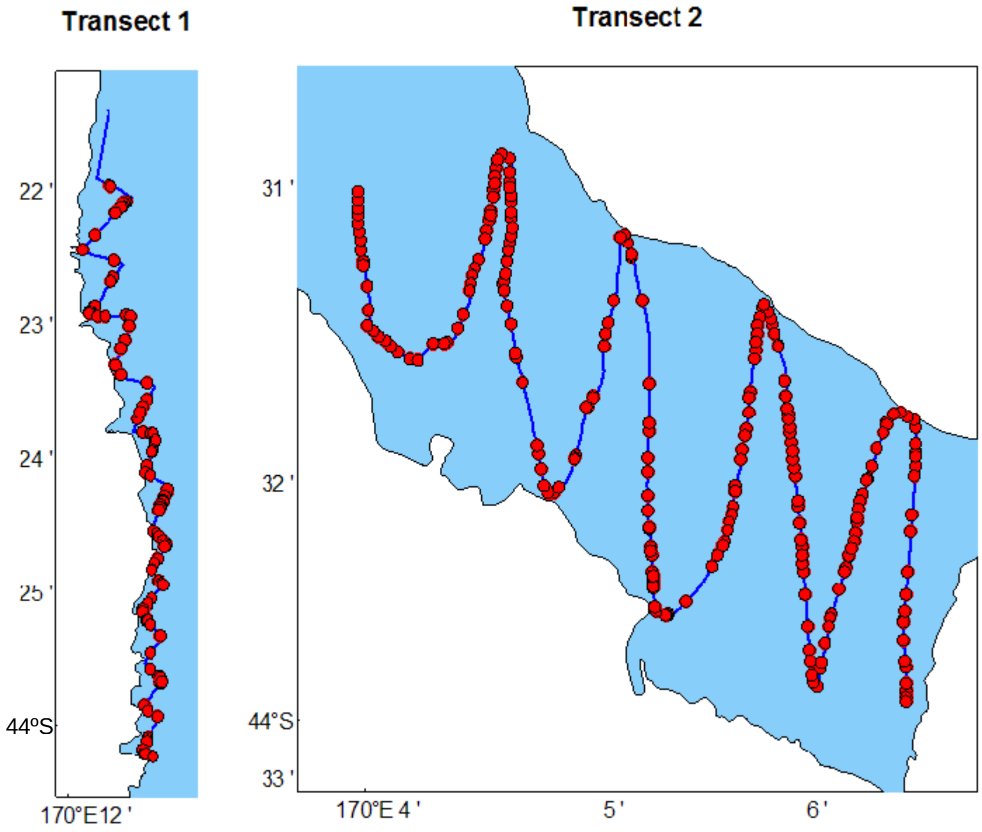
18 '
171°E
30 '
31 '


Transect 4
14 '
15 '
16 '
43°S
171°E
27 '
28 '

7.5. Lake Benmore transect maps

Location of transects within Lake Benmore. Detailed views of each transect show fish target locations (red dots).

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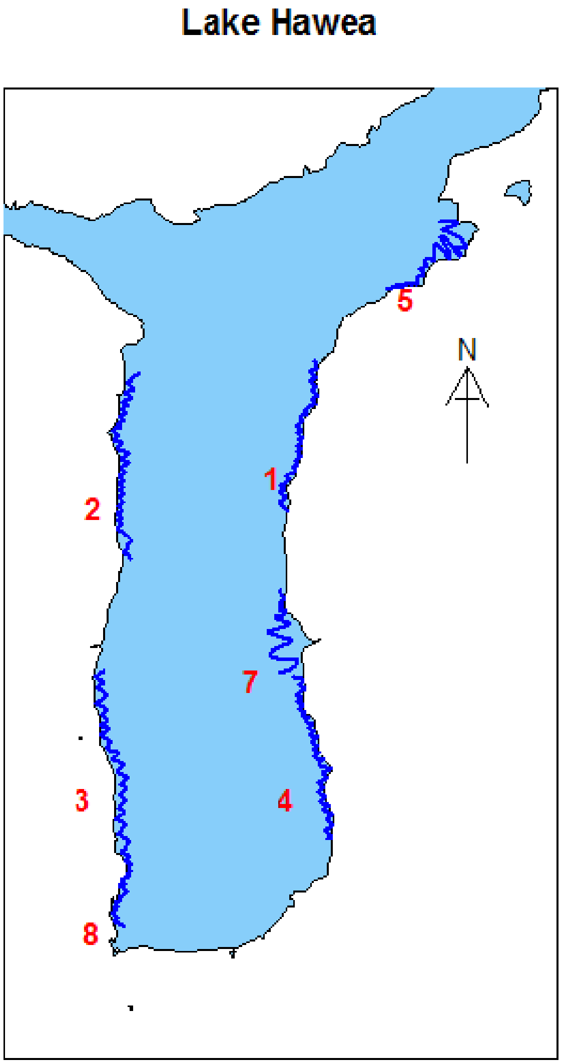
23 '
24 '
25 '
44ºS
170°E12 '
Transect 2
31 '
32 '
44°S
33 '
170°E 4 '
5 '
6 '

-

7.6. Lake Hawea transect maps

Location of transects within Lake Hawea. Detailed views of each transect show fish target locations (red dots).



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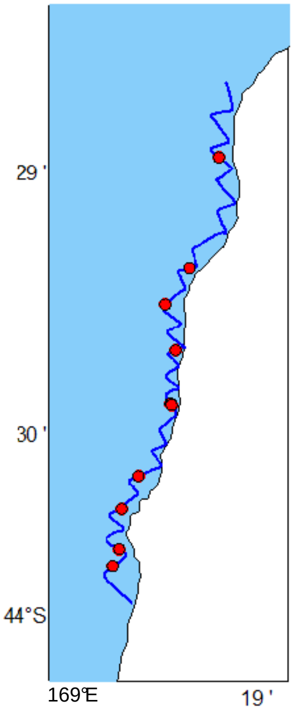

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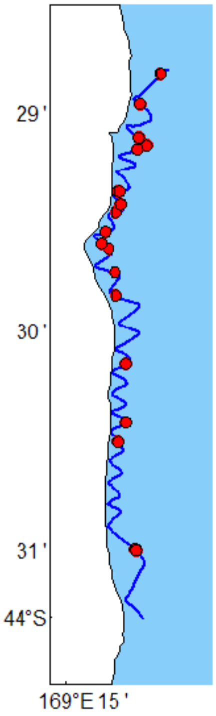

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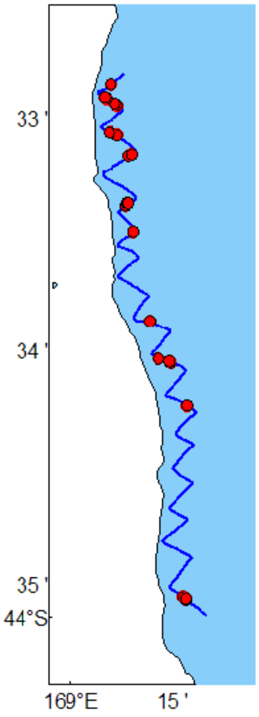

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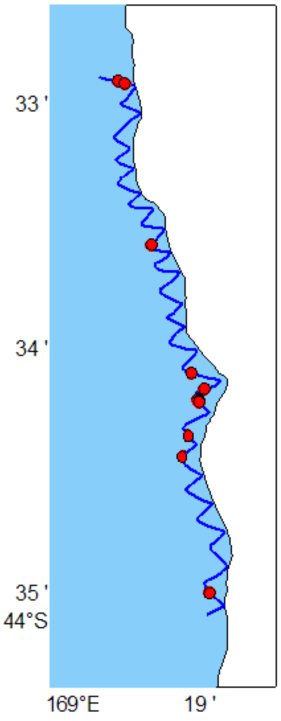

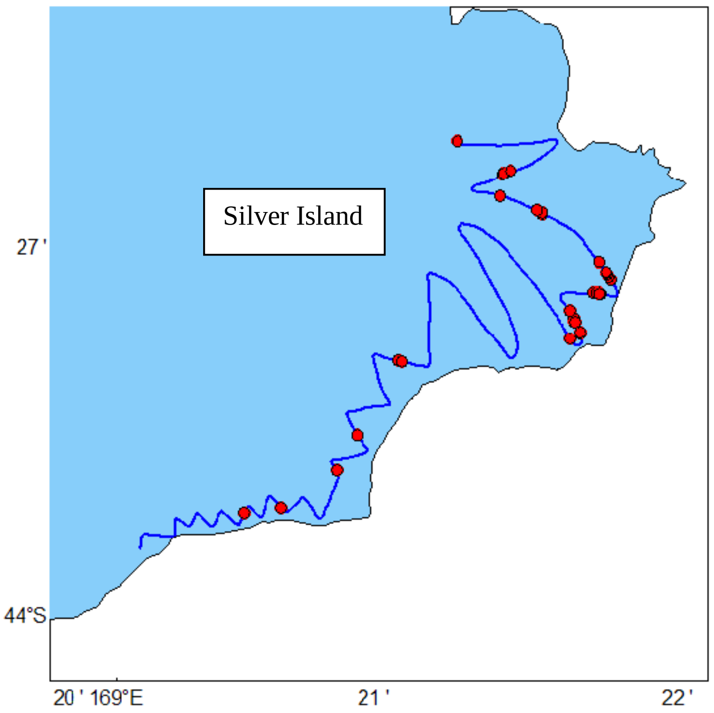

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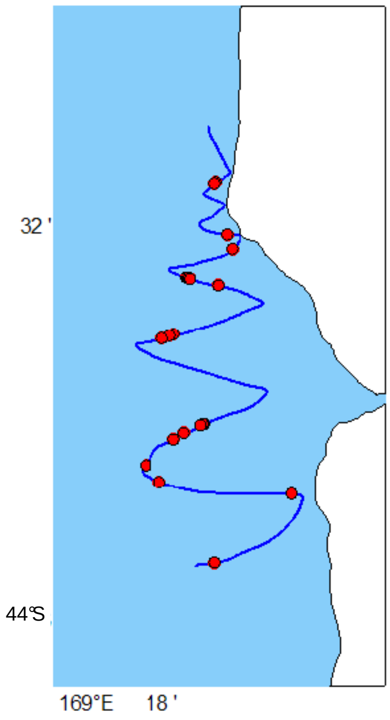

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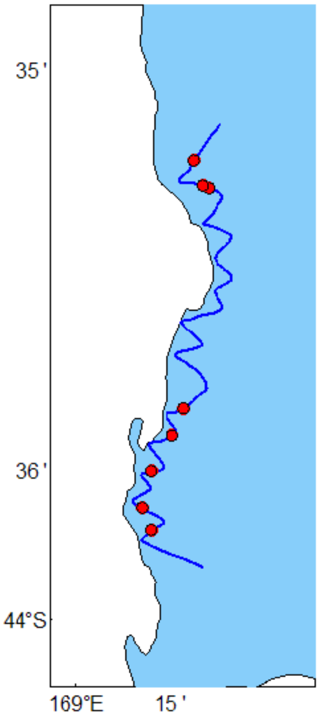
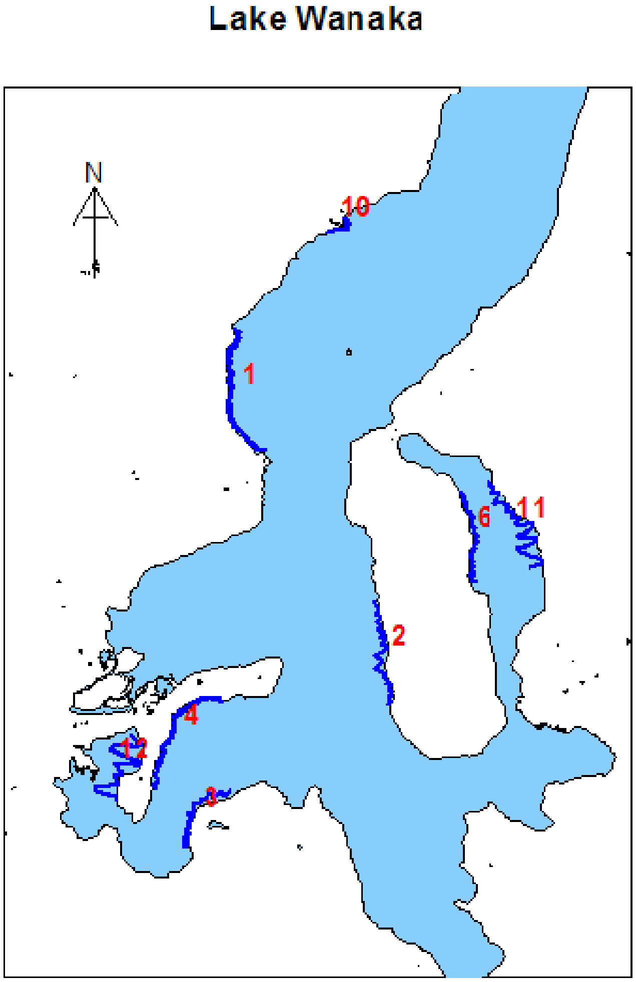


Transect 8

7.7. Lake Wanaka transect maps

Location of transects within Lake Wanaka. Detailed views of each transect show fish target locations (red dots).



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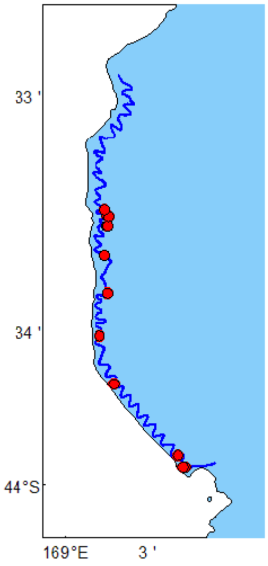

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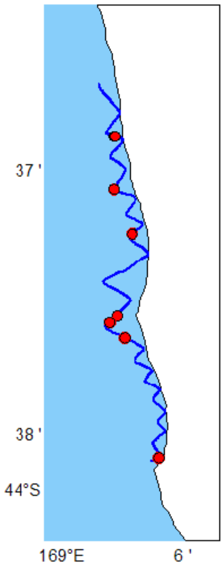

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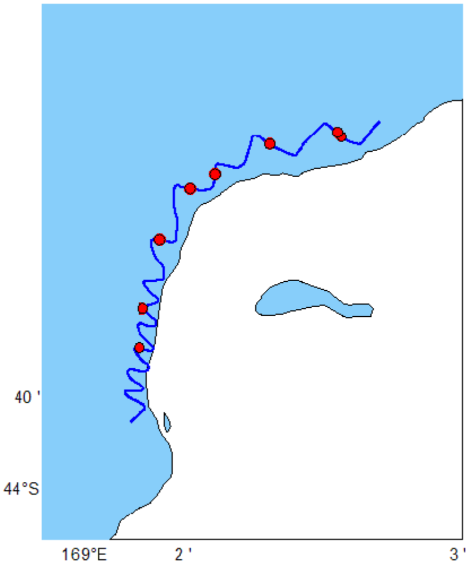

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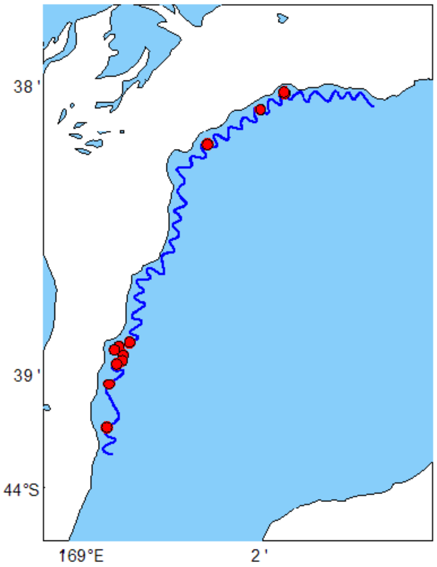

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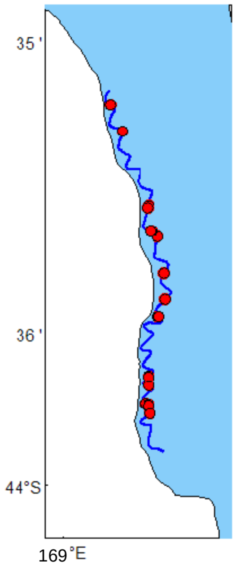

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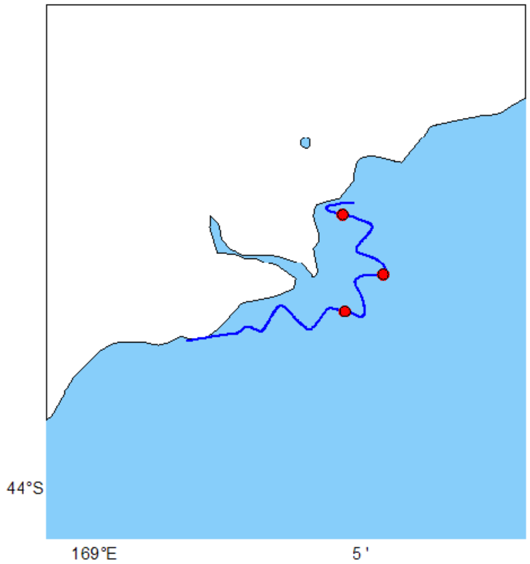

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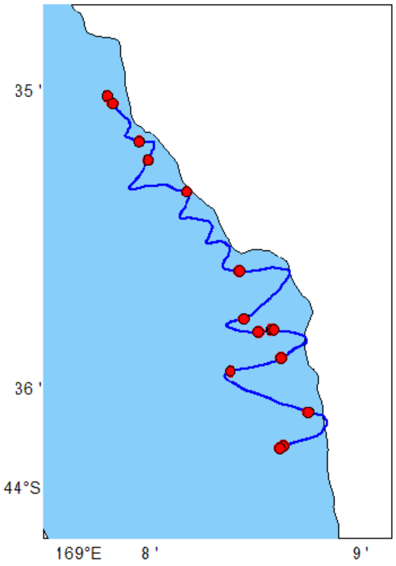

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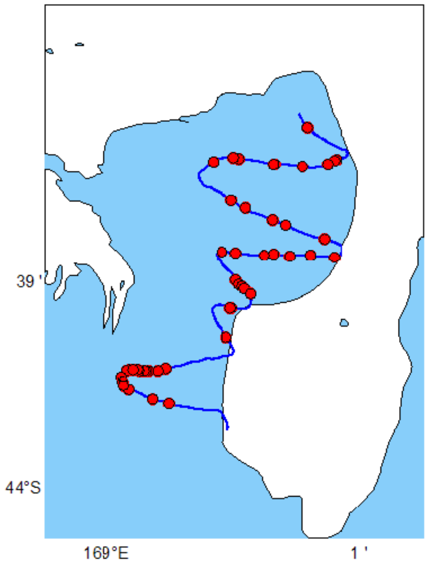
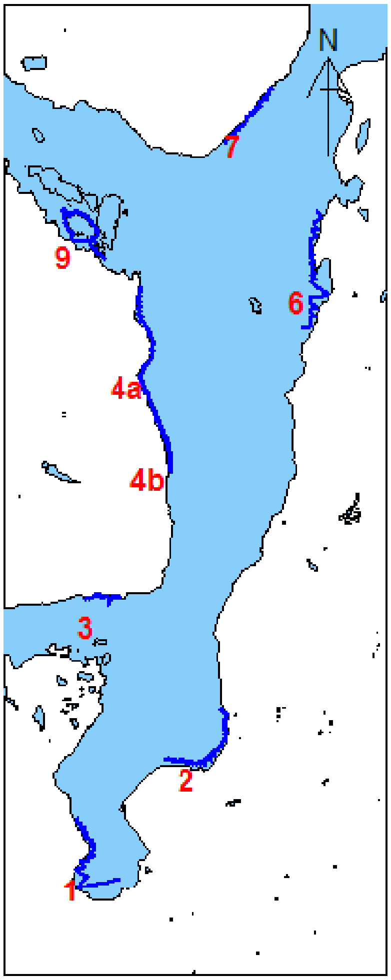
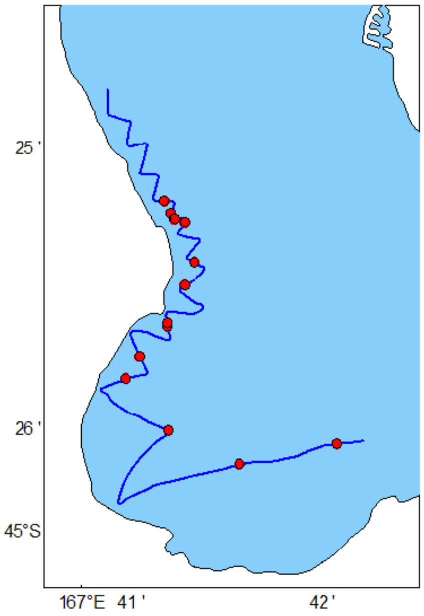


7.8. Lake Te Anau transect maps

Location of transects within Lake Te Anau. Detailed views of each transect show fish target locations (red dots).

Lake TeAnau





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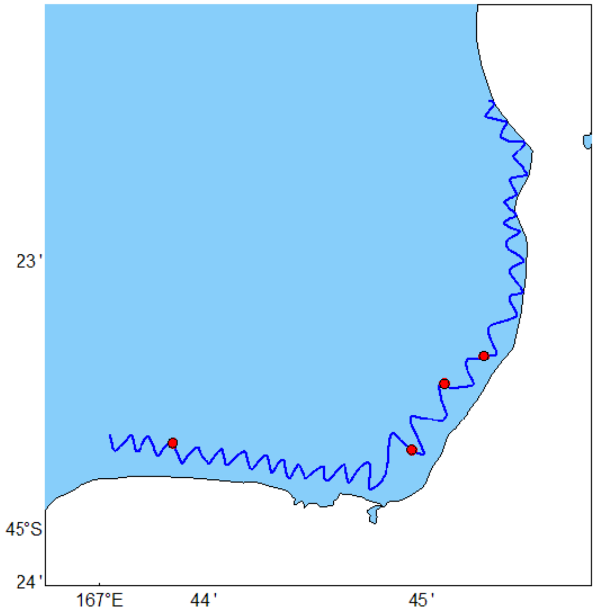

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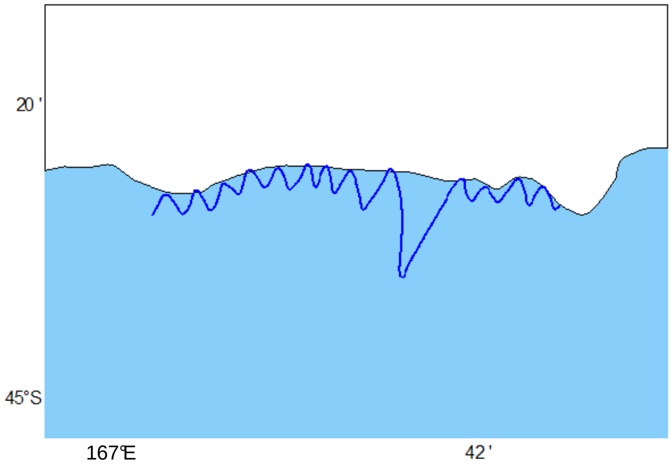

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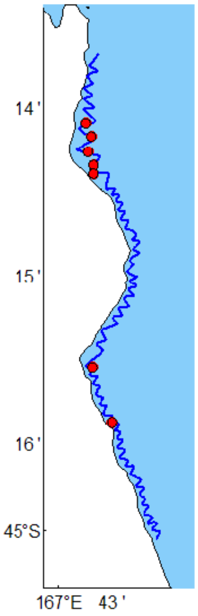
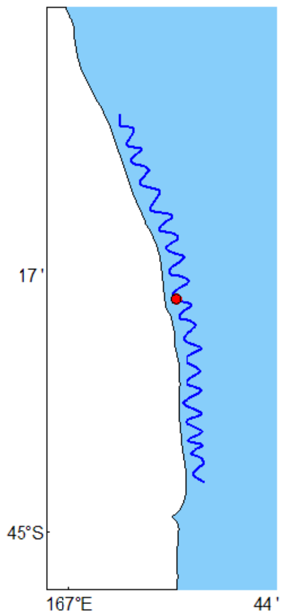


Transect 4a

Transect 4b



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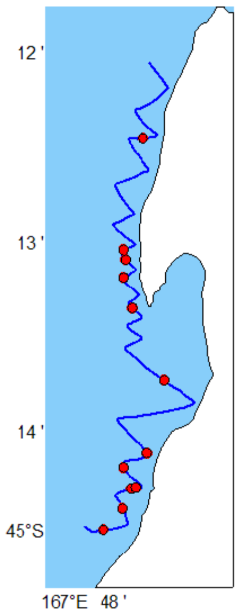

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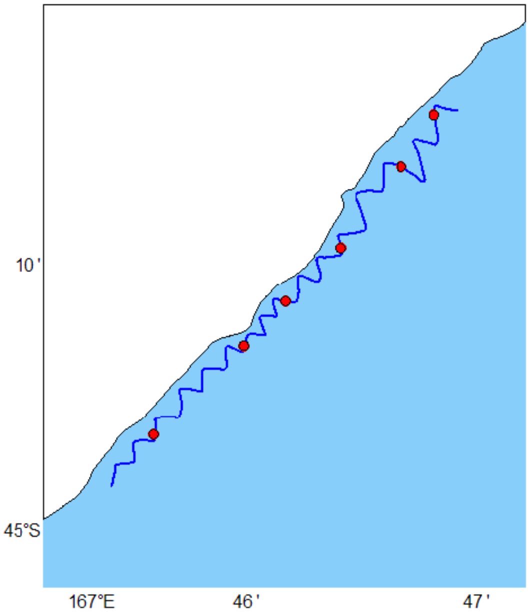

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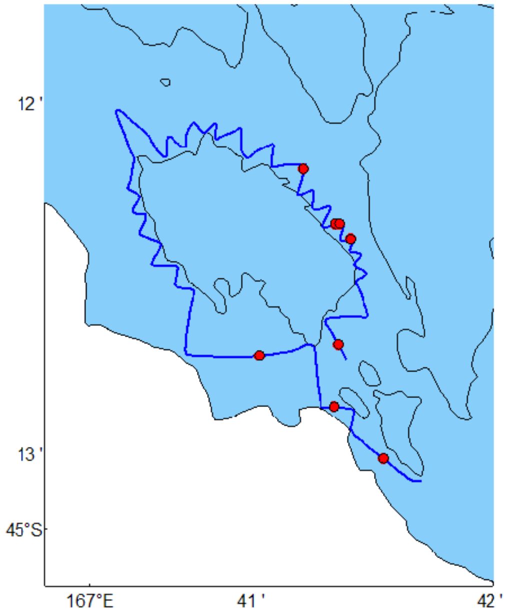
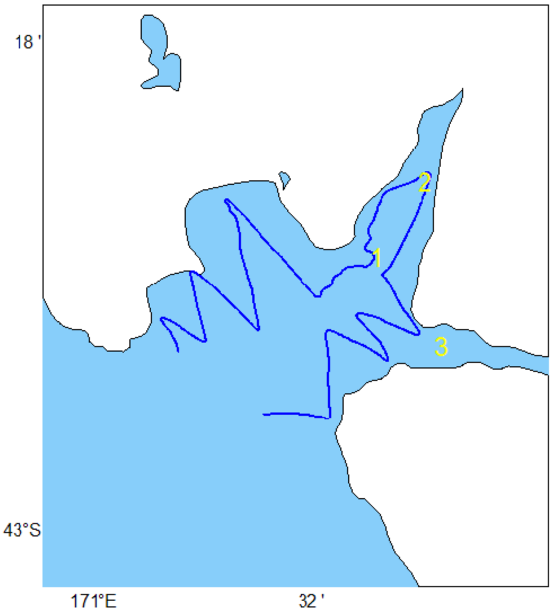


7.9. Gillnets location in Lakes Coleridge and Benmore

Locations of gillnet sets within Lake Coleridge and Lake Benmore.

Lake Coleridge

Transect 1



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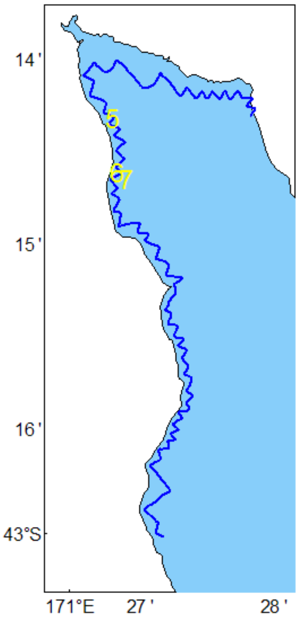
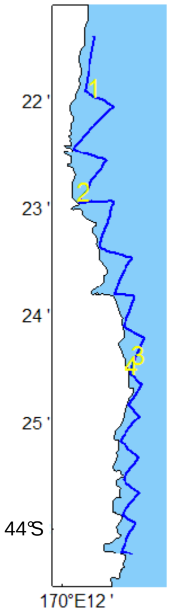


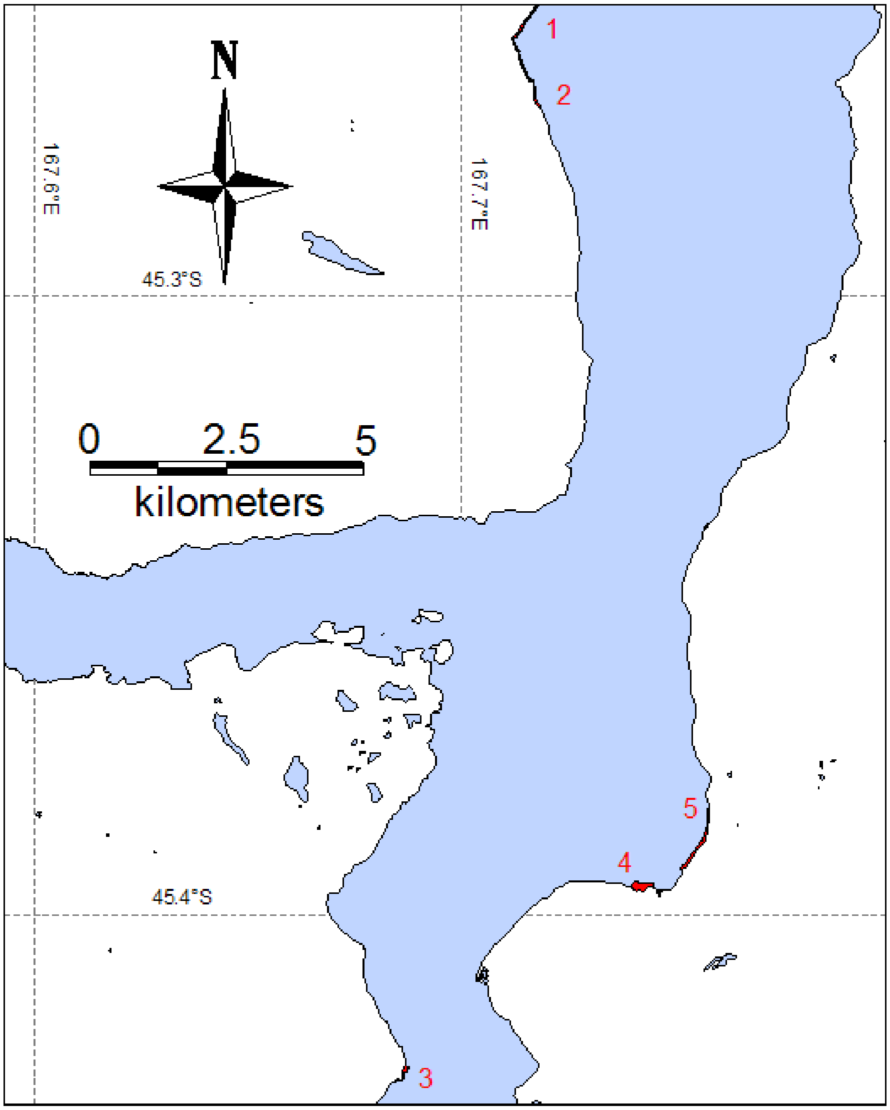
Lake Benmore

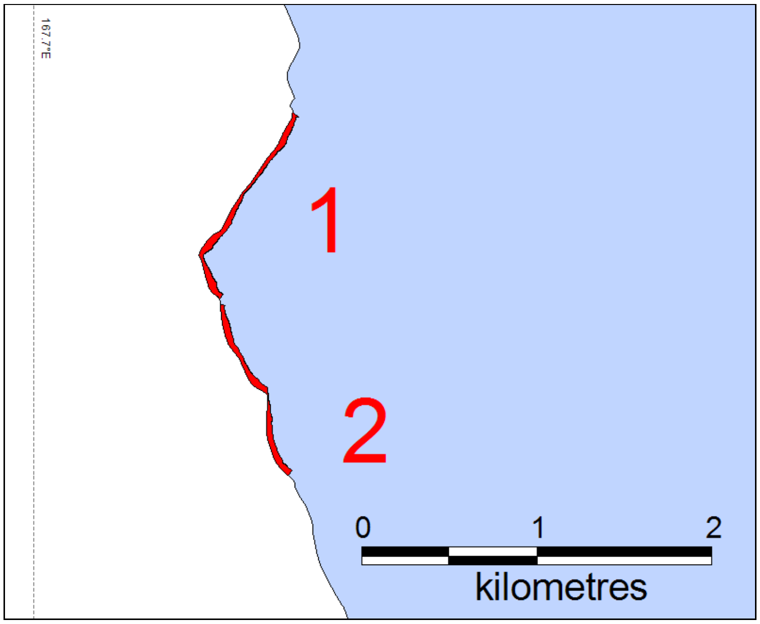
Transect 1

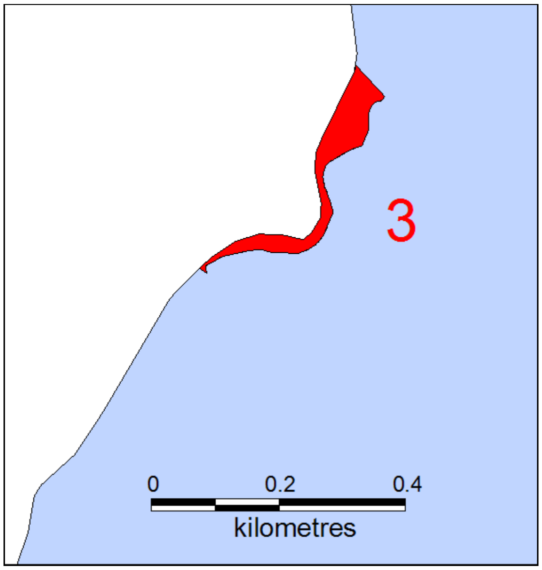


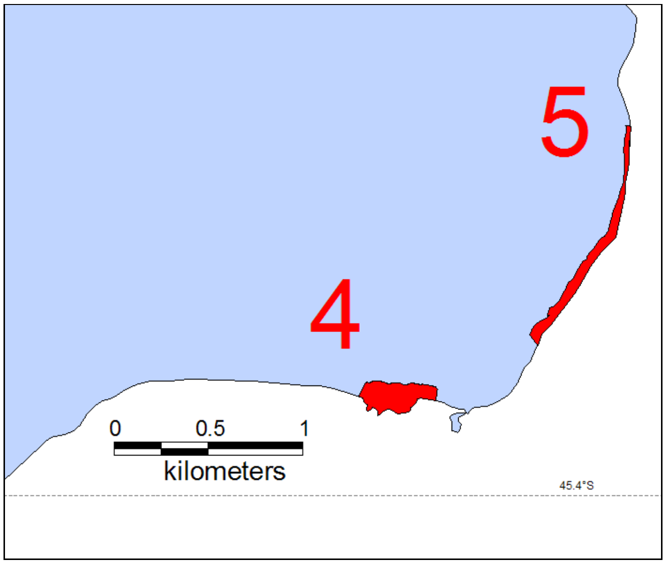
7.10. Visual transects in Lake Te Anau

Location of visual transects within Lake Te Anau. Following maps show the area covered by each transect.




167.7°E
1
2
0
1
2
kilometres


3
0
0.2
0.4
kilometres


5
4
0
0.5
1
kilometers
45.4°S