Arapuni Reservoir 2024 Spawning Report and Stocking Recommendations

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Executive summary/management implications

The proportion of wild rainbow trout (*Oncorhynchus mykiss*) returned in the Lake Arapuni fishing competition fell from an average of 51% (2006-2012) to below 10% (2016 and 2017). Although wild fish rebounded to 60% of the catch in 2024, Auckland/Waikato Fish and Game Council prioritised spawning surveys in Lake Arapuni to evaluate natural spawning. The management implication of surveys and the subsequent review of hatchery stocking was to determine if the fish stocking program was best practice or if natural spawning alone was sufficient to sustain the Lake Arapuni rainbow trout fishery.

Four spawning surveys were conducted between 21 June and 13 September. With peaks in spawning during June and September. It is highly likely spawning began in May, and future surveys should begin in late May or early June. The surveys indicated that ample spawning was occurring in Tributary C to sustain fish stocks in the lake, but the other monitored streams were underutilised.

Previous studies of Lake Arapuni spawning tributaries have not identified why rainbow trout predominantly spawn in Tributary C and avoid several other similar tributaries. During the 2024 spawning surveys temperature loggers were installed to monitor Tributary C and two underutilised streams with suitable habitat. The temperature profile of Tributary C was vastly different from the neighbouring streams, with a far less fluctuation in daily temperature indicating groundwater infiltration (spring fed). It is highly likely that Lake Arapuni rainbow trout are selecting Tributary C due to the ground water rather than other factors like spawning gravel availability. Spawning salmonids are known to select spring fed streams as the cool water and stable flow can increase spawning success. Restoration of neighbouring streams that are not spring fed would likely be pointless as the rainbow trout are excluding the tributaries due to a lack of groundwater.

Nearly 20% of the spawning rainbow trout observed during the 2024 spawning surveys were tagged hatchery fish. The high proportion of hatchery spawning fish could have significant population level implications. Recent publications have indicated that stocking salmonids (salmon and trout) has unintended detrimental effects that potentially lower the population size by adding hatchery fish. It is possible that stocking fish in Lake Arapuni has reduced the overall population size by lowering the survival of the offspring of spawning fish. Hatchery fish are known to pass on traits selected for in the hatchery environment that are detrimental to wild populations, significantly reducing the survival of hatchery offspring for several generations. Recruitment models based on Lake Arapuni spawning data indicate the potential for a significant reduction in the overall population due to hatchery releases. The negative impacts of stocking salmonids are not limited to Lake Arapuni and should be considered when evaluating stocking programmes around the country.

The sterile trout program will not be concluded until 2026 but has yielded ample data to draw some conclusion about stocking rainbow trout in Lake Arapuni. The sterile trout used in the study were intended to address the negative genetic impacts of stocking trout in Lake Arapuni but catch rates were low for sterile fish. The cost of stocked Lake Arapuni sterile trout is about $80 per fish caught. Non-sterile hatchery fish cost about $40 per fish caught and an adult one-day fishing licence sells for $25. Overall, the stocking program is not cost effective and may be reducing the overall rainbow trout population in the lake.

Staff recommendations include:

1. There is an overwhelming body of evidence endorsed by Trout Unlimited that indicates hatchery releases should only be used to prevent extinction or where no natural recruitment exists. The following policies are recommended for Auckland/Waikato Fish & Game and should also be considered for the NZ Fish & Game Council:
    a. Hatchery releases should be considered detrimental to wild spawning fish and are only advantageous to fish populations that have no natural spawning.
    b. Prior to hatchery releases being funded there must be a documented recruitment failure of natural spawning or no natural spawning.
2. Many fisheries like Lake Arapuni have had significant drops in angler use with no review of the need for continued supplemental stocking. A request to NZ Council for an independent review of the funding for all New Zealand Fish & Game salmonid stocking programs would be a prudent step considering the high cost and dubious benefits to anglers.
3. Although Lake Arapuni has limited spawning habitat it is recommended that stocking is paused for a period of five years or until there is evidence of recruitment failure. The impact of spawning fish may linger for multiple generations so it is likely that there will be reduced catch rates for up to four years.
4. Temperature monitoring should be expanded to identify other spring fed tributaries to Lake Arapuni for potential thermal refuges and spawning enhancement.

Background

Lake Arapuni is the single biggest fishery in the Auckland/Waikato region, with angler use similar to the Whakapapa River at about 3,800 angler days in the 2021 angler use survey (Stoffels & Unwin, 2023). Since angler use data has been collected, fishing pressure at Lake Arapuni has halved from 7,298 angler days in 1994 to a low of 3,371 in 2014 (Stoffels & Unwin, 2023) like other Waikato fisheries (Figure 1).

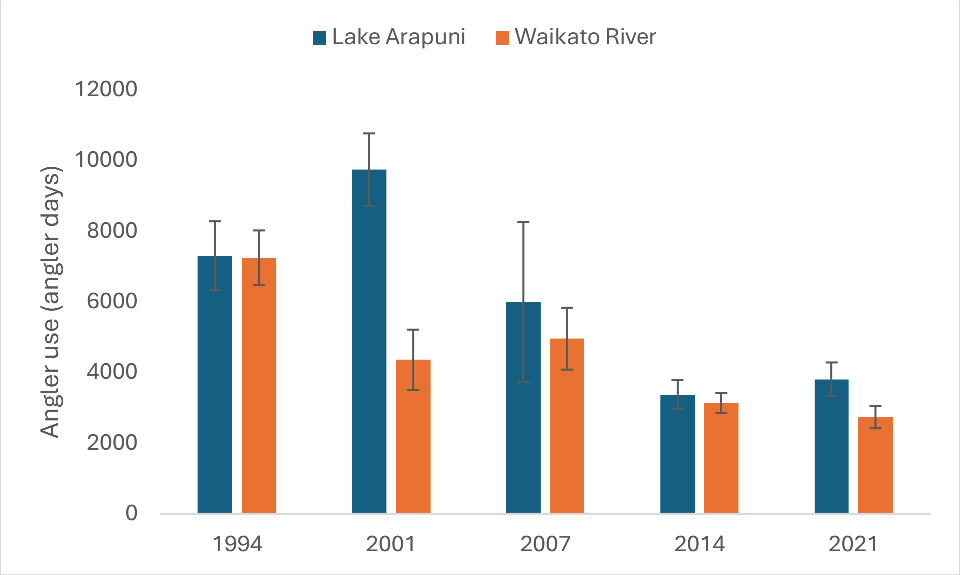

Figure 1. Angler use of Lake Arapuni and the Waikato River (below Karapiro Dam).

The first significant liberations of trout in Lake Arapuni were conducted in August of 1964. Tag returns from 1964-1974 averaged 1.7% with fish reaching the 2.6 kg mark. The size of fish has not changed dramatically with the largest rainbow trout caught annually from 2005-2020 averaging 2.5 kg (3.1 kg max). The average tag return rate during this period was 3.6%.

Lake Arapuni was originally identified as having limited spawning success in the 1980's (Strickland 1980, Ward 1983). In addition, it was suggested that spawning could be improved by fencing and planting Tributary C or adding spawning gravel (Strickland 1980). The fencing and planting were completed in the 1990's resulting in a full canopy cover over and riparian margin along Tributary C. Subsequent spawning surveys indicated that natural spawning was successful in Tributary C so additional spawning gravel was not tested as it was unnecessary.

The annual Lake Arapuni fishing competition held on the second weekend in May has produced a significant long-term dataset that can be used to track the wild and hatchery population from 1998 to present. The proportion of wild rainbow trout (Oncorhynchus mykiss) returned in the Lake Arapuni fishing competition fell from an average of 51% from 2006-2012) to below 10% in 2016 and 2017 (Figure 2).

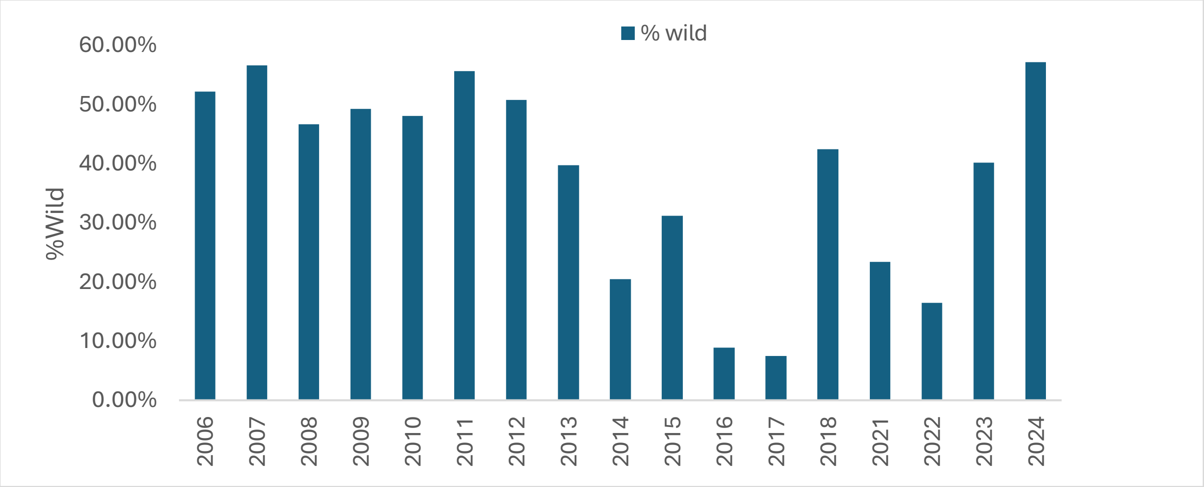

Figure 2. Percentage of wild rainbow trout returned in the annual Lake Arapuni Fishing Competition 2006-2024.

A test of sterile hatchery fish is ongoing in the lake and as a result all hatchery fish are marked providing a unique opportunity to identify all hatchery fish in spawning streams. Approximately 1000 sterile and 1000 normal hatchery trout from the Ngongotaha Trout Hatchery were released annually in Lake Arapuni from 2020 to 2023. Half of the overall hatchery population would not be expected to spawn or migrate into spawning streams as they are sterile. There are no documented "spawning" events of sterile trout in the wild but sterile salmon have gone through the motions when placed next to spawning females in laboratory studies (Fjelldal et al., 2014a). If male sterile hatchery trout did induce spawning in the wild the resulting ova would be unfertilised.

Hatchery releases of rainbow trout in Lake Arapuni during the 1990's occurred in response to high fishing pressure and have not been reviewed in the last three decades. Reductions in the proportion of wild rainbow trout harvested from 2014-2018 (Figure 2) has prompted a review of literature on the impacts of hatchery releases and a spawning survey to ensure natural reproduction is occurring if hatchery releases are paused.

Current hatchery releases

During the last four years 2000 tagged hatchery fish from the Eastern Region Fish hatchery have been released annually. Half of the hatchery released fish were sterile, and to date, none of the 4000 sterile fish have been captured at the base of the Waipapa Dam during the annual spawning run. Sterile trout were also sampled to ensure they were triploid (sterile) by the University of Waikato and 100% of trout checked were triploid. Sterile fish should not have the urge to spawn and should not enter small tributary streams for the purpose of spawning. However, some sterile male salmonids placed in tanks next to viable females have displayed spawning behaviour during laboratory experiments despite being infertile (Fjelldal et al., 2014) indicating the possibility of spotting sterile male trout in spawning streams despite there being no possibility of genetic interactions.

The use of sterile fish could eliminate the negative genetic effects of introducing hatchery fish in terms of disrupting wild spawning success. Similar to results from studies of sterile trout in North American lakes, Lake Arapuni sterile trout have been caught at lower rates compared to non-sterile hatchery fish (Koenig et al., 2011; Pease et al., 2023). Tag returns for sterile trout in Lake Arapuni have been about half the rate of non-sterile hatchery fish making them prohibitively expensive to realise the equivalent benefits for anglers (Table 1). However, even when factoring in a 50% reporting rate for tags (based on 2024 angler survey data) even non-sterile hatchery fish cost licence holders about $40 each (Table 1).

Table 1. Number of "sterile" and "non-sterile" rainbow trout tagged and "released" in Lake Arapuni. "Returned" indicates the number of rainbow trout returned for each group during each release "year". Percent returns are calculated from the total number of tagged fish released divided by tag returns. Cost is based on the actual cost to release fish divided by the number of returns and corrected for an estimated 50% return rate.

	Sterile			Non-sterile		
Year	Released	Returned	% Return	Released	Returned	% Return
2020	1000	41	4%	1000	66	7%

2021	1000	16	2%	1000	48	5%
Total	2000	57	3%	2000	114	6%
% returns			33%			67%
Cost 50% return			$79.65			$39.82

Arapuni Reservoir hatchery fish grow quickly and do not often survive more than three years in the reservoir with only 9% of tag returns from fish exceeding 2 years in the lake (3 years old) and only 1% exceeding 3 years (4 years old; Figure 3). Rainbow trout can live up to 10 years in streams making the Arapuni hatchery fish relatively short lived. The likely cause of mortality of hatchery released fish is heat and spawning stress. Tag returns from hatchery released fish vary from year to year but average about 4% excluding the 2016 and 2017 release years where tag returns were reduced due to covid lockdowns (Figure 4).

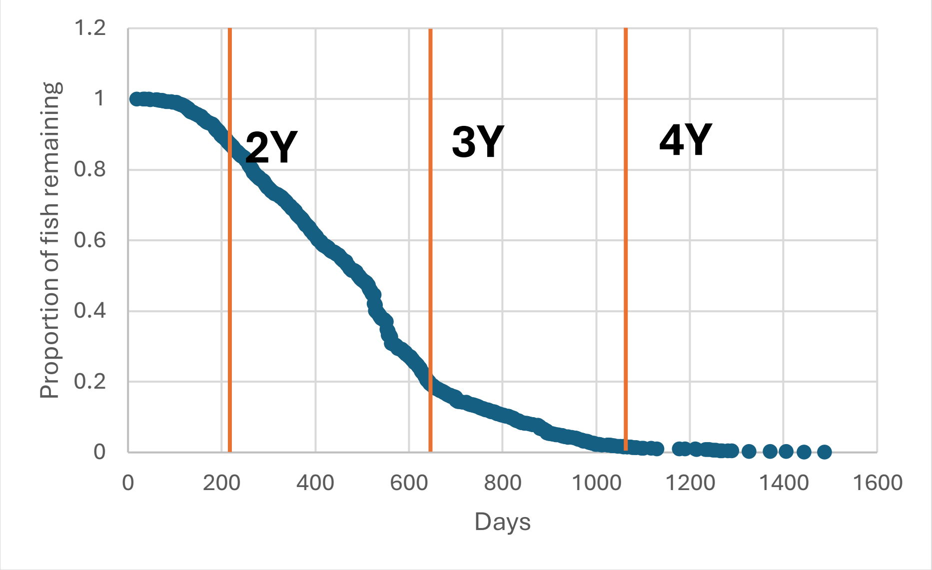

Figure 3. Estimated survival curve derived from the proportion of hatchery released fish remaining in Lake Arapuni over time (N=2050).

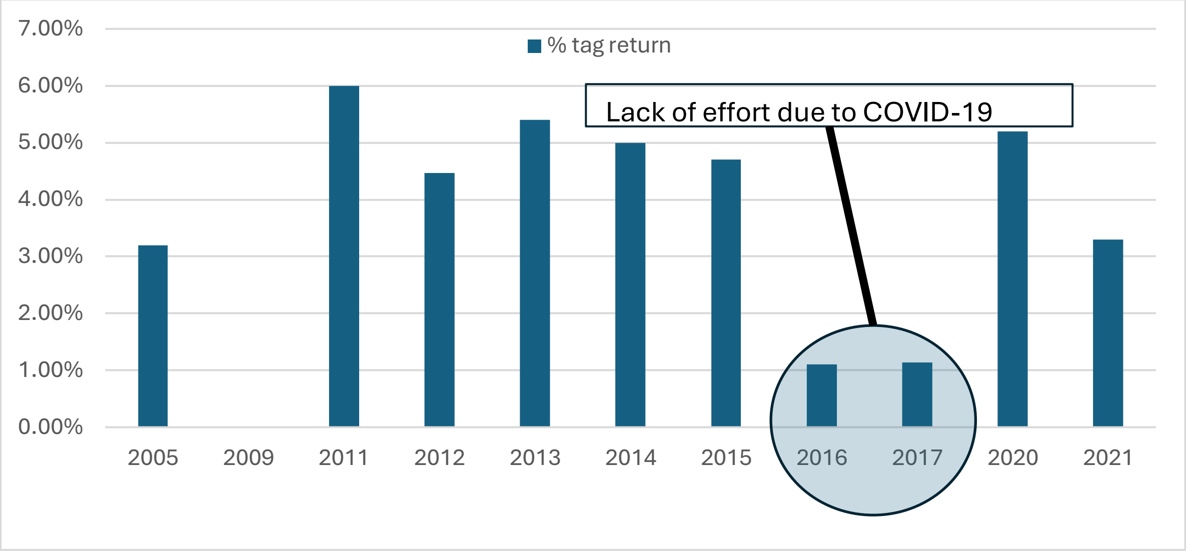

Figure 4. Percent of tagged fish reported by release year.

Hatchery fish released in Lake Arapuni are from the Eastern Region Fish hatchery and are selected from the Lake Tarawera or Ngongotaha Stream fish traps. The Eastern Region Fish breeding program selects the largest and best-looking trout to create the hatchery stock with most of the fish coming from Lake Tarawera. Lake Tarawera is oligotrophic with water clarity of nearly 6 m and maximum summer temperatures of 22 °C. In comparison the Arapuni Reservoir is riverine in the upper third of the reservoir with water clarity of just over 2 m and a maximum water temperature of 24 °C.

Methods

Study area

Streams identified as spawning sites in previous surveys (Strickland 1980, Ward 1983 and Unknown 1993) and streams with resident trout populations potentially contributing to the Lake Arapuni population are listed in Table 2 and mapped in Figure 5. The 2024 surveys were focused on streams with previous known spawning (Table 1; Figure 5). Streams with trout populations that could be contributing to the lake Arapuni population have also been listed and mapped (Table 1 A-D; Figure 5 A-D). Previous spawning reports have not documented the survey reaches, so the areas surveyed are based on access and likely historical sites.

Table 2. Spawning streams (1-4) and streams with known or suspected upstream resident trout populations (A-D) that could contribute to the Lake Arapuni trout population. “**Map**” indicates the label for each site in Figure 5. “**Max**” is the maximum observed spawning trout (“**R**” rainbow & “**B”** brown trout).

Map	Stream name	Max	X	Y
1	Makomako Stream	6B	175°40'28.39"E	38°13'8.85"S
2	Mangarewa	11R	175°40'48.67"E	38°13'17.62"S
3	Te Rimu	17R	175°40'39.95"E	38°14'41.67"S
4	Tributary C	95R	175°40'38.38"E	38°15'43.11"S
A	Mangare	0*	175°36'47.49"E	38° 7'0.72"S
B	Mangawhio	0*	175°40'46.91"E	38°16'32.24"S

C	Tumai	0*	175°41'10.53"E	38°17'9.97"S
D	Waipapa	*	175°40'49.19"E	38°18'4.93"S

* Potential contribution from resident upstream populations.

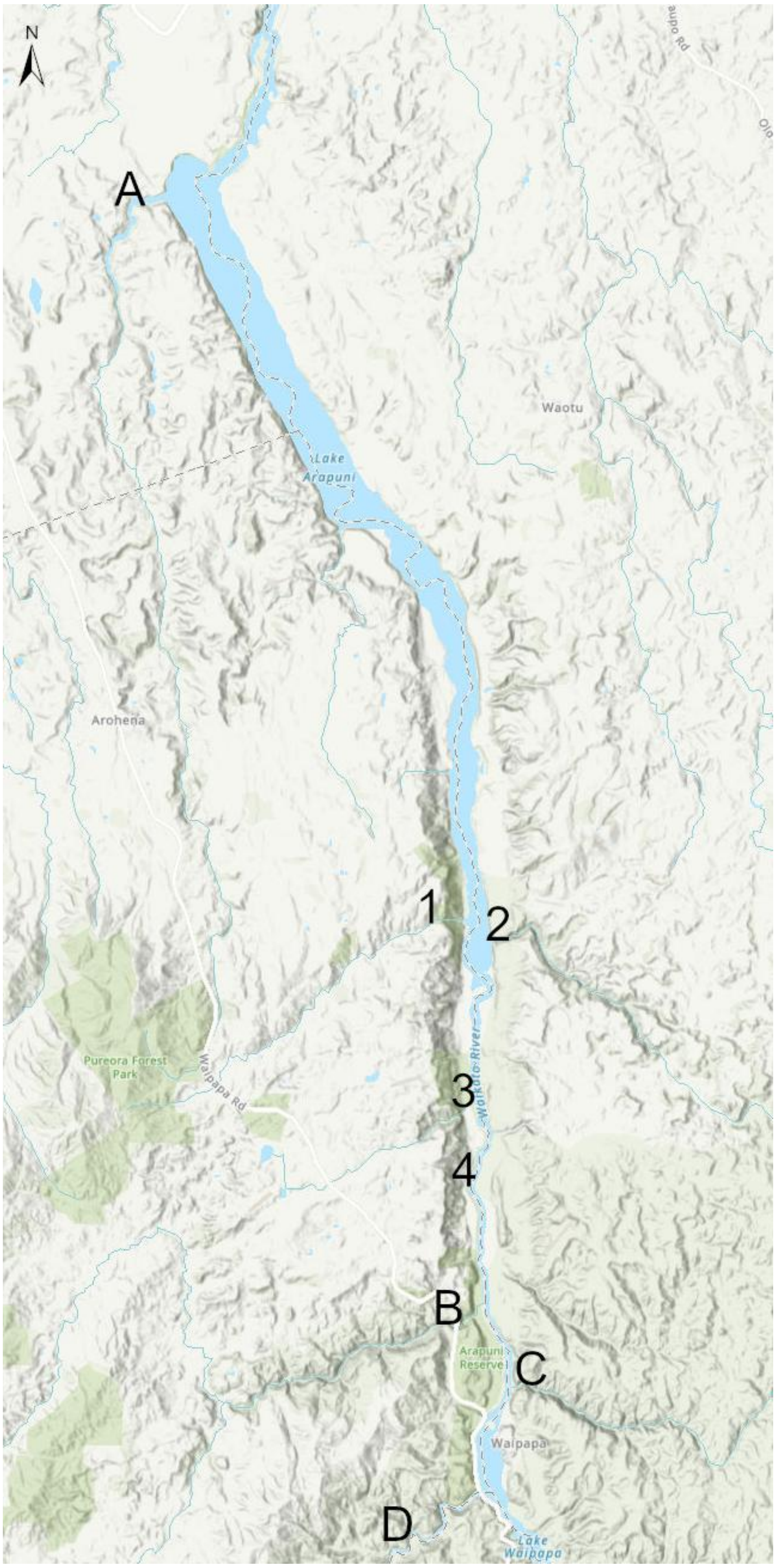

Figure 5. Known spawning streams 1-4 and steams with known or suspected upstream resident populations A-D that could contribute to the Lake Arapuni trout population. Stream names and coordinates are listed in Table 1.

Makomako Stream

Makomako Stream (38°13'8.85"S 175°40'28.39"E) was surveyed for approximately 70m from the confluence of Lake Arapuni to the first impassable waterfall (Figure 6). Although there was limited habitat available fresh gravel from a slip had replenished the stream with 30-60 mm stones (Figure 7).

Figure 6. Makomako Stream survey area (red dotted line) with start and end points marked with red dots.

Figure 7. Makomako Stream with spawning brown trout, fine sediment (bottom of photo) and fresh gravel.

Mangarewa Stream

The Mangarewa was surveyed from the confluence (38°13'17.64"S, 175°40'48.64"E) for approximately 100m upstream (38°13'18.01"S, 175°40'50.87"E; Figure 8 and 9). The area had some spawning substrate but was of steep gradient with logs and boulders. Future studies should attempt to access the stream from the bike trail to look further upstream.

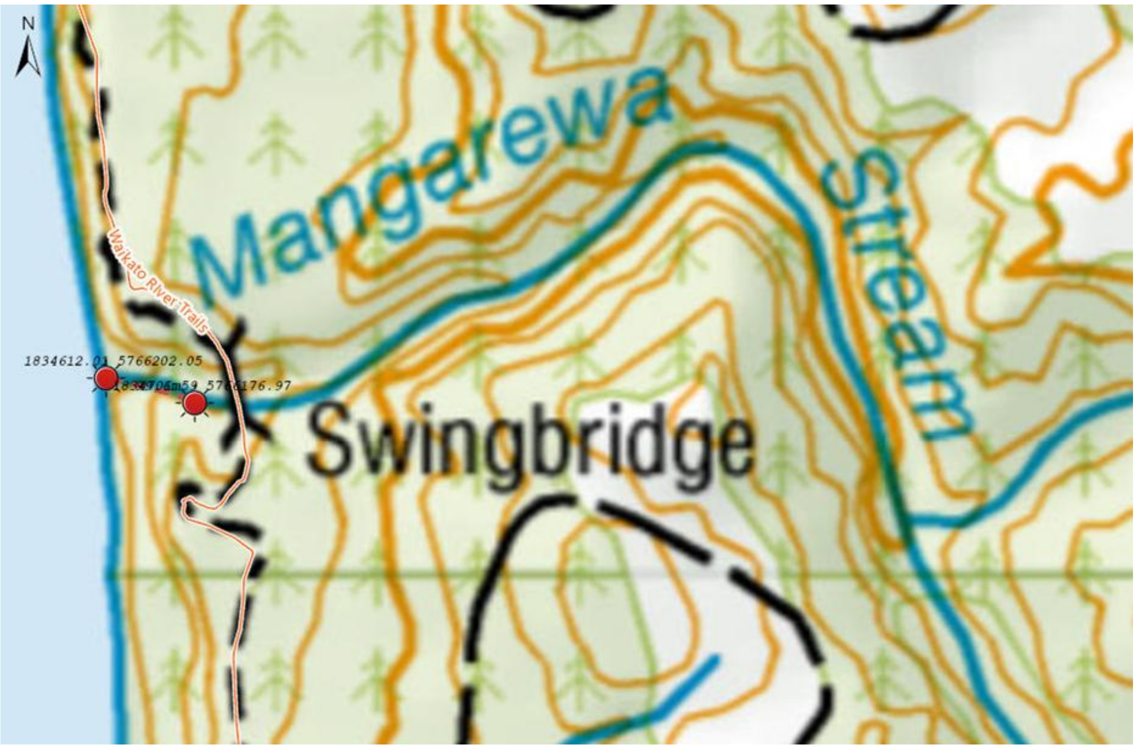

Figure 8. Mangarewa Stream survey area (red dotted line) with start and end points marked with red dots.

Figure 9. Mangarewa Stream survey area (red dotted line) with start and end points marked with red dots.

Te Rimu Stream

The Te Rimu Stream was surveyed from 136 m below the waterfall to the base of the falls (38°14'45.11"S, 175°40'35.26"E; Figure 10 and 11). The substraight was predominantly sand and fine sediment but areas of suitable spawning gravel were present.

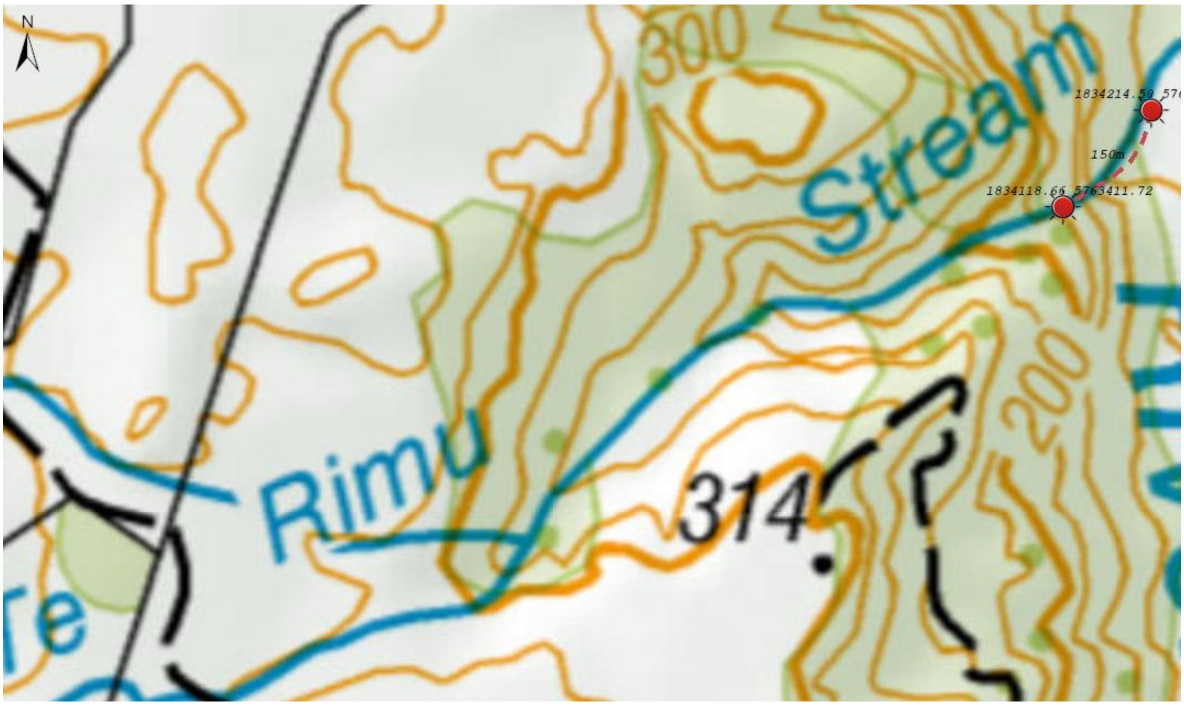

Figure 10. Te Rimu Stream survey area (red dotted line) with start and end points marked with red dots.

Figure 11. Te Rimu Stream survey area (red dotted line) with start and end points marked with red dots.

Trib C

Tributary C was surveyed from the confluence with the Waikato River to a point approximately 615m upstream (straight line distance; 38°15'43.11"S 175°40'38.38"E; Figure 12 and 13). It is possible that historic surveys continued further upstream into private land. The stream bed had sparse spawning gravel in the first 300m with a high percentage of fine gravel and sand with large areas of scour. The upper half of the survey area had several moderate sized gravel beds (Figure 14) suitable for spawning.

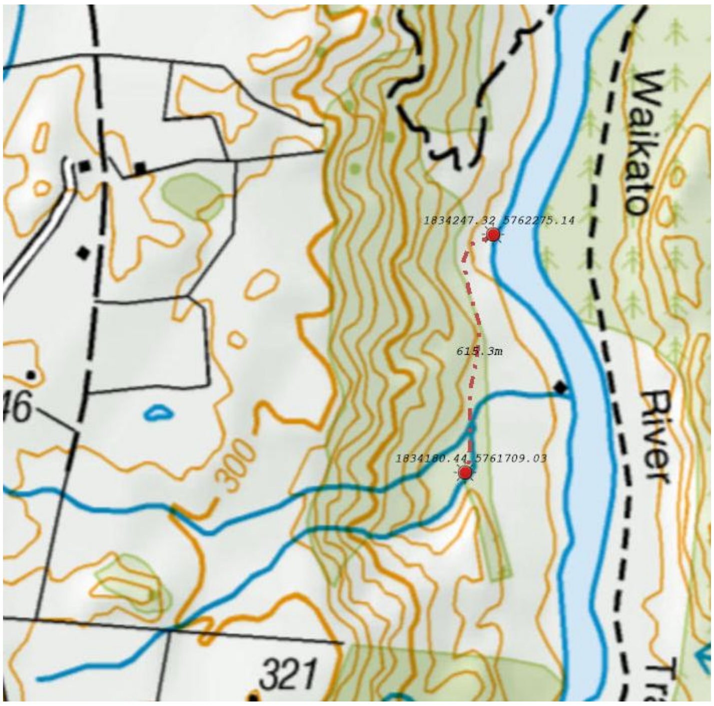

Figure 12. Tributary C survey area (red dotted line) with start and end points marked with red dots.

Figure 13. Tributary C survey area (red dotted line) with start and end points marked with red dots.

Figure 14. One of several gravel beds in the upper reaches of the Tributary C (left) with gravel predominantly from 18-25mm (right).

Tumai Stream

The Tumai Stream (Figure 15) was surveyed in the hope gravel from the adjacent bike path may have improved conditions in the stream. The survey was conducted approximately 60 m from the confluence to just below the first waterfall. The substrate was not ideal for spawning and was dominated by sand, but an upstream population of trout could be present.

Figure 15. Tumai Stream survey area (red dotted line) with start and end points marked with red dots.

Spawning survey

Due to the small size (<1 m wide and under 200mm average depth) and good water clarity staff were able to slowly walk from the Arapuni Reservoir up the spawning streams to observe spawning fish. Although logs and undercut banks provided some cover most fish were defending reds (spawning beds) prior to being disturbed and were mid-stream in gravel beds. Fish were identified by species and rainbow trout were checked for tags to identify hatchery fish. All hatchery released fish in Lake Arapuni were tagged during the 2024 survey due to the ongoing sterile fish project. Fish were categorised as tagged, wild or unknown as some fish could not be observed long enough to rule out a tag.

Due to a lack of detail in previous spawning surveys reports it is unlikely that surveys have been conducted in a similar way and should not be directly compared to historic surveys. Tributary C was likely undercounted in 2024 due dense blackberry and private property. The area that was covered was sufficient to determine if spawning was occurring.

Spawning interaction calculation

The estimate of hatchery reared fish during the spawning survey was derived from the total number of fish released adjusted using the survival curve derived from tag returns (Figure 3). The population estimate for spawning fish was then calculated using a conservative estimate of spawning wild fish (80%; based on catch data and spawning data) to give a total population of 4835 adult rainbow trout. A simple model of 15 offspring surviving the first year per pair (1500 ova at 1% survival) was adjusted using relative fitness data from McMillan et al. (2023) based on a global synthesis of 208 peer-reviewed papers. Fish were assigned random paring based on the ratio of wild and hatchery fish observed during spawning surveys and then thee relative fitness scenarios were tested including “Best”,” Mid” and “Worst” based on the relative survival rates (Table 3) from (McMillan et al., 2023). For example, the “Best” relative fitness would give a single offspring for tow wild parents and 0.6 offspring for a wild hatchery cross and 0.2 offspring for a hatchery X hatchery cross. For every 10 fish produced by two wild parents we would estimate only 2 surviving offspring from two hatchery parents.

Due to the relatively high proportion of wild fish observed during the spawning survey the relative fitness estimate will not show the worst-case scenario where up to 90% of fish could be of hatchery origin based on Lake Arapuni competition data. Due to the assumptions used in deriving a population estimate the spawning interaction calculation should be used as an example of potential impacts rather than a true model of actual conditions. The purpose of theoretical model is to show the potential impact of hatchery fish spawning in the wild based on observed field data from published sources.

Table 3. “Best,” “Mid,” and “Worst” relative survival rates from derived from McMillan et al. (2023). “Wild” represent a wild spawning rainbow trout parent and “Hatch” is a hatchery parent.

Cross	Best	Mid	Worst
Wild X Wild	1.00	1.00	1.00
Wild X Hatch	0.60	0.50	0.20
Hatch X Hatch	0.20	0.10	0.02

Temperature monitoring

Onset pendant temperature data loggers were installed on waratahs (steel fence posts) on the stream bed of Tributary C, Te Rimu, and Makomako Streams from 20 August to the 5th of November 2024. The loggers were intended to identify differences in the temperature profile of Tributary C compared to the other streams that do not support significant spawning despite having some suitable habitat. This information could inform the council about the restoration potential of streams not currently being utilised by trout for spawning. The temperature monitoring was installed mid spawning season after suitable and available spawning habitat was observed to be unused.

Results

Spawning surveys

Five streams were surveyed in total during four survey trips from Jun to August of 2024 (Table 4). Only Tributary C and the Makomako stream were observed on each survey. All of the rainbow trout observed during the 2024 spawning surveys were located in Tributary C with a maximum count of 22 fish in June (Table 4) despite other tributaries having similar habitat. Most of the trout counted in Tributary C were located in the upper reaches of the survey area and it is likely there were more spawning fish upstream. The lower reaches of Tributary C are a mix of scoured bed, fine gravel and sand (Figure 16).

Table 4. Spawning survey data from Lake Arapuni June to September 2024. The total number of fish counted (Fish), fish identified as hatchery or wild (I.D.) and fish identified with tags (Tag). Blanks indicate no survey was conducted and counts ending in "B" were identified as brown trout.

Stream	21 June 2024			1 Aug 2024			20 Aug 2024			13 Sep 2024		
	Fish	I.D.	Tag	Fish	I.D.	Tag	Fish	I.D.	Tag	Fish	I.D.	Tag
Trib C	**22** **2B**	20	5	**13**	11	4	**11**	10	2	**21**	10	1
Makomako	**6B**			**2B**			**0**			**0**		
Mangarewa				**0**								
Te Rimu				**0**			**0**			**0**		
Tumai	**0**											

Figure 16. Adult rainbow trout in Tributary C on an area of sand and fine gravel.

Of the rainbow trout counted in the 2024 spawning survey, 23% were identified as hatchery released fish. Accounting for tag loss and unidentified fish it is likely that up to a quarter of the spawning fish in Lake Arapuni were hatchery released fish reared from Lake Tarawira brood stock.

Only ten brown trout were spotted during the three spawning surveys with eight of the ten browns located in the Makomako Stream with the remaining two in Tributary C. The Makomako Stream has recently experienced a slip that left course gravel in the limited habitat below the waterfall. It is likely that brown trout are spawning earlier in the year and were missed in the 2024 surveys.

The Te Rimu Stream did not have any spawning fish and is dominated by fine sediment in the lower reaches but does have suitable unused gravel near the waterfall. The Mangarewa had large amounts of slash and moderate rockfalls that could pose as passage barriers, but no fish were spotted in the limited available spawning habitat. Although the Tumi is dominated by sand in the accessible reaches there may be an upstream population of trout. Similarly, the Mangare Stream has unsuitable habitat for spawning near the lake but is likely to have a resident trout population upstream. The Waipapa River and Mangawhio Stream were not surveyed but both streams hold significant populations of resident trout that could be contributing to the Lake Arapuni population via downstream migration.

Temperature Monitoring

The temperature profile of Tributary C has far less variation than the Makomako Stream or Te Rimu Stream (Figure 17), indicating some form of thermal buffering. The Makomako and Te Rimu Streams had nearly identical temperature profiles that better represent swings in air temperature. Tributary C's relatively stable temperature is likely due to groundwater influence (springs) keeping the temperature from varying drastically with air temperature. The temperature profile of Tributary C seems to be unique for the area and should be investigated further.

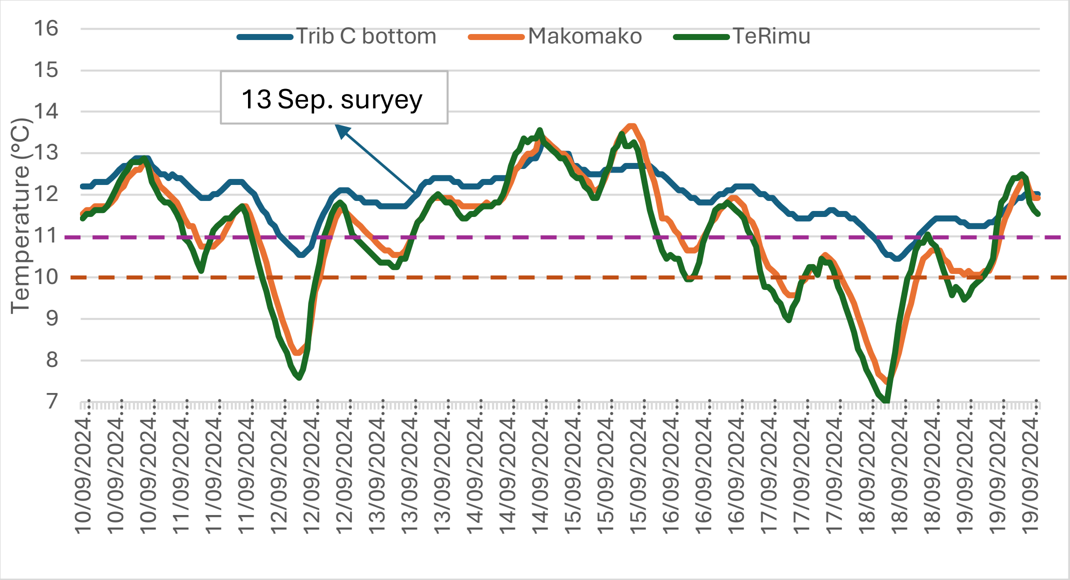

Figure 17. Hourly water temperature of Tributary C (blue), Makomako Stream (orange) and Te Rimu Stream (green) from 10 September to 19 September 2024. Dashed lines indicate the theoretical maximum temperature rainbow trout (purple dashed line) and brown trout (brown dashed line) initiate spawning. The arrow marks the approximate time of the 13 September 2024 survey.

Rainbow and brown trout eggs can mature in a wide range of temperatures, but the act of spawning is only initiated at a maximum of 10°C for brown trout and 11°C rainbow trout. Temperature monitoring was started mid spawning season and water temperatures did not often fall below 11°C but a cold snap prior to the 13 September 2024 survey (Figure 17) may explain the large number of fish observed so late in the spawning season. Maximum weekly average temperature for spawning and embryo survival of brown and rainbow trout are 8°C and 9°C respectively (Brungs & Jones, 1977) and the minimum weekly average temperature recorded in this study was in excess of 11°C. It is likely that temperatures earlier in the spawning season prior to monitoring were within this range.

Temperature monitoring was not continuous with several floods causing significant bed movement in the streams that damaged posts (Figure 18) and likely removed any reds present at the time. Reduced flows in October were noticeable and the Te Rimu Stream logger was exposed to air 22 October 2024.

Figure 18. Staff member Adam Daniel with a damaged logger mounting post in the Makomako stream.

Discussion

Spawning in Lake Arapuni tributaries

There is no indication of spawning failure in Lake Arapuni. The lake has limited but suitable spawning tributaries Although spawning does not indicate recruitment success the high adult returns of wild fish in 2024 would suggest there are no chronic recruitment issues. The main rainbow trout spawning season last from May to September in the Arapuni Reservoir with historic surveys averaging 34 individuals per count. Compared to historic surveys of Tributary C the 2024 surveys recorded the lowest daily peek on record (Figure 19). It is likely that there were additional uncounted fish upstream of the survey area on private land and the peak of spawning was missed as previous surveys have occasionally documented peak spawning in June.

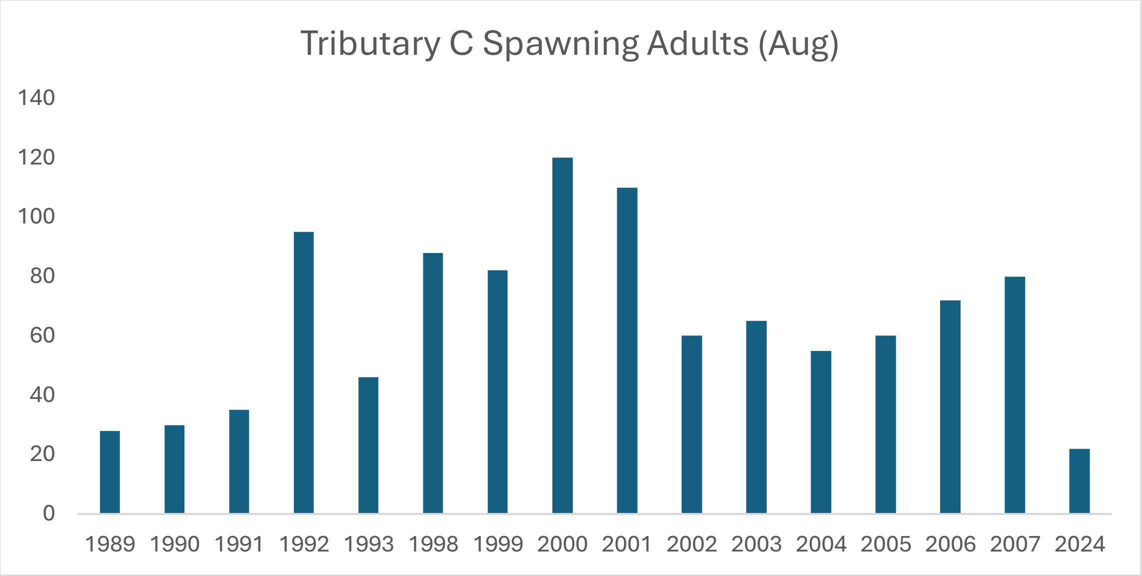

Figure 19. Historic annual peak daily counts of rainbow trout in Tributary C.

It would only take a small number of successful spawning females to naturally restock Lake Arapuni. For example, if we use a simple model based on moderate survival during the first year (3%) with only 100 females successfully spawning annually the adult population would be approximately 4,500 fish. When the additional fish washing in from upstream populations are considered it is likely that the naturally spawning fish are sufficient to sustain the Lake Arapuni population. However, with all or nearly all of the spawning fish in a single tributary there is a higher risk of recruitment failure due to flooding, slips or other natural causes. Evidence of historic poaching was also uncovered at the site raising concerns about the vulnerability of the population.

Restoration options

The discovery of groundwater infiltration in Tributary C is very important for determining potential restoration options for Lake Arapuni spawning streams. Survival of rainbow trout eggs in well oxygenated ground water influenced streams with sand bottoms is extremely high (Sowden & Power, 1985) making the addition of spawning substrate unnecessary. Although spawning gravel was traditionally thought of as essential for spawning success spring creeks like the upper Waihou have little or no suitable spawning gravel and very high recruitment rates.

It is unlikely that restoring other nearby streams that lack groundwater influence would be successful in terms of improving recruitment to Lake Arapuni. The temperature profile of Tributary C is unique and explains why the stream is the preferred spawning location. However, it may be possible to locate other groundwater influenced streams in the reservoir through temperature monitoring although the remaining unmonitored streams are small and restricted by falls and other obstacles.

Contributions for upstream populations

Lake Arapuni has two upstream populations of resident fish that could be contributing to a small proportion of the population. It is likely that rainbow trout from both the Waipapa River and Mangawhio Stream are washed into Lake Arapuni. Tag return data has documented that 2.5% (13 of 513) of hatchery fish released in Lake Arapuni passed the dam into Lake Karapiro and 13.3% of tag returns (2 of 15) from fish released in Lake Karapiro were recovered in the

Waikato River. It is likely that trout from upstream populations are washed into Lake Arapuni during years of significant rainfall. However, based on comparable data it is likely to be a relatively small proportion of the population.

The impact of hatchery stocking (literature review)

Hatchery stocking has long been seen as detrimental to wild populations of trout and salmon. A recent comprehensive review of published papers on hatchery stocking found that 83% reported adverse effects on wild spawning trout and salmon (McMillan et al., 2023). There are several detrimental impacts of hatchery stocking on wild spawning fish including disease, direct competition, competition for spawning reds and the dilution of advantageous adaptations. There has been no sign of new disease in the Lake Arapuni rainbow trout population but there was a sustained dip in the wild fish catch during 2016 and 2017 (Figure 20).

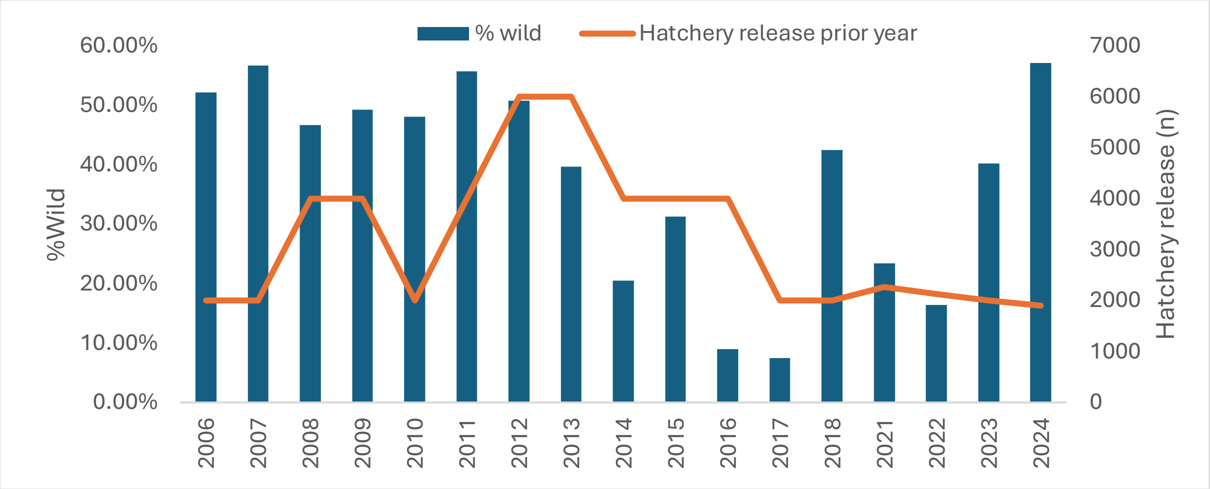

Figure 20. Percentage of wild fish returns annually (blue bars) from the Lake Arapuni Fishing Competition on the left axis and the number of hatchery rainbow trout releases the prior year (orange line) right axis.

Hatchery selection has long been known to rapidly alter fish populations because traits that allow fish to survive in hatcheries are very different than traits that help wild fish survive (Araki et al., 2008). The detrimental traits selected for in hatcheries reduce wild populations when hatchery fish interbreed with wild spawning fish that have adapted to the local environment by passing on detrimental traits. For example, in the hatchery fish that aggressively come to the surface when they see a shadow (hatchery worker with food) are likely to be eaten by shags or other predators in the wild.

The reproductive success of hatchery and wild fish are compared using “relative fitness”. For example, the relative fitness of hatchery wild hybrids (one hatchery and one wild parent) may be 0.50 indicating that for every surviving offspring from wild fish (two wild parents) there are 0.50 (half) the surviving offspring from hatchery hybrid fish (one wild and one hatchery parent). Most studies are conducted on sea run rainbow trout and the only comparable lake run rainbow trout study found that compared to wild spawning fish hatchery wild hybrids only produce 0.59 as may returning adults with pure hatchery fish returning only 0.21 as many adults (Miller et al., 2004). This detrimental impact is reduced with each generation spawning in the wild but can last for several generations.

Nonlocal (fish from another catchment) hatchery stocks are notorious for poor recruitment in the wild with some salmonid stocks returning only 2 offspring for every 100 produced by wild fish (Araki et al., 2008). Lake Arapuni is stocked with fish from another catchment entirely so traits that are advantageous in Lake Tarawira are added to the selection that occurs in the hatchery. The relative fitness of hatchery sea run rainbow trout compared to wild fish ranged from 0.02-0.80 with a mean of 0.42 (Araki et al., 2008). There is no way of knowing the extent of the negative selection and corresponding reduction in population caused by adding hatchery fish to the Arapuni Reservoir, but it is highly likely that the impact is negative.

Spawning interaction example

As a theoretical example, if we have a population of 4000 adult trout and 25% of fish spawning are hatchery stock using a 0.70 relative fitness for hatchery hybrids and 0.60 relative fitness for pure hatchery fish (mean overall fitness of 0.77 after a generation) the next generation would return 3080 fish. By continually diluting the traits of successful wild spawning fish hatchery releases could be effectively reducing the population by at least as much as the 1000 fish planned for the 2025 release. Sterile hatchery fish were intended to address the hatchery wild interactions but are not a cost-effective option due to the low catch rates to date.

Table 3 shows three simple models to demonstrate a potential range of outcomes from using best to worst relative fitness of hatchery fish spawning in the wild based on 20% hatchery to wild spawning fish and fitness estimates from McMillan et al. (2023). The resulting recruitment after a year “1000 1-year-old release” is compared to the estimated population with “No release”. The resulting reduction in recruitment ranges from 2842-5243 fish after their first year. The theoretical change in recruitment is between 16-30%. It is important remember that the estimates presented are far from an exact model, but they are useful to demonstrate the potential detrimental effects of hatchery releases.

Table 3. Estimated recruitment for a population of 4835 adult trout one year after spawning with and without hatchery releases of 1000 fish annually. “**Best**”, “**Mid**” and “**Worst**” estimates are based on the relative survival rates from (McMillan et al., 2023). The percent changed from the no hatchery release option “**% Reduction**” is compared to the three relative survival scenarios with hatchery fish spawning in the population.

	Recruitment		
	Best	Mid	Worst
1000 1-year-old release	14,918	14,279	12,517
No release	17,760	17,760	17,760
% Reduction with stocking	-16%	-20%	-30%

Hatchery stocking and catch rates

Hatchery stocking can have significant advantages and is necessary where there is no natural production like dune lake fisheries. There is a perception that adding hatchery fish will increase catch rates but the catch per unit effort (CPUE) from the Lake Arapuni Fishing Competition is not well correlated with fish stocking. The R value for the correlation between fish stocking the previous year and CPUE is only 0.26 with 0 being no correlation and 1 a direct correlation. Water temperature is far better correlated with an R value of -0.63 indicating an inverse effect with increased water temperature producing lower catch rates.

Catch rates in Lake Arapuni are low to moderate at 0.27 fish/hr. In comparison, Otago Lake fisheries have a historic mean of 0.41 fish/hr (range 0.16-0.71; Scott & Wright, 2007). The mean condition factor of trout in Lake Arapuni is good at K=1.3 (range 1.12-1.57) indicating that food availability is not a limiting factor. It is possible that the reduced catch rates are related to the timing of the monitoring period (March) when the lake temperature is above optimal for fishing. There is scope to improve catch rates with education around optimal summer fishing methods.

Cost benefit of stocking Lake Arapuni

The cost of hatchery stocking in terms of the price per fish caught by anglers has not been well documented. Based on tag return rates from a 2024 angler survey 44% of anglers return tags. If we use a conservative estimate of 50% reporting rate each hatchery reared fish caught by anglers in the Arapuni Reservoir would cost the council about $40. If sterile trout were used in the reservoir to reduce the impact of genetic interactions the cost would rise to about $80 per fish caught. Considering that an adult day licence is only $25 and catch rates are not well linked to hatchery stocking it seems unlikely that stocking Lake Arapuni is benefiting anglers.

Conclusions

Rainbow trout spawning in tributary C are likely sufficient to restock Lake Arapuni with the current angler use. Hatchery liberations in Lake Arapuni should be paused for a period of at least five years to determine the impact of naturally spawning hatchery fish on the overall population. To determine if eliminating disruptive hatchery genes from entering the Arapuni population is effective no other interventions should be trailed during this period. However, it would be prudent to continue monitoring Tributary C and to try to identify other spring fed tributaries.

There are risks to pausing hatchery liberations primarily related to extreme weather events or poaching. Both extreme heat during the summer and flooding during the spawning season could reduce the Lake Arapuni fish population. The lack of hatchery fish could also reduce catch rates in the short term but may not impact the overall population or future catch rates. It will be critical to continue monitoring the Lake Arapuni fishing Competition to evaluate the impact of any changes made.

The temperature monitoring data revealed that Tributary C is likely spring fed and the overwhelming preference for this spawning site may not be related to available spawning gravel or factors associated with being fenced and planted. Trout and salmonids in general have a strong preference for groundwater upwelling or springs in spawning streams (Schuett-Hames & Pleus, 1996). Spawning in fine sediment (like tributary C) can be very successful in spring fed systems where fish select for areas of high oxygen rather than spawning gravel (Sowden & Power, 1985).Spawning gravel allows water to flow over deposited ova to keep them oxygenated but is not a requirement for successful spawning in spring creeks when oxygen levels are high making the enhancement of spawning beds unproductive.

The thermal refuges created by cool tributaries are critical to the local trout population. Identifying spring creeks in the Arapuni reservoir and enhancing summer thermal refuges could benefit the trout population but will be difficult to achieved.

Reducing hatchery liberations would have a significant financial benefit for the Auckland/Waikato Fish & Game Council (A/W Council) and the New Zealand Fish & Game Council. Pausing the Lake Arapuni liberations for five years would save the A/W Council over $41,000.

Staff recommendations

1. There is an overwhelming body of evidence endorsed by Trout Unlimited that indicates hatchery releases should only be used to prevent extinction or where no natural recruitment exists. The following policies are recommended for Auckland/Waikato Fish & Game and should also be considered for the NZ Fish & Game Council:
    a. Hatchery releases should be considered detrimental to wild spawning fish and are only advantageous to fish populations that have no natural spawning.
    b. Prior to hatchery releases being funded there must be a documented recruitment failure of natural spawning or no natural spawning.
2. Many fisheries like Lake Arapuni have had significant drops in angler use with no review of the need for continued supplemental stocking. A request to NZ Council for an independent review of the funding for all New Zealand Fish & Game salmonid stocking programs would be a prudent step considering the high cost and dubious benefits to anglers.
3. Although Lake Arapuni has limited spawning habitat it is recommended that stocking is paused for a period of five years or until there is evidence of recruitment failure. The impact of spawning fish may linger for multiple generations so it is likely that there will be reduced catch rates for up to four years.
4. Temperature monitoring should be expanded to identify other spring fed tributaries to Lake Arapuni for potential thermal refuges and spawning enhancement.

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