Tasman District Council's Jobs for Nature Fish Passage Evaluation Report
- 2024/25 season -

Prepared for:

Tasman District Council

Prepared by:

Tim Olley[1], Ricky Olley[1] and Robin Holmes[2]

[1]Olleycology Limited

[2]Cawthron Institute

Reviewed by: Trevor James
Senior Resource Scientist Freshwater & Estuarine Ecology,
Tasman District Council

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Introduction

Evaluation of the success of fish migration past in-stream structures was carried out as part of a Fish Passage Restoration Project managed by Tasman District Council. This five-year project began in July 2021 and was funded by Ministry for the Environment under the Jobs for Nature (J4N) initiative. The aim of the project is to assess the characteristics of at least 4300 in-stream structures in the Nelson / Tasman region and restore fish passage at one third of these.

There are two main objectives for the J4N fish passage evaluation studies:

1. Evaluate the efficacy of the typical package of cost-effective fish passage remediation methods applied to culverts as part of the J4N Fish Passage project. These methods include flexible baffles, flexible rubber ramps with mussel-rope, and floating ramps.
2. Determine the range of fish passage barriers (e.g., as determined by culvert slope and degree of perching) where flexible baffles and fish ramps are appropriate fish passage

This report documents three studies, undertaken during the spring whitebait run in 2024. The focus of these studies was to evaluate the performance of two different ramp types most commonly used in the J4N project to date.

The field evaluation studies in the 2024/25 season described in this report compare fish capture rates (past fish ramps) and passage efficacy (% of fish passing) after remediation in two small coastal streams:

- Dominion Stream, near Mapua, Tasman
- Williams Creek, near Tasman Village, Tasman

At the Dominion Stream site, this was achieved by comparing the number of fish making it passed a perched culvert for three different remediation treatments (flexible rubber ramp, single floating ramp and double floating ramps) and a control (no remediation) over a 40 day period. In addition, passage efficacy of a single floating ramp treatment was assessed using the release and recapture method and involved releasing a known number of fish downstream and evaluating the percent that successfully passed the over ramp.

At the Williams Creek site, passage efficacy rates were assessed using the release and recapture method and applied to a flexible rubber ramp and a floating ramp. This helped to determine the effectiveness of these ramps for a range of perch heights.

Dominion Stream trials

Site description

Dominion Stream is a third order stream which flows into the Waimea Inlet in Tasman Bay. Approximately 70m upstream of its confluence with the Waimea Inlet, Dominion Stream flows through a concrete box culvert under Mapua Drive (Figure 1). This structure is the first barrier fish would encounter while moving up from the coast. The culvert is 3.0 m wide by 1.5 m high and 18 m long. At the commencement of the evaluations at Dominion Stream on the 18th of October 2024, the culvert was undercut 320 mm, had a perch height of 550 mm, and a gradient of 0.5%. The maximum water velocity through the culvert was recorded at 0.3 m/s.

Figure 1. Perched box culvert at Dominion Stream prior to the beginning of the fish passage evaluations, October 2024

Trial 1 – In-situ monitoring

Objective

To determine the effectiveness of three different in-situ ramp remediation treatments for providing fish passage (flexible rubber ramp, single floating ramp and a double floating ramp) compared to no treatment.

Remediation Treatments

Three fish ramp treatments were used at the Dominion Stream site, a flexible rubber ramp, a single floating ramp and a double floating ramp. Both rubber and floating ramp types consist of separate components that are combined to form each ramp. Flexible rubber ramps consist of a piece of smooth rubber belting with mussel rope bundles attached to their surface. Floating ramps consist of a smooth, v-shaped plastic mould with four plastic Miradrain® sheets welded to their surface, and a piece of smooth rubber belting that creates a hinge to connect the ramp to the culvert invert.

Water flowing through box culverts is more spread out than in round culverts and this means some manipulation of the flow is often required. Fish baffles (Flexi-baffles) were used in conjunction with all remediation treatments. This involved fixing baffles onto the culvert apron to either steer water towards or away from the ramps. This allowed the ramps to function as per their design. Water was steered towards the single and double floating ramps with a baffle on each outside edge of the hinge, while water was steered away from the flexible rubber ramp using a single baffle. The latter was done to ensure a low-velocity wetted margin (film of water) on the true right hand side of the flexible rubber ramp. A wetted margin did not need to be created when using the floating ramps as the cross-section is v-shaped which provides a continuous wetted margin at a range of flow rates. The baffle configuration associated with each of the three remediation treatments did not change throughout the trial period.

Treatment 1 – Flexible rubber ramp

With reference to the Fish Passage Remediation Training Aid (Olley et al 2022), a flexible rubber fish ramp was installed on the true right hand side of the outlet of the culvert (Figure 2). The ramp was 900 mm wide by 1300 mm long and lay near vertical. The distance down the ramp between the culvert invert and the water level was 600 mm.

One Flexi-baffle was secured onto the culvert apron to steer water away from the ramp. The baffle was 900 mm wide and 150 mm high.

Figure 2. Dominion Stream culvert remediated with a flexible rubber ramp.

Treatment 2 – Single floating ramp

With reference to the Fish Passage Remediation Training Aid (Olley et al 2022) and NZ Fish Passage Guidelines (Franklin et al 2024), a plastic floating fish ramp was installed at the centre of the culvert outlet (Figure 3). The ramp was 540 mm wide and 2400 mm long and lay at a gradient of 15.5 degrees. The distance down the ramp between the culvert invert and the plunge pool was 2100 mm.

Two Flexi-baffles were secured onto the culvert apron to steer water towards the ramp. The baffles were 900 mm wide and 150 mm high.

Figure 3. Dominion Stream culvert remediated with a single floating fish ramp.

Treatment 3 – Double floating ramp

With reference to the Fish Passage Remediation Training Aid (Olley et al 2022) and NZ Fish Passage Guidelines (Franklin et al 2024), two plastic floating fish ramps were installed at the centre of the culvert outlet (Figure 4). The ramps were 540mm wide and 2400mm long and lay at a gradient of 15.5 degrees. The distance down both ramps between the culvert invert and the plunge pool was 2100 mm.

Two Flexi-baffles were secured onto the culvert apron to steer water towards the ramp. The baffles were 900 mm wide and 150 mm high.

Figure 4. Dominion Stream culvert remediated with a double floating fish ramp.

Method

An A-frame fish trap was installed at the culvert inlet to capture fish that successfully entered and negotiated the culvert during the trial period. Because the culvert width was wider than the inlet trap entrance, mesh screens were used to block upstream movement out of the culvert. The inlet trap entrance and base of the screens were secured firmly to the base and side walls of the culvert so that the only upstream pathway for fish was into the trap, and so that passage into the inlet trap was not compromised. The inlet trap was designed with "non-return" zones to prevent fish from escaping (Figure 5).

Placement of the A-frame trap was limited to the culvert inlet because the net required a depth of water to comfortably hold fish for up to 24 hours, and placement at the top of the ramp, at the culvert outlet, would have influenced flow over the ramps. This meant the experiment tested the ability of fish to ascend the ramps and move through the untreated culvert. Due to its wide width, and roughened concrete invert, there were small areas for fish to rest and water velocities were low within the culvert (<0.3 m/s). An assumption was made that the culvert was unlikely a velocity barrier to fish. Apart from the baffles placed on the culvert apron to direct flow over the ramps, there was no treatment inside the culvert i.e. it was left bare, allowing the ramps to be evaluated without the confounding influence of other treatments within the culvert.

Preliminary trapping suggested that the culvert was not a complete barrier to banded kōkopu and elvers. Therefore, fish exclusion modifications were made to the outlet of the culvert to, as far as practical, limit the upstream movement of all species of fish and as a result create a complete barrier. These modifications involved the addition of thin sheets of steel securely fastened and sealed to the lower lip of the culvert undercut. Subsequent trapping suggested these modifications were successful at blocking upstream fish movement.

Figure 5. Inlet A-frame trap and screening wings at the Dominion Stream box culvert.

The three remediation treatments trialled; flexible rubber ramp, single floating ramp, and double floating ramp were installed and removed sequentially in a rotating order with a control (no ramp) period in between each block of methods, see: Figure 6.

Replicate	1	2	3	4	5	6	7	8	9	10
Sequence	ABCD	ACDB	ADBC	ABCD	ACDB	ADBC	ABCD	ACDB	ADBC	ABCD

Letter	Treatment
A	Control
B	Flexible rubber ramp
C	Single floating ramp
D	Double floating ramp

Figure 6. Order of the remediation treatments tested at Dominion Stream.

Each treatment period ran for 24hrs, with the trap checked once daily at the same time each morning. In doing this the total trial period ran for 40 days, with each ramp type and the control repeating 10 times throughout that period. The reason for this daily rotation was to control for environmental variation throughout the period of the study e.g. flow, tide cycle etc.

Prior to the commencement of the trial, and following each trap check in between each treatment period, the culvert was thoroughly searched with spotlights and hand nets to capture and remove all fish from within the structure. After this search the culvert was swept with wide brooms to wash out any fish that may have evaded capture.

The ramps were fixed to the culvert outlet with bolted wedge anchors in such a way so that they could be quickly removed and installed at the beginning of each treatment. The process of checking the trap, clearing the culvert and changing the ramp type took no longer than one hour.

The process of checking the inlet trap involved first blocking the trap opening so that no fish could either leave or enter. All fish were then removed into buckets. Each species of fish was identified and the first 15 of each species was measured, with a count made of the remaining individuals. All fish were then released upstream. The inlet trap prevented any movement back downstream. No mortality occurred throughout the trial period prior to fish release.

Because base flow declined over the course of the trial period, flow down both the single and double floating ramps that was recorded at the beginning and end of the experiment gave an indication of the maximum and minimum flow for these treatments. Only a thin film of water flowed over the flexible ramp at all times so flow was not recorded for this treatment.

Throughout the trial period a water level staff recorded fluctuations in water height in a stable pool immediately upstream of the culvert. During the trial period the trial was paused if flows increased as a result of rain, and then re-started once the water level had declined back down to a stable state.

Over the trial period the trial was paused for rain three times, for six, two and two days respectively, meaning that the trial commenced on the 18th of October and finished on the 6th of November during the spring whitebait migration of 2024.

The number of banded kōkopu and īnanga passing the culvert was modelled as a function of remediation treatment using a suite of count-response models and formal model comparison. First, a generalised linear model (GLM) was fitted with a Poisson error distribution and log link, with remediation treatment as the predictor of the number of fish that passed the culvert per day. Model dispersion was assessed via the ratio of residual deviance to residual degrees of freedom. A ratio notably greater than 1.0 indicates overdispersion relative to the Poisson assumption. To account for over dispersion a negative binomial (NB) model was fitted. To check for zero-inflation the number of observed and model predicted zeros was quantified. Zero-inflation was not supported and the NB model was retained as the preferred specification. The Poisson and NB models were compared using Akaike's Information Criterion (AIC), with the NB model having lower AIC scores indicating a better balance of fit and parsimony.

Using estimated marginal means (via the emmeans R package (Length and Piaskowski 2025), Tukey-adjusted pairwise contrasts were conducted among the remediation treatment levels to identify which treatments differed in expected counts of fish passes.

Overall, this workflow established an appropriate count model for fish passes based on different remediation treatments, verified distributional assumptions (dispersion and zero inflation), selected the most suitable model using AIC, and provided multiple-comparison-adjusted estimates fish pass numbers for each of the remediation treatment levels (Dobson and Barnett 2018).

Results

In total five species of fish were captured throughout the course of the trial period; banded kōkopu, īnanga, redfin bully and both long and short fin eel elvers (recorded collectively). Banded kōkopu and īnanga were the most common species making up 61% and 37% of the catch, respectively.

Banded kōkopu (n=6) and īnanga (n=1) were captured during the control treatment (Table 1).

Banded kōkopu (n=741) and eel elvers (n=14), were captured during the flexible ramp treatment, while, banded kōkopu (n=152 and n=269), īnanga (n=240 and n=466), and redfin bully (n=3 and n=3) were captured during the single and double floating ramp treaments (Table 1).

Table 1. Total numbers of fish caught upstream of the culvert for all treatments over all ten replicates, including the size range of all fish in millimetres.

	Remediation treatments			
Species	**Control**	**Flexible rubber ramp**	**Single floating ramp**	**Double floating ramp**
Banded kōkopu	6 (37-45mm)	741 (36-43mm)	152 (36-43mm)	269 (37-43mm)
Īnanga	1 (52mm)	0	240 (48-57mm)	466 (47-80mm)
Redfin Bully	0	0	3 (42-56mm)	7 (38-74mm)
Elver	0	14 (60-107mm)	0	1 (115mm)
Total	7	755	395	743

The average daily pass rate for banded kōkopu was 0.6 fish per day during the control treatment, 74.1 fish per day over the flexible rubber ramp, 15.2 fish per day over the single floating ramp and 26.9 fish per day over the double floating ramp (Figure 7).

The average daily pass rate for īnanga was 0.1 fish per day during the control treatment, 0 fish per day over the flexible rubber ramp, 24 fish per day over the single floating ramp and 46.6 fish per day over the double floating ramp (Figure 7).

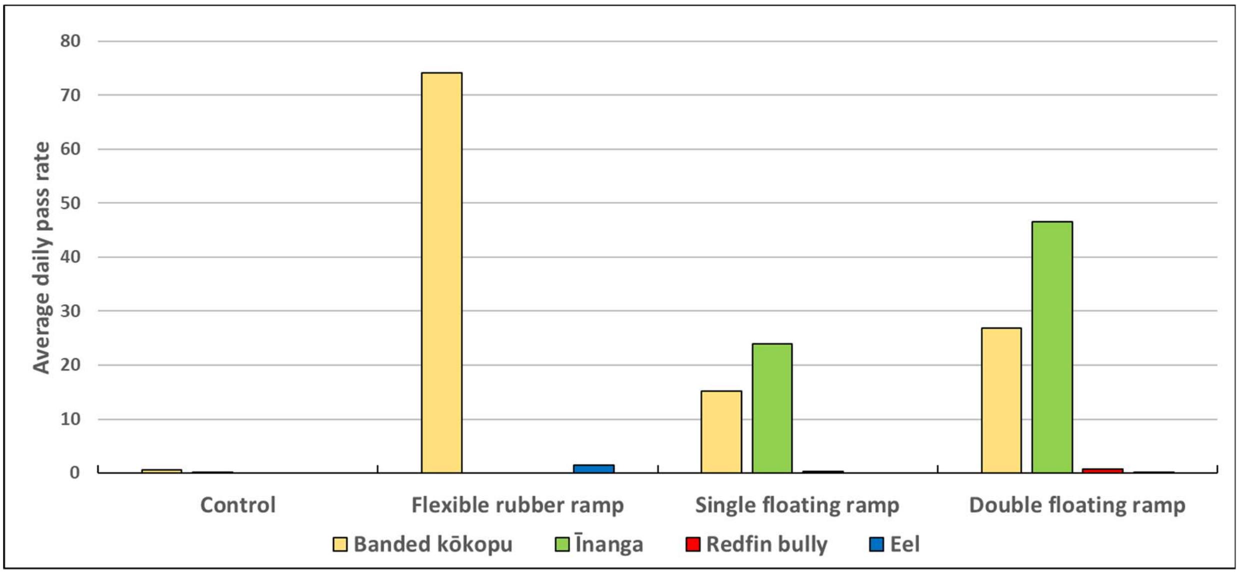

Figure 7. Average daily pass rates of all species for each remediation treatment over the trial period.

All treatments significantly improved passage for banded kōkopu relative to the control treatment. The flexible rubber ramp was significantly better for banded kōkopu passage than the single floating ramp but not the double floating ramps. The double floating ramp was not significantly better than the single floating ramp (Figure 8).

For īnanga the flexible rubber ramp did not differ significantly from the control treatment, indeed, no īnanga used the flexible rubber ramp over the trial period. The single floating ramp significantly improved īnanga passage relative to the control treatment, but the double floating ramp was not significantly better than the single floating ramp (Figure 8).

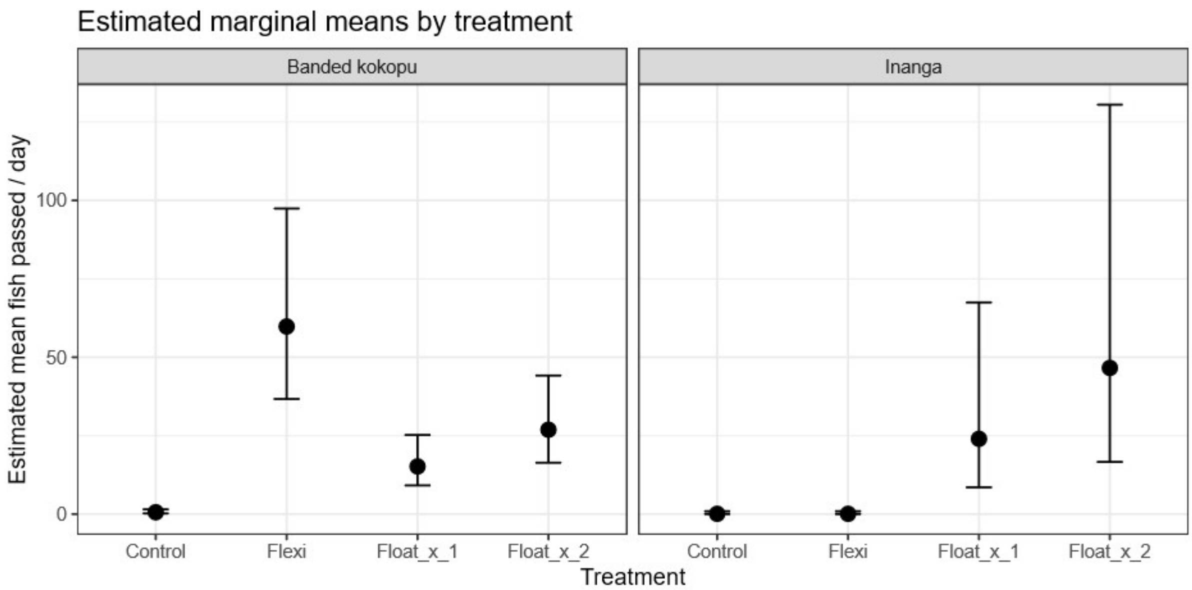

Figure 8. Estimated marginal means and 95% confidence intervals for fish passed by structure per day by treatment for banded kōkopu (left) and īnanga (right)

Table 2. Tukey-adjusted pairwise comparison among control and barrier remediation treatments for banded kōkopu. Note estimates are given on the log scale.

Contrast	Estimate	SE	DF	Z ratio	P value
Control – Flexible rubber ramp	-4.60	0.53	Inf	-8.56	<0.001
Control – Single floating ramp	-3.23	0.54	Inf	-5.96	<0.001
Control – Double floating ramp	-3.80	0.53	Inf	-7.04	<0.001
Flexible rubber ramp - Single floating ramp	1.36	0.35	Inf	3.81	<0.001
Flexible rubber ramp - Double floating ramp	0.798	0.35	Inf	2.25	0.109
Single floating ramp - Double floating ramp	-0.57	0.36	Inf	-1.57	0.391

Table 3. Tukey-adjusted pairwise comparison among control and barrier remediation treatments for īnanga. Note estimates are given on the log scale.

Contrast	Estimate	SE	DF	Z ratio	P value
Control – Flexible rubber ramp	<0.01	1.59	Inf	<0.01	1.000
Control – Single floating ramp	-5.48	1.24	Inf	-4.39	<0.001
Control – Double floating ramp	-6.14	1.24	Inf	-4.93	<0.001
Flexible rubber ramp - Single floating ramp	-5.48	1.24	Inf	-4.39	<0.001
Flexible rubber ramp - Double floating ramp	-6.14	1.24	Inf	-4.93	<0.001
Single floating ramp - Double floating ramp	-0.66	0.74	Inf	-0.89	0.809

The flow rate over the single floating ramp at the beginning and end of the trial period was 0.91 L/s and 0.14 L/s, respectively. The flow rate over the double floating ramps at the beginning and end of the trial period was 1.67 L/s and 0.13 L/s (true right ramp), and 1.82 L/s and 0.26 L/s (true left ramp), respectively (Figure 9).

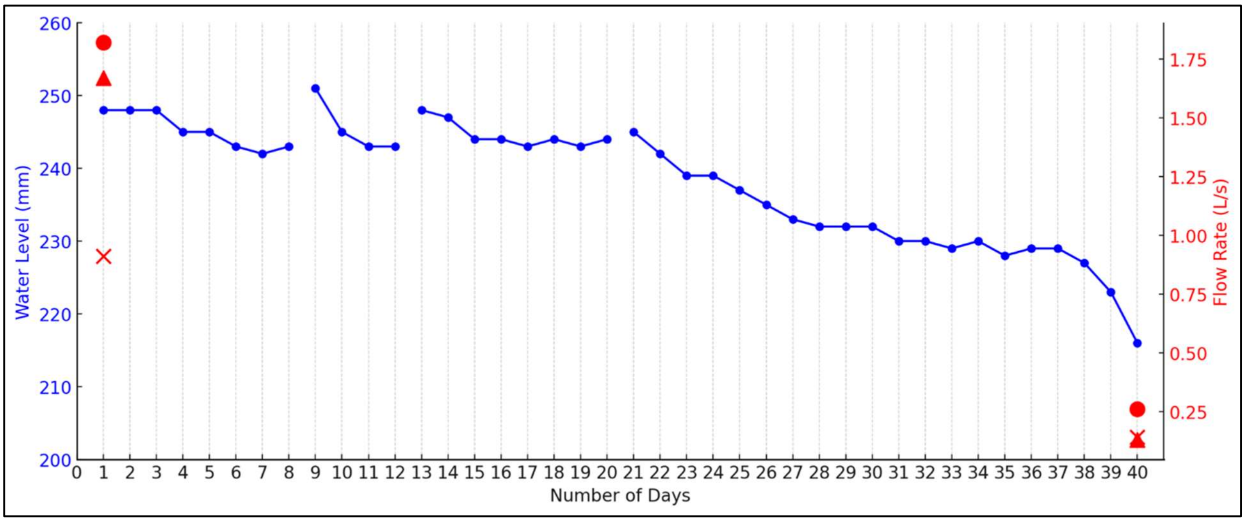

Figure 9. Water level and flow rate throughout the trial period. Water level is shown as a blue plotted line and measured in mm on the left hand axis. Flow over the floating ramps was taken at the beginning and end of the trial period and is shown as X = single floating ramp, ▲ = true right floating ramp, and ● = true left floating ramp, measured in L/s on the right hand axis.

Trial 2 – Release and Recapture

Objective

Undertake a release and recapture trial to assess effectiveness (% passage success) of a single floating ramp for juvenile īnanga at a perched box culvert.

Remediation Treatment

– Single floating ramp

The installation of the single floating ramp examined in the release and recapture trial was the same as in the in situ trial, however, because of the low stream flows at the time of the trial, additional Flexi-baffles were used on the culvert apron to match the flow down the ramp with the flow where high numbers of īnanga were found to use the single ramp in the in situ trial. For a description of this remediation treatment see page 5: Treatment 2.

Method

Prior to the commencement of the trial, the culvert was thoroughly searched with spotlights and hand nets to capture and remove all fish from within the structure.

An A-frame fish trap was installed at the culvert inlet to capture fish that successfully negotiated the culvert during the trial period. Because the culvert width was wider than the inlet trap entrance, mesh screens were used to block upstream movement out of the culvert. The inlet trap entrance and base of the screens were secured firmly to the base and side walls of the culvert so that the only upstream pathway for fish was into the trap, and so that passage into the inlet trap was not compromised. The inlet trap was designed with "non-return" zones to prevent fish from escaping (Figure 5).

Placement of the A-frame trap was limited to the culvert inlet because the net required a depth of water to comfortably hold fish for up to 24 hours, and placement at the top of the ramp, at the culvert outlet, would have influenced flow over the ramps. This meant the experiment tested the ability of fish to ascend the ramps and move through the untreated culvert. Due to its wide width, and roughened concrete invert, there were small areas for fish to rest and water velocities were very low within the culvert (<0.3 m/s). An assumption was made that the culvert was unlikely a velocity barrier to fish. Apart from the baffles placed on the culvert apron to direct flow over the ramps, there was no treatment inside the culvert i.e. it was left bare, allowing the ramps to be evaluated without the confounding influence of other treatments within the culvert.

A single floating ramp was installed at the outlet of the culvert, and an outlet net was created around the base of it within the culvert plunge pool (Figure 10). The outlet net was constructed of fine mesh (0.5mm) material and had within it areas of low velocity where fish could rest.

Figure 10. Single floating ramp and outlet net at the Dominion Stream box culvert.

100 īnanga were captured from the 50m reach immediately downstream of the culvert. Fish were captured using scoop nets and then counted and transferred into a live capture bin situated within the culvert plunge pool where they were acclimatised overnight for 12hrs prior to the start of the trial.

The trial began at 7am (17th December) when all fish were gently transferred from the live capture bin into the outlet net. The outlet net was then left undisturbed for the duration of the trial.

The culvert inlet trap however was checked after 12, 36 and 48hrs.

The process of checking the inlet trap involved first blocking the trap opening so that no fish could either leave or enter and all fish were then removed.

Immediately following the 48hr check, the outlet of the culvert was blocked off and all fish from within the culvert were captured with hand nets. Once this process was complete fish from within the outlet net were removed.

Following re-capture all trial fish were measured and then released upstream. No mortality occurred throughout the trial period.

Flow over the ramp was taken at the beginning and end of the trial period.

This method was generally consistent with Baker et al.'s (2024) recommendations for monitoring fish passage success.

Results

A total of four fish (4%) successfully swam up the single floating fish ramp and through the culvert (Figure 11). No fish were recovered from within the culvert after the 48hr trial period and 96 fish were captured from the outlet net having failed to negotiate the ramp.

Those four successful fish measured 55, 57, 63 and 73 mm; all of these fish were in the longest 10% of fish lengths for the trial (Figure 12).

The flow rate over the ramp at the beginning and end of the trial period was 0.8 L/s.

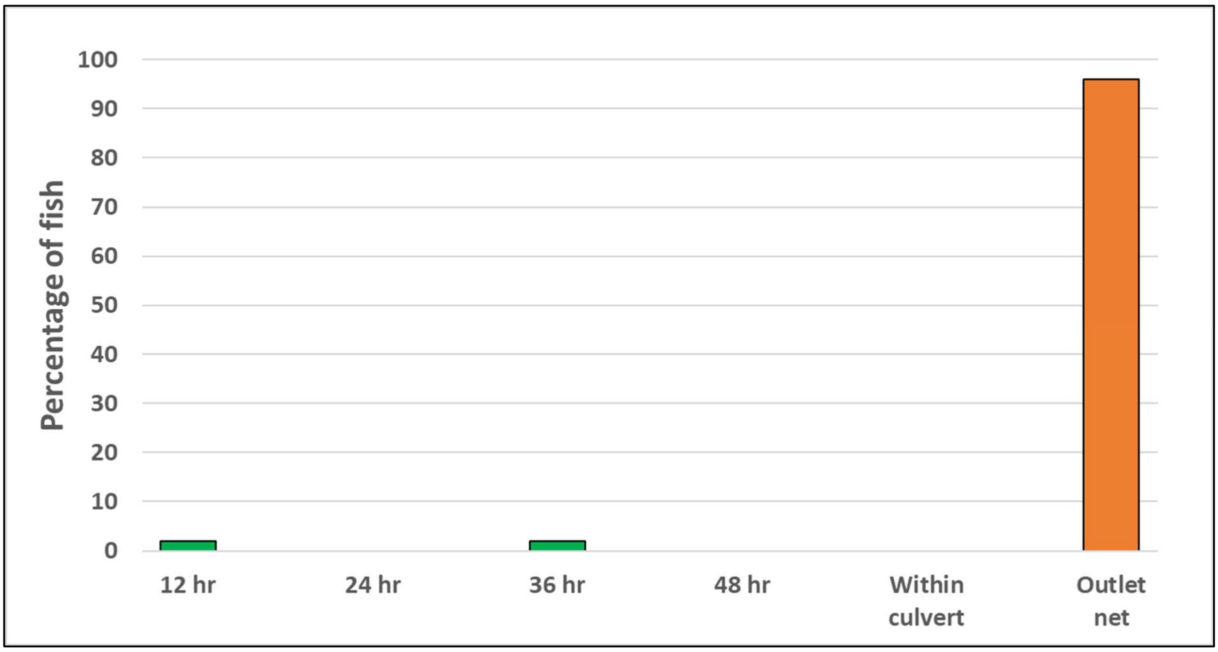

Figure 11. The percent of successful fish recovered from the culvert inlet trap after each twelve hour time period is shown as green bars. Also shown is the percent of successful fish recovered from within the culvert (blue bar), and the unsuccessful fish recovered from the outlet net (orange bar) after the full 48 hour time period.

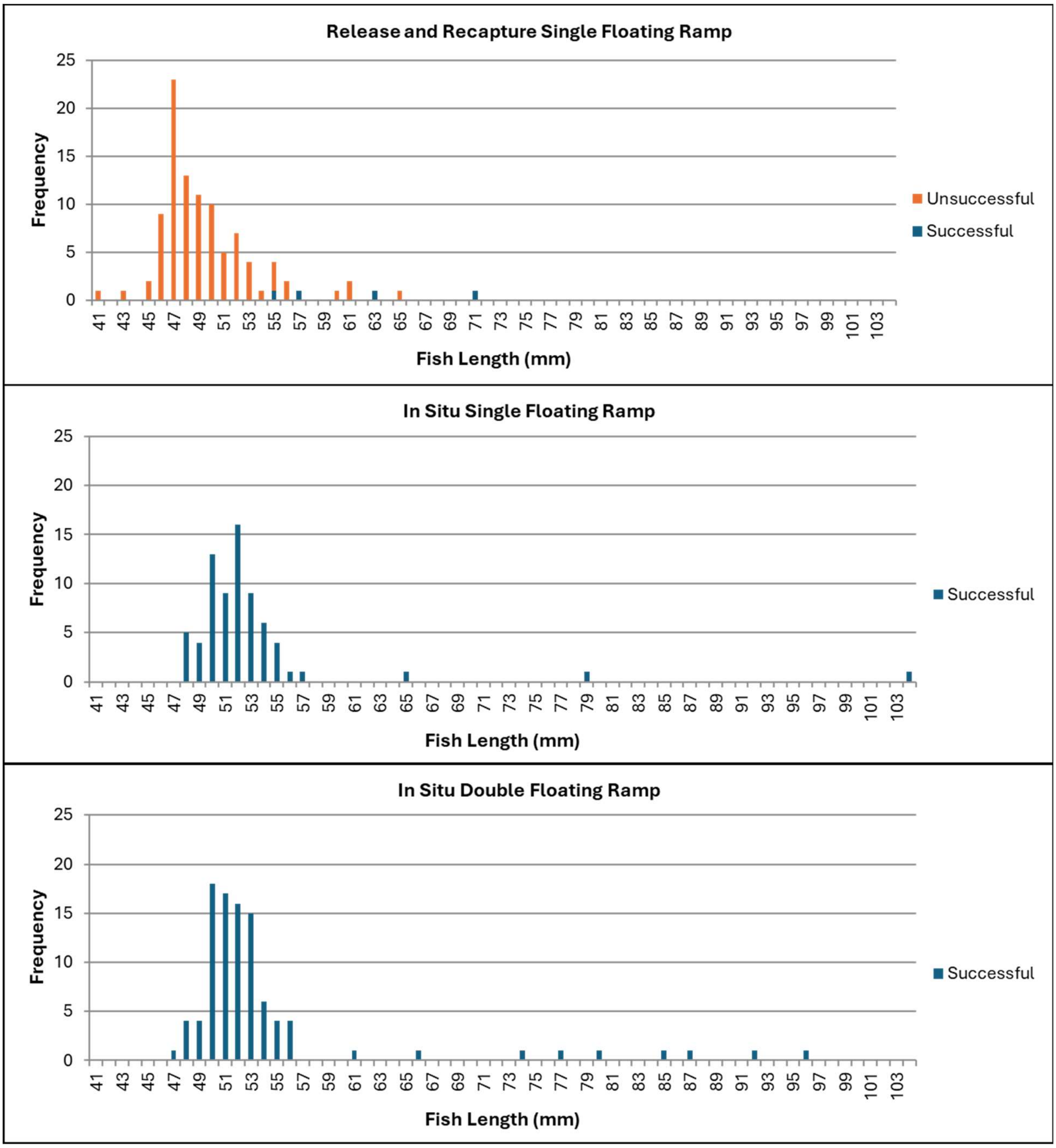

Figure 12. Length data for unsuccessful (orange bars) and successful (blue bars) īnanga over the single floating ramp during the release and recapture trial and successful īnanga (blue bars) over both the single and double floating ramps during the in situ trial.

Williams Creek trial

Site description

Williams Creek is a small tributary of Tasman Valley Stream which flows into the Moutere Inlet in Tasman Bay. Diadromous fish species with a predicted presence greater than 10% include īnanga, banded kōkopu, giant kōkopu, long and shortfin eels, and common bully (Leathwick 2008). Approximately 500 m upstream of its confluence with Tasman Valley Stream, Williams Creek is piped through two concrete culverts where it crosses Williams Road (Figure 13). This crossing is located about 1.5 kms inland from the Moutere Inlet and is the second barrier fish encounter when moving upstream from the coast. Both culverts are 1200 mm in diameter, 9.6 m long and have gradients less than 1%. Under base flow conditions, the entire stream flows through the true left hand culvert, and therefore this was the culvert chosen to complete the trial. At the commencement of the evaluations at Williams Creek on the 18th of November 2024, the flow rate through the true left culvert was 2.1 L/s. The maximum water velocity through the culvert was recorded at 0.3 m/s.

Figure 13. Perched round culverts at Williams Creek prior to the beginning of the fish passage evaluations, November 2024

Objective

Undertake a release and recapture trial to assess effectiveness (% passage success) of a flexible rubber ramp at three different perch heights, and a single floating ramp at the highest perch height for juvenile īnanga at a perched round culvert.

Remediation treatments

Treatment 1 – Flexible rubber ramp

With reference to the Fish Passage Remediation Training Aid (Olley et al, 2022), a flexible rubber ramp was installed at the outlet of the culvert (Figure 14). The ramp was 750 mm wide by 1200 mm long and the gradient was approximately 37 degrees for each of the three perch heights. For each of the three perch heights the distance between the culvert invert and the plunge pool was 370 mm at a 150 mm perch, 470 mm at a 200 mm perch and 570 mm at a 250 mm perch.

Figure 14. Remediation at Williams Creek showing a flexible rubber ramp.

Treatment 2 – Floating ramp

With reference to the Fish Passage Remediation Training Aid (Olley et al 2022) and NZ Fish Passage Guidelines (Franklin et al 2024), a plastic floating fish ramp was installed at the culvert outlet (Figure 15). The ramp was 540mm wide and 1500mm long and lay at a gradient of approximately 12.5 degrees. The distance down the ramp between the culvert invert and the plunge pool was 1150 mm at a 250 mm perch.

Figure 15. Remediation at Williams Creek showing a floating ramp.

Method

Prior to the commencement of the trial, the culvert was thoroughly searched with spotlights and hand nets to capture and remove all fish from within the structure.

An A-frame fish trap was installed at the culvert inlet to capture fish that successfully negotiated the ramp and culvert during the trial period. The inlet trap entrance was secured firmly to the base and side walls of the culvert so that the only upstream pathway for fish was into the inlet trap, and so that passage into the inlet trap was not compromised. The inlet trap was designed with “non-return” zones to prevent fish from escaping (Figure 16).

Figure 16. Inlet A-frame trap at the Williams Creek culvert.

The trial was then run in three sub trials. A flexible ramp was installed at the outlet of the culvert. The height of the culvert perch was then dictated by adjusting sandbags downstream of the culvert to manipulate the depth of the plunge pool. The performance of the flexible ramp was then examined over a 150, 200 and 250 mm perch height. A floating ramp was then installed at the outlet of the culvert and examined over a perch height of 250 mm.

The first sub trial examining the flexible ramp over a 150 mm perch height began on the 18th of November. The further three sub trials were run over successive days with the trial ending on the 28th of November.

An outlet net was created around the base of both the flexible and floating ramps within the culvert plunge pool (Figures 17 & 18). The outlet net was constructed of fine mesh (0.5mm) material and had within it areas of low velocity where fish could rest.

Figure 17. Single floating ramp and outlet net at the Williams Creek round culverts.

Figure 18. Flexible rubber ramp and outlet net at the Williams Creek round culverts.

For each sub trial 100 īnanga were captured from lower in the catchment as barriers downstream of the culvert prevented them from reaching the study culvert in sufficient numbers. Fish were captured using scoop nets and then counted and transferred into a live capture bin situated within the culvert plunge pool where they were acclimatised over night for 12hrs prior to the start of each sub trial.

Each sub trial began at 7am, upon which fish were gently transferred from the live capture bin into the outlet net. The outlet net was then left undisturbed for the duration of the trial; however, the inlet trap was checked after 12, 36 and 48hrs.

The process of checking the inlet trap involved first blocking the trap opening so that no fish could either leave or enter and all fish were then removed.

Immediately following the 48hr check the outlet of the culvert was blocked off and all fish from within the culvert were captured with hand nets. Once this process was complete fish from within the outlet net were removed.

Following re capture all trial fish were measured and then released upstream. No mortality occurred throughout the trial period.

Flow over each ramp was taken for each sub trial.

This method was generally consistent with Baker et al.'s (2024) recommendations for monitoring fish passage success.

Results

Including those fish captured from within the culvert after the 48hr trial period, the number of successful fish negotiating the flexible ramp at a 150mm and 200mm perch height was similar at 54% and 44% respectively. At a 250 mm perch height however numbers declined substantially to 20%. The floating ramp had the highest success rate at 86% at a 250 mm perch height (Table 4).

Table 4: The proportion of fish that either, moved up the ramp and through the culvert (top net), moved up the ramp but were recovered from the culvert barrel (within culvert), or failed to leave the outlet net (outlet net) after the full 48 hour time period for the three different perch heights.

Trials		Portion of fish (%)		
Perch height (mm)	Remediation	Top Net	Within culvert	Outlet net
150	Flexible ramp (Figure 19)	48	6	46
200	Flexible ramp (Figure 20)	43	1	56
250	Flexible ramp (Figure 21)	19	1	80
250	Floating ramp (Figure 22)	68	18	14

Generally, the number of fish passing successfully for all treatments was spread fairly evenly over the 48hr trial period (Figures 18, 19, 20 and 21).

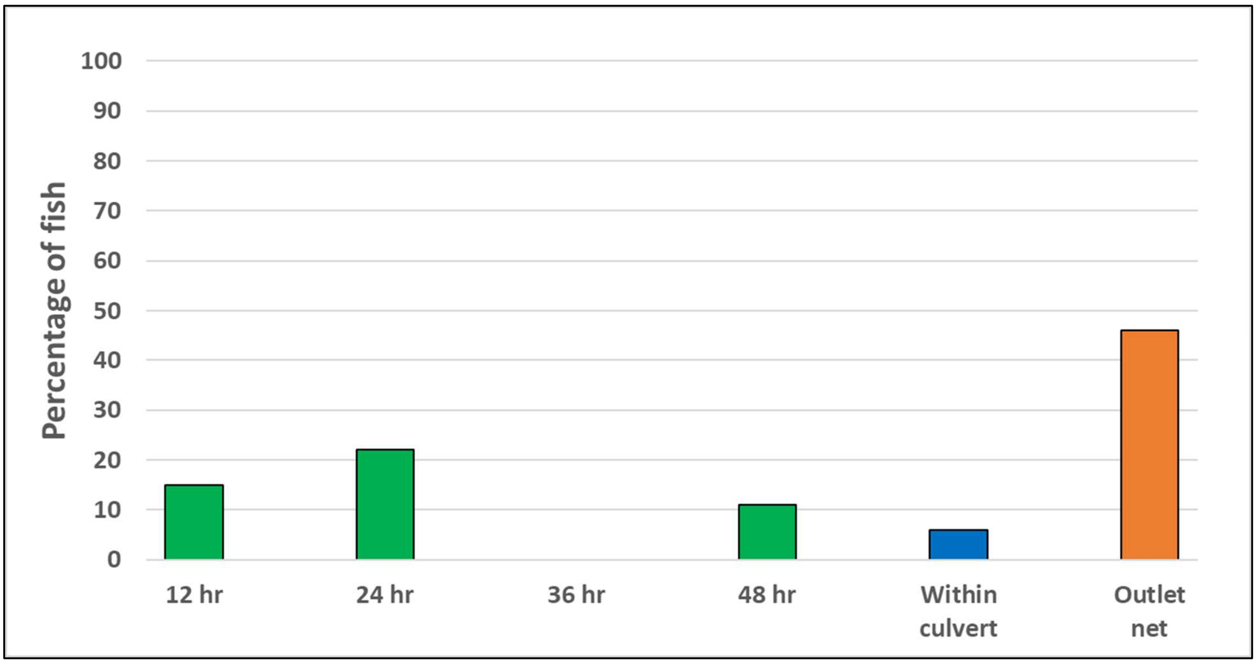

Figure 19. For the flexible rubber ramp trial over a 150mm perch the successful fish recovered from the culvert inlet trap after each twelve hour time period is shown as green bars. Also shown is the percent of successful fish recovered from within the culvert (blue bar), and the unsuccessful fish recovered from the outlet net (orange bar) after the full 48 hour time period.

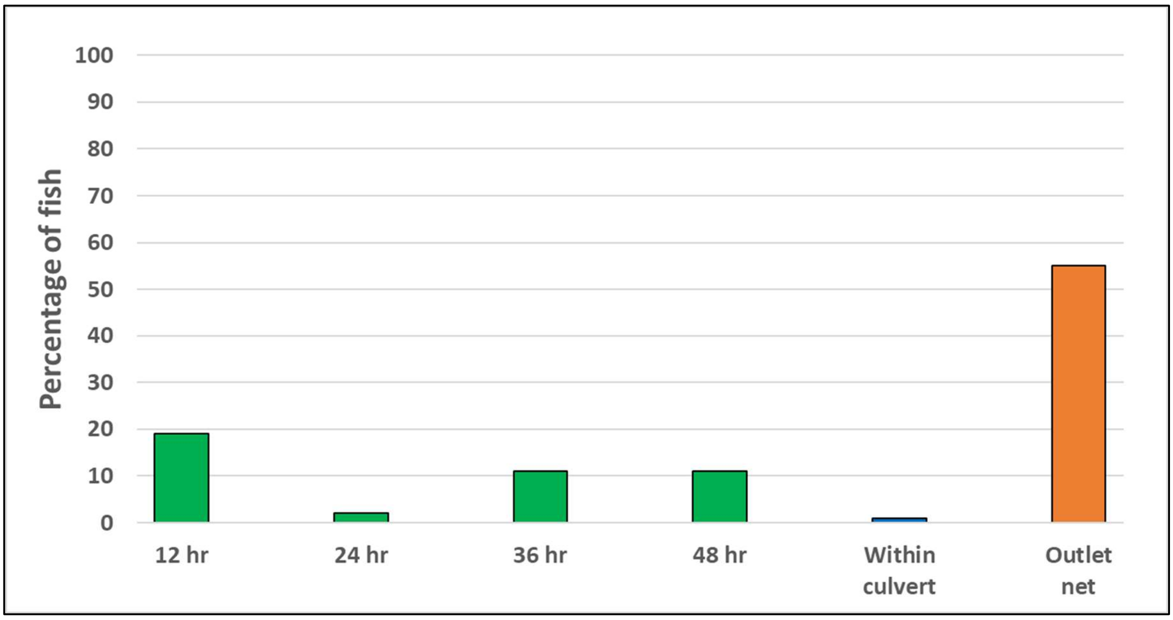

Figure 20. For the flexible rubber ramp trial over a 200mm perch the percent of successful fish recovered from the culvert inlet trap after each twelve hour time period is shown as green bars. Also shown is the percent of successful fish recovered from within the culvert (blue bar), and the unsuccessful fish recovered from the outlet net (orange bar) after the full 48 hour time period.

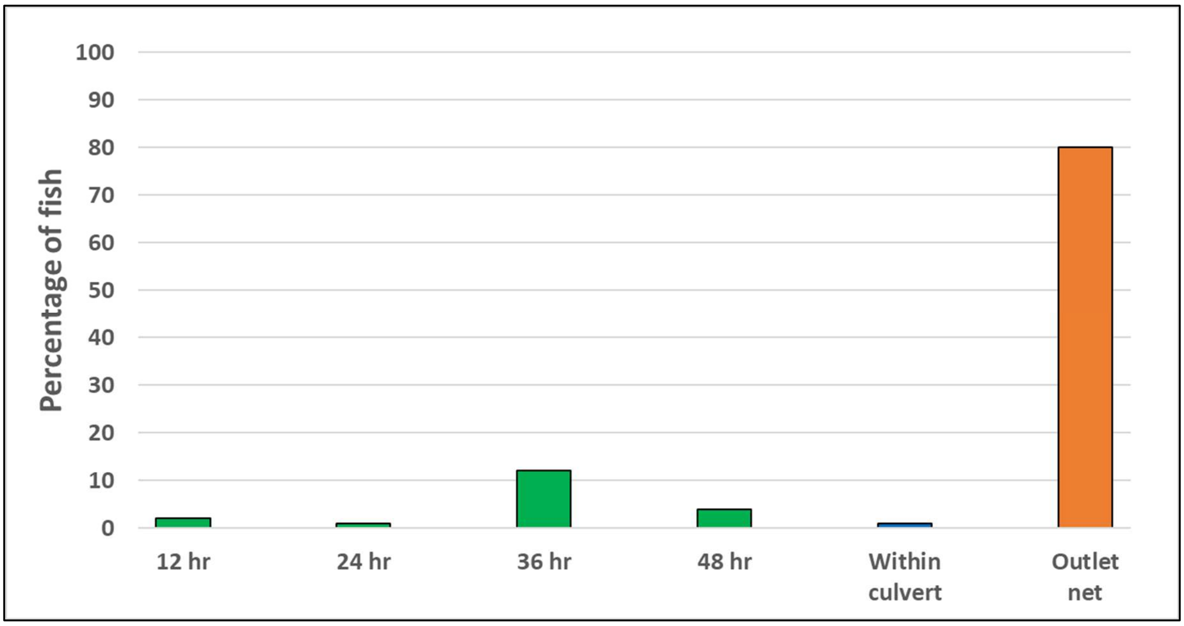

Figure 21. For the flexible rubber ramp trial over a 250mm perch the percent of successful fish recovered from the culvert inlet trap after each twelve hour time period is shown as green bars. Also shown is the percent of successful fish recovered from within the culvert (blue bar), and the unsuccessful fish recovered from the outlet net (orange bar) after the full 48 hour time period.

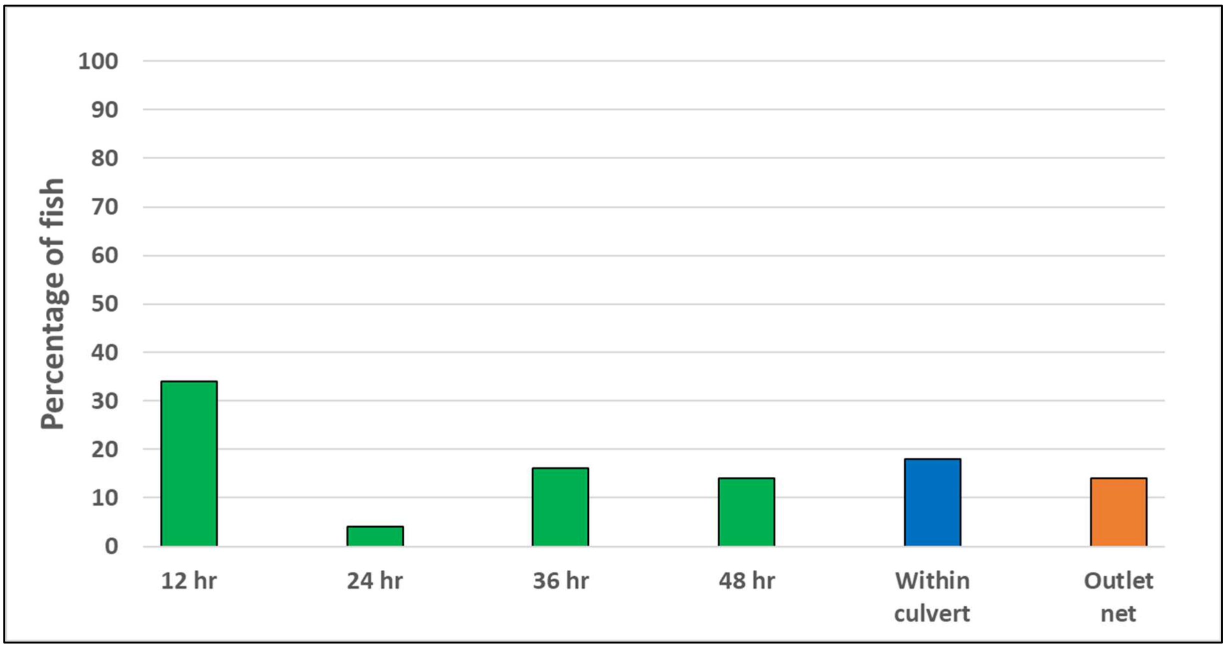

Figure 22. For the floating ramp trial over a 250mm perch the percent of successful fish recovered from the culvert inlet trap after each twelve hour time period is shown as green bars. Also shown is the percent of successful fish recovered from within the culvert (blue bar), and the unsuccessful fish recovered from the outlet net (orange bar) after the full 48 hour time period.

Successful fish were on average longer than unsuccessful fish, and for the flexible ramp trials, the difference in mean size between successful fish and unsuccessful fish increased as the perch height increased (Table 5).

Table 5: Mean lengths of successful and unsuccessful fish, the difference between the means, p=value and statistical significance.

	Successful fish	Unsuccessful fish			
Trials	Mean length (mm)	Mean length (mm)	Mean difference (mm)	P-value	Statistical significance ($p < 0.05$)
Flexible 150mm	49.46	47.39	2.07	0.00000036	Yes
Flexible 200mm	50.64	47.81	2.82	0.00000028	Yes
Flexible 250mm	51.25	47.93	3.32	0.00000145	Yes
Floating 250mm	48.94	45.79	3.16	0.0011	Yes

The flow rate through the true left culvert barrel at the beginning and end of the trial period was 2.1 L/s.

Discussion

The results from both the Dominion Stream and Williams Stream evaluations suggest that the cost-effective ramp additions used in the Tasman District Council J4N fish passage project can be effective solutions to the fish passage barriers created by perched box and round culverts. Flexible rubber ramps are a particularly useful design for providing passage for climbing species such as banded kōkopu, but can also restore at least partial passage for swimming species such as īnanga over small perch heights. Floating ramps can provide passage for both climbing species (including poor climbing species such redfin bullies) and non-climbing species such as īnanga.

In the Williams Creek release and recapture trials for round culverts with a perch height 200 mm or less, a flexible rubber ramp provided passage close to 50% for īnanga, and at a perch height of 250 mm a floating ramp provided passage close to 90% for īnanga.

In the Dominion Stream in situ trial for a box culvert with a perch height of 550mm only the floating ramps provided passage for īnanga and redfin bullies. However, the flexible rubber ramp was significantly better for banded kōkopu, suggesting they present a better option over floating ramps where only good climbing species are present, in particular juvenile galaxiids and eels.

The Dominion Stream in situ trial suggests that elvers struggle with floating ramps. Apart from one elver that used the double floating ramp on the final day of the experiment, all other elvers captured (n=14) used the flexible rubber ramp. Furthermore, the number of elvers recovered from the inlet trap likely only represents a portion of those individuals using the flexible rubber ramp. On several occasions during the culvert clear out following the flexible ramp treatment, elvers were found within the culvert or within the ropes on the flexible ramp, sometimes in their dozens. A possible explanation may be that 24 hours is not long enough for elvers to navigate the ramp and move through the culvert. No elvers were observed during the culvert clear outs following either the control or floating ramp treatments.

When remediating a perched box culvert, using both flexible rubber ramps and floating ramps in combination could be the best option to maximise passage for both climbing and swimming species of fish.

Generally the number of īnanga successfully passing the culvert for all Williams Creek ramp treatments was spread fairly evenly over the 48 hour trial period and īnanga were still successfully negotiating the ramps and culvert right up to the end of the trial periods. It seems reasonable to expect that higher success rates would have resulted from a longer trial period.

Both the gradient and length of a ramp are likely to be important factors influencing fish passage success. The floating ramp gradient in the Dominion Stream trial was slightly steeper to that in the Williams Creek trial at 15.5 degrees compared to 12.5 degrees respectively, and the Dominion Stream ramp was longer at 2400 mm compared with 1500 mm. The flexible rubber ramps at the Williams Creek trials were at a steeper gradient than all floating ramp trials, but over a much shorter distance.

The release and recapture trial at Dominion Stream may suggest that a 2400 mm long floating ramp installed at a perch height of 550 mm may be getting close to the upper limit for this type of remediation. Likewise, a 1200 mm long flexible rubber ramp installed at a perch height of 250 mm as seen in the Williams Creek was challenging for the majority of the trial īnanga.

Flow over ramps is also likely to be an important factor determining the efficacy of the ramps. These trials attempted to keep flow consistent and representative of base flow. How flexible rubber ramps and floating ramps perform during a range of flows requires further work.

The vast majority of the īnanga examined in all of the evaluations were young of year fish, having recently moved into the freshwater environment. For juvenile īnanga in particular, size is likely an important determining factor for passage success over both flexible rubber ramps and floating ramps.

Across all four Williams Creek release and recapture trials the mean size of successful īnanga passing the remediated culvert was greater than unsuccessful īnanga. For the flexible rubber ramp trials, the difference in mean size between successful īnanga and unsuccessful īnanga increased as the perch height increased. However, only in the 250 mm perch trial were none of the īnanga from the shortest 40% of length classes successful. For both the 200 mm and 150 mm trial at least some of the smallest īnanga were successful.

Although 86% of īnanga in the Williams Creek floating ramp trial were successful in passing the structure, all of the five īnanga in the trial under 45mm were unsuccessful at ascending the ramp.

During the Dominion Stream release and recapture trial only 4% of īnanga managed to negotiate the single floating ramp. This was a surprisingly low number when compared with the Dominion Stream in situ trial where 151 īnanga were observed passing over the single floating ramp and 211 īnanga over the double floating ramp during a 24hr period. The successful four īnanga in the Dominion Stream release and recapture trial were in the longest 10% of fish lengths for the trial.

However, size alone is unlikely to fully explain the poor passage success seen in the Dominion Stream release and recapture trial. Of those īnanga measured, the successful īnanga in the Dominion Stream in situ trial for both the single ramp and the double ramp were, bar one individual that measured 47 mm, 48 mm or longer. 64% of the īnanga used in the Dominion Stream release and recapture trial were 48 mm or greater, suggesting more should have been capable of ascending the ramp.

Fish passage success in short duration evaluations such as release and recapture trials may not always accurately reflect the ability fish have passing a structure. Other factors such as environmental conditions at the time of the trial (stream flow, temperature or moon phase for example) or fish motivation may be important in determining the level of success at any given time.

Equally, it is possible that an unknown number of fish were attempting and failing to ascend the floating ramps in the Dominion Stream in situ trial, and it is a weakness in the experimental design that passage effectiveness (% passage success) cannot be calculated.

It is the failings of any one method of fish passage evaluation that makes it important to consider the results of multiple evaluations collectively when generalising the merits of a given fish passage solution.

While the potential limitations of cost-effective ramp additions are acknowledged, the fish passage evaluations presented here would suggest that given a large enough source population, high numbers of fish could be expected to pass structures remediated with these additions throughout the course of a migration season.

In general terms, the degree to which this is considered a success is largely going to be driven by the environment in which the remediation is used. For a number of structures providing passage for only a proportion (e.g., 20 – 30%) of those migrating fish may be good enough to maintain a healthy upstream population, especially in small 1st and 2nd order catchments where density dependent constraints on native fish populations can be strong. This may not be the case in larger catchments with good low-gradient habitat close to the coast. Here, other more complex and expensive remediations (such as engineered rock ramps) or the complete removal of structures may be preferred options.

When taking a wider catchment view, a trade off should be considered between the number of remediation's that are possible, and the likely efficacy of each remediation.

These results suggest both flexible rubber ramps and floating ramps represent valuable remediation options when attempting catchment scale fish passage work programmes.

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