A dyed salmon study to test the effectiveness of the NOIC fish barrier

NIWA Client Report: CHC2009-187
April 2010

NIWA Project: NOI10501

A dyed salmon study to test the effectiveness of the NOIC fish barrier

Julian Sykes
Don Jellyman
Greg Kelly

NIWA contact/Corresponding author

Julian Sykes

Prepared for

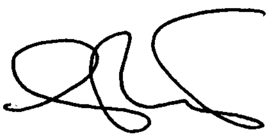
North Otago Irrigation Company

NIWA Client Report: CHC2009-187
April 2010
NIWA Project: NOI10501

National Institute of Water & Atmospheric Research Ltd
10 Kyle Street, Riccarton, Christchurch 8011
P O Box 8602, Christchurch 8440, New Zealand
Phone +64-3-348 8987, Fax +64-3-348 5548
www.niwa.co.nz

Contents

Reviewed by:



Marty Bonnett

Approved for release by:

Jeff Bluett

Executive Summary

1. This report describes an experiment that was conducted on the 27th of October 2009 that investigated the effectiveness of an artificial rock barrier designed to screen out juvenile quinnat salmon from entering an irrigation canal. The North Otago Irrigation company (NOIC) had the rock wall constructed (and later improved) at the entrance of the NOIC canal in Bortons pond, from here, water flows down the canal to a pumping station where it is pumped over into the headwaters of Waiareka Creek (a tributary of the Kakanui River).

2. The results from this study are only relevant for the period of October through to December which represents the main migration period of salmon moving downstream through the Waitaki catchment. It is also important to note that the study results are only relevant for one of the two irrigation pumps, as the second pump is not normally used until after December when the demand for irrigation is greater.

3. Although the smallest salmon fry were not tested during this study (<39mm) the smallest hatchery fish tested were 39 mm and larger fish ranged up to 59mm in length. This size range was representative for most of the wild out-migrant salmon fry in the Waitaki River.

4. The fish that were tested were placed into enclosures in front of the barrier and allowed to swim around the upstream side while the pump was operational. The pump was run for two 30 to 40 minute periods which represented a normal operating regime for this time of year. A batch of red dyed fish and then a batch of blue and yellow dyed fish were used to identify each of the two pump runs.

5. Only one red dyed fish of 55mm from the first pump run was recorded from behind the barrier in the downstream capture nets following the completion of the experiment. This result shows that the barrier is >95% effective in screening out juvenile hatchery salmon of 39-60mm. These results are only relevant for the hours of daylight as it was not possible at the time to test fish during the hours of darkness.

6. The approach velocities in front of the barrier were estimated to be 0.10 m/s this velocity is within the acceptable range of velocities (<0.15 m\s) documented by Clay 1995 for the smallest (<35mm) quinnat salmon fry.

1. Introduction

The North Otago Irrigation Company (N.O.I.C) has consent to abstract up to 8 cumecs of water (consented 2003) from Bortons pond on the South bank of the Waitaki River. From Bortons pond ,the water flows along a canal to a pumping station beside the main road (SH2) at Georgetown; the water is then pumped over the hill to the upper reaches of the Waiareka River (Kakanui River catchment). The water is supplied to over 80 farms and used predominately for dairying (Figure 1)

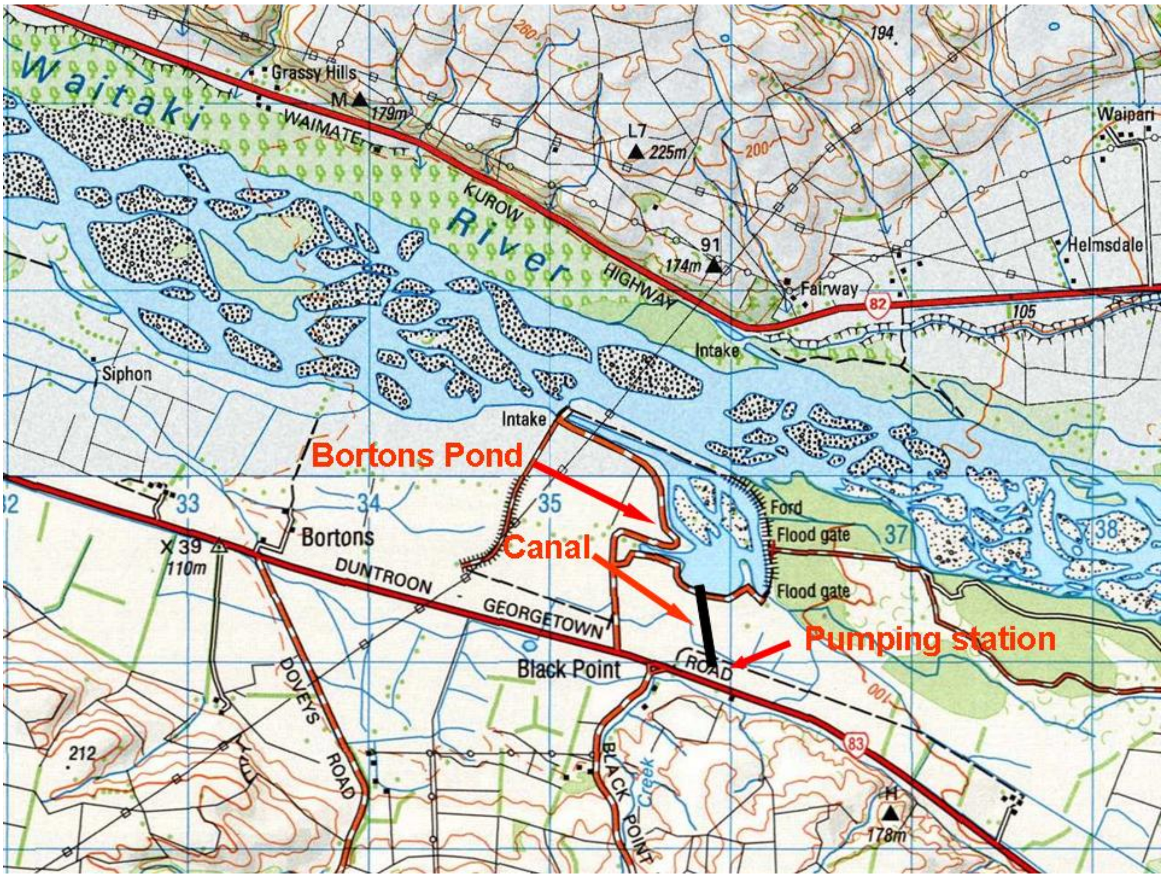


Figure 1: Site map

To prevent the entrainment of juvenile Chinook salmon, an 80m rock wall was built across the entrance of the canal at Bortons Pond (Figure 1). This original rock wall was constructed in 2005, and following inspection by Central South Island Fish and Game and Environment Canterbury, it was decided that it would not be effective enough to screen out downstream migrating salmon fry. Accordingly in August 2008 the existing rock barrier was modified to more effectively screen out salmon fry from entering the canal. The modifications included, deepening of the canal and pond on either side of the barrier by excavation, widening the barrier to an average of width of 8m, and the introduction of coarse gravel to fill some of the interstitial spaces. It was envisaged that the excavations on either side of the barrier would reduce the approach velocities on the Bortons Pond side by creating a greater surface area, and permeability would be spread over a greater area. In addition, the widening of the barrier and additional coarse gravel would hopefully reduce sweep velocity and prevent salmon juveniles from becoming entrained, and also discourage fish from penetrating very far into the barrier.

NIWA was commissioned by N.O.I.C to design and carry out an experiment to determine the effectiveness of the barrier in screening out salmon juveniles (a N.O.I.C consent condition that Ecan and Fish and Game would support). NIWA provided two options, (appendix#1). It was decided that the best option was the dyed salmon study (option 1) as it would provide the most reliable and immediate measure of the barriers performance. This option was submitted to Ecan, who agreed it was an appropriate means of evaluating the performance of the barrier. This study was carried out on the 27th of October 2009.

2. Background

This experiment used dyed salmon juveniles which were released into a partial enclosure on the upstream side of a rock barrier and those that pass through the barrier are recaptured on the downstream side. The results from this provide a direct measure of how effective the rock barrier was in preventing juvenile wild salmon (Waitaki out-migrant stocks) 40-60mm, from passing though the barrier and becoming entrained into the canal to the pumping station.

In order to achieve a relevant result there were a number of considerations.

- Large numbers of wild fry were too difficult to obtain so hatchery reared juveniles were used.

- The size of the hatchery fish needed to be a similar size to the wild out-migrant Waitaki fry. It was not possible to use fish <40mm as we were constrained by containment and capture mesh sizes.

- The timing of this experiment needed to coincide with the peak Waitaki fry outmigration (end of October) ie the experimental hatchery fish needed to be at a suitable size (circa 40mm) at this time.

- The pumping station would need to be run at a normal rate and duration, and drawing close to the mean volume of water abstracted, for that time of year.

3. Methods

3.1. Experimental salmon juveniles

For this experiment the fish were donated by North Canterbury Fish and Game. The salmon juveniles were obtained from the Montrose hatchery in the upper Rakaia River. At the time of the experiment the average weight of the fish was 1.3g, for the experiment a total weight of 2.6kgs or 2000 individuals were used*. The water temperature of Bortons Pond on the day measured at 1400 hrs was 13.0^{o}C. The temperature of the tank of transported salmon at this time was 12.3^{o}C. The fish were dyed in buckets using tank water which was slowly adjusted to the Bortons pond water temperature. The fish were then transported to Bortons Pond in a black 250 l tank fitted with an adjustable air system and a dissolved oxygen (DO) probe so that DO levels could be monitored (i.e. maintained around 11ppm).

To minimise handling stress, the fish were not counted out individually and the total number was estimated from the total weight.

The fork length (tip of snout to fork in tail) of a random sample of 20 fish was also measured to show the size range of salmon juveniles that were tested. The lengths ranged from 39-59 mm with a mean length of 51 mm (N=20).

3.2. Site selection, equipment installation, and equipment design

At Bortons Pond, a suitable section of the rock barrier for the experiment was selected based on closeness to the main canal intake pipes, as the true LHS of the barrier was closer to the intake pipes. (b) A section of the barrier that appeared reasonably permeable i.e. many interstitial spaces for water or fish to pass through. This section was representative to the rest of the barrier, with respect to; through flow, depth of water, and size of substrate.

Following the site selection, both the up and downstream containment structures were installed. (Figure 2.)

The containment structure (Figure 3) on the upstream side of the wall consisted of a stainless steel live box(1.0m long, by 0.6m wide, and 0.5m deep) open at one end joined into a 2.5m deep seine net made with bully mesh (10mm stretched). The seine had a square hole cut up near the float line that the live box opening fitted into. The live box had four floats to keep it on the surface and two ropes with attached anchors to hold the structure at a desired distance from the wall. The ends of the seine were then both attached to the barrier forming an enclosure.

Figure 2: **The experimental setup on either side of the barrier with the containment enclosure on the left and capture nets on right.**

Figure 3: **The containment enclosure**

On the downstream side of the barrier a 20m seine net 2.5m deep was used as a stop net to partition off the canal on the true left bank (adjacent to, but overlapping the containment structure on the upstream side of the barrier), and designed to lead any dyed fish with the flow of water into a fyke net for capture (Figure 4) A second back-up seine net was installed in an arc alongside the first net (Figure 5) with both ends attached to the barrier to capture fish that managed to avoid the first seine net.

Figure 4: The first capture net and attached fyke net

3.3. Pumping regime and timing of experiments

During the early months of the irrigation season (October to December), only one of the two pumps is used to pump water and the average amount of water abstracted is about 2 cumecs. The pump(s) are generally run for periods of around 40-50 minutes (the time it takes to fill reservoirs in the Waiareka catchment). At the time of this study there had been a reasonable amount of rain in the area so the demand for water was less than normal for that time of year. Consequently the pump could only be run for about 80 minutes over a 24 hour period, and this would not include any night-time pumping. Although this was unfortunate it did represent a typical situation at this time of year. By running the pump on a manual operating mode it was possible to undertake two trials.

Figure 5: The second back-up capture net

- At 1550 hrs the pump was run for 40 minutes, drawing approximately 2 cumecs, and shutting down at 1630hrs for 30 minutes.
- At 1700hrs the pump was run for 30 minutes drawing approximately 2 cumecs, and shutting down at 1735hrs.

The experiment was terminated one hour after the final shutdown.

3.4. Dyed salmon trials

The 2.6 kg of salmon were divided by weight into three batches of around 650 fish. The (photo) first batch was put into a solution of 1:50,000 neutral red dye for 30 minutes prior to the first trial. The 2nd and 3rd batches were placed into solutions of Nile blue and Acidine orange respectively, both at concentrations of 1:150,000. Dyeing of the 2nd and 3rd batches occurred following the first trial during the 30 minute shutdown. At the beginning of each trial the dyed fish (Figure 6) were transferred to the containment structure by a person in a wetsuit. Fish remained in the containment structure for the duration of the study (160 minutes); the neutral red fish were in the structure for about 70 minutes longer than the blue* and yellow fish (90 minutes).

Figure 6: Dyed salmon juveniles (red ,blue and yellow in descending order)

During the pumping phase the enclosure on the downstream side of the barrier, and areas within the capture nets were closely observed for the presence of any dyed fish. In the upstream containment enclosure the fishes behaviour was also observed and photos taken.

At the conclusion of the experiment, the containment structure was carefully pulled towards the barrier using ropes attached to the leadline (to prevent the leadline lifting up and fish escaping). The fish were then removed, killed by anaesthesia and put into plastic bags. The capture seine nets and fyke net were also carefully removed in a similar manner and checked for any dyed fish that had passed through the barrier.

*Note some of the blue fish were adversely affected by the Nile blue dye, so it was decided place the yellow fish into the containment structure at the same time.

3.5. Results

Only one juvenile salmon (red dye) was observed emerging from between the boulders on the downstream side of the rock barrier during the second pump run. The fish then swam into the capture net; it measured about 55mm in length. No other fish were seen or captured during either of the two pumping runs, the shutdown period, or the hour following the final shutdown. The clarity of the water was sufficient to allow observation of the entire barrier down to the bottom of the rocks (about 2.0m) within the capture seines. Small current streams of water flow entering and exiting the barrier were also very visible.

In the containment enclosure during both pump runs, the fish were observed swimming in the current amongst the boulders, and darting around the small eddies created by the water passing through the barrier. There were no signs of any fish being forced to swim in any direction or being sucked into the interstices (Figure 7).

Figure 7: Fish swimming around barrier boulders. Note water clarity is good for observations.

The approach velocities along the entire length of the barrier were relatively low due to the length of the barrier the depth of water and the amount of water being drawn. Assuming that 10% of the barrier was permeable, the approach velocities averaged 0.10 m\s.

4. Discussion

The results from this experiment have shown that the improved rock barrier will discourage >95%* of hatchery quinnat salmon juveniles (39-60 mm) from entering the NOIC canal during the hours of daylight. This situation only applies when one pump is operational. It was not possible at the time of the study to test the barrier performance during the hours of darkness, as the pump was not operational during this time.

During the dryer months of the irrigation season (December to March), the second pump is commissioned which would double the volume of water drawn from Bortons Pond. This situation would have the effect of increasing the sweep velocities in front of the barrier and possibly increasing the likelihood of small salmon juveniles entering the barrier. However the Waitaki salmon fry migration peak occurs around the end of October (Power 1992), so the increased volume of water drawn from December onwards is not likely to have a significant impact.

The behaviour of the salmon in the containment enclosure during the trials appeared to be normal for healthy unstressed hatchery fish, as most of the fish were darting and swimming around the boulders of the barrier looking for food. It is not clear whether the fish chose not to follow the currents of water passing through the barrier due to the darkness and uncertain path through the obstruction, or for natural concealment reasons. The one dyed fish that emerged from the barrier was obviously stressed as it was swimming swiftly, in one direction, and just beneath the surface of the water. The disturbed behaviour of this individual was probably also due to being separated from the main shoal.

It is clear from these observations that the majority of salmon chose not to penetrate far into the barrier and the only fish that did had inadvertently become disorientated and separated from the main shoal. The sweep velocities in front of the barrier were not forcing the fish to swim into the barrier and they could easily swim against the flow to avoid penetrating too far into the barrier..

It was concluded by Clay 1995 that an acceptable approach velocity for the smallest Pacific salmon fry (quinnat salmon) is 0.12m\s, the estimated approach velocity for the N.O.I.C rock barrier on the day of the trials was 0.10 m\s. Hopkins and Unwin (1987) recorded that migrating quinnat salmon fry averaged 35mm during the period from August to November in the upper Rakaia River. All the juvenile salmon tested during this experiment were larger than the smallest fry so it can be concluded that the approach velocities were well within the acceptable range documented by Clay 1995.

It was not possible to obtain wild salmon for this experiment so it was concluded that the Rakaia hatchery fish would have similar behavioural responses. This seemed a reasonable assumption as the fry were reared in flowing water and showed schooling behaviour as do similar sized wild fish.

The sizes of salmon tested were in the range of 39-59mm, it was not possible at the time of this experiment to test newly emergent salmon fry (35mm, Rakaia data) due to the limitations of the mesh sizes being used. Using a smaller mesh size may have resulted in reducing water flow though the netting and subsequently reducing sweep velocities in the study area.

As mentioned in the methods; the fish numbers were calculated by using average weights. At the conclusion of the experiment the weight of fish remaining equated to 1250 fish. This means that around 750 fish had escaped from the containment enclosure into Bortons Pond. This was due to the enclosure net not providing a very effective seal against the large angular boulders of the barrier. However, all these fish had chosen to swim amongst the front line of boulders and escape instead of passing through the barrier into the capture nets.

At the time of this experiment it was hoped that some useful information could be gained by capturing, by beach seining, some wild migrant salmon fry in the Bortons pond area and the canal itself. This information would have, firstly, shown if there were any wild fish around at the time of the study, and secondly, if reasonable numbers of salmon fry were present whether any had passed through the barrier. However it proved impractical to use a beach seine in Bortons pond due to the extensive amounts of riprap, wooden debris, and aquatic weed growth (mainly elodea spp). Seining in the canal itself would have been workable, but as seining in the pond was not possible, it was considered to be not worthwhile as any results would have been inconclusive.

For the purpose of obtaining information in the future on the numbers of wild migrant salmon fry present in Bortons pond and the canal, a trapping program using several stationary fry traps would be the best method. This approach would only give an indication of the performance of the rock barrier; it would not provide any direct measure of efficiency.

The results (one fish passing through the barrier) are expressed as a percentage due to the reduced accuracy of weighing the fish rather than individual counting.

5. Conclusions

- The barrier was effective for discouraging >95% of 39-60mm hatchery quinnat salmon juveniles from entering the canal.
- This experiment was conducted during daylight hours; the efficiency of the barrier was not tested during the hours of darkness.
- The performance of the barrier has only been tested when one pump was running, drawing about 2 cumecs.
- The sweep velocities were low enough at <0.12 m/s to not have any noticeable effect on the fishes swimming behaviour.

6. Acknowledgements

We would like to thank the following staff at Fish and Game for assisting us with this project. Without being able to obtain fish of an appropriate size in October, this experiment would have been seriously compromised.

Allan Brooks. For making it happen and always coming up with solutions to issues. Dirk Barr. For providing the fish of the desired size. Ross Millichamp. For granting permission to use Montrose hatchery fish. Mark Webb For putting us in contact with the right people and discussing ideas.

7. References

Clay, C. (1995). Design of fishways and other fish facilities. 2nd edition. 248p.

Hopkins, C.L.; Unwin, M.J. (1987). River residence of juvenile chinook salmon(*Oncorhynchus tshawytscha*) in the Rakaia River, South Island, New Zealand. *New Zealand Journal of Marine and Freshwater Research 21*: 163-174.

Power, G. (1992). Seasonal growth and diet of juvenile chinook salmon *(Oncorhynchus tshawytscha)* in demonstration channels and the main channel of the Waitaki River, New Zealand, 1982-1983. *Ecology of Freshwater Fish 1*: 12-25.