Smelt monitoring in the Ohau Channel and Lake Rotoiti 2012-2013

Prepared for Bay of Plenty Regional Council

July 2013

Authors/Contributors:
David Rowe
Eddie Bowman
Adam Dunford
Josh Smith
Ben Harding
George Proud

For any information regarding this report please contact:

David Rowe
Principal scientist
Fish
+64-7-856 1757
d.rowe@niwa.co.nz

National Institute of Water & Atmospheric Research Ltd
Gate 10, Silverdale Road
Hillcrest, Hamilton 3216
PO Box 11115, Hillcrest
Hamilton 3251
New Zealand

Phone +64-7-856 7026
Fax +64-7-856 0151

NIWA Client Report No:	HAM2013-081
Report date:	July 2013
NIWA Project:	BOP13202

Contents

Tables

Figures

Reviewed by

P. Franklin

Approved for release by

D. Roper

Formatting checked by

Executive summary

In 2008, a diversion wall was installed at the outlet of the Ohau Channel in Lake Rotoiti to divert the nutrient-enriched water from Lake Rotorua out of Lake Rotoiti and down the Kaituna River. In time, this diversion is expected to reduce nutrient loading into Lake Rotoiti and hence the deterioration in its water quality. Concerns over the effect of this wall on smelt migrations up the Ohau Channel and on the smelt population in Lake Rotoiti are being addressed through a long-term monitoring programme started in 2005 by the Bay of Plenty Regional Council. This report presents the results for the 2012/2013 year and interprets these within the context of data obtained over the previous seven years.

Results obtained in 2012/2013 indicated that several runs of 'adult' smelt occurred in the Ohau Channel during spring 2012, whereas two runs of 'juvenile' smelt occurred in the summer and autumn of 2013. Monitoring of smelt runs in the Ohau Channel has been improved by combining the analysis of trapping data with the morning and/or evening observations of both smelt movements and shag and gull numbers in the Channel. The use of both methods of detection (trapping and observation) is now allowing better data on the duration and frequency of runs to be obtained, with the more frequent observations extending the less frequent trapping results. The results obtained in 2012/2013 confirm those obtained in previous years, indicating that upstream migrations of both adult and juvenile smelt still occur in the Ohau Channel despite installation of the diversion wall.

The density of larval smelt in Lake Rotoiti in December 2012 was the highest since monitoring began in 2005, continuing the general increase observed in previous years. Smelt recruitment therefore appears to be increasing as lake water clarity improves indicating a positive response to the effect of the diversion wall on lake trophic status. However, larval smelt density in Lake Rotoiti is still below the level measured in 1995/96 and, so long as other factors affecting smelt recruitment (e.g., the area of shallow sandy beach area) do not change, further improvement can be expected as lake trophic status increases.

The high recruitment of larval smelt in spring 2012 coincided with the lowest recorded spring abundance of adult smelt in the hypolimnion of Lake Rotoiti to date. This could indicate that the acoustic sampling did not encompass all adult smelt because of a change in distribution (e.g., adult smelt were spawning) or that there is no simple stock-recruit relationship for smelt in this lake. Assuming the decline in adult smelt is real and not a consequence of changed smelt distribution in 2012, it continues the general decline noted since 2005 well before the diversion wall was installed. A wide range of factors could explain such a general decline in adult smelt in the hypolimnion of Lake Rotoiti. Better knowledge of the factors affecting smelt population dynamics is required to identify the causes of this long-term decline.

1 Introduction

In 2008, a diversion wall was installed at the outlet of the Ohau Channel in Lake Rotoiti to divert the nutrient-enriched water from Lake Rotorua out of Lake Rotoiti and down the Kaituna River. In time, this diversion is expected to reduce nutrient loading into Lake Rotoiti and hence the deterioration in its water quality.

Eastern Region Fish and Game Council were concerned that this diversion wall may reduce the migrations of smelt up the Ohau Channel from Lake Rotoiti and thereby affect the trout fishery in the Channel. In addition, there were concerns that changes to smelt migrations up this Channel could affect the population dynamics of smelt in Rotoiti, resulting in an impact on the trout fishery in this lake. Local iwi were also concerned that their fishery for smelt in the Ohau Channel would be affected.

Studies were therefore initiated by the Bay of Plenty Regional Council to provide more information on the smelt migrations up the Channel and to provide a baseline for assessing any impact of the diversion wall (Rowe et al. 2006). These studies have been continued on a near annual basis since 2005 to provide further information on the smelt migrations as well as to establish any effects of the diversion wall, which was completed in July 2008, on smelt in the Channel and in Lake Rotoiti (Rowe et al. 2008, 2009, 2010, 2011, 2012).

The results of annual monitoring up to June 2012 showed that the wall had not prevented the migration of either adult or juvenile smelt through the Ohau Channel (Rowe et al. 2012). However, as there was insufficient data on smelt runs in the Channel to determine whether the wall had had any effect on the size, frequency or seasonal timing of smelt runs, daily data from visual observation (by George Proud and Frank Thompson) and trapping (by NIWA) were collated and analysed to determine the seasonal timing of smelt migrations up the Channel and to see whether this was influenced by water temperature, flow rate or moon phase. These analyses indicated that runs of juvenile smelt were seasonal and tended to occur only in summer months (December to April). In comparison, runs of adult smelt occurred in nearly all months of the year, but tended to be more frequent in both spring (October/November) and in autumn (March-May) months (Rowe et al. 2012). Despite this seasonality in runs, there was no relationship between the timing of runs for juveniles or adults and water temperature in the Ohau Channel, nor with the mean daily flow rate or moon phase. Other factors are therefore influencing the timing of these runs, but long-term data sets required to investigate these factors are not available.

Acoustic monitoring of adult smelt (TL>50 mm) in Lake Rotoiti was not carried out in September 2011 because the adult population had shown little change over the past five years. In contrast, larval smelt in Lake Rotoiti showed a marked increase in abundance in 2011/2012 relative to the previous five years (Rowe et al. 2012). As a consequence, the Technical Advisory Group recommended that full monitoring including trapping in the Ohau Channel, an acoustic survey of adult smelt in Lake Rotoiti and sampling to measure larval smelt numbers in Lake Rotoiti be carried out in 2012/2013.

In this report, we present the results of the September 2012 acoustic survey of adult smelt abundance in Lake Rotoiti, the monitoring of smelt runs in the Ohau Channel (from September 2012 to June 2013) and the results of the summer surveys to determine larval smelt density in Lake Rotoiti over the 2012/2013 summer season.

2 Methods

2.1 Smelt trapping in the Ohau Channel

The locations of the sites used to monitor smelt movements in the Ohau Channel over the past five years are shown in Figure 2-1. Only trap sites 1 and 2 were used in 2012 and 2013 as the contribution of Sites 3 and 4 was generally minor (Rowe et al. 2011) and Sites 1 and 2 have been monitored since 2006 so they provide a longer record.

Figure 2-1: Location of sampling sites used for smelt trapping in the Ohau Channel. Only sites 1 and 2 were trapped in 2012. Inset shows a smelt trap and the platform below which it is set.

Trapping was carried out at three to four week intervals during the ten month period from September 2012 to June 2013. Traps were placed close to the bank at each site, facing downstream in order to capture upstream migrants. The traps were triangular with a 1 m by 0.5 m wide opening tapering to a 20 cm wide capture compartment (Figure 2-1). Mesh size was 2 mm. Traps were usually set close to daybreak and the catch removed every 3-4 hours until late evening. The total number of smelt caught per trap per day and the total time for which the trap was fished per day were recorded. Depending on the number of fish present, all or a subsample were used to determine the proportions of juveniles and adults. Both the length (under or over 45 mm total length) and coloration of smelt were used to distinguish juveniles from adults. The proportion of each size group in the total catch per site was determined from the subsamples. The daily catch per unit of effort (CPUE) for smelt on each sampling date was calculated as the total daily catch for the two traps divided by the total trapping time in minutes.

Shag numbers (both on the banks and in trees lining the channel) were counted along the channel's entire length on each sampling occasion. Shags are predators of smelt and their abundance provides an additional measure to detect the presence of high densities of migratory smelt (Rowe et al. 2010, 2011).

In addition to the smelt monitoring, water temperatures (Tidbit© data loggers), water clarity (black disc visibility), water velocities at the entrance to each trap, the discharge of water through the channel, and the by-catch of other species (common bullies, koaro, trout, koura) were also recorded.

We were also fortunate to obtain the daytime observations of smelt and birds near the top of the Channel made by George Proud on 40 days during the period October 2012 to May 2013. These observations were used to help extend the trapping data and so provide more information on the frequency and timing of smelt runs.

2.2 Acoustic survey of adult smelt

Acoustic surveys of adult smelt density in Lake Rotoiti were first carried out in Lake Rotoiti in September 2000 (for the Eastern Fish and Game Council). This survey was repeated annually from 2005 until 2010 using the same transects (Figure 2) and methods as used in previous surveys (Rowe et al. 2011).

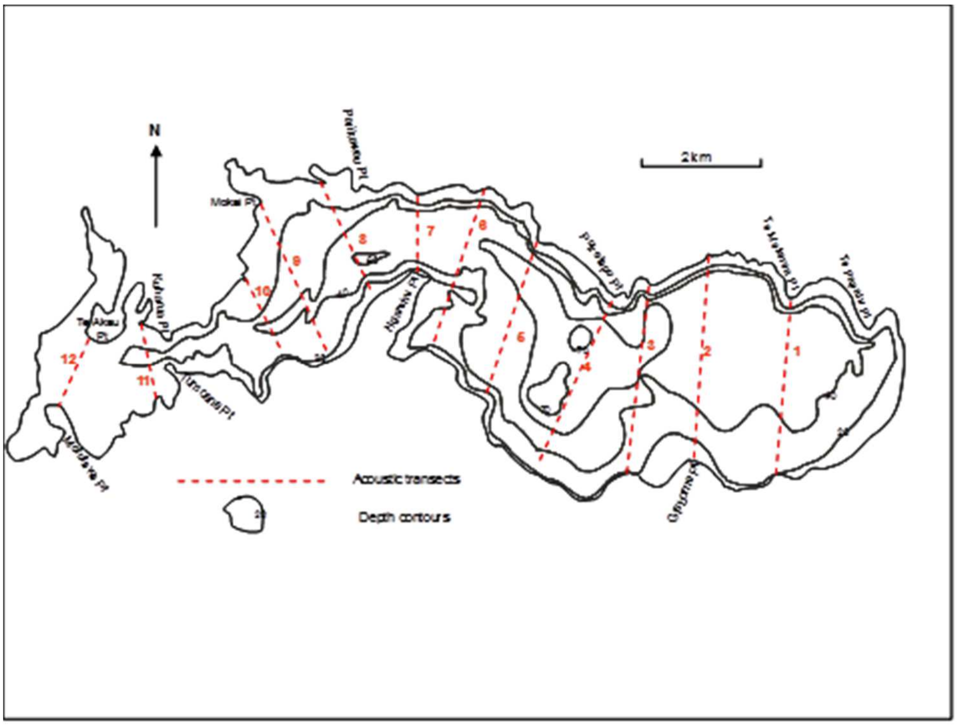

Figure 2-2: Transects (dashed red lines, labelled 1-12) used for the acoustic survey of Lake Rotoiti in September 2009 .

The 2012 survey used the same SIMRAD EK60 machine operating at 120 kHz as in the past but with the transducer mounted on a bracket attached to the hull of the boat, instead of in the towed V-fin. The stanchion-mounted 120 kHz transducer had a 7º beam angle and was made for NIWA by Callaghan Innovation (formerly IRL) to duplicate the transducer in the V-fin. The change in transducer mounting meant that the survey encompassed shallower water than in the past, but echoes in shallow water are not included in the analysis. The echosounder was calibrated in situ on the day of the survey and data on ambient 'noise' that could potentially confound the results were obtained. The lake was then acoustically surveyed along each transect and the data saved for later processing. This involved identification and delineation (on the echogram for each transect) of the fish depth layer within which the adult smelt occurred (i.e., echoes with target strengths ranging between -55dB and -45dB generally occur in a layer of fish between 20 and 40 m). This process excludes the majority of the smaller, juvenile smelt present in the near-surface waters (0-10 m), which are not amenable to acoustic sampling. Although some juvenile smelt are present in the depth zone occupied by the adult smelt, their number is assumed to be both small relative to those in near-surface waters and relatively constant between years. At present, these assumptions cannot be tested because there is no feasible way of estimating the abundance of juvenile smelt in this lake.

The spatial regions where the adult smelt were present in each echogram were delineated and the acoustic data from each region analysed using ESP2 (McNeil et al. 2003) to determine the total amount of acoustic backscatter received from each region. This will include backscatter from juvenile smelt, from adult rainbow trout and from the larval bullies present in these regions. However, juvenile smelt and larval bullies are generally present in shallower waters, above the adult smelt layer (Rowe & Chisnall 1995). Therefore, overlap in fish distributions is minimised. Although the presence of some trout in the adult smelt layer could result in over-estimation of the acoustic backscatter from adult smelt alone, this is expected to be minor and similar each year.

The amount of backscatter for each transect was calculated per m^2 of lake surface area and compared with that measured each year from 2000 to 2010 to identify any changes in the spatial patterns of smelt abundance in the lake. The mean areal backscatter for adult smelt over the entire lake was calculated and divided by the acoustic backscatter produced by a single, average-sized adult smelt to provide a measure of the mean number of adult smelt in the lake in September 2012. The backscatter for an individual smelt was calculated from the mode of the frequency distribution of decibel counts from individual echoes. As the backscatter produced by a single, average-sized smelt may differ between years (e.g., because of differences in growth rate and hence fish size), any bias related to smelt size were reduced by using the modal value for smelt in the target strength frequency distribution.

2.3 Larval smelt density in Lake Rotoiti

Larval smelt in Lake Rotoiti have been sampled annually to determine whether a decline in natural recruitment occurs, or if annual changes in larval abundance could account for any marked variations in adult smelt abundance in the lake and the Channel. In the Rotorua lakes, smelt have an extended spawning period lasting from spring until the end of summer. After hatching, the larvae become pelagic and remain in the water column at depths down to 50 m until they reach a length of around 25 mm. They have no air-bladder so, unlike the smaller larval bullies that do contain an air bladder, they cannot be detected acoustically, even at high frequencies (i.e., 200 kHz). The peak months for larval smelt density in Lake Rotoiti are unknown, and may vary between years. However, the larvae can be expected to be present for up to 5 months post-hatch. Although the growth rate of smelt larvae in lakes and hence the duration of the larval phase is unknown, studies on the growth rate of galaxiid larvae (which have a similar life history to smelt in lakes) indicate that smelt are likely to remain in the pelagic zone for 3-5 months before they metamorphose and form schools of juveniles near the lake surface. Estimates of larval smelt abundance in Lake Rotoiti are therefore carried out in both December and April to encompass, and slightly lag, the main spawning periods of spring and summer.

Vertical drop netting using a closable Wisconsin plankton net (mouth area of 0.25 m^2, mesh size 250 µm) was used to sample larval smelt throughout the water column (surface to near the lake-bed) of Lake Rotoiti in both December 2012 and April 2013. Sampling was carried out at 30 sites spread throughout the lake. Larval fish sampled from the water column at each site were sorted into species (larval bullies vs. larval smelt), counted and measured to the nearest millimetre. Secchi disc depth was also measured because the overall number of smelt larvae in lakes has been found to co-vary with water clarity reflecting trophic status in the Rotorua lakes (Rowe & Taumoepeau 2004). The lake-wide mean CPUE (Catch Per Unit Effort) of larval smelt over the spawning season (December plus April data) was calculated for the 2012/2013 spawning season and plotted against secchi disc depth to indicate any change in density independent of changes in water clarity and trophic status. The data for the 2012/2013 season were then compared to those for previous seasons to determine any marked change or long-term trends in larval density.

3 Results

3.1 Smelt runs in the Ohau Channel

Runs of smelt in the Ohau Channel are detected primarily by high catch rates (>2 smelt/minute) in traps located on the edge of the channel (Rowe et al. 2012). The minimum threshold for a ‘small’ run of smelt is 2 fish/minute and this was determined from an analysis of the frequency distribution of daily trap catches combined with bank-based observations of smelt school size and rate of movement upstream (Rowe et al. 2012).

Trapping during 2012/2013 detected a small run of smelt (2.2 fish/minute) on 16 October 2012, another small run (3.0 fish/minute) on 29 January 2013, with a larger run (18 fish/minute) occurring on 2 May 2013 (Figure 3-1). The runs detected on 16 October 2012 and 2 May 2013 coincided with periods of days in which runs were detected by visual observations (see Appendix 1). Visual observations of smelt, and/or gulls and shags feeding on smelt (see Appendix 1), indicated that there were probably a number of smelt runs up the Channel between the 7 and 27 October 2012.

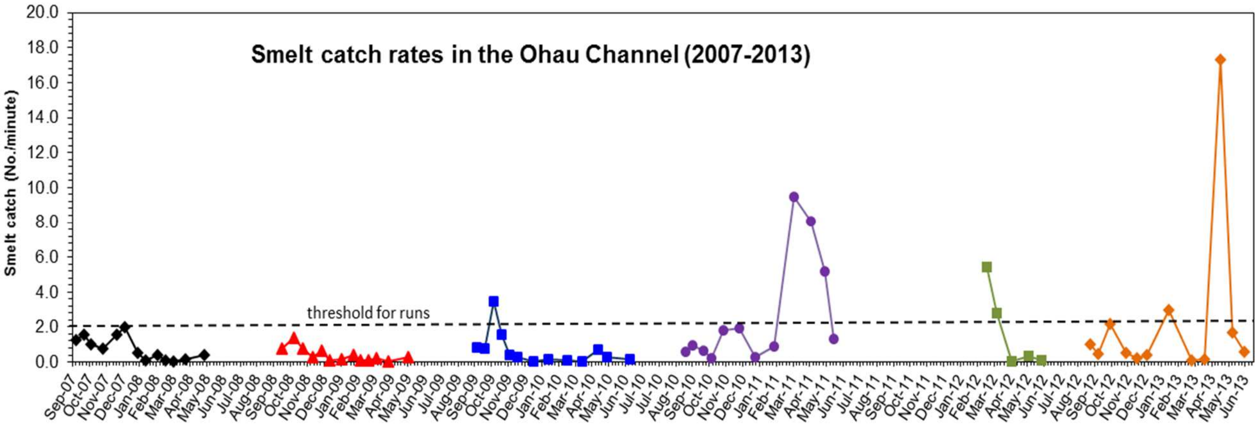

Figure 3-1: Mean daily CPUE for smelt in traps set in the Ohau Channel from August 2012 to June 2013, compared to previous years. The dashed horizontal line is the 2 fish/minute threshold over which trap rates reflect runs of smelt.

Analysis of the proportions of adults and juveniles in October 2012 (Figure 3-2) indicated that the ‘spring’ runs comprised primarily adult smelt (>97%). The relatively high occurrence of shags present at this time (see Appendix 1) is further evidence that a run of adult smelt had or was occurring, as shags congregate in the channel when runs of adults smelt occur (Rowe et al. 2010, 2011, 2012). Small runs of adult smelt were also likely to have occurred on 18 and 19 November as indicated by the occurrence of many gulls (see Appendix 1).

The small run of smelt detected by trapping on 29 January 2013 consisted primarily of juvenile smelt (76%) and the larger run detected by trapping on 2 May comprised 68% juvenile smelt. Visual observations indicated that the autumnal run of juvenile smelt continued sporadically until the 11 May 2013 (Appendix 1). The lack of gulls and shags at this time is consistent with previous observations that avian predation on smelt in the Ohau Channel is focussed more on the larger adult than on the juvenile smelt (Rowe et al. 2010, 2011).

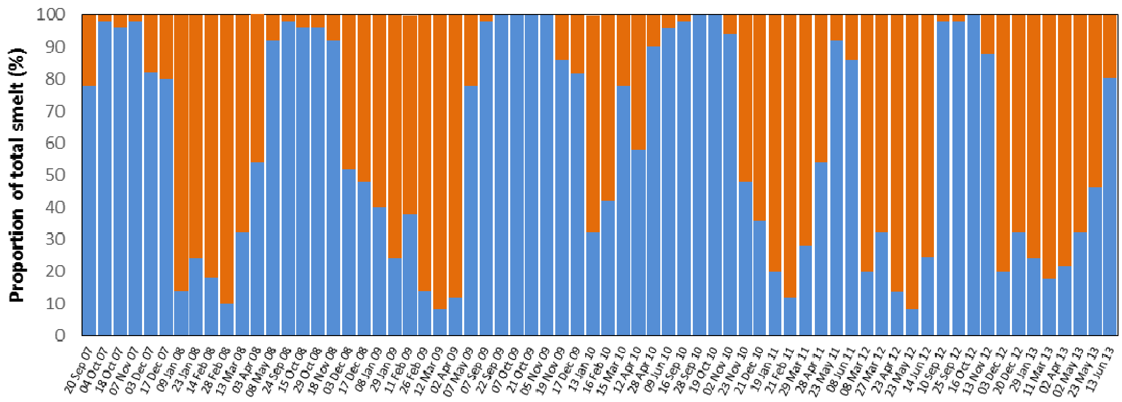

Figure 3-2: Proportions of adult versus juvenile smelt in trap catches from the Ohau Channel 2007-2013. (Proportions of adults are in blue and juveniles in orange).

The May 2013 runs of juvenile smelt are the first record of a predominantly juvenile smelt run in May. In the past, runs of juvenile smelt have only been recorded between December and April (Rowe et al. 2102). The seasonal pattern of predominantly juvenile runs over summer/autumn months (i.e., December-May), with adult runs occurring in all other months but primarily in spring, continued in 2012/2013 (Figure 3-1, 3-2).

Flow rates in the Ohau Channel during the 2012/2013 sampling periods were within the range for previous years (Figure 3-3) and water clarity as measured by secchi disc depth was relatively high (>3.0) during summer months as in the previous year (Figure 3-4). This is likely to reflect the increased quality of Lake Rotorua water in the Ohau Channel.

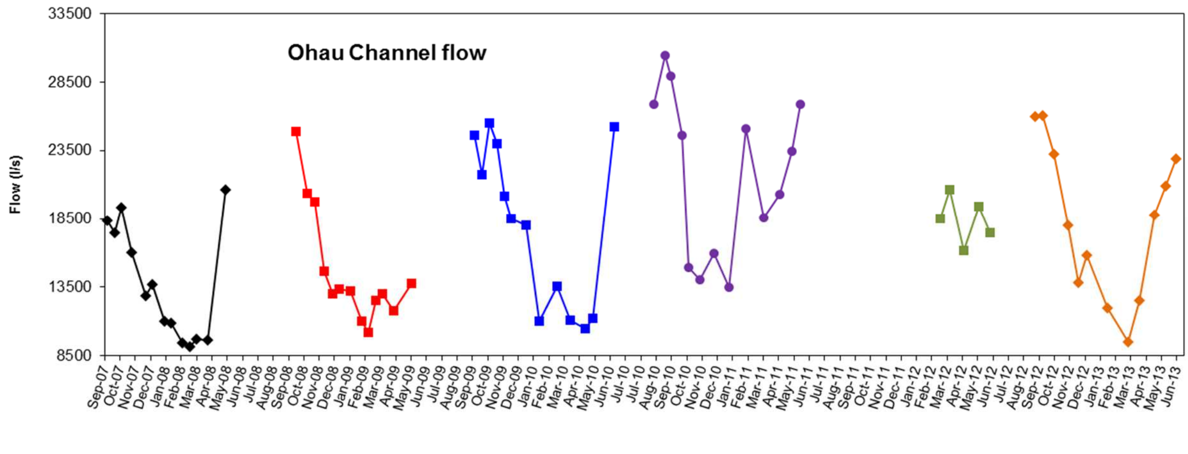

Figure 3-3: Mean daily flow (L s^{-1}) in the Ohau Channel on the days when smelt were trapped in the Ohau Channel.

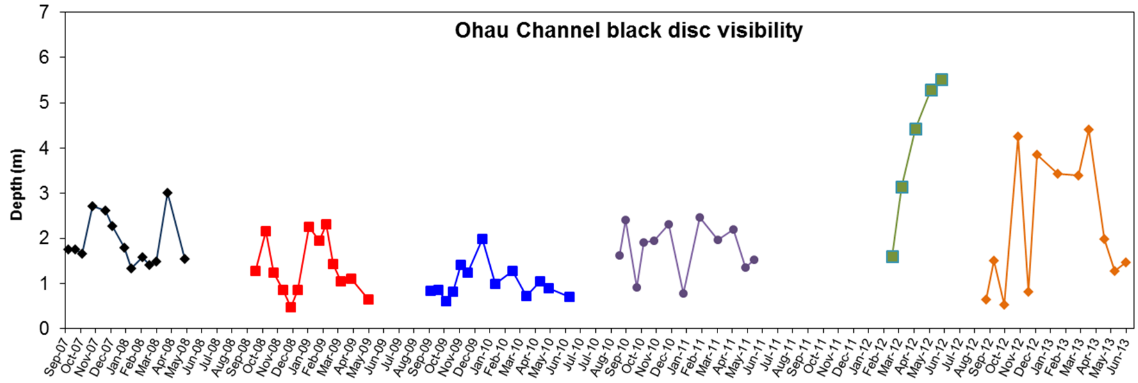

Figure 3-4: Water clarity (black disc visibility) in the Ohau Channel on the days when smelt trapping occurred.

Analysis of the trap by-catch indicated that juvenile koaro were caught sporadically and mainly in December. Gambusia were absent this year. A trend that is now becoming more apparent is the decline of common bullies in trap catches from the Ohau Channel (Figure 3-5). Peak catches have dropped progressively since 2007 with the regression of mean catch against year having a negative slope coefficient ($R^2 = 0.90$, $F = 37.6$, $P < 0.05$).

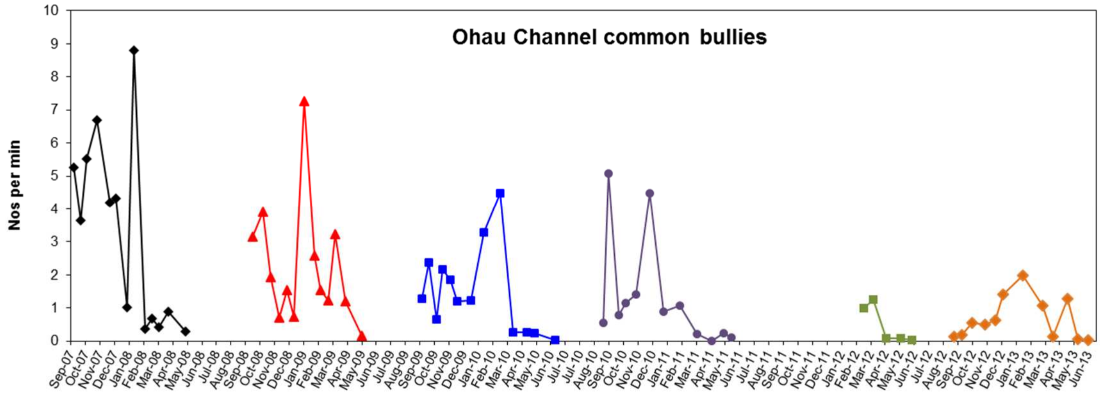

Figure 3-5: Mean daily catch of common bullies in the Ohau Channel in 2012/2013 compared with previous years.

Runs of both adult and juvenile smelt up the Ohau Channel occurred during the 2012/2013 season (Figure 3-2, 3-6). Comparison of smelt catch data in 2012/2013 with that for previous years indicated that these 2012/2013 runs add to the post-wall runs of juvenile smelt recorded in 2009, 2011 and 2012 and of adult smelt in 2010 (Figure 3-6). Collectively, the results indicate that the diversion wall has not prevented smelt from migrating up the Channel. However, there are no useful data on the frequency and size of runs to indicate whether these characteristics of the runs have been altered. The combination of 2-4 weekly trapping and the near daily observations carried out in 2012/2013 allowed the detection of 2 runs of adults and 2 runs of juveniles, with some runs occurring on most days over a period of 3 weeks.

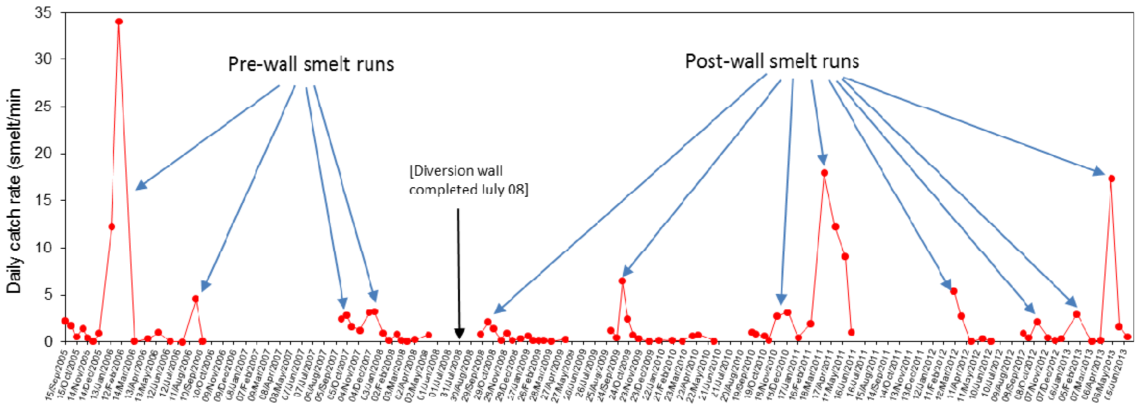

Figure 3-6: Occurrence and relative size of smelt runs in the Ohau Channel before and after installation of the diversion wall. Blue arrows indicate runs of smelt (catch rate >2 smelt/minute).

3.2 Larval smelt densities

The larval smelt density in Lake Rotoiti in December 2012 was the highest recorded since 2005 and was responsible for the overall increase in smelt larvae for the 2012/2013 summer season (Table 3-1). In contrast the April 2013 density was among the lowest recorded to date.

Table 3-1: Mean catch rate of larval smelt in Lake Rotoiti during the 2012/2013 summer period compared with previous summers.

Summer	Net hauls per survey	Mean catch rate (No. net^{-1} ± SD) per survey		
		December	April	Overall
2005/2006	15	0.60 ± 0.74	0.47 ± 0.52	0.53 ± 0.63
2007/2008	30	0.65 ± 1.28	0.94 ± 1.15	0.79 ± 1.22
2008/2009	30	1.00 ± 1.34	0.42 ± 0.76	0.71 ± 1.12
2009/2010	30	2.52 ± 1.39	1.68 ± 1.49	2.10 ± 1.49
2010/2011	30	0.81 ± 1.22	0.97 ± 1.14	0.89 ± 1.17
2011/2012	30	4.07 ± 0.48	2.58 ± 0.39	3.32 ± 0.32
2012/2013	30	10.5 ± 1.60	0.45 ± 0.14	5.47 ± 1.02

The large sample size obtained in December 2012 enabled the first comprehensive length frequency distribution for larval smelt in this lake to be determined. It indicated a range of 4-33 mm total length (TL), with most smelt being between 7 and 26 mm TL (Figure 3-7). The multimodal distribution of lengths indicates the likely presence of several cohorts from a number of spawnings over the previous two to three month period (September to November). The density of larval smelt recorded in April 2013 was one of the lowest recorded over the past 7 years indicating either minimal spawning or high egg mortality between January and April 2013.

The overall summer recruitment of larval smelt during the 2012/2013 spawning season was the highest recorded for Lake Rotoiti since 2005 (Table 3-1) but was still lower than the high overall density (>8 larvae/net) recorded in Lake Rotoiti in 1995/96 (Figure 3-8). The overall, long-term trajectory for larval smelt recruitment in Lake Rotoiti is still upward and towards the highest recorded densities found in clear-water, oligotrophic lakes (viz. 15 and 25 larvae/net in Lake Okataina and Rotoma respectively) (Figure 3-8).

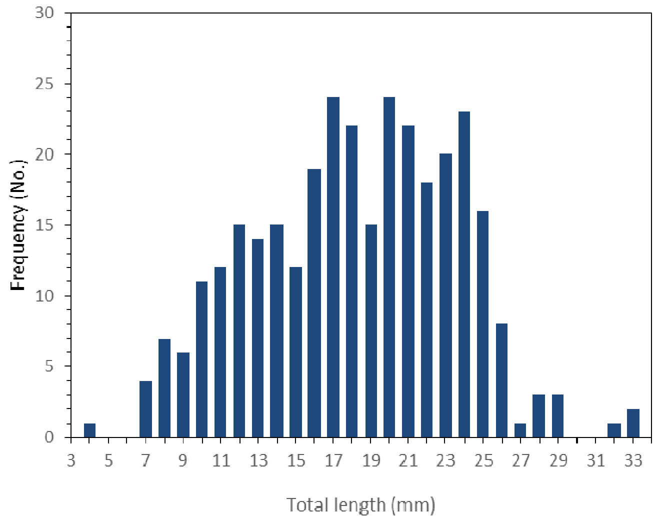

Figure 3-7: Length frequency distribution of larval smelt sampled by drop netting in the limnetic zone of Lake Rotoiti in December 2012.

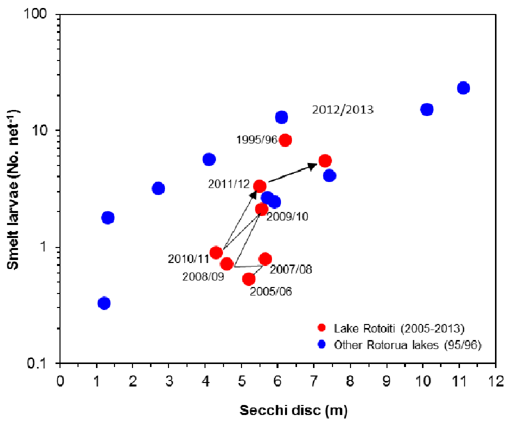

Figure 3-8: Mean catches of larval smelt in Lake Rotoiti over summer periods since 2005/2006 versus mean secchi disc at the time of sampling. Red circles are data for Lake Rotoiti. Blue circles are corresponding data for other Rotorua lakes obtained in 1995/96 and providing the context for interpreting changes in relation to lake water clarity. Arrows indicate trajectory for larval smelt abundance in Lake Rotoiti over time.

3.3 Acoustic estimate of adult smelt population in Rotoiti

The density of adult smelt was low in all transects during September 2012 (Figure 3-9). The modal size of smelt as indicated from the target strength frequency distribution was no different to that in previous years (apart from 2007 when smelt were larger) (Figure 3-10).

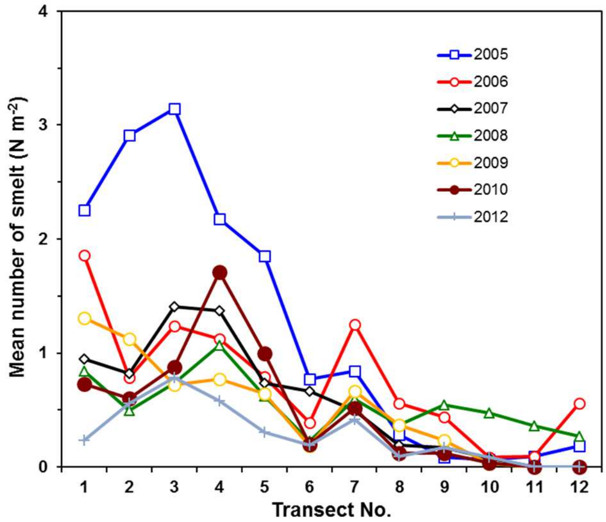

Figure 3-9: Mean number of smelt estimated per transect across Lake Rotoiti from the annual measurements of acoustic backscatter since 2005. Transect numbers correspond to those in Figure 2-2.

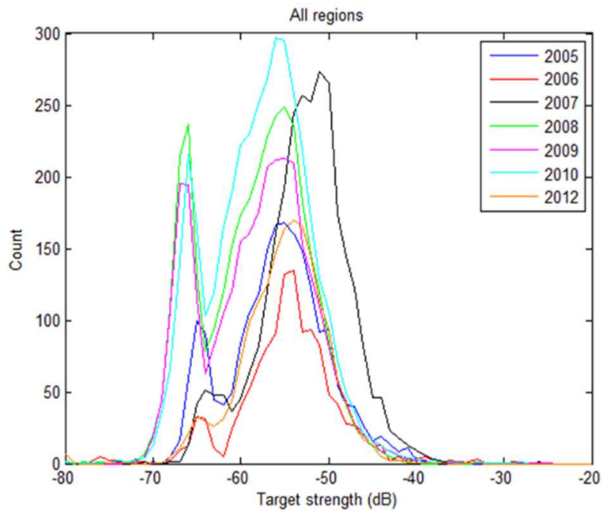

Figure 3-10: Frequency distribution for peak target strengths obtained from single fish echoes recorded in Lake Rotoiti during the annual acoustic surveys. Filtering removed all echoes smaller than -80 dB. The mode at -67 dB represents larval bullies, whereas the mode at -55db represents smelt (both adults and juveniles combined).

The mean density of adult smelt in Lake Rotoiti (across all transects) was lower in 2012 than in previous years (Figure 3-11). The regression of density against year indicated a continuation of the long-term decline in adult smelt abundance in Lake Rotoiti and was statistically significant ($P<0.005$), even when the data for 2000 and 2005 were excluded. This decline started before the wall was commissioned and has continued after its construction was completed. It is therefore likely to reflect the impact of other factors on smelt population dynamics in Lake Rotoiti.

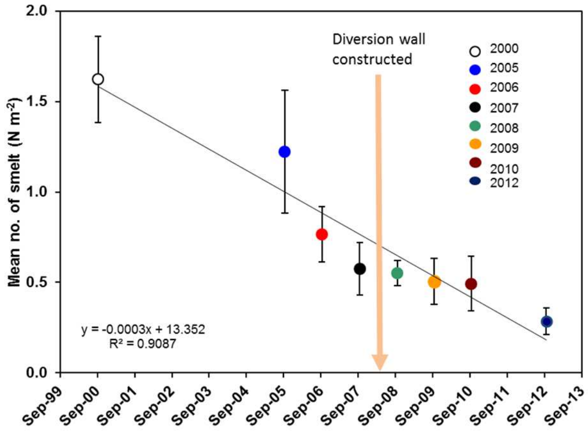

Figure 3-11: Change over time in the mean density of adult smelt estimated for Lake Rotoiti during the September acoustic surveys. The beige arrow indicates the completion of the diversion wall. Vertical bars are standard errors, and the solid line is the regression of mean density against year.

4 Conclusions

Monitoring of smelt runs in the Ohau Channel has been improved by combining the 2-4 weekly analysis of trapping data with the more frequent morning and/or evening observations of smelt movements and shag and gull numbers in the Channel. The finer scale daily observations complement the trapping and provide useful information on the duration and frequency of smelt runs.

Results obtained in 2012/2013 indicated that there was good agreement between both methods with smelt runs being detected during the same periods by both methods. Observation of large numbers of gulls and shags in the Channel usually occur at times when there are large numbers of adult (but not juvenile) smelt there. The fact that no smelt were always seen at the time of these observations suggests that the run for that day was then over.

Results from both methods were combined in 2012/2013 to show that runs of both adult and juvenile smelt occurred on a number of days over at least two periods. For adults, the first period was from 7 to 27 October and the second from 18 to 19 November. For juveniles, the first was on 29 January and the second from 2 to 11 May 2013. Variability in the observations of runs indicates that they can occur on just a single day, or over a number of days, albeit not sequential days, for a period of up to 3 weeks. Moreover, the seasonal timing of runs (main month of migration) for both adults and juveniles varies from year to year (Rowe et al. 2102). The timing of smelt runs up the Channel is therefore complex and currently not predictable. Daily observations of smelt runs in the Channel coupled with the collection of concurrent data on a wide range of physical variables both in the Ohau Channel and in Lake Rotoiti would be required to determine what physical factors trigger the runs.

The results for smelt runs in the Ohau Channel obtained in 2012/2013 reinforce those obtained in previous years, indicating that upstream migrations of both adult and juvenile smelt still occur in the Ohau Channel despite the installation of the diversion wall. The use of both methods of detection (trapping and observations) allows better data on the timing and frequency of these runs to be obtained but the daily observations are provided courtesy of George Proud and are not part of the ‘formal’ monitoring programme.

There has been no reduction in larval smelt recruitment in Lake Rotoiti over the past 6 years as would be expected if the diversion wall was reducing smelt abundance in this lake. Instead, recruitment appears to be increasing as lake water clarity improves. This is expected and reflects the general pattern noted for smelt across the Rotorua lakes in 1995/1996. A noticeable feature of smelt recruitment patterns in 2012/2013 was the relatively poor recruitment over summer/autumn months compared with the very high recruitment in the previous spring. Over the past 6 years, larval density has usually been higher in December than in the following April, indicating that most smelt spawning occurs during spring months. This pattern appears to have been amplified in 2012/2013, perhaps because of much better spawning conditions in spring than in previous years or better survival rates for the eggs and larvae.

The high recruitment of smelt larvae in spring coincided with the lowest recorded abundance of adult smelt in Lake Rotoiti to date. This could indicate that the acoustic sampling did not encompass all adult smelt. For example, if most adult smelt were spawning at the time of the acoustic survey in September 2012, then many may have been present in shallow waters close to sandy beaches rather than in the hypolimnion. If the decline is real, then there is no correlation between spawning stock and juvenile recruitment in this lake. In reality, a wide range of factors could explain the decline in adults despite an increase in larvae and few of these factors can be monitored at present. For example, large adult smelt (>50 mm long) are often common in more eutrophic and turbid lakes than in clear oligotrophic ones, and are also common in lakes lacking a trout population (pers. obs.). The decline of adult smelt in Lake Rotoiti in 2013 may therefore reflect the recent improvement in lake water quality in Rotoiti, or increased predation from trout as a consequence of the increase in stocking rate in 2011/12. More data on smelt population dynamics in this lake would be required to understand the processes responsible for the continued decline in adult smelt.

5 References

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Appendix A Daily observations of smelt 2012-2013 by George Proud

1/10/2012	8.00am. Shags 0-5, No gulls and a few herons. A few smelt seen, 20 fisherman and fish caught.
1/10/2012	19.30pm. No shags or gulls and a few herons. A few smelt seen. 11 fisherman and fish caught.
2/10/2012	8.00am. No shags or gulls or herons. A few smelt seen. Seven fisherman and fish caught.
3/10/2012	7.30am. No shags or gulls and a few herons. No smelt seen. Two fisherman and fish caught.
6/10/2012	7.30am. A few shags and no gulls or herons. A few smelt seen. Three fisherman and no fish caught.
6/10/2012	19.00pm. A few shags and no gulls or herons. A few smelt seen. Two fisherman and no fish caught.
7/10/2012	630am. Shags 10-20, many gulls and a few herons. A run of smelt. One fisherman and fish caught.
7/10/2012	20.00pm. A few shags, no gulls and a few herons. A few smelt. Five fisherman and fish caught.
12/10/2012	6.30am. Many shags and gulls and a few herons. A few smelt. Four fisherman and fish caught.
14/10/2012	7.00am. Shags 10-20, many gulls and herons 5-10. Water dirty so could not see smelt. Three fisherman and fish caught.
14/10/2012	19.00pm.Shags 5-10, no gulls and herons 10-20. Water dirty so could not see smelt. Two fisherman and fish caught.
21/10/2012	7.00am. Shags 10-20, many gulls and herons 5-10. No smelt seen. Six fisherman and fish caught.
21/10/2012	14.00pm. Shags 5-10, gulls 5-10 and a few herons. No smelt seen. Six fisherman and fish caught.
22/10/2012	7.00am. Shags 5-10, gulls 10-20 and a few herons. Water dirty so could not see smelt. Three fisherman and no fish caught.
22/10/2012	6.30am. Shags 10-20, many gulls and herons 5-10. No smelt seen. One fisherman and no fish caught.
27/10/2012	6.45am. Shags 10-20,many gulls and a few herons. A few smelt seen. Two fisherman and fish caught.
28/10/2012	19.30pm. Shags 10-20, gulls 10-20 and a few herons. A few smelt seen. Four fisherman and fish caught.
3/11/2012	19.15pm. No shags, a few gulls and herons. No smelt seen. No fisherman and no fish caught.
4/11/2012	7.30am. A few shags, gulls 10-20 and a few herons. Water dirty so could not see smelt. Five fisherman and no fish caught.
10/11/2012	6.30am. A few shags, gulls 10-20 and a few herons. A few smelt seen. Three fisherman and fish caught.
11/11/2012	19.30pm. Shags 5-10, a few gulls and herons 5-10. No smelt seen. Two fisherman and fish caught.
14/11/2012	7.35am, Shags 5-10, many gulls and a few herons. No smelt seen. One fisherman and no fish caught.
17/11/2012	7.30am. No shags, gulls 5-10 and a few herons. No smelt seen. Two fisherman and fish caught.
18/11/2012	18.45pm. A few shags, many gulls and a few herons. Water dirty so could not see smelt. No fisherman and no fish caught.
19/11/2012	7.30am. Shags 5-10, many gulls and a few herons. Water dirty so could not see smelt. No fisherman and no fish caught.
24/11/2012	21.30pm. No shags or gulls and herons 5-10. No smelt seen. Two fisherman and no fish caught.
25/11/2012	7.15am. No shags, gulls 10-20 and herons 5-10. Water dirty so could not see smelt. No fisherman and no fish caught.
28/11/2012	19.00pm. A few shags and gulls, herons 10-20. No smelt seen. One fisherman and no fish caught.
5/12/2012	7.15am A few shags and herons. Gull 5 -10. No smelt seen. No fishermen and no fish caught.
15/12/2012	19.00pm. No gulls and a few shags and herons. A few smelt seen. No fishermen and no fish caught.
23/03/2013	8.00 am. A few shags and no gulls or herons. No smelt seen. No fisherman and no fish caught.
23/03/2013	18.30pm. No shags and a few gulls and herons. No smelt seen. No fisherman and no fish caught.
6/04/20013	18.00pm. A few shags and herons. No gulls. No smelt seen. No fisherman and no fish caught.
13/04/2013	14.45pm. A few shags and herons. No gulls. No smelt seen. No fishermen and no fish caught.
14/04/2013	18.00pm. A few shags and herons. No gulls. No smelt seen. No fisherman and no fish caught.
20/04/2013	18.15pm. No shags or gulls. A few herons. No smelt seen. No fisherman and no fish caught.
22/04/2013	18.00pm. A few shags and herons. No gulls. A few smelt seen. No fisherman and no fish caught.
27/04/2013	7.00am. Shags 10-20. Gulls and Herons 5-10. Channel too dirty to see smelt. No fisherman and no fish caught.
24/04/2013	18.30pm. No shags or gulls and a few herons. No smelt seen. No fisherman and no fish caught.
4/05/2013	18.00pm. A few shags and herons. No gulls. A run of smelt. One fisherman and fish caught.
5/05/2013	8.00am. A few shags and 5-10 gulls and herons. A run of smelt Two fisherman and fish caught.
10/05/2013	16.00pm. No shags and a few gulls and herons. A few smelt. No fisherman and no fish caught.
11/05/2013	17.00pm. A few smelt and herons. No gulls. A run of smelt. Two fisherman and no fish caught.
23/05/2013	17.30pm. No shags or gulls. A few herons. A few smelt. One fisherman and fish caught.
25/05/2013	7.30am. A few shags. No gulls or herons. No smelt. Three fisherman and fish caught.