Smelt monitoring in the Ohau Channel and Lake Rotoiti: 2010-2011

Prepared for Bay of Plenty Regional Council

June 2011

Smelt migrations attract gulls and shags in the Ohau Channel [Eddie Bowman, NIWA]

Version 1

Authors/Contributors:
David Rowe
Eddie Bowman
Adam Dunford
Stephane Gauthier
Julie Proud
Joshua Smith

For any information regarding this report please contact:

Dr David Rowe
+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:	HAM2011-068
Report date:	May 2011
NIWA Project:	BOP11226

Contents

Tables

Figures

Reviewed by

P. Franklin

Approved for release by

D. Roper

Formatting checked:

A. Bartley

1 Executive summary

The water quality of Lake Rotoiti deteriorated rapidly between 1950 and 2000 resulting in toxic algal bloom formations that closed the lake over summer months during the early 2000s. The main inflow into Lake Rotoiti is water from Lake Rotorua, which enters Rotoiti via the Ohau Channel. This water contains high levels of plant nutrients (N and P) and, in summer months, large amounts of cyanophycean algae. It was identified as a major cause of the decline of water quality in Lake Rotoiti. Consequently a decision was made to divert this water around the edge of Lake Rotoiti and down the Kaituna River.

This decision raised concerns about the impact of the proposed diversion wall on fish and fisheries. There is a small iwi fishery for smelt in the Ohau Channel based on the upstream migration of smelt from Lake Rotoiti into Lake Rotorua. Trout feed on these smelt near the weir at the top of the channel creating a valued seasonal trout fishery. The main concern was that the diversion wall could prevent smelt from migrating up the channel as this could reduce both these fisheries. In addition, there were concerns about the affect of the diversion wall on smelt population dynamics in Lake Rotoiti and on the trout fishery in this lake. This was because some trout also migrate between the two lakes and, in Lake Rotoiti, trout feed primarily on smelt. Because of these concerns, a monitoring programme was created as a condition of the resource consents. As a part of this programme, smelt monitoring was carried out by NIWA in both the Ohau Channel and in Lake Rotoiti for several years before and after completion of the diversion wall in June 2008. In this report we provide the results for the 2010/2011 season and compare these with the results of previous years.

Migration of juvenile smelt occurred up the Ohau Channel over a 4 week period during April-May 2011. Migrations of both juvenile and adult smelt have, therefore, now been recorded up the Ohau Channel after completion of the diversion wall. These results show that the diversion wall is not a physical barrier to either juvenile or adult smelt. There is, therefore, no need for the construction of a special pass in the wall to allow entry of smelt and facilitate their upstream passage from Lake Rotoiti to Lake Rotorua.

The acoustic surveys carried out in Lake Rotoiti over the past 6 years indicated that the September abundance of adult smelt in this lake declined steeply between 2000 and 2007, but has not changed greatly since 2007. The density of larval smelt in Lake Rotoiti over the 20010/2011 summer season indicated that there has been no major change in recruitment since 2005/2006. There has, therefore, been no major decline in adult smelt abundance in Lake Rotoiti since the diversion wall was installed.

In summary, monitoring of smelt in both the Ohau Channel and in Lake Rotoiti before and after completion of the diversion wall has shown that: (a) the wall is not a physical barrier to the upstream movement of smelt, (b) migrations of juvenile and adult smelt still occur up the Ohau Channel during spring and autumn respectively, (c) there has been no significant, or sustained, drop in the abundance of adult smelt in Lake Rotoiti following the wall's construction, and (d) larval recruitment in Lake Rotoiti has not declined since the wall's completion.

2 Introduction

In June 2008, construction of the diversion wall in Lake Rotoiti was completed. This wall guides the outflow from Lake Rotorua around the edge of Lake Rotoiti to the mouth of the Kaituna River, which is the outlet for Rotoiti. The intent of this diversion is to divert nutrients in the water of Lake Rotorua from entering Lake Rotoiti.

Concerns that this wall may also divert or restrict fish movements between the two lakes were raised by the Eastern Fish and Game Council and later by local iwi. Migrations of smelt up the Ohau Channel (from Lake Rotoiti into Lake Rotorua) were known to occur (Mitchell 1989; Donald 1996) and these supported a small iwi fishery in the channel. In addition, the runs of smelt attracted trout and resulted in a localised and seasonal trout fishery at the entrance to the channel. This is thought to occur when high water levels occur in the channel and the flow over a weir just below the entrance creates a velocity barrier which restricts the upstream movement of smelt. Large aggregations of smelt build up behind the weir and attract trout, as well as other predators such as shags and gulls (see photo on front cover). Anglers were concerned that if the diversion wall prevented the upstream migration of smelt in the channel, the trout fishery at the channel mouth could be affected. Similarly, local iwi were concerned that the diversion wall may prevent smelt migrations up the channel and so destroy the smelt fishery. These localised issues aside, the role of the migratory smelt in the wider dynamics of the smelt population of Lake Rotoiti was unknown, but was of concern because smelt are the main food for trout in this lake (Rowe 1984). A decline in smelt recruitment to Lake Rotoiti could reduce trout production in this nationally significant fishery.

These potential issues were listed in an impact assessment report commissioned by Environment Bay of Plenty (Rowe et al. 2006). This described the possible mechanisms and pathways by which an impact on smelt and trout might arise. The AEE also pointed out that the diversion wall was an essential measure, because failure to halt the nutrient flow from Lake Rotorua into Lake Rotoiti would inevitably lead to the long-term deterioration of water quality and fish habitat in the lake, resulting in the decline of both trout and smelt populations. Subsequently, Environment Bay of Plenty commissioned NIWA to carry out a series of investigations to determine the best options for monitoring smelt in the channel and lake, and to establish a monitoring baseline for detecting any impacts.

The Environment Court approved the application by Environment Bay of Plenty to construct the diversion wall and placed a number of conditions on the consent. These required pre-wall monitoring to establish a baseline, and then post-wall monitoring of smelt in both the Ohau Channel and in Lake Rotoiti to determine whether the wall affected smelt migrations in the channel and/or smelt abundance and recruitment in Lake Rotoiti. Provision was made in the consents for the creation of a small pass in the wall to allow passage for smelt, should the monitoring indicate the need for this.

Pre-wall monitoring was carried out in 2005/2006 and 2007/2008 to provide a baseline and construction of the diversion was completed in June 2008. As there can be a delay of a year or more before fish populations respond to changes in their environment, monitoring in 2008/2009 was not expected to provide a true post-wall comparison. Monitoring in 2009/2010 therefore provided the first valid opportunity to detect any impact of the wall on smelt. Monitoring in 2010/2011 was repeated to confirm the results obtained in 2009/2010.

This report provides the results of monitoring carried out during the 2010/2011 year and relates these to the results obtained over the past five years. Overall. the annual monitoring was designed to determine: (a) whether or not smelt migrations continue in the Ohau Channel; and (b) whether the smelt population in Lake Rotoiti remains stable (within the limits of natural annual variability in population size) or declines to the point where trout production could be affected. Methods used have not changed between monitoring years so that the results for 2010/2011 can be compared directly with the results from previous years reported in Rowe et al. (2006; 2008; 2009; 2010).

3 Methods

3.1 Smelt migrations in the Ohau Channel

The location of the four sites (2 upstream, 2 downstream) used to monitor smelt movements in the Ohau Channel are shown in Figure 3-1.

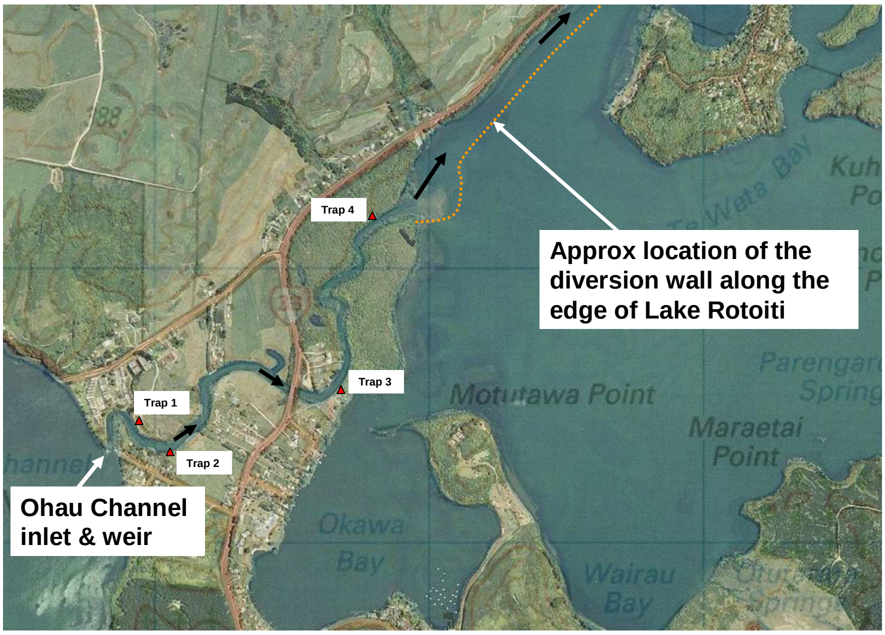

Figure 3-1: Location of smelt trapping sites (red triangles) in the Ohau Channel (black arrows indicate the direction of water flow).

Trapping was carried out at two to three week intervals during the nine month period from 16th September 2010 until 9th June 2011. 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. 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 and the total time for which the traps were fished were recorded and, depending on the number of fish present, all or a subsample were removed for determining the proportion of juveniles to 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 catch per unit of effort (CPUE) for smelt on each sampling date was calculated as the total catch for all four traps per day 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 after 2006. Shags are predators of smelt and their abundance provides an additional measure to detect the presence of high densities of smelt occurring during migrations (commonly termed runs).

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 common bullies, koaro and trout were also recorded. Daily observations of birds and anglers fishing near the mouth of the Ohau Channel were recorded by Mr George Proud for long periods of time throughout the monitoring period. These are also reported as they provide a measure of temporal variation in the channel trout fishery and complement the measurement of smelt runs.

3.2 Adult smelt density

Acoustic surveys designed to determine trout abundance were carried out in Lake Rotoiti in September 2000 for the Eastern Fish and Game Council (Rowe et al. 2001a, 2001b). The data from these surveys were re-analysed to provide a measure of adult smelt abundance. Juvenile smelt are not included in this estimate as they occur in large schools near surface waters (0-5 m) and so are not amenable to acoustic sampling. The same survey has been repeated annually from 2005 to 2010 using the same transects (Figure 3-2) used in the September 2000 survey.

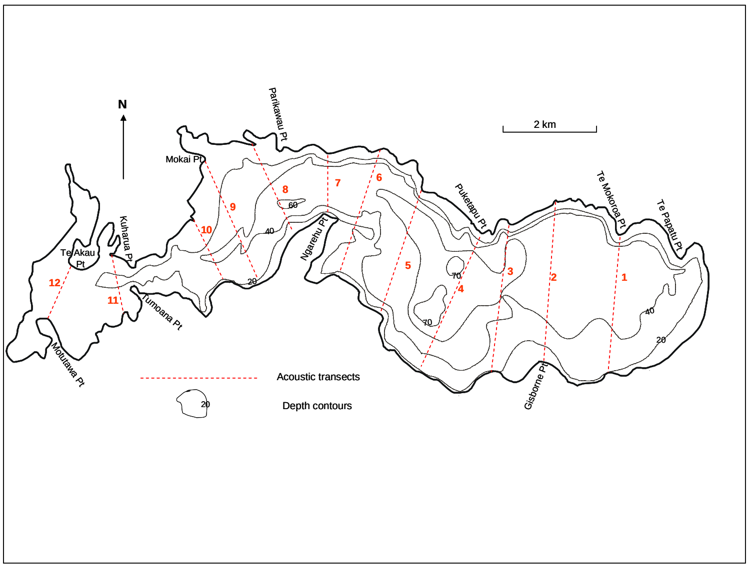

Figure 3-2: Transects (dashed red lines, labelled 1-12) used for the acoustic survey of Lake Rotoiti in September 2010.

The September 2010 survey was carried out with the SIMRAD EK60 machine operating at 120 kHz, with the transducer mounted in a V-fin which was towed at a depth of 2-3 m below the boat. The V-fin is borrowed from the Department of Conservation (Turangi) and ensures vertical and horizontal stability of the transducer when wave action from strong winds is high and the boat pitches and rolls. The 2010 survey was carried out on 15th September 2010.

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 acoustically surveyed along each transect and the data saved for later processing. This processing involved identification and delineation (on the echogram for each transect) of the fish layer, within which the adult smelt occurred (i.e., echoes with target strengths ranging between -55dB and -45dB mostly at depths between 30-50 m).

This process excludes larval bullies (target strength -60 to -70 dB and depth range10-20 m) and the smaller, juvenile smelt that are present mainly in surface waters (0-5 m) and which are not amenable to acoustic sampling. However, in 2009 and 2011, some schools of fish were observed in shallow waters (10-20 m), above the adult smelt layer and the target strengths of individual echoes indicated that they were adult smelt. As a consequence they were also delineated and marked for later processing.

The acoustic data present in the adult smelt regions of each transect were analysed using ESP2 (McNeil et al. 2003) to determine the total amount of acoustic backscatter received from each region (i.e., a measure of the total sound energy reflected by the fish present within a depth delineated region on each transect). This process can be expected to include backscatter from adult rainbow trout and some larval bullies present in these regions. However, trout are generally present in shallower waters above the adult smelt layer (Rowe & Chisnall 1995) with adult smelt occupying deeper waters in lakes to avoid trout predation. Overlap in distributions is therefore generally 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 total amount of backscatter produced in the adult smelt regions for each transect was calculated for the 2010 survey and divided by the backscatter produced by a single adult smelt (based on its modal target strength) to provide an estimate of total smelt number per m^2 per transect. This was compared with the equivalent estimates for 2005 to 2009 to identify any changes in the spatial patterns of smelt abundance in the lake.

The mean abundance of smelt across all transects was calculated to provide a basin-wide estimate of adult smelt abundance. Regression analysis was used to determine the statistical significance of temporal trends in abundance.

3.3 Larval smelt density

Larval smelt in Lake Rotoiti are sampled to determine whether a natural drop in recruitment could account for any marked decline in smelt abundance. Smelt have an extended spawning period lasting from spring until the end of summer. Eggs are deposited on clean sand in shallow (0.5-2 m deep) waters around the lake margin as well as in shallower waters on the sandy substrate of inlet streams. The larvae hatch in 10-25 days (depending on lake water temperature) and become pelagic. Newly hatched larvae are around 6-7 mm long and are transparent. In general, larvae remain in the water column until they reach a length of 25 mm. They have no air- bladder so, unlike the smaller larval bullies that do possess an air bladder, they cannot be detected acoustically, even at high frequencies (i.e., 200 kHz). Smelt spawning occurs between September and April, hence the monthly or seasonal period for peak larval smelt density in lakes is unknown. The growth rate of larvae in lakes is also unknown, but studies on the growth rate of the very similar galaxiid larvae at sea indicate that such larvae are likely to remain in the pelagic zone for 3-5 months before they metamorphose and become juveniles. 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 (spring and summer).

Vertical drop netting using a closable Wisconsin plankton net (mouth area of 0.25m^2, mesh size 250µm) was used to sample larval smelt throughout the water column (surface to near the lake-bed) of Lake Rotoiti in December 2010 and in April 2011. 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 mm. Secchi disc depth was also measured because the overall number of smelt larvae in lakes has been found to co-vary with water transparency (Rowe & Taumoepeau 2004). The lake-wide mean catch of larval smelt for the summer period (December plus April) was calculated for the 2010/2011 spawning season and expressed in relation to secchi disc depth to indicate any change in density independent of changes in water clarity. The data for 2010/2011 were then compared to those for previous years to determine any significant trend.

4 Results

4.1 Smelt movements up the Ohau Channel

The proportions of smelt caught by the four traps are shown in Figure 4-1. As in the past, most smelt were caught by trap 1. An exception occurred on 21 February 2011 when trap 1 was out of action. The platform supporting the trap had been eroded by the high flows and had collapsed. This was repaired in time for the next scheduled sampling, a fortnight later.

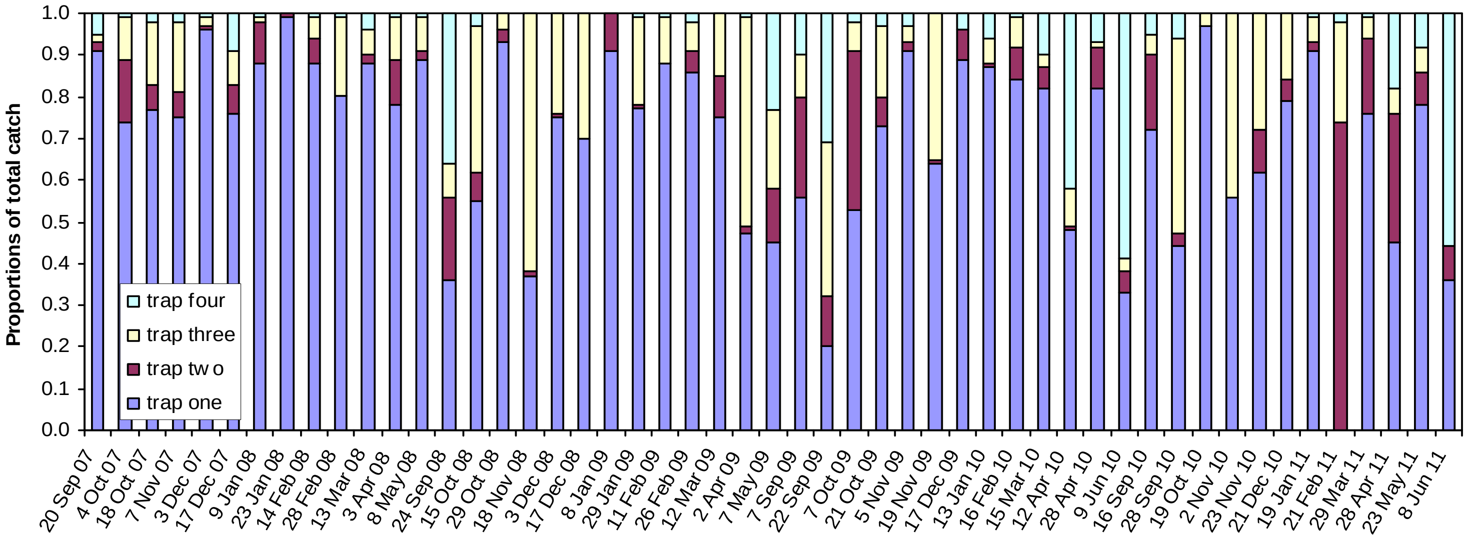

Figure 4-1: Proportion of the total smelt catch caught by each of the four traps in the Ohau Channel between September 2007 and June 2011.

Flow rates in the Ohau Channel were generally higher during the 2010-2011 year than in previous years (Fig. 4-2) and water velocities were generally higher at sites 1 and 3, but not 2 and 4 (Fig. 4-3).

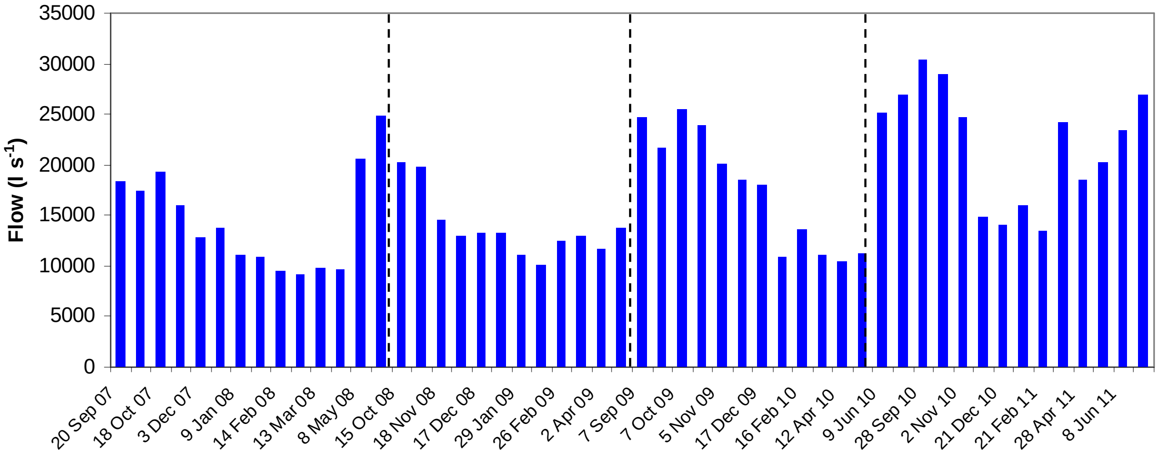

Figure 4-2: Flows in the Ohau Channel at the time of sampling from September 2007 to June 2011.

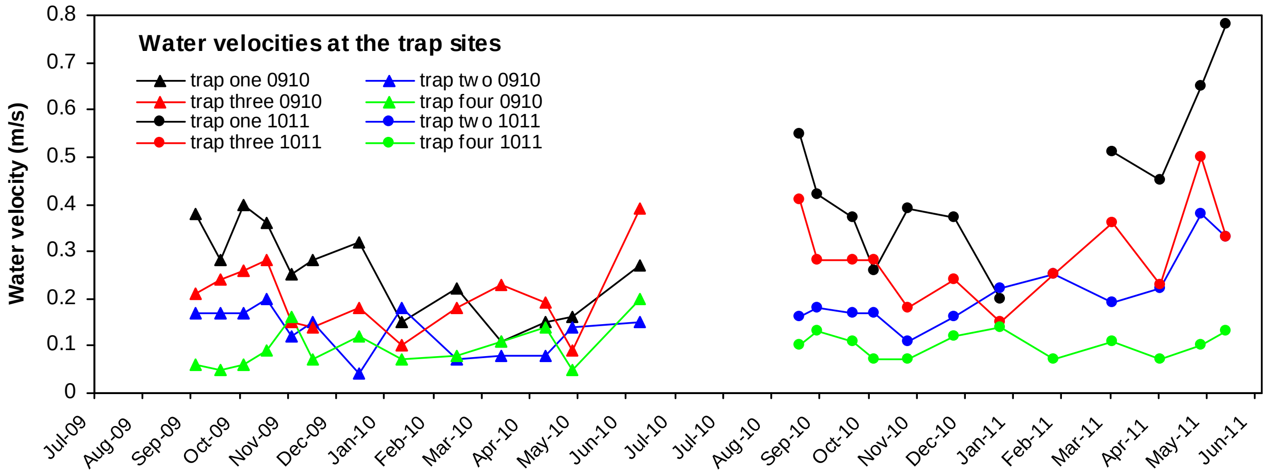

Figure 4-3: Water velocities at the mouth of each trap in the Ohau Channel- September 2007 to June 2011.

The daily catch rate of smelt peaked on 29 March 2011 at 9.5 fish minute^{-1} (Fig. 4-4). This is the highest abundance of smelt recorded in the channel since 2007, and was well above the peak of 3.5 recorded on 7 October 2009, when a run of adult smelt occurred in the channel and attracted large numbers of shags, gulls, trout and anglers (Rowe et al. 2010). Smelt abundance in the Ohau Channel was almost as high (8.0 fish minute^{-1}) on 28 April 2011, declining to 5.1 fish minute^{-1} by 23 May 2011.

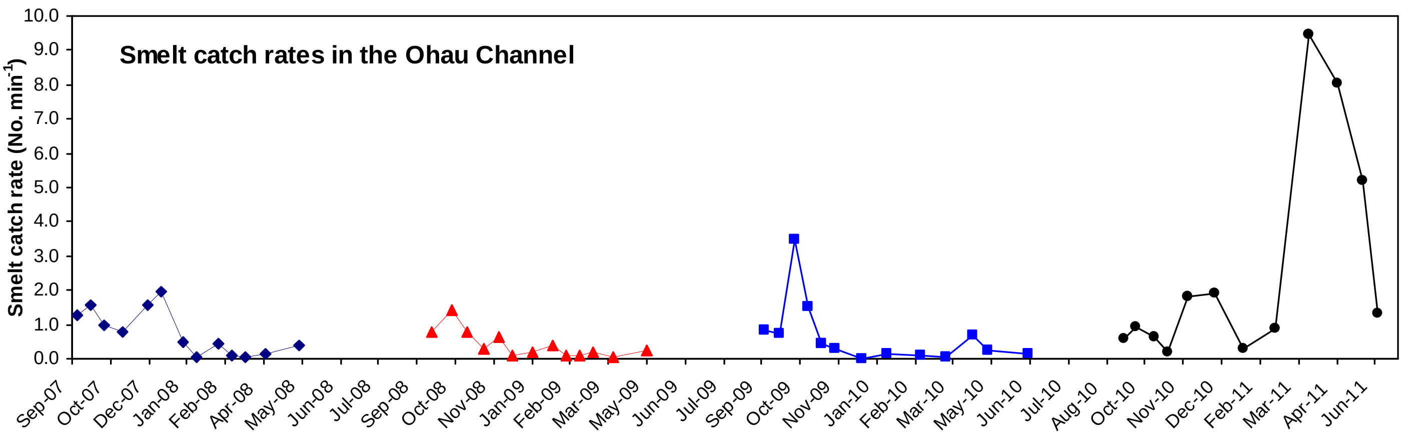

Figure 4-4: Daily catch rate for smelt in the Ohau Channel on each sampling date between September 2007 and June 2011.

The high numbers of smelt recorded on 29 March 2011 comprised mainly juvenile fish (72%, Fig. 4-5), with the run recorded on 28 April 2011 containing similar numbers of adults and juveniles. By 23 May 2011, the run was dominated by adult smelt (Fig. 4.5).

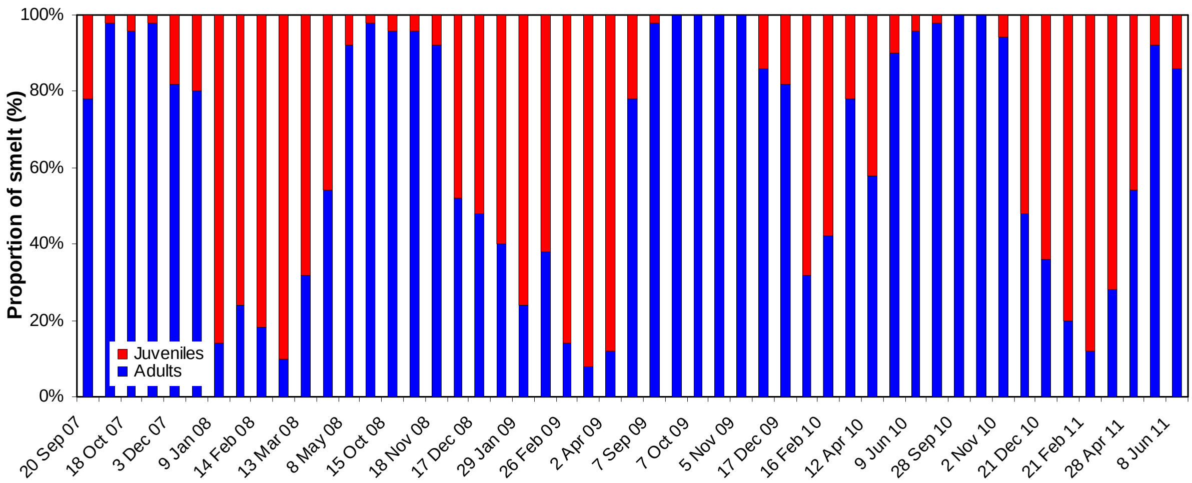

Figure 4-5: Proportions of juvenile versus adult smelt in Ohau Channel traps on each sampling occasion between September 2007 and June 2011.

There was no observable increase in shag numbers in the channel during May 2011 (Fig. 4-6). This was somewhat surprising, because large numbers of shags occurred in the vicinity of the Channel during the upstream migrations of adult smelt in spring 2009. These predators may feed elsewhere during autumn months, or may feed on adult rather than juvenile smelt.

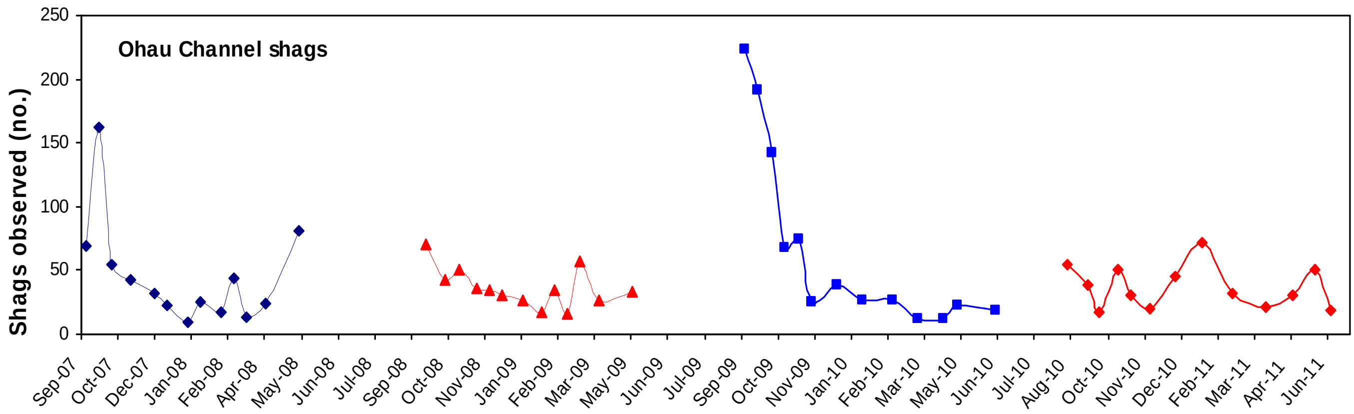

Figure 4-6: Number of shags (*Phalacrocorax* spp.) observed along the sides of the Ohau Channel on each sampling occasion between September 2007 and June 2011.

The clarity of water in the Ohau Channel exhibited a similar range (0.8-2.5 m) to that in previous years and was relatively high in April 2011 (Fig. 4-7). Reduced water clarity (and hence reduced ability to visually locate prey) would not account for the scarcity of shags in the Channel at this time.

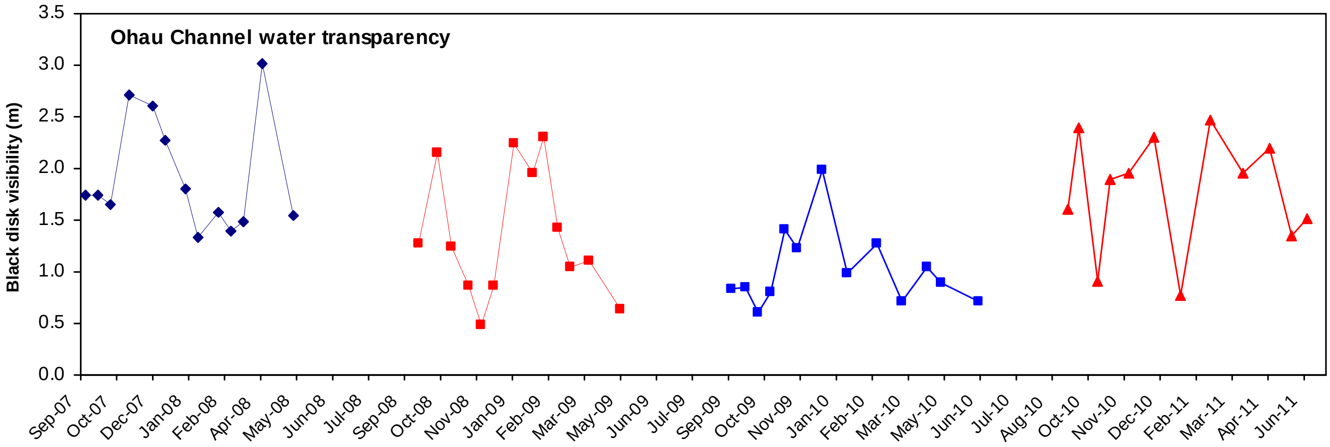

Figure 4-7: Water transparency in the Ohau Channel on each sampling date between September 2007 and June 2011.

The by-catch of common bullies (Fig. 4-8) showed no major trend or difference relative to previous years, and the number of trout and koaro was again minimal (<20 per annum). However, the number of koura caught increased over the 2010-2011 season (Fig. 4-9).

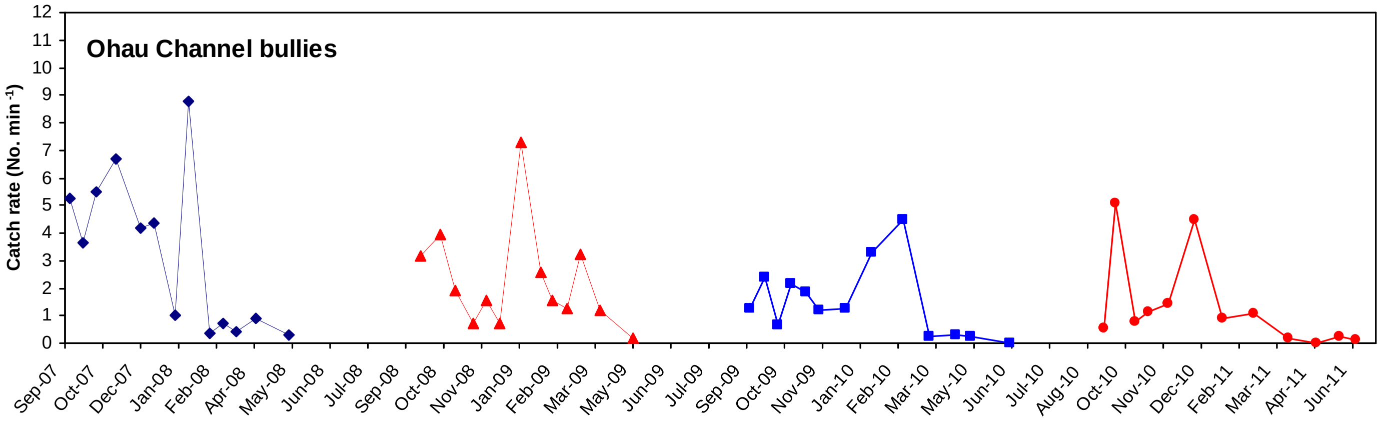

Figure 4-8: Catch rate for common bullies in the Ohau Channel on each sampling date between September 2007 and June 2011.

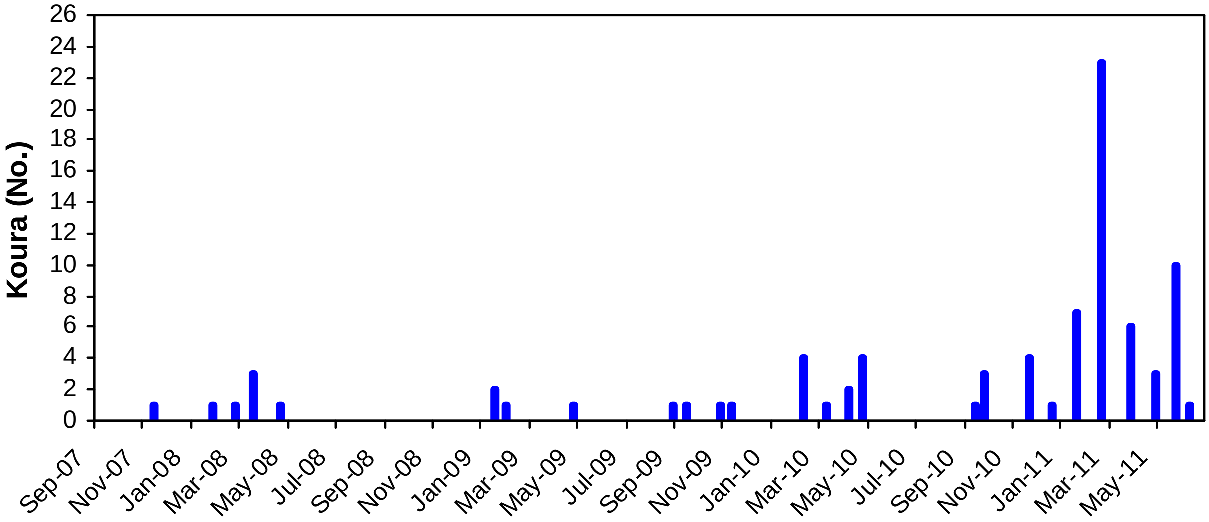

Figure 4-9: Total number of freshwater crayfish (koura) caught by daily trapping in the Ohau Channel, September 2007 to June 2011.

Observations on trout angler activity, birdlife and the relative abundance of smelt in the Ohau Channel provided by Mr George Proud are recorded in Appendix 1. These observations indicated that large numbers of smelt are likely to have occurred in the channel on at least two days in spring (22 October, 5 November 2010) and for longer periods in autumn (March and April 2011). Adults dominated catches in spring 2010 (Fig 4-5) so the large numbers of smelt observed at this time would have been adults. Although the trapping did not record a spring migration of adult smelt, these observations suggest that migrations did occur in 2010 albeit not on the days when trapping was scheduled.

4.2 Adult smelt density

In September 2010, the density of adult smelt was again higher in the deeper, eastern basin of the lake (transects 1-5) than in the shallower western basin (transects 6-12). Once again it tended to decline in an east to west direction (i.e., from transect 1 to 12) (Fig. 4-10).

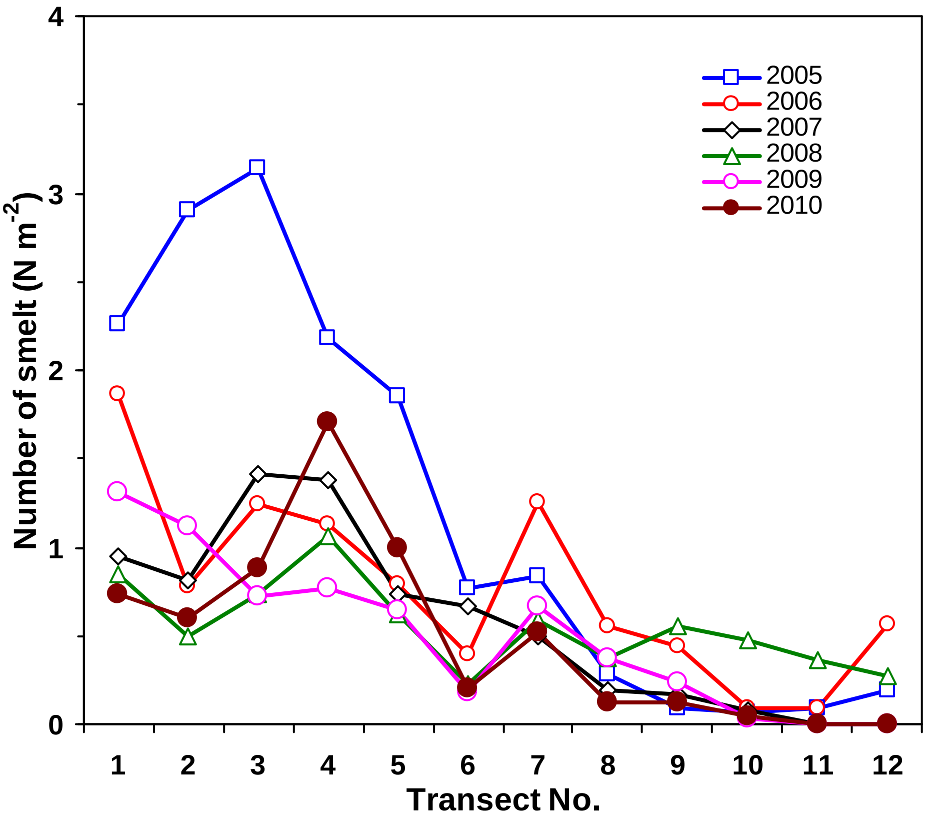

Figure 4-10: Spatial differences in the density of adult smelt in Lake Rotoiti on 15 September 2010 compared to previous surveys.

Data have now been obtained for six years and some consistent differences in density among transects are apparent. Although there is an overall decline in adult smelt density from east to west, the mean density of smelt in transect 2 is often lower than in transects 1 and 3 (4 out of 6 years). Similarly, smelt density in transect 7 is generally higher than in transects 6 and 8 (5 out of 6 years). The low densities of smelt that tend to characterise transects 2 and 6 relative to adjacent transects are not related to transect length (Fig. 3-2) and therefore represent a persistent, within-lake, spatial pattern in abundance. Reasons for such a pattern are unknown but can be expected to be related to interactions among lake hydrodynamics in September, the resultant spatial pattern of zooplankton abundance at this time, and trout predation patterns.

The frequency distribution of individual target strengths indicated that the modal size of adult smelt in September 2010 was again -56 dB (Fig. 4-11). This is consistent with smelt size in 2005, 2008, and 2009. Smelt were much larger (-52 dB) in 2007, and less so (-54 dB) in 2006.

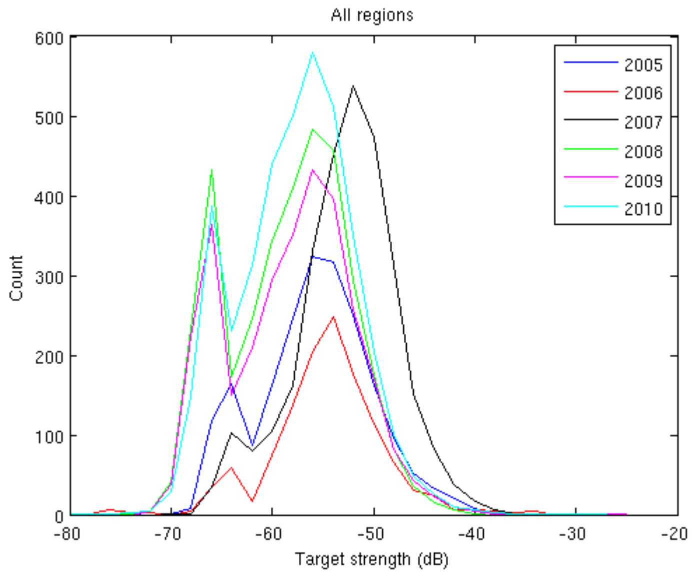

Figure 4-11: Modal target strength for echoes obtained via a 120 kHz echosounder in Lake Rotoiti during each September survey from 2005 to 2010.

To provide a lake-wide estimate of smelt abundance (i.e., irrespective of spatial differences), the mean density of adult smelt was determined for all 12 transects. In September 2010, this was close to 0.50 smelt per m^{-2} and was no different to that recorded annually since 2007 (Fig. 4.12). Standard deviation bars represent the annual variation in smelt density among transects, and hence provide a measure of the spatial variation in smelt throughout the lake.

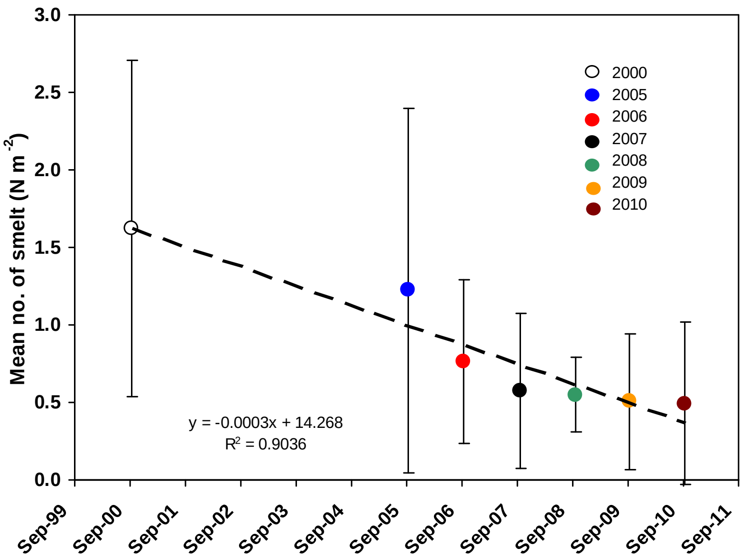

Figure 4-12: Mean density (±SD) of adult smelt estimated from acoustic surveys in Lake Rotoiti in September 2000 and annually from 2005 to 2011. Dashed line is the linear regression.

4.3 Larval smelt density

Mean catch rates for larval smelt in December 2010 and April 2011 were not as high as in December 2009 and April 2010 (Table 4-1). However, they were higher than in December 2005 and April 2006.

Summer	Net hauls per survey	Mean catch rate (N net-haul^{-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

Table 4-1: Mean catch rates for larval smelt in Lake Rotoiti between 2005 and 2011.

The overall mean catch of smelt larvae in Lake Rotoiti for the 2010/2011 summer period (i.e., data for December and April pooled) was 0.89 larvae net-haul^{-1} (Table 4-1). Differences between the means were significant (ANOVA, $F = 16.7$, $P<0.001$) and the catch rate for the 2010/2011 season was lower than the mean catch rate of 2.1 larvae net-haul^{-1} recorded in summer 2009/2011, but no different to the rates obtained in the 2007/2008 and 2008/2009 seasons.

Larval smelt abundance is correlated with lake water clarity, and the mean secchi disc depth for the December 2010 and April 2011 sampling periods (4.3 m) was lower than in the past four years (Fig. 4-13). A sustainable increase in larval smelt density would not be expected until summer secchi disc depths in Lake Rotoiti exceed 6 m. The relatively high density of larvae recorded during the 2009/2010 summer, when secchi disc was 5.6 m, was not repeated during the 20010/2011 summer.

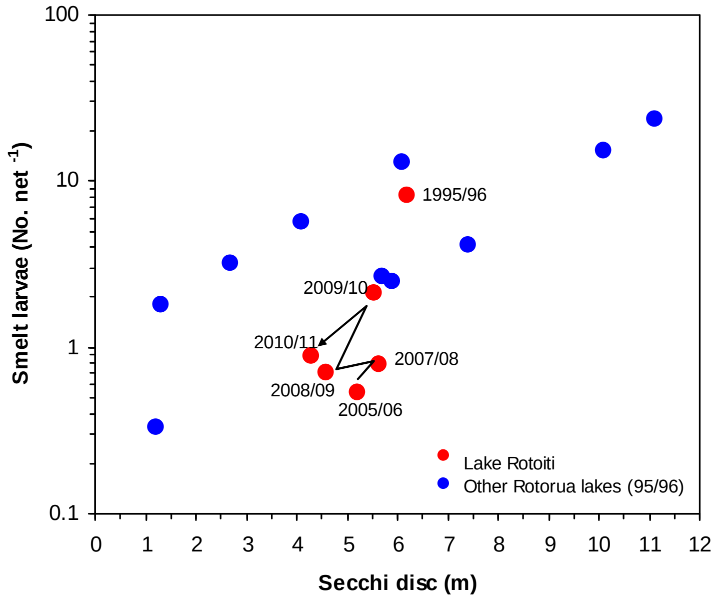

Figure 4-13: Mean abundance of larval smelt (No. net-haul^{-1}) in Lake Rotoiti for each summer season from 2005/2006 to 2010/2011 (red circles) versus mean secchi disc depth. Black arrows indicate change over time. Blue circles are data for other lakes showing the relationship between larval smelt abundance and water transparency that provides the context for interpreting changes in Lake Rotoiti.

The length frequency distribution of larval smelt for each sampling period indicated that recently hatched larvae (TL < 5 mm) occurred in both the December and April samples for 2010 and 2011 respectively (Table 4-3). This pattern also occurred over the 2009/2010 summer period, indicating that smelt spawning occurs over an extended summer period in Lake Rotoiti.

Length range	2005/2006		2007/2008		2008/2009		2009/2010		2010/2011	
(TL mm)	Dec	Apr	Dec	Apr	Dec	Apr	Dec	Apr	Dec	Apr
0-5				4			3	1	2	2
6-10	6	4	12	16	13	5	30	19	9	13
11-15	3	3	7	6	9	7	38	25	6	13
16-20			0	3	7	1	7	7	7	2
21-25			1		1		2			

Table 4-2: Length frequency distributions for larval smelt in Lake Rotoiti between 2005 and 2011. Data are the number of fish per length class.

5 Discussion

Migrations of smelt up the Ohau Channel were first described by Jolly (1967). In 1957, she observed migrations from Lake Rotoiti into Lake Rotorua by way of the Ohau Channel and noted that local Maori netted the migratory smelt for food. The migrations occurred in spring and autumn, and she found that the proportions of adults to juveniles varied in autumn. Mitchell (1989) noted that migrations of juvenile smelt occurred in autumn (March-April), whereas mature adults migrated mostly in spring (October-December). This seasonal difference in the migration of adults versus juveniles was later confirmed by Donald (1996) who found that adults were present in November 1995 and were 40-60 mm long, whereas juveniles were present in February 1996 and ranged from 29 to 50 mm.

These studies confirmed the existence of seasonal smelt migrations of both adult and juvenile smelt up the Ohau Channel, but there were no data to indicate whether these runs occurred every year, nor whether the seasonal timing of the runs varied from year to year.

Prior to installation of the diversion wall, NIWA carried out fortnightly monitoring of smelt movements up the Ohau Channel and found that migrations of juveniles occurred over a 3-4 week period between January and February 2006, with adults migrating over a shorter 1-2 week period in August 2006 (Fig. 5-1). No migration of adult or juvenile smelt was recorded between September 2007 and May 2008 (i.e., before the diversion wall was completed), nor between September 2008 and June 2009 (the first summer after wall completion).

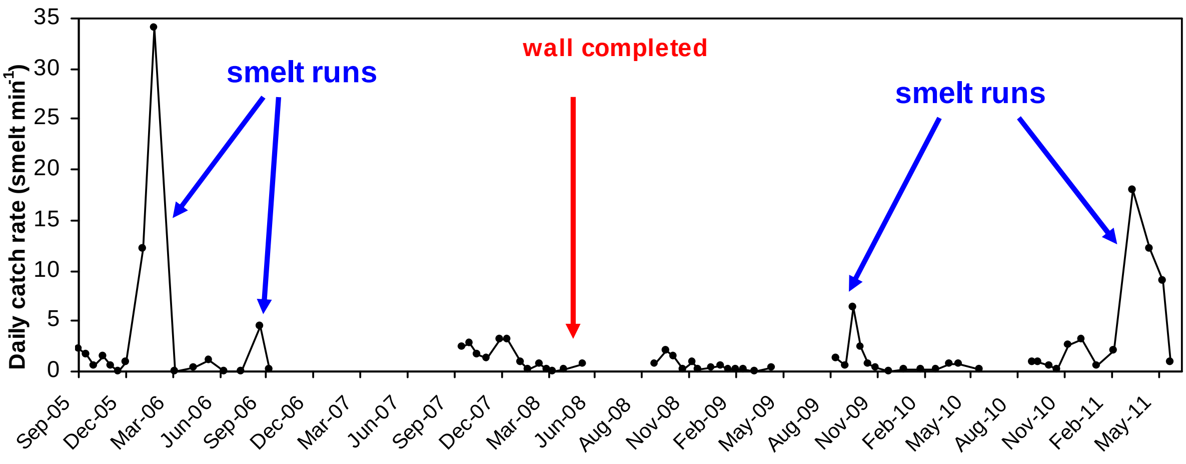

Figure 5-1: Long term change in the mean CPUE of smelt in the Ohau Channel using data from traps 1 and 2 (traps 3 and 4 were not installed until the 2007/2008 year).

In October 2009, a migration of mature adults was recorded in the Ohau Channel indicating that the presence of the wall was not a barrier to adult smelt. Because the smaller, and hence weaker-swimming, juvenile smelt may not be able to penetrate as far up the channel as adults, monitoring was continued for another year and, in April 2011, a migration of juveniles was recorded (Fig. 5-1). In addition, observations of smelt activity in the channel (Appendix 1) indicated that a high number of smelt occurred there during at least two days in spring 2010 and during a longer period in autumn 2011.

Migrations of both juvenile and adult smelt have therefore now been recorded up the Ohau Channel to the weir near its mouth. It is apparent from both the measurements and observations obtained over the past two years that the diversion wall is not a barrier to either juvenile or adult smelt, and that smelt migrations up the channel are not prevented by the diversion wall.

The long term (5 year), fine-scale (fortnightly) monitoring has confirmed that migrations of smelt from Lake Rotoiti into Lake Rotorua are still possible. Moreover, it indicates that the runs of both juveniles in spring and adults in autumn can vary both with time (e.g., on one day but not the next), and in duration (e.g., from one day to periods of weeks). The reasons for such temporal variability in the annual and seasonal timing of the smelt migrations between Rotoiti and Rotorua are not yet understood.

Jolly (1967) hypothesized that such migrations may result in a net loss of smelt from Lake Rotoiti and so result in a reduction in smelt density in this lake. However, smelt abundance in the Rotorua lakes also declines as lake water quality deteriorates and water transparency (measured by secchi disc depth) decreases. The acoustic surveys carried out in Lake Rotoiti over the past 6 years indicate that the September abundance of adult smelt in this lake declined between 2000 and 2007, but that this decline has tended to level off over the past 4 years. This may indicate that a decline in smelt recruitment in Lake Rotoiti has been halted, or that predation pressure on adult smelt is no longer increasing. Such questions cannot be answered with any great certainty at present because they depend on knowledge of variation in both the annual recruitment of smelt and mortality rates from trout predation.

The September water transparency in Lake Rotoiti has not changed greatly over the past 6 years (range 4.3 to 5.7 m) but is still lower than it was in 1995 (6.2 m), when larval smelt density was higher. The recruitment of larval smelt in Lake Rotoiti is therefore not expected to be as high as it was in 1995, and would not even be expected to increase significantly until water transparency as measured by secchi disc depth increases to 6 m or more. Even then, it may not increase because the recently approved changes in the operation of the level of Lake Rotoiti may now act to reduce smelt recruitment. In particular, the new lake level regime which requires a minimum level in June and a maximum level in August, contrasts greatly with the lake’s natural pattern of water level variation (minimum in late summer, maximum in spring). As a consequence, much of the smelt spawning habitat (sandy substrates between 0.5 and 2.5 m deep) in this lake may soon be compromised by the shallower encroachment of weed and/or by siltation. Resulting changes in littoral zone wave dynamics and disturbance may also encourage an increase in predators of smelt eggs (i.e., common bully). These changes in lake level regime may therefore act to further reduce smelt recruitment in Lake Rotoiti and compromise any future monitoring designed to disentangle the effects of the diversion wall from other factors affecting smelt abundance in this lake.

6. Conclusions

Monitoring of smelt in the Ohau Channel and in Lake Rotoiti for two years before and two years after the completion of the diversion wall has shown that: (a) the wall is not a physical barrier to the upstream movement of juvenile or adult smelt; (b) migrations of juvenile and adult smelt still occur up the Ohau Channel during spring and autumn respectively; (c) there has been no significant, nor sustained drop in the abundance of adult smelt in Lake Rotoiti following the wall's construction; and (d) larval recruitment in Lake Rotoiti has not diminished significantly since the wall's completion. Taken together, these results indicate that the diversion wall has had no major negative impact on smelt in Lake Rotoiti to date, and is not expected to have any adverse effect on smelt migrations in the Ohau Channel. In particular, there is no need for the construction of a fish pass for smelt in the wall to facilitate their upstream passage to Lake Rotorua.

These conclusions indicate that further monitoring of smelt, at least at the same effort and intensity as used to date, is no longer required.

7 Acknowledgements

We thank Joe Butterworth and Brent Caldwell for their assistance with the smelt trapping and Fleur Matheson who helped with the larval smelt sampling. We also acknowledge the very useful observations provided by George Proud.

8 References

Donald, R. (1996). An assessment of smelt migrations over the Ohau Channel fish pass. *Environment Bay of Plenty, Environmental Report 96/8*.

Jolly, V.J. (1967). Observtions on the smelt *Retropinna lacustris* Stokell. *New Zealand Journal of Sceince 10*: 330–355.

McNeil, E.; Macaulay, G.; Dunford, A. (2003). ESP2 (Phase 5): User Documentation, Version 1.94.

Mitchell, C.P. (1989). Environmental assessment of the Lake Rotorua control structure. *New Zealand Freshwater Fisheries Miscellaneous Report 24.*

Rowe, D.K. (1984). Factors affecting the foods and feeding patterns of lake-dwelling rainbow trout (*Salmo gairdnerii*) in the North Island of New Zealand. *New Zealand Journal of Marine and Freshwater Research 18*: 129–141.

Rowe, D.K.; Chisnall, B.L. (1995). Effects of oxygen, temperature and light gradients on the habitat and depth distribution of adult rainbow trout (*Oncorhynchus mykiss*) in two central North Island lakes, New Zealand. *New Zealand Journal of Marine and Freshwater Research 29:* 421–434.

Rowe, D.K.; Macaulay, G.; Pitkethely, R. (2001a). Acoustic estimation of trout abundance in Lake Rotoiti before and after stocking in September 2000. *NIWA Client Report NZF01504*.

Rowe, D.K.; Macaulay, G.; Pitkethley, R.; Dunford, A. (2001b). Acoustic estimation of trout abundance in Lake Rotoiti – differences between duplicate surveys taken 3 days apart in June 2000. *NIWA Client Report NZF01504/2*.

Rowe, D.K.; Taumoepeau, A. (2004). Decline of common smelt (*Retropinna retropinna*) in turbid, eutrophic lakes in the North Island of New Zealand. *Hydrobiologia 523*: *149–158.*

Rowe, D.K.; Richardson, J.; Boubee, J.; Dunford, A.; Bowman, E. (2006). Potential effects of diverting Ohau Channel water out of Lake Rotoiti. *NIWA Client Report HAM2006-116.*

Rowe, D.K.; Bowman, E.; Dunford, A.; Smith, J. (2008). Smelt in Lake Rotoiti and the Ohau Channel, 2007-2008. *NIWA Client Report HAM2008-081.*

Rowe, D.K.; Bowman, E.; Dunford, A.; Smith, J. (2009). Smelt in Lake Rotoiti and the Ohau Channel, 2008-2009. *NIWA Client Report HAM2009-077.*

Rowe, D.K.; Bowman, E.; Dunford, A.; Smith, J. (2010). Smelt in Lake Rotoiti and the Ohau Channel, 2009-2010. *NIWA Client Report HAM2010-064.*

9 Appendix 1

Date	Observation
28/08/2010	Bird count only NIWA gauging.
16/09/2010	1 st NIWA smelt survey
28/09/2010	2 nd NIWA smelt survey
1/10/2010	6.30 am. Few shags. No gulls, few herons. One hundred plus anglers and some fish caught. No smelt.
1/10/2010	7.30 pm. No shags, gulls or herons, 30+ anglers and some fish caught. No smelt evident.
2/10/2010	7.30 am. A few shags and gulls. No herons, 15 anglers and some fish caught. No smelt seen.
2/10/2010	7.30pm. A few shags, no gulls, few herons, 12 anglers and some fish caught. No smelt seen.
3/10/2010	6.30 pm. No shags or gulls. A few herons, 11 anglers and no fish caught. No smelt evident.
4/10/2010	6.00 am. 10-20 shags, a lot of gulls >20, 13 anglers and fish caught. A few smelt evident.
4/10/2010	7.00 pm. No shags or gulls. A few herons, 7 anglers and no fish caught. No smelt evident.
8/10/2010	6.30am. 10-20 shags and 10-20 gulls. A few herons, 11 anglers, some trout caught, a few smelt seen.
8/10/2010	7.30 pm. A few shags, No gulls and a few herons. Twenty plus anglers and some fish caught. No smelt evident.
10/10/2010	6.30 am. A lot of shags >20, 10-20 gulls and 5-10 herons. Four anglers and fish caught. No smelt evident.
10/10/2010	7.30 pm. A lot of shags >20, 10-20 gulls and a few herons. Five anglers and fish caught. No smelt evident.
13/10/2010	6.30 pm. A few shags and gulls and 5-10 herons. Three anglers and fish caught. No smelt evident.
16/10/2010	7.00 pm. A few shags, no gulls and 5-10 herons. One angler and no fish caught. A few smelt evident.
17/10/2010	6.30 am. 10-20 shags, 10-20 gulls and a few herons. Two anglers and no fish caught. A few smelt evident.
18/10/2010	7.00 am. 10-20 shags, many gulls > 20 and 10-20 herons. Six anglers and no fish caught. A few smelt evident.
18/10/2010	7.30 pm. A few shags, No gulls and a few herons. Three anglers and some fish caught. A few smelt evident.
19/10/2010	3rd NIWA survey
22/10/2010	7.00 pm. A few shags, no gulls and 5-10 herons. Eight anglers and some fish caught. A lot of smelt evident.
23/10/2010	7.30 am. 5-10 shags and 10-20 gulls. A few herons. 12 anglers and some fish caught. No few smelt evident.
24/10/2010	9.30 am, 5-10 shags, 5-10 gulls and a few herons. 20 anglers and some fish caught. No smelt evident.
24/10/2010	7.30 pm. A few shags, no gulls and 5 - 10 herons. One anglers and no fish caught. No smelt evident.
28/10/2010	8.00 pm. No shags or gulls and 5 - 10 herons. Seven anglers and some fish caught. No smelt evident.
30/10/2010	7.00 am. No shags, 5 - 10 gulls and a few herons. Two anglers and no fish caught. No smelt evident.
2/11/2010	4 th NIWA survey
5/11/2010	6.30 pm. Shags 5-10, Gulls 10-20 and herons 10-20. Four anglers and fish caught. A lot of smelt evident.
7/11/2010	7.30 pm. Shags 5-10, A few gulls and 10-20 herons. Three anglers and fish caught. A few smelt seen.
9/11/2010	8.00 pm. Shags 10-20, A few gulls and 5-10 herons. Three anglers and no fish caught. A few smelt seen.
11/11/2010	6.00am. Shags 10-20, Gull 10-20 and herons 5-10. Four anglers and fish caught. A few smelt seen.
13/11/2010	8.00 pm. Shags 5-10, No gulls and herons 5-10. Two anglers and fish caught. No smelt seen.
14/11/2010	7.30 am. A few shags, gulls and herons. Two anglers and no fish caught. No smelt seen.
15/11/2010	7.30 am. Shags 10-20, gulls 10-20 and herons 5-10. No anglers and smelt seen.
20/11/2010	8.30 pm. No shags or Gulls. Herons 10-20. Five anglers and fish caught. No smelt seen.
21/11/2010	7.30 am. Shags 5-10 and no gulls or herons. One anglers and fish caught. No smelt seen.
23/11/2010	5 th NIWA survey
24/11/2010	8.30 pm. Shags 10-20. No gulls and 5-10 herons. Four anglers and fish caught. No smelt seen.
29/11/2010	8.00 pm. Shags 5-10, gulls 5-10 and a few herons. No anglers and no smelt seen.
6/12/2010	8.00 pm. A few shags and gulls. Herons 5-10. No anglers and no smelt.
10/12/2010	7.00am. Shags 10-20 and a lot of gulls. A few herons. One anglers and fish caught. A few smelt seen.
11/12/2010	7.30 am. Shags 5-10 and lots of gulls. Herons 5-10. No anglers or smelt.
11/12/2010	8.45 pm. Shags 0-5, gulls 0-5 and herons 5-10. One anglers and fish caught. No smelt seen.

Date	Observation
18/12/2010	8.00 am. Shags 5-10, gulls 10-20 and herons 0-5. No anglers and no smelt seen.
18/12/2010	7.15 pm. Shags 10-20, no gulls and herons 0-5. No anglers and a few smelt seen.
20/12/2010	7.45 am. Shags 0-5, no gulls and herons 0-5. No anglers and a few smelt seen.
21/12/2010	6 th NIWA survey
19/01/2011	7 th NIWA survey
21/02/2011	8 th NIWA survey
9/03/2011	6.45 pm. Shags 5-10, gulls 0-5 and herons 10-20. No anglers and lots of smelt seen.
13/03/2011	6.30pm. Shags 5-10, gulls 0-5 and herons 5-10. Five anglers, no fish caught, run of smelt.
19/03/2011	6.45pm. Shags 5-10, gulls 0-5 and herons 10-20. no anglers and a run of smelt.
20/03/2011	7.00am. Shags 0-5, gulls 5-10 and herons 5-10. Three anglers, no fish caught, run of smelt.
20/03/2011	7.15pm. Shags 5-10, Gulls 0-5 and herons 10-20. No anglers and a run of smelt.
26/03/2011	6.30pm. Shags 5-10, gulls 0-5 and herons 5-10. Two anglers, fish caught and few smelt seen.
27/03/2011	7.45am. Shags 10-20, gulls and herons 5-10. Two anglers, fish caught and a few smelt seen.
29/03/2011	9 th NIWA survey
29/03/2011	7.35am. No shags or gulls seen and 0-5 herons. No anglers and a few smelt seen.
10/04/2011	7.30am. Many shags seen, gulls 10-20 and herons 0-5. Two anglers, fish caught and a lot of smelt seen.
16/04/2011	5.30 pm. Shags and gulls 0-5, herons 10-20. Two anglers, no fish caught and a run of smelt.
17/04/2011	6.45am. Shags 0-5, gulls 5-10 and herons 0-5. Two anglers, fish caught and a run of smelt
18/04/2011	7.00am. Shags 0-5, gulls 5-10 and herons 5-10. No anglers and water too dirty to see smelt.
18/04/2011	6.30pm. No shags or gulls, herons 5-10. No anglers and water too dirty to see smelt.
24/04/2011	6.45am. Shags 0-5, gulls 0-5 and herons 0-5. Four anglers, fish caught and a run of smelt
24/04/2011	5.30pm. No shags or gulls, herons 0-5. Two anglers, no fish caught and a lot of smelt.
27/04/2011	7.00am. Shags 0-5, gulls 0-5 and herons 5-10. Two anglers, no fish caught and a few smelt.
28/04/2011	10 th NIWA survey
6/05/2011	4.45pm. Shags 0-5, no gulls and herons 5-10. Six anglers, fish caught and a few smelt
14/05/2011	7.00am. Shags 5-10, gulls 5-10 and herons 0-5. Five anglers, no fish caught and a few smelt.
14/05/2011	6.30pm. Shags 5-10, no gulls and herons 5-10. Seven anglers, fish caught and a few smelt.
22/05/2011	7.30am. Shags 10-20, many gulls and herons 5-10. Nine anglers, fish caught and a few smelt seen.
22/05/2011	5.30pm. Shags 0-5, no gulls and herons 0-5. No anglers and no smelt seen.
23/05/2011	11th NIWA survey
23/05/2011	5.30pm. No shags or gulls, herons 5-10. Three anglers, fish caught and too dirty to see smelt.
26/05/2011	6.30am. Many shags and gulls, herons 10-20. Five anglers, fish caught and too dirty to see smelt.
28/05/2011	6.30am. Shags 5-10, gulls 5-10 and herons 5-10. Ten anglers, fish caught and too dirty to see smelt.
28/05/2011	5.30pm. Shags 5-10, no gulls and herons 5-10. Six anglers, fish caught and too dirty to see smelt.
31/05/2011	7.00am. Many shags, gulls 10-20 and herons 10-20. Two anglers, fish caught and too dirty to see smelt.
3/06/2011	7.00am. Shags 5-10, A few gulls and herons. A few smelt, five anglers and fish caught.
4/06/2011	6.30am. A few shags, no gulls or herons. A few smelt. Eleven anglers and fish caught.
4/06/2011	5.30pm. No shags or gulls and a few herons. No smelt, three anglers and no fish caught.
8/06/2011	12th NIWA survey.
11/06/2011	7.00am. A few shags and herons and no gulls. Dirty so no smelt seen. Eleven anglers and fish caught.
11/06/2011	5.30pm. A few shags and herons and no gulls. A few smelt. Four anglers and fish caught.
19/06/2011	7.30am. Shags 5-10, a few herons and no gulls. A lot of smelt. Six anglers and fish caught.
19/06/2011	6.00pm. No shags or gulls and a few herons. A lot of smelt. One anglers and fish caught.
23/06/2011	5.00pm. No shags or gulls and a few herons. No smelt seen. Six anglers and fish caught.
25/06/2011	7.30am. A few shags and herons and no gulls. A few smelt. 15 anglers and fish caught.
25/06/2011	6.00pm.No shags or gulls and a few herons. A few smelt. Eight anglers and fish caught.
26/06/2011	8.00am. A few shags and herons and no gulls. A few smelt. Eight anglers and fish caught.
27/06/2011	5.00pm. No shags or gulls and a few herons. No smelt seen. Three anglers and no fish caught.
30/06/2011	8.00am. A few shags and no gulls or herons. No smelt seen. Four anglers and no caught.
30/06/2011	6.00pm. No shags or gulls and a few herons. No smelt. Three anglers and no fish caught.