Smelt monitoring in the Ohau Channel and Lake Rotoiti 2011-2012

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Smelt trap and trapping platform in the Ohau Channel, Lake Rotoiti. [Eddie Bowman, NIWA]

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Executive summary

This report presents the results of smelt monitoring in the Ohau Channel and Lake Rotoiti for 2012 and compares them with the results obtained annually since 2006. This monitoring is carried out to determine whether the diversion wall, installed in Lake Rotoiti in 2008 to divert nutrient-enriched water from Lake Rotorua out of Rotoiti and down the Kaituna River, has affected either the smelt migrations from Rotoiti to Rotorua, or the smelt population in Rotoiti. The monitoring is a condition of consents held by the Bay of Plenty Regional Council for the diversion wall and the monitoring is overseen by a technical advisory group (TAG) of fishery experts.

Monitoring up to 2010/2011 has indicated that the wall was not preventing the migrations of either adult or juvenile smelt from Lake Rotoiti into Lake Rotorua via the Ohau Channel. However, this finding does not indicate that the size or frequency of runs is unaffected. Moreover, the TAG indicated that more than three years post-wall monitoring would be required for it to be assured that the wall is having no effect on smelt migration. Monitoring was therefore continued in 2012. In addition to this annual monitoring, an analysis of the factors influencing the seasonal timing of the smelt runs was requested to determine whether the wall could have influenced the frequency or size of smelt runs by changing the attractant cues that may draw them from Lake Rotoiti into the Channel.

The results for 2012 indicated that:

- runs of juvenile smelt occurred in the Ohau Channel during March 2012
- post-wall runs of juvenile smelt have now been recorded in the Ohau Channel in both 2011 and 2012, whereas runs of adult smelt have been recorded in 2009 and 2010
- the abundance of larval smelt in Lake Rotoiti over the 2011/2012 summer season was the highest recorded since 2005/2006 and indicates that there has been no decline in smelt recruitment in this lake
- runs of adult smelt up the Ohau Channel have been recorded during all months of the year except June, whereas runs of juvenile smelt are restricted to summer months (December-April)
- daily water temperature in the Channel, mean daily discharge, water velocity and moon phase do not directly influence runs of smelt in the Ohau Channel.

Overall, the results obtained to date indicate that the diversion wall has not prevented runs of adult or juvenile smelt up the Ohau Channel and that the smelt population in Lake Rotoiti has not been adversely affected. However, the effects of the wall on the frequency and size of smelt runs up the Channel is not known.

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 down the Kaituna River, thereby by-passing Lake Rotoiti. In time, this diversion is expected to reduce nutrient loading into Lake Rotoiti and to reduce the deterioration in its water quality.

The Eastern Region Fish and Game Council were concerned that this diversion wall may affect the migrations of smelt (and trout) up the Ohau Channel from Lake Rotoiti (affecting the trout fishery in the Channel) and that smelt dynamics in Rotoiti may change, resulting in an impact on the trout fishery in this lake. Local iwi were also concerned that the fishery for smelt in the Ohau Channel would be affected.

Before and after studies to determine the effects of the diversion wall on smelt were therefore initiated by the Bay of Plenty Regional Council in 2006. Rowe et al. (2011) reported on the results of annual monitoring up to June 2011 and concluded that the wall had not prevented the migration of either adult or juvenile smelt through the Ohau Channel. However, this does not discount the possibility that the size and frequency of smelt runs up the Channel has changed.

There is insufficient pre-wall data on smelt runs in the Channel to determine whether the wall has had any effect on the size, frequency or seasonal timing of smelt runs. Even if there were sufficient data, other changes in the environment could confound any post-wall comparison. For example, annual and long-term changes in smelt abundance in Lake Rotoiti could affect run size, whereas seasonal changes in factors such as water temperature, smelt growth rate, and water flow down the Channel could all alter the occurrence and timing of runs. A way around this is to identify the factors influencing the frequency and occurrence of smelt runs up the Ohau Channel and to then see if these factors have been affected by the wall.

Observational data collected by George Proud and reported in Rowe et al. (2010) indicated that smelt runs can vary on a daily basis. Daily data are therefore required to determine the factors affecting run timing and frequency and whether these have been affected by the wall. The quantitative monitoring obtained by trapping (e.g., Rowe et al. 2011) has been carried out at fortnightly to monthly intervals and therefore only provides a coarse indication of smelt run size and frequency. However, some historic and current daily data on smelt runs in the Channel are available. Frank Thompson had indicated to Eastern Fish and Game that he had collected such data since 1994 and George Proud has collected similar data since 2009. A large amount of daily data may therefore be available to attempt such an analysis.

The Technical Advisory Group (TAG) constituted by the Bay of Plenty Regional Council to advise it on changes in monitoring (as required by the Resource Consent), advised that the annual smelt monitoring should continue during 2012, but just at sites 1 and 2 because monitoring at sites 3 and 4 was not producing any useful, additional information (Rowe et al. 2011). Furthermore, and because a large amount of daily observational data were potentially available, the TAG recommended that an investigation be carried out to determine what factors might influence the timing and frequency of smelt runs up the Ohau Channel.

Because this decision was made in November 2011, there was insufficient time to carry out monitoring during spring 2011, nor to carry out the annual acoustic survey of smelt abundance in Lake Rotoiti in September 2011. Monitoring of smelt runs up the Ohau Channel was therefore carried out only during autumn (March-June 2012) and not in spring 2011. Surveys to determine the summer density of larval smelt in Lake Rotoiti were carried out in December 2011 and April 2012, as per previous summers, and the acoustic survey of adult smelt in Lake Rotoiti was postponed until 2012. In addition, daily observations of the presence/absence of smelt runs up the Ohau Channel were obtained and collated from two sources (George Proud and Frank Thompson) and analysed in conjunction with the data obtained by trapping to provide an insight into factors controlling the occurrence and frequency of smelt runs.

In this report, we present the results of the summer monitoring of smelt in the Ohau Channel (March to June 2102) and the annual survey to determine larval smelt density in Lake Rotoiti over the 2011/2012 summer season. We also present an analysis of the factors potentially influencing the occurrence and frequency of smelt runs based on the available daily data for the presence/absence of smelt runs.

2 Methods

2.1 Smelt runs in the Ohau Channel

The location 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 as the contribution of Sites 3 and 4 is generally minor (Rowe et al. 2011) and Sites 1 and 2 have been monitored since 2006, therefore providing 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 four month period from March to June 2012. 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 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 catch for the two 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. Shags are predators of smelt and their abundance provides an additional measure to detect the presence of high densities of migratory smelt.

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. Daily observations by George Proud for 2012 are listed in Appendix 1.

2.2 Larval smelt density in Lake Rotoiti

Larval smelt in Lake Rotoiti are sampled to determine whether a decline in natural recruitment occurs, or if annual changes in abundance could account for any marked variations in adult smelt abundance in the lake. 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 edge, as well as in shallower waters on the sandy substrates of inlet streams. The larvae hatch in 10-25 days (depending on water temperature) and become pelagic. Newly hatched larvae are around 6-7 mm long and are transparent. Larvae remain in the water column 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). Smelt spawning occurs between September and April, but the peak months for larval smelt density are unknown, and they may vary between years. The growth rate of larvae in lakes is also unknown, but studies on the growth rate of galaxiid larvae (which have a similar life history to smelt) indicate that smelt larvae 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 (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 2011 and April 2012. 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 (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 2011/2012 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 2011/2012 season were then compared to those for previous seasons to determine any marked change or long-term trend in larval density.

2.3 Factors influencing the timing of smelt runs

An indication of smelt abundance in the Ohau Channel can be obtained by visual observation from the bank as well as from trapping. Smelt are generally confined by high water velocities in mid-channel to the shallow margins of the Channel (Brijs et al. 2008, Hicks & Tana 2011) and are readily observed there. Visual observations of smelt in the Ohau Channel have been made at various times by both Frank Thompson and George Proud.

Although the absence of smelt is readily determined from observation, as is the presence of many smelt, the occurrence of a few smelt is problematic and raises the issue of what level of smelt movement constitutes a run. Frank Thompson categorised changes in the relative abundance of smelt as ‘slow’, ‘moderate’, or ‘heavy’: where ‘slow’ is 3 shoals (schools) of 40-50 fish passing upstream over an hour; ‘moderate’ is two larger shoals of approximately 100 fish passing upstream per minute; and one shoal of 250-350 fish or more passing upstream per minute is 'heavy'. These ratings suggest that the size of smelt runs is related to the size of the shoals as well as to their rate of movement upstream. On some occasions, smelt were observed to be present and 'milling around' (i.e., not moving upstream), or were moving both up and downstream over small distances. A 'run' was therefore defined as the continuous upstream movement at a rate of over 2 smelt per minute (i.e., > 3 schools of 40 fish per hour). A sample of smelt was often netted by hand to determine the size range of fish and adults were deemed to be over 45 mm TL, whereas juveniles ranged from 30-45 mm.

Frank Thompson is an ex-wildlife and fisheries ranger with the Auckland Fish and Game Council and has expertise, as well as experience and training, in wildlife observation. He lived close to the Ohau Channel for many years and provided an annotated diary that documents many daily observations obtained between January 1994 and August 2005. This diary will be deposited in the NIWA Archive for Project BOP12205. George Proud is a local angler and is also a keen observer of wildlife. He too lives close to the Ohau Channel and has made similar observations from 2009. In addition, some daily data on smelt runs in the Channel were available from the two to four weekly NIWA trapping carried out between September and May for most years since 2006.

Whereas a run of smelt can be readily determined from visual observation at a specific point on the Channel bank over a period of hours, the determination of a run from trap CPUE data gained over an entire day is more problematic. The frequency distribution of daily CPUE (Figure 2-2) was used to distinguish the high CPUE estimates that characterise runs from the lower and more common CPUE estimates occurring as a consequence of the milling behaviour of smelt in the Channel. This cut-off value was set at 2 smelt per minute because the distribution of low counts indicated that this value would normally be exceeded for less than 2% of the time (Figure 2-2). This value is also in accord with Frank Thompson's observation that a 'slow' run is characterised by more than 2 smelt per minute (i.e., > 3 schools of 40 fish per hour).

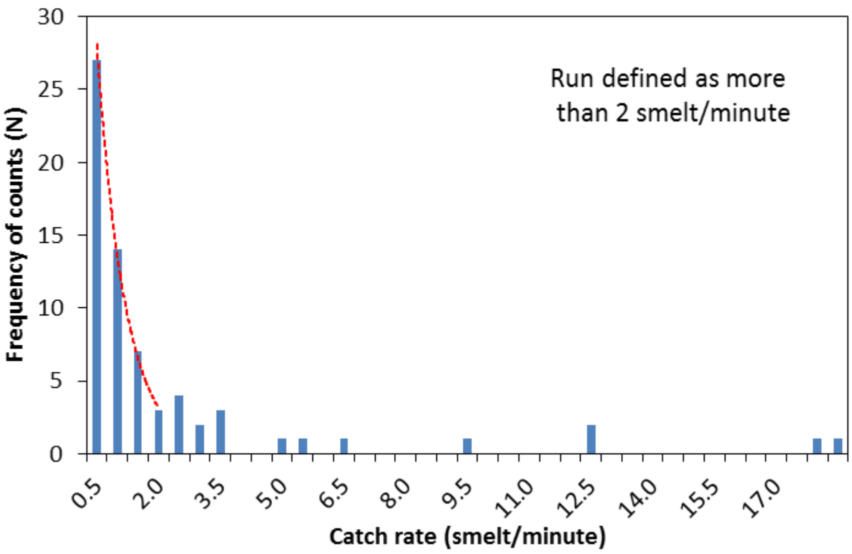

Figure 2-2: Frequency distribution for daily smelt CPUE. Red dashed line provides best fit to low values.

The presence/absence of smelt runs was determined for each of the days when observations were made, and when trapping was carried out, resulting in a database of 323 observations over the period 1994 to 2011 (Table 2-1).

Table 2-1: Number of days on which the occurrence of smelt runs was determined for the Ohau Channel.

Year	No. of days	Observer(s)	Main months covered
1994	58	Frank Thompson	Jan-Jun, Oct-Dec
1995	36	Frank Thompson	Jan-Apr, Oct-Dec
1996	14	Frank Thompson	Jan-Aug
1997			
1998			
1999	12	Frank Thompson	Aug-Dec
2000	24	Frank Thompson	Jan-Sep
2001			
2002	11	Frank Thompson	Jan-Oct
2003			
2004			
2005	25	Frank Thompson, NIWA (7)	Mar-Jul, Sep-Dec
2006	8	NIWA	Jan-Sep
2007	6	NIWA	Sep-Dec
2008	13	NIWA	Jan-Dec
2009	41	George Proud, NIWA (14)	Jan-Apr, Sep-Dec
2010	53	George Proud, NIWA (12)	Jan-Jun, Oct-Dec
2011	22	George Proud, NIWA (6)	Jan-May

Data on the diurnal water temperature in the Ohau Channel were obtained from spot measurements by Frank Thompson (1994-1996) and from the mean diurnal temperature calculated from data obtained by data loggers installed in the channel by NIWA (2006 and 2008-2011). Daily mean flow rates in the Ohau Channel were calculated from the Lake Rotorua water level data stored in NIWA's national hydrometric database.

Previous results (Rowe et al. 2010, 2011) indicated that adult smelt runs occurred mainly in spring, whereas juvenile runs occurred in summer. To identify the monthly pattern of runs by both adults and juveniles, the number of years for which for smelt runs occurred in each month was determined for the daily records collected between 1994 and 2011.

The approach used to identify environmental factors that may affect the daily occurrence of runs was based on a comparison of the few environmental variables measured per day and the presence/absence of smelt runs on those days. This approach cannot include data for days when no observations were made. Nor can it include data on the full range of environmental variables suspected of influencing fish migrations because these are not routinely measured. It is therefore limited in scope and can only indicate whether the variables measured may have an influence on runs (or not). It cannot establish any cause and effect relationship.

The effect of diurnal (daytime) water temperature on run occurrence was determined by calculating the frequency distribution for water temperatures measured in the Channel on the days when smelt runs occurred and comparing this with the distribution for days when no runs occurred. A similar analysis was also carried out for mean daily flow rates to determine whether runs could be influenced by flow, and hence water velocities as velocity near the margins of the Channel are strongly correlated with flow rate (Rowe et al. 2008).

Moon phase can influence the migrations of some fish species, so the frequency of occurrence for runs on days close to full moon (± 2 days either side), and to new moon, was calculated and compared with the frequency of runs on days when there was no full or new moon. These frequencies were compared to determine whether smelt runs occurred more frequently at times of full or new moon, or were not influenced by moon phase.

The examination of other factors that may directly influence smelt runs (e.g., water level in Lake Rotoiti, wind strength and direction, water chemistry differences, daily differences in water temperature between lakes Rotorua and Rotoiti, or changes in state such as rising and dropping temperatures etc.,) was not attempted as these data were either unavailable or their collation was beyond the scope of this project. Similarly, data on water clarity in the channel were only available for the times when NIWA sampled the smelt and so are too few to determine the effect of water clarity (or turbidity) on smelt migration patterns.

3 Results

3.1 Smelt runs in the Ohau Channel in 2012

Runs of smelt (defined as a daily total CPUE in traps of > 2.0 smelt/min) occurred in the Ohau Channel on the two trapping dates in March 2012 (8th and 27th March; Figure 3-1). Daily observations by George Proud also recorded smelt runs on certain days in March 2012 (18th and 30th), but not on other days (11th, 17th or 25th March 2012, Appendix 1). No smelt runs were detected by either trapping or daily observation in April or May 2012 (Figure 3-1, Appendix 1). As in previous years, the smelt present in spring months (September to November) were mainly adults and those present in late summer (January to April) were mainly juveniles (Figure 3-2).

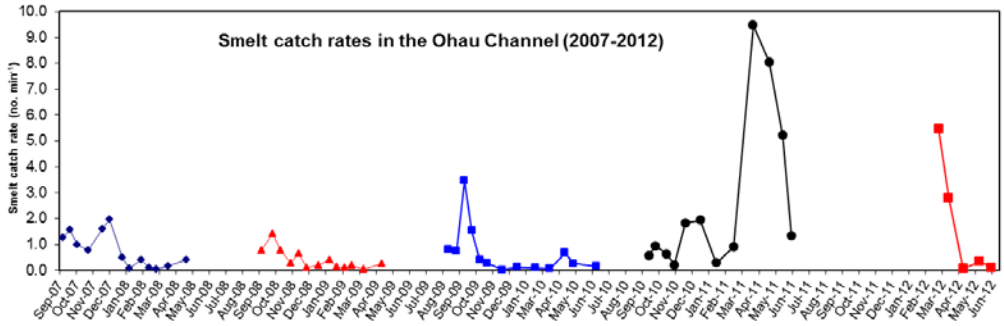

Figure 3-1: Mean daily CPUE for smelt in traps set in the Ohau Channel during January to June 2012 and during previous survey years.

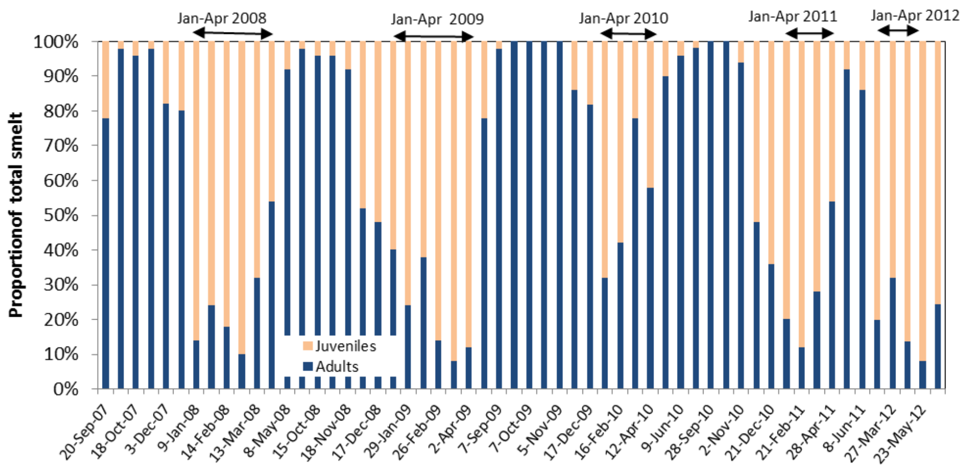

Figure 3-2: Proportions of adult versus juvenile smelt in trap catches from the Ohau Channel 2007-2012. Arrows at the top of the figure show late-summer samples. (NB. There was no spring sampling in 2011).

Flow rates in the channel on the sampling days in 2012 were in the range for those encountered during previous years (Figure 3-3), but water clarity was much higher in 2012 reaching levels not seen in the past four years (Figure 3-4).

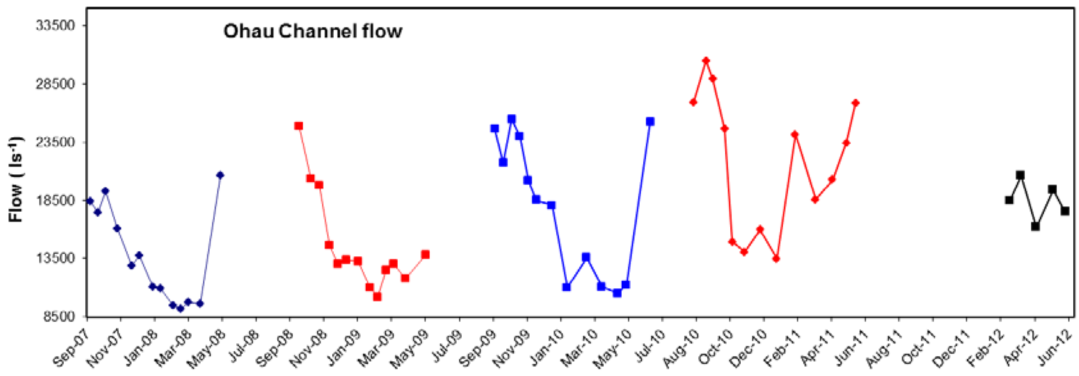

Figure 3-3: Mean daily flows (Ls^{-1}) at the times smelt were trapped in the Ohau Channel 2007-2012.

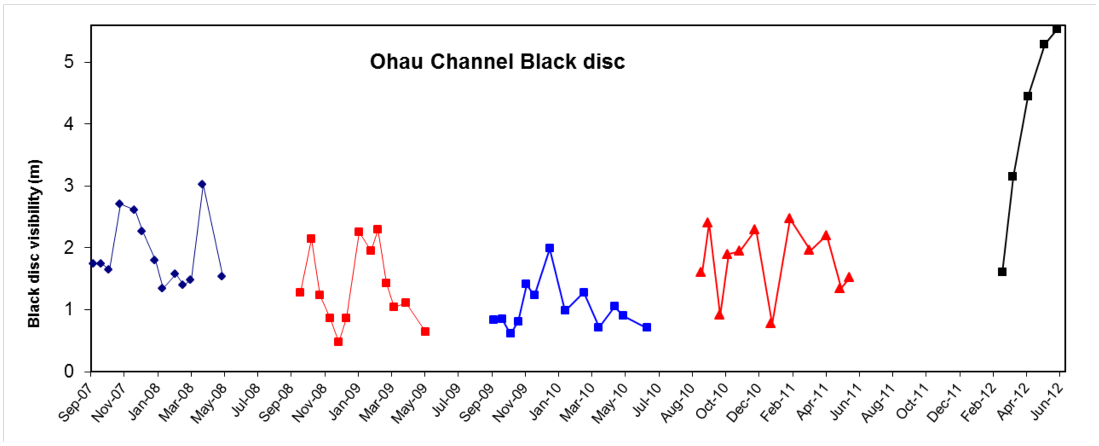

Figure 3-4: Water clarity (black disc visibility) measurements in the Ohau Channel in 2012 compared with previous years.

Shag numbers have been observed to increase markedly in the Channel and along its banks when smelt runs occur, but this did not happen in 2012 (Figure 3-5). This is consistent with the low occurrence of shags in 2011 when juvenile smelt were running. It now seems more likely that shags only increase markedly when runs of predominantly adult smelt occur, but more data are required to substantiate this. Other factors may also influence the occurrence of shags in the Channel.

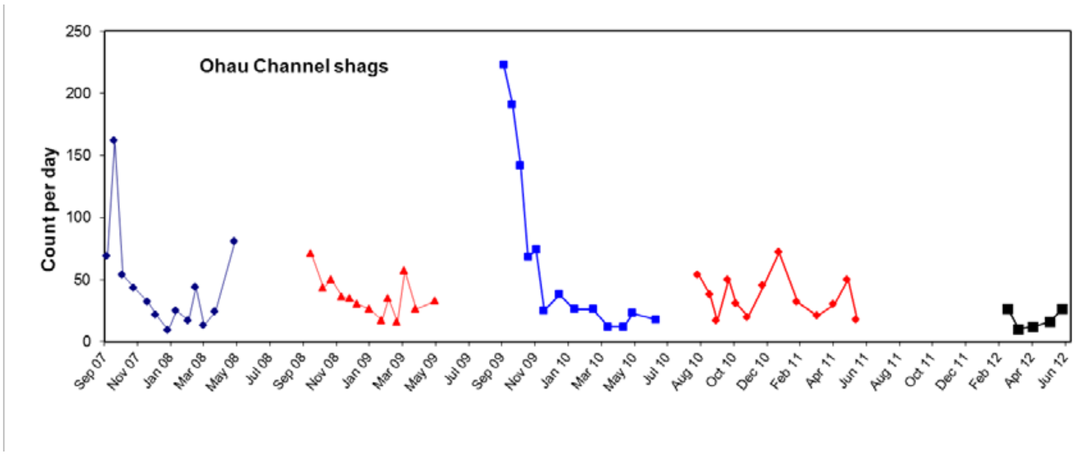

Figure 3-5: Counts of shags in the Ohau Channel in 2012 compared with previous years.

The mean daily catch of common bullies was relatively low between January and June 2012 (Figure 3-6), but this was because CPUE for common bullies tends to decline as summer progresses and no sampling occurred between September 2011 and February 2012. There were no marked changes in the occurrence or number of trout or koura in the traps in 2012 compared with previous years.

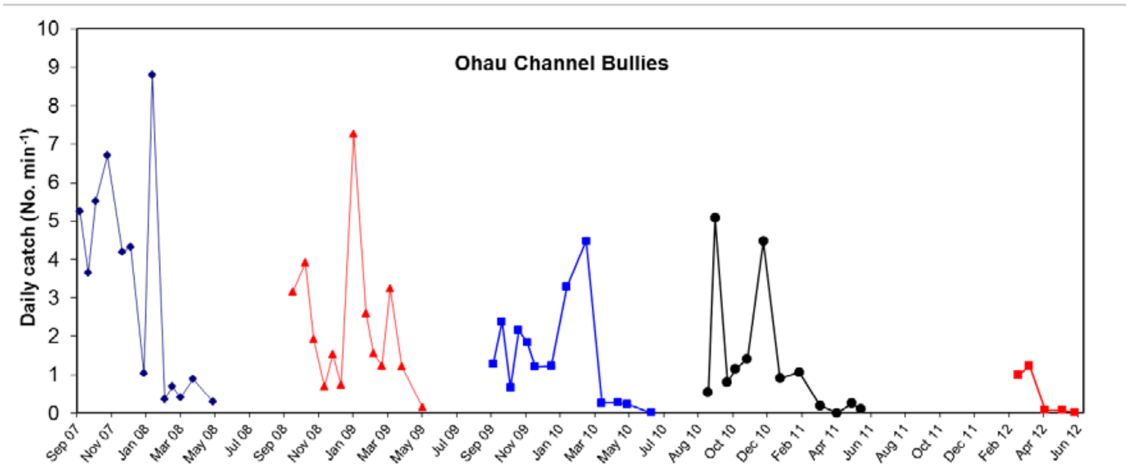

Figure 3-6: Mean daily catch of common bullies in the Ohau Channel in 2012 compared with previous years.

3.2 Larval smelt density in Rotoiti

The mean density of larval smelt in Lake Rotoiti was much higher in 2011/2012 compared with previous seasons, and was high in both December and April (Table 3-1).

Table 3-1: Mean catch rate of larval smelt in Lake Rotoiti during the 2011/2012 summer compared with previous summers.

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
2011/2012	30	4.07 ± 0.48	2.58 ± 0.39	3.32 ± 0.32

As water clarity improves in Lake Rotoiti, increases in larval smelt over the entire spawning season can be expected because of the general (across lakes) relationship between larval smelt density and lake water clarity (Rowe & Taumoepeau 2004). The mean secchi disc measured at the time of larval smelt sampling in Rotoiti provides a ‘snapshot’ of water clarity at that time and so cannot be expected to reflect water clarity over the entire summer period. Nevertheless, it allows comparison with the general relationship. The high catch rates in 2011/2012 were associated with a relatively high mean water clarity (>5.5 m) for Lake Rotoiti at the times of sampling, and the long-term trajectory in larval smelt abundance is towards the 1995/1996 point (Figure 3-7). Many factors other than water clarity are expected to influence larval fish abundance in lakes and so the relationship with water clarity can be expected to vary between years, and this variation is apparent in Figure 3-7.

Although there is considerable inter-annual variation in larval smelt density, as well as variation between December and April estimates (Table 3-1), the mean values for 2009 /2010 and 2011/12 were significantly higher than for other years (ANOVA, $F = 29.7$, $P < 0.001$). Smelt recruitment therefore appears to be increasing over the long term (Figure 3-8), especially since 2008.

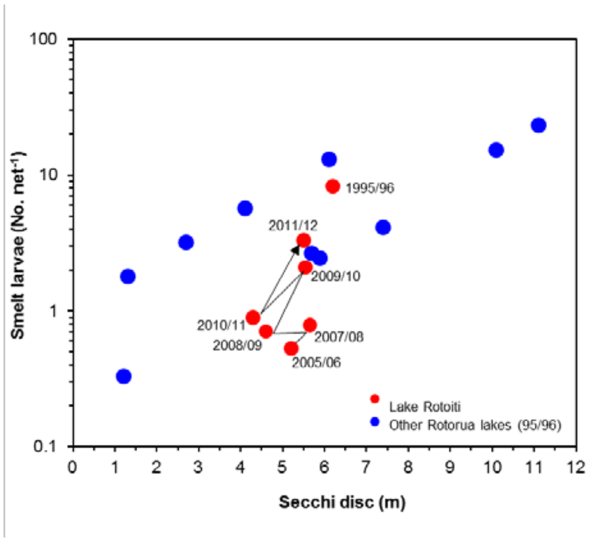

Figure 3-7: Mean catches of larval smelt (No. haul^{-1}) in Lake Rotoiti over each summer season since 2005/2006 versus mean secchi disc depth (red circles). The black line shows sequential changes over time. Blue circles are data for other lakes in 1995/1996 showing the overall relationship between larval smelt abundance and water clarity that provides the context for interpreting temporal changes in Lake Rotoiti.

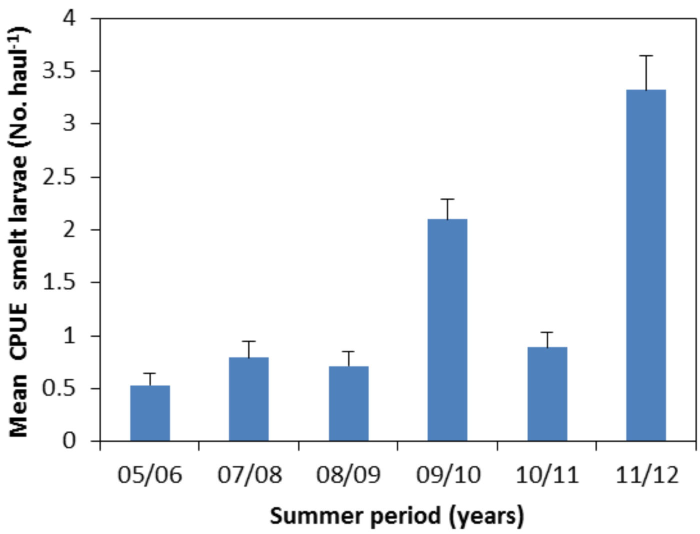

Figure 3-8: Mean catch rates (plus standard errors) for larval smelt in Lake Rotoiti over summer months between 2005 and 2012.

3.3 Factors influencing smelt runs

Daily runs of mainly adult smelt have been observed in the Ohau Channel in all months of the year except July (Figure 3-9). However, there is a major peak in the frequency of runs in October/November indicating that most runs occur during spring months. A secondary peak occurred between March and May indicating a small increase in runs during autumn months. In comparison, runs of juvenile smelt were limited to the months of December to April (i.e., summer).

The seasonal timing of runs by adult smelt is consistent with their spawning season in lakes in terms of both its length (spring through to autumn) and peak periods (spring and autumn). Observations on adult smelt caught in the Channel have indicated that many are mature or close to it (Rowe et al. 2006).

The timing of runs by juveniles is consistent with their observed entry into tributary streams of lakes in summer months, and is likely to be ontogenetically analogous to the spring/summer migration of juvenile diadromous smelt from the sea into rivers.

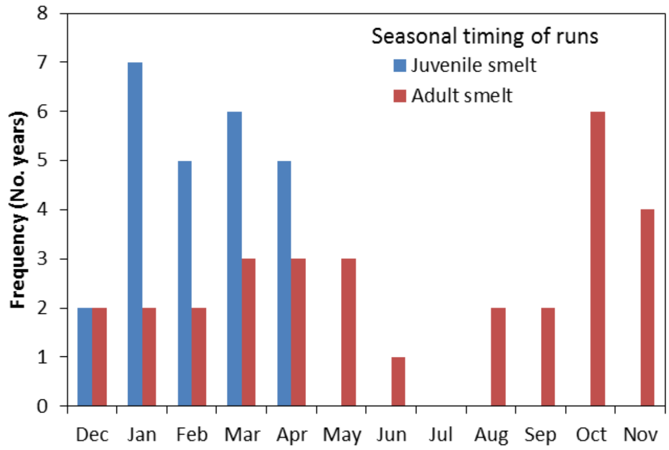

Figure 3-9: Frequency distribution for adult and juvenile smelt runs per month. Data are the number of years in which runs have occurred for each month.

There was no difference in the cumulative frequency distribution for diurnal water temperatures on days when adult smelt were running and days when they were not running (Figure 3-10A). Accordingly water temperature is unlikely to be a major factor influencing the occurrence of adult smelt runs. In contrast, the cumulative frequency distribution curve for days when juvenile smelt were running was shifted to the right relative to that for water temperatures on days when smelt were not running (Figure 3-10B) and the median temperature for days on which juvenile smelt were running was 20ºC versus 15ºC for days when smelt were not running.

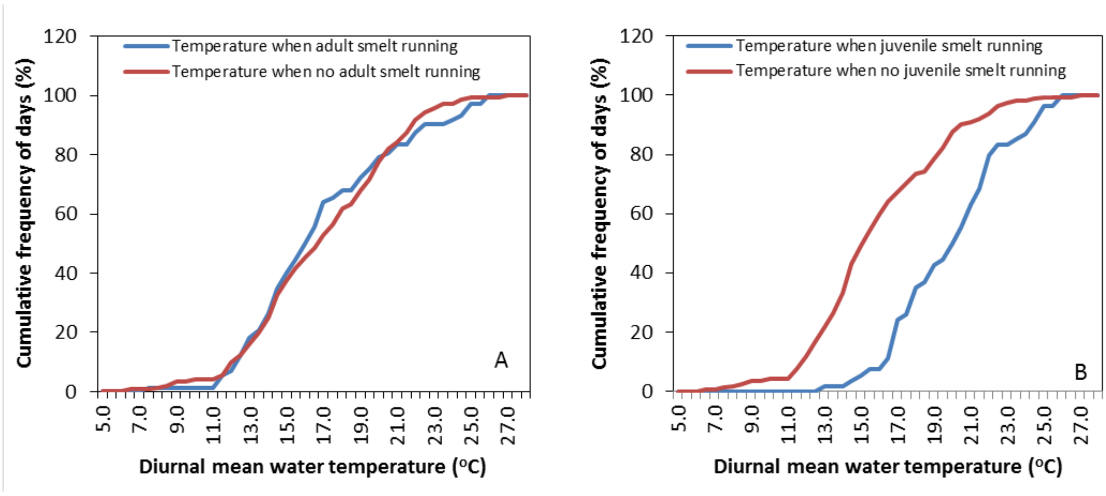

Figure 3-10: Cumulative frequency distributions for daytime mean water temperatures in the Ohau Channel on the days when smelt were running and the days when no runs occurred: A. adult smelt; B. juvenile smelt.

There was no difference in the cumulative frequency distribution curves for water flow (discharge) for adult smelt in the Channel indicating that these fish are not influenced by flow rates (Figure 3-11A). However, the curve for days when juvenile smelt were running was shifted well to the left compared to that for days when no runs occurred (Figure 3-11B). This indicates that juvenile smelt runs occur primarily on days when flows were low. The median flow for days when runs occurred was 11.8 m^3/s versus 18.5 m^3/s for days when no runs occurred.

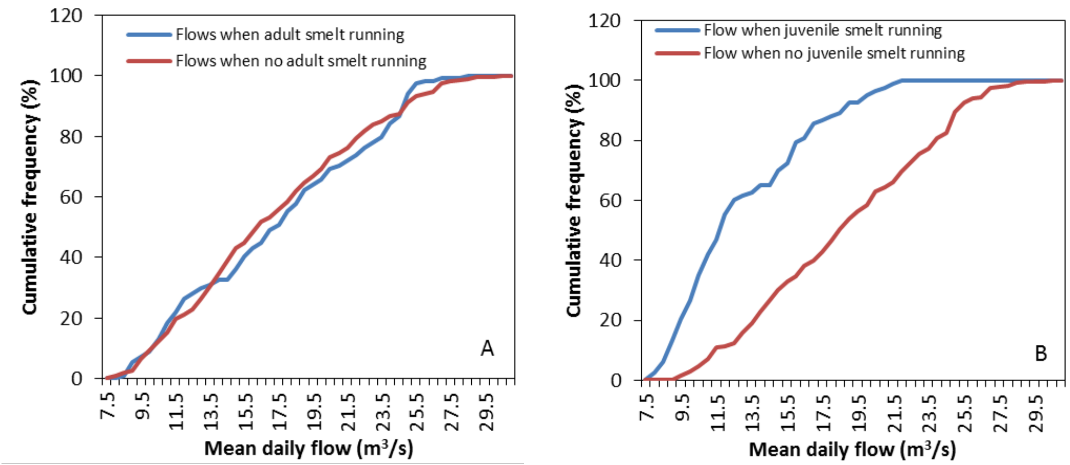

Figure 3-11: Cumulative frequency distributions for daily mean flows in the Ohau Channel on days when smelt were running and days when no runs occurred: A. adult smelt; B. juvenile smelt.

These analyses indicate that runs of adult smelt were not affected by either the daytime water temperature in the Channel or mean daily flow and this reflects the wide seasonal distribution of adult runs. However, runs of juvenile smelt only occurred in summer months and this may account for their association with both high water temperatures and low flows.

Another useful (if more subjective) way of looking at these relationships is to compare the scatter plots for the distribution of temperature and flow on days when runs occurred with the plots for days when no runs occurred. The plot for both mean daily water temperature and mean daily flow on days when adult smelt were running showed complete overlap with the plot for days when adult smelt were not running (Figure 3-12A). There was therefore no indication of selection for water temperature or flow, or any combination of these. The same plot for juveniles shows that their runs occurred mainly during periods of low flow and high water temperature (Figure 3-12B). However, when the data were restricted to just summer days (i.e., January-April), there was complete overlap (Figure 3-13) indicating that, when the seasonal nature of their runs is taken into account, there is no selection by juveniles for warmer daily water temperatures or lower mean daily flows, at least within the range of temperatures and flows encountered to date. Avoidance may therefore occur at higher velocities and water temperatures.

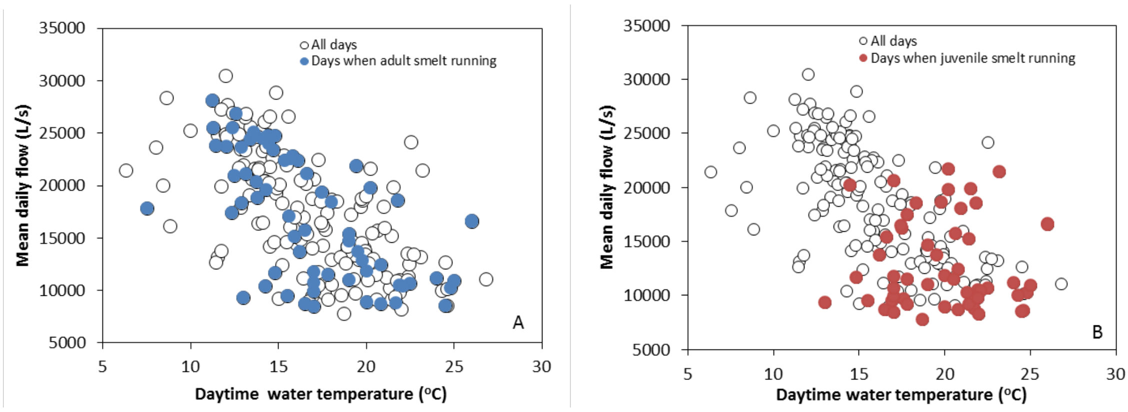

Figure 3-12:Scatter plot for water temperature and flow on days when smelt were running and not running: A. Adult smelt; B. Juvenile smelt.

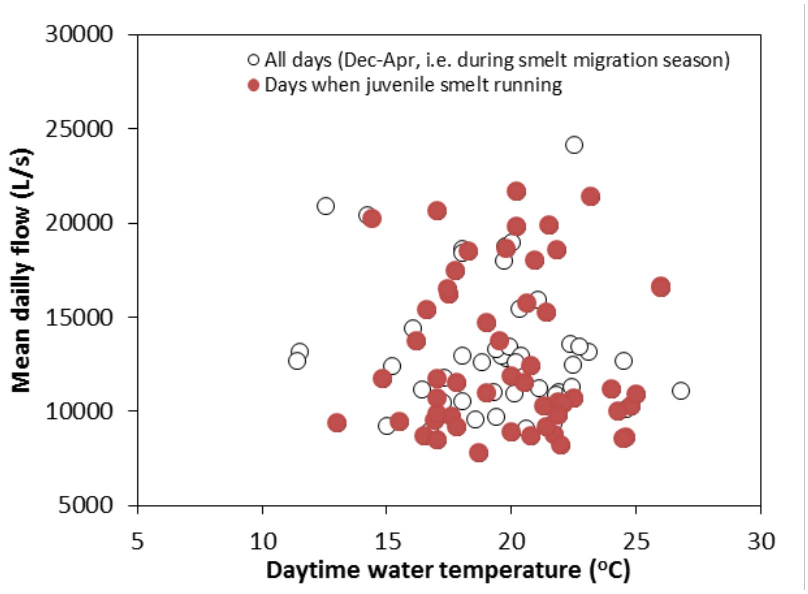

Figure 3-13:Scatter plot for water temperature and flow on summer (January-April) days when juvenile smelt were running and not running.

A comparison of frequencies of occurrence for smelt runs was used to identify any effects of moon-phase on their timing (Table 3-2). There was no difference between the frequency of runs on, or close to new moon or full moon for either juvenile or adult smelt (Table 3-2). Frequencies of runs during the periods of full moon were both lower (<0.2) than on all other moon phases (>0.7), indicating that moon-phase had no strong influence on the daily timing of smelt runs in the Ohau Channel. Moon phase may well have an influence on the occurrence of nocturnal migrations, but has no discernible influence on diurnal migrations.

Table 3-2: Frequency of occurrence for adult and juvenile smelt runs on days when the moon was full (or close to it), new (or close to it), and neither full nor new.

Moon phase	Frequency of adult smelt runs	Frequency of juvenile smelt runs
New	0.145	0.144
Full	0.145	0.144
Neither	0.710	0.712

4 Conclusions

Runs of juvenile smelt were recorded on 4 of the 7 days in March 2012 when monitoring by trapping and/or by daily observation was carried out, but none were recorded on any of the 14 days in April, May and June when an assessment was made. To date, and using the trap rate of 2 or more smelt/minute to indicate a run, summer runs of juvenile smelt in the Channel have now been recorded in 2011 and 2012, whereas spring runs of adult smelt have been recorded in 2009 and 2010. A spring run may also have occurred in 2011 but no monitoring was carried out at that time.

The results for 2012 reinforce those obtained for juvenile smelt in 2011 and indicate that runs of both adult and juvenile smelt have now occurred in the channel after completion of the diversion wall in July 2008. The results show that the diversion wall does not prevent adult or juvenile smelt from entering the Ohau Channel from Lake Rotoiti and migrating upstream towards Lake Rotorua.

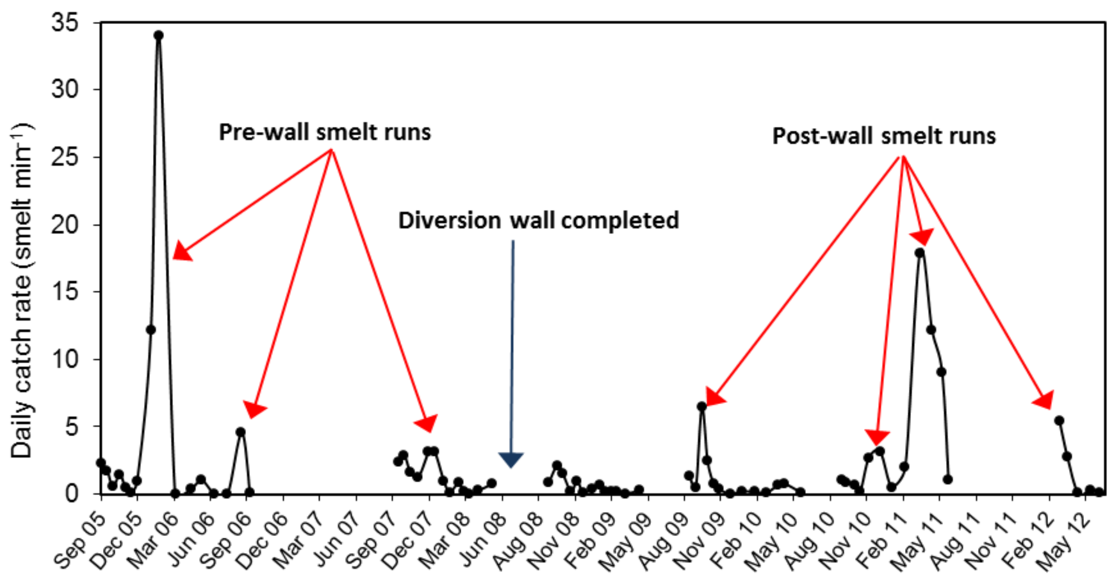

Figure 4-1: Occurrence of smelt runs in the Ohau Channel after installation of the diversion wall across its outlet.

Although smelt can clearly find the entrance to the Channel and migrate up it, little can yet be said about the effects of the diversion wall on the size or timing of these runs. It is becoming more apparent as the amount of data increases, that whereas runs of juvenile smelt are restricted to summer months, adult smelt runs occur over a much wider period encompassing spring, summer and autumn. These seasonal differences in timing are consistent with the known life history and ontogenetic movements of the diadromous stocks of smelt from which the lacustrine ones are derived. For example, the summer migrations of juveniles from Lake Rotoiti into the Ohau Channel are analogous to the late-spring/summer migrations of diadromous juvenile smelt from the sea into rivers noted by Ward et al. (2005). Similarly, the migration of mature adult smelt into the Ohau Channel is analogous to the migration of diadromous adults to suitable spawning habitats in rivers (*loc cit*.). It is also similar to the movement of adult smelt into the larger tributary streams of Lake Taupo to spawn (Stephens 1976). As such, the seasonal (as against daily) movements of the lacustrine stocks in Rotoiti are expected to be controlled more by the ontogenetic and endogenous factors inducing migratory behaviour in fish than by environmental variables thought to influence the daily timing and frequency of runs.

Of the few environmental variables investigated, there was no evidence that daily water temperature or mean daily discharge (which is strongly correlated with water velocities in the Channel; Rowe et al. 2008) directly influenced the timing of smelt runs up the Ohau Channel. Similarly, there was no indication of a relationship between moon phase and the occurrence of daily runs. However, the importance of other environmental cues and other elements of the temperature and flow regime (e.g., rates of change) on the daily occurrence of runs are still unknown.

In pre-wall times, water from the Ohau Channel was often colder than lake water in Rotoiti during summer and autumn months. Being denser, it formed a plume that plunged under the surface water layer of Rotoiti (epilimnion) and travelled down toward the deeper eastern end of the lake before becoming fully mixed with lake water. The water in this plume would have contained more plankton from the more productive surface waters of Lake Rotorua and it would have been colder and possibly more oxygenated. It would also have provided a small current to potentially induce a rheotactic response in smelt. As such, this under- or inter-flow of Lake Rotorua water into Lake Rotoiti may have provided a range of attractant cues (greater concentration of food, cooler water temperature, higher oxygen levels, water velocity) for smelt in Rotoiti, with these factors combining to draw smelt towards and into the Ohau Channel. Although daily water temperature in the Channel and mean daily flow on the day of an observed run are unlikely to be factors that directly influence the migrations of smelt into the Ohau Channel, the existence of other physical cues cannot yet be discounted. A greater understanding of both the physical and physiological variables controlling smelt migrations, along with more extensive daily data on smelt migrations up the channel would be required to resolve this and could potentially provide a useful topic for postgraduate study.

The data on larval smelt in Lake Rotoiti indicate that recruitment has not dropped following installation of the diversion wall and that it may in fact be increasing as water quality (indicated by higher water clarity data, pers. comm. Andy Bruere) improves. However, annually varying climate conditions conducive to larval fish survival may also have contributed to the higher smelt recruitment in 2011/2012. Rowe & Taumoepeau (2004) found that while larval smelt density was highest in clear, oligotrophic lakes and lowest in turbid, more productive ones, the converse applied to common bully larvae. This relationship indicates that an improvement in water clarity can be expected, all else being equal, to increase smelt larvae while decreasing bully larvae. However, the number of larval bullies captured in Rotoiti over the 2011/2012 summer was much higher than in previous years (author’s unpubl. data). Survival of all larval fish is therefore likely to have been higher in Rotoiti during summer 2011/2012 and factors other than water clarity may have influenced larval fish abundance over this period.

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6 Appendix 1: Daily observations of smelt 2012

Date	Observations by George Proud
11/03/2012	7.30am. Shags 10-20, herons 5-10, and many gulls. No smelt seen. No fishermen.
17/03/2012	6.30am. Shags and herons 5-10, gulls 10-20. No smelt seen. Two fishermen and fish caught.
17/03/2012	6.00pm. Shags and gulls 0-5 and herons 5-10. No smelt seen. No fishermen.
18/03/2012	7.00am. Shags 10-20, herons 0-5 and many gulls. A lot of smelt. Two fishermen and fish caught.
25/03/2012	5.30am. Shags 5-10, herons 0-5 and gulls 10-20. No smelt seen. Two fishermen and fish caught.
25/03/2012	7.00pm. Shags and gulls 0-5 and herons 5-10. No smelt seen. No fishermen.
30/03/2012	6.00pm. Shags and herons 10-20, many gulls. A lot of smelt. One fisherman and fish caught.
7/04/2012	7.30am. No shags, 10-20 herons and many gulls. No smelt seen. Five fishermen and fish caught.
7/04/2012	6.00pm. No shags or gulls, 5-10 herons. No smelt seen. Three fishermen, no fish caught.
8/04/2012	7.00am. Shags and herons 0-5, many gulls. No smelt seen. Five fishermen and fish caught.
14/04/2012	6.00am. Shags and herons 0-5, gulls 10-20. No smelt seen. Four fishermen, no fish caught.
14/04/2012	5.45pm. No shags or gulls, herons 5-10. No smelt seen. Two fishermen, no fish caught.
16/04/2012	6.00pm. No shags or gulls, herons 0-5. No smelt seen. No fishermen.
17/04/2012	6.30am. Shags 0-5, herons 5-10 and many gulls. No smelt seen. Six fishermen, no fish caught.
21/04/2012	6.00am. Shags and herons 0-5, and many gulls. No smelt seen. One fisherman, no fish caught.
21/04/2012	5.00pm. Shags 0-5, herons 5-10 and many gulls. No smelt seen. One fisherman and fish caught.
25/04/2012	5.00pm. No shags or herons and 0-5 gulls. No smelt seen. No fishermen.
11/05/2012	6.30am. No shags or gulls, and 0-5 herons. No smelt seen. No fishermen.
19/05/2012	7.30am. Shags and herons 0-5, no gulls. No smelt seen. One fisherman, no fish caught.
28/05/2012	5.30pm. No shags or gulls, herons 0-5. No smelt seen. No fishermen.
2/06/2012	6.35am. Shags and herons 0-5, no gulls. No smelt seen. No fishermen.
10/06/2012	7.30am. Shags and herons 0-5, gulls 10-20. No smelt seen. Ten fisherman and fish caught.
14/06/2012	5.15pm. Shags 5-10, herons 0-5 and no gulls. No smelt seen. Three fishermen, no fish caught.
16/06/2012	7.30am. Shags and herons 0-5 and no gulls. No smelt seen. Two fishermen, no fish caught.