Smelt monitoring in the Ohau Channel and Lake Rotoiti 2018/2019

Prepared for Bay of Plenty Regional Council

July 2019

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NIWA CLIENT REPORT No: 2018258HN
Report date: July 2019
NIWA Project: BOP16202

Quality Assurance Statement		
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Contents

Figures

Executive summary

In 2008, a diversion wall was installed in Lake Rotoiti to channel the nutrient-laden water flowing out of Lake Rotorua around the edge of Lake Rotoiti and down the Kaituna River. This flow diversion was designed to reduce the nutrients entering Lake Rotoiti from Lake Rotorua thereby assisting in the restoration of water quality. Concerns were raised that this diversion wall could adversely affect the migrations of smelt and trout up the Ohau Channel, which connects Lake Rotoiti to Lake Rotorua. Hence, monitoring was carried out before and after the diversion wall was constructed to identify any significant adverse impacts of the wall on these fish. In this report, we present the results of the smelt monitoring for the 2018/19 season, the eleventh year since the diversion wall was constructed.

Overall, the results for 2018/19 complement and add to those obtained in previous years and indicate that:

(a) The diversion wall does not prevent the movement of either adult or juvenile smelt into and up the Ohau Channel because migrations of both have continued after the wall was constructed. Common bully migrations also appear unaffected.

(b) Adult smelt migrate up the Ohau Channel in all months from September to June, but runs occur most frequently in spring (September to November). In contrast, juvenile smelt predominantly migrate up the Channel during summer and early autumn (December to April). This seasonal pattern of migration of adults and juveniles has occurred every year over the past decade.

(c) Before installation of the wall, the maximum size of a run detected by trapping was 34 smelt/minute (February 2006). This was exceeded in October 2013 (38 smelt/minute) and March 2017 (48 smelt/minute). In the most recent sampling season the largest smelt run was only 3 smelt/minute (September 2018), However this is within the variation observed in run sizes since the diversion. Hence, there is no long-term trend in the monitoring data indicating a decline in the size of smelt runs.

Given the daily variation in runs detected by both trapping and observation over the past decade, it is apparent that runs do not occur every day, and that the daily occurrence of runs is sporadic with high temporal variability. Given such variability, detection of a change in the frequency of smelt runs up the Channel before and after the diversion wall would require near daily monitoring over five years both before and after the installation of the wall. This was not feasible, hence other approaches are required to detect changes in the daily frequency of smelt runs up the Ohau Channel.

Migratory species such as the common smelt have both physiological and environmental controls (e.g., endocrinological processes, water temperature, changes in flow) over the timing of their migrations. From a management perspective, the identification of the environmental cues can help to assess or predict how natural or anthropogenic changes (e.g., the diversion wall or climate change) may influence the size, timing and frequency of migrations. It would also allow for the estimation of population dynamics before the diversion wall was constructed, thus providing stronger historical (baseline) data to compare against. All data collected over the last 13 years were analysed to investigate any trends between flow (mean daily flow, seven-day mean flow, 24-hour change in flow), water clarity and water temperature during sampling in the channel and the size of the smelt runs. Regressions indicated that the size of smelt migrations tended to increase with increasing mean daily flow and seven-day mean flow, while juvenile run size tended to decrease slightly with increasing temperatures, beyond 14°C. These findings suggest a link between flow and temperature and the size of smelt runs, but more detailed research is needed to better understand the mechanisms involved. The ecological driver for the migrations (e.g., spawning, foraging) also remains unknown and presents an important area for future research. This information will provide a greater understanding of the size, timing and frequency of smelt runs allowing for more effective management of smelt populations in Lake Rotorua and Lake Rotoiti for the associated trout fishery.

1 Introduction

1.1 Background

During the summers of 2003, 2004 and 2005, Lake Rotoiti was closed to contact recreation because of potentially toxic algal blooms caused by cyanophycean or blue-green algal cells. During summer, these blooms developed in the epilimnion of the lake and spread throughout its surface waters until the end of autumn. The blooms are believed to be related to the accumulation of nutrients (nitrogen and phosphorus) in Lake Rotoiti over the past century (i.e., eutrophication of the lake) and by seeding of cyanophycean species entering Lake Rotoiti from Lake Rotorua.

The relatively large concentrations of both nutrients and algae entering Lake Rotoiti from Lake Rotorua via the Ohau Channel were thought to be responsible for much of the deterioration in the water quality of Rotoiti. Hence, a diversion wall was installed at the outlet of the Ohau Channel to divert the nutrient-enriched water entering Lake Rotoiti down the Kaituna River (the lake's outlet). From July 2008, after the diversion wall was completed, this water was channelled along the lake edge such that it flowed down the Kaituna River. Over time, this diversion was expected to reduce the nutrient loading in Lake Rotoiti and hence its trophic status. It would also reduce the summer influx of phytoplanktonic cyanophycean from Rotorua that seeded and likely contributed to the toxic algal blooms in Lake Rotoiti.

An improvement in water quality in Lake Rotoiti was required primarily to reduce the frequency of toxic algal blooms, but it was also required to prevent deterioration in this lake's world-class rainbow trout fishery. A number of studies on the trout populations in the lakes of the central North Island plateau of New Zealand have established that trout growth rate and condition are generally lower in the eutrophic lakes compared with oligotrophic lakes (Fish 1964; Fish et al. 1968; Rowe 1984; Blair 2012). Furthermore, the decline in trout condition correlates closely with a reduction in trout predation on smelt, and this fits with observations of reduced smelt abundance in eutrophic lakes (Rowe 1984; Rowe & Taumoepeau 2004). Hence, the future status of trout in Lake Rotoiti was at risk because of the deterioration in the lake's water quality. Because of this risk, the Eastern Region Fish and Game Council supported measures proposed to reduce the decline in this lake's water quality. However, the Council was also concerned that the diversion wall may affect the migrations of smelt up the Ohau Channel from Lake Rotoiti and thereby affect the trout fishery in the Channel. Changes in the population dynamics of smelt in Lake Rotoiti, as a consequence of the diversion wall, were also a concern as this could reduce smelt abundance in the lake and hence trout growth rates. In addition, local iwi were concerned that the fishery for smelt in the Ohau Channel would be adversely affected.

Studies were therefore initiated by the Bay of Plenty Regional Council between 2005 and 2008 to provide more information on smelt migrations up the Channel prior to the installation of the wall. These studies were also designed to provide a pre-wall baseline for assessing any future impacts of the diversion wall on smelt runs up the Channel (Rowe et al. 2006, 2008). These initial studies were subsequently continued on an annual basis after the diversion wall was completed in July 2008 to provide further information on the smelt migrations up the Ohau Channel and to establish any effects of the wall on smelt in both the Channel and in Lake Rotoiti. The results of these studies are reported in Rowe et al. (2009, 2010, 2011, 2012, 2013, 2014, 2015, 2016) and Shelley et al. (2017, 2018).

Results from the annual trapping of smelt runs in the Ohau Channel between 2006 and 2018 showed that runs of both juvenile and adult smelt occurred in most years after the wall was constructed. It was, therefore, concluded that the wall had not prevented the movement of either adult or juvenile smelt up the Ohau Channel (Rowe et al. 2015; Shelley et al. 2018).

This aside, concerns were expressed (by anglers) that the maximum size of smelt runs up the Ohau Channel was no longer as high as it was prior to the construction of the wall and that the annual frequency of runs had declined. Smelt runs recorded in October 2013 and March 2017 were higher than the highest run recorded prior to 2008, hence this supports the notion that there hasn't been a decline in the maximum number of smelt recorded running up the Channel since the diversion wall was installed.

The monitoring carried out to date has established that there is considerable variation in the daily duration and timing of smelt runs and hence in their frequency. This variation prevented the monitoring programme from establishing whether the frequency of smelt runs per season has exhibited temporal changes. Data indicates that near-daily monitoring would have been required over the four years prior to installation of the diversion wall to provide an adequate baseline for assessing temporal changes, which was not feasible. Other approaches to resolving this issue are possible (e.g., modelling) but this would require knowledge of the environmental factors controlling the onset of smelt runs up the Ohau Channel. In turn, this would require research to identify such factors and determine the feasibility of modelling.

In addition to smelt monitoring in the Ohau Channel, the abundance of larval smelt in Lake Rotoiti was monitored biannually to determine whether the smelt population in Lake Rotoiti changed greatly after the diversion wall was installed. The rationale for this monitoring was that a large decline in larval smelt in Lake Rotoiti over a period of three or more years would indicate a lake-wide decline in recruitment due to a reduction in the adult smelt population. In turn, the decline in adult smelt in the lake would be expected to reduce the growth of trout (as smelt are their main prey) as well as the size of smelt runs up the Ohau Channel. Conversely, an increase in larval smelt in Lake Rotoiti would indicate that water quality was improving because larval smelt abundance has been shown to be closely related to water clarity in the Rotorua lakes (Rowe & Taumoepeau 2004). Thus, monitoring of larval smelt in Lake Rotoiti was undertaken annually since completion of the diversion wall in 2008 until 2018.

Smelt monitoring in the Ohau Channel and Lake Rotoiti is part of a broader programme of annual fish monitoring carried out under the auspices of the Bay of Plenty Regional Council who hold the resource consent for the diversion wall. In addition to the smelt monitoring, trout fishery monitoring in Lake Rotoiti and in the Ohau Channel is carried out annually by the Eastern Fish and Game Council. The University of Waikato undertakes an annual boat-based, electric-fishing survey of fish in the Ohau Channel, and Dr Ian Kusabs carries out monitoring of koura and kakahi in Lake Rotoiti.

1.2 Smelt monitoring in 2018/2019

A Technical Advisory Group (TAG) of independent experts was established in 2008 to consider and evaluate the results of this annual fish monitoring and to advise the Bay of Plenty Regional Council on any changes required, including actions considered necessary to address any decline in fish detected by the monitoring. In considering all the results available up to November 2015, the TAG recommended that the Bay of Plenty Regional Council continue smelt monitoring in the Ohau Channel and Lake Rotoiti until 2017 as the resource consent was being renewed at that time. At that point, the TAG decided to continue the full monitoring of smelt due to the value of the long-term dataset in assessing temporal changes in the fishery. In 2018, the programme was again reassessed, and the TAG decided to refine the monitoring to focus on key migration months for smelt within the Ohau Channel. The group also thought there was limited value in continuing the bi-annual larval smelt sampling in Lake Rotoiti as the snapshot it provided had limited value in assessing temporal trends in smelt spawning and recruitment within the lake. Based on the outcomes of the TAG meeting on in 2018, a reduced monitoring programme has been be carried out in 2018/19. The reduced monitoring programme entails monitoring of smelt migrations in the Ohau Channel for six months of the year; September, October and November 2018, and March, April and May 2019. Data on larval smelt densities in Lake Rotoiti were not collected.

In this report, we present the results of smelt monitoring carried out in the Ohau Channel from September 2018 to June 2019. These data are interpreted with respect to the baseline data obtained before the wall was constructed and the monitoring results obtained annually since then.

2 Methods

2.1 Monitoring of smelt runs and environmental conditions in the Ohau Channel

The locations of the sites used to monitor smelt movements in the Ohau Channel since 2006 are shown in Figure 2-1. Only trap sites 1 and 2 have been used after 2012 as the contribution of Sites 3 and 4 was generally minor (Rowe et al. 2011). Trap sites 1 and 2 have been monitored since 2006 so provide a longer record for comparing temporal changes.

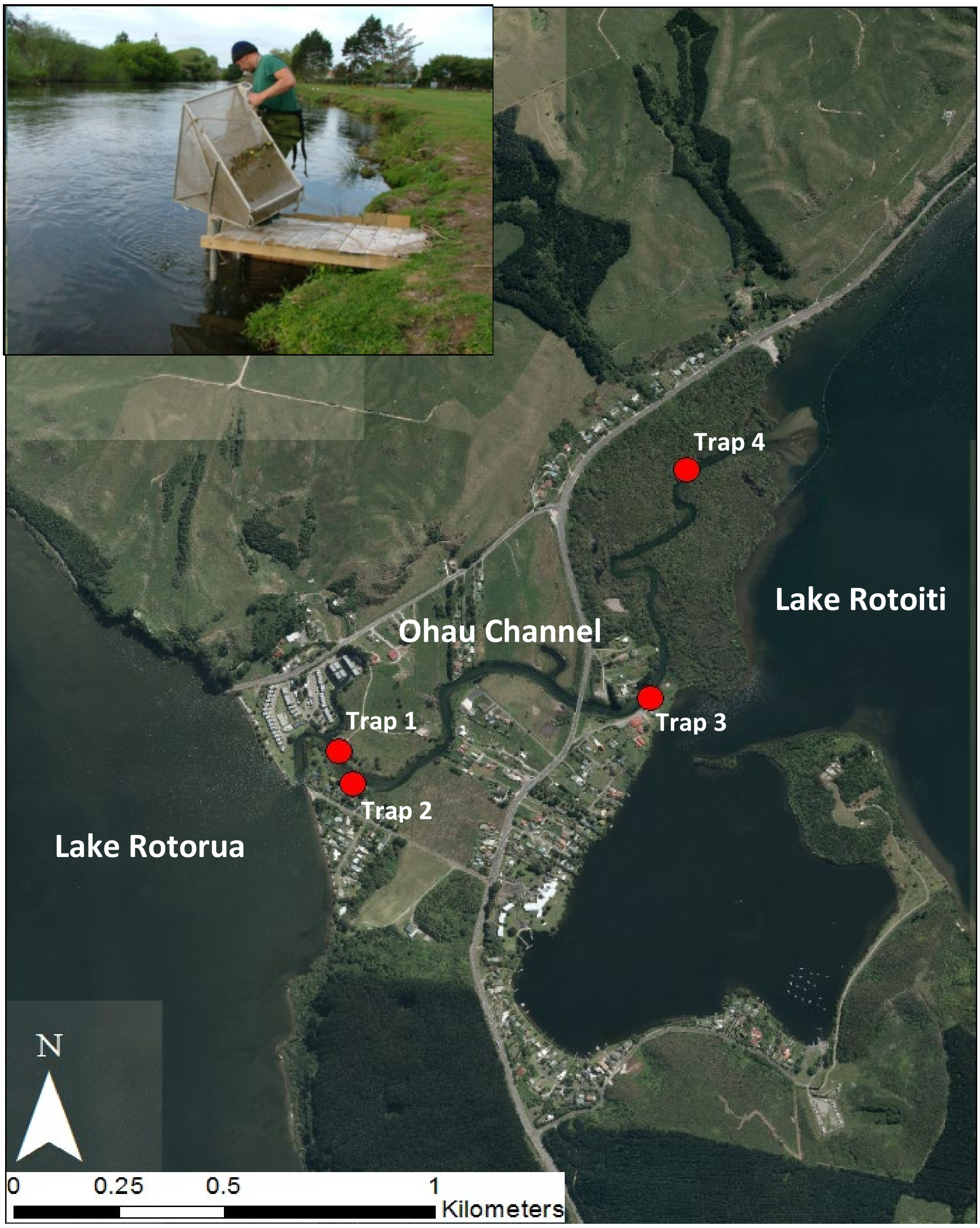

Figure 2-1: Location of sampling sites used for smelt trapping in the Ohau Channel. Only sites 1 and 2 have been monitored since 2012. Inset shows a smelt trap and the platform below which it is set.

In 2018-19, trapping of smelt was carried out in the Ohau Channel approximately once per month for six months of the year; September, October and November 2018, and March, April and May 2019. Prior to 2018, trapping was carried out at approximately 4 weekly intervals during the ten-month period from September to June.

Traps were placed close to the bank at each site, facing downstream in order to capture upstream migrant smelt. The traps were triangular with a 1 m wide by 0.5 m deep opening tapering to a 20 cm wide capture compartment (Figure 2-1 inset). 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 in the catch. Both the length (under or over 45 mm total length) and coloration of smelt were used to distinguish juveniles from adults. The daily catch per unit 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.

Runs of smelt were defined through both long-term direct observation and the trapping data as either the movement of two schools of 50-60 smelt, or one school of 100-120 smelt per hour past a given point on the bank of the Ohau Channel, or a trap-based catch rate of over 2 smelt per minute (Rowe et al. 2012). In addition to these data, water temperatures (Tidbit© data loggers), water clarity (black disc visibility), water velocities near the entrance to each trap, the flow of water through the Ohau Channel (data provided by Bay of Plenty Regional Council), and the by-catch of other fish species (i.e., common bullies, koaro, trout) were recorded.

2.2 Relationships between environmental variables and smelt run size

Smelt migrations up the Ohau Channel could potentially be influenced by environmental variables such as flow, water temperature and water clarity. Although Rowe et al. (2012) found no significant correlation between the occurrence of smelt runs and these variables, Shelley et al. (2017, 2018) found that the number of smelt in a run tended to increase with increasing mean daily flow and with mean flow over the 7 days prior to sampling, while the number of adults tended to decrease slightly with increasing temperatures beyond 14°C. Conversely, no significant correlation was observed between the size of smelt runs and water clarity. There was also no significant correlation between run size and the change in flow over the 24 hours prior to the end of sampling (i.e., whether the sampling was undertaken on the rising or falling limb of a flow event or at a steady flow). Here, we reinvestigate these relationships incorporating data from the 2017/18 and 2018/19 sampling. To investigate any influence of our measured habitat variables on run size, Local (Loess) regressions of the mean daily flow, diurnal water temperature and water clarity against the catch rate (fish/minute) on sampling days were utilised. Although smelt migrate through the channel throughout the year, there are clear peaks in the timing of these runs for both adults (April-December) and juveniles (December-April) (Rowe et al. 2016). Therefore, we focussed our analysis on these respective periods. Interpretation of Loess regressions focusses on the fitted curve and the confidence intervals. If at any given point, the curve and its confidence intervals deviate entirely from another point along the curve (representing either an increase or a decrease) it is considered that the observed pattern between those points is significant. The narrower the confidence intervals are, the more confidence there is in the regression model fit and any observed relationship. The interpretation of the relative strength of those relationships is based on professional opinion.

3 Results

3.1 Comparison of environmental conditions to previous sampling seasons

2018-19 was a relatively dry year and the range of flows that occurred during the study period was small, varying from 5 – 25 $m^3 s^{-1}$ (Figure 3-1). As expected, the higher flows occurred during spring 2018, however, contrary to normal seasonal patterns, the largest flow event in the study period occurred during December 2018 and early January 2019. Low flows during late summer persisted throughout autumn and early winter.

Sampling in 2018-19 also occurred over a limited range of flows compared to previous years (Figure 3-2). Notably, no sampling was conducted at flows above 22 $m^3 s^{-1}$ and in this regard the 2018/19 year was most similar to the years 2014/15, 2013/14, and 2007/08. The sampling in November 2018 was undertaken on the rising limb of a flow event, but all other sampling was undertaken at time when flow changed little over the 24 hours period prior to sampling.

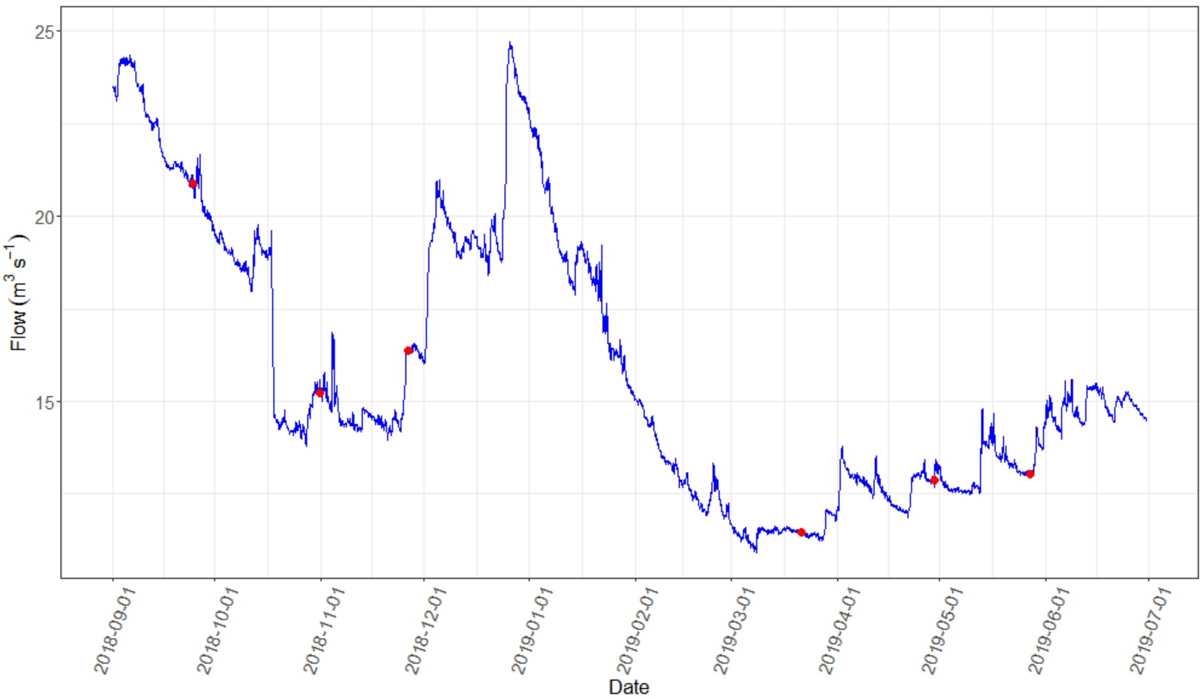

Figure 3-1: Hourly flow record in the Ohau Channel during the 2018/19 season and the days on which smelt monitoring was undertaken (red dots).

Figure 3-2: Flow in the Ohau Channel on the smelt monitoring days between 2007 and 2019.

Water clarity measurements made in the Ohau Channel on sampling days in 2018-19 were typical of water clarity on sampling days since 2015, and prior to 2012, with black disk visibility ranging from 1 m and 2.5 m (Figure 3-3). No sampling days in 2018/19 had the high clarity (> 3.5 m) measured occasionally during the 2012-14 period. The water clarity reflects instantaneous conditions, and the lower visibility on sampling dates in 2018/19 is not thought to reflect a deterioration in water quality in the channel over time. Fewer samples in 2018/19 may also mean that high clarity days simply did not coincide with sampling dates.

Water temperatures in the Ohau Channel were typical of seasonal patterns and similar to previous years (Figure 3-4). Water temperatures for the four most recent sampling years are presented for comparison.

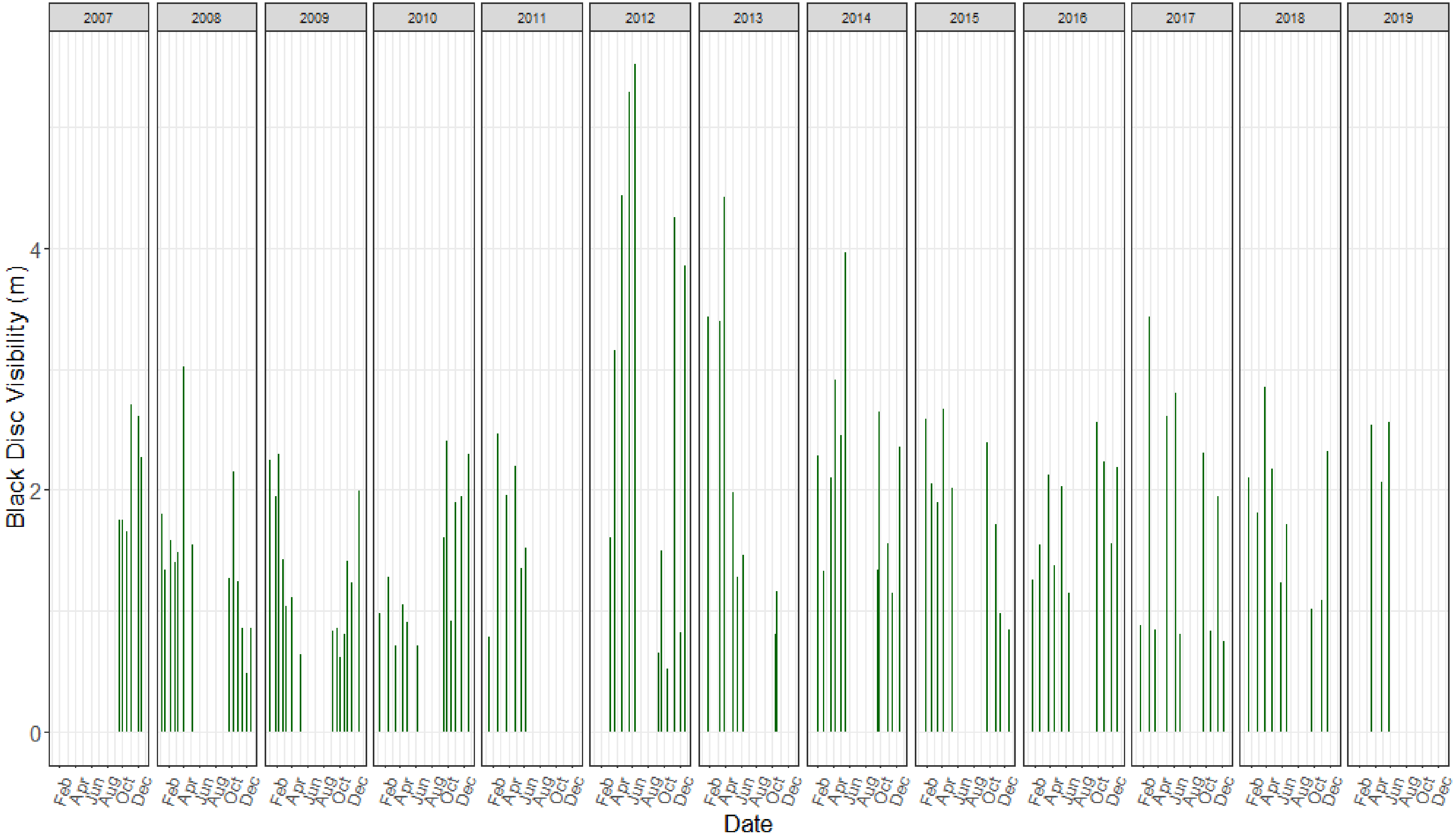

Figure 3-3: Water clarity (as measured by secchi disc depth) on the smelt monitoring days between 2007 and 2019.

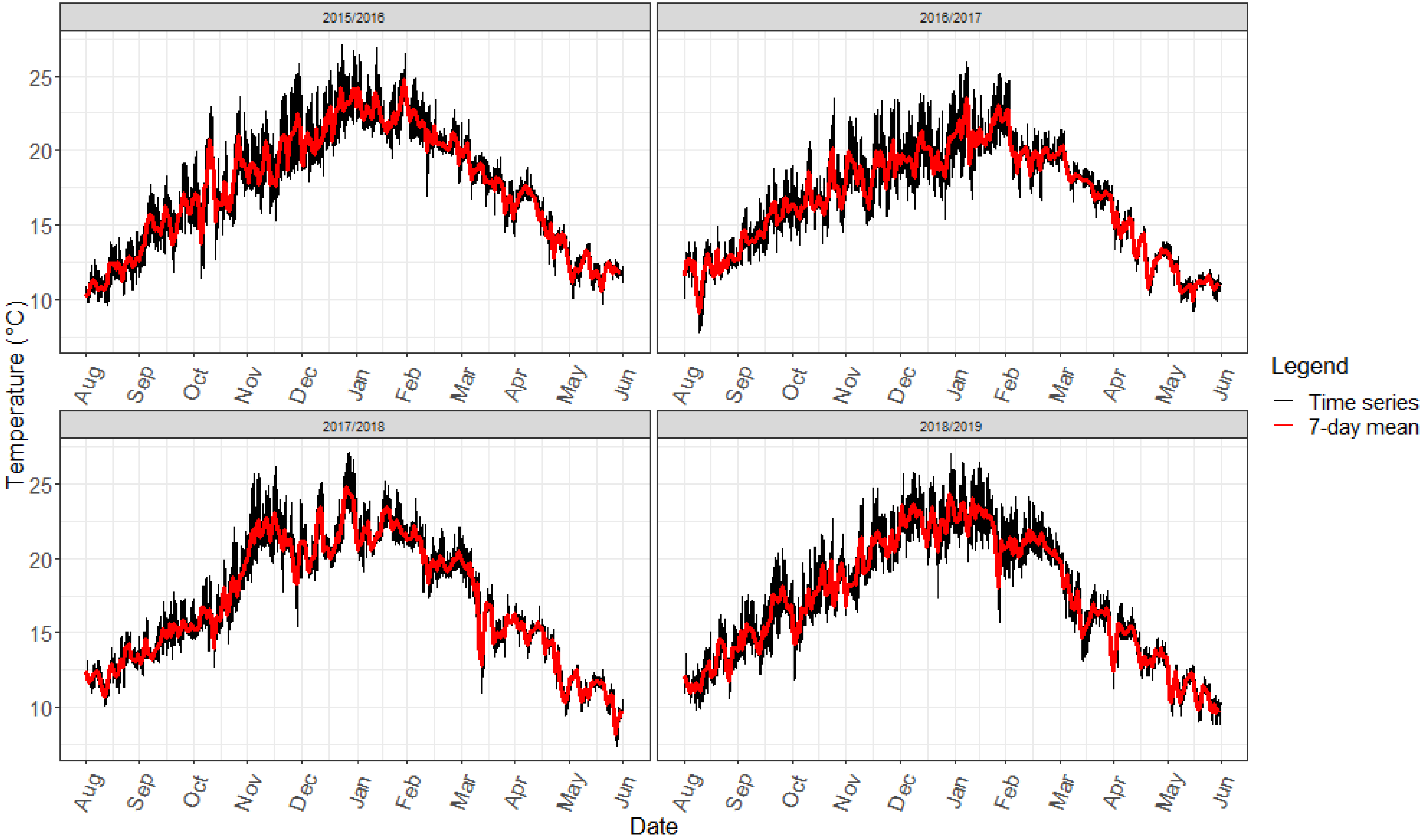

Figure 3-4: Water temperatures in the Ohau Channel across the sampling periods between 2015 to 2019.

3.2 Relationships between environmental variables and smelt run size

For both adult and juvenile smelt, the number of fish migrating tends to increase with increasing flow (at the time of sampling and mean flow over the last seven days), although juveniles were predominantly migrating at lower flows than adults (< 20 $m^3 s^{-1}$) (Figure 3-5). Overall (i.e., total catch) there was a steady and clear increasing trend in the number of smelt migrating with increasing flow. There was little difference between the relationship between the number of fish migrating and flow at the time of sampling or the mean flow over the last seven days. Observations from the 2018/19 field season were in line with existing trends that suggest flow has an influence on run size. The direction of change in flow did not appear to influence the number of adult fish migrating through the channel, suggesting that adult migration does not occur preferentially on the rising or falling limb of a flow event. While there appears to be an increase in juvenile fish migrating when flows recede between 0.2–0.7 $m^3 s^{-1}$ over the course of 24 hours, compared to when flows showed little change or were increasing, few observations were made on the rising limb of a flow event and so the observation may be biased.

The number of adult smelt captured showed a slight decreasing trend with decreasing water clarity, although the number of observations at water clarity greater than three metres are relatively few, limiting any interpretations (Figure 3-6). The number of juvenile smelt did not appear affected by water clarity and overall, no relationship between the number of smelt captured and water clarity was observed. Observations from the 2018/19 field season were generally in line with those from previous years.

The number of adult smelt migrating each monitoring day showed a slight decreasing trend with increasing diurnal water temperatures, above 14°C (Figure 3-6), however observations from the 2018/19 field season were counter to this decreasing trend. The number of juvenile smelt captured showed no correlation with diurnal water temperature and overall (total catch) no relationship was observed.

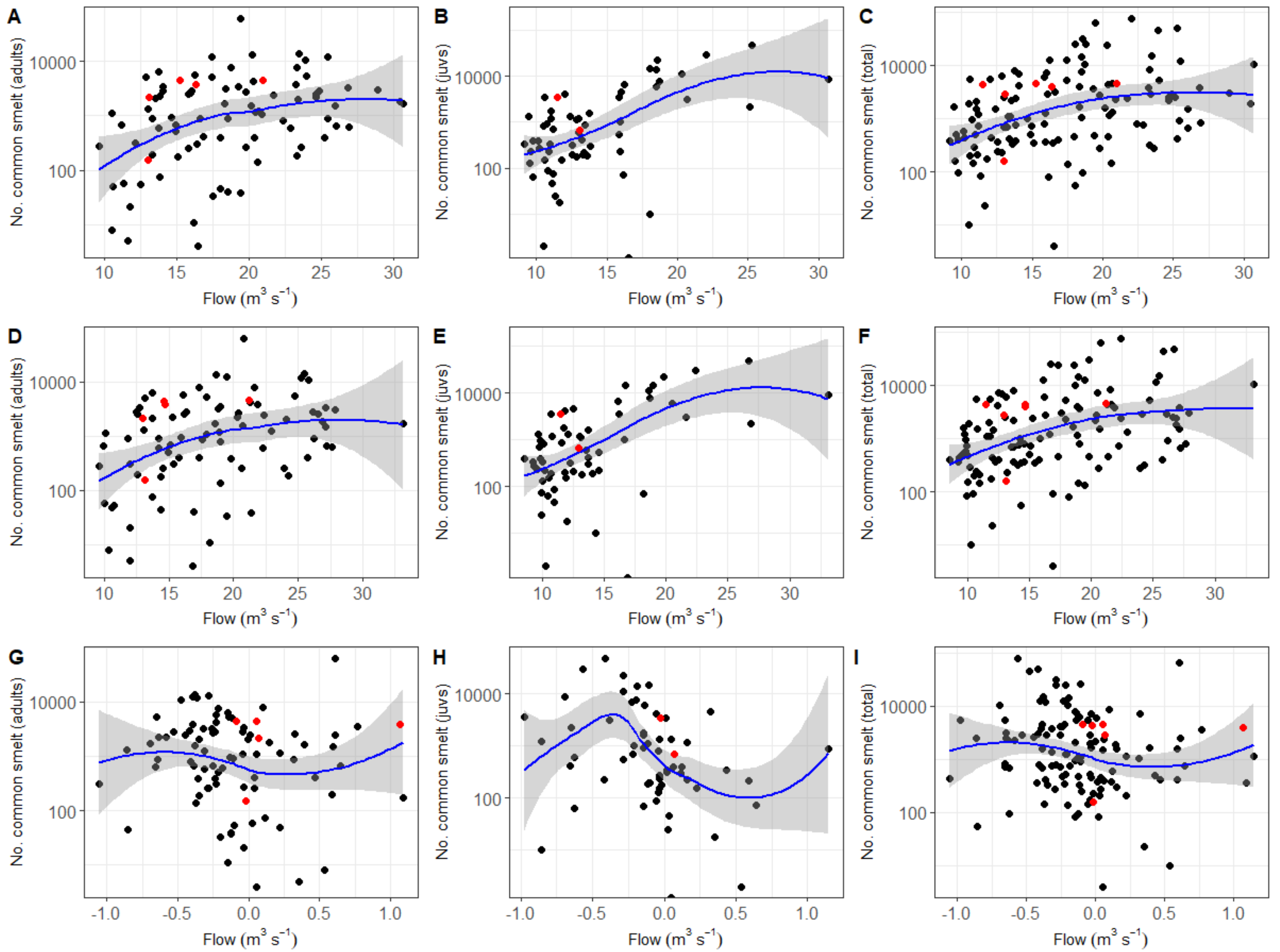

Figure 3-5: Local (Loess) Regressions of the number of common smelt adults, juveniles (juvs), and total catch as a function of flow at the time of sampling (A, B, C), 7-day mean flow leading up to each sampling event (D, E, F), and the 24 hour change in flow on the day of sampling (G, H, I). Data points collected during the 2018/19 sampling season are depicted as red dots. Confidence intervals are shaded grey. Adult data is from peak running season (April-December), juveniles (December-April). Total catch includes all sampling days.

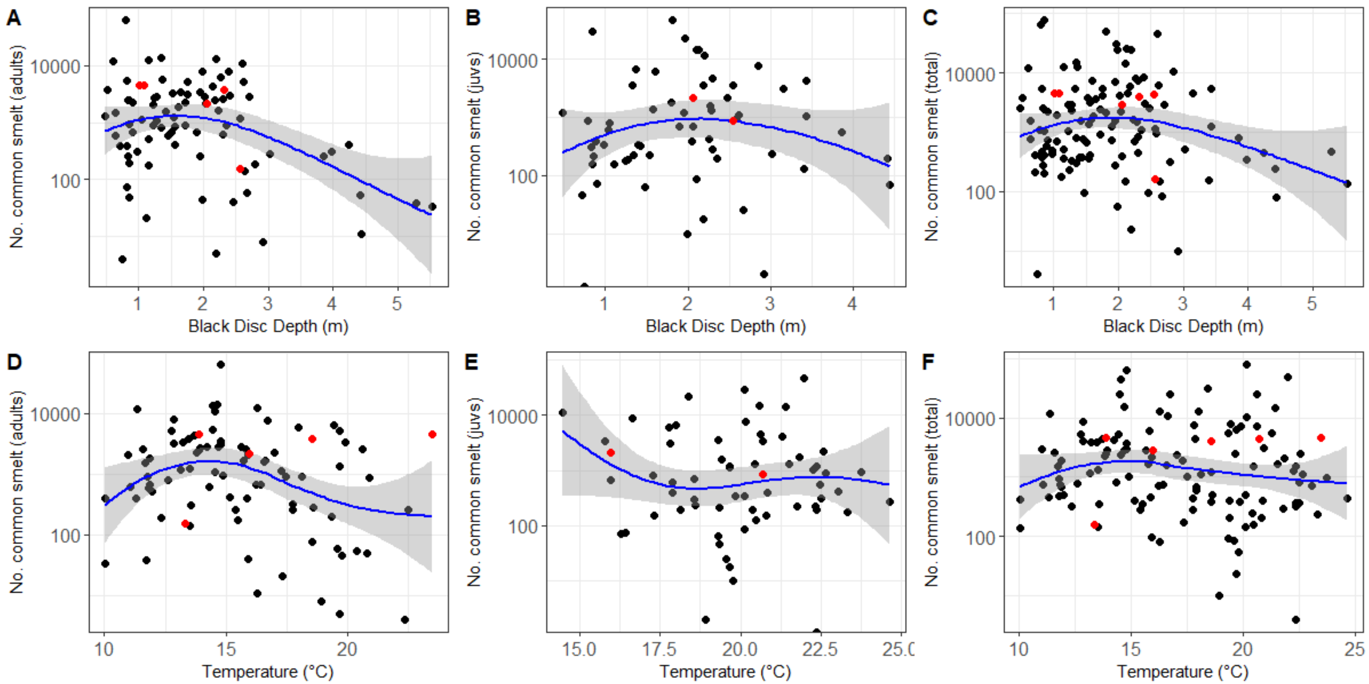

Figure 3-6: Local (Loess) Regressions of the number of common smelt adults, juveniles (juvs), and total catch as a function of water clarity (A, B, C) and diurnal water temperature (D, E, F). Data points collected during the 2018/19 sampling season are depicted as red dots. Confidence intervals are shaded grey. Adult data is from peak running season (April-December), juveniles (December-April). Total catch includes all sampling days.

While runs of adult smelt occur throughout the year, our findings since 2005 indicate that they predominantly run between mid-autumn (May) and late spring (November), whereas juveniles largely migrate in the summer months (January, February, March) (Shelley et al. 2018). Essentially equal proportions of adults to juveniles run in April and December. The results of the 2018-19 sampling concur with the observations of Rowe (2012) about the timing of movements of adult and juvenile smelt and with the ongoing monitoring results as presented in Figure 3-7. The two largest catches of juvenile smelt were sampled during March and April 2019, while the three largest catches of adult smelt were during September, October and November 2018. The absolute catches of both adult and juvenile smelt were lowest during May 2019.

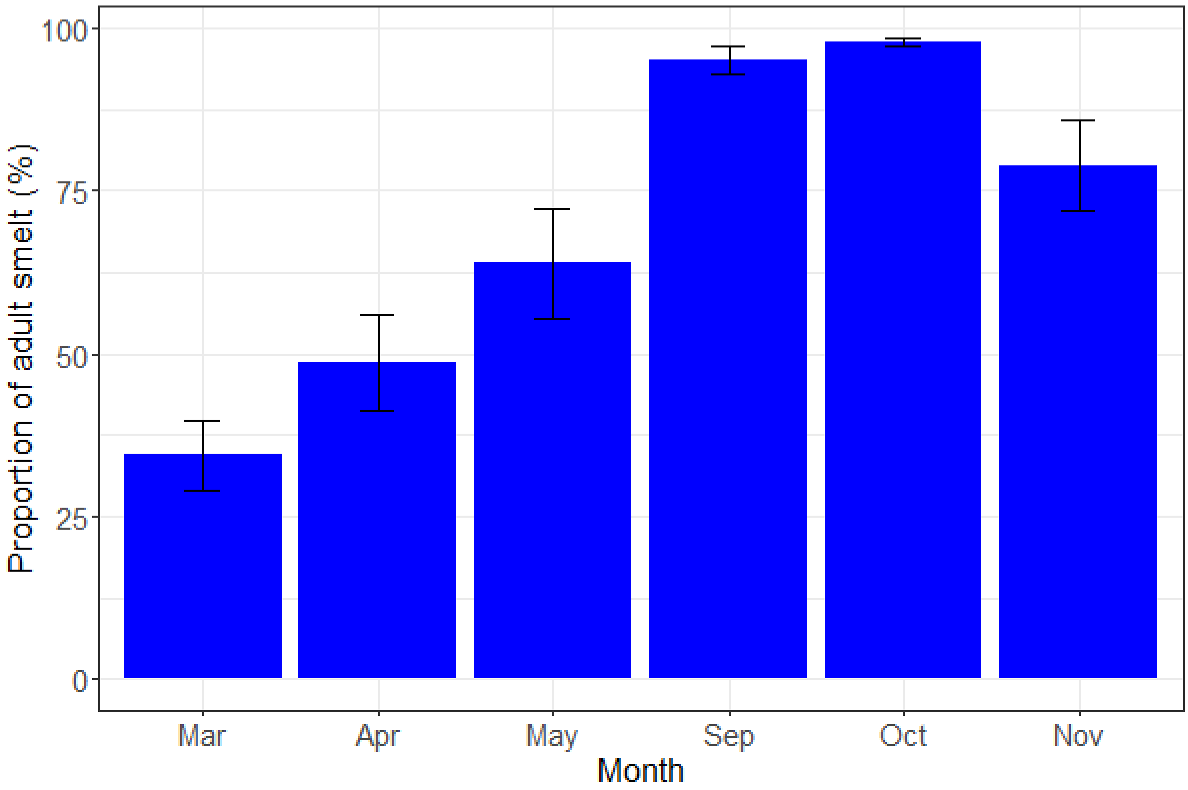

Figure 3-7: Mean proportion of adults in the smelt catch for each March-May and September-November over the period 2005-2019. Error bars represent ± standard error.

Five runs were observed during 2018/19 sampling period. All the observed runs were small, with the largest of these seen on the 24th September 2018 (3.01 smelt/min, 98% adults). Three other runs were also dominated by adults: 31st October 2018 (2.84 smelt/min, 98% adults), 26th November 2018 (2.3 smelt/min, 96% adults), and 29th April 2019 (2.08 smelt/min, 76% adults). One run was dominated by juveniles, on 21st March 2019 (2.86 smelt/min, 80% juveniles). While only small runs were observed during the study period, the size of runs is within the range of variability observed in previous years.

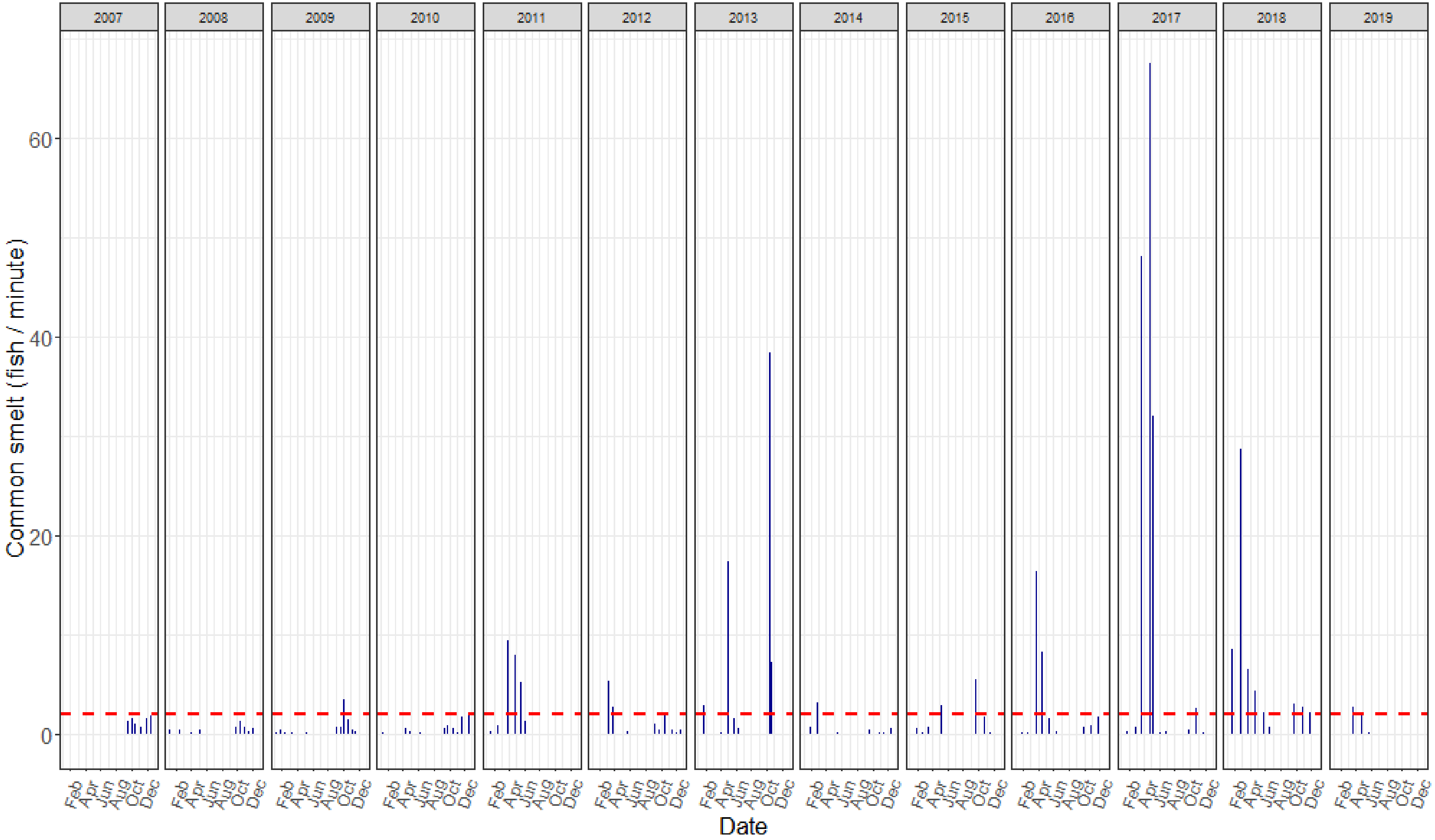

Figure 3-8: Smelt catch rates recorded in the Ohau Channel between 2007 and 2019 showing days when runs of smelt were recorded. The diversion wall was completed in July 2008. The CPUE threshold of 2 smelt/minute defines a run of smelt (red-dashed line).

Rowe et al. (2013) noted a gradual but statistically significant decline in the catch rates of common bullies over the seven-year period between 2007 and 2013. Because this decline occurred steadily each year after 2008 when the diversion wall was installed, it was thought that it may reflect a decline in common bullies moving upstream in the Ohau Channel. However, bully catch rates consistently increased between 2013 and 2017. Catch rates decreased in 2017/18, and again in 2018/19. Although a decrease was seen this monitoring year, catches were still greater than in 2013. Overall a cyclic pattern in bully catch rates is appearing, which suggests that the construction of the diversion wall is unlikely to be causing a long-term decrease or change in the number of bullies moving upstream through the Ohau Channel.

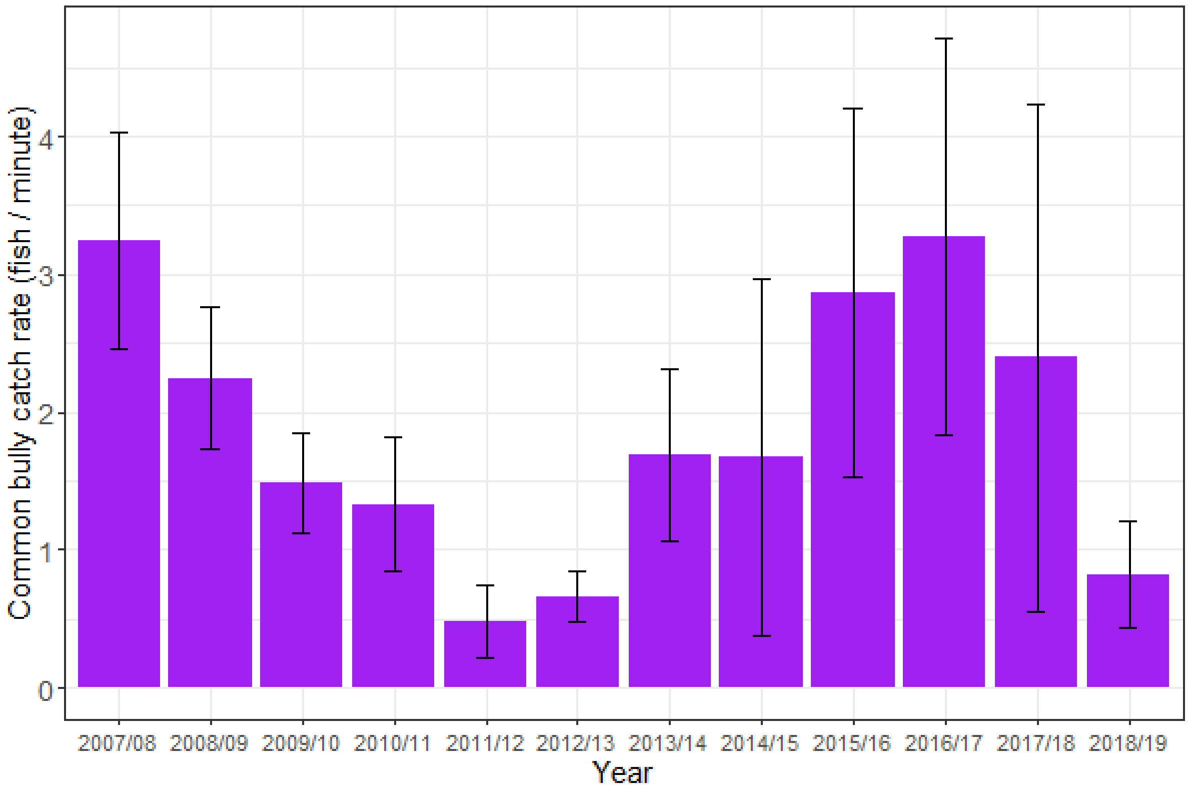

Figure 3-9: Catch rates for common bully in the Ohau Channel between 2007 and 2019. The diversion wall was completed in July 2008. Error bars represent ± standard error.

4 Discussion and conclusions

4.1 Does the diversion wall impact on smelt and bully migrations?

Results from 2018/19 support previous monitoring in that the diversion wall does not adversely impact smelt migrations up the Ohau Channel. Although there is limited data from before the diversion wall, the size and duration of smelt migrations does not appear to have changed since the diversion was installed. Both adult and juvenile smelt continue to migrate, and catch rates frequently exceed pre-diversion catch rates. While the smelt runs observed in 2018/19 were considerably smaller than those in recent years, they were still within the variability seen both before and after the installation of the diversion wall.

Similarly, the migration of bullies appears unaffected. As was the case for smelt, 2018/19 was a year in which catch rates of bullies were lower than previously. However, a cyclic pattern in catch rates is becoming apparent. In any lake system bully population dynamics are complex, and a number of biotic and abiotic factors will influence reproduction, growth, migration and mortality of common bullies (Stephens 1982). Therefore, a variety of factors could have contributed to the cyclic pattern in catch rates that is starting to occur and the Ohau Channel wall is unlikely to be a major factor influencing their migration patterns.

Other aspects of the smelt migration, such as the frequency of the runs (i.e., the number of days when a run occurs per annum) cannot be determined from the data obtained under the design of this monitoring programme. Such information would allow the assessment of any decline in run frequency, which would provide more detail on how the diversion wall may be affecting smelt populations. In addition, the monthly monitoring program coupled with the high temporal variability in the size and occurrence of smelt runs means that the data collected are not a true reflection of population abundance.

4.2 What environmental factors are influencing smelt runs?

Migratory species have evolved innate senses that detect changes in the environment (e.g., increased flow) and trigger migratory movements (Liedvogel et al. 2011). From a management perspective, the identification of these drivers is important as it allows for the assessment or prediction of how natural or anthropogenic changes (e.g., the diversion wall) may influence these migratory cues and the size, timing and frequency of migrations.

With the addition of recent monitoring data, investigations into the influence of average daily flow, seven-day mean flow and 24-hour change in flow preceding the completion of sampling, average diurnal water temperature, and water clarity on the size of smelt migrations strengthened trends relating to flow and water temperature. The size of smelt runs showed a moderate, but clear increasing trend with increased mean daily flow and seven-day mean flow that held true for both juvenile and adult fish. Furthermore, a slight decreasing trend between adult smelt numbers and diurnal water temperature were observed. Conditions experienced within the Ohau Channel largely reflect the conditions in Lake Rotorua, which is the source waterbody. While some smelt may live in the channel, it predominantly represents temporary habitat for fish that are migrating between the lakes. For instance, during the peak migration season over 10,000 fish were observed moving up the Ohau Channel on a given sampling day. For those transitory smelt, changes in flow and temperature may indicate that lake conditions have changed in their favour, thus instigating more fish to migrate.

The analysis discussed here has identified trends between increasing flows and temperature, and the size of smelt runs. Further research is needed to conclusively establish these relationships and to better understand the mechanisms involved. Further research efforts should also focus on other elements of the temperature and flow regime (e.g., rate of change, direction of change) and investigate other environmental cues not included in this study. The ecological driver for the migrations (e.g., spawning, foraging habitat) also remains unknown and presents an important area for future research. Together, this information will provide a greater understanding of the size, timing and frequency of smelt runs allowing for more effective management of smelt populations in Lake Rotorua and Lake Rotoiti to benefit the associated trout fishery.

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