# OPTIMISATION OF OUTLET CANAL OPENING TIMING FOR SUSTAINABLE MANAGEMENT OF WHITEBAIT AND EEL FISHERIES IN LAKE FORSYTH (TE ROTO O WAIREWA).

Migrating shortfinned eels congregated at the end of the closed canal, April 2010 (R. Wybrow)

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## INTRODUCTION

Christchurch City Council (CCC) has responsibility for managing the levels of Lake Forsyth to ensure that public and private property is protected from flooding. Lake levels were permanently held below the natural maxima cycle by cutting temporary canals through the shingle barrier beach, in response to rising lake levels. Such temporary works have been carried out for nearly 150 years.

Impacts upon fish stocks and traditional fisheries had become severe and NIWA predicted complete collapse of the eel fishery unless openings were made at the times of juvenile eel immigration (Jellyman & Cranwell 2007). In 2007-8, at the instigation of W. Alexander & C. Mitchell, Wairewa Runanga applied for Resource Consents allowing trials on construction of a permanent canal to the sea, together with a groyne intended to cause down-current erosion (Terminal groyne syndrome) that would reduce shingle build up. The aim of this project was to construct an outlet to the lake that remained open to the sea for longer periods. The long-term aim remains to develop a permanent outlet to the lake. A range of benefits were foreseen, including provision of fish passage for eels, whitebait and other taonga species, potential to manage toxic algae blooms that occur regularly in the lake and provision of better management options for rehabilitation of the only Ngai Tahu customary lake. To date the canal has performed well for fish passage and algae blooms have declined dramatically (Mitchell 2011). CCC has been very supportive of the project and has used the canal for all openings since 2009.

## SEASONAL TIMING OF OPENINGS

The primary responsibility of CCC is management of lake levels to prevent flooding. Therefore openings are most frequently made during the winter. Analysis of opening records (Fig 1, Table 1) from 2006-2010 shows that the main period of openings for flood control is from May until August. This is thought to lie outside both the main period of both glass eel migration (Jellyman et al 1999) and spring whitebait migrations. However there were still four October openings during those 5 years (Fig 1, Table 1).

Examination of a further set of opening records (~~E.Can~~Environment Canterbury) showed that in most years the lake was opened at least briefly in September or October (Table 1). This indicates that at least some elvers and whitebait should be able to get into the lake in most years.

## Annual periods of lake openings

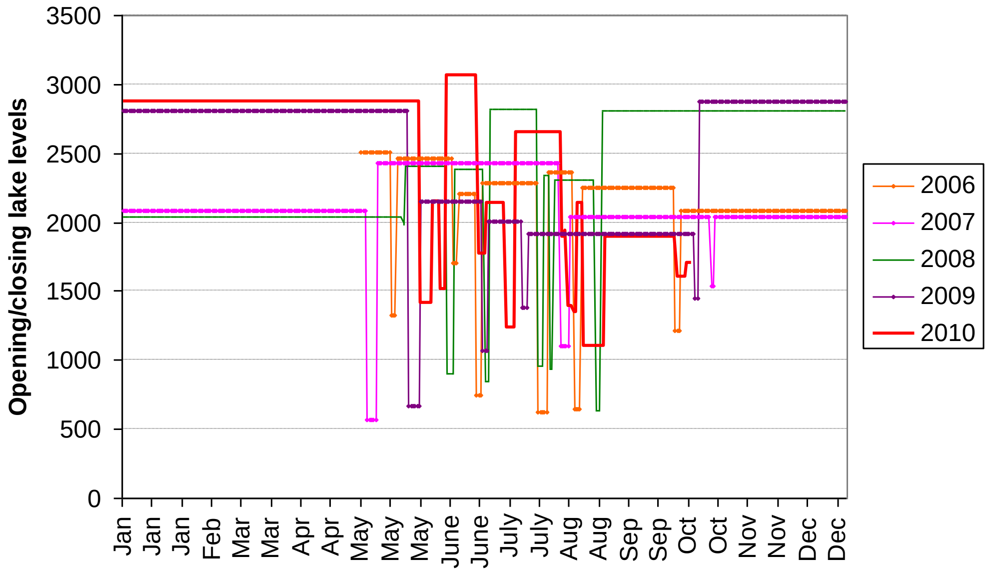


Fig 1. Start/finish opening levels for a 5 year period showing the strong winter seasonality of opening times. Note: Four October (spring) openings, but no openings at all from January until May – This period includes critical autumn adult eel spawning migration times, plus whitebait spawning and hatching periods.

Table 1. Records of September/October Lake openings over 15 years.

| Date | Days open |
|---|---|
| 15 September 1995 | 4 |
| 11 October 1995 | 2 |
| 4 September 1996 | 4.5 |
| 17 October 1998 | 4.2 |
| 28 September 2000 | 7.5 |
| 15 October 2000 | 3 |
| 12 September 2001 | 4 |
| 9 October 2002 | 5.5 |
| 22 October 2002 | 6 |
| 12 September 2003 | 4 |
| 13 October 2003 | 5.5 |
| 29 September 2004 | 2 |
| 14 October 2005 | 4 |
| 6 October 2006 | 2.5 |
| 24 October 2007 | 2 |
| 16 October 2009 | 8 |
| 07-October-2010 | 5 |

However, successful recruitment of significant numbers of elvers and whitebait into the lake during an opening obviously depends upon there actually being fish out in the ocean close by, waiting to come in at the precise and very brief periods (2-10 days per year) over which the lake was open. Openings at times when fish are most likely to be migrating would appear an environmentally sound strategy.

## INCREASING FREQUENCY AND DURATION OF OPENINGS

Over winter 2010, the first year the canal was in service, the lake was opened 7 times, for a total period of about 42 days from June until mid October, or for just over 30 % of this period (~~E.Can~~Environment Canterbury lake level recorder data). This is much better than the old beach opening scenario (Fig 1, Table 1) but still remains a fraction of the spring period, when most juvenile fish arrive.

As the canal has 'matured', surf-driven gravel deposition appears to be reducing and the canal is currently remaining open for increasing periods. In winter 2013 the canal was opened in early June and remains open at the end of July, following a self-opening during the 23 June rainfall event which caused widespread flooding around Lake Ellesmere.

Obviously, a permanent opening during migration periods would give fish the best opportunity to enter and leave the lake. But even at present, the narrow and highly permeable canal beach berm which builds up between openings is likely to have significantly extended the period when elvers may get into the lake. Eel fishermen have reported seeing elvers entering the lake by worming through outflows between the gravels (B. Ruru pers comm.).

## DOWNSTREAM MIGRATION TIMING

It is probable the lake now has significantly improved recruitment of elvers and whitebait. But it can be seen from Fig 1 that lake openings from November until May remain unlikely for flood control. This 7 month period brackets the downstream migrations when both eels and whitebait must leave the lake to return to the sea. Both the spawning and hatching of whitebait require tidal conditions as well.

It is already well accepted that lake openings which allow juvenile eels and whitebait to enter the lake are important for maintenance of populations of these valued fishes. However, in terms of sustainable management, allowing the return migrations to close fish life-cycles is equally important. In lieu of a permanent outflow from the lake, timed lake openings planned by CCC and Ngai Tahu to allow desirable levels of return fish passage should be included in the next step in better lake management, which the canal and groyne has made possible.

## PREDICTING MIGRATION OPENING TIMES

The following section is intended to clearly define those periods in autumn when even brief lake openings predicted by tidal cycles should be most effective for facilitating the compulsory return migrations from freshwater to the sea that eels and whitebait have to perform. Predictions for 2014 are given to demonstrate how this work can be planned years in advance.

### 1. EEL MIGRATIONS

Hobbs (1948) reported on the out-migration behaviour of eels at Taumutu, Lake Ellesmere (Waihora), in an era (1942) when the populations were still unfished and most abundant. Although now affected by fishing, it is assumed that the same instinctive migratory behaviour and timing still occurs at Ellesmere and also at Wairewa.

Hobbs found the timing for shortfinned eel migration was earlier in the autumn than for longfinned eels. Male shortfinned eels began to appear along the beach at Taumutu, beside the opening area, in February. Shortfinned females next dominated the catch from mid March until the end of April. Longfinned eels migrated from April until June with males (?) migrating after the females (McDowall (1990) reported that other researchers considered longfinned males leave before the females, in a similar fashion to shortfinned eels).

Hobbs (1948) estimated the shortfinned eel migration in 1942 was nearly 1 million fish with an average weight of 0.52 kg. This implies that around 500 tonnes of eels were attempting to leave the lake, peaking over just 4-5 spring-tide nights in the entire year. Longfinned eels were later and much less common. Only about 20 tonnes attempted to leave the lake beginning in late April, peaking in May and extending into June. Again, most movement was on the same spring-tide nights. In years when Lake Ellesmere (43 degrees S) remained unopened into the winter, shortfinned eels appeared to eventually give up and most returned back into the lake by the end of April. Only a few migrants were seen in May and by June none remained around the outlet area.

This is identical to my experience in culturing shortfinned eels at Raglan (37 degrees S). Spawning migrant fish are attracted to the screened pond sluices, during peak spring tide inflows. Migration only occurs in the same months as Ellesmere, from late February until the end of April. The migrations then stop. In ponds where migrants were not fully harvested, at least some mortality of migrant eels may occur over winter, although captured migrants can be held alive in corf nets for up to 12 months.

It would appear likely that all eels in New Zealand undertake a synchronised annual migration. Males migrate earlier than females owing to their smaller size and thus lower optimum swimming speed, in order to reach the distant spawning grounds at the same time as the females. Finding fully sexually mature spawning partners in the dimly lit vastness of the deep tropical Pacific Ocean, at precisely the right place, depth and time for a few minutes of ovulation, appears an incredible navigational feat, followed by total mortality. But this is the only way we know to make new eels. Breeding our own with aquaculture is not going to happen. If the fishery and lake openings at Wairewa can be managed to allow at least some natural escapement to occur, the future supply of eels would appear more likely and a new level of expertise in natural resource management in NZ will have been demonstrated.

Keeping the lake constantly open is not necessary. Hobbs (1948) found migration peaked after dark during the autumn high spring tides associated with full moon or new moon along the Canterbury Coastline. The main migration nights were 2-3 nights after full or new moon. This is when the highest tides occur. Strong outflows from the lake on 'dark' nights (heavy cloud/rain) was considered to stimulate the greatest migration activity. Obviously this is the best time to open the lake. Tidally controlled migrations occur for eels, elvers and whitebait, offering a good degree of predictability for fisheries management activities.

Opportunities presented for consideration include:

a). There should be an effort made to coincide any lake openings required, with the tidal cycle.

b). There should be guidance and methods given in the Consent Conditions to allow calculation of timing of dates of openings with eel and fish migrations and spawning.

c). Consent Conditions should provide the ability to open the lake or move gravels on the canal berm to allow fish passage, in addition to flood control openings.

d). The Consent Conditions should allow the option of insertion of fish passage structures such as flexible piping, through the canal berm to allow eels and other fishes to leave the lake when opening is not possible.

In contrast to tidal migration activity found at coastal locations, research on inland adult eel migrations above hydro-dams (Boubee et al 2007) has found that rainfall and the resulting flooding had the major controlling influence on migration activity for these populations (Fig 2). However, considering that there is virtually no significant rainfall in Canterbury during most autumns, it is unlikely that CCC would be required to open the lake during this time for flood control purposes. Clearly, the demands of sustainable management of the lakes biological resources are not particularly well matched to flood control, whereas tidal cycles offer brief but very predictable opportunities to achieve better ecological management

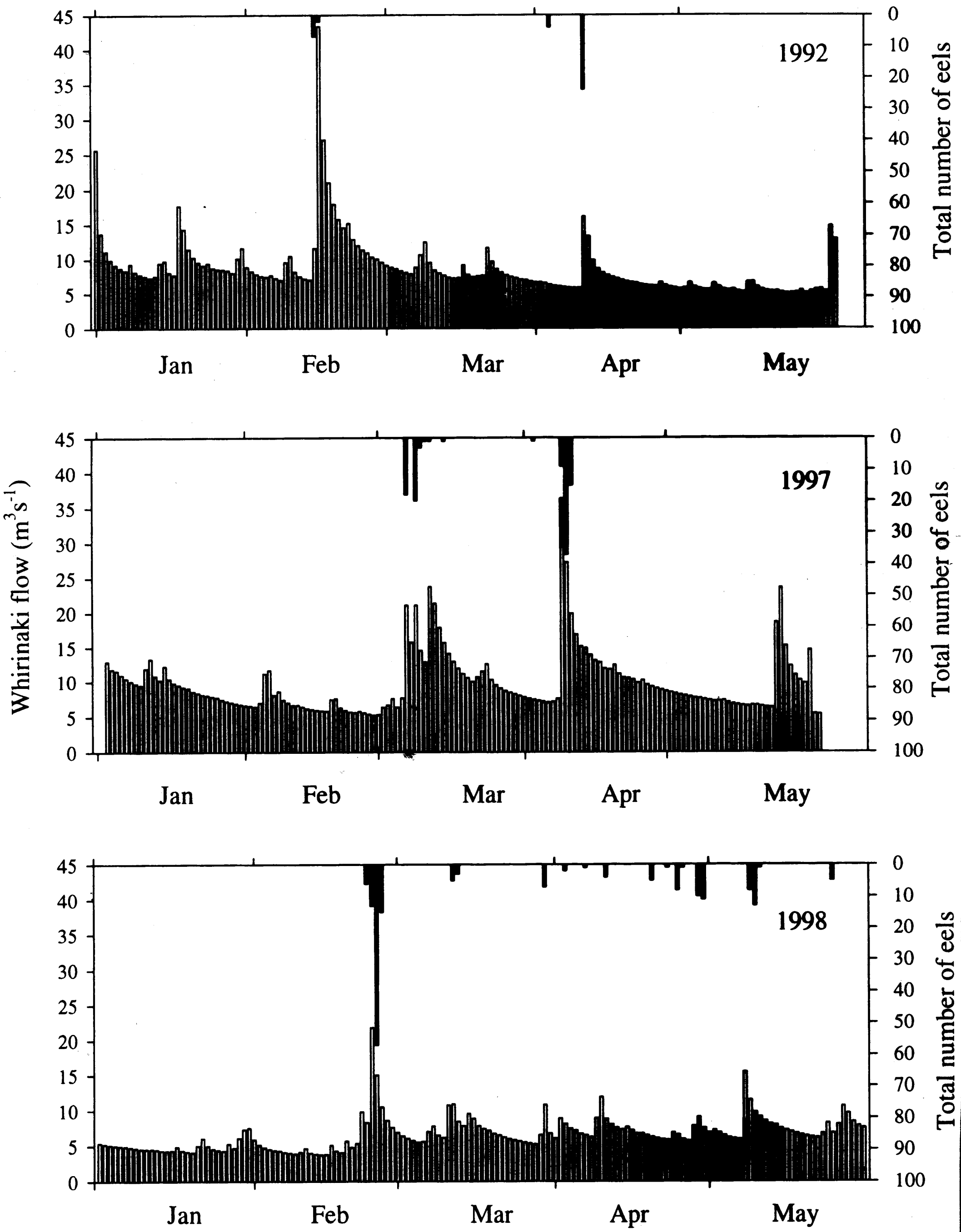


**Fig. 2** Variation in flow (open bars) of the Whirinaki River (WS 15410), New Zealand, and number of mature migrant eels (*Anguilla* spp.) collected from Aniwhenua Power Station during autumn 1992, 1997, and 1998 (dark bars).

Using predicted tide height values calculated by NIWA, tables can be prepared to identify optimum lake opening periods. Fig 3 shows the tide cycles when shortfinned eel migrations can be predicted for 2014. Only three night openings for 1-2 days a month from March until the end of April would probably be perfectly adequate to provide spawning escapement for this species. More generous opening periods of six days per month are suggested (Table 2).

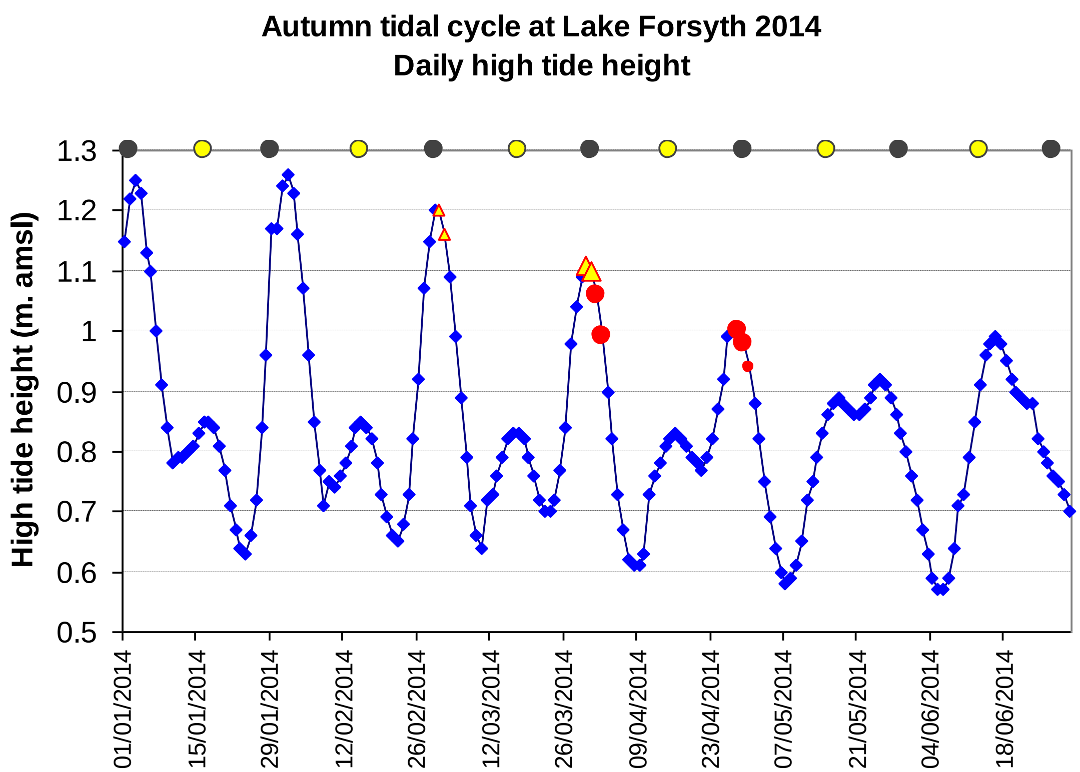


Fig 3. Major shortfinned eel migration intervals and tidal (NIWA) / lunar cycles for autumn 2014. Yellow triangle - male migration, red circle – female migration. Large symbol, most migration likely.

Compared with shortfinned eels, longfinned eels are relatively uncommon in lake habitats. This species is known to migrate after shortfinned eel numbers have peaked (McDowall 1990). Concerns have been expressed that this endemic species may be in serious decline and so lake opening management to ensure spawning escapement would be supported by Conservation organisations. The later timing of the longfinned eel migration also means that lake openings for water level control in May-June are likely to allow these fish to escape to breed anyway. Fig 4 shows optimal opening times over the autumn tidal cycle. Table 2 identifies the dates when migration activity is likely to peak./

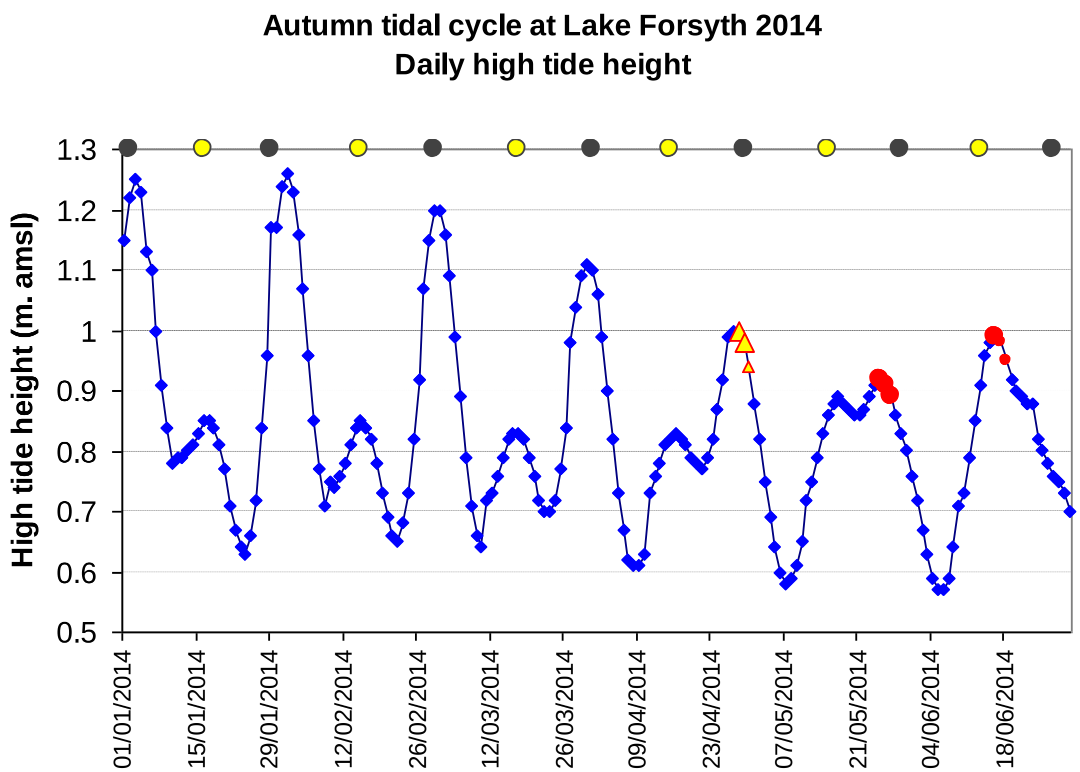


Fig 4. Major longfinned eel migration intervals for autumn 2014. Yellow triangle - male migration, red circle – female migration. Large symbols, most migration likely to occur.

Fig 5. Migratory form female shortfinned eel showing coloration, enlarged, darkened pectoral fin, lips and eye. At this stage this eel will never feed again. She has metamorphosed to migrate thousand of kilometres into the tropical Pacific, spawn and die.

Fig 6. Migrating eels crowded at the closed off end of the Lake Forsyth (Wairewa) outlet canal (R. Wybrow). Numbers will be much higher at night and it is probable that this activity in daylight could irreparably bleach sensitive visual pigments plus expose the crowded fish to bird predation.

Fig 7. Migrating eels crowded at the gravel bar (berm) blocking the outlet canal. Note the water level and gravel berm level against the red rock strata on the opposite bank (R. Wybrow).

Fig 8. The outlet canal level after an opening. Note the red rock strata and remnant layer of gravel marking the previous level of the gravel bar (as seen on the RH side of Fig 7). At this stage the canal is tidal.

## 2. Whitebait enhancement opportunities

Common whitebait (*Galaxias maculatus*) is the most valuable whitebait and by far the dominant species in the Canterbury whitebait catch. Although even brief openings in October may sometimes allow considerable numbers of common whitebait to enter Wairewa, the high biological productivity cannot be exploited to regularly produce large numbers of whitebait because there are no lake openings in the autumn period. Adult whitebait spawn within the very upper intertidal zone, which is only flooded for a few hours each month, in the very lowest freshwater reaches of lowland river systems.

Eggs are deposited at precise water levels, in very shallow water flooded during spring tides, just after the high tide has turned. As a result, the prime areas selected for spawning occupy a narrow zone of tidal land. At Lake Forsyth this can be expected to occur within a zone 0.9-1.25 m. above mean sea level. When the lake is opened, these tidal levels will occur along the canal sides.

Once the spring tides return the next month, the eggs hatch and the larvae are carried out to sea by the ebbing tide. Inanga has the smallest yolk volume of any whitebait species and so the larve must reach the sea quickly after hatching. Fig 9 shows whitebait spawning at Raglan among vegetation bordering an artificial tidal pond.

Fig 9. Inanga left wriggling across eggs (white dots) laid on dead raupo stalks, as the tide falls. Note water milky with sperm.

Timing and water levels required for successful inanga spawning and hatching at Wairewa can be predicted. Spawning is known to occur during high tide (day and night) 1-4 days after the peak spring tide for that cycle (Fig 10). Hatching occurs over the next series of tides high enough to reflood the eggs, 23-28 days later (Fig 10).

Clearly the demands of sustainable management of lake biological resources are not particularly well matched with flood control. On the other hand, managing works around tidal cycles offers brief but very predictable opportunities to achieve better management of biological resources.

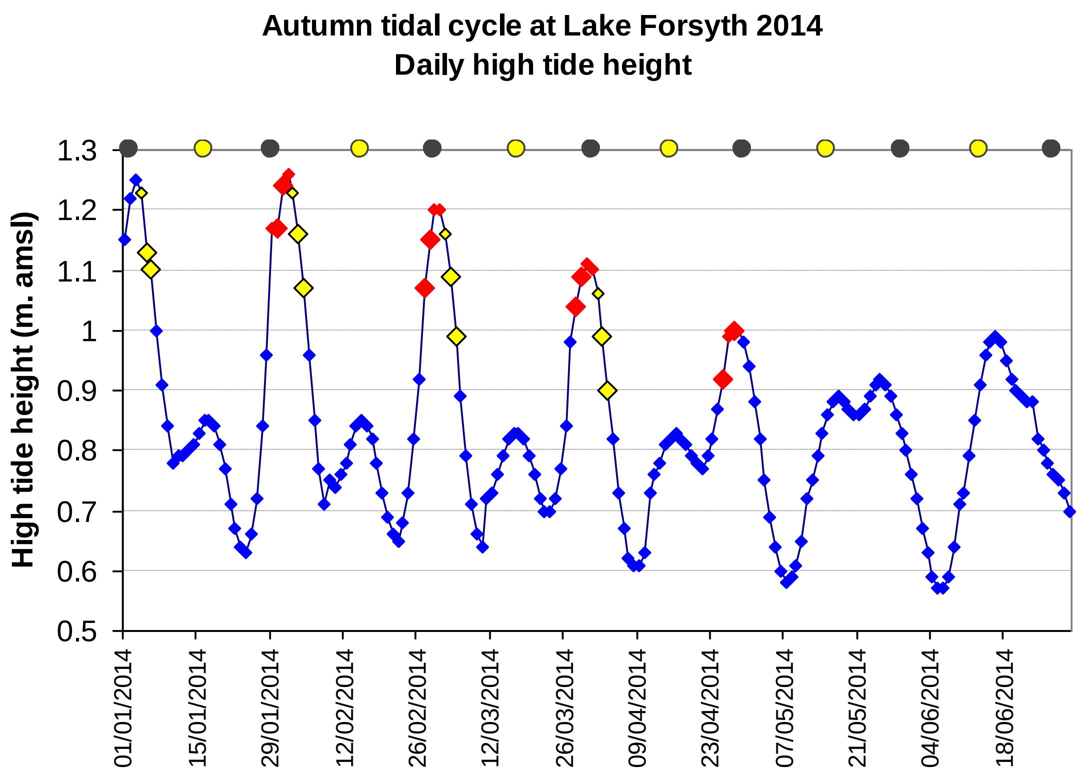


Fig 10. Major common whitebait (inanga) breeding activity intervals predicted for autumn 2014. Yellow diamond – spawning tides, red circle – Egg hatching tides. Large symbols, most activity likely.

**Whitebait spawning habitat at Wairewa**

Research into the spawning ecology of common whitebait (Hefford 1933, Benzie 1968, McDowall 1968, Mitchell 1991, Mitchell & Eldon 1991) has long been based on the assumption that pre-spawning fish will only select tidally flooded areas of thick herbaceous riparian vegetation within which to spawn. Areas like this are scarce along the tidal reaches of unstable gravel common to rivers along the South Island East Coast, including Wairewa Canal.

But in spite of our ‘understanding’ the specialised requirements for whitebait spawning, it is also known that considerable whitebait runs may enter New Zealand rivers where apparently little suitable spawning habitat occurs. Therefore it was of great interest when Messrs Bruce and Davis found inanga spawning within loose gravel at Waihao Box in 2004.

Spawning occurred in February after the box had been opened and the lagoon had become tidal. At high tide, large shoals of inanga were seen moving along the shoreline of Waihao Lagoon in a purposeful manner. These fish were in very shallow water and were not feeding. Within the area selected for spawning, groups of fish were seen working their way into the gravels. As the water level slowly dropped fish were left milling in shallow water or emerged from the exposed gravels with splashing and frantic activity. The water in the area had a milky discolouration. Fish were not very aware of the presence of observers and the very thin spent fish could be easily picked up off the wet gravels as the tide receded. As the tide fell fish were seen still emerging from the gravels up to 2-3 metres from the waters edge, attempting to wriggle back to the water.

Excavations into the steep and unstable beach found that fish were present down to 100-150 mm below the surface. Eggs were found deposited over the gravels and to a considerable depth down into the gravels. As low tide level was reached the fish gradually stopped spawning. This was not a minor spawning event. For two days large numbers of fish were observed spawning along 500-600 metres of the gravel barrier bar between the sea and the lagoon. Thousands of fish were involved and the water was turned milky with milt in the area as the tide fell.. Even by the third day, considerable numbers of fish were still present.

Waihao Lagoon was low and tidal at the time of spawning as the gravel bar had previously been breached by the river. These are the only conditions under which the lagoon is actually tidal to any degree. About 3 days later a heavy sea rebuilt the bar and the water level slowly rose up to cover the spawning site.

It can be inferred that if the lake outlet canal is opened for every spring tide over autumn, a total of 5 spring tides each year, spawning along the canal sides and thus whitebait production from the lake could be maximised. As openings to allow eel migrations are needed over the same peak tide cycle times from March until June, only openings in January and February would be needed specifically for whitebait.

**Optimum Lake Opening Cycle**

Table 2 shows the dates in autumn 2014 when the canal should be opened to maximise fish life-cycle production for each species. It can be easily seen that most tidal cycles are used by two or more species. Six targeted openings lasting from 6-10 days would optimise biological production gains possible from this natural interaction between the sea and lake ecology.

Table 2. Optimised lake openings for autumn 2014 to allow valuable native fish breeding and migratory behaviour.

| Fish Species | Life-cycle stage | Sex | Month | Dates | Days |
|---|---|---|---|---|---|
| **Shortfinned eel** | Mature migrants | M<br>M/F<br>F | | 28 Feb- 5 March<br>29 March-3 April<br>26 April-1 May | 6 d<br>6 d<br>6 d |
| | | | | | **18 d** |
| | | | | | |
| **Longfinned eel** | Mature migrants | M<br>M/F<br>F | | 26 April – 1 May<br>23 May – 28 May<br>12 June – 17 June | 6 d<br>6 d<br>6 d |
| | | | | | **18 d** |
| | | | | | |
| **Inanga** | | | | | |
| *Larvae releases* | Spawning<br>Hatching/Spawning<br>Hatching/Spawning<br>Hatching | | | 2 Jan-7 Jan<br>26 Feb-6 March<br>27 March-4 April<br>24 April – 2 May<br>23 May-28 May | 6 d<br>9 d<br>9 d<br>10 d<br>6 d |
| | | | | | **40 d** |

## CONCLUSIONS

This analysis shows that targeted lake openings from as little as 18-40 days during the 7 month annual period when the lake usually remains closed to the sea, or from 8 %-18 % of this total period, concentrated in the autumn months, could greatly enhance and sustain biological values and ecological processes in the lake.

These recommendations have solely considered the fish passage requirements necessary to optimise production of valuable native fish from the lake. Benefits from this activity would obviously include sustainable fish stocks. However, the requirements of the 'traditional' fishery, which utilises the behaviour of eels trapped in the lake when there is no outlet, is another whole issue. Control of the fishery is the responsibility of Wairewa Runanga. How these Resource Consents will provide approvals to allow them to achieve optimum sustainable yields will be a further important component of better lake management.

It is suggested that provision for fish passage lake openings from March until June should be consented, together with openings between September until November to allow return fish passage of whitebait and elvers plus mullet, flounder, smelt and seatrout.

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