Inanga spawning habitat quality, remediation and management in the Wellington Region

Prepared for:

Greater Wellington Regional Council, Wairarapa Moana Wetlands Group, Porirua City Council, and Wellington City Council

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A developing inanga egg from the lower Porirua Stream, Porirua City, April 2016

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Contents

Tables

1 Executive Summary

The Greater Wellington Regional Council, Wairarapa Moana Wetlands Group, Porirua City Council and Wellington City Council seek information on the location, protection, and remediation of inanga spawning grounds in the Wellington Region. Aquatic Ecology Limited (AEL) was commissioned to undertake field surveys in April 2016 across a range of pre-selected sites. The sites selected for surveying in 2016 were largely based on sites previously reported in Taylor and Kelly (2001; 2002), which was when the last known comprehensive surveys of inanga spawning habitat were undertaken in the region.

The key objectives of the surveys were to assess the quality of the habitat at each site for inanga spawning, where possible compare with earlier survey information in 2001/02 to assess any changes in habitat quality and to provide site-specific and general information on any management issues or restoration opportunities identified. Field methodology was similar to previous surveys, using saltwater intrusion on the high tide to locate the approximate area of search, followed by a low tide visit to search for eggs. A small motor boat was used to facilitate movement around large waterbodies. The field surveys were complemented with assessments of Google Earth imagery.

During this survey, we identified ten new spawning sites. These sites are: Waikanae River, Taupo Stream, Kakaho Stream, Horokiri Stream, Pauatahanui Stream, Porirua Stream, Kenepuru Stream, Waiwhetu Stream, Wainuiomata River and Pounui Stream. However, three sites do come with a caveat. The small size of the Waikanae River site and the abundance of other potentially suitable habitats nearby mean that it is unlikely we found the main spawning ground. No spawning was thought to have been found in Taupo Stream until field photos were closely scrutinised and eggs were possibly found. The exact spawning location in Pounui Stream was not found, but the presence of ripe (pre-spawning) fish indicates that we were very close to it.

Overall, across all the sites surveyed, spawning habitat conditions had generally improved when compared with the last surveys in 2001/02. Improvements were recorded at the northern tributary of the Otaki River, Kakaho Stream, Horokiri Stream, Porirua Stream (mainstem) and Kenepuru Stream With regards to sites such as the Kakaho and Horokiri Streams in Te Awarua-o-Porirua Harbour, the significant improvement in habitat quality can be attributed to active restoration). In other cases, improvements might be due to normal fluvial processes (Otaki River). Unfortunately some sites showed degradation. This included minor degradation (e.g., stock access on the Wainuiomata River) to significant modification of the Opahu Stream outlet. Whitebait access into Opahu Stream could be restricted by a new flood control structure, and while a potential inanga spawning habitat has been created, this is disconnected from rearing grounds in the natural course of the Opahu Stream.

Many of the sites surveyed have various management issues associated with them. We make a number of recommendations, including the following: possible erection of public information signs (Waikanae River); fencing improvements to exclude stock (Kakaho Stream and Wainuiomata River); weed/willow monitoring/control (Kakaho Stream and Pauatahanui Stream); ensuring mowing does not occur during the spawning season (Kenepuru Stream); bank naturalisation and/or re-grade (Porirua Stream and possibly Taupo Stream) and flood management practices resulting in inanga mortality (Pounui Stream).

Recommendations for future monitoring of inanga spawning habitat are also presented.

2 Introduction

2.1 Inanga life history

Inanga (*Galaxias maculatus*) are one of five species of native fish whose juveniles are collectively known as 'whitebait'. Inanga whitebait normally form the bulk of the catch in low-gradient rivers. This is especially so in catchments which have been converted to agriculture or developed for residential purposes. In the Bay of Plenty, which possess similar semi-developed catchments to the Wellington Region, inanga whitebait formed between 84-99% of the whitebait catch (Rowe *et al.* 1992). Similarly on the west coast of the South Island, inanga whitebait was usually the dominant species in the mixed-species catch, but in the few rivers with significant lowland pakihi habitat (acidic wetlands), the banded kokopu (*G. fasciatus*) whitebait was prevalent (McDowall & Eldon 1980). In contrast, koaro (*G. brevipinnis*) were more common, but rarely numerically dominant, in rivers with relatively high glacial water content. Whitebait of the less common species, the giant kokopu (*G. argenteus*), and the shortjaw kokopu (G. postvectis) form minor proportions of the whitebait catch.

Inanga whitebait generally migrate into rivers in the spring, but with some runs at other times of the year. Most fish rear over the summer in habitats suitable for each species, but in autumn, schools of adult inanga swim downstream into tidally influenced reaches. On the spring tide, they spawn amongst the dense riparian vegetation that becomes inundated by the tidal waters, although this water is often quite fresh. Spawning activity peaks in March and April. Once the tide recedes, the eggs develop in the humid microhabitat around the bases of the riparian vegetation. The humidity is maintained by rainfall, plant and microbial respiration, and following a cold night, condensation from dew. Near soil level, introduced grasses often have fine stolons, or for native rushes and sedges, dense stem growth. This dense vegetation near the soil provides a stable substrate upon which eggs can adhere, preventing the eggs from being washed away. Hill (2013) showed that in the absence of suitable vegetation, inanga will spawn in sub-optimal habitats, but with consequently lower egg survival. Recent research shows that inanga often survive spawning and spawn again in later years (Hill 2013).

A shallow bank provides a greater and more stable surface area for spawning than steep banks, but too shallow may cause ponding and weak vegetation growth. On very shallow banks, spawning inanga can become trapped amongst the foliage and die amongst the vegetation as the tide recedes. Soil structure appears important, as high sand content is associated with unsuitably low humidity at soil level and lower stem density. Similarly, poor draining soils, due to high clay content, may produce weak foliage growth and stem density.

Eggs are re-submerged a few days before the following spring tide (approx. 3.5 weeks in Benzie 1968b)). The re-immersion of the eggs induces hatching and the larvae are swept downstream into the ocean. Over the autumn and winter months, whitebait larvae feed on marine plankton and rear for six months before returning to rivers as whitebait.

2.2 The New Zealand fishery and fishing methods

Inanga are considered taonga in the Wellington Region, where they were traditionally valued by Maori as food during both the juvenile and adult stages. The adults were fat and rich, and although the juveniles were less sought-after, whitebait were still collected (McDowall 1990). This author writes of reports that Maori would spend the spring fishing for whitebait in Westland (South Island), apparently using flax nets.

Modern nets are more efficient and long-lasting, and a variety of methods are used based on what works best in the local rivers. These involve scoop nets, pole nets, box traps and screens, drag nets, and funnel-shaped traps (e.g. Southland sock).

2.3 Threats to inanga lifecycle

There has been ongoing concern expressed about the status of the whitebait fishery, largely based on the perception of declining catches. This perception of reduced whitebait and inanga numbers is reflected in the recent elevation of the conservation status of inanga to 'declining' (Goodman *et al.* 2013). The difficulty with the whitebait fishery is that is largely unmonitored, and catches are often under-reported. This 'declining' conservation status is described as not qualifying as 'threatened' because they are buffered by large populations in New Zealand and form secure populations overseas. Globally inanga are widely dispersed, and are also found in Australia including Tasmania, Chile, and Argentina. It is also found on several small oceanic islands, the Falkland Islands, and Lord Howe Island (McDowall 1990). Inanga are also found on the remote the Chatham Islands of New Zealand.

Assuming whitebait avoid whitebaiters nets, they are at risk from predation from a number of fish predators. The upstream whitebait run coincides with the downstream movement of large trout as they return to the lower river from spawning, and trout will consume whitebait to restore condition. Eels, and other large fish (e.g. banded kokopu, giant kokopu) are active predators on whitebait. As inanga whitebait migrate, they seek lowland habitat where they can rear. With ongoing lowland land development for farming, and more recently, residential and urban development, rearing habitats are vulnerable to depletion from loss of baseflow and drainage.

Spawning habitats are also vulnerable to human impacts. For any one river where the riparian vegetation and river morphology is stable, inanga are known to spawn, *en masse,* in the same habitat year-on-year, but with annual egg numbers dependant on the size of the breeding population. For inanga, the consistent use of suitable habitat is a two-edged sword. On the positive side, it provides scope for inanga spawning grounds to be managed to promote egg development once the potential or actual spawning grounds are determined. Without management, and with all the catchment's eggs concentrated in a short reach, significant loss of breeding potential could occur.

In urban settings, the grassy river margins which would otherwise form ideal inanga spawning habitat, is often closely mown to provide a short sward for pedestrians and picnickers. Short grass swards provide insufficient humidity to prevent inanga eggs from drying out, and the eggs could also be crushed by pedestrian traffic. It is also common that the potential spawning habitat is clad in hard materials such as concrete to prevent bank erosion, or vegetated in plants with foliage which doesn't support inanga spawning. Pollution can be a problem in urban environments, as can fine-sediment deposition when catchments are subject to development. Further, urban areas may have higher populations of rodents (e.g. mice and rats), and at least mice have been recorded eating inanga eggs (Baker 2006). Some predation by slugs has been reported in experimental environments (Mitchell *et al.* 1992), but this predation was not significant in a natural setting.

In rural settings, stock access is often damaging to spawning grounds. Eggs can be crushed and the grass grazed to a stubble insufficient to maintain a humid environment for egg development. Stock access, depending on stock density and bank hardness, can cause bank erosion and collapse, and create a bank aspect unsuitable for inanga spawning.

3 Objectives

Several agencies Greater Wellington Regional Council (GWRC), Wairarapa Moana Wetlands Group, Porirua City Council (PCC) and Wellington City Council (WCC) contracted Aquatic Ecology Ltd (AEL) to undertake assessments of inanga spawning habitat at selected sites in the Wellington Region. Previous studies had found a number of potential inanga spawning habitats, but only two confirmed habitats where eggs were identified (Taylor and Kelly 2001; 2002)

The principal objectives of this study are outlined below:

- assess the current state of inanga spawning habitat at sites selected by GWRC, Wairarapa Moana Wetlands Group, PCC and WCC[1].
- where possible assess the quality of the spawning habitat to that reported from the earlier surveys in Taylor and Kelly (2001; 2002).
- Discuss general and site-specific management issues and habitat restoration opportunities

[1] GWRC, Wairarapa Moana Wetlands Group, PCC and WCC underwent a separate site prioritisation process to identify potential sites to be included in the surveys carried out in 2016. These potential sites were largely selected from sites that were previously surveyed and reported on in Taylor & Kelly (2001 & 2002).

4 Methods

4.1 Field methods

In practice, for multiple-river surveys, locating inanga spawning grounds by conducting egg searches is more practicable than attempting to locate reaches where inanga spawning is actually taking place. This is because inanga spawn for short periods, 30 minutes or so, and are easily missed.

We have found the following is the best approach to locating hitherto unknown spawning grounds on rivers, especially where several rivers are surveyed in the one season. Ideally, the process involves a 2-stage approach on any one river:

- Firstly, at high tide, determine the upstream extent of the saltwater intrusion into freshwater, and geo-reference this limit. At the time, make notes on any conspicuous inanga shoals or activity, and the location of suitably dense riparian vegetation which could provide potential spawning habitat.

- Secondly, undertake an egg search once the high tide has sufficiently receded, starting at suitable vegetation near the upstream extent of the saltwater intrusion, and working through suitable vegetation around that point, mapping both the distribution of eggs and the distribution of suitable/unsuitable vegetation.

We had more rivers to survey than daytime high tide events, so we had to compromise on this approach, and attempt to determine saltwater intrusion on several systems on the one high tide. This meant that occasionally saltwater intrusion was determined a little earlier and later than the high tide, although, depending on stream gradient, this was unlikely to be a major problem. This was because it was often clear how far the tidal water level had fallen from peak tide, and, combined with data on the rate in which the saltwater layer was diminishing upstream, an estimate could be made on the distance the full extent of the saline intrusion would intrude. This location was then logged as a best estimate.

4.1.1 High-tide survey and conductivity readings

For rivers discharging directly to the coast, and prior to survey, the projected time of the high tide was determined using NIWA's coastal tidal model (Goring 2001; Walters *et al.* 2001). In Wellington Harbour the Met Service's tide table was more convenient and appropriate. Surveys were undertaken with a shallow-draft motorboat on most waterways (Fig. 1). The boat was powered with a 10hp outboard engine, and capable of reaching planing speed with 2 surveyors.

The saline wedge is regarded as an important cue for spawning inanga, therefore determining the location of the wedge with a conductivity meter is an important shortcut for finding the general location of spawning grounds without recourse to egg surveys. Locating eggs amongst bank vegetation is time-consuming, requires good eyesight, persistence, and a measure of luck as eggs are easily missed. Note also that intensively searching for eggs also modifies a delicate environment dependant on high humidity, both for inanga eggs and other biota. Therefore egg searches should be minimised where just locating the site is the principle objective. Water conductivity readings (Schott HandyLab LF12) were taken off the bow to avoid water disturbance generated by the propeller. The sensor had a 5 m cable, making it ideal for detecting saltwater at the bottom of deep channels, or for taking readings from low bridges. With the outboard engine removed, the vessel was light enough to be carried by two people a short distance, and capable of being transported upside down on the roof rack of a 4WD.

Figure 1. A small aluminium dinghy was used to survey rivers. The long-cabled salinity sensor can be seen coiled in the black plastic box.

Being denser than fresh water, salt water tends to follow the deepest part of the channel, and extends upstream along the river channel on the rising tide. The salt wedge is usually, but not always, near the centre of the channel. In particular, on river bends, the deepest water, and the saltwater intrusion, tends to follow closer to the outside of the bend.

During the boat survey, any incidental observations of noxious weeds were noted and geo-referenced with the GPS receiver.

4.1.2 Lower-tide survey and egg search

This survey was undertaken when the water level was at mid-to-low tide. Egg searches were initially conducted in what was deemed from the most suitable vegetation from the upstream limit of the saltwater intrusion, with the egg search working downstream.

In some catchments, there was no saltwater intrusion at high tide. Exploratory egg searches were nevertheless conducted in the zone of where some tidally-influenced water level change could be determined.

Habitat suitability was assessed based on the root matrix/microclimate, bank gradient, vegetation and soil. If near-soil humidity is high, a root matrix forms across the bank surface and provides a substrate upon which eggs adhere.

4.2 Desk-top methods and approach

GPS waypoints were downloaded and plotted using MapToaster (ver. 5.5) and Google™ Earth Pro software. For all spawning grounds, Google Earth imagery was used to interpret general temporal changes, e.g. the pattern of river mouth closures, reaches that could prove productive for future spawning surveys and temporal channel changes. Site photographs were used to evaluate vegetation change.

Maps of inanga spawning locations were generated using Goggle™ Earth or Map Toaster ver. 5.5. The distance- measuring tool in Google™ Earth Pro was used for obtaining approximate distances and areas cited in the text.

4.3 Classification of habitat quality for inanga spawning

For some catchments, especially the smaller systems with defined saltwater boundaries, spawning habitats are generally more easily located. In larger rivers, or those lacking a saltwater terminus, locating spawning grounds was much more difficult due to the size of the potential spawning area, even when inanga were clearly present. In the case of catchments where spawning grounds were not determined, the spawning potential of a waterway was classified further as suitable or not suitable, based on inanga access, anthropogenic or natural effects, and the quality of the riparian microclimate (bank soil structure, vegetation stem density, bank slope).

For each surveyed catchment, the survey extent was indicated in each site map by either a green, orange, red or yellow line. A green line indicates where eggs were found and orange where no eggs were found but conditions were considered suitable for spawning. A red line indicates the reach was searched, but the habitat was considered unsuitable for a variety of reasons and a yellow line indicates the length that was searched and its suitability for spawning may be dependent on remediation.

4.4 Sites surveyed

The sites surveyed and worked field itinerary is presented below (Table 1), along with a regional map of the site locations (Fig. 2).

Table 1. Worked field itinerary: HT=High tide survey, LT=Low tide survey.

Catchment	Location	Survey Date(s)	Wedge determined (y/n)
Otaki River	Northern tributary	16th April (HT, LT)	No wedge. Mouth open to sea, but no wedge, lagoon entirely fresh.
Otaki River	Southern tributary	16th April (HT)	No wedge. Mouth open to sea, but no wedge, lagoon entirely fresh.
Waikanae River	Mainstem	17th April (HT, LT)	Yes
Taupo Stream	Mainstem	18th April (HT, LT)	Yes
Kakaho Stream	Mainstem	21st April (HT), 22nd April (LT)	Yes
Horokiri Stream	Mainstem	21st April (HT), 22nd April (LT)	Yes
Pauatahanui Stream	Mainstem	21st April (HT), 22nd April (LT)	Yes
Duck Creek	Mainstem – determination of saltwater wedge only as this site was not included in the list of sites to be surveyed and was opportunistically sampled	22nd April (HT)	Yes
Porirua Stream	Mainstem	17th April (LT), 18th April (HT)	Yes
Porirua Stream	Kenepuru Stream	17th April (LT), 18th April (HT)	Yes
Makara River	Mainstem	15th April (HT), 18th April (LT)	Yes
Hutt River	Mainstem	13th April (HT)	Partial, fresh upstream of Railway Avenue.
Hutt River	Opahu-lower bunded reach	14th April (HT)	No wedge
Hutt River	Opahu- upstream of bunded reach and control structure	15th April (HT)	No, gate tightly closed
Hutt River	Waiwhetu Stream	13th April (HT), 14th April (LT)	Yes
Hutt River	Sladden Park boat ramp area	13th April (HT), 15th April (LT)	No, but saline at entrance to Hutt River.
Hutt River	Te Mome Stream	13th April (HT)	No, controlled by flap valve, but tidally influenced.
Wainuiomata	Mainstem	14th April (HT)	Vertically mixed transition from fresh to brackish, mouth closed during survey
Lake Onoke	Away from freshwater feeders (west bank)	20th April (mouth appeared closed)	No wedge
Lake Onoke	North and east banks and tributaries	19th April (mouth appeared closed)	No/ No wedge
Lake Onoke	Ruamahanga River	19th April (mouth appeared closed)	No
Lake Onoke	Pounui Lagoon	20th April (mouth appeared closed)	Yes
Lake Onoke	Pounui Stream	20th April, 21st (mouth appeared closed)	No
Whangaimoana	Mainstem	20th April (mouth closed)	No, mouth closed during survey

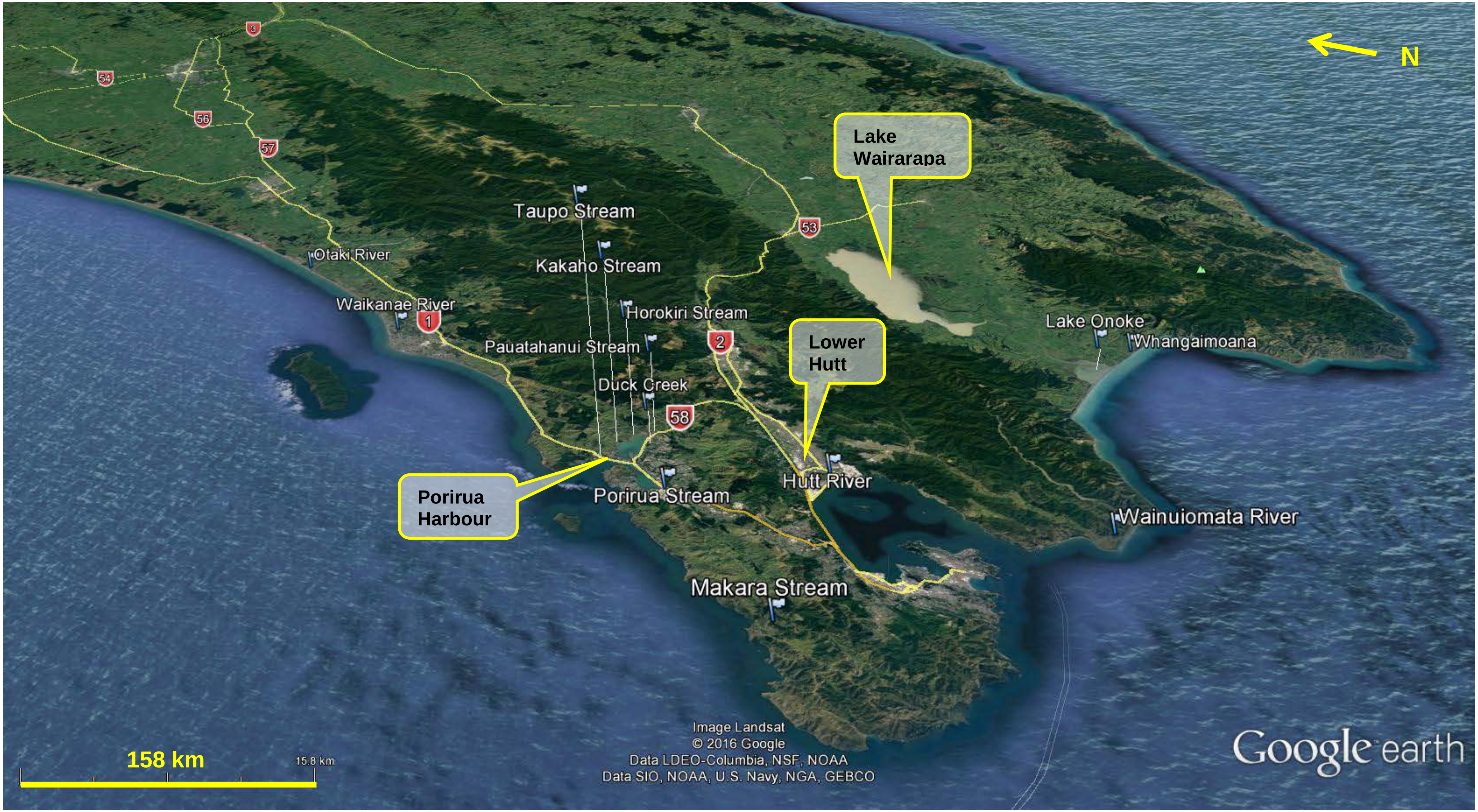

Figure 2. Overview of the surveyed catchments in the Wellington Region (2016).

5 Results

5.1 Tabulated summary of the 2016 inanga spawning survey and comparison with earlier surveys

Results from the survey are summarised in Table 2 which follows in A3 landscape format. Confirmed spawning grounds are summarised in Section 5.2 and detailed site specific information is provided in sections 5.3 - 5.13.

Table 2. Summary of results. Green text in fourth column highlights where eggs were found during this survey.

Waterway	Page Number	Eggs found previously? (report/year)	Eggs found (y/n)	Change since 2001/2002?	Spawning ground definition	Subjective spawning ground quality	Subjective spawning ground size	Remediation effort required (minor, moderate, major)	Priority for work/remediation with qualifiers in brackets	Management issues	Additional survey/s recommended?
Otaki River, Northern tributary	13, 14	No (Taylor & Kelly 2001)	No	Some improvement	Generally suitable, but spawning unconfirmed	unknown	Lagoon- Probably large. Downstream of tidegates- Probably large Upstream of tide gates- Unknown	Yes- Minor	Low (unknown spawning location)	Upstream of the tide gates- Monitor parrots feather and width of willow weed to ensure inanga can reach the banks to spawn.	Yes
Otaki River, Southern tributary	13, 16	No (Taylor & Kelly 2001)	No	Blind river braid: significant improvement Upstream of the tidegates: some degradation	Suitable, but spawning unconfirmed	Blind river braid- probably high Upstream of tide gates- Probably low.	Blind river braid- Probably large Upstream of tide gates- Probably large	Yes- Moderate	Low (unknown spawning location)	Upstream of tidegates- vegetation is not optimal General- Anecdotal evidence to suggest area may be subject to over fishing	Yes
Waikanae River	18	No (Taylor & Kelly 2001)	Yes	Some degradation	Egg distribution requires further definition	Medium	Currently small, but after further surveying likely to be larger	Yes- Minor	Low (main spawning ground not yet found)	Interpretations signs and determine the distribution of inanga spawning.	Yes
Taupo Stream	20	No (Taylor & Kelly 2001)	Possibly, based on site photos	No apparent change	Suitable, but remedial and management work is required	Low (overly steep)	Medium	Yes- Major	Medium (major management issues, but spawning site has probably been located)	Improve water quality, ensure mowing is not to the bank toe and riparian vegetation is not sprayed during spawning season. If a re-survey finds Taupo Stream is unable to support inanga spawning in its present state, a bank re-grade and replant may be useful.	Yes
Kakaho Stream	22	No (Taylor & Kelly 2001)	Yes	Significant improvement	Egg distribution requires further definition	High	Medium	Yes- Minor	High (high quality habitat with minor management issues)	Monitor willow growth, reduce size and stabilise stock water access points.	Yes
Horokiri Stream	24	No (Taylor & Kelly 2001)	Yes	Significant improvement	Egg distribution well defined	High	Large	Yes- Moderate	High (large, high quality habitat with moderate management issues).	There is stock-accelerated erosion and therefore stock fencing is required through the spawning reach. Some blackberry growth requires control.	Yes
Pauatahanui Stream	25	No (Taylor & Kelly 2001)	Yes	No apparent change	Egg distribution requires further definition	Medium	Currently small, but after further surveying likely to be larger	Yes- Minor	Medium- High (minor management issues, medium quality habitat of potentially large size)	Monitor willow growth	Yes
Duck Creek	27	No (Taylor & Kelly 2001)	No, but no egg search conducted	No apparent change	Potentially suitable	Unknown	Unknown	Yes- Minor	N/A (spawning location unknown)	Ensure mowing is not to tidal bank edge during the spawning season.	Yes
Porirua Stream Mainstem	29	No (Taylor & Kelly 2001)	Yes	Saltwater wedge: No change Spawning location: Significant improvement	Egg distribution requires further definition	High	Small	Yes-Major	Medium (major management issues, but improvement should result in a large, high quality rearing and spawning habitat)	Vertical concrete banks prevent spawning at the wedge, we recommend a full redesign of the stream downstream of the saltwater wedge to provide spawning and rearing habitat for multiple species, improved stream heterogeneity, high aesthetic values and maintain the required drainage. An upstream weir appears to prevent inanga migration into rearing areas.	Yes, especially on grassy banks on true right bank.
Porirua Stream, Kenepuru Stream tributary	29, 31	No (Taylor & Kelly 2001)	Yes	Significant improvement	Egg distribution well defined	Medium	Medium	Yes- Minor	Low (minor management issues and the cost vs benefit may be quite high)	Removal of low weir	Yes
Makara Stream Mainstem	32	No (Taylor & Kelly 2001)	No	At saltwater wedge: some degradation, but this location may not coincide with spawning habitat. Lower reaches: no apparent change	Suitable, but spawning unconfirmed	True right bank- Low. Island- Medium'. True left bank- Unknown	True right bank- Large. True left bank- Small. Island- Large.	No	Low (no management issues and spawning location unknown)	Bamboo control required, as may be compromising some of the spawning habitat suitability of the riparian zone.	No
Hutt River Mainstem	35	No (Taylor & Kelly 2001)	No	No comparison available	Partly suitable	Unknown	Unknown	Unknown	Low (spawning location unknown)		Yes
Hutt River, Opahu Stream tributary- lower bunded reach	35, 37	No (Taylor & Kelly 2001). Yes by DOC 1996 prior to redevelopment	No	Change unknown	Suitable, but other issues important	Unknown	Unknown	Moderate- Major	Low (moderate- major management issues and unknown spawning potential)	Multiple possible causes for lack of eggs, including overfishing, poor plant placement and removal of adult habitat. Some gorse invasion.	No
Hutt River, Opahu Stream tributary- reach upstream of control structure	35, 39	No (Taylor & Kelly 2001)	No	Significant degradation	Suitable, but remedial work is required due to anthropogenic effects	None	None (potentially small)	Yes- Minor	High (minor management issues and no spawning habitat currently available)	No inter-tidal vegetation. Planting of creeping vegetation over the rip-rap may be enough to facilitate some spawning. Some gorse requires spraying.	No

Table 2 (cotd.). Summary of results. Green text in fourth column highlights where eggs were found during this survey.

Waterway	Page Number	Eggs found previously? (report/year)	Eggs found (y/n)	Change since 2001/2002?	Spawning ground definition	Subjective spawning ground quality	Subjective spawning ground size	Remediation effort required (minor, moderate, major)	Priority for work/remediation with qualifiers in brackets	Management issues	Additional survey/s recommended
Hutt River, Waiwhetu Stream	35, 42	Not evaluated	**Yes, true right bank**	No comparison available	Egg distribution requires further definition	Medium	Small	Yes- Minor	High (minor management issues and medium quality)	Some improvement in vegetation or control around mowing of the spawning area. Planting in appropriate areas to improve both the quality and size of the spawning habitat	Yes
Hutt River, Sladden Park boat ramp area	35, 44	Yes (Elliott 1996)	No	Some improvement	Suitable, but remedial work is required to offset natural erosion	Low	Medium	Yes- Major	Medium- High (medium sized spawning ground with eroding banks that may soon impact of public amenity areas)	It is recommended that the true right (north) bank is regraded and planted.	No
Hutt River, Te Mome Stream tributary	35, 45	Not evaluated	No	No comparison available	Potentially suitable	Unknown	Unknown	Moderate?	Low (moderate management issues and unknown spawning location)	There are water quality issues here and fish passage appears to be impeded (but not prevented) by a long culvert with swift flow.	Yes
Wainuiomata River Mainstem	47	No (Taylor & Kelly 2001)	**Yes, true right bank**	Some degradation	Egg distribution requires further definition at limits	High	Large	Yes- Minor/Moderate	Medium- High (minor-moderate management issues, large, high quality habitat for both rearing and spawning)	The spawning area should be fenced from stock and adventive weeds monitored	Yes
Lake Onoke, away from freshwater feeders (west bank)	49	No (Taylor & Kelly 2001)	No, but no egg search conducted	No apparent change	Unsuitable				N/A (unsuitable for spawning)		No
Lake Onoke, north and east banks and tributaries	49	No (Taylor & Kelly 2002), yes by DOC	No	No change/ No comparison available	Potentially in north-west corner, restricted to dynamic freshwater inflows	Unknown	Potentially large	Minor	Low (unknown spawning location)	Ensure that stock do not have access to the spawning grounds in the freshwater feeders	No
Ruamahanga River	49, 53	No (Taylor & Kelly 2002)	No	No comparison available	Suitable, but spawning unconfirmed	Unknown	Unknown	N/A	N/A (unknown spawning location)	The saltwater wedge terminus was not located, looking too far downstream.	Yes, limited survey as outlined in text
Pounui Lagoon	49, 55	Not evaluated previously	No	No comparison available	Potentially suitable, may be restricted to freshwater inflows	Unknown	Potentially large	None observed	Low (no observed management issues)		Yes
Pounui Stream	49, 57	Not evaluated	No, but ripe fish in vicinity	No comparison available	Suitable vegetation,	Unknown	Unknown	Yes- Minor	High (minor management issues, location of site not relevant to issues raised)	Restrictions are required on river works undertaken during the spawning season.	Yes, to determine precise location of spawning
Whangaimoana	59	Yes (Taylor & Kelly 2002)	No, but only partial egg survey conducted on true right bank.	No change	Suitable, but spawning unconfirmed	Probably high	Probably Medium	No	Low (no management issues)	Ensuring that the covenant is respected	Yes

5.2 Summary of confirmed spawning grounds

Accurate (time-averaged) GPS locations of the ten confirmed spawning grounds are tabulated below (Table 3). However, two sites do come with a caveat. No spawning was thought to have been found in Taupo Stream until field photos were closely scrutinised and eggs were possibly found. The exact spawning location in Pounui Stream was not found, but the presence of ripe fish indicates that we were very close to it.

A list of scientific and common plant names mentioned in the text is provided in Appendix III. Plants listed in red are those where inanga eggs has been previously recorded from in New Zealand.

Table 3. GPS locations of the ten inanga spawning grounds determined during this survey. Location refers to the downstream margin.*. During report preparation we identified what we think are inanga eggs from a habitat photo. ** Eggs were not found at this site, but very ripe fish were and so the spawning ground must be very close.

Waterway name	NZTM East	NZTM North
Waikanae River	1769572.0	5473024.5
Taupo Stream*	1756899.7	5450345.1
Kakaho Stream	1759105.6	5449847.1
Horokiri Stream	1760153.3	5449077.2
Pauatahanui Stream	1760957.6	5447567.7
Porirua Stream mainstem	1754667.5	5444679.5
Kenepuru Stream; Porirua Stream	1754667.5	5444679.5
Waiwhetu Stream	1760886.4	5434208.7
Pounui Stream (approx.)**	1777990.3	5420046.1
Wainuiomata River mainstem	1757648.5	5413918.5

A précis is provided below on each of the respective habitats with brief physical descriptions based on our observations and Google Earth imagery. The surveyed waterways are then presented in geographic order, from the west to the south coast.

5.3 Otaki River

The Otaki River catchment is one of the largest to rise from the native forests of the Tararua Ranges and is engorged through much of its passage through the bush-clad hills. Once it leaves the constraints of the hills, the river braids and meanders across a broad river plain, with the flood plain converted to largely pastoral use (App. I, Fig. i). Some of the aggraded gravels are quarried in the lower reaches. The braided river flows to the south of the townships of Otaki, and Otaki Beach, and unlikely to receive storm runoff from these environments.

Over time, based on Google Earth imagery, the river mouth shifts between the southern and northern tip of the river bed, and the main lagoon receives inflow from a stable tributary on each of the two banks. The main lagoon behind the mouth was entirely fresh, and the river level appeared to be higher than the high tide level of the sea.

5.3.1 Northern tributary

The northern tributary is fed by two streams which drain rural land on the true right floodplain. These two waterways flow through fish-friendly flap valves before converging together and entering the Otaki River lagoon.

Possible Spawning Locations

It is thought that due to the dynamic nature of the Otaki River mouth, any potential spawning location in the northern tributary could be highly variable from one year to another, depending on the location of the mouth and the extent of any salt intrusion. There were three areas that were considered possible spawning locations within the northern tributary: the lagoon, downstream of the tidegates and upstream of the tide gates (Fig. 2a).

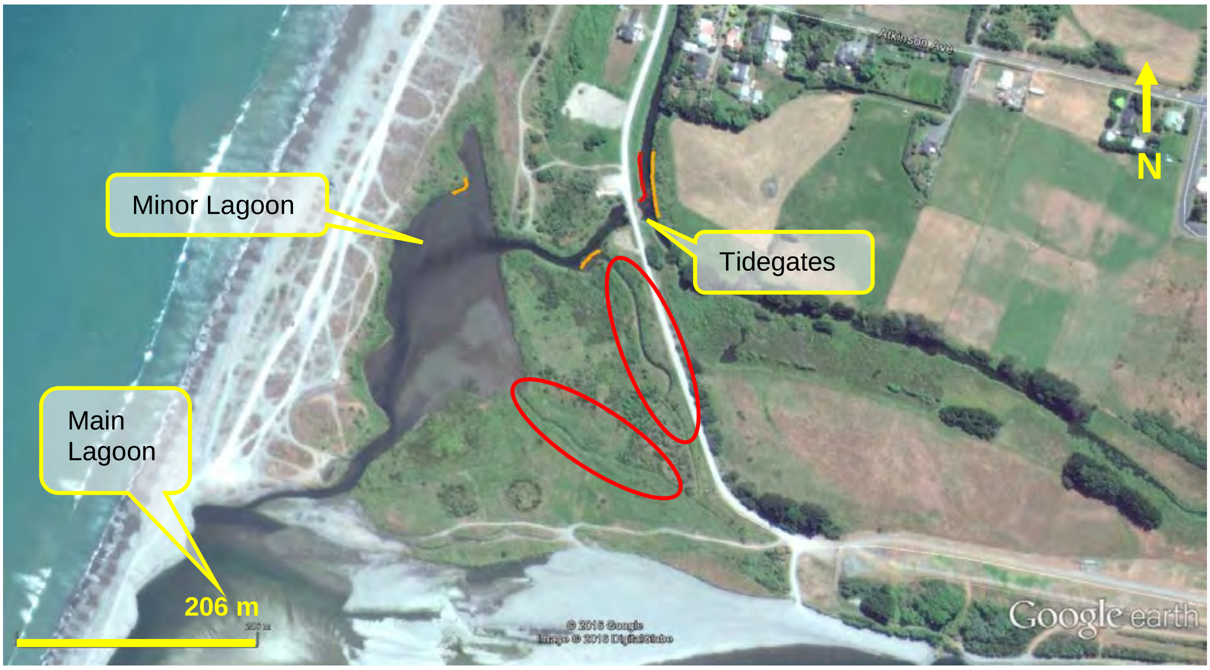

Figure 2a. Otaki River, northern tributary, Otaki. Orange line indicates the area that was unsuccessfully searched, but still considered suitable. Red line indicates the area that was searched, but considered unsuitable for spawning. Red circles indicate where further surveys may be productive.

Minor Lagoon

The conductivity of the lagoon and its outlet at mid-high tide was fresh and ranged from 148- 250 µS/cm. A large school of inanga were seen scouting the shallows at the northern tip of the lagoon (Fig. 2a), but while a brief egg search was undertaken, no eggs were found in otherwise suitable vegetation.

Downstream of tidegates

No conductivity readings were recorded here, but it is unlikely that they would be higher than in the lagoon (i.e. downstream). Large schools of mullet were observed, but no inanga. Generally the area downstream of the tide gates was considered unsuitable for spawning due to steep banks, however a stand of raupo was briefly searched at mid tide and considered to be suitable, although no eggs were found. The raupo stand could have significant potential for inanga spawning should inanga choose to utilise this habitat.

Upstream of tide gates

Although no conductivity readings were recorded here, it is likely to contain fresh water. There were no inanga seen here at mid-tide, but there were rafts of aquatic macrophytes extending out into the waterway which may have obscured their presence (Fig. 2b). It is possible that these rafts of vegetation also prevent inanga from reaching the bank vegetation upon which to spawn. The true right bank was considered unsuitable for spawning as it was very steep. The vegetation on and extending from, this bank consisted of an unidentified grass, willow weed and parrots feather, the latter a notified weed with a sprawling habit. The true left bank was more suitable, being both shallower and having more suitable vegetation-New Zealand rush/Edgar's rush (with an unusually discontinuous pith), buttercup and a thick sward of willow weed, with clover and plantain also present. The ability of inanga to spawn in the presence of such thick vegetation swards is unknown, therefore the potential of this site to support inanga spawning is unknown.

The submerged macrophyte flora was also diverse, and included red pondweed/manihi, milfoil, Canadian pond weed and charophytes.

Figure 2b. Looking downstream at the area upstream of the tidegates that was unsuccessfully searched for spawning. Note the thick rafts of weed extending out from each bank. The approximate location of bank edges are indicated by red arrows.

Barriers to fish migration, and management issues for the Northern Otaki River tributary

The northern tributary appeared to be a stable, gently flowing waterway and the flap valves that connect to the lagoon were fish friendly. Given the unknown impact of vegetation swards that extend into the waterway, the growth of willow weed and parrots feather should be monitored upstream of the tide gates. Neither the northern tributary nor the Otaki River mainstem appear to undergo any mouth closures, although the width of the Otaki River mouth does seem to vary (thereby creating a variable velocity), as does its location along the coast. No weirs or barriers to upstream migration were observed along the surveyed channel. Overall, we consider that there are no significant barriers to fish migration between the sea and potential spawning habitats, nor from rearing grounds to inanga spawning grounds.

Should the Otaki river mouth shift north again, and a salinity gradient develop in the lower lagoons, it is possible areas near the tidegates may be utilised by spawning inanga. However, the raupo bed on the other side of the tide gates, if remaining above saline influence, may also be utilised by spawning inanga.

Survey limitations and additional survey suggested

Time limitations for this survey meant that both of the extensive areas downstream of the tidegates were unable to be thoroughly searched, and searching the raupo stand by boat would have been beneficial. Due to time limitations, additional surveys are recommended in the ringed tributaries in Fig. 2a.

5.3.2 Otaki River, southern tributary

The southern tributary that enters Otaki Lagoon rises from old braids from the Otaki River, and is fed by the rivers shallow groundwater. The tributary flows through pastoral land near the south bank of the Otaki River, and then under the Otaki River flood-protection levee via a flap-valve. From there, the tributary discharges into the Otaki River (main) lagoon close to the current mouth position.

Possible Spawning Locations

It is thought that due to the dynamic nature of the Otaki Mainstem mouth, the spawning location in the southern tributary could be highly variable over time. There were two areas that were considered possible spawning locations within the southern tributary: the blind river braid and upstream of the tide gates (Fig. 3a).

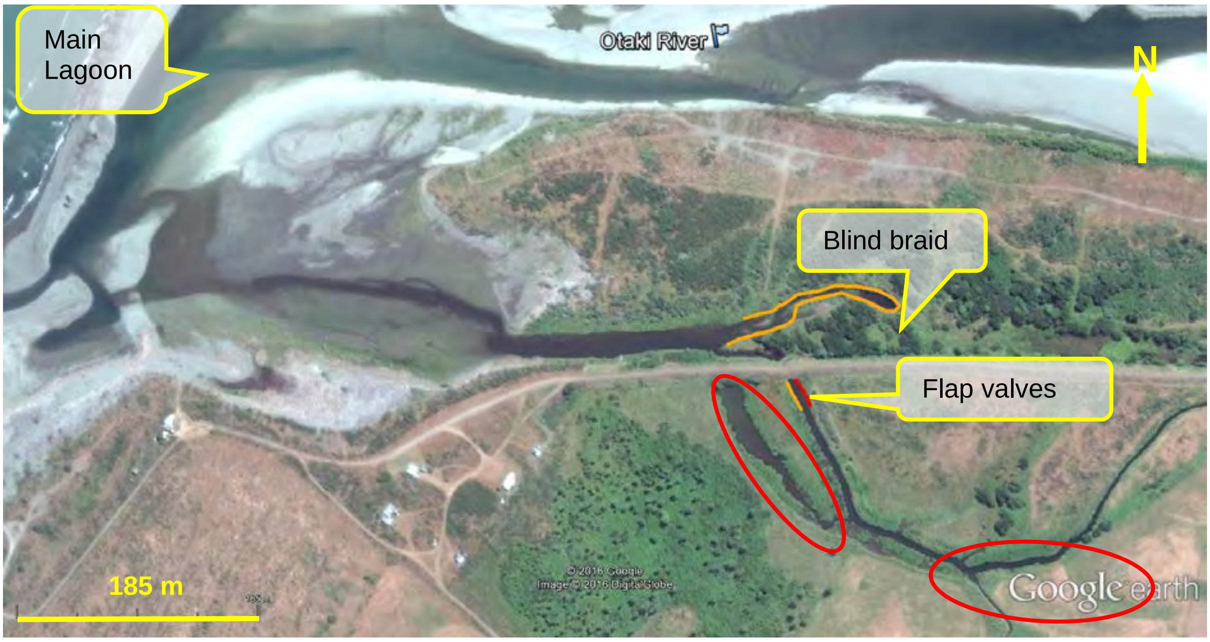

Figure 3a. Otaki River, southern tributary, Otaki. Orange line indicates the blind braid area was unsuccessfully searched, but still considered suitable. Upstream of the flap valves, the orange line indicates the reach of unknown suitability, but which should be re-assessed. Red line indicates the area that was searched, but considered unsuitable for spawning. Red circle indicates where a further survey may be valid.

Blind river braid of the Otaki River

No salinity readings were recorded in the braid, but it is likely to be entirely fresh because the water was fresh between this location and the sea. Large schools of inanga and smelt were seen at low tide. A very brief egg search was undertaken in the area indicated in Fig. 3 a (photos 3b, c) but no eggs were identified along the grassy margins. The dominant vegetation here consisted of tall fescue and toetoe. Overall, this site, and the microhabitats evaluated, appeared to have high potential for inanga spawning.

Figure 3b. Looking upstream into the old, blind braid where large numbers of inanga and smelt were seen, spawning may occur in this braid.

Figure 3c. The top of the old blind braid at low tide, exhibiting some suitable spawning grasses at high-tide water levels. The braid would still be fed by shallow groundwater from the Otaki River mainstem.

Southern Tributary upstream of the flap valve

A conventional double-culvert and double-flap valve assembly probably impedes tidal influence beyond the levee (Fig. 3 d). However, we did not take water salinity readings here, given that the Otaki lagoon waters downstream were clearly fresh on the high tide. Large numbers of mostly juvenile inanga were observed in the channel upstream of the flap-valves, indicating that passage is not significantly impeded. The true right bank was considered unsuitable for spawning as it was very steep, dry and had little- no root hair matrix (left bank in Fig. 3 e). The vegetation on this bank consisted of creeping jenny, willow weed and buttercup. The true left bank was shallower than the right bank, boggy, and possessed a low sparse sward of plant that resembled willow weed (right bank in Fig. 3 e). It is possible that this bank has been sprayed in the recent past. The vegetation was not characteristic of inanga spawning sites, and its suitability is unknown. We consider it worthwhile that this reach be re-checked at a later date. Currently, this site is probably of large size, but a mixture of low and unknown quality owing to the sparse root matrix and uncharacteristic vegetation.

Figure 3d. Looking upstream at the old-style flap valves that protect the southern tributary.

Figure 3e. Looking upstream (from the levee) at the area upstream of the tidegates that was searched for inanga eggs.

Barriers to fish migration, and management issues

The southern tributary appeared to be a stable, sluggish waterway and the flap valves that connect it to the blind braid were not fish friendly, but evidently did not prevent upstream migration (Fig. 3 d). Often flap valves with a high upstream debris load don't seal completely due to clogging from branches and leaves. With incomplete closure, inanga and other fish can pass through on the turn of the tides when water velocities are low (pers. obs.).

Neither the southern tributary nor the Otaki River mainstem appear to undergo any mouth closures, although the width of the Otaki River mouth does seem to vary (thereby creating variable velocity). No weirs or other barriers to upstream migration were observed, although the full length of the stream was not surveyed. The vegetation upstream of the tidegates was generally a bit sparse. Anecdotes from locals suggest that the area may be subject to heavy and/or illegal whitebaiting.

Survey limitations and additional surveys suggested

Time limitations prevented a thorough search of the area and so two additional surveys are recommended upstream of the flap valve (ringed in Fig. 12 a). One is located upstream of the searched reach and the other in the blind channel west of the area searched. A more intensive search of the blind river braid is also recommended.

5.4 Waikanae River

The Waikanae River rises from the forested western foothills of the Tararua Ranges, at an elevation of 465 m a.s.l. The upper catchment consists predominantly of regenerating and mature native bush, with the lower river flat pastoralised. For most of its length, the river is shallow and flows over a gravel bed, upon which weak short braids can form. The river skirts the southern boundary of the Waikanae township, and has a permanent but mobile mouth which discharges into the Tasman Sea opposite Kapiti Island (App. I, Fig. i).

Spawning Location

The saltwater wedge terminus was identified at high tide, approximately 1.6 km upstream of the river mouth (Fig. 4a). The spawning survey was undertaken at low tide and the identified spawning reach was approximately 15 m on the true right bank. No eggs were found on the true left bank. No shoals of inanga were observed in the vicinity, but the shallow water at low tide would deter shoaling at that time. Dominant bank vegetation consisted of tall fescue and clover (Figs. 4b, c), with jointed wire rush/oioi upstream of the spawning site. Eggs were located within stands of tall fescue (Appendix II, Fig. 1). Where eggs were found, the soil was moist, with a fine structure, but elsewhere soil moisture and texture were variable, ranging from pasty to sandy and tall fescue was sparse with little root mat.

Intensive searching in the vicinity revealed that the site was small and egg numbers were low, but eggs were developed with discernible eyes. Overall habitat quality was considered to be of fair and variable quality.

Barriers to fish migration, and management issues

At the time of survey, the Waikanae River had a flow of 1.8 m^3/s (GWRC flow gauge), and the mouth was wide with no hindrance to a potential whitebait run (Appendix II, Fig. 2). Google™ Earth aerials from 2005-2016 indicate no closures, and that the flow of this river is sufficient to keep the mouth open permanently, although its location has shifted west over this time frame. There were no observed weirs. The only management issue was the pedestrian/cycleway alongside the spawning area, and only an issue if people and/or pets stray from the path, thereby causing damage to riparian vegetation, bank stability and eggs. The erection of an interpretive sign for public information may reduce this slight risk, but more importantly provide public engagement in their local environment.

Survey limitations and additional surveys

While egg were located at this site, this is unlikely to be the main, or only, spawning habitat. This assessment is due to the small size of the spawning habitat in relation to the apparent amount of rearing habitat within the catchment and the easy access to the catchment by whitebait. Using Google Earth imagery, four additional sites in the lower catchment were considered to be worth surveying in the future (Fig. 4a). Two are located on the true right bank: The upstream end of Waimeha Lagoon located below the spawning area and an oxbow approximately 470 m upstream of the confirmed spawning area. On the true left bank there are two tributaries just below the located spawning area (ringed in red in Fig. 4a).

Figure 4a. Waikanae River, Waikanae. Green line indicates spawning reach, while orange line indicates the area that was unsuccessfully searched, but still considered suitable. Red circles indicate possible other habitats where spawning may occur.

Figure 4b. Waikanae River, looking downstream from the tip of the salt water wedge at high tide. Spawning was located at the tip of the wedge.

Figure 4c. Waikanae River, looking upstream from the tip of the salt water wedge at high tide. Spawning was located at the tip of the wedge.

5.5 Taupo Stream

Taupo Stream is a small waterway which drains a small saddle catchment near the mouth of Porirua Harbour. The catchment rises from unnamed twin peaks (262 m, 166 m a.s.l), opposed across its valley, but the waterway receives flow from multiple small tributaries as the stream flows south. For much of its length, Taupo Stream flows through a wide marshy valley (i.e. the Taupo Swamp). In its lower reaches the stream is channelised and straightened as it flows through the township of Plimmerton (App. I, Fig. ii). Downstream of the Plimmerton Reserve bridge, the riparian foliage in the domain appeared to have been sprayed. However, a predominantly native vegetated buffer strip is preserved for its length. At the time of our surveys, the stream was discharging into the sea.

Possible Spawning Location

There was no saltwater wedge identified at high tide, with the conductivity of Taupo stream ranging from 508 µS/cm on the beach to 452 µS/cm 660 m upstream in Plimmerton Domain. This conductivity is high for a freshwater system and is probably partly due to the soft-rock catchment and nutrient runoff from the pastoralised valley slopes. Consistent with streams draining wetland areas, the water was brown and tannin-stained. A school of inanga were seen upstream of Steyne Road at high tide, and a few eels were also observed.

A brief exploratory egg search was undertaken low tide along the lowest 500 m of Taupo Stream, extending up from the sea into the Plimmerton Domain (Fig. 5a). The deeply-shaded 30 m reach upstream of the Steyne Avenue bridge was not suitable for spawning as the lack of light produced very little riparian vegetation and the banks were lined with anti-scour material (Fig. 5b).

Figure 5a. Taupo Stream, Porirua. Yellow line indicates the length that was searched and suitability for spawning may be dependent on remediation. Red bracket = area recommended for re-survey, green section=possible post-survey egg identification, orange=suitable vegetation but eggs not found.

Further upstream, adjacent to the historic railway station, more light entered the channel and bank vegetation varied between a mixture of grasses, herbs and scrub, including tall fescue, fennel, flax/harakeke, toetoe, shrubs and blackberry. There was also aquatic weed present, including cape pondweed, a pest species (Fig. 5c). We were informed that this weed was being managed on an ongoing basis by St Theresa's School and PCC as part of a Healthy Harbours Porirua school Kaitiaki project (GWRC, pers comm.). We also suspect some of the riparian grass had been sprayed recently, and an oily scum was noted at one point, although hydrocarbon scums can derive from natural causes. Bank slope was suitable in some places, but rather steep in others. Particularly suitable habitat was recorded in the lower reaches through Plimmerton Domain, downstream of the bridge to the railway station, although the soil was quite dry at the time (Fig. 5 d).

While no eggs were recorded in the field at this location in fading light (5 pm), close scrutiny of microhabitat photos revealed what may be three inanga eggs (App. II, Fig. 3).

Figure 5b. Looking upstream at the sand banks and anti-scour in lower Taupo Stream, under the Steyne Avenue bridge.

Figure 5c. Looking upstream at Taupo Stream, from the bridge to Plimmerton Station.

Figure 5d. Riparian vegetation looking downsream from the Plimmerton Station access bridge. Some of the vegetation may have been recently sprayed. Note the cape pondweed, a pest species in the Greater Wellington Region (Greater Wellington Regional Council und.). Red arrow = a possible egg nest location, based on a habitat photo.

Barriers to fish migration, and management issues

There were no observed barriers to upstream migration from the stream mouth upstream to Plimmerton Domain, although the water quality to appear to be poor. There were some places in Plimmerton Domain where the grass had been mown very close to the toe of the bank (see Fig. 5d), it was also suspected that the banks had been sprayed near the domain. In much of the surveyed reach, the vegetation was either unsuitable, or where it was suitable, the bank slope was generally too steep for significant spawning. If no eggs are found during the egg resurvey suggested in the paragraph below, then bank re-grading and planting should be undertaken to increase the inanga egg yield.

Survey limitations and additional surveys suggested

The high tide survey at this site was midway between the neap and spring tides. Therefore, while we didn't record a saltwater wedge, it is possible that a saltwater wedge may intrude into the channel on higher tides. Time limitations also meant that the search was focused on sites that were the most superficially suitable. However, given the possible identification of eggs in the habitat photo, we recommend a more intensive egg survey of the 50 m reach downstream of the Plimmerton Station bridge (bracketed in Fig. 5a). It may also be worthwhile surveying the water level fluctuation over a spring tide cycle, this would be useful information for regrading and planting.

5.6 Kakaho Stream

The Kakaho Stream rises from 440 m a.s.l from hills on the northern side of the Pauatahanui Inlet arm of Te Awarua-o-Porirua Harbour. The upper catchment is vegetated in native bush, and while the lower hills are grassed, some remnant bush is present in the lower gullies. The lower reaches meander through rural farmland, but most of the lower stream (approx. 2 km) is now fenced from stock by a fairly wide (c. 5 m) vegetated buffer strip (App. I, Fig. ii). The mouth discharges into Pauatahanui Inlet and Google Earth imagery suggests that the mouth is always open, allowing whitebait to enter.

Spawning Location

The saltwater wedge terminus was identified at high tide, approximately 105 m upstream of Grays Road (Fig. 6a) but at the time, no shoals of inanga were observed in the vicinity. The spawning survey was undertaken at low tide and the identified spawning reach was approximately 40 m long, with eggs found on both banks. The dominant bank vegetation consisted of giant umbrella sedge, tall fescue, with some toetoe, flax/harakeke and *Hebe* (Figs. 6b, c). The soil structure varied from soil-sand and was moist where eggs were found and the eggs were clean of silt (App. II, Fig. 4). Overall this site was well-sized in relation to the catchment area and rearing habitat area (suggesting that this is the principal site), and the egg microhabitat observed was of high quality.

Downstream of the confirmed spawning area, the vegetation consisted primarily of salt-tolerant jointed wire rush/oioi. The banks were much shallower here than those upstream, and although no eggs were found, general conditions were considered to be suitable.

Barriers to fish migration, and management issues

Kakaho Stream is a small, gently flowing waterway that does not appear to undergo any mouth closures. No weirs or other barriers to upstream migration were observed, although the survey did not extend further upstream than the tip of the saltwater wedge. The primary management issue, like many rural waterways, is stock access to the river and resultant riparian damage and associated problems. However, the spawning area was fenced from stock, with Google™ Earth imagery indicating that fencing of most of the waterway took place between 2006 and 2009. This fencing and subsequent planting was initially undertaken as part of the Pauatahanui Vegetation Framework initiative funded through GWRC and Porirua City Council. This programme subsidised riparian fencing and revegetation to enhance biodiversity and reduce sediment runoff into Porirua Harbour. It has now been replaced with a dedicated GWRC Land Management officer working with farmers across the catchment (GWRC, pers comm.).

To date, some short reaches are not fenced to allow access for stockwater, and it is possible these could be reduced in size, and the stock down-ramp to the waters-edge be stabilised with geotextile to reduce bank erosion. It will be also important to ensure that willow and other unsuitable woody shrubs and trees do not establish and shade out the spawning vegetation.

Survey limitations and additional survey suggested

No other areas are recommended for survey, with no additional channels near the sea. However, due to time limitations and the low gradient of the bank, a more intensive search in the jointed wire rush/oioi stands downstream of the confirmed spawning area could provide further information on the downstream extent of the spawning area.

Figure 6a. Kakaho Stream, Pauatahanui Inlet. Green line indicates spawning reach, while orange line indicates the area that was unsuccessfully searched, but still considered suitable.

Figure 6b. Kakaho Stream, near the tip of the salt water wedge, looking downstream at the spawning area, at low tide. Note the luxuriant riparian vegetation.

Figure 6c. Kakaho Stream, looking upstream at the tip of the salt water wedge at low tide. Spawning was located downstream of this point.

5.7 Horokiri Stream

By catchment area, Horokiri Stream is the third largest waterway that discharges into Te Awarua-o-Porirua Harbour. The headwaters of Horokiri Stream consist of two main branches, the 'East Branch' originating in the Akatarawa Forest and the 'West Branch' which follows the Paekakariki Hill Road. It passes through a mixture of native bush and farmland, before discharging into the northern side of the Pauatahanui Inlet (App. I, Fig. ii). At the time of survey, the stream had a small estimated baseflow of just under 0.1 m^3/s.

Spawning Location

The saltwater wedge terminus was identified about 2 hrs after the local high tide, and was approximately 18 m downstream of Grays Road (Fig. 7a). At the time, a school of approximately 50 adult inanga were observed just upstream of Grays Road. The dominant bank vegetation consisted of giant umbrella sedge and tall fescue, with some creeping bent, buttercup, flax/harakeke and blackberry (Appendix II, Fig. 5). The banks were gentle and eggs were located well away from the low-tide water edge (Fig. 7 b, c). At this site, there was time to conduct a more intensive egg search at low tide, and eggs were located over an approximate 150 m reach along both banks. This site was large in respect to the rearing habitat, and considered to be of high quality.

In addition to the inanga egg distribution, four eggs from an unknown species were located within the survey area, these eggs resembled inanga eggs but were approximately 25% larger (Appendix II, Fig. 6). We may have found what may have been kokopu eggs, as kokopu (banded, giant and shortjaw) have been identified from the catchment. Like inanga, kokopu also spawn in riparian vegetation that is submerged either tidally or during stormflow.

Barriers to fish migration, and management issues

Horokiri Stream is a medium-sized waterway with sufficient power to maintain a permanent mouth into the Te Awarua-o-Porirua Harbour. No weirs or other barriers to upstream migration were observed, although the survey did not extend further upstream than the tip of the saltwater wedge.

The spawning reach upstream of Grays Road, and the river generally, was subject to some stock-accelerated erosion due to stock accessing the stream from the water-side of the fence line. The stream ecology would benefit from more complete fencing and bank remediation (Fig. 7c). However, hinged bank collapse has provided a convenient sloping grassy bank for inanga to spawn, but ongoing channel erosion and widening will eventuate in a muddy shallow stream profile not conducive for inanga spawning. We noted blackberry at this site, and this needs to be controlled as it can cover and shade out vegetation and reaches which would be otherwise suitable for inanga spawning.

Survey limitations and additional surveys suggested

Due to time limitations, a tributary on the true right bank was not surveyed (Fig 7a). This tributary appears to be superficially suitable for spawning and so it is recommended that a survey be under taken of this waterway.

Figure 7a. Horokiri Stream, Pauatahanui Inlet. Green line indicates spawning reach, while orange line indicates the area that was unsuccessfully searched, but still considered suitable. Red circle indicates where a further survey may be valid.

Figure 7b. Horokiri Stream, looking downstream towards the lower end of the spawning reach at low tide. Red arrow = egg deposits

Figure 7c. Horokiri Stream, looking downstream from the top of spawning reach at low tide. Note the slumping and slumped grazed bank. Red arrows = egg deposits

5.8 Pauatahanui Stream

Pauatahanui Stream has a reticulated catchment, with several branches largely draining the recent residential hill suburbs of Whitby. These branches carried virtually no flow during the autumn survey and were choked with weed. Most of the catchment's baseflow arose from the catchment and wetlands adjacent to Paremata Haywards Road (App. I, Fig. ii).

Spawning Location

The saltwater wedge terminus was identified at high tide, approximately 40 m upstream of Paremata Haywards Road bridge, near the roundabout with Paekakariki Hill Road (Fig. 8). No shoals of inanga were observed at this site and egg distribution was patchy on both banks. The dominant bank vegetation consisted of tall fescue, with some prostrate creeping buttercup and clover. Downstream of the Paremata Haywards Road bridge, low terraces featuring stands of giant rush, tall fescue, and buttercup yielded eggs on the true right bank (Appendix II, Figs. 7, 8). While a patchy distribution of eggs were found here, this could reflect our rather dispersed survey effort, and it is possible the distribution is more extensive and intensive than our initial results suggest.

Barriers to fish migration, and management issues

In its lower reaches, Pauatahanui Stream is a wide, gently flowing waterway that does not appear to undergo mouth closures. No weirs or other barriers to up/downstream migration were observed in the lower river, although a thorough search of the full length of the stream was not undertaken. There was a patchy distribution of willows throughout the inanga spawning site and it is recommended that these be monitored to ensure they do not shade out the spawning reach.

In the future, an opportunity may arise where an adjacent riverflat (i.e. Lanes Flat) could be restored into a meandering channel conducive to inanga rearing. The hydraulic requirements for inanga rearing a specified in (Richardson & Taylor 2002).

Survey limitations and additional surveys suggested

No other sites are recommended for survey, but due to time limitations, a more intensive search of the *J. pallidus* stand downstream of Paremata Haywards Road could provide more detailed distribution information (ringed in Fig. 5).

Figure 8. Pauatahanui Stream, eastern edge of the Pauatahanui Inlet. Green line indicates spawning reach, while orange line indicates the area that was unsuccessfully searched, but still considered suitable. Red circle indicates where a further survey may be valid.

5.9 Duck Creek

Duck Creek rises from Round Knob (410 m a.s.l.) on the south side of the Pauatahanui Inlet arm of Te Awarua-o-Porirua Harbour (App. I, Fig. ii). The catchment formerly included a mixture of open grassland, scrub and bush, and in the hinterland, production forest. However, more recently some of production forest and scrubland is being converted to residential developments. Approximately 230 m upstream of its discharge into Porirua Harbour a lowland tributary enters the main channel from the true right (east) bank. The confluence is in the vicinity of 6 Shoal Place, which is a new roadway off James Cook Drive. The lower tidal reaches of Duck Creek are located in DOC reserve which consists of salt marsh vegetation.

Duck Creek was not one of the preselected sites and this survey was undertaken opportunistically given that we were at the general location at high-tide. The objective of our high-tide survey in Duck Creek was to determine the high-tide upstream intrusion of the saltwater wedge. No egg search was undertaken, with the understanding that an egg search can be undertaken at a later date.

Possible Spawning Location

Conductivity readings in Duck Creek and its lowland tributary were taken at the peak of a full moon tide and the termini of the saltwater wedges were determined on both main tributaries (Fig. 9a). In the vicinity, bank vegetation on the mainstem of Duck Creek was predominantly composed of a mixture of grasses, which appeared superficially suitable for spawning (Figs 9b-c).

Barriers to fish migration, and management issues

In its lower reaches, Duck Creek is a small, gently flowing waterway that flows freely into Porirua Harbour and, based on Google™ Earth imagery, does not experience mouth closures. At high tide, the harbour waters flood the mouth and there is no beach. In respect to whitebait in-migrants, there did not appear to be any barriers to inanga accessing the lower reaches, and there appeared to be suitable inanga rearing habitat close to the sea (Fig. 9 d). Given that the location of the spawning ground in unknown, and based on evident issues around the saltwater limits, the main management issue observed was residential grass mowing and gardening within the inter-tidal zone.

Survey limitations and additional surveys suggested

This survey was limited by time, as such only the location of the saltwater wedge tip was determined. Therefore, it is recommended that a proper egg search is undertaken in both the mainstem and tributary (ringed in Fig. 9a).

Figure 9a. Duck Creek (mainstem and tributary), Whitby. Red circle indicates where a further survey may be valid.

Figure 9b. Looking downstream at the saltwater wedge tip on Duck Creek (mainstem).

Figure 9c. Looking upstream at the riffle where the saltwater wedge terminated on Duck Creek (mainstem).

Figure 9d. Looking upstream along Duck Creek (Google™ Earth imagery, Feb 2015). The house in the top of the picture is at the confluence of the main river and the lowland tributary.

5.10 Porirua Stream

5.10.1 Porirua Stream mainstem

Porirua Stream flows from the bush and gorse-covered hills around Newlands-Johnsonville (264 m a.s.l) and flows northwards, adjacent to the main railway line through Porirua City CBD (App. I, Fig. ii). Through the CBD and outlying suburbs the waterway is well-shaded with mixed exotic and native vegetation and is the probable recipient of direct stormwater from this urban environment. During summer, the baseflow is composed of a shallow run, punctuated by the occasional turbulent riffle. Further north through the light-industrial zone of Tawa/Porirua, in the vicinity of Wall Place, the stream is quite channelised and completely unshaded. It remains largely unshaded into the southern approach to Porirua City CBD.

Approaching the Porirua City CBD, the channel remains highly modified and is straightened and lined with large rip rap until about 160 m upstream of the Station Road entry bridge. At that point, a low weir has been constructed for flow-gauging purposes by the GWRC. Downstream of that point, through the CBD, the channel is confined by vertical concrete banks and the river flows as a shallow, featureless run, thus unchanged from the NIWA survey in 2001 (see physical description pages 21-22 *in* Taylor & Kelly 2001).

Spawning Location

The saltwater wedge tip was identified on the high tide, approximately 420 m upstream of The Ramp, 62 m downstream of the downstream Station Road East bridge (Fig. 10a). This is opposite the New World supermarket on Lyttelton Avenue. A large school of inanga were seen at, and upstream of the saltwater wedge. It was considered unlikely that inanga would attempt to spawn on bare concrete cladding at this location (Fig, 10 b). Instead, the low-tide spawning survey was conducted amongst suitable riparian vegetation downstream of the concrete cladding, with eggs found on a small grassy peninsula approximately 170 m downstream of the saltwater wedge (Fig. 10 c). This location is a confluence of Porirua Stream and a tributary (stormwater drain) entering from the true left bank, adjacent to Bullock Lane. The dominant bank vegetation at the spawning area consisted of tall fescue, with some rushes, flax/harakeke and toetoe. Eggs were found on tall fescue that had fine roots hairs over the soil and were considered highly suitable (Appendix II, Figs. 9, 10). This site was small and considered to be of high quality.

Barriers to fish migration, and management issues

Porirua Stream is a wide, gently flowing waterway that discharges into the southern end of the Onepoto Arm of Te Awarua-o-Porirua Harbour. It is the only major freshwater input to the Onepoto Arm. It does not appear to undergo any mouth closures, and would be managed to avoid closure, given it drains a municipal area. A weir is located approximately 550 m upstream of the saltwater wedge tip (Appendix II, Fig. 11), which may present a significant barrier to fish passage at low water levels, including migrating whitebait and inanga during low or even typical stream flows. No other barriers to upstream migration were observed.

At the saltwater wedge tip, the banks of Porirua Stream consisted of vertical concrete and it was considered impossible for inanga to spawn at this location. Instead, some eggs were located 170 m downstream in suitable grasses. In total, the concrete banks extend for approximately 500 m, about 120 m of which was below the saltwater wedge tip. If the banks were naturalised, at least in part, then the spawning area could be greatly increased. This work could be subject to an extension study of this preliminary work.

Grassy embayments, peninsulas, islands, and confluences appear to be preferred by spawning inanga, especially in the Porirua Stream which is stripped of flow impediments. We consider that this behaviour has evolved because these zones form back eddies and backwaters of low water velocity in the shallows during the spawning process. These disturbances would serve to concentrate the male fish's milt over the ova, possibly increasing the probability of complete egg fertilisation.

A preferred option would be to recontour the entire flow course so the river has a more serpentine course between the hard structures. The meanders, if planted out in grasses and pliant shrubs, would provide some public amenity during baseflows. This would create more hydraulic complexity (both across and along the channel), which in turn should accommodate more biodiversity in respect to fish and invertebrates. This potential may be limited by water quality issues. The sloped banks of such structures, if reinforced with AP40 (crushed gravel aggregate), and Enkamat™ (a geotextile) would provide good inanga spawning habitats. In Christchurch, steep spawning banks were graded and stabilised with AP40 and Enkamat™, to reduce erosion and facilitate drainage, and then planted with suitable vegetation (App. V). Good drainage is important for inanga spawning sites (Mitchell & Eldon 1990). We note the esplanade strip is fairly wide, so could easily accommodate a reasonable level of ecological function and recreational amenity needs.

Another option is to create low-lying peninsulas intruding a few metres into the channel within the CDB to facilitate inanga spawning, and vegetated with soft *Carexs* which lie flat when subjected to the current. During high flow stages (c. 0.5 m), water would flow over the top.

Additional survey suggested

No other sites are recommended for survey, but a more intense survey on both banks in the vicinity of the spawning area, particularly on the apparently suitable grassed true right bank, could yield more inanga eggs.

Figure 10a. Porirua Stream, Porirua. Green line indicates spawning reach, while orange line indicates the area that was unsuccessfully searched, but still considered suitable.

Figure 10b. Porirua Stream, looking upstream towards the terminus of the saltwater wedge at high tide. Note the unsuitable vertical concrete banks.

Figure 10c. Porirua Stream inanga spawning site near Bullock Lane, true left bank. Red arrows indicate egg nests.

5.10.2 Kenepuru Stream (tributary of Porirua Stream)

Kenepuru Stream is a major tributary of Porirua Stream. It drains the new Aotea Block and Porirua East residential areas, and the Belmont Regional Park. The tributary enters the mainstem approximately 480 m upstream of the Porirua Stream mouth (App. I, Fig. ii). There were no tide gates at its confluence with Porirua Stream.

Spawning Location

The saltwater wedge terminus was identified at high tide, approximately 110 m downstream of Johnsonville-Porirua Motorway (Fig. 11a). The dominant bank vegetation consisted of tall fescue, giant umbrella sedge, toetoe, buttercup, mint, flax/harakeke and other soft herbs (Fig. 11b). Eggs (Appendix II, Fig. 12) were found at low tide on tall fescue (both banks) over a 20 m reach and found bound to creeping buttercup/and an unidentified Carex (Fig. 11c). Overall, both the size and quality of this site are considered of moderate importance, but further investigations could result in these classifications being upgraded. During the high tide survey, large shoals of inanga were observed near this site and one shoal was estimated to contain as many as a thousand fish.

Barriers to fish migration, and management issues

Kenepuru Stream is a small, gently flowing waterway that does not undergo any mouth closures. A low weir was located about 50 m downstream of Johnsonville-Porirua Motorway, and although it does not inhibit upstream migration of inanga, its removal (if redundant) is recommended. No other weirs or barriers to upstream migration were observed, although the full length of the stream was not surveyed.

There is a major subdivision development occurring on final stages of the Aotea Block development, which divides the Kenepuru Stream catchment from Porirua Harbour and Porirua Stream. The southern tip of the development would appear to transgress into the Kenepuru Stream catchment upstream of the spawning location (Fig. 11a), although there appears to be a substantial vegetated buffer strip between the development and the stream. At the time of writing, we regard the development as not likely to have an impact on inanga spawning in the Kenepuru Stream.

The rough grassy vegetation along the spawning reach is clearly suitable, and it would be best not to modify the ecological balance unnecessarily. A simple monitoring programme before the season, say in November, to remove any unsuitable plants would be advised. Introduced grasses, fortuitously, function very well in providing the right environment for inanga egg development. To ensure a luxuriant grass sward to facilitate inanga egg development, these grasses should be left uncut after the end of November through to about mid-May.

Survey limitations and additional surveys suggested

No other sites are recommended for survey, but a more intensive search of the area following a peak high tide could provide more detailed distribution information.

Figure 11a. Kenepuru Stream, Porirua. Green line = spawning reach, orange line = suitable but no eggs. Google™ Earth imagery date December 2015.

Figure 11b. Kenepuru Stream, looking downstream towards the tip of the saltwater wedge at low tide.

Figure 11c. Inanga egg deposits (arrowed) located at low tide.

5.11 Makara Stream

Makara Stream rises from the steep scrub-covered slopes of Makara Hill (412 m a.s.l.), which forms the western edge of Karori, a suburb of Wellington city. The Makara catchment drains westwards away from Karori, flowing north-east along a narrow valley through the township of Makara towards the Tasman Sea (App. I, Fig. iii). Little native vegetation is left in the catchment, which has been converted to dryland grazing, with some remnant scrub thickets in the gullies.

Downstream of the intersection with Takarau Gorge Road, where a major tributary joins the river, the valley broadens and the combined flow takes a gentle, meandering course across the valley floor. In the lower reach the river is deep, sluggish and log-strewn. The river continues to meander across the pastoralised valley floor to the sea at Ohariu Bay. At the time of our survey, the river mouth was open, and, when inspecting Google Earth imagery (14 years) the permanent mouth appears to be the normal state of affairs. The mouth is protected from storm surge by a bluff on the true right bank, and does not seem to shift away from the bluff.

Possible Spawning Locations

The saltwater wedge terminus was identified at high tide, approximately 1.9 km upstream of the beach (Fig. 12 a, b). No confirmed inanga were seen, but inanga-like fish were seen shoaling in the boat ramp area. These fish could have been smelt, which look very similar when viewed from above.

An egg search was undertaken at high tide at the saltwater wedge tip and at low tide in the lower reaches (Figs. 12 a, b). At the saltwater wedge terminus the bank vegetation mostly consisted of tall fescue, toetoe, flax/harakeke and shrubs, but the root matrix was considered unsuitably sparse and muddy (Figs. 12 c, d). In the lower reaches, where the second egg survey was conducted, the bank vegetation was more variable. On the eastern side of Makara Stream, vegetation was predominantly native rushes and tall fescue, with minor components of other vegetation (App. II, Figs. 13- 14). This area was generally muddy as well, but there were frequent patches of suitable habitat where spawning could occur. This site was considered to provide a large area of low-quality spawning habitat.

The island vegetation was more variable, dominated by flax/harakeke, shrubs and native rushes (App. II, Figs. 15-16). The root matrix suitability for spawning was variable, but generally suitable and the site was considered to provide a large area of medium quality spawning habitat. The small section of vegetation that was searched on the true left (west) bank in the lower Makara Stream was different to the other sites - it was comprised almost entirely of thick mercer grass on a steep bank. There were horizontal runners over the soil which could be used as a substrate for inanga eggs and the site was considered to provide a small area of spawning habitat of mixed quality.

Barriers to fish migration, and management issues

Makara Stream is a gently flowing waterway of moderate size that was open to the sea at the time of the survey. There were no tidegates at the mouth and no other barriers to upstream migration were observed, although the full length of the stream was not surveyed. There were no general management issues noted in regard to inanga spawning, however, the banks of the river were lightly grazed by stock in places and if the spawning location could be identified, local management may be required. Management issues not relating to inanga spawning were noted as follows: Several downed trees blocked the waterway and may present flooding issues in the future. Further to this, a 30 m long thicket of bamboo on the true left bank requires control, and the location is 1:50000 Map BQ31 NZTM 1743785.8 5434170.7 (our waypoint No. 129). Bamboo is a plant pest species as categorised in the WRC pamphlet on pest plants (Greater Wellington Regional Council und.).

Survey limitations and additional surveys suggested

The low river gradient meant that the saltwater wedge extended a significant distance upstream, and there was insufficient time to investigate the entire potential spawning reach thoroughly. Time was further constrained by the necessity to carry the boat a few times to negotiate trees which had fallen across the river. In respect to future surveys, a waterway with some promise for inanga spawning is a small tributary, flowing through Hawkins Gully, which enters the lower reach about 250 m upstream of the beach (ringed in Fig. 12 b). This tributary appears to possess a buffer strip in its lower reaches, and could be accessible by foot, although boating across the main river may be quicker.

Figure 12a. Makara Stream, Makara Beach. Red line indicates the area that was searched, but considered unsuitable for spawning. Location of bamboo thicket is arrowed.

Figure 12b. Makara Stream, Makara Beach. Orange lines indicate the area that was unsuccessfully searched, but the vegetation was still considered suitable. Red circle indicates where a further survey may be valid.

Figure 12c. Looking downstream at Makara Stream, at the saltwater wedge tip.

Figure 12d. Looking upstream at Makara Stream, from the saltwater wedge tip.

5.12 Hutt River

5.12.1 Hutt River Mainstem

The Hutt River drains a significant catchment area (655 km^2, GWRC) which rises from the southern and western flanks of the Tararua and Rimutaka Ranges. For the most part, the mainstem is shallow with a gravel base, and in the lower section, the banks are partially clad in rip-rap to reduce erosion during floods and from wave action. The cladding is required because the mouth of the Hutt River faces the entrance to Wellington Harbour (App. I, Fig iv), and is exposed to a significant wind fetch from the south.

While the mainstem provides little apparent habitat for inanga, several sluggishly-flow lowland tributaries had the potential to provide rearing habitat for this fish. These include the Waiwhetu Stream, and Opahu Stream, draining Lower Hutt, and Te Mome Stream draining Petone/Gear Island. The Sladden Park boat ramp area has proven potential for inanga spawning. All of these habitats are also depicted in App I. Fig. iv.

Possible Spawning Locations

The saltwater wedge was not directly determined, but does not extend far upstream in the Hutt River. At 2 km upstream from the harbour, adjacent to the Opahu Stream confluence with the main river (i.e. 90 m upstream of the railway bridge), the river waters at the bottom of the channel were 50.5 mS/cm, essentially salt water. A high-tide reading a further 1.1 km upstream indicated that the river was entirely fresh at 100 µS/cm and surprisingly shallow. The tip of the saltwater wedge clearly falls between the railway bridge and the road bridge (Railway Avenue).

Downstream of our freshwater record, the banks of the Hutt River are vegetated down to the gravel bed. Based on Google Earth imagery, the river shallows appreciably directly upstream of the Opahu Stream mouth, with the deep channel following the true right (west) bank, then with distance upstream, shifting to the true left (east) bank downstream of the Railway Avenue bridge. If inanga spawn along the mainstem, it would occur along the reach adjacent to the Rimutaka Cycle Trail (Fig. 13). Superficially, this reach looks quite suitable for inanga spawning, with tall uncut grasses extending down into the intertidal zone.

Barriers to fish migration, and management issues

As the mouth of the Hutt River is permanently open, there is no physical barrier to inanga whitebait access along the mainstem until the river shallows upstream of Railway Avenue.

Downstream of the Opahu Stream tidegate structure, the true left (east) bank is composed of rip rap (App. I, Fig 17), providing no habitat for inanga spawning. The true right is heavily vegetated in trees, scrub, and toetoe, which is too woody and lacks the stem density and suitability required for inanga spawning. In summary, the mainstem downstream of the Opahu Stream confluence provides little habitat for either inanga spawning or rearing.

Survey limitations and additional surveys suggested

Due to time limitations, no egg search was conducted on the mainstem upstream of the Opahu Stream confluence. However, a survey is recommended in the area between the railway bridge and Railway Avenue. The reach is accessible from the mown esplanade strip. A habitat suitability map for inanga spawning is provided below (Fig. 14).

Figure 13. The Hutt River at high tide upstream of the Opahu River mouth. This is the true left (east) bank which has vegetation superficially suitable for inanga spawning.

Figure 14. The reach (ringed), which may hold potential for inanga spawning.

5.12.2 Opahu Stream (Black Stream) - lower bunded reach

In recent years, the lower Opahu Stream has been bunded and isolated from its natural stream course and catchment. Instead, water inflow has been provided by a flap-valve culvert from the Hutt River (App. I, Fig iv), and the inflow passes through a 530 m vegetated channel before exiting its natural mouth (Figs. 15a-c) and back into the mainstem.

Possible Spawning Location

No conductivity readings were taken, but the reach was tidally influenced, with an inter-tidal sward of saline-tolerant vegetation (e.g. jointed wire rush)(Figs. 15 d, e). A small shoal of immature inanga was observed at the upstream end, as freshwater bullies were abundant. An egg search was undertaken at low tide from the tidegates downstream to the mouth. Bank vegetation was comprised of jointed wire rush/oioi, tall fescue, *Juncus* sp., flax/harakeke and toetoe. The inundated margins of the vegetation have developed an aerial matrix of fine root hairs or stolons which looked suitable (App. II, Fig. 18). However, towards the mouth, the jointed wire rush planting needed to be extended up the bank more, as the bank was steeper, and the high tide level was too high above the potential spawning vegetation provided by rushes.

At the most upstream 20 m of the reach, and towards the downstream end, the banks were comprised of rip-rap and so offered no spawning habitat. In the reach towards the mouth, the bank profile was unsuitably steep, providing less of an intertidal zone for egg deposition.

In its present state, the lower bunded section of Opahu Stream provides some spawning habitat, but the vegetation levels require some work, especially at the downstream end near the mouth.

Barriers to fish migration, and management issues

There are no barriers to upstream whitebait migration into this area; however there are several potential management issues. We consider that the jointed wire rush and/or tall fescue has been planted too low, at least in some places, to be utilised by spawning inanga. Towards the mouth especially, the best option is to obtain accurate levels for the spring tides, possibly re-grade the banks, and re-plant to these levels.

While providing inanga spawning habitat is important, appropriate habitat for whitebait to rear to adult spawning size is also required and there must be sufficient whitebait to rear to mature adults after natural mortality. This created wetland provides limited adult habitat. Inanga is a riverine fish which prefers some slow water current and moderate depth, this allows them to feed on slowly drifting invertebrates (Jowett 2002; Jowett & Richardson 2008). They also prefer a higher degree of marginal vegetation and bank cover (Richardson & Taylor 2002), which this habitat currently lacks. It is possible that inanga rearing in tributaries which are not tidally influenced may swim down the Hutt River in search of suitable spawning habitat. However, it is unclear if they would then swim upstream into the mouth of the lower river which would seem unnatural behaviour.

While we have not observed the Opahu spawning habitat at various tide stages, we are not confident that the physical habitat provides sufficient good rearing habitat for inanga (e.g. depth, velocity and marginal habitat). In a natural setting, inanga rearing habitats occupy a significant length of stream channel upstream of the spawning grounds, with the spawning fish migrating downstream to spawn on the spring tide (Burnet 1965). This habitat was built to provide spawning habitat as mitigation for some hard edge protection works in the area (Alton Perrie, GWRC, pers. comm). Unfortunately, in its present form, it lacks functional rearing habitat for the spawning adults.

Moreover, we didn’t see any mature inanga in the wetland, although some juvenile specimens were observed. If the water is clear, spawning inanga are normally seen in the vicinity of spawning grounds. We also heard anecdotal reports of whitebait over-fishing and illegal fishing methods being used in this wetland and this may explain the consequent paucity of adult fish. We would also like to draw attention to some recent gorse establishment along the margins that should be dealt with before it becomes more of a problem.

Survey limitations and additional surveys suggested

This site was well searched and management issues should be addressed before further surveys are undertaken.

Figure 15a. Lower Opahu Stream, Lower Hutt. Orange lines indicate the area that was unsuccessfully searched, but the vegetation was still considered suitable; red line indicates the area that was searched, but considered unsuitable for spawning.

Figure 15b. The 'upstream' end on the bunded wetland.

Figure 15c. The downstream 'mouth' of the bunded wetland.

Figure 15d. Looking downstream at lower Opahu Stream.

Figure 15e. Looking upstream at lower Opahu Stream.

5.12.3 Opahu Stream- reach upstream of control structure

Opahu Stream is a small, lowland waterway which appears to rise upstream of Laings Road in Lower Hutt. The Hutt River tributary meanders through Lower Hutt for nearly 2km (Fig. 16a) before discharging into the Hutt River at Whites Line West. The outlet has a significant control structure (App. II, Figs. 19- 20).

Possible spawning location

An egg search was undertaken on a low but rising tide from the tidegates upstream to Wai-iti Crescent (Fig. 16a). No conductivity readings were taken in the reach upstream of the tidegates, but some saline intrusion takes place, and a slight trickle of incoming Hutt River water was heard passing through the control structure. Within the lowest reach, estuarine crab holes could be seen in the banks, and there was a clear tide mark on the banks (0.5 m above L/T level). Small schools of inanga were present, as well as an abundance of common bullies (*Gobiomorphus cotidianus*).

Bank vegetation varied depending on land tenure. It ranged between tall grasses, mown lawn, soft herbs, bamboo, shrubs and trees, and sometimes bare ground (Figs. 16b-d). The banks within the inter-tidal zone were steep and stony near the tidegates, and composed of a vertical mud slope further upstream. Aerial root mats or stolons were either non-existent or too exposed to the air (due to mowing).

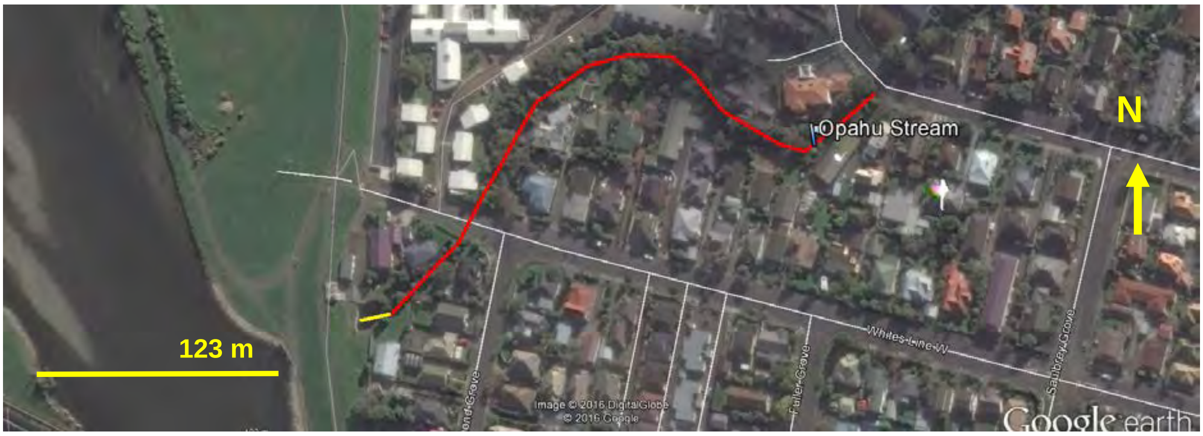

Figure 16a. Opahu Stream, Lower Hutt. Red line indicates the area that was searched, but considered unsuitable for spawning; yellow line indicates the length that was unsuccessfully searched and suitability for spawning may be dependent on remediation.

Near the tide gates, riparian vegetation had been replaced with rip rap, which provides little (if any) habitat for successful spawning (Fig. 16b). Some of the large boulders were lifted to check for inanga eggs, and within the network of creeping herbs across their surfaces. However, no eggs were found. Upstream of that point banks remained unvegetated within the intertidal zone. The culvert under Whites Line West has a buried invert and is easily passable, but the banks were still bare of vegetation, and the estuarine crab holes were clearly present (Fig. 16c). The distribution of estuarine crab holes extended upstream almost to Wai-iti Crescent (Fig. 16d, e). It is clear the stream has a very low gradient, which explains the deep upstream penetration of estuarine ecology in the waterway.

In its present state, Opahu Stream provides little to no spawning habitat downstream of Wai-iti Street, largely due to the lack of suitable, in fact any, intertidal vegetation. It is possible that some spawning may occur upstream of Wai-iti Crescent, but the channel winds through a suburban environment with no esplanade strip. In these situations, riparian vegetation is usually modified to each landowner's particular aesthetics, and one which usually precludes the dense grassy vegetation required for inanga spawning. We conclude that there is little or no potential for inanga spawning downstream of Wai-iti Crescent culvert, and there may be some potential upstream, but the chances are slim based on the riparian management we observed on this waterway.

Figure 16b. Looking upstream at Opahu Stream, note the steep, rock-clad banks and minimal vegetation.

Figure 16c. Looking downstream at the Whites Line W culvert. There was no intertidal vegetation upstream and downstream of that point.

Figure 16d. Looking downstream at Opahu Stream, note the steep muddy and rocky banks as well as the bare ground on the true right bank (right in this picture).

Figure 16e. Looking upstream at Opahu Stream, note the steep muddy banks and short grass.

Barriers to fish migration, and management issues

The flood gates evidently did not provide a complete barrier to upstream fish migration because inanga were present upstream of the flood gates. No other barriers were observed upstream to Wai-iti Terrace.

The primary management issue at this site was the steep, unvegetated banks, and the reason for that is unknown. If appropriate plants were trained over the riprap, some inanga spawning could be supported. Appropriate plants could include: monkey musk, creeping buttercup, mint, creeping Jenny (grass), twitch etc.

Survey limitations and additional surveys suggested

This site was thoroughly searched and so additional surveys are not recommended. It may be beneficial to revisit on a spring tide and check the salinity gradient. It is possible, but we consider improbable, that limited inanga spawning could take place upstream of Wai-iti Terrace.

5.12.4 Waiwhetu Stream

Waiwhetu Stream, a lowland tributary of the Hutt River, rises from the bushed sides of the Wainuiomata hills (391 m a.s.l) which flank the eastern side of the Hutt Valley (App. I, Fig. iv). The headwaters quickly descend onto the wide valley floor, where it receives direct stormwater runoff from the residential zone of Lower Hutt as well as runoff and historical pollutants from the light industrial zone around Port Howard. Waiwhetu Stream discharges into the Hutt River very close to the Hutt River mouth in Wellington Harbour. Lacking tidegates, the Waiwhetu River is subject to the full amplitude of the Wellington Harbour tidal variation and southerly storm fetch. Consequently, the permanently open mouth is reinforced with rip rap, and the banks of the lowest reach are clad in concrete.

Further upstream, a significant proportion of the riparian margin through the residential zone has been subject to restoration plantings by the 'Friends of Waiwhetu Stream'. Friends of Waiwhetu Stream are a volunteer organisation focused on the environmental restoration of the river including the riparian plantings of a mixture of native rushes, sedges, shrubs, and small trees.

Spawning location

The tip of the saltwater wedge was identified on the spring high tide, and reaches the low weir at Whites Line East (Fig. 17a). The weir appears to be construction necessary to obtain accurate flow estimates from the GWRC flow recorder. Large shoals of inanga were observed near this site, but also throughout much of the downstream waterway. At low tide, starting at the saltwater terminus and working downstream, suitable riparian vegetation was searched for inanga eggs. Inanga eggs were discovered on the inside bend of the river at the end of Hayward Terrace, near the mow-line of private property (Appendix II, Figs. 21). The bank vegetation was dominated by tall fescue, but with some lawn grass (brown-top fescue etc.) creeping buttercup, creeping bent, and Yorkshire fog. Eggs were found adhered to both creeping bent (App. II, Fig. 22) and Yorkshire fog. The spawning survey was undertaken at low tide and eggs were found over a 15 m reach on the true right bank. Our egg survey on the Waiwhetu Stream was terminated due to lack of daylight, but its likely further egg deposits would be found further downstream, due to the large number of inanga present in the system, and the suitability of some reaches further downstream. Soil moisture retention following the high tide was high, and the habitat conditions for egg development were considered good. We noticed several large river rats in the vicinity (App. II, Fig. 23).

Barriers to fish migration, and management issues

Waiwhetu Stream has a permanently established mouth into the Hutt River and consequently Wellington Harbour. Our boat survey revealed no impediments to fish passage up until to the low weir/flow gauging station under Whites Line East, which produced a potential velocity trap for up-migrants, but then only at low tide. The presence of inanga upstream of the structure indicates that it does not significantly inhibit upstream migration for whitebait. No other barriers to upstream migration were observed, with significant inanga rearing habitat upstream of the GWRC weir.

At the identified spawning location, eggs were deposited near the mow line, and the grass length was just long enough to preserve humidity around the eggs, which were viable. However, it is recommended that either: the area is left un-mown during the spawning season or at least the mow-line is retracted back one further metre from the bank edge to preserve the microhabitat around the inanga eggs. In the longer-term it would possible to plant vegetation suited for inanga spawning so the ecology of the site is less precarious. Management should be concentrated where water velocity is low, these occur in embayments and on the inside curve of the river bank. Areas that were considered unsuitable for spawning (i.e. red lines in Fig. 17a), had near-vertical banks and either an insufficient root matrix or the root matrix was covered in fine sediment. Rats may be a significant predator on eggs in this urban habitat and the significance of these rodents to inanga spawning will be revisited in the discussion.

Survey limitations and additional surveys suggested

Additional surveys are recommended in Waiwhetu Stream downstream of Hayward Terrace as numerous large schools of inanga were observed displaying pre-spawning behaviour in the vicinity of suitable vegetation, but were not searched as part of this survey (ringed in Fig. 17b). We consider, therefore, that further spawning reaches are likely to exist downstream of Hayward Terrace.

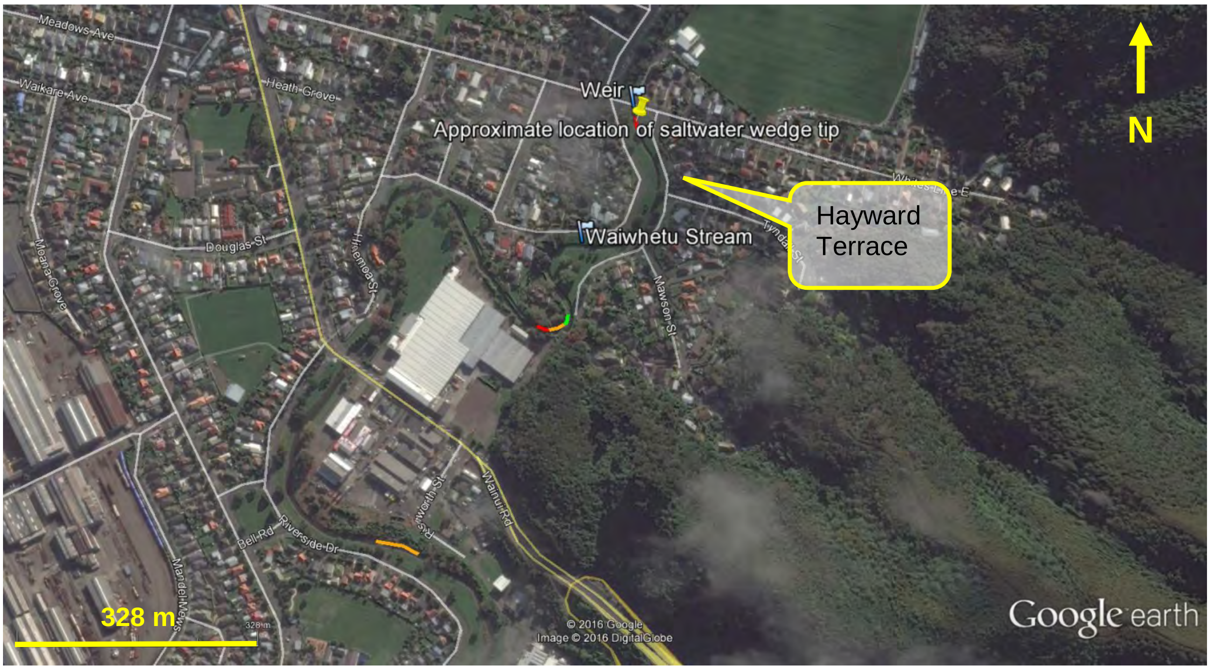

Figure 17a. Waiwhetu Stream, Lower Hutt. Green line indicates spawning reach, while orange line indicates the area that was unsuccessfully searched, but still considered suitable. Red line indicates the area that was searched, but considered unsuitable for spawning.

Figure 17b. Waiwhetu Stream, Lower Hutt. Green line indicates spawning reach, while orange line indicates the area that was unsuccessfully searched, but still considered suitable. Red line indicates the area that was searched, but considered unsuitable for spawning. Red circles indicate where further surveys should be undertaken, based on fish activity.

5.12.5 Sladden Park boat ramp area

The Sladden Park boat ramp area is a backwater (approx. 4,500 m^2) on the east (true right) bank of the lower Hutt River, approximately 380 m downstream of the main railway line (App. I, Fig. iv). It is accessed from Bracken Street, heading east, and then into the Sladden Park Drive past the football ground. A map of the habitat is provided in Figure 18a.

Possible Spawning Location

No conductivity readings were taken within the boat ramp area as spawning has been reported here previously by the Department of Conservation. In the mid-channel of the Hutt River out from the boat ramp area, we measured the river bottom conductivity as that of seawater (50 mS/cm), with the surface quite fresh (104 µS/cm). The shallow surface water within the boat ramp area was also likely to be fresh.

Within the harbour, there was significant tidal variation (c. 1 m), and at high tide large shoals of inanga were observed actively feeding in the shallows. An egg search was undertaken at low tide around the perimeter (Fig. 18a). University students at the site, who were undertaking a study on inanga, reported that they had had relatively poor catch rates of adult inanga from this area.

Near the boat ramp on the more suitable north bank, vegetation was mostly comprised of tall fescue, but the banks were often steeply shelved at the full tide line (Fig. 18b). Anecdotally, the banks (especially the north) are subject to wave erosion from the Hutt River during southerly storms and storm surge. On the less suitable south bank, the grassy banks near the boat ramp had become slumped or undercut, also likely through wave action (Fig. 18c). Closer to the Hutt River both banks were clad in concrete and hard-fill and therefore were not suitable for spawning. Generally the aerial root/stolon matrix was suitable, but patchily distributed. In its present state, the Sladden Park boat ramp area provides a medium area of size and quality in respect to spawning habitat.

Barriers to fish migration, and management issues

There were no barriers to inanga accessing this site, as the Hutt River is always open to Wellington Harbour. However there are some management issues, primarily the collapsing north bank. It is thought that the erosion of the north bank is caused by storm-surge during southerlies. To combat bank erosion while maintaining suitable spawning habitat we recommend that the north bank be re-graded and sloped at about 40 degrees with crushed AP40 (gravel aggregate) then lined with Enkamat™ or similar geotextile, and re-sown in suitable grasses. The hard subsoil should protect the bank from further wave erosion, and provide a wider zone for inanga egg dispersal. AEL holds plans and elevations of a successful inanga spawning ground re-establishment for the Heathcote River (Christchurch) which could provide a basis of repairing this bank.

Survey limitations and additional surveys suggested

This site supported some inanga spawning in past decades, prior to bank erosion. However, larger rearing and spawning habitats may be found in the Waiwhetu Stream, and arguably priority should be placed there. However, bank stabilisation and restoration of this site, as suggested above, because of its good public access, may be useful as an educational resource, and public education amenity.

Figure 18a. Sladden Park boat ramp area, Lower Hutt. Orange lines indicate the area that was unsuccessfully searched, but the vegetation was still considered suitable; red lines indicate the area that was searched, but considered unsuitable for spawning.

Figure 18b. Looking downstream at the true left (north) bank of the Sladden Park Boat Ramp area. What appears to be the old bank (concrete wall) is arrowed.

Figure 18c. Looking upstream at the true right (south) bank of the Sladden Park Boat Ramp area.

5.12.6 Te Mome Stream

Te Mome Stream rises on the Hutt River flood plain, flows through a 30 m culvert under Waione Street, and discharges into the lower reaches of the Hutt River *via* flap valves (Figs, 19a, b; App. I, Fig. iv). The waterway encircles Sladden Park, almost forming an island within the Hutt River, the so-called Gear Island, as identified on NZ Map sheet BQ32 on NZMS 1:50,000 Series (Fig. 19a).

Possible Spawning Location

No conductivity readings were taken when this site was surveyed opportunistically on a falling tide during our surveys on other Hutt River tributaries. A small number of inanga, common bullies and possibly giant bullies were seen immediately upstream of the culvert at what would probably be the terminus of the saltwater wedge (ringed in Fig. 19a). Tall fescue and raupo were present on the banks downstream of Bracken Street (Fig. 19c), and given the observed water level elevation at high tide (0.3 m above observed), this foliage could provide some support for inanga egg development. Both plant species are known to support inanga spawning (Taylor 2002).

There is likely to be a significant salinity gradient near the tide gates at high tide, and this may be sufficient to trigger inanga spawning on the limited vegetation available at this location. We have observed tidegate spawning at other waterways in the South Island. The location of this area is also indicated in Fig. 19a. At the time of survey, we received anecdotal reports of significant inanga spawning in Te Mome stream in the past by a local whitebaiter.

Barriers to fish migration, and management issues

A potential substantial impediment for whitebait immigration into the waterway was a 30 m long three-flap culvert which controlled water level in Te Mome stream (Fig. 19b). Although the construction of the flap-valves superficially looked passable to fish, the water velocity through the culverts was extremely fast and would deny fish access at the time. The water velocity would decline significantly as the water level between the Hutt River and Te Mome stream decreased, which is evidently enough to allow access for some whitebait, and other sea-migratory fish species (i.e. bullies). However, we noticed too (and depicted in Google™ Earth imagery) that at low tide that surface water access from the Hutt River becomes very shallow, and time periods in which sea-migrants could enter the system may be quite short, and limited to a window near the top of the flood tide.

We also noticed bankside signs which alluded to poor water quality, and significant amounts of filamentous algae which may be caused by unnaturally high nutrient inputs, particularly phosphorous. A 2014 government environmental grant application describes Te Mome stream as having high levels of sediment-bound heavy metals attributed to its partly industrialised catchment. Inanga have an 'intermediate' tolerance to many pollutants (Richardson & Taylor 2002), but the impacts of pollutants on other aspects of their feeding ecology in particular invertebrates and primary production could have indirect adverse impacts on inanga.

Survey limitations and additional surveys suggested

Time restraints meant that an egg search and conductivity readings were unable to be undertaken at this site and only general access and some site notes were made. We recommend that the two ringed areas in Fig. 19a be searched for inanga spawning.

Figure 19a. Te Mome Stream, Lower Hutt. Red circles indicate where a further survey is warranted.

Figure 19b. Looking upstream (from the Hutt River side) at the flap valves on Te Mome Stream.

Figure 19c. Looking upstream at Te Mome Stream upstream of the flap valves. Suitable grass down-gradient from the mow-line.

5.13 Wainuiomata River mainstem

The Wainuiomata River is a large river which rises from the bushed southern flanks of the Rimutaka Range (632 m a.s.l) and the equally bushed lower Wainuiomata Hills. On the valley floor, the river also receives stormwater runoff from the township of Wainuiomata as it flows south towards Baring Head (App. I, Fig. v). The mouth is fully exposed to the storm surge from southerly storms, and the mouth was closed by a substantial gravel bar during our site visit. Based on Google Earth imagery this mouth normally has a tenuous opening to the sea.

Spawning location

The water behind the gravel bar was quite fresh (245 µS/cm), with no detectable vertical conductivity/salinity gradient. Neither was a horizontal saltwater wedge detectable. With no saltwater wedge present, suitable riparian vegetation was checked for eggs close to the waterline. The water was too turbid to detect inanga shoals, but nevertheless inanga eggs were identified from a 95 m reach of the true right (west) bank (Figs. 20a,. 20b). The dominant bank vegetation consisted of the native giant umbrella sedge, tall fescue, with some native rushes, pasture grass, buttercup and toetoe. Gorse was also present, but up-gradient from the spawning zone. Eggs were affixed to giant umbrella sedge (Fig. 20c) and grass/buttercup stems (Appendix II, Figs. 24, 25).

Barriers to fish migration, and management issues

At the time of our survey the mouth was closed, but Google™ Earth imagery indicates that the river does connect to the sea on occasion, with the latest connection shown around December 2015. No weirs or other barriers to upstream migration were observed, although the full length of the stream was not surveyed. Improbable as it may seem, whitebait can traverse gravel bars by surfing the waves across the top of the bar during storm surges or high spring tides.

Palatable grasses on the true right bank were clearly grazed to a low sward by stock, and no riparian fence was present. Gorse thickets behind the spawning vegetation possibly provide some protection from stock (Appendix II, Fig. 26), but we found eggs only attached to the native rushes which are probably unpalatable to stock. There was one area in the middle of the spawning grounds that was grazed and no eggs were found here (Appendix II, Fig. 26). It is possible continued grazing by stock inhibits further colonisation of the bank toe by giant umbrella sedge, and we would recommend that this spawning reach be fenced from stock. The exclusion period should be from December to May inclusive, which allows time for grasses to recover condition in the spring prior to spawning, and for egg development in late autumn.

Survey limitations and additional surveys suggested

Due to time limitations, additional surveys are recommended on the true right bank downstream of the identified spawning reach and on both banks above it (ringed in Fig. 9a).

Figure 20a. Wainuiomata River, Wainuiomata. Green line indicates spawning reach, while orange line indicates the area that was unsuccessfully searched, but still considered suitable. Red line indicates the area that was searched, but considered unsuitable for spawning. Red circles indicate where a further survey may be warranted.

Figure 20b. The spawning reach on the true right (west) bank of the Wainuiomata River.

Figure 20c. Inanga eggs were found at the bases of giant umbrella sedge (background) and another, unidentified sedge, possibly *Carex geminata* (foreground). Most of the stock-palatable grasses had been close-grazed and therefore unsuitable for inanga spawning.

5.14 Lake Onoke

Lake Onoke is a brackish wind-exposed coastal waterbody primarily fed by the Ruamahanga River and discharges into Palliser Bay, Cook Strait (App. I, Fig. vi). It also receives discharge from Pounui Lagoon. In combining these two catchments, it is the receiving water body for much of the Wairarapa basin between the Tararua Range to the west and the Aorangi Range and east coast hills. Lake Onoke has an area of approximately 642 Ha. The mouth closes regularly under natural environmental conditions.

5.14.1 Lake Onoke, away from freshwater feeders (west bank)

In 2002, the entire west side of Lake Onoke was intensively surveyed and was considered unsuitable for inanga spawning (high salinity, stony banks, sparse vegetation)(Taylor & Kelly 2002). This habitat was considered constrained by prevailing geology which was unlikely to change, and this reach was not surveyed during this survey. The wetland in the south-west corner adjacent to Ocean Beach Road was not surveyed, as it was evaluated during the 2002 survey and was found to be too saline, with no moisture-retentive soil structure. Priority was given to the eastern and northern shores where inanga spawning had been recorded in the past.

5.14.2 Lake Onoke, north and east banks and tributaries

This section covers the north and east banks of Lake Onoke, an un-named tributary in the north-west corner and the Turanganui River (Fig. 22a), see section 5.12.1 for the west bank and 5.12.3 for the Ruamahanga River. The Turanganui River was composed of brackish-water (20.5 mS/cm), but at the observed lake level, the river had the form of disconnected shallow pools throughout much of the surveyed reach.

Possible spawning locations

At the time of our survey (19/4/16) Lake Onoke, in its entirety, was quite brackish, with a conductivity ranging from 26- 28 mS/cm (i.e. about half sea-water), except near some freshwater inlets where conductivity roughly halved (Fig. 22b). There were no inanga positively identified in the lake, despite there usually being bottom visibility, but schools of small inanga and smelt were seen in both of the surveyed inflowing tributaries addressed in this section (Figs. 22 c, d). The banks of the Turanganui River were particularly well grassed with rank tall fescue to the water's edge with an appreciable soil profile.

In sheltered lakeside locations, the vegetation was predominantly comprised of rushes, especially jointed wire rush (App. II, Fig. 27), but near the mouth, and other exposed locations, inter-tidal vegetation was very sparse or composed of bare gravel and boulders (App. II, Fig. 28). Within sheltered tributaries near the lake, grasses, especially tall fescue, grew to the water's edge (App. II, Fig. 29).

Inanga can access the canal network behind the north-eastern edge of the lake at least in 3 locations (blue arrows in Fig. 22a). These access channels could provide routes for inanga schools to access the extensive canal network which extends around the periphery of the north-east corner of the lake. There was no apparent stock access to the canal network, and the banks were well-grassed. With easy inanga whitebait access to the canals, it is likely these canals could form suitable inanga rearing habitat, and in areas of fresh water seeps, some spawning could potentially take place.

We evaluated a nearby location on the east shore where inanga had been historically reported as spawning (DOC record). It was clear that the freshwater lagoon in that location was now closed to the lake by a gravel bar and the margins were pugged by stock (App. II, Fig. 30).

Away from freshwater feeders, the exposed eastern bank of Lake Onoke, like the west bank, was generally considered unsuitable for spawning. This was largely due to its saline nature and, on exposed shores, a lack of vegetation and water retaining soil. Such areas didn't warrant intensive egg searches.

Barriers to fish migration, and management issues

The main barrier to inanga migration is potentially the gravel bar between Lake Onoke and Cook Strait. Preferably this should be open during the whitebait run, but if the bar is narrow, whitebait can 'surf' the wave surge on a flood tide. However, the mouth is exposed to southerly storm surge and closes frequently. It appeared closed during our site visit on 19th April 2016. Examination of Google™ earth imagery shows that the mouth opens and closes regularly. We note the mouth was closed and open at different times during the last whitebait season (closed 12th Sept 2015, open 5th Nov 2015). The GWRC attempts to maintain an open mouth to prevent flooding and it would be ecologically advantageous if it remains open during the whitebait run. Managing lake openings to benefit the whitebait run, while an obvious strategy is likely to be a futile exercise given the power of the sea surge in this exposed environment. When the spawning grounds are located, they need to be fenced from stock.

We consider that the canal network on the north-east corner of the lake still provides potential for both inanga spawning and rearing. However, this habitat is very isolated and does not appear to be under any discernible threat at the time of our survey.

Survey limitations and additional surveys suggested

Most of the margin of Lake Onoke is considered to provide little spawning habitat given its high salinity and variable sparse vegetation. However, the freshwater canals that follow the periphery of the north-west bank are likely to incorporate localised salinity gradients and freshwater rearing habitats for inanga. We consider that the canal network in the north-west corner of the lake still holds potential for inanga spawning, but further survey should be a low priority, given the lack of imminent threats. Access to this area may be restricted to small boats.

Figure 22a. Overview of Lake Onoke and the three areas addressed in this section (Un-named tributary, Turanganui River and the north/east banks of Lake Onoke). Blue arrows = where inanga may access the wetland behind the eastern bank. Orange lines = the area that was unsuccessfully searched, but still considered suitable; red lines = area that was searched, but considered unsuitable for spawning.

Figure 22b. Conductivity of waters in Lake Onoke illustrating the lower readings in the vicinity of freshwater seeps along the north and eastern shoreline. Red line = Ruamahanga River course. Red value is conductivity in an occluded lagoon formed by a historic old braid, separated from the lake by a gravel bund.

Figure 22c. Turanganui River, and north-east bank of Lake Onoke. Orange lines = the area that was unsuccessfully searched, but still considered suitable

Figure 22d. Un-named tributary of Lake Onoke, South Wairarapa. Orange lines = the area that was unsuccessfully searched, but still considered suitable; red lines = area that was searched, but considered unsuitable for spawning. The outlet of Pounui Lagoon to Lake Onoke is arrowed in red.

5.14.3 Ruamahanga River

The Ruamahanga River is the longest river in the Wellington Region, and flows fairly centrally through the region's length (Fig. 23 a). We digitally estimated the river had a length of approximately 149 km. Its headwaters rise in the bushed Haukura Ridge of Tararua Ranges (1335 m a.s.l) and it meanders south-west through the wide Wairarapa valley close to the townships of Masterton and Martinborough. The river continues to meander south-west as it receives the outflow of the largest lake in the Wellington Region, Lake Wairarapa. The river flows for a further 8.6 km until it discharges into the coastal lagoon, Lake Onoke (App. I, Fig. vi).

Possible spawning location

The saline influence in the receiving water body, Lake Onoke, is likely to extend many kilometres up the Ruamahanga River. By boat, we measured the rate of decline in mid-water salinity over the lower 800 m, and assuming linearity of saline wedge depth decline, saline influence could extend 14 km upstream. GWRC records saline conditions at least 10 km upstream of the Lake Onoke mouth (Alton Perrie, GWRC, pers. comm.) Even 800 m upstream of the Ruamahanga River mouth, the surface water was quite brackish (10 mS/m), with no decline in the high salinity (30 mS/cm)at the bottom of the channel.

Locating the saltwater terminus and searching the banks was impracticable by small boat, so we undertook a brief egg search in favourable areas within several hundred metres of the lake, and indicated in Fig. 23 b. The dominant vegetation on the true left bank consisted of three square, jointed wire rush/oioi, and sea rush- flora consistent with brackish surface water conditions. This site was located well downstream of the likely saltwater wedge terminus in the Ruamahanga River, and therefore it is probable that this site is well downstream of any inanga spawning grounds in the main channel.

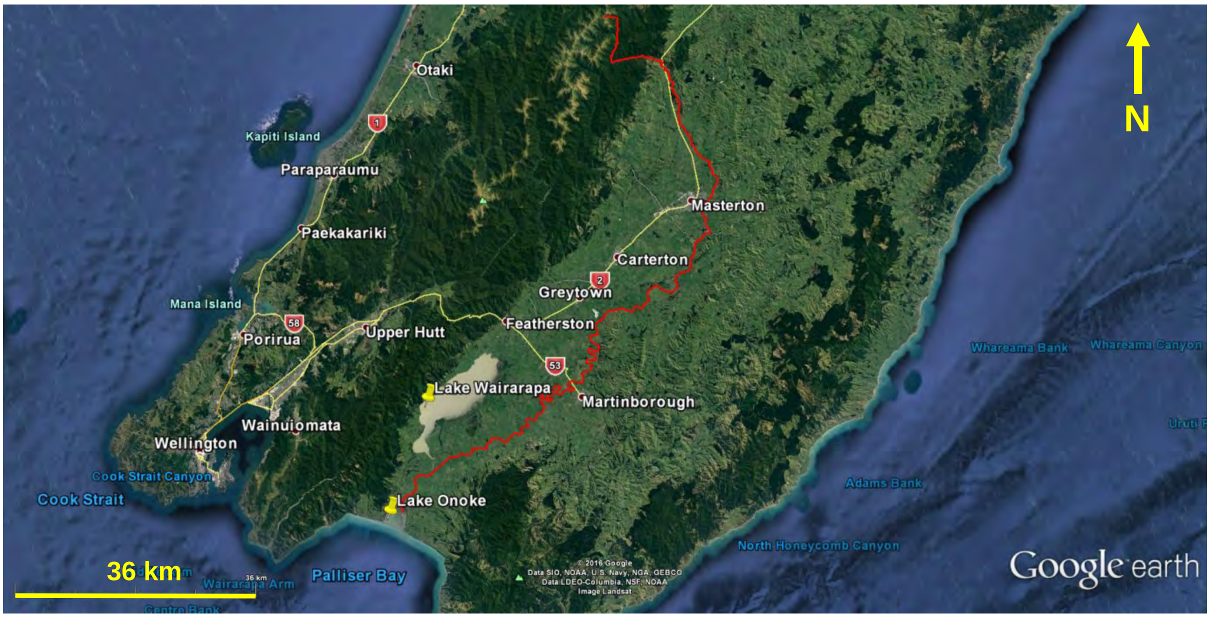

Figure 23a. The course of the Ruamahanga River (red line) flows centrally through the length of the Greater Wellington Region.

Figure 23b. Ruamahanga River, Wairarapa. Orange location (arrowed) indicates the area that was searched for eggs, the vegetation was considered suitable, but the water salinity was uniformly high.

Barriers to fish migration, and management issues

Within the reaches which inanga are likely to occupy, the Ruamahanga River was deep, with moderate flow, suitable for inanga habitation. There was no stock access to the riparian zone, and the banks were stable and well-vegetated. There is no impediment to fish passage along the main river, both of up-migrating whitebait, or down-migrating adults or larvae.

The river has a permanent deep mouth into Lake Onoke, which would be maintained, if necessary, by local authorities to ensure efficient drainage of this significant catchment. In respect to fish passage to and from the sea, based on our observations south of Lake Ferry, the Lake Onoke mouth appeared closed at the time of survey (19th April 2016). Within the Ruamahanga River, there are no known impediments to fish passage, as least in the habitat range which adult inanga would be expected to rear. Inanga are known to penetrate as far upstream as Masterton, approximately 98 km upstream.

Survey limitations and additional surveys suggested

Due to time limitations the saltwater wedge terminus was not located. It is recommended that further survey be undertaken on this major waterway, possibly by taking conductivity readings much further upstream, possibly in the vicinity of the Kahutara Road bridge, and initiating a boat-based survey there. The saline influence is likely to be downstream of that point. We also heard of anecdotal reports of inanga spawning near the Lake Wairarapa control gates on East West Access Road, where salinity changes could be expected.

Small freshwater tributaries entering the brackish Ruamahanga River could also produce localised salinity changes near their confluences, and which may induce spawning. Some possible locations are shown below (Fig. 23c).

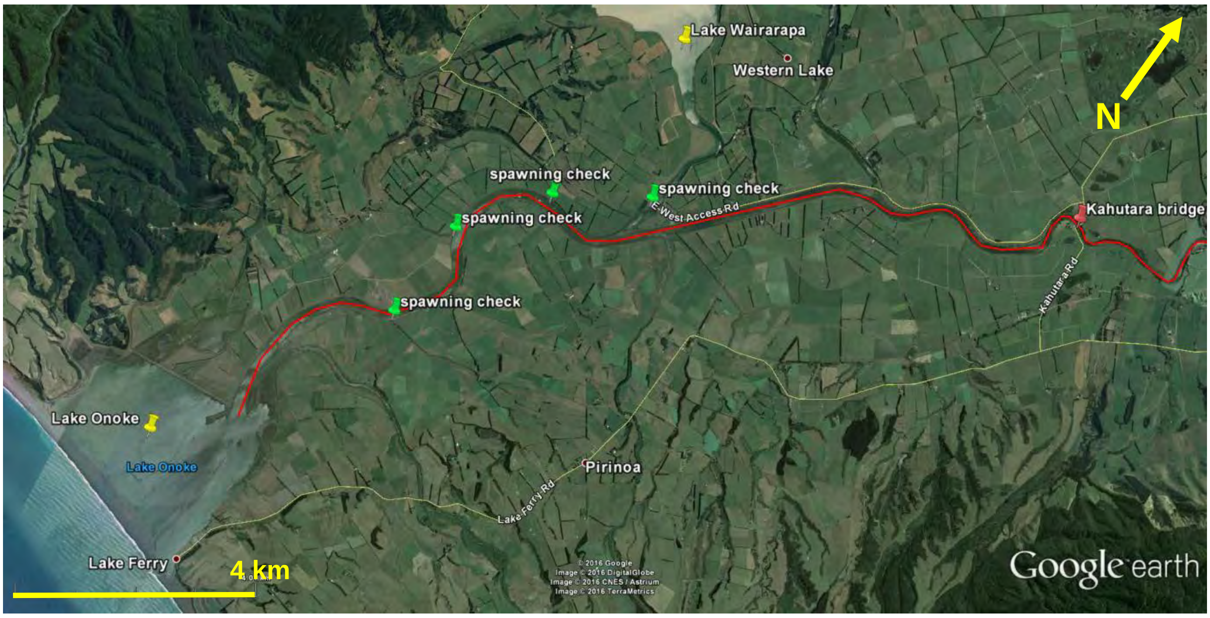

Figure 23c. Possible localised inanga spawning locations on the Ruamahanga River. Motorised boat access required from Kahutara Bridge.

5.14.4 Pounui Lagoon

Pounui Lagoon is a shallow brackish wetland which discharges into Lake Onoke (App. I, Fig. vi). This wetland is fed by Pounui Stream, the outlet from Lake Pounui. Pounui Lagoon is not labelled on Map Series 1:50,000, Map BQ32, but is the waterbody with Sheep Hill Island to the south and Western Lake Road to the east.

Possible spawning location

Pounui Lagoon was brackish, with a conductivity of about 28 mS/cm near Lake Onoke. Near the freshwater inlet (presumed to be Pounui Stream), lagoon conductivity decreased to 9 mS/cm, with a sharp salinity/conductivity change near the stream mouth. We undertook a thorough egg search around the surrounding islands near the inlet (Fig. 24a). No inanga were positively identified in the lagoon and neither were eggs found.

The bankside vegetation in the lagoon was predominantly comprised of jointed-wire rush, flax/harakeke and toetoe (Figs. 24 b, c). Given the vast area of the lagoon and impracticality of searching its entirety, the lagoon island near a salinity transition was considered to provide some potential for spawning habitat, although no inanga eggs were found. Even at the stream mouth, we suspect the salinity was still too high to trigger significant whitebait spawning.

Barriers to fish migration, and management issues

Migrating inanga have several obstacles that they must negotiate before reaching Pounui Lagoon. First, the mouth of Lake Onoke must be open to the sea during the whitebait run and second, they must pass through the culvert separating Lake Onoke and Pounui Lagoon. Although there are flap-valves on the culvert between Lake Onoke and Pounui Lagoon, they have been fitted with a 'slot' in an attempt to allow fish passage (Alton Perrie, GWRC, pers. comm.) The culvert does not appear to present a velocity barrier to inanga, at least not during all phases of the tidal cycle. Inanga clearly enter the lagoon, because inanga were present in Pounui Stream. The path inanga take to get from Pounui Lagoon to the upper reach of Pounui Stream where they were observed is unknown, but it may be through the swamp on the northern bank of Pounui Lagoon (Fig. 24a). During our survey, when tracking Pounui Stream downstream, the flow appeared to flow towards the ringed wetland depicted in Fig. 24a.

There were no observed stock influences, and stock appears to be well fenced away from the boggy margins of the lagoon. At the time of our survey, we could not identify any pressing management issues at this isolated location.

Survey limitations and additional surveys suggested

Although several likely locations were searched, the vast area of the lagoon meant that a relatively small proportion was surveyed. Significant resources would need to be imparted to conduct a thorough search of the lagoon, but our current thinking is the lagoon is too saline for inanga spawning.

Figure 24a. Pounui Lagoon. Orange lines = reaches around the inlet that were searched for inanga eggs; red circle = a further survey region, blue line = Pounui Stream. Note that at the time of sampling the water level of Pounui Lagoon was lower than what is depicted here and the 470 µS/cm reading was taken at the mouth.

Figure 24b. Looking downstream at the island near the Pounui Lagoon inlet.

Figure 24c. Isolated stands of wire rush near the suspected Pounui Stream inlet into Pounui Lagoon.

However, ripe male inanga were identified in Pounui Stream a short distance from the lagoon, and it is possible that the inanga population target freshwater/brackish water interfaces around the lagoon periphery, and within the stream channel itself. In particular, the canal network to the south-east of Pounui Stream may have potential for inanga spawning (ringed in Fig. 24a).

5.14.5 Pounui Stream

Pounui Stream is the outlet for Lake Pounui which links the lake to Pounui Lagoon. Lake Pounui is a small coastal (47.4 Ha. 20 m a.sl.) bush-lined waterbody, which fills a small basin near the southern end of the Rimutaka Range. Pounui Stream is a small, shallow, gravel-bottomed stream which flows onto the pastoralised basin of the greater Lake Wairarapa catchment via 'Pounui Lagoon' (App. I, Fig. vi). It meanders tightly for 700 m before meeting Western Lake Road, at which point the channel straightens for 1.5 km as it approaches Pounui Lagoon (Fig. 25a).

Possible Spawning Location

The spawning location within Pounui Stream was not fully determined. Approximately 450 m downstream of Western Lake Road, Pounui Stream was quite fresh (conductivity 175 µS/cm). When we approached from the Pounui Lagoon end, we took conductivity readings from what we thought was the Pounui Stream outlet into Pounui Lagoon. At the mouth outflow, the conductivity was 470 µS/cm, and decreasing to 400 µS/cm 130 m upstream. However, as indicated in Fig. 25a, the outlet course into Pounui Lagoon tracking upstream differs from the course of Pounui Stream when we tracked it in a downstream direction. We are of the present view that the two approaching stream flows do not connect directly, although there may be a diffuse groundwater connection.

We identified stranded ripe (pre-spawning males) inanga amongst freshwater bank vegetation (Fig. 25 b, c) in the location bracketed in Fig. 25a, presumably migrating downstream to spawn. The vegetation at this location was monkey musk and eggs are commonly found attached to this vegetation. However, the water here was quite fresh and likely to be beyond tidal or Seiche wave influence from Pounui Lagoon.

No spawning inanga, nor eggs, were found in the brackish Pounui Lagoon, presented in the above section, which implies spawning in Pounui Stream is likely to take place in the lower reaches between where we identified stranded ripe inanga and Pounui Lagoon. The inanga, along with other native fish, were stranded because this reach of Pounui Stream had been mechanically diverted away from its natural course on the 21st April, and into an excavated side channel. However, our fortuitous discovery of the stranded fish on the same day at least allowed the transfer of some survivors into flowing water.

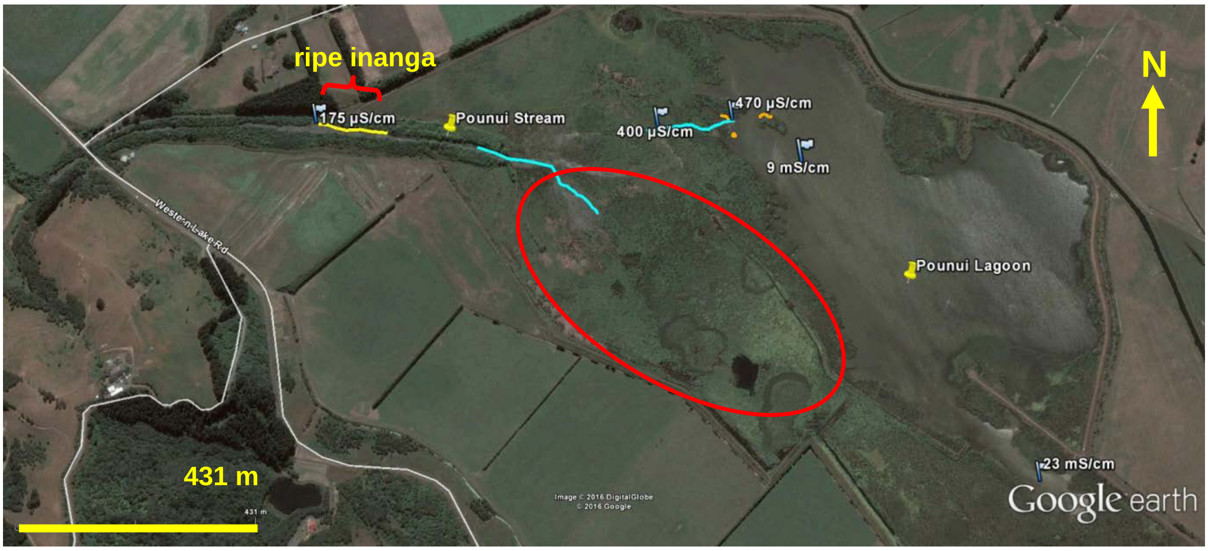

Figure 25a. Pounui Stream and Pounui Lagoon, with water conductivity (salinity) readings, and reconnoitred water path (light blue). Ripe inanga were identified within the bracketed region, with potential spawning habitat ringed in red.

Figure 25b. Looking downstream at Pounui Stream (20/04/2016), before its diversion the next day. The marginal monkey musk is arrowed.

Figure 25c. One of many ripe male inanga found within monkey musk after a section of Pounui Stream was diverted from its bed on the 21st April.

Near Pounui Lagoon the well-vegetated banks of Pounui Stream were comprised of toetoe, flax, suitable grasses (including tall fescue) and rushes. Further upstream, the waterway banks were comprised predominantly of gravels forming the exposed bed, interspersed with a few patches of monkey musk and other soft herbs. Due to the time involved to salvage stranded fish from the dewatered channel, there was insufficient time to quantify the size and quality of downstream spawning areas.

Barriers to fish migration, and management issues

While Pounui Stream is well inland from the sea, in-migrating inanga whitebait would appear to have few impediments to hinder their upstream passage. This is providing the mouth of Lake Onoke is open during the spring-time whitebait run and fish have passage through Lake Onoke and into Pounui Lagoon. We have walked most of the lower reach of Pounui Stream, and there were no manmade structures which would impede whitebait passage, the waterway appeared to be naturally channelised in parts. Our observations of fish passage from the sea into Lake Onoke, and then from Lake Onoke into Pounui Lagoon are described previously in the respective Lake Onoke (5.12.2) and Pounui Lagoon (5.12.4) sections.

The most obvious management issue pertaining to Pounui Stream was the re-alignment of the stream without the precaution of preventing fish stranding and sediment control. Affected species included, but were not limited to, migrating spawning inanga, torrentfish (App. II, Fig. 31), native bullies and koura. From our experience in Canterbury, fish salvage prior to diversion or dewatering are a condition of local government global consents pertaining to river works. In shallow small waterways like Pounui Stream, fish salvage is fairly straightforward operation efficiently achieved using an electric-fishing machine, and a team of three operators. The use of filter fences, sediment tanks, geotubes™ should be used to minimise the downstream transport of resuspended fines.

In this instance, we consider that further steps could have been undertaken to minimise the impacts on inanga and inanga spawning habitat. These steps, which could apply to a range of activities undertaken in waterways, include avoiding undertaking:

- Works that might generate discharges of sediment before and during the inanga spawning season (January through to the end of May). Areas to avoid working in should not be limited to the actual inanga spawning area but should include at least 1 km upstream

- Works that might impact on the quality of inanga spawning habitat vegetation 3 months prior to the inanga spawning season and during the inanga spawning season (e.g. from Dec to May, incl.).

Following disturbance, recovery of suitable vegetation of inanga spawning habitat will likely require at least this amount of time;

- Works near or in inanga spawning habitat during the spawning season and, when diversions do occur at other times, undertake a fish relocation exercise prior to the diversion to minimise the potential of fish being stranded. After the diversion, a thorough check of the dewatered channel (including checking in and under macrophytes and larger streambed substrates as far as practicable) should also be carried out to ensure that any fish missed during the earlier fish salvage can be relocated to a clear flowing section of stream.

Heavy iron floc was observed in the lower Pounui Stream, which we have taken to be a natural phenomenon due to the upwelling of iron-laden groundwater (App. II, Fig. 32). The impact, if any, of iron floc on inanga spawning is unknown, nor if the region of iron floc coincides with any inanga spawning habitat.

Survey limitations and additional surveys suggested

The egg survey in Pounui Stream was circumvented by the stream diversion works which occurred just prior to the egg survey. The works dewatered a river reach which required an immediate fish salvage operation to minimise fish mortalities. The works also made the downstream reach highly turbid, so that the channel downstream of the works could not be surveyed. Consequently the egg search survey on the lower Pounui Stream was abandoned. It is recommended that the lower reach of Pounui Stream be resurveyed during another inanga spawning season, as the presence of numbers of ripe fish suggests that there is a spawning ground of some significance in the vicinity.

5.15 Whangaimoana Stream

Whangaimoana Stream possesses a small coastal catchment, rising from a coastal hill of 565 m a.s.l in the foothills of the Aorangi Range. Flowing north-west out of the foothills, the river flows through predominantly rural land with a largely intact buffer strip (App. I, Fig. vi). Based on Google Earth imagery, its flow in the middle and upper reaches may be intermittent in the summer months.

The coastal reach of Whangaimoana Stream is protected by a QEII covenant (Hugh Prickett Covenant, Appendix II, Fig. 33). This covenant is based on wildlife values, including that for inanga spawning based on the local signage.

Possible spawning location

No conductivity readings were recorded here and no schools of inanga were seen on the falling tide. A brief egg search was undertaken on the true right bank to check habitat conditions (Fig. 26a). The dominant vegetation here consisted of mercer grass and giant rush (Figs. 26b, c). Flax/harakeke and tall fescue were also present. Soil humidity and tiller density (i.e. the density of stems at soil level) was high. The true left bank was not accessible due to deep water, but the general spawning habitat was considered highly suitable for spawning.

Figure 26a. Whangaimoana Stream, Whangaimoana. Orange line indicates the area that was unsuccessfully searched, but still considered suitable for inanga spawning.

Figure 26b. Looking upstream at Whangaimoana Stream, where spawning has previously been identified on the true left bank (right in this picture).

Figure 26c. Looking downstream at Whangaimoana Stream, where spawning has previously been identified on the true left bank (left in this picture).

Barriers to fish migration, and management issues

At the time of our site visit (20th April, 2016), the mouth was closed by a high gravel bar. However, examination of Google earth imagery indicates that the mouth of Whangaimoana Stream does open at times, and that some waves may be sufficient to breach the gravel bar.

No weirs or other barriers to upstream migration were observed, although the full length of the stream was not surveyed. The primary management issue at this site would be ensuring that the public respect the covenant and adhere to the access paths indicated in the onsite sign. Whangaimoana Stream appeared to have a slow flow, with a stable true left bank.

Survey limitations and additional surveys suggested

The survey at this site was limited by time, light, site priority and poor access. Thus, only the true right bank was searched and spawning had previously been confirmed on the true left bank (Taylor & Kelly 2002). The principal objective was therefore to assess the quality of the spawning habitat where eggs were found in 2002. Our survey confirmed that inanga spawning habitat quality was adequate for spawning.

6 .Discussion

6.1 General factors influencing inanga spawning success

6.1.1 Spawning vegetation

There has been recent research in spawning site preferences using an experimental approach (Hickford *et al.* 2010; Hill 2013), which now complements bodies of information on known inanga spawning grounds, in the Wellington Region (Taylor & Kelly 2002), the North Island (Mitchell 1990), and the South Island (Taylor *et al.* 1992).

Inanga egg density and survival was positively associated with stem density and the thickness of the aerial root-mat (Hickford *et al.* 2010). These findings were ratified by experimental work by Hill (2013), where inanga spawning preferences were studied under controlled conditions in the laboratory. Of the four vegetation types trialled, the highest egg numbers were found in creeping bent (introduced grass, *Agrostis stolonifera*), and then the common native rush “Edgar’s rush” (wiwi or *Juncus edgariae* formerly *Juncus gregiflorus)*. Lower numbers of eggs were found in *Carex virgata* and even less in the common grass tall fescue (*Schedonorus phoenix*, formerly *Festuca arundinacea*). Amongst these plant species, the density of stems (termed the tiller density) was positively related to the number of eggs found, but the vegetation type was not statistically significant. The author considered that the high variation in the treatment replicates would mask real preference differences in vegetation preference. In the absence of suitable vegetation, inanga have been observed to spawn in sub-optimal habitats where humidity and exposure to the elements and predators is high (Waihao River *in* Davis *et al.* 2003). Hill (2013) demonstrated this experimentally where inanga were confined to force spawning on stones, but these eggs dried-out and died quickly. When the experiment was modified to provide a choice of spawning substrates, the stones were completely ignored in preference to vegetation.

During our environmental studies in both the Wellington Region and other parts of New Zealand, vegetation of all types are used; from exotic grasses to native rushes and sedges, provided the soil was damp, and 100% humidity was preserved near soil level. High humidity is required, as like other fish, inanga eggs lack a waterproof shell, and the eggs are small and dry out very quickly, moreover, UVB rays from sunlight are known to kill the eggs (Hickford & Schiel 2011). Therefore, shading eggs is important, although given how eggs are so deeply embedded amongst the vegetation, they are unlikely to be exposed to any sun, unless the vegetation is grazed or mowed during the egg development period.

6.1.2 Salinity

The results of this survey indicate that, as has been found elsewhere in New Zealand (Taylor 2002) and in earlier studies (Benzie 1968a; Burnet 1965), the location of the saltwater/freshwater interface provides an approximate upstream limit for inanga spawning in any given waterway. Typically, this terminus is characterised by a trace of saline/high conductivity water near the bottom of the deepest part of the channel, but with the surface water and bank vegetation reflective of fresh water conditions. The location is approximate, because the spawning shoals reconnoitre the banks investigating suitable habitat in which to spawn. We have never found microhabitats where the eggs are potentially exposed to even brackish surface waters. However, historical accounts of inanga spawning in estuaries suggests egg deposition in generally saline habitats (McDowall 1968). However, without specific location information egg depositions might be close or within freshwater feeders, which is the situation we found in brackish Lake Ellesmere/Te Waihora, and Washdyke Lagoon (Taylor *et al.* 1992; Taylor & Marshall 2014). In brackish lagoon environments, we have only found eggs within freshwater tributaries, but close to where they flow into the lagoon (e.g. Lake Ellesmere, Washdyke Lagoon). Other early researchers report entirely fresh water at the egg level with eggs surrounded by animals and plants completely intolerant to saline water (Benzie 1968a).

Inanga eggs will not fertilise in full saltwater, but can survive quite brackish conditions. Laboratory experiments by Hicks *et al.* (2010), in Australia, showed that inanga fertilisation success was high (80%) at salinities up to 21 ppt (about 60% seawater). At 24 ppt there was a sharp decline in fertilisation success (40%) and at 28 ppt (80% seawater) no fertilisation occurred. A salinity of 24 ppt related to a electrical conductivity of 39 mS/cm, therefore if inanga eggs were deposited in Pounui Lagoon, or Lake Onoke, surface-water salinity is unlikely to be an issue. However, the eggs may be prone to desiccation, as many luxuriant plants in freshwater soils which are known to support inanga egg development will not tolerate brackish estuarine conditions.

This demonstrates the usefulness of using a conductivity meter to reduce the potential search area for eggs, as manual egg-searching is a labour-intensive exercise. In most channels, the upstream extent of the saltwater wedge tip, and often the upstream limit of inanga spawning, can only be determined by the use of a conductivity meter or salinity meter. We consider that the longitudinal range of inanga spawning lies between an approximate upstream limit where the out-migrating spawning adults detect some saline increase near the bottom of the channel, and a physiological limit to brackish water at the surface. The downstream limit may be near the fertilisation limit of 24 ppt seawater, or spawning behaviour may be inhibited first at a lower salinity. Within that longitudinal range, inanga will then actively seek out vegetation with a sufficiently high stem density to preserve water humidity around the eggs, as experimentally demonstrated by Hill (2013). The downstream boundary for egg distribution could be determined by the limit of suitably dense vegetation, or by increasingly brackish conditions as outlined in the previous paragraph.

It is our opinion, but untested in the literature, that suitable vegetation swards may be pheromonally imprinted by fish during distinctive ‘pre-spawning’ reconnoitre-type behaviour as observed and described in earlier studies (page 39 *in* McDowall 1968; Taylor *et al.* 1992). Pre-spawning behaviour involves tight shoals of ripe fish entering and exploring tidally-inundated shallows on tides on the days prior to spawning, but without the deposition of eggs. Our hypothesis is that this behaviour may provide a short-term pheromonal imprinting upon the vegetation, attracting and triggering spawning on successive tides. There is evidence of pheromonal imprinting in other galaxiid species, but no evidence of long-term imprinting for inanga (Baker & Hicks 2003; Baker & Montgomery 2001). However, Mitchell (pers. comm.) found that when spawning site turf was placed side-by-side with identical turf which had not been used for spawning, ripe inanga ignored the unused turf.

6.1.3 Humidity and temperature

Inanga eggs, like all fish eggs, lack a waterproof shell. Therefore high humidity is a critical factor to avoid egg desiccation, and must be maintained over the egg development period. Vertical profiles through inanga egg nests in Christchurch demonstrated 100% relative humidity (at 20^{o}C) in dense grass 20 cm high, even when the open-air humidity was only at 11% relative humidity during dry hot north-west conditions (Taylor 1995). The layer of absolute humidity extended to 10 cm above the soil. Shorter grass (12 cm) also maintained high humidity at soil level, but the layer of high humidity above the soil was thinner (6 cm above soil).

A number of studies have evaluated temperature regime around developing inanga eggs (Table 4). An early study in Canterbury used min-max thermometers to estimate the temperature range over the January to May period, with an estimated diurnal range for a single egg batch (Benzie 1968a). Our early work used temperature loggers to monitor temperature regimes in March and April in Christchurch (Taylor 1997; Taylor 1998). On any one day, on the Heathcote River in March 1997, the soil temperatures were usually about 3-4 degrees cooler than concurrently-recorded open air temperatures, and diurnal range varied significantly, but normally about 4 ^{o}C. At the Avondale River spawning site in May 1997, conditions were cooler, and the diurnal range, although also variable during egg development, were about 5 ^{o}C. Under the recorded temperature regime, full egg development took 21 days, with eggs ready to hatch on the next spring tide sequence.

At the Goughs Bay (Banks Peninsula) spawning site, in long (303 mm depth) grass, median soil-level temperature was 8.1 °C, 1.6 °C less than the ambient air temperature. Further, peak temperatures above 15 °C did not occur (Hickford & Schiel 2011). Where the grass was cut back, soil temperatures reached 30 °C. In this particular study, egg survival was recorded during the trials, but not egg development rates.

To summarise, in addition to enhancing humidity, tall dense vegetation can effectively moderate temperatures around the eggs so that ambient soil-level temperatures, where the eggs develop, do not become excessively high (e.g. in excess of 18 °C). Hill (2013) noted in egg incubation experiments that eggs developed at elevated constant temperature (17 °C) had more difficulty hatching than eggs exposed to a natural cooler variable temperatures in the field, she concludes the cool and variable temperatures facilitates egg hatching and development. A summary of known temperature-regime studies is provided below in Table 4.

Table 4. Summary of known temperature-regime studies in inanga egg habitats.

Study	Locale and month	Grass type & height	Minimum	Mean	Max	Method
Benzie (1968a)	Saltwater Ck, Jan-May, but daily range	Pasture grass and clover	5 °C	n.d.	18°C	Min-Max Thermometer
Taylor (1997)	Heathcote River, March	Tall fescue, creeping bent, c 180 mm	7 °C	12.6 °C	17.5 °C	Onset™Logger
Taylor (1998)	Avon River, May	Creeping bent, c 120 mm	3 °C	n.d.	14.3 °C	Onset™Logger
Hickford and Schiel (2011),	Goughs Bay, Banks Peninsula, April	Creeping bent, tall fescue, Yorkshire fog,	3 °C	Median= 8.1 °C	15 °C	Onset Hobo™ Logger

6.1.4 Tidal inundation and egg hatching

Egg development increases rapidly with temperature. In Christchurch, we found that in May 1998, egg development took 21 days, which coincides roughly with spring-tide inundation period for eggs on the east coast of the South Island. The east coast of the South Island also only gets 1 spring tide per 28 days (either a full moon or new moon depending on the year), but eggs get re-immersed about 3.5 weeks after deposition (Benzie 1968a), earlier than the full monthly spring-tidal cycle. This is because inanga spawn a few days after the highest spring tides, and eggs are deposited somewhat lower than the peak tide level, because inanga spawn, on average, about 30 minutes after high water (Taylor 2002). We also observed that inanga eggs lose their originally sticky nature, and tend to disperse along and down the bank as they experience some tidal inundation on lower tides. In respect to the Wellington Region, historical observations of inanga spawning on the Waimeha Stream also reports of some eggs being found within the daily tidal range (McDowall 1968).

In the Wellington Region, while spring tides follow the lunar phases, on the Kapiti Coast tides follow the full moon and the new moon phases (2 spring tides per 28 days), whereas on the east coast, and around Palliser Bay/Wellington, the spring tides follow either the new moon tides or full moon tides in any one year, but not both (Figs. 27 a, b). Therefore, it is likely that Wellington's east coast and Cook Strait catchment eggs may have to continue to draw on their yolk sac for several days after they are fully developed before they are covered by tidal waters and can hatch. This is unlikely to be a problem. To the best of our knowledge, no one has found fully developed eggs which have died due to yolk exhaustion at normal tide levels.

However, (Benzie 1968a) found dead eggs after inanga spawned on high water following flooding, and were never re-immersed in water. McDowall (1968) comments that 50% of his bagged eggs from the Waimeha Stream (just north of the Waikanae River) hatched after being bagged for 8 weeks.

Hatching will only occur after full egg development and requires re-inundation by water in a sequence described in detail by Benzie (1968b). Egg inundation can occur during spring tides, or in the case of coastal lakes, observed during wind-induced Seiche waves (e.g. Lake Ellesmere/Te Waihora *in* Taylor *et al.* 1992). Hatching is considered to be triggered by the low oxygen levels associated with tidal water flooding the riparian border, and may also involve a hatching enzyme to soften the shell (i.e. chorion) (Benzie 1968b; Mitchell 1989).

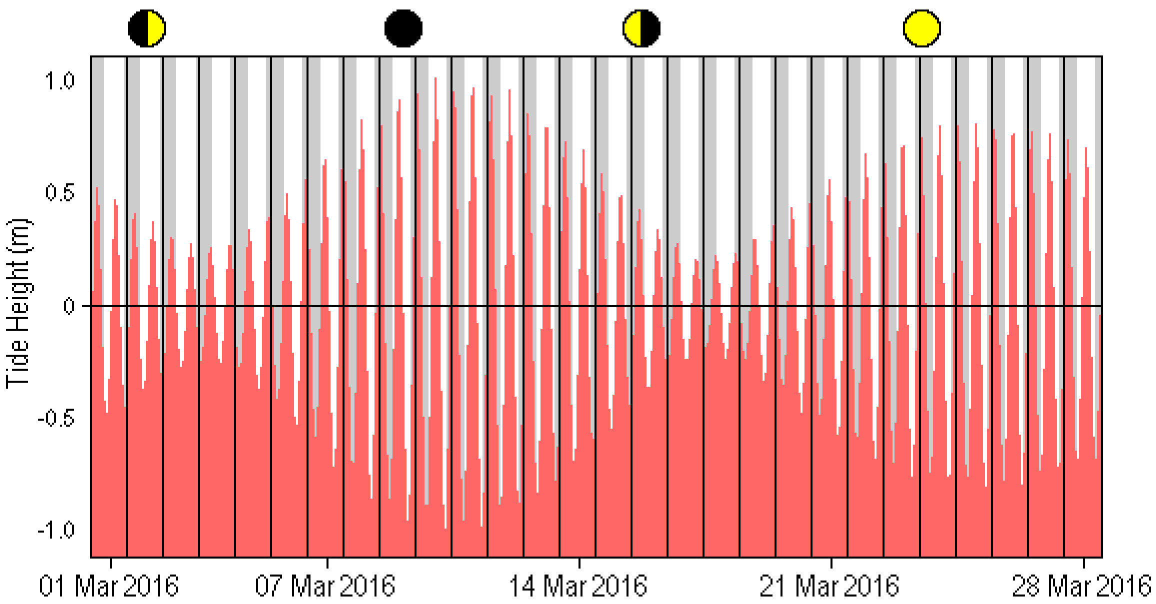

Figure 27a. Output from NIWA's coastal tidal model for the Kapiti Coast, 40° 53' 0.0" S, 174° 55' 30.0" E (off Waikanae River).

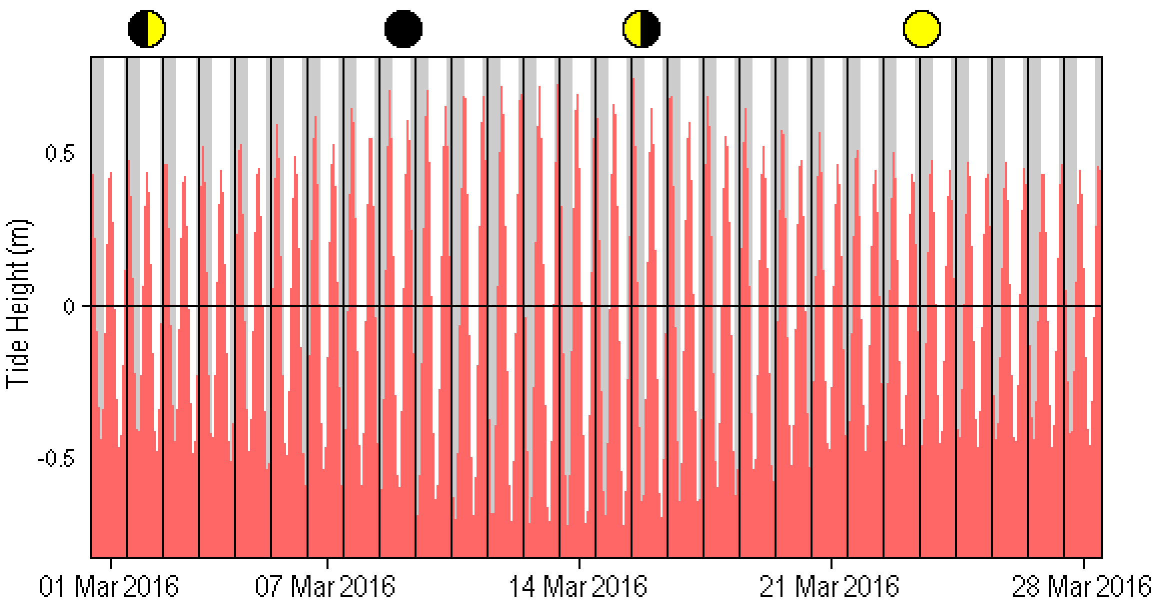

Figure 27b. Output from NIWA's coastal tidal model for Palliser Bay 41° 28' 20.0" S, 174° 56' 50.0" E

6.2 Temporal changes in habitat and management issues at spawning sites identified in 2016

In respect to spawning site management, new research has shown that inanga are not a species predominantly limited to a one year lifespan capable of spawning only once, as described in McDowall (1990). Instead, histological analysis of the eggs demonstrated that the majority of inanga live for more than one year and spawn multiple times (or itereoparous), but only once per spawning season (Hill 2013). Hill (2013) also found egg-stage evidence of out-of-season (spring) spawning which has been observed and reported previously. For example there was a significant spawning event observed in the Hawkes Bay in October 1996 (Tukituki River *in* Taylor 2002).

While the repeat-spawning of inanga is of significant benefit to the whitebait fishery, Hill (2013) also found that, after intensive histological work, fecundity per fish was substantially lower than previously recorded by McDowall (1968). Nevertheless, repeated annual re-use of spawning grounds by individual inanga explains the apparent paradox in how whitebait runs involving many millions of fish can be sustained by rather compact spawning grounds. The other issue to consider is the sheer numbers of eggs which can be supported in functional vegetated spawning grounds. University of Canterbury researchers have calculated mean egg densities of 600/0.01 m^2 (the area of the 10 cm square sampling quadrat) for some Canterbury habitats in April, with much lower numbers in March and May (Hickford *et al.* 2010). However, eggs survival is poor (less than 30%), depending on the nature of the vegetation and the month which eggs were deposited.

The University of Canterbury has also been active at looking at how inanga egg survival is influenced in both rural and urban settings (Hickford & Schiel 2014). They experimentally demonstrated that, after 4 years of vegetation recovery, egg densities in stock-excluded enclosures was 400 times higher than in grazed controls. In urban environments, mowing grass to a 50 mm sward 2 months prior to spawning reduced egg densities by 75% and survival by 25%. Our work on the complete restoration of the Heathcote inanga spawning site (bank profiling, reseeding) led to large increase in egg numbers after 3 years of vegetative development and the exclusion of the Council lawnmowers (Taylor 2002). However, this urban site did eventually suffer from a lack of maintenance and weeding which led to an invasion of non-preferred woody plants, which can be problem depending on location and weed dispersal paths.

Below is a brief discussion of management issues on the spawning sites located within the ten waterways where spawning was identified.

6.2.1 Rural habitats accessible to stock

The adverse impact of stock grazing and trampling within inanga spawning areas, along with other adverse factors, has been known since the 1930s (Historical account in App. I in McDowall 1968). These problems include the trampling of inanga eggs, and the cropping of the overlying grass sward so that the eggs dry out and die.

It has only been in the last 30 years, when the whitebait fishery has been in perceived decline, that the government (through the Department of Conservation, DOC) has encouraged the identification and restoration of inanga spawning grounds, including rural catchments (Taylor *et al.* 1992).

A number of stock exclusion trials, mostly in the North Island, have been conducted over the decades. All of these have reported good, if not spectacular, early success in respect to subjective evaluations of general spawning activity and egg numbers. As described above, increased vegetation improves both inanga egg numbers and survival. However, problems with plant community succession in permanent enclosures have also been reported in the North Island, and after 4 years leading to plant communities not preferred by spawning inanga and causing actual avoidance of enclosed areas (Mitchell 1994). More recently, exclusion studies in Canterbury found that unsuitable plant succession did not occur (Hickford & Schiel 2014). The problem of weeds and undesirable plants invading sites is probably site-specific, and will depend on a range of complex inter-relationships and dispersal paths between riparian plants and weed source areas.

During this survey, we identified spawning reaches in 5 rural catchments. On the west coast of the region these were the Kakaho, Horokiri, and Pauatahanui Streams. The **Kakaho Stream** has undergone a complete environmental transformation since our visit 15 years ago. In 2001, the environmental description of the spawning habitat was damning, with ‘no possibility’ of inanga spawning in the system. Looking at the recent photographs, it’s hard to believe it is the same stream (App. IV, Figs. 1,2 a, b).

The **Horokiri Stream** has also been effectively fenced since our 2001 visit and while there is some evidence of stock access to the inside of the true right fence, there has also been a significant improvement in spawning habitat, from very effectively zero to luxuriant (App. IV, Fig 3, 4a, b). In 2001, it was felt there was some potential downstream of the bridge, especially on the gently-shelved true right bank which had been recently planted in flax. In 2016, it was satisfying to find inanga spawning on both banks of the Horokiri Stream, and over a greater longitudinal range than the vegetation suitability outlined in 2001.

Another rural waterway that stock can potentially access is the **Wainuiomata River.** In 2001 it was considered to have good potential, and similar to this survey, the mouth was closed and no saltwater intrusion was detected (Taylor & Kelly 2001). The river mouth receives the full force of southerly gales and it is suspected it is closed most of the time. Possibly for this reason, suitable freshwater vegetation encroaches close to the sea. In 2001, there was no mention of stock access and the suitable true right bank appeared ungrazed (App. IV, Fig. 5a). This is in contrast to the state of the same bank in 2016, where pasture grasses, but not rushes and sedges, were close-grazed (App. IV, Fig. 5b). Looking at the historical imagery on Google™ Earth, sheep can be clearly seen winding through the gorse thickets within 65 m of the spawning reach in April 2014, but the quality of the imagery from 2002 is insufficient to determine if stock had access. We identified eggs and suitable habitat in the upstream 1/3 of the suitable habitat range depicted in Taylor and Kelly (2001)(App. IV, Figs 6a, b). Our view is the site is compromised by stock access (see Sec. 5.11.7), and while eggs were affixed to giant umbrella sedge, more eggs could have been found in the suitable grasses, if it hadn’t been grazed to a stubble.

While fencing stock away from the water’s edge would be one option, another would be to line the bank with the native giant umbrella sedge which appears to grow well here, supports viable numbers of eggs (Appendix II, Figs. 17, 18) and is evidently rather unpalatable to grazing stock. These plants may be able to dominate over the pasture grass. It’s likely that there will be a plenty of shallow groundwater at this location so a simple scrape-hole(s) may provide a simple solution in respect to stockwater. Grazing seems to be by sheep, so another option would be to set up a simple detachable electric fence several metres from the water’s edge at least 3 months before the season (i.e. operational by beginning of December, removed at the end of May)..

6.2.2 Rural habitats lacking stock access

Landuse on the lower reaches of the Waikanae River has evolved from former rural landuse to a partially suburban and rural area. The south bank remains largely rural, with drier areas used for stock grazing, but with a wide esplanade strip accessible by recreational walkways. The north bank is suburban, but retains a wide grassy esplanade strip which has recreational amenity and serviced by walkways.

The lower reaches of the **Waikanae River** were first assessed for inanga spawning in 2001 (Taylor & Kelly 2001), with suitable vegetation found on the south bank (App. IV 7a), although no eggs were found. At the time, the south bank was regarded as sunny, steep but stable, with grasses (tall fescue, creeping bent) interspersed by flax and toetoe (Fig. 47 *in* Taylor & Kelly 2001). By contrast, the true right (north) bank was considered less suitable at the time, as it was heavily shaded with tall pines and had a thin soil structure which exhibited poor moisture retention.

On the 2016 trip, we placed the saline wedge further downstream than on the 2001 survey, and our assessments and location of inanga eggs were also further (c. 150 m) downstream (App. IV 7b). We note the south bank reach regarded as suitable in 2001 had undergone some change with the development of a close-mown esplanade strip over the downstream half (downstream of Kokako Road), although the upstream section seems to be preserved in a fairly suitable state. The north bank, and the shading tall conifers still remain at this location. We didn't find many eggs on the Waikanae River, and we recommend that the south-bank reach marked in the 2001 should be evaluated more closely. However, the north bank, opposite Kakaho Road, and downstream of the shading pine trees appears to have more unsuitable gravel in 2016 than depicted in 2001 and commented on in Taylor and Kelly (2001). The river bends north, so bed aggradation tends to occur on the inside of the bends (i.e. north bank). However, soil profiles over the gravel also deepen over time, as accumulating organic matter improves soil structure. We recommend that the north bank opposite Kokako Road is also evaluated.

During the 2001 survey the SH58 was unfortunately being re-bridged over the lower reaches of **Pauatahanui Stream**, in an area considered to have suitable vegetation for inanga spawning (App. IV Fig. 8a, b). By all accounts, the upstream limit of suitable vegetation appears have changed very little, that is commencing upstream of the new SH58 bridge and extending downstream towards the old Paremata Road bridge. The bank vegetation seems to have changed slightly over time as there is no mention of giant rush *(J. pallidus)* in the 2001 report, nor creeping buttercup, as we found in 2016. On the other hand we didn't record toetoe or mints being present during this survey, but blackberry thickets were found further away from the water's edge. It is quite possible that further suitable vegetation could exist near the old Paremata Road bridge, as the 2001 survey extended a little further downstream than the 2016 survey.

In 2016, of course, the spawning habitat was not suffering from the perturbation caused by the bridge build. We consider it possible that the 2001 spawning success was compromised by the building activity (noise and vibration). We noted at the time that sediment control at the site was of a high standard. In 2016, eggs were readily found at this location, and we found inanga eggs in grasses at the confluence of the SH58 road drain and the stream on the true left bank (App. IV, Fig. 8d), although this drain didn't exist in 2001. Inanga spawn preferentially near confluences, within bank embayments, and other areas where the current is slack, but tidal currents are close by. Given the more settled nature of the site in 2016, and the growth of suitable vegetation for spawning and rearing, we regard the habitat has improved since 2001.

Two other streams surveyed in rural environments were Pounui Stream and Whangaimoana River. Neither of these was accessible to stock. Stock on either side of **Pounui Stream** is fenced well away from the river and the banks are well-vegetated with willow. While the actual spawning site for Pounui Stream has not been established, it is clear from the aerial photos that stock have no access to the Pounui Stream delta as it nears Pounui Lagoon. The spawning area is likely to be in the inaccessible scrublands to the west of the lagoon. In the absence of grazing stock, suitable spawning vegetation can change to woody saplings, especially willow and alder, depending on the distance to seed sources. Temporal change in the habitat quality of Pounui Stream is unknown because it was not part of the 2001 or 2002 surveys, and its exact location has not been defined. Therefore management options for this site cannot be provided. However we recommend the spawning location be traced, probably easiest by working downstream from the access road, so its potential vulnerability can be assessed.

Pounui Stream provides a flow-stable high-value aquatic habitat, including as a conduit for spawning inanga. We strongly recommend that the flowing channel is not subject to river works immediately before and during the inanga spawning season. Environmental controls are environmentally justified at other times of the year, and these our outlined in Section 5.12.5. During consented river works, consent conditions pertaining to the protection of aquatic fauna needs to be enforced in the Wellington Region.

Eggs were found along the lower reaches of **Whangaimoana Stream** in 2002, some of which were retained for development staging (est. spawning date 6th April *in* Taylor & Kelly 2002). Using the NIWA coastal tidal model (Walters *et al.* 2001), this places spawning 4 days after peak tide cycle, which is the typical lag phase between peak spring tides and spawning (Taylor 2002). On our recent site re-visit we used the old GPS waypoints and coastal hill features to position ourselves to within a metre of two of where eggs were found (App. IV. Figs, 9a, b). The mercer grass sward still dominated the plant community on both banks and the tall Juncus (*Juncus pallidus*) was still present. It has been our observation that *Juncus pallidus* stands are very attractive for inanga shoals, as they take refuge amongst its large stems. In this case, the vegetative isolation of this spawning site has reduced the probability of weed invasion and plant community succession, and required management appears minimal at this stage. Some weed management prior to the inanga spawning should be carried out to ensure unsuitable adventive plants do not become established.

Comparative photographs of the site, 14 years apart, are provided in App. IV, Figs. 9-10a, b. There does seem to be a degree of vegetative growth along the top of the erosion-prone bluffs and in the gullies. Within the gullies, there appears to be arboriculture, possibly dryland pine tree production. In respect to the riparian vegetation, the riparian plant communities look similar to those in 2002, and remain suitable for inanga spawning.

6.2.3 Urban settings

Inanga spawning grounds in urban settings pose different management issues than rural habitats. The riparian strips of lowland rivers in urban areas often become attractive areas for pedestrians and picnickers, who, while normally appreciative of the natural environment, are not generally aware of the ecological linkages between the river banks and river life. This is probably particularly so for the habitat requirements of inanga spawning, which while becoming more publicised, are not widely known among the general public.

In the past, these ecological links have also not been apparent to local authorities with responsibilities for city infrastructure and drainage. However, in the last 15 years or so, the responsibilities of local authorities have been expanded to include the enhancement and consideration of environmental values within their regions. This has largely to do with local interpretations of Principle 14 of the Local Government Act 2002 and a general increase in the awareness of ecological values and activities that impact on these values.

For **Taupo Stream,** the habitat suitability maps for 2001 and 2016 are fairly similar, although in 2016 we surveyed the channel further upstream into the Plimmington Domain (App. IV, Figs. 11a, b). The same grassy, steep but generally suitable section was identified where the channel bends towards the railway station, as is the deeply shaded lower section which lack riparian spawning grasses.

In April 2001 the channel within Plimmerton Domain was very weed-choked. This year, we found the channel free-flowing, but with some cape pondweed (App. IV, Figs. 11c,d) which we understand is managed. The clear channel is important because it will facilitate passage for inanga shoals between the downstream spawning habitats and the upstream rearing habitats.

For the **Porirua Stream mainstem** the channel appeared completely unchanged since 2001, which is unsurprising because it course is, literally, set in concrete and the banks through the CBD are maintained as part of a manicured urban esplanade setting. The only possibility for ecological change is for change in the reaches either side of the CBD. Looking through the historical Google™ Earth imagery of the Bullock Lane spawning site, it would appear the small peninsula was only partly formed in 2002, and was created by what appears to be a sand spit. Patchy vegetation only formed in 2005, with full vegetation present after about 2009. It is likely that the peninsula wasn't present in 2001 when we undertook the first survey, nor was it marked as having potential in the map of the area.

The weir that was observed upstream of the saltwater wedge tip would substantially reduce the size of adult rearing habitat. Even when viewed at high tide, there appeared no possibility of upstream inanga passage, although the weir was observed only from the nearest bridge and was not closely scrutinised. During floods the weir would over-top, and during flow recession there may be an opportunity for inanga to negotiate this structure, but this migration window would be short.

For the **Kenepuru Stream** (a lowland tributary of the **Porirua Stream)** the same reach of channel was searched and surveyed in 2001 and 2016 (App. IV, Figs. 12a, b). This time however, good numbers of eggs were located as shown in the results. However, in 2001, the true right bank was mown close over the bank toe to the water line (App. IV, Fig. 12c), compared to in 2016, where many eggs were found on the true right bank (App. IV, Fig. 12d), as well as the left. Running through our photos though, the channel morphology looked unchanged over the 15 years between surveys and the low weir present in 2001 was still there in April 2016.

By accident or design, local authorities have desisted mowing the grass along this spawning reach on Kenepuru Stream, at least for the current inanga spawning season. We recommend, as mentioned in Sec. 5.9.2, that in the future mowing does not take place after end of November in this reach, to allow adequate regrowth for the spawning season commencement in March.

Based on Google Earth aerials, the rough grassy patch immediately downstream of the confluence of Kenepuru Stream with Porirua Stream, has also undergone change over time. There has been a degree of botanical development and improvement since 2002. We conclude that, largely by good fortune, the spawning habitat on the lower Kenepuru Stream was in a better state in 2016 than in 2001.

Waiwhetu Stream, which drains Lower Hutt, has a legacy of heavy metal pollution from industrial sources. Waiwhetu Stream was demonstrated to be the most heavily polluted area in the Wellington Harbour system, based on heavy metals bound to lower-river sediments (Stoffers *et al.* 1986). Lead and zinc levels placed the waterway in the extremely polluted range, and other metals (e.g. copper, cadmium, and mercury) were within the moderately to strongly polluted category. However, the sediment profiles did indicate some reduction in metal levels over time. We expect present-day metal levels to have decreased further since the 1980s.

However, inanga are relatively tolerant of many urban pollutants (Hickey 2000; Richardson & Taylor 2002), but have habitat requirements like other fish, including rearing but particularly spawning habitats. Recent initiatives have been undertaken to reduce pollution levels and undertake physical habitat restoration in Waiwhetu Stream (eg, planting by the friends of the Waiwhetu Stream). Based on the large numbers of fish we saw during our boat survey, the combined impact of reduced pollution and significant riparian planting is clearly benefiting the inanga population.

Hydraulically, the Waiwhetu Stream, with its deep sluggish flow, is an ideal waterway for inanga spawning. However, inanga prefer a balance of open water and marginal overhanging banks and overhanging bank vegetation (Richardson & Taylor 2002), and the plantings we observed assist in providing this refuge. The plantings incorporating soft sedges and rushes in the tidally influenced reaches downstream of Hayward Terrace are likely to be used by spawning inanga, providing the tidal range covers the bank toe. Spawning inanga target bank embayments and reaches on the inside of river beds where the water velocities are low. It would be possible for AEL to evaluate the plantings in more detail during a later visit.

Notably, we saw several rats in the location where inanga eggs were found, and these rodents are probably an effective predator on inanga eggs. Based on hidden camera footage, even the small house mouse (*Mus musculus*) have proved to be efficient consumers of inanga eggs in natural settings (Baker 2006), as is the common mud crab (*Helice crassa*). It is easy to consider that rats, if anything, would be even greater predators. Controlling these rodents in an urban setting, where domestic dogs and cats are common, would be difficult.

6.3 Temporal change in previously surveyed habitats where spawning wasn't recorded in 2016

Otaki River – northern tributary (Nga Toko Toko)

In 2001, the foot survey was confined to the area downstream of the tidegate, whereas this year we also spent some time tracking fish around the freshwater lagoon. The raupo thicket downstream of the tidegates was there in 2001 and was considered suitable for spawning, as it was in 2016. However, the greened seaward side of the lagoon had become more luxuriant since 2005, based on Google Earth imagery.

We expect, in the order of decades, such areas will be lost to floods when the main river shifts back to the north. Google Earth imagery indicates the mouth is quite mobile over the 10 years since aerial images have become available. The lagoons form, gradually vegetate, and wash away as part of the normal process of an alluvial river's hydrogeomorphology.

Otaki River – southern tributary

The southern tributary was assessed around the tidegates in 2001 (App. IV, Fig. 14a), and the area was subject to an extended egg search and habitat suitability mapping in 2016 (App. IV, Fig. 14b). We considered that habitat suitability upstream of the tidegates had decreased over time, but in 2016 more potential was available in the vegetating old braid which was fed by Otaki River shallow groundwater and was full of inanga. This braid was almost completely unvegetated in 2005 (Google earth imagery) and may not have been present in 2001. The blind braid is gradually becoming more grassed over time, but is likely to be destroyed when the river mainstem heads south again.

Makara Stream – mainstem

Habitat suitability remains high around the islands in the lower Makara Stream, although they are a long way downstream of the saltwater terminus. Both of the two islands have been stable in shape over the last 14 years of Google Earth imagery and remain fairly suitable as inanga spawning habitat. However, two small areas further upstream towards the wedge tip were regarded as superficially suitable in 2001 after careful scrutiny were not considered so in 2016 (sparse root matrix and muddy see Sec. 5.10).

The mouth is always open and stabilised against the bluff to the east, and the river's geomorphology and fish habitat seems stable over time. We regard it possible that inanga spawning does take place in this stream. There is historic information on spawning shoals and spawning in the Makara Stream, but also the Waimeha and Waikanae River. This old information, dating from the early 1930s, may still be relevant today, but will require some further researching to locate.

In summary, this isolated river would appear to have changed little since our last visit. Management of the catchment for inanga spawning should be regarded as a low priority unless there is significant land development, particularly residential development near the esplanade strip, or if the riparian zone is compromised.

Hutt River mainstem

Inanga spawning has not be reported in the main channel of the Hutt River, possibly due to problematic access for surveying (best by boat) and the harsh inhospitable conditions provided by tide, wave swell, and long reaches of inhospitable rip rap. A longitudinal survey was not conducted in 2001, and it is easy to generally discount this large river based on the general unsuitability for inanga.

However, as reported above (Sec. 5.11.1), we noticed superficially suitable habitat upstream of the Railway Bridge, where both banks are grassed and not too far from the saltwater intrusion limit, which is surprisingly short for such a large river. We recommend that the two reaches be searched for inanga spawning during low tide. The aerial maps suggest the bank edges would be quite wadeable at low tide, especially the true left bank.

Sladden Park Region, Hutt River

No eggs have been found in this area, despite being surveyed in 2001 and 2016. However, eggs were found here by DOC in April 1996 (area 25 m^2). Comparing the habitat suitability maps from 2001 and 2016, it does suggest habitat recovery on north bank near the playground. In 2001, the north bank was eroding and collapsing, with sparse grass and generally low habitat suitability. In contrast, this season the north bank was considered more suitable. It would appear the steep bank has slumped to a stable grade, and the tall fescue vegetation appeared longer and more luxuriant. It is possible this bank may attract inanga spawning again in the future if the grass is allowed to grow long during the season. The south bank (the golf course) side still has suitability near the boat ramp, but suitability decreases towards the Hutt River where the bank is shaded by large trees, and the sward of suitable riparian grass is sparse.

Opahu Stream (Black Creek)

DOC reported inanga spawning near the railway bridge in 1996 (Taylor 2002). In 2001, 40m of ‘excellent’ habitat was reported on the true right bank away from the Hutt River, although eggs were not identified on that occasion. This year we discovered that this former spawning reach has been removed, and an attempt has made, from what we can discern, to create an isolated inanga spawning wetland form part of the lower channel. The upper reach of Opahu Stream, which probably provided breeding stock to the original lower spawning ground, is now disconnected from this construct and has a separate control structure outlet into the Hutt River.

This system, therefore, has undertaken a radical change from its state reported in 2001. We found no evidence of inanga spawning in either habitat, although there is some suitable vegetation in the new wetland.

6.4 General comments regarding inanga habitat remediation in the Wellington Region

We have made management and habitat improvement comments in the results section for each site surveyed. However, the following is a quick commentary about some commonly-encountered issues affecting inanga spawning in the Wellington Region.

Over-steep banks

To meet the demands of pedestrians in urban settings, it is common to provide a mown sward of nearly horizontal grass, but which then requires a steep bank at the water’s edge. Steep banks are almost never stable ones, especially in the tidal zone when the soft soil horizon is burrowed into by estuarine crabs. Near vertical banks also provide the minimal intertidal horizontal for inanga eggs and more chance eggs will be washed into the river by the currents and eaten by eels and bullies.

The obvious solution is to provide concrete or paved banks to stabilise the banks. There are reports of inanga depositing eggs on stones and other hard surfaces, but only in the context of ‘desperation’ spawning and the eggs do not last long (Hill 2013). We have also found eggs associated with the flat narrow ledges formed between stacked rows of gabion baskets, but adhering to the root hairs of monkey musk or water cress (Taylor 2004).

In the case of the lower Porirua Stream, the steep banks coincide with the location where inanga could be expected to spawn, given the location of the terminus of the saltwater wedge. We have presented two options in the management section specific for this waterway (Sec. 5.9.1), in order to facilitate some change in the way this waterway can be managed as an ecosystem. In Taupo Stream, potential inanga spawning grounds are also too steep (downstream of Plimmington Reserve), but inanga eggs, being initially sticky, can even stick to near-vertical banks if there is a good root, leaf, or rhizome mat for the eggs to adhere. Further, on a vertical bank, water is deep and velocities are higher during rain events, so eggs are likely to be washed away or eaten by large fish.

It is important to remember that inanga eggs are deposited at high spring tide level, so in some settings (Kenepuru Stream, Fig. 7c, but not Taupo Stream), the band of eggs will be above the bank toe, so it is the gradient of this level which will be important, and often not the gradient from the normal water level to the toe. However, the potential spawning zone is very narrow in terms of spawning width over the 30 minutes in which inanga spawn.

Even a moderately-steep gradient provides much more spawning area. In rural settings, lowland soils and subsoils are often soft, and rivers are often deeply incised below ground level. Stock can facilitate the erosion of the high banks, as they congregate around the water to drink or graze the lush riparian grasses. Sometimes, stock will induce ‘hinged bank collapse’ where a vertical bank will collapse, causing the grass sward to form a convenient grassed ramp on which inanga can spawn (see Fig. 4c, Horokiri Stream). Unfortunately, this is only positive outcome for stock access to inanga spawning grounds (reducing bank slope), as stock will trample the eggs and graze the sward so that eggs will die.

Grass mowing

Relevant to council and privately-owned esplanade strips is that recent research suggests that egg survival and production is more sensitive to sward height than previously thought. In a Christchurch study (Hickford & Schiel 2014), even with the cessation of mowing 2 months prior to spawning, the physical properties of the mown vegetation was still inferior to the vegetation that hadn’t been mowed. However, after 88 days (i.e. 3 months), the mown vegetation trial has similar beneficial properties, and inanga density and survival, as the control vegetation. Thus, if we assume that April is the peak month for inanga spawning, then grass mowing through inanga spawning habitats should cease at Christmas, so there is recovery growth through January, February, and March before peak spawning in April. Ideally, as there is some spawning in March, mowing should cease at the end of November.

Why mow spawning habitats at all? It’s a question of ecological context. On some sites, the removal of the sward tends to prevent woody plants from slowly dominating the site (e.g. willow, alder, blackberry), and in a conventional urban aesthetic, mown grass esplanade is more comfortable for pedestrians, and dog walking. Further, provided the inanga spawning vegetation is dense, we have observed that the mown-sward boundary the can be quite close to eggs (c. 1 m) without materially reducing their viability. At the large Avondale inanga spawning site on the Avon River in Christchurch, the inanga spawning habitat has functioned literally side-by-side with the mown sward used by pedestrians, but with bollards and interpretation signs established to prevent mowing by gang mowers. Instead the site is mown prior to the season using portable power trimmers.

Should additional inanga spawning habitat be established in the CBD of Porirua City, it is possible for it to be integrated beside a public pedestrian area, along with the establishment of a habitat management regime.

Plant succession

We have observed problems with plant succession in Christchurch spawning habitats over a timeframe of 15 years. Yellow-flag iris has been a problem in the lower intertidal zone where it can form a forest of thick stems, shading out soft herbs more suited for inanga spawning. However, this was (surprisingly) well controlled by a local application of herbicide, even though recolonisation from outside sources does occur, re-growth was slow and controllable. On other sites, even in the city, gorse and blackberry may intrude into suitable habitat and willow and other sapling regrowth is always a problem.

Beyond Christchurch, there have also been problems with floating weed mats which extend out across the water surface within spawning grounds. This includes reed canary grass in the South Island, but parrots feather and monkey musk in the Wellington Region during this survey (Otaki River, northern tributary) and on the Waimeha Stream on the previous survey (Taylor & Kelly 2001). Some inanga eggs have been found in thickets of reed canary grass, but there is little information on how other floating weeds inhibit spawning, if at all.

Adult fish access

Any spawning site requires a supply of adult fish to utilise the habitat, and a whitebait run and rearing habitat to supply mature adults. The Wellington Region coastline is one with a significant amount of wind fetch and power, as such, river mouths close frequently. However whitebait are surprisingly adept at crossing gravel bars, and will surf the waves up and over a gravel bar, so a mouth with a shallow bar, and a big sea, may not stop whitebait juveniles from entering the system. From the mouth, after avoiding whitebaiters, whitebait require access to rearing habitat, which is generally beyond the saline influence. Weirs in the lower reaches of rivers can be a problem for inanga to negotiate, although they can 'wait out' low river levels and cross barriers during higher flows. The same applies to tide gates, although we noticed two (Pounui Lagoon and, the northern tributary of the Otaki River) which had been modified to better provide for whitebait access. Downstream access for the spawning shoals is also required, but usually less problematic. In any system to be surveyed for inanga spawning potential, it is recommended that some consideration is given to the size and quality of rearing habitat and that clear passage routes are available for inanga lifestages to swim from sea to rearing habitat to spawning habitat.

Inanga require suitable habitat in which to rear over the summer, but fortunately have fairly broad requirements (Richardson & Taylor 2002)and are a moderately resilient species to low-level pollution (McDowall 1968). Given that inanga are now known to live and spawn for multiple years, it is important that these links remain open, along with the quality of the rearing and spawning habitats being maintained.

6.5 Suitable plants for inanga spawning habitats

During this trip we recorded a number of inanga spawning sites within various catchments, of which we could identify most of the common plant species (App. V). A frequently encountered plant species in the Wellington Region was the native giant umbrella sedge, which appeared as a dominant plant in several spawning habitats (Kakaho Stream, Horokiri Stream, Kenepuru Stream, and Wainuiomata River). It appeared to have a relatively low palatability compared to surrounding grasses in a grazed pastoral setting. Other suitable native species included jointed wire rush (in non-saline settings) and New Zealand rush. In the South Island, we have found eggs on the decaying leaves within raupo stands, but these stands are very difficult to search and hence the extent to which they provide spawning habitat is difficult to determine. The softer sedges, especially *Carex virgata* is also utilised by spawning inanga.

There are a host of introduced grasses and herbs which are associated with inanga spawning. Many have a creeping rhizome habit, have aerial root mats, or pubescent leaves, all of which facilitate eggs adhering to the vegetation just above soil level, and thus keeping them moist. These introduced plants include clover, creeping buttercup, creeping bent, creeping jenny, mercer grass, mint, monkey musk, tall fescue, twitch and Yorkshire fog.

6.6 Future monitoring programme

Based on the 2016 surveys, a catchment listing for further inanga spawning surveys along with a potential timetable of implementation is provided below (Table 5). Due to time limitations during this survey there were some catchments where we suspected inanga may spawn, but eggs were not found. For others catchments, some eggs were found, but the distribution of the spawning reach was not determined due to time limitations. These are also listed below. Waterways recommended for resurvey in 2017 are based on these areas and tabulated in Section 8 (See Tables 6 and 7 in Section 8 for further details on the requirements of these surveys).

We also recommend that it would be useful to undertake a desktop assessment that examines aerial photos and Google Earth imagery to help identify likely inanga spawning sites across the Wellington Region. Such an exercise would be useful to help prioritise sites for future surveys.In the absence of any significant management issues or restoration efforts, sites where the habitat quality is expected to remain stable over time probably only need to be resurveyed every five to ten years. These surveys would be based on suitability and quality of inanga spawning vegetation at known sites, or in the reaches where inanga are suspected of spawning.

Table 5. Proposed schedule for inanga spawning surveys over the next ten years. * Lower priority site as spawning has been located, with further investigations focussed on improving knowledge of egg distribution. See Table 6 in Section 8 for further details on the requirements of these surveys.

Year	Action
2017	Resurvey the following sites: • Otaki River, Northern tributary • Otaki River, Southern tributary • Waikanae River* • Taupo Stream • Kakaho Stream* • Pauatahanui Stream* • Duck Creek • Porirua Stream Mainstem* • Kenepuru Stream* • Makara Stream • Hutt River Mainstem • Opahu Stream tributary- reach upstream of control structure • Waiwhetu Stream* • Sladden Park boat ramp area • Te Mome Stream tributary • Wainuiomata River Mainstem* • Lake Onoke, north and east banks and tributaries (Turanganui River) • Ruamahanga River • Pounui Lagoon • Pounui Stream
2018	Aerial photograph assessment of: • Other rivers with spawning potential (considering general habitat suitability, landuse, access, stream gradient and geomorphology)
2019	Survey the following sites: • All sites recommended in the 2017 survey and sites located during the 2018 desktop study
2020	Survey the following sites: • Any sites unable to be sufficiently surveyed in 2019
2021	Resurvey the following sites, focussing on the quality/size of habitat, changes over time and management issues (rather than actively searching for eggs): • All sites listed in this and/or subsequent reports, with the exception of Lake Onoke, away from freshwater feeders (west bank). Excluded because site is unsuitable for spawning
2026	Resurvey the sites determined by the process above, focussing on the quality/size of habitat, changes over time and management issues (rather than actively searching for eggs): • All sites listed in this and/or subsequent reports, with the exception of Lake Onoke, away from freshwater feeders (west bank). Excluded because site appears permanently unsuitable for spawning

7 Management recommendations

AEL makes the following site-specific recommendations, with further detail in Sec. 5. This list excludes recommended further survey work tabulated in Table 5 above.

- **Waikanae Stream –** Interpretations signs and determine the distribution of inanga spawning.

- **Taupo Stream –** Curtailment on riparian grass mowing and weed spraying during the inanga spawning season (Dec-May incl.). If spawning is not found in the next survey, then it is recommended that the bank is regraded and replanted.

- **Kakaho Stream –** Fence and reduce stockwater access ways through fenced buffer strip. Some blackberry control required. Use Enkamat™ or similar geotextile to stabilise and reinforce any stock watering ramp way.

- **Horokiri Stream –** Fence and reduce stockwater access ways through fenced buffer strip. Some weed control required (blackberry thickets).

- **Pauatahanui Stream –** Some willow will require monitoring and possible control in the future

- **Porirua Stream mainstem –** Naturalise specific reaches in CBD to provide some habitat for inanga spawning. Options are presented in the text. Provide fish passage past the GWRC weir noted upstream of the saltwater wedge tip.

- **Kenepuru Stream –** Curtailment on riparian grass mowing during the inanga spawning season (Dec-May incl.).

- **Waiwhetu Stream –** Curtailment on riparian grass mowing during the inanga spawning season (Dec-May incl.) and/or planting with appropriate vegetation.

- **Wainuiomata River mainstem –** Fencing or at least stock control during the inanga spawning season. Stock should be excluded December through to May inclusive.

- **Pounui Stream –** Stream works should not be undertaken immediately before or during the inanga spawning season, and aquatic life must be transferred out of natural channel which are to be de-watered.

- **Lake Onoke** – Fencing of stock from freshwater seeps in the north-west corner of the Lake, which served as former inanga spawning ground as reported by DOC (see App. II, Fig. 30).

8 Synopsis of 2016 surveys, summary of key management issues and potential further work

During this survey, ten new spawning sites were located. These sites are: Waikanae River, Taupo Stream, Kakaho Stream, Horokiri Stream, Pauatahanui Stream, Porirua Stream, Kenepuru Stream, Waiwhetu Stream, Wainuiomata River and Pounui Stream. However, three sites do come with a caveat. The small size of the Waikanae River site and the abundance of other potentially suitable habitats nearby mean that it is unlikely we found the main spawning ground. No spawning was thought to have been found in Taupo Stream until field photos were closely scrutinised and eggs were possibly found. The exact spawning location in Pounui Stream was not found, but the presence of ripe fish indicates that we were very close to it.

Despite our best efforts, in the areas searched during this survey, we have found a number of apparently suitable habitats but have either failed to locate eggs or we have been unable to determine the full size of the spawning reach. These sites are tabulated below, along with unsurveyed habitats which may hold potential for inanga spawning (Table 6).

Since the 2001/2002 surveys, significant improvement in habitat suitability for inanga spawning has been seen in the blind braid in the northern tributary of the Otaki River, Kakaho Stream, Horokiri Stream, the spawning location on the Porirua mainstem and Kenepuru Stream. On the other hand, degradation was observed upstream of control structure on Opahu Stream. For all other sites where a comparison was available, there was minor improvement, minor degradation, or no change. The success of the Kakaho, Horokiri and Porirua Streams is most likely a result of restoration efforts. With regards to the Waiwhetu Stream, while the spawning site we located was not in an area targeted by the active “Friends of Waiwhetu Stream” group, this does not mean that their plantings are not being utilised by spawning inanga. Rather, this is a reflection of limited field survey time.

Many of the sites have various management issues that need to be considered and addressed, including the following: possible erection of public information signs (Waikanae River); fencing improvements to exclude stock (Kakaho Stream, Horokiri Stream and Wainuiomata River); weed/willow monitoring/control (Kakaho Stream, Horokiri Stream and Pauatahanui Stream); ensuring mowing does not occur during the spawning season (Taupo, Kenepuru and Waiwhetu Streams); planting banks with more luxuriant vegetation (Waiwhetu Stream); bank naturalisation and/or re-grade (Porirua Stream and possibly Taupo Stream) and flood management practices (Pounui Stream).

Table 6. Summary of additional locations to survey, or re-surveys of 2016 habitats. NZTM co-ordinates refer to the downstream margin of the recommended search area demarked in red on the result maps.

Waterway (mainstem)	Location	Surveyed in 2016? (y/n)	Downstream co-ordinates (NZTM)
Otaki River, northern tributary	Tributary running adjacent to, and east of Kapiti Lane	No	1777860.8E, 5486232.1N
	Small tributary to the south west of the above tributary	No	1777781.1E, 5486120.4N
Otaki River, southern tributary	Both banks from (approximately) 100 m upstream of the searched area	No	1777953.1E, 5485498.3N
	Blind channel west of the tidegates	No	1777842.2E, 5485606.1N
Otaki River, southern tributary	Blind braid	Yes	1777854.9E, 5485642.1N
Waikanae River	Downstream lagoon, on the true right bank	No	1769804.5E, 5473748.8N
	Oxbow on true right bank	No	1770014.5E, 5472944.6N
	Small tributary downstream of Petrel Close-Makora Road	No	1769412.1E, 5472932.1N
	Main tributary downstream of Petrel Close-Makora Road	No	1769427.7E, 5472925.4N
Taupo Stream	50 m reach downstream of the bridge to Plimmerton Station	Yes	1756885.0E, 5450314.9N
Kakaho Stream	Upstream from Grays Road to the downstream margin of the confirmed spawning reach	Yes	1759092.3E, 5449796.6N
Horokiri Stream	Tributary below Grays Road, on the true right bank	No	1760106.5E, 5449108.1N
Pauatahanui Stream	*J. pallidus* stand downstream of Paremata Haywards Road	Yes	1760978.0E, 5447563.5N

Table 7 (cotd.). Summary of additional locations to survey, or re-surveys of 2016 habitats. NZTM co-ordinates refer to the downstream margin of the recommended search area demarked in red on the result maps.

Waterway (mainstem)	Location	Surveyed in 2016? (y/n)	Downstream co-ordinates (NZTM)
Duck Creek	Duck Creek mainstem (Saltwater wedge)	No	1759471.4E, 5447455.6N
	The affected area opens into a wide flood plain	No	1759598.4E, 5447525.2N
Porirua Stream mainstem	On both banks in the vicinity of the spawning area	Yes	1754669.7E, 5444686.4N
Kenepuru Stream	Between the rail bridge and SH1 following a monthly peak high tide	Yes	1754730.1E, 5444633.4N
Makara Stream tributary	The affected area opens into a wide flood plain	No	1743831.5E, 5435303.7N
Hutt River mainstem	Between the railway bridge and Railway Avenue, east bank.	No	1759230.0E, 5435040.0N
Waiwhetu Stream (Hutt River tributary)	Six locations through Waiwhetu Stream, downstream of the confirmed spawning reach (see figure for more detailed location)	No	1759796.5E, 5433260.3N 1760404.7E, 5433527.1N 1760529.8E, 5433573.1N 1760748.8E, 5433730.2N 1760617.9E, 5434197.5N 1760768.2E, 5434292.2N
Te Mome Stream (Hutt River tributary)	Upstream from the tidegates	No	1759072.2E, 5433695.3N
Wainuiomata River	Both banks upstream of the identified spawning reach	No	1757684.0E, 5414003.5N
	True left bank downstream of the identified spawning reach	No	1757471.36E, 5413787.29N
Ruamahanga River	Both banks well upstream of Lake Onoke, and near Lake Wairarapa	No	At map locations indicated in Fig. 23c 1780525 E, 5420370 N 1780795 E, 5422060 N 1782035 E, 5423370 N 1783640 E, 5423980 N
Pounui Lagoon	Wetlands to the west of the Lagoon.	No	1778040.0E, 5419340.0N
Pounui Stream	Survey the lower reach	No	1778010.39E, 5419909.75N
Whangaimoana Stream	Resurvey the same reach	Yes	1782089.3E, 5413294.97N

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10 References

Baker, C. F. 2006: Predation of inanga (*Galaxias maculatus*) eggs by field mice (Mus musculus). *Journal of The Royal Society of New Zealand 36* (*4*): 143-147.

Baker, C. F.; Hicks, B. J. 2003: Attraction of migratory inanga (*Galaxias maculatus*) and koaro (*Galaxias brevipinnis*) juveniles to adult galaxiid odours. *New Zealand Journal of Marine and Freshwater Research 37*: 291-299.

Baker, C. F.; Montgomery, J. C. 2001: Species-specific attraction of migratory banded kokopu juveniles to adult pheromones. *Journal of Fish Biology 58* (*5*): 1221-1229.

Benzie, V. 1968a: Some ecological aspects of the spawning behaviour and early development of the common whitebait *Galaxias maculatus attenuatus* (Jenyns). *Proceedings of the New Zealand Ecological Society 15*: 31-39.

Benzie, V. 1968b: Stages in the normal development of *Galaxias maculatus attenuatus* (Jenyns). *New Zealand Journal of Marine and Freshwater Research 2*: 606-627.

Burnet, A. M. R. 1965: Observations on the spawning migrations of Galaxias attenuatus (Jenyns). *New Zealand Journal of Science 8* (*1*): 79-87.

Davis, K.; Bruce, M.; Mitchell, C. P. 2003. Inanga spawning on gravel substrates, Waihao River. 12 p.

Elliott 1996. National Inanga Spawning database: Card number 386 .

Goodman, J. M.; Dunn, N. R.; Ravenscroft, P. J.; Allibone, R. M.; Boubée, J. A. T.; David, B. O.; Griffiths, M.; Ling, N.; Hitchmough, R. A.; Rolfe, J. R. 2013. Conservation Status of New Zealand freshwater fish. Department of Conservation, Wellington. *No*. 16 p.

Goring, D. 2001: Computer Models Define Tide Variability. *The Industrial Physicist*: 14-17.

Greater Wellington Regional Council und. Pest Plants of the Wellington Region; a quick guide. In Council, G. W. R. (Ed.).

Hickey, C. W. 2000: Ecotoxicology: laboratory and field approaches.415 *In:* Collier, K. J.; Winterbourn, M., J. *eds*: New Zealand Stream Invertebrates: Ecology and Implications for Management. New Zealand Limnological Society. Christchurch.

Hickford, M. J.; Cagnon, M.; Schiel, D. R. 2010: Predation, vegetation and habitat-specific survival of terrestrial eggs of a diadromous fish, *Galaxias maculatus* (Jenyns, 1842). *Journal of Experimental Marine Biology and Ecology 385*: 7.

Hickford, M. J.; Schiel, D. R. 2011: Synergistic Interactions within disturbed habitats between temperature, relative humidity and UVB radiation on egg survival in a diadromous fish. *PLoS ONE 6* (*9*): 8.

Hickford, M. J.; Schiel, D. R. 2014: Experimental Rehabilitation of degraded spawning habitat of a diadromous fish, *Galaxias maculatus* (Jenyns, 1842) in rural and urban streams *Restoration Ecology 22* (*3*): 8.

Hicks, A.; Barbee, N. C.; Swearer, S. E.; Downes, B. J. 2010: Estuarine geomorphology and low salinity requirement for fertilisation influence spawning site location in the diadromous fish, Galaxias maculatus. *Marine and Freshwater Research 61* (*11*): 1252-1258.

Hill, J. 2013: Reproductive biology, movement and spawning dynamics of Galaxias maculatus in central New Zealand (MSc Thesis, School of Biological Sciences). University of Canterbury, Jowett, I. G. 2002: In-stream habitat suitability criteria for feeding inanga (*Galaxias maculatus*). *New Zealand Journal of Marine and Freshwater Research 36*: 399-407.

Jowett, I. G.; Richardson, J. 2008. Habitat use by New Zealand fish and habitat suitability models. National Institute of Water and Atmospheric Research, *NIWA Science and Technology Series No*. *55*. 148 p.

McDowall, R. M. 1968. *Galaxias maculatus* (Jenyns), the New Zealand Whitebait. Fisheries Research Division; New Zealand Marine Department, Wellington. *Fisheries Research Bulletin No*. *2*. 83 p.

McDowall, R. M. 1990: New Zealand Freshwater Fishes: A Natural History and Guide. Auckland, Heinemann Reed. 553 p.

McDowall, R. M.; Eldon, G. A. 1980. The Ecology of Whitebait Migrations (Galaxiidae: *Galaxias* spp.). Fisheries Research Division, Christchurch. *Fisheries Research Bulletin No*. *20*. 170 p.

Mitchell, C. P. 1989: Laboratory culture of Galaxias maculatus and potential applications. *New Zealand Journal of Marine and Freshwater Research 23*: 325-336.

Mitchell, C. P. 1990. Whitebait spawning grounds in the Bay of Plenty. Freshwater Fisheries Centre, MAF Fishries, Rotorua. *New Zealand Freshwater Fisheries Miscellanous Report No*. 19 p.

Mitchell, C. P. 1994. Whitebait Spawing Ground Management. Department of Conservation, *Science and Research Series No*. *69*. 23 p.

Mitchell, C. P.; Eldon, G. A. 1990. How to locate and protect whitebait spawning grounds. Christchurch. 49 p.

Mitchell, C. P.; Madgewick, H. H.; Strickland, R. R.; Van Boven, R. J. 1992. The use of larval fish as an aid to identifying whitebait spawning grounds, and the role of slugs as predators on whitebait eggs. MAF Fisheries, Rotorua. *New Zealand Freshwater Fisheries Miscellaneous Report No*. 16.

Richardson, J.; Taylor, M. J. 2002. A guide to restoring inanga habitat. National Institute of Water and Atmospheric Research, Wellington. *NIWA Science and Technology No*. *50*. 29 p.

Rowe, D. K.; Saxton, B. A.; Stancliff, A. 1992: Species composition of whitebait (Galaxiidae) fisheries in 12 Bay of Plenty rivers, New Zealand: evidence for river mouth selection by juvenile Galaxias brevipinnis (Günther). *New Zealand Journal of Marine and Freshwater Research 26*: 219-228.

Stoffers, P.; Glasby, G. P.; Wilson, C. J.; Walter, P. 1986: Heavy metal pollution in Wellington Harbour. *New Zealand Journal of Marine and Freshwater Research 20*: 495-512.

Taylor, M. J. 1995. Inanga spawning on the Heathcote River. National Institute of Water and Atmospheric Research, Christchurch. *Consultancy Report No*. *CCC007*. 10 p.

Taylor, M. J. 1997. Inanga spawning activity on the Avon and Heathcote Rivers. National Institute of Water and Atmospheric Research, Christchurch. *NIWA Client Report*. 9 p.

Taylor, M. J. 1998. Inanga spawning on the Avon and Heathcote Rivers, April 1998. National Institute of Water and Atmospheric Research Limited, Christchurch. *NIWA Client Report*. 12 p.

Taylor, M. J. 2002. The National Inanga Spawning Database: trends and implications for spawning site management. Department of Conservation, *Science for Conservation No*. *188*. 37 p.

Taylor, M. J. 2004. Inanga spawning grounds on the Avon and Heathcote Rivers. Aquatic Ecology Limited, Christchurch. *AEL Report No*. *22*. 34 p.

Taylor, M. J.; Buckland, A. R.; Kelly, G. R. 1992. South Island inanga spawning surveys, 1988-1990. Ministry of Agriculture and Fisheries, Christchurch. *New Zealand Freshwater Fisheries Report No. 133*. 69 p.

Taylor, M. J.; Kelly, G. R. 2001. Inanga spawning habitats in the Wellington Region, and their potential for restoration. National Institute of Water and Atmospheric Research, Christchurch. *NIWA Client Report No. CHC01/67*. 61 p.

Taylor, M. J.; Kelly, G. R. 2002. Inanga spawning habitats in the Wairarapa Region. Aquatic Ecology Limited, Christchurch. *AEL Report No. 11*. 32 p.

Taylor, M. J.; Marshall, W. 2014. Inanga Spawning Survey of the Canterbury Region. Aquatic Ecology Ltd, Christchurch. *No. 119*. 61 p.

Walters, R. A.; Goring, D.; Bell, R. 2001: Ocean tides around New Zealand. *New Zealand Journal of Marine and Freshwater Research 35*: 567-579.

11 Appendix I. Overview maps

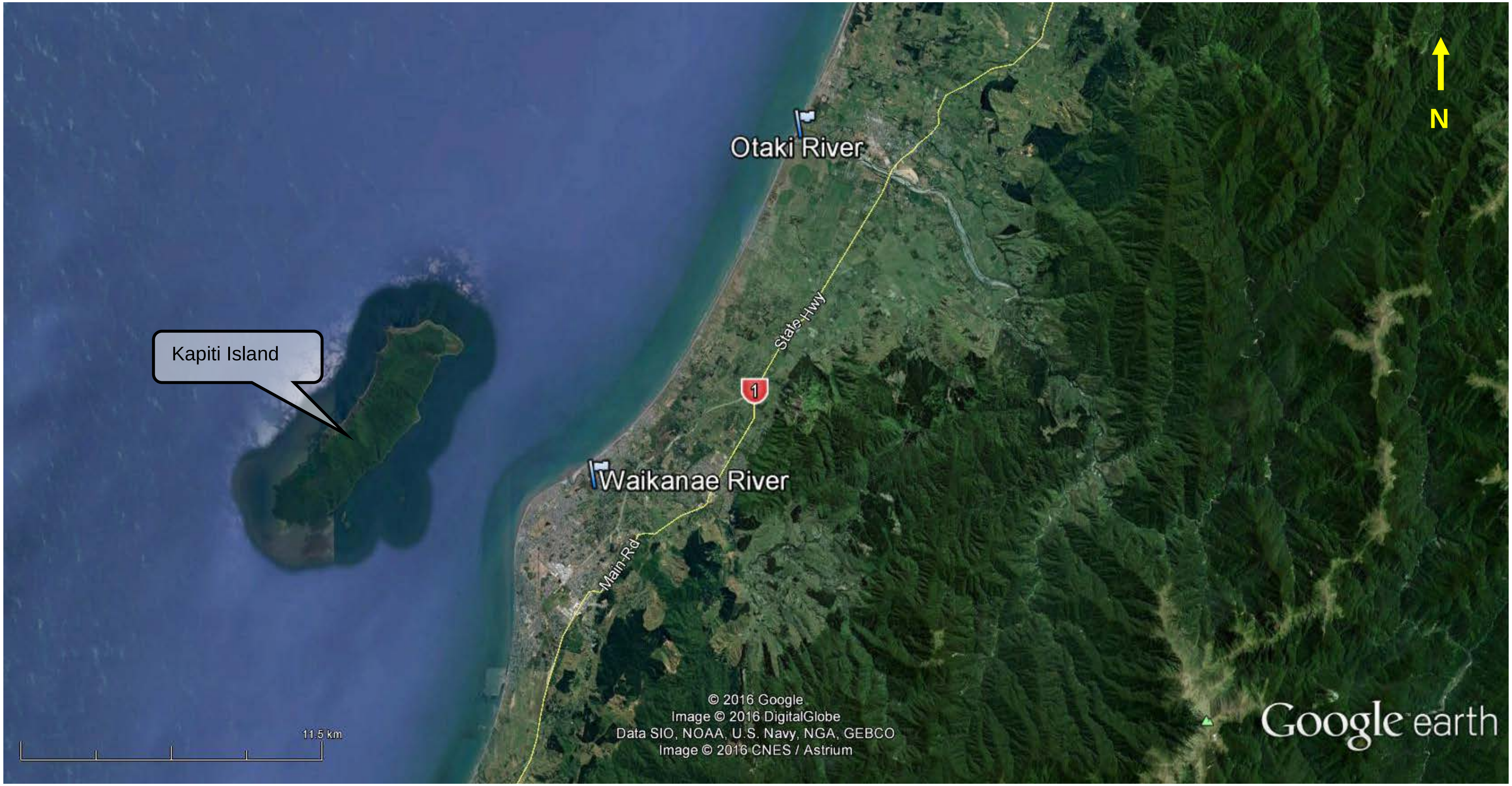

Figure i. Overview map of the sites surveyed on the Kapiti Coast.

Figure ii. Overview map of the sites surveyed in Te Awarua-o-Porirua Harbour.

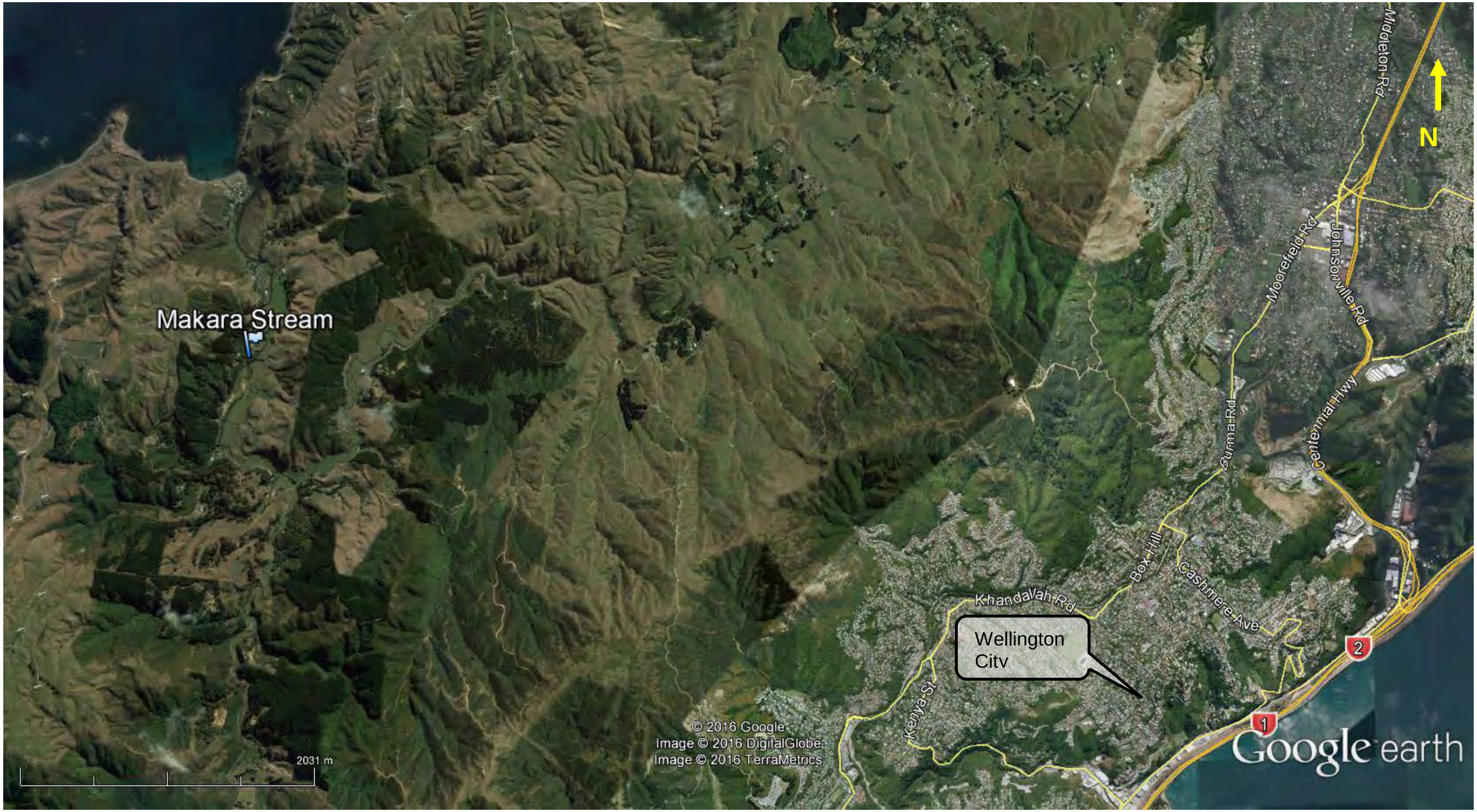

Figure iii. Overview map of the site surveyed in Wellington.

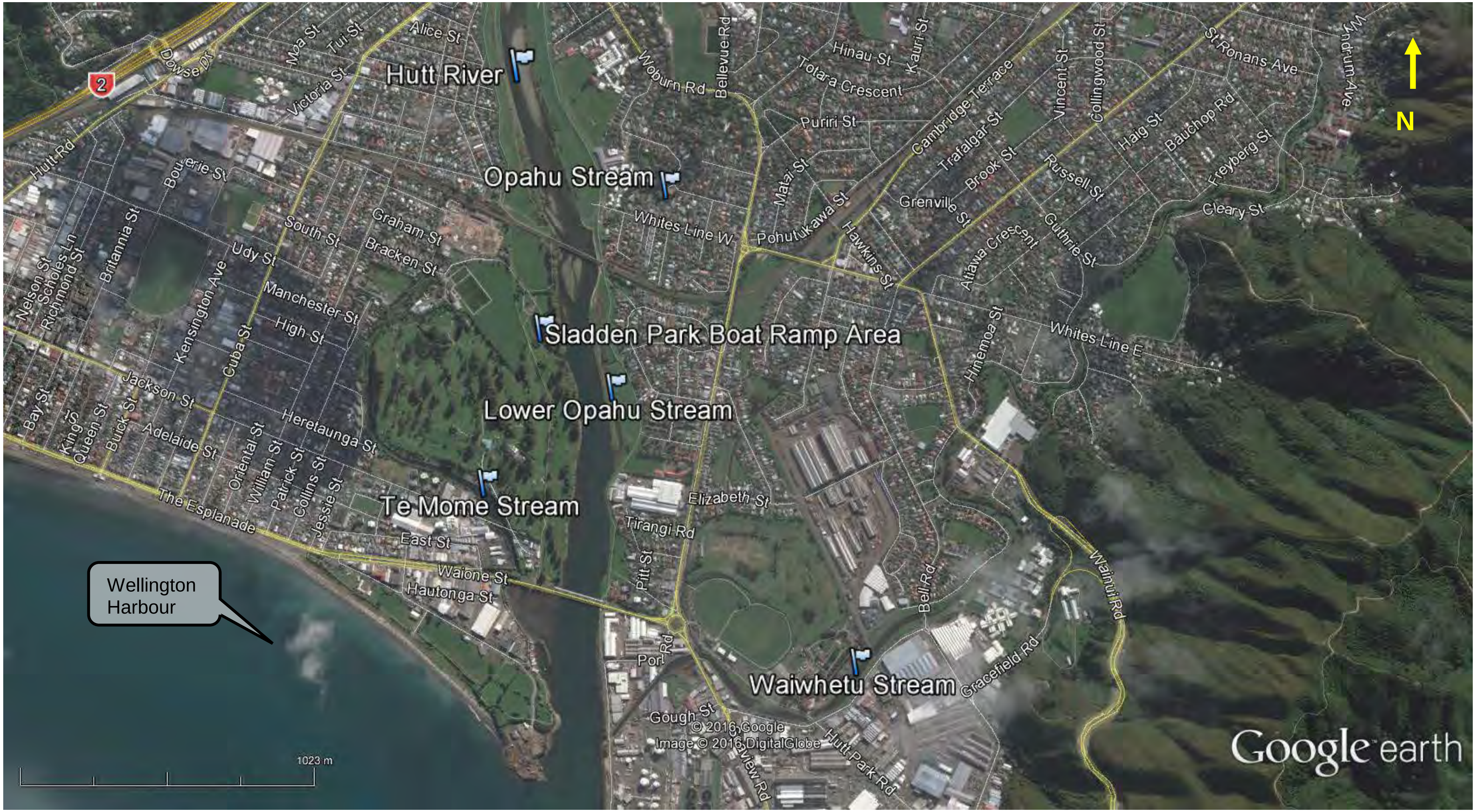

Figure iv. Overview map of some the sites surveyed in the Hutt River.

Figure v. Overview map of the site surveyed in the Wainuiomata River.

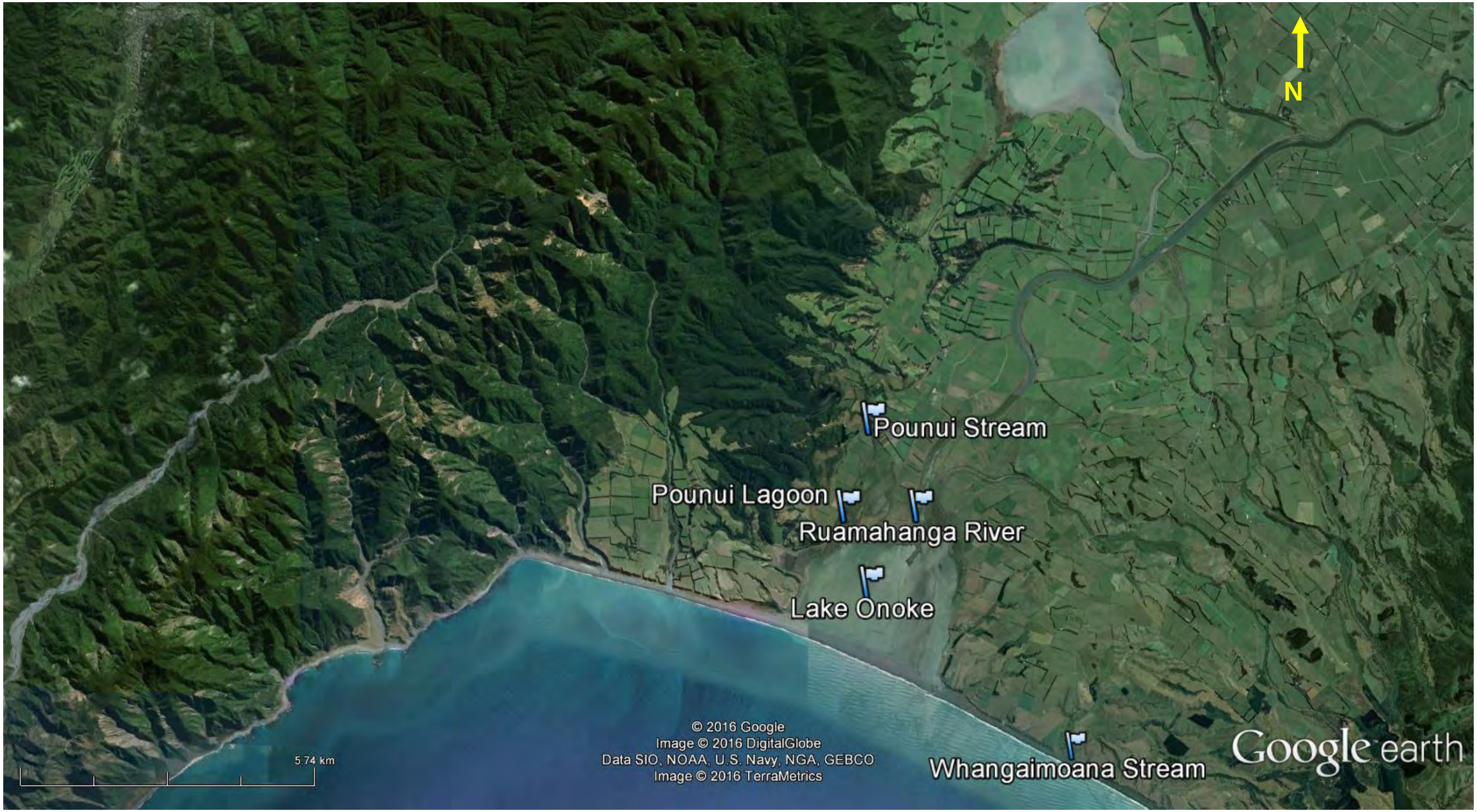

Figure vi. Overview map of the sites surveyed in the South Wairarapa.

12 Appendix II. Additional site photographs

Figure 1. Waikanae River (Waikanae), eyed (developed) inanga eggs located on tall fescue (arrowed).

Figure 2. Waikanae River (Waikanae), looking downstream at the river mouth showing its width.

Figure 3. Looking upstream at Taupo Stream, from the bridge to Plimmerton Station. Possible eggs are arrowed.

Figure 4. Developed Inanga eggs in Kakaho Stream attached to the basal stems of tall fescue grass (Porirua Harbour catchment).

Figure 5. Inanga eggs on tall fescue, Horokiri Stream, Porirua.

Figure 6. Eggs (arrowed) from an unknown species found in Horokiri Stream, Porirua.

Figure 7. Inanga Spawning on tall fescue on Pauatahanui Stream, Porirua.

Figure 8. Inanga spawning amongst creeping buttercup, giant rush,and tall fescue in Pauatahanui Stream, Porirua.

Figure 9. Close up of an eyed inanga egg on tall fescue stems in Porirua Stream, Porirua city.

Figure 10. Tall fescue inanga spawning vegetation on the Porirua Stream, Porirua city.

Figure 11. Looking upstream at the weir in Porirua Stream (Porirua), photo taken about one hour before high tide.

Figure 12. Kenepuru Stream, Porirua. Inanga spawning on tall fescue (arrowed).

Figure 13. Looking upstream at the true right (eastern) bank of lower Makara Stream.

Figure 14. Looking downstream at the true right (eastern) bank of lower Makara Stream.

Figure 15. Looking downstream at the southern end of eastern bank of the island in lower Makara Stream.

Figure 16. Looking downstream at the western bank of the island in lower Makara Stream.

Figure 17. Looking downstream at a section of the Hutt River that is protected by anit-scour

Figure 18. The matrix of fine root hairs present in the jointed wire rush in lower Opahu Stream.

Figure 19. Looking upstream at the tidegates on Opahu Stream

Figure 20. Looking downstream at the tidegates on Opahu Stream

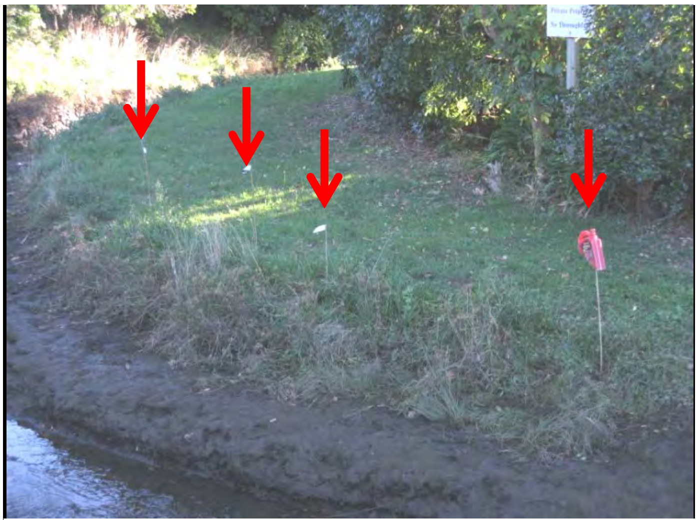

Figure 21. Inanga spawning location on Waiwhetu Stream, Lower Hutt. Red arrows = identified egg nests.

Figure 22. Inanga eggs, around the bases of creeping bent, Waiwhetu Stream, Lower Hutt.

Figure 23. Several large river rats were observed near the inanga spawning grounds on Waiwhetu Stream.

Figure 24. Inanga eggs on giant umbrella sedge bases on the Wainuiomata River, Wainuiomata.

Figure 25. Inanga egg on grass/buttercup in the Wainuiomata River, Wainuiomata.

Figure 26. The grazed section in the middle of the spawning grounds on Wainuiomata River. Note the thicket of gorse behind it (arrowed).

Figure 27. Looking at the shoreline of Lake Onoke, and a stand of jointed wire rush.

Figure 28. Looking downstream (south) at the exposed eastern lake bank

Figure 29. Tall fescue swards bordering the banks of the Turanganui River near Lake Onoke.

Figure 30. The stock-pugged freshwater lagoon off the east coast of Lake Onoke.

Figure 31. A stranded dead torrentfish collected from Pounui Stream on the 21st April 2016.

Figure 32. Looking upstream into Pounui Stream, about 130 m upstream of Pounui Lagoon. The orange substance is iron floc, considered to be an occasionally encountered natural phenomenon.

Figure 33. The sign at Whangaimoana Stream indicating the covenant area.

13 Appendix III. Plant List

Table i. Plants highlighted in red are those which eggs have been attached to from other parts of New Zealand.

Common name	Scientific name	Native/Introduced
Macrophytes		
Canadian pond weed	*Elodea canadensis*	*introduced*
Cape pondweed	*Aponogeton distachyus*	*introduced*
Common Water Milfoil	*Myriophyllum propinquum*	*native*
Parrots feather	*Myriophyllum aquaticum*	*introduced*
Red pondweed/manihi	*Potamogeton cheesmanni*	*native*
Bank vegetation		
blackberry	*Rubus* sp.	*introduced*
Carex geminata **(species ID unconfirmed)**	*Carex geminata*	*native*
Clover	(*Trifolium sp.*).	*introduced*
Creeping bent	*Agrostis stolonifera*	*introduced*
Creeping buttercup	*Ranunculus* repens	*introduced*
Creeping jenny	*Lysimachia nummularia*	*introduced*
Fennel	*Foeniculum vulgare*	*introduced*
Flax/harakeke	*Phormium tenax*	*native*
Giant rush/Pale rush	*Juncus pallidus*	*native*
Giant umbrella sedge	*Cyperus ustulatus*	*native*
Hebe	*Various species*	*native*
Jointed wire rush/oioi	*Apodasmia similis*	*native*
Jointed rush	*Juncus articulatus*	*native*
Lotus	*Lotus major*	
Mercer grass	*Paspalum distichum*	*introduced*
Mint	*Mentha* sp.	*introduced*
Monkey musk	*Mimulus guttatus*	*introduced*
New Zealand rush/Edgar's rush (wiwi)	*Juncus edgariae, formerly Juncus gregiflorus*	*native*
Plantain	*Various species*	*introduced*
Raupo	*Typha orientalis*	*native*
Rushes	*Juncus* sp.	
Sea rush	*Juncus maritimus*	
Swamp sedge (pukio)	*Carex virgata*	*native*
Tall fescue	*Schedonorus phoenix (formerly Festuca arundinacea)*	*introduced*
Three square	*Schoenoplectus pungene*	*native*
Toetoe	*Austroderia richardii*	*native*
Twitch (Onion)	*Arrhenatherum elatius*	*introduced*
Willow weed	*Persicaria decipiens*	*introduced*
Yorkshire Fog	*Holcus lanatus*	*Introduced*

14 Appendix IV. Temporal changes in recently determined spawning sites

Figure 1a. The graded and grazed Kakaho Stream in 2001 (Taylor & Kelly 2001).

Figure 1b. The vegetated and fenced Kakaho Stream in January 2015. Google™ Earth image.

Figure 2a. The grazed Kakaho Stream upstream of the bridge

Figure 2b. The spawning reach looking downstream towards the road bridge (April 2016).

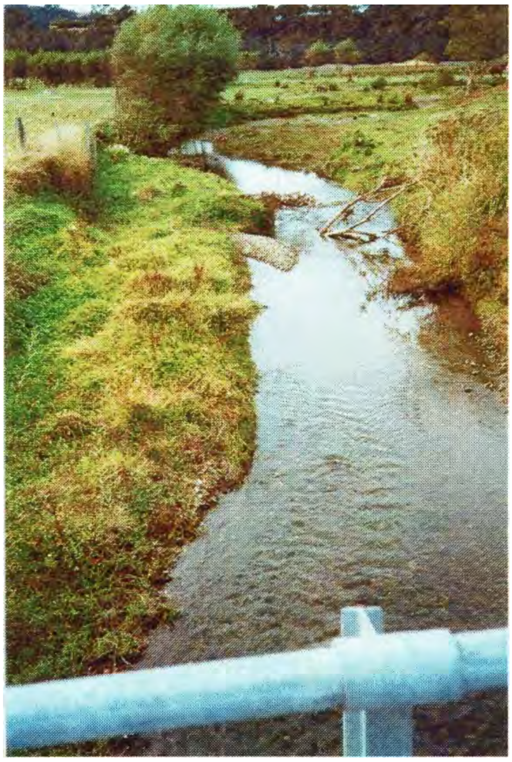

Figure 3a. The Horokiri River in 2001.

Figure 3b. The Horokiri River in January 2015 (Google™ Earth imagery). Largely fenced. However some collapsed bank obscured on the right bank suggests some stock access (see Fig. 4c).

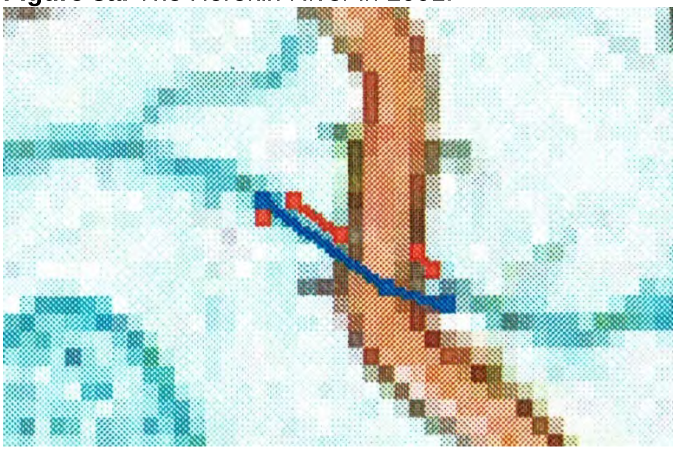

Figure 4a. Excerpt from (Taylor & Kelly 2001). Horokiri River. Red line = suitable vegetation for inanga spawning in 2001. Blue line = extent of survey.

Figure 4b. Green line = inanga egg distribution 2016, orange = vegetation suitability. Yellow pin = approx. inland intrusion of saltwater.

Figure 5a. Apparently ungrazed grasses in the lower reaches of the Wainuiomata River in 2001.

Figure 5b. The grazed true right bank of the Wainiuiomata River in 2016. Eggs were located in the native rushes, but not in the grazed grasses.

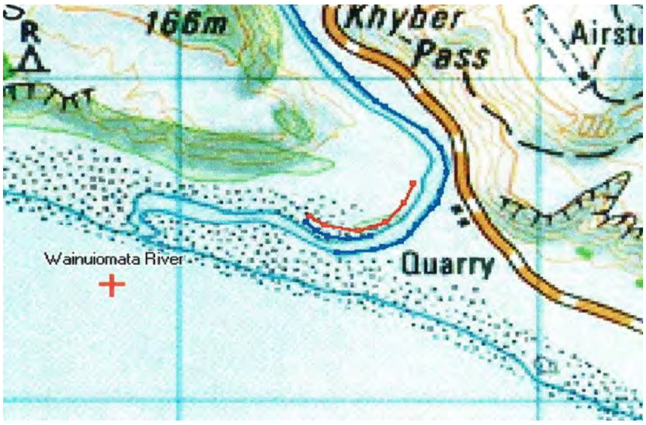

Figure 6a. The range of suitable vegetation as mapped in 2001 (Wainuiomata *in* Taylor & Kelly 2001).

Figure 6b. The scope of utilised (green) and potential vegetation (orange) on the Wainuiomata in 2016.

Figure 7a. Search zone for the Waikanae River (Taylor & Kelly 2001). Red = suitable reach.

Figure 7b. The search area, suitable vegetation, and egg locations in 2016. Orange=suitable vegetation, green=egg location.

Figure 8a. Reaches on the Pauatahanui Stream deemes suitable in 2001 (map from Taylor & Kelly 2001). Red=suitable, but no eggs found. The location of the new bridge is arrowed

Figure 8b. Reaches with suitable vegetation (orange), and where eggs were found (green).

Figure 8c. Suitable inanga spawning habitat just upstream of the new bridge over Pauatahanui Stream, on the true left bank (Taylor & Kelly 2001)**.**

Figure 8d. Egg nests on the true left bank upstream of the highway bridge, at the confluence of the new road drain.

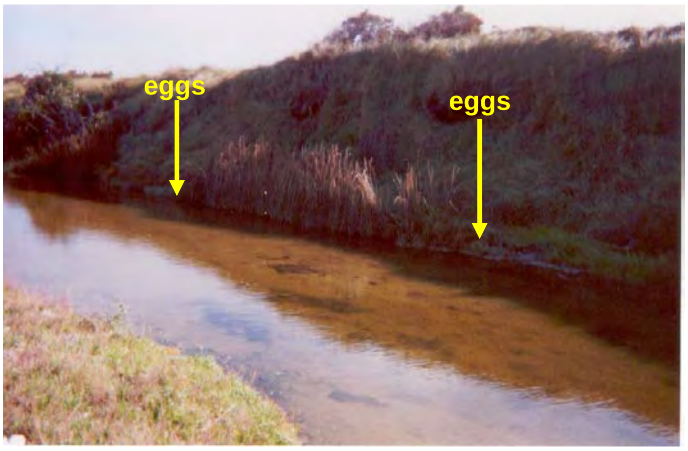

Figure 9a. From (Taylor 2002). Inanga spawning grounds on the Whangaimoana Stream. Eggs were found either side of the tall *Juncus* vegetation amongst the introduced weed Mercer grass.

Figure 9b. The same reach as in Fig. 8a. There appear to be more Mercer grass, tall Juncus vegetation on the photo left bank now.

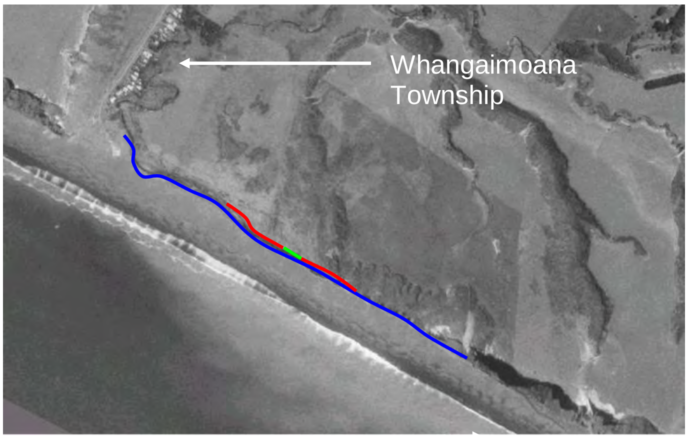

Figure 10a. The lower reaches of the Whangaimoana Stream, the blue line indicates the extent of the foot survey, the red section indicates area of suitable vegetation, and the green section an area where inanga eggs were found.

Figure 10b. The suitable vegetation search in 2016. There is marginally more vegetation on the bluffs and gullies, the latter appearing to be production forest (imagery 4/1/16).

Figure 11a. Taupo Stream in 2001 showing the scope of survey (blue), and the range of suitable vegetation (red) (Taylor & Kelly 2001)

Figure 11b. The scope of the 2016 survey, which extended further upstream than in 2001. Green=possible egg locations, orange=suitable habitat.

Figure 11c. The weed-chocked channel in the Plimmerton Domain, April 2001. The old culvet is discernible in the photograph.

Figure 11d. Taupo Stream in the Plimmington Domain, April 2016. The old culvert is in the background.

Figure 12a. In 2001, the lower Kenepuru Stream was regarded as suitable (red line).

Figure 12b. The spawning reach (green line) bracketed by suitable but lacking eggs (orange line), and unsuitable reaches (red line).

Figure 12c. Lower Kenepuru Stream looking downstream from the low weir towards the 2016 spawning reach. Note the trimmed grass on the right bank.

Figure 12d. Lower Kenepuru Stream, at low tide, looking downsream at the spawning reach. This is a little further downsream than in Fig. 12c.

Figure 13a. The restricted survey around the tidegates in 2001. Red=suitable habitat. Much of seaward side of the lagoon was gravel, as indicated.

Figure 13b. Orange=suitable spawning areas on the northern Otaki. Red=unsuitable habitat. The edges of the lagoon are becoming more grassed over time. Imagery January 2015.

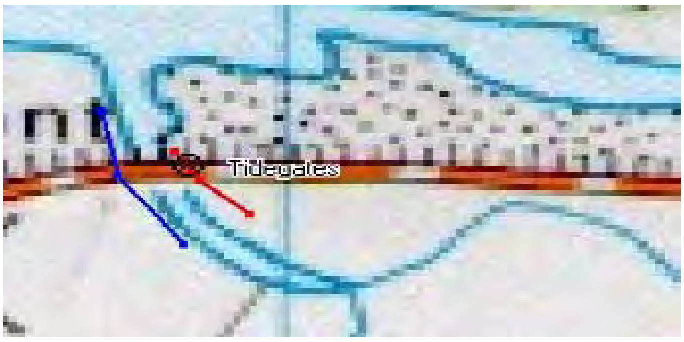

Figure 14a. The basic habitat suitability for the southern tributary discharging into the Otaki River mainstem in 2001. Red=suitable habitat. Much of seaward side of the lagoon was gravel, as indicated.

9.019

Figure 14b. Habitat suitability in 2016. Habitat suitability was considered (just) suitable on the true left (seaward) channel.

Figure 15a. Suitable spawning areas in the lower Makara Stream.

Figure 15b. Suitable habitat around the island in the vicinity of the settlement at Makara Beach.

15 Appendix V. Example of bank stabilisation and planting regime for the Heathcote inanga spawning site

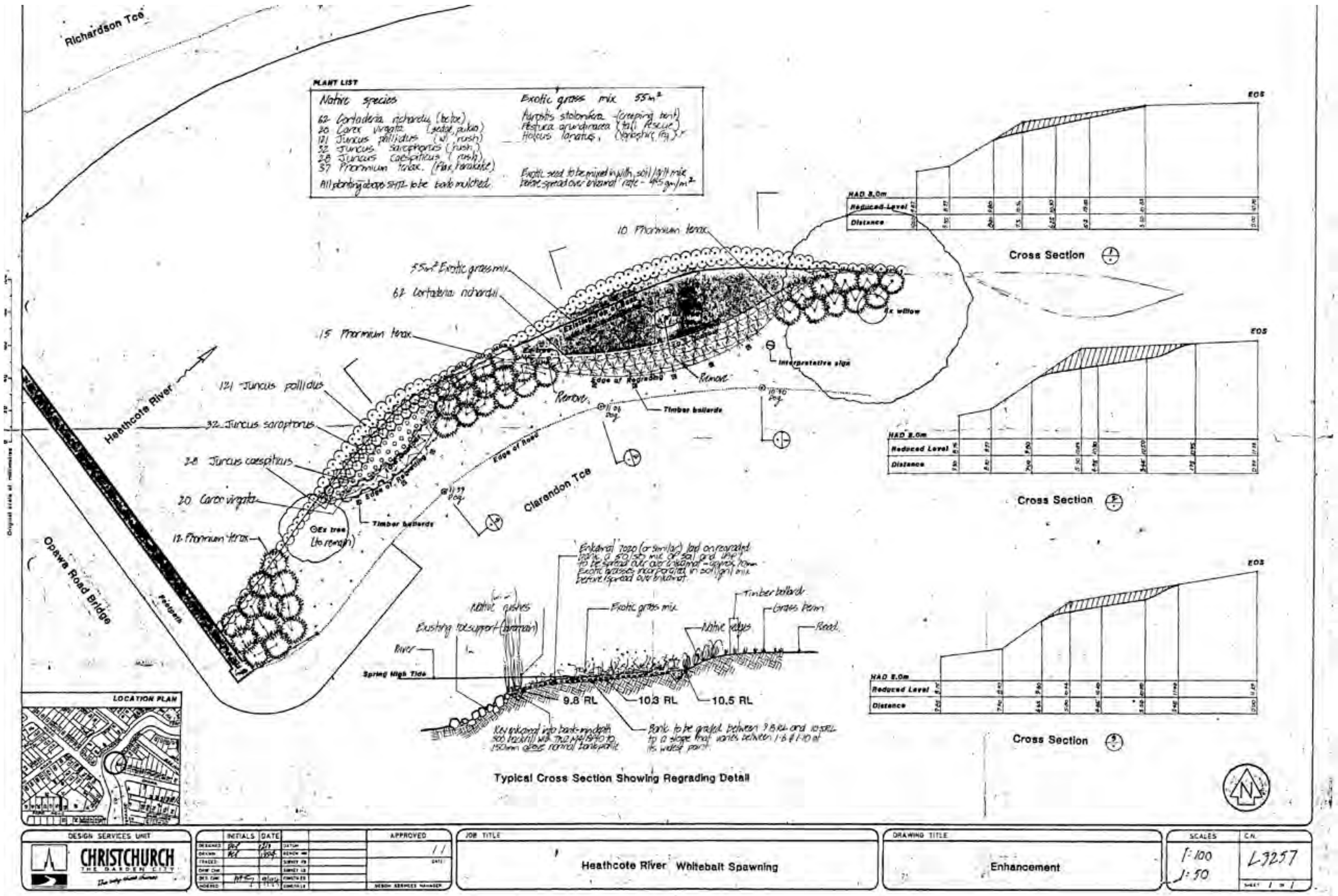

Figure i. Bank regrading profiles, plans and cross-sections, for the Heathcote inanga spawning site.