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Inanga spawning investigations in the lower Whanganui River catchment Autumn 2019

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Prepared for

Department of Conservation

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1 EXECUTIVE SUMMARY

The Whanganui River is one of New Zealands's largest rivers and nationally significant culturally and ecologically. Its immense cultural importance to Māori led it to be the first in the world to be given its own identity as a living entity — Te Awa Tupua. The inanga (*Galaxias maculatus*) is one of many freshwater fish species prized and harvested by generations of iwi, it forms the basis of the present day whitebait fishery in the Whanganui for which the Department of Conservation (DOC) has management responsibility — including for the protection of inanga habitat. Yet like so many of our freshwater fish inanga is now on the list of threatened fish species and listed as an 'At Risk Declining' species (Dunn et al 2018). The loss of inanga spawning habitat is widely recognised as a key reason for the decline of inanga nationally and reductions in the whitebait catch over the years (e.g. Goodman 2018).

Inanga lay their eggs in autumn months in tidally influenced river reaches at the top of the spring tide level. The patches of eggs vary in size and are deposited in the humid environment provided by thick vegetation growth-most often rank grasses and herbaceous species. The eggs hatch out when submerged by the following spring tide cycle usually about a month later. This a very vulnerable habitat and in the Whanganui River like most large river systems in New Zealand it has been heavily modified, so the quantity and quality of spawning habitat has shrunk dramatically.

Because of its concern to conserve the inanga population in the Whanganui River and protect the whitebait fishery DOC commissioned survey work to locate spawning areas to assist in their protection and to gather information on spawning habitat features, egg productivity and to identify further survey and information requirements.

To locate spawning in the extensive tidal habitat of the lower Whanganui River earlier spawning records from Horizons Regional Council, satellite imagery of riparian margins and reconnaissance by vehicle, on foot and by boat were used. Eight new spawning sites were found in the Whanganui mainstem and three in tributaries giving a total of 12 mainstem and 4 tributary sites for the lower Whanganui River system. Inanga spawning was found at most sites from March—May with no spawning found in February. Of the new mainstem sites discovered the most notable finding was 2 spawning sites several kilometres further upstream of those previously known. The most upstream location was found on the mainstem true right bank about 28.4 km upstream of the river mouth; on the true left bank spawning was found about 26.8 km upstream. The total distance over which

spawning was found was 18.5 km. The most downstream spawning was found at the Kowhai Park north boat ramp about 9.9 km upstream of the mouth and approximately 300 m further downstream than previous records.

In the mainstem the common feature of areas where eggs were found was their location in riverbank areas free of the extensive areas of large shading trees (mostly willows and alders) that typify the rivers riparian zone. The stronger light environment away from heavy shading allowed rank grasses (typically mercer grass, tall fescue and creeping bent), some Juncus and herbaceous species (commonly ranunculus and lotus) to develop and provide suitable habitat for inanga to spawn in. In addition to these main vegetation species used for spawning, in the shadier environments within the tributaries the weed tradescantia was also used for spawning.

Egg patch sizes varied greatly across both mainstem and tributary sites. The primary factor shaping egg patch size, where the vegetation was suitable, was bank shape and slope. Tall steep banks (often 40° to 80 °) that had collapsed to form various sized irregular shapes of more gentle slope (often 20° to 45 °) were characteristic of both mainstem and tributary sites. Small patches of eggs (e.g. 0.02 m^2 to 1.0 m^2) ranging from a few hundred up to about 10,000 occurring irregularly over long distances of river bank (e.g 260-700 metres) typified many sites. Where there were occasional larger areas of more gently sloping bank, larger patches of eggs occurred. Less commonly, where larger areas of bank had deformed or slumped to suitable slopes, even larger (e. g 1.7–6.9m^2) egg patches occurred producing higher numbers of eggs (e.g. 90,000–150,000). In two locations extremely large patches of eggs were found over long areas of low gradient bank. One was found at the Mateongaonga Stream covering approximately 25 m^2 and the other along a reach near the Aramoho rowing club buildings which covered approximately 70 m^2. Both of these sites produced more than 1M eggs each. At the Aramoho site a spawning event was observed in April allowing observations to be made of spawning behaviour including predation by eels on adult inanga.

Overall productivity levels for the mainstem and tributary sites for March and April were estimated at approximately 1. 4 million eggs for each month. Using these estimates as a basis it was speculated that for the period covering March –June total productivity could be about 5.3 M eggs. Comparison of this level of egg productivity with the likely size of the whitebait harvest in the

Whanganui River and the extent of spawning habitat loss and modification suggest that the population is not likely to be self-sustaining. Further survey is recommended to better quantify the extent of spawning and egg productivity in the upper tidal zone and tributaries. To clarify the overall level of egg productivity it is recommended that egg mortality levels be investigated along with the extent to which spawning may occur on both of the monthly spring tide cycles. Whitebait harvest levels, habitat use by adult inanga and their population structure are additional areas of investigation that will assist in a better understanding of the Whanganui River inanga population.

A collaborative approach using shared resources and guided by an overall plan for locating, protecting and enhancing inanga spawning areas is suggested as a way forward to progress a catchment wide approach to enhancing the inanga population. For each of the individual spawning sites identified the key issue is to protect them from immediate threats and to monitor their condition long term to ensure their productivity is maintained. Specific recommendations are made for each site to form the basis for discussion with the landowner/land manager and other interested parties where relevant. This includes raising general awareness of the need to protect spawning areas and freshwater habitat generally.

This report commissioned by DOC has provided important new information on the location and productivity of spawning habitats in the lower Whanganui river system. It makes recommendations for protection of existing sites and key areas for future survey and investigation. Longer term, they will help achieve protection of inanga and safeguard the whitebait fishery in one of the country's most culturally and ecologically significant river systems.

Key recommendations:

- Communicate the findings of this study and seek feedback from iwi, landowners, land managers, councils and wider community of interest to raise awareness on the importance of protecting spawning habitats
- Promote a collaborative approach to develop a longer term catchment wide plan and work programme to locate and protect inanga spawning and adult habitats, including addressing information and research needs on inanga
- Protect known spawning habitats by undertaking proposed site specific actions
- Undertake further survey work for spawning sites especially in the upper tidal reaches
- Investigate egg mortality and other key aspects affecting productivity in the Whanganui River and tributaries.

2 INTRODUCTION

2.1 Background

The young of the inanga (*Galaxias maculatus*) make up more than 90% of the whitebait that run into the rivers and streams of New Zealand, they form the basis of the Whanganui River's very important fishery for whitebait. The great importance of the fishery to Whanganui iwi for both the adult inanga and their whitebait, including the sophisticated techniques and devices used to capture them, is well documented (e.g. Anon. Waitangi Tribunal 1999, Best 1929). Yet the inanga is now classified as an 'At Risk Declining' species (Dunn et al 2019) reflecting the massive loss and degradation of inanga habitat. This includes both the habitat where inanga whitebait grow to adult size and the special spawning habitat that the adults need to breed in when they reach maturity. Having enough good quality spawning habitat is critical for the species to sustain itself (Goodman 2018 and references therein). Besides the very significant issues of habitat loss there is also increasing concern over the impact that whitebaiting might be having on the inanga population and the other whitebait species (e.g. Goodman 2018).

As the statutory manager of the whitebait fishery (controlled by the Whitebait Fishing Regulations) and having general responsibility for the protection of native freshwater fish species and their habitats the Department of Conservation (DOC) needs information on the state of inanga populations and the condition of their habitats to address its responsibilities for their conservation. Another part of that role is to partner with iwi and work with other agencies (e.g. Councils) and communities in a collaborative way to protect and enhance inanga populations and habitats.
The current investigation was commissioned by DOC to investigate inanga spawning habitats in the lower Whanganui River catchment to improve knowledge of the location and features of inanga spawning habitats and to consider their levels of productivity and priorities for their protection and management.

2.2 Inanga life history and spawning ecology

The inanga (*Galaxias maculatus*) is one of five species that have a whitebait juvenile as part of their lifecycle. The four others include three kokopu species: the giant (*G. argenteus*), banded (*G. fasciatus*) and short jawed kokopu (*G. postvectis*) and the koaro (*G. brevipinnis*). The adults of these species all look quite different to inanga and all are significantly larger with the biggest species the giant kokopu commonly reaching about 40 cm. The others are about 20 cm long while inanga are typically about 10 cm long. The ecology of these other species and references to relevant studies and research can be found in Goodman (2018). During the whitebait run besides inanga whitebait which make up around 90% of the catch there could be any of the four other species.

Beginning with the familiar springtime runs of inanga whitebait into river and stream mouths, the inanga whitebait, around 50 mm long, gradually move upstream feeding and growing as they go. The range of habitats they may enter and grow to maturity in (usually taking 1–3 years) is varied and includes small streams, major rivers, marginal wetlands, lagoons and lakes. They are not a strong swimming species and usually don't penetrate long distances inland, but in large slow flowing rivers (like the Whanganui) they have been found around 200km upstream. Slow flowing water is the preferred adult habitat where the adults can easily feed on drifting aquatic and terrestrial insects and stay together in shoals.

Leading into autumn the maturing adult inanga migrate into the tidally influenced reaches of rivers and streams where they seek out and spawn (typically peaking from March—May) during the spring tide cycle in dense riparian vegetation (most commonly introduced grasses, rushes and herbaceous species). The eggs mostly settle around the bases of plant stems and rootlets close to the soil where there is a humid microclimate and the eggs have a stable substrate to attach to. Preferred spawning vegetation is that which is most effective in maintaining the high levels of humidity critical for egg survival. Vegetation of a good height and thickness with dense stems and thick root mats will achieve this. Recent research has shown that inanga will select for these features irrespective if the vegetation is native or introduced and will also utilise artificial habitats (Hickford et al 2017).

Once deposited the eggs develop and hatch out when inundated on the following springtide cycle which may be either 2 or 4 weeks away depending on where in New Zealand the location is. The larvae (about 7 mm long) gradually drift downstream to rear in the plankton community of the marine environment for about 5–6 months to reach whitebait size. They then migrate back to rivers and streams primarily during spring to repeat the lifecycle. While some adults may die after spawning many fish survive to spawn in subsequent years (Hill 2013).
As observed by Taylor and Marshall (2016) while water levels are influenced by the spring tide, the water where spawning occurs is very typically freshwater- often with an underlying wedge of

saltwater nearby. The upstream limit of the saltwater wedge can be a useful guide as to where spawning may occur, although spawning has been recorded well upstream of saltwater influence (as appears to be the case in the present study) and downstream (e.g. Taylor 2002) but still under significant tidal effect.

Bank slope is a critical factor in influencing the productivity of inanga spawning habitat because it controls the length of the horizontal area that gets submerged within the spring tide zone where inanga lay their eggs. A steep slope means only a small horizontal area is available for egg deposition while a gradual slope allows more eggs to be deposited. Therefore, banks with more gentle sloping habitat (about 10-20 °) will maximise egg production but at the same time not be so flat that fish get trapped and die in vegetation after they have spawned. Drainage is important too so that sloping banks will assist drainage of heavy soils but steep bank slopes may dry out soils too much.

Other issues with steep banks include their being unstable and prone to collapse making them unreliable for egg laying and catastrophic for eggs deposited in the case of collapse. Steep banks are also exposed to higher current velocities than lower gradient banks increasing the risk that eggs will be more easily washed away from their attachment or resting points to places lower on the bank where they can be more easily eaten by predators such as eels and bullies.

2.3 Threats to inanga rearing and spawning habitats

Inanga are considered an 'At Risk Declining' species because of the extent of the loss of both the quality and quantity of freshwater habitat- both for the fish to grow to adult size within and more critically for them to undertake their spawning. Habitat losses arise from an accumulation of impacts. Key impacts include the extensive loss and modification of catchment vegetation (e.g for agricultural uses), the impact of the drainage of wetland areas, river channelisation and stop banking , reduced flows from large scale diversion of water by various structures including dams and weirs ; water abstraction for irrigation, drinking water and industrial uses; the degradation of water quality from the discharge of contaminants including nutrients, bacteria, viruses, sediment, pesticides, heavy metals, hydrocarbons etc. (e.g. Young et. al. 2004, NZCA 2011, MFE 2017).

Water diversion structures such as dams, weirs and improperly installed culverts also seriously compromise the passage of inanga (adults and whitebait) given their weak swimming ability and limited ability to negotiate obstacles. This prevents or restricts access to adult rearing and spawning habitats which seriously compromises their ability to complete their lifecycle, reducing their population size.

Further adverse impacts arise from the impact of introduced fish (Collier and Grainger 2015) which predate inanga (e.g. trout, perch) or compete with and interact negatively with them (e.g. gambusia) or compromise the condition of habitat (e.g. koi carp). Although its impact is still being debated, the take of multiple tonnes of whitebait each year during the whitebait season adds a further burden the population must carry.

The spawning habitat requirements of inanga are very specific and the amount of that particular habitat type left — the very narrow margin of rivers and streams that occurs at the spring tide level that also has suitable vegetation, slope and soil conditions, is very small. It has shrunk dramatically under the land use changes discussed above, in particular, the scale of wetland drainage and grazing of riparian margins in New Zealand has vastly reduced the habitat available and survival of eggs in such areas. Eggs are soft and easily trampled and the grazing down of grass, besides causing mechanical damage to eggs, also destroys the humid microclimate that allows the eggs to stay moist, respire and survive; it also exposes eggs to ultraviolet radiation which is harmful. Stock grazing on river margins especially heavier animals like cattle also can accelerate erosion and the collapse of banks that support spawning areas (and other important biodiversity). Many studies have shown that fencing out stock from spawning areas allows the spawning grounds to recover to be productive again (e.g. Hickford et al., 2010).

In urban areas the spawning vegetation may be subject to control by weed-eaters, mowers or controlled by weedicides to maintain them in a tidy condition for amenity purposes. However, the effect is the same in causing the loss of eggs and degrading the quality of spawning habitat. Hard surfaces over or adjacent to riparian zones for amenity purposes such as pedestrian and bicycle pathways also may impinge on what would once have been spawning habitat. Likewise the prevalence of hard surfaces in urban areas may change run-off patterns and soil/water balance characteristics and adversely affect riparian vegetation growth.

While egg predators such as rats and mice (Baker 2006) are present in rural areas they may be more common in urban areas and may add an extra burden of mortality to deposited eggs. Culverting, stream channelisation and the establishment of tidegates and floodgates to provide for the speedy movement of water and protect urban infrastructure from flooding impinge on the passage of spawning inanga, natural salinity patterns and the condition and availability of spawning areas. There are many examples of restoration projects in urban waterways that have protected and enhanced spawning areas. In particular there is a large and ongoing research and restoration programme in Christchurch rivers to restore the damage caused to spawning habitats caused by the Canterbury earthquakes (e.g Hickford et al 2014, Orchard 2018)

2.4 Background on the Whanganui River

2.5 Physical features

The Whanganui River and its tributaries rise on the central plateau volcanic mountains of Tongariro, Ngauruhoe and Ruapehu. The massive catchment of approximately 7,000 hectares generates an average river flow of about 316 cumecs and correspondingly large flood events. A flow of approximately 5,150 cumecs was recorded in the June 2015 flood that was rated as a one in 130-year event. By flow volume the Whanganui is the second largest river in the North Island and at approximately 320 kilometres (km) long it is New Zealand's third longest. From its upper reaches the Whanganui River follows a winding course through steep rugged hill country of siltstone, sandstone and limestone basement rocks. The river is confined within very narrow and steep sided valleys nearly to the sea, with a small alluvial plain beside the lowest reach, where the city of Whanganui is located.

The river drops about 680 metres (m) before it reaches the sea, most of this is in the reaches above Taumarunui (which is 160 m above sea level). South of Taumarunui the river is well entrenched and there are more than 230 rapids, there are also many islands built up by accretion of gravels and sediment. In the area below Pipiriki as the river widens, it becomes sluggish, and rapids decrease. The gentle gradients made for easy navigability and the river is the longest navigable river in New Zealand. As a result of its gentle gradient the river has a substantial tidal range of more than 1.8 m in the lower reaches and the effects of the tide extend upstream for about 40 km. The estuarine area that is strongly influence by saltwater was estimated to cover an area of 353 hectares (Stevens and Robertson 2017).

2.5.1 Cultural and ecological features

From a cultural and ecological perspective, the Whanganui River is nationally and internationally significant. The river was the first in the world to be given its own legal identity and rights as Te Awa Tupua (an integrated, living whole) in recognition of the integral relationship of generations of iwi with the river (DOC 2012, Anon. 1999). For example, the River supplied the great variety and abundance of fish and other aquatic species that sustained iwi. Special techniques were developed to target the life stages of various fish species (e.g. Best 1929). Many of these freshwater species are of ongoing importance for cultural harvest e.g. tuna (eel), whitebait, kakahi (freshwater mussels) and piharau (lamprey). Inanga were a prized food both as whitebait and adults which were taken during the downstream migration to spawn when they were rich and full of eggs. Captured fish were either dried in the sun or on rocks. Preservation in this manner meant that the fish could be kept in an edible state for months (McDowall 2011).

Under progressive land use changes about 35% of the catchment has been intensively developed and is predominantly used for sheep, beef and dairy farming with remaining large areas in forest (56% native, 8% exotic) and the remainder urban. In the wider context, degradation of freshwater habitat in the Whanganui River especially in the lower tidal reaches, is similar to that found in most other large river systems throughout the country (e.g. Young et. al. 2004; NZCA 2011; MFE 2017). There have been wide ranging impacts on the catchments biodiversity generally (e.g. Department of Conservation 2012 and references therein).

Besides impacts on inanga as mentioned earlier, freshwater habitat degradation has obviously affected the health of the range of freshwater fish species occurring in the catchment. This also includes the effects on other freshwater dependent communities of invertebrates, plants, birds and bats. Many of these are threatened species of great cultural and ecological importance (e.g. DOC 2012; McCarthur 2007; Stevens and Robertson 2017).

While compromised, freshwater habitats support at least 18 species of native freshwater fish. Besides inanga many others are threatened or ‘At Risk Declining’ (Dunn et. al. 2018). This includes lamprey (piharau) (*Geotria australis*), longfin eel (tuna) (*Anguilla dieffenbachii*), torrentfish (papanoko) (*Cheimmarichthys fosteri*) , redfin bully (toitoi) (*Gobiomorphus huttoni*), Koaro

(*Galaxias brevipinnis*), short jaw kokopu (*Galaxias postvectis*), bluegill bully (toitoi), (*Gobiomorphus hubbsi),* and inanga (*Galaxias maculatus*). Besides fish, two large invertebrate species: kakahi (freshwater mussel) *Echyridella menziesii*) and koura (*freshwater crayfish*) (*Paranephrops planifrons*) are also considered 'At Risk Declining' (Grainger et. al. 2018), like the fish they are of great importance to iwi.

Ecological values and the condition of the habitat in the rivers lower estuarine reaches have been assessed by Stevens and Robertson (2017). They recognised the large scale extent of habitat modification and loss from wetland drainage, flood protection and river channelisation and the general impacts of urbanisation with replacement of original estuarine vegetation with hard surfaces. The extensive loss of saltmarsh habitat, presence of turbid water, heavy sediment deposition and local deoxygenation were noted. By virtue of the very strong tidal effects the flushing of pollutants and nutrients into the coastal waters assists in maintaining the estuaries ecological condition. Overall it was considered the estuarine reaches were in a 'moderate' state of ecological health.

While degraded, the estuary is nevertheless regarded of national importance recognising the following attributes: a nursery and feeding ground for freshwater and estuarine fish species (including inanga spawning) and for the migration pathway it provides for whitebait, eel, lamprey (and other migratory fish); its strategic location for migratory and threatened bird species including as a roosting and feeding area (especially shellfish beds) for wading birds and for the presence of residual saltmarsh habitat at Corliss Island.

Upstream from the estuarine reaches and transitioning from the urban zone into the rural environment the rivers riparian corridor becomes dominated by a thick cover of exotic trees (primarily willow and alder) and a great diversity of weed species. These have replaced the original native riparian swamp forest association. The extensive riverine wetlands and backwater areas once connected to the river that would have supported extensive habitats for native fish (notably habitat and spawning areas for inanga) and other species have largely been lost.

3 OBJECTIVES

The main survey objectives were to locate inanga spawning sites in the tidal reaches of the Whanganui River and selected tributaries over the period from February to May 2019. This included egg production estimates at sites, documentation of observations of vegetation, banks and the general condition of spawning sites.

The overarching objective of the work was to equip the Department of Conservation Whanganui with an improved understanding of the location, key features and vulnerabilities of inanga spawning sites. This information and recommended site protection, future survey and information requirements could then form the basis of discussion with landowners, land managers, and other agencies as appropriate.

4 METHODS

4.1 Background

The upstream distance of the Whanganui River influenced by a tidal effect is approximately 40 km. This made undertaking detailed inanga spawning surveys of the entire area outside the time and budget resources of the present study. The survey focused primarily on finding new inanga spawning sites within about the lower 25 km of the river over the period from February to May and to gather more detailed information on spawning at these sites. Repeat egg surveys were undertaken at most sites in March and April with a non quantitative more general assessment of spawning extent made during May. A one-off upstream boat survey on 21 May to a distance of approximately 32 km upstream scoped out the possible upstream extent of spawning. The method used a driver and two observers experienced in identifying optimal spawning habitat scanning the banks and directing the boat driver to the favorable looking locations to check.

The upstream distance of the saltwater wedge was not used as a method to guide locating spawning areas (e.g see Taylor and Marshall 2016), however, this is recommended as part of future survey work to interpret its location in relation to spawning sites –notably the site located 28.4 km upstream (see Discussion section 6.2).

Other practical constraints on the number of sites which could be adequately surveyed were the amount of time available to conduct egg surveys at the low–mid tide level and the timing of the tide in terms of progressively reducing daylight hours going into autumn.

The Whanganui River has two spring tide cycles each month. Therefore, spawning could potentially be happening twice monthly. Surveys over both spring tide cycles each month at multiple sites was not practical, so monthly surveys were undertaken on the second spring tide cycle (typically days 20 to 22 of the month, coinciding with the full moon; refer Appendix 1). Likewise, resourcing did not permit measuring the levels of egg mortality (see Discussion).

4.2 Site selection

Unpublished data from survey work in April 2016 provided by Horizons Regional Council (Logan Brown pers. comm.) was used to guide the initial selection of potential spawning sites to visit. Inspection showed these areas were mostly free of large stature vegetation and in rank grass. Based on these observations, satellite imagery (Whanganui Council GIS, Google Maps) and field reconnaissance (vehicle, foot survey and a boat survey on 21 May 2019) focused on locating sites primarily free of large shading trees, having grasses and herbaceous vegetation present over favorable bank profiles (i.e. less steep banks with more rounded collapsed areas and benches). The use of a jet boat on 21 May to a distance approximately 32 km upstream allowed a quick general assessment of the river environment looking for the features mentioned above. The method used a driver and two observers experienced in identifying optimal habitat viewing the banks and directing the boat driver to optimal locations to check.

The upstream distance of the saltwater wedge was not used as a method to guide locating spawning areas, however, this is recommended as part of future survey work to interpret its location in relation to the site located 28.4 km upstream (see Discussion section 6.2).

4.3 Locating and counting eggs

Once at the survey site and guided by the identified upper level of the spring tide (typically well delineated by flotsam), eggs were searched for on foot by slowly walking along the bank, parting vegetation down to root/stem bases exposing eggs attached there or on vegetation. The width of the zone searched below the upper spring tide level was usually about 0.5 m. Once eggs were located the length of the egg patch was determined by progressively searching upstream and downstream of the initial find. When eggs were located, further detailed checking was used to determine the extent of the egg patch and which was delineated using stakes. The length and width of the patch was then measured, with additional measurements of width made for long patches and these used to calculate mean widths. The location of the centre of egg patches was recorded using a handheld Garmin GPS unit.

Initially a 10 x 10 cm quadrat was used to randomly subsample eggs within egg patches, however, this proved impractical with the time available to complete the surveys. It was also noticed that getting the quadrat down into the spawning vegetation at soil level to count the eggs caused a significant amount of disturbance to the spawning vegetation with possible damage to eggs. A 5 x 5 cm quadrat was used instead with five quadrats used to sub-sample eggs at random locations within the patch in smaller egg patches (e.g. 0.1–0.7m^2) while for larger egg patches (>approx.0.7m^2) the number of quadrats was increased to 10 and increased further to 20 –30 roughly proportional to the increased patch size.

At a few egg patches (see annotations in Appendix 3) egg densities were estimated using a photograph, however, while this method had promise as being much quicker and less damaging than quadrat methods it also proved time consuming when resolving eggs in photographs so would need further refinement (refer Discussion).

The production of eggs for each individual egg patch was calculated by multiplying mean egg density by the area of the patch, and then the total number of eggs for all patches aggregated to calculate the total production for the site as a whole for the sampling date. General observations of egg development were made with eggs noted as un–eyed or eyed with un-eyed eggs being freshly deposited and eyed eggs signaling they had been there for at least 2–3 days. No estimates of egg mortality were made (refer Discussion).

4.4 Observations made at spawning sites

At each spawning site general subjective observations were made of the key species of vegetation used for spawning, its height range (estimated in cm) the general rootlet, stem and soil moisture features within egg patches, the bank features and slope (estimated subjectively). Other observations made at sites that could put eggs at risk such as the presence of livestock, invasive plant species and evidence of egg predators were also noted. In the case of the tributaries general observations of stream habitat features were made subjectively including the cover available for adult inanga and any fish passage issues. Photographs of the general site, spawning patch vegetation and sometimes eggs were also taken to supplement observations (see Appendix 4, a separate pdf file has additional photographs of sites).

4.5 Observations of spawning fish

Throughout the survey period, particularly around the peak of the spring tide cycle and the few days following it, visual observations were made opportunistically at spawning sites. The purpose was to identify aggregations of adult fish that might signal they were going to spawn nearby- which could then be observed and the location checked for eggs once the tide had had receded. When spawning adult fish were found at the Aramoho rowing buildings reach on 20 and 21 April photographs and video were taken of spawning behaviour supplemented by field notes of the observations made (see Table 2).

5 RESULTS

5.1 Location of inanga spawning sites

Inanga spawning was found at 12 mainstem sites (site numbers 1–12) and four tributary sites (site numbers 13–16) over the survey period. The general location of sites is shown in Figure 1.

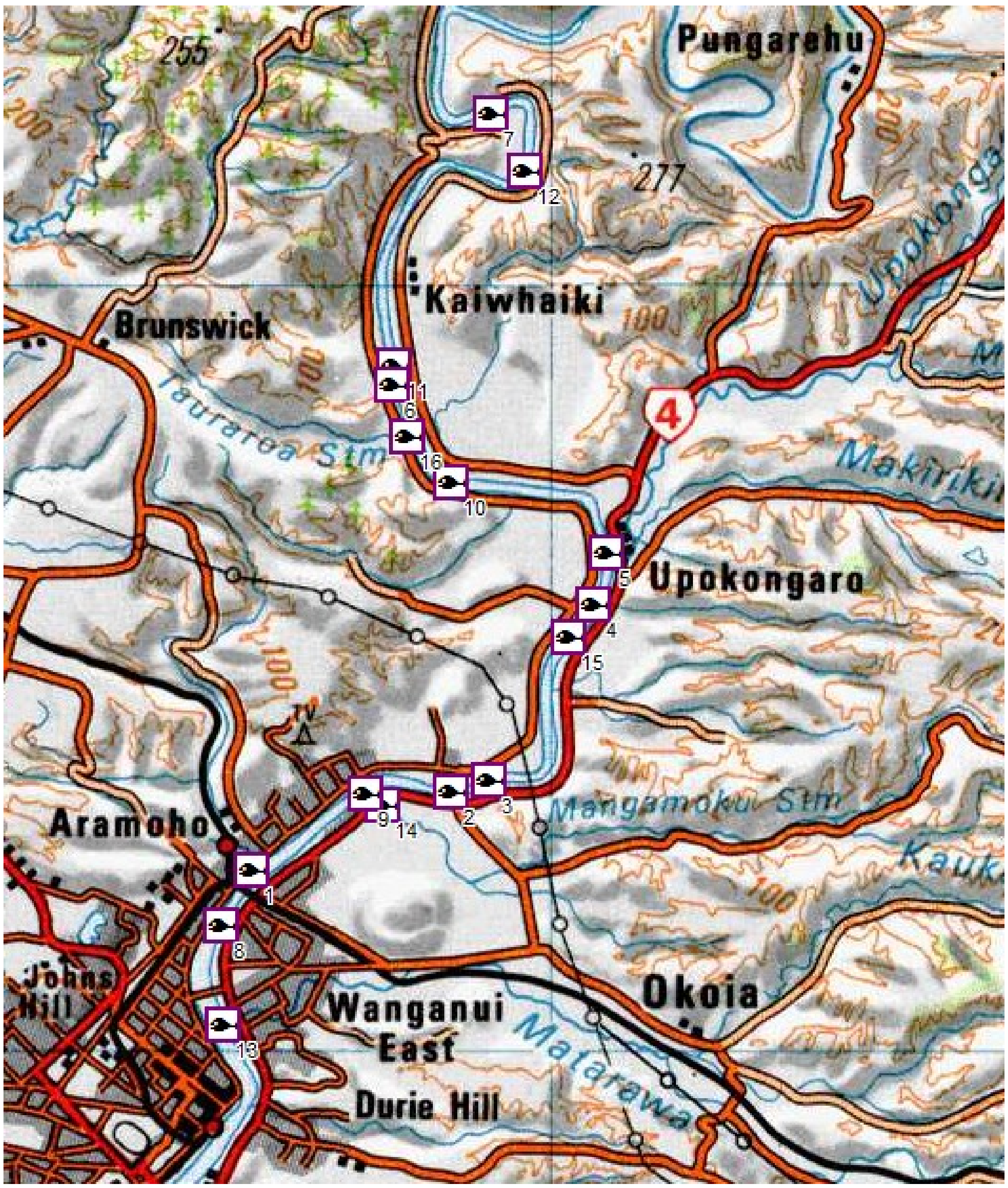

Figure 1: Whanganui River inanga spawning survey sites; see Table1 for site names corresponding to numbers.

Summary data of site features and the findings from the spawning surveys are shown in individual tables (Tables 2–17) for each site. Detailed raw data for each site is presented in Appendix 3 (separate pdf file). A summary of monthly egg productivity or estimated levels for sites is shown in Table 1.

Table 1: Summary of egg productivity estimates by month.

		Sampling period (refer Tables 2–17 for dates)		
Site no.	**Site name**	**March**	**April**	**May (general observations) ***
1	Aramoho rowing buildings reach	3,812	1,049,988	Similar levels to April
2	Top 10 Holiday Park boat ramp	88,301	42,910	Similar levels to April
3	Opposite Aramoho Cemetery	29,457	No eggs	No eggs
4	Papaiti Road–Waireka Road reach	111,468	6,645 (flood impacts)	Lower levels than April
5	Opposite Upokongaro reach	4,055	7,763	Lower levels than April
6	Papaiti Road — Middle	No eggs	243	Similar levels to April
7	Poutama Road	n.a.	n.a.	22,066 *
8	Kowhai Park North reach	No eggs	152,774	Similar levels to April
9	Reach downstream of Mateongaonga Stream mouth	46,502	34,403	Similar levels to April
10	Kaiwhaiki Road — Lower	No eggs	5,182	No eggs
11	Kaiwhaiki Road — Middle	No eggs	575 (sampled 1 May)	Similar levels to April
12	Kaiwhaiki Road — Upper	n.a	n.a	92,639*
13	Matarawa Stream	41,053	163,438	Similar levels to April
14	Mateongaonga Stream	104,9686	No eggs	No eggs
15	Un-named stream near 221 Papaiti Rd	1,510	No eggs	Similar levels to March
16	Tauraroa Stream	598	788	Similar levels to April
	Total eggs or estimated numbers	**1,376,442**	**1,464709**	**1.4 M estimated for May and 1M for June (refer discussion)**

*One-off productivity estimates for two upper river sites on 21 May

5.2 Whanganui River mainstem true right bank survey sites

5.2.1 Aramoho rowing buildings reach

This spawning site was the most downstream mainstem site found on the true right bank and centred on the Aramoho rowing buildings. Eleven spawning patches were found across the approximately 475 m reach over the survey period (Table 2). As far as is known, this is the first record of spawning in this area.

Figure 2: Measuring tape and stakes marking the shape of the extensive egg patch along the gently sloping margin at the Aramoho rowing buildings reach.

The reach was selected for spawning checks because it is relatively free of heavy shading by large trees and because of the promising looking very long low gradient bench occurring at the upstream end of the site. However, it was not until the April surveys that eggs were found along the very large low gradient area- consistent with observations that showed that previous to this time the site was dry with some damper areas in patches. On March 25 spawning was found at just one place where there was a small flat topped area of collapsed bank between the rowing shed buildings.

The Aramoho reach was the largest and most productive of all mainstem sites with an estimated April production of 1.049 million (M) eggs across the aggregated area of egg patches. Egg densities were not unusually high at around 10,000–15,000/m² (Appendix 3) but the aggregated area of eggs was large at nearly 80 m² (Table 2). Most eggs came from two very large patches along the low gradient area. The largest continuous egg patch of 31 m (Figure 2) contributed 769,000 eggs. The next largest patch contributed 193,000 eggs (Appendix 3). Based on general observations across the site in May it was considered that the likely number of eggs deposited (i.e. May productivity) was similar to that in April (see Discussion section 6.6)

The thickening rank grasses and Juncus through April and May provided very good spawning habitat as shown during the observations on 22 May of a similar extent of spawning as was recorded in April. Pig and fish carcasses, boat wakes, pedestrian and dog tracks through the egg deposition zone and invading willows and alders were all noted as potential issues at the site.

Observations on 20 April revealed very large numbers of fish spawning at the low gradient area of the site and at the small site between the boatsheds (Figure 3A; Appendix 3, Appendix 4 for additional photos and video details). Observations also showed the vulnerability of fish to predation by both eels and shags (observed on 21 April) and the risks of spawning fish getting trapped at very flat sites especially if large amounts of flotsam are present (Figure 3B).

Table 2: Data summary table Whanganui River mainstem true right bank (trb): Aramoho rowing buildings reach.

Site location: A survey reach extending approximately 475 metres (m) upstream from the pontoon jetty E:1776302 N:55808730 upstream to E:177632 N:5580873					
Key features: Reach is free of large willows, but smaller willows and alders (1–5 m) are establishing along site. Lower 250 m of reach characterised by steep (30–60°) slumping undercut banks approximately 2.5 m high, some less steep (20–30°) slumps form benches and knobs. Upstream from here is approximately 180 m of re-profiled bank area (a series of stepped retaining walls) of gentler slope (10–20°) at the top of the bank, banks revert to a steeper profile upstream of this. Tall banks are dominated by mercer grass and some tall fescue, low gradient area has variable thickness cover dominated by mercer and creeping bent mixture 20–75cm long, with thick developing patches of short (10–25 cm) juncus (*Juncus bufonius*?) and taller (20–40 cm) juncus (*Juncus edgariae?)* species with some herbaceous species such as ranunculus in damper areas. Horsetail (*Equisetum arvense*) patches occur at downstream end of site. There were fish and pig carcases on the margins. Reach subject to frequent boat wakes.					
Month of visit	**Summary**	**No. egg patches**	**Mean egg patch size(m²)**	**Total area eggs (m²)**	**Total no. eggs**
February 2019	22 February: No spawning fish and no eggs found	n/a	n/a	n/a	n/a
March 2019	25 March: Spawning in just one small seepage affected area of slumped bank between rowing shed buildings, where vegetation thick. Dead	1	0.266	0.266	3,812

	inanga found in vegetation.				
April 2019	20 April: Major spawning event was observed along the low gradient reach — several hundred fish were spawning leaving a milt signature, eels were predating fish and some fish were stranded on debris. Patches of thick small Juncus seemed particularly favoured for spawning in. 21 April showed lower level spawning but shags feeding along edge of site (see Appendix 1 for details).	n/a	n/a	n/a	n/a
	26 and 28 April: Egg survey shows mix of fresh and eyed eggs in an extensive spawning patch across reach especially heavy and largely continuous in the low gradient re-profiled bank area (coinciding with observations of spawning fish). Flotsam thick across egg deposition zone.	11	7.27	79.97	1,049,988
May 2019	22 May: Observations showed the extent and density of eggs is similar to that found during the 26 and 28 April survey. Fresh and eyed eggs were present. Vegetation is thicker and moister at bases, the rushes have grown and thickened up the most. It appears that the smaller soft rush is supporting high egg densities. There is a lot of flotsam across the entire reach. The most upstream area of the site is very damp as it appears there is stormwater draining into it.	n/a	n/a	n/a	n/a

A)

B)

Figure 3: A) Heavy spawning event during the 20 April survey; B) Dead inanga trapped in grasses at a flat area at the reach on 25 March.

5.2.2 Top 10 Holiday Park boat ramp reach

Spawning has not previously been recorded at this location. Spawning was found consistently at this site from March to May. Eggs were deposited in a narrow band in mercer grass along both the very steeply profiled bank continuous with the more flattened benched area where creeping bent was mixed with mercer grass.

Figure 4: Highlight marks approximate location of egg band centre along benched area extending downstream into the steeper area of bank.

Egg productivity was estimated at 88,301 and 42,910 for March and April respectively. The number and extent of eggs observed in May were similar to those found during the April survey. Encroachment of nearby willows on to the site was noted as a risk to its on-going productivity.

Table 3: Data summary table Whanganui River mainstem true right bank (trb): Top 10 Holiday Park boat ramp

Site location: A 17 m long south-facing site, immediately adjacent to the downstream margin of the slipway. Middle of site E:1778635 N:5581730

Key features: Bank has a flattish (10–30°) bench area of approximately 4 m adjoining a steeper area of bank (45–70°). This site has protection from the current, as it is set back from the main river flow, so slower water velocities occur along the bank in this area. Small willow trees are growing at the site. Vegetation is predominantly rank mercer grass (15–80 cm long- down bank) with creeping bent mixed amongst it. More thick creeping bent is growing over the flatter part of the bench; rank mercer grass trails down the face of the steep part of the bank.

Month of visit	Summary	No. egg patches	Mean egg patch size(m^2)	Total area eggs (m^2)	Total no. eggs
February 2019	22 February: No spawning fish and no eggs found	n/a	n/a	n/a	n/a

March 2019	6 March: No eggs or adult fish seen at site. 25 March: Mostly eyed and some fresh eggs across site.	1	6.30	6.30	88,301
April 2019	25 April: Eyed and fresh eggs across area at a lower density, but slightly increased area because of higher spring tide water level.	1	6.93	6.93	42,910
May 2019	23 May: General check showed eyed and fresh eggs present to a higher level on bank compared to April survey. Density not measured, but it appears higher than found during the April survey. Vegetation thicker with more stems and rootlets, moister soil.	n/a	n/a	n/a	n/a

5.2.3 Aramoho Cemetery reach

Horizons information indicated two small spawning patches at this location in April 2016. During the current survey, eggs were found in March only. Total estimated egg production was 29,457 eggs across approximately 6 m of the total 9 m width of slumping and undercut bank. Proximity to the small upstream tributary (not surveyed during the Horizons or this survey) may attract fish to this site. However, the reason why there was no observed spawning in April and May is uncertain. Being a shady, cool site that was developing increasingly thick and damp vegetation may be an explanation. The nearby tributary had a perched culvert that would prevent fish passage and it was noted there was a large amount of dumped rubbish and offal (pig and fish frames) in the stream.

Figure 5: Yellow rectangle shows the approximate location of egg patch at the mainstem site opposite Aramoho Cemetery.

Table 4: Data summary table Whanganui River mainstem true right bank (trb): Opposite Aramoho Cemetery

Site location: A small bench about 30 m downstream of an unnamed stream. Middle of site E: 1779184 to N: 5581904

Key features: South-facing bench approximately 9 m long and 1 m wide formed from an area of flatter topped (10–20°) but steep faced (30–60°) slumping bank, undercut bank. Site bordered by thick willows and weeds, some native regeneration. Spawning vegetation is a thick mixture of creeping bent, tall fescue and mercer grass with some convolvulus and arum present. Site was very damp in April and May, vegetation taller and denser. Stream nearby heavily choked by trees was not checked for spawning, has perched culvert, rubbish and carcasses dumped in it.

Month of visit	Summary	No. egg patches	Mean egg patch size(m^2)	Total area eggs (m^2)	Total no. eggs
February 2019	22 February: No spawning fish and no eggs found	n/a	n/a	n/a	n/a
March 2019	26 March: Eyed eggs found across 6.1 m length of bench.	1	4.39	4.39	29,457
April 2019	27 April: No eggs found, or fish seen. Perched culvert noted in nearby stream. Evidence of pig and fish offal.	n/a	n/a	n/a	n/a
May 2019	22 May: No eggs found, or fish seen. Site shady and damp.	n/a	n/a	n/a	n/a

5.2.4 Papaiti Road — Waireka Road reach

Egg patches located were variable in size over the survey period but mostly of smaller size overall. A large patch found downstream of the unnamed stream accounted for most of the higher egg production in March (Appendix 3). Steep banks (Figure 6) with limited more gentle slopes were not favorable for establishment of larger egg patches. Productivity of eggs for the more than 500m. surveyed appears to be low given the long distance involved with 111, 000 eggs in March and a much reduced number of 6,600 in April (Table **5**) which at least partially reflects flooding occurring over the period. General observations suggested that egg production in May was similar to the low levels in April, with 5 small egg patches observed along the reach. The predominant spawning vegetation used along the reach was typical of many mainstem sites with rank mercer grass, tall fescue and creeping bent predominant with areas of lotus and ranunculus where conditions were damper.

A)

B)

Figure 6: Papaiti Road–Waireka Road reach 27 March showing A) general bank profiles; B) small egg patch on steep bank marked by flag tape.

Table 5: Data summary table Whanganui River mainstem true right bank (trb): Papaiti Rd — Waireka Rd reach.

Site location: A 550 m reach that extends upstream from a point 40 m downstream of unnamed stream near 221 Papaiti Rd. E:1780142 N:5583744 to E:1780497 N:5584175

Key features: Steep (30–60°) collapsing and undercutting banks 2.5–4 m high forming irregular mounds, slumps and small—medium length benches and knobs. Limited areas of surfaces with gentler slopes under 30° on slumped areas. Sandy soil and well drained steep banks make site prone to drying. Soil and stem zone thicker and moister into later April. Spawning vegetation 20–80 cm long, dominated by mixtures of rank mercer grass, creeping bent, tall fescue with lesser amounts of lotus, ranunculus and convolvulus in damper areas. Tall fescue often central within spawning patch with other vegetation growing under and around it — providing shade. Largely free of larger willows but smaller willows and alders establishing along banks with field horsetail, some gorse, blackberry establishing in places. Rat footprints along reach, ducks fouling vegetation roosting on and tracking over spawning vegetation in places.

Month of visit	Summary	No. egg patches	Mean egg patch size(m^2)	Total area eggs (m^2)	Total no. eggs
February 2019	22 February: No spawning fish and no eggs found	n/a	n/a	n/a	n/a
March 2019	26 and 27 March: Eggs found in several patches across the reach on the diverse bank topography preferring the limited areas of reduced slope although small in horizontal extent.	6	1.03	6.225	111,468
April 2019	30 April and 1May: Eggs in fewer patches. On 30 April some eggs had been washed away or site	3	0.335	1.01	6,645

	was not able to be checked because of high water levels. One area of the bank, where eggs had been in March, had collapsed.				
May 2019	24 May: Located 5 small new patches of fresh eggs during a general check along the reach. Some of these new patches partially overlapped patches found in April. Egg densities appeared generally lower than in the April survey. Eggs were deposited higher up the bank.	n/a	n/a	n/a	n/a

5.2.5 Opposite Upokongaro reach

Results for this reach were similar to those for the Papaiti Road-Waireka Road reach a short distance downstream with spawning occurring from March through to May mostly in rank grasses in smaller widely separated egg patches (Table 6). The banks showed a similar steep profile (Figure 7A). Just one egg patch was recorded in the March survey with about 4,000 eggs and 7,700 eggs in total recorded for April in six egg patches (Figure 7B). May general observations showed eggs to be less abundant than the April survey. Rat footprints were commonly observed at the site and in May large numbers of ducks using the river margins were fouling and flattening vegetation by roosting and tracking over it. The reach is relatively free of large willows, but young willows and alders were present and horsetail, blackberry and some gorse were present along the reach. The Horizons April 2016 survey detected multiple larger egg patches along this reach.

A)

B)

Figure 7: Opposite Upokongaro reach A) general bank profile; B) Small egg patch on steep bank, lowest horizontal stake marks bottom of egg patch.

Table 6: Data summary table Whanganui River mainstem true right bank (trb): Opposite Upokongaro reach

Site location: A 270 m reach opposite Upokongaro settlement between the landing wharf and pontoon jetty. From E:1780586 N:5584919 to E:1780668 N:5584631.

Key features: Reach currently free of large willows and alders. Steep (30–60°) collapsing banks 2.5–4 m high forming irregular mounds, slumps and small benches sometimes undercut. Eggs on smaller less steep sloping areas of these larger elements. Mercer grass and tall fescue dominate vegetation with patches of creeping bent and lotus mixed in. Vegetation height 20–65 cm. Rat footprints common, more than 100 ducks disturbed from margins — significant flattening and fouling of vegetation and tracks across spawning vegetation — may cause egg losses. There is horsetail, willows, alders, blackberry and some gorse along reach.

Month of visit	Summary	No. egg patches	Mean egg patch size(m^2)	Total area eggs (m^2)	Total no. eggs
February 2019	22 February: No spawning fish and no eggs found	n/a	n/a	n/a	n/a
March 2019	26 March: One patch of eyed eggs	1	0.465	0.465	4,055
April 2019	28 April: Six patches of eyed eggs	6	0.319	1.91	7,763
May 2019	24 May: General check for egg patches along the reach. Five patches of fresh eggs were found. These were partially overlapping some April locations. Egg densities were not measured but observations showed them generally at lower density than 28 April survey.	n/a	n/a	n/a	n/a

5.2.6 Papaiti Road Middle

This reach was reasonably long at 350 m. There was one small egg patch in a tall fescue clump (Figure 8A) with a few hundred eggs. This smaller clump was located during the April survey. Eggs were found again in the same location during the general check in May. However, eggs were found nowhere else making productivity just a few hundred eggs for the reach. Steep and tall banks (Figure 8B) with limited areas of more gently sloping surfaces within the spring tide zone characterised the site. Spawning has not been recorded from this location previously (Table 7).

A) **B)**

Figure 8: Papaiti Road Middle; A) Small egg patch in tall fescue; B) Typical bank profile.

Table 7: Data summary table Whanganui River mainstem true right bank (trb): Papaiti Road—Middle

Site location: A 350 m long site, facing north-east begins opposite number 711 Papaiti Road extends to fence at 736 Papaiti Road
Key features: Approximately half the site is free of large willows or other large stature vegetation. Banks 2.5–3.5 m tall, steep -often 30–60°. With dry sandy faces, some of the collapsing bank profiles opportunistically provide relatively few small flatter- topped (15–30°) benched areas, slumps, knobs and

promontories with undercutting in places. Evidence of grazing. These occur between medium to large and sapling willows, some dead willows and old willow snags. Bank vegetation includes mix of mercer grass, tall fescue and creeping bent, horsetail (spreading), willow herb, lotus, other unidentified weeds, some small patches short Juncus. Vegetation height range 15–75 cm.					
Month of visit	**Summary**	**No. egg patches**	**Mean egg patch size(m^2)**	**Total area eggs (m^2)**	**Total no. eggs**
February 2019	Not checked	n/a	n/a	n/a	n/a
March 2019	27 March: No eggs or fish observed	n/a	n/a	n/a	n/a
April 2019	26 April: one small isolated egg patch found. (E: 175079881 N: 39850246)	1	0.018	0.018	243
May 2019	21 May: General check found eyed eggs in same single patch over similar area and density. No additional egg patches found from check of optimum looking areas nearby. Conditions still relatively dry for May.	n/a	n/a	n/a	n/a

5.2.7 Poutama Road

This site was discovered during the jet boat upstream survey on 21 May. It is the most upstream of all the mainstem spawning sites approximately 28.4 km upstream from the river mouth. Based on existing information it is the most upstream of any inanga spawning site recorded in New Zealand. Spawning occurred in thick creeping bent over approximately 5 m of a narrow flat-topped bench (Figure 9). Productivity for the patch which occupied 3.6 m² was 22,066 eggs (Table 8). Density of eggs was relatively low at 6,072/m² (Appendix 3).

Figure 9: Poutama Road. Site of egg patch showing low gradient bank with thick cover of creeping bent and mercer grass.

Table 8: Data summary table Whanganui River mainstem true right bank (trb): Poutama Road

<table>
<tr><td colspan="6">Site location: An egg patch approximately 5 m long on part of a longer bench about 20 m long, approximately 2.2 km downstream of Hipango Park (centre of egg patch E: 175.093079 N: 39.816132)</td></tr>
<tr><td colspan="6">Key features: The long narrow (approximately 1 m wide) bench has a gentle slope 5–15°. It lies at the base of a steep slope which is covered in rank grasses — with dense patches of creeping bent. No trees or other large stature vegetation shade the site. Eggs in 10–25 cm high creeping bent with small amount of mercer grass (20 cm) mixed in. Rootlet zone is well developed, lots of brown senescing stem material, soil moist with freshly deposited sediment present around root zone with some sediment coating eggs. The bench is very vulnerable to the effect of even small to medium flooding events given eggs closer to flood level from the progressively reducing tidal effects further upstream.</td></tr>
<tr><th>Month of visit</th><th>Summary</th><th>No. egg patches</th><th>Mean egg patch size(m²)</th><th>Total area eggs (m²)</th><th>Total no. eggs</th></tr>
<tr><td>February 2019</td><td rowspan="3">Not applicable, site found on 21 May</td><td>n/a</td><td>n/a</td><td>n/a</td><td>n/a</td></tr>
<tr><td>March 2019</td><td>n/a</td><td>n/a</td><td>n/a</td><td>n/a</td></tr>
<tr><td>April 2019</td><td>n/a</td><td>n/a</td><td>n/a</td><td>n/a</td></tr>
<tr><td>May 2019</td><td>21 May: New site. Un-eyed eggs found over part of long narrow bench. Eggs have dusting of sediment.</td><td>1</td><td>3.63</td><td>3.63</td><td>22,066</td></tr>
</table>

5.3 Whanganui River mainstem true left bank survey sites

5.3.1 Kowhai Park North

A series of more prominent benched areas formed from the progressive slumping of the banks along the long reach is a characteristic feature (Figure 10A), as is the predominance of rank mercer grass which covers most of the banks. The Horizons April 2016 survey located several small egg patches along the reach. During this survey no spawning was found in February or March (dry conditions noted) but was found in April and during the May general survey. During the April survey eggs were found in 11 patches of medium size (Figure 10B) with an average size of 1.74 m² and a total area of 19.17m² and productivity of 152,774 eggs (Table 10). The general survey in May showed eggs at similar locations and densities as the April survey but with eggs located about 10 cm higher up banks. In May a new egg patch was discovered at the most downstream end of the reach. This was located immediately upstream from the slipway in thick mercer grass and appears to be the most downstream location known of spawning in the mainstem Whanganui River.

A)

B)

Figure 10: Kowhai Park North reach; A) General bank profile; B) larger egg patch in mercer grass on lower gradient bank

The large number of sapling alders and willows, presence of horsetail at the downstream end of the site and the significant threat they pose to spawning vegetation was noted. Likewise, the potential impact of high use of the area by people and dogs and possible damage to deposited eggs requires some consideration. Also, while observations suggest there currently is no active trimming or spraying of spawning vegetation it is important that councils are aware of the location of spawning sites so they can be protected. Boat wakes at high tide sweep into spawning vegetation risking eggs being dislodged and elevating mortality risks. Risks and control measures should be investigated.

Table 9: Data summary table Whanganui River mainstem true left bank (tlb): Kowhai Park North

Site location: An approximately 780 m reach extending from the boat ramp: E:175.053312 N 39.915365 to the railway bridge E: 175.056723 N: 39.909744
Key features: Reach is dominated by tall (approx. 2.5–5.5 m) steeply sloping 40-60° banks, slumping and undercut in

places. Slumped areas have stabilised to form small promontories and benched areas which have reduced angles of approximately 20-40° some of which occur within spring tide zone. Mercer grass (20–75 cm) is main spawning vegetation mixed with areas of tall fescue (60–75 cm) and creeping bent (20–30 cm). Density of rootlets and stems and soil moisture increasing late March to May. Area subject to significant boat wakes which may be affecting deposited eggs. Alder and willow saplings invading reach, horsetail near ramp, high traffic from dogs and people, top of bank mowed but appears above spawning vegetation zone.					
Month of visit	**Summary**	**No. egg patches**	**Mean egg patch size(m^2)**	**Total area eggs (m^2)**	**Total no. eggs**
February 2019	21 February: No spawning fish and no eggs found	n/a	n/a	n/a	n/a
March 2019	16 and 19 March: No eggs found, no adult inanga observed. Conditions dry at soil and rootlet -stem base zone.	n/a	n/a	n/a	n/a
April 2019	23 April: Eyed eggs found across multiple larger more protruding benches/flatter slumps. Egg patches of variable size over range of vegetation types but mostly under thick mercer grass	11	1.74	19.17	152,774
May 2019	22 May One new patch of eggs 8 m upstream of the ramp in mercer grass — most downstream extent of eggs. Field horsetail patches near boat ramp are a concern if they spread into sites.	n/a	n/a	n/a	n/a

5.3.2 Reach downstream of Mateongaonga Stream mouth

This is a new location for inanga spawning. Several small to medium sized egg patches were found across the reach (Figure 12A) during each survey in March, April and May. The predominant vegetation where spawning was located was mercer grass, tall fescue and creeping bent. Egg productivity estimates for March and April were 46,502 and 34,403 eggs respectively (Table 10). Except for the absence of larger egg patches at the downstream end of the site, the May survey indicated a similar spawning pattern to April, however, eggs were observed to be deposited higher up the bank than in April with large amounts of flotsam occurring through the egg patches reflecting higher tides and greater debris. The site has been grazed and damage to the banks (Figure 12B) and pugging as well as drying out of the riparian margins was noted. Spawning vegetation including grasses and rushes had been subject to browsing. Egg survival under grazed vegetation is typically very low.

A)

B)

Figure 11: A) View of the mainstem downstream of Mateongaonga Stream, highlight indicates area where several small egg patches were found; B) 28 March view of bank area where isolated egg patches were found.

Table 10: Data summary table Whanganui River mainstem true left bank (tlb): Reach downstream of Mateongaonga Stream mouth

Month of visit	Summary	No. egg patches	Mean egg patch size(m^2)	Total area eggs (m^2)	Total no. eggs
Site location: A 280 m reach extending downstream from Mateongaonga Stream mouth. E: N: to E:1777378 N:5581588					
Key features: Area is protected from current on the inside of river bend, it has more gradual sloping profile and lower bank height than most other sites — an area of sediment deposition. It is a broken series of low (0.4–1.0 m high) narrow benches that are moderately sloping (10–30°), there are broken collapsing and undercut areas that are grazed, tracked and pugged by cattle. Spawning vegetation (15–80 cm) is predominantly a mixture of mercer grass, creeping bent, tall fescue with occasional kikuyu. Localised damper areas also have some lotus and clover mixed in. Some rushes (*Juncus edgariae*?) within the upper spring tide zone had some eggs in their bases.					
February 2019	Not checked	n/a	n/a	n/a	n/a
March 2019	28 March: Eyed eggs mainly found in small patches across the series of benches. However, there were the occasional larger patches at the more elevated downstream end of site.	7	0.539	3.775	46,502
April 2019	24 April: As above	7	0.785	5.496	34,403
May 2019	25 May: Generally fresh eggs located in the same places as the April survey but at the downstream end, eggs are not present over the larger areas of sloping bench. Flotsam across egg deposition zone.	n/a	n/a	n/a	n/a

5.3.3 Kaiwhaiki Road — Lower

Horizons April 2016 survey reported the location of two small egg patches along this reach. During this survey eggs were found only during April when one egg patch was found containing 5,182 eggs (Table 11). This site has steep banks (Figure 12) which were noted to be very dry until about April. It is uncertain if the site may have been grazed in the past.

Table 11: Data summary table Whanganui River mainstem true left bank (tlb): Kaiwhaiki Road— Lower

Site location: A 260 m south-facing reach, approximately 3.1 km downstream of Kaiwhaiki Village. From E: 175.090916 N:39.859491 to E:175.086715 to N: 39.859167
Key features: Has some large willows and large stature trees. Tall (3–4 m) banks that have collapsed to form more slumped areas of a variety of slopes from near vertical to 20–30°, with occasional small flat-topped knobs and benched areas within the spring tide zone. Soil sandy and rootlet zone dry with sparse vegetation, area becoming

moister into April and May, but overall site prone to drying. Very few suitable spawning areas. Horsetail patches are spreading down into river margin zone. Clumps of tall fescue, creeping bent in damper patches provide main potential spawning vegetation. Vegetation height range 20–70 cm.					
Month of visit	**Summary**	**No. egg patches**	**Mean egg patch size(m²)**	**Total area eggs (m²)**	**Total no. eggs**
February 2019	Not checked	n/a	n/a	n/a	n/a
March 2019	22 March: No eggs found, or adult fish observed at site	n/a	n/a	n/a	n/a
April 2019	30 April: One small patch of eyed eggs found	1	0.316	0.316	5,182
May 2019	21 May: No eggs found at optimum looking sites checked along reach. Small juncus plants (10– 20 cm) are growing vigorously on river margins	n/a	n/a	n/a	n/a

Figure 12: Kaiwhaiki Road Lower site, 30 April, showing bank features.

5.3.4 Kaiwhaiki Road — Middle

Across this long reach eggs were first found in 3 small egg patches on 1 May with aggregated production of 575 eggs (

Table 12). The 21 May general check also recorded three small egg patches. Horizons April 2016 survey reported the location of some small egg patches within the reach. Tall steep banks (Figure 13) that have slumped to form small widely spaced areas of potentially suitable spawning habitat are characteristic of the reach. The reach has been grazed and shows damage to banks and spawning habitat along the river margins.

Figure 13: Kaiwhaiki Road Middle 1 May showing bank features.

Table 12: Data summary table Whanganui River mainstem true left bank (tlb): Kaiwhaiki Road — Middle

Site location: A 700 m west-facing reach, approximately 1.5 km downstream of Kaiwhaiki village. E: 175.079803 N:39.847301 to E:175.081248 N:39.85071					
Key features: Approximately 700 m of western facing reach of true left bank, about 1.5km downstream of Kaiwhaiki Village. Reach has significant areas free of willows and other large trees. Tall (3.5–4.5 m) steep banks, collapsed to form variety of slumps of variable slopes from near vertical to 20–30°, small flat-topped knobs and promontories and benched areas between dead and regenerating willows and old snags. Cattle grazing have accelerated bank erosion and collapse and drying of the sandy soil. Field horsetail is establishing in significant patches along reach. Damper conditions occurred in May, preceding this the site was generally dry at the soil, stem and rootlet zone, clumps of tall fescue and creeping bent were the primary spawning vegetation with lotus and some Juncus in damper patches. Vegetation overall height range 10–70 cm.					
Month of visit	**Summary**	**No. egg patches**	**Mean egg patch size(m^2)**	**Total area eggs (m^2)**	**Total no. eggs**
February 2019	Not surveyed	n/a	n/a	n/a	n/a

March 2019	22 March: No eggs found, or adult fish observed at site	n/a	n/a	n/a	n/a
April 2019	No visit to site (1 May below)	n/a	n/a	n/a	n/a
May 2019	1 May: Three small patches of eggs	3	0.097	0.293	575
	21 May: General check of reach area shows 3 small egg patches with freshly deposited eggs at low to medium density (not measured)	n/a	n/a	n/a	n/a

5.3.5 Kaiwhaiki Road — Upper

Eggs were located at this site during the jet boat upstream survey on 21 May. It is the most upstream of the mainstem inanga spawning sites on the rivers true left bank and is approximately 26.8 km upstream from the river mouth. A feature of the site (Figure 14A) was its low gradient and the extent to which spawning predominantly occurred in species of Juncus in a range of egg patch sizes ranging from 0.23–9.18m² (Appendix 1) with total egg production of 92,639 (Table 13) covering an aggregated area of 13.84 m ². An interesting observation at the site was the deposition of significant numbers of eggs on the bare open surfaces amongst sparser patches (Figure 14B) of vegetation. This is likely to increase egg mortality. The site is surrounded by willows which will gradually encroach on to the spawning area and would require management to keep them under control. Horsetail is also present and represents a similar risk if it establishes thickly.

Table 13: Data summary table Whanganui River mainstem true left bank (tlb): Kaiwhaiki Road — Upper

Site location: A 20 m long area of bank north-west orientated, approximately 2.1 km upstream of Kaiwhaiki village E: 1779468 N: 5589583 approximate centre of site.					
Key features: The area within which eggs patches were found covers about 20 m length of bank. It is located at the base of a tall steep bank and is influenced by seepage from the water table in the road cutting upslope which stimulates vegetation growth and is keeping the vegetation very moist. The general area is of gentle gradient 0–15°. It appears to have been built up by deposition of fine river sediment as it is protected from the direct current. Sediment is soft and muddy with more elevated areas drier. Vegetation is distinctively different from other mainstem sites because it is heavily dominated by Juncus species – with both a short (10–30 cm) and tall species (50–70 cm) present, with just a small amount of creeping bent, horsetail and umbrella sedge mixed in. The vegetation, especially the short Juncus, is very open in places with eggs exposed within it and on the bare soil in places- mortality of eggs is likely to be high in these areas. Willow encroachment and presence of horsetail are main risks to the sites integrity.					
Month of visit	**Summary**	**No. egg patches**	**Mean egg patch size(m²)**	**Total area eggs (m²)**	**Total no. eggs**

February 2019	No eggs found, or adult fish observed at site during a preliminary reconnaissance survey in February.	n/a	n/a	n/a	n/a
March 2019	Not checked	n/a	n/a	n/a	n/a
April 2019	Not checked	n/a	n/a	n/a	n/a
May 2019	21 May: 4 egg patches ranging from large to small with freshly deposited un-eyed eggs. Some eggs deposited on bare soil surface.	4	3.46	13.84	92,639

A)

B)

Figure 14: Kaiwhaiki Road Upper 21 May; A) shows main area of concentration of eggs over low gradient bank; B) eggs deposited in sparse Juncus and on bare soil.

5.4 Whanganui River tributary survey sites

5.4.1 Matarawa Stream

This is the most downstream of the tributary sites its confluence with the Whanagnui River is approximately 8.8 km upstream of the Whanganui River mouth, it is located in Kowhai Park south within the urban zone and heavily used by the public. Whitebaiting is also popular in the stream. Matarawa Stream was the first site where spawning was found which was on 18 March, but small aggregations of adult fish had been seen near the mouth in February. As far as is known this is first time actual spawning at this stream has been recorded. The March spawning occurred in just one location at a small collapsed area of the true left bank (Figure 15) just downstream from the playground access road bridge. The site was lower, damper, flatter and had thicker more suitable spawning vegetation than anywhere else in the stream. Steep banks, heavy shade and very limited suitable spawning vegetation characterised much of the 540m reach surveyed.

Estimated egg productivity for March at the site was 41,053 eggs and with the discovery of four new egg patches in April the total productivity of eggs was estimated at 163,438 (Table 14). These new egg patches were a large one on the true right bank about opposite the true left bank site just downstream of the access road bridge and in 3 smaller patches about 50m upstream downstream of the playground bridge in tradescantia, montbretia iris and tall fescue under heavy shade. An interesting finding during the April survey was two live adult inanga trapped in the vegetation on the flat bank of the site on the true left bank –these were able to be returned to the stream.

General observations made at the site in May showed ongoing spawning at all the previous egg patches at about the same areas and density as in April. Heavy leaf fall and generally increased vegetation thickness and soil moisture made riparian areas quite wet by May.

Besides the need to protect the spawning vegetation from further invasion by willows and weeds this urban site requires more intensive management given the high use of the area. Using signs to publicise the spawning areas, the planting of native riparian species and control of invasive trees and weedy species are options to protect and enhance productivity at the site. Bank re-contouring to a more gradual productive profile may be an option as part an enhancement programme. Location of the site lends itself to involving the wider community as part of a restoration and advocacy approach (see Recommendations).

Figure 15: Matarawa Stream 23 April showing approximate area of spawning on collapsed bank area on tlb.

Table 14: Data summary table Whanganui River tributaries: Matarawa Stream site.

Site location: Matarawa Stream from Anzac Parade Bridge (near Kowhai Park south) approximately E: 1775728 N: 5578660 to Matarawa Stream mouth. Approximately 540 metres in length.					
Key features: The stream varies in width between approximately 2–5m over the reach. Stream depth varies between 0.3–1 m. at low tide. This increases by approximately 1.5 m at the Kowhai Park playground road access bridge ('playground bridge') staff gauge at high spring tide. There is good instream cover for adult inanga from woody debris and snags. The reach is heavily shaded by large exotic trees including black poplar, alder, plane trees, and willows. These create a shady canopy over most of the stream and significant leaf fall in autumn. There is an understory of bamboo, smaller willow, a few cabbage trees and coprosma. Weedy species, including tradescantia and nightshade, have developed where areas of bamboo have been removed. Ongoing vegetation control will help improve inanga spawning habitats. The site has limited suitable inanga spawning areas due to the heavy shade and the steep banks, Banks mostly about 45–70° with some limited areas at top of banks of lower angles (20–40°) and collapsed areas 0–5°. Eggs found in mix of mercer grass, creeping bent, tall fescue, willow herb and ranunculus (15–60 cm) in higher light zone; while eggs under tradescantia (trailing down bank for 1m), montbretia iris in heavier shade upstream of playground bridge.					
Month of visit	**Summary**	**No. egg patches**	**Mean egg patch size(m²)**	**Total area eggs (m²)**	**Total no. eggs**
February 2019	18 and 20 February: Small groups of adult fish were seen near mouth. Very dry under vegetation — limited stem and rootlet	n/a	n/a	n/a	n/a

	development, dry soil.				
March 2019	18 March: One large patch of eyed eggs found on a 5 m damper, flat-topped, collapsed area of the true left bank (tlb).	1	2.706	2.706	41,053
April 2019	23 April: Mixture of eyed and un-eyed eggs found in patches on both banks immediately below bridge and at 3 small patches about 50 metres upstream of bridge. Two live adults spawned out fish found stranded on flat topped collapsed bank area tlb. Conditions getting damper at soil level, vegetation thicker with better developed rootlet zone.	5	1.16	5.804	163438
May 2019	22 May: Fresh un-eyed eggs found in all patches located on 23 April. Whole reach getting damper with heavier leaf fall, vegetation thicker and taller, increased amount of decomposing stem and leaf material. Noticed carcasses of animals and rubbish deposited in stream below playground bridge.	n/a	n/a	n/a	n/a

5.4.2 Mateongaonga Stream

Horizons unpublished data indicated spawning at this site in April 2016. During this study, spawning was found at the site only in March. It extended in a long, narrow, nearly continuous band for approximately 100 m across the flatter-topped margin of the bank (Figure 16A). The band covered an area of 25.6 m² and had an estimated productivity of almost 1.05 M eggs (Table 15). The thickly developed vegetation with high density stems and rootlets and dense tradescantia (Figure 16B) supported large numbers of eggs. The stream provided good cover for adult inanga that were aggregating to spawn. Visits to the site in April and May showed that vegetation had become extremely thick and wet and no eggs were found. Key issues for the site are maintaining the spawning area free of encroaching willows and other weeds. There is also the possibility that existing vegetation may need to be cut to prevent it becoming so thick inanga cannot enter into it to spawn and to prevent them from getting trapped in vegetation when they try to leave the site. The area is popular for whitebaiting so there may be benefit in signage to increase awareness of the spawning area and prevent unnecessary damage by whitebaiters.

(A) (B)

Figure 16: A) Mateongaonga Stream 27 March highlight marks continuous egg patch along top of bank; B) Dense eggs under tradescantia at western end of spawning patch.

Table 15: Data summary table Whanganui River tributaries: Mateongaonga Stream site.

Site location: 116 metre stretch of the true right bank (trb) starting approx. 70 m upstream of Riverbank Road Bridge site: E:1777725 N:5581658 upstream to E: 1777660 N:5581593
Key features: Adjacent the site the stream has excellent cover for adult inanga from logs and smaller woody debris, undercut bank areas and overhanging vegetation. The site is oriented north and receives shading from large trees on true left bank (tlb) and the tall (6–7 m) bank at the western end of the site — where shade has promoted development of a 10 m long stretch of thick, long tradescantia. Estimated stream width at middle of site 6 m, low tide depth 0.5 m. The true right bank is free of large stature vegetation except for 2 small willows. Bank along site is about 1.5 m high and steep faced (45–60°) with some slumping, the slope reduces near the bank top 0–5° and transitions to near horizontal where the egg band was located. The flat-topped area and the long narrow margin where eggs were found is thickly covered in a mixture of rank grasses (creeping bent, tall fescue, mercer grass),

ranunculus, and convolvulus. Vegetation in March was 20–30cm long with stem and rootlets dense and thick with moist conditions and increased to about 45–50cm long in May -becoming extremely damp and thick.					
Month of visit	**Summary**	**No. egg patches**	**Mean egg patch size(m^2)**	**Total area eggs (m^2)**	**Total no. eggs**
February 2019	Not checked	n/a	n/a	n/a	n/a
March 2019	27 March: freshly deposited un-eyed eggs extend around perimeter of site but stop around 2 small willows.	3	8.54	25.64	1,049,686
April 2019	24 April: no eggs found or fish seen — vegetation thicker and very damp, increased stem and rootlet density	n/a	n/a	n/a	n/a
May 2019	25 May: no eggs found or fish seen. Vegetation even thicker and damper 45-50 cm high.	n/a	n/a	n/a	n/a

5.4.3 Un-named stream near 221 Papaiti Road

This is a new location for inanga spawning. The stream is small, incised with steep banks and has only limited areas of more gradual slope suitable for spawning. It is currently relatively free of large shading vegetation except for the area immediately downstream of Papaiti Road (Figure 17). The culvert under the road provides passage for fish and there is good cover in the stream for adult inanga especially further downstream. Rank grasses and herbaceous vegetation provided the spawning vegetation for the four very small egg patches found in March producing a total of 1,510 eggs (Table 16). No spawning was recorded in April and the May general check showed fresh spawning in the same locations as March at similar density. Small alders and willows are establishing along the stream margins.

Figure 17: Looking downstream from Papaiti Road Bridge at the unnamed stream (site number 15).

Table 16: Data summary table Whanganui River tributaries: Unnamed stream at 221 Papaiti Road site

Site location: An unnamed stream located near 221 Papaiti Road. It enters mainstem Whanganui River true right bank approx. 350 m south of Waireka Road. Centre of site: E1780148 N5583764					
Key features: Small incised stream oriented east–west, at site the stream is about 0.5- 1 m wide and 0.3 m deep at low tide. Banks are steep (1–2m high, slope 45–60°) with some slumped areas forming lower angle surfaces 25–40° higher up. While a small stream, there is reasonable cover for adult inanga with instream debris,undercut banks and overhanging vegetation present. Survey reach is relatively free of large shading trees except for the area immediately downstream of the bridge, however, young willows, poplars and alders (1–4 m) are developing further downstream. High light environment has allowed development of thick mixture (15–60 cm high) of creeping bent, tall fescue, lotus, ranunculus, convolvulus and willow herb; rootlets generally well developed with moderate stem density and moist soil.					
Month of visit	**Summary**	**No. egg patches**	**Mean egg patch size(m^2)**	**Total area eggs (m^2)**	**Total no. eggs**
February 2019	Not checked	n/a	n/a	n/a	n/a
March 2019	26 March: 4 small egg patches found with eyed eggs (centre of patches E1780148 N5583764)	4	0.071	0.286	1,510
April 2019	27 April: No eggs or fish seen. Site vegetation thickening, damp underneath.	n/a	n/a	n/a	n/a
May 2019	21 May: General check shows un-eyed eggs patches similar to March locations and similar	n/a	n/a	n/a	n/a

	numbers. Vegetation longer, thicker and damper than April.				

5.4.4 Tauraroa Stream

This is a new location for inanga spawning. The stream enters the mainstem approximately 1.2 km upstream of Mosquito Point. It is the most upstream tributary where spawning has been recorded. The stream has very tall steep banks (Figure 18A) and is heavily shaded by large trees. Three very small egg patches found during March supported a total of 598 eggs. One patch of 788 eggs was found in April (Table 17) and two small patches were found during the May survey. Tradescantia (Figure 18B) was the main plant used for spawning in this shady stream with some creeping bent and ranunculus mixed in where there was increased light. A complex series of culverts under Papaiti Road block upstream passage for fish to the significant catchment upstream; improving fish passage is highly desirable for inanga and other native fish. Control of large trees and weeds would improve the light environment in the stream, and replanting in native species could be considered.

A)

B)

Figure 18: A) Tauraroa Stream showing the steep banks and restricted area of suitable spawning habitat; B) Flag tape marks small egg patch on steep bank under tradescantia.

Table 17: Data summary table Whanganui River tributaries: Tauraroa Stream site

Site location: Enters the mainstem Whanganui River at approximately 1.2 km upstream of Mosquito Point. Centre of egg patches E: 1779290 N: 5585582					
Key features: This deeply incised stream is heavily shaded by large exotic trees (e.g. black poplar) and thick growths of woody weedy species; its banks are very steep (45–80°) and high (1.5–5 m). The stream is 1–2.5 m wide and 0.2–0.7m. deep through the site reach. Its larger flows are reflected in a complex series of large capacity, perched culverts running under Papaiti Rd that block passage for inanga and other fish. Carcasses and rubbish observed dumped into stream. Downstream of culverts, there is good cover for fish — woody debris, larger logs, undercut banks. No vegetation is growing on the steepest shady areas of bank. The few slumped and slightly benched areas of bank with slopes of about 30–40° have some egg patches, others are on very steep areas. Tradescantia is the main spawning vegetation present because of the shady light regime. Ranunculus, creeping bent, climbing dock and convolvulus grow where it is less shady.					
Month of visit	**Summary**	**No. egg patches**	**Mean egg patch size(m²)**	**Total area eggs (m²)**	**Total no. eggs**
February 2019	Not checked	n/a	n/a	n/a	n/a
March 2019	27 March: 3 small patches eyed eggs.	3	0.085	0.255	598
April 2019	April 27: 1 small egg patch	1	0.087	0.087	788
May 2019	23 May: General check shows eggs present in 2 small patches amongst tradescantia, site shady and damp.	2	n/a	n/a	n/a

6 DISCUSSION

6.1 Seasonal pattern of spawning

Of the months surveyed from February to May no spawning was found in February at any site. Spawning was recorded at most sites during March, April and May. This pattern of spawning fits within the general pattern reported for sites elsewhere in the North Island with spawning mostly concentrated over the months from March- June, but with spawning found as late as October in a few locations (Taylor 2002). Unfortunately, logistical issues prevented surveying during June so that conclusions about the extent of June spawning remain unknown and likewise for the months following. Undertaking survey work in June as part of future spawning survey work is recommended. The absence of spawning in February (assuming February spawning usually occurs in normal seasons) was not surprising given the near record-breaking hot, dry conditions and dry conditions in potential spawning vegetation and soils. Inanga like many other fish can delay their spawning (Richardson and Bowman 2005) and because of the dry conditions presumably postponed it until the March spring tide series.

At some sites such as opposite the Aramoho Cemetery spawning occurred once only in March and was not found subsequently, likewise in the tributaries surveyed, spawning occurred once only in the Mateongaonga Stream during March. The explanation for such patterns remains unknown, possibly in the case of the Cemetery site it may have become too damp — given it was a shady site, but this seems unlikely. At the very productive Mateongonga Stream site (more than 1 M eggs produced) very thick spawning vegetation on a low gradient bank was present in March and by April had further increased in height, thickness and dampness. It is possible the low gradient and thick vegetation presented a too high risk of fish becoming trapped during spawning (as was observed at the Matarawa Stream and Aramoho sites) so that spawning was abandoned. It is recommended that the condition of the spawning vegetation at the Mateongaonga Stream spawning site is monitored and maintained to ensure it remains suitable for spawning. This might be effected by weed-eating it down to a lower height well before the spawning season to allow it to recover. Succession of rank grasses to the point where they become too thick has been reported elsewhere (e.g. Taylor 2002).

At the two most upstream mainstem spawning sites where spawning was located on 21 May, monitoring the monthly use of these sites over the entire spawning season would be helpful and could form part of a broader spawning survey programme that included the relatively unexplored upper tidal zone of the river including upper tributaries (see Recommendations).

6.2 Longitudinal distribution of spawning sites

Mainstem inanga spawning sites located during the study stretched from the most downstream site on the true left bank adjacent to the boat launching ramp at north Kowhai Park (approximately 9.9 km upstream of the mouth) to the most upstream on the true right bank approximately 28.4 km upstream from the mouth near Poutama Road (about 2.2 km downstream of Hipango Park). The total distance between the upstream and downstream limits of spawning is approximately 18.5 km. These findings extend the previously known downstream limit of spawning by about 300 metres and the upstream limit by about 5.4 km further upstream. About 18.5 km (i.e. 37 km length including both banks) is a long distance within which inanga could potentially spawn and this distance may well extend further upstream given that tidal influence is reported to extend upstream for approximately 40 km.

Only a few hours on 21 May were spent exploring upstream sites by boat, so while it has highlighted the much-increased potential for upstream spawning sites it provides a limited picture. As discussed above more intensive boat-based surveys over the spawning season are recommended to more thoroughly explore the upper river reaches to get more detailed information on spawning locations and determine if spawning does occur further upstream. The advantage of the boat was its speed in covering large areas and because it provided clear views of the bank at water level height for observers. It is also recommended that sites further downstream of the boat ramp at North Kowhai Park also be checked by boat to maximise efficiency. If resources permit it is recommended that surveys extend from February until July.

The reasons for the large longitudinal distance spanned by spawning in the river relates to the rivers low gradient allowing tidal influence to penetrate about 40 km upstream. This then creates the water level change under the spring tide cycle that allows for inanga to deposit their eggs in the same way they do further downstream. At 28.5 km upstream the site on the true right bank appears to be the farthest upstream inanga spawning has been recorded in a New Zealand river.

As noted in methods the survey did not measure salinity levels to locate the upstream distance of the saltwater wedge which is often used as a reference point to guide locating spawning areas (e.g. see Taylor and Marshall 2016). This raises the question of the proximity of the wedge or salinity levels in general in relation to the finding of spawning about 28 km upstream. It is recommended that future survey work undertakes salinity measurements to locate the upstream limits of the wedge in relation to the most upstream spawning site and in relation to spawning sites located further downstream.

Of the tributaries surveyed the Matarawa Stream is the most downstream and enters the Whanganui River's true left bank approximately 8.8 km upstream from the mouth. Early and extended spawning here right through March to May possibly reflects that it is one of the first tributaries encountered by inanga living in the lower river reaches that are ' interested' in spawning and therefore may receive more attention because of this. The Mateongaonga Stream also entering on the true left bank is a further 4.7 km upstream at about 13.1 km from the mouth and attracted very heavy spawning in March only. The next two tributaries the unnamed stream near 221 Papaiti Road and the Tauraroa Stream are about 17.3 km and 20.5 km respectively upstream from the mouth. Only limited spawning was found in these two tributaries but is more likely a reflection of their poor habitat as opposed to upstream distance.

The tributaries surveyed occurred over a significant longitudinal distance, but by no means represent a comprehensive picture of tributary spawning. Particularly, the Upokongaro Stream is a priority to survey given its larger size and the smaller tributaries further downstream such as the Kaikokopu and un-named streams near Putiki and Corliss Island would also be worth investigating.

Of particular interest in terms of the upstream extent of tributary spawning is the large Kauarapoa Stream approximately 31 km upstream from the mouth and about 2.3 km upstream of the most upstream mainstem spawning site near Poutama Road. It seems likely that spawning in both the stream and at its confluence with the Whanganui River is likely to be occurring. Confluence areas are well known to be targeted for inanga spawning (e.g. Taylor 2002) and tributaries are of key importance in compensating for poor egg survival and limited spawning areas in mainstems of large rivers (e.g. Hickford and Schiel 2011). It is recommended that as part of a longer-term spawning survey programme surveys are undertaken in the streams mentioned and others as appropriate.

6.3 Light environment along riparian margins

The key feature of all the spawning locations found on the mainstem was that they were located in areas free of the very thick growths mainly of willows, alders and other weedy species. Very limited or no spawning under thick canopies of willows has been reported in other studies (e.g. Taylor 2002 and references therein). Where gap areas occurred at mainstem sites the light environment was strong enough to allow the development of vegetation of a type suitable for inanga spawning, i.e. thick and able to maintain a humid microclimate within it. This vegetation consisted primarily of rank introduced grass species — typically mercer grass, tall fescue and creeping bent and some herbaceous species — typically lotus and ranunculus with some Juncus.

From the survey and reconnaissance work done to date, areas with a strong light environment appear limited as observations showed willows alders and other woody species were adept at rapidly colonising and establishing themselves for considerable distances upstream. Therefore, control of these species and other particularly invasive ones such as field horsetail (*Equisetum arvense*) an unwanted organism under the Biosecurity Act is needed. Horsetail is progressively invading into the riparian margins and was observed penetrating into vegetation used for spawning at many spawning sites (see additional photos in Appendix 4).

The alternative to not controlling invasive vegetation will be the loss of the vegetation assemblage currently supporting spawning. This is a key ongoing management issue. There may be opportunities to undertake willow and alder control at suitable mainstem sites and trial plantings of native species in association with a mix of native and exotic grass species suitable for spawning. Likewise, in the tributaries larger invasive trees and weeds will eventually completely overtake and shade out spawning vegetation.

6.4 Spawning vegetation features

As discussed above spawning vegetation at surveyed sites was dominated by a core of rank introduced grass species — typically mercer grass, tall fescue and creeping bent and some herbaceous species-typically lotus and ranunculus with some Juncus. These species have been widely reported as being used by spawning inanga (e.g. Taylor 2002). However, having mercer grass as the often-predominant species for spawning appears to be much less commonly reported.

Mercer grass which can be seen in great profusion along the Kowhai Park North spawning reach was observed to develop very long stolons some well over a metre long and to establish a very thick mat and high stems densities (refer to Appendix 4 additional photographs) by about mid-April. It then got progressively thicker into May. While it did not develop dense rootlets the high stem densities provided an excellent humid microclimate for eggs. When rank the height (often 40–60 cm) and weight of the plants tends to pull them over into a very thick mat which can become very wet underneath providing large surface areas for egg deposition. Long mercer stems also were able to grow thickly over and down banks for long distances and provide some degree of protection of the bank from erosion. This feature saw mercer providing good cover over the broken and irregular bank surfaces at many sites.

Tall fescue appeared to be a great “anchoring” species for spawning because of its exceptional size with many plants 60–80 cm tall or higher. Besides the central stem bases and rootlet zone being favourite targets for spawning, the tall plants were able to help provide shade and shelter for other lower stature grasses and herbs. These then grew around and mixed within them to some degree and were also utilised for spawning. When egg searching, locating a tall fescue plant in the spring tide zone was very often successful in identifying an egg patch that extended into adjacent vegetation or areas of bank nearby.

At just a few locations, such as at the very large Aramoho spawning site and the Kaiwhaiki Road Upper site, Juncus species were also important for spawning. The Juncus species was the primary spawning vegetation at the Kaiwhaiki Road Upper site. The soft foliage of the smaller Juncus plants (*J. bufonius*?) seemed to be a preferred spawning target for inanga as was observed during the spawning event at Aramoho on 20 April when large numbers of fish were concentrated amongst it. However, spawning in sparsely developed Juncus with low stem densities and with a high proportion of bare soil at the root base was observed in some egg patches at Kaiwhaiki Road Upper site. Eggs deposited in this situation appeared very vulnerable to increased levels of mortality because they were poorly protected .

At the tributary sites in situations of higher light rank grasses and herbs were able to develop- such as over the extensive flat spawning area in the Mateongaonga Stream and at the Matarawa Stream spawning sites at the playground access road bridge. Otherwise the shady entrenched nature of tributary sites led to shade adapted tradescantia developing thick, long growths that were able to trail down the steep faces of banks. Spawning was found under and amongst thick tradescantia growths and reached high densities in some places. A more unusual spawning plant used under heavy tree shade at the Matarawa Stream was the iris montbretia. This species had very heavy spawning under its flattened and decomposing leaves. At the same site very heavy leaf fall from large deciduous specimen trees - plane trees and black poplar provided a thick carpet in places serving to keep very moist conditions at soil level.

Protecting spawning vegetation at spawning sites from mowing, spraying, grazing, trampling or other mechanical removal or disturbance is obviously very important, and it is recommended that a collaborative approach with the relevant controlling agencies and landowners is taken to investigate options for site protection. Inter-planting native plant species amongst exotic grasses is an option to enhance spawning vegetation while maintaining ongoing spawning in existing vegetation. Such plantings can also help signal and delimit spawning areas that might otherwise appear as 'just grass and weeds' to the general public and so get better visibility and protection. Options for protection and enhancement of spawning vegetation are discussed further in the Recommendations section.

6.5 Features of banks at spawning sites

Easily erodible soils under the impact of floods have led to tall (e.g. 2.5-5.5m.), steep (e.g. 40-70°) and often under cutting banks at various stages of slumping (e.g. 15–40° slopes over slumped surfaces) becoming predominant at nearly all the mainstem and tributary sites surveyed.

Depending on where the spring tide zone intercepted the bank the amount of suitable spawning area was highly variable. Generally areas where slumps had deformed into larger flatter topped areas (i.e. larger areas of more gentle slopes) where larger areas of spawning could occur were limited. Tall banks are also prone to drying out and erosion prone, as was noted at several locations and further accentuated by cattle grazing. When eggs are deposited on steep slopes it also exposes them to increased current velocities and the increased likelihood of them being washed away. As discussed below with respect to productivity the slope of the bank at the egg deposition zone of spawning sites was a primary factor governing egg productivity.

In terms of grazed mainstem sites, these if fenced should allow banks to stabilise and support greater areas of vegetation that assist bank stabilisation and greatly increase spawning habitat quality and egg survival. Besides this the options for re-profiling large areas of mainstem banks may be more limited. But, as discussed below, the mainstem's most productive site found at Aramoho was in fact supported by a series of long wooden retaining walls that allowed the bank to stabilise at 10-15° and optimize egg production. Other sites could be designed to emulate this, however, they would need to be carefully located and engineered not to de-stabilise adjacent banks. Other options may also include bank protection works such as gabion baskets that are set within the spring tide zone and established with material suitable to support the growth of spawning vegetation.

Re profiling of banks in small urban streams has been trialed successfully in some Christchurch waterways to improve the bank slopes for inanga spawning. Given the regular spawning in the relatively small areas of habitat in Matarawa Stream, bank re-profiling could be trialed to boost egg productivity in this stream. This could be undertaken in conjunction with other enhancements involving native plantings and control of invasive riparian vegetation (see Recommendations section). As discussed below the extent to which steep bank slopes may be affecting egg mortality could be part of work to refine egg productivity estimates. Consideration of the impact of climate change and sea level rise and the increased tidal amplitude in spawning areas will need to be factored in to both spawning vegetation plantings and other enhancements such as bank re-contouring.

Along the Papaiti- Waireka Road reach a small bank collapse where an egg patch was formerly located was noted during surveys on 1 May following flooding. This illustrates the transient nature of the spawning habitat and the very significant impact that major floods would have on both the eggs deposited during flood periods and also on banks formerly used for spawning when they are scoured away. While this impact is largely uncontrollable the impact of floods and how they affect banks and eggs would be useful additional information to have to assist in understanding the bigger picture dynamics of the inanga population and whitebait productivity levels.

6.6 Productivity of the mainstem and tributaries

The survey showed a huge variation in egg productivity across the 16 sites surveyed in the mainstem and tributaries (see summary Table 1.). The two largest sites in the Mateongaonga Stream (spawning in March only) and at the Aramoho rowing buildings site (April and May) covered extensive areas over low gradient banks with each contributing more than 1 M eggs. The extensive length of these low gradient areas was quite exceptional compared with the typical steep bank profiles. These two areas contrasted with the multiple mostly small patches of eggs (a few hundred to around 10,000 eggs) found at many sites (e.g. sites 4–7 and 10–11) covering from about 0.02-1.0 m² on collapsed banks with limited areas of gentler bank slope for egg deposition. In between these extremes were larger egg patches on longer areas of bank with less steeply sloping surfaces (sites 2,3,7 and 12). Examples of these were the benched areas along the Kowhai Park North reach (mean egg patch size of 1.7m² and productivity for April 152,000 eggs) and the benched area at the Top 10 Holiday Park boat ramp with 6.3 m² and 88,300 eggs in March and 6.9 m² and 94,290 eggs in April. Therefore, given the presence of suitable vegetation the productivity range of spawning sites located was primarily controlled by bank slope.

The purpose of estimating egg productivity at the spawning sites was to get at least a preliminary idea of the potential overall number of eggs that might be being produced at the sites located in the mainstem and tributaries over some of the spawning months. March and April were the months when egg density measurements were made while in May eggs were not counted (except at the two most upstream sites), but their extent and density were observed to be generally similar to the April survey.

Using the aggregated egg totals (Table 1) for March (1. 37 M) and April (1.46 M) and assuming May spawning produced similar egg totals to Aprils (1.46 M), then the production of eggs over the 3 months would be around 4.3 M eggs. No spawning information exists for the June period, but based on known June spawning in other streams in the region (Logan Brown pers. comm.) and more generally in the North Island then June spawning is very likely in the mainstem and tributaries. If productivity was assumed to be about 1 M eggs for June then overall egg production for March-–June for the mainstem and tributaries would be around 5.3 M eggs over the 4 months.

The discovery of large egg patches at Poutama Road (22,066 eggs) and Kaiwhaiki Road Upper (92,639 eggs) as part of the upper river survey on 21 May raises the question as to how many other such patches might exist that have been missed. If there was significant egg deposition over several months in the upper reaches then that would substantially boost overall productivity. Therefore, it is likely that the speculative estimate of 5.3 million eggs may considerably underestimate egg productivity, but only additional survey work can properly answer this question given the extent of the area to check based on the egg finds more than 28 km upstream.

Research on inanga egg productivity in other large New Zealand rivers (Hickford and Schiel 2011) suggests that because of the great extent of loss of large river spawning habitats these rivers rely on egg production in other smaller more pristine rivers to sustain their whitebait fisheries. In their study only two of the 14 large rivers they surveyed produced in excess of 1 M eggs. Compared to these larger rivers the estimate of 5.3 M eggs for the Whanganui eggs looks positive. However when compared with the Avon River in Christchurch where a total of about 14M eggs were found during 2016 (Orchard 2018) then 5.3 M eggs seems a small number of eggs for a river the size of the Whanganui. Given this and the scale of spawning habitat loss in the Whanganui – especially of the once extensive wetlands and backwater habitats that would have been protected from the floods in the main river, it seems much more likely that the Whanganui is not self sufficient in producing its “own” whitebait. Hickford and Schiel (2011) named rivers relying on whitebait produced in other rivers to sustain their whitebait harvest as population “sinks” and the rivers producing large amounts of whitebait that entered other rivers as “source” populations.

Without knowledge of the whitebait harvest, however, the scale of difference between the harvest and potential productivity cannot be determined. Currently there appears to be no quantitative information on whitebait harvest. Based on anecdotal information though the whitebait harvest in the Whanganui appears to be of a large size — likely measured in the tonnes or tens of tonnes. Given the cultural and ecological importance of inanga and the whitebait fishery obtaining this information or getting a more robust estimate of the catch level is a high priority (see Recommendations section).

Other important information needed to better understand egg productivity includes determination of the levels of egg mortality in the Whanganui River - which was not specifically addressed in this study. This requires more detailed labour intensive monitoring of the eggs to determine their survival history from the time of first deposition until they hatch. If the condition of spawning vegetation is poor at spawning sites then egg mortality can be very high. However, except for the survey sites where grazing was occurring and observations of eggs being deposited in sparse Juncus and on the bare soil in places (Kaiwhaiki Road Upper) the spawning vegetation at microclimate level appeared to be suitable to support reasonable levels of egg survival. However, without specific studies on egg mortality the question of the accuracy of egg productivity estimates will remain open and specific investigation of this is recommended. As discussed above, the bank slope at egg deposition sites would be an important additional factor to consider in investigating mortality.

Currently egg density estimates rely on very labour intensive counting of eggs in the field. Evaluating methods to simplifying and speed up this part of the process and reduce the disturbance of the sensitive egg microclimates would be very helpful to increasing the efficiency of future survey work (see Recommendations section).

An additional important matter to better quantify egg productivity is the extent to which inanga may be spawning on each of the two spring tide cycles that occur each month in the Whanganui region. The present study was able to monitor just the 2nd monthly cycle, if spawning is occurring twice each month then this could substantially increase productivity estimates. It is recommended that this question is addressed as part of future survey and investigation work. This work will need to develop methods capable of discriminating eggs deposited at each of two main spawning events in the same location.

It seems likely that the large, slow flowing Whanganui River provides very large areas of suitable habitat for the rearing of inanga whitebait to healthy adult size. However, determining the habitats used and the distribution and population features of adult inanga would help in more fully understanding their total lifecycle requirements in the Whanganui. This information could then assist in protecting adult rearing habitat and assessing the potential for improving and enhancing it (see Recommendations section).

Observations of: rats, crabs, pedestrian and dog foot traffic, duck roosting on and fouling of spawning vegetation, significant boat wakes and heavy deposition of flotsam and other anthropogenic floating material in spawning areas were other potential sources of egg mortality noted at sites. The extent to which they may impose an additional burden of mortality on eggs is unknown and could be further investigated. As discussed, the level of mortality caused by the whitebait fishery is the other key component to investigate. As observed by other authors (e.g. Orchard and Hickford 2016) there is also substantial mortality of larvae in the marine environment to consider as part of the broader full lifecycle mortality burden.

6.7 Conclusion

The current survey has helped in locating and better defining the distribution, habitat features and levels of productivity of nanga spawning sites distributed over apparently the greatest longitudinal distance of any New Zealand river. As the Whanganui is the country's longest navigable river with gentle gradients in the extensive zone under tidal influence this is probably not surprising. Unfortunately, given the large scale modification of the lower river environment and the extensive loss of inanga spawning habitat it is probable that the river may prove to be a "population sink". However, the extent to which this may be the case will not be known until significant further survey and investigation work is undertaken to better quantify the extent and location of further egg producing areas. Other important questions relating to the levels of egg mortality, extent of whitebait harvest and the extent of twice monthly spawning have been identified as key areas for further work.

For the spawning sites that have already been identified the top priority is to protect them following appropriate consultation with iwi, landowners and land managers including the Whanganui District Council and Horizons Regional Council and other interested parties. A draft list of general and site-specific recommendations   has been developed below as a "without prejudice" starting point to make progress on protection. Under the "whole catchment approach" it has been suggested that a collaborative and coordinated approach to addressing future surveying, monitoring and research needs is taken. This recognises the time and resources needed to address the Recommendations section below. This report commissioned by DOC has provided important new information on the location and productivity of spawning habitats in the lower Whanganui River system. Addressing the recommendations listed below will help achieve protection of inanga and safeguard the whitebait fishery in one of the country's most significant river systems.

7 RECOMMENDATIONS

This section discusses recommendations that apply to:

- the whole catchment
- common to the surveyed inanga spawning sites
- specific to a particular inanga spawning site
- future ongoing monitoring, research and data collection.

7.1 Whole catchment approach

These three recommendations apply to the entire Whanganui River catchment:

1. **Maintain and expand existing multi-agency initiatives** with iwi, industry, landowner and community throughout the entire catchment. Collaboration across these groups on initiatives that include fencing and planting riparian areas, restoring wetlands, improving fish-passage and controlling predators and pest plants will improve freshwater habitat conditions and water quality that will benefit inanga and biodiversity over the entire catchment.
2. **Communicate the key findings in this report to**:
    - Iwi, to get their feedback and input and to explore options for future kaitiaki collaborations
    - regional and local planning authorities to add any new locations to and revise existing biodiversity schedules to consider newly identified spawning locations and include the measures to protect them, where relevant
    - the general public, community and other groups e.g. whitebaiters, fishing clubs to raise awareness about the importance of protecting habitat and actions they can take.

3. **Investigate a collaborative approach** that engages iwi, local and regional authorities and community groups) to participate in developing a catchment-wide plan to protect inanga spawning and adult rearing habitat including integrated work programmes e.g. for survey and research, site protection and restoration and education and advocacy etc

7.2 General recommendations for spawning sites

These recommendations are common to the surveyed inanga spawning sites.

7.2.1 *Control of invasive plant species*

Issue: Suitable spawning vegetation is shaded-out by invasive plant species, e.g. willow and alder, horsetail and other weeds. Inanga will abandon these sites eventually.

Recommendation(s):

1. Implement a work programme that monitors and controls invasive plant species across all known spawning sites.

7.2.2 *Grazing*

Issue: Large animals were seen grazing at three inanga spawning sites, at Downstream of Mateongaonga Stream reach, Kaiwhaiki Road — Middle, and Papaiti Road — Middle during the survey. (other grazing currently unknown may be occurring elsewhere).

Recommendation(s):

1. Provide education to landowners about the location and importance of inanga spawning habitats on their properties.
2. Investigate funding options to support landowners to fence these habitats.

7.2.3 *Improving bank profiles for spawning*

Issue: 'Benches' that gently slope down the riverbank to the water maximise egg productivity making ideal inanga spawning locations. There are very few of these areas along the Whanganui River and tributaries.

Recommendation(s):

1. Investigate suitable locations to re-contour bank profiles, e.g. the existing re-contoured area at the Aramoho rowing buildings site is an example of what could be achieved. Use straw bales to help identify the suitability of potential areas for bank and vegetation enhancements.
2. Investigate and trial the use of gabion baskets (topped with growing media), or other bank protection structures to establish suitable spawning vegetation within.

7.2.4 *Communication*

Issue: There is a general lack of awareness of the location and importance of inanga spawning sites, and our native fish more generally.

Recommendation(s):

1. Distribute copies of this report to all landowners/land managers and councils.
2. Do 'walkabouts' with landowners to show them the spawning sites on their land.

3. Provide online access to this report, or key findings from this report on DOC and council websites and social media.
4. Create regular opportunities to share information about inanga spawning and habitat needs at relevant local community events, e.g. science society, the farmers market etc.
5. Install inanga spawning and habitat information panels at high profile spawning sites, as per recommendations for the Matarawa Stream and Aramoho rowing buildings and Kowhai Park North sites.

7.3 Site-specific recommendations

The general recommendations made in the section above should be applied to all spawning sites identified in this survey. However, the recommendations below are unique and specific to individual inanga spawning sites.

7.3.1 Matarawa Stream

Specific to this site: This is the only urban stream of the sites surveyed.

Recommendation(s): Because of its high-profile location, any inanga spawning habitat restoration work done here would be public and visible. This site could have signage to raise awareness about inanga and what they need for their populations to improve. It is also easy for the community to get to, to participate in any restoration activities. These activities could be part of a council and/or community-based habitat protection and education programmes:

- Trial re-contouring the existing bank to a gentler slope to increase egg productivity
- Use straw bales to assist in identifying suitable spawning sites for plantings and enhancements
- Native planting and invasive weeding days around the riparian and spawning areas
- Install information panels about inanga and their preferred habitat and the importance of their protection.

In addition, consider these activities to support spawning at this site:

- ensure existing vegetation management programmes, i.e. spraying and grass control, do not damage vegetation at the identified spawning areas
- control large-stature vegetation at strategic places to enhance spawning vegetation
- install “No rubbish dumping” signs and regularly monitor the area.

7.3.2 Aramoho rowing buildings reach

Specific to this site: This long, low-profile reach was the largest spawning site located during the survey and has very high productivity. As for the Matarawa Stream above, this site has high visibility — it is used daily for rowing by individuals and school groups.

Recommendation(s): As for those recommendations listed for the Matarawa Stream above. This site could also be part of council and/or community-based habitat protection and education programmes.

In addition, consider these activities to support spawning at this site:

- control the invasion of willows, alders and other weed species
- consider controlling pedestrian traffic during the peak spawning season between March—June
- install inanga spawning information panels and 'No rubbish dumping' signs
- plant suitable native species to delineate the spawning habitat and improve other biodiversity values and aesthetics
- monitor spawning and effectiveness of any protection measures implemented.

7.3.3 Kowhai Park North

Specific to this site: This is a long reach with larger egg patches scattered throughout its length. As for the Matarawa Stream and Aramoho rowing buildings sites above, this site has high visibility — it is used daily for recreational purposes.

Recommendation(s): As for those recommendations suggested for the Matarawa Stream and Aramoho rowing buildings sites above. Significant boat wakes wash over the benched areas where eggs are deposited when the tide is high. These reach into the egg deposition zone increasing the risk of eggs being dislodged and becoming vulnerable to increased mortality. Reducing boat speeds and its benefits should be investigated. This site could also be part of council and/or community-based habitat protection and education programmes.

7.3.4 Mateongaonga Stream

Specific to this site: This site supported extremely high numbers of eggs. Maintaining its productivity is very important. The stream is popular with whitebaiters so could be a good location for advocacy about the spawning area and 'environmentally-friendly whitebaiting'.

Recommendation(s):

Consider these activities to support spawning at this site:

- Monitor and maintain the condition of spawning vegetation at the spawning site (may require cutting to prevent rank growth becoming to thick to allow successful spawning)
- investigate the use of this area by whitebaiters to ensure that the spawning site is not adversely affected by their activities
- investigate options to enhance the lower reaches of the stream and confluence with the Whanganui River to encourage more spawning.
- implement catchment-wide activities to improve water quality

7.3.5 Tauraroa Stream

Specific to this site: This is a very large catchment so is a high priority site.

Recommendation(s):

- Address the fish passage blockage caused by the culverts
- Install inanga spawning information panels
- Install 'No rubbish dumping' signs and monitor the area
- Consider selective control of shading trees to improve light environment to enhance spawning environment.

7.4 Recommendations for future survey[1], monitoring and research work

These recommendations propose the continuation of ongoing survey work in other areas of the Whanganui River and monitoring those sites identified in this survey. It is essential that data is collected across time and sites to support evidence-based restoration of spawning habitats.

- Monitor general spawning extent and site condition at existing mainstem and tributary sites.
- Undertake further boat-based survey of spawning in upper river reaches and upper tributaries, survey mainstem lower reaches downstream of boat ramp, ensure new spawning areas found are publicised and protected.
- Investigate the location of the saltwater 'wedge' and salinity patterns in the Whanganui River in relation to the distribution of spawning areas.

[1] Levels of future resourcing will determine the monthly extent of survey work. March–June period is recommended as core survey months for mainstem and tributary sites, the lack of information for June is a key gap to address. Surveys either side of these months would contribute useful additional information but is not critical.

- Survey further tributary sites including: Upokongaro Stream and streams in and around Corliss Island and Putiki.
- Select a suitable mainstem spawning site, e.g. Aramoho rowing buildings reach and tributary spawning site, e.g. Matarawa Stream to determine whether spawning occurs over both monthly spring tide cycles. This would inform understanding of overall egg productivity for the Whanganui River mainstem and tributaries.
- Determine levels of egg mortality at a range of representative mainstem and tributary sites to improve the accuracy of egg productivity estimates. Consider doing some of this work at the same time and location as the work on monitoring spawning over monthly spring tide cycle.
- Review methods used to estimate egg productivity to determine levels of accuracy needed , investigate options for use of simplified less invasive methods to estimate egg density and increase survey efficiency
- Investigate adult inanga distribution and rearing habitat features in the Whanganui River.
- Investigate the current harvest levels of whitebait in the Whanganui River, look at catch effort, inanga species caught and by-catch of other fish species.
- As part of longer term information gathering investigate if the following may be affecting egg mortality: rats, mice, crabs, duck roosting on and fouling of spawning vegetation, boat wakes, deposition of flotsam and other anthropogenic floating material

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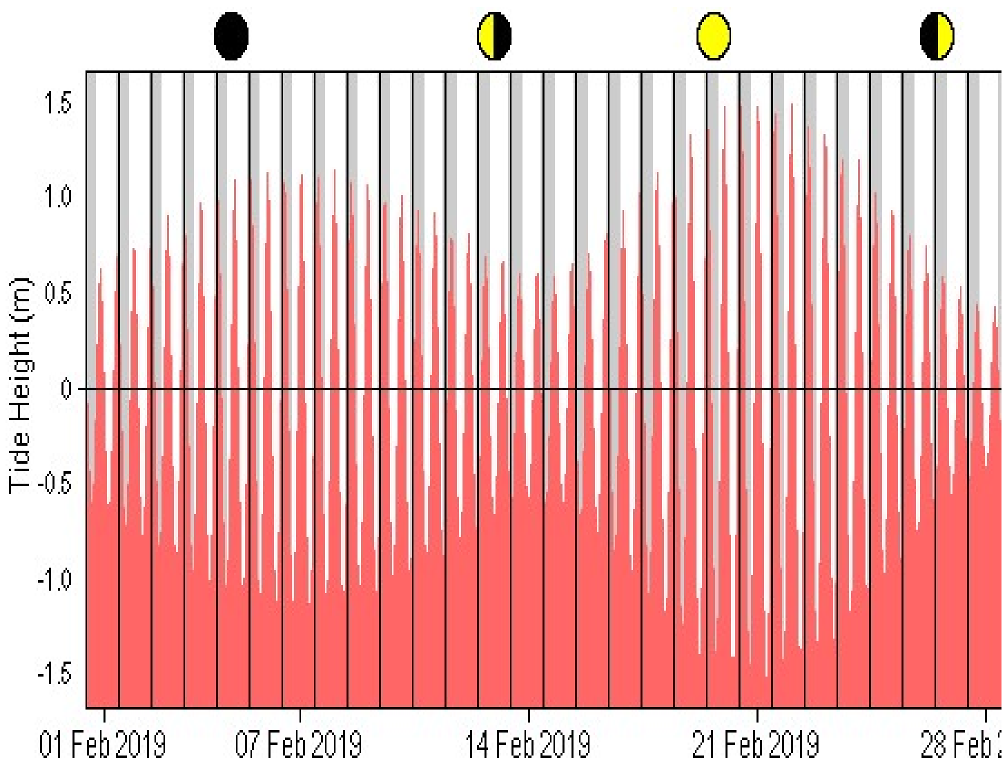
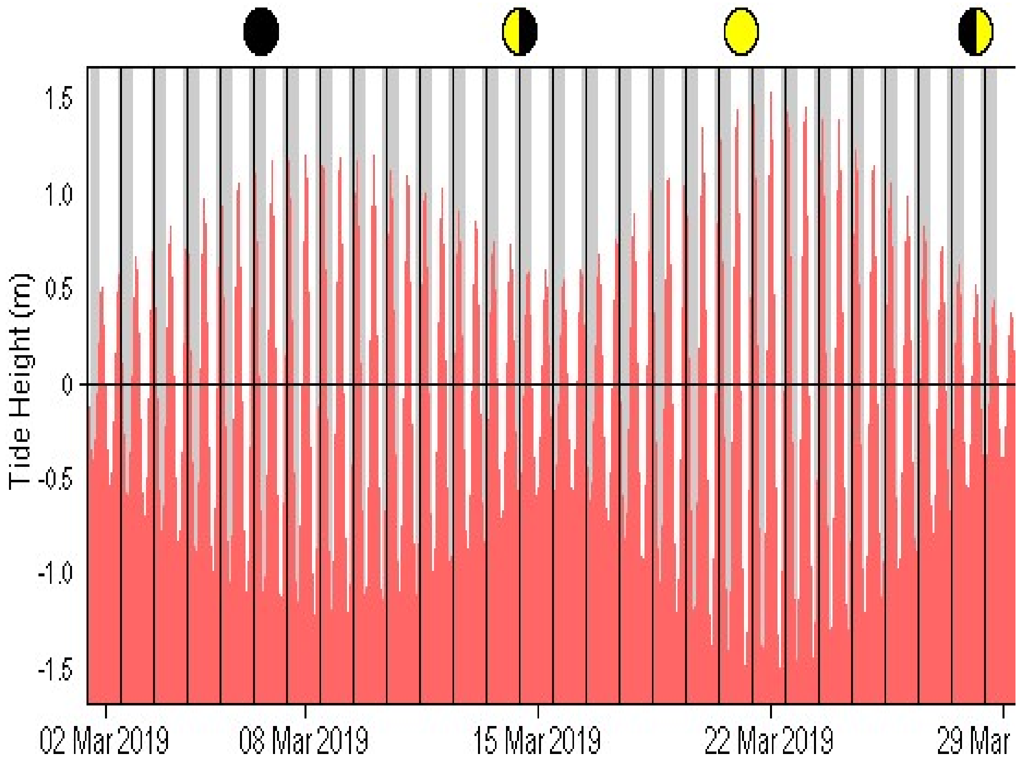
10 APPENDICES

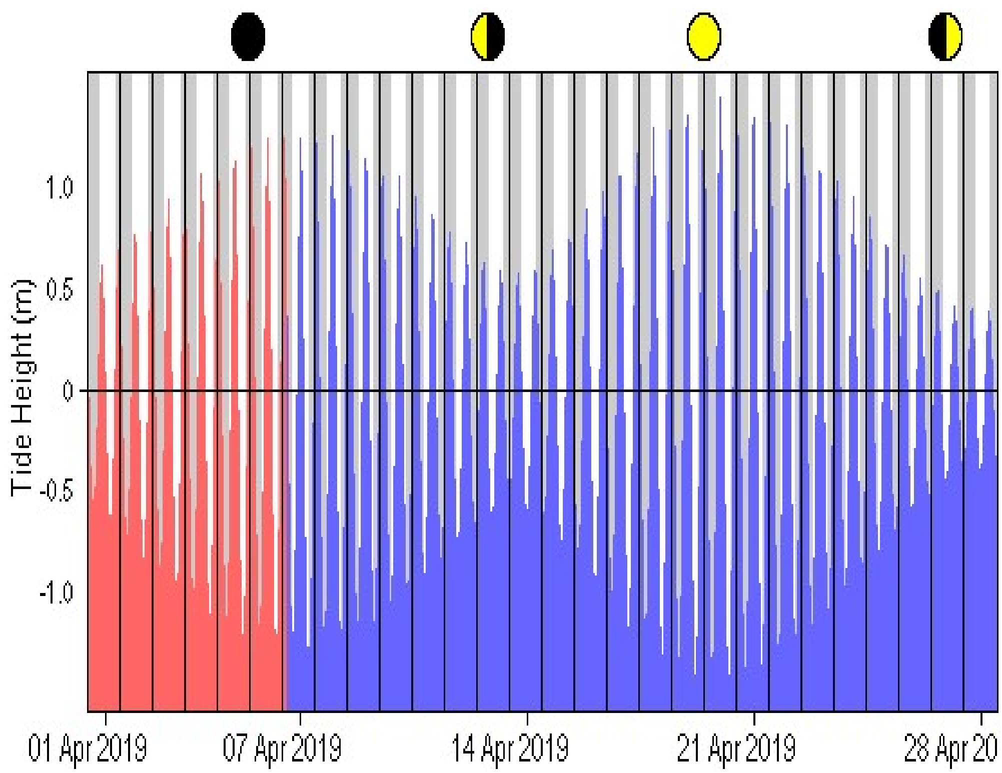
Appendix 1: Tide data for Whanganui region, February–May 2019

Note that the blue shading indicates the end of New Zealand (NZ) daylight time.

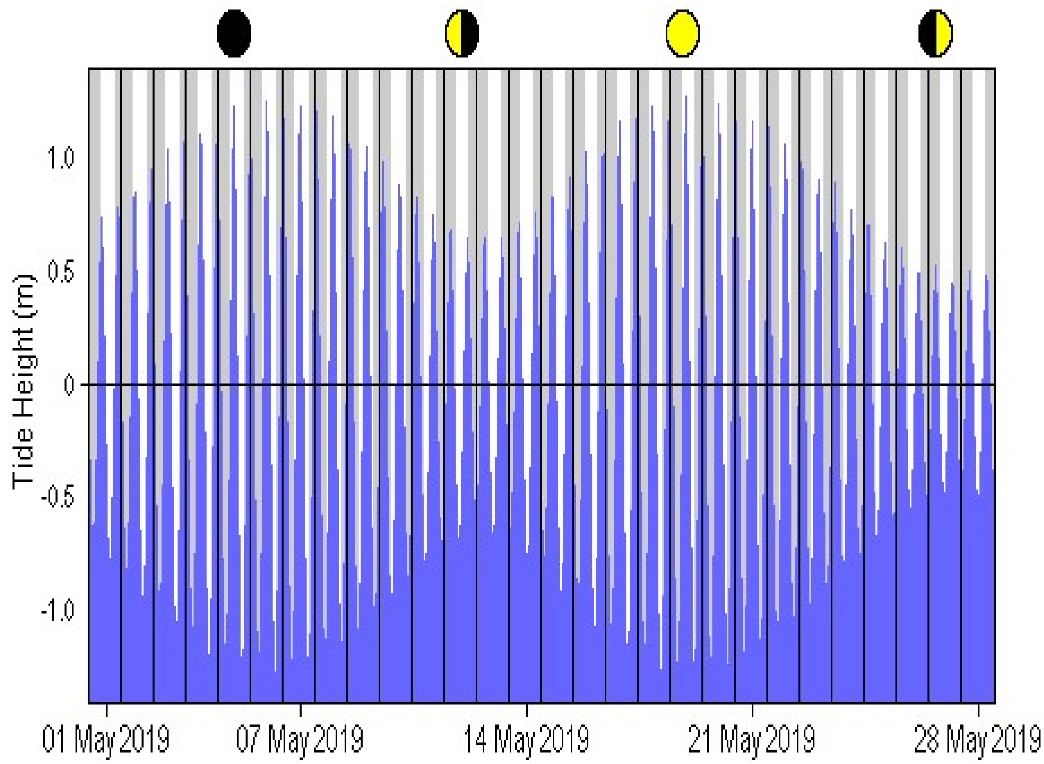




Tide Height (m)
1.5
1.0
0.5
0
-0.5
-1.0
-1.5
02 Mar 2019
08 Mar 2019
15 Mar 2019
22 Mar 2019
29 Mar



Tide Height (m)
1.0
0.5
0
-0.5
-1.0
01 Apr 2019
07 Apr 2019
14 Apr 2019
21 Apr 2019
28 Apr 20



Appendix 2: List of plant species mentioned in this report.

Common name	Species name	Common name	Species name
Pampas	*Cortaderia selloana*	**Field horsetail**	*Equisetum arvense*
Woolly nightshade	*Solanum mauritianum*	**Black alder**	*Alnus glutinosa*
Kikuyu	*Pennisetum clandestinum*	**Buttercup**	*Ranunculus repens*
Creeping bent	*Agrostis stolonifera*	**Plantain**	*Plantago coronopus*
Mercer grass	*Papsalum distichum*	**Swamp willow weed**	*Persicaria maculosa maculosa*
Tall fescue	*Schedonorous arundinaceus*	**Umbrella sedge**	*Cyperus eragrostis*
Blackberry	*Rubus fruiticosus agg*	**Dock**	*Rumex sagittatus*
Wandering Jew	*Tradescantia fluminensis*	**Gorse**	*Ulex europaeus*
Crack willow	*Salix fragilis*	**Toad rush**	*Juncus bufonius*
Lotus	*Lotus pedunculatus*	**Edgars Rush**	*Juncus edgariae*
Convolvulus	*Calystegia silvatica*	**Arum lily**	*Zantadeishica ethiopica*
Montbretia	*Cocrosmia cocrosmiflora*		

Appendix 3: Raw data sets for Whanganui River mainstem and tributaries.

See separate pdf file.

Appendix 4: Additional site photographs

See separate pdf file.