# Potential Inanga Spawning Areas in Southland Rivers

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## Technical Report

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# Executive Summary

Southland's whitebait fishery is of high value to recreational fishers and the local community in general. This fishery consists of the juvenile stages of five native *Galaxias* species; the most commonly caught is known as Inanga, *Galaxias maculatus*. This species is known to spawn on high spring tides, in the area where salt water meets fresh riverine water in the upper estuary or lower river (commonly known as the 'salt wedge'). Eggs are deposited in root mats, on grass stems, or at the base of ground-storey layers of riparian vegetation, just below the water line. As the tide recedes, these eggs are left to develop aerially which places them at risk from terrestrial impacts such stock trampling, desiccation, and UVB exposure. Hatching occurs as the next spring tide re-submerges previously deposited eggs, and flushes newly-hatched larvae out to sea. Larvae develop at sea, or in an estuary, and return a few months later in schools of what are commonly known as whitebait. The aim of this report is to identify areas of New River, Jacob's River, Waikawa, and Fortrose catchments that exhibit physical characteristics required for Inanga spawning.

Surveys were carried out on the Oreti, Waikiwi, Waihopai, Aparima, Pourakino, Mataura, and Waikawa Rivers, as well as the Otepuni and Kingswell Creeks, during spring tides between late summer and early winter 2013. Field staff used a salinity meter to measure surface and bottom waters along longitudinal profiles of the above water ways. The results of this survey enabled potential spawning areas to be mapped and analysed using GIS technology. This was followed up with targeted egg searches on the Waihopai River, and Otepuni and Kingswell Creeks, to determine exact spawning sites within each identified potential spawning area.

Inanga eggs were found at two separate sites on the Waihopai River, one site on the Otepuni Creek, and four sites on the Kingswell Creek. Waihopai sites were in excellent condition, with large riparian margins, shallow battered gradients, and densely grassed banks. In contrast, the site found on the Otepuni Creek was in a heavily modified area with steep banks and relatively high salinity levels. All egg sites on the Kingswell Creek were distributed along an 80 m stretch of water with grassy banks on either side. The true left bank of this section is too steep to mow and the grass has been left to grow long, providing ideal habitat for egg development. The true right bank, however, was mowed during the 2013 season which is likely to cause significant egg mortality. Evidence of spawning activity at the above sites was first found in mid-February, and had tailed-off significantly by June.

The findings of this project present an excellent opportunity for Environment Southland to protect, and even enhance, inanga spawning habitat in the region. This is especially relevant for the Kingswell and Otepuni Creek sites, where simple management steps such as modification of the riparian mowing regime, or more elaborate solutions such as habitat enhancement, could significantly benefit inanga spawning. It is also recommended that further riparian assessments are carried out by the council to identify and protect other inanga spawning habitats within the region.

# Introduction

The New Zealand whitebait fishery is centred on the juvenile stages of five native *Galaxias* species. The adult stages of the five species live and reproduce in different freshwater environments, but larvae typically develop in the sea (Chapman, Morgan et al., 2006). Whitebaiters target the juvenile stages as they return to freshwater after 3-6 months growth at sea (McDowall, 1990).

The most commonly caught whitebait species is inanga, *Galaxias maculatus*. This species spawns in the upper estuary/lower river area (Taylor, 2002; Hickford and Schiel, 2011a). Inanga have a specialised reproductive strategy that is synchronised with the spring tide cycle. On high spring tides, usually between late summer and early winter, spawning takes place in the flooded riparian margins of tidally influenced, but low salinity, waterways (Hicks et al., 2010). The exact location is usually in close proximity to the upstream extent of penetration of salt water (the salt wedge) (Taylor, 2002). Eggs are deposited just below the high spring tide water level (Hickford and Schiel, 2011), such that they are stranded and develop aerially when the tide recedes (Benzie, 1968a; Richardson and Taylor, 2002). Terrestrial development puts the eggs at risk of stock trampling, desiccation and UVB damage (Hickford and Schiel, 2011), and when these riparian areas are heavily grazed and/or devoid of suitable vegetation, the chance of successful reproduction and egg development is low (Taylor, 2002; Hickford et al., 2010; Hickford and Schiel, 2014). As such, identifying and protecting current or potential inanga spawning areas is a proactive step towards increasing whitebait numbers.

One of Environment Southland's critical roles is to maintain the life-supporting capacity of the environment, and whitebaiting is a high value and quintessential aspect of the Southland way of life. The provision of high quality spawning habitat is critical to reproduction in fishes, and deterioration of spawning habitat reduces the life-supporting capacity of the environment. Identifying and providing for the protection of inanga spawning areas should help this species thrive and produce more fish for whitebaiters to catch.

This report identifies likely inanga spawning areas in tributaries of the New River, Jacob's River, Waikawa and Fortrose Estuaries. It also documents the likely spawning period in Southland based on local observations. It is intended as a guide for the Council's Land Sustainability team, land owners, community groups or anybody else interested in protecting and enhancing inanga spawning habitat in Southland. It builds upon the pioneering research undertaken by Vivienne Benzie in the 1960's (e.g. Benzie, 1968a), as well as the strategic identification and restoration of inanga spawning sites that began in the 1980s (see Taylor, 2002).

# Methods

## Spawning habitat

Inanga tend to spawn in the upper estuary/ lower riverine areas near the upstream penetration of the salt wedge (Fig. 1) during spring tides between late summer and early winter (Taylor, 2002). Likely spawning areas can be identified by measuring salinity along a profile of the lower riverine areas during spring tides, so as to identify the location of this salt wedge (Richardson and Taylor, 2002). Actual spawning areas can be confirmed by returning to these sites after the spring tides have passed and looking for eggs, which are usually found on the humid root mats, grass stems and other ground-storey layers of riparian vegetation (Taylor, 2002).

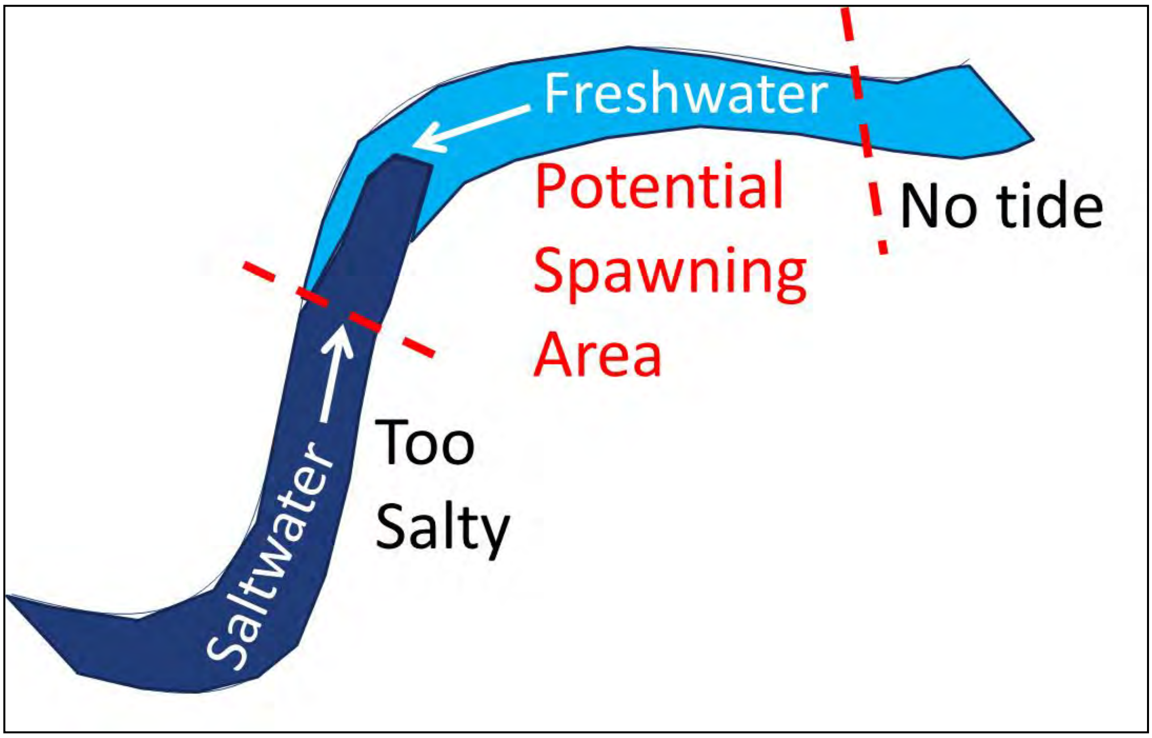


**Figure 1. Stylised schematic of potential inanga spawning area. Spawning sites are usually located in the tidal freshwater reaches of estuaries near the upstream penetration of saltwater.**

We used a conductivity/temperature meter (YSI Pro 2030) to measure the salinity of surface and bottom water as close as possible to the mid-channel flow, along profiles in the Oreti, Waikiwi, Waihopai, Aparima, Pourakino, Mataura and Waikawa Rivers, as well as Otepuni and Kingswell Creeks. The surveys were taken as near to the predicted spring tide as was practicable, although the logistical challenge of travel distances meant this was not always possible (see Table 1 for details). We did not undertake surveys during high flows because the increased freshwater discharge pushes the salt wedge downstream and may not give a good indication of the likely spawning areas. For the larger rivers (Oreti, Aparima, Pourakino, Waikawa and Mataura), salinity surveys were undertaken using a 4.3 m pontoon jet boat. For the remaining smaller rivers, salinity surveys were undertaken on foot.

**Table 1. Environmental conditions during salinity profiling in the different systems. Predicted high tide details for Bluff were obtained from LINZ. Observed tidal range is given from Waihopai River at Stead Street for all New River Estuary tributaries for the time the survey took place. River flow information relates to simulated total discharges of the respective waterways (ES hydrology), except for the Waikawa River which is based on flow at Biggar Road.**

| Estuary system | River system | Date and time surveyed | Predicted Bluff high tide level (above chart datum/m.a.s.l.) and time | Observed water level range (m.a.s.l.) | Approx river flow during survey in cumecs (median flow) |
|---|---|---|---|---|---|
| New River | Oreti River | 25/3/2013<br>12:33-14:55 | 2.7<br>12:20 | 1233-722 | 6.3<br>(40.401) |
| | Waikiwi River | 25/3/2013<br>13:53-15:04 | 2.7<br>12:20 | 1001-678 | 0.3<br>(0.692) |
| | Waihopai River | 30/1/2013<br>16:21-18:32 | 2.7<br>15:56 | 1186-561 | 0.78<br>(0.692) |
| | Otepuni Creek | 29/1/2013<br>16:03-16:58 | 2.7<br>15:16 | 1083-788 | 0.15<br>(0.275) |
| | Kingswell Creek | 9/1/2013<br>11:27-12:26<br>and<br>25/1/2013<br>15:48-16:15 | 2.6<br>14:20<br>and<br>2.5<br>12:46 | 1440-1221<br><br>and<br>340-226 | 0.35<br>(0.083)<br>and<br>0.07<br>(0.083) |
| Jacobs River | Aparima River | 22-July-2013<br>12:27-12:39 | 2.9<br>13:17 | n/a | 27.6<br>(15.674) |
| | Pourakino River | 23-July-2013<br>13:31-14:05 | 3.0<br>14:09 | n/a | 7.6<br>(5.747) |
| Fortrose | Mataura River | 24-May-2013<br>13:25-14:20 | 2.9<br>12:57 | n/a | 41.2<br>(72.415) |
| Waikawa | Waikawa River | 25-July-213<br>16:25-16:47 | 2.9<br>15:50 | n/a | 4.95<br>(2.8)* |

*** Flow data from Waikawa River at Biggar Road is limited; hence the median flow for this site may be inaccurate.**

The tidal influence of an estuary extends upstream of the salt wedge and may still contain potential spawning areas. The position of the salt wedge on a given day can be strongly influenced by river discharge and atmospheric factors influencing tidal surge, therefore a single salinity survey provides only a rough indication of where potential spawning habitat may be. Additionally, the logistical challenge of needing to cover a long reach of river to capture the salinity profile means the upstream extent of the salt wedge on a given tide may be missed. As such, we also attempted to measure the extent of the tidal influence in the smaller rivers (Waihopai, Otepuni and Kingswell Creeks). Delineating the extent of tidal influence in the lower river areas allowed us to demarcate the full potential freshwater tidal area that may be potential inanga spawning area in these creeks. This involved deploying tide staffs marked with a vertical line in blank ink that dissolved when wetted. The staffs were set at different sites along the creek with the blank ink indicating the water level before the salinity survey began. After the survey was finished, these staffs were checked to see whether any of the ink had dissolved, and to hence determine which sites had experienced a tidal water level rise. The wooden tide staffs were covered in plastic tape to prevent capillary action dissolving the ink and given a false impression of tidal activity. The staffs were only used under stable river flows, and the lapping action of the water did decrease the accuracy of this approach.

Egg searches were undertaken in the New River tributaries between February (after spent fish were observed) and July, to try and identify specific spawning sites.

## Spawning time

Inanga usually spawn in late summer and autumn, but spawning can occur over a protracted period and may be influenced by latitudinal climate patterns (Taylor, 2002; Barbee et al., 2011). We wanted to confirm when spawning activity occurred in Southland to enable flexible management of spawning areas – e.g. seasonal rather than permanent fencing of spawning habitat, or not mowing grass in urban recreational areas when eggs are (or will soon be) present (Hickford and Schiel, 2014).

### Reproductive state

One way we estimated the spawning time was by gauging the reproductive status of the population. This involved catching adult fish in lower riverine areas and trying to express their milt (for males) or eggs (for females) by gently applying pressure to their abdomens with repeated, squeezing strokes (Fig. 2). When fish are not getting ready to spawn, this stroking action will not produce any milt or eggs (i.e. if no milt or eggs can be expressed, spawning is not going to happen any time soon). When male inanga are getting ready to spawn, it is possible to express their milt, but it is quite viscous in consistency, like a paste. When spawning is imminent, their milt has a very low viscosity, like milk. Similarly, when females are getting ready to spawn it is possible to express their eggs, but the eggs are irregularly shaped and are opaque in colour. When they are just about to spawn, the eggs are more rounded and translucent. After reproducing, the abdominal area becomes concave, and the presence of skinny 'spent' fish indicate that some spawning has already occurred. It is useful to confirm spawning has already occurred before starting the very time consuming process of looking for eggs.


**Figure 2. Reproductive state of inanga can indicate spawning time. A female with eggs visible through membrane of abdomen but not able to be expressed (far left) indicates this individual is not going to spawn soon. The milky consistency of expressed sperm indicates a male that is ready to spawn (middle). And a spent fish with concaved belly indicates a female that has already spawned (gender was confirmed by looking at abdomen, i.e. not depicted here) . Note, different individuals within a population will spawn at different times, and males may spawn repeatedly over the season. All of these images were taken in early February, indicating that spawning had already taken place in this system and was likely to continue for some time.**

## Egg searches

The more direct way we estimated spawning time was by looking for freshly spawned eggs at spawning sites. When first laid, the eggs are round and clear and to the naked eye do not have any conspicuous structures inside the membrane (i.e. they look clear when held against the sky). After a few days of development the eyes of the developing embryo inside the egg become darkly pigmented (Benzie, 1968b), and can be seen as two little black specks when held up against a light background (Fig. 3). Hence, by examining the stage of egg development, we were able to determine whether spawning had only just occurred (only non-eyed eggs present at a site) or whether spawning had occurred at least a few days previously (eggs have visible black eyes). In the middle of the season, there would be clear eggs and conspicuously dark-eyed eggs present, which represented multiple spawning events over consecutive spring tides (e.g., freshly laid and 2 week old eggs). It was difficult to tell whether eggs had eyes in the field if they were covered with detritus (Fig. 3), in which case a subsample of eggs was taken back to the laboratory to confirm whether eyes were darkly pigmented under a microscope.

The eggs at spawning sites in the Waihopai River, Otepuni Creek and Kingswell Creek were repeatedly checked over the season to try to gauge the duration of the spawning activity.


**Figure 3. Inanga eggs have conspicuous eyes after a few days of development (above), which are discernible to the naked eye as twin black specks. The 1-1.5mm eggs are usually deposited amongst root mats and vegetative material (below).**

# Results

## Salinity surveys and potential spawning areas

The results of the salinity surveys are depicted in the following figures. For all figures, different coloured polygons are used to highlight areas of interest for inanga spawning. Blue polygons indicate the areas that salinity profiles indicated as potential inanga spawning habitat. The riparian habitat in these areas should be considered a high priority for protection. Green polygons indicate areas that are also likely to be potential spawning areas, but where no salinity surveys were undertaken (e.g. tributaries of the main stem downstream of the salt wedge). It would be worthwhile conducting salinity surveys on foot within the green polygons to help refine the likely spawning areas. Pink polygons are areas that may be potential spawning areas based on likely salinity patterns, but where we are not confident that the waterways involved would support breeding populations of inanga. It would be worthwhile undertaking both fish surveys and salinity profiles in these areas to confirm the presence of inanga before investing energy into spawning habitat work. In all figures, any pink shaded areas are owned by Environment Southland.

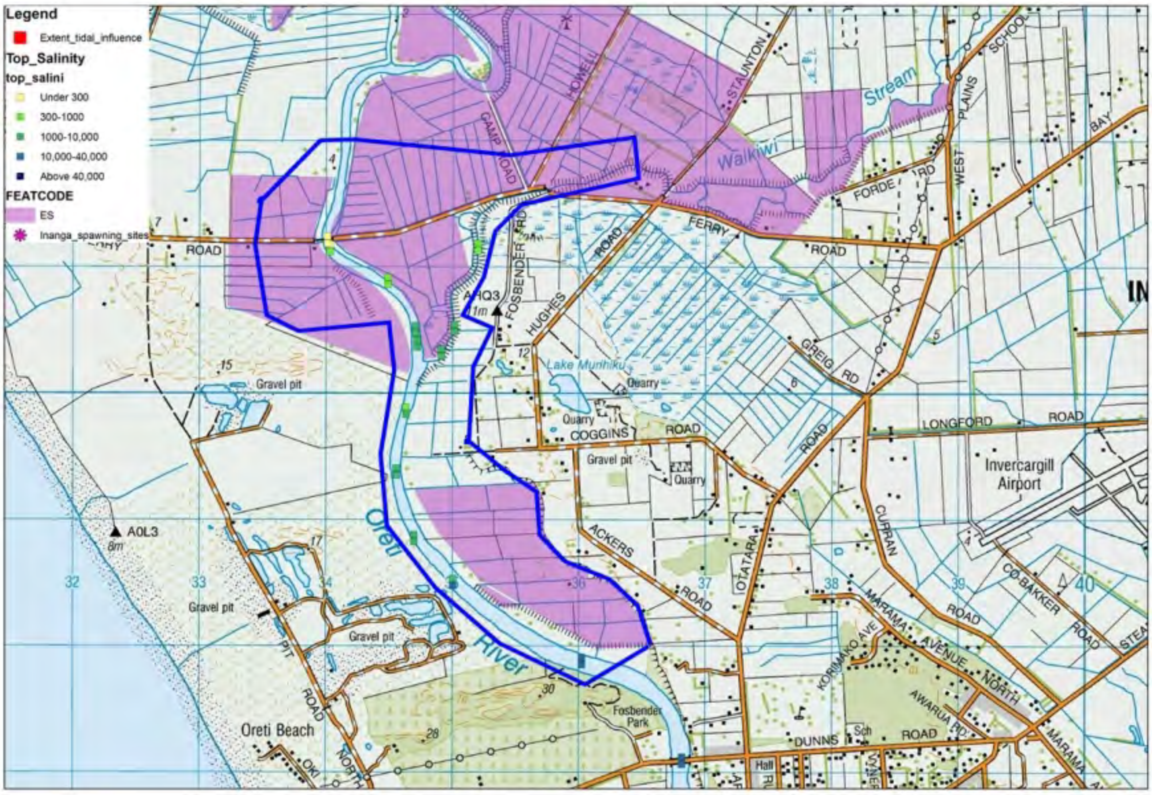


**Figure 4. Oreti River.**

In the Oreti River (Fig. 4), the tidal influence extended a long distance upstream of Ferry Road, but the high freshwater discharge probably means inanga will spawn between Dunns Road and Ferry Road, and we would give particular focus to the confluence with the Waikiwi River. The smaller drainages and tributaries that enter the Oreti downstream of the Waikiwi River should also be investigated and protected.

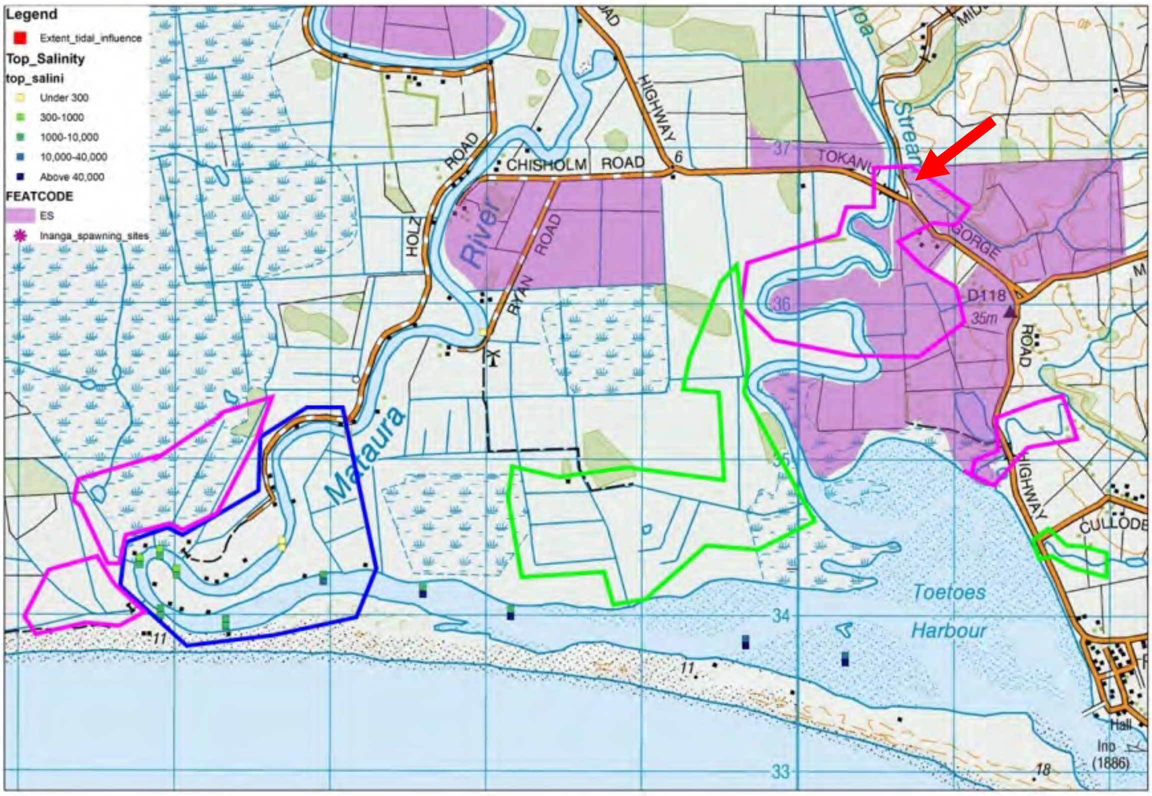


**Figure 5. Mataura and Titiroa Rivers.**

In the Mataura River (Fig. 5), saltwater only penetrated into the vicinity of the Big Bend, and so focus should be given to this area. The small tributaries that enter the river near the Big Bend may also support inanga spawning and salinity profiles of these tributaries would help refine the zone to focus upon. In the Titiroa, saltwater will not penetrate upstream of the significant tidal gate structures upstream of the Tokanui-Gorge Road Highway, but the water gets very salty on the downstream side of these gates (B. Leigh, data not shown). Because high salinity water limits fertilisation success (Hicks et al., 2010), it is unlikely the areas downstream of the tide gates would be suitable spawning habitat, which severely limits the available spawning area in this system. The red arrow in Figure 5 indicates a tributary that enters the Titiroa Stream immediately downstream of the tide gates, and this area should be a high priority as it may provide the only major freshwater-tidal area in the Titiroa system. It would also be worthwhile confirming there are no other freshwater inflows in the area downstream of the tide gate (contained within pink polygons), and investigating the smaller tributaries that enter Toetoes Harbour that may support adult inanga (green polygons).

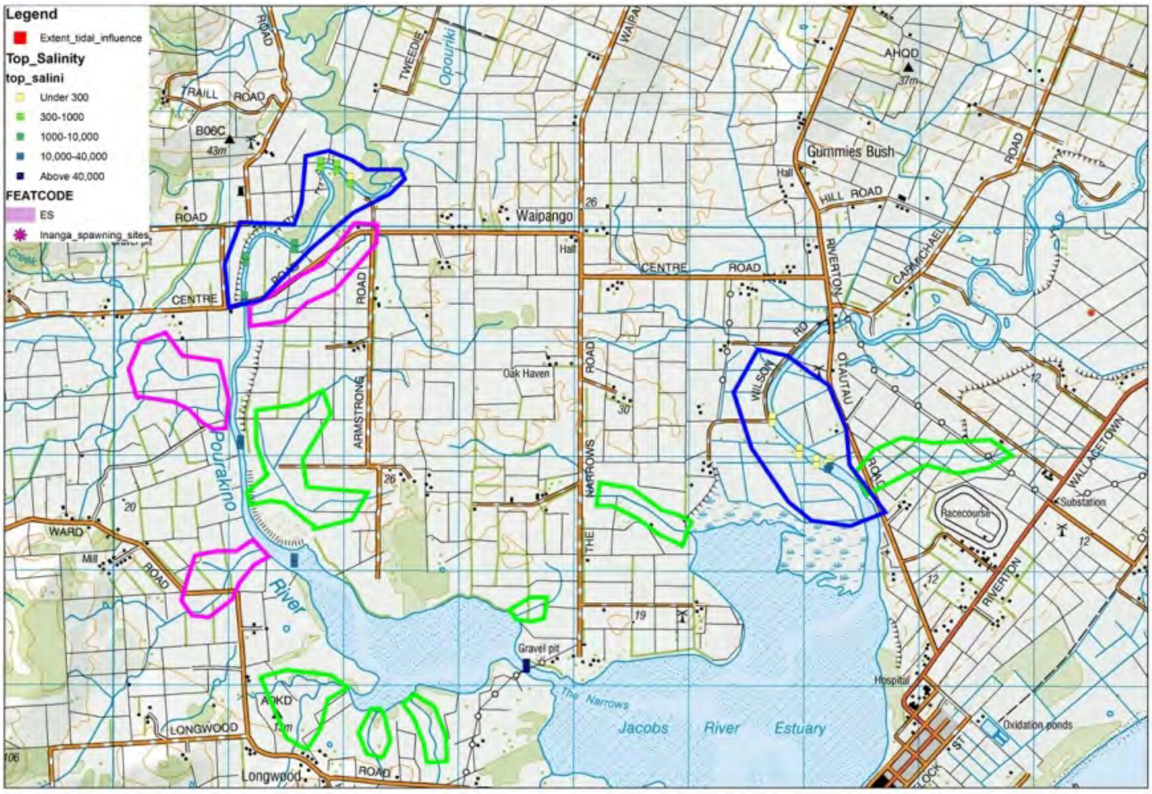


**Figure 6. Jacobs River Estuary**

The salinity gradient in the Aparima River was very abrupt (Fig. 6), and the area inside the blue polygon where the drains and tributaries enter the main river channel would be the areas to check first, as well as the main channel itself. The salt wedge was more protracted in the Pourakino River, and there are numerous smaller tributaries entering this arm that would be worth investigating further, as well as the primary area of interest within the blue polygon.

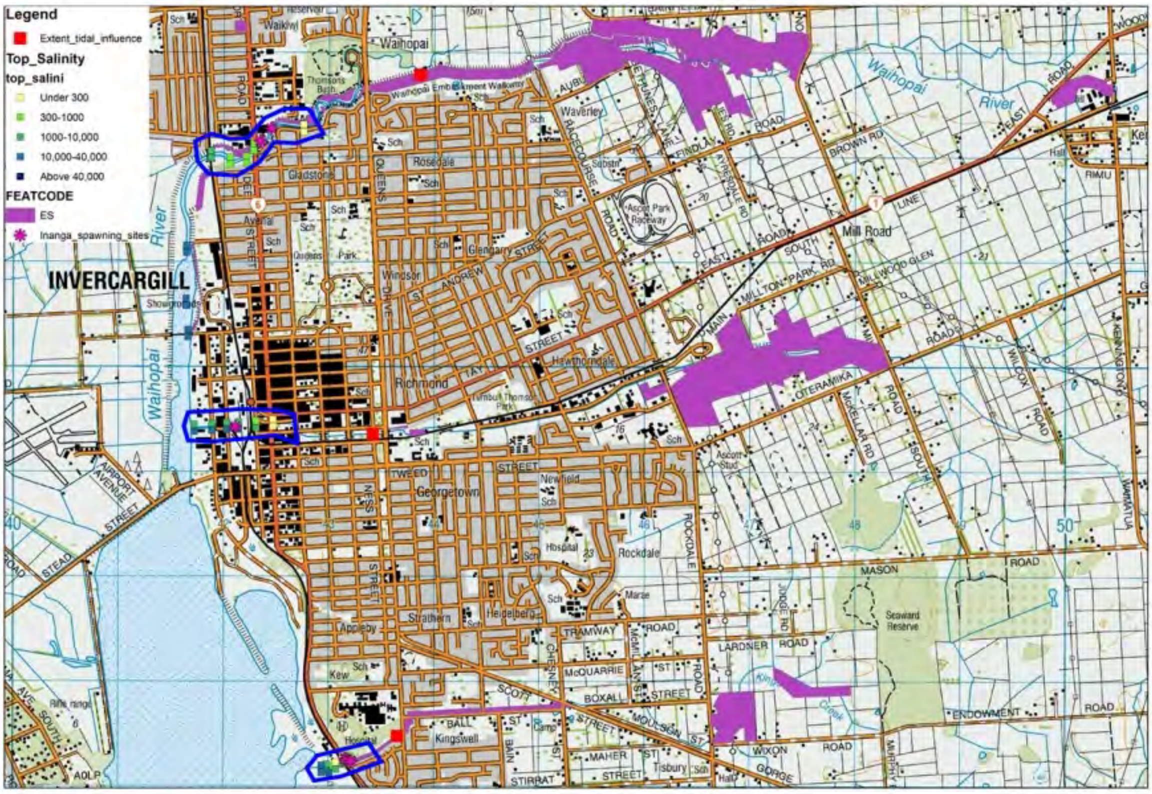


**Figure 7. Invercargill Streams (New River Estuary)**

Saltwater did not penetrate very far up the three smaller streams flowing through Invercargill City (Fig. 7), and so potential spawning areas were relatively close to the open water area of the Waihopai Arm. The area of tidal influence (i.e., red squares) identified during the surveys for the Kingswell and Otepuni Creeks were approximately 200 metres downstream of the known tidal extent (R. Wilson pers. comm.). Eggs were later found within the blue polygons in these tributaries (pink stars) which will be elaborated on in the next section.

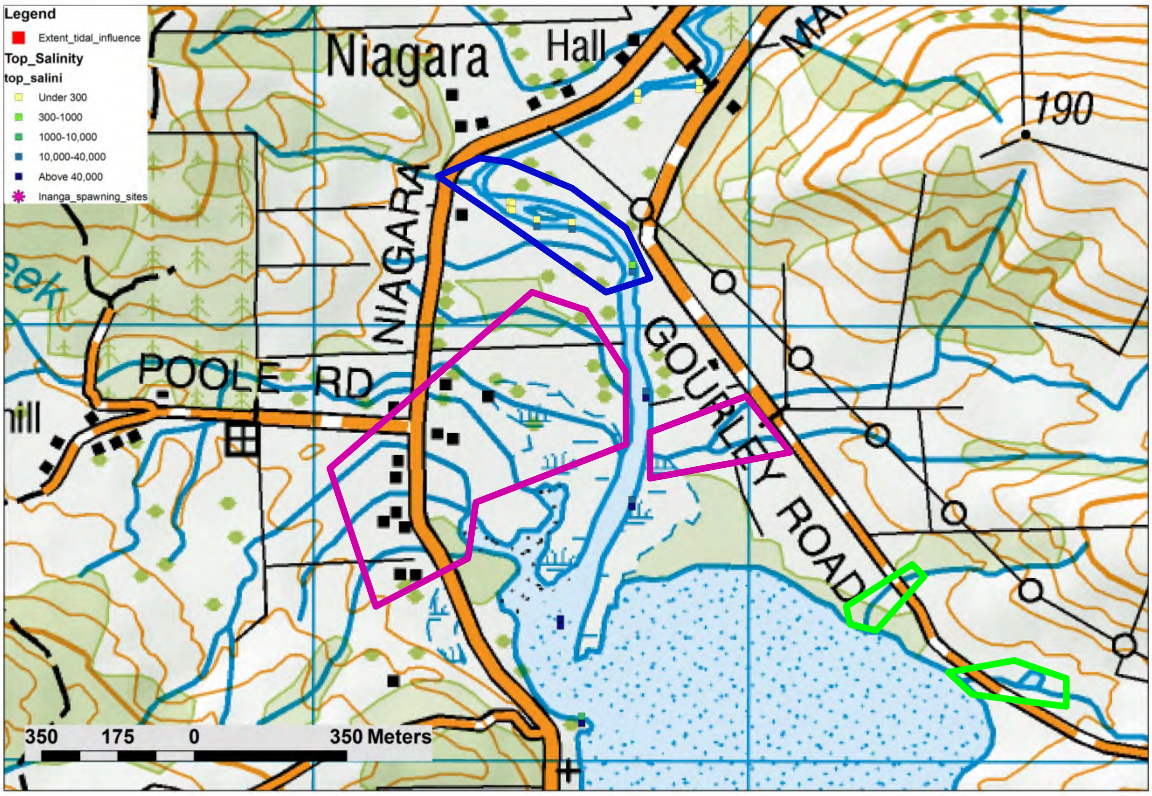


**Figure 8. Waikawa River**

The tidal influence extends to the upper Niagara Falls in the Waikawa River (Fig. 8; immediately upstream of the depicted bridge), but the saltwater influence was only observed to penetrate to the lower falls (depicted as an island), and so it is around this area that spawning is most likely to occur (blue polygon in Fig. 8). The lower tributaries should also provide spawning area, which needs to be refined further with follow up salinity surveys (pink polygons), as well as other small tributaries draining directly to the Waikawa Harbour.

# Confirmed spawning sites


Figure 9. Location of inanga eggs found on the lower Waihopai River

In general, the wide riparian margins, shallow batter and densely grassed banks provided ideal inanga spawning areas throughout the area identified as probable spawning area in the Waihopai River (Fig. 9). Eggs were later found within this zone immediately upstream of the North Road bridge on the true right bank (see pink stars in Figure 9). This is probably not the only area used for spawning in this river, but thorough searches through the entire area (particularly downstream of the bridge) were considered too time consuming and not a high priority given the excellent condition of the habitat, and because some eggs had already been found.


**Figure 10. A close-up view of the habitat where inanga eggs were found on the lower Waihopai River (immediately upstream from the North road bridge).**


**Figure 11. Location of inanga eggs found on the Otepuni Creek**

In contrast to the Waihopai River, the riparian margins of the Otepuni Creek were heavily modified throughout the potential spawning area and provided poor spawning habitat (Fig. 11). Most of the banks in the low-salinity tidal area were vertical and concreted. Nevertheless, eggs were found in a relatively salty area on the downstream side of the railway bridge complex, where grass was growing on steep banks on the true left (Fig. 11). An area was also identified that is currently poor habitat, but could be retrofitted with more suitable spawning substrate to increase the spawning potential in this system (Fig. 12).


**Figure 12. An area of the Otepuni Creek that could be retrofitted to increase spawning potential.**


**Figure 13. Egg sites on Kingswell Creek**

There were large riparian margins and dense grass covering what could be ideal spawning habitat in the Kingswell Creek (Fig. 13). Eggs were found on the true left and right banks immediately upstream of the Bluff Highway, which coincided with the upstream penetration of saltwater. However, the grass on the true right bank was mowed during the spawning period in 2013 when eggs were present. Now that we know where spawning occurs in this system, the council will alter the management of this site accordingly (see Hickford and Schiel, 2014). During site visits in November 2013, there was also discussion about potentially using this site as an environmental education project, and to engage students in trialling different management strategies to see what seems to promote the best conditions for eggs (R. Wilson and P. Hoffman, pers. comm.).

## Spawning time

Spent female fish were first found in the Waihopai River on 13 February. Freshly spawned eggs (no eyes) were first discovered in the Kingswell Creek on 14 February, and were intermittently present at this site until 7 June when only a low abundance of eyed (older) eggs could be found. Eggs were present at the Waipohai River and Kingswell Creek spawning sites from February to May, but were not present in June. Generally, spawning activity was first found in mid-February and had tailed-off by June.

# Discussion

Salinity surveys have been used to identify probably inanga spawning areas in river systems around Southland. Some actual spawning sites were also located, and mirrored the expected association between the upstream penetration of saltwater on spring tides (Richardson and Taylor, 2002). In many cases, the potential spawning area includes council-owned land, which creates an ideal opportunity for Environment Southland to identify, protect and even enhance inanga spawning habitat in the region. In some instances, no real changes would be required (e.g. excellent and expansive spawning habitat in the Waihopai River), only minor alterations may be necessary (e.g. modifying the mowing programme for the riparian strip in the Kingswell Creek spawning area) or some more elaborate solutions may be required (e.g. habitat enhancement in the Otepuni Creek).

We have put most emphasis on using patterns in salinity dynamics, rather than the location of actual eggs, to define the potential inanga spawning habitat. We have also erred on the side of more, rather than less, when defining this potential spawning area. We do this for a number of reasons: firstly, habitat degradation may prevent inanga from using an area that may be preferred under more natural conditions. Hence, concentrating on these smaller remnant areas, rather than a larger potential area, may constrain the egg production that a particular system can achieve. Secondly, short- and long-term climatic variability and sea level changes may cause temporal variation in the location of sites that are suitable for spawning. If there is only a very restricted area that is currently suitable for spawning, this may result in there being no suitable areas when conditions change. Thirdly, the habitats used by inanga for spawning are also likely to be key wetland habitat for a range of other valued species (tuna, bittern, fernbird, etc.). Protecting a larger area that may be suitable for inanga spawning will also benefit these species. In some cases this has resulted in quite large tracts of the lower river and upper estuaries being singled out for follow-up work. This may seem like a larger area than it needs to be, but it is worth pointing out that Barbee et. al. (2011) found inanga eggs over 7 km of the Yarra River in Victora, Australia, which highlights the importance of targeting large areas of potential spawning habitat to have confidence that inanga will have a high chance of reproducing successfully.

Inanga eggs were first found in February, and some eggs were still developing on the banks of Kingswell Creek into June. Therefore, if grazing or mowing is to occur within the potential inanga spawning areas, it should not occur during this time period. When combined with the recently adopted 3 m winter grazing rule, which states that all stock must be kept more than 3 m away from the edge of waterways between 1 May and 30 September, this means that riparian margins in potential spawning areas should only really be grazed between late spring and Christmas to allow grass time to re-grow before the spawning period commences (Hickford and Schiel, 2014).

The patterns of inanga spawning in southland corroborated observations around the rest of New Zealand (Benzie, 1986a, Taylor, 2002) and in Australia (Hicks et al., 2010; Barbee et al., 2011). The suggested methodology of identifying potential spawning areas using patterns in salinity appears robust and we recommend using this as a basis for the implementation of a programme of strategic and targeted riparian assessments to ensure potential inanga spawning areas in Southland are protected and/or enhanced.

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