Īnanga spawning in Takamatua Stream, Banks Peninsula

Shane Orchard

Prepared for

Christchurch City Council
May 2018

Cover photograph:
Field surveying at Takamatua Stream with members of the Takamatua Enhancement and Kaitiakitanga Group (TEK). Photo: S. Orchard

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Document revision and status

Revision	Date	Status	Approved by	Issued by
v1	28/05/2018	Draft for client review	S. Orchard	S. Orchard
vFinal	08/06/2018	Final	S. Orchard	S. Orchard

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EXECUTIVE SUMMARY

Christchurch City Council (CCC) is supporting a riparian restoration project being led by local community members in the Takamatua Stream catchment, in Akaroa Harbour on Banks Peninsula. Although the project is in the early stages of development, the major objectives include working together to enhance the ecology of Takamatua Stream, with a focus on riparian restoration and the enhancement of spawning habitat for īnanga (*Galaxias maculatus*). To support this project, a field survey of the lower Takamatua Stream catchment was completed in the 2018 īnanga spawning season. The methodology consisted of salinity measurements taken on two spring high tides, and searches of riparian vegetation for eggs using a census-style approach. The survey was conducted over two months, March and April 2018.

The upstream limit of salt water was located in a similar position on both months. This was part way up the first major riffle where the stream gradient increases markedly. Downstream of this riffle, peak salinities on spring high tides increased markedly, consistent with the relatively short distance to the stream mouth despite some stratification in the water column.

Nine īnanga spawning sites were found in the March survey, three on the true right and six on the true left bank. The sites were located between Old French Road and the first major riffle upstream, and included spawning in the same location as the only previously recorded spawning site in the catchment (found in 2012). The largest and most productive site was 12 m in length and located at the end of Old French Road. The total area of occupancy (AOO) of the March spawning sites was 4.98 m^2, with sites on the true left contributing 84%. Total egg production was 133,000 eggs with sites on the true left contributing 98%.

The April survey identified repeat use of many of the spawning sites found in March, and the overall distribution was also very similar. A new site was found on the true right bank bringing the number of individual spawning sites to ten for the study overall. The AOO for April was 4.66 m^2, and total egg production was 146,600 eggs. The spawning site at the end of Old French Road was again the largest site and contributed the most eggs.

This study has confirmed that Takamatua Stream is an important waterway for īnanga spawning, and and the information recorded will provide a useful baseline for future monitoring. All of the spawning sites identified were located within a relatively short stretch of the catchment (ca. 100 m) and it is important that this area is effectively protected to achieve conservation objectives.

Recommendations arising from these findings include:

- Continue monitoring of īnanga spawning habitat to help confirm trends and to guide the development and implementation of restoration work.
- Monitor water heights to ascertain inundation levels on the river terraces under a range of conditions (e.g. stream discharge and tidal cycle combinations).
- Collate spatial data from the above records and the footprint of confirmed spawning sites to assist with landscape design and restoration planning.
- Ensure that vegetation changes and infrastructure that may be introduced in restoration work does not reduce the quality or area of īnanga spawning habitat.
- Ensure that bank stabilisation properties of the current riparian plant community are maintained in the design of restoration strategies.

1. Introduction

1.1 Background

Christchurch City Council (CCC) is supporting a riparian restoration project being led by local community members in the Takamatua Stream catchment in Akaroa Harbour on Banks Peninsula. The groups involved include CCC, local land-owners, and the Takamatua Enhancement and Kaitiakitanga Group (TEK), a subsidiary of the Takamatua Ratepayers Association. Although the project is in the early stages of development, the major objectives include working together to enhance the ecology of Takamatua Stream, from the mouth of the stream to where it flows under the Christchurch Akaroa Road. These have recently been confirmed in a Memorandum of Understanding for the key tasks of collaboratively developing a landscape plan, and the implementation of ecological enhancements such as planting and access improvements (CCC & TEK 2018). To support this project an īnanga spawning survey of the Takamatua Stream catchment was completed in the 2018 spawning season (Figure 1).

The Takamatua stream mouth is a key locality for the local community. The enhancement of īnanga (*Galaxias maculatus*) spawning habitat is a particular focus that will contribute to the wider restoration strategy.

Specific goals of the restoration project include:

1. Improve ecological habitat and biodiversity, through:
   a. planting the riparian margin to provide dense shading and overhanging vegetation, using a variety of native locally sourced plants
   b. increasing available spawning habitat (measured over time by an increase in egg productivity and the number of sites where spawning occurs), and

2. Increase local community's awareness, engagement and 'ownership' of the stream through:
   a. collective action to enhance the stream, such as community involvement in planting and looking after the planting
   b. installation of interpretation signs about the site providing īnanga spawning habitat and the restoration project

Īnanga is a diadromous fish that spawns on riparian margins in coastal waterways (Benzie 1968). It is one of the five galaxiid species that support New Zealand's iconic whitebait fishery, in which the juvenile fish are caught during their upstream migration from the marine environment into freshwater systems (McDowall 1984). However, īnanga is currently listed as 'at risk - declining' in the New Zealand Threat Classification System (Goodman et al., 2014). Along with other threatened galaxiid species, the conservation of īnanga is a therefore a contemporary and urgent issue that is important to the sustainability of the fishery.

The degradation of riparian margins in lowland waterways has been a particular concern for īnanga conservation due to reliance on these areas for spawning habitat (Hickford & Schiel 2011a). However, there has been wide degradation of lowland waterways in recent New Zealand history, often accompanying conversion of adjacent areas to more intensive land use activities (Department of Conservation and Ministry for the Environment 2000). Particular threats include the channelisation of streams and rivers, modification of erosion and sedimentation rates, vegetation removal, and associated changes to the light, temperature and humidity environment (Hickford & Schiel 2011b; Mitchell 1994; Orchard et al. 2018a). Although addressing these threats at īnanga spawning sites is a practical focus for management, this has been hampered by relatively limited knowledge of where spawning sites occur (Taylor 2002). Recent studies in Christchurch have focussed on improving the detection of spawning through comprehensive surveys (Orchard & Hickford 2016; Orchard & Hickford 2018a), and the use of artificial habitats (Orchard et al. 2018b).

1.2 Scope and objectives

The purposes of this study were to assess egg production and distribution to determine how the stream is functioning as a spawning site, and to guide how restoration methods (e.g. planting of suitable riparian vegetation) could be carried out in the long term to enhance spawning habitat.

The scope was:

i) monitoring of Takamatua Stream to estimate īnanga egg numbers and determine whether spawning occurs in this waterway. This consisted of:
   - Monitoring of salinity during two spring tides, to determine characteristics of salt water intrusion in this waterway and spawning habitat suitability.
   - Monthly surveys of riparian vegetation during March and April to determine the distribution of spawning, including estimation of inanga egg numbers

ii) Assessment and feedback on a restoration plan for the site.

The remainder of this report is set out as follows: Section 2 describes the field survey methodology. Section 3 presents the major findings and a comparison of the results with data from the earlier survey, Section 4 provides a brief discussion of management implications, and Section 5 summarises the key conclusions and recommendations for restoration work.

Figure 1. Field survey of riparian margins for īnanga spawning sites in March 2018 with the assistance of members from the Takamatua Enhancement and Kaitiakitanga Group (TEK). Photos: Natasha Coad.

2. Methods

2.1 Study area

The project area was the lower stream margins from the stream mouth to the Christchurch – Akaroa highway (Figure 2). This area includes council owned land either side of the stream, other crown land, and private land in the riparian margin. There has been one īnanga spawning site recorded previously in the catchment. This was discovered by University of Canterbury researchers in 2012 near Old French Road (Figure 2). Spawning had occurred along 16 m of riverbank on the true left and the area occupied by eggs was approximately 3 m^2 (Mike Hickford, pers. comm.).

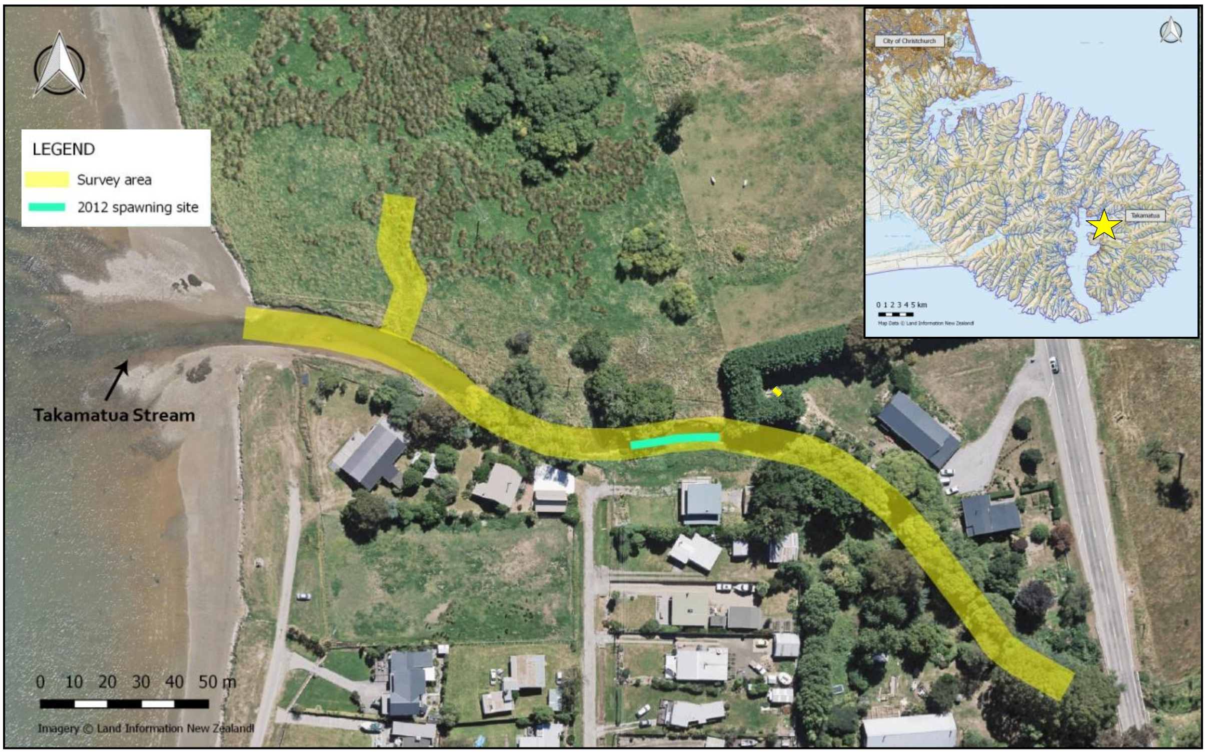

Figure 2. Location map of Takamatua Stream in Akaroa harbour showing reaches surveyed in this study and location of the previously recorded īnanga spawning site.

2.2 Salinity surveys

Salinity was measured using a YSI 30 salinity meter at regular intervals upstream from the stream mouth on the spring tides of March 1 and 31. The survey was timed to follow the incoming tide upstream following Orchard & Hickford (2018a). Measurements were taken at the bottom and 10 cm from the top of the water column at each monitoring point. Three monitoring points (centre, left and right in relation to the main channel) were measured at five locations where the stream was relatively wide. A single monitoring (centre) was measured further upstream where the stream narrowed for a total of 18 monitoring points (Figure 3).

Figure 3. Location of salinity monitoring points Takamatua Stream.

2.3 Spawning site surveys

Egg searches

Spawning site surveys were completed in March and April commencing 9-10 days after the peak spring tide sequence each month (Table 1). A census survey approach following Orchard & Hickford (2018a) was used with the objective of locating all spawning sites in the catchment. Habitat condition across the search area was first assessed in a subjective survey of the riparian vegetation, using set criteria to define areas of high, moderate and poor quality habitat (Table 2). All areas of moderate and high quality habitat were then searched systematically to detect egg occurrence. This involved conducting three searches at random locations for every 5 m length of river bank in these areas. Each search involved inspecting the stems and root mats of the plants along a transect line spanning and perpendicular to the high water mark. Typically a 0.5 m wide swathe of vegetation 1-2 m long was inspected on each transect depending on the bank slope and degree of difficulty locating the high water mark. Where eggs were found the survey was extended at least 50 m either side of the last occurrence to confirm the full extent of the spawning site.

Table 1. Tidal cycle data and egg survey periods for the 2018 survey.

Survey Month	Peak tidal cycle start	Peak tidal cycle end	Peak tidal height* (m)	Survey periods
March	Mar 1	Mar 3	2.8	Mar 13 – 14
April	Mar 30	Apr 2	2.7	Apr 11 - Apr 12

* predicted tide levels above Chart Datum at French Bay (Lat. 43° 48' S Long. 172° 58' E) (Source: LINZ).

Table 2. Habitat quality classes.

Class	Quality of habitat for supporting spawning	Expected egg mortality rate	Criteria
1	Poor	High	Vegetation cover <100% or Stem density <0.2cm^{-2}
2	Moderate	Moderate	Vegetation cover 100% Stem density >0.2cm^{-2} Aerial root mat depth <0.5cm
3	High	Low	Vegetation cover 100% Stem density >0.2cm^{-2} Aerial root mat depth >0.5cm

Classification schema

A. Vegetation cover <100% Class 1
   Vegetation cover >100% Class 2 or 3
B. Stem density <0.2cm^{-2} Class 1
   Stem density >0.2cm^{-2} Class 2 or 3
C. Aerial root mat depth <0.5cm Class 2
   Aerial root mat depth >0.5cm Class 3

Area of occupancy (AOO)

All egg occurrences were associated with a given location that was identified as a spawning site (Orchard & Hickford 2018a). Individual sites were defined as continuous or semi-continuous patches of eggs with dimensions defined by the pattern of occupancy. For all egg occurrences the upstream and downstream extents of the patch were established, and the length along the riverbank measured. GPS coordinates were recorded using hand-held units in the field and corrected in QGIS v2.18 (QGIS Development Team 2017) with the assistance of ground-truthed landmarks. For each spawning site, the width of the egg band was measured at each search transect inspected within the extent of the site. A minimum of three measurements were taken at all sites and mean width calculated from these data. Zero counts were recorded when they occurred such as where the egg distribution was not a continuous band. AOO was calculated as length x mean width.

Spawning site productivity

Productivity was assessed by direct eggs counts using a sub-sampling method (Orchard & Hickford 2016; Orchard & Hickford 2018a). At each transect, as above, a 10 x 10 cm quadrat was placed in the centre of the egg band and all eggs within the quadrat counted. Egg numbers in quadrats with high egg densities (> 200 / quadrat), were estimated by further sub-sampling using five randomly located 2 x 2 cm quadrats and the average egg density of these sub-units used to calculate an egg density for the larger 10 x 10 cm quadrat. The mean egg density was calculated from all 10 x 10 cm quadrats sampled within the site. Productivity was calculated as mean egg density x AOO.

3. Results

3.1 Salinity surveys

Salinity measurements taken on the two spring high tides sampled showed a consistent pattern in this stream. A defined salt water 'wedge' (Richardson & Taylor 2002) forms on incoming tides terminating in a relatively sharp salinity front at a major riffle where the stream gradient increases markedly (Figure 4). On the largest predicted tide that was sampled (2.8 m) the tidal flow did not reach the top of this riffle. The furthest upstream position of salt water intrusion was approximately midway 'up' this riffle at the same location of the furthest upstream spawning site found later that month (see below). Downstream of this riffle the salinity regime is relatively stratified on the incoming tide (Figure 5). A deeper stretch of the stream (the 'pool below willow') appears to influence the stratification characteristics, possibly due to the slower flow in this stretch allowing greater mixing of the bottom layer with water closer to the surface (Figure 5). Alternatively this may reflect the influence of localised upwelling at the positions where measurements were taken. The influence of a small freshwater input from a side drain on the true left can also be seen in Figure 4 near the stream mouth.

Another characteristic of the incoming tide is the presence of periodic tidal 'pushes' that have a strong influence on flow patterns and the water level. Salinity was typically observed to spike during these pushes. Measurements were generally taken to capture the maximum salinity at each monitoring site. At some sites, repeat measurements were taken at rapid intervals to ascertain the influence of tidal pushes as they came through.

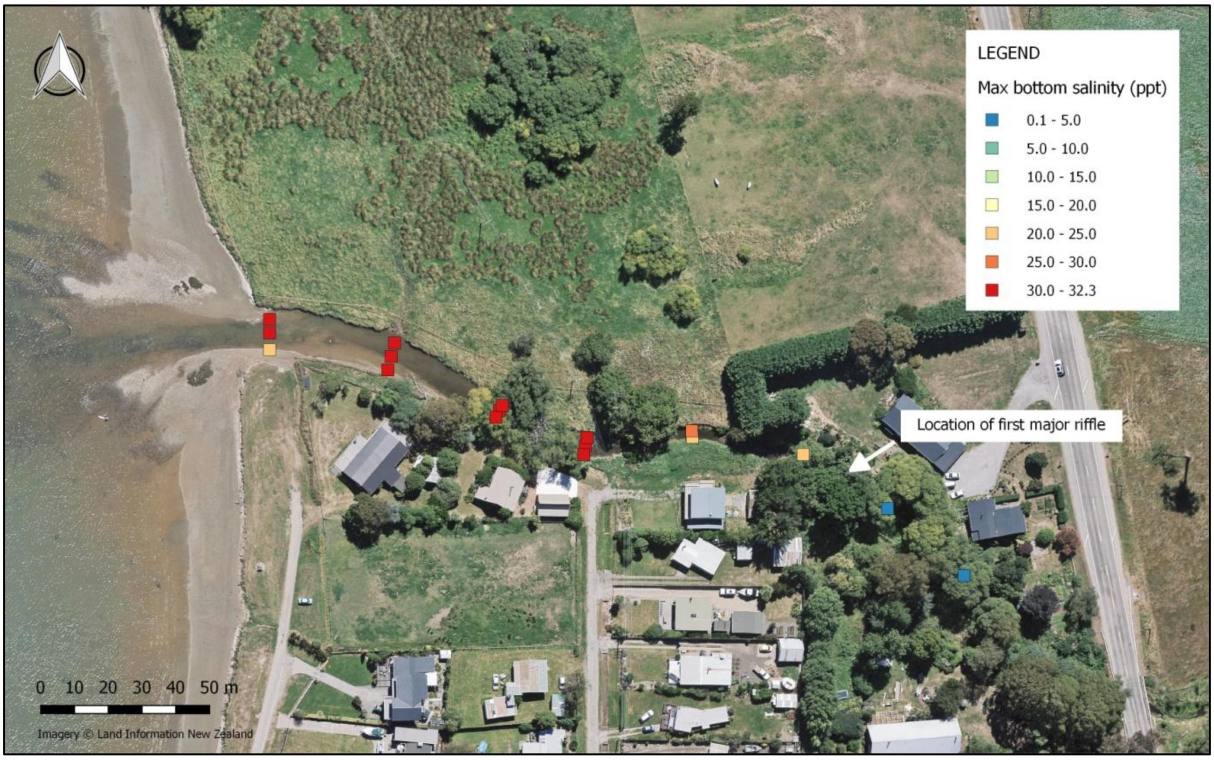

Figure 4. Typical spring high tide salinity ranges at Takamatua Stream. Data shown are the maximum bottom salinity recorded at each monitoring site on the spring high tide of 1 March 2018.

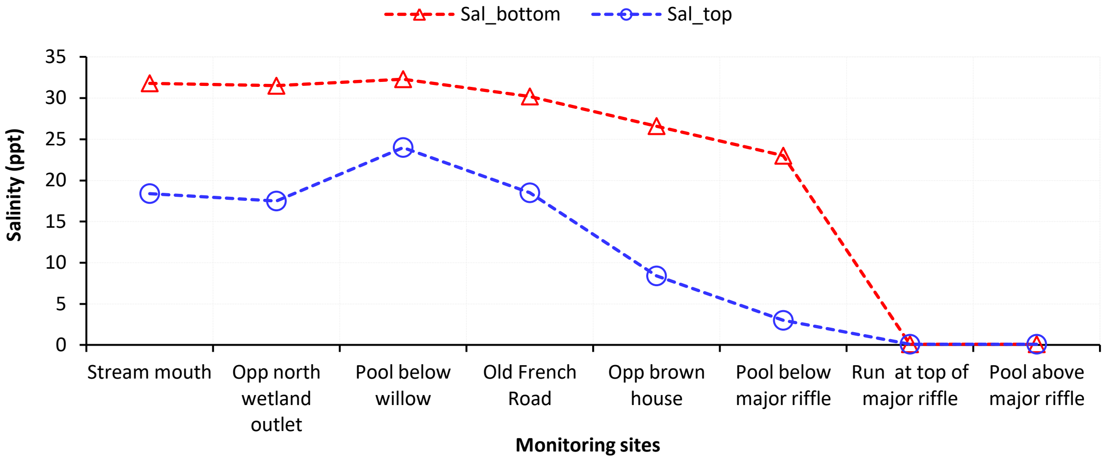

Figure 5. Plot of maximum salinity at the bottom, and 10 cm from the top of the water column, as recorded at monitoring sites in Takamatua Stream on the spring high tide of 1 March 2018.

3.2 Spawning site surveys

3.2. 1 Distribution of spawning sites

Nine spawning sites were found in the vegetation searches in March, three on the true right and six on the true left (Figure 6). All of the sites were located between Old French Road and the first major riffle upstream, and included spawning at same location as the previous record in 2012. The total length of the spawning reach was around 100 m. Repeat use of most of the March sites was observed in April. The egg band occupied a similar elevation range between months at most sites with some slightly lower (by 5–10 cm) in April. The downstream limit of spawning was the same in both months, and the upstream limit was similar (Figure 6).

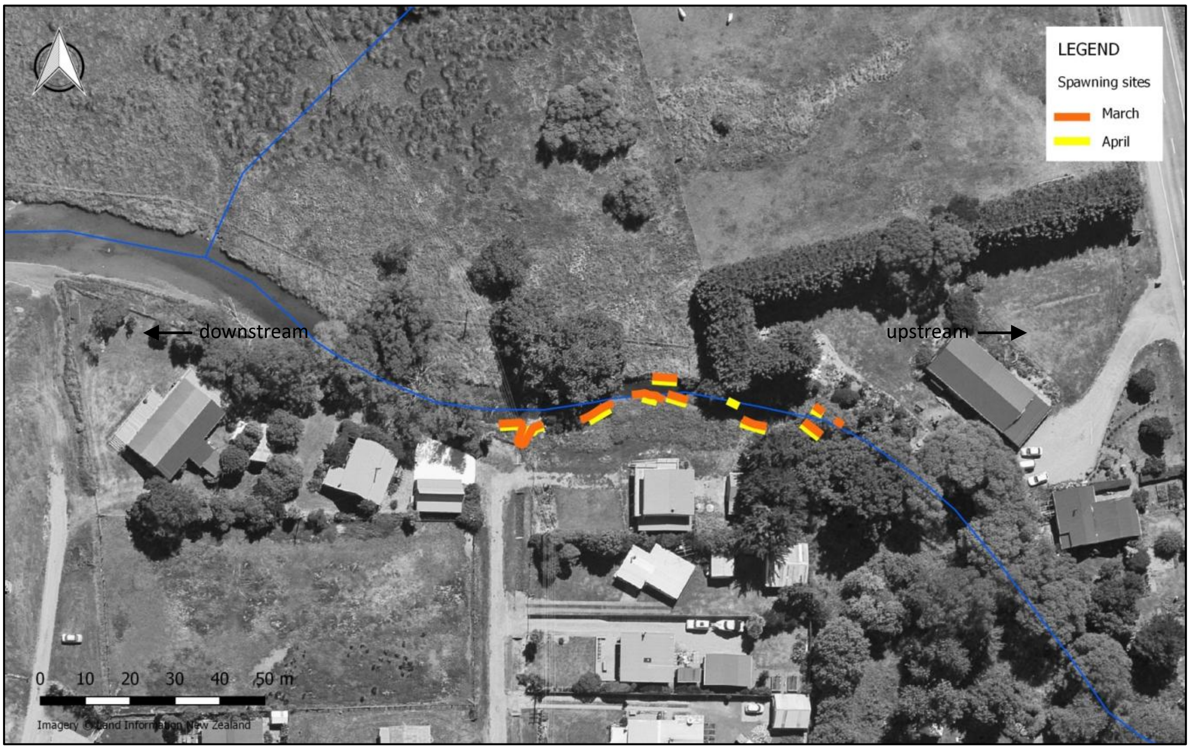

Figure 6. Location and extent of īnanga spawning sites identified in Takamatua Stream in March and April 2018.

The largest spawning site in both months was located on the true left at the end of Old French Road (Figure 7a). The site extended along the main riverbank and around the outlet of a small side drain and was the furthest downstream of all sites found. The stretch of high quality habitat extends downstream to where bank reinforcement with concrete and rubble has affected the waterway margin. Other spawning sites on the true left were located on steep banks and small ledges upstream of Old French Road (see photos in Appendix 1). Vegetation in contact with the eggs was mainly tall fescue (*Schedonorus arundinaceus*) and creeping bent (*Agrostis stolonifera*).

On the true right only small stretches of high quality habitat were found with the largest spawning site being on a section of slumped bank (Figure 7b). On this bank the vegetation is mostly sparse at the level of the high tide waterline with relatively recent bank erosion in some places.

Figure 7. Two examples of īnanga spawning sites found at Takamatua Stream in March 2018. (a) the largest site found located at the end of Old French Road on the true left. (b) a site on a section of slumped bank on the true right.

3.2.2 Area of occupancy (AOO) and egg production

The total area of occupancy (AOO) of spawning sites was 4.98 m^2 in March and 4.66m^2 in April.
In both months of the survey the true left bank supported a greater number of spawning sites and higher AOO. In March, the true left accounted for 84% of the AOO, and 85% in April. The AOO of spawning sites generally decreased towards the furthest upstream site (Figure 8). The site at the end of Old French Road (TL1) contributed the most to total AOO in both months (35% in March, 38% in April).

The total egg production in March was 133, 000 eggs of which spawning sites on the true left contributed 98%. The largest site (TL1) contributed 77% of the total eggs found (Figure 8). This site included some patches with very high egg densities (see Appendix 1B). Most of these were in the base of tall fescue plants. In April the egg production was 146,600 eggs, being slightly more than in March despite the lower AOO. On the true right, a new site (TR2) was found with relatively high egg numbers despite its small size (Figure 9). Spawning sites on the true left contributed 84%of the total. Site TL1 again contributed the most eggs (71%). The spatial distribution of egg production based on combined data is shown in Figure 10.

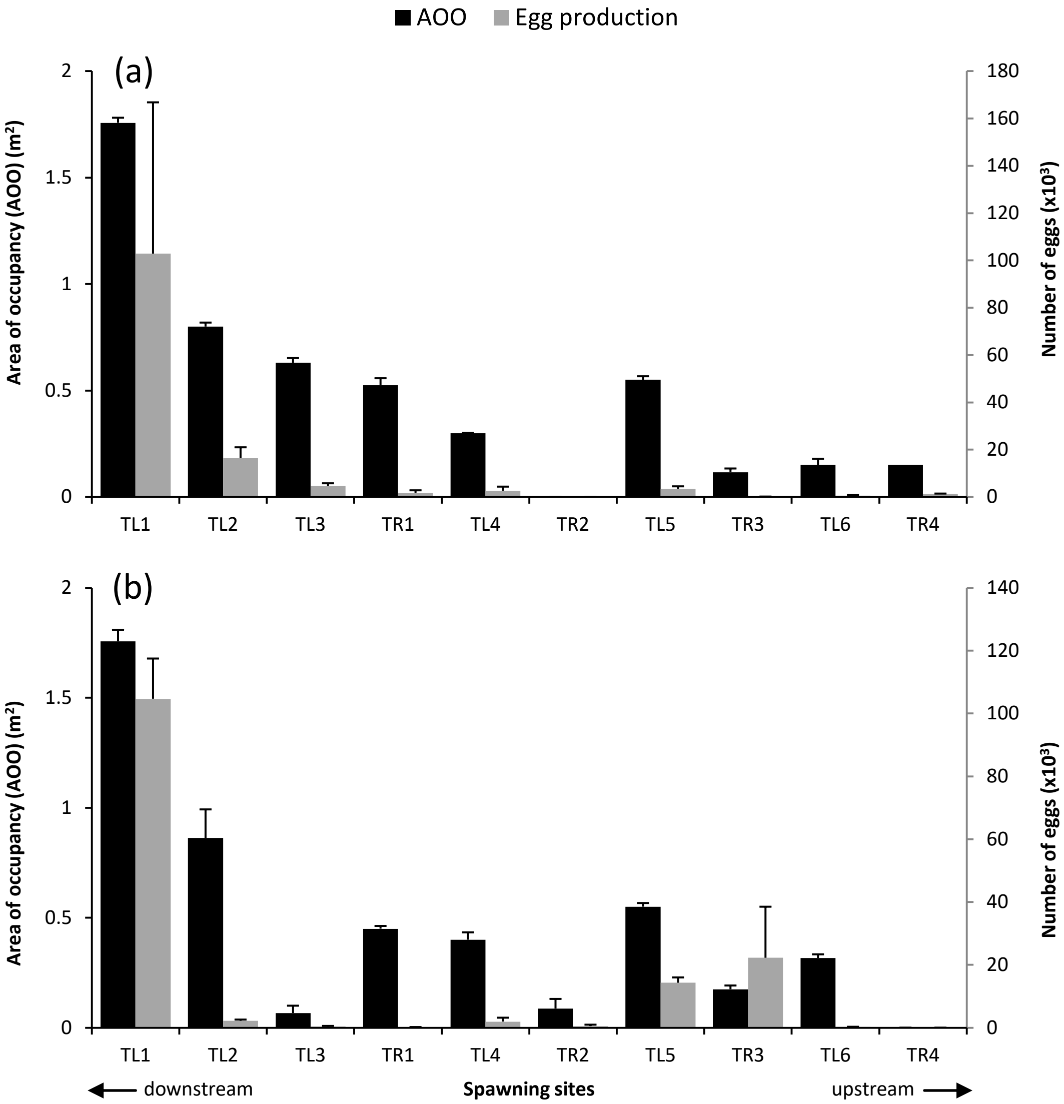

Figure 8. Area of occupancy (AOO) and egg production of ten īnanga spawning sites in the Takamatua catchment in 2018. (a) March, (b) April. All ten spawning sites found over both months of the survey are shown on the X axis. Errors bars are standard errors of the means.

Figure 9. High egg densities at a spawning site in April 2018. This site (TR2) was located on the true right in a clump of tall fescue.

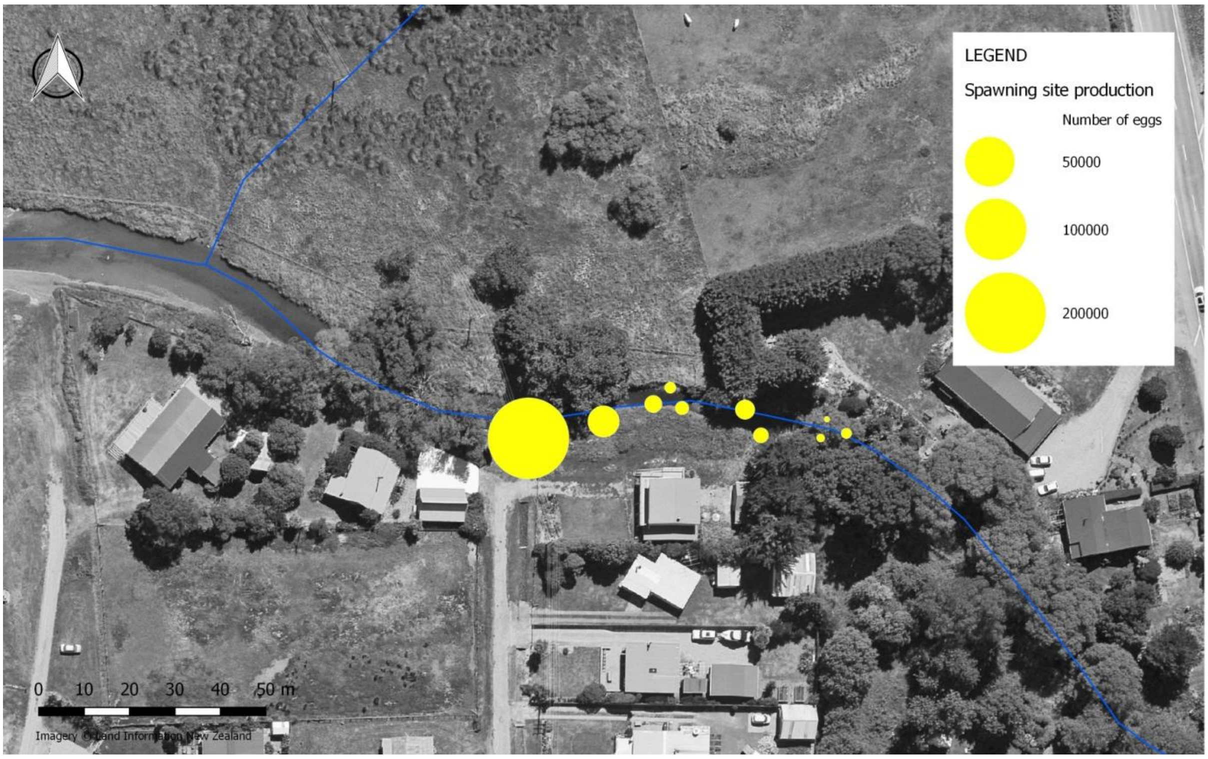

Figure 10. Spatial distribution of īnanga egg production in Takamatua Stream in 2018 showing combined totals for each of ten spawning sites recorded in field surveys conducted in March and April.

4. Discussion

This study provides a useful follow-up to the first record of īnanga spawning at Takamatua Stream in 2012. It confirms that spawning occurs in the same general location and provides further information on the upstream and downstream limits, area of occupancy of spawning sites, and the spatial distribution of egg production.

Salinity profiling results and field observations suggest that the salinity regime largely controls the spawning site distribution. There is a relatively steep salinity gradient between the stream mouth and upstream limit of salt water. Within this area, habitat conditions for īnanga spawning generally improve from the stream mouth upstream. Salinities of <20 ppt, as are required for successful egg fertilisation (Hicks et al. 2010), occur in the vicinity of Old French Road. Above here, the upstream limit of salt water is confined by a prominent riffle where the bed gradient steepens markedly. Observations on the 'king tide' in early March showed that the peak tidal water height does not reach the top of this riffle, whereas the smaller spring tides reach the bottom of this riffle. Overall, the salinity profiling results together with the spawning observations suggest that the spawning may reliably occur in this relatively short stretch of the lower catchment. To achieve īnanga conservation objectives, it is important that this area is effectively protected.

In comparing results from the two months surveyed in this study, the occurrence of spawning sites in similar locations is also notable, with the same patches of vegetation being used in both months at some sites. Many of the spawning sites were located on steep banks either on the lip of the river terrace (the 'knuckle') or on the steep bank face itself. These relatively consistent results provide a useful baseline to inform protection mechanisms and the proposed stream restoration project. Despite this, a factor to bear in mind is that the spring high tide water level was similar on the two months surveyed. The location of spawning sites may be found to have greater variation if spawning occurred at times of different water heights. This is particularly likely in areas with gentle bank gradients where small changes in inundation levels can translate to substantial horizontal shifts of the high water mark (Orchard 2017). For example, considerable variation in water levels was detected in surveys conducted over multiple months in Christchurch, for the spring high tides on which spawning occurred. This included instances where the water had over-topped the obvious (visual) line of the river bank leading to shifts in the location of the spawning sites (vertically but also horizontally) in relation to other months (Orchard et al. 2018a). In combination, these effects also suggest that suitable habitat in the vicinity of known sites should be included in the areas identified for habitat protection (Orchard & Hickford 2018b), and this is a relevant consideration for Takamatua Stream.

Restoration strategies
For the design of restoration work, threats to īnanga spawning habitat include incompatible infrastructure such as bank armouring or poorly located walking tracks, and vegetation changes that may also reduce the area of suitable habitat available. Spatial planning is the key for integrating restoration treatments with the protection or enhancement of īnanga spawning habitat.

Many spawning sites on the true left bank occurred on steep banks (>30°) buttressed by the root structure of tall fescue (*S. arundinaceus)*. Protection of the existing habitat depends, in part, on the stabilisation properties of this existing plant community. It appears to have successfully stabilised relatively steep surfaces that are otherwise exposed to erosion from period flood events. As a result, the true left bank has few signs of bank erosion at the elevation of the īnanga spawning habitat. On the true right bank more erosion is evident and this is consistent with being on the outside of a prominent bend where the substrate would be exposed to higher flows in flood events. Re-creating the current habitat structure using other plant species poses a significant restoration challenge, particularly with regards to maintaining resistance to erosion. A gradual introduction of native species into the riparian margin environment is recommended to determine the best species for different locations at the relatively fine scales involved. Monitoring is also important to ensure that spawning continues to be supported.

To assist restoration planning, further information on water heights under different stream flow and tidal conditions may also be useful. An aspect of particular interest would be to ascertain whether slightly higher water levels than were observed in this survey could occur on high tides with higher river flows. If so, it is likely that the spawning may occur higher on the terraces at some locations, especially where there is a network of small water-worn channels in the stands of tall fescue. This combination has been found to produce large and very productive spawning sites in other rivers (e.g. Orowaiti and Okari Rivers on the West Coast).

Limitations

Limitations of this study include egg detection issues that may arise from mortality between the date of spawning and the date of survey (Hickford & Schiel 2011b; Orchard et al. 2018b). This can have a bearing on the number of sites detected, the AOO observed, and the estimation of egg numbers. The duration of the survey was also insufficient for establishing seasonal trends such as total production and the months of peak activity. A longer time series of spawning data is needed for these aspects, and to facilitate comparisons between years. The relatively short distance between the harbour and the upstream limit of salt water results in a well defined search area at Takamatua. Although most of the areas of good quality habitat are easy to identify (being mainly in tall fescue), some occur in steep areas that are difficult to access. It is important to ensure that these areas are not overlooked in repeat monitoring, despite requiring more search effort to access.

5. Recommendations

Recommendations:

- Continue monitoring īnanga spawning habitat to help confirm trends and to guide the development and implementation of restoration work.
- Monitor water heights to ascertain inundation levels on the river terraces under a range of conditions (e.g. stream discharge and tidal heights). This could suit community involvement through TEK.
- Collate spatial data from the above records and the footprint of confirmed spawning sites to assist with landscape design and restoration planning. Recommended accuracy in the vertical dimension is ±1- 2 cm (e.g. RTK-GPS survey), and ±10 - 20 cm in the horizontal (e.g. field survey or photogrammetry).
- Compile information into a detailed restoration plan to assist design of the access tracks and to support the community and contractors in identifying features on the ground.
- Ensure that vegetation changes and infrastructure introduced in restoration work do not impact negatively on īnanga spawning habitat.
- Ensure that bank stabilisation and erosion resistance properties of the riparian plant community are maintained in the design of restoration strategies.
- Investigate bank profiles and vegetation communities at reference sites to help determine species mixes and placement strategies that may be useful for restoration plantings at Takamatua.
- Monitor whitebait recruitment into the catchment during and after the migration season, and consider collecting demographic information on the fish population as this is also likely to be useful for predicting trends.

6. Acknowledgements

This study was commissioning by Christchurch City Council. Particular thanks to Dr. Belinda Margetts for coordinating the fieldwork and other aspects of the restoration project. Spawning site survey data from 2012 was provided by Dr. Mike Hickford at the Marine Ecology Research Group, University of Canterbury. Thanks to members of the Takamatua Enhancement and Kaitiakitanga Group for supporting the fieldwork and many lively discussions. Some of these surveys took place on private land within the proposed restoration area which is also acknowledged.

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Appendix 1. Examples of īnanga spawning sites in the Takamatua Stream catchment.

A. March 2018 spawning sites above Old French Road. These sites are located on steep banks and small ledges near the stream channel.

Appendix 1. Examples of īnanga spawning sites in the Takamatua Stream catchment.

B. Three views of the March 2018 spawning site at the end of Old French Road on the true left (the same location as the spawning site recorded in 2012). Eggs were found in clumps along a 12 m stretch of river bank with very high egg densities in some places as shown bottom right.

Appendix 1. Examples of īnanga spawning sites in the Takamatua Stream catchment.
C. Two views of the spawning site at the end of Old French Road in April 2018. The position of the egg band was similar to the March spawning event at this site, with many of the same clumps of vegetation being used.

Appendix 1. Examples of īnanga spawning sites in the Takamatua Stream catchment.

D. April 2018 spawning sites above Old French Road

Appendix 1. Examples of īnanga spawning sites in the Takamatua Stream catchment.

E. April 2018 spawning sites near the upstream limit of salt water. (a) & (b) sites on the true right. (c) & (d) sites on the true left.