Sustainable Wild Whitebait Fishery: comparative assessment of īnanga spawning at the Punakaiki River

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Prepared for

Department of Conservation
West Coast *Tai Poutini* Conservancy
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Cover photograph:
View of the spring-fed tributary stream of the Punakaiki River that supported the majority of īnanga spawning in 2016 and 2020. The orange flags mark the location of spawning sites.
Photo: S. Orchard

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TABLE OF CONTENTS

Executive summary

A census survey of īnanga spawning activity was completed for the Punakaiki River during the 2020 summer. The survey concentrated on the known spawning location upstream of the State Highway road bridge and was designed to inform the implementation of channel enhancement works under the Sustainable Wild Whitebait Fishery (SWWF) project facilitated by the Department of Conservation. The survey period (Feb-May inclusive) also enabled comparison with a similar census survey completed in 2016.

Spawning sites were found at many of the same locations recorded in 2016. All of the known sites are located within a spring-fed tributary network and associated riparian wetland system on the true left of the Punakaiki River floodplain, as was the case in 2016. Within this relatively compact area, a total of 19 discrete spawning sites were recorded in the 2020, and 14 sites in 2016. Many of these sites are located in close proximity to others, often separated by only small stretches of less favourable vegetation. Field observations showed these similarities are associated with a relatively stable period in which geomorphology and vegetation changes have been relatively minor in this part of the catchment, and several micro-terrain features have supported spawning in both years.

In the 2020 survey, the maximum area of occupancy (AOO) of spawning sites (31 m^2) was recorded in March and was primarily the result of large, low density sites rather than a greater number of eggs overall, in comparison to the other months. For example, the smallest AOO was recorded in February (13 m^2) but this was associated with high egg densities and resulted in higher overall egg production than the March spawning event. In both the February and April spawning events, egg production was ca. 1 million eggs, with slightly lower numbers in March (~900,000 eggs), and May (~700,000 eggs).

This represents a relatively broad temporal peak in spawning activity compared to the current knowledge of īnanga spawning ecology nationwide. However, information on spawning activity in the adjacent months (i.e., January and June) would be necessary to further understand these patterns and there is also the need to consider potential variation between years. With regards to the SWWF project, this information may be useful for day-to-day management to inform the timing of works at the Punakaiki River restoration site, or to assess the impacts of other disturbance activities. It is also necessary for a full understanding of egg production trends which is an important for the evaluation of management outcomes in the context of improving whitebait stocks.

Notable differences in the pattern of spawning activity between 2016 and 2020 include total egg production across the comparable survey months (February-April), with 1.5 million eggs in 2016 and 3 million eggs in 2020. This included much greater egg production in February 2020 compared to February 2016. However, the peak spawning activity in 2016 was recorded in April and was 3-times that recorded in February. This suggests the potential for a later spawning season than in 2020, which may have included appreciable spawning activity in May. If so, the 2016 survey results are likely to have underestimated egg numbers for the season in comparison to 2020.

Despite the above comparative difficulties, the total egg production recorded in 2020 (3.7 million eggs) is the highest ever recorded in the Punakaiki catchment. Relative to other rivers and their known spawning locations, this represents the production of a large number of eggs from a small spawning area (total reach length of ca. 100 m), and has practical implications for the identification of protected areas for the improvement of whitebait stocks. On one hand, the priority sites for protection are currently located within a relatively small footprint located on existing public conservation land. On the other hand, this concentrated area of spawning could be vulnerable to natural hazards such as large flood events and associated erosion. Therefore, resilience-enhancing measures such as

extension of the channel network and improvement of hydrological connections on the floodplain may provide a useful management strategy to reduce risks associated with extreme events.

Results from the 2020 survey also indicate that the SWWF channel works have not adversely affected spawning activity, and some new spawning sites were recorded in May on excavated surfaces that had developed sufficient vegetation cover due to the growth of herbs and grasses over the survey period. Fish counts were also conducted on two occasions. Up to 900 fish were observed in the newly constructed channel despite the relatively raw condition of the new habitat and limited availability of in-stream and overhanging cover. These observations bode well for the habitat-enhancement aspects of the SWWF project and restoration of the riparian plant communities in the newly engineered areas will be the next point of focus.

Additionally, these results also indicate the existence of a healthy īnanga population in 2020. It is highly likely that the riparian wetland system in the vicinity of the spawning area provides the majority of suitable habitat for īnanga rearing, thereby supporting the fish population. Within that area, the spawning grounds, as documented here, can be regarded as critical habitat that is absolutely necessary for completion of the life cycle, and the production of whitebait.

Looking ahead, the SWWF demonstration project is well placed to investigate the potential for further enhancement through a combination of additional habitat creation and effective protection measures. The baseline data presented here will be invaluable for assessing the outcomes of that work, although the influence of variable whitebait recruitment between years should always be kept in mind. To resolve this, longer term trends as revealed by repeat monitoring are the most appropriate point of focus for outcomes evaluation, along with direct measures of effective management such as egg survival rates.

1. Introduction

1.1 Sustainable Wild Whitebait Fishery (SWWF) project

To help sustain the whitebait fishery and improve the conservation status of migratory galaxiids the Department of Conservation is facilitating the Sustainable Wild Whitebait Fishery (SWWF) project on the South Island's West Coast. Key themes within the project include strategies for reversing the historical decline of whitebait species and the identification of practical opportunities for enhancing whitebait stocks through habitat restoration and protection measures.

As part of the SWWF project, a restoration site is being developed at the Punakaiki River. Its objectives include showcasing ecological engineering and habitat enhancement approaches for improving whitebait stocks. Due to a combination of accessibility to the public, and the potential for trialling innovative measures, the Punakaiki projects lends itself to the development of a demonstration site (Orchard 2020).

The demonstration site is located on the Punakaiki River floodplain on the true left of the main river upstream of the State Highway bridge. This area features a spring-fed tributary that originates from a nearby subterranean source before spreading out into a network of meanders and shallow wetlands that merge with old floodplain braids of the main river. The SWWF project site is located within public conservation land in this area, and a Ngāi Tahu nohoanga site is located nearby (Fig. 1). The SWWF project site contains all of the previously recorded īnanga *(Galaxias maculatus*) spawning sites in the Punakaiki catchment, and the lower reaches of the spring-fed tributary which is known to provide suitable habitat for adult fish.

1.2 Previous knowledge of īnanga spawning in the catchment

The conservation of īnanga is an important aspect of the SWWF project. Īnanga makes up the bulk of the whitebait catch in most rivers (McDowall 1965; Yungnickel et al. 2020), although other whitebait species such as banded kōkopu (*G. fasciatus*) may also be present at the Punakaiki restoration site. Īnanga spawning ecology is a crucial aspect of conservation because of the largely annual life cycle (McDowall 1984). Each season's cohort of juveniles (i.e., whitebait) are highly dependent on the success of the previous spawning season and this is influenced by the abundance and condition of each year's adult fish as well as variation in egg and larvae survival rates.

Previous spawning surveys at the Punakaiki River have been completed by University of Canterbury researchers in 2006, 2007 and 2016. The 2006 and 2007 surveys contributed to a study that considered the productivity of spawning sites in relation to the size of river catchments and their adult fish populations, and sampled two spawning events each year (Hickford & Schiel 2011). Results from the study provided an early indication of the importance of smaller rivers which can often be highly productive in comparison to larger rivers that may be acting as 'population sinks' due to high egg mortality rates. In 2006, surveys were completed in mid April and early May, with the latter having the highest egg numbers (~1 million eggs). In 2007, surveys were completed in early and late May with the first of these having the highest egg numbers (~1.6 million eggs) (M. Hickford, pers. comm.).

The 2016 surveys were completed as part of a six-river comparative study that assessed the spatial distribution of spawning grounds in relation to salinity characteristics and associated morphological aspects of the lower rivers and river mouths (S. Orchard, unpubl. data). This study included surveys over three months (February – April) as an estimate of whole-season egg production following a census survey approach (Orchard & Hickford 2018). However, results for the Punakaiki River showed that the most spawning activity occurred in April during the survey period, and it was not possible to confirm whether this was the true peak of spawning activity without having surveyed at least one more month (i.e., May). The 2020 survey included a four month period (February – May) to enable a direct comparison with the 2016 results and to assess the contribution of additional spawning in May. Results from both surveys are presented to illustrate differences and trends (see section 3.4).

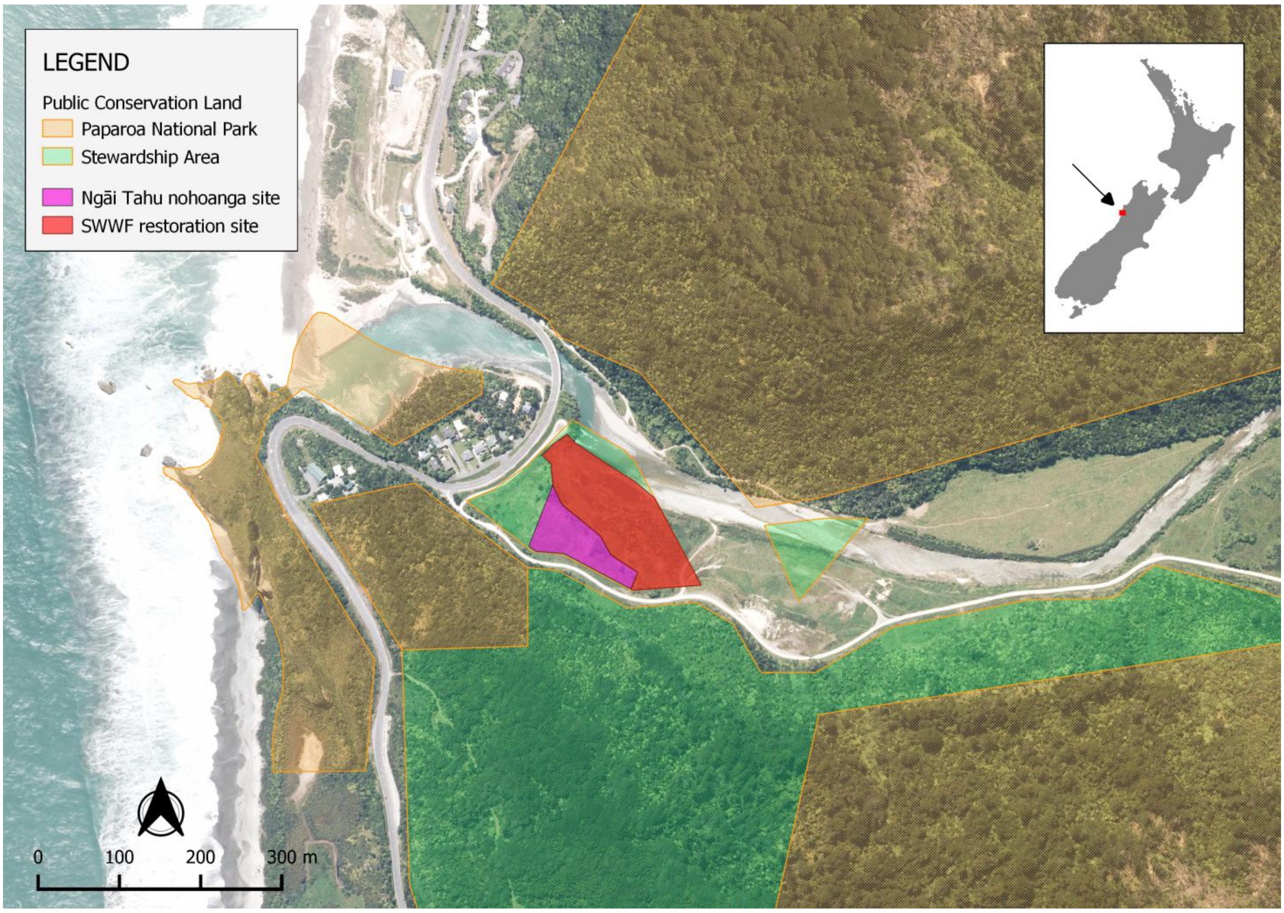

Fig. 1. Location of the Sustainable Wild Whitebait Fishery (SWWF) demonstration site at the Punakaiki River on the South Island's West Coast.

1.3 Scope and objectives

The primary objectives of this project were to provide an updated assessment of īnanga spawning activity and an indication of fish movements in the vicinity of the known spawning area to assess potential impacts associated with SWWF engineering work.

An additional objective involved a comparative assessment of spawning activity that considered results from the 2020 survey and the previous University of Canterbury survey in 2016.

The scope of the 2020 field surveys included:

- detection and quantification of spawning activity over four spawning events (Feb – May), and
- field observations in the newly constructed channel that provide an estimate of adult fish occupancy in this waterway.

The remainder of this report is set out as follows: Section 2 describes the field survey methodology. Section 3 presents findings from the 2020 field surveys and a comparison with data from 2016, and Section 4 discusses management implications for the SWWF project with a focus on further development of the demonstration site.

2. Methods

2.1 Spawning site surveys

Egg searches

The search area was restricted to the lower reaches of the waterway network within the SWWF project site described in Section 1 (Fig. 1). This general area was the only locality in which spawning sites were found in the 2016 survey which covered a much larger survey area and included all riparian vegetation downstream to the river mouth on both river banks (S. Orchard, unpubl. data). The 2006 and 2007 surveys also found spawning sites in the same area but not elsewhere (M. Hickford, pers. comm.).

Spawning surveys were completed for four consecutive spawning events (Table 1) using the census survey approach (Orchard & Hickford 2018). The field survey technique involved conducting systematic surveys for eggs in the vicinity of the high water mark following spring high tides. For every 5 m length of river bank three searches were made at random locations. Each search involved inspection of the stems and root mats of riparian vegetation along a transect line oriented perpendicular to the river bank. Typically a 0.5 m wide swathe of vegetation 1-2 m long was inspected on each transect depending on the bank slope. Due to the relatively compact nature of the Punakaiki River spawning grounds, all vegetation of interest can be surveyed by a team of two in approximately half a day. The area covered included the banks of several small islands within the wetland channel network, and a short section of the main river in the vicinity of the confluence area where vegetation is present at the elevation of spring high tides.

Table 1. Tidal cycle data and survey periods.

Survey Month	Peak tidal cycle start	Peak tidal cycle end	Peak tidal height* (m)	Spawning survey dates
February	Feb 10	Feb 12	3.6	Feb 19
March	Mar 10	Mar 12	3.6	Mar 16
April	Apr 8	Apr 10	3.6	Apr 28
May	May 7	May 9	3.5	May 27

* predicted tide levels above Chart Datum at Charleston (Lat. 41° 54' S Long. 171° 26' E) (Source: LINZ).

Area of occupancy (AOO)

All egg occurrences were associated with a given location that was identified as a spawning site (Orchard & Hickford 2018). 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. Spawning sites coordinates were recorded using a hand-held GPS in the field and corrected in QGIS v3.4 (QGIS Development Team 2019) with the assistance of site photographs and landmarks. For each spawning site, the width of the egg band was measured at the position of each search transect. A minimum of three measurements were taken at all sites. Zero counts were recorded when they occurred within a spawning site, as is common where the egg distribution is not a continuous band. AOO was calculated as length x mean width.

Spawning site productivity

Egg production was assessed by direct eggs counts using a sub-sampling method (Orchard & Hickford 2016, 2018). 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, inclusive of zero counts. The productivity of each site was calculated as mean egg density x AOO.

2.2 Fish surveys

Visual assessments of the newly excavated channel were made on 19th February and 11th March. On both occasions the water was clear enough to see the bottom. In-stream cover was generally sparse which allowed for fish to be readily observed, although shadows from overhanging vegetation and steep banks on the true left made observations more difficult at some sites. The abundance of adult fish was estimated by observing each shoal for a period of time. In most cases this presented an opportunity to see the full extent of the shoal against a suitable background during which individual fish could be clearly seen. Fish numbers were estimated within three size classes (6-8 cm, 8-10 cm, and 10 cm+) for each shoal.

3. Results

3.1 Distribution of spawning sites

Spawning sites were located in all four months of the survey. All of the sites (and the spawning area as a whole) are located within a series of floodplain channels that connect with the main river on a prominent bend. The total length of the spawning reach is approximately 100 m (Fig. 2).

A total of 19 discrete spawning sites were recorded over the four months of surveys in 2020. However, many of these were located in close proximity to others, often separated by only small stretches of less favourable vegetation. The number of spawning sites recorded per spawning event varied between 8 and 13, with several of these being used on more than one month reflecting the influence of suitable vegetation and relatively similar peak water heights.

All spawning sites except one were located within the same tributary stream, which includes a fork around a small island near its confluence with the Punakaiki mainstem. The other site (site 1) was located in an adjacent tributary to west. Both of these tributaries have been the subject of SWWF engineering works to extend the channel network upstream of the known spawning sites (Fig. 2).

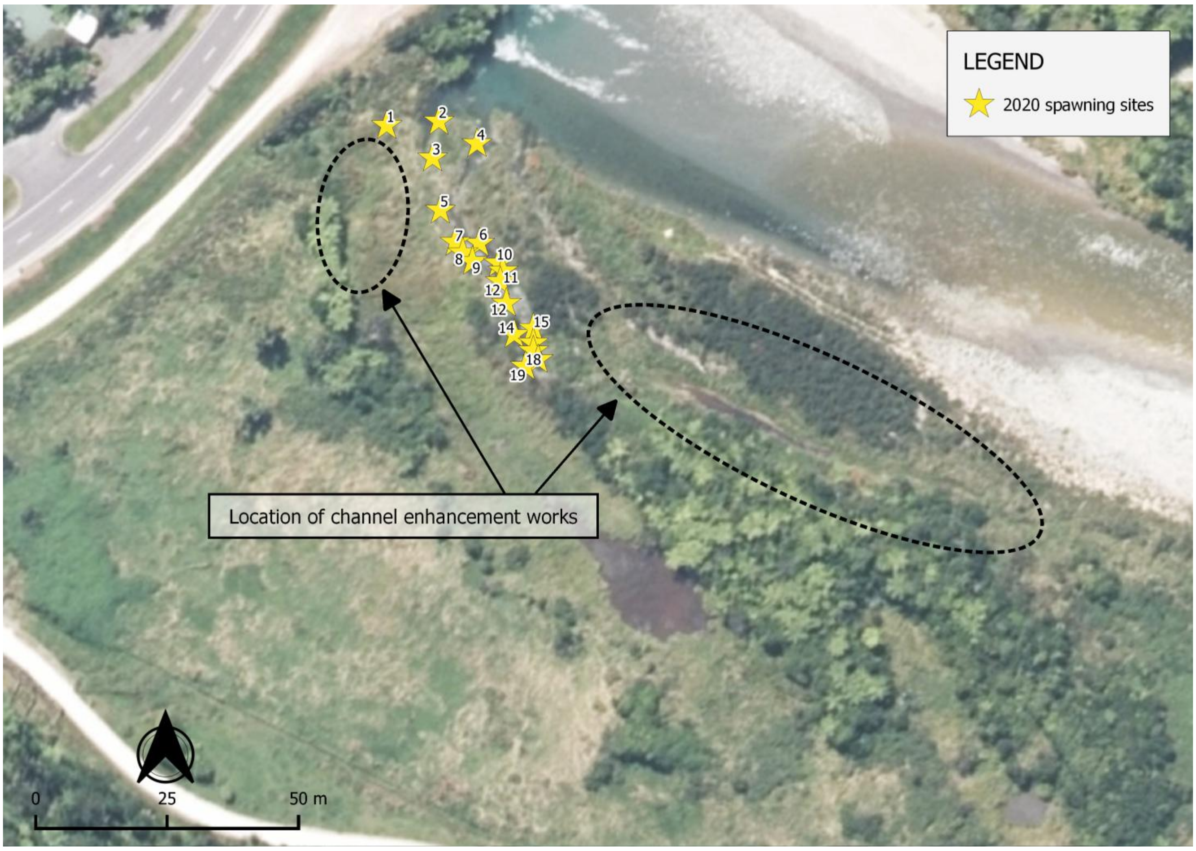

Fig. 2. Location of the 19 individual spawning sites recorded over four months of surveys in 2020.

Fig. 3. View of the main spawning tributary on the true left of the Punakaiki River. Orange flags mark the position of spawning sites.

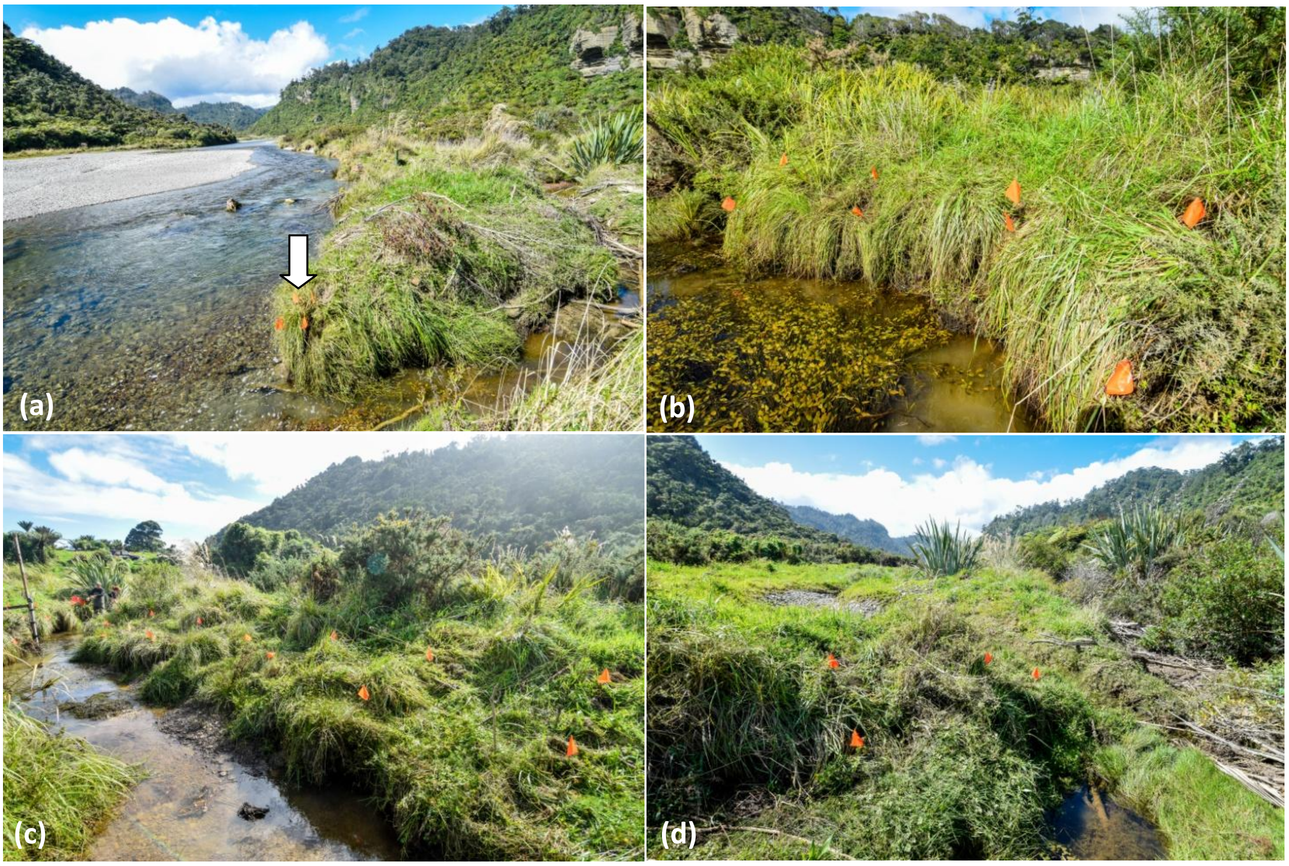

Fig. 4. (a) view of the confluence area showing a small spawning site (arrowed), Punakaiki River mainstem on left.(b) one of several spawning sites located on ledges within the network of tributary streams. Flags mark the position of the egg band. (c) a relatively large spawning site (site 5 in 2020) located on a wide bench. (d) at the upstream limit of spawning several small sites were found on recently excavated surfaces that had developed vegetation cover.

3.2 Area of occupancy and egg production

The area of occupancy (AOO) of spawning sites was highest in March (31.7 m^2) and lowest in February (12.9 m^2), with an average of 23.3 m^2 across all months (Fig. 5). With the exception of February, the monthly AOO was influenced by the presence of at least one large patchy site. For example, in both March and April, site 5 contributed over half of the AOO (17 m^2 in both months), and similarly in May (11 m^2). Unlike many other sites that occupy small ledges on relatively steep banks, this site occupied a variable proportion of a wide bench on the true right of the tributary stream (Fig. 4c). Across all sites, the maximum AOO recorded per month provides an indication of the area to protect which takes into account fluctuations between spawning events (Fig. 5a). Currently, all of the known sites are in close proximity and all located within public conservation land. In addition, most of sites are located on relatively steep banks that are typical of the tributary stream, with only one site (as above) occupying a wide bench. This reduces the potential for fluctuation in the position of spawning sites in relation to the channel network since most of the riparian terrace features are too high to be inundated on typical spring tides.

Egg production was unevenly distributed across the 19 individual sites, reflecting differences in both egg densities and AOO (Fig. 5b). Total egg production over the four months was 3,700,000 eggs. In both the February and April spawning events, egg production was ca. 1 million eggs, with slightly less in March (~900,000 eggs), and May (~700,000 eggs). The most productive individual site recorded was site 11 in the February survey with 825, 000 eggs (Fig. 6), reflecting the influence of a relatively large AOO (5.5 m^2) coupled with high egg densities (average 15 cm^{-2}). Other sites with > 100,000 eggs included sites 5 and 7 in March, sites 5, 6 and 13 in April, and sites 5, 7 and 12 in May (Fig. 6).

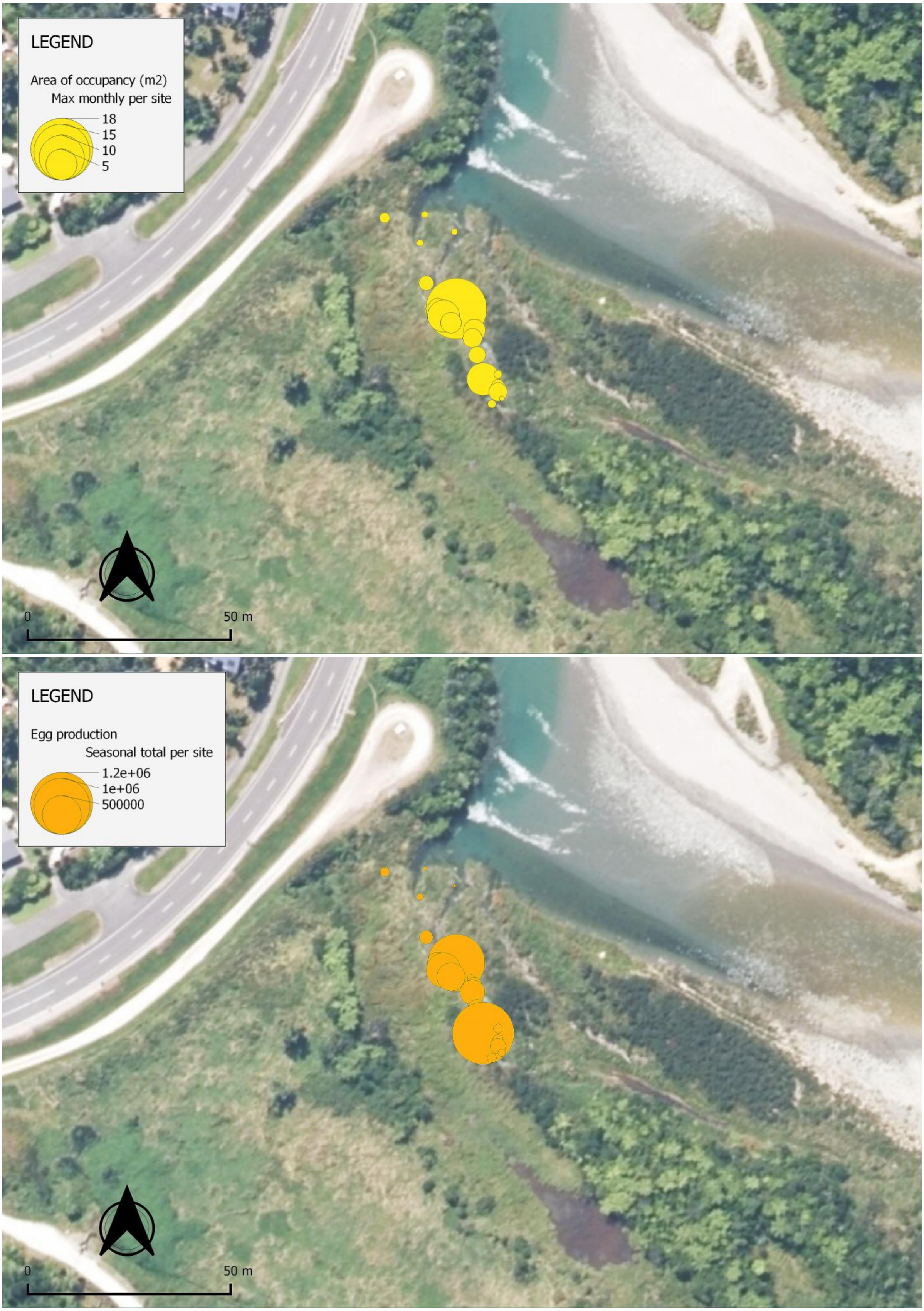

Fig. 5. Spatial patterns in īnanga spawning activity at the Punakaiki River in 2020. (a) Maximum area of occupancy (AOO) of individual spawning sites as recorded over four spawning events (February – May). (b) Total egg production of individual spawning sites (February – May). Point locations represent the approximate centre of each spawning site. Base imagery: Land Information New Zealand.

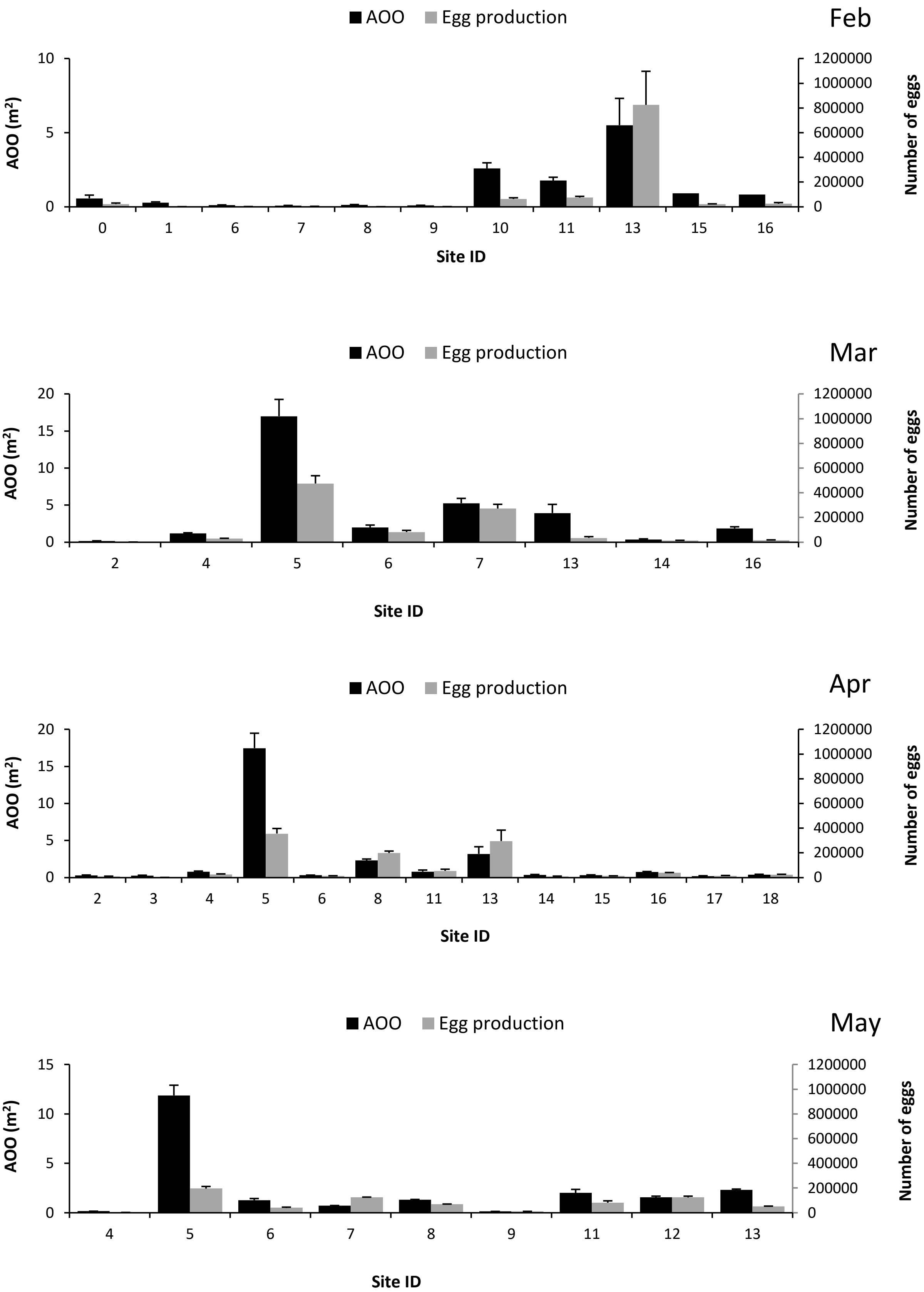

Fig. 6. Area of occupancy (AOO) and egg production of īnanga spawning sites at the Punakaiki River over four months in 2020. Errors bars are standard error of the mean.

Variation in the contribution of different spawning sites to the total production per spawning event can be clearly seen in the pattern of spawning activity between months (Fig. 6). These aspects show that different sites are relatively more important at different times, and may include important 'new' sites not used at other times. These patterns are likely to the reflect variation in the prevailing environmental conditions during spawning events (e.g., vegetation conditions and water heights) and behavioural aspects of the spawning behaviour that influence the location of fish aggregations and spawning activity on the day.

The lack of a consistent relationship between AOO and egg production is also evident and reflects the influence of variable egg densities at individual spawning sites. For example, although the smallest AOO was recorded in February (13 m^2), this was associated with high egg densities on average and resulted in higher overall egg production than the March spawning event.

3.4 Comparison with 2016

The location of spawning in 2020 was similar to that recorded in University of Canterbury surveys in 2016, with many of the same topographical features being used. In general, the morphology of these channels has remained relatively stable since 2016 with the main changes being erosion of some of the small islands close to the Punakaiki River mainstem.

In 2016, the total egg production was 1.5 million eggs with April being the peak month followed by March (Fig. 7a). For comparison, egg production over the same three months in 2020 was 3 million eggs (Fig. 7b). The increases are accounted for by much greater spawning activity in February, as well as higher spawning on average over the three month period, with around 1 million eggs produced in each of those months in 2020.

The contribution of May should also be noted since this month was not surveyed in 2016, and April was the month of highest spawning activity within the three month survey period. This suggests that a May spawning survey would have ideally been conducted to confirm the timing of peak spawning activity across the season as a whole. This also indicates a possible trend towards a relatively late spawning season that year. If so, this would have direct implications for interpretation of the 2016 survey results as a seasonal census for comparison to other years, with the potential for appreciable spawning in May to have increased egg numbers overall.

Differences in AOO patterns between years are more nuanced and reflect monthly variation in the characteristics of individual spawning sites in addition to the influence of egg numbers overall. The striking trend in 2016 involved a relatively large AOO being recorded in April (48 m^2) that was associated with several large low density patches of eggs. Similar effects were also seen in March 2020 which had the largest AOO that year (31 m^2) and was primarily the result of low density sites rather than a greater number of eggs in comparison to February, April and May. Results from both years illustrate a relatively weak correlation between the size of areas utilised for spawning and egg production trends.

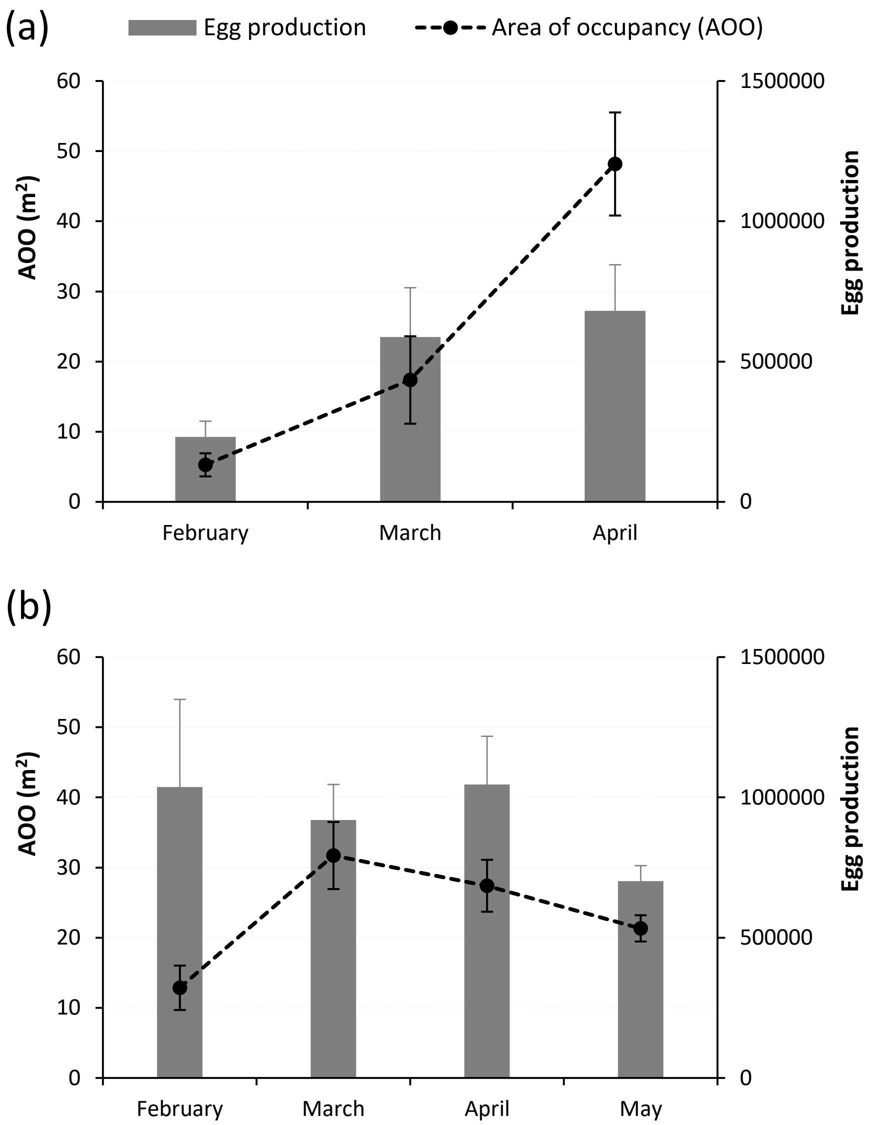

Fig. 7. Comparison of monthly totals for the area of occupancy (AOO) and productivity of īnanga spawning sites at the Punakaiki River. (a) results from 2016 surveys by the University of Canterbury. (b) results from 2020 surveys (this report).Errors bars are standard error of the mean.

3.5 Fish survey results

Visual surveys showed that the newly engineered channel upstream of the main spawning site was being utilised by fish, with several shoals recorded in the series of pools that have been excavated along a channel length of ca. 150 m (Fig. 8). Many of these fish were utilising cover created by shade from the southern bank despite a general lack of in-stream woody debris or emergent plants. In the February survey, a total of 263 fish were recorded in the channel and the survey was conducted on the same day as the spawning survey, approximately one week after the spring high tides (Table 2). Since the movement of fish into the channel was not directly observed, the following month's survey was scheduled to coincide with the spring high tide. On the survey day (March 11) large shoals of īnanga were seen in the spawning reach around the time of the high tide, together with several long fin eels (*Anguilla dieffenbachii*). Following the spawning event, several shoals of īnanga were observed moving into the engineered channel on the dropping tide. Once above the lower riffle of the new channel (Fig. 8a) these shoals generally moved further upstream. These observation suggested that the lower riffle was functioning as a sill as intended, by allowing fish passage during spring high tides or high river flows and otherwise retaining water on low tides (to prevent the channel from drying out due to the lack of a base flow). The visual survey was conducted later that day after these fish movements had ceased, at which time the water level in the spawning reach had receded and was relatively low. A total of 880 fish were recorded in the new channel, being appreciably more than recorded in February several days after that month's spring high tides (Table 2).

These observations confirm that adult fish are utilising the new habitat, at least for a period of time following spring high tides. However, further information is needed to characterise the residence times of fish as needed to determine its contribution to instream habitat overall. It is also important to consider the potential for negative effects, especially whilst the riparian and in-stream habitat conditions are in a development phase and since there is potential for fish to become trapped in the reach for several days if under conditions of low flows.

Table 2. Summary of results from fish surveys in the newly engineered channel in February and March 2020 at the SWWF Punakaiki demonstration site.

Survey date	Size class			Total fish
	6-8 cm	8-10 cm	10 cm+	
Feb 19	13	227	23	263
Mar 11	10	460	410	880

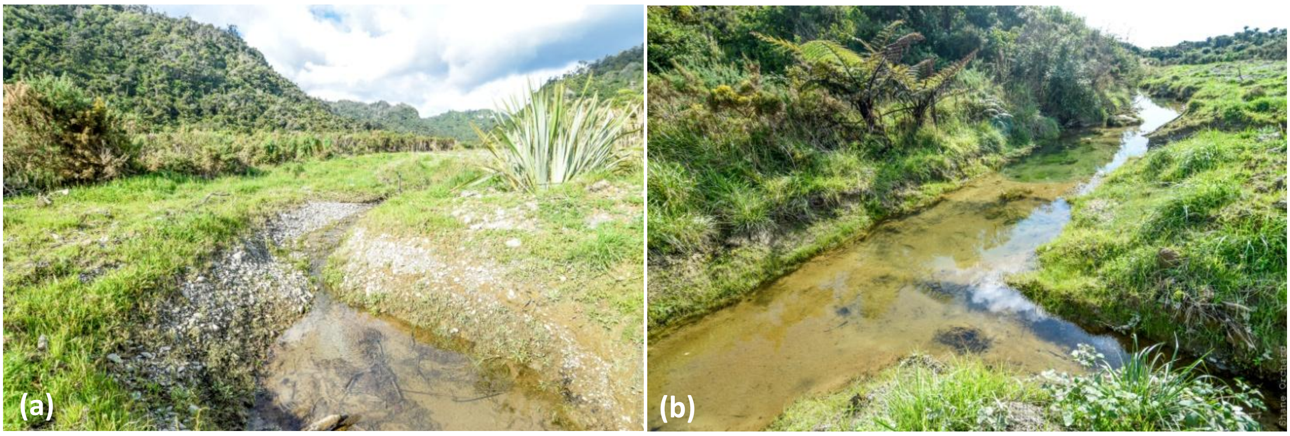

Fig. 8. Two views of the newly created channel upstream of the main spawning area. (a) the lower riffle located close to the (current) upstream limit of spawning. This acts as a sill to prevent drying of the channel during low tide periods, with the channel profile being deeper further upstream. (b) upper section of the channel showing in-stream and riparian conditions in February 2020. Riparian planting is planned for the exposed surfaces on the right.

4. Discussion and conclusions

4.1 Īnanga spawning activity

These results indicate the existence of a healthy īnanga population in 2020 based on the observation of high egg numbers at the spawning site. Although this is the most comprehensive census survey conducted in the catchment to date, the total egg production suggests higher productivity than measured in previous years. It is highly likely that the riparian wetland system in the vicinity of the spawning area provides the majority of suitable habitat for īnanga rearing, thereby supporting the fish population. Within that area, the spawning grounds, as documented here, can be regarded as critical habitat that is absolutely necessary for completion of the life cycle and the successful production of whitebait larvae.

The 2020 spawning survey results show a relatively broad temporal peak in spawning activity compared to the current knowledge of īnanga spawning ecology nationwide. Information on spawning activity in the adjacent months (i.e., January and June) would be necessary to further understand these patterns and is recommended for consideration in future surveys. There is also the need to assess potential variation between years. The temporal difficulties highlighted in the assessment of change since 2016 shows that some variation in the month(s) of peak spawning activity is occurring, and this suggests that a greater survey effort is required to obtain reliable measures of spawning activity for the purposes of long term monitoring or comparative studies. This is necessary for a full understanding of egg production trends which is an important focus for monitoring in the context of improving whitebait stocks. Information on the timing of spawning and relive contribution of different months may also be useful for day-to-day management to inform the timing of works associated with the SWWF project, or to assess the impacts of other disturbance activities on īnanga spawning ecology at the demonstration site.

4.2 Impact of ecological engineering

Results from the 2020 survey show that the SWWF channel works have not adversely affected spawning activity. It was also encouraging that new spawning sites were recorded in May on excavated surfaces that had developed sufficient vegetation cover due to the growth of herbs and grasses over the survey period.

The observation of a large number of fish in the newly constructed channel suggests that the habitat enhancement measures are functioning as intended at this early stage, despite the relatively raw condition of the new habitat and limited availability of in-stream and overhanging cover. Restoration of the riparian plant communities in the newly engineered areas will be the next point of focus.

4.3 Spatial planning aspects

Relative to other rivers and their known spawning locations, this represents the production of a large number of eggs from a small spawning area (total reach length of ca. 100 m), and has practical implications for the identification of protected areas for the improvement of whitebait stocks. On one hand, the priority sites for protection are currently located within a relatively small footprint located on existing public conservation land within the SWWF project area. On the other hand, this concentrated area of spawning could be vulnerable to natural hazards such as large flood events and associated erosion or deposition events that rework this part of the floodplain. Therefore, resilience-enhancing measures such as extension of the channel network and improvement of hydrological connections on the floodplain may provide a useful management strategy to reduce risks associated with extreme events. The current engineering work has indeed reactivated an old floodplain channel by clearing accumulated sediments that had effectively prevented water from reaching the upper channel at most river flows. This demonstrates how human agency can help tip the balance towards desirable habitat creation through targeted interventions at appropriate times. In the future, however, further changes can be expected during extreme events and these may provide both new opportunities and risks to the current enhancement work. A flexible and adaptive approach to ecological engineering is therefore needed over the longer term.

4.4 Next steps

Looking ahead, the SWWF demonstration project is well placed to investigate the potential for further enhancement through a combination of additional habitat creation and effective protection measures. The baseline data presented here will be invaluable for assessing the outcomes of that work, although the influence of variable whitebait recruitment between years should always be kept in mind. To resolve this, longer term trends as revealed by repeat monitoring are the most appropriate point of focus for outcomes evaluation, along with direct measures of effective management such as egg survival rates.

5. Acknowledgements

Thanks to Thomas Falconer and Nina Robb for assistance with the 2020 field surveys and Dr. Mike Hickford and other UC staff for assistance with the 2016 surveys mentioned here. Thanks also to Joy Comrie at the Department of Conservation for coordinating the SWWF project on the West Coast.

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