SURVEY OF JUVENILE RAINBOW TROUT IN THE UPPER TUKITUKI CATCHMENT

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Executive Summary

The Tukituki River and tributaries in southern Hawkes Bay attract nearly 12,000 angler days of effort per season (National Angling Survey 2007/08), making it one of the most important river trout fisheries in New Zealand. The fishery comprises both brown and rainbow trout. Not a lot is known about the rainbow fishery. However typically in New Zealand rainbow trout tend to spawn in the river headwaters and smaller tributaries.

An electric fishing survey of what was considered suitable fry habitat was undertaken in a number of the tributaries in December 2011 to assess the level of rainbow trout spawning. The highest density of fry was measured in the upper Makaroro River, followed by Dutch Creek (a tributary of the Makaroro) and the spring fed Mangaonuku. Densities were also high in the upper Waipawa and upper Tukituki river sites.

The densities are influenced by the amount of suitable fry habitat present, the extent of which varied between locations. The difference between whether habitat was suitable or not appeared to be subtle, and also occur at a micro scale which makes estimation of the total available habitat very difficult and outside the scope of this study. However it was more difficult to find suitable sites to survey in the Makaroro, upper Tukituki and smaller spring fed streams than lower down the catchment and in the Mangaonoku.

Densities are also influenced by the age of the fish present as numbers typically decline rapidly following emergence due to death and emigration downstream. Newly emerged fry occurred in large numbers in the Makaroro River and Dutch Creek but were absent from the sites lower down and the spring creeks. Whether this indicates that spawning does not occur lower down, or alternatively that warmer water temperatures preclude later spawning in spring is not known.

The lower Mangaonuku Stream held large numbers of rainbow fingerlings and also had a lot of emergent vegetation which provided extensive suitable habitat. Of the sites fished this stream appears to be the most important to the Tukituki fishery.

This survey suggests that most rainbow trout spawning occurs in the very headwaters of the major rivers and smaller side streams between June to October, the fry emigrating downstream as they grow. The Makaroro River and Dutch Creek would appear to be important sites despite the relatively small count of spawning adults made in August and September 2011 (Maclean 2011).

However that spawning may occur lower in the catchment earlier in the winter when water temperatures are more suitable for incubation cannot be discounted.

Introduction

The Tukituki River and tributaries in southern Hawkes Bay is one of the most important river trout fisheries in New Zealand, attracting nearly 12,000 angler days of effort per season (National Angling Survey 2007/08). The fishery comprises both rainbow (*Oncorhynchus mykiss*) and brown trout (*Salmo trutta*).

Not a lot is known about the rainbow fishery. Typically in New Zealand rainbow trout tend to spawn in the river headwaters and smaller tributaries, the juvenile trout dropping downstream to rear in the lower river or associated lakes before migrating back as mature adults to spawn themselves.

A rainbow female lays about 1500 eggs per kilogram of body weight (McDowall 1990) and studies as summarised by Hayes (1988) have shown that the resulting fry experience very heavy mortality of 90% or more during the first six months of life. As a consequence larger juveniles that have managed to survive this initial period are now much more likely to reach maturity, and so are relatively more important to the fishery than the newly emerged fry.

A potential dam on the Makaroro River has raised the question whether this significant headwater tributary may be an important rainbow trout spawning area for the wider Tukituki fishery. A first assessment of rainbow trout spawning above the proposed dam site undertaken in September 2011 observed a density of 4.1 adult trout/ kilometre in the Makaroro River and 5.6 trout/km in Dutch Creek, a side tributary (Maclean 2011). The author concluded that the number of trout and redds in the Makaroro River were relatively low. By way of explanation Maclean suggested that either the peak spawning may have occurred at a different time of year, or that the instability of the Makaroro affected spawning success and recruitment in many years, or that there was an excess of suitable spawning habitat throughout the Tukituki catchment such that spawning densities were generally low in most areas.

To confirm whether or not the Makaroro River is of relatively low importance for rainbow trout spawning in comparison to some other Tukituki tributaries, a survey of rainbow trout fry densities and average fish size was undertaken at a series of sites in the upper Tukituki catchment in December 2011.

Study Site

The Tukituki River is one of two large rivers flowing across the Ruataniwha plains in central Hawke's Bay and is approximately 125km in length (Maxwell & Pitkethley 2006). Rising in the foothills of the Ruahine Range, the Tukituki drains a catchment area of 2473km^2 (Dravid et al 1997). Major tributaries include the Waipawa, Makaretu and Tukipo rivers. In turn the Makaroro River is a significant tributary of the Waipawa River.

The streams and tributaries of the Tukituki can be classified into three types on the basis of their water source, bed material and channel slope (Wood 1998).

- Rivers deriving from the Ruahine ranges, including the Tukituki, Waipawa (and Makaroro) and Makaretu. These have a greywacke fluvial deposit geology, meander freely within the flood plain and are subject to considerable groundwater losses as they flow across the unconfined aquifer.
- Rivers deriving from the foothills of which the Tukipo is the only example. This river is often short of water during the summer months. It contains a fair amount of gravel but displays a wider range of bed material than the rivers listed above.
- Plains streams including the Kahahakuri, Black Stream and lower Mangaonuku. These are characterised by a strong base flow component from either springs or seepage, and the bed material is dominated by clays, silts and organic material.

At times the entire flow of the upper Waipawa River infiltrates the river bed with much resurfacing as springs in the Mangaonuku and Kahahakuri Streams. Similarly, at times the whole flow of the upper Tukituki River infiltrates and reappears in the Tukipo catchment (Ludecke, 1988).

The upper Tukituki Catchment can also be described using the River Environment Classification (REC) system as shown in figure 1.

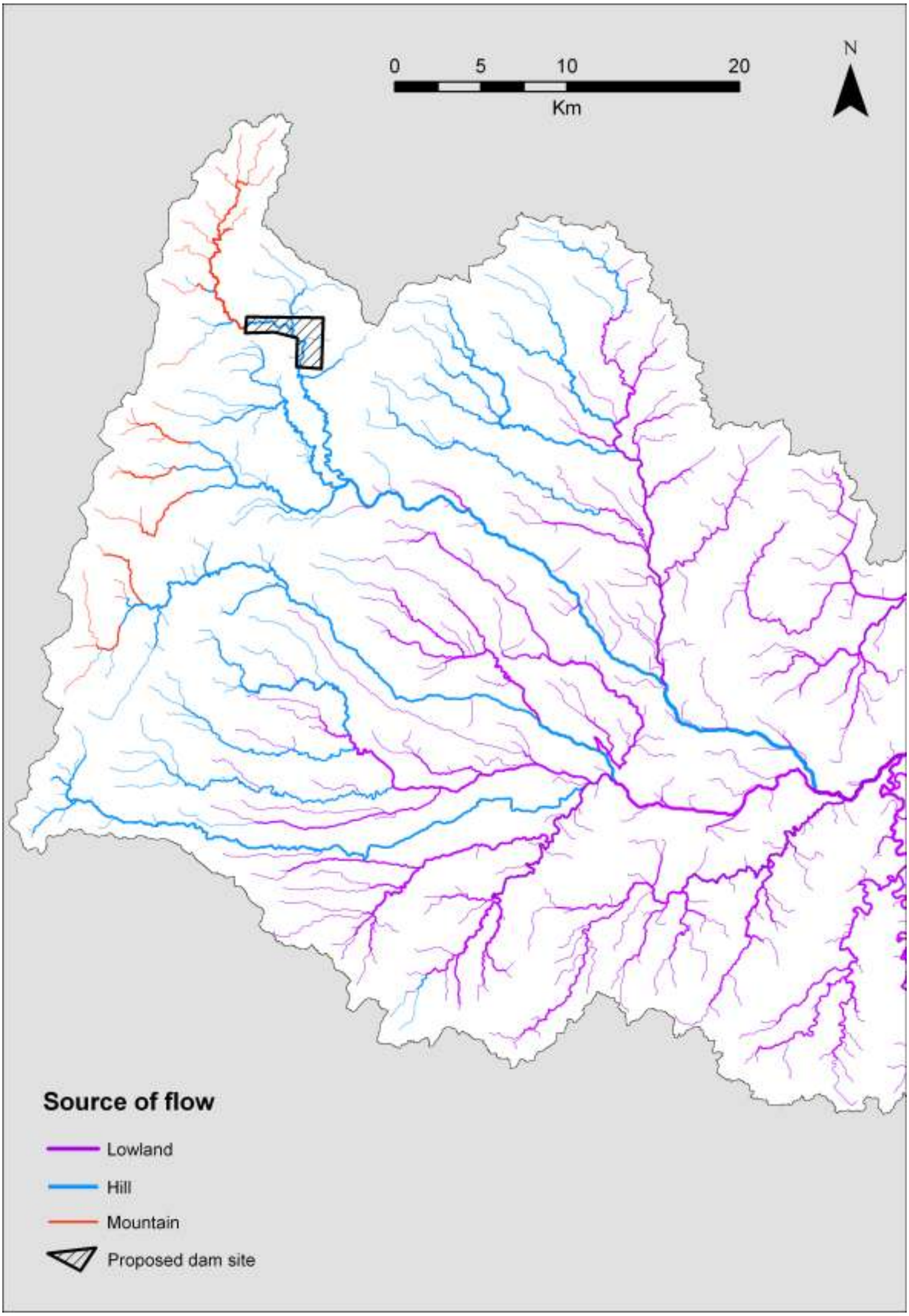


Figure 1: The upper Tukituki Catchment showing source of flow classes from the River Environment Classification (REC) system and proposed dam site on the Makaroro River (figure courtesy Cawthron Institute, Nelson)

Methodology

A series of 12 survey locations were selected in the upper Tukituki catchment to represent streams and rivers of each source of flow class using the River Environment Classification system. However it was not possible to readily access the 'mountain' flow class areas on either the Waipawa or Tukituki rivers and in these cases the survey location was a short distance downstream of this zone. A GPS co-ordinate (NZ Transverse Mercator) and the source of flow class at each location are listed in table 1.

Table 1: Survey locations in the Tukituki catchment

Location	Description	GPS co-ordinate (NZTM)	Source of flow Class
1	Makaroro River upstream of Dutch Creek confluence	E1879440 N5595510	Mountain
2	Lower Dutch Creek	E1879960 N5595404	Hill
3	Upper Waipawa above Mangataura confluence	E1881323 N5584869	Hill
4	Upper Tukituki (Tukituki road)	E1882390 N5577998	Hill
5	Lower Waipawa (above Mangaonuku confluence)	E1898478 N5576477	Hill
6	Lower Mangaonuku	E1901305 N5576494	Lowland
7	Makaretu at Speedy Road	E1894298 N5567421	Hill
8	Middle Tukituki above Tukipo confluence	E1897506 N5571027	Hill
9	Lower Tukipo at Ashcott Road	E1896318 N5569408	Lowland
10	Porangahau Stream below Takapau	E1887704 N5564210	Lowland
11	Cochranes Creek	E1902132 N5572914	Lowland
12	Lower Tukituki at Patangata	E1918521 N5578027	Lowland

These locations are also shown in figure 2.

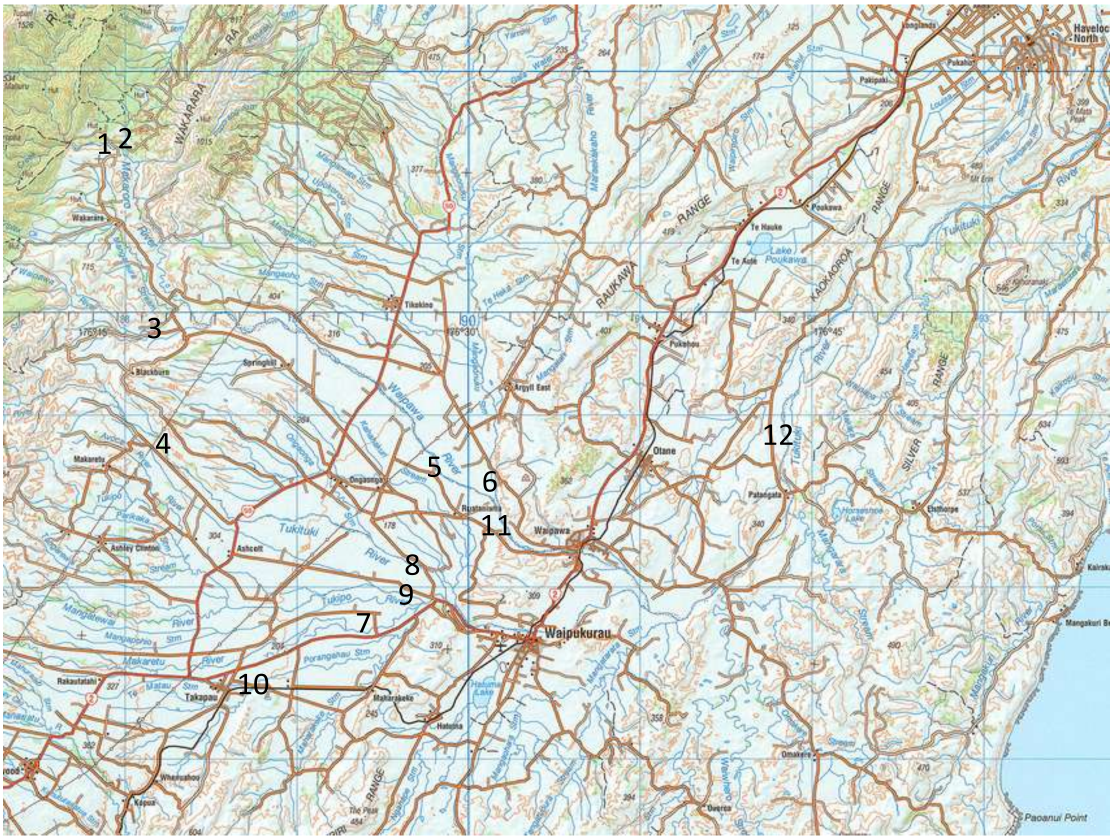


Figure 2 Survey locations (by number) in the Tukituki catchment

At each location three replicate sites were selected and electric fishing used to capture any trout present. The sites were selected on the basis of what the operators considered to be the most suitable trout fry and juvenile habitat in the vicinity. Typically this habitat involved low current velocities and cover – either cobbles and boulders or instream debris and vegetation. In the more unstable streams suitable habitat was typically found in the shallow margins along the edges of runs and riffles (photo 1); in the spring fed streams suitable habitat was often associated with deeper water and bankside vegetation (photo 2).

Photo 1 Electric fishing site in the upper Waipawa (Location 3)

Photo 2 Lower Mangaonuku Stream (Location 7)

At each site a thirty metre rope was laid out on the bank adjacent to the area selected to be fished. Beginning at the downstream end of the rope the catcher stood level with the end of the rope. The electric fishing machine operator stood several metres upstream and to the side of the catcher. The operator then fished in a downstream direction covering a metre wide strip down to the catcher, who used a stop net to collect any stunned fish. A single pass was made and once this sweep was completed the catcher moved up to where the operator had begun fishing, and the operator in turn moved another couple of metres further upstream, making sure they did not walk through the area to be fished. When the operator reached the upstream end of the rope this marked the end of the survey, in effect a 30 m^2 area fished each time. Depending on where the operator felt the best habitat was the area fished could be adjacent to the bank or further out in the channel. Thus consecutive sweeps were not always contiguous with the previous sweep.

This method was previously developed by the author to monitor trout fry and young of the year numbers and growth over time and between rivers in the Taupo Sports Fishery. The technique provides a quantitative method of fishing preferred habitat, however it does not provide an estimate of the total production from the stream.

Two 2 person teams undertook the survey over three days using EFM300 electric fishing machines set on a pulse width of 3ms and a frequency of 70pps. The EFM 300 machine is designed to operate effectively in waters with an electrical conductivity of between 10 and 400uS/cm, of which all the sample sites fell within (table 2). The operator set the voltage so as to have a maximum of 5 of the 6 lights on the hand wand illuminated.

Where practical all fish observed in the electric field were netted irrespective of species, and placed in water in a plastic bucket. On completing the survey these fish were then identified, counted and recorded before being released. The length of any trout caught was also measured to the nearest millimetre. If numbers were very large then a sample was measured, taken by swirling the water in the bucket and then sieving a sample of trout out at random. Other fish observed but not captured were also recorded. A photo was also taken of each site, the GPS co-ordinates noted and a brief description of the habitat made.

The data for the three sites at each location was then combined to determine the total fry and juvenile trout numbers per 90 M^2 fished, and from this a mean density per M^2 was calculated. In addition the mean length and standard deviation of all the trout measured was determined.

Results

The physical parameters measured at each location at the time of survey are shown in table 2.

Table 2 Dissolved oxygen (mg/l and % saturation), conductivity (uS/cm) and water temperature (C^o) for the survey locations in the upper Tukituki catchment December 2011

Location	Dissolved oxygen (mg/l)	Dissolved oxygen (% saturation)	Conductivity (uS/cm)	Water temperature (C^o)
1	9.93	102.6	91.1	14.5
2	9.84	100.1	100.3	14.0
3	9.74	103.5	103.2	16.4
4	9.23	104.3	84.5	19.4
5	10.23	122.7	101.2	22.7
6	11.54	123.9	188.4	17.8
7	9.26	99.9	86	19.1
8	10	109.7	88	19.9
9	10.32	109.2	129	18.1
10	10.52	114	341	17.8
11	8.06	82.7	148.2	15.0
12	7.94	83.2	163	17.3

The total number of juvenile rainbow trout (caught or seen but not captured) at each location is summarised in table 3, along with the mean density per M^2 and the average length (mm) of the fish captured. Where sufficient fish were measured the standard deviation is also listed in ()'s.

Table 3 Number and density of juvenile rainbow trout recorded at each location along with the mean length of the fish captured (and standard deviation where appropriate)

Location	Total number juvenile rainbow trout	Density/ M^2	Av length (mm), (S.D)
1	122[a]	1.02[a]	37 (9.5)
2	53	0.59	30 (4.8)
3	22	0.24	51 (9.6)
4	19	0.21	48 (10.3)
5	7	0.08	58 (14.2)
6	54	0.60	74 (17.5)
7	1	0.01	80
8	1	0.01	47
9	2	0.02	40
10	0	0	
11	2	0.02	35
12	1	0.01	

[a] calculated over 4 sites (120M^2) rather than 3 sites (90M^2) used at the other locations

The density of juvenile trout observed at each location is also shown on a map of the Tukituki catchment in figure 3.

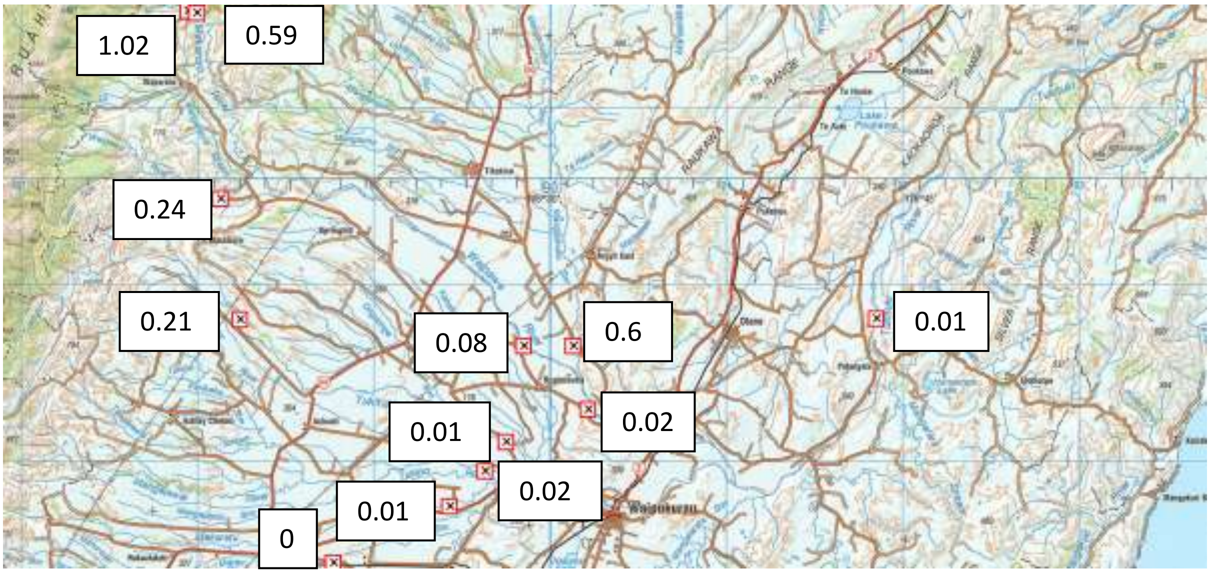


Figure 3 Map of the upper Tukituki catchment showing the number of juvenile rainbow trout observed at each location.

The same can also be done to highlight the average length of the trout (and standard deviation) at each location where sufficient data is available, as shown in figure 4.

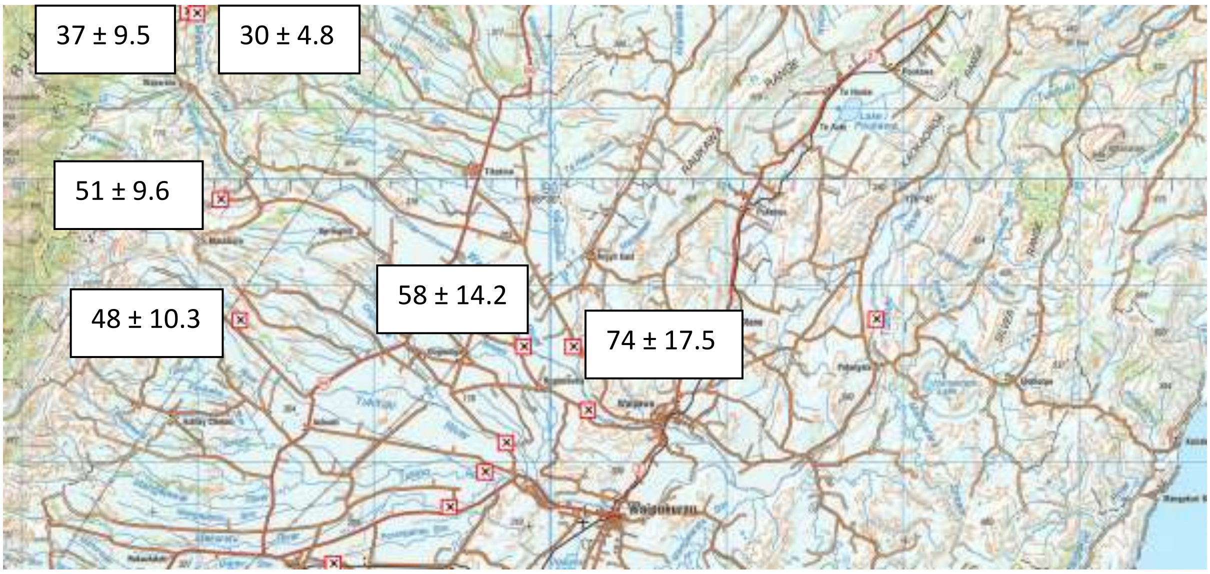
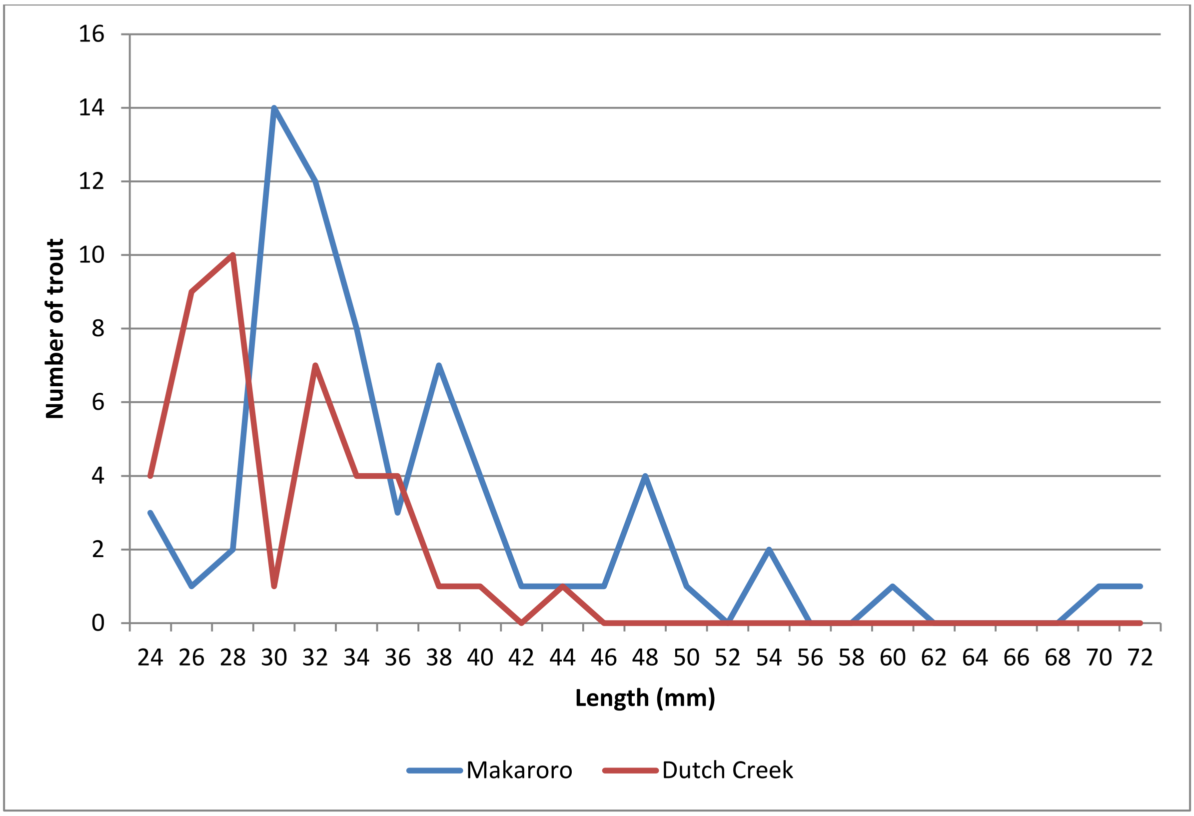
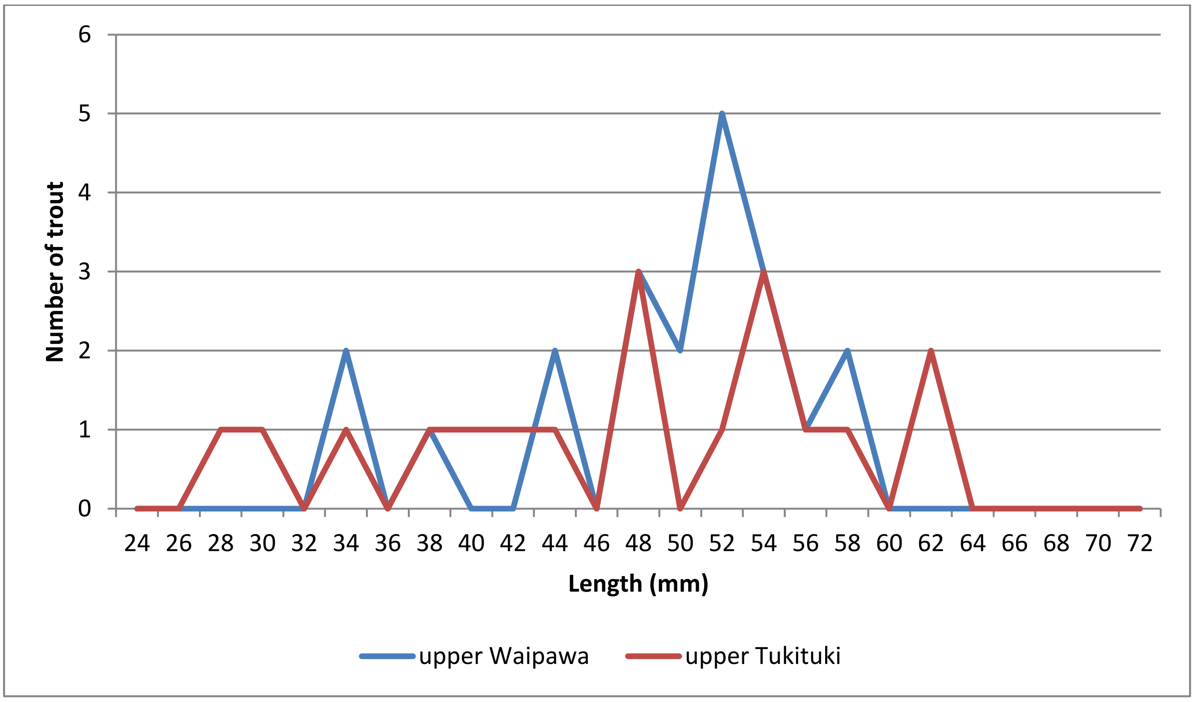


Figure 4 Average length (mm) and standard deviation of juvenile trout measured at each location in the upper Tukituki catchment (where sufficient data exists).

The distribution of fish lengths for the trout measured at each location was also calculated. Graphs 1 and 2 show the number of trout caught in each 2mm length interval at the Makaroro and Dutch Creek locations, and also for the upper Waipawa and Tukituki locations.



Graph 1 Number of trout caught in each 2mm length interval at the Makaroro and Dutch Creek locations December 2011 (the interval begins at the number shown, for example 24 represents fish from 24 to 25.9mm long)



Graph 2 Number of trout caught in each 2mm length interval at the upper Waipawa and Tukituki locations December 2011

Discussion

Density

Ideally it would be preferable to calculate the amount of suitable habitat present at each location and so estimate the total number of fry and juvenile trout present. However given the subtle but clearly significant variations between what is suitable or not which often occurs at a very localised or micro scale, then to accurately estimate this parameter would be a very considerable undertaking and was outside of the scope of this study.

For example, in the upper Makaroro we fished four apparently similar sites, catching 54, 3, 22 and 43 rainbow trout respectively. This highlights the localised concentration of juvenile trout into some sites, and also the difficult in defining just what is suitable habitat (photos 3 and 4).

Photo 3 - Site 2 Makaroro River, 3 juvenile trout were caught

Photo 4 - Site 4 Makaroro River, 43 juvenile trout were counted here

Where habitat is limited then what fish are present are likely to be concentrated in the prime habitat, which was targeted in this survey. We noticed when undertaking the electric fishing that suitable fishing sites (habitat) were less easy to locate in the Makaroro and upper Tukituki (and the smaller spring fed streams) than in Dutch Creek, the upper Waipawa and the hill/ lowland class rivers and streams lower down.

In the lower sites around Waipukurau the wide meandering nature of the river channels and low gradient suggested extensive areas of habitat likely to be suitable for juvenile trout. The very low densities recorded may in part reflect this fact, alternatively the habitat may not be as suitable as initially appears.

With the exception of the Mangaonuku we struggled to find suitable areas to fish in the smaller spring fed streams (sites 10 & 11), and in case of the Kahahakuri Stream abandoned this site altogether due to this fact.

This discussion therefore focusses on the measured density per M^2 of prime habitat fished. This density is not a measure of the overall density in the stream reach.

The numbers of juvenile rainbow trout caught high in the catchment were much larger than at the locations lower down, with the exception of the largely spring fed Mangaonuku Stream. The highest measured density (1.0 trout/M^2) was recorded in the Makaroro River above the proposed dam site, and was several orders of magnitude higher than most of the other locations. The next highest densities (0.6 trout/ M^2) were the Mangaonuku and Dutch Creek (a tributary of the Makaroro), followed by the uppermost Waipawa and Tukituki sites.

While the upper Waipawa and Tukituki sites appear lower in the Tukituki catchment than the Makaroro site, all three sites are a similar distance from the top of their respective catchments and the rivers of a similar size and nature at these sites.

None of the densities measured were comparable to those measured by Hayes (1988) who recorded rainbow trout fry densities of up to 7.7 fish/M^2 in Scotts Creek, using multiple pass electric fishing. Scotts Creek is a major spawning tributary for Lake Alexandrina, however it is only a small, highly stable stream (mean flow $0.125m^3s^{-1}$) providing approximately 1.5km of water for the up to 3000 spawning adults (Hayes 1988). Given the very large amount of potentially suitable spawning water identified in the Tukituki catchment (Maxwell & Pitkethley 2006) and the unstable nature of much of it, combined with an apparently not very large adult population then it might perhaps be a surprise if any of the spawning areas were fully saturated as clearly occurred in Scotts Creek.

On the survey days measured water temperatures ranged from 14^{o}C to 22.7^{o}C. Different temperatures will influence the behaviour of the trout, and potentially may affect their susceptibility to capture. In this case the variation of temperatures is generally small and within the optimum range, and the effects are not expected to be significant.

Size and age

The trout density will also be influenced by the age of the fish present. Typically rainbow trout spawn in the headwaters and small streams, the juveniles displaying a propensity to migrate downstream as they grow. Some studies as summarised by Hayes (1988) have shown losses (mortality and/or emigration) in excess of 95% over the first 6 months of life. In other words we would expect to have higher densities of fry than older (and larger) juveniles, all other variables being equal.

However trout size is also influenced by the thermal regime they have been subject to, developing and growing faster in warmer water (growth is reduced again once temperatures exceed approximately 20 C^o – McCullough et al 2001). Therefore larger juveniles may not necessarily be older.

Rainbow fry typically emerge from the gravels at between 26 to 29mm in length. For example Zimmerman et al (1999) measured emerging steelhead and rainbow fry from 10 different traps in the Deschutes River, Oregon, the mean length for each trap varying from 25.7 to 29.6mm. Rosenau (1991) suggests a minimum of 25mm for rainbow trout fry in several streams in the Taupo Fishery and in my own experience in this fishery most emergent fry are 26 to 28mm long. Hayes (1988) described emergent fry as trout less than 30mm in length, and this is the definition I am using here.

In Dutch Creek (Graph 1) the majority of trout captured were less than 30mm indicating that these fish were newly emerged. However Dutch Creek is relatively small (photo 5) and it is possible that the emergent fry were all from a single redd just upstream. The bulk of the remaining trout were between 32 and 37mm long, perhaps several weeks to a month older on the basis of the rates of growth Hayes (1988) and Rosenau (1991) measured.

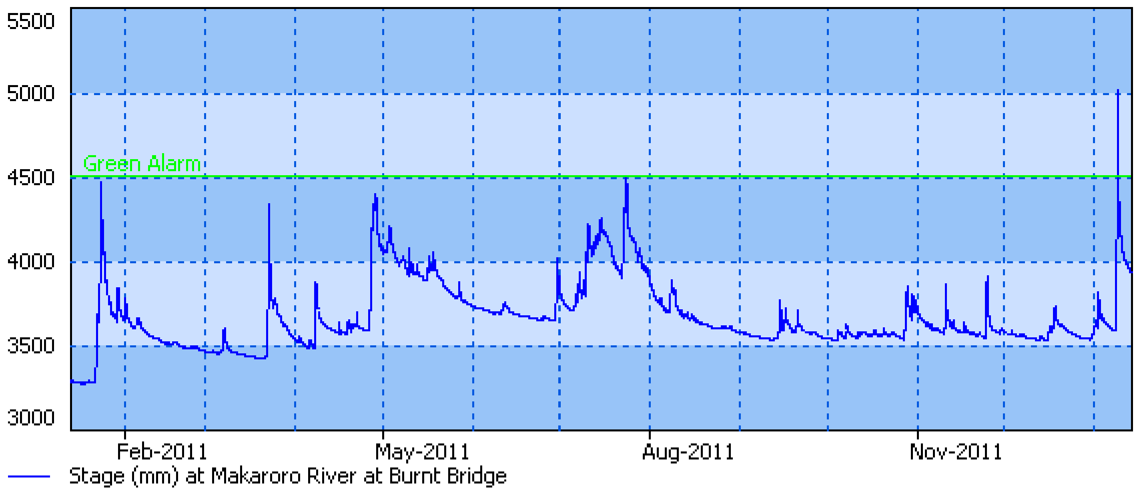
On the day of survey the water temperature was measured at 14 C^o. However it is generally accepted that above 12 C^o rainbow trout egg survival through to hatching and emergence declines significantly (McCullough et al 2001). If we assume that the water temperature was at or below this temperature when these fry were in the gravels, then the relationship developed by Crisp (1988) would predict a period of 55 days between fertilisation and swim up at 10 C^o and 43 days at 12 C^o. This would equate to spawning taking place somewhere around the beginning of October for the older fry and late October/ beginning of November for the newly emerged fry. The almost total absence of trout larger than 40mm in the stream despite a number of redds observed in early September as part of the spawning survey suggests that fry emigrate out of Dutch Creek soon after emergence.

By contrast the Makaroro data indicates a number of different size classes present (graph 1), the smallest fish reflecting a latest spawning about early October. Assuming that the trout measured have all experienced a similar thermal regime then the range of sizes likely reflects a spawning period extending back three or four months from the last spawning to late June/ early July. Each peak is progressively smaller than the one before suggesting mortality and/ or emigration downstream is occurring. The lack of fish between the peaks may simply be an artefact of the relatively small sample size (68 measured trout), alternatively it may reflect that the trout are derived from relatively few redds.

In the upper Waipawa and upper Tukituki rivers the majority of trout measured were 45mm or longer. These rivers were slightly warmer than the Makaroro and Dutch Creek on the survey day at 16.4 C^o and 19.4 C^o (the Tukituki was also measured earlier in the day at 16.5 C^o reflecting that there is significant diurnal variation). The presence of a few smaller fish including recently emerged fry suggests some late spawning has occurred. Perhaps the most likely scenario is that the spawning areas are well upstream of these locations, the larger fish present reflecting the progressive emigration of older fry downstream.

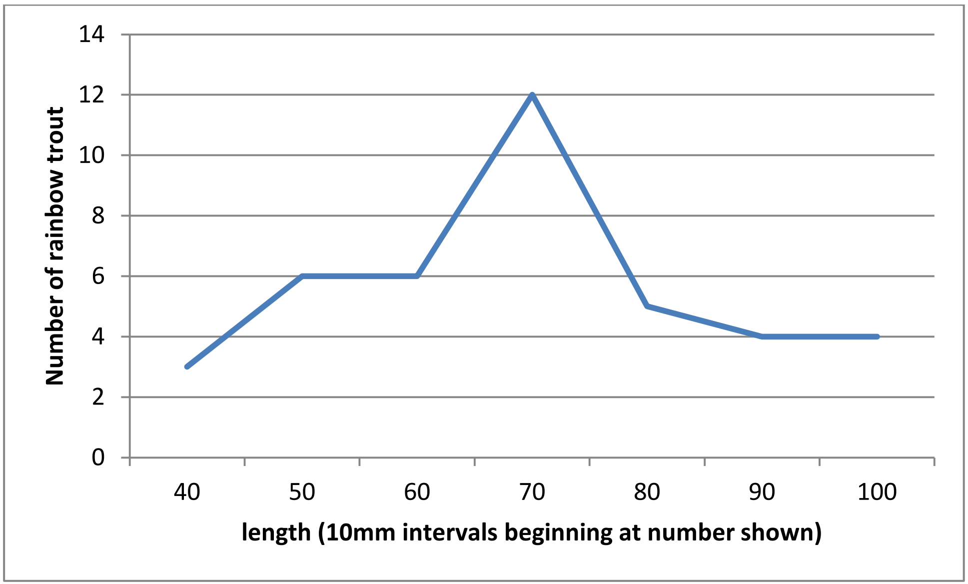
Photo 5 Site 3 on Dutch Creek December 2011

The movement of fry downstream will be assisted by the occurrence of freshes. Typically the Makaroro River is a volatile river as demonstrated by the unstable nature of the bed. However from late July to early January 2012 conditions have been relatively benign for the Tukituki catchment as reflected by the flow records from the Makaroro River at Burnt Bridge (graph 3). Therefore the downstream migration of fry emerging in mid to late 2011 may have been less than in some other years.



Graph 3 Stage height recording for Makaroro River at Burnt Bridge for the year ending January 13th – courtesy Hawkes Bay Regional Council

Significant numbers of juvenile rainbow (and brown) trout were also caught in the lower Mangaonuku Stream. However the smallest rainbow caught was 46mm long and as graph 4 shows many fish were around 70 to 80 mm long.



Graph 4 Number of rainbow trout caught in 10mm length classes in the lower Mangaonuku Stream 2011

In the lower reaches where the sampling took place the Mangaonuku is spring fed and stable, characterised by extensive areas of instream emergent vegetation (photo 2). The electric fishing took place along the margins of this vegetation and therefore the density measured (0.6 trout/ M^2) is likely to reflect a significant population of larger juvenile rainbow trout.

No fry at all were observed. However the author has previously noted that the tiny 'hill class' streams in the headwaters of the Mangaonoku catchment appear to provide favourable spawning conditions despite their small size. Given the large numbers of larger juveniles in the lower river it is suggested that significant spawning is likely to take place in these smaller streams.

On the other hand only one 35mm fry was captured in Cochrane's Creek which is also spring fed, despite this stream at least historically having a known spawning run of 50 to 150 rainbow trout (T Winlove pers. com). However the electric fishing team commented on the difficulty of finding suitable fry habitat to fish and it maybe that any fry born in this stream drop quickly into the mainstem.

The numbers of fish measured at the other sites spread down the catchment were too low to draw any conclusions, other than no fish smaller than 40mm were recorded. However the very low numbers and lack of any recently emerged fry is consistent with spawning occurring higher in the catchment. Potentially spawning could occur down here, so long as the winter and spring temperature regime is suitable. On the other hand any fry produced or emigrating to here will grow faster due to the warmer temperatures. In a summary of the technical literature reviewing the role temperature exerts on the physiology of various salmonids, McCullough et al (2001) noted that growth of juvenile rainbow trout is commonly reported to be optimal between 15 C^o and 21 C^o on a satiation diet, though some authors report lower optima between 13 C^o and 16 C^o. They note it is important to provide the full range of natural potential temperature longitudinally, meaning very cold headwaters, cold midreaches and cool lower reaches. This will produce in general lower than optimal growth in the headwaters, optimum growth in the midreaches and lower than optimum growth downstream.

The survey focused on fishing fry and young juvenile habitat along the river edges rather than the faster velocities often favoured by larger juveniles (the stable, vegetation dominated nature of the Mangaonuku meant that in this case the two habitat types overlapped). Therefore it is quite possible that there were many more larger juveniles present at the lower sites. This may indeed be expected if there is a progressive downstream movement of the juveniles as they grow.

Conclusion

The size range of the fry and juveniles caught in the survey suggests most spawning occurs in the Tukituki catchment between late June or early July to as late as the end of October. A mid-winter start to spawning is consistent with the historical operation of the fish trap on Cochranes Creek which typically was installed in the first week of July. This trap was often removed in late August, though it is unlikely given how fish traps were generally operated in the past that the trapping covered the whole period of the run. Nevertheless significant numbers of trout were clearly spawning through the trapping period.

Spawning would appear to occur predominately in the uppermost parts of the catchment, the fry emigrating downstream. Particularly in the smaller streams this emigration is likely to occur within a few weeks of emergence. Lower water temperatures (less than 12 C^o) likely favour spawning in these areas, conversely the fry will potentially grow faster in the warmer temperatures found lower down.

Rainbow trout are a very plastic species as demonstrated by their ability to adapt to a wide range of different conditions around the world, and in this population there will be individuals that do not follow this general pattern. For example a recently excavated redd was observed in the middle Tukipo River upstream of the State Highway 50 bridge in early September 2011.

It is not possible to compare the densities measured in the different locations due to the likely variations in the amount of available habitat, and varying size (and presumably age) of the trout present. However a significant level of spawning seems to occur in the Makaroro River and Dutch Creek, in contrast to the spawning counts I undertook in August and September 2011 which suggested that perhaps a maximum of 200 adult trout spawned here (Maclean 2011).

A possible explanation is that suitable fry habitat is very limited in the Makaroro and so a significant proportion of the juvenile population was in the areas fished. However immediately above the survey site the river flattens out and there are more braids, creating greater areas of apparently suitable habitat.

Another possible explanation is that the upper Makaroro potentially provides ideal spawning conditions, and in the absence of any major freshes through August to December 2011 may have allowed for very high survival from each redd, such that the offspring are the product of relatively few adult pairs.

Alternatively if spawning occurs between late June and late October then it is probable that some spawning fish were not present in the upper river when the escapement (spawning) counts were done in early August and early September (although 50% of the estimate of 200 adult trout is an allowance for this).

The final possibility is that there is not as many adult trout in the Tukituki catchment as we intuitively think, and that the escapement counts reflect a significant proportion of the total spawning population. This is in part consistent with the findings of Maxwell and Pitkethley (2006) who conclude the Tukituki fishery is not limited by the amount or quality of available spawning or juvenile rearing habitat, rather the availability and quality of adult trout habitat. However in the absence of any available hard data on the size of the adult population, the impact of limited adult habitat on determining the numbers of adult trout is unknown.

Of all the locations fished the Mangaonuku appears the most important to the Tukituki fishery, rearing large numbers of fingerlings which presumably then enter the wider fishery with a relatively high chance of survival.

Overall it appears that on the basis of these results that most spawning occurs in the very upper reaches of the main tributaries and the Mangaonuku, and in some of the small side tributaries where conditions are suitable.

These spawning areas appear to be largely separate from the rearing areas downstream.

The location of key spawning areas could be further refined using a combination of escapement and/or electric fishing surveys in likely areas in late winter and early spring. Similarly a review of the extensive water temperature records collected by Hawkes Bay Regional Council would shed light on whether successful spawning may potentially take place in the mid reaches of the main tributaries.

Acknowledgements

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