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Figure 9 (Right) River bank recontouring, lower Waioeka River, 1991.

Figure 10 (Below) Natural canal leading to a natural spawning ground .

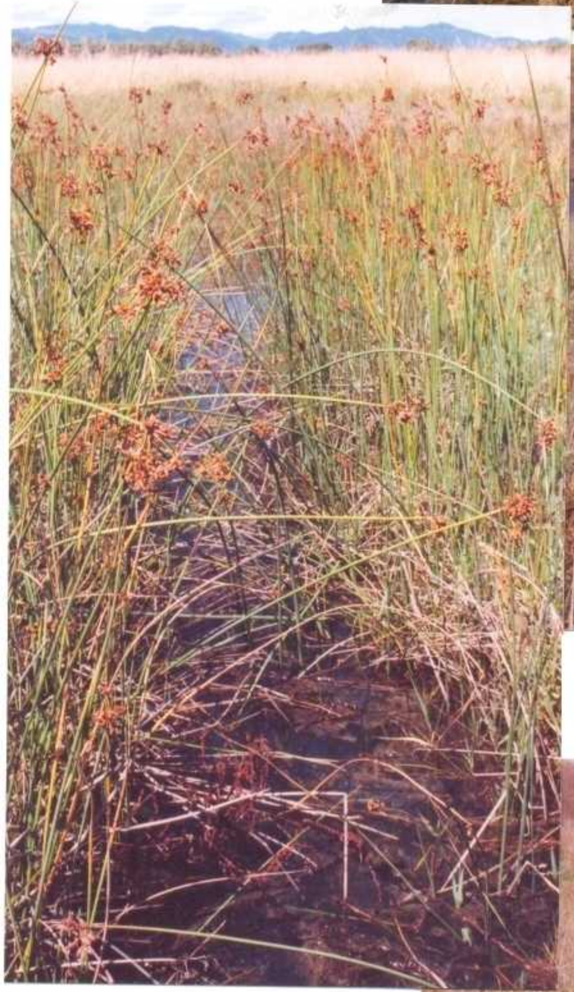

Figure 11 (Above) Proportions of a canal to an artificial spawning ground: the canal is too shallow.

Figure 12 (Right) Excavation for an artificial whitebait spawning ground dug in 1991 (photographed in 1993).

ground is now very dense (Fig. 14), and may be approaching the state of the fenced off area on the Kaituna River. However, whitebait spawned in this area over April 1993 (K. Hogan pers comm.). Fully developed eggs from that spawning were found along the riverbank margins in May 1993, although there was no evidence for spawning in the densely vegetated central bowl which was previously used.

A regularly used whitebait spawning site on the nearby Waiari River is used as a holding area for stock being driven along the East Coast. This site, therefore, experiences episodes of intense grazing, followed by often lengthy periods with no grazing at all.

Figure 13 *(Left)* Vegetation on a spawning ground on DoC leased land. Site is grazed annually and spelled after January each year to allow vegetation regrowth for whitebait spawning. This spawning area is well used.

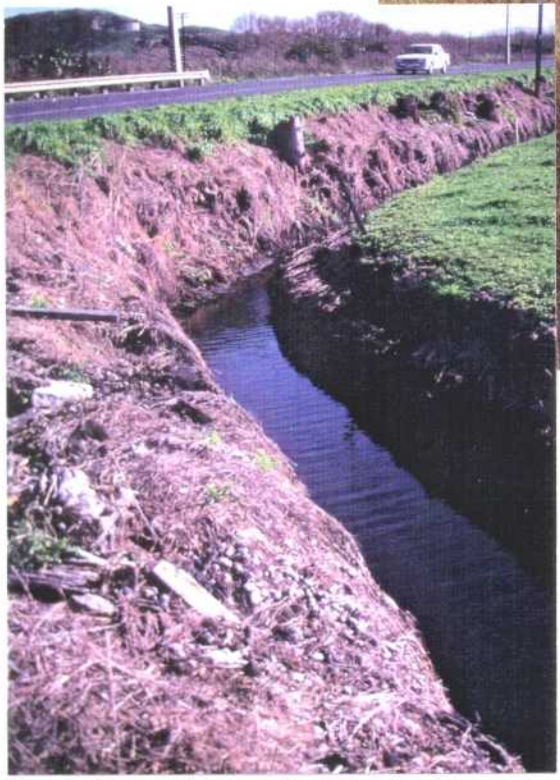

Figure 15 *(Above)* Chemical weed control along the banks of a coastal stream, Western Bay of Plenty (G. Williamson).

Figure 16 *(Right)* Whitebait eggs in willow-leaf litter, lower Waimakariri River (G. Kelly).

4. DISCUSSION

Larval fish studies showed that whitebait spawning occurred up to 11 km upstream from the river mouth, within the zone of tidal influence, but far above the upstream limits of saltwater penetration. It had previously been considered that whitebait spawning sites were clustered around a zone defined by the limits of upstream penetration of saltwater on spring tides. It may be that this zone merely delimits the last spawning sites downstream. Tributary streams and side channels play an important role. A common finding for this study, and for other rivers around New Zealand, has been that whitebait spawning is frequently encountered on the banks of small tributary streams, within the zone of tidal influence. Larval fish studies showed tidal tributary streams well upstream from the limits of saltwater penetration were also important spawning sites.

Tributaries are easily modified by human activity. Farming and drainage have destroyed the natural values of most New Zealand lowlands. Areas with native plants and even approximations of native plant communities are scarce. However on many rivers, the main banks are often left to revert to a relatively "natural" condition once the impact of stop banking and other river control works has subsided. In contrast, small tributary streams become floodgated or cutoff completely by pump-stations. Because they flow across privately owned land they are commonly channelised, straightened and their wetland areas drained or filled. Small stream size, therefore, carries the implication that farming can have a disproportionate effect on the ecology. Herbicide spraying to control riparian vegetation is one obvious activity where whitebait spawning will not be the only natural value to suffer (Fig. 15).

Why should small tributary streams be important as whitebait spawning grounds? A number of reasons can be suggested. Perhaps they function as points where fish can congregate, with an easily recognised odour and low flow pattern. The gradient of tributary streams is likely to be low and they are usually more stable than the main river. This means that the impacts of flooding and silt deposition are likely to be less severe. The author has seen whitebait eggs buried and smothered by siltation resulting from flooding. Riparian vegetation in tributary streams is commonly denser and covers the banks completely, in contrast to the main stream, where beaches and gravel banks can be expected. A more stable microclimate and reduced rates of desiccation are a feature of dense riparian vegetation (Mitchell 1991).

Floodgating small tributaries is a very common agricultural practice. Floodgates prevent back-flow from the river during floods. In the tidal zone, floodgates also block back-flow from the river at high tide. However, depending on flow in the tributary, there will be a secondary backing up of tributary water as the normal outflow is interrupted by the closed floodgate. Despite this "secondary" tidal effect, little evidence for whitebait spawning was recorded from behind floodgates.

I observed many instances of the uneasy balance that seems to exist between whitebait spawning and cattle grazing, without considering the implications fully. A first impression is that grazing is an obviously destructive event for whitebait spawning grounds. But whitebait are frequently found to spawn within grazed pasture, risking all.

Regrowth after grazing can produce a sward of exotic grasses suitable for spawning. Whitebait do seem to be very particular about the length of vegetation they will spawn amongst. Vegetation that is too short will not be used for spawning. One finding of this study is that vegetation can also become so lank and dense, that it is no longer suitable for spawning.

Hayes, the first person to describe whitebait spawning, noticed the same effect in the 1930s (Hefford 1931). He described the impact of livestock grazing and deplored the potential losses caused by trampling. What must be considered is that the areas on the Manawatu River, where Hayes conducted his pioneering studies, had already been grazed for 50-60 years by the 1930s. The replacement of native plants with pasture grasses and exotic weeds must have been essentially complete, in that area, by that time. Grazing is a very powerful process of vegetation modification, rapidly leading to complete replacement of plant communities.

A large scale study on the use of controlled grazing to manage riparian vegetation in a suitable condition for whitebait spawning, has been proposed for the Rangitaiki River mouth (Mitchell 1993). Owing to inadequate flood plain design, only grass can be allowed to grow in the whitebait spawning zone. Two alternative approaches for managing grassed banks for whitebait spawning have been suggested. One approach is to graze from mid-winter to mid-summer followed by spelling before and during the spawning season. The second approach is to graze on a biannual basis. For biannual grazing the river margin is to be managed as two lengths spanning the known whitebait spawning area. Each length is grazed one year and then spelled the next. If this study goes ahead, it should show which of these grazing systems results in the best sward of vegetation for whitebait spawning.

Whitebait are an annual fish. Ovulated females have some 48 hours, or two daylight tides, to find a spot with the exacting terrestrial requirements which developing eggs need (Mitchell, unpublished data). Few if any, females survive to spawn twice (McDowall 1968). What is most interesting is the apparent care with which spawning sites, often the same discrete areas, are selected. These small fish, over high tide, appear to select small and often widely spaced sections of flooded river bank, which will offer a very similar terrestrial environment over the neap tide cycle.

Riparian revegetation has obvious potential benefits for preventing erosion of river banks. In addition there are benefits for water quality and in the provision of wildlife habitat. However at this present stage of understanding of the requirements of spawning whitebait, fencing and retiring river banks does not appear to automatically result in the types of vegetation favoured by whitebait for spawning.

Apparently the sere of exotic grasses and weeds that develops over several years when grazing pressure is removed, becomes too dense and impenetrable for whitebait to enter and spawn amongst. In pre-European New Zealand, a river bank community of native trees and shrubs with an understory of sedges, ferns and leaf litter mats would have been present (Meurk 1990). Shading of patches of the understory by the taller plants and trees would have always resulted in a mosaic of areas of greater and lesser suitability for whitebait spawning.

Willows are now the most abundant tree along New Zealand river banks. An area of swamp, overgrown with willow, was searched during this study. No evidence for whitebait spawning was found along the margins of the tidal channels draining this area. This area was similar to much of the lower Waikato River delta. Willows, by virtue of their summer shading and autumn leaf fall, appear to allow only sparse understory vegetation, unsuitable for whitebait spawning, to develop (Mitchell 1987b). However, there are records of spawning beneath willows. Whitebait eggs were found within leaf litter mats beneath old willows in an area where stock had been totally denied access for some years (Fig. 16). An understory of *Coprosma* spp. and *Cordyline australis* had developed in this area on the banks of the Waimakariri River.

Management techniques which result in stable plant associations suitable for whitebait spawning are needed. On the Waikato River delta a plant community of black alder (*Alnus glutinosa*) with an understory of flax and wandering jew appeared to provide good sites for whitebait spawning (Mitchell 1987b). Shading provided by black alder, which is only partially deciduous at coastal Northern North Island sites, appeared to mimic that provided by native forest. Within the microclimate formed beneath this fast growing, nitrogen fixing pioneer species, plantings of appropriate native climax species such as kahikatea would succeed. Both black alder and wandering jew can be considered as weeds of river banks and waste ground. Herein lies advantage: plants are cheap to obtain, easy to establish and sure to survive grazing "mistakes", flood events, pests and diseases.

This approach is certain to attract criticism. In principle DoC should aim to restore native plant communities. But a quick consideration of costs involved with pre-planting herbicide applications, purchase of genetically appropriate nursery stocks of native plants, planting and subsequent tending, suggests the "correct" approach may not be affordable, apart from show areas.

It is suggested that one half of the fenced area at Kaituna be opened to grazing for the winter of 1993, to be closed again in November to allow grass regrowth. The gate to this area was opened in May. Part of the second half should be shaded with a canopy of shade netting to imitate the effect of a tree canopy. A further part could be planted with black alder trees, and the remainder left as a control.

5. CONCLUSIONS

1. Simply fencing river banks may not, at least in the medium term, lead to a vegetation type suitable for whitebait spawning. After 4 years regrowth following fencing, vegetation apparently become unacceptable for spawning.

A long-term, relatively low intensity study should be made of methods for establishing stable plant associations suitable for whitebait spawning. In the absence of repeated grazing, the most effective technique for establishing a stable mosaic of low growing plants of varying densities would the planting of appropriate trees. Based on observations in the Waikato Basin, black alder would be a suitable tree, compatible with a long term goal of allowing the regeneration of native woody vegetation. Experiments with shade netting on the fenced spawning ground would allow this concept to be quickly investigated. Controlled grazing has already proven successful at DoC managed sites.

2. Larval fish netting proved valuable for locating spawning sites.

   2.1 Seven new spawning areas were discovered, most were along the margins of tributary streams and drains.

   2.2 Riparian revegetation work resulted in a similar pattern of dense vegetation growth as that found within the fenced spawning ground. For this reason it is considered unlikely that whitebait spawning will be enhanced within these fenced areas (at least in the medium term). Development of techniques to grow vegetation appropriate for whitebait spawning has value for the long term management of riparian zones.

   2.3 Floodgates appear to provide poor conditions for whitebait spawning in the streams above the floodgates. This conclusion was suggested by the results of larval fish sampling. Few fish larvae were caught above floodgates and only one *Galaxias maculatus* larvae was caught. A study is required to look at the numbers and species of fish which actually can get past floodgates on their upstream migration. Techniques for allowing fish passage past floodgates may be necessary.

3. By default, chemical control of aquatic weeds does not appear to impact upon whitebait spawning areas in the lower Kaituna River. In this river, floodgates may prevent spawning in most areas where chemical weed control occurs.

4. Whitebait spawning grounds can be artificially constructed. Observations of the conditions which had developed after two years on artificially constructed sites has led to a series of recommendations to improve the design, size and layout of artificial spawning grounds.

6. ACKNOWLEDGEMENTS

This study would not have been possible without the support of DoC staff. Gavin Williamson participated enthusiastically, even to waiting around until two in the morning for the tide to turn above a floodgate. Kerry Hogan was also tolerant of my obsession about whitebait spawning grounds and contributed greatly to the section on construction of spawning grounds. Supplementary funding was provided by the Western Bay of Plenty District Council.

As a new consultant I am grateful for this opportunity given by DoC S&R Division to continue monitoring of such a long term project. My former controlling officer A.M.R. Burnet once told me "By all means monitor a site for one season, or four or more, but try to avoid two. One year will always differ wildly from the other!" Without long term monitoring, conclusions could be drawn quite rightfully, from a limited data set, that could eventually even be detrimental to the protection and enhancement of whitebait spawning grounds.

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