SCIENCE & RESEARCH SERIES NO.69

WHITEBAIT
SPAWNING GROUND MANAGEMENT

by

C.P. Mitchell

Published by
Head Office,
Department of Conservation,
P 0 Box 10-420,
Wellington,
New Zealand

ISSN 0113-3713
ISBN 0-478-01608-5

The project was jointly funded by DoC and the Western Bay of Plenty District Council. This publication originated from work done under Department of Conservation contract No.1531, and was approved for publication by the Director, Science and Research Division, Department of Conservation, Wellington.

Cataloguing-in-Publication data

Mitchell, C. P. (Charles P.), 1950-
Whitebait spawning ground management / by C.P. Mitchell.
Wellington, N.Z. : Dept. of Conservation, 1994.
1 v. ; 30 cm. (Science & Research series, 0113-3713 ; no.69.)
Includes bibliographical references.
ISBN 0478016085
1. Galaxias fisheries--New Zealand. I. New Zealand. Dept. of Conservation. science and Research Division. II. Title. III. Series: Science & research series ; no. 69.
597.550993 20
zbn94-059875

Keywords: whitebait, *Galaxias maculatus*, riparian management, coastal streams, freshwater fishery, vegetation management

CONTENTS

WHITEBAIT SPAWNING GROUND MANAGEMENT

by
C.P Mitchell
Charles Mitchell & Associates, Te Manu Road, RD 2, Rotorua

ABSTRACT

After two years of high use by whitebait, a whitebait spawning ground on the banks of the Kaituna River, Bay of Plenty, which was fenced in 1989, was progressively abandoned after 1990. Four years regrowth had apparently resulted in vegetation too dense and matted for normal spawning. It is postulated that simply fencing river banks does not, at least in the medium term, automatically lead to a vegetation type suitable for whitebait spawning. Riparian vegetation dominated by exotic grasses may require periodic mowing or grazing to maintain a suitable sward. In autumn 1993 one half of the spawning ground was reopened for grazing over winter and spring.

Methods for establishing stable plant associations suitable for whitebait spawning are needed. In the absence of repeated grazing, the most effective technique for establishing a stable mosaic of low growing plants of varying densities, would be shading by trees compatible with a long term goal of regeneration of native vegetation.

Seven new spawning areas were discovered, most were along the margins of tributary streams and drains. Larval fish netting proved valuable for location of spawning areas.

Few fish larvae were netted above floodgates and only one Galaxias maculatus larvae was caught. The impact of floodgating obscured any evaluation of the impact of chemical control of aquatic weeds in the lower Kaituna River. Floodgating of all but 2 of 13 major tributaries and drains has effectively blocked whitebait spawning. Areas requiring weed control were mainly above floodgates, where a combination of slow water flow and nutrient loadings from agricultural activities contribute to rapid weed growth.

Within the two remaining open tributaries, impacts of high silt loadings, effluent discharge, mechanical drain cleaning and channelising were compounded with impacts of chemical control of aquatic weeds. Design criteria for construction of artificial spawning grounds are suggested.

1. INTRODUCTION

McDowall and Eldon (1980) commented: "maintenance of a productive whitebait fishery on West Coast rivers during the past 30 years, when there has been a major decline in other parts of New Zealand, is due to the relatively slight agricultural development of the West Coast". Decline of whitebait numbers in New Zealand rivers has paralleled the advance of agriculture.

The Kaituna River lowlands in the Bay of Plenty are agriculturally developed (Figs 1 & 3). The whitebait catch has declined. In the 1930s this river produced a commercial whitebait catch which averaged 2900 kg per annum (New Zealand Marine Department Annual Reports, 1932-1939). In contrast, Saxton *et al.* (1987) estimated the total 1984 catch to be only 75 kg.

Whitebait lay their eggs on river banks at spring tide level. Eggs remain on the banks while they develop. Hatching occurs after 20 to 50 days (Mitchell 1991), when the eggs are reflooded by later series of spring tides. The ecology of whitebait spawning leaves eggs very vulnerable to the effects of human use of river banks. Grazing of livestock, particularly cattle, has had a far reaching effect upon the ecology of sites on New Zealand river banks where whitebait spawn. Grazing results in the replacement of native plants with grazing tolerant exotic grasses. Grazing affects the microclimate where eggs must develop, the soil chemistry, microbiology and even invertebrate fauna.

Whitebait spawning has been studied on the lower Kaituna River since 1987 (Mitchell 1987a). Both the Department of Conservation and MAFFish made a considerable investment into this research. More recently the Western Bay of Plenty District Council has also supported the work. Over the past five years a known whitebait spawning ground has been monitored over every spawning season.

A number of methods important for management of whitebait spawning grounds around New Zealand have been investigated. In 1989 fencing was used to stop grazing of one part of this spawning ground. Studies have since been conducted of vegetation succession, spawning site microhabitat, egg survival and the effect of predators on whitebait eggs (Mitchell 1991, Mitchell *et al.* 1992).

Over autumn 1991 an extensive survey was conducted to look at larval fish distribution in the lower Kaituna River. This survey coincided with a year of reduced spawning activity on the known spawning ground. A trend of reduced activity was reinforced in 1992 when no evidence for spawning could be found within the fenced off spawning ground. Despite the lack of eggs on the known site, larval fish studies showed that whitebait larvae remained abundant in the river ichthyoplankton, with the highest density coming out of tributary streams (Mitchell *et al.* 1992).

1.1 Aims of the study

Over autumn 1993 the following topics were investigated:

1. Patterns of whitebait spawning at the fenced off spawning ground.
2. The existence of other spawning sites:

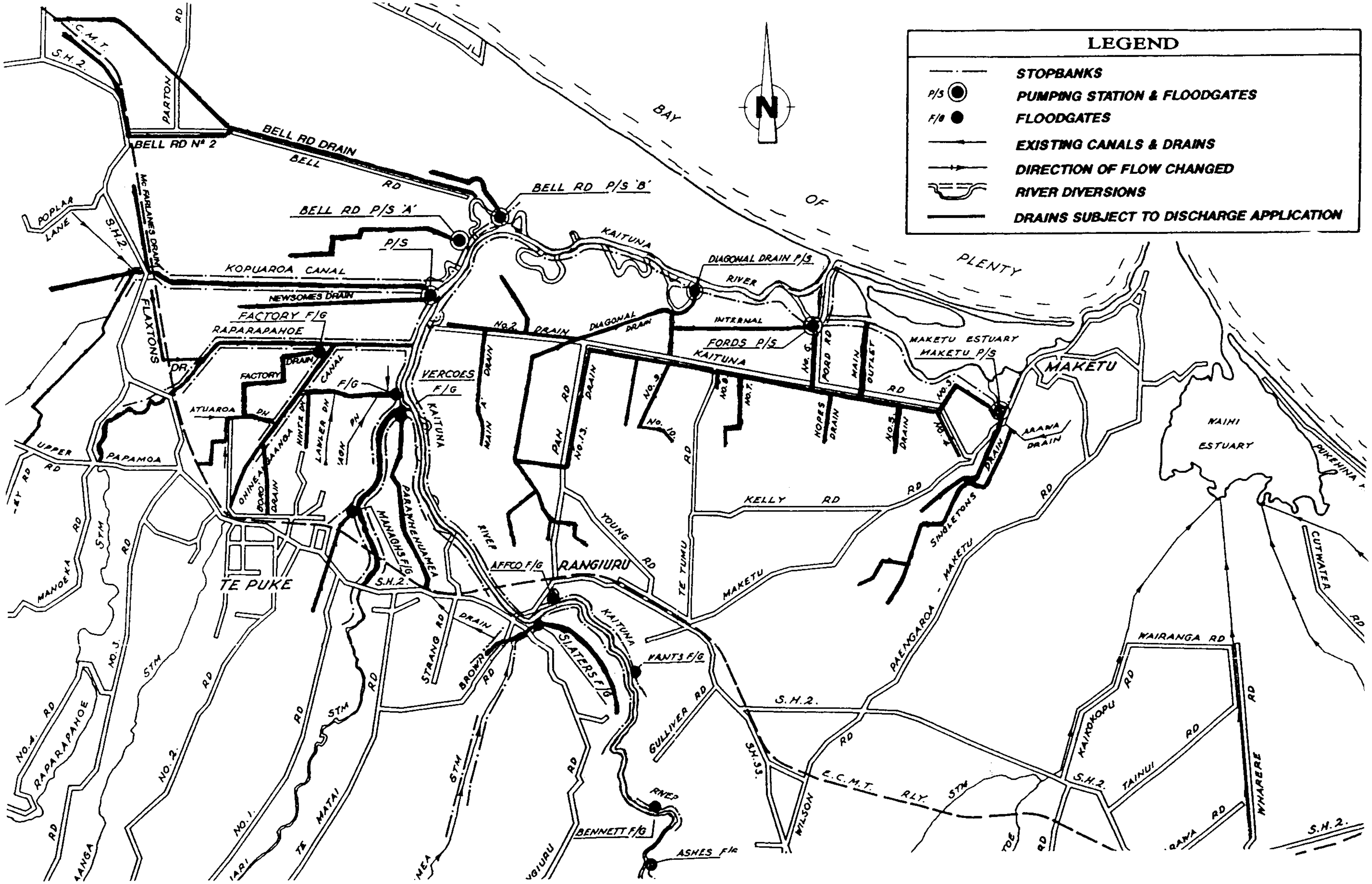

Figure 1 Lower Kaituna River floodplain drainage system showing areas of chemical weed control (heavy lines), floodgates, and other water control structures.

a. Tributaries known to produce large numbers of whitebait larvae over a wide range of tidal levels were searched.
b. A repeat search of a riparian area along the main river which was replanted with flax and fenced off 5 years ago by the Bay of Plenty Regional Council.
c. Spawning above floodgates was assessed by ichthyoplankton netting immediately above floodgates.

3. Impact of riparian vegetation management upon whitebait spawning. This included an examination of the effects of aquatic weed control with herbicide sprays.
4. Impact of floodplain recontouring (including areas excavated to create sites suitable for whitebait spawning).

2. METHODS

2.1 Whitebait spawning at the fenced off spawning ground

The fenced off spawning site was visited following peak spring tides in April and May 1993. The site, stretching 50 m along the bank and 12 m wide, was searched for whitebait eggs. A total of four hours was spent at the site. Known microsites used in previous years were carefully searched and a series of spot checks made through the spawning ground.

2.2 Location of other spawning sites

2.2.1 Tributary streams Following peak spring tides in April and May 1993, tributaries from the fenced spawning ground upriver to the Waiari stream, were visited and searched for whitebait eggs. From half an hour to two and a half hours were spent at each tributary. Particular attention was paid to areas of swamp vegetation, where root mats of Typha orientalis and Mimulus guttatus extended from normal water levels up to the spring tide level.

2.2.2 Regional Council Riparian Revegetation Project Following searches for eggs along the tributary streams, this area was visited and a series of spot searches made along the banks. Notes were made of patterns of vegetation succession and dominant species.

2.2.3 Spawning above floodgates Using 0.25 m^2 mouth opening, 300 micron mesh ichthyoplankton nets, four floodgated tributaries were netted for evidence of whitebait spawning, upstream of the floodgates. Nets were set at night, as the tide fell. Preserved subsamples of fish larvae were measured to ±0.2 mm, using a binocular microscope. Measurements were compared with larval fish reference dimensions established for larval fish in a previous study (Mitchell et al. 1992).

2.3 Riparian vegetation management and the impact of aquatic weed control

Sections of the lower Kaituna River drainage system where chemical control of aquatic weeds has occurred, were identified from Regional Council Records (Fig. 1). Streams known to produce high concentrations of whitebait larvae were examined. These areas were walked or inspected by boat (where possible). Searches were made in promising areas for whitebait eggs. Observations were made of any impacts on the suitability of these reaches for whitebait spawning, after chemical control of aquatic weeds.

2.4 Flood plain contouring

The Bay of Plenty Regional Council undertook extensive lowering of the floodplain of the Waioeka and Otara Rivers in 1991. The work was overseen by DoC and an attempt was made to create areas suitable for whitebait spawning. Two summers have elapsed since this recontouring, regeneration of riparian vegetation is now substantial. These sites and known whitebait spawning grounds were visited with Kerry Hogan (DoC Opotiki), to assess the value of artificially created spawning habitats.

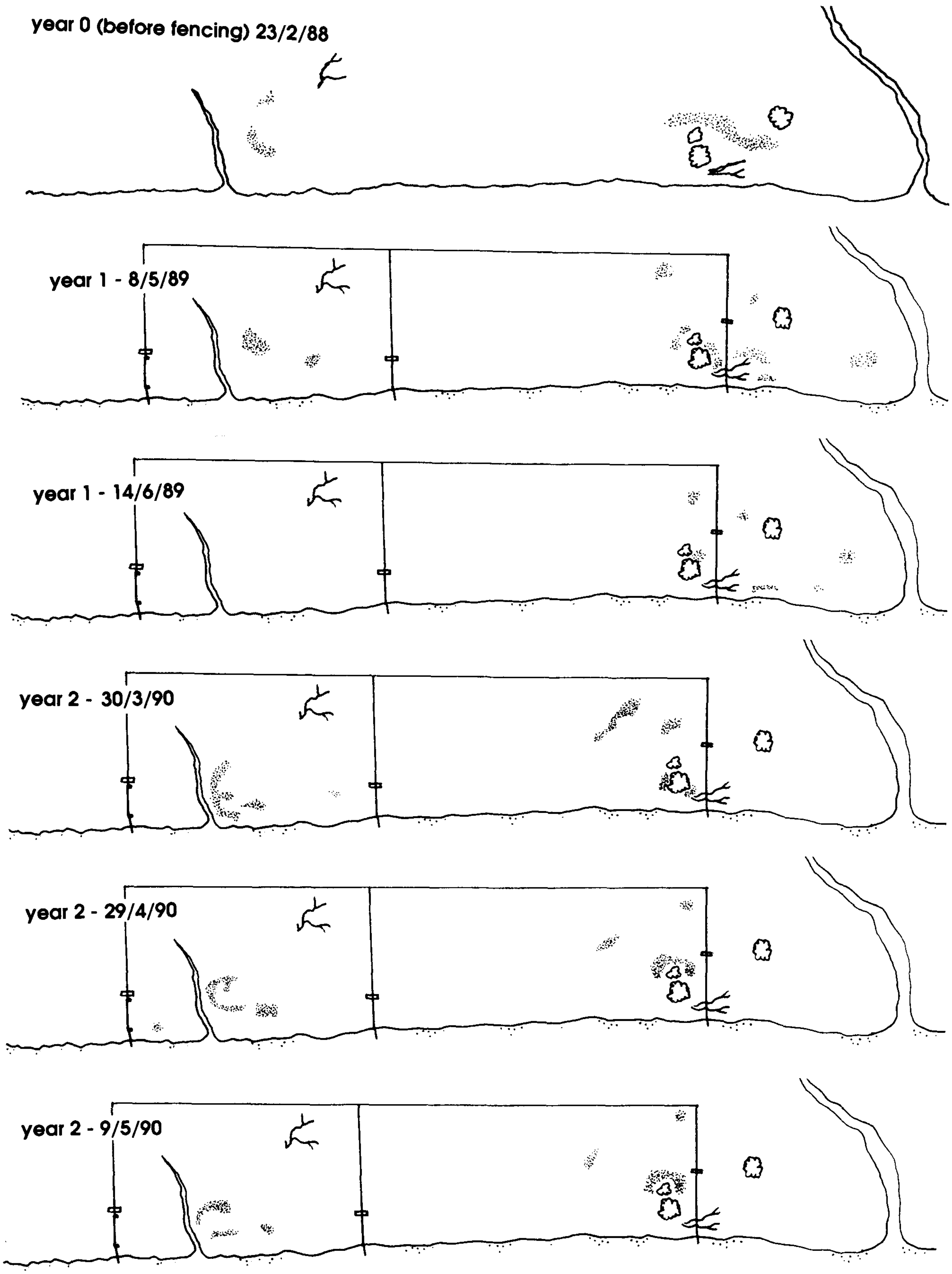

Figure 2 **The fenced site, 1988-1993, showing areas used for whitebait spawning (fine stipple).**

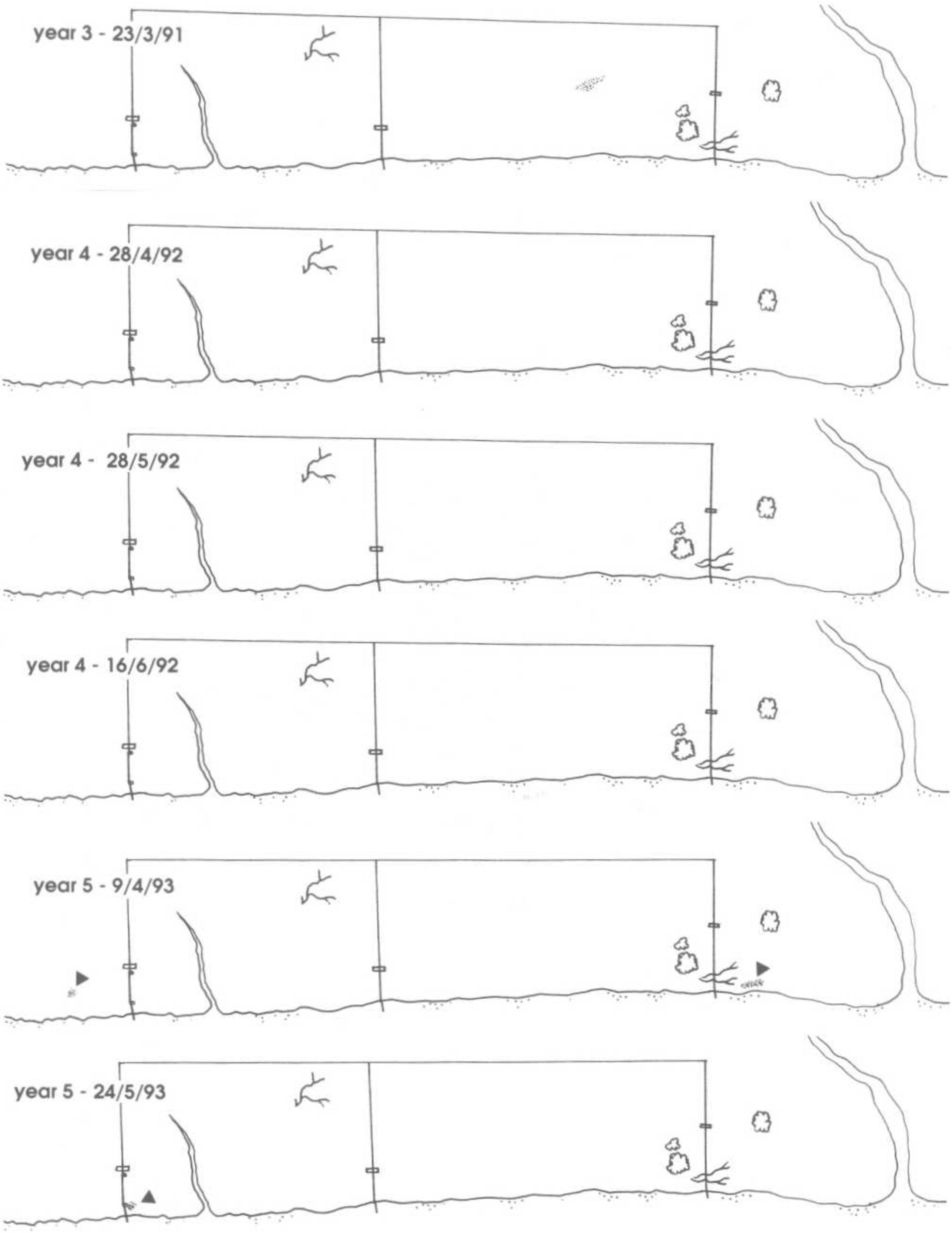

Figure 2 (Continued)

3. RESULTS

3.1 Whitebait spawning at the fenced off spawning ground

Figure 2 shows the changes in whitebait spawning intensity since 1988. The significant feature is an increase in the intensity of usage over the first two years after fencing, followed by a tapering off in spawning activity. This pattern was maintained in 1993 with only one small patch of spawning found, in May only, adjacent to the fenceline where cattle had cropped the *Glyceria maxima* down. The pattern of vegetation types had not altered greatly from previous years apart from an extension of *G. maxima* into the higher ground formerly dominated by tall fescue (*Festuca arundinacea*) Therefore an initial pattern of rapid change in the plant community (Mitchell 1991) had become almost stabilised within 4 years.

One instructive feature of autumn 1993 was there had been no grazing of stock on the surrounding land for six months. The area was used to grow a maize crop over summer. After no grazing for this period, creeping bent (*Agrostis stolonifera*) and Festuca had reached a length of 15-30 cm along the river bank. In April, whitebait spawning was found in this grass only, straddling the fenced spawning ground (Fig. 2 & 4). Unfortunately cattle were returned to the paddock before these eggs would have had time to hatch (Fig. 5). In May a small patch of spawning was found on the edge of the fenced area, where cattle reaching through the fence had shortened the grass.

It was observed that a peat like layer of organic material derived from the breakdown of grass litter had developed on the surface of the soil within the fenced area. Possibly this layer of rich organic material up to 20 cm thick further reduced suitability of the site for spawning. Measurements of vegetation height and stem density indicated that little change was apparent since 1990 (Fig. 6)

3.2 Existence of other spawning sites

3.2.1 Small tributaries Several new spawning areas were found during the course of this study (Fig. 7). Perhaps the most significant was that found along the banks of the small tributary known as Cabbage Tree Creek. Larval fish studies (Mitchell et al. 1992), had previously indicated that this small stream/cut off river meander, was a consistent producer of larval *Galaxias maculatus* (common whitebait). Fine-mesh fyke nets set in the stream caught large numbers of recently spawned adult *G. maculatus* as the tide fell. However searches for spawning fish revealed only a few, spawning within clumps of rush (*Juncus gregiflorus*) at the mouth of the stream. Careful searches along the stream banks finally revealed that large numbers of eggs had been deposited along the upper margins of a raupo (*Typha orientalis*) stand bordering the stream on one bank. Eggs were laid within creeping bent (*Agrostis stolonifera*), musk (*Mimulus guttatus*) and on the decaying mat of raupo stems. A scattering of eggs right down to mid-tide level suggested how this stream could remain a producer of whitebait larvae over all but neap tides (Mitchell *et al.* 1992). Repeated draglining along the other bank had left steep, muddy sides unsuitable for whitebait spawning.

This raupo-dominated community was obviously acceptable for whitebait spawning whereas conditions leading to encroachment by raupo onto the formerly grass dominated

Figure 3 Grading the lower Kaituna River floodplain.

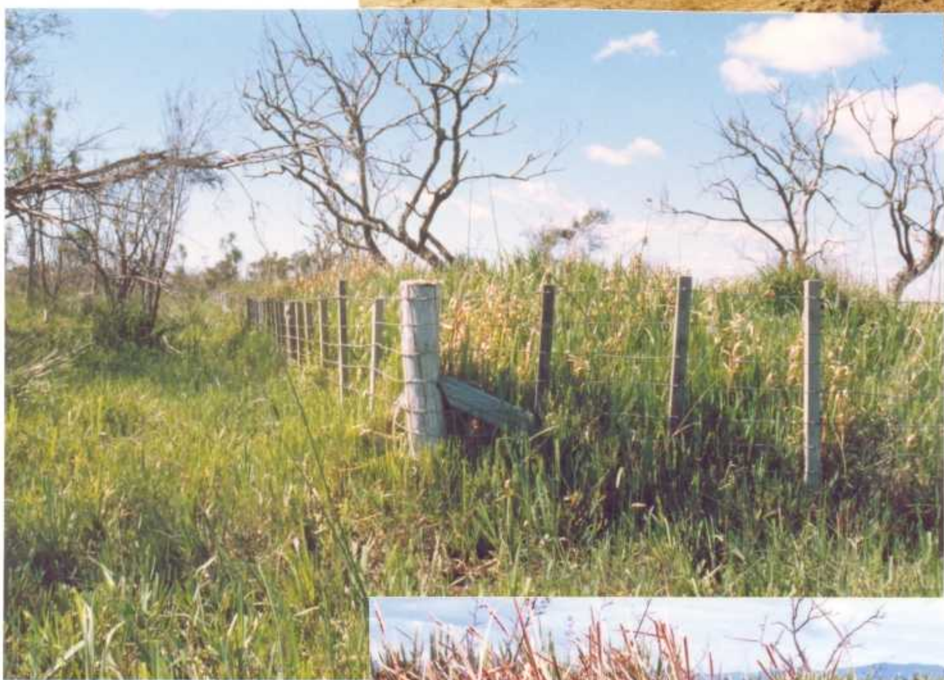

Figure 4 Vegetation outside enclosure before grazing, April 1993.

Figure 5 Vegetation outside enclosure after grazing, May 1993.

fenced spawning ground, resulted in a plant community apparently unacceptable to whitebait. One clue is given by the fact that cattle do gain access to the spawning ground used on Cabbage Tree Creek, although the soft soil and surrounding swamp means that only light grazing occurs. There was nothing remarkable about the other nine spawnings found. Eggs were laid within lank grass (*Agrostis*, *Festuca*), wandering jew (*Tradescantia fluminensis*) and rushes, in lightly grazed or recently spelled areas.

3.2.2 Regional Council Revegetation Project First impressions were that excellent regeneration of plants had occurred along the margins of the Kaituna River fenced off by the Regional Council. Unfortunately the area chosen for this work lies above the known upstream limits of whitebait spawning on the Kaituna River (Fig. 7). However, inspection showed that a plant community similar in many aspects to the fenced off spawning ground had developed. Dominant plants were flaxes planted by the Regional Council and the aggressive weed, pampas grass (*Cortaderia* sp.). Exotic weeds such as *Glyceria maxima* and *Bindens frondosa* were in evidence. Bushes of *Coprosma robusta*, *Buddleia davidii* and other woody species had also begun to appear. Good plants of *Carex* (*C. secta* and C. *geminata*) were present in places along the tideline. Mats of bidibid (*Acaena novaezelandiae*) covered extensive sections of the area. One result of this lush plant growth was a dense mat of decaying plant stems and peat, similar to the fenced off spawning ground. As in previous years, searches failed to find any whitebait eggs. A plant community suitable for whitebait spawning clearly does not invariably develop as a result of riparian fencing.

Margins of the Raparahoe Canal have also been fenced off and retired (after a fashion) from grazing. This area was examined; whitebait spawning was found at an area of slumped bank, at the canal mouth, but outside the fenced area. Retirement from grazing for long periods had resulted in a plant community dominated by pampas grass, pussy

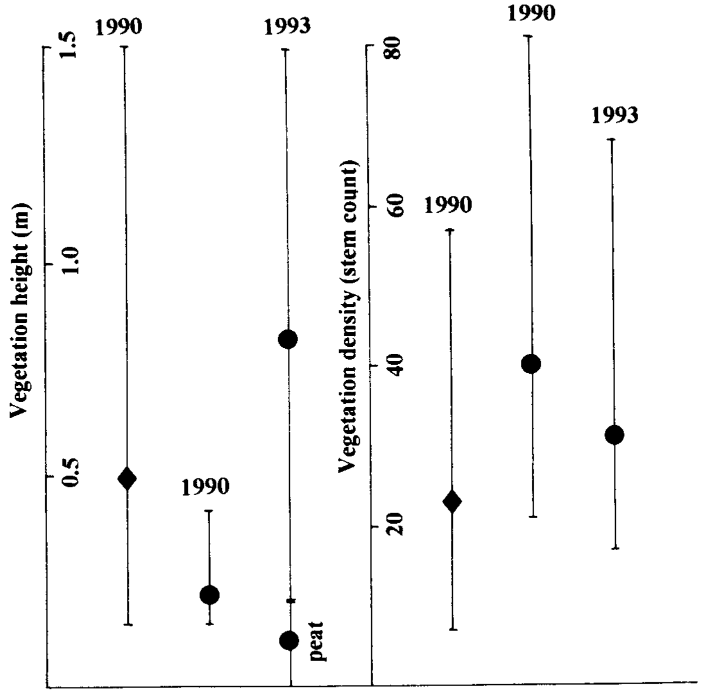

Figure 6 Vegetation height and stem density changes in grazed (♦) and ungrazed (●) spawning sites. Bars indicate maximum and minimum values.

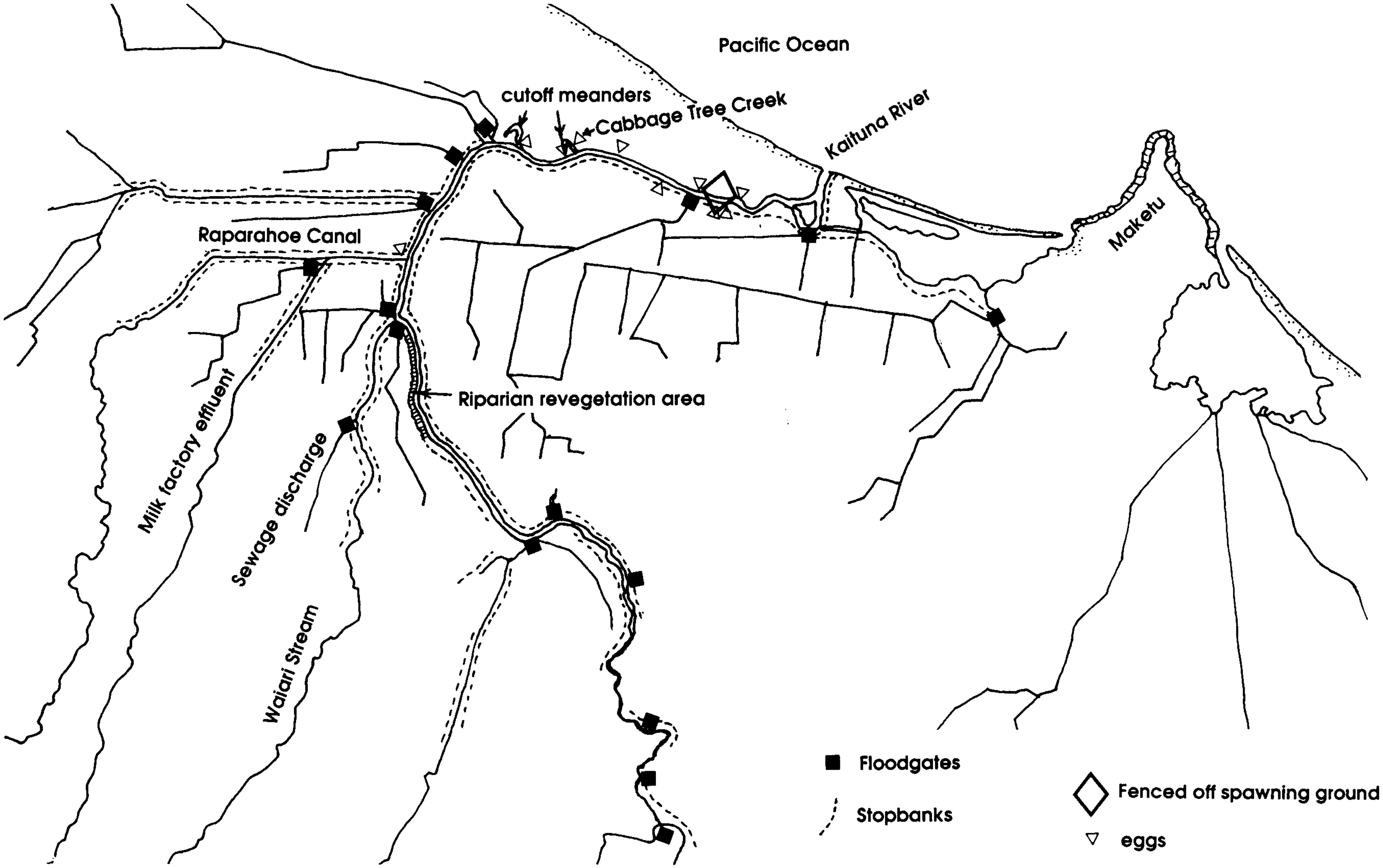

Figure 7 Whitebait spawning sites found on the lower Kaituna River.

willow and *Buddleia* on the higher and drier ground. The steep sides of the canal appeared superficially suitable for spawning, being covered with tall fescue, wandering jew and hard fern (*Paesia scaberula*), although patches of blackberry (*Rubus fruictosa*), with a resulting bare understory, were also evident. However, apparent episodic floods of silt laden water had resulted in smothering of the lower layers of stems which whitebait spawn amongst. As a result the vegetation was simply too sparse to be suitable for spawning. An investigation was made of a small tributary of the Raparahoe Canal, (the Ohineaanga Drain). This tributary had vegetation which appeared better for whitebait spawning. Silt loadings were apparently less, although the drain carries effluent from the Te Puke Dairy Factory. No evidence for whitebait spawning was found. Larval fish studies had previously indicated only the lower reaches of the Raparahoe Canal to be a significant source of whitebait (*Galaxias*) and smelt (*Retropinna*) larvae.

3.2.3 Spawning above floodgates The catch of larval fish from the Waioeka River was disappointing, perhaps whitebait spawning and hatching is more closely linked to tide levels than in the Kaituna River. However one larval *G. maculatus* was netted from Huntress Creek, well above the floodgates (which had recently developed a major leak). This solitary larvae was caught in a net set overnight in a drain leaving a wetland area. This wetland has botanical values which give it potential for restoration (K. Hogan pers. comm.). An overnight set in the main channel of Huntress Creek caught nothing apart from cyclopoid copepods and *Paratya curvirostris* (freshwater shrimp).

Table 1 The catch of larval fish from the various sites sampled.

River	Site	Time	Nil Catch	*G. maculatus*	*R. retropinna*	*G. cotidianus*	Kokopu
Kaituna 24/5/93							
	Cabbage Ck	15 min night		6	6	1	3
	Bell Rd Floodgate	30 min night			1	1	
	Wetland Floodgate	20 min night	**				
	Parawhenuamea Drain	20 min day	**				
	Ohineaanga Drain	20 min day	**				
Waioeka 10/5/93							
	Huntress Ck.(trib)	8 hours night		1			
	Huntress Ck.	8 hours night					
	Right bank below bridge	25 min night	**				
	Right bank above bridge	20 min night	**				
	Left bank at bridge	20 min day					
	Tributary	20 min day	**				
Otara							
	Spawning ground	40 min day					

None of the three floodgates fished on the Kaituna River appeared to provide habitat upstream suitable for whitebait spawning, although one *R. retropinna* and one *G. cotidianus* larvae were taken from above the Bell Road floodgate in a 30 minute net set. In contrast, 6 *G. maculatus*, 3 *Galaxias* sp. and 5 *Retropinna retropinna* larvae were netted by a 15 minute set in Cabbage Tree Creek on the same night (Table 1). One pertinent observation was the greatly reduced tidal range behind the floodgates. With a dry period preceding the study, the amount of water backed up over the tidal cycle was not great, less than 20 cm. It required 5 hours after the turn of the tide before water began to flow out of the Bell Road floodgate. Whitebait may simply not respond to such a small tidal fluctuation for spawning. It seems more likely that fish migrate downstream past the floodgates, to spawning sites where levels fluctuate naturally.

3.3 Riparian vegetation management and aquatic weed control

Figure 1 shows the relevant areas affected by chemical weed control. As the great majority of weed control areas were above floodgates, the findings of the ichthyoplankton study were relevant. Spawning does not appear to occur above floodgates and so weed control impacts in these areas do not include loss of whitebait spawning habitat. Only two of 11 major tributaries of the Lower Kaituna River were not floodgated in 1993. These two tributaries, the Raparahoe Canal and the Waiari Stream were boated and walked, looking for whitebait spawning sites.

Despite aquatic weed control the previous summer, beds of *Elodea canadensis* were present in the Waiari Stream. An abundant fish community of trout, smelt and inanga was seen, although this stream carries the sewage effluent from Te Puke township. From the mouth of the Waiari Stream to the railway bridge, long stretches of dense pasture, apparently suitable for whitebait spawning was present. No whitebait eggs were found although whitebait spawning was in progress on the lower Kaituna at the time.

Fast flowing water and the unstable sandy substrate of the lower Raparahoe Canal evidently restricts growth of aquatic plants. Weed control spraying had not noticeably affected marginal vegetation, although the relatively sparse growth of wandering jew and tall fescue on the canal banks could have been due to spray drift rather than smothering by flood events. The whitebait spawning site found at the mouth of the Raparahoe Canal was in grazed pasture, within tall fescue regrowth, along a slump line at the top of the canal bank.

3.4 Floodplain contouring

Areas affected by floodplain recontouring on the Waioeka and Otara Rivers were visited. Recontouring, involving a general lowering of the inside berms of the stopbanks, was done in 1991 by the Bay of Plenty Regional Council (Fig. 9). Areas for whitebait spawning were excavated at this time.

A total of four artificial spawning areas were examined. After two years a plant community apparently suitable for whitebait spawning had regrown. At the correct level for spawning, the plant community was dominated by tall fescue and white clover (*Trifolium repens*). Whitebait eggs were found on one area but the others had not been used. Based on experience at other sites, the spawning areas were assessed for

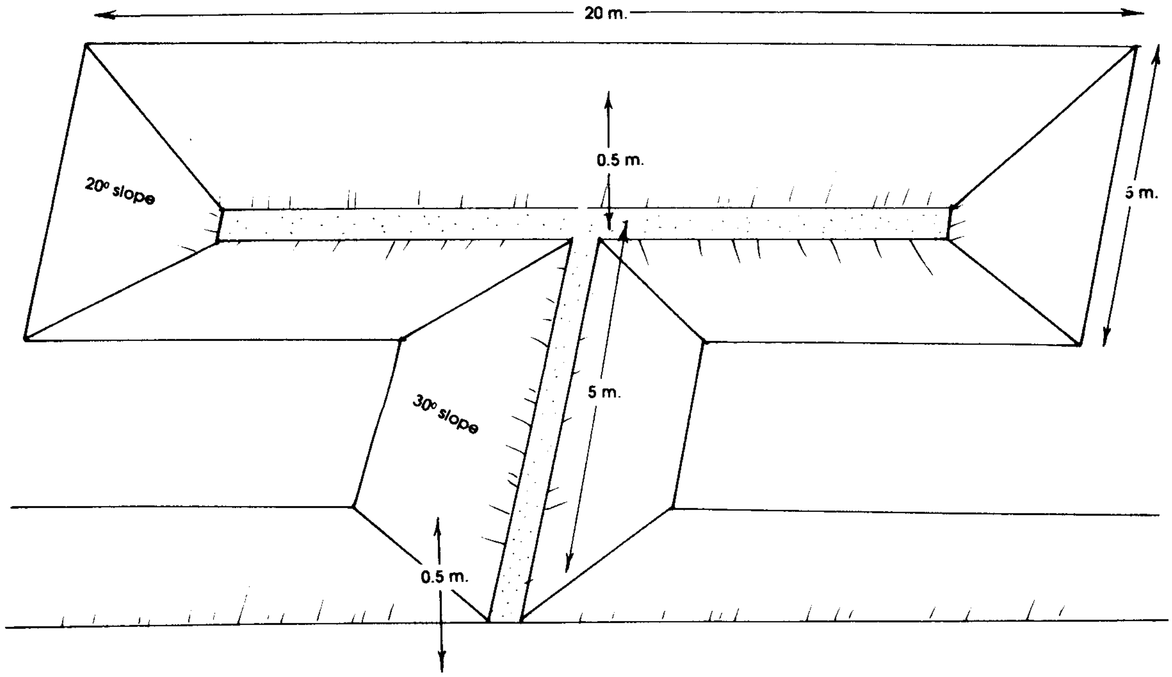

Figure 8 **Diagram of an excavation to create artificial spawning grounds.**

modifications which could make them more suitable. Figure 8 shows a diagrammatic layout of the features considered necessary for an artificial spawning ground. The first requirement is a channel at or below mean river level leading into the spawning ground (Fig. 10). Figure 11 shows Mr K. Hogan standing in the channel excavated between the spawning ground and the Otara River. The channel is considered not to be deep enough. Leading off from the canal is a bowl (Fig. 12). Whitebait spawning should take place on the sides of the inlet canal and around the margins of the bowl. This bowl must be large and deep enough to hold a reasonable volume of water at full tide. It is thought the stimulus of water flowing into and out of the spawning area as the tide rises and falls, is a large part of the attraction to whitebait, causing schools to congregate and stream into the area. The one artificial site used by whitebait was on the eastern bank of the Waioeka River, and exposed to the prevailing winds (in the area shown in Fig. 9). Driftwood was stranded along the shoreline of this area and it may be wind assisted surges which explain the attractiveness of this relatively high level spawning site.

Artificially constructed spawning grounds have the potential to be successful and may be able to compensate to at least some extent, for the major losses of spawning habitat which have occurred with flood control works on New Zealand rivers (Figs 2 & 9).

The spawning ground on the island in the Waioeka River where DoC has controlled the grazing regime over several years was examined. Spelling for 2 months before the spawning season, in the warm coastal climate of Opotiki, results in patches of *Paspalum paspaloides* and *Agrostis stolonifera* long and dense enough for whitebait spawning (Fig. 13). In contrast the spawning ground on the Otara River has not been grazed heavily for the past four years. Vegetation of this previously outstanding spawning

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.

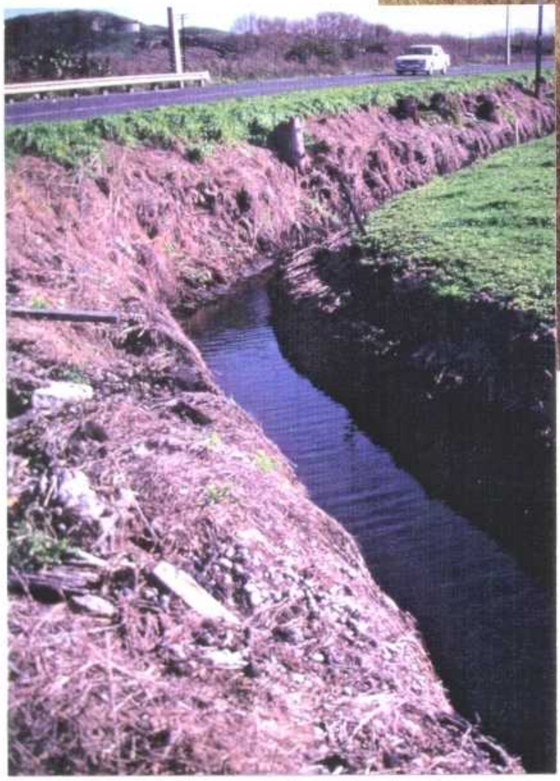

Figure 15 *(Above)* Chemical weed control along the banks of a coastal stream, Western Bay of Plenty (G. Williamson).

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.

7. REFERENCES

Hefford, A.E. 1931: Whitebait. *Report of the Inspector of Fisheries, New Zealand Marine Department 1930*: 21-23.

Meurk, C.D. 1990: Inanga spawning habitat on the West Coast, South Island. Report to MAF Fisheries, DSIR Land Resource/Botany, Christchurch, New Zealand. 25p.

McDowall, R.M. 1968: *Galaxias maculatus* (Jenyns), the New Zealand whitebait. *New Zealand Ministry of Agriculture and Fisheries, Fisheries Research Bulletin No.* 2. 84p.

McDowall, R.M., Eldon, G.A. 1980: The ecology of whitebait migrations (Galaxiidae: *Galaxias* spp.). *New Zealand Ministry of Agriculture and Fisheries, Fisheries Research Bulletin No. 20.* 171p.

Mitchell, C.P. 1987a: Whitebait spawning grounds in the Bay of Plenty. *New Zealand Ministry of Agriculture and Fisheries, New Zealand Freshwater Fisheries Miscellaneous Report No. 40.* 20p.

Mitchell, C.P. 1987b: Whitebait spawning grounds on the lower Waikato River. *New Zealand Ministry of Agriculture and Fisheries, New Zealand Freshwater Fisheries Miscellaneous Report No. 42.* 12p.

Mitchell, C.P. 1991: Whitebait spawning ground management: interim report. *New Zealand Ministry of Agriculture and Fisheries, New Zealand Freshwater Fisheries Report No. 131.* 20p.

Mitchell, C.P. 1993: Management of riparian margins of the lower Rangitaiki River to enhance whitebait spawning success. *Conservation Advisory Science Notes No. 27.* 5p.

Mitchell, C.E, Madgewick, H.H., Strickland, R.R., and Van Boven, R.J. 1992: The use of larval fish as an aid to identifying whitebait spawning grounds, and the role of slugs as predators on whitebait eggs *New Zealand Ministry of Agriculture and Fisheries, New Zealand Freshwater Fisheries Miscellaneous Report No.* 127. 34p.

Saxton, B.A., Rowe, D.K., Stancliff, A.G. 1987: Species composition and relative importance of whitebait fisheries in 13 Bay of Plenty rivers. *New Zealand Ministry of Agriculture and Fisheries, Fisheries Environmental Report No. 79.* 63p.