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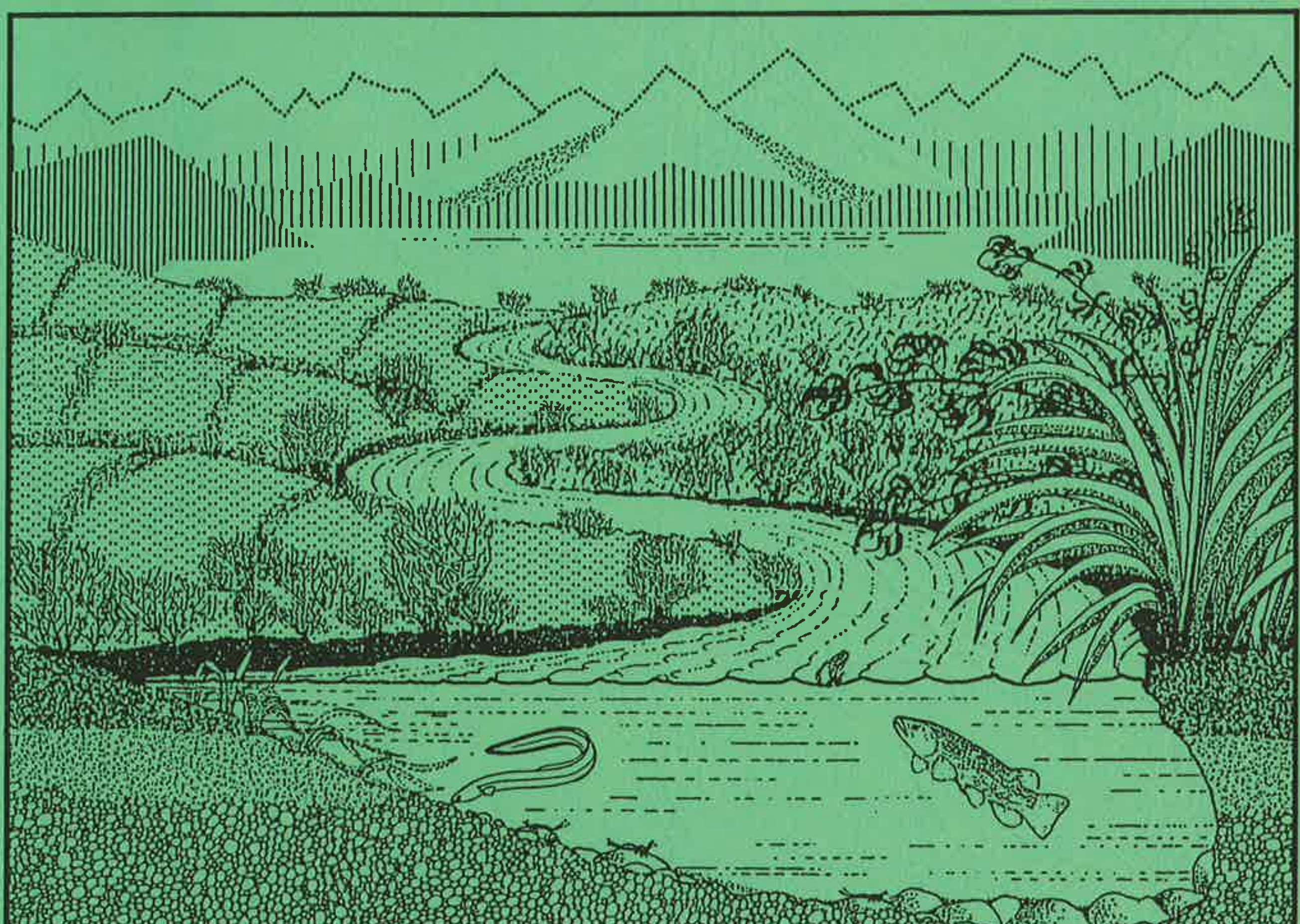

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Recolonisation of a stream diversion by aquatic invertebrates and fish, Big Hohonu River, Westland

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MINISTRY OF AGRICULTURE AND FISHERIES
TE MANATU AHUWHENUA AHUMOANA

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SUMMARY

A gold-mining diversion of a reach of a small mountain and forest drainage river on the West Coast of the South Island was studied for one year to ascertain recolonisation times by aquatic fauna, and to assess the practicalities of creating stream improvement features.

Floods removed all trace of stream improvements, such as boulder-drops, within a few months. Aquatic fauna was severely depleted in the short term. Invertebrates recolonised to their former level within 91 days, but numbers declined subsequently, owing to continued deposition of silt from eroding banks.

Blue-gilled bully numbers decreased initially, but were approaching the numbers recorded in a control reach at the end of the year. Long-finned eel numbers declined and were still declining at the end of the study, probably owing to continued siltation from erosion of the mined flood bed. Brown trout numbers fluctuated seasonally, but were higher at the end of the study than at the start.

1. INTRODUCTION

The Big Hohonu, or Greenstone, River rises in the Hohonu Range, 32 km east of Hokitika (Fig. 1). The river flows in a generally west-north-west direction for 20 km to join the Taramakau River on the north bank, opposite Kumara, about 10 km from the sea.

The Hohonu Range comprises chiefly Palaeozoic grey or pink granite, and this material forms 85% of the bed material of the Big Hohonu River. The remaining material is greywacke and volcanic rock derived from the Main Divide, with some outcrops of marine silt and sandstone. The substrate is coarse relative to other waterways in the region.

The Big Hohonu River was the site of the first goldrush in the Kumara region (Young and Foster 1986), and the lower reaches are not mapped because of the confusion created by gold tailings, among which the channel is lost to aerial photography. Evidence of historical mining at the study area was visible from a mining tunnel which carries the whole flow of the river through a bluff.

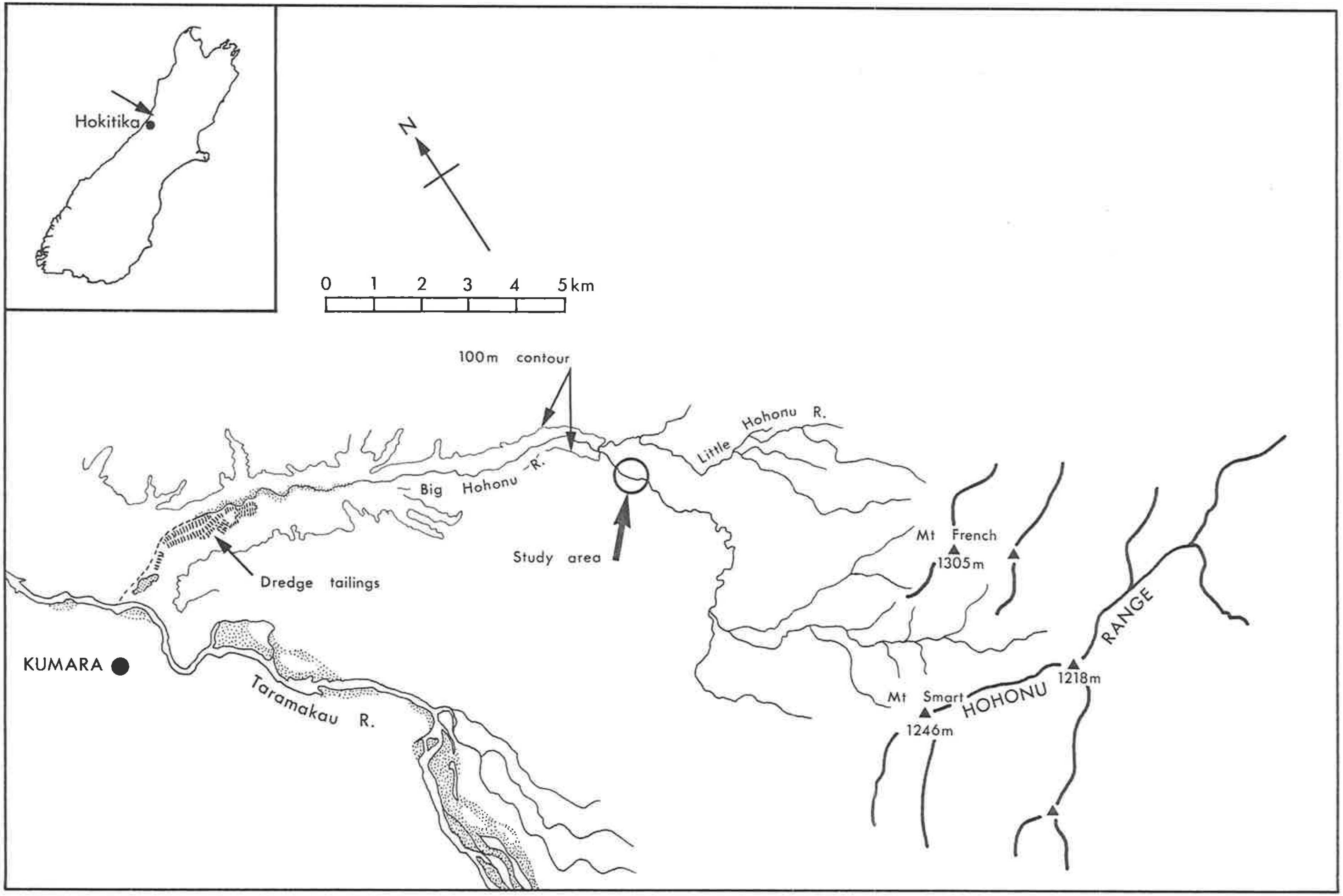

FIGURE 1. The Big Hohonu River, showing the study area.

In 1987, Thames Minerals Ltd. were mining the floodplain of the Big Hohonu River upstream of its tributary, the Little Hohonu River (Fig. 1). To mine the river's channel - prohibited under the existing water right - the company applied for a water right to divert some 530 m of the river into a new, permanent channel. Traditionally, diversion of the river would result in a new channel with parallel banks and uniform substrates. As such, it would provide little variability and cover for fish and result in a net reduction in the quality and quantity of fish habitat.

Freshwater Fisheries Centre staff saw this as an opportunity to study the effects of stream diversion on the aquatic fauna, and to evaluate the benefits of incorporating habitat variability into the new channel. The new channel was 530 m long and 30 m wide at the base. The upper 260 m was bulldozed to a flat, uniform substrate of cobbles and gravel with few boulders, whereas the lower reach was enhanced with considerable boulder cover and drops to provide varying fish habitat and a variety of flows. Once these features were incorporated, a cut was made and the entire flow of the river diverted into the new channel.

2. STUDY AREA

At the Thames Minerals Ltd. claim, the flood bed of the Big Hohonu River had been mined for gold for several months prior to the start of this study (Figs. 2 and 3). The stream channel itself had not been mined at the study site, although it had been constricted in places (Fig. 4) and there were several fords for machinery. Also, at that time there was considerable loss of water from the channel into the tailings, so that the stream diminished in volume from 0.759 m^3/s above the mining operations, to 0.293 m^3/s at the lower end of the study reach.

Below the study area, another company had worked the stream channel, as well as the floodplain, within the previous twelve months. This had caused gross discolouration of the water downstream, as well as local destruction of aquatic habitat, and there may well have been disruption to recruitment of diadromous fish to the study area.

FIGURE 2. Thames Minerals Ltd. concession on the Big Hohonu River, August 1987. Visible are an excavator and dredge (centre); untouched river channel (indicated); dredge ponds; stockpiled fines for re-distribution after mining ended; and (bottom right, curving into the centre immediately in front of the bush line) the excavated channel to carry the diversion.

FIGURE 3. Mining machinery in operation, Big Hohonu River, August 1987. Note the clear water in the channel in the foreground. There was some leaching of coloured water from the dredge ponds through the tailings to the stream channel lower down but it was not considered to be excessive.

FIGURE 4. Big Hohonu River study area, August 1987, showing that although the channel had not been mined, it had been constricted in places by the spoil from mining of the floodplain on each side.

Mining operations had resulted in the removal of all vegetation from the floodplain, but during this study, gorse seedlings (Ulex europaeus) and grass (Poa spp.) recolonised the area.

3. METHODS

Field work commenced in August 1987, about a week before the diversion was made, and was repeated at approximately three-monthly intervals. The study area was considered in two parts:

(i) the Diversion Reach, which was the entire length of the channel to be diverted and subsequently was the new channel designed by us;

(ii) the Control Reach, which was a length of the river immediately upstream of the Diversion Reach.

For clarity, when referring to the Diversion Reach, upper case first letters will be used; when referring to the act of diversion, lower case letters will be used.

3.1 Physical Features

The channel was divided into sections based on the visual appearance of flow type, e.g., fast run, riffle, run, pool, etc. Sections were identified by spraying adjacent boulders with paint. Each section was measured longitudinally, and the width recorded at three points. At the mid point of each section in the initial survey, and at all three points in subsequent surveys, depth and velocity (measured with a Gurley Pygmy flow meter) were recorded at 0.25, 0.50, and 0.75 of the width. Substrate composition for each third of the transect was estimated by eye, using the following categories: sand (<2 mm), fine gravel (2-20 mm), gravel (20-60 mm), small cobbles (60-125 mm), large cobbles (125-260 mm), and boulders (>260 mm).

A substrate index for the reach as a whole (comprising a number of water types) was calculated. This index, which is proportional to general substrate coarseness, is based upon the original index code used for Instream Flow Incremental Methodology (IFIM) models in the United States (Bovee 1982). However, because finer distinctions were made between adjacent substrate classes in this study, substrate codes intermediate to those used in the IFIM models were adopted. The codes used in this study, and those employed in the IFIM technique, are shown in Table 1.

The following formula was used to calculate a substrate index for each water type:

$$a \times \frac{(7b + 6c + 5.5d + 5e + 4.5f + 4g)}{100}$$

where: a = water type area/reach area; b = % water type area comprising boulders; c = % water type area comprising large cobbles; d = % water type area comprising small cobbles; e = % water type area comprising coarse gravel; f = % water type area comprising fine gravel; g = % water type area comprising sand. The substrate indices for each water type were then summed to produce a substrate index for the whole reach.

TABLE 1. Substrate codes used in the Big Hohonu River study, 1987-1988.

Substrate description	Code used in this study	IFIM Code
Sand	4.0	4
Fine gravel	4.5	-
Coarse gravel	5.0	5
Small cobbles	5.5	-
Large cobbles	6.0	6
Boulders	7.0	7

Although the stream channel in the Control Reach had not been mined, the floodplain had been mined for a considerable distance. This created some problems in that, following floods, the control sections proved too unstable to provide a continuity of information from one survey to another. Therefore on each survey, physical data were collected only from Control Reach sections actually fished, and these varied from time to time.

3.2 Aquatic Invertebrates

Benthic invertebrates were collected from a riffle and a run in each of two sections in the Diversion Reach and one section in the Control Reach. Five replicate benthic samples were collected from each riffle and run using a 0.1 m^2 Waters and Knapp sampler (Waters and Knapp 1961) fitted with 350 micron mesh net. The substrate delineated by the sampler was brushed and/or stirred to a depth of about 10 cm. Using this procedure, 10-20 samples were collected from the Diversion Reach and 10 from the Control Reach each sampling period.

Drift was collected from two sites in the Diversion Reach and one in the Control Reach, using replicate samplers (Field-Dodgson 1985) fitted with 400 micron mesh nets. These samplers were in place overnight for all sampling periods except October and November 1987, when flooding prevented their collection. Water velocity at the mouth of each net was measured with a Gurley Pygmy meter to enable calculation of the volume of water filtered.

In the laboratory, the invertebrates were counted and identified to species whenever possible. The head capsule widths of a sub-sample of Deleatidium from a riffle in each of the Diversion and Control Reaches were measured to the nearest 0.05 mm before all invertebrates were dried and weighed.

3.3 Fish

Whole sections or sub-sections were fished according to estimated fish densities and the amount of time available. As many sections as possible were sampled during four days field work; sections were not worked in any particular order, priority being given to obtaining data from a variety of water types. Fish were collected using a battery-powered, pulsed D.C. electric fishing machine, in conjunction with two hand-held stop nets located 2-3 m downstream from the electrode, and a long stop net set across the entire width of the stream at the bottom of the section or sub-section. Pools were sometimes fished only once, because they contained very low numbers of fish, but at all other sites, two or three sweeps were made, the long stop net being emptied at the end of each sweep. The catch from each sweep was recorded separately.

Captured fish were anaesthetised with benzocaine and measured to the nearest mm. Small fish were weighed in batches (species per sweep) to the nearest 0.1 g; larger fish were weighed individually to the nearest gram. All fish were held in live boxes for subsequent release into the sections from which they had been caught, except that on the first survey, prior to the diversion being cut, all fish captured in the Diversion Reach were transferred to the Little Hohonu River.

When the diversion was cut, and the original channel dewatered (Fig. 5), it was patrolled by three people to verify that electric

FIGURE 5. The diversion of the Big Hohonu River being cut, August 1987. The new channel was cut at a lower level than the stream. This allowed the diversion to take place without any sediment entering the old channel, and facilitated the salvage of fish from the residual water.

fishing had removed most of the fish, and had given a true indication of species composition. The relative abundance of species obtained in the electric fishing survey was compared with the salvage to provide data on the effectiveness of electric fishing for different species.

The fish population in each section electric fished was estimated by the removal method. Fish numbers per linear metre of channel and per 100 m^2 wetted area were calculated for each water type, based only on the sections fished. Estimates for the whole reach had to include sections not fished. For these sections, their physical data (velocity, depth, substrate) were compared with adjacent sections, and with sections of similar water type, to arrive at an approximation of probable fish numbers.

4. RESULTS

4.1 Physical Features

Details of the physical features of the study area and the subsequent changes during the study period are shown in Tables 2-4. At the first post-diversion visit in December, the Big Hohonu River was still settling into its new bed. The river came down in a fresh during the field work, so data for this period are incomplete. Little fishing was done and no transects were measured.

During the study period, the Big Hohonu River flooded on several occasions, notably on 29 October (Fig. 6). This flood effectively wiped out the boulder drops and variations incorporated in the lower half of the Diversion to provide variable habitat. During the following months, all trace of these modifications vanished and there was an increase in finer substrate material, which reduced the boulder cover available to fish throughout the study area (Fig. 7). Substrate change was most noticeable in the Diversion Reach, but occurred also in the Control Reach, where bifurcation occurred, indicating that natural flood events were the primary cause of the changes to the substrate.

The channel of the Diversion Reach was considerably wider than that of the original channel (Table 2, Fig. 8), and during the study the mean width remained constant. However, the stream did not stabilise and its

TABLE 2. Physical composition of the Big Hohonu River Diversion Reach (upper) and of sections fished in the Control Reach (lower), prior to the diversion being cut (August 1987) until September 1988 (one year after the diversion was cut).

Date	Net length of reach (m)	Gross length of channels (m)	Mean width* (m)	Mean depth* (cm)	Mean velocity* (m/s)	Wetted area (m^2)	Water type as % of the channel(s): run %L°	run %A#	riffle %L	riffle %A	rapid %L	rapid %A	pool %L	pool %A
DIVERSION REACH														
Aug 87	478**	478**	5.9**	26**	0.281**	2811**	78.8	67.2	11.2	19.7	0	0	5.1	7.9
Dec 87	516	516	-	-	-	-	43.6	-	48.4	-	8.0	-	0	0
Mar 88	506	531	9.8	18	0.339	5205	61.3	64.2	23.4	23.3	9.2	9.2	6.0	3.3
Jun 88	530	610	9.8	23	0.383	5955	43.6	39.5	43.3	49.2	7.9	8.6	5.2	2.8
Sep 88	539	721	9.8	24	0.412	7070	67.3	75.3	23.4	15.4	7.1	7.3	2.2	1.6
CONTROL REACH														
Aug 87	+	99	8.1	38	0.363	804	43.3	44.0	8.6	7.0	15.6	17.4	32.5	31.6
Dec 87	+	23†	8.3	-	-	196	0	0	100.0	100.0	0	0	0	0
Mar 88	+	114	3.1	17	0.458	354	0	0	7.4	15.6	78.6	63.5	14.0	20.9
Jun 88	+	217	3.7	17	0.274	726	0	0	86.6	79.3	0	0	11.5	20.7
Sep 88	+	55	4.6	29	0.578	253	9.1	13.9	-	-	63.6	53.4	27.3	32.7

* = weighted by length of flow type.
° = % length.
= % area.
** = data include ford, not itemised elsewhere.
- = no data.
+ = length of the control reach varied, because the morphology of the channel constantly changed.
† = not applicable, as full width of the channel was not fished.

TABLE 3. Physical features of water types in the Big Hohonu River Diversion Reach (upper) and of sections fished in the Control Reach (lower), prior to the diversion being cut (August 1987), until September 1988 (one year after the diversion was cut).

	Runs			Riffles			Rapids			Pools		
Date	W*	D**	V†	W	D	V	W	D	V	W	D	V
DIVERSION REACH												
Aug 87	5.0	28	0.276	10.3	18	0.414	-	-	-	9.1	75	0.053
Mar 88	10.3	16	0.370	9.8	15	0.288	9.8	18	0.329	5.3	45	-
Jun 88	8.8	25	0.376	11.1	20	0.399	10.7	17	0.425	5.2	45	0.239
Sep 88	11.0	24	0.392	6.5	24	0.460	10.2	17	0.529	7.2	58	0.160
CONTROL REACH												
Aug 87	8.2	24	0.523	6.6	23	0.398	9.0	28	0.504	7.9	75	0.073
Mar 88	-	-	-	6.5	19	0.391	2.5	13	0.518	4.6	49	0.154
Jun 88	-	-	-	3.4	15	0.387	-	-	-	6.0	30	0.110
Sep 88	7.0	36	0.300	-	-	-	3.9	24	0.770	5.5	43	0.232

* = weighted mean width (m).
** = weighted mean depth (cm).
† = weighted mean velocity (m/s).
\- = no data.

TABLE 4. Substrate composition (%) of the Big Hohonu River Diversion Reach and of sections fished in the Control Reach (in brackets), weighted by flow type area.

Date	Boulders	Large cobbles	Small cobbles	Gravel	Fine gravel	Sand
Runs						
Aug 87	46.2 (40.0)	21.1 (33.3)	16.3 (20.0)	8.4 (10.0)	3.7 (3.3)	4.3 (3.3)
Mar 88	25.4 (-)	41.8 (-)	19.6 (-)	9.5 (-)	3.6 (-)	0.1 (-)
Jun 88	23.1 (-)	36.3 (-)	22.7 (-)	11.1 (-)	2.4 (-)	4.4 (-)
Sep 88	24.5 (0.0)	22.9 (20.0)	18.3 (36.6)	17.9 (3.3)	12.0 (6.7)	4.4 (33.3)
Riffles						
Aug 87	32.4 (20.0)	27.1 (50.0)	18.2 (20.0)	13.2 (10.0)	5.1 (0.0)	3.9 (0.0)
Mar 88	22.1 (30.0)	31.2 (47.5)	19.1 (18.3)	18.3 (4.2)	6.4 (0.0)	2.8 (0.0)
Jun 88	29.7 (27.3)	33.8 (22.1)	17.2 (21.1)	12.3 (16.2)	5.3 (4.7)	1.7 (8.5)
Sep 88	18.9 (-)	35.1 (-)	27.7 (-)	11.7 (-)	5.6 (-)	1.2 (-)
Rapids						
Aug 87	- (30.0)	- (40.0)	- (30.0)	- (0.0)	- (0.0)	- (0.0)
Mar 88	34.0 (31.9)	40.2 (25.0)	19.5 (18.9)	6.3 (11.7)	0.0 (7.5)	0.0 (5.0)
Jun 88	13.3 (-)	30.6 (-)	33.6 (-)	12.2 (-)	7.2 (-)	3.0 (-)
Sep 88	28.7 (31.4)	27.3 (30.3)	32.0 (30.7)	10.6 (7.2)	1.5 (0.4)	0.0 (0.0)
Pools						
Aug 87	10.0 (23.3)	70.0 (33.3)	16.7 (20.0)	3.3 (3.3)	0.0 (6.7)	0.0 (13.3)
Mar 88	- (36.7)	- (12.2)	- (21.1)	- (11.1)	- (4.4)	- (14.4)
Jun 88	22.5 (22.5)	20.8 (29.2)	26.7 (12.5)	23.3 (10.0)	3.3 (5.0)	3.3 (20.8)
Sep 88	23.3 (23.4)	15.5 (10.0)	15.5 (15.0)	6.7 (16.7)	10.5 (13.4)	28.3 (21.7)
Overall						
Aug 87	40.4 (27.2)	26.4 (35.6)	16.7 (21.7)	9.0 (6.1)	3.7 (3.6)	3.8 (5.7)
Mar 88	25.4 (32.6)	38.3 (25.9)	19.4 (19.3)	11.9 (10.4)	4.1 (5.7)	0.9 (6.2)
Jun 88	25.5 (26.4)	34.1 (23.3)	21.1 (19.7)	12.1 (15.2)	4.3 (4.8)	2.9 (10.5)
Sep 88	23.9 (24.0)	25.0 (22.1)	20.7 (26.9)	16.2 (10.3)	10.2 (5.6)	4.0 (11.7)

- = no data.

FIGURE 6. The Big Hohonu River in flood, 19 October 1987.

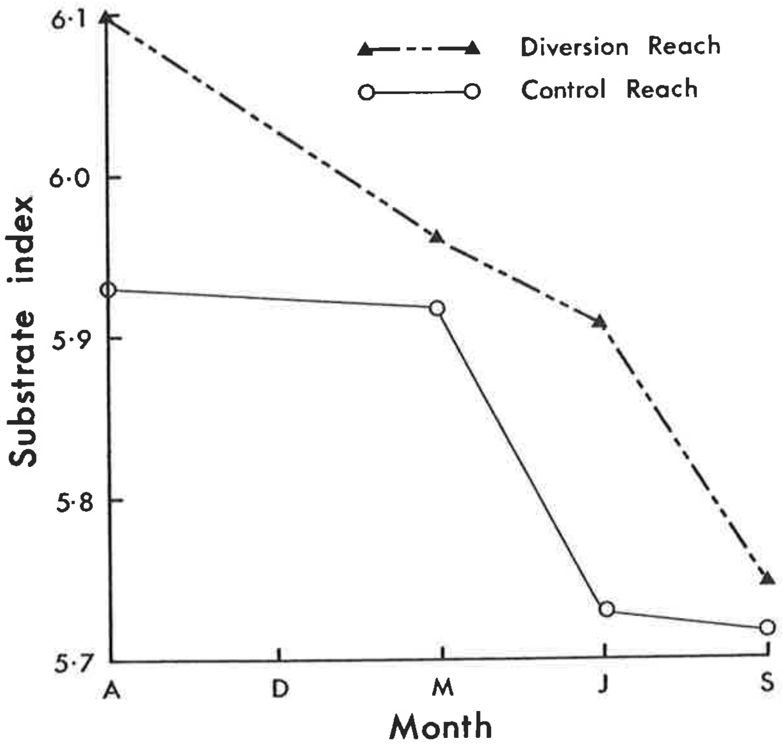

FIGURE 7. Reduction in substrate size, Big Hohonu River, August 1987 - September 1988.

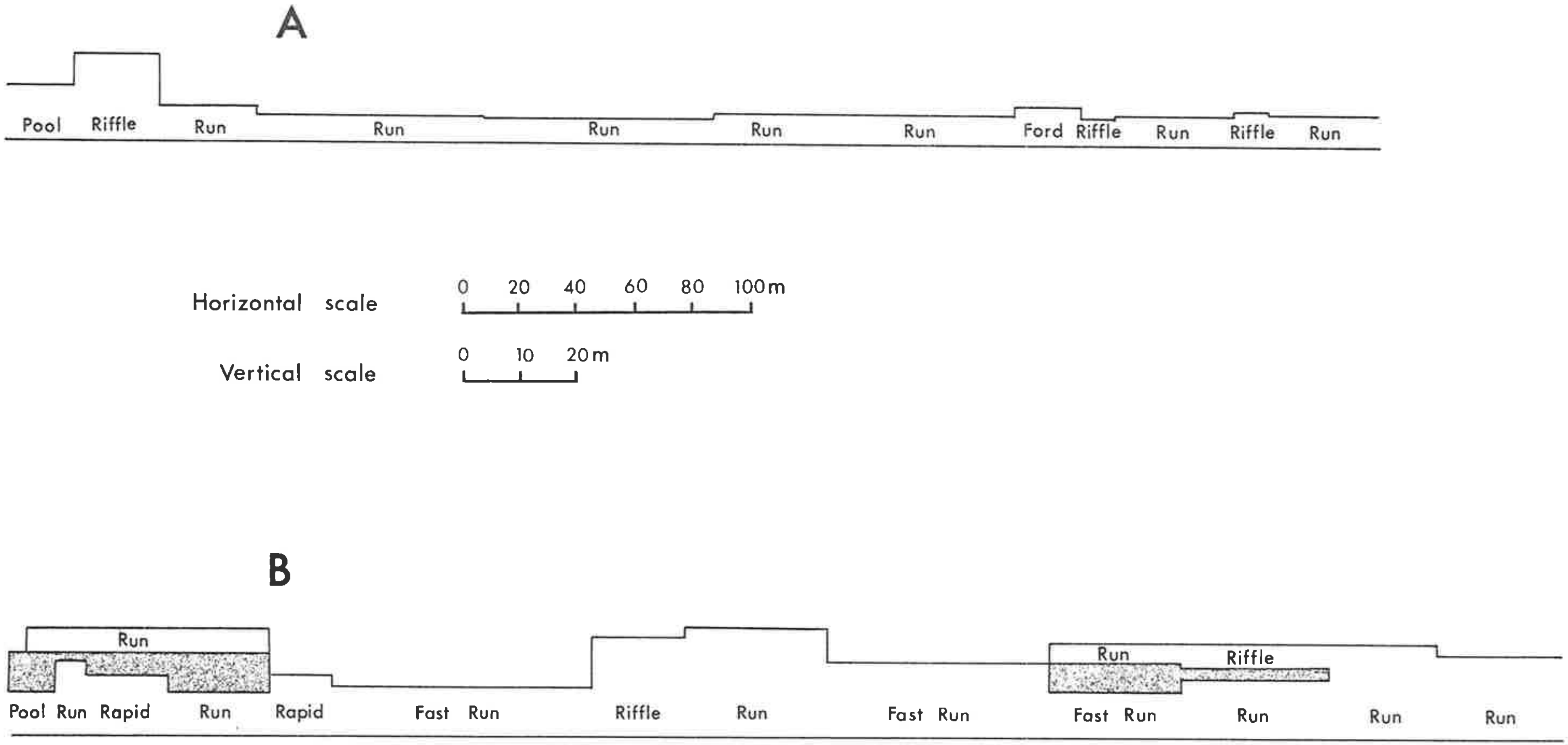

FIGURE 8. Relative channel width in the Big Hohonu River before diversion, August 1987 (A), and one year after diversion, September 1988 (B). Dark areas in (B) are islands.

position in the channel shifted from time to time, with braids forming and re-forming (Figs. 9-11).

4.2 Aquatic Invertebrate Populations

4.2.1 Benthic Invertebrates

A total of 38 taxa was collected from the benthos, with 34 taxa occurring in the Diversion Reach and 33 in the Control Reach (Tables 5 and 6). Larvae of the mayfly *Deleatidium* spp. were most abundant and comprised more than 76% of all animals collected. Mean densities of *Deleatidium* in the Diversion Reach ranged from 118 m^{-2} in October 1987 to 1540 m^{-2} in May 1988, and in the Control Reach from 892 m^{-2} in November 1987 to 2698 m^{-2} in August 1987. Other taxa which were common and present in the Diversion Reach in all sampling periods were *Nesameletus* sp. and Chironomidae. Those taxa common and present in all samples of the Control Reach were oligochaetes, *Nesameletus* sp., *Stenoperla prasina*, *Zelandoperla decorata*, *Helicopsyche albescens*, *Hydrobiosis frater*, *Hydora* sp., and Chironomidae.

The taxonomic composition of benthic invertebrate assemblages in the Diversion and Control Reaches were very similar both before and after diversion of the river (Table 7). Application of both the Jaccard Coefficient and Percentage Similarity Coefficient (Table 7) showed that most taxa were common to both reaches, and that the structure of the assemblages (in terms of the relative abundance of taxa) was almost identical.

Density, number of taxa, and standing biomass varied considerably throughout the year (Figs. 12 and 13). In the Control Reach, density was highest in August 1987 and then declined rapidly, being lowest at the end of November that year. Presumably this decline in the density of invertebrates was associated with the severe floods during this period. After November, the density increased again and peaked at the end of May. The decrease in density which was recorded in early September 1989 was presumably linked to the higher river flows which occurred in spring. Benthic invertebrates in the Diversion Reach appeared to be affected by mining operations prior to the diversion, because the density was much lower than that in the Control Reach

FIGURE 9. The Big Hohonu River Diversion, March 1988. Stock-piled topsoil is being re-distributed over the floodplain. The stream tends to the true right of the channel.

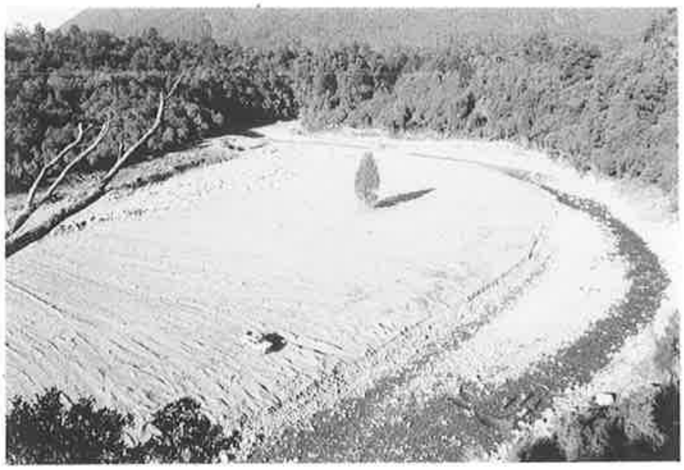

FIGURE 10. The Big Hohonu River Diversion, June 1988. The stream has shifted to the true left of its channel, but also has eaten away at the right bank.

FIGURE 11. The Big Hohonu River Diversion, September 1988. The stream has reverted to the true right of the channel and is generally much broader than formerly.

TABLE 5. Systematic list of invertebrates recorded in the benthos of the Diversion Reach, Big Hohonu River, August 1987 - September 1988. (Mean densities (per 0.1 m^2) are given for taxa which average >1 individual per sample.)

Taxa	24.8.87	6.10.87	30.11.87	7.3.88	30.5.88	5.9.88
ANNELIDA						
OLIGOCHAETA	1.7	-	-	2.7	1.1	+
MOLLUSCA						
GASTROPODA						
Potamopyrgus antipodarum	-	-	-	+	-	-
INSECTA						
EPHEMEROPTERA						
Deleatidium spp.	99.3	11.8	89.3	140.8	154.0	49.5
Coboburiscus humeralis	-	-	-	+	+	-
Nesameletus sp.	+	+	+	+	+	+
PLECOPTERA						
Acroperla trivacuata	-	-	-	-	1.0	+
Stenoperla prasina	+	-	+	+	-	+
Zelandobius confusus	-	-	+	-	+	-
Zelandobius sp.	-	-	+	-	+	+
Zelandoperla decorata	2.6	-	+	6.8	2.8	1.2
Megaleptoperla grandis	-	-	+	+	-	-
Megaleptoperla sp.	-	+	-	-	-	-
TRICHOPTERA						
Helicopsyche albescens	-	-	+	1.8	+	+
Olinga feredayi	-	-	+	+	+	-
Pycnocentria evecta	-	-	+	-	-	-
Beraeoptera roria	-	-	+	+	+	+
Pycnocentrodes sp.	-	-	-	+	-	-
Aoteapsyche spp.	+	+	-	2.3	+	+
Costachorema xanthoptera	-	-	-	-	-	+
Costachorema spp.	-	-	-	+	+	+
Hydrobiosis frater	+	-	+	1.1	+	+
Hydrobiosis spp.	-	+	-	-	-	-
Psilochorema spp.	+	-	+	+	+	+
MEGALOPTERA						
Archichauliodes diversus	-	-	-	+	-	-
COLEOPTERA						
Hydrophilidae	-	-	-	+	-	-
Helodidae	-	-	-	-	+	-
Hydora sp.	+	-	1.6	+	+	+
DIPTERA						
Chironomidae	5.3	1.1	5.8	12.5	1.3	+
Austrosimulium sp.	+	-	+	+	+	-
Empipidae	+	-	-	-	+	-
Stratiomyidae	-	-	-	-	-	+
Eriopterini	+	-	-	+	+	+

TABLE 5. (ctd.)

Taxa	24.8.87	6.10.87	30.11.87	7.3.88	30.5.88	5.9.88
DIPTERA (ctd.)						
Muscidae	-	-	-	-	+	-
Aprophila neozelandica	-	+	-	+	-	+
No. of taxa	13	7	16	23	22	19

+ = present.
- = not found.

TABLE 6. Systematic list of invertebrates recorded in the benthos of the Control Reach, Big Hohonu River, August 1987 - September 1988. (Mean densities (per 0.1 m^2) are given for taxa which average >1 individual per sample.)

Taxa	24.8.87	6.10.87	30.11.87	7.3.88	30.5.88	5.9.88
ANNELIDA						
OLIGOCHAETA	5.2	8.7	+	1.5	2.3	+
MOLLUSCA						
GASTROPODA						
Potamopyrgus antipodarum	-	-	+	+	-	-
INSECTA						
EPHEMEROPTERA						
Deleatidium spp.	269.8	188.5	89.2	186.2	253.7	108.5
Austroclima jollyae	-	-	+	-	-	-
Coloburiscus humeralis	-	+	-	+	-	-
Nesameletus sp.	+	1.1	+	1.1	1.2	+
PLECOPTERA						
Acroperla trivacuata	-	-	-	-	+	+
Spaniocerca zelandica	-	-	+	-	-	-
Stenoperla prasina	+	+	+	+	+	+
Zelandobius confusus	-	-	-	-	-	+
Zelandobius sp.	-	-	+	+	+	-
Zelandoperla decorata	5.1	1.6	+	6.6	5.6	1.1
Megaleptoperla grandis	-	-	-	-	+	-
Megaleptoperla sp.	-	2.9	1.0	-	-	-
TRICHOPTERA						
Helicopsyche albescens	+	+	3.4	3.4	+	1.1
Olinga feredayi	+	+	-	1.2	+	+
Beraeoptera roria	-	-	+	+	+	+
Pycnocentrodes sp.	+	+	-	-	-	-

TABLE 6. (ctd.)

Taxa	24.8.87	6.10.87	30.11.87	7.3.88	30.5.88	5.9.88
TRICHOPTERA (ctd)						
Aoteapsyche spp.	-	+	-	3.5	+	+
Hydrobiosella stenocerca	-	+	-	-	-	-
Costachorema xanthoptera	-	-	+	-	-	-
Costachorema spp.	-	+	+	+	+	+
Hydrobiosis frater	+	+	+	+	2.1	+
H. parumbripennis	-	+	-	-	-	-
Hydrobiosis spp.	-	-	-	-	+	+
Psilochorema spp.	+	+	-	+	1.3	1.3
MEGALOPTERA						
Archichauliodes diversus	-	+	+	+	-	+
COLEOPTERA						
Hydora sp.	5.6	2.3	4.0	+	2.5	1.6
DIPTERA						
Chironomidae	6.5	8.3	2.0	5.3	1.0	1.0
Austrosimulium sp.	-	-	-	+	+	-
Empipidae	-	+	-	-	+	-
Stratiomyidae	+	-	-	-	-	-
Eriopterini	+	+	+	-	+	+
No. of taxa	14	21	19	19	21	19

+ = present.
- = not found.

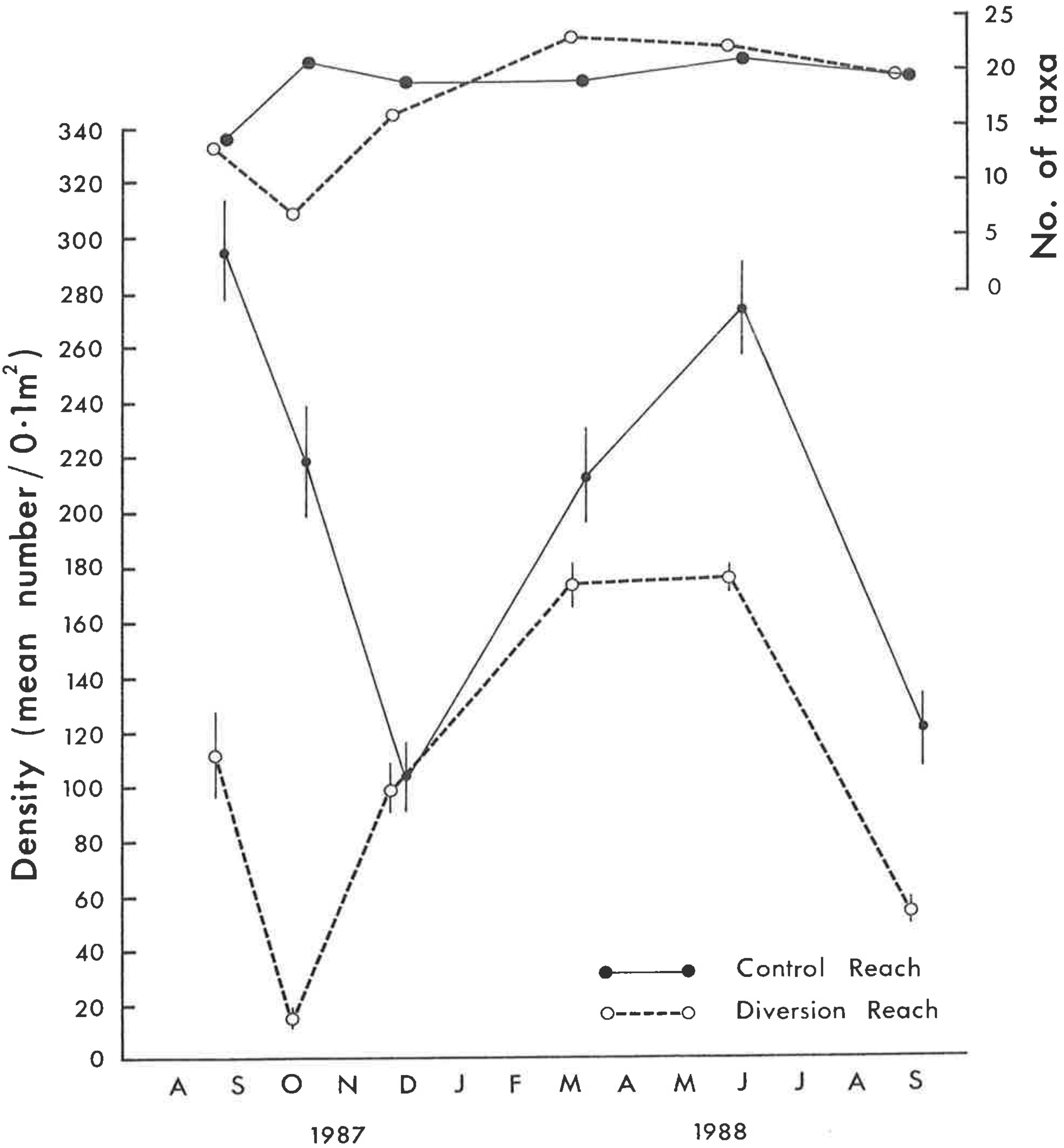

FIGURE 12. Density ($\bar{x} \pm 1$ SE) and number of taxa of aquatic invertebrates in benthic samples from the Big Hohonu River, 24 August 1987 - September 1988. (● = Control Reach; o = Diversion Reach.) The plots for the Diversion Reach have been offset slightly for clarity.

TABLE 7. Measures of similarity (based on taxonomic composition of benthic invertebrates) between the Control Reach and the Diversion Reach, Big Hohonu River, August 1987 - September 1988.

Date	Jaccard coefficient	Percentage similarity coefficient
Aug 1987	0.59	96.55
Oct 1987	0.22	87.00
Nov 1987	0.40	94.65
Mar 1988	0.75	92.00
May 1988	0.72	98.57
Sep 1988	0.65	98.11

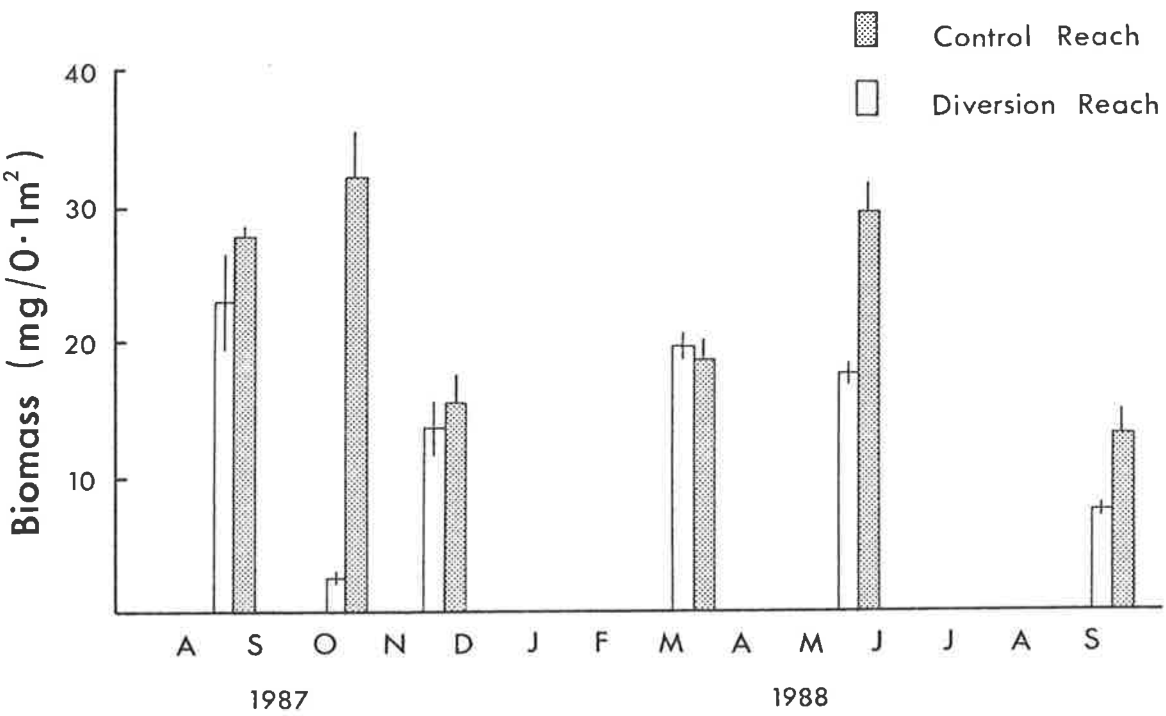

FIGURE 13. Biomass ($\overline{x}$ + 1 SE) of invertebrates collected in benthic samples, Big Hohonu River, 24 August 1987 - 5 September 1988. (Dark bars indicate the Control Reach, open bars indicate the Diversion Reach, and vertical lines indicate ± 1 SE.)

samples collected in August 1987. The low density of invertebrates in the Diversion Reach during the October sampling period was associated with diversion of the river. However, this was short-lived, because the density of invertebrates had increased to about the pre-diversion level by the end of November. Thereafter, the density of invertebrates in the Diversion Reach, although significantly lower, followed the trend of that in the Control Reach.

The number of taxa in the Diversion Reach was halved following diversion of the river, but the number soon recovered and by March 1988 was greater than that in the Control Reach (Fig. 12). Biomass of invertebrates essentially followed the same trend as the density of invertebrates (Fig. 13).

4.2.2 Drift

Forty-three taxa were collected from the drift, with 41 taxa occurring in the Diversion Reach (Table 8) and 35 taxa in the Control Reach (Table 9). Again, larvae of *Deleatidium* spp. were the most abundant, comprising between 53% and 87% of all animals in any sample. Late instar larvae of the stonefly *Zelandoperla decorata* were the next most abundant species and comprised 3-21% of each sample. Other taxa present in all samples of drift from both reaches were the mayflies *Austroclima jollyae*, *Neozephlebia scita*, *Coloburiscus humeralis*, and *Nesameletus* sp.; the trichopterans *Helicopsyche albescens* and *Psilochorema* spp.; the coleopteran *Hydora* sp.; and Chironomidae.

Drift density in the Diversion and Control Reaches ranged from 110.2 to 194.9, and 95.4 to 198.9 animals per 100 m^3, respectively. In August 1987, drift density in the Diversion Reach was substantially higher than in the Control Reach (Fig. 14). During the 1988 sampling periods, drift in the Diversion Reach was relatively constant, whereas it fluctuated in the Control Reach.

4.2.3 *Deleatidium* Larvae

Size frequency distributions of *Deleatidium* larvae collected in the benthos and drift are shown in Figures 15 and 16. Early instar larvae (<0.6 mm head capsule width) dominated the populations in the benthos of

TABLE 8. Systematic list of invertebrates recorded in the drift of the Diversion Reach, Big Hohonu River, August 1987 - September 1988. (Mean densities (per 100 m^3) are given for taxa which averaged >1 individual per sample.)

Taxa	24-25.87	7-8.3.88	30-31.5.88	5-6.9.88
CRUSTACEA				
COPEPODA	-	+	+	+
INSECTA				
EPHEMEROPTERA				
Deleatidium spp.	170.4	60.9	99.0	59.1
Austroclima jollyae	1.2	+	+	8.1
Neozephlebia scita	+	+	+	1.2
Zephlebia sp.	-	1.3	-	+
Coloburiscus humeralis	+	1.0	+	1.3
Nesameletus sp.	+	+	3.4	1.0
Ameletopsis perscitus	-	-	+	-
PLECOPTERA				
Acroperla trivacuata	+	-	+	8.3
Austroperla cyrene	+	-	-	+
Spaniocerca zelandica	+	-	+	1.5
Stenoperla prasina	-	-	+	+
Zelandobius confusus	+	+	+	+
Zelandobius sp.	1.0	-	-	+
Zelandoperla decorata	8.9	11.3	3.3	9.3
Z. agnetis	+	-	-	-
Megaleptoperla grandis	-	1.2	-	-
Megaleptoperla sp.	+	-	+	-
TRICHOPTERA				
Helicopsyche albescens	+	+	1.0	1.7
Philorheithrus agilis	-	+	-	-
Olinga feredayi	+	+	-	+
Pycnocentria evecta	-	-	+	-
Beraeoptera roria	-	2.6	2.5	2.6
Confluens olingoides	3.5	-	-	-
Aoteapsyche spp.	-	4.0	-	+
Oxyethira albiceps	-	1.6	+	+
Paroxyethira sp.	-	+	-	-
Hydrobiosella stenocerca	-	+	-	-
Polyplectropus sp.	+	-	-	+
Costachorema xanthoptera	-	-	-	2.6
Costachorema spp.	-	2.8	+	3.2
Hydrobiosis frater	1.0	2.4	-	1.1
H. parumbripennis	+	+	-	+
Hydrobiosis spp.	+	1.0	-	-
Psilochorema spp.	+	5.9	+	1.6
Neurochorema sp.	-	-	-	+
COLEOPTERA				
Hydora sp.	1.6	+	+	+

TABLE 8. (ctd.)

Taxa	24-25.87	7-8.3.88	30-31.5.88	5-6.9.88
DIPTERA				
Chironomidae	2.1	13.2	+	1.8
Austrosimulium sp.	-	+	-	-
Eriopterini	-	+	-	+
Paralimnophila skusei	+	-	-	-

+ = present.
- = not found.

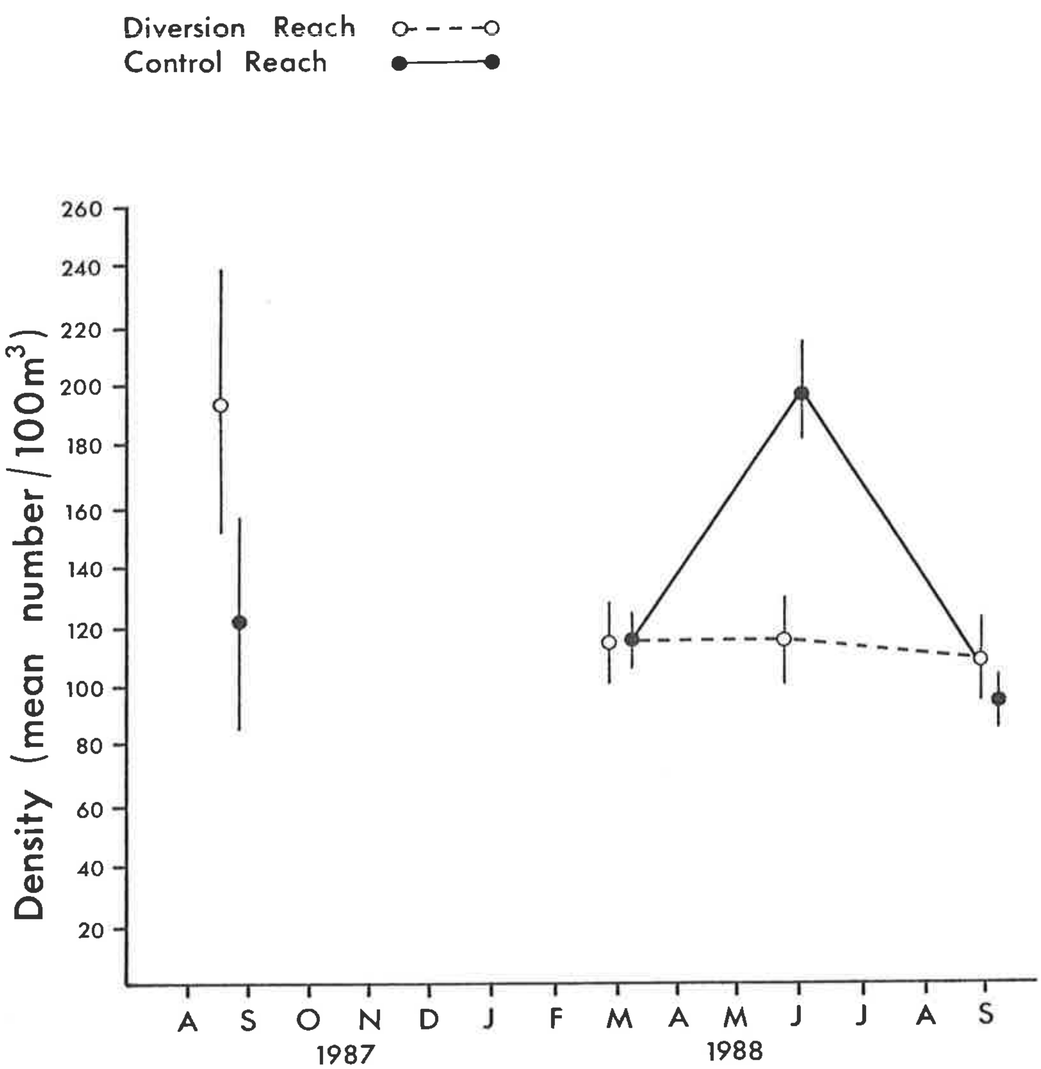

FIGURE 14. Density ($\bar{x}$ + 1 SE) of aquatic invertebrates in drift samples, Big Hohonu River, 24 August 1987 - 6 September 1988. (● = Control Reach; o = Diversion Reach.)

TABLE 9. Systematic list of invertebrates recorded in the drift of the Control Reach, Big Hohonu River, August 1987 - September 1988. (Mean densities (per 100 m^3) are given for taxa which averaged >1 individual per sample.)

Taxa	24-25.87	7-8.3.88	30-31.5.88	5-6.9.88
INSECTA				
EPHEMEROPTERA				
Deleatidium spp.	95.2	38.0	170.0	65.9
Austroclima jollyae	+	+	+	6.2
Neozephlebia scita	+	2.1	+	+
Zephlebia sp.	-	-	-	+
Coloburiscus humeralis	+	3.2	+	+
Nesameletus sp.	+	+	1.5	+
Ameletopsis perscitus	-	-	-	+
PLECOPTERA				
Acroperla trivacuata	-	-	+	2.7
Austroperla cyrene	-	-	-	+
Spaniocerca zelandica	-	-	+	+
Spaniocercoides cowleyi	+	+	-	+
Stenoperla prasina	-	-	1.5	+
Zelandobius confusus	-	-	+	-
Zelandobius sp.	1.5	-	-	+
Zelandoperla decorata	9.8	24.3	12.4	8.7
Megaleptoperla grandis	-	1.9	-	-
Megaleptoperla sp.	+	-	-	+
TRICHOPTERA				
Helicopsyche albescens	+	1.2	+	+
Olinga feredayi	+	2.1	-	+
Pycnocentria sylvestris	-	-	-	+
Beraeoptera roria	-	4.5	4.4	1.6
Confluens olingoides	3.0	-	-	-
Pycnocentrodes sp.	+	-	-	-
Aoteapsyche spp.	-	5.1	1.2	+
Oxyethira albiceps	+	3.0	-	+
Hydrobiosella stenocerca	-	1.5	-	-
Polyplectropus sp.	-	-	-	+
Costachorema xanthoptera	-	-	-	+
Costachorema spp.	+	-	1.6	1.4
Hydrobiosis frater	+	+	-	+
Hydrobiosis spp.	-	1.2	-	-
Psilochorema spp.	2.3	5.3	+	+
COLEOPTERA				
Hydora sp.	1.6	1.5	+	+
DIPTERA				
Chironomidae	1.9	11.9	+	-
Austrosimulium sp.	+	-	+	-

+ = present.
- = not found.

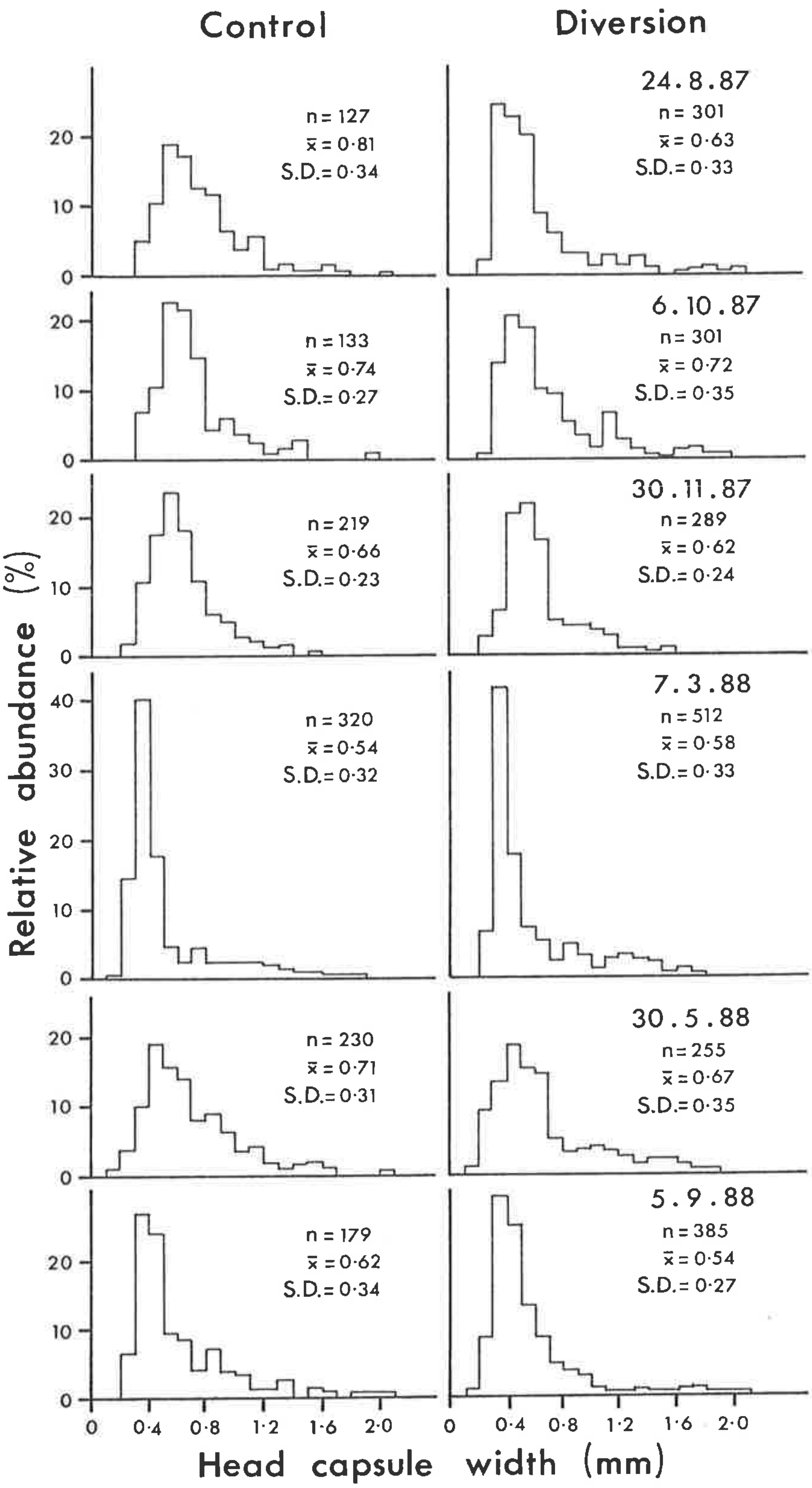

FIGURE 15. Size frequency distributions of Deleatidium larvae collected in benthic samples, 24 August 1987 - 5 September 1988. (Samples sizes (N), mean size of larvae ($\bar{x}$), and standard deviation (SD) of mean size also are shown.)

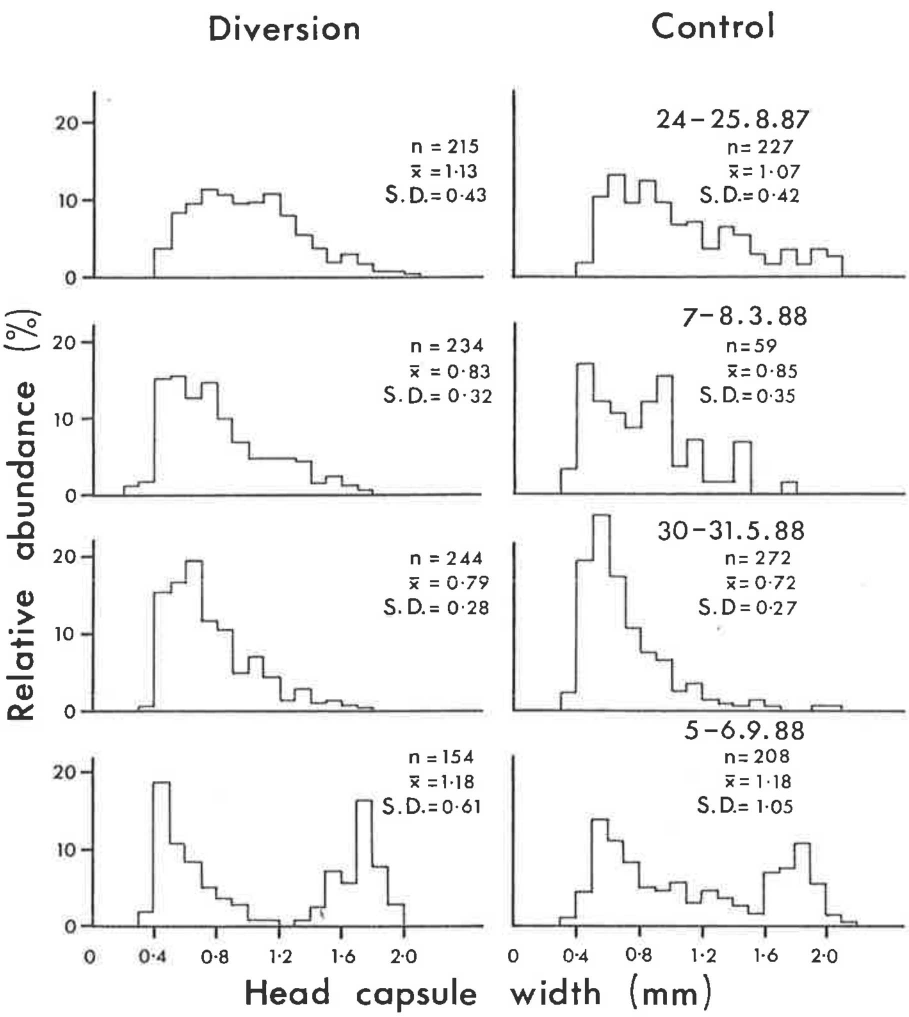

FIGURE 16. Size frequency distributions of Deleatidium larvae collected in drift samples, 24 August 1987 - 5 September 1988. (Sample sizes (N), mean size of larvae ($\bar{x}$), and standard deviation (SD) of mean size also are shown.)

both the Diversion and the Control Reaches. On 6 October, 36 days after the diversion was cut, the size composition of Deleatidium larvae in the Diversion and Control Reaches was similar, comprising early and late instars.

Late instar larvae comprised the majority of drifting Deleatidium in the Diversion and Control Reaches, except in May when early instar larvae predominated in both reaches.

4.3 Fish

Details of the fish population and subsequent changes are shown in Appendices I and II. Prior to the diversion being cut, the Diversion Reach contained seven species of fish, but two of these (short-jawed kokopu and upland bully) were each represented by a single fish. Blue-gilled bullies and long-finned eels were well represented; brown trout were few, and red-finned bullies and koaro were rare (Appendix I). Species composition determined by electric fishing was confirmed by the fish salvage conducted as soon as the diversion was cut. The only anomaly found was that fishing plus salvage produced more red-finned bullies than the population estimate predicted from fishing alone. This reflects the habitat and behaviour of red-finned bullies, which makes them less readily caught than other species. Other species were salvaged in numbers consistent with the electric fishing results, and no additional species were found.

Although fish numbers in the Diversion Reach decreased during the study, the total drop in the population was not as severe as indicated by the density per linear metre or per 100 m^2 of channel (see Figs. 17-19, later this section). This was because the wetted area within the Reach increased, i.e., the stream was longer (following the curve of the valley) and broader (see Figs. 8-11). Thus, fewer fish were spread over a greater area of habitat.

4.3.1 Blue-gilled Bully

Blue-gilled bullies were the most abundant fish in the Big Hohonu River throughout the study period, both in the Diversion and in the Control Reaches. Estimated total numbers in the Diversion dropped to about 43% of pre-diversion numbers in December (Fig. 17), with a further drop in June, but recovered to 67% by September 1988. By this time, the fish were larger and heavier than they had been the previous year (Table 10), and total biomass was 77% of the pre-diversion level.

In the Control Reach, by contrast, estimated numbers per 100 m^2 of channel rose greatly in December, to almost three times the pre-diversion level. By July, the numbers had fallen to substantially the same level as those recorded in the Diversion Reach (Fig. 17).

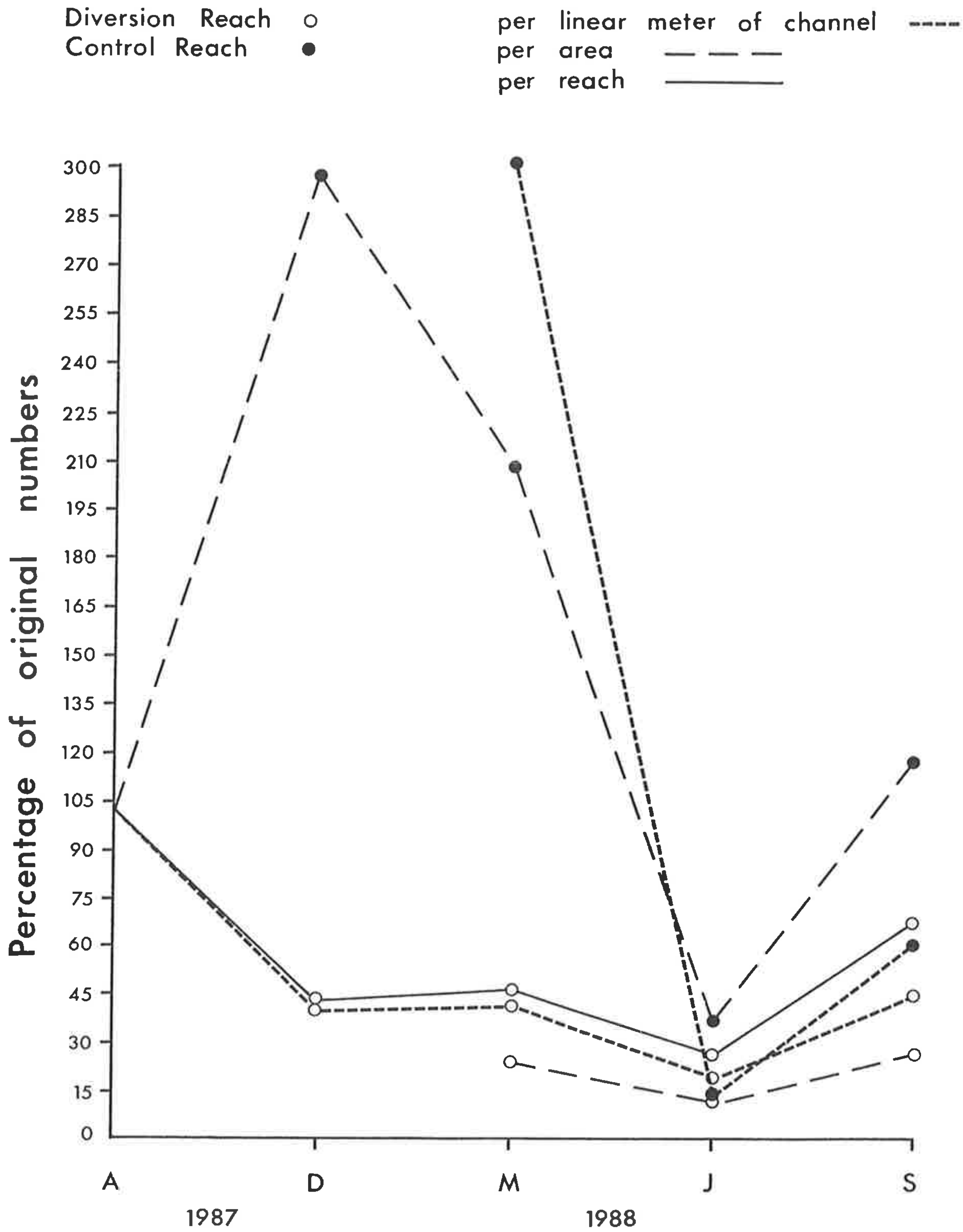

FIGURE 17. Percentage change in the estimated numbers of blue-gilled bullies in the Big Hohonu River, August 1987 - September 1988. (Data for pools in the Control Reach have not been included.)

TABLE 10. Mean lengths (mm) and mean weights (g) of three species of fish from the Big Hohonu River Diversion Reach prior to the diversion being cut (August 1987), until September 1988 (one year after the diversion was cut).

Date	Blue-gilled bully			Long-finned eel			Brown trout (underyearlings)			Brown trout (1+)		
	No.	Length	Weight	No.	Length	Weight	No.	Length	Weight	No.	Length	Weight
Aug 87	165	74.1	4.1	102	254.5	44.1	-	-	-	14	135.1	34.0
Dec 87	54	75.3	4.4	15	269.7	119.5	14	49.7	2.3	1	171.0	61.4
Mar 88	64	73.8	-	53	234.7	-	27	104.2	-	-	-	-
Jun 88	72	76.1	4.3	23	284.9	55.7	31	127.1	26.4	4	415.0	816.0
Sep 88	89	76.9	4.6	33	272.7	108.9	2	27.0	0.2	36	148.0	42.7

4.3.2 Long-finned Eel

Initially, the long-finned eel was the second most-abundant fish in the Big Hohonu River. Fluctuations in numbers (Fig. 18) are complicated by the normal seasonal variation in catchability of eels; eels are much easier to catch during summer than during winter, when they tend to "hibernate" deep in the substrate.

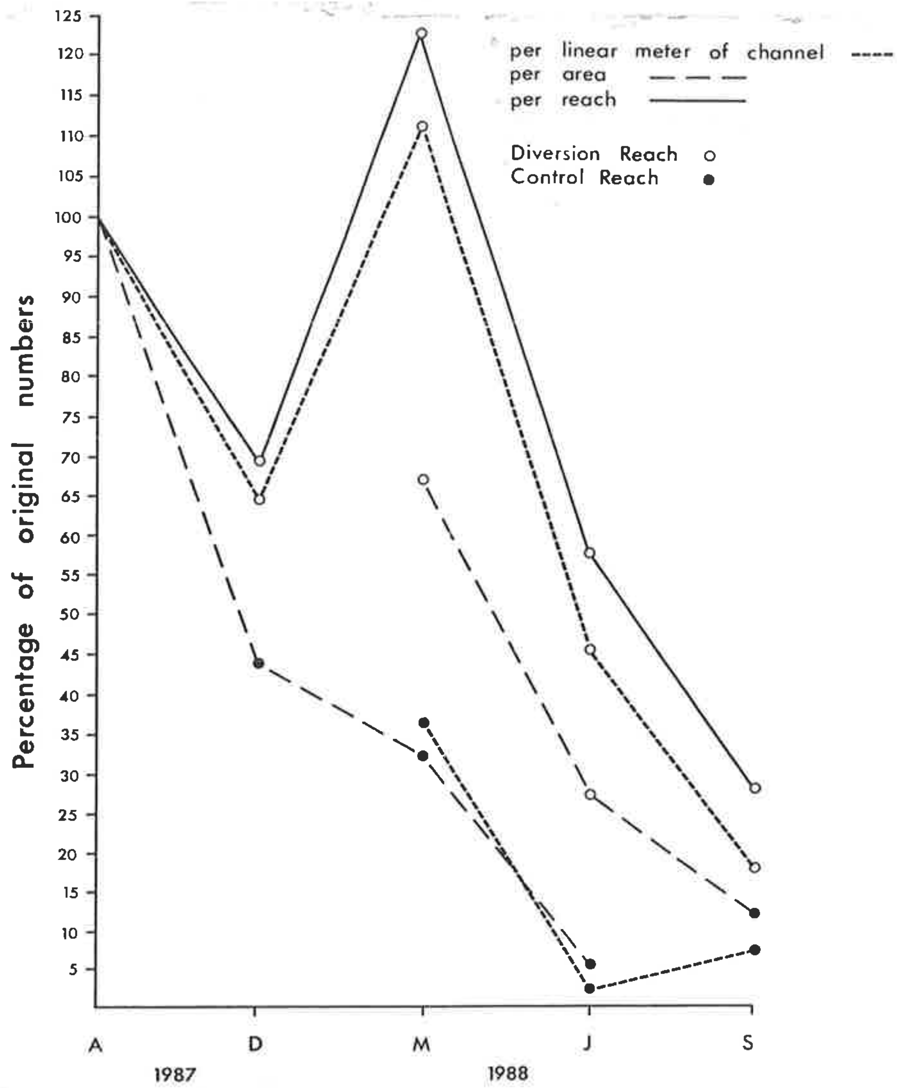

FIGURE 18. Percentage change in the estimated numbers of long-finned eels in the Big Hohonu River, August 1987 - September 1988.

The initial fall in numbers in December, therefore, is contrary to normal expectations, and could be associated with the diversion work were it not for the fact that numbers in the Control Reach were similarly affected. The Diversion Reach numbers increased by March, but numbers continued to fall in the Control Reach. By September numbers had fallen to almost the same percentage in both reaches, and were much lower than they had been the previous year.

4.3.3 Brown Trout

The seasonality of the occurrence of trout in the Big Hohonu River is clearly shown in Appendix I and Figure 19. At the time of the pre-diversion fishing, in the last week of August 1987, fry of the year were not present, although two were salvaged when the diversion was cut in the first week of September. The majority of fish captured in August were yearlings, with a few two-year-olds. By December, there were numerous fish of the year and their numbers peaked in March. In June there were some adult spawners present, and by September the new season's fry were appearing. The numbers of yearling trout present in the Diversion Reach were more than double those of the previous year.

4.3.4. Red-finned Bully

During the initial survey, red-finned bullies were present in small numbers over much of the study area (Appendices I and II). Although the number in the Diversion Reach was estimated to be nine from electric fishing, the salvage showed that there were at least 20.

No red-finned bullies were seen in December, but very little water was fished. Fish were present in both Reaches in March, but none was seen in the Diversion Reach thereafter. In the Control Reach, a few red-finned bullies were present again in September 1988.

4.3.5 Koaro

In the initial survey, the number of koaro in the Diversion Reach was estimated at 12 fish. Unlike red-finned bully, koaro had a restricted habitat and were easy to catch; it is unlikely that the estimate is more than 20% inaccurate. Most of the fish were taken from a single section of broad riffle. After the diversion, no similar habitat formed and no more koaro were found in the Diversion Reach.

In the Control Reach, koaro were still present in March, in a similar section to that in which they had principally been present in the Diversion Reach in August. No more koaro were found subsequently, although the habitat remained apparently little changed.

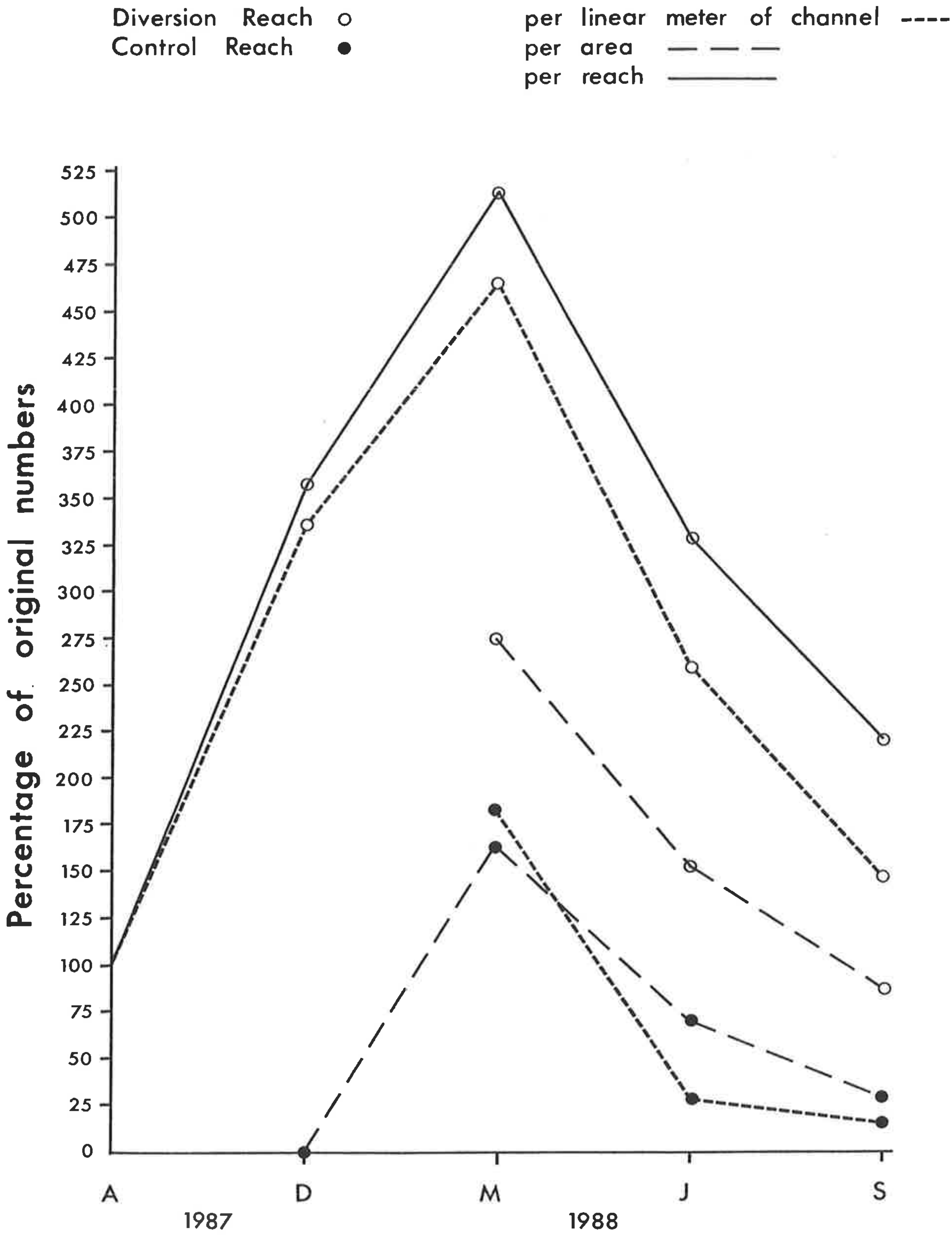

FIGURE 19. Percentage change in the estimated numbers of brown trout in the Big Hohonu River, August 1987 - September 1988.

4.3.6 Upland Bully

A solitary fish was recorded from the Diversion Reach in August 1987.

4.3.7 Short-jawed Kokopu

One small adult fish was recorded from the only pool present in the Diversion Reach in August 1987.

4.3.8 Torrentfish

One fish only was recorded during the study; it was taken in the Control Reach during June 1988.

5. DISCUSSION

The downgrading of the aquatic habitat in the Big Hohonu River Diversion Reach, following commissioning of the new channel, was probably due in great measure to the floods which occurred throughout the year. Similar downgrading occurred in the Control Reach, where there had been no interference with the stream channel.

Unfortunately, because the floodplain had been mined upstream of, and alongside, the Control Reach, it is not possible to be categorical that flood events alone were responsible for the downgrading. Had normal floods occurred, the proximity of mined floodplain would not have been a major problem. The fact that an exceptional flood in October 1987 scoured a second channel in the Control Reach makes our results less conclusive.

What is abundantly clear, is that there are no cheap options for habitat improvement in such waters. The large boulders placed as drops and groynes to provide the lower half of the Diversion Reach with varied habitat were brushed aside by the floods as though they had never existed. While it is important for most purposes to maintain as coarse a substrate as possible, and to return boulders and large cobbles to the stream channel, there is little point in arranging these in other than a random dispersal.

The Diversion Reach was colonised quickly by the more abundant species of fish in the Big Hohonu River. The great upsurge in density of blue-gilled bullies in the Control Reach in December was something of an enigma. Had fish from the Diversion Reach been transferred upstream, or even left in situ to make their own escape when the diversion was cut, an explanation would seem obvious, but this was not the case. All fish taken during the electric fishing in August 1987 were transferred to the Little Hohonu River; those taken in the salvage operation when the diversion was cut, were transferred some distance downstream. The length frequency of the December fish did not suggest that they included recent migrants.

Whatever the cause of the large difference in blue-gilled bully density between the Diversion and the Control Reaches in December, the densities in the two reaches by September were similar to those recorded in the pre-diversion survey. There was evidently going to be no long-term suppression of blue-gilled bully numbers from the diversion operation.

There was a substantial reduction in eel numbers in both reaches during the study period. This was probably an effect of flood damage, but may have been exacerbated by earlier mining activity. The amount of cover for eels was reduced considerably by the broadening of the channel(s) and flattening of the channel edges. Initially there was much more cover among boulders (Table 2), especially along the margins of the single narrow channel which prevailed before the diversion was cut. It has to be pointed out, however, that those features of the stream at that time were at least partially artificial, being due to the mining activity on the floodplain.

The 1987 year class of brown trout colonised the Diversion Reach to the extent that, in September 1988, they considerably outnumbered the previous year class in August 1987. However, this may represent simply a return to normal, or near normal, conditions, for the numbers of trout in August 1987 were believed to be low owing to the mining activity in the vicinity. As trout grow they normally change their habitat and it would be natural for them to drop downstream to the Taramakau River during their second year; this out-migration could have been hastened by the mining activity.

The spasmodic appearance of red-finned bullies may or may not have been influenced by cutting the diversion. These bullies tend to frequent somewhat less rapid flows than those predominating in the Big Hohonu River, and where these fish did occur they were among large boulder cover which contributed to their avoidance of capture. While it is safe to assume that their numbers were lower after the diversion was cut, it can not be assumed that they were entirely absent.

By contrast, koaro, which were also a minor component of the fauna and which were present in similar numbers to red-finned bullies prior to the diversion, disappeared altogether from the Diversion Reach. Koaro inhabit water which is ideal for electric fishing, and they are easily captured when present. However, the diversion was not the sole cause of the demise of koaro, because they disappeared also from the Control Reach. Little is known about the natural history of koaro, and it is possible that they move readily from one location to another, as and when floods change their environment.

One of the unexplained features of the Big Hohonu fish populations, both at the beginning and during the study, was the absence of torrentfish. Our experience of native freshwater fishes led us to expect this species to be present in large numbers, but only a solitary fish was recorded during the five visits. Eric Graynoth (pers. comm.) asserts that he recorded torrentfish from the river during the 1970s. We hypothesise that the absence of this fish may be associated with the instream mining activity that took place downstream of the study site prior to the study.

Although invertebrate density, biomass, and number of taxa were severely reduced by diversion of the river, the fauna recovered to pre-diversion levels within 91 days (i.e., by 30 November). This is indicated by the similarity in the density and number of taxa recorded in the Diversion Reach on 24 August and 30 November. This recovery was made against the trend in density recorded in the Control Reach, where the severe flood during 29 October presumably caused the significant decrease in the density of benthic invertebrates recorded between 6 October and 30 November.

The further increase in the density and number of invertebrate taxa in the Diversion Reach by March indicates that this section of the river was probably adversely affected by mining operations during the August sampling period. Although the composition of the fauna in both reaches was similar from March onwards, density in the Diversion Reach was consistently less than that recorded in the Control Reach. This may have been the result of substrate instability in the Diversion Reach, where there was an increase in the proportion of fine substrates and the pattern of the river channel changed between sampling periods (compare Figs. 10 and 11). Such substrate instability presumably was a result of the considerable modifications to the design of the Diversion Reach which were undertaken following the completion of mining operations. Subsequent floods initiated a re-sorting of the substrates, and this process was continuing at the completion of our field work, together with bank erosion and movement of substrates. Eventually, the composition of the substrate remaining should be similar to that in the Control Reach.

There was no evidence that diversion of the river caused any changes to the aquatic invertebrate fauna. Furthermore, the relative abundance of the four most common taxa (Deleatidium, Chironomidae, Z. decorata, and Oligochaeta) was similar before and after diversion. The artificial diversion of a section of the Big Hohonu River into a new channel is similar to one of the effects of natural floods, when the braiding pattern of the river is changed. There was no change in the composition and relative abundance of the fauna in the Rakaia and Ashley Rivers following severe floods (Sagar 1986, Scrimgeour et al. 1988), so it is not surprising that the fauna of the Big Hohonu River behaved similarly.

Drifting aquatic invertebrates are a major food for many fish, and they also probably represent the primary means by which invertebrate populations re-establish in areas following disturbance. The size range of Deleatidium present in the benthos of the Diversion and Control Reaches on 6 October was similar, and included early and late instar larvae. This indicates that the late instar larvae at least would have colonised from the drift, whereas the early instar larvae could have colonised via oviposition and/or drift. Similarly, in an experimental study in the Rakaia River, Sagar (1983) found that late instar Deleatidium larvae were the first mayflies to colonise a channel, and that the size structure of the Deleatidium drift population was similar to that of the control riffle only after a fresh. Here drift also was assumed to be the primary source of colonising Deleatidium. Scrimgeour et al. (1988) emphasised the importance of refuge areas as a source of colonising larvae, and in this study such an area was represented by the Control Reach and other upstream areas.

5.1 Conclusion

In rivers such as the Big Hohonu, where a narrow stream occupies a comparatively broad flood bed, the stream naturally changes its meander pattern from time to time. The diversion of the Big Hononu was not "straight-jacketed" into a confined sluice between stopbanks, and had little effect on the aquatic fauna in the medium term, because it was not dissimilar to events that happen in nature when large floods occur.

Diversion of the Big Hohonu River had a severe, but short-term, impact on the aquatic invertebrate fauna. The rate of recovery of the invertebrate fauna of the Diversion Reach was probably enhanced by the proximity of the Control Reach, which was a source of colonisers. Hence the composition and relative abundance of taxa in the two reaches was similar.

The effect of the diversion on fish was confused by the effects of floods, which possibly delayed recolonisation. Fish numbers and diversity both decreased following diversion, but numbers were showing signs of recovery after 12 months, especially for the most abundant species, blue-gilled bully. The reduction in the eel population was offset to some extent by an increase in trout numbers, but it seems likely that the change in relative abundance would be short term. We anticipate that relative abundance would return to the original balance within another year or two, provided that the channel morphology settled down.

Red-finned bullies and koara can be expected to return in due course, as the channel stabilises. The disappearance of barely represented species cannot be regarded as significant. If suitable habitat re-establishes, it will be occupied by short-jawed kokopu. If channel morphology continues to shift, the persistent deposition of fines from erosion of the true right bank will prevent the habitat recovering, and eels in particular will not regain their former abundance.

6. RECOMMENDATIONS

In such a dynamic waterbody as the Big Hohonu River, there is nothing to be gained from elaborate stream improvement structures. Not only will floods remove any such structures, but should any by chance remain, it would be solely because the channel had shifted and by-passed them.

The cutting of a diversion channel is seen as greatly preferable to instream mining and/or discharge of sediment-laden water. The channel should be sufficiently broad to allow the stream to adopt its own meander pattern and thus develop variable flow types. The coarsest substrate material available should be distributed on the surface of the new channel. The planting of natural riparian vegetation is recommended where there is a reasonable chance of its becoming established.

7. ACKNOWLEDGEMENTS

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APPENDIX I. Mean numbers and biomass (g) of fish by length and area of water type for sections fished, and estimated numbers and biomass for the entire reach, in the Big Hohonu River Diversion Reach, 1987-1988.

BLUE-GILLED BULLIES

Date	No. and biomass per linear m		No. and biomass per 100 m^2	
Runs				
Aug 87	1.248	4.860	24.517	95.464
Dec 87	0.514	2.510	-	-
Mar 88	0.508	-	4.885	-
Jun 88	0.147	0.628	1.663	7.127
Sep 88	0.228	1.016	1.771	7.382
Riffles				
Aug 87	3.147	13.752	30.491	133.241
Dec 87	0.702	2.956	-	-
Mar 88	0.575	-	5.339	-
Jun 88	0.314	1.355	2.833	12.218
Sep 88	1.053	4.907	16.300	75.943
Rapids				
Aug 87	----------	----------	----------	----------
Dec 87	-	-	-	-
Mar 88	0.571	-	5.846	-
Jun 88	0.521	2.281	4.883	21.387
Sep 88	1.078	5.410	10.557	52.956
Combined Riffles and Rapids				
Aug 87	3.147	13.752	30.491	133.241
Dec 87	0.702	2.956	-	-
Mar 88	0.573	-	5.500	-
Jun 88	0.346	1.497	3.140	13.58
Sep 88	1.059	5.024	14.445	68.518
Pools				
Aug 87	0	0	0	0
Dec 87	----------	----------	----------	----------
Mar 88	-	-	-	-
Jun 88	0	0	0	0
Sep 88	0	0	0	0

Estimated population and biomass of blue-gilled bullies for the reach, including sections not fished

Aug 87	591 fish,	2387g
Dec 87	254 fish,	1106g
Mar 88	271 fish,	-
Jun 88	147 fish,	632g
Sep 88	397 fish,	1846g

LONG-FINNED EELS

Date	No. and biomass per linear m		No. and biomass per 100 m^2	
Runs				
Aug 87	0.274	16.662	5.392	327.308
Dec 87	0.144	13.522	-	-
Mar 88	0.437	-	4.206	-
Jun 88	0.305	16.194	3.455	183.728
Sep 88	0.082	2.269	0.639	17.586
Riffles				
Aug 87	1.155	47.709	11.186	462.238
Dec 87	0.305	15.591	-	-
Mar 88	0.433	-	4.027	-
Jun88	0.061	3.059	0.546	27.587
Sep 88	0.124	1.233	1.923	19.075
Rapids				
Aug 87	----------	----------	----------	----------
Dec 87	-	-	-	-
Mar 88	0.306	-	3.132	-
Jun 88	0	0	0	0
Sep 88	0.059	1.312	0.576	12.841
Combined Riffles and Rapids				
Aug 87	1.155	47.709	11.186	462.238
Dec 87	0.305	15.591	-	-
Mar 88	0.391	-	3.750	-
Jun 88	0.051	2.588	0.465	23.483
Sep 88	0.109	1.251	1.488	17.060
Pools				
Aug 87	0.247	2.704	2.713	29.711
Dec 87	----------	----------	----------	----------
Mar 88	-	-	-	-
Jun 88	0.031	0.122	0.590	2.300
Sep 88	0.063	130.313	0.868	1809.896

Estimated population and biomass of long-finned eels for the reach, including sections not fished

Aug 87	171 fish,	8329g
Dec 87	118 fish,	9668g
Mar 88	212 fish,	-
Jun 88	98 fish,	5458g
Sep 88	41 fish,	1614g

APPENDIX I. (ctd.)

BROWN TROUT

Date	No. and biomass per linear m		No. and biomass per 100 m^2	
Runs				
Aug 87	0.036	1.044	0.712	20.499
Dec 87	0.081	0.207	-	-
Mar 88	0.122	-	1.176	-
Jun 88	0.117	2.948	1.322	33.444
Sep 88	0.079	3.086	0.610	23.917
Riffles				
Aug 87	0.186	7.004	1.804	67.856
Dec 87	0.260	1.479	-	-
Mar 88	0.554	-	5.151	-
Jun 88	0.163	57.151	1.468	515.468
Sep 88	0.071	3.027	1.099	46.850
Rapids				
Aug 87	----------	----------	----------	----------
Dec 87	-	-	-	-
Mar 88	0.143	-	1.461	-
Jun 88	0.063	1.081	0.586	10.137
Sep 88	0.196	5.461	1.919	53.455
Combined riffles and rapids				
Aug 87	0.186	7.004	1.804	67.856
Dec 87	0.260	1.479	-	-
Mar 88	0.418	-	4.009	-
Jun 88	0.147	48.530	1.337	440.288
Sep 88	0.100	3.591	1.364	48.983
Pools				
Aug 87	0	0	0	0
Dec 87	----------	----------	----------	----------
Mar 88	-	-	-	-
Jun 88	0.063	3.384	1.179	63.856
Sep 88	0.063	5.156	0.868	71.615

Estimated population and biomass of brown trout for the reach, including sections not fished

Aug 87	24 fish,	767g
Dec 87	86 fish,	472g
Mar 88	123 fish,	-
Jun 88	79 fish,	4144g
Sep 88	53 fish,	2146g

RED-FINNED BULLY

Date	No. and biomass per linear m		No. and biomass per 100 m^2	
Runs				
Aug 87	0.026	0.229	0.509	4.496
Dec 87	0	0	-	-
Mar 88	0.038	-	0.362	-
Jun 88	0	0	0	0
Sep 88	0	0	0	0
Riffles				
Aug 87	0.037	0.250	0.361	2.418
Dec 87	0	0	0	0
Mar 88	0	0	0	0
Jun88	0	0	0	0
Sep 88	0	0	0	0
Rapids				
Aug 87	----------	----------	----------	----------
Dec 87	-	-	-	-
Mar 88	0.020	-	0.209	-
Jun 88	0	0	0	0
Sep 88	0	0	0	0
Combined riffles and rapids				
Aug 87	0.037	0.250	0.361	2.418
Dec 87	0	0	0	0
Mar 88	0.007	-	0.065	-
Jun 88	0	0	0	0
Sep 88	0	0	0	0
Pools				
Aug 87	0.082	0.802	0.904	8.818
Dec 87	----------	----------	----------	----------
Mar 88	-	-	-	-
Jun 88	0	0	0	0
Sep 88	0	0	0	0

Estimated population and biomass of red-finned bully for the reach, including sections not fished

Aug 87	9 fish,	77g
Dec 87	0 fish.	
Mar 88	13 fish,	-
Jun 88	0 fish.	
Sep 88	0 fish.	

APPENDIX I. (ctd.)

KOARO

Runs

Date	No. and biomass per linear m		No. and biomass per 100 m^2	
Aug 87	0.010	0.156	0.203	3.062
Dec 87	0	0	0	0
Mar 88	0	0	0	0
Jun 88	0	0	0	0
Sep 88	0	0	0	0

Riffles

Date	No. and biomass per linear m		No. and biomass per 100 m^2	
Aug 87	0.149	2.030	1.443	19.666
Dec 87	0.	0	0	0
Mar 88	0	0	0	0
Jun 88	0	0	0	0
Sep 88	0	0	0	0

Rapids

Date	No. and biomass per linear m		No. and biomass per 100 m^2	
Aug 87	---	---	---	---
Dec 87	-	-	-	-
Mar 88	0	0	0	0
Jun 88	0	0	0	0
Sep 88	0	0	0	0

Pools

Date	No. and biomass per linear m		No. and biomass per 100 m^2	
Aug 87	0	0	0	0
Dec 87	---	---	---	---
Mar 88	-	-	-	-
Jun 88	0	0	0	0
Sep 88	0	0	0	0

Estimated population and biomass of koaro for the reach, including sections not fished

Aug 87	12 fish,	139g
Dec 87	0 fish.	
Mar 88	0 fish.	
Jun 88	0 fish.	
Sep 88	0 fish.	

- = no data.
--- = water type was not present during sampling.

APPENDIX II. Mean numbers and biomass (g) of fish, by length and area of water type, in the Big Hohonu River Control Reach, 1987-1988.

BLUE-GILLED BULLIES

Date	No. and biomass per linear m		No. and biomass per 100 m^2	
Runs				
Aug 87	0.930	4.344	11.344	52.978
Dec 87	-----	-----	-----	-----
Mar 88	-----	-----	-----	-----
Jun 88	-----	-----	-----	-----
Sep 88	1.600	6.600	22.857	94.286
Riffles				
Aug 87	0.706	3.282	10.695	49.733
Dec 87	2.383	9.957	28.630	119.632
Mar 88	1.412	-	21.719	-
Jun 88	0.076	0.360	2.240	10.607
Sep 88	-	-	-	-
Rapids				
Aug 87	0.452	2.594	5.018	28.817
Dec 87	-----	-----	-----	-----
Mar 88	0.489	-	19.556	-
Jun 88	-----	-----	-----	-----
Sep 88	0.314	1.374	8.154	35.660
Combined riffles and rapids				
Aug 87	0.542	2.838	6.650	34.820
Dec 87	2.383	9.957	28.630	119.632
Mar 88	0.569	-	19.980	-
Jun 88	0.076	0.360	2.240	10.607
Sep 88	0.314	1.374	8.154	35.660
Pools				
Aug 87	0	0	0	0
Dec 87	-----	-----	-----	-----
Mar 88	0	0	0	0
Jun 88	0.120	0.596	2.000	9.933
Sep 88	0	0	0	0

LONG-FINNED EELS

Date	No. and biomass per linear m		No. and biomass per 100 m^2	
Runs				
Aug 87	1.465	28.130	17.867	343.052
Dec 87	-----	-----	-----	-----
Mar 88	-----	-----	-----	-----
Jun 88	-----	-----	-----	-----
Sep 88	0	0	0	0
Riffles				
Aug 87	0.471	6.541	7.130	99.109
Dec 87	0.383	11.366	4.601	136.554
Mar 88	0.471	-	7.240	-
Jun 88	0.013	0.823	0.395	24.244
Sep 88	-	-	-	-
Rapids				
Aug 87	0.968	34.484	10.753	383.154
Dec 87	-----	-----	-----	-----
Mar 88	0.067	-	2.667	-
Jun 88	-----	-----	-----	-----
Sep 88	0.086	0.754	2.224	19.570
Combined riffles and rapids				
Aug 87	0.792	24.588	9.714	301.687
Dec 87	0.383	11.366	4.601	136.554
Mar 88	0.102	-	3.570	-
Jun 88	0.013	0.823	0.395	24.244
Sep 88	0.086	0.754	2.224	19.570
Pools				
Aug 87	0.062	1.406	0.784	17.792
Dec 87	-----	-----	-----	-----
Mar 88	0.125	-	2.717	-
Jun 88	0.040	124.000	0.667	2066.667
Sep 88	0	0	0	0

APPENDIX II (ctd)

BROWN TROUT

Date	No. and biomass per linear m		No. and biomass per 100 m^2	
Runs				
Aug 87	0.140	3.733	1.702	45.519
Dec 87	--------	--------	--------	--------
Mar 88	--------	--------	--------	--------
Jun 88	--------	--------	--------	--------
Sep 88	0	0	0	0
Riffles				
Aug 87	0	0	0	0
Dec 87	0	0	0	0
Mar 88	0.235	-	3.620	-
Jun 88	0.031	1.153	0.922	33.968
Sep 88	-	-	-	-
Rapids				
Aug 87	0.323	10.284	3.584	114.265
Dec 87	--------	--------	--------	--------
Mar 88	0.056	-	2.222	-
Jun 88	--------	--------	--------	--------
Sep 88	0.029	0.569	0.741	14.752
Combined riffles and rapids				
Aug 87	0.208	6.642	2.556	81.493
Dec 87	0	0	0	0
Mar 88	0.071	-	2.497	-
Jun 88	0.031	1.153	0.922	33.968
Sep 88	0.029	0.569	0.741	14.752
Pools				
Aug 87	0	0	0	0
Dec 87	--------	--------	--------	--------
Mar 88	0.063	-	1.359	-
Jun 88	0	0	0 0	0
Sep 88	0	0	0	0

RED-FINNED BULLY

Date	No. and biomass per linear m		No. and biomass per 100 m^2	
Runs				
Aug 87	0	0	0	0
Dec 87	--------	--------	--------	--------
Mar 88	--------	--------	--------	--------
Jun 88	--------	--------	--------	--------
Sep 88	0.200	0.600	2.857	8.571
Riffles				
Aug 87	0.118	1.306	1.783	19.786
Dec 87	0	0	0	0
Mar 88	0.118	-	1.810	-
Jun 88	0	0	0	0
Sep 88	-	-	-	-
Rapids				
Aug 87	0	0	0	0
Dec 87	--------	--------	--------	--------
Mar 88	0	0	0	0
Jun 88	--------	--------	--------	--------
Sep 88	0	0	0	0
Combined riffles and rapids				
Aug 87	0.042	0.458	0.511	5.624
Dec 87	0	0	0	0
Mar 88	0.010	-	0.357	-
Jun 88	0	0	0	0
Sep 88	0	0	0	0
Pools				
Aug 87	0	0	0	0
Dec 87	--------	--------	--------	--------
Mar 88	0	0	0	0
Jun 88	0	0	0	0
Sep 88	0.133	1.880	2.424	34.182

APPENDIX II. (ctd)

Date	No. and biomass per linear m		No. and biomass per 100 m^2	
KOARO				
Runs				
Aug 87	0.023	0.333	0.284	4.056
Dec 87	------	------	------	------
Mar 88	------	------	------	------
Jun 88	------	------	------	------
Sep 88	0	0	0	0
Riffles				
Aug 87	0.235	1.718	3.565	26.025
Dec 87	0.	0	0	0
Mar 88	0	0	0	0
Jun 88	0	0	0	0
Sep 88	-	-	-	-
Combined riffles and rapids				
Aug 87	0.583	7.133	5.624	87.526
Dec 87	0	0	0	0
Mar 88	0.061	-	2.140	-
Jun 88	0	0	0	0
Sep 88	0	0	0	0
Pools				
Aug 87	0	0	0	0
Dec 87	------	------	------	------
Mar 88	0	0	0	0
Jun 88	0	0	0	0
Sep 88	0	0	0	0
Rapids				
Aug 87	0.581	10.103	6.452	112.258
Dec 87	------	------	------	------
Mar 88	0.067	-	2.667	-
Jun 88	------	------	------	------
Sep 88	0	0	0	0

------ = water type was not present during sampling.
- = no data.