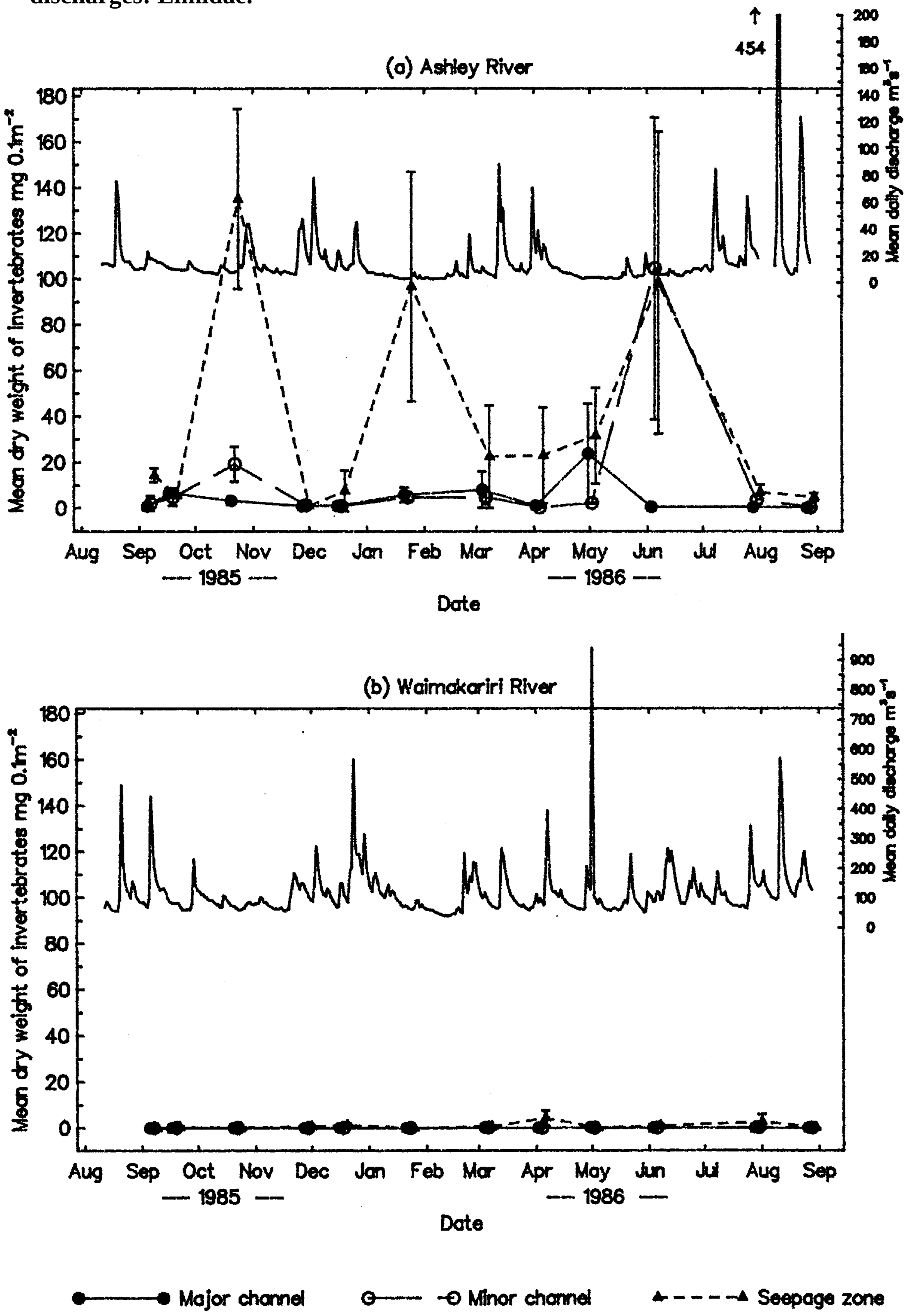
**Figure 12 : Dry weight of benthic invertebrates (x ± 1SE) in samples from Ashley and Waimakariri rivers 4 September 85 - 28 August 86 compared with daily mean discharges: Elmidae.**



Hydrophilidae
The abundance of hydrophilid larvae was similar between rivers although none were recorded in the Waimakariri until March 1986 (Appendix Figures A5 and A6). The abundance pattern in the Ashley was similar to that of elmid larvae and generally highest densities and weights occurred in seepage channels.

Staphylinidae
Staphylinid larvae were recorded in very low weights and densities in both rivers (Appendix Figures A7 and A8).

### 4.2.5 Two-winged flies (Order: Diptera)

Six families of Diptera were recorded, with all but Tabanidae being present in both rivers. Dominant among these families were Chironomidae, followed by Tipulidae and Simuliidae. Dipteran densities were generally highest in the Waimakariri, and in both rivers major channels were the most important, followed by minor channels. For the Ashley River densities ranged from 4.6% (seepage) to 7.4% (major channel) of total mean invertebrate densities, and for the Waimakariri they ranged from 10.0% (seepage) to 16.2% (major) of total mean densities.

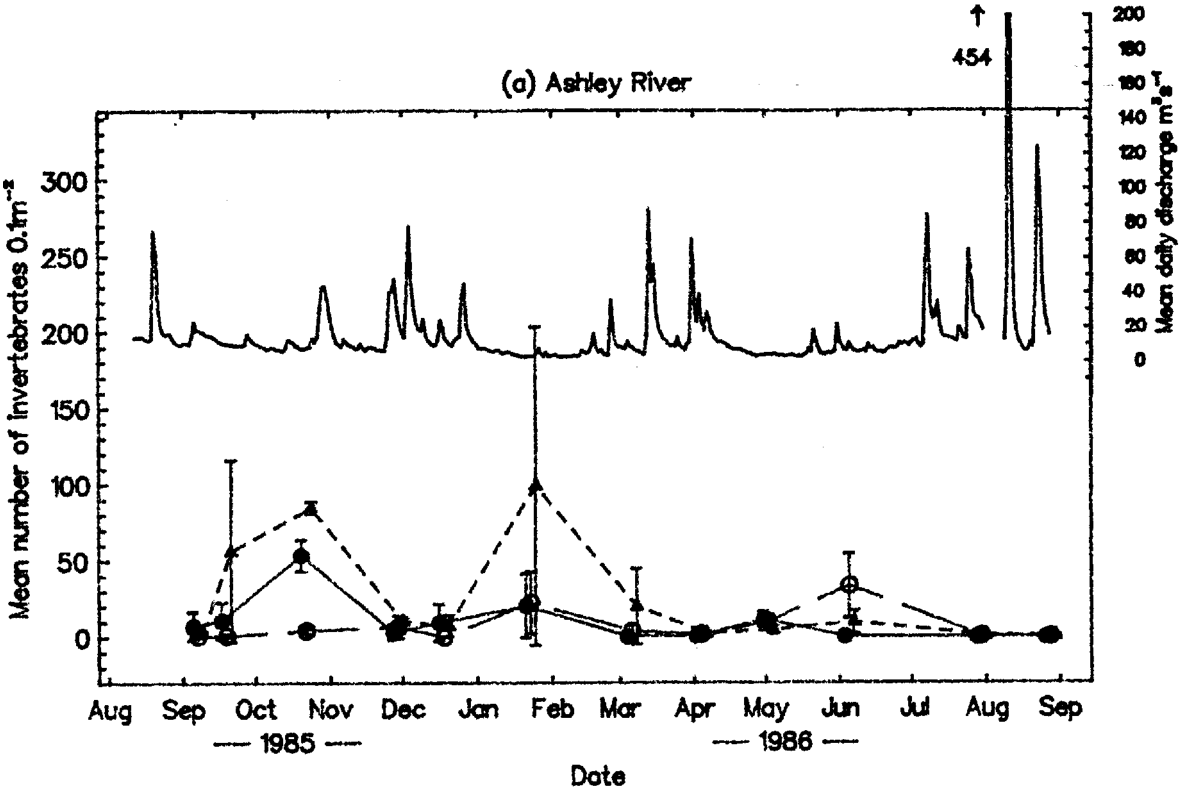
Dipteran dry weights were dominated in the Ashley by tipulids followed by tabanids and chironomids; on the Waimakariri chironomids were the dominant group followed by tipulids. For the Ashley mean proportional dry weights ranged from 4.63% (minor) to 5.90% (seepage) for the various sampling sites. Proportions for the Waimakariri River were 4.33% (seepage) to 7.27% (minor).

Chironomidae
Chironomid larvae densities (Figures 13) were highest in Waimakariri seepage channels in June and in Ashley seepage channels in January. In the Ashley high densities occurred during low flows and low densities after floods. The greater instability of Waimakariri River flows confused the relationship for that river. Dry weights peaked during periods of stable flow in both rivers (Figures 14). Greatest weights of chironomids occurred in seepage channels of both rivers, with peaks in January and July in the Ashley and Waimakariri respectively.

Tipulidae
Densities of tipulid larvae (Figure 15) were greater in the Ashley than the Waimakariri in most months. Population figures show no clear pattern for either river although a summer low and winter-spring high pattern are apparent for the Ashley River. Dry weights of tipulid larvae varied greatly on the Ashley (Figure 16). They were high from September-November and low from December-April; the latter was a long period of stable flows. A similar, if somewhat attenuated, pattern occurred in the Waimakariri.

Simuliidae
Simuliid larvae densities (Appendix Figures A9 and A10) peaked on 3 occasions in the Ashley, during spring, summer and winter when densities in minor and major channels were generally higher than in seepage channels. Only one substantive peak occurred in the Waimakariri and that was in seepage channels during summer. Dry weights were low in both rivers, with the highest channel mean being 0.57 mg 0.1 $m^{-2}$ in the Ashley seepage channel. Ashley dry weight changes could be related to the flow regime, high weights occurring during stable flows and low weights after high flows.

**Figure 13 : Density of benthic invertebrates (x ± 1SE) in samples from Ashley and Waimakariri rivers 4 September 85 - 28 August 86 compared with daily mean discharges: Chironomidae**



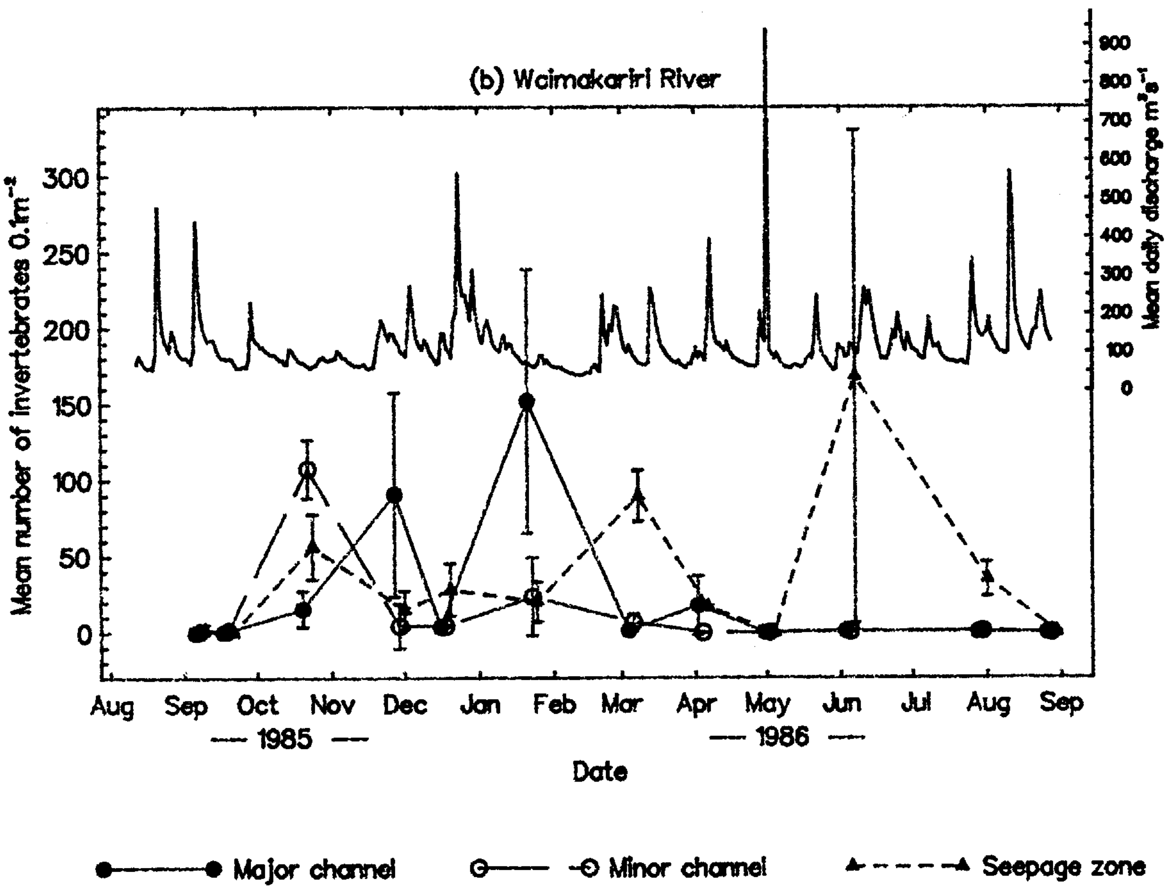



**Figure 14 : Dry weight of benthic invertebrates (x ± 1SE) in samples from Ashley and Waimakariri rivers September 85 - 28 August 86 compared with daily mean discharges: Chironomidae.**

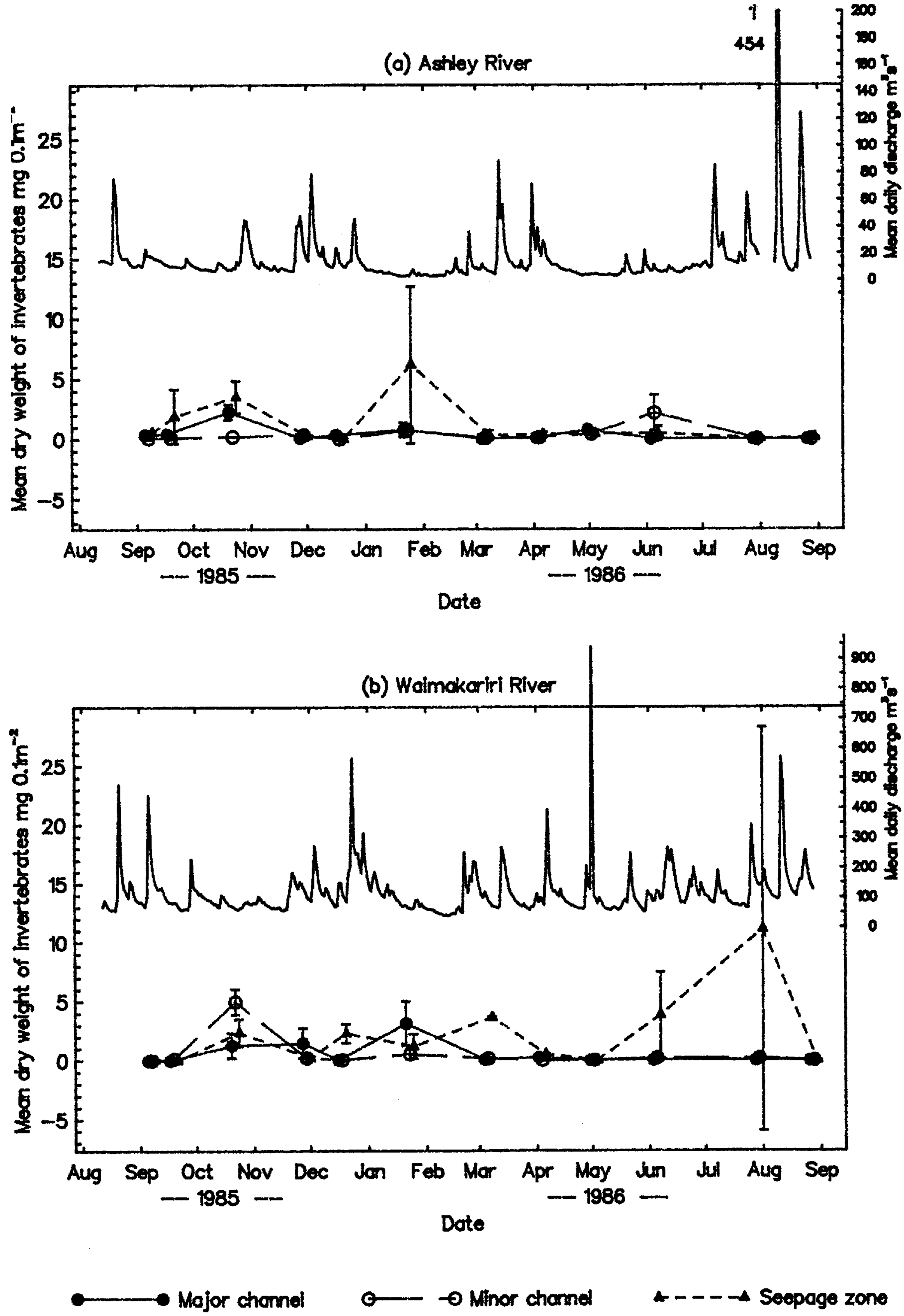


**Figure 15 : Density of benthic invertebrates (x ± 1SE) in saples from Ashley and Waimakariri rivers 4 September 85 - 28 August 86 compared with daily mean discharges: Tipulidae.**

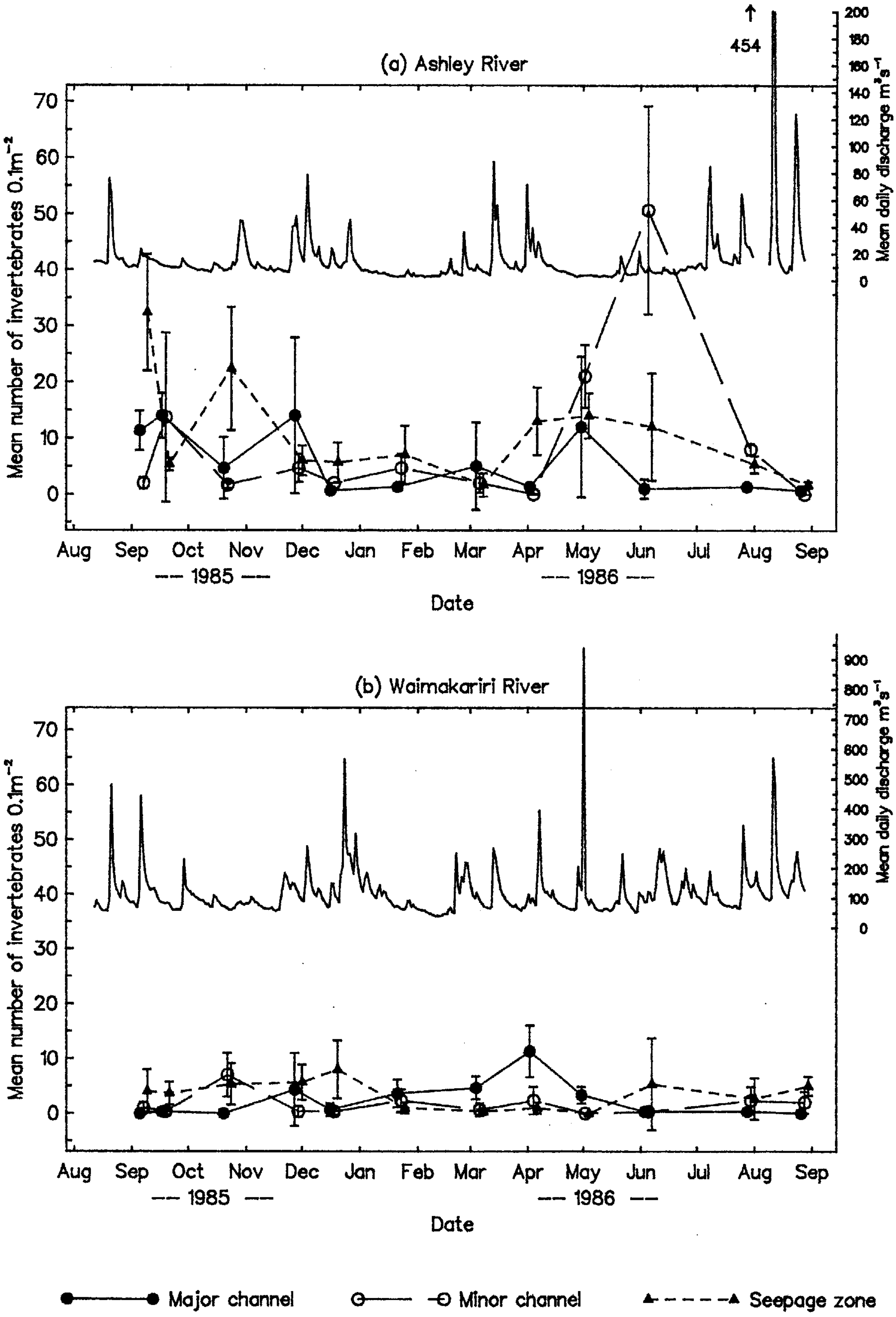
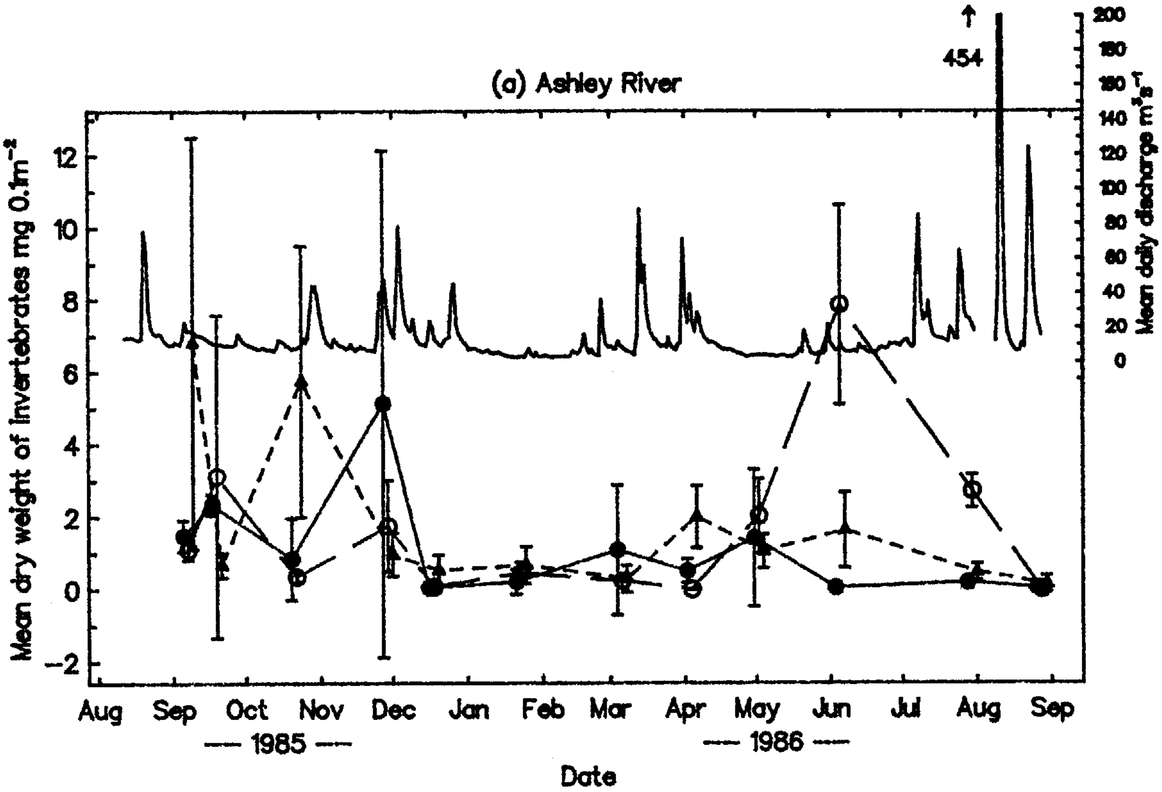
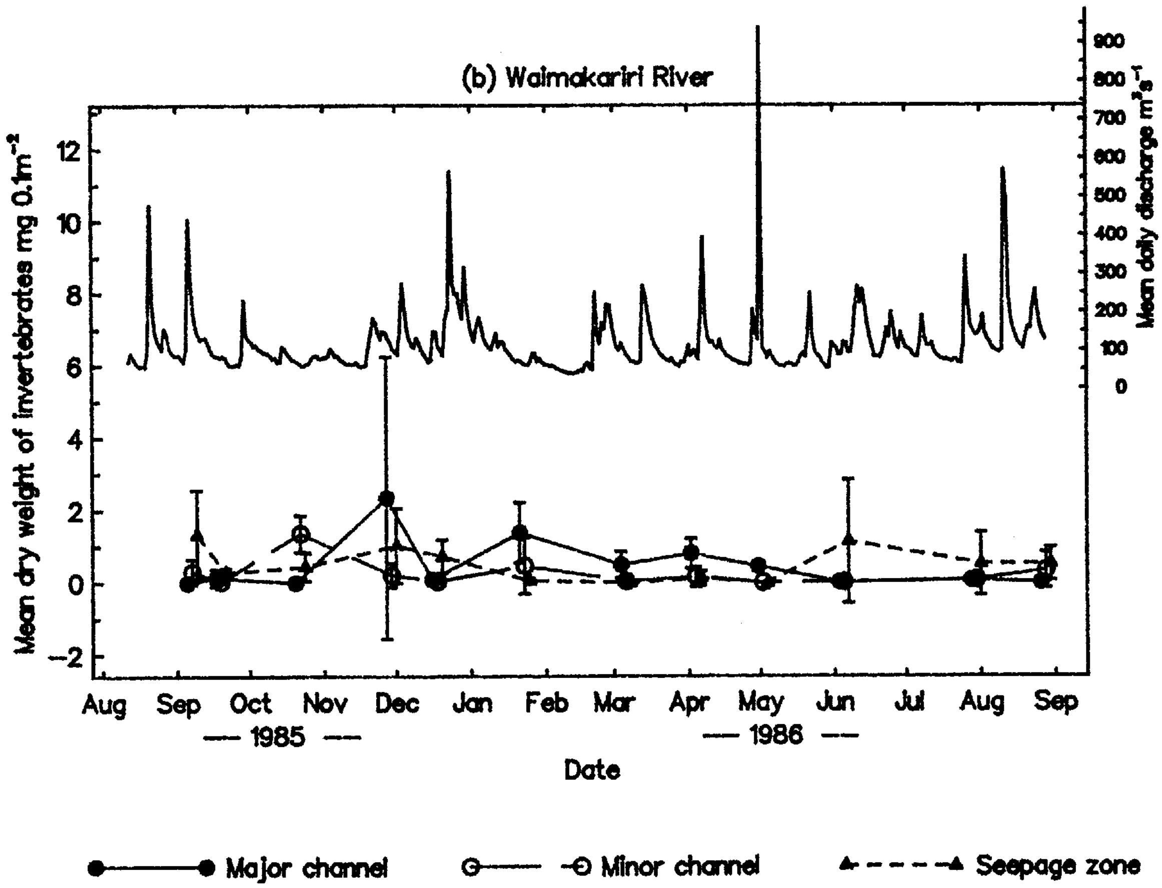


**Figure 16 : Dry weight of benthic invertebrates (x ± 1SE) in samples from Ashley and Waimakariri rivers September 85 - 28 August 86 compared with daily mean discharges: Tipulidae.**



Ephydridae

Densities of ephydrid larvae were generally low in both rivers (Appendix Figures A11 and A12) with a significant peak in density occurring in Ashley seepage channels during November. Their peaks in dry weight did not correlate consistently to low flows in the Ashley River. The highest dry weight (1.7 mg 0.1 $m^{-2}$) was recorded in seepage channels in September 1985 after a short period of low flows. Seepage channels had the greatest weight of ephydrid larvae in the Ashley River, but in the Waimakariri the greatest peak was recorded in major channels. Dry weights of ephydrids were similar in seepage and major channels for the rest of the sample period.

Ceratopogonidae

Ceratopogonid larvae were rare in both rivers (Appendix figures A13 and A14); though present during most spring and summer months their densities were too low to identify trends. Their dry weights were always less than 1 mg 0.1 $m^{-2}$. Peaks of dry weight in the Ashley were associated with low flows; a clear pattern was not apparent for the Waimakariri River.

Tabanidae

Tabanid larvae were only found in the Ashley River (Appendix Figures A15 and A16) and then almost solely in seepage channels where major peaks of density occurred in October and January during long periods of stable flows. Significant dry weights occurred on the Ashley in October, January and May.

### 4.2.6 Nematodes (Phylum: Nematoda)

Nematodes were not identified to order or family. They occurred in only low densities in all channels except the Waimakariri seepage channel where they became numerous during early winter. All other channel types of both rivers recorded similar low proportions of nematodes. For the Ashley River densities ranged between 0.8% (seepage) to 1.7% (minor) of total mean invertebrate densities and the Waimakariri River ranged from 1.8% (major) to 12.0% (seepage).

Densities of nematodes were mainly low on the Ashley River, but occasionally reached very high totals on the Waimakariri River, especially in seepage channels in April and June (Figures 17 and 18). Nematodes occurred in substantial weights only in April in the Waimakariri seepage channel, when the weight of nematodes (mean = 24 mg 0.1 $m^{-2}$) was equivalent to a third of the total mean weight of invertebrates in that seepage zone (69.52 mg 0.1 $in^{-2}$). This represents a significant, if brief, food resource.

### 4.2.7 "Miscellaneous"

The "miscellaneous" group consists of unidentified organisms as well as identified organisms which occurred so infrequently that they did not warrant separate taxonomic treatment. Seepage channels of the Ashley River had the highest weights and densities although proportionally the values for all three channels of both rivers are very similar.

"Miscellaneous" also represents a very small fraction of the total average invertebrate density as shown in the range of the Ashley River, 0.5% (major) to 3.6% (seepage), and 1.0% (major) to 2.6% (seepage) for the Waimakariri River.

"Miscellaneous" densities were only significant in November 1985 and January 1986 for the Ashley, and in June 1986 for the Waimakariri (Figures 19 and 20). Densities were always highest in seepage channels of both rivers.

"Miscellaneous" dry weight rose at times of low flow and fell immediately after floods. The "miscellaneous" group contributed 7.58% (Ashley) and 4.94% (Waimakariri) to total dry weight, mainly in seepage channels of both rivers.

**Figure 17 : Density of benthic invertebrates (x ± 1SE) in samples from Ashley and Waimakariri rivers 4 September 85 - 28 August 86 compared with daily mean discharges: Nematoda.**

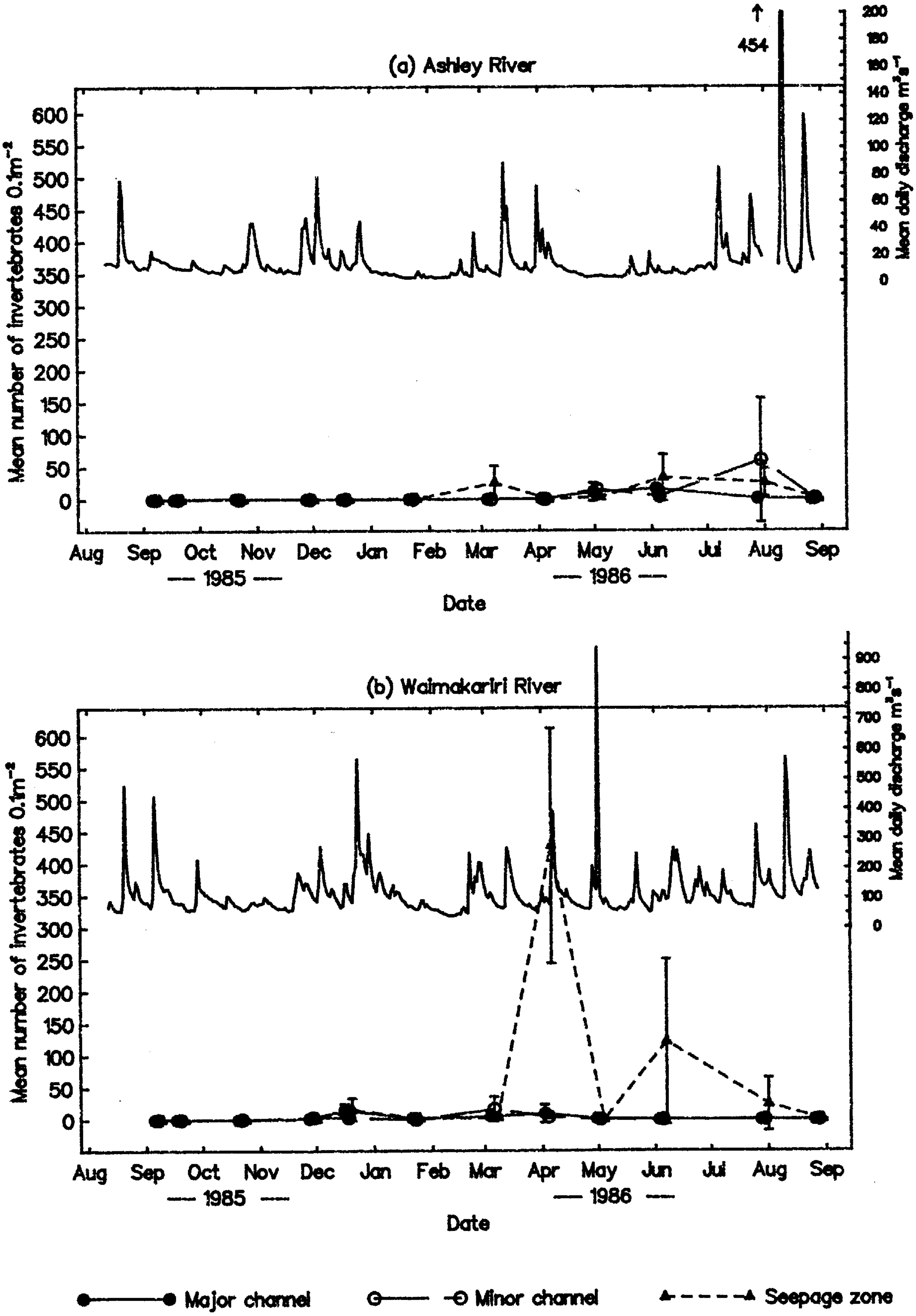


**Figure 18 : Dry weight of benthic invertebrates (x ± 1SE) in samples from Ashley and Waimakariri rivers September 85 - 28 August 86 compared with daily mean discharges: Nematoda**

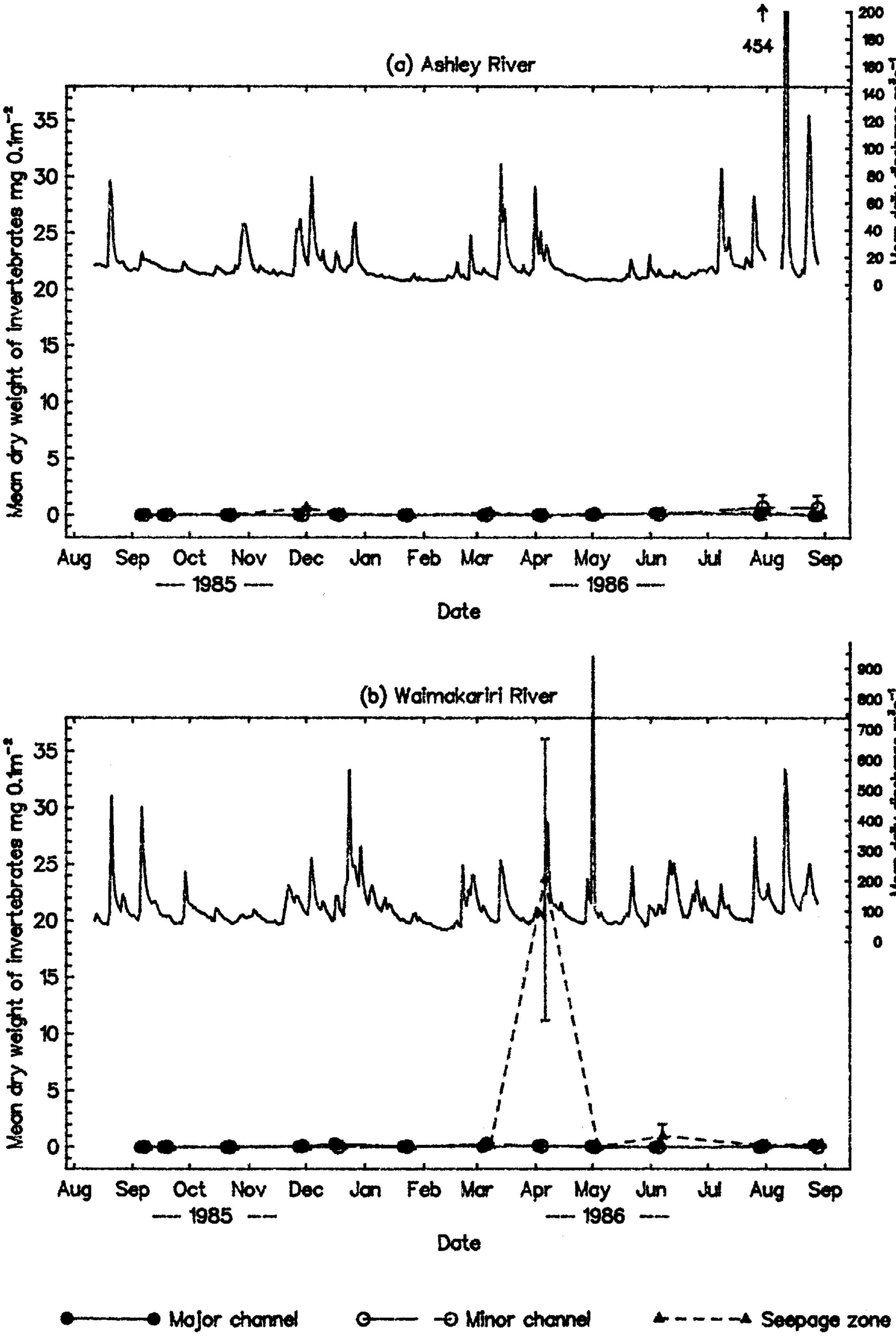


**Figure 19 : Density of benthic invertebrates (x ± 1SE) in samples from Ashley and Waimakariri rivers 4 September 85 - 28 August 86 compared with daily meal discharges: Miscellaneous.**

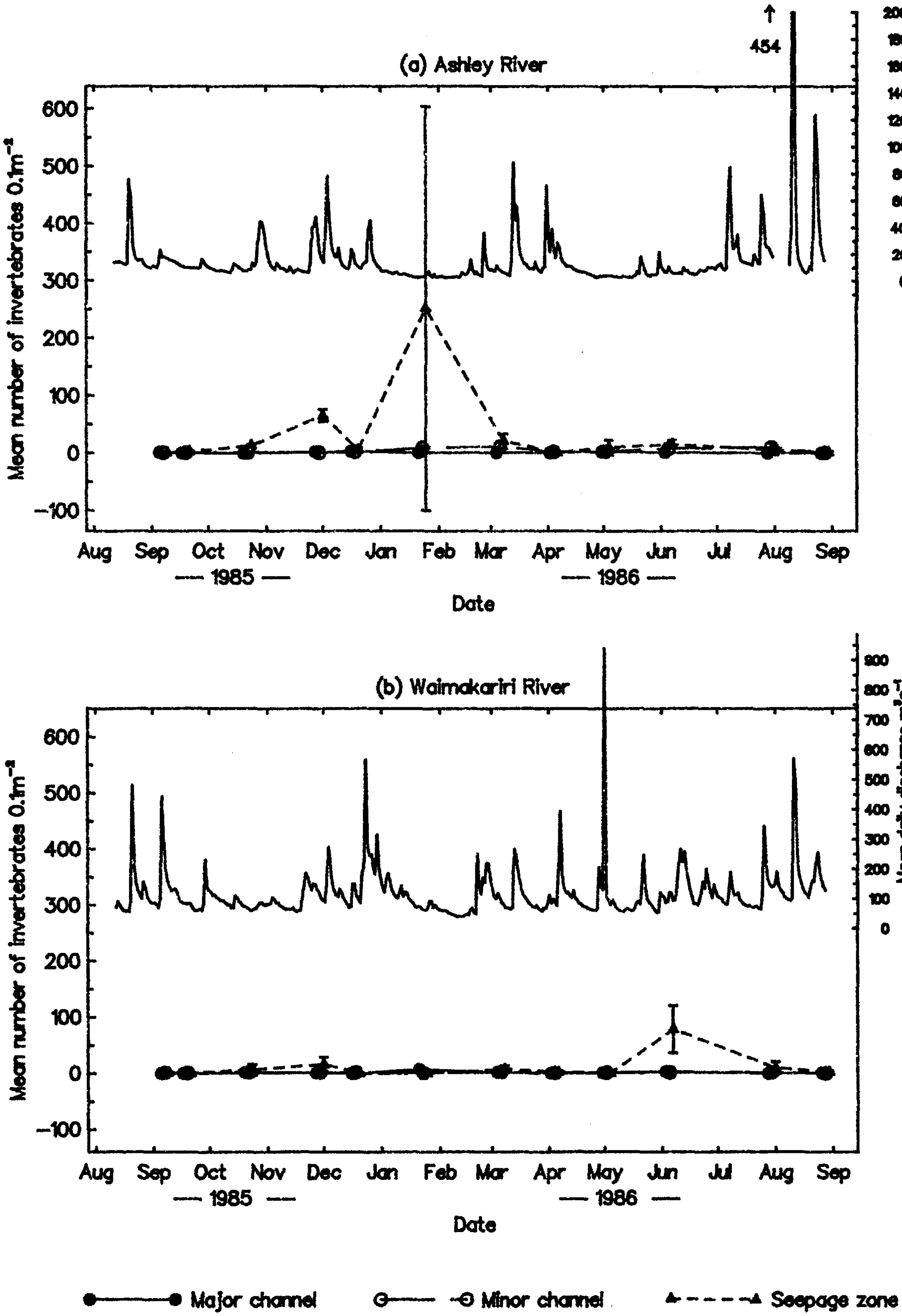
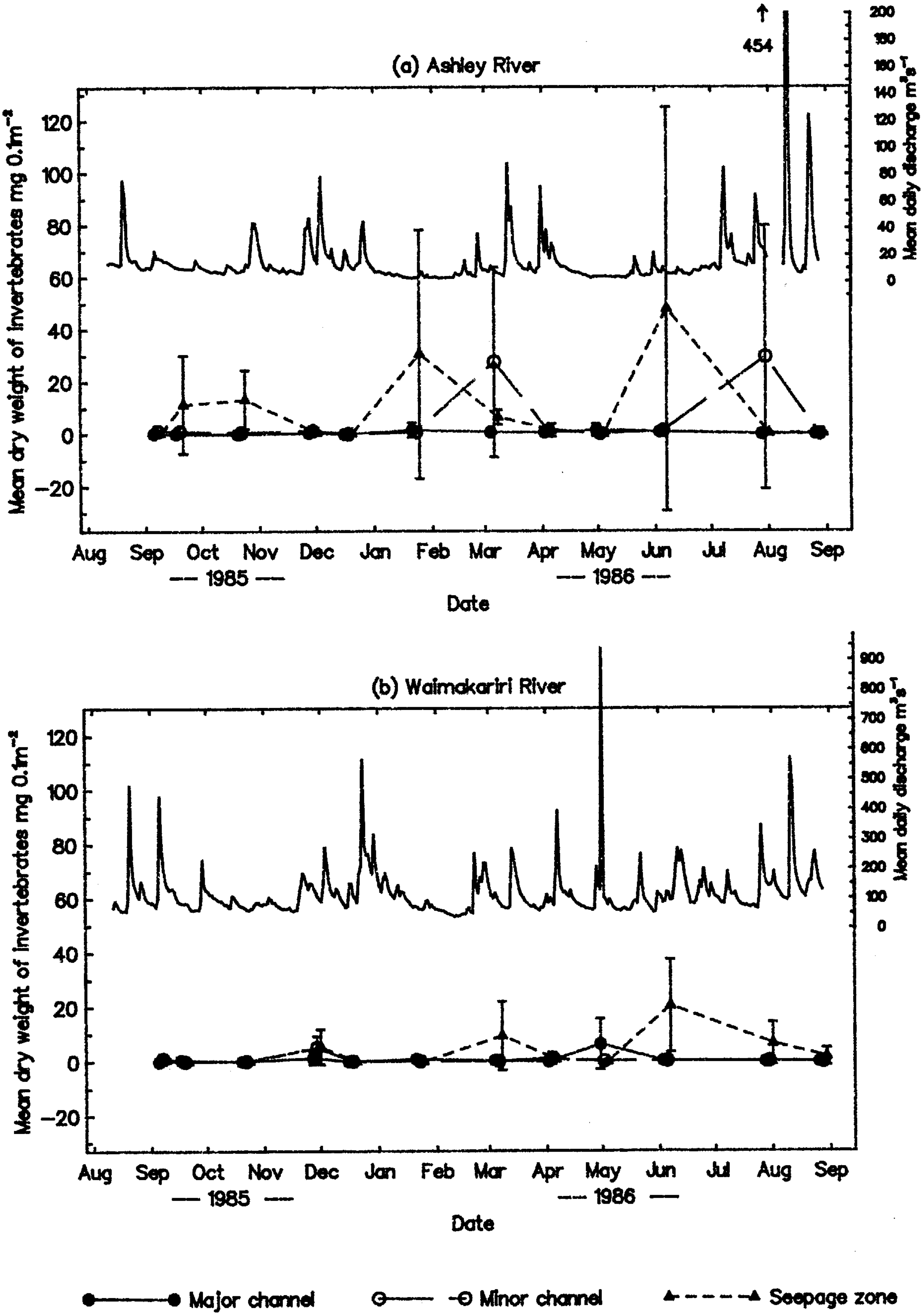


**Figure 20 : Dry weight of benthic invertebrates (x ± 1SE) in samples from Ashley and Waimakariri rivers September 85 - 28 August 86 compared with daily mean discharges: Miscellaneous.**



### 4.2.8 Total invertebrate densities and dry weights

Averaged over the year studied total invertebrate densities were more than twice as high in the Ashley as the Waimakariri (Table 2). In the Ashley, seepage channels had an invertebrate density almost four tunes that of major channels and twice that of minor channels. Densities in Waimakariri seepage channels were more than twice those in major channels and slightly less than four times the density of minor channels (Table 2).

For the Ashley River densities in seepage channels were always higher than in other channel types (Figures 21 and 22). A similar pattern occurred in the Waimakariri, but in March and May 1986 seepage channel densities were less than for other habitat types. The pattern of high and low counts in the Ashley corresponded with low and high flows respectively. The pattern was not so clear for the Waimakariri River.

Total invertebrate weights showed a very similar pattern to that of the densities. Seepage channels were consistently the most productive habitat and maxima occurred in all channel types during periods of low flow.

## 5. DISCUSSION

### 5.1 Significance of results

This is the first study of aquatic invertebrates in New Zealand to compare two morphologically similar but hydrologically distinct braided rivers (see section 5.2). The findings indicate major differences in terms of densities and dry weights of invertebrates between the Ashley and Waimakariri rivers, but little difference in the occurrence of major taxonomic groups. Total invertebrate densities and dry weights were much greater in the Ashley River than in the Waimakariri and this can be partly explained by the different flow regimes of the two rivers; the Waimakariri had a high frequency of floods while the Ashley had long periods of stable flow separated by only occasional floods. Thus, lower densities and dry weights of invertebrates in the Waimakariri appear to be largely in response to the flood-dominated flow regime (Sagar 1983a, Pierce 1986).

The dominance of *Deleatidium* spp. larvae in the aquatic invertebrate fauna of both rivers is not surprising (Winterbourn et al. 1971, Scrimgeour et al. 1988). What is at first surprising is the relative importance of elmid larvae in the Ashley River compared to the Waimakariri River. The relatively long interval between major floods in the Ashley River can result in extensive periphyton growth and substrate compaction, particularly in the smaller channels (Scrimgeour and Winterbourn 1989, Hughey pers. obs.), conditions which contribute to suitable habitat for elmids (Penny 1976, Rutledge 1987). An increase in the relative abundance of elmids and a decline of *Deleatidium* larvae with change from major to minor to seepage channels in the Ashley River may reflect increasing bed stability associated with substrate compaction and growth of periphyton. The major and minor channels of the Waimakariri were usually very unstable (Hughey pers. obs.); *Deleatidium* is well adapted to cope with this instability (Sagar 1983b). Periods of increased stability in Waimakariri seepage channels were reflected in slightly diminished proportions of *Deleatidium* and increases in some other taxa.

There were occasions when the pattern of densities and dry weights for each taxon differed within each river. Periods with highest densities did not necessarily coincide with greatest dry weights, and vice versa. *Deleatidium* samples in seepage channels of the Waimakariri River are examples; whereas densities peaked in June, dry weights were highest in the November-January period. These patterns reflect changes in the size-frequency distributions of invertebrate populations during different life history stages. Thus, numerous early in-star larvae may have a lower dry weight than the less numerous later larval stages. We did not quantify these relationships.

**Figure 21 : Density of benthic inverbrates (x ± 1SE) in samples from Ashley and Waimakariri rivers 4 September 85 - 28 August 86 compared with daily mean discharges.**

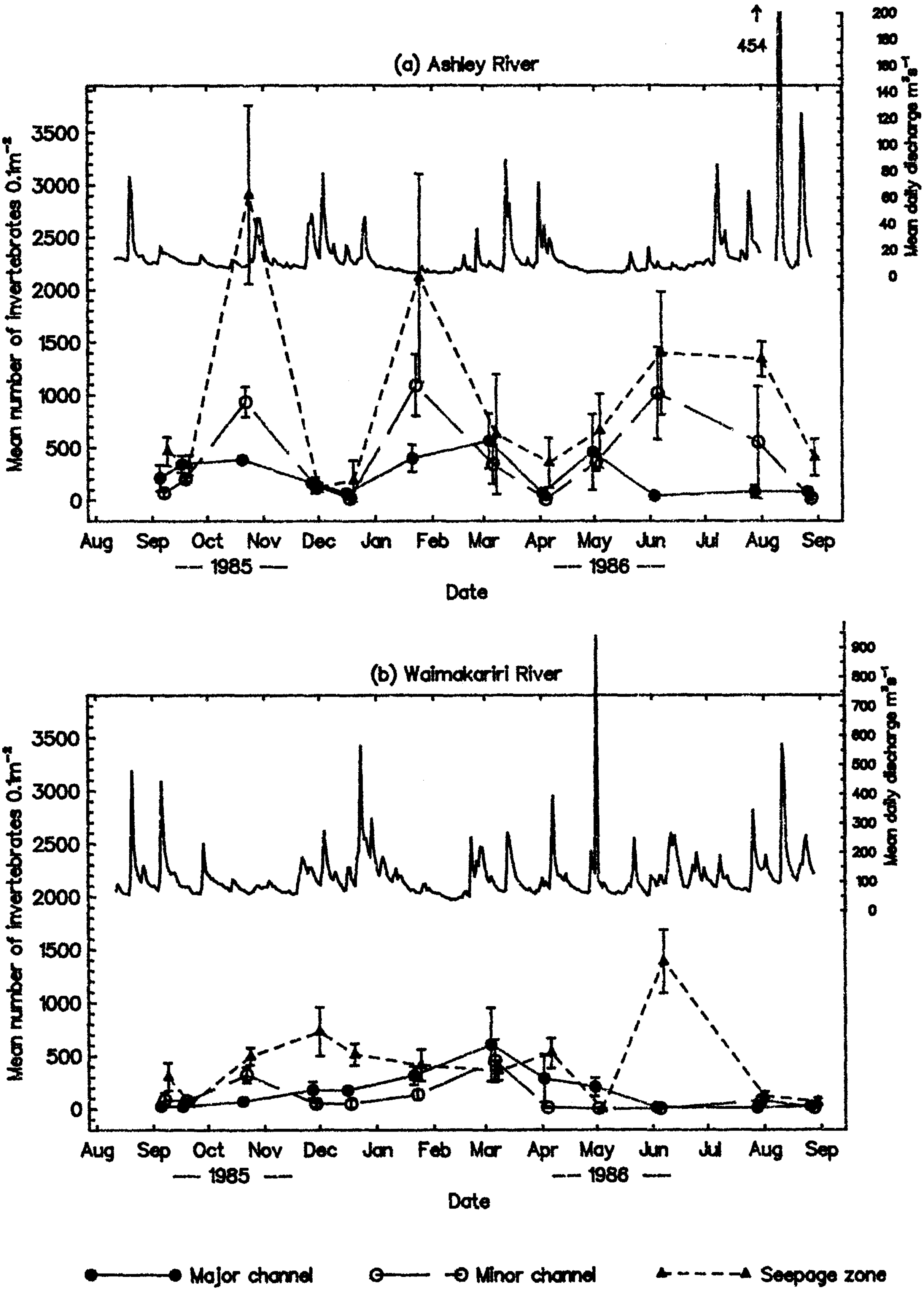
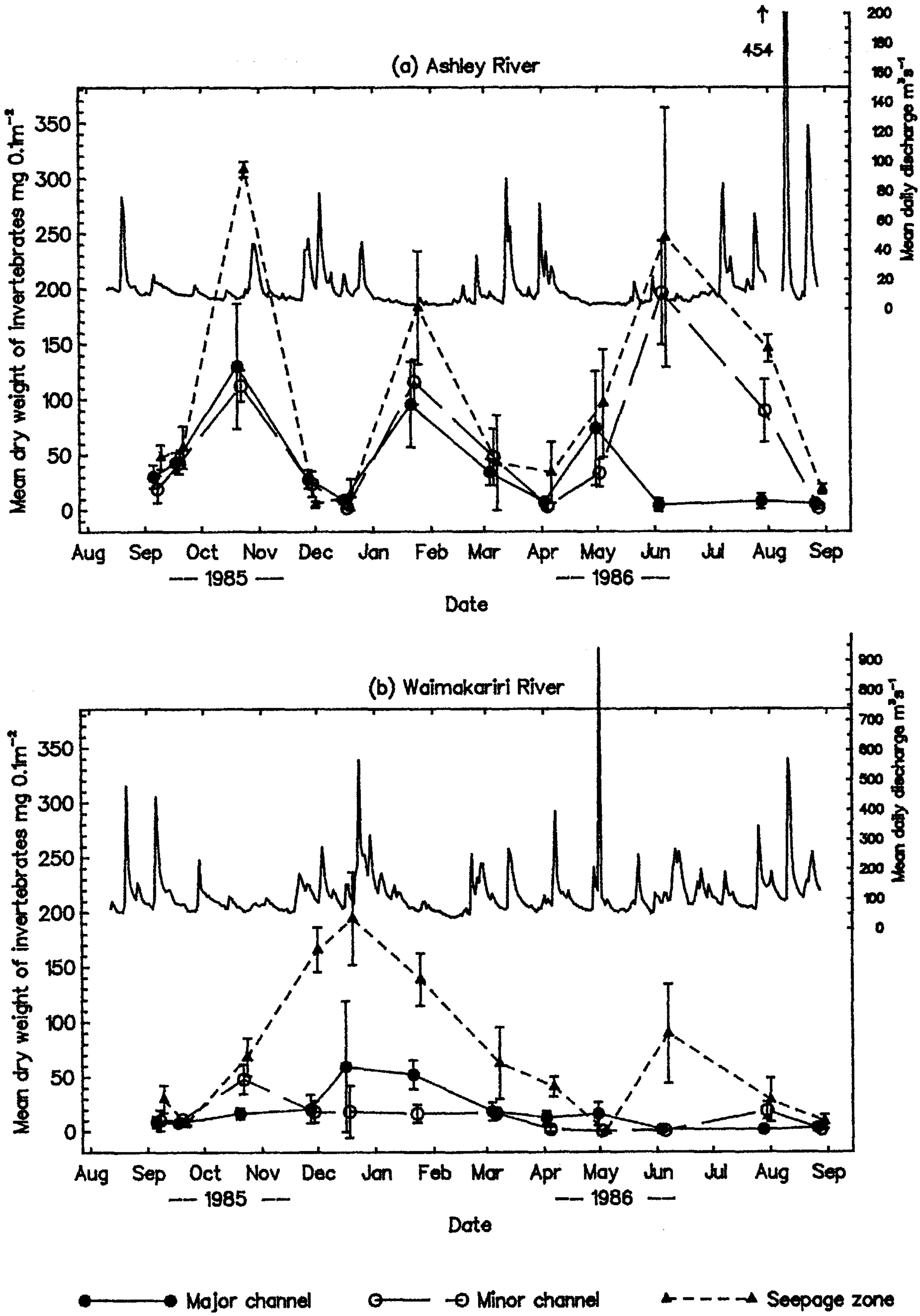


**Figure 22 : Dry weight of benthic invertebrates (x ± 1SE) in samples from Ashley and Waimakariri rivers September 85 - 28 August 86 compared with daily mean discharges.**



In both rivers seepage channels always had substantially greater biomass of invertebrates than minor or major channels. However, there were no significant differences in invertebrate abundance between minor and major channels, confirming a pattern already noted by Sagar (1983a) for deeper channels. Apart from immediately after major flood events seepage channels consistently supported significant populations of invertebrates throughout the year, even when major and minor channels sustained catastrophic declines. Thus, seepage channels represent potentially important feeding sites for wading birds such as wrybill, banded dotterel and South Island pied oystercatcher.

## 5.2 Application of the study findings to other rivers

Most eastern South Island braided rivers have similar physical characteristics (Mosley 1983, Carson and Griffiths 1987). Differences occur in terms of the flow regime, i.e. mountain catchment or foothill catchment rivers and rivers of different size, and in terms of development impacts, e.g. water abstraction, hydro-electric dams, exotic weed encroachment or channelisation (Hughey 1983, O'Donnell and Moore 1983, Robertson et al. 1983, Robertson et al. 1984 for descriptions of impacts).

The Ashley and Waimakariri study areas are morphologically very similar to the lower Waitaki (Griffiths pers. comm.; and Carson and Griffiths 1987). However, the bed of the lower Waitaki differs physically from that in other braided rivers due to flow modification caused by upstream hydro-electric dams (Jowett 1983). The bed of the Waitaki has become armoured due to low bedload movement and increased siltation, whereas most other braided rivers have comparatively unstable beds. Rutledge (1987) attributed many of the benthic faunal differences between the Waitaki and other braided rivers to this siltation and armouring. He found the invertebrate fauna was dominated by elmids in all seasons with generally low proportions of *Deleatidium* larvae.

The modified flow regime of the Waitaki River has led to an invertebrate fauna different to other braided rivers and probably different to the pre 1935 situation when no dams were present on the Waitaki. It appears likely that prior to 1935 the invertebrate faunas of the Waitaki and Waimakariri rivers were similar (Percival 1932; Sagar pers. comm.). Without major development projects the flow regimes of both rivers would have been similar at that time (Griffiths pers. comm.). Thus, conditions on other braided rivers, especially the Waimakariri and possibly the Ashley, probably reflect the invertebrate community structure which should be aimed at on a river managed for wildlife, such as the Waitaki.

## 5.3 Applicability of the study to wildlife management

We only examined the aquatic invertebrates of riffle areas in braided rivers (see section 2 for justification). Some wading birds using braided rivers for feeding make heavy use of riffles, especially those occurring in minor channels, e.g. wrybill, banded dotterel and South Island pied oystercatcher, and to a lesser extent pied stilt (Hughey 1985b). We consider that riffles, the major food producing areas, are indicators of general habitat quality for potential food resources in the riverbed, i.e. if riffles are productive then remaining aquatic habitats will be productive. It also follows that if the birds that use riffles are supplied with food and other essential habitat requirements then this will also be an indicator of environmental health in the riverbed.

Robertson et al. (1984) reported a high degree of similarity between rivers in the general pattern of habitat use by different bird species. Wrybill and banded dotterel feeding was studied on the Ashley and Rakaia rivers and Hughey (1985b) found that patterns of habitat use and diet were similar. Hughey (1985b) studied the feeding of several wading bird species and found that for wrybills mayfly larvae were an important component of the diet (Pierce 1979).

However, while habitat use patterns were similar on most rivers, patterns differed for waders on the Waitaki (Table 6). The wader species used minor channel pools of the Waitaki as their main feeding habitat while minor channel riffles were never even of secondary importance. Riffles probably were poor habitat because of bed-armouring of the coarse substrate making invertebrates unavailable to probing birds (whereas the sand-silt substrate of pools remains usable). This results in a shortage of preferred food items in riffles and a reduction in the amount of minor channel riffle habitat in the lower Waitaki compared for the other rivers.

Given that hydrological and morphological conditions are standard between braided rivers and that bird habitat use is similar on all braided rivers with largely natural flow regimes then the findings of this study should be widely applicable. Consequently, the most appropriate management guidelines for providing bird feeding habitat and food resources in future river development is to try and emulate conditions of other more natural lowland braided rivers.

### 5.4 Applicability to future development of the lower Waitaki River

The management option chosen for conserving the wading birds of the lower Waitaki River should ensure provision of an adequate food supply. The food supply should include mayfly larvae as a major component, should be prolific and should be in a loose substrate to match behavioural needs of feeding birds. The key finding from this invertebrate study of the Ashley and Waimakariri rivers is the importance of seepage channels as potential food sources. It is these conditions which future management of a residual river on the Waitaki should aim to copy. However, the flow regime in these channels should be such that bed armouring does not occur.

All of the bird species present on the Waitaki are found on the Ashley and Waimakariri rivers. Although overall densities of endemic and native wading bird species are similar on the three rivers the numbers and densities of some species on the lower Waitaki are low and, or, patchy, e.g. wrybill, banded dotterel, pied stilt and South Island pied oystercatcher. There are several reasons for this: firstly, the lower Waitaki riverbed is heavily vegetated with a variety of exotic plants which restricts the area of potential nesting habitat; secondly, the very high numbers of southern black-backed gulls exclude some species from otherwise suitable nesting areas; and, thirdly the armoured riverbed tends to make benthic invertebrates less available to wading birds (Robertson et al. 1984 and Rutledge 1987). The first two reasons apply also on the lower Waimakariri but only the first is significant on the Ashley. Certainly the beds of both the Ashley and lower Waimakariri rivers are less compacted than the lower Waitaki suggesting greater aquatic invertebrate availability on the former two rivers. Therefore total invertebrate abundance may be a poor indication of real food availability or potential for exploitation by wading birds. Use of the *Deleatidium* indices from this study is a better way of showing such differences.

Three development schemes have been selected as demonstrating the range of practical alternatives for developing the power potential of the lower Waitaki River between Waitaki Power Station and Black Point (Electricorp 1988). All options involve the construction of canals and therefore a floodway will be needed along the full length of the development to discharge surplus water. Conservation interests have been recognised by creating the concept of a residual river. Such a river would be designed to cater for a range of instream user requirements and would incorporate a specified flow regime and other management needs. While the final details are not defined the same concept is applicable to all three schemes.

These three-part options provide a range of opportunities for wildlife habitat. Residual river studies have focused on providing habitat for fish and recreational fishing opportunities (Graybill et al. 1988). Provision of specific breeding and feeding habitat needs would give habitat for waders. For waders large bare areas of shingle are needed for breeding (Hughey 1985b) with provision of minor braids for feeding. A complication is that the provision of nesting and feeding habitat for these birds will not be completely compatible with habitat needs of a salmonid fishery. The latter requires protective overhead cover by riparian vegetation.

**Table 6 : Use of aquatic habitat types by feeding wading birds on 4 braided rivers in Canterbury.**

| Bird species | Minor channel | | | | | | | | Major channel | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Riffle | | | | Pool | | | | Riffle | | | | Pool | | | |
| | A | R | As | W | A | R | As | W | A | R | As | W | A | R | As | W |
| banded dotterel | 1 | 1 | 2 | | | | 1 | 1 | | | | | 2 | | | |
| wrywill | 1 | 1 | 1 | | | 2 | 2 | 1 | 2 | | | | | | | |
| pied stilt | 1 | 1 | 2 | | 2 | 2 | 1 | 1 | | | | | | | | |
| SI pied oystercatcher | 1 | 2 | 1 | | 2 | 1 | | 1 | | | 2 | | 2 | | | |

Current plans for lower Waitaki power development are for a residual river with a flow of $40m^3s^{-1}$ with the flow spread between 1-3 channels -the main channel having about $30m^3s^{-1}$ and the minor channels about $5m^3s^{-1}$ each. Periodic floods and freshes in the residual river would be used to maintain only a partially stable riverbed (Graybill et al. 1988). Substantial vegetation cover would be allowed for, but room would exist for the maintenance of several large vegetation-free islands. If the flow regime of the residual river can more closely approximate the conditions of a natural river than those of the existing lower Waitaki then the invertebrate stocks would shift toward the Ashley and Waimakariri rivers' situation where the fauna is dominated by mayfly larvae and a reduced stock of elmid larvae. This change would be beneficial to wading birds as riffles would again become a usable habitat for feeding.

Another option could be considered if the residual channel is designed primarily for salmonid fishery needs at the expense of wading birds. The floodway will be a shingle-bottomed riverbed subject to periodic flooding and certainly to an extreme range of flows. Depending on floodway location in relation to elevation and other physical factors it seems likely that some water will always be present, as either continuous flow, seepage channels or disconnected pools. The existence of these seepage channels may provide a significant food resource as demonstrated in this study for other rivers. Such a food source may sustain a riverbed bird community, including a variety of wading birds, on the flood channel. On the Ashley, Waimakariri and Rakaia rivers seepage channels of 100m or more in length are very heavily used by wading birds for feeding (Hughey pers. obs.). Unfortunately there are as yet no data to show what the flow regime of a flood channel on the lower Waitaki would look like. Whether a bird community could survive in the flood channel and its significance will depend on food availability and the availability of suitable nesting habitat. These matters are reported on elsewhere (Hughey 1989).

## 6. CONCLUSIONS

Seepage channels are a prolific source of benthic invertebrates in braided riverbeds, as shown for the Ashley and Waimakariri rivers. Flow acts as a dominant control on invertebrates in rivers, so that highly unstable rivers like the Waimakariri have lower densities of invertebrates than the more stable foothill catchment rivers like the Ashley. The presence of seepage channels is important for wading birds as these channels provide ideal feeding habitat in terms of food resource and its availability. Due to the morphological similarity between eastern South Island braided rivers, and similarities of bird habitat use, the results of this study help provide a baseline from which to make management recommendations for the lower Waitaki River.

The flow regime of the lower Waitaki River has been greatly modified by hydro-electric power schemes and this has affected the benthic fauna (Rutledge 1987). Future development of the lower river with a combination canal option provides scope for meeting wildlife habitat needs; the value and extent of bird habitat will be dependent on an appreciation of basic habitat features and on a willingness to meet these needs. It is apparent from this study that the provision of minor channels and seepage zones will provide a large and exploitable food resource. However, it is also clear from the Waitaki experience that excessive stability reduces the usefulness of habitat to wading birds. It is therefore necessary to provide instability by the scheduling of flood flows in managed channels; such flows will lead to an unstable substrate that meets feeding behavioural and resource needs. It is also apparent for the Waitaki that the planned flood channel could provide significant food resources if it contains substantial areas of seepage channels. Whether this will be sufficient to maintain a viable bird community will be dependent on the occurrence and extent of these seepage channels, as well as on the provision of nesting habitat.

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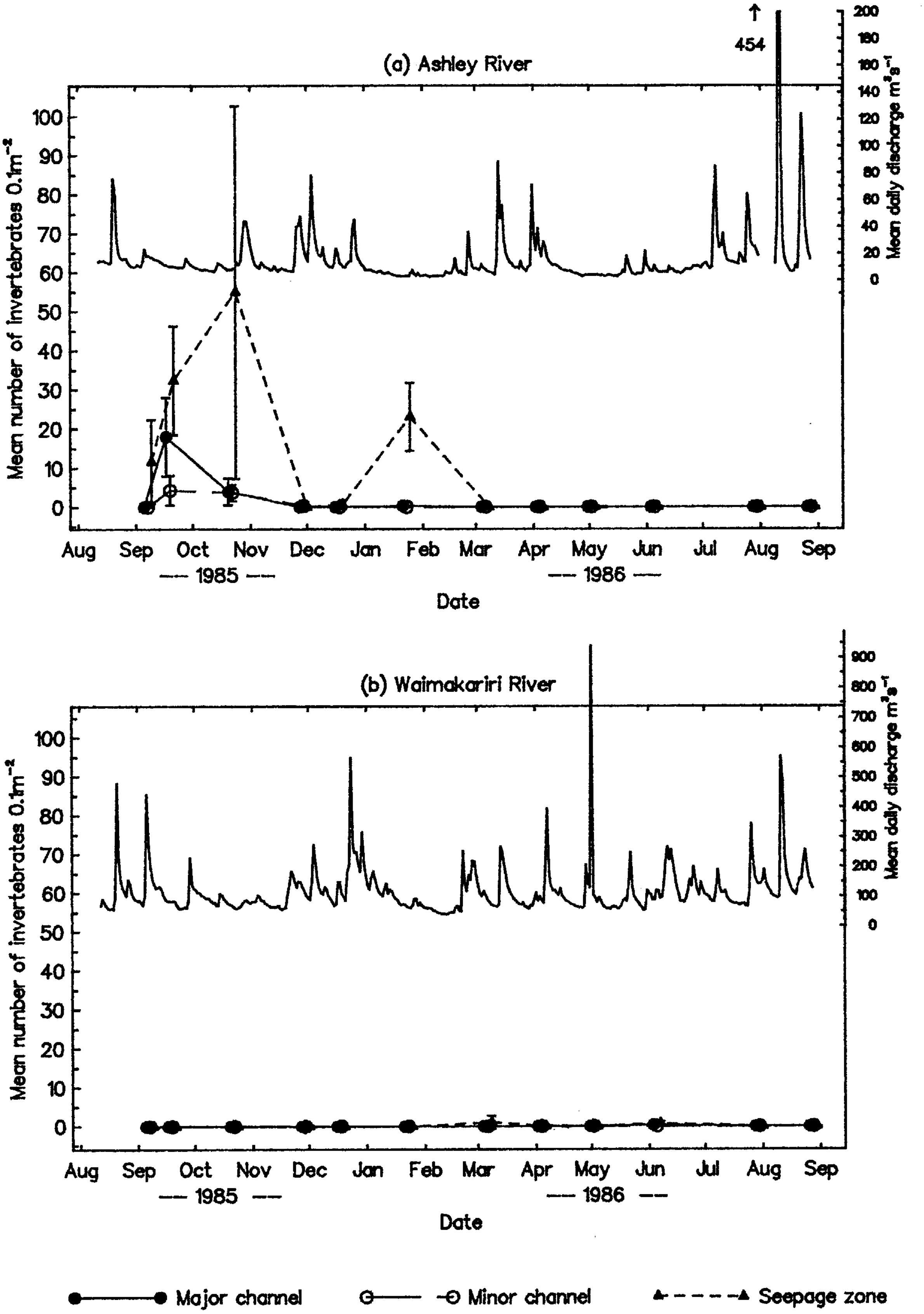
**Appendix 1 : Mean densities and dry weights of benthic invertebrates (mean ± 1SE) in samples from Ashley and Waimakariri rivers 4 September 85 - 28 August 86 compared with daily mean discharges: less numerous taxa.**

**Figure AI : Density of benthic invertebrates (x ± 1SE) in samples from Ashley and Waimakariri rivers 4 September 85 - 28 August 86 compared with daily mean discharges: Conoesucidae.**

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