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LONG-TERM INFLUENCE OF HUNGRY HORSE DAM OPERATION ON THE ECOLOGY OF MACROZOOBENTHOS OF THE FLATHEAD RIVER

REPORT TO

Montana Department of Fish, Wildlife & Parks
Special Project Bureau

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INTRODUCTION

During the past two decades, the ecological effects of river regulation have received extensive scientific investigation. Results of these studies demonstrate physical, chemical, and biological responses to regulation relative to ecosystem variables (e.g. catchment size, water budget, land use, reservoir limnology) and hydropower operations (e.g. flow regimes, dam release design) (Armitage 1984; Garcia de Jalon et al. 1988; Rader and Ward 1988; Stanford and Hauer 1992; Stanford and Ward 1993, Jourdonnais and Hauer 1994). Vannote et al. (1980) formalized the concept of predictable changes in physical, chemical and biological interactions along the length of a hypothetical stream-river ecosystem (i.e., River Continuum Concept). Ecological studies of regulated rivers have generally agreed with the theoretical predictions of the Serial Discontinuity Concept (see Ward and Stanford 1983), which relates resets (i.e., upstream or downstream shifts in the predicted variables) in the river continuum with location and nature of the stream regulation.

One of the most intensively studied regulated systems in the world is that of Hungry Horse Dam operation and effects on the South Fork and mainstem Flathead River (Stanford 1975, Stanford and Hauer 1978, Hauer and Stanford 1982a, Clancey and Fraley 1986, Perry et al. 1986, Fraley and Decker-Hess 1987, Perry et al. 1987, Beattie et al 1988, Stanford et al. 1988, Beattie, et al. 1990, Stanford and Hauer 1991, and many others). These studies have demonstrated numerous biophysical changes as a result of regulation which impact important populations of freshwater biota. Several of these studies have verified that modifications of natural discharge patterns and temperature regimes were significant factors affecting density, growth, reproduction and completion of life histories of organisms inhabiting the South Fork and mainstem Flathead River downstream of Hungry Horse Dam.

Dam release design at Hungry Horse only permits withdrawal of water from the hypolimnion of the reservoir. Thus, dam tailwaters are nearly isothermal; water temperatures range annually from 2 - 8°C. Stanford and Hauer (1978) reported a significant loss of species composition from the macroinvertebrate community in the South Fork below the dam and Hauer and Stanford (1982a 1982b, 1986), Perry (1984) and Stanford et al. (1988) found that many macroinvertebrate species in the mainstem below the confluence of the South Fork were significantly displaced in their relative distributions and abundances resulting from changes in thermal regimes, annual degree day criteria, and changes in seston dynamics. Perry et al. (1986) reported differences in growth rates and emergence times of a mayfly and caddisfly species. They noted that peak emergence times were often 2 to 4 weeks later and the duration of emergence periods extended in regulated areas where summer water temperatures were cooler than in upstream, unregulated reaches. Hauer and Stanford (1982b) recognized a similar relationship among the small net-spinning caddisflies.

The stochastic nature of discharge patterns from Hungry Horse Dam have also had significant ecological impact on both vertebrate and invertebrate fauna (Fraley and Decker-Hess 1987, Beattie et al. 1988, Stanford and Hauer 1992). Stanford (1975) reported that rapid fluctuations in the discharges from Hungry Horse Dam resulted in desiccation and/or freezing of stonefly nymphs massing at the river's edge during early spring waiting for emergence cues. Fraley and Graham (1982) described the damaging effects of dewatering salmon redds during autumn and winter months.

Although having occurred periodically in past decades, during the most recent 5-6 years there has been increased frequency of discharge from Hungry Horse Dam during August and September. A distinct exception to this general pattern occurred during this study, in summer 1993. The State's concern over the draw-down of Hungry Horse Reservoir and Lake Koocanusa behind Libby Dam on the Kootenai River in Northwest Montana resulted in the governor of Montana threatening litigation against the Bonneville Power Administration and the National Marine Fishereries Service.

Extremely high summer flows from Hungry Horse Dam were noted in the late 1980's along with the hydrologic effects of those flows on the alluvial groundwater system of the Kalispell Valley (Stanford and Ward 1993). Stanford and Hauer (1992) suggested that summer flows from Hungry Horse Dam may become even more frequent and sustained as efforts for Pacific salmon restoration call for increased flows in the downstream main Columbia. They based their thesis on the observation that flows throughout the Columbia River System had changed dramatically in each succeeding decade since the 1940's due to steadily increased upstream storage. Furthermore, the completion of several high Canadian dams in the 1980's would require flow augmentation from the US dams to provide high summer flows.

In 1991 the Power Planning Council, under authority of the Northwest Power Planning Act, approved a Hungry Horse mitigation plan (Jack citation help!!!). An article of that plan included the installation of dam modifications that would permit selective withdrawal of water from Hungry Horse Reservoir. The purpose of retrofitting Hungry Horse Dam would be to permit dam operators to withdraw water from different depths of the reservoir so that the temperature of dam discharge waters could be matched with temperature of the unregulated mainstem river above the South Fork.

Although the South Fork and mainstem Flathead River is one of the most intensively studied regulated systems in the world, we did not know what the effect of recent changes in discharge regimes had been or what the comparative result would be of naturalizing river temperature regimes in conjunction with possible changes in annual discharge patterns. The purpose of this study was to describe the current state of 1) riverine flow-temperature relationships, and 2) macroinvertebrate community structure and temporal frequency dynamics of trophically important benthic species. We particularly demonstrate herein how changes in stream regulation by Hungry Horse Dam may influence riverine characteristics and macroinvertebrate responses.

MATERIALS AND METHODS

Study Area

The Flathead River drains 22,241 km^2 of the Rocky Mountains in British Columbia and Montana and has an average annual discharge of 11,760 cfs. Glaciation and the porous nature of the sedimentary bedrock have greatly influenced basin and channel morphology. The Flathead River consists of three forks; the North Fork, Middle Fork, and the South Fork of the Flathead River (Figure 1). The landscape in each of these major drainages is dominated by coniferous vegetation. The North Fork originates in the southeastern corner of British Columbia and flows south-southeast across the international border. Side tributaries of the North Fork originate in Glacier National Park to the east and the Glacier View Ranger District on the Flathead National Forest to the west. The Middle Fork of the Flathead River originates in the Great Bear and Bob Marshall Wilderness areas. Upon emergence from the wilderness areas,

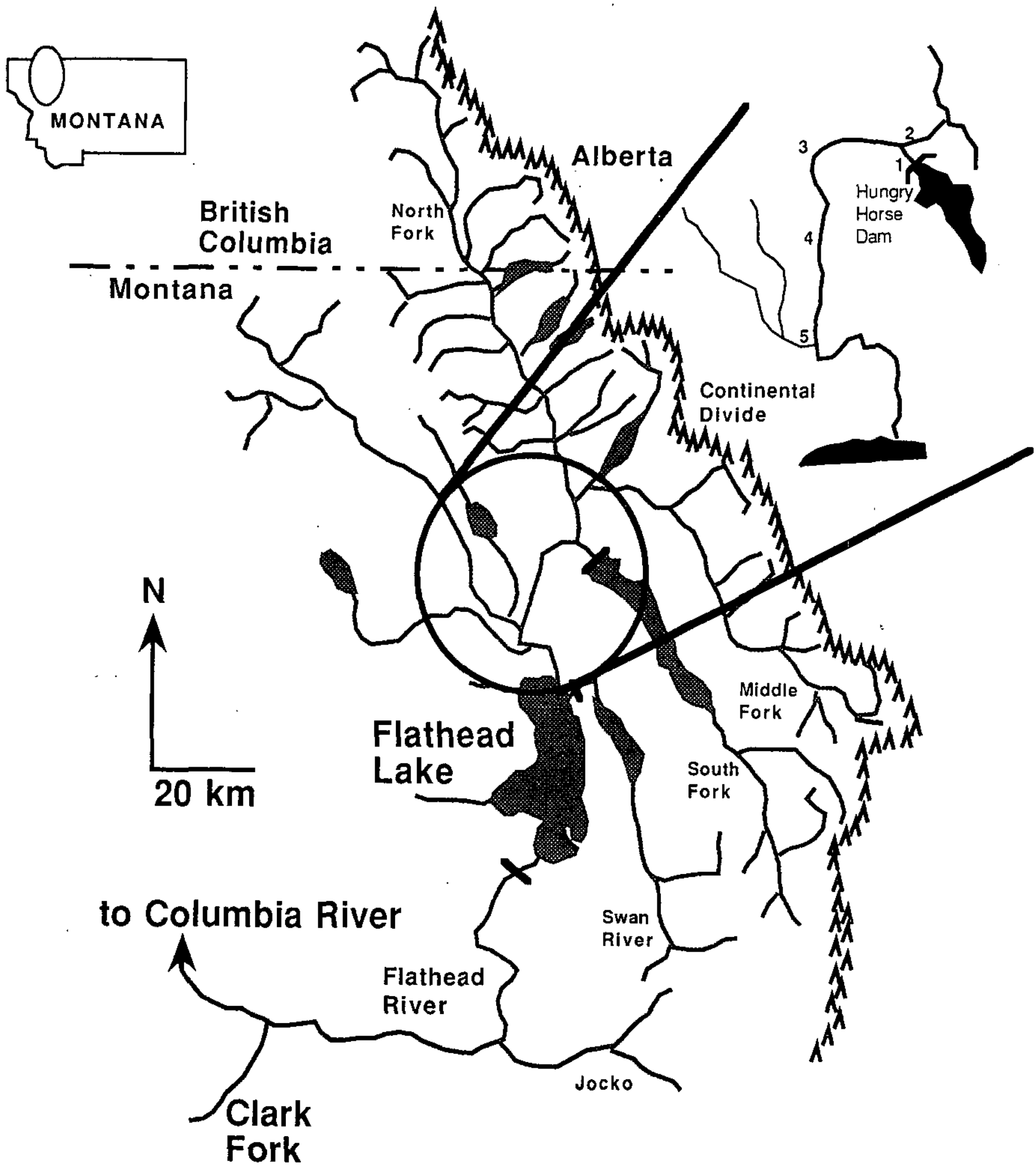


Figure 1. Map of the Flathead Basin. The circle projection shows the locations of the five sample sites used in this study. Site 1 was located on the South Fork below Hungry Horse Dam. Site 2 was located on the mainstem above the confluence of the South Fork. Sites 3, 4, and 5 were located sequentially downstream on the mainstem below the confluence of the South Fork and above Flathead Lake.

the Middle Fork comprises the southwestern boundary of Glacier National Park before joining the North Fork to form the mainstem Flathead River. The South Fork of the Flathead River also flows northwest out of the Bob Marshall Wilderness and joins the mainstem river ≈20 km below the confluence of the Middle Fork and North Fork. Approximately 6 km above the confluence with the mainstem, the South Fork is impounded by 153 meter high Hungry Horse Dam creating 55 km long Hungry Horse Reservoir.

Immediately downstream of the South Fork confluence, the mainstem Flathead River flows through a short, narrow canyon and then flows across the alluvial floodplain of the Kalispell Valley. Throughout this alluvial river segment, the Flathead River is extensively interactive between its channel and a complex of subsurface paleo-river channels, thus forming the largest documented channel-hyporheic system anywhere in the world (Stanford and Ward 1988). The channel-groundwater interactions profoundly affect virtually all aspects of the river's physical, chemical and biological character (Stanford and Ward 1993). As the mainstem Flathead River flows toward the north end of Flathead Lake it encounters the post-glacial Flathead Lake delta, just upstream of Foy's Bend, at which point the river rapidly undergoes a transition from a classic Piedmont Valley Floodplain river to a Coastal Plain river type (see Stanford and Ward 1993).

Five sampling sites were located along the longitudinal gradient of the river system (Figure 1). Sampling Station 1 was located on the regulated South Fork of the Flathead below Hungry Horse Dam a short distance downstream of the USGS gauging site; the same site as used in Stanford (1975), Stanford and Hauer (1978) and Perry et al. (1986). Station 2 was sited on the unregulated mainstem river ≈2 km above the confluence of the South Fork. Station 3 was located ≈12 km below the confluence of the South Fork at Kokanee Bend fishing access site. Station 4 was located ≈30km below the confluence with the South Fork at Presentine Bar fishing access site. Station 5 was located ≈50km below the confluence of the South Fork at the Kiwanis Bridge access. A few km down river of Site 5 the Piedmont Transition occurs where the mainstem river is profoundly influenced geomorphically by paleo-Flathead Lake and in a modern sense by lake regulation of Flathead Lake.

Stations 3, 4 and 5 are considered partially regulated sites on the mainstem river because regulated flows from Hungry Horse Dam on the South Fork of the Flathead are mixed with natural flows from the North and Middle Forks.

River Flow and Temperature

River discharge data were obtained from the Montana NRIS database in Helena. The database is composed of USGS records for the North Fork, Middle Fork, South Fork and mainstem Flathead River (USGS sites 12355500, 12358500, 12362500, and 12363000, respectively). Data were analyzed for the period of record after the construction and initiation of operation of Hungry Horse Dam. Temperature and flow data are expressed as daily means.

Seston

Particulate organic matter was sampled simultaneously with zoobenthos at each of the sampling stations. Three drift nets with a 820 cm^2 opening and a net mesh size of 500 µm were placed perpendicular to the river flow in current velocities of 0.4 to 0.6 m sec^{-1}. Drift nets were allowed to continuously sample the river flow for 30 to 40 minutes. Current velocity was measured directly in front of each drift net on each sampling date and location. The total volume of water sampled by the drift net was calculated as CV x A x T = V

where CV = current velocity

A = area of the drift net opening

T = total time the drift net was deployed

V = total volume of water sampled

The seston collected by each drift net was placed in a separate container and returned to the laboratory. Particulate organic and inorganic matter concentrations were determined gravimetrically using methodology described in American Public Health Association Standard Methods (1989) with adaptations as described in Hauer (1989).

Zoobenthos

Benthic macroinvertebrates were sampled on six dates distributed within a seasonally patterned sampling regime. The temporal periodicity of sampling was distributed throughout the year to optimize differentiation of organismal distribution and abundance as well as variabilities based on known life history traits. Benthic macroinvertebrates were sampled in riffle areas at each site using a modified kick-net technique developed by Hauer (1980), and also used by Perry (1984) on the Flathead and Kootenai Rivers. Three replicate 0.25 m^2 plots were sampled at each site. Samples were field preserved in 95 percent ethanol. Upon return to the laboratory, samples were rinsed onto a 125 µm mesh sieve. All macrozoobenthic organisms were removed from the organic and inorganic material and sorted by taxonomic order. Samples were fractionated to appropriate subsample sizes dependent on macroinvertebrate density (Resh and Jackson 1992). All picked and sorted organisms were identified to the lowest practical taxon, usually the species level except for Chironomidae and Simuliidae, which were identified to the family level. Examination of organisms was made using Wild M5 dissecting microscopes at 6X to 50X magnification. Taxonomic keys by Merritt and Cummins (1984), Jensen (1966), Stewart and Stark (1988), and Wiggins (1977) were used for identification.

RESULTS

Flow and Temperature

River discharge in the North and Middle Forks of the Flathead River demonstrate a very predictable pattern of low flow during the late summer, fall and winter and higher flows during spring and early summer (Figure 2). In contrast, the regulated South Fork does not exhibit a typical snowmelt hydrograph (Figure 3), but rather discharge is changed dramatically on a seasonal, weekly, or daily basis. It is not uncommon for discharge to fluctuate from <500 cfs to >10,000 cfs in less than 15 minutes. These changes in discharge, from an ecological perspective, are totally unpredictable; occurring any day of the year and at any time. The North and Middle Forks combined represent approximately 60% and the South Fork 40% of the annual flow in the mainstem Flathead River at Columbia Falls. Partial regulation has led to a mainstem hydrograph that is dominated by North and Middle Fork flows during late April, May, June and early July, but closely tied to Hungry Horse Dam discharge regimes the remainder of the year as flows in the two unregulated tributaries generally remain ≈1000 ± 200 cfs (Figure 4).

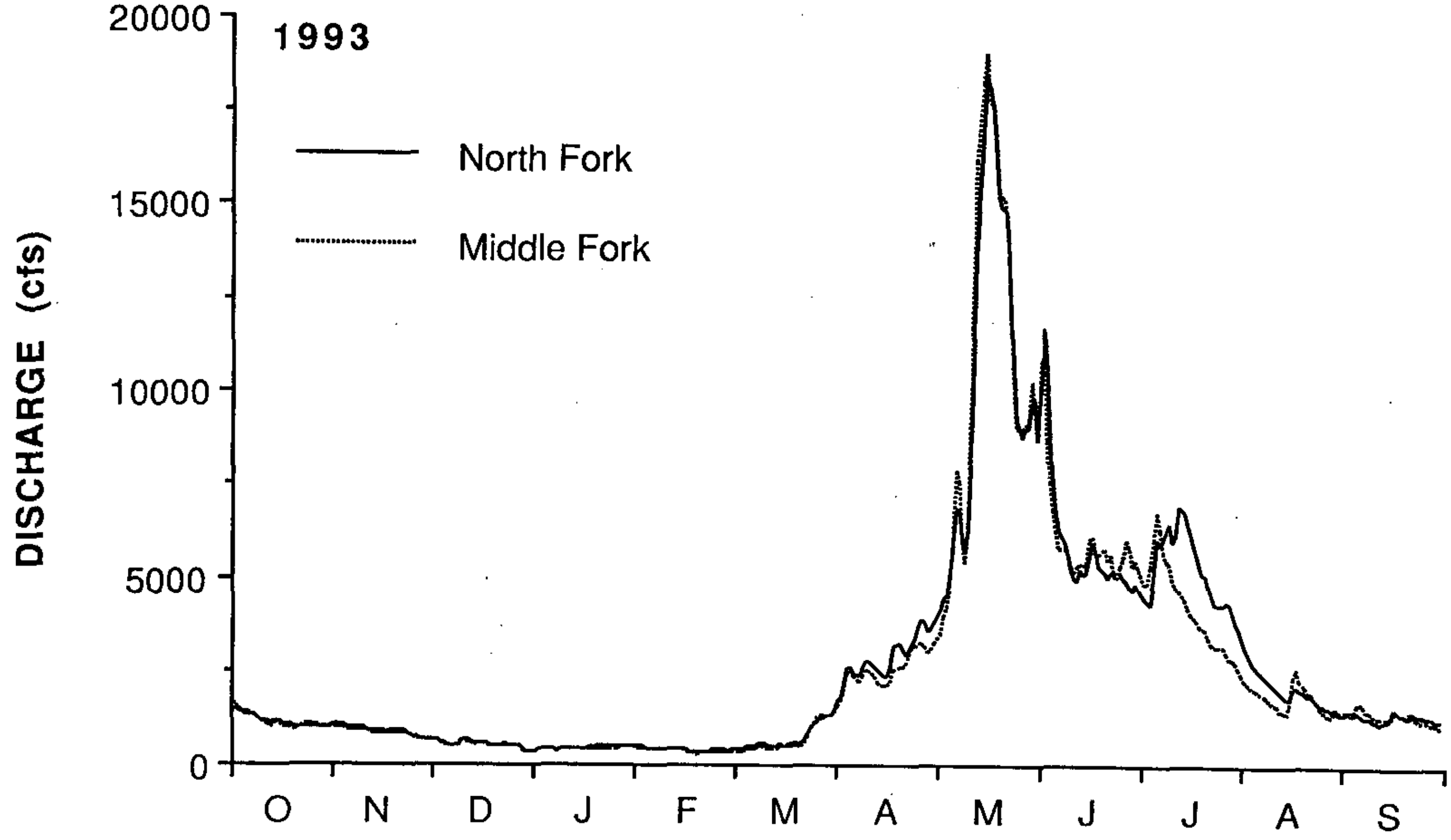


Figure 2. River discharge (cubic feet per second) in the North Fork and Middle Fork of the Flathead River in Water Year 1993.

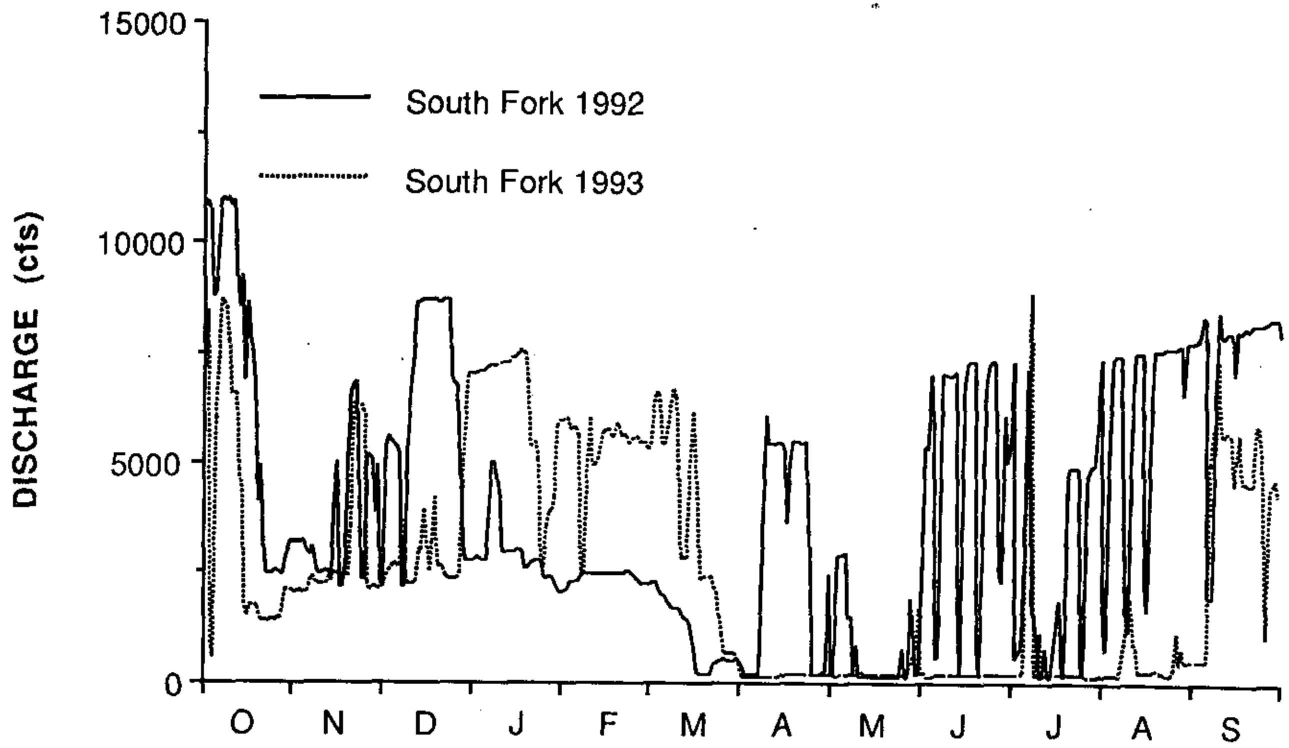


Figure 3. River discharge (cubic feet per second) in the South Fork of the Flathead River below Hungry Horse Dam in Water Years 1992 and 1993.

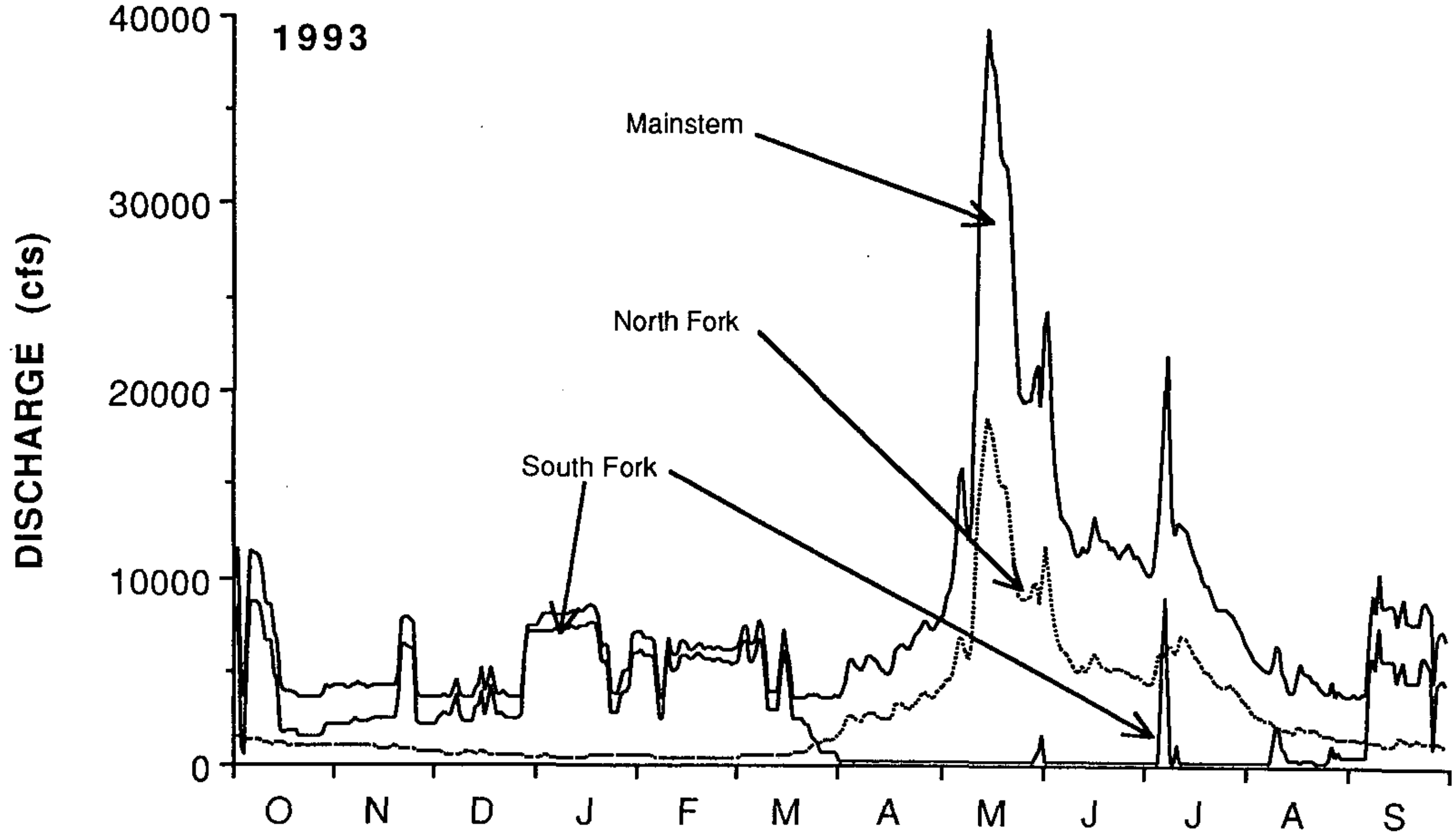


Figure 4. River discharge (cubic feet per second) in the South Fork, North Fork and mainstem Flathead River in Water Year 1993

During the first two decades of Hungry Horse operation, high discharge from the dam occurred primarily during fall and winter months; seasons of higher power demand (Stanford and Hauer 1992). More recently, generation patterns have been increasingly oriented toward late summer generation. During summers 1989, 1991, and 1992 Hungry Horse Dam fluctuated significantly during July, August and September (Figure 5). See Appendix A for detailed graphical presentation of South Fork discharge from Water Year 1970 through 1993.

Generation from Hungry Horse Dam also has significant effects on river temperatures. In the South Fork below the dam, river temperatures fluctuate between a low of 2°C in winter to a summer maximum of 6 to 8°C, occurring during minimum flows when radiant energy, air temperatures, and warmer side flows from small tributaries elevate the temperature of the hypolimnetic-release waters. However during higher discharge, water temperatures are generally around 4°C, the temperature of the reservoir hypolimnion. This is particularly significant during late summer months, when increased discharge from the dam is coupled with decreased discharge from the North and Middle Forks resulting in markedly decreased temperatures in the mainstem. This was very evident in summers of 1989, 1991 and 1992 (Figure 5) when discharge from Hungry Horse was high during week-days, but was reduced to minimum flows during the week-ends. These fluctuating discharges were then strongly reflected in fluctuation in Mainstem River temperatures (Figures 6, 7 and 8).

Seston

The transport of large particulate organic matter (POM > 500 μm) was spatially and temporally complex. Concentrations of POM reached maximum levels in the South Fork below the dam (Site 1) prior to spring run-off (Figure 9)

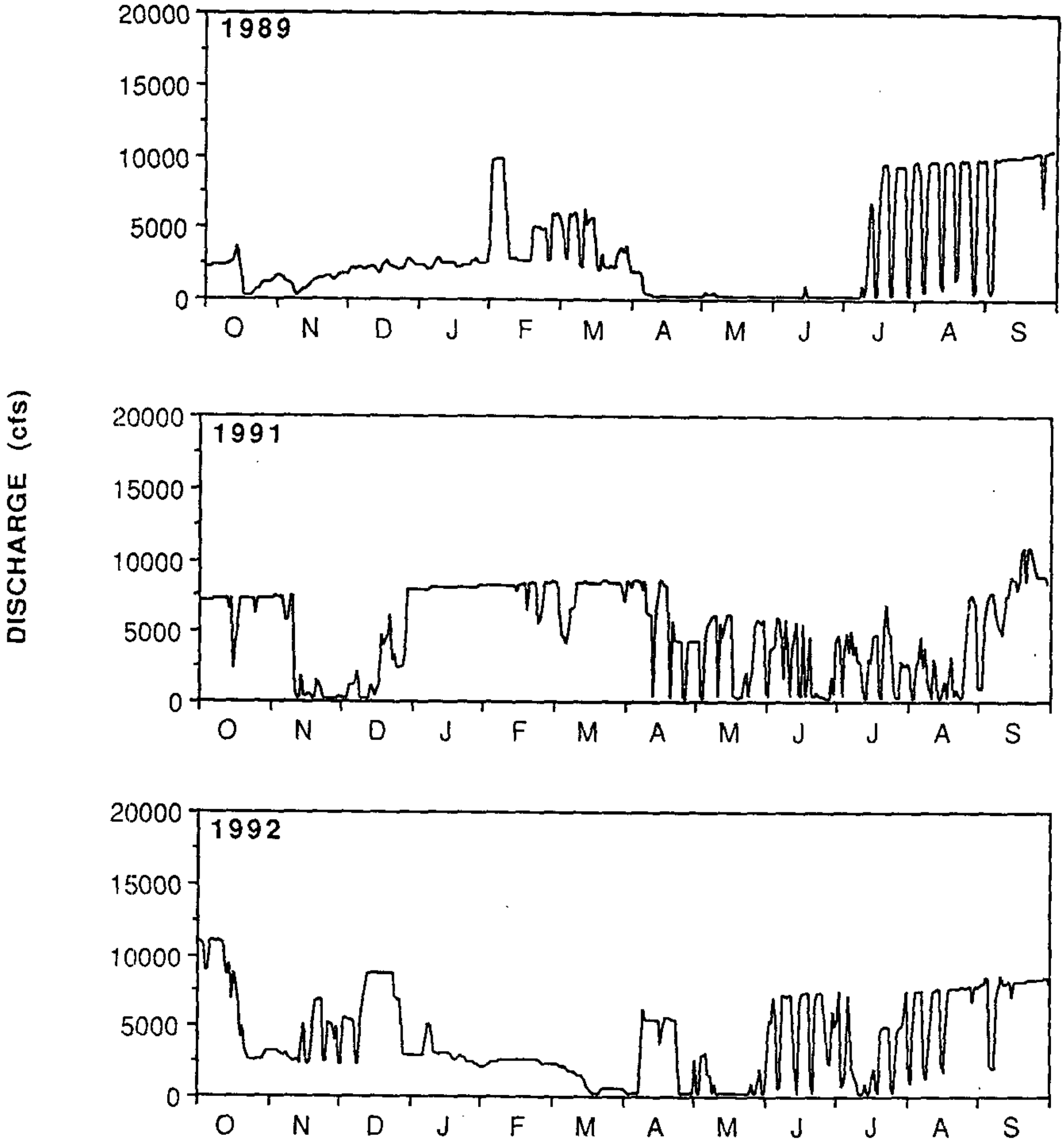


Figure 5. River discharge (cfs) in the South Fork of the Flathead River in Water Years 1989, 1991, and 1992.

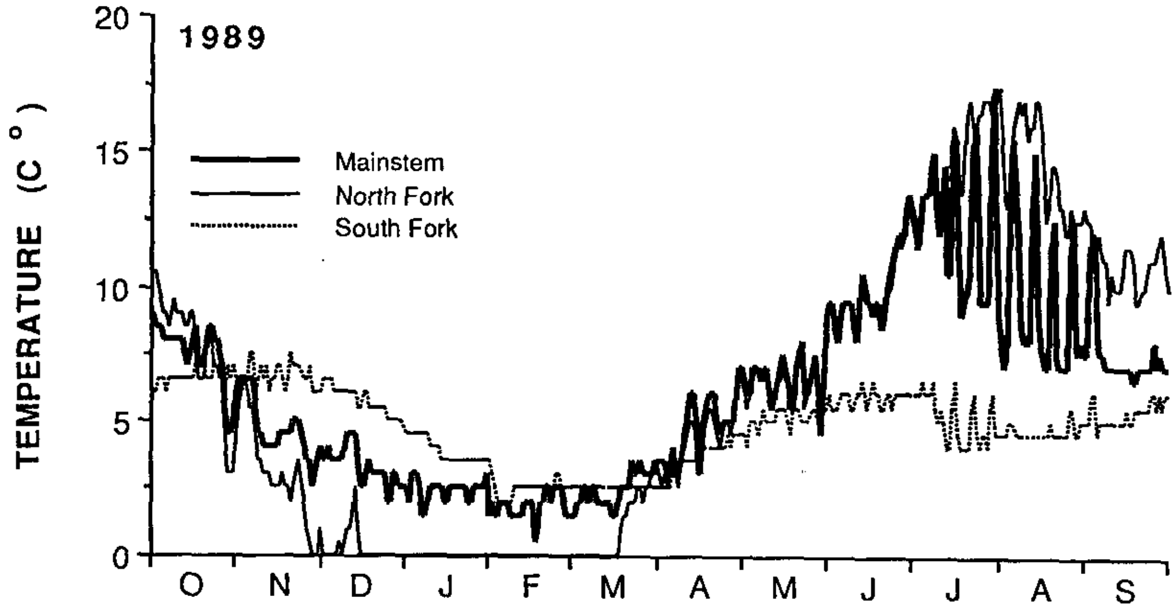


Figure 6. Water temperature (C) in the Mainstem, North Fork and South Fork of the Flathead River in Water Years 1989.

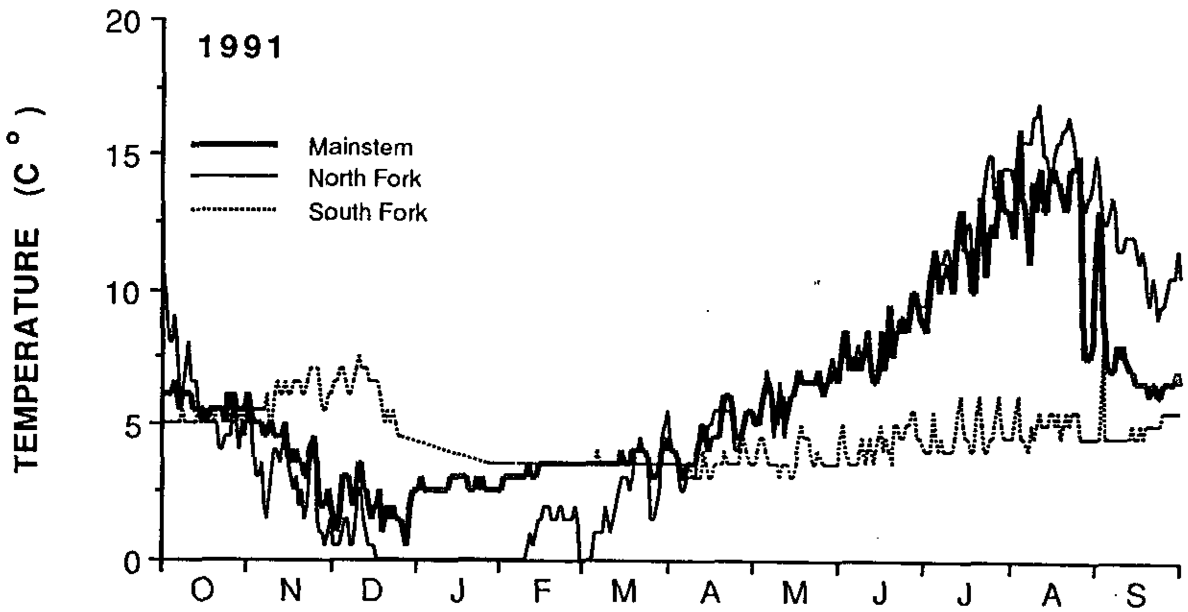


Figure 7. Water temperature (C) in the Mainstem, North Fork and South Fork of the Flathead River in Water Year 1991.

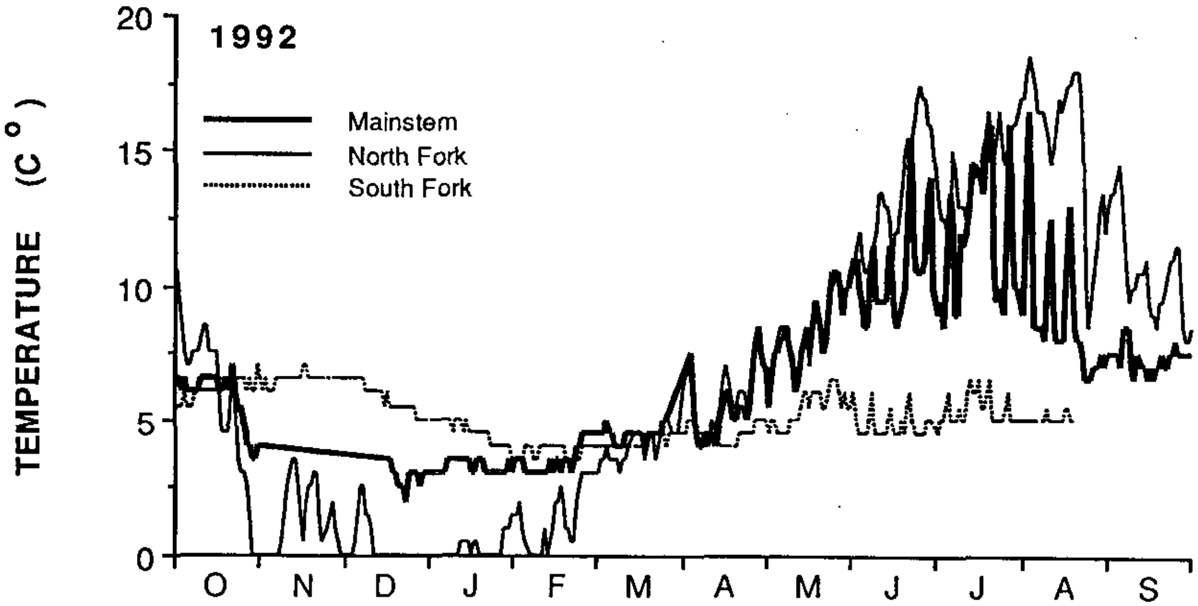


Figure 8. Water temperature (C) in the mainstem, North Fork and South Fork of the Flathead River in Water Year 1992.

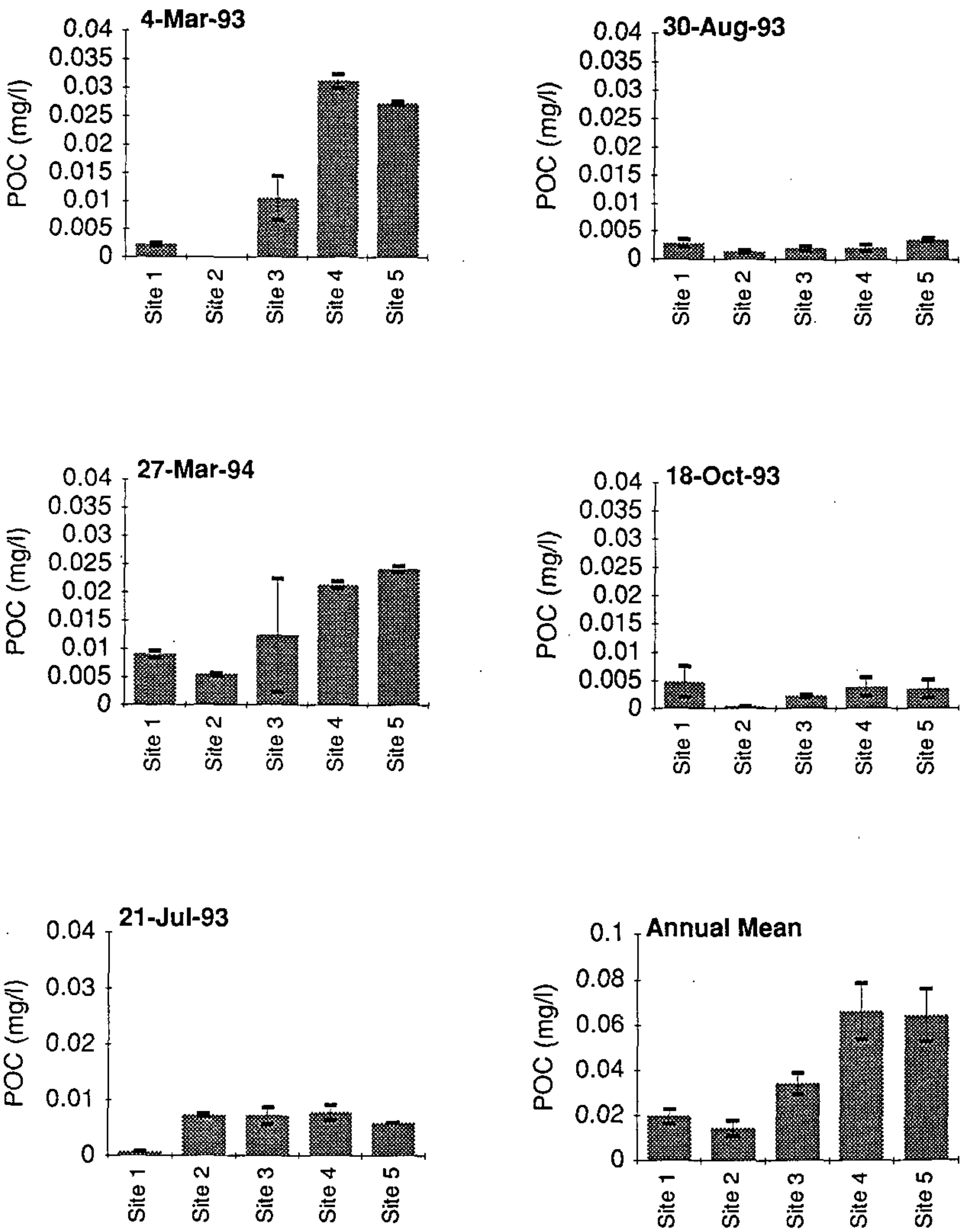


Figure 9. Particulate Organic Matter at each of the five sample sites on the Flathead River on five sampling dates. Error bars equal one standard deviation.

then decreased in July and increased again in late August and October. In contrast, POM concentrations at the unregulated site (Site 2), peaked in July followed by a sharp decline in August and October. In the partially regulated mainstem, POM achieved maximum concentrations prior to spring run-off in a similar fashion to Site 1. However, unlike Site 1 where POM concentrations were low in July, at Sites 3, 4, and 5 values were similar to those of the unregulated river (Figure 9). Sites 3, 4 and 5 had the highest annual mean POM concentrations, substantially greater than that found at Sites 1 and 2.

Total suspended solid (TSS) concentrations, which include both organic and inorganic materials, peaked at Site 1 on March 27, 1993 (Figure 10), decreased dramatically during early summer, but increased in August and October. At Site 2, TSS concentrations displayed no dramatic differences between the March and July samplings, however were substantially lower in August and October. The partially regulated sites contained the highest TSS concentrations. In March, TSS concentrations at the partially regulated sites were significantly higher than TSS concentrations at the unregulated site and the regulated site. During July, TSS concentrations at the partially regulated sites were similar to values at Site 2. In August, all five sites had similar TSS concentrations.

Zoobenthos

The macrozoobenthic community was dominated at each sampling site by the aquatic insect orders Ephemeroptera, Plecoptera, Trichoptera, and Diptera, and large segmented worms, the Oligochaeta. However, taxa response to river regulation was very species-specific. See Table 1 for the list of species and general frequency of occurrence at the five sampling stations.

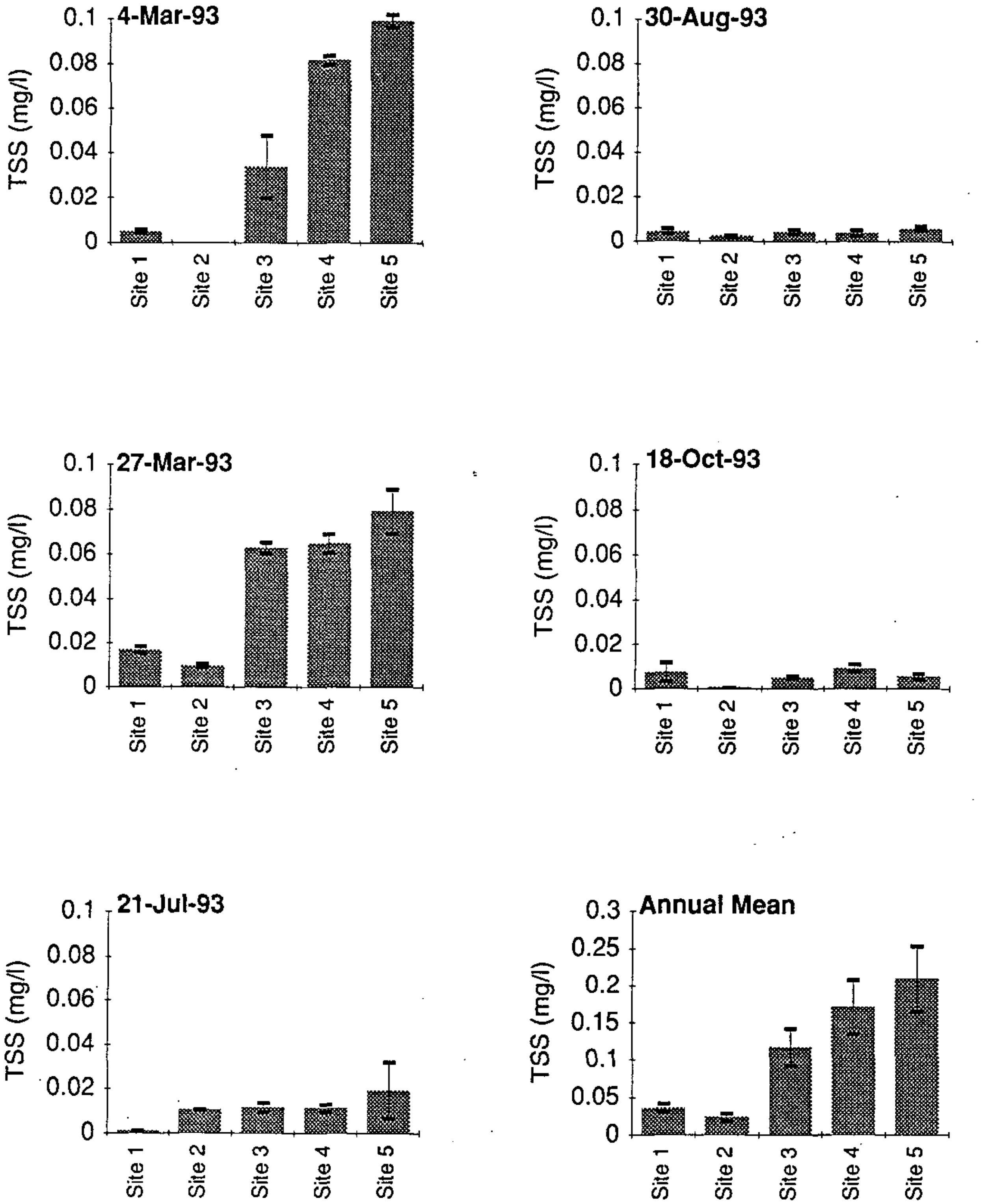


Figure10. Total Suspended Solids at the five sampling sites on the Flathead River on five sampling dates. Error bars equal one standard deviation.

Table 1. List of taxa collected from the mainstem and South Fork of the Flathead River between November 1992 and October 1993.

Ephemeroptera
- *Ameletus sp.*
- *Attenuatella margarita*
- *Baetis bicaudatus*
- *Baetis flavistriga*
- *Baetis insignificans*
- *Baetis tricaudatus*
- *Caudatella sp.*
- *Cynigmula spp.*
- *Drunella doddsi*
- *Epeorus albertae*
- *Epeorus decptivus*
- *Epeorus longimanus*
- *Ephemerella flavilinea*
- *Ephemerella grandis ingens*
- *Ephemerella inermis*
- *Ephemerella infrequens*
- *Ephemerella spinifera*
- *Eurylophella sp.*
- *Leptophlebia sp.*
- *Paraleptophlebia memorialis*
- *Paraleptophlebia sp.*
- *Rhithrogena morrisoni*
- *Rhithrogena robusta*
- *Rhithrogena undulata*
- *Serratella tibialis*

Plecoptera
- *Bolshecapnia sp.*
- *Capnia confusa*
- *Claasenia sabulosa*
- *Cultus aestavalis*
- *Despaxia augusta*
- *Hesperoperla pacifica*
- *(Isocapnia spp.)*
- *Isogenoides sp.*
- *Isoperla fulva*
- *Isoperla sp.*
- *Kogotus sp.*
- *Malenka sp.*
- *Paraperla frontalis*
- *Podmosta sp.*
- *Prostoia besametsa*
- *Pteronarcella badia*
- *Pteronarcys californica*

Plecoptera continued
- *Skwala parallela*
- *Sweltsa sp.*
- *Taenionema pacificum*
- *Utacapnia spp.*
- *Visoka cataractae*
- *Zapada cinctipes*
- *Zapada columbiana*

Trichoptera
- *Apatania spp.*
- *Arctopsyche grandis*
- *Brachycentus americanus*
- *Brachycentrus occidentalis*
- *Glossosoma alescence*
- *Hydropsyche cockerelli*
- *Hydropsyche occidentalis*
- *Hydropsyche oslari*
- *Hydroptila sp.*
- *Lepidostoma sp.*
- *Rhyacophila angelita*
- *Rhyacophila arnaudi*
- *Rhyacophila coloradensis*

Coleoptera
- *Cleptelmis sp.*
- *Optioservus sp.*
- *Zaitzevia sp.*

Diptera
- *Antocha sp.*
- *Atherix sp.*
- *Chelifera sp.*
- *Clinicera meigen*
- *Hexatoma sp.*
- *Nanoclacius sp.*
- *Oregoneton sp.*
- *Parochlus sp.*
- *Simulium sp.*
- *Tipula sp.*
- Chironomidae

Oligochaeta

Ephemeroptera

The various species of mayflies that are common in the Flathead River system responded in very distinctive ways to river regulation. *Leptophlebia* spp., a common species in the fifth order North and Middle Forks and Mainstem River was absent from Site 1, the regulated site (Figure 11). The mean annual density of *Leptophlebia* nymphs was highest at Site 3 and declined progressively downstream at Sites 4 and 5 resulting in densities similar to the unregulated site, Site 2. *Leptophlebia* typically have a 1-year life cycle in northern climates and generally emerge in the summer months (Edmunds et al 1979). The absence of Leptophlebiids from the South Fork below the dam is consistent with what has been found in past studies (Stanford and Hauer 1978, Perry 1984). Since these nymphs have relatively long growing periods, it is exceedingly likely that they are not able to complete their life histories in the South Fork due to insufficient thermal criteria. Another factor may be that rapidly fluctuating discharge precludes successful colonization.

Baetis spp, a very common genera in lotic environments, achieved highest mean annual densities at Site 2 (Figure 11), the unregulated site. *Baetis* density at the partially regulated sites, although relatively high ($\approx$3000 m^{-2}) decreased progressively from Sites 3 to 5. *Baetis* densities were highly variable throughout the annual cycle at most sites (Figure 12). At Site 1, the regulated site on the South Fork, numbers of *Baetis* were generally low during winter months, but increased significantly to > 6000 individuals m^{-2} during late summer. Although decreasing substantially by late October, numbers remained relatively high for this regulated river segment. At Site 2 and at the three partially regulated sites, *Baetis* nymphs were low in abundance during late summer, likely in conjunction with adult emergence.

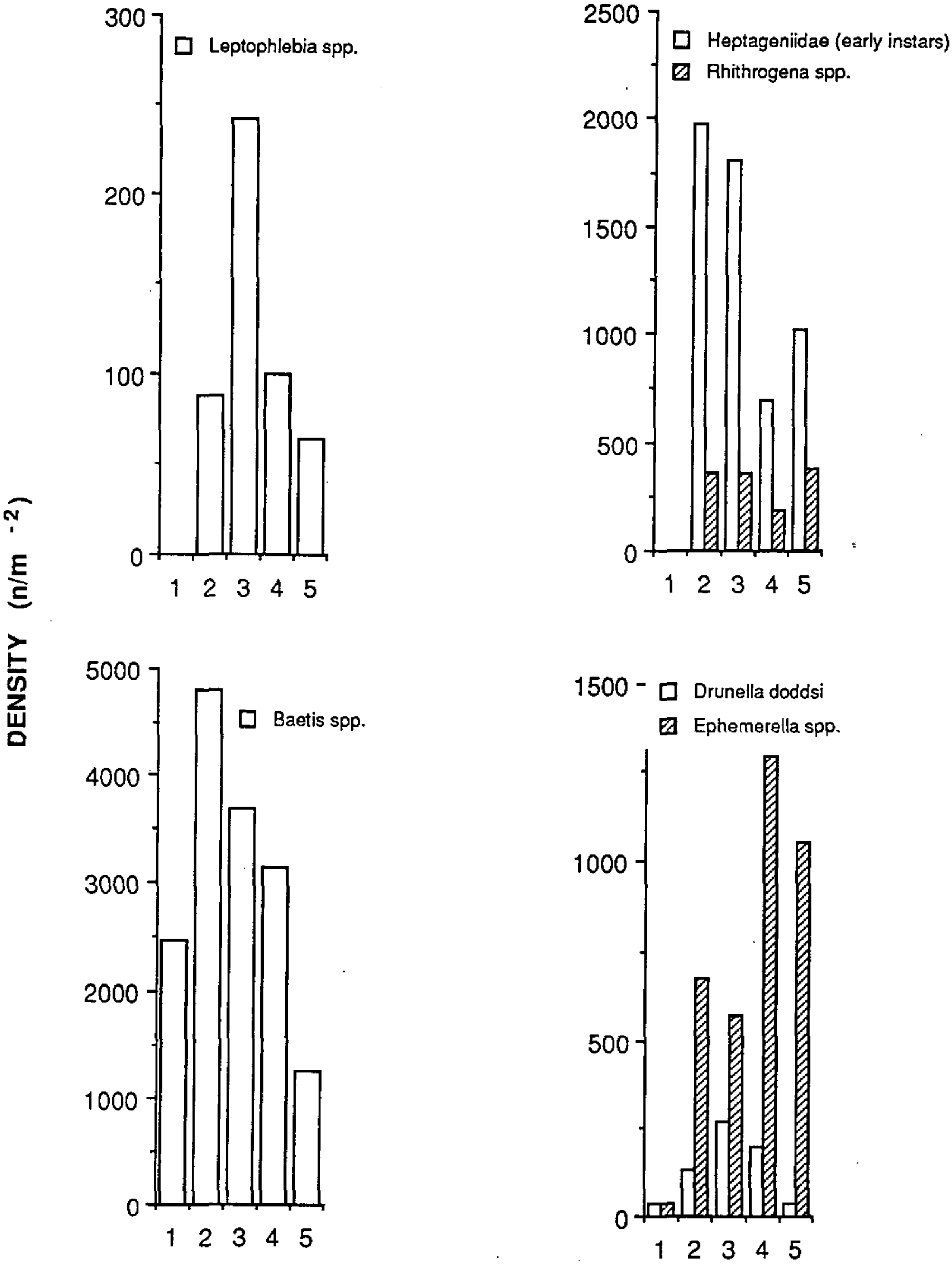


Figure 11. Mean annual density of abundant mayflies at each of the five sampling sites on the South Fork and mainstem Flathead River.

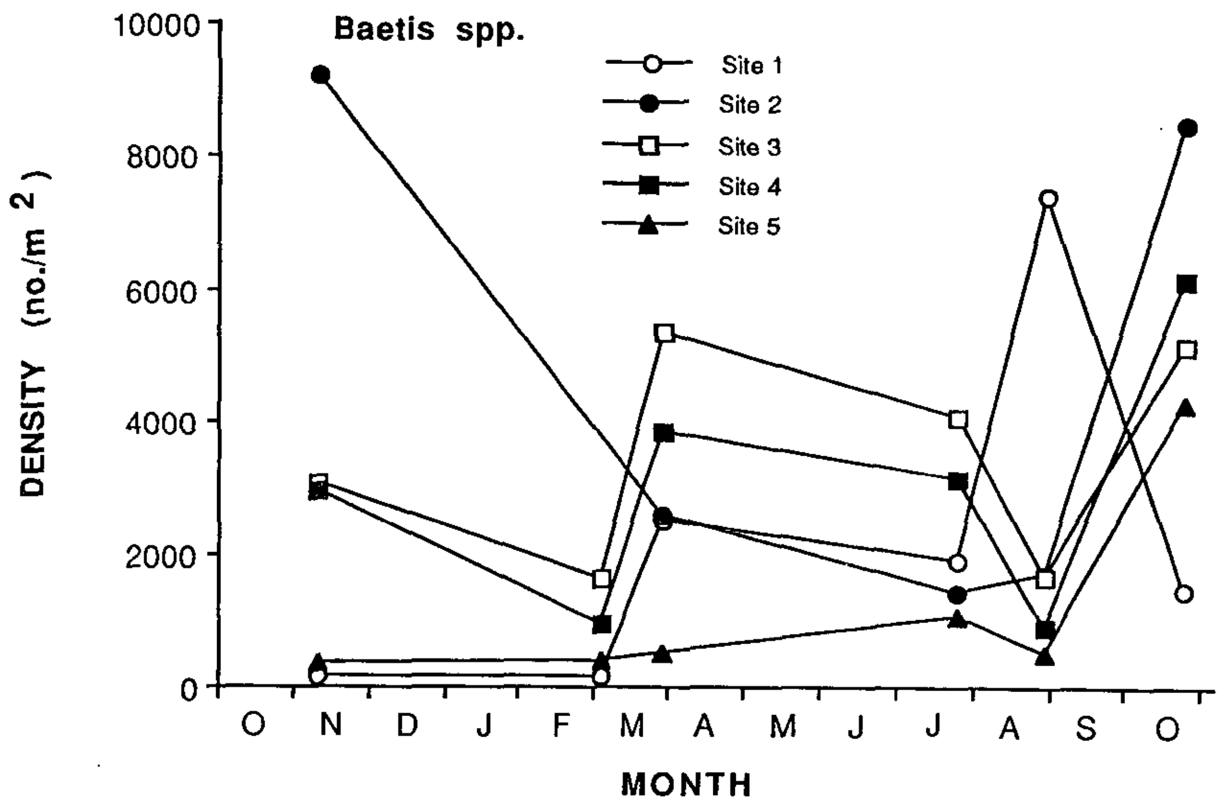


Figure 12. Density of *Baetis sp.* at each of the five sampling sites on each sampling date throughout Water Year 1993.

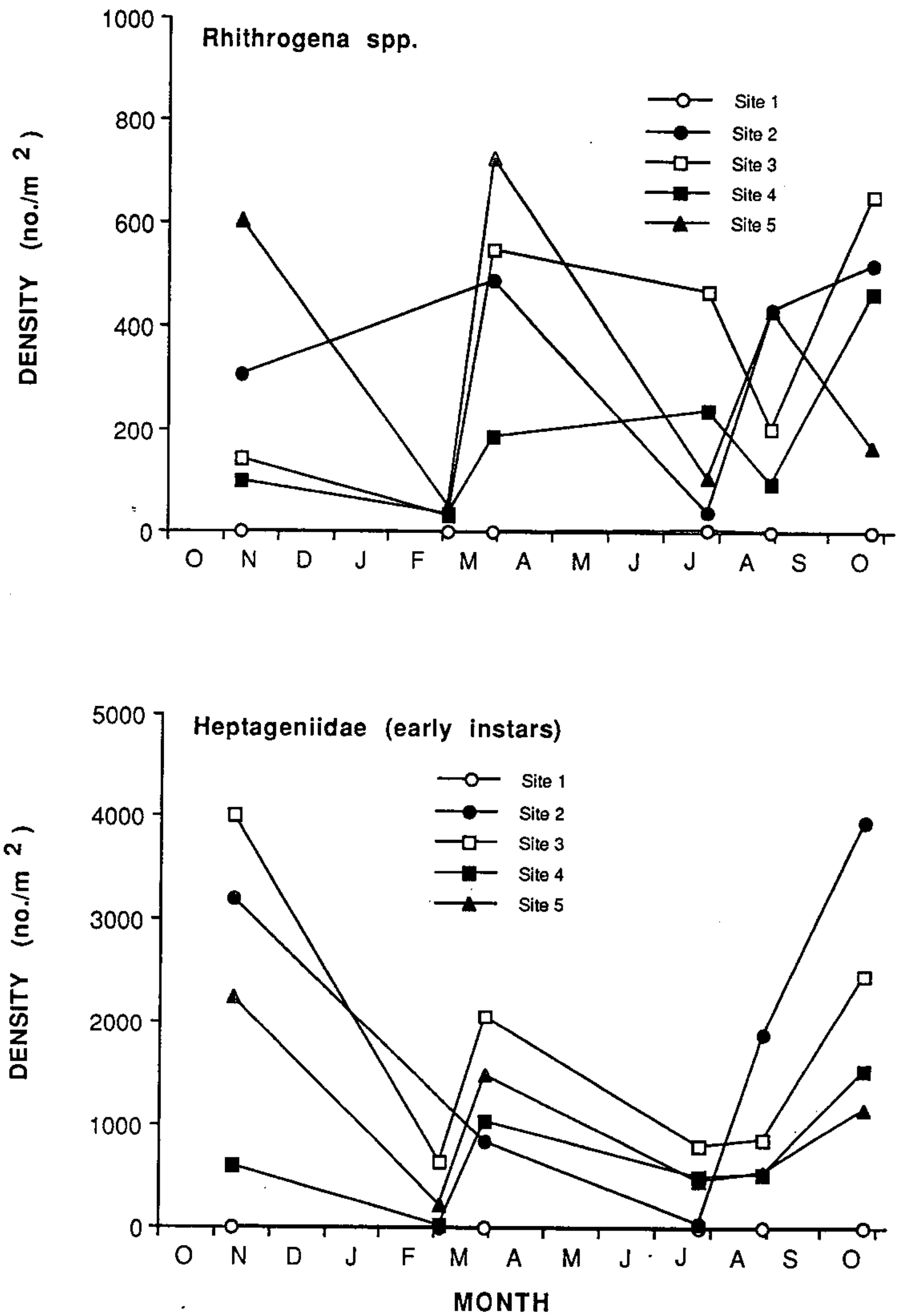


Figure 12. Density of late instar *Rhithrogena spp.* and early instars of all Heptageniidae at each of the five sampling sites on each sampling date throughout Water Year 1993.

Baetis typically have a fast life cycle with as many as 3 cohorts annually. The fast life cycle demonstrated by most species of *Baetis* permit growth and completion of life histories in environments that often experience high levels of frequent disturbance which preclude other, slower growing species. This was most evident from their high numbers in the South Fork during late August 1993.

The dorsoventrally compressed, grazing genera of the family Heptageniidae were also relatively abundant at Site 2 and the partially regulated Sites 3, 4 and 5, but like the Leptophlebiids were absent from the South Fork, Site 1 (Figure 11). Even very small Heptageniidae were absent from Site 1, suggesting strong exclusion forces preventing even early colonization in the South Fork. No significant differences in *Rhithrogena* spp mean annual density were discernible from Sites 2 through 5. Thus, *Rhithrogena* mean annual density appears similar at unregulated and partially regulated sites. Highest mean annual densities were found at Sites 2 and 3 . *Rhithrogena* and early instar Heptageniids collectively, showed a similar response to changes dam releases comparing 1992 to 1993 (Figure 13). Unlike the multivoltine Baetids, *Rhithrogena* is generally univoltine, thus leaving it increasingly vulnerable to the vagaries of fluctuating discharge in the South Fork.

The two most commonly occurring Ephemerellid mayflies, Drunella *doddsi* and *Ephemerella inermis* were significantly affected by Hungry Horse regulation, both being virtually extirpated from the South Fork below the dam. However, mean annual density of both species was highest in the partially regulated mainstem, although *Drunella* achieved maximum densities at Site 3 while *Ephemerella* nymphs were most abundant at Site 4 (Figure 11). For both species, densities decreased at Site 5 compared to the upstream sites.

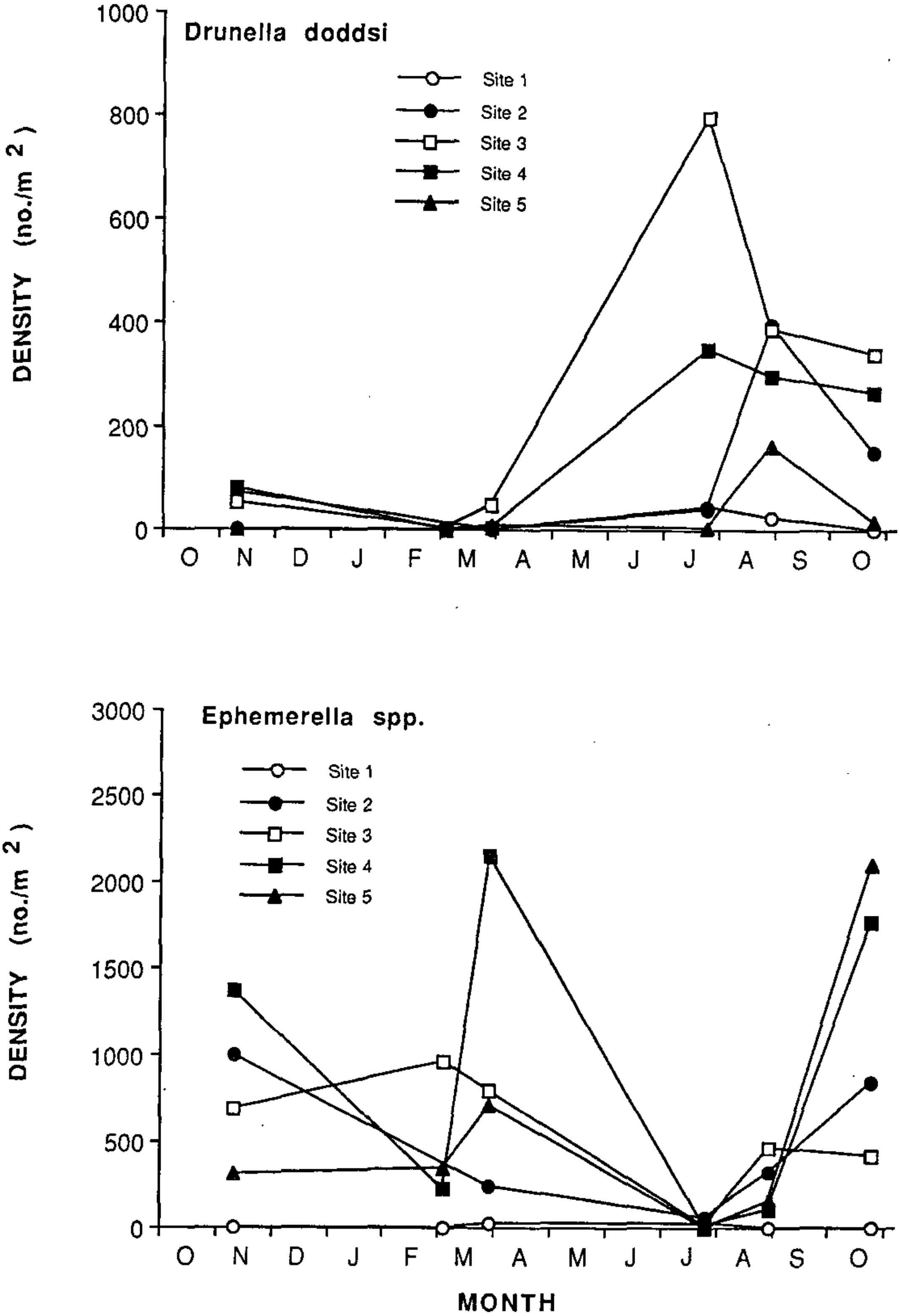


Figure 14. Density of *Drunella doddsi* and *Ephemerella spp.* at each of the five sampling sites on each sampling date throughout Water Year 1993.

Drunella nymphs were nearly absent from all collections in the fall of 1992, but relatively common at Sites 2 through 5 during summer and fall 1993 (Figure 14).

Plecoptera

Stonefly nymphs also continued to be affected by Hungry Horse discharge. Most stonefly species were either completely eliminated or very rare at Site 1 (Figure 15). Among those species that did remain in the South Fork below the dam only the winter emerging Capniids were able to complete their life histories and emerge as adults (Figure 16). Other species present in the South Fork (e.g., *Taeneonema pacificum, Isoperla fulva*) occurred almost exclusively as very small nymphs, the consequence of colonization (Figure 17). Although *Capnia* spp densities were relatively low at all sites in March 1993, species of this genera typically emerge in late February and March; thus, low densities during the March sampling were most likely due to emergence prior to the spring sampling. Similar to *Drunella, Capnia* spp. nymph densities were substantially higher at all sites in late October 1993 compared to early November 1992 (Figure 16), we believe largely a function of the significantly different discharge regimes of the preceding two summers.

Taeneonema pacificum and *Isoperla fulva* were relatively abundant during autumn in both 1992 and 1993 (Figure 17). Abundance achieved maximum values at the partially regulated sites, particularly at Sites 3 and 4. Low abundance during spring is likely the consequence of life history sequence and emergence rather than negative responses to regulation. *Pteronarcella badia* mean annual density was highest at Site 3 (Figure 15) and decreased downstream at Sites 4 and 5 to levels similar to those found at Site 2. Although it is not completely clear as to the reason for higher density of P. *badia* nymphs

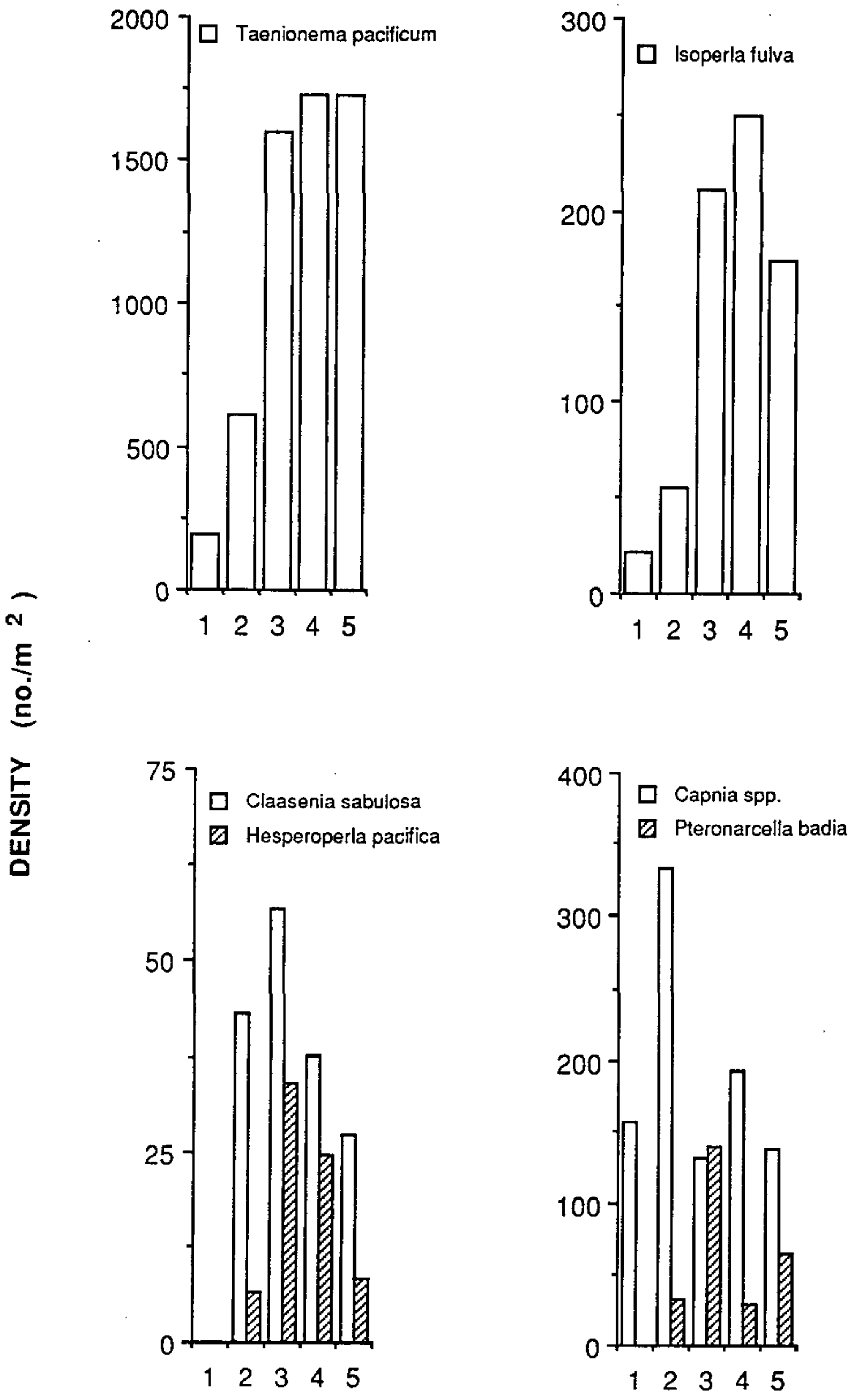


Figure 15. Mean annual density of abundant stoneflies at each of the five sampling sites on the South Fork and mainstem Flathead River.

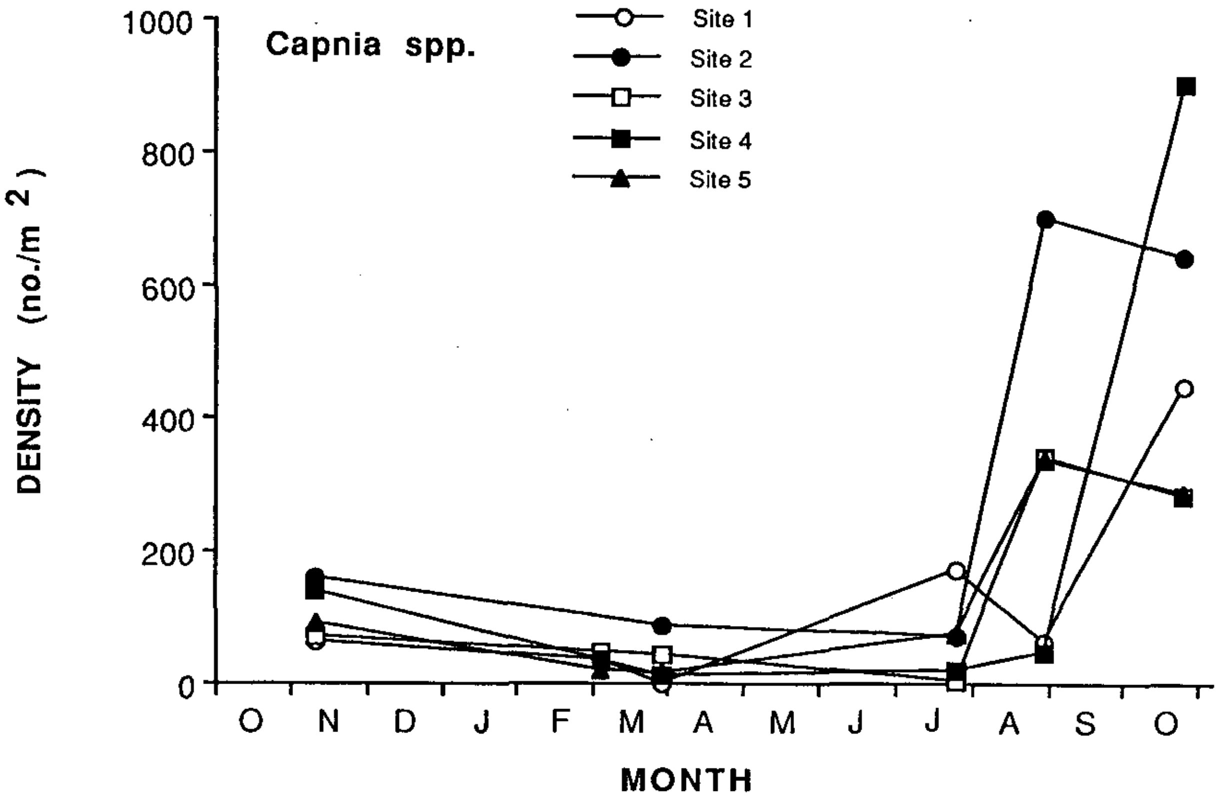


Figure 16. Density of *Capnia spp.* at each of the five sampling sites on each sampling date throughout Water Year 1993.

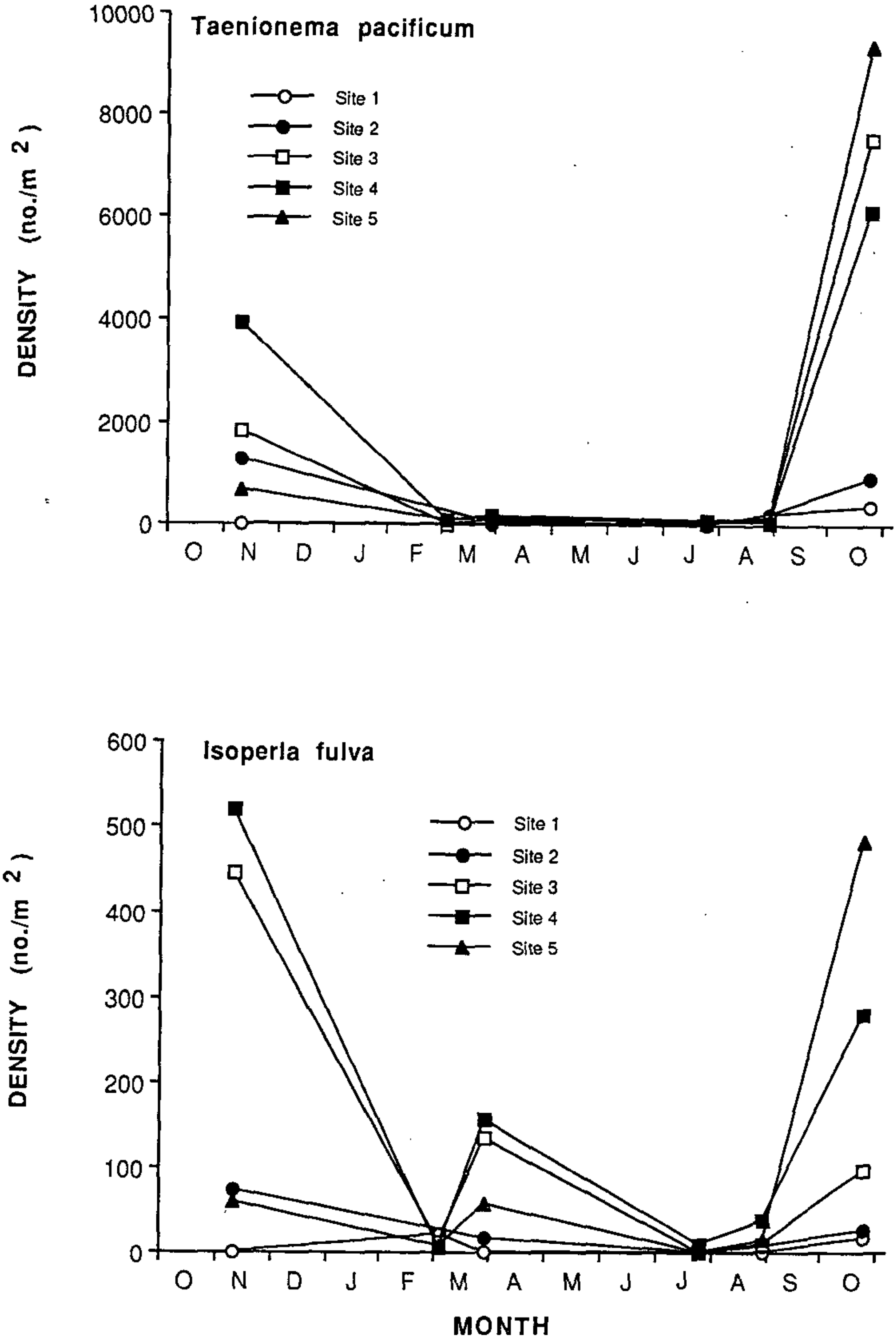


Figure 17. Density of *Taenionema pacificum* and *Isoperla fulva* at each of the five sampling sites on each sampling date throughout Water Year 1993.

at Site 3, it is likely related to the extensive growths of algae growing on the river bottom in this river reach. *Pteronarcella* is regarded as a collector/gather and shredder that will feed on accumulations of organic matter. *Pteronarcella* density at Site 3 was markedly higher in late 1993 compared with 1992 (Figure 18), although densities were very similar between the other mainstem river sites for both years.

Mean annual density of *Hesperoperla pacifica* and *Claasenia sabulosa* showed similar patterns at the three partially regulated sites (Figure 15). Both species were never found at Site 1. Density was highest at Site 3 for both species then declined at each successive downstream site. *H. pacifica* at Site 2 had a mean annual density substantially less than that found at Site 3. Mean annual density of *Claasenia sabulosa*, on the other hand, was only slightly less at Site 2 than Site 3. Both species are predators with semivoltine life cycles. Surprisingly, *Claasenia sabulosa* was either absent (Site 3) or low in density (Sites 4 and 5) at the partially regulated sites in November of 1992 (Figure 19). *Claasenia* density was highest at the unregulated site in November 1992 and March 1993. However, in October of 1993, the partially regulated sites contained the highest densities (4X) of *C. sabulosa*, at Site 3 on the respective dates. *Hesperoperla pacifica* had a higher density at the partially regulated sites than the unregulated site for half the sampling dates (Figure 19). Nymphal densities at the unregulated site were relatively consistent between sampling dates. Site 3 had the highest density on four sampling dates: November 1992, July, August and October of 1993. Sites 4 and 5 also had higher densities than Site 2 on several sampling dates.

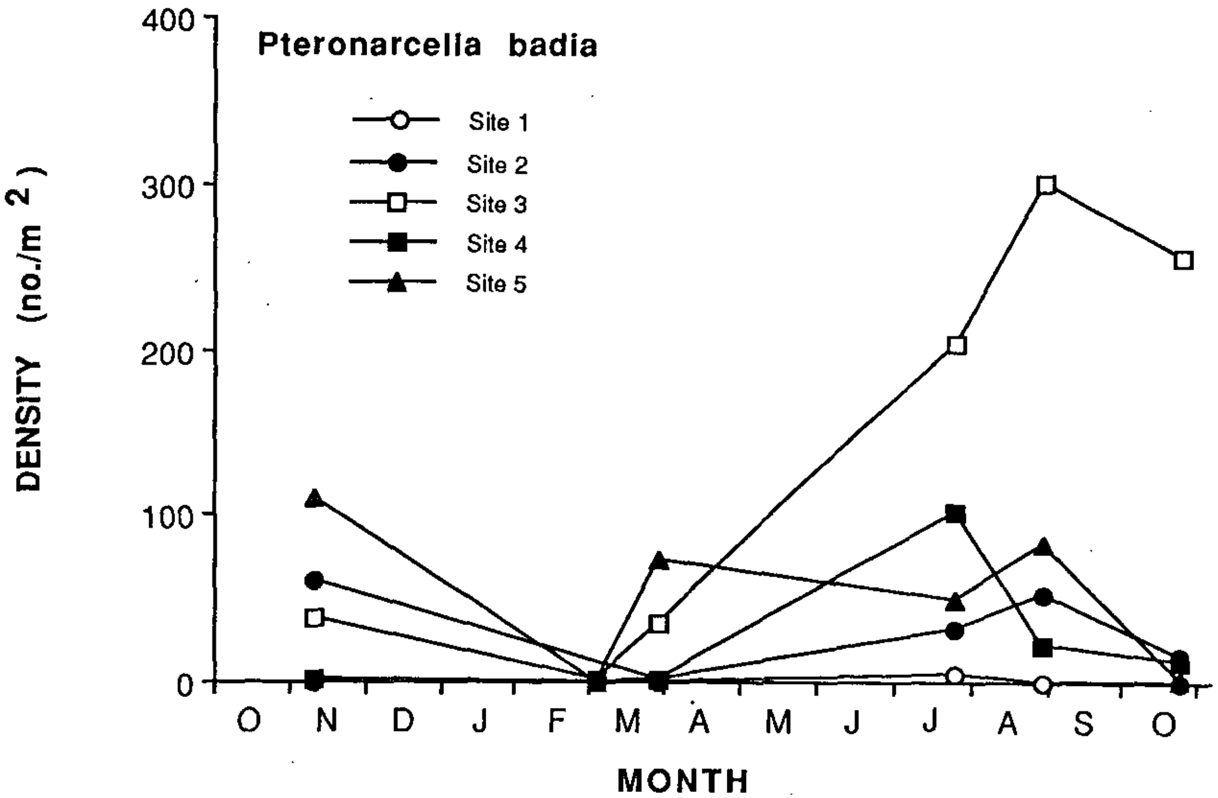
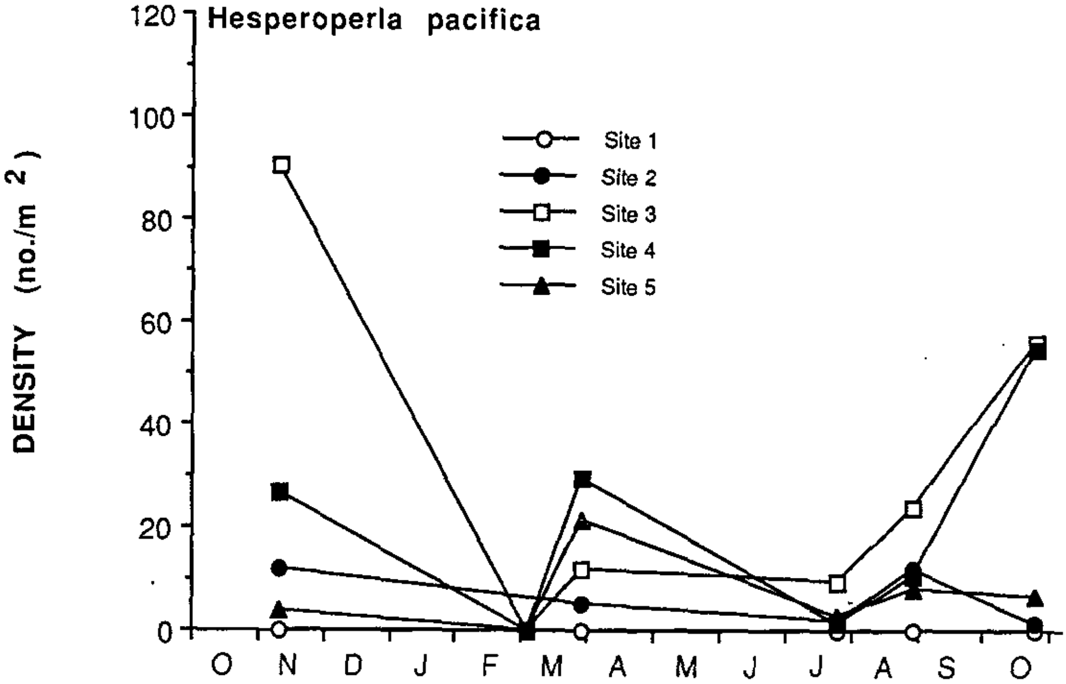


Figure 18. Density of *Pteronarcella badia* at each of the five sampling sites on each sampling date throughout Water Year 1993.



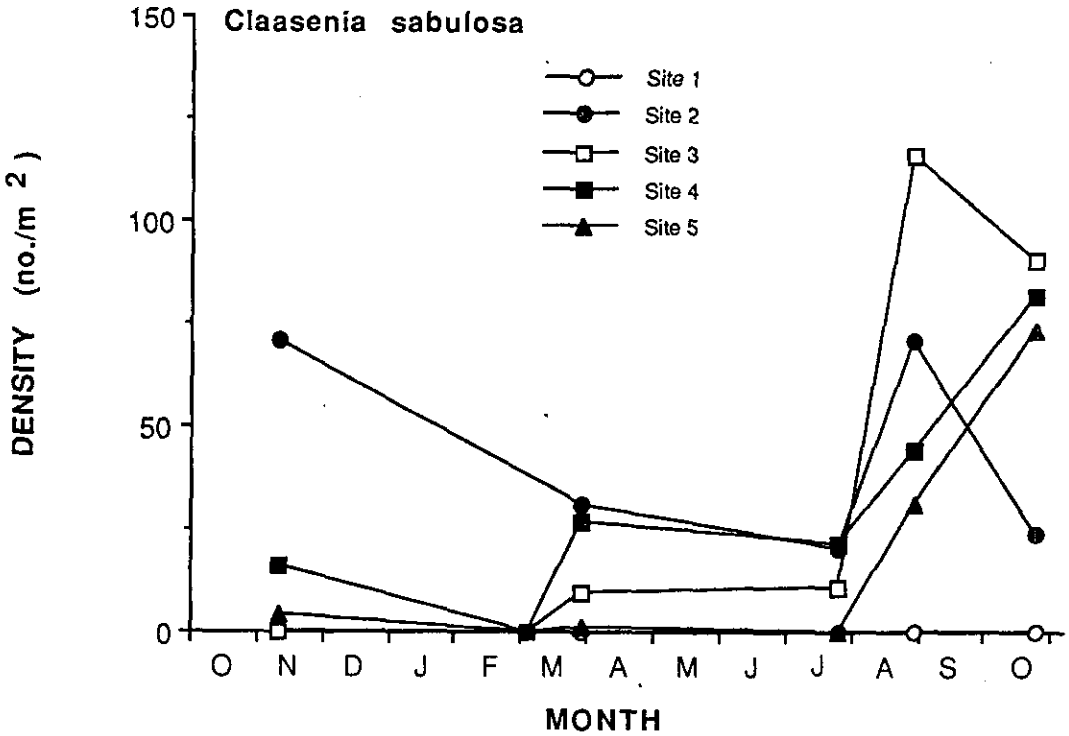


Figure 19. Density of *Hesperoperla pacifica* and *Claasenia sabulosa* at each of the five sampling sites on each sampling date throughout Water Year 1993.

Trichoptera

The net-spinning caddisflies were the most abundant of the Trichoptera collected in the study. Four species of the family Hydropsychiidae occur abundantly in the fifth-order North and Middle Forks and sixth-order mainstem Flathead River (Hauer 1980, Stanford et al. 1988). Responses of these collector species to stream regulation in the Flathead River was detailed by Hauer and Stanford (1982a). During this study, all four species were virtually absent from the South Fork below Hungry Horse Dam. Only a few larvae of *Hydropsyche cockerelli* were collected at Site 1, most likely individuals that drifted downstream from small tributaries that enter the South Fork below the dam. At the other sites along the continuum, Site 2 to Site 5, the Hydropsychidae exhibited distinctive responses to river regulation. *Arctopsyche grandis* mean annual density was more than 5 times greater at Site 3 than at Site 2 (Figure 20). Larval density then declined with each progressive downstream site (i.e., Site 4 then Site 5), but remained above levels at the unregulated site. Density tended to be higher during autumn 1992 than the same time the following year, in direct contrast to what was observed for many of the other species (Figure 21). The higher larval densities at Sites 3 and 4 after higher discharges from Hungry Horse in the summer may be related to increased organic seston associated with dam discharge (Hauer and Stanford 1982a) as well as thermal criteria and the river continuum resetting nature of the hypolimnetic discharges (see Vannote et al. 1980 and Ward and Stanford 1982).

Three species in the genus *Hydropsyche* were collected at the unregulated and partially regulate sites. *Hydropsyche oslari* was most abundant at Site 2, with declining densities at each successive downstream sampling site. Similarly, *Hydropsyche occidentalis* was most abundant at Site 2, however,

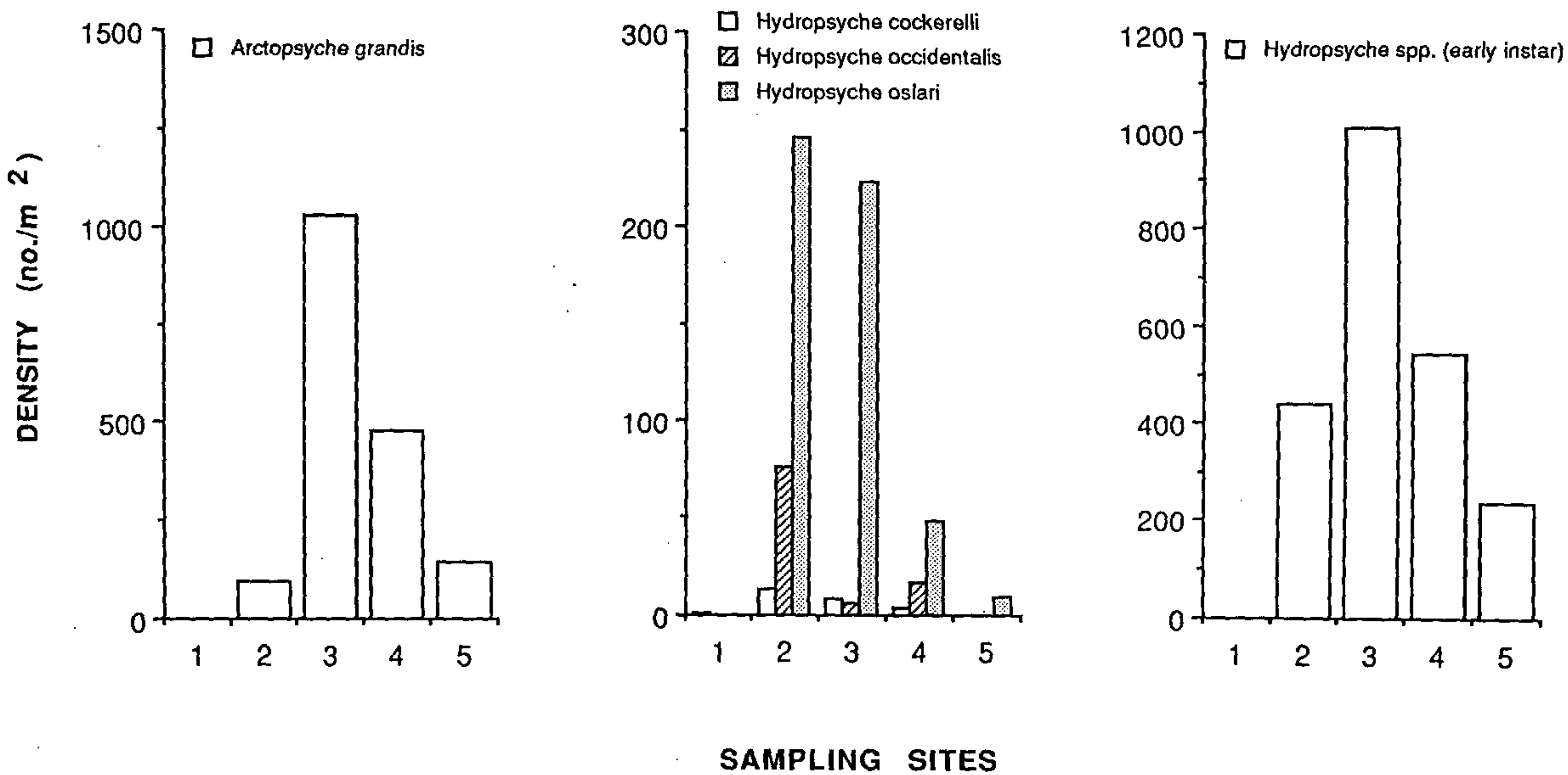


Figure 20. Mean annual density of abundant caddisflies at each of the five sampling sites on the South Fork and mainstem Flathead River.

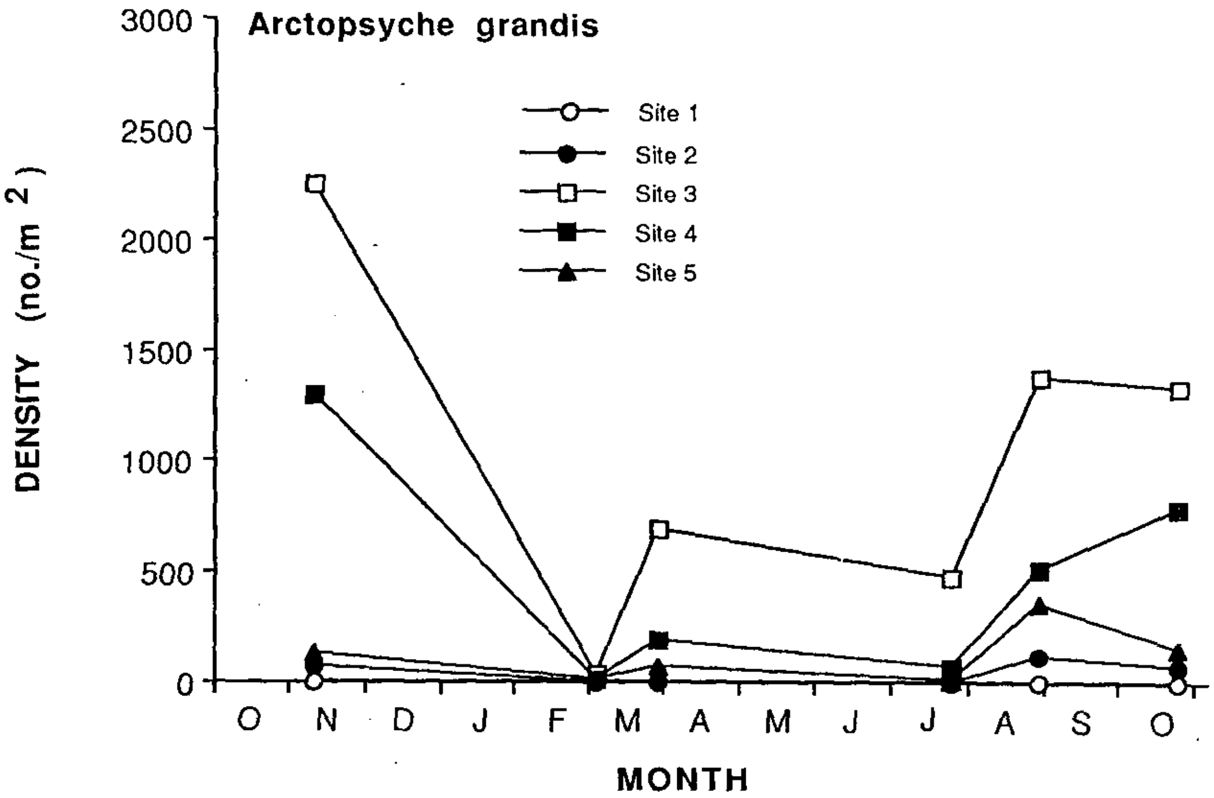


Figure 21. Density of *Arctopsyche grandis* at each of the five sampling sites on each sampling date throughout Water Year 1993.

larval densities were substantially lower at the partially regulated Sites 3, 4 and 5 compared to the relative abundance relationships shown by *H. oslari.*. *Hydropsyche cockerelli* was an uncommon at Sites 3 through 5, as was expected from earlier studies; however, larvae of this species were also unexpectedly low at Site 2. Densities of all *Hydropsyche* spp. combined (Figure 22) were substantially higher during autumn months in both 1992 and 1993 than during other times of the year. This was likely due to factors associated with life histories, but may also be at least partially due to winter fluctuations in discharge at Sites 3 through 5 as a result of dam operation. However, the significant increase in early instar larvae, primarily *H. oslari*, between autumn 1992 and autumn 1993 at Sites 3 and 4 were most likely due to the significant difference in dam operations between those two years.

Diptera

Lotic Diptera are taxonomically very complicated; just in the family Chironomidae for example, there are over 2000 species in the Nearctic Region (Coffman and Ferrington 1984). Furthermore, most larvae in this order cannot be taxonomically distinguished much beyond the tribe level of identification without extensive and tedious microscopy. Therefore, for the purpose of this study, we identified Diptera to the family level of resolution with the understanding that there are distinct, species level responses to river regulation. However, this approach is also justified by the knowledge that within the various families, trophic relationships and ecological position with respect to the lotic food web, is fairly consistent (Merritt and Cummins 1984).
Among the Chironomidae mean annual density was highest at Site 1 and Sites 3 and 4. Densities at these three sites were ≈4 times higher than Site 2 (Figure 23). However, at Site 5 the partially regulated site furthest downstream, larval

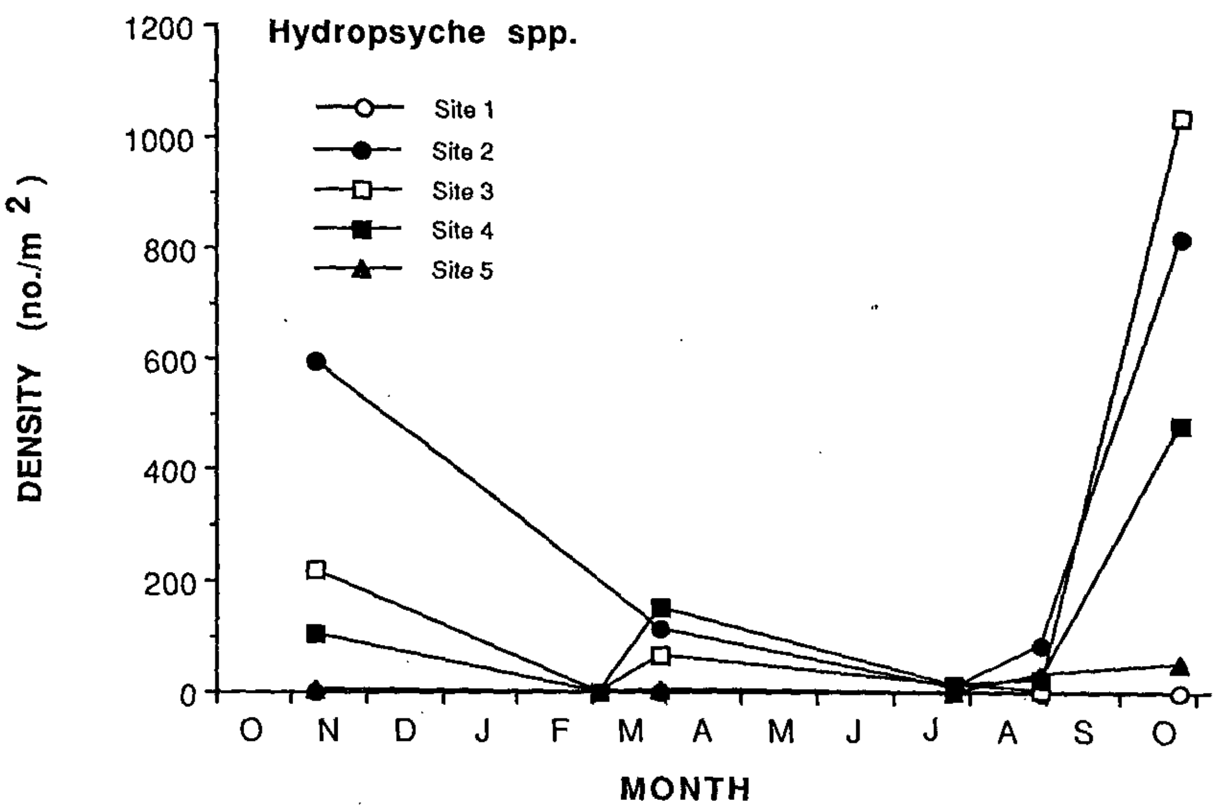


Figure 22. Density of *Hydropsyche spp.* at each of the five sampling sites on each sampling date throughout Water Year 1993.

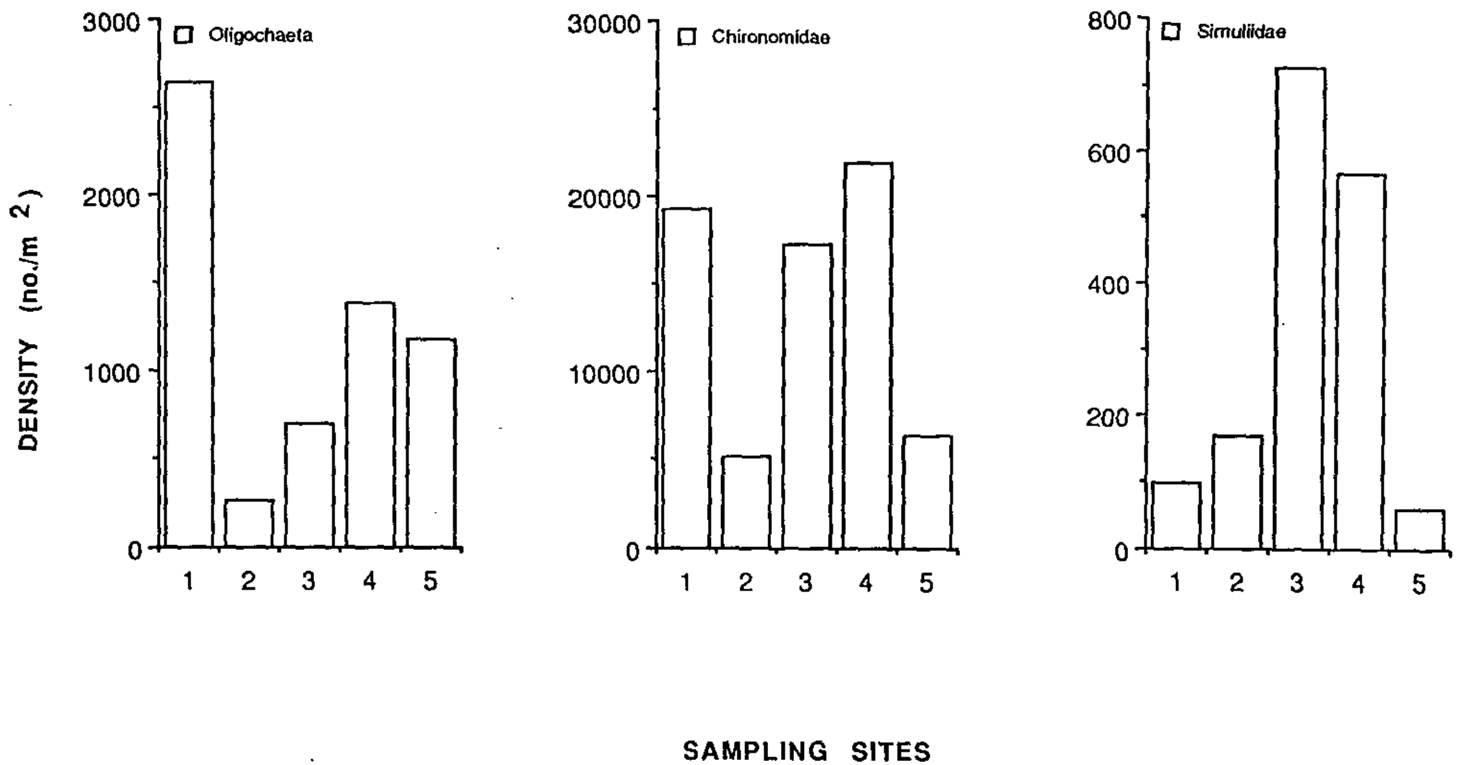


Figure 23. Mean annual density of Oligochaeta, Chironomidae and Simuliidae at each of the five sampling sites on the South Fork and mainstem Flathead River.

densities were approximately equal to densities at Site 2. The high densities of chironomids occurred primarily where abundant, attached algae provided both trophic support and stabile microhabitat. Chironomid larvae were most frequently observed in direct association with either the stalked diatom *Gomphonema* or within the gelatinous structure *Ulothrix*.

Larvae of the dipteran family Simuliidae had highest mean annual density at Sites 3 and 4 (Figure 23). Simulid larvae, which feed by filtering very small particles from the seston, were generally observed in clumped distributions in very specific microhabitats. Simulids also appeared most abundantly during mid-summer (Figure 24) in conjunction with warmer temperatures in the mainstem river the summer of this study, as a result of unusually low dam discharge in summer 1993.

Oligochaeta

Although common in most lotic habitats, Oligochaetes significantly increased in abundance in the regulated and partially regulated river, in comparison to the unregulated sampling site (Figure 23). Oligochaete density was highest at Site 1, where individuals were typically associated with the protective microhabitat matrix afforded by *Gomphonema*. Elevated density of Oligochaetes is generally indicative of organically enriched river systems. Although not intensively enriched by municipal sewage, agricultural runoff or other cultural organic augmentation, Hungry Horse does increase organic matter loading to the mainstem by increasing nutrient availability, with a subsequent response by the benthic algae. It is within this context that the density of Oligochaetes are supplemented in the regulated and partially regulated river.

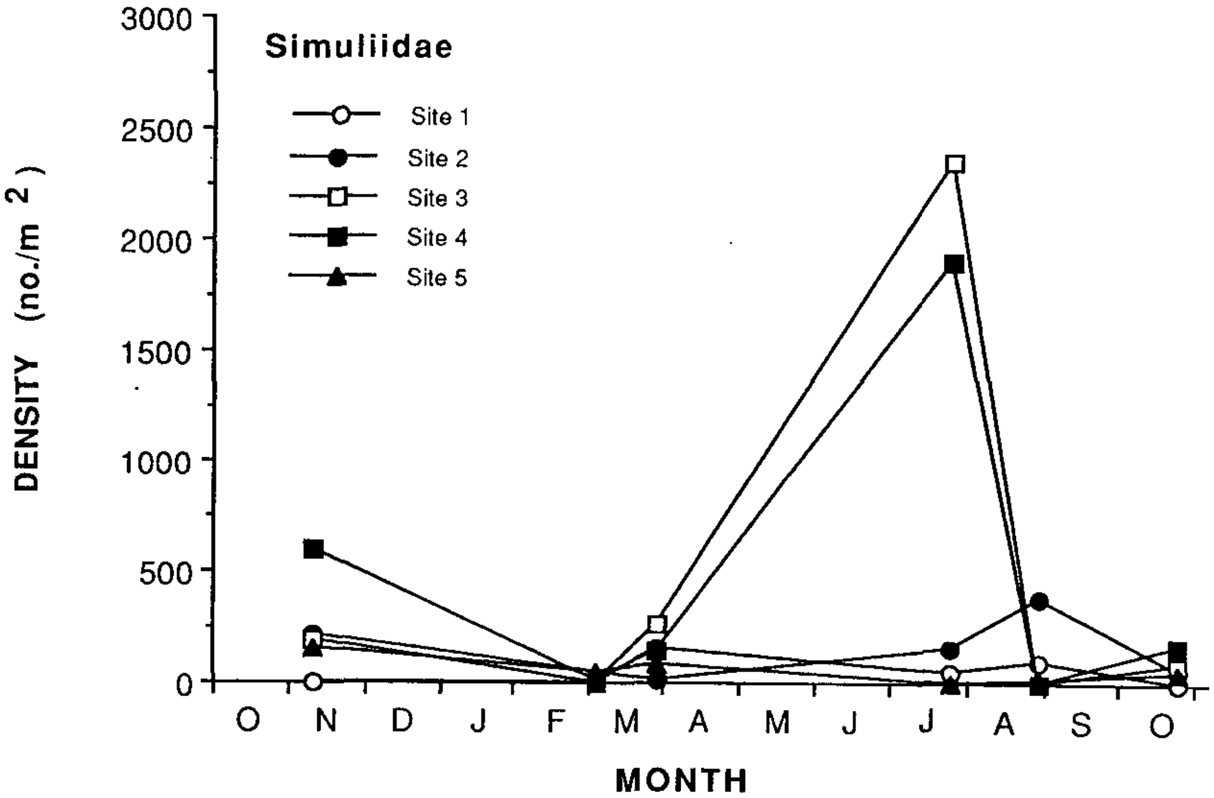


Figure 24. Density of Simuliidae at each of the five sampling sites on each sampling date throughout Water Year 1993.

DISCUSSION

Discharge and Temperature

River regulation in the South Fork of the Flathead River has been highly variable since the beginning of Hungry Horse Dam operations in the early 1950's. Discharge is almost exclusively a function of energy production, although dam operators can release additional water through an adjustable ring gate. Generally, maximum discharge is ≈12,000 cfs (11.4 Kcfs before and 12.5Kcfs after generator upgrade in late 1980's and early 1990's) and minimum discharge ≈145 cfs. During water year 1993 the maximum mean daily discharge was 8880 cfs and the minimum mean daily discharge was 96 cfs. These extremes in discharge can, and often do, occur very quickly. In less than 15 minutes Hungry Horse Dam can change from minimum to maximum generation, or vice versa. Although maximum or minimum generation can occur at anytime during the year, generally during the first decades of operation Hungry Horse generated primarily during the late fall, winter and spring seasons. The reservoir was generally filled during spring runoff with discharge near minimum from May through June.

In recent years, particularly since the later half of the 1980's, mid-summer discharge has occurred with increased frequency, duration, and flow. The summer season has also experienced a greater variability in discharge as operators have sought minimum flow on week-ends to facilitate week-end recreation and power conservation since week-ends also tend to have lower electrical energy demand. The consequence is that during several recent years South Fork flows have fluctuated between maximum discharge during the summer week-days and minimum discharge on the summer week-ends.

The discharge regime described by weekly maximum to minimum fluctuation during late summer months has very significant ecological effects. Not only are significant portions of the river bottom rapidly dewatered each time dam discharge is reduced and then reinundated when generation and flows are increased, thus creating a large varial zone (see Stanford and Ward 1992), but also water temperatures are very significantly affected. For example during late July and August 1989, Hungry Horse Dam was operated at maximum discharge on week-days and taken to minimum flow on the week-ends. Typically, water temperatures in the mid-channel of the mainstem river at a location between Sites 3 and 4 was ≈18°C whenever Hungry Horse was not discharging and ≈8°C when the dam was at maximum discharge. The maximum temperature change recorded over a 2 hour period that summer was >11°C.

Seston

Seston also remains greatly affected by dam discharge. Originally quantified by Hauer and Stanford (1982a, 1986) and Perry et al. (1986), seston values are significantly increased in the partially regulated mainstem, particularly during the fall, winter and spring. Results of nutrient analyses from the South Fork, North and Middle Forks, and the mainstem river demonstrate that hypolimnetic waters from Hungry Horse Reservoir are comparatively high in biologically available forms of phosphorous and nitrogen (Stanford et al 1992). Furthermore, the exceptionally large alluvial aquifer associated with the mainstem river from just above Site 3 to below Site 5 also contributes bioavailable P and N. This results in 'hot-spots' of biological activity in up welling zones as periphyton rapidly sequesters the nutrients (Stanford and Ward 1988, 1993).

Relative seston concentration in the 5th and 6th order forks and mainstem Flathead Rivers is consistent with general theory of river ecology (Vannote et al. 1980); as it is primarily derived from instream primary production throughout most of the year. Seston values tend to be low in the mid-summer as periphyton communities are recolonizing and growing after the spring-early summer runoff, which tends to scour the river bottom. Transport of organic matter generally increases during fall and reaches highest levels during spring as algal accumulations slough from the river bottom. The increase in attached algae occurring in the mainstem river is reflected in steadily increased seston concentrations from Site 2 to Site 5 as increased length of river contributes to the seston load. These conditions lead to two generalized trends: 1) a spatial trend of increased seston concentration in a downstream direction after the confluence of the regulated South Fork, and 2) a temporal trend of increased seston concentration from summer to the following spring when spring runoff then resets the annual periphyton and seston cycle.

Macroinvertebrates

The response of the macroinvertebrate community to the biophysical template of the regulated and partially regulated Flathead River system was similar in this study to what was observed in the 1970's and presented by Stanford (1975) Hauer (1980) and Perry (1984) and in their subsequent journal publications (see Literature Cited). However, populations of macrozoobenthic species exhibited responses suggesting that they remain greatly influenced not only by river regulation in general, but also are strongly influenced by year to year variation in discharge regime.

Density of riverine macroinvertebrates is usually highly variable throughout an annual cycle, particularly for fast growing, univoltine species.

Species that grow rapidly over a very short time period may be present as nymphs for only a few months. Or, in the case of multivoltine species, such as *Baetis* and many of the Chironomidae, some species may be capable of rapidly colonizing habitats or entire river segments after disturbance (see Resh et al. 1988). Often such species become numerically dominant in regulated river systems as longer-lived univoltine or multivoltine species are constrained by impacted niche requirements or life histories that are incompatible with repeated and frequent disturbance.

Based on earlier studies, we know a great deal about the life histories and ecology of macroinvertebrates in the Flathead River Ecosystem. Numerous species or taxonomically closely related taxa that are similar in trophic function have been shown to respond in a very predictable way to river regulation in the Flathead River. The net-spinning caddisflies, comprised of *Arctopsyche grandis*, *Hydropsyche cockerelli*, *H. oslari*, and *H. occidentalis*, typically occur along the longitudinal gradient of the main forks and mainstem river. Species replacement in a downstream gradient is such that *A. grandis* is dominant in 4th order tributary streams and upper reaches of the North and Middle Forks, although the three *Hydropsyche* species are also present (Hauer and Stanford 1982a). As the river increases in size and temperature (i.e., summer maximum and annual degree days) *A. grandis* is replaced by the *Hydropsyche*. Prior to construction and operation of Hungry Horse Dam *Hydropsyche* were, with high probability, the dominant net-spinners in the mainstem Flathead River. However, because of the reduced temperatures in the summer due to hypolimnetic discharge *A. grandis*, the upstream dominant, replaced *Hydropsyche* as the dominant species of the trophic group in the partially regulated mainstem (Hauer and Stanford 1982a, Stanford et al. 1988). Although this relationship was still present among the hydropsychids during this study, we observed some shifts in densities that had occurred between the 1970's and the 1990's and subtle differences between the autumns of 1992 and 1993.

Hauer (1980) reported the density of *A. grandis* at Site 4 to increase between fall and spring, with maximum density of ≈400 m^{-2}. Perry (1984) found annual mean density of *A. grandis* at Site 3 to be 190 m^{-2}. We found much higher densities of this net-spinner at both sites in 1992 and 1993. At Site 3 the mean density in November 1992 was ≈2250 m^{-2} and in October 1993 ≈1500 m^{-2}. At Site 4 the November 1992 density was ≈1400 m^{-2} and the October density was ≈1000 m^{-2}. These densities represent an approximately 3 to 5 times increase in *A. grandis* density between the late 1970's and early 1990's. Other species of caddisflies were also significantly different in abundance comparing densities incurred in late 1970's and during this study. Hauer (1980) found *Brachycentrus americanus*, *B. occidentalis*, and *Glossosoma alascense* to be relatively abundant in the mainstem river at Site 4. *Brachycentrus* larvae had mean annual density of 17.8 m^{-2} and a maximum density of 78 m^{-2} (Hauer and Stanford 1986). During this study the *Brachycentrus* mean annual density was <1 m^{-2} and a maximum density of 4 m^{-2}. *Glossosoma* also appear to be strongly affected. Hauer (1980) reported a spring density of ≈120 m^{-2} at Site 4; however, in this study we collected no *Glossosoma* larvae at that site. These differences between our studies in the late 1970's and early 1980's and this study may possibly be the result of food web changes, particularly the relationship between attached periphyton and seston. Based on trophic relationships of these caddisfly species, significant increase in periphyton could result in spatial exclusion and thus decreased density of grazers (*Brachycentrus* and *Glossosoma*) and an increase in filter-feeder density (*Arctopsyche*)

Among the stoneflies, *Taenionema pacificum*, *Isoperla fulva*, *Pteronarcella badia*, and several species of capniids were the most abundant taxa in the mainstem Flathead River. Perry (1984) reported an annual mean density of *T. pacificum* of 721 m^{-2} at Site 3. In this study *T. pacificum* nymphs were approximately twice as abundant at all three of the mainstem, partially regulated sites. On a temporal basis, *T. pacificum* densities were markedly higher during the autumn of 1993 than autumn 1992. It appears that *T. pacificum* nymphs were significantly affected by the high late summer discharges from Hungry Horse during summer 1992 that were largely absent in 1993, permitting nymphs to achieve significantly higher densities.

The mean annual density of Capniid nymphs, probably *Capnia confusa*, was highest at Site 2. Decreases in Capniid mean annual density could possibly be attributed to mortality of pre-emergent nymphs caused by fluctuations in discharge during winter months. *Capnia* nymphs migrate to lateral margins of the river channel in February and March prior to emerging. Fluctuating discharge levels strand pre-emergent nymphs and leave them susceptible to freezing at night as temperatures drop below -2°C (Stanford 1975). However, similar to *T. pacificum, Capnia* densities in the mainstem during autumn of 1993 were significantly higher than in autumn 1992. This pattern of higher density during autumn 1993 than 1992 was also observed for the stonefly *Pteronarcella badia*, which had densities similar to those report by Perry (1984).

The predaceous stoneflies, *Hesperoperla pacifica* and *Claasenia sabulosa*, appeared to be more abundant during this study than what was reported a decade earlier. Maximum density of *H. pacifica* was ≈90 m^{-2} and *C. sabulosa* was ≈110 m^{-2} at Site 3 compared with annual means of 7 and 10 m^{-2}, respectively, reported by Perry (1984). Environmental conditions at the partially regulated sites seemed to favor *Hesperoperla pacifica* and *Claasenia sabulosa.*

Like many of the caddisflies and stoneflies, several species of mayflies were more abundant in autumn 1993 than in autumn the previous year. *Baetis* density increased from ≈3000 m^{-2} to ≈ 6000 m^{-2} between these two years. However, in both cases these densities were less than what was observed at the unregulated mainstem site above the confluence of the South Fork. Also, these *Baetis* densities are ≈ 4 to 6 times that observed by Perry (1984). Density of *Ephemerella inermis* was as much as 10 times higher during this study as reported by Perry, with highest abundances observed at Site 4. In contrast, *Serratella tibialis* was 3 to 4 times more abundant at Site 3 in the late 1970's than what we observed during this study.

Chironomid larval density at Sites 2 and 5 remained relatively constant throughout the study. Explanation for this observation may be held in these sites are the least affected by regulation (i.e., Site 2 was located above the regulated South Fork and Site 5 was located the farthest downstream). The distance to Site 5 coupled with the fact that this site is only partially regulated allowing for considerable mixing of waters and warming could account for the similarity in larval density between Site 5 with Site 2. Partially regulated sites, 3 and 4, in closer proximity to the confluence of the South Fork Hungry Horse Dam as well as Site 1 (i.e., the regulated South Fork) displayed high variation within sites and between seasons. Chironomid larval densities at Sites 3 and 4 were highest in November 1992 and March 1993, but demonstrated much less variation between the last three sampling dates and closely resembled densities at Sites 2 and 5. Zoobenthos communities dominated by Chironomidae are generally considered degraded. High densities at Sites 3 and 4 on the first three sampling dates could be a reflection of frequent hypolimnial releases of large magnitude in August and September of 1992. Likewise, Simuliidae densities were highest in the partially regulated mainstem section at Sites 3 and 4 and reflect the abundance of seston.

SYNTHESIS

Regulation of the South Fork by Hungry Horse Dam has vastly altered the character of the riverine environment and community from the dam to the confluence with the mainstem. Hydropower production may vary flow from 100 to 12,000 cfs daily or may sustain any discharge level for several weeks. The varial zone of the South Fork is described by that portion of river bottom that is exposed between the high and low water marks of maximum and minimum discharge. Because the South Fork receives only minor side flow between the dam and the confluence with the mainstem river, most of the river bottom is within the varial zone (i.e., outside the permanently wetted channel). This portion of the river bottom is virtually devoid of life other than microbial organisms (i.e., bacteria, fungi and algae). Within the permanently wetted channel the substatum is covered with algae as a result of relatively high concentrations of labile nutrients from the reservoir and a lack of annual scour from spring snowmelt. Biodiversity of macroinvertebrates in the permanently-wetted channel has been significantly reduced due to constant temperatures, armoring of the river substratum, and unpredictable flow fluctuations. Few macroinvertebrates that would normally be integral components of the community remain (i.e., Chironomidae, Oligochaeta, Capniidae).

The physical character, nutrient concentrations and biota of the partially regulated mainstem Flathead River continue to be significantly influenced by river regulation from the South Fork. During early summer months, naturally high flows from the North and Middle Forks dominate the total discharge and consequently river temperatures in the mainstem river. After runoff, however, mainstem river flows and temperatures are greatly influenced by the hypolimnetic waters of the South Fork. During July, August and September when water coming from the North and Middle Forks achieve maximum daily temperatures of 18 to 20°C and their combined, unregulated flows generally receded to <2000 cfs, high discharge from Hungry Horse significantly depresses temperature and increases discharge. Changes in flow and temperature can and often do occur over very short time periods (e.g., <2 hrs) and with relatively high frequency (e.g., maximum to minimum discharge fluctuation daily or weekly). Mainstem discharge may change from 2000 cfs to 14,000 cfs and temperatures from >18 to <8°C in less than 1 hour. During fall and spring the temperature effect of hypolimnetic flows is greatly reduced as natural temperatures are similar to those of the South Fork. In winter unregulated river temperatures frequently are at 0°C, while the regulated South Fork and the partially regulated mainstem water temperatures are generally 1-3°C, thus producing sufficient winter warming to preclude ice cover and ice flows.

Biodiversity of the partially regulated mainstem Flathead River has remained relatively high and consistent throughout the years of study. However, significant impacts on the biota have been documented as a consequence of regulation. Perry (1984) showed that periphytic algal growth was significantly enhanced within the permanently-wetted channel and Hauer and Stanford (1982a) and the present study demonstrated the significant increase in seston concentration along the longitudinal gradient of the mainstem as a result of sloughing of the algal mat. Although no lotic insects have been eliminated by partial regulation the zoobenthic community has shown distinct signs of stress. We observed very significant changes among several important functional groups of invertebrates in the mainstem between the late 1970's and 1992-93. The dominant net-spinning caddisfly, *Arctopsyche grandis* that replaced the *Hydropsyche* spp. as a river continuum reset (see Vannote et al 1980, Ward and Stanford 1982, Hauer and Stanford 1982a) , was even more abundant in this study at Sites 3 and 4. Likewise, densities of several species of stoneflies (e.g., *Isoperla fulva* and the capniids) , diptera (e.g., chironomids and blackflies), and mayflies (e.g., *Baetis* sp.) increased 2 - 4X between the late 1970's and this study. Most species that were more abundant in this study, however, tend to be species that have short life histories, are sessile, or are predaceous. Many of the univoltine species that are grazers or collector/gatherers, or have slow larval growth throughout the annual life cycle, were far less abundant than was reported in the earlier studies (e.g., *Serratella sp., Brachycentrus sp., Glossosoma sp.*). Although other factors may be important in affecting these results, we strongly suspect that summer discharge from Hungry Horse Dam has played a very significant role in the density of macroinvertebrates in the mainstem river in autumn and winter. This can be readily seen in the significantly lower density of most species in the fall of 1992 after a summer of high discharge fluctuation compared with autumn 1993 after a summer of almost no discharge from Hungry Horse during July and August.

Several studies have shown that declining water levels, caused by Hungry Horse operations, tended to strand insects in the varial zone. Hauer and Stanford (1982c) observed large limnephilid caddisfly larvae stranded on sand bars and in small remnant pools in mid summer after declining Hungry Horse discharge. Such insects then became increasingly vulnerable to desiccation and predation by birds. Stanford (1975) and Perry (1986) reported that declining water levels during winter months tended to strand nymphs of winter emerging stoneflies, thus significantly increasing their vulnerability to desiccation or freezing. Many of the insect species that have been identified as highly vulnerable to impacts due to thermal or flow changes in past studies (Stanford 1975, Hauer and Stanford 1982a, 1982b, 1982c, Perry 1984, Perry et al. 1986, Hauer and Stanford 1986, Stanford et al. 1988) were the most infrequently collected species during this study. It appears that the increased summer discharge and high variability of discharge, not only in summer but throughout the year, has increased stress and vulnerability on most components of the macrozoobenthic community. A very limited number of these species, however, have apparently been able to tolerate the variability and unpredictability of the modifications due to regulation and exploiting organic resources that have been enhanced (e.g., *Arctopsyche grandis*, Chironomidae, Simuliidae, *Claasenia sabulosa, Hesperoperla pacifica, Baetis* spp.).

The results of this study are consistent with and reinforce the conclusions of Stanford and Hauer (1992) regarding mitigation of impacts of stream regulation in the Flathead Basin. They stated that the most pervasive problem of stream regulation is the effect on temperature of hypolimnial releases from Hungry Horse Dam during warm summer months. They pointed out that this problem could be solved in one of two ways: 1) the dam could be retrofitted with a selective withdrawal outlet structure that would permit water in the reservoir to be taken from different depths, and thus dam operators could match temperatures in the dam tailwaters with those in the river above the South Fork confluence, and 2) a simple alternative would be to restrict discharge from Hungry Horse during late fall, winter and spring when the river is naturally cold. Although this second alternative would effect discharge flexibility of hydropower. Nonetheless, the results of this study further support their conclusions, particularly since numerous species are at even lower levels of abundance than was observed in the late 1970's and 1980's.

The other major effect of Hungry Horse operations remains short-term volume fluctuations. Although radical and rapid fluctuation in discharge is the direct consequence of load factoring (i.e., peaking) or load following (i.e., load and frequency control), which is desirable for maximizing the flexibility of hydropower within the interconnected electrical power network (Jourdonnais and Hauer 1993), both lead to daily or weekly 'yo-yo' (i.e., maximum to minimum discharge swings) of the river and the problems associated with varial zone dewatering. The results presented in this study show that the mainstem river appears to be even more affected now by Hungry Horse operations than was found a decade ago. The only solution to this problem is to smooth the annual discharge pattern at the dam and eliminate peaking or load control that involves radical swings in dam discharge. Again, the recommendations of Stanford and Hauer (1992) are supported by the results of this study.

Over 150 species of Plecoptera, Ephemeroptera and Trichoptera have been identified as part of the mainstem river community, and we continue to work on the taxonomically very difficult diptera which could have as many species as the other three orders combined. Of those, we observed only 14 taxa that were highly abundant. Furthermore, with the marked exception of *Arctopsyche grandis*, *Isoperla fulva*, and *Taeneonema pacificum*, the density of macrozoobenthos was higher in the autumn of 1993 than 1992; the summer of 1992 had high and variable discharge from Hungry Horse while the summer of 1993 had very flow and infrequent discharge. Thus, the value of stabilizing flows and reducing the negative effects of cold water and rapid temperature fluctuation is readily apparent.

Future mitigation, including the planned retrofitting of Hungry Horse Dam for selective withdrawal, should include mechanisms that allow continued evaluation. This will be important for determining, not only the response of the riverine community to specific mitigation actions, but also effects upon other components of the Flathead River/Lake Ecosystem (e.g., migratory fish, nutrient loads to Flathead Lake, etc.).

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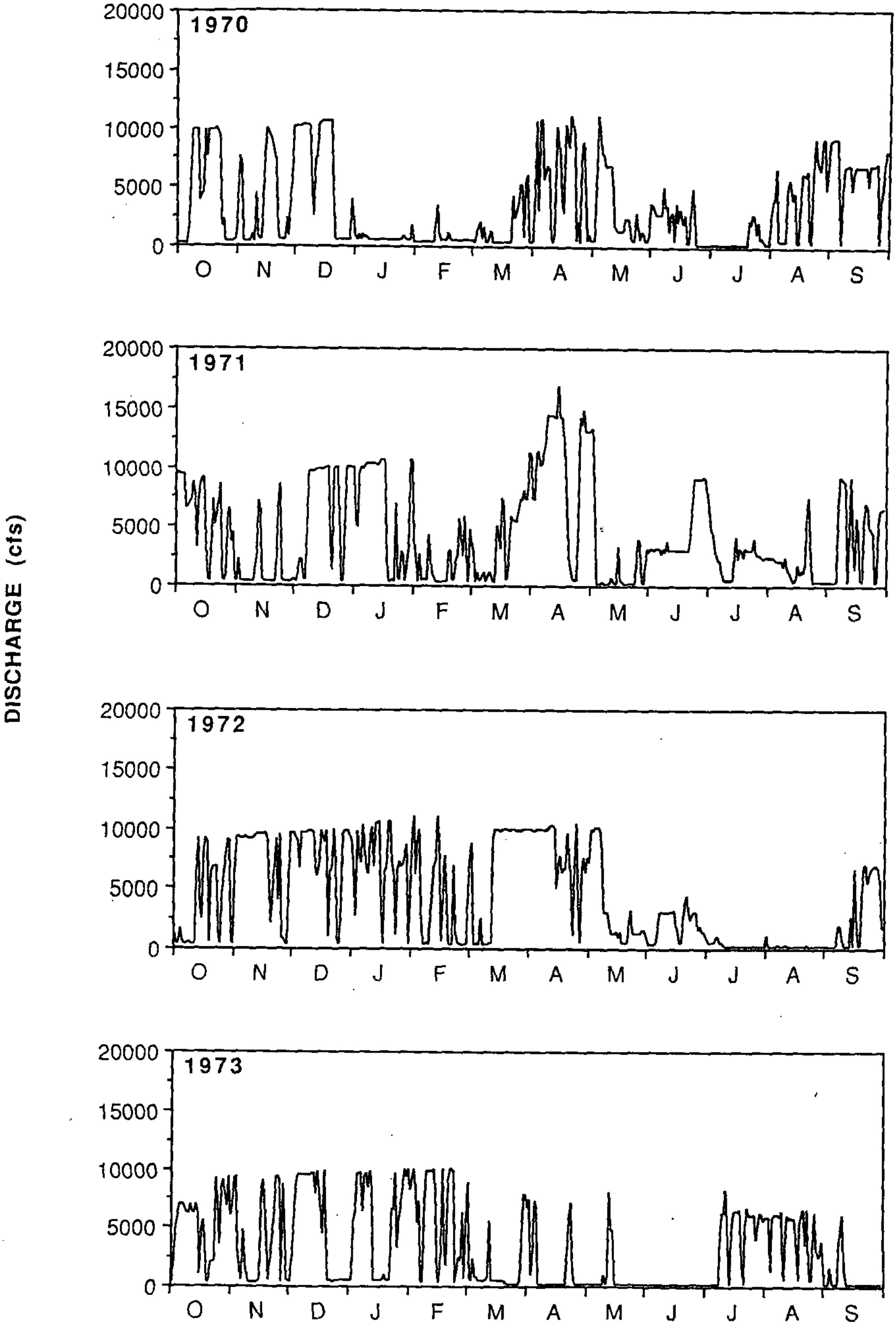
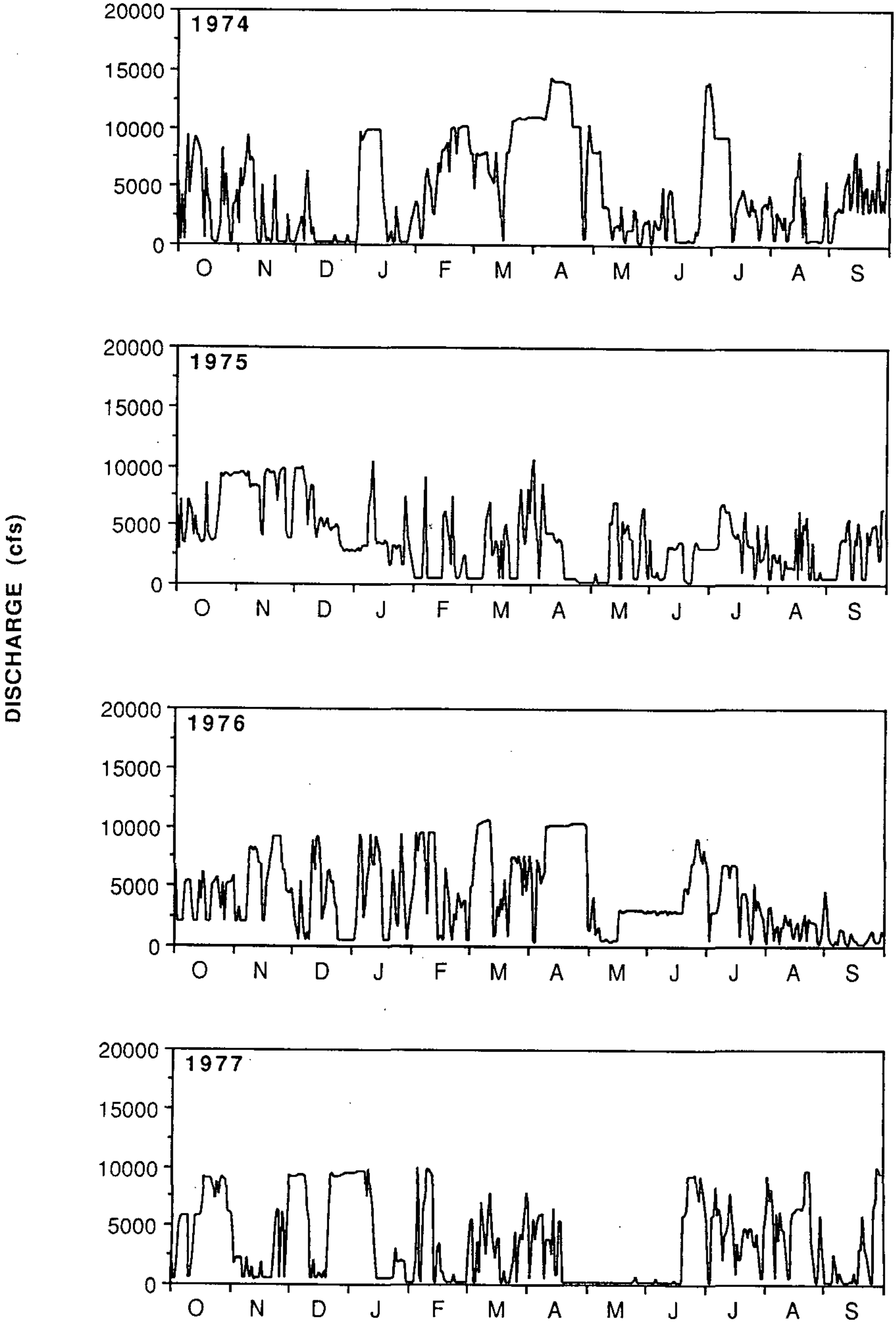
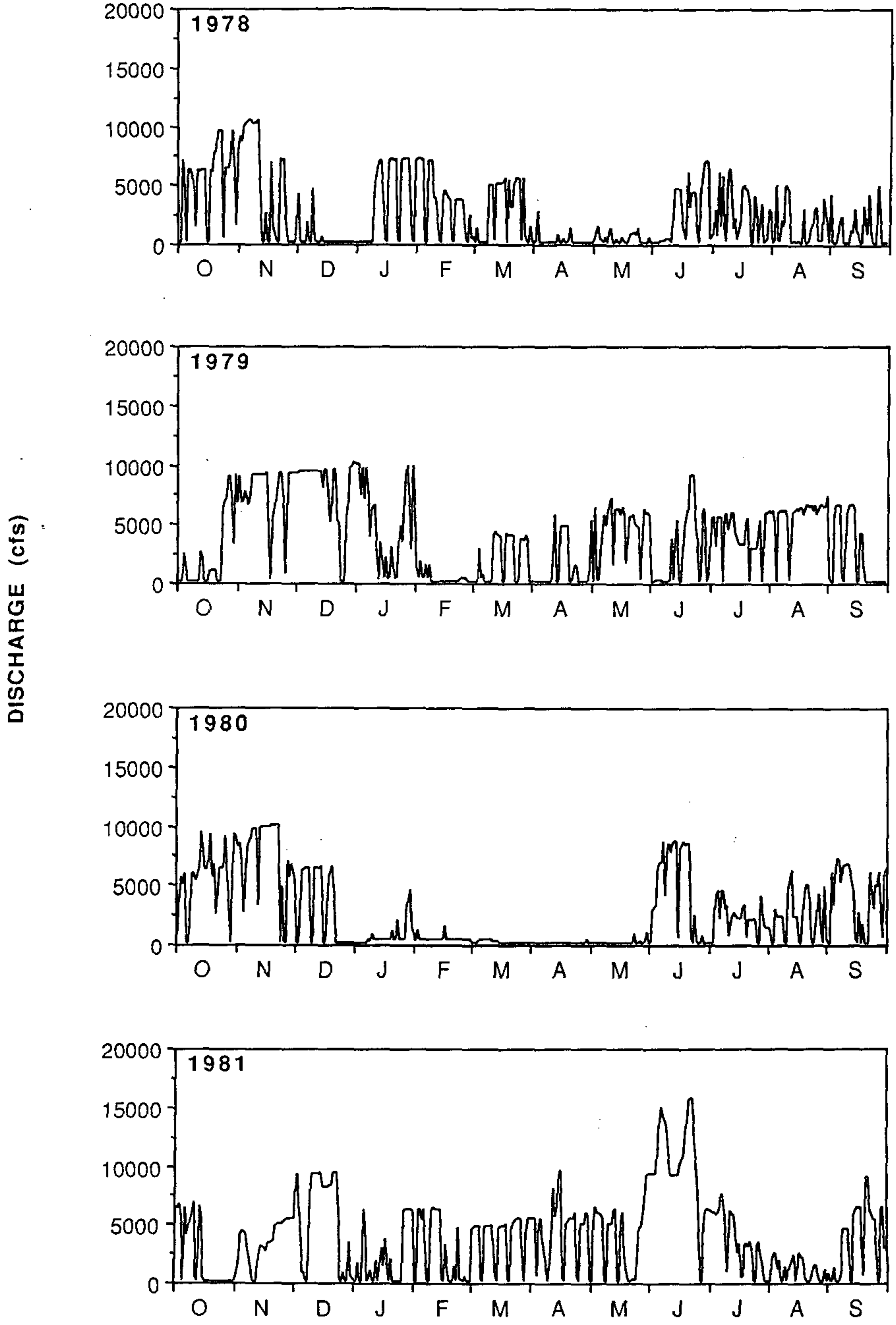
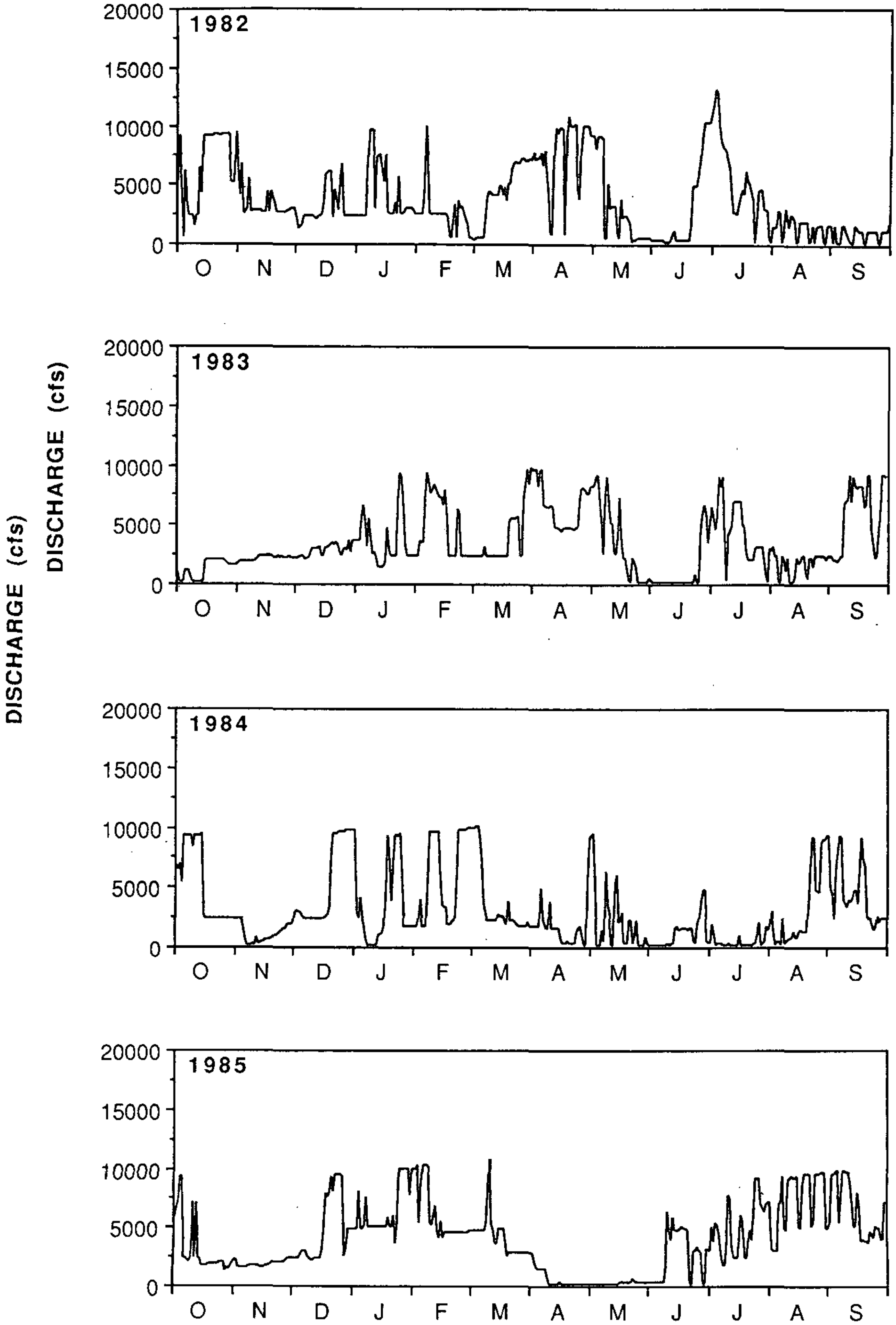
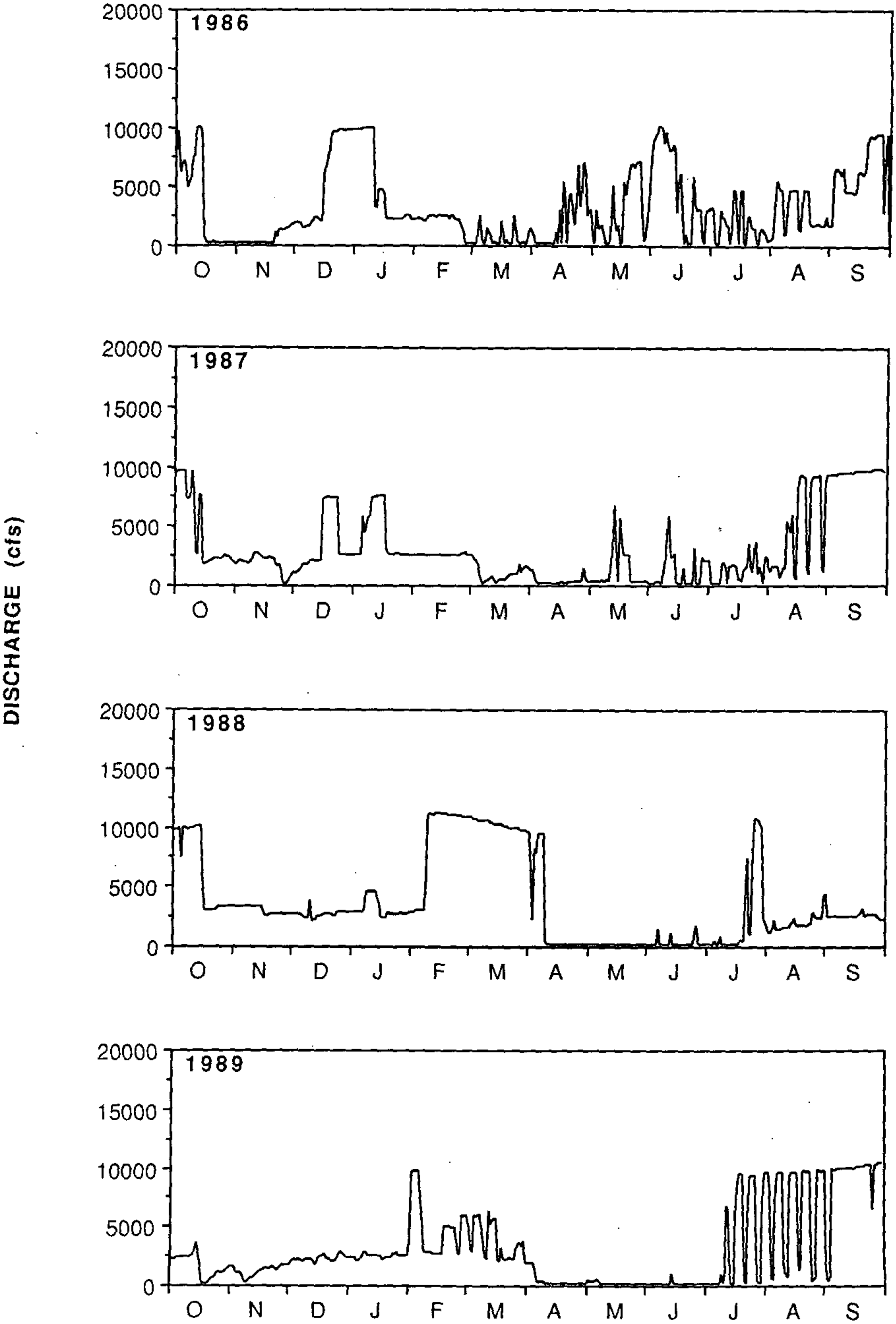
APPENDIX A. Discharge (cfs) in the South Fork of the Flathead River for each water year from 1970 through 1993.

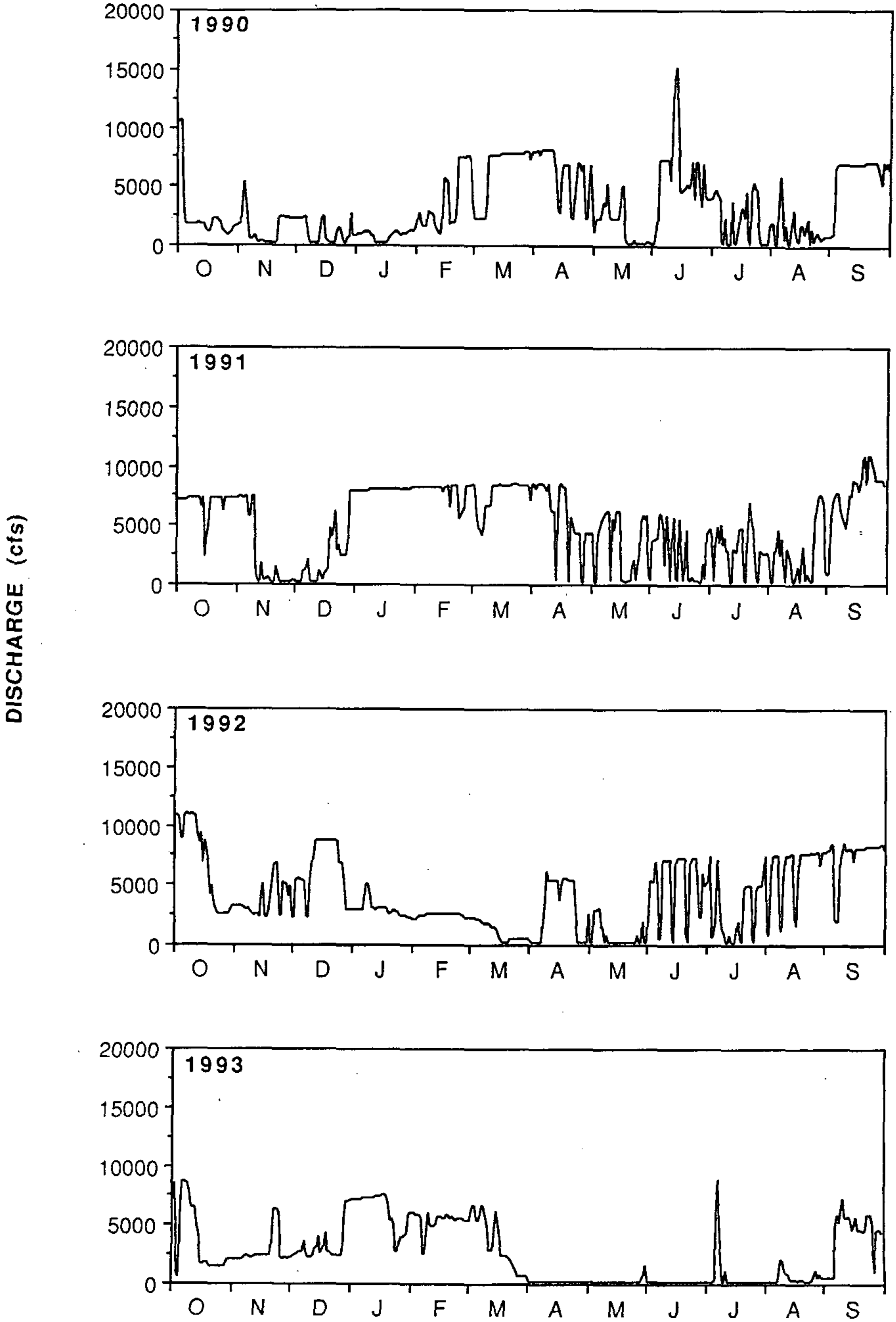

DISCHARGE (cfs)
1970
1971
1972
1973
20000
15000
10000
5000
0
O N D J F M A M J J A S


DISCHARGE (cfs)
1974
1975
1976
1977
20000
15000
10000
5000
0
O N D J F M A M J J A S


DISCHARGE (cfs)
1978
1979
1980
1981
20000
15000
10000
5000
0
O N D J F M A M J J A S


1982
1983
1984
1985
DISCHARGE (cfs)
DISCHARGE (cfs)
20000
15000
10000
5000
0
O N D J F M A M J J A S


DISCHARGE (cfs)
1986
1987
1988
1989
20000
15000
10000
5000
0
O N D J F M A M J J A S


DISCHARGE (cfs)
1990
1991
1992
1993
20000
15000
10000
5000
0
O N D J F M A M J J A S