MONITORING THE AQUATIC FOOD BASE IN THE COLORADO RIVER, ARIZONA DURING FISCAL YEAR 2000

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ANNUAL PROGRESS REPORT

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APPENDICES

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ABSTRACT

Discharge from Glen Canyon Dam (GCD) strongly influences the lower trophic levels (phytobenthos and macroinvertebrates) of the aquatic ecosystem in Grand Canyon National Park. The aquatic food base in the Colorado River is affected by the duration and timing of low releases from GCD, as well as the range of daily fluctuations. The overall objectives of this project are to seasonally monitor the effect of discharge characteristics below GCD, under modified low fluctuating flow criteria, on the distribution, standing mass and composition of primary and secondary producers in the benthos and drift, and to examine the linkages between lower and higher trophic levels. This information is critical because the lower aquatic trophic levels provide essential resources to both aquatic and terrestrial components of the fluvial ecosystem in Grand Canyon National Park.

Jume 2000 water quality monitoring of the Colorado River below GCD is within the typical seasonal ranges for conductivity, pH and dissolved oxygen. River temperature increased from 10.7° to 18.8°C at Diamond Creek as a result of the steady 8,000 flows. We have insufficient baseline data to determine if nutrient concentrations are within typical ranges. Overall Oscillatoria and Cladophora biomass estimates were lower than in June 2000 in comparison to 1999. However, MAMB and detritus increased. Macroinvertebrate mass estimates were greater than the 1991 reference data in June 2000 at RKM 0.8, Lees Ferry cobble bar and 98.6 RKM 3.1, just above the LCR. All other macroinvertebrate estimates are equal to 1991 data at those sites. Macroinvertebrate composition and biomass was skewed by a large increase in snail number in Glen and Marble Canyons These patterns are very similar to those of 1991; low benthic biomass and taxa richness with high variability.

Dual stable isotope analysis in the regulated Colorado River through Grand Canyon National Park, USA, revealed a food web that varied both temporally and spatially through this arid biome. Down river enrichment of $\delta^{13}C$ data was detected across three trophic levels resulting in a sectioned food web. Both native and introduced sport fishes were dependent on the alien post- dam aquatic food base for sustenance. Fish trophic position is positively correlated with standard length indicating piscivory by larger fishes.

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Micheal Kersley, of NAU, provided us within near shore vegetation estimates through Grand Canyon. Owen Gorman and Dennis Stone of the U.S. Fish and Wildlife Service provided various fish specimens from Grand Canyon for our food web construction and Dave Speas of Arizona Game and Fish provided us with fish specimens from Glen Canyon for dual stable isotope analysis. Tom Maddox of the University of Georgia and George Koch of Northern Arizona University processed our dual stable isotope samples.

INTRODUCTION

Discharge from Glen Canyon Dam (GCD) strongly influences the lower trophic levels of the aquatic ecosystem in Grand Canyon National Park (Blinn et al. 1992, 1993, 1994, 1995a,b,1998, Shannon et al. 1996a). The aquatic food base in the Colorado River is affected by the duration and timing of low releases from GCD, as well as the range of daily fluctuations. The objectives of this project is to seasonally monitor the effects of discharge characteristics below GCD, under the Bureau of Reclamation's modified low fluctuating flow criteria, on the composition, distribution and standing mass of primary and secondary producers in the benthos and drift. This information is valuable because the lower aquatic trophic levels provide essential resources for both aquatic and terrestrial components of the fluvial ecosystem.

Grand Canyon National Park's Colorado River Management Plan (NPS 1989) states that its resource management goals are "to preserve the natural resources and environmental processes of the Colorado River corridor and the associated riparian and river environments.... (and) to protect and preserve the river corridor environment (NPS 1989:9). Among its objectives are:
1) "establish.....a long-term monitoring program to assess changes in the status of natural....resources. This program will require definition of present resource status (NPS 1989:10)"; and 2) "advocate and support operational objectives for the Glen Canyon Dam (GCD) which are most compatible with protection of the intrinsic resources of the Colorado River within Grand Canyon National Park (NPS 1989:10). The aquatic food base is an integral part of the natural resources in Grand Canyon National Park.

The Secretary of the Interior authorized implementation of modified low fluctuating flow criteria from Glen Canyon Dam (GCD) in August 1996 based on the recommendations set forth by the Environmental Impact Statement (1990-1992). These flows are designed to mitigate impacts of dam operations on downstream riverine resources. The flows consist of low-, medium-, and high-volume months, with low flows during the spring and late fall, moderate flows in May and September, and high flows during mid-summer and mid-winter. These flows have a maximum discharge of 566 $m^3 s^{-1}$, a reduced range of daily fluctuation, and reduced up- and down-ramping rates.

The Environmental Impact Statement (USBR,1995) on the operation of GCD identified the aquatic food base as an "indicator resource" and important habitat for wildlife. Wildlife linked directly to the aquatic food base include native and non-native fish, insectivorous birds and bats, reptiles and waterfowl. Indirect links to the aquatic food base include peregrine falcons feeding on waterfowl, swifts, swallows and bats, as well as king fishers, great blue herons, osprey and bald eagles preying on fish.

The National Park Service and the Bureau of Reclamation have both stated the importance of understanding the aquatic food base in the Colorado River below GCD through Grand Canyon National Park. This can only be accomplished through continued monitoring which will add to the established data base and provide the foundation for long-term adaptive management planning.

This report provides information on the following objectives;

Objective 1: Monitor the effects of modified low fluctuating flows from Glen Canyon Dam (GCD) on the benthic community in the Colorado River between Glen Canyon Dam and Diamond Creek.

Objective 2: Monitor the effects of modified low fluctuating flows from GCD on the organic drift in the Colorado River between GCD and Diamond Creek.

Objective 3. Assess the benthos and drift of major tributaries in Grand Canyon National Park.

Objective 4. Construction of an aquatic/riparian food web using stable isotope analysis.

Objective 5. Preliminary analyses on the use of Cladophora, Oscillatoria, and total plant carbon as indices for general community health of the regulated Colorado River below Glen Canyon Dam, Arizona.

METHODS

Objective 1: Monitor the effects of modified low fluctuating flows from Glen Canyon Dam (GCD) on the benthic community in the Colorado River between Glen Canyon Dam and Diamond Creek.

Biomass, composition, and habitat requirements of primary and secondary producers were monitored during the low to moderate flow months of March, June and October of each year within the mainstem of the Colorado River ($\underline{n}$ = 3 sampling trips per year). Seven sites will be monitored at the start and end of three major sections below GCD, including Glen, Marble, and Grand Canyons ($\underline{n}$ = 6 sites), and in Middle Granite Gorge ($\underline{n}$ = 1 site, Table 1).

These locations generally correspond with the monitoring sites used by Blinn et al. (1993, 1994, 1995b) and Shannon et al. (1996b) with the following modifications. The collection sites at the USGS gauging stations previously used by the NAU Aquatic Food Base Program will be dropped because they provide limited information (Blinn et al. 1992, 1993, 1994, Shannon et al. 1996b). These sites were originally selected for continuous flow across the channel and uniform depth in a pool above a rapid for gauging purposes, whereas pools below debris fans provide slow water velocities that collect fine organic and sediment particles. The previous gauging sites will be replaced with a site in the Middle Granite Gorge (RKM 203) to assess the food base of the largest mainstem humpback chub aggregation (Valdez and Ryel 1995). Sites were selected that will provide the most amount of information about the food base and for fish monitoring programs based on the past seven years of collecting in the Grand Canyon, and the allowed budget while decreasing river user days (Table 1).

Three habitat types (pools, riffles, and near shore habitats) were monitored at each site. Sampling was conducted along three transects 30 m apart in each habitat type. Petersen or Petit Ponar dredges will be used in the fine sediment and Hess substrate samplers will be utilized on cobble bar riffles. Pool habitats were sampled at five locations along the three transects; thalweg, <28 m^3/s, baseflow (142 m^3/s), lower-varial (~280 m^3/s), and upper-varial (~500 m^3/s). Cobble riffle collections were taken at the greatest depth possible with three paired samples along with lower and upper-varial samples.

Table 1. Collection Sites, River Kilometer (RKM), Elevation (m), Orientation, Reach Type, and Habitat in the Colorado River Below Glen Canyon Dam for Cobble Riffles, Pools and Tributaries within Glen, Marble and Grand Canyons, Arizona. Habitat describes area of collecting activity.

Name	RKM	Elevation	Orientation	Reach Type	Habitat
GLEN CANYON					
1. Glen Canyon Gauge	-23.2	953	Southwest	Narrow	Drift
2. Lees Ferry	0.0L	947	Southwest	Wide	Pool/Drift
Lees Ferry Cobble	0.8R				Cobble
Paria River	1.0R				Tributary
MARBLE CANYON					
3. Two-mile Wash	2.9R	876	South	Wide	Drift
Two-mile Cobble	3.1R				Cobble
Two-mile Pool	3.1L				Pool
Cathedral Island	4.0L				Shore
Vasey's Paradise	50.8R				Tributary
4. 60 Mile Gauge	95.7L	831	South	Wide	Pool
Gauge above LCR	98.4L				Shore/Drift
LCR Island	98.6C				Cobble
LCR	98.6L	826			Tributary
GRAND CANYON					
Lava Chuar	104.0R	815			Tributary
5. Tanner Canyon	108.8R	808	Southwest	Wide	Pool/Shore
Tanner Cobble	109.6L				Cobble/Drift
Bright Angel Creek	140.8R	739			Tributary
6. 127 Mile Rapid	202.9R	616	Northeast	Narrow	Cobble/Drift
Middle Granite Gorge	203.2L				Pool/Shore
Tapeats Creek	214.8R	610			Tributary
Kanab Creek	231.2R	572			Tributary
Havasu Creek	249.6L	544			Tributary
7. Spring Canyon	326.4R	454	South	Wide	Pool/Shore
205 Mile Rapid	328.8R				Cobble/Drift
Spring Canyon Creek	327.2L	454			Tributary
Diamond Creek	361.6L	424			Tributary

Samples were processed live within 48 h and sorted into five biotic categories: C. glomerata, Oscillatoria spp., detritus, miscellaneous algae and macrophytes, and macroinvertebrates which were numerated into Gammarus lacustris, chironomid larvae, simuliid larvae, and miscellaneous invertebrates. Miscellaneous invertebrates included lumbriculids, tubificids, physids, trichopterans, terrestrial insects and unidentifiable animals. Detritus was composed of both autochthonous (algal/bryophyte/macrophyte fragments) and allochthonous (tributary upland and riparian vegetation) flotsam. Each biotic category was oven-dried at 60°C and weighed to determine dry weight biomass. Samples were then ashed (500°C, 1 h), and reweighed for ash free dry mass estimates. Preservatives alter biomass estimates and accurate dry weights are required for building an energetics model. Adult and pharate specimens will be collected with sweep nets, white and UV lights, spot samples, and Thienemann collections for taxonomic verification. Specimens are housed at NAU and logged according to NPS requirements.

Water temperature, dissolved oxygen, pH, specific conductance, substratum type, microhabitat conditions, Secchi depth, water velocity or stage, depth, date, site, and time of day will be recorded at each sample site. Depth integrated light intensity data loggers will be deployed at five collection sites. These sites corresponded with those initiated in the FY97 Steady High Flow Program. Benthic biomass estimates were compared between clear and turbid water sites with light as a predictor variable. The protocol outlined above will help depict the relationship between benthic biomass, discharge and light variability.

Nutrient levels were monitored at each collection site. The following nutrients were analyzed; ammonia, phosphate and nitrate-nitrogen. Triplicate samples were collected, acidified and analyzed within one month of collecting on a Technicon Auto Analyzer II™ after digestion.

Shoreline habitats were sampled for invertebrates in emergent vegetation, fine sediments and tychoplankton. These nearshore habitats have become quite extensive throughout the river corridor due to steady, low fluctuating flows and preliminary observations indicate they provide an important habitat for fish; similar to return current channels, but with greater stability. These low velocity near-shore habitats, composed primarily of Equisetum (horsetails) may provide similar habitat to backwaters, but are more abundant and readily available for invertebrate and small fish colonization. Presently, only minimal data exists for these abundant shoreline habitats. The following collections will be made from kayaks in an effort to reduce damage to this fragile and potentially critical habitat.

1)Triplicate harvests of shoreline emergent vegetation were taken in circular stovepipe samplers (0.02 m^2 area) just above the sediment, and screened as it's pulled through the water column in an effort to capture macroinvertebrates associated with the vegetation.

2)Triplicate plankton collections (156 μm,) were taken along the outer interface of shoreline vegetation. Samples were preserved in 70% EtOH and sorted in the lab with a dissecting scope into the following categories: Copepoda (Calanoida, Cyclopoida, Harpacticoida), Cladocera, Ostracoda, and miscellaneous zooplankton which include small chironomids, Gammarus lacustris, planaria, hydra, etc. Large samples were split with either 1 ml, 5 ml or 10 ml sub-samples sorted from a 100 ml dilution. Zooplankton densities of each category, general condition, reproductive state and presence of nauplii were recorded. Samples were processed for dry mass estimates and converted to ash-free dry mass using regression equations (Shannon et al, 1996b). The remaining organic material was filtered through a 1 mm sieve to remove CPOM and then filtered onto glass fiber filter (Whatman® GF/A, μm mesh) with a Millipore Swinex® system. These filters were dried at 60°C and combusted for 1 h at 500° C. Volumetric estimates (mass/m^3/s) were estimated from hand-pumping 15L of river water at each transect.

3)Triplicate sediment samples were taken with a Petite Ponar (0.02 m^2 area) and sieved for benthic macroinvertebrates. Macroinvertebrates were processed with the same protocol as emergent vegetation collections. Sediment was dried and sieved for clast fractioning.

4) Six minnow traps (0.48 m x 0.22 m) were set at an adjacent near-shore habitat for 12 h overnight to determine if fish utilize the habitat. Size, weight, total length, and standard length of each fish species were determined. General condition factors were determined for each fish population with the following equation:

$$K = \frac{W \cdot X}{L^3}$$

where W = weight in grams, L = total length in millimeters and constant $X = 10^5$ (Moyle and Cech, 1988). This information will determine the importance of the shoreline habitat for fish as a food resource and refuge. Appropriate permits were obtained from Arizona Game and Fish and US Fish and Wildlife Service.

Multivariate statistical analysis (MANOVA) using abiotic predictor variables and biotic response variables were used to determine significant patterns in composition, distribution and biomass of the benthic community. Also, relationships between AFDM of biotic components and the physical, chemical, spatial and temporal variables were examined with multivariate canonical correspondence analysis (CANOCO, Ter

Braak 1992, Palmer 1993). The SYSTAT computer software package (Version 5.1, Wilkenson 1989) and/or the NAU mainframe was used for all calculations.

Objective 2: Monitor the effects of modified low fluctuating flows from GCD on the organic drift in the Colorado River between GCD and Diamond Creek.

Drift was collected on each river trip from sites at or near the above sampling stations (Table 1). Two components of stream drift were assessed:

1) Coarse Particulate Organic Matter (CPOM).

Near-shore surface drift samples (0-0.5 m deep) were collected at each pool site for CPOM during each collection trip. Collections were taken in triplicate between 1000 h and 1500 h at each site to establish the affects of discharge on drift. Collections were made with a circular tow net (48 cm diameter opening with 500 μm mesh) held in place behind a moored pontoon raft or secured to the river bank. Samples were sorted and processed live for biota as outlined for the shoreline emergent vegetation in Objective 1. Current velocity was measured with a Marsh-McBirney electronic flow meter and collection duration were measured for volumetric calculations (mass/m^3/s).

2) Fine Particulate Organic Matter (FPOM). FPOM drift was collected at the same time and with the same general protocol as CPOM ($\underline{n} = 3$). The net has a 30 cm diameter opening with 153 μm mesh. Samples were preserved in 70% EtOH and sorted in the lab with a dissecting scope according to procedures outlined in Objective 1 for plankton tows near shoreline vegetation.

Multivariate statistical analysis as outlined in Objective 1 was employed to determine significant patterns in the composition, distribution and biomass of drift along the river corridor.

OBJECTIVE 3. Assess the benthos and drift of major tributaries in Grand Canyon National Park.

Benthic Collections: Aquatic macroinvertebrates, phytobenthos and detritus were collected during January 1999 from 11 major tributaries of the Colorado River through Grand Canyon. At each tributary, two Hess samples were taken along three transects, 30 m apart ($\underline{n} = 6$). All tributary transects were located above the influence of the mainstem ($\geq$2,265 m^3/s), starting at least 10 m above the mesquite line at the old high water zone. Biomass samples were sorted into the five biotic categories as outline for benthic collections (Objective 1) in the Colorado River for comparison with benthos in the mainstem.

Taxonomic samples were collected, preserved in 70% alcohol, identified to the lowest taxonomic level possible, counted, and measured for total length. Water temperature, dissolved oxygen (DO), pH, specific conductance, and time of day were measured at each sampling site. Current velocity and depth was measured at each sample location.

Drift Collections: Both CPOM (n = 3) and FPOM (n = 3) collections were made following the same protocol as used in the mainstem (Objective 2). Tributary discharge were estimated by measuring the channel geometry and water velocity along a transect perpendicular to flow.

Past collections in the tributaries in Grand Canyon were made bimonthly in 1991 and annually in June 1992, 1993, 1994, 1996, and 1997 by the NAU Aquatic Food Base Monitoring Program. Shannon et al. (1996b) reported the month of January had the highest biomass and biodiversity which supported findings by Hofknecht (1981). This may result from low hydrologic disturbance during this period. June tributary discharge changes were dependant on the timing and amount of snow-melt. Changing the collection period is not only sound science but is also wise from a river ethic standpoint. June is the peak commercial river running season and all of the perennial streams in Grand Canyon are attraction sites.

This work is proposed to provide additional abiotic and biotic information on 11 major tributaries of the Colorado River through Grand Canyon National Park. These tributaries vary widely in physicochemical characteristics and yield a variety of different biotic communities, all of which may potentially invade the mainstem under favorable conditions (Shannon et al. 1996b). The information collected in this study will help characterize the seasonal abiotic conditions of tributaries in the Canyon and will provide information on their suitability as a habitat for native and exotic fishes. It will also provide knowledge on the diversity and biomass of macroinvertebrates that serve as food for native and exotic fishes in Grand Canyon. Some tributaries are highly susceptible to flash floods and periods of reduced or no flow which are common to many southwestern desert streams, while other spring-fed tributaries have more stable flow conditions. A comparison of these widely disparate systems will not only provide distributional information on aquatic macroinvertebrates within the Grand Canyon but will offer valuable information on abiotic variables that might determine their distribution.

Monitoring these tributaries is also a valuable management tool for assessing biota that are sensitive to changes within a given watershed. Therefore changes in land practices both within and outside the boundaries of Grand Canyon National Park may be monitored. Management decisions such as seasonally adjusted steady flows, as described in the U.S. Fish and Wildlife Service Biological Opinion, or the installation of multiple withdrawal structures on GCD will have an impact on the aquatic food base in the Colorado River. Both of these management options will have an influence on at least the temperature range within the mainstem. Recruitment of aquatic macroinvertebrates into the mainstem will initially be from the tributaries. Understanding these tributaries may help resource managers determine reasonable ranges for important variables such as seasonal water temperature and discharge regimes.

OBJECTIVE 4. Construction of an aquatic/riparian food web using stable isotope analysis.

A valuable management tool, for critical ecosystem level decisions, is the development of a comprehensive food web. To date, a data based food web has not been constructed for the Colorado River ecosystem through the Grand Canyon aquatic/riparian community. Blinn et al. (1994) presented an aquatic energetics model for the tailwaters, Angradi (1994) developed a dual isotope model for Glen and Marble Canyons, and the NAU Aquatic Food Base Program used dual stable isotopes to track the origin and composition of organic drift (Shannon et al. 1996b). The above data sets were used to further expand our understanding of a system-wide food web with an emphasis on native fish food habitats. Schell and Ziemann (1993) used $\delta^{13}C$ natural isotope abundances to derive a food web in the Arctic coastal plain, which is similar to the Colorado River ecosystem in terms of simplicity.

Food web construction using stable isotopes has the advantage of defining the source of organic drift, which is visually uniform and a critical carbon source in lotic ecosystems. Stable isotope analysis also depicts what is assimilated by an organism, which eliminates "last meal" bias, and the complication of digestion rates that gut-analysis alone can lead to (Rosenfield and Roff 1992).

All potential major carbon sources within the aquatic/riparian communities of the Colorado River ecosystem were collected and analyzed for $\delta^{13}C$, $\delta^{15}N$, and $\delta^{33}S$ natural isotopic ratios. Triplicate samples of major plant and animal components of the riparian and upland vegetation, the benthic community in the river, and plankton from Lake Powell were taken throughout the Colorado River ecosystem. Fish and bird samples were obtained from incidental deaths from the projects monitoring these animals. The technique does not require the release of radioactive tracers to follow the path of ^{13}C, ^{15}N and ^{33}S through a food web. Samples were air-dried immediately after collection in the field or laboratory and ground to a powder (<0.05 mm particle size) with a Whir-L-Bug™. Samples were analyzed with a mass-spectrophotometer. We obtained muscle plugs or fin clips from endangered fish for non-lethal data in cooperation with the fish monitoring projects.

Establishing Reference Data

Although the management objective for the aquatic food base states that it should be "maintained or enhanced" the exact levels were not defined. After analysis of our data from 30-plus river trips and 80-plus collections in the Lees Ferry area we have concluded that the data defining the aquatic food base in 1991 was the most degraded. It was during this time period of the GCES/ BOR sand movement research flows that included two 3-d steady 142 $m^3 \cdot s^{-1}$ flows each month, highly variable ramping rates and flows up to 934 $m^3 \cdot s^{-1}$. We have since learned that these flow regimes are the worst possible for the aquatic food base. It was also during this time period that the trout in Glen Canyon were in poor condition and native fish down river were also in poor health from an increase in parasitism. Therefore a reference data set has been developed for both pool and cobble habitats for each site which should be maintained or enhanced.

A reference data set was developed by using the mean biomass for each bi-monthly collection trip in 1991 for Cladophora, Oscillatoria, detritus and macroinvertebrates at each site. Miscellaneous algae, macrophytes and bryophytes or MAMB were not a separate category in 1991 so the means from the 1992 seasonal collections from each site were used. This procedure results in six data points being used at each site for each biotic category. MANOVA was then run for each monitoring collection trip against the 1991 reference data.

Results of the MANOVA for each biotic factor or univariate probability would indicate if the biotic resource was enhanced significantly, maintained or nonsignificant change and if the biotic resource was degraded significantly. This determination was made after comparing the mean data for the monitoring trip and the 1991 reference data. **An increase in biomass of the biotic categories during monitoring would indicate an enhanced resource. Oscillatoria is the only biotic factor that is does not enhance the aquatic food base with increasing biomass, therefore reduced Oscillatoria biomass over 1991 reference data would be an enhanced resource.**

RESULTS

Objective 1: Monitor the effects of modified low fluctuating flows from Glen Canyon Dam (GCD) on the benthic community in the Colorado River between Glen Canyon Dam and Diamond Creek.

June 2000 water quality monitoring of the Colorado River below GCD is within the typical seasonal ranges for conductivity, pH and dissolved oxygen. River temperature increased from 10.7° to 18.8°C at Diamond Creek as a result of the steady 8,000 flows. We have insufficient baseline data to determine if nutrient concentrations are within typical ranges.

June 2000 primary producer biomass estimates indicated high variability in Cladophora and MAMB categories (Table 2). With a system wide increase in MAMB and decrease in Cladophora. Oscillatoria decreased in biomass while detritus increased.

Macroinvertebrate mass estimates were greater than the 1991 reference data in June 2000 at RKM 0.8, Lees Ferry cobble bar and 98.6 RKM 3.1, just above the LCR. All other macroinvertebrate estimates are equal to 1991 data at those sites.

Macroinvertebrate composition and biomass was skewed by a large increase in snail number in Glen and Marble Canyons These patterns are very similar to those of 1991; low benthic biomass and taxa richness with high variability.

Comparing June 1996 benthic biomass estimates to the 1991 reference data showed the biotic categories to either be maintained or enhanced (Table 3). This collection trip generally had the highest biomass estimates documented through the study site and macroinvertebrate biomass was enhanced at all cobble sites. We can attribute this pattern to consistent flows with little daily fluctuations and possibly a result of clear water conditions from scour after the 1996 Spike Flow. These results indicate that if during normal dam operations, including management or research flow scenerios, the biotic factors comprising the food base were degraded at enough to warrant remediation then we recommend steady flows of at least 400 $m^3 \cdot s^{-1}$ for several months.

Table 2. Comparison of benthic biomass from 1991 reference data to monitoring data collected from June 1999 and June 2000 at nine sites in the Colorado River through Grand Canyon. Results of MANOVA are depicted as follows for each biotic factor; (+) resource enhanced significantly, (=) resource maintained, nonsignificant change and (-) resource degraded significantly. Miscellaneous algae, macrophytes and bryophytes are depicted by MAMB. Pool habitats are indicated by P and cobble habitats by C. **Oscillatoria is the only biotic factor that does not enhance the aquatic food base with increasing biomass, therefore a + means reduced Oscillatoria biomass over 1991 reference data.**

Site/Date	Cladophora	Oscillatoria	Detritus	MAMB	Macroinvertebrates
June 1999					
Rkm 0.0 P	–	+	=	=	=
Rkm 0.8 C	+	=	+	–	=
Rkm 3.1 C	+	=	+	+	+
Rkm 95.7 P	–	+	+	=	=
Rkm 98.6 C	=	=	+	=	=
Rkm 108.8 P	+	+	+	+	=
Rkm 109.6 C	=	–	=	+	=
Rkm 326.4 P	=	+	+	=	=
Rkm 328.8 C	+	=	=	=	=
June 2000					
Rkm 0.0 P	–	+	=	=	=
Rkm 0.8 C	+	=	+	+	+
Rkm 3.1 C	=	=	+	+	=
Rkm 95.7 P	–	+	+	=	=
Rkm 98.6 C	=	=	+	+	+
Rkm 108.8 P	=	+	=	=	=
Rkm 109.6 C	-	–	=	=	=
Rkm 326.4 P	=	+	+	=	=
Rkm 328.8 C	+	-	+	=	=

Table 3. Comparison of benthic biomass from 1991 reference data to data collected in June 1996 at nine sites in the Colorado River through Grand Canyon. **This analysis demonstrates how reduced daily flow fluctuations can enhance the aquatic food base.** Results of MANOVA are depicted as follows for each biotic factor; (+) resource enhanced significantly, (=) resource maintained, nonsignificant change and (-) resource degraded significantly. Miscellaneous algae, macrophytes and bryophytes are depicted by MAMB. Pool habitats are indicated by P and cobble habitats by C. **Oscillatoria is the only biotic factor that does not enhance the aquatic food base with increasing biomass, therefore a + means reduced Oscillatoria biomass over 1991 reference data.**

Site/Date	Cladophora	Oscillatoria	Detritus	MAMB	Macroinvertebrates
June 1996					
Rkm 0.0 P	-	=	=	-	=
Rkm 0.8 C	=	=	=	=	+
Rkm 3.1 C	=	=	+	+	+
Rkm 95.7 P	=	=	=	=	=
Rkm 98.6 C	=	=	+	+	+
Rkm 108.8 P	=	=	=	=	=
Rkm 109.6 C	=	=	+	+	+
Rkm 326.4 P	=	+	=	=	=
Rkm 328.8 C	=	=	+	=	+

Objective 2: Monitor the effects of modified low fluctuating flows from GCD on the organic drift in the Colorado River between GCD and Diamond Creek.

Organic drift in the Colorado River below Glen Canyon Dam reflects both the productivity of the benthos and scouring effects of daily fluctuating flows (Shannon et al. 1996; A202-A320). In June 2000 CPOM drift was very similar to June 1999, even though the flows were steady 8,000 cfs. These were not high estimates and maybe because of the spring 30,000 cfs "spike" as part of the summer low flow experiment, scouring the benthos.

Objective 3. Assess the benthos and drift of major tributaries in Grand Canyon National Park.

We collected in January 1999 and 2000. This dataset will be analyzed with the summary report all tributary data collected during the past 20 years. This report is scheduled for completion in December 2001.

Objective 4. Construction of an aquatic/riparian food web using stable isotope analysis.

Food Web Design

Due to the spatial variability in $\delta^{13}C$ throughout the study area we constructed a "sectioned food web" for Colorado River below GCD (Fig. 1). By sectioned we mean the food web is divided into two regions depicting $\delta^{13}C$ and $\delta^{15}N$ data within the first 100 km and >100 km down stream from GCD. These distances were selected to be above and below the Little Colorado River which has the greatest drainage area of all Grand Canyon tributaries (69,790 km^2)

Values for $\delta^{13}C$ revealed the variability in carbon source for the two regions of the sectioned food web (Fig. 1). Aquatic macrophyte and herbaceous riparian vegetation $\delta^{13}C$ values were more enriched than algae, 1.2 and 2.3 ‰, respectively, in the < 100 km food web. Woody riparian vegetation $\delta^{13}C$ was enriched 3.5 ‰ in comparison to algae and probably contributed little to the < 100 km food web. Algal $\delta^{13}C$ data are sectioned by 5.1‰ between the two regions and macroinvertebrates by 2.7‰, with the down river region more enriched. This sectioned food web (Fig. 1) is not the definitive food web for the entire study site, but is meant to depict two possible carbon path-ways and trophic positions by region. Therefore inclusion or exclusion of sites for specific areas of the study site, such as the critical habitat reach for humpback chub near the Little Colorado River, need to be statistcally evaluated before conclusions can be drawn about the food web of that reach.

Trophic position of fish was significantly ($p<0.01$) and positively related to size class, indicating a change in feeding behavior between size classes for all fish taxa (Fig. 2). $\delta^{15}N$ values suggested that smaller size classes fed upon aquatic macroinvertebrates while larger fish were predaceous as indicated by a 2 ‰ depletion across all four size classes. This relationship $\delta^{15}N$ depletion held for all species of fish collected ($f=0.1$; $n=144$; $p=0.8$) For example, the native speckled dace (Rhinichthys osculus) reached a maximum size within the 50-99 mm size class and therefore would be analyzed with young-of-the-year fish in other larger fish taxa. Humpback chub $\delta 13C$ and $\delta 15N$ data from muscle plugs and fin clips did not differ signficantly so were combined for analysis ($n=27$; $p=0.4$). McCarthy and Waldron 2000 also reported that adipose fin and white muscle δ13C and δ15N measurement were statistically insignificant for the brown trout, Salmo trutta.

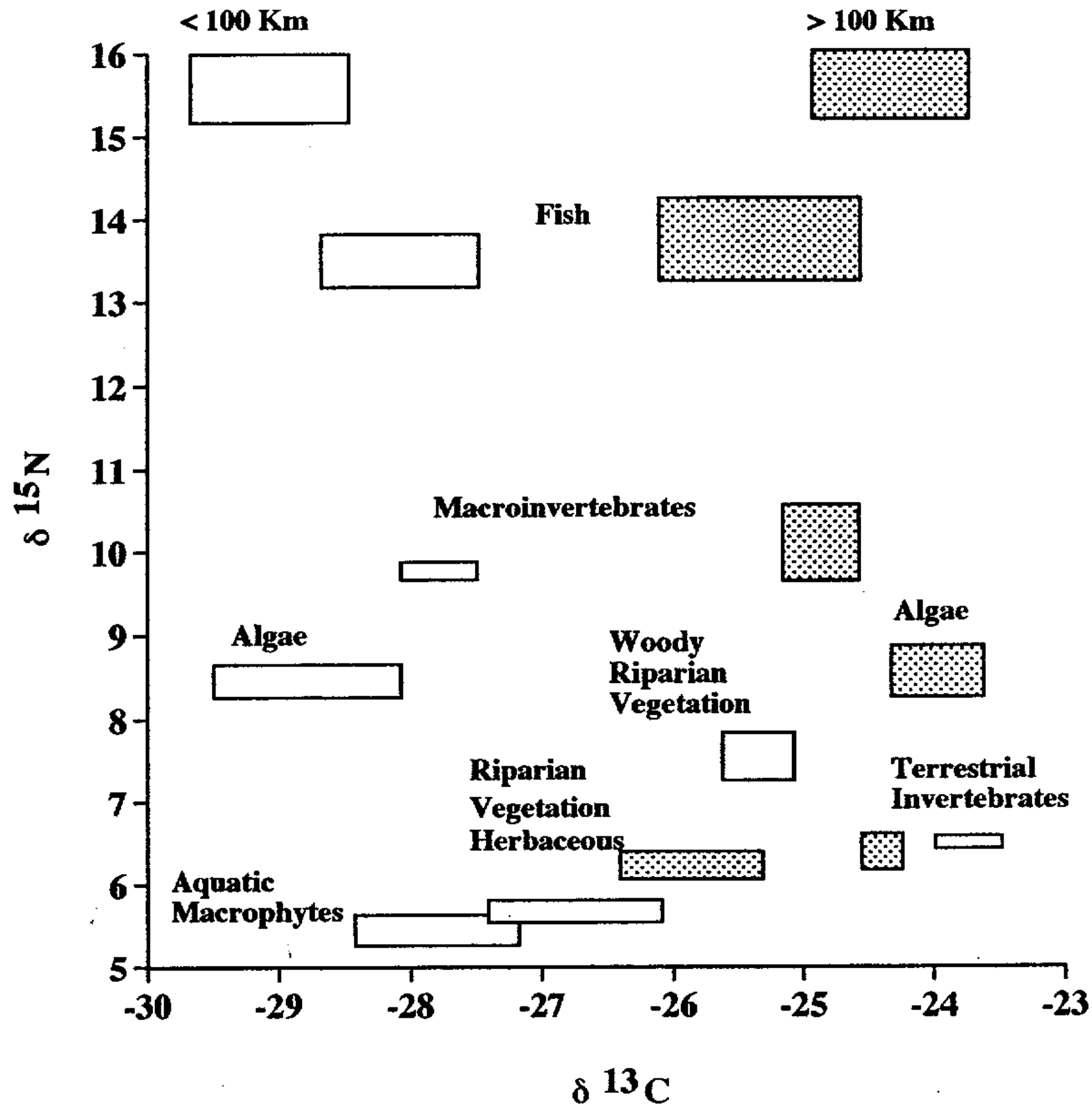

Figure 1. Dual isotope plot ($\delta^{13}C$ and $\delta^{15}N$) for the sectioned food web of the Colorado River through Grand Canyon National Park. The center of each box is the average $\delta^{13}C$ and $\delta^{15}N$ value and box size represents the standard error. Clear boxes indicate data collected in the upper 100 km, or sites 1-4 (Fig. 1). Grey boxes indicate data collected from sites in the lower100 km, or sites 5-7 (Fig. 1). Fish data represent two size classes; 1= 50-149 mm and 2 = 150-250 mm.

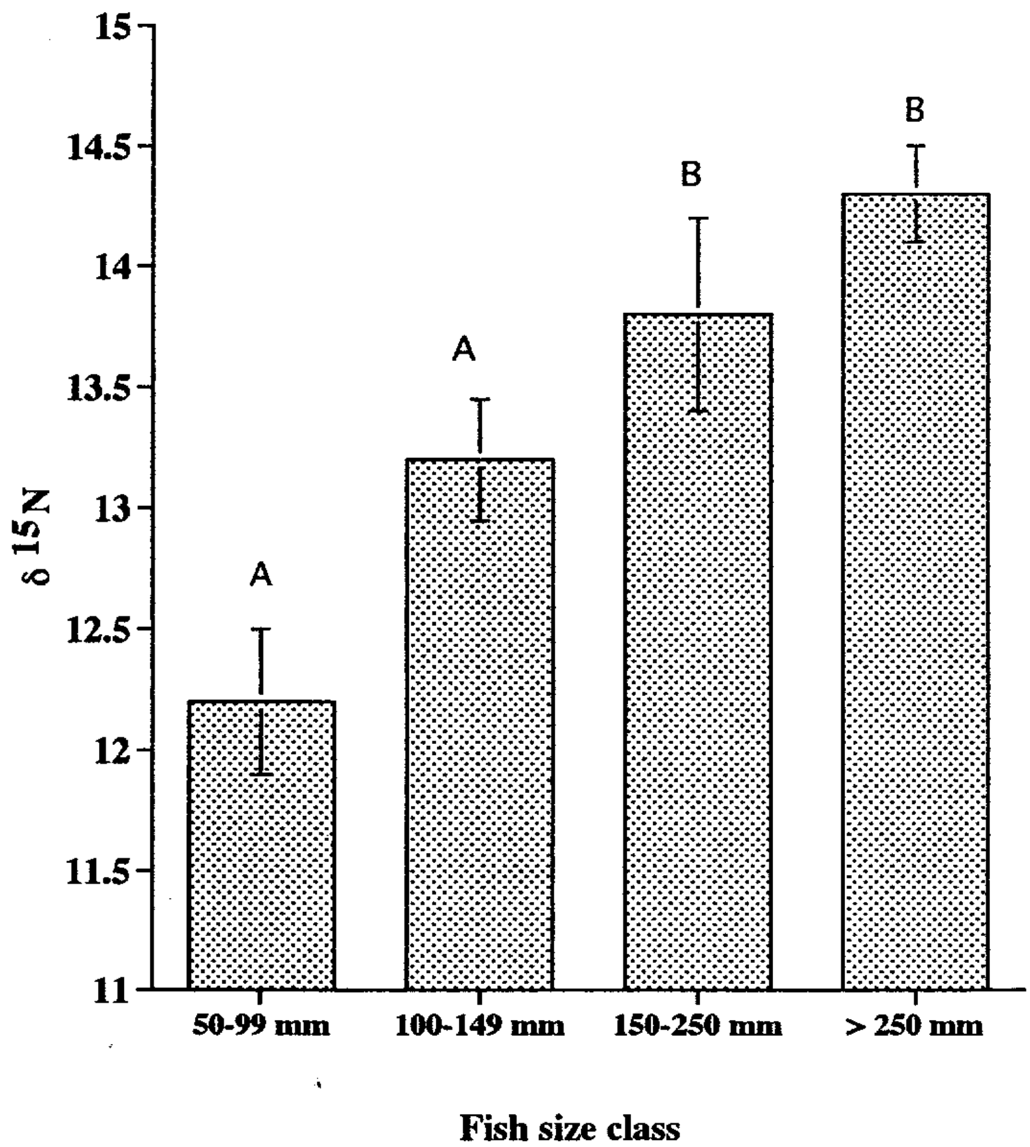

Figure 2. Fish size class and average $\delta^{15}N$ values (±sd) from eight fish taxa collected from Colorado River below Glen Canyon Dam. Letters indicate significant differences between size classes ($p<0.03$).

Objective 5. Preliminary analyses on the use of Cladophora, Oscillatoria, and total plant carbon as indices for general community health of the regulated Colorado River below Glen Canyon Dam, Arizona.

INTRODUCTION

Cladophora glomerata serves as a keystone species in the food web in the tailwaters below Glen Canyon Dam (GCD). Previous studies on the tailwaters below GCD have repeatedly shown that C. glomerata is the preferred habitat for the alien macroinvertebrate assemblage in the regulated river in comparison to other available habitats including other filamentous algae and cyanobacteria, aquatic bryophytes, and macrophytes (Blinn and Cole, 1991, Blinn et al. 1992, Angradi 1994, Shannon et al. 1994, Shaver et al. 1997, Stevens et al. 1997, Ayers and McKinney 1998, Benenati 1998, Shannon et al. 1998, Benenati et al. 2000). The highly branched filaments of C. glomerata provide a large surface area for the colonization of epiphytes as well as habitat for invertebrate reproduction and a refugium from predators (Stevenson and Stoermer 1982, Leskinen and Hallfors 1990, Dodds and Gudder 1992, Hardwick et al. 1992, Blinn et al. 1998).

Due to the critical role of C. glomerata in the food web of the regulated Colorado River below GCD (see Blinn et al. 2000), we propose that this green filamentous alga be considered as a potential index for community health in the Colorado River throughout Grand Canyon. In order to develop an index, based on C. glomerata ash-free dry mass (AFDM), we compiled and analyzed phytobenthic data collected from cobbles from 1991 through 1996 by the Northern Arizona University Aquatic Food Base Program. The relationships between C. glomerata and total invertebrate biomasses and Oscillatoria and total invertebrate biomasses were determined. The relationship between total plant carbon biomass (autochthonous and allochthonous) and invertebrate biomass was also examined.

METHODS

Collections: The data presented in this report result from 6 years of effort between 1991 and 1996 by the Northern Arizona University Aquatic Food Base Project (Blinn et al. 1992, Blinn et al. 1993, Blinn et al. 1994, Blinn et al. 1995a, Shannon et al. 1996, Shannon et al. 1997). The data set contained 1,122 data points starting in January 1991 and continued through 1996. Although this project has had various objectives over the last decade, many of the sampling sites and methodologies have remained constant throughout. The data used for these analyses have been taken from the data base and represent common sites and common collecting methods throughout the period, although there may not be an even representation of sites or an even number of sample periods among years.

Between 1 and 6 sample raft trips were made down the Colorado River each year. The number of trips per year reflected the available funding for food base research and the project objectives at the time. A summary of the number of trips for each calendar year is given in Table 1. Samples were taken from cobble bars at 11 different sites between Lees Ferry (RK 0) and Diamond Creek (RK 360). Sites were located along the length of the river to determine the influence of distance from GCD (RK -26.0) and the influence of tributaries on the aquatic benthos. A list of sample sites and locations is given in Table 2.

All samples were taken with a modified Hess substrate sampler on cobble substrates. Samples were collected by stirring the benthos with a metal trowel for 30 s. Benthos dislodged from the substrate was flushed into the collection net portion of the sampler and transferred to plastic containers for further processing. Samples were taken from the permanently wetted area of the cobble bar as opposed to the varial zone which is subject to regular de-watering due to fluctuating flows from GCD. Previous studies have shown that the varial zone has a different benthic community composition and limited standing mass compared to the permanently wetted area (Blinn et al. 1995b, Shaver et al. 1997, Benenati et al. 1998). The cobble bar at each site was divided into 3 transects approximately 30 m apart. Two randomly spaced samples were taken at each transect to give a total of 6 samples for each site. Collections in 1991 have only 3 samples per cobble bar since half the samples were used for taxonomic purposes during that period.

All samples were sorted within 48 h of collection. Samples were originally sorted into 11 different biotic categories as described by Blinn et al. (1995b). Samples were dried to a constant weight at 60°C then weighed and ashed for 1 h at 500°C to estimate ash-free dry mass (AFDM). During the later part of the study, AFDM was estimated from dry weight using regression equations for each benthic category. For the purpose of these analyses, the original 11 categories were reduced to 4 broad categories: total macroinvertebrates, C. glomerata, Oscillatoria spp. crust,and detritus. Some analyses compared total primary carbon to other categories. Total primary carbon is composed of all algae and detrital categories in the phytobenthic community. All analyses are based on AFDM m^{-2} standing mass of each category.

Statistical methods: We used logistic linear regressions to test the hypothesis that specific categories of primary carbon (C. glomerata, Oscillatoria spp., detritus, total carbon, or a ratio of Oscillatoria standing mass to C. glomerata standing mass) would be good predictors of invertebrate standing mass in the Colorado River. Regression models were tested with one predictor at a time rather than in multiple regression models since the objective of this research is to provide information that will help simplify field collection and processing methods rather than build predictive models from multiple predictors. Each Hess sample represents a single sample and no attempt has been made to look at relationships within a specific site, although the relationship of primary carbon at the Lees Ferry site was compared to the relationship at all other sites to determine the effect of constantly clear water with sites subject to occasional high suspended sediment concentrations.

All data were transformed using a 4th root transformation to improve homoscedascity (Sokal and Rolf, 1992). Data were further refined by removing all samples with '0' values for predictor values. For each analysis we attempted to improve the fit of the linear equation by removing outliers from the analysis. Outlier points were identified using a Cooks-D coefficient (Sokal and Rolf, 1992). Data were analyzed using JMP IN® Ver. 3.2.1 statistical software (SAS Institute, 1989).

RESULTS AND DISCUSSION

Our preliminary analyses indicated that C. glomerata has a strong potential of serving as a functional index for community health in the regulated Colorado River below GCD. This is based on the strong positive relationship between C. glomerata AFDM and total invertebrate AFDM ($R^2 = 0.415$, $p < 0.001$) in the tailwaters of GCD (Fig. 1). Therefore, since invertebrates make up a large proportion of the diet of native and nonnative fish (Valdez and Ryel 1995, McKinney and Persons 1999) in the tailwaters of GCD, this index should provide good insight into the overall health of the Colorado River system. In fact, the relationship between C. glomerata and invertebrate biomass was slightly stronger ($R^2 = 0.390$, $p < 0.001$) than that for total carbon (all algae, detritus, and other plant material) in the regulated Colorado River (Fig. 2).

In contrast, there was no relationship between Oscillatoria spp. AFDM, and total invertebrate AFDM ($R^2 = 0.009$; Fig. 3). This is not surprising since Oscillatoria spp. only become numerically important in the regulated Colorado River in highly stressed regions of the tailwaters such as those habitats in high varial zones and under conditions of high suspended sediment (Shaver et al. 1997, Benenati et al. 1998). Furthermore, C. glomerata communities contribute an order of magnitude more potential energy to the ecosystem than Oscillatoria spp. mats (Shaver et al. 1997).

In addition to our original scope of work, we are attempting to link food base variables (primary carbon and invertebrates) to the next highest trophic level (fish). Arizona Game and Fish Department (AGFD) maintains a large data base from the Lees Ferry trout management program that spans the same time frame as the food base data. We believe that the AGFD trout fishery data represent the most complete data set with a common method throughout any of the Grand Canyon fisheries research projects. As such, it represents our best opportunity to link food resources to fisheries with an existing data set. We are cooperating with AGFD through Dave Speas and Bill Persons to acquire and correlate these data with food base data. To date, NAU is in receipt of a mean data set for Lees Ferry trout from 1991 through 1998. Initial attempts have been made to correlate food standing mass and fish condition (Kn) or catch per unit effort (CPUE). These methods need to be refined and are problematical given the location and timing of the two sampling regimes. We will continue to analyze these data in cooperation with AGFD in the upcoming year.

Other workers have found a strong relationship between organic carbon standing crop and invertebrate abundance, biomass, and production in streams (Wallace et al. 1999). Filbert and Hawkins (1995) reported a strong relationship between drifting mass of invertebrates and condition of rainbow trout in the Green River, Wyoming. In fact, Wallace and Webster (1996) proposed that "effective fisheries management must account for fish-invertebrate linkages and macroinvertebrate linkages with resources and habitats".

These same relationships apply to linkages between algae and terrestrial plant carbon mass (standing organic plant carbon) and macroinvertebrates (Winterbourn 1990). Therefore, from a bottom-up perspective, it may be feasible to use either C. glomerata mass and/or standing carbon mass as a simple, but functional index, for ecosystem health in the regulated Colorado River. Scheduled collections of plant organic carbon may be implemented into the long-term monitoring program to determine general condition of the Colorado River community below GCD.

We plan to refine the C. glomerata total plant carbon community index over the next six months. Our goal is to try to determine relationships between fish biomass and/or density with C. glomerata and/or total plant carbon biomass. Results from these analyses will be presented in the final report.

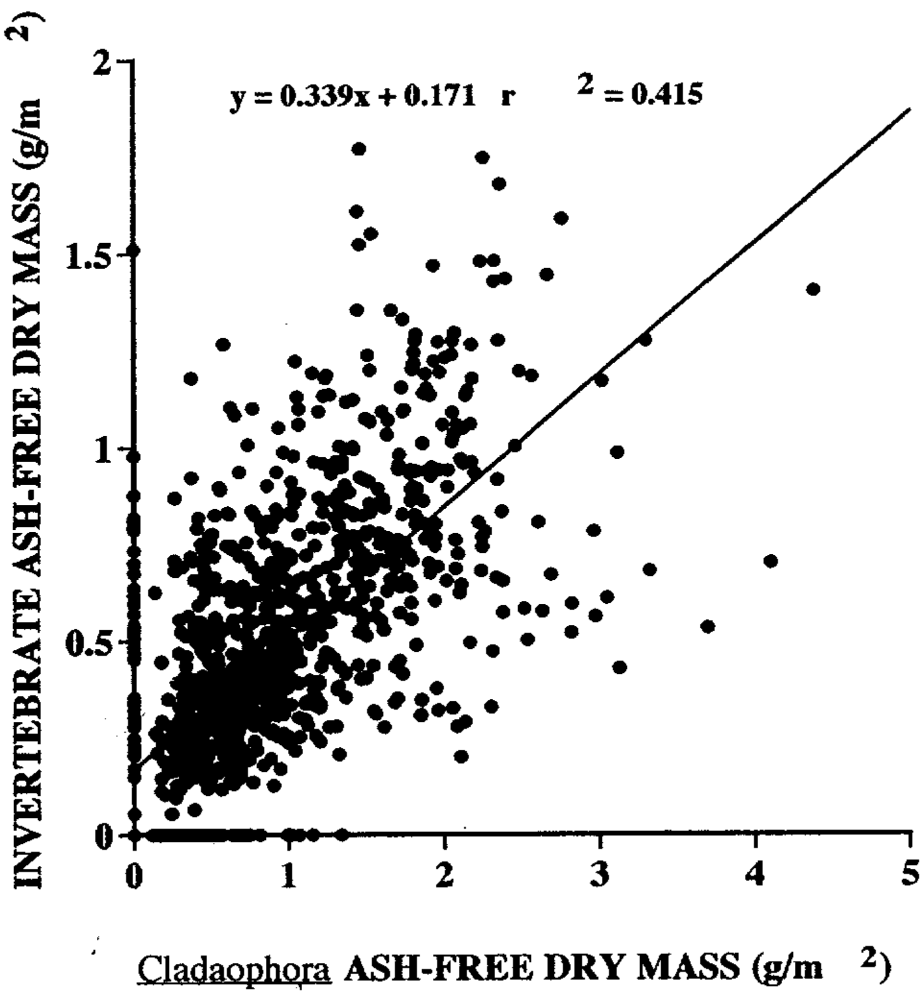

Figure 1. Relationship between Cladophora glomerata biomass and total invertebrate biomass in the Colorado River below Glen Canyon Dam, AZ.

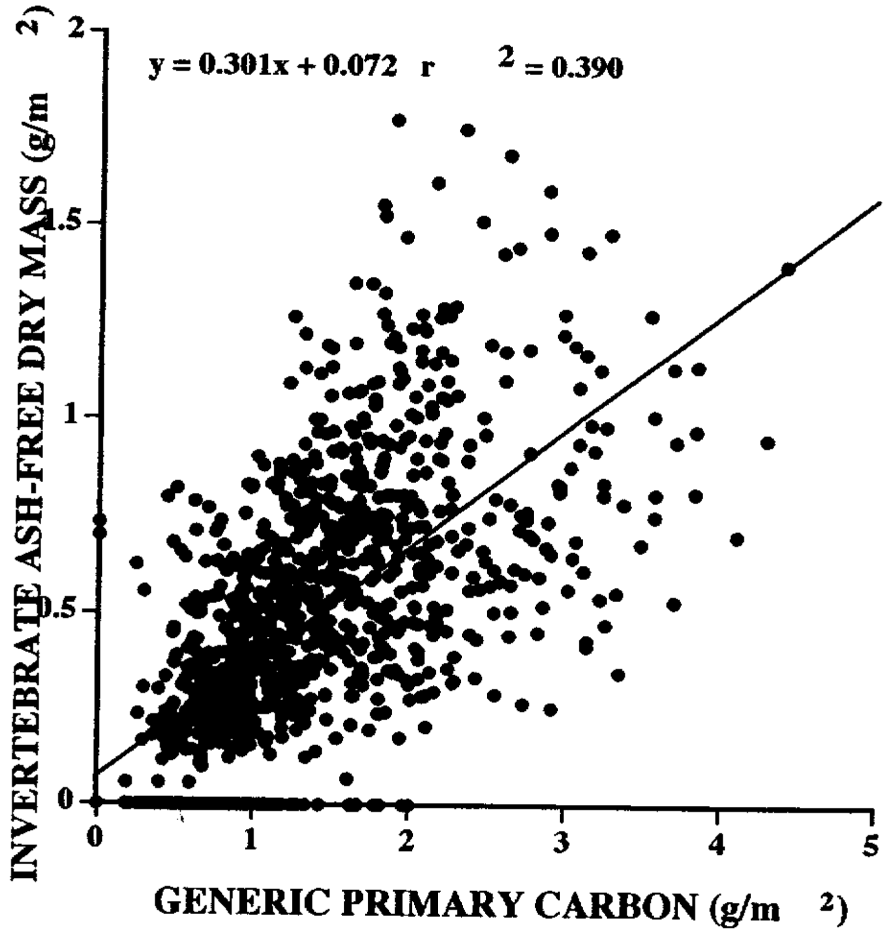

Figure 2. Relationship between primary carbon biomass and total invertebrate biomass in the Colorado River below Glen Canyon Dam, AZ.

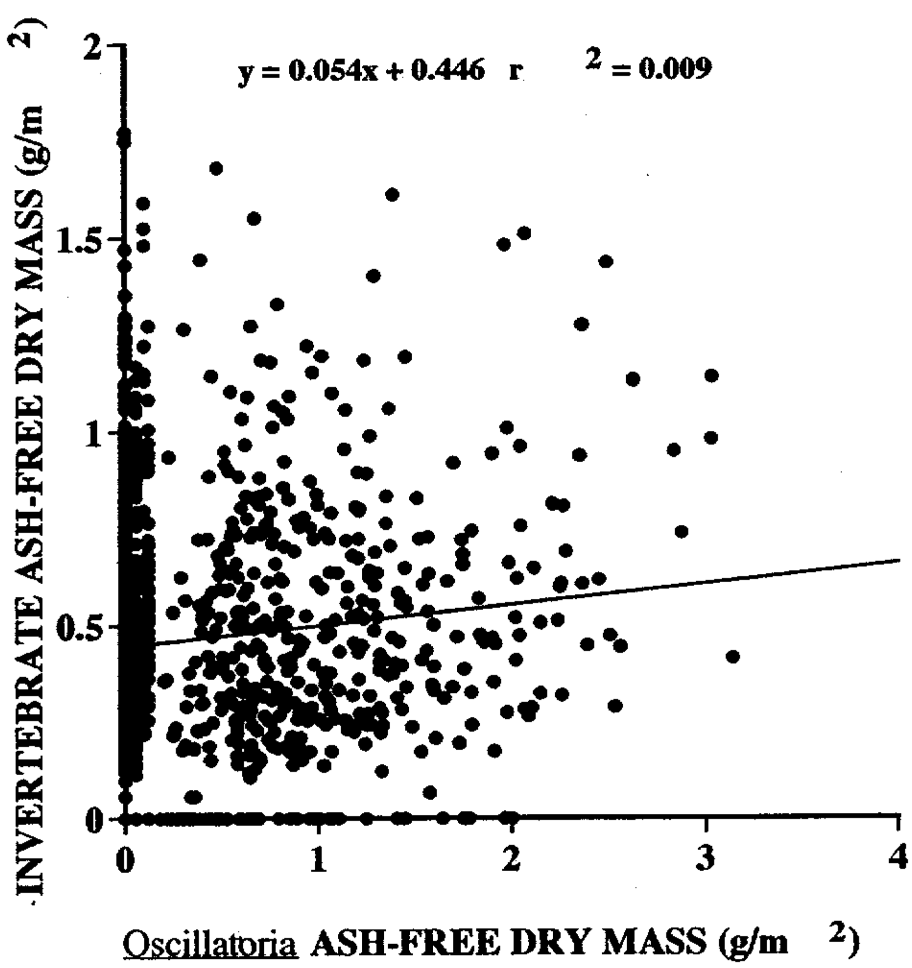

Figure 3. Relationship between <u>Oscillatoria</u> spp. biomass and total invertebrate biomass in the Colorado River below Glen Canyon Dam, AZ.

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APPENDICES

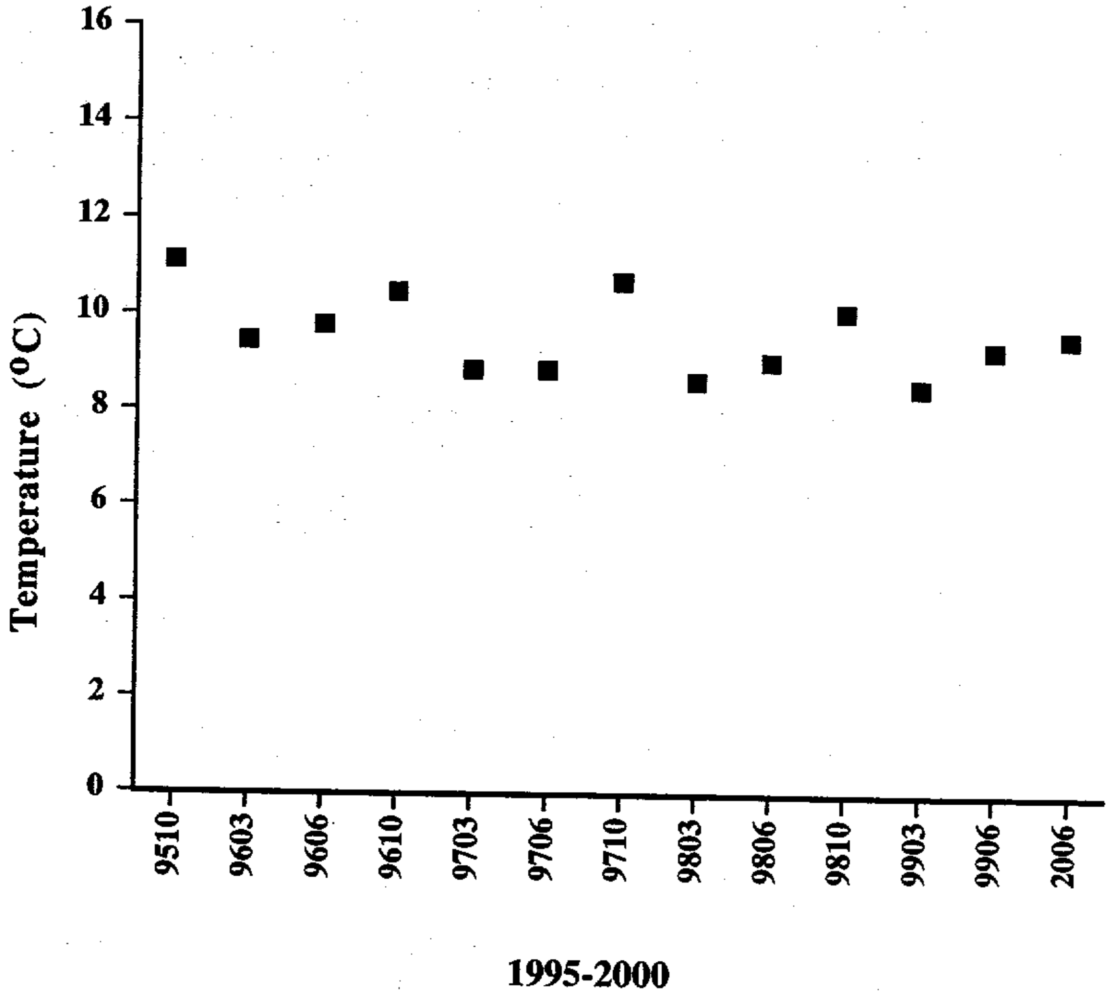

Figure 2. Water temperature (°C) collected at Glen Canyon Gauge Rkm -23.2 from October 1995 to June 2000.

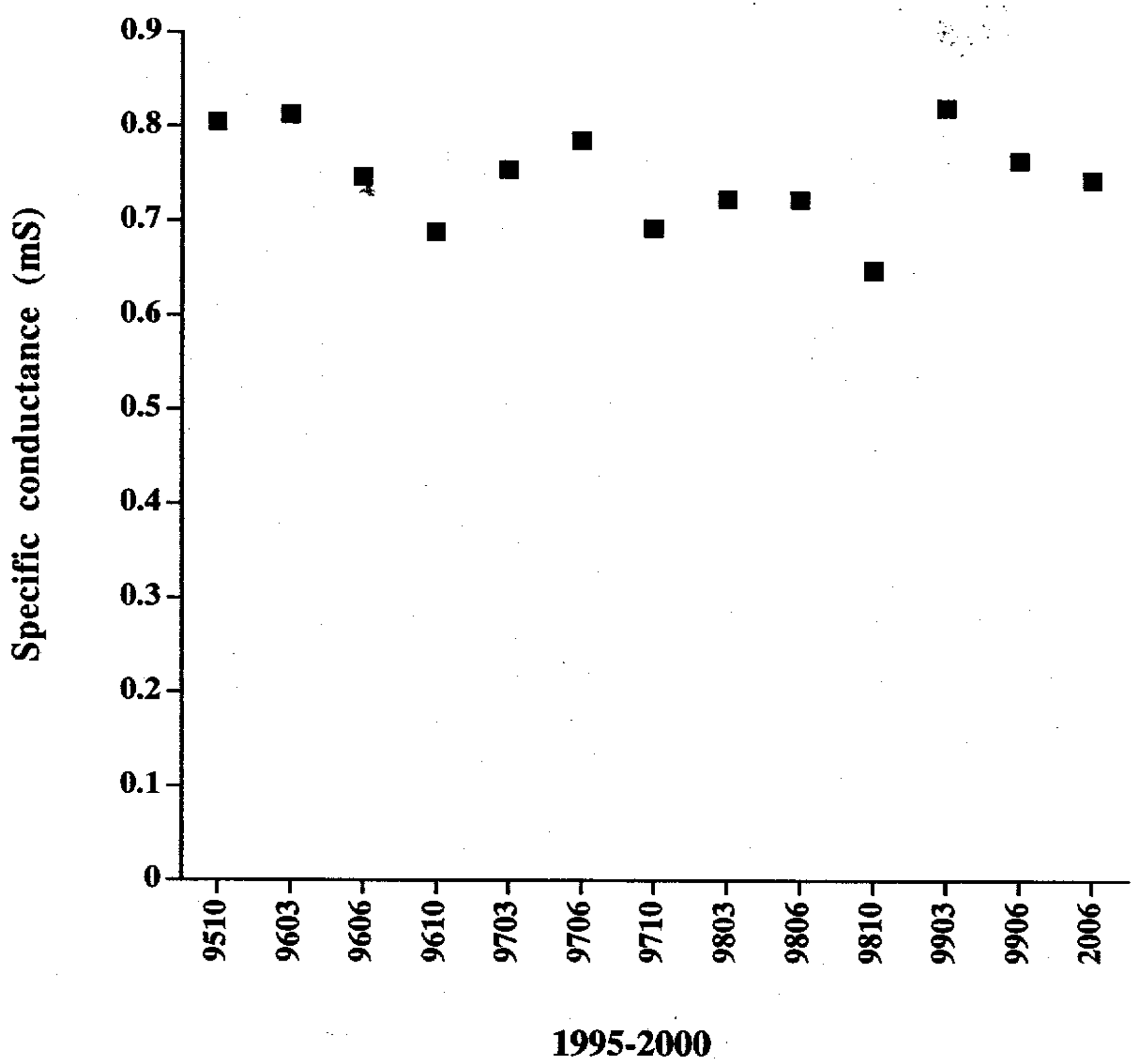

Figure 3. Specific conductance (mS) collected at Glen Canyon Gauge Rkm -23.2 from October 1995 to June 2000.

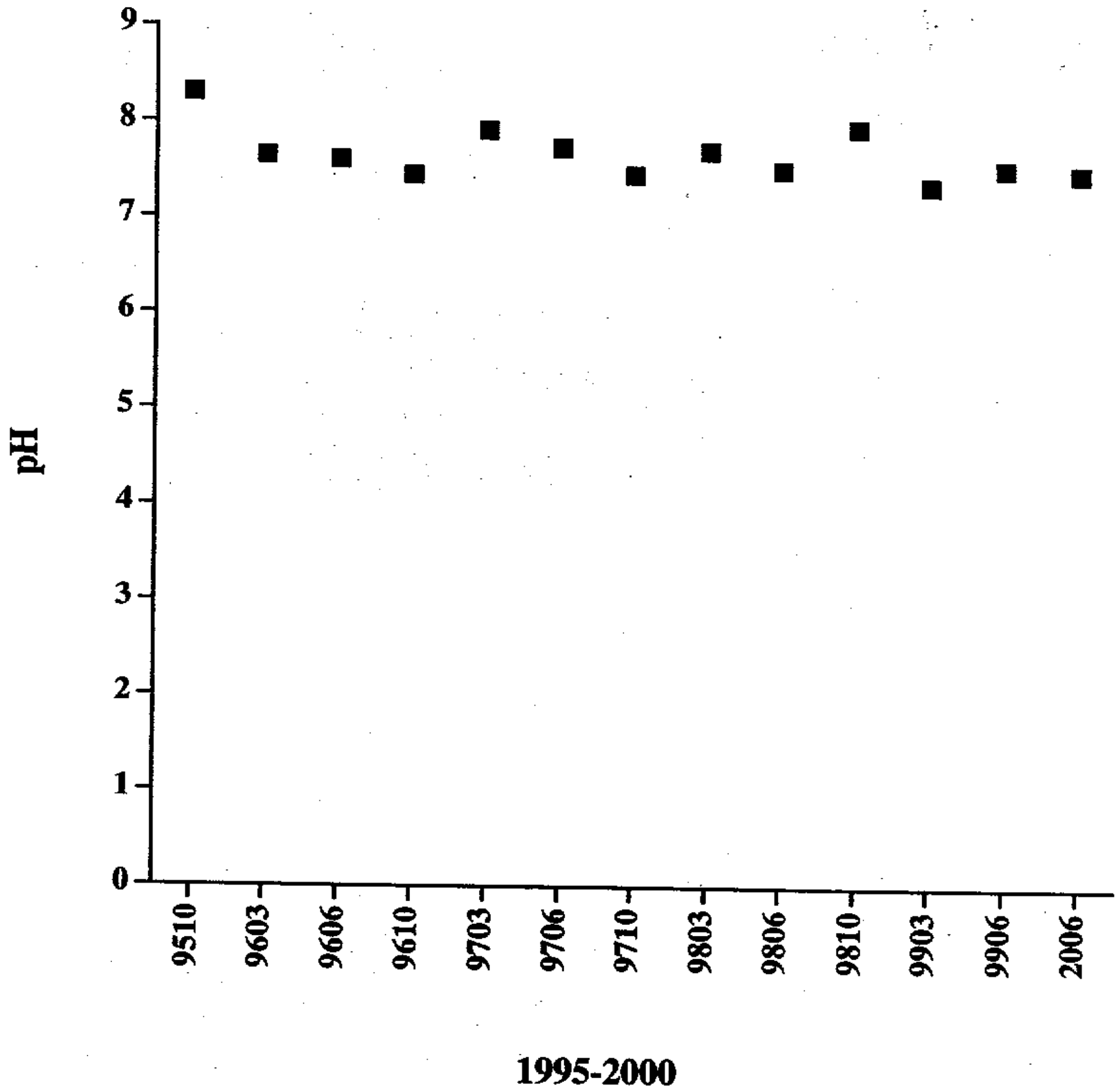

Figure 4. pH collected at Glen Canyon Gauge Rkm -23.2 from October 1995 to June 2000.

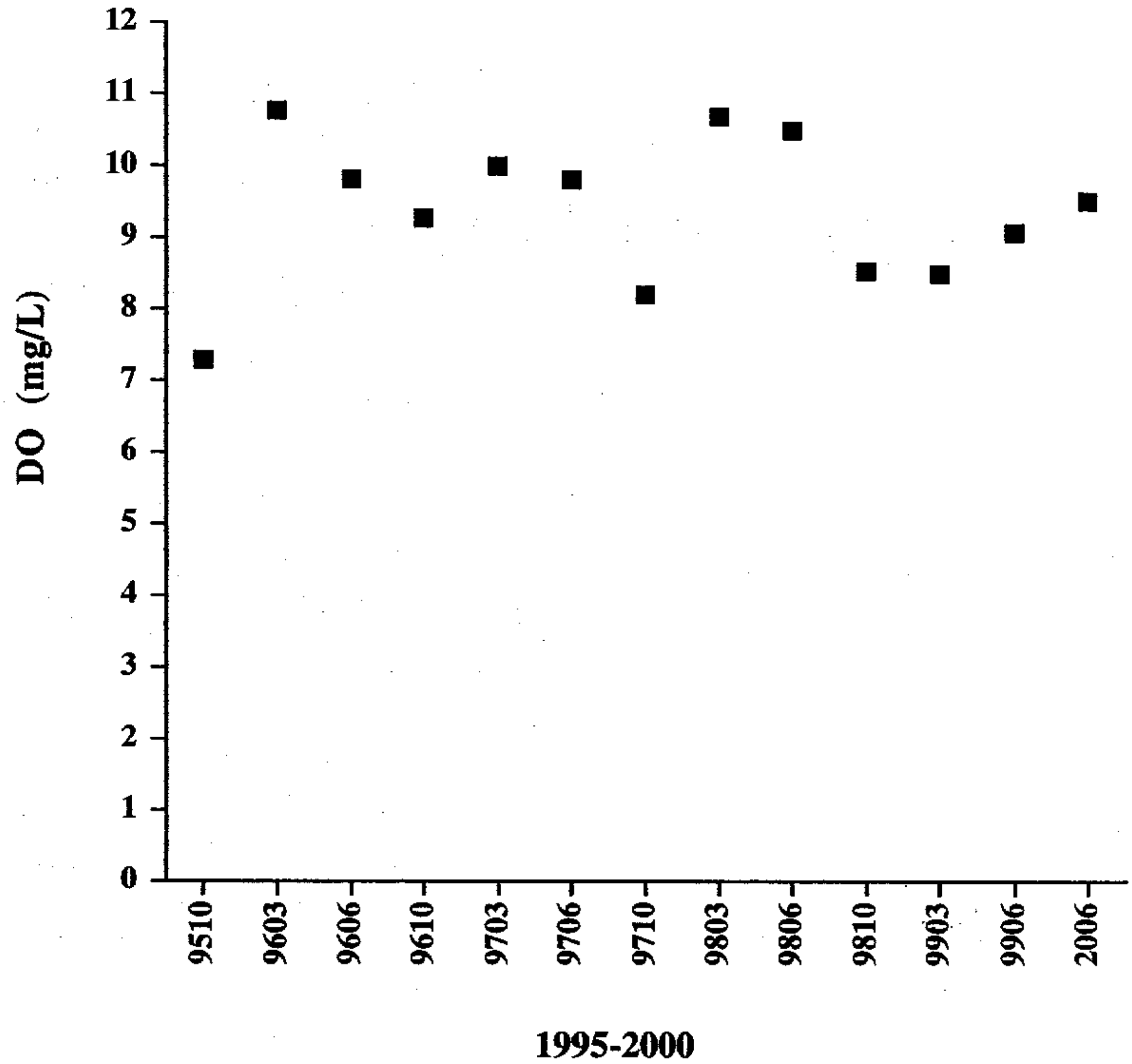

Figure 5. Dissolved oxygen (mg/L) collected at Glen Canyon Gauge Rkm -23.2 from October 1995 to June 2000.

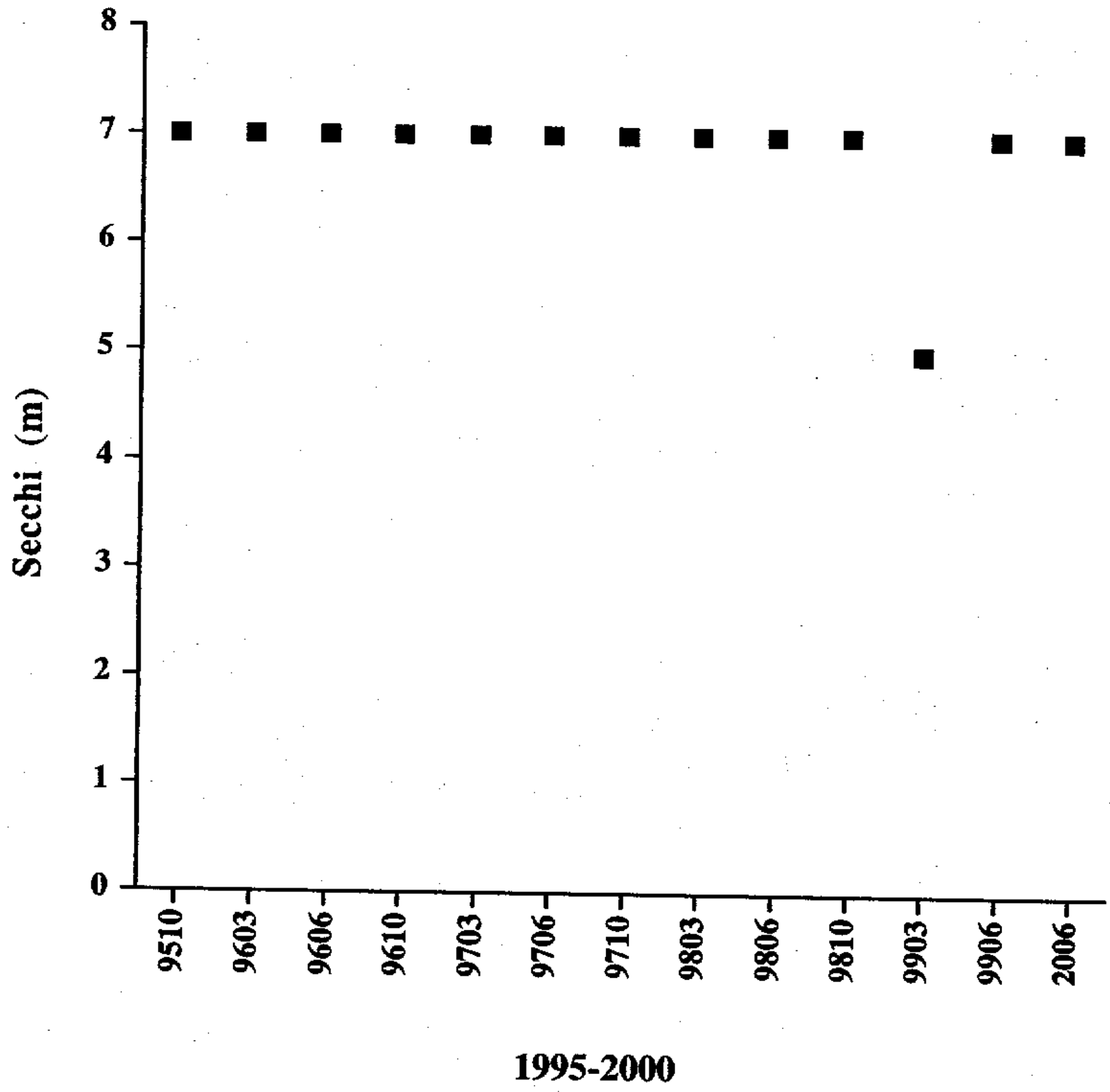

Figure 6. Secchi depth (m) collected at Glen Canyon Gauge Rkm -23.2 from October 1995 to June 2000.

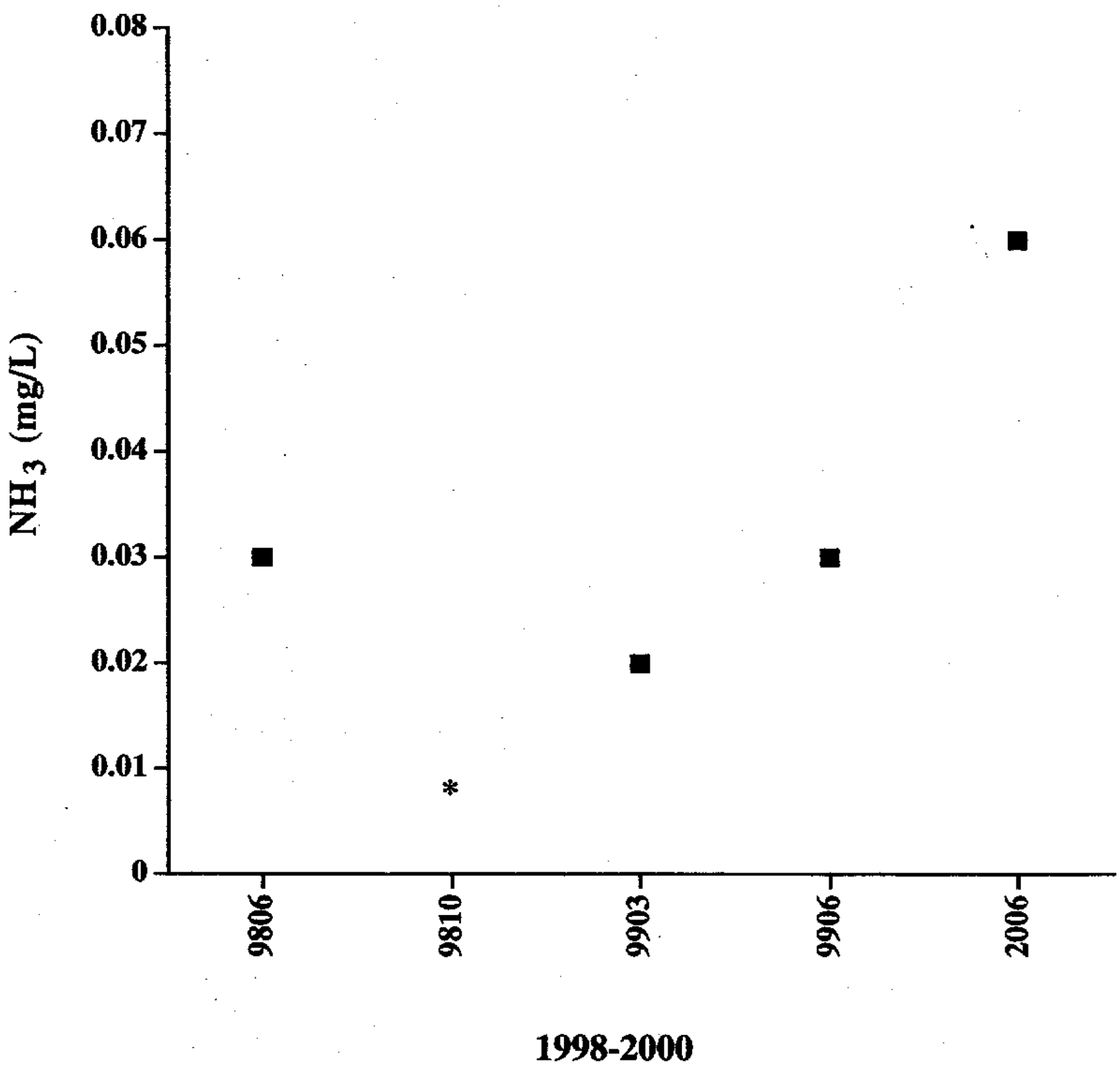

Figure 7. Ammonia (NH_3 mg/L) collected at Glen Canyon Gauge Rkm -23.2 from June 1998 to June 2000. Samples below detectable levels are represented by (*).

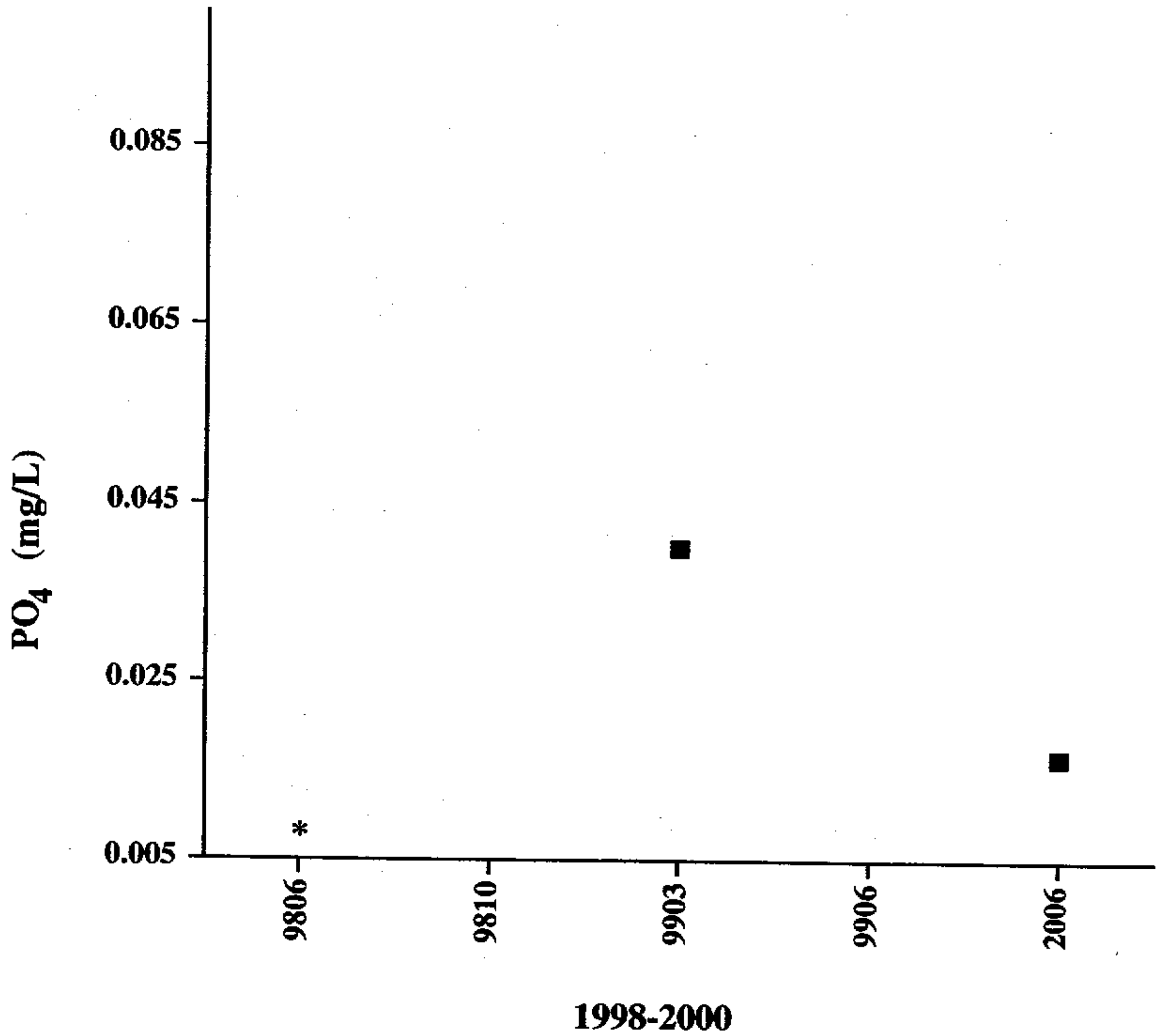

Figure 8. Phosphate (PO_4 mg/L) collected at Glen Canyon Gauge Rkm -23.2 from June 1998 to June 2000. Samples below detectable levels are represented by (*).

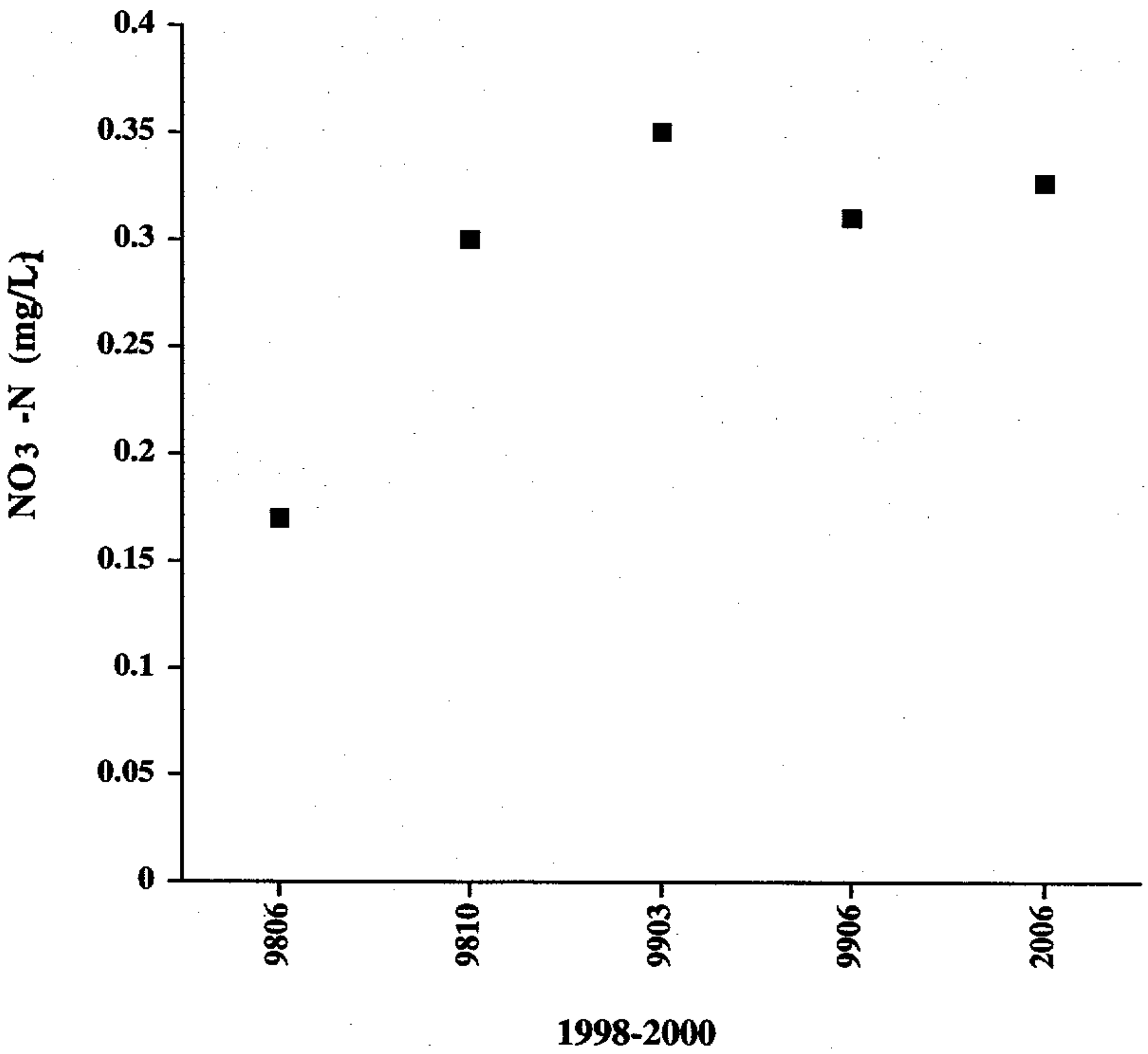

Figure 9. Nitrate-nitrogen (NO_3-N mg/L) collected at Glen Canyon Gauge Rkm -23.2 from June 1998 to June 2000.

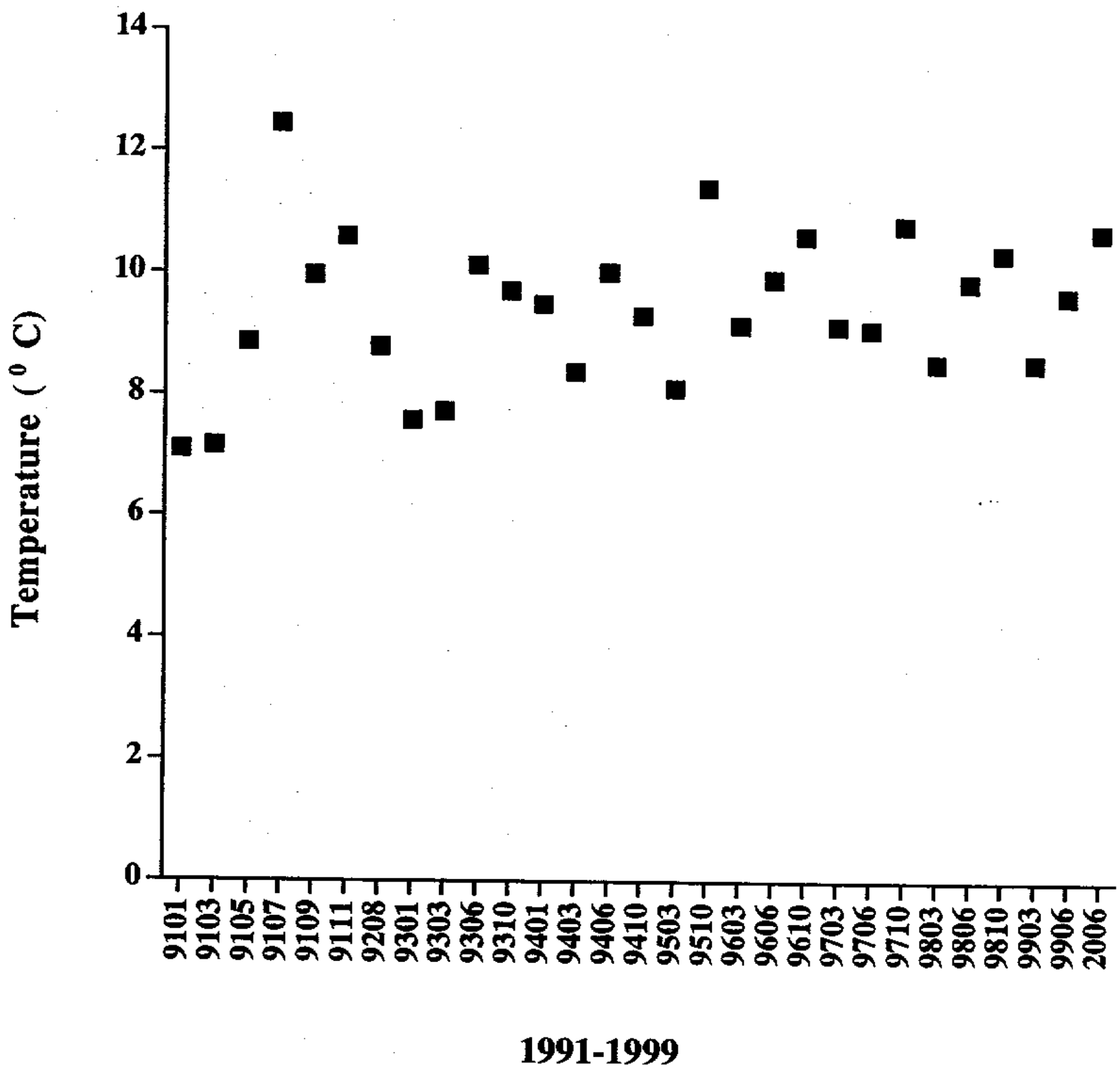

Figure 10. Water temperature (°C) collected at Lees Ferry Rkm 0.0 from January 1991 to June 1999.

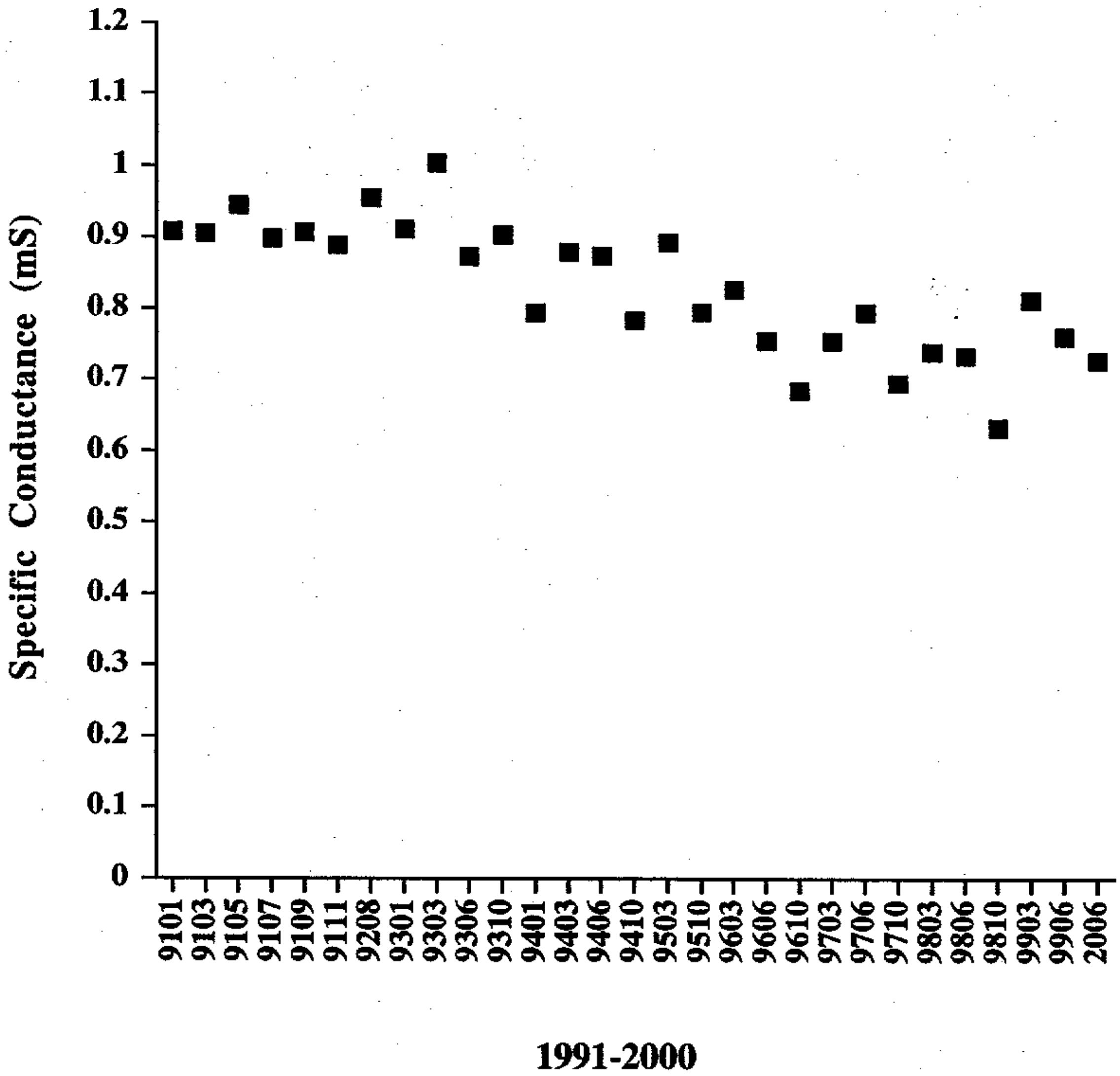

Figure 11. Specific conductance (mS) collected at Lees Ferry Rkm 0.0 from January 1991 to June 2000.

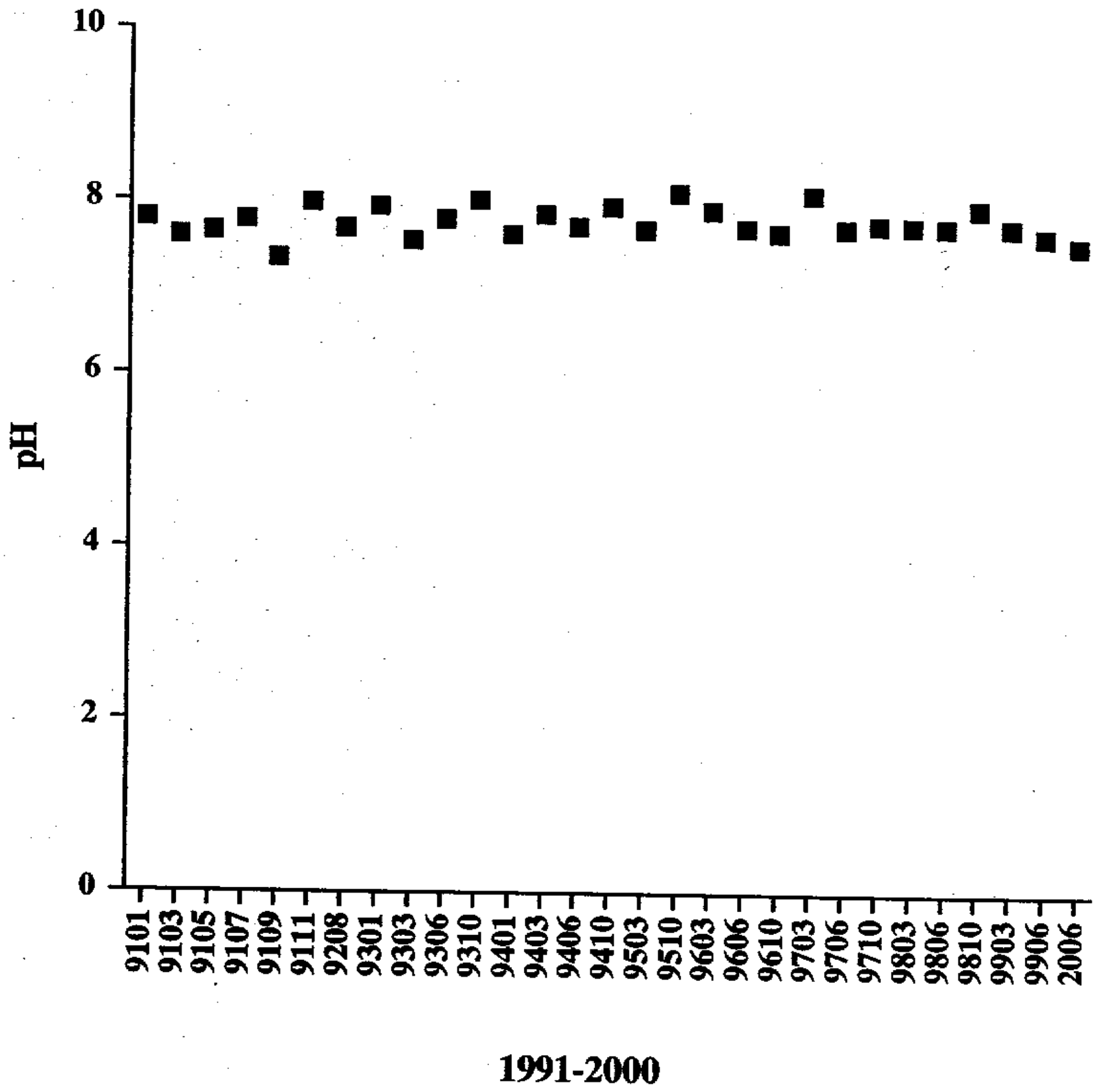

Figure 12. pH collected at Lees Ferry Rkm 0.0 from January 1991 to June 2000.

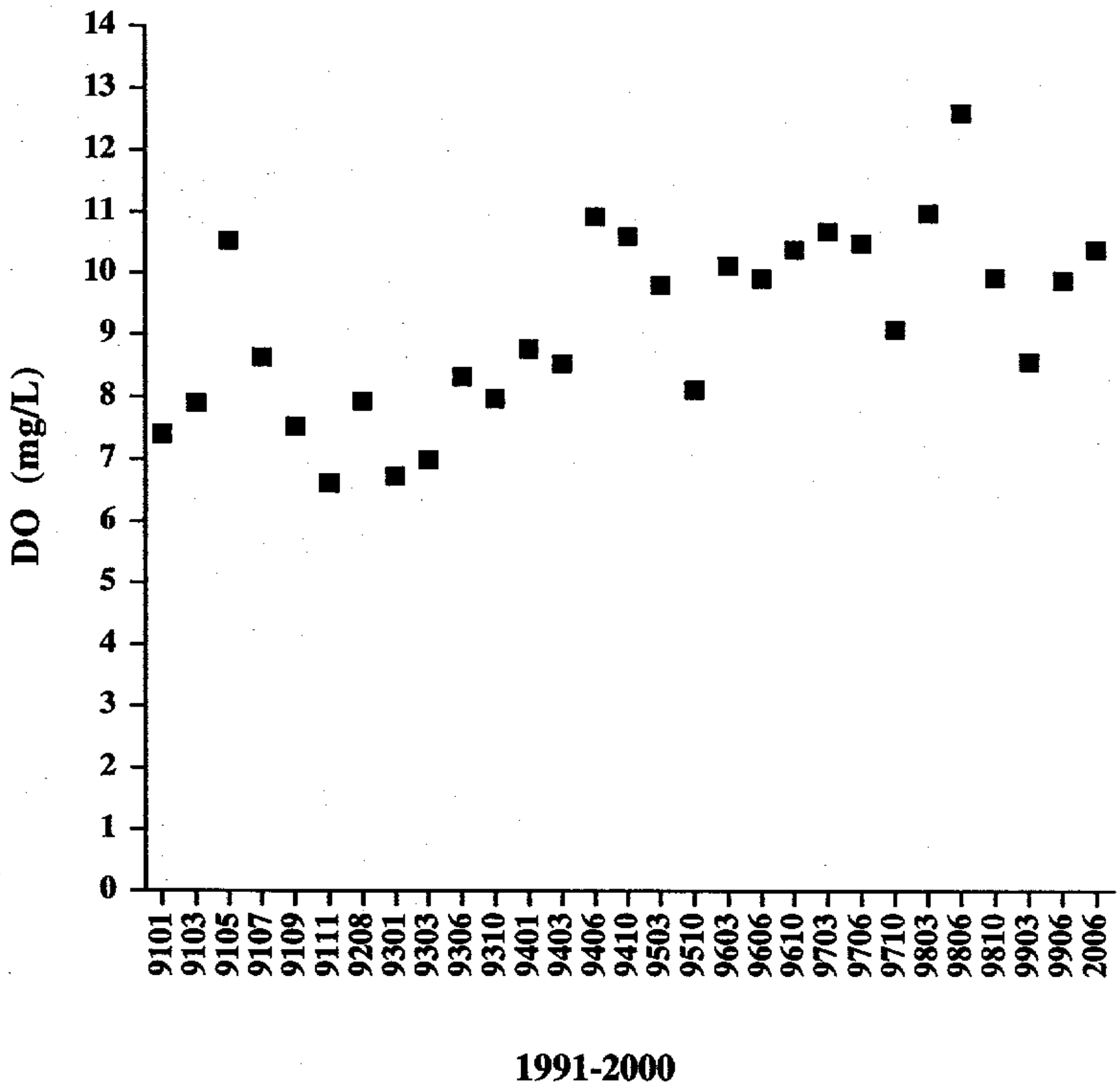

Figure 13. Dissolved oxygen (mg/L) collected at Lees Ferry Rkm 0.0 from January 1991 to June 2000.

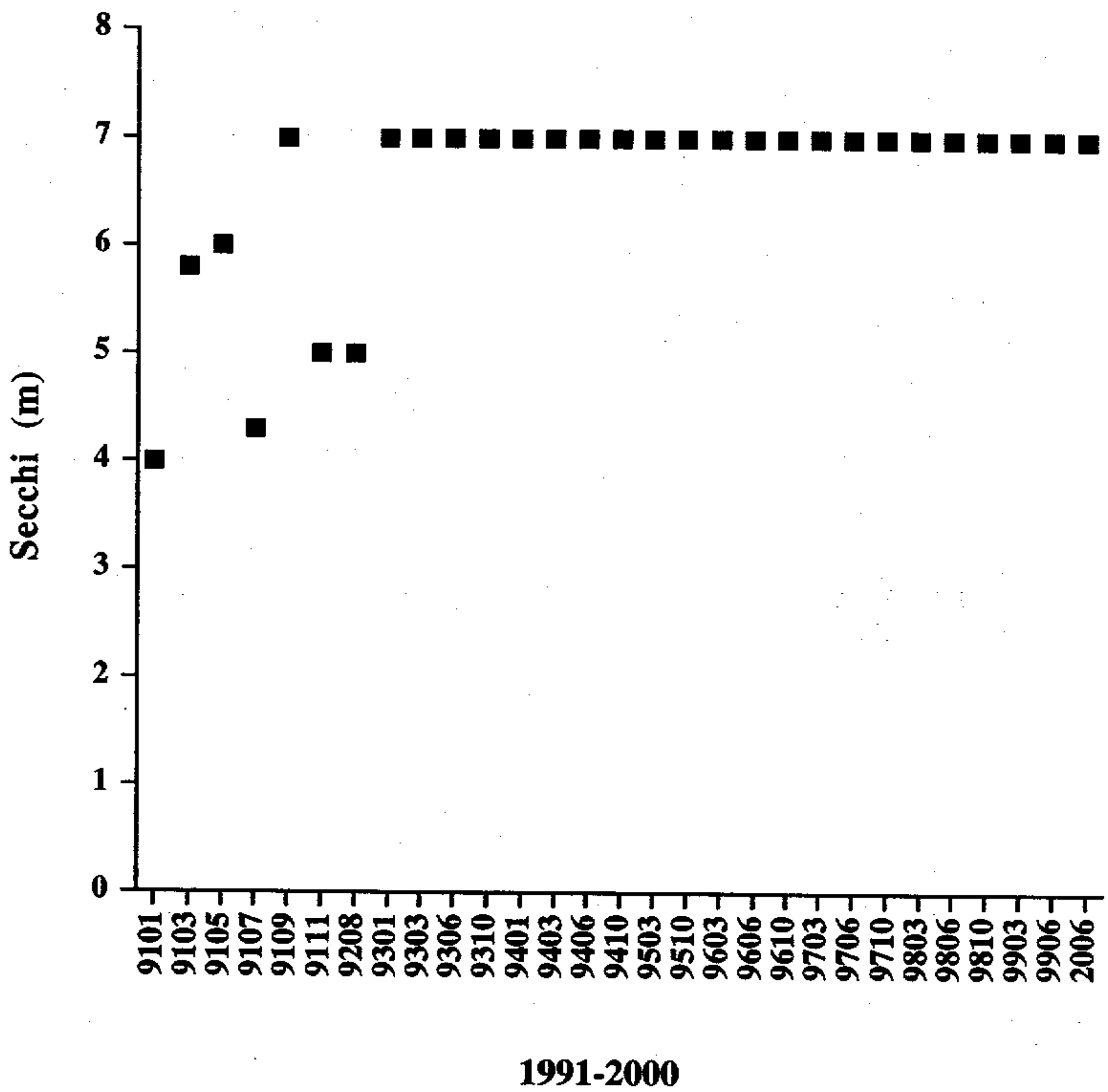

Figure 14. Secchi depth (m) collected at Lees Ferry Rkm 0.0 from January 1991 to June 2000. Lees Ferry clear water conditions allow Secchi depth readings to bottom of channel. Prior to 1992, high fluctuating flows decreased this depth to less than 7 meters.

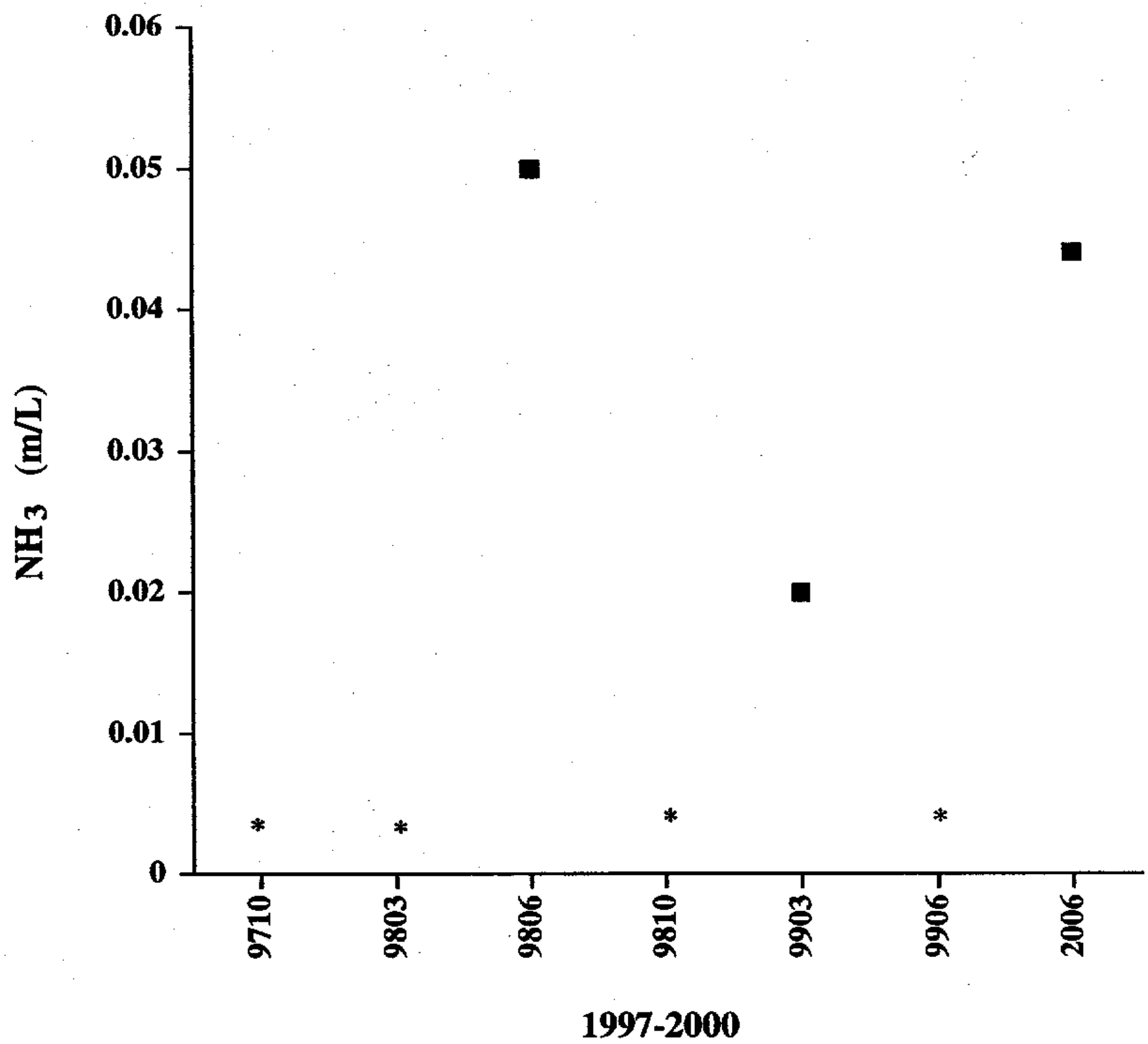

Figure 15. Ammonia (NH $_3$ mg/L) collected at Lees Ferry Rkm 0.0 from October 1997 to June 2000. Samples below detectable levels are represented by a (*).

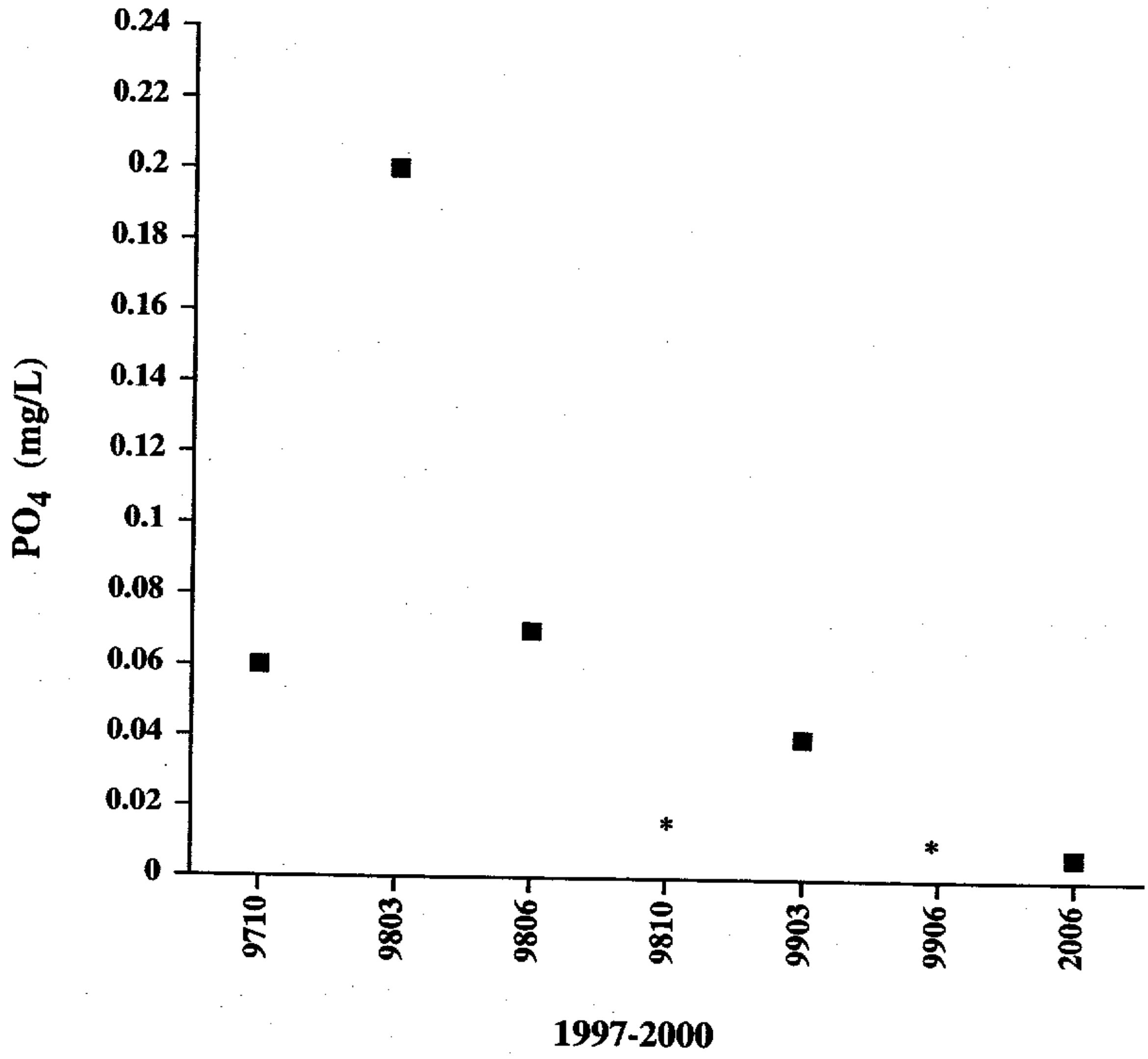

Figure 16. Phosphate (PO_4 mg/L) collected at Lees Ferry Rkm 0.0 from October 1997 to June 2000. Samples below detectable levels are represented be a (*).

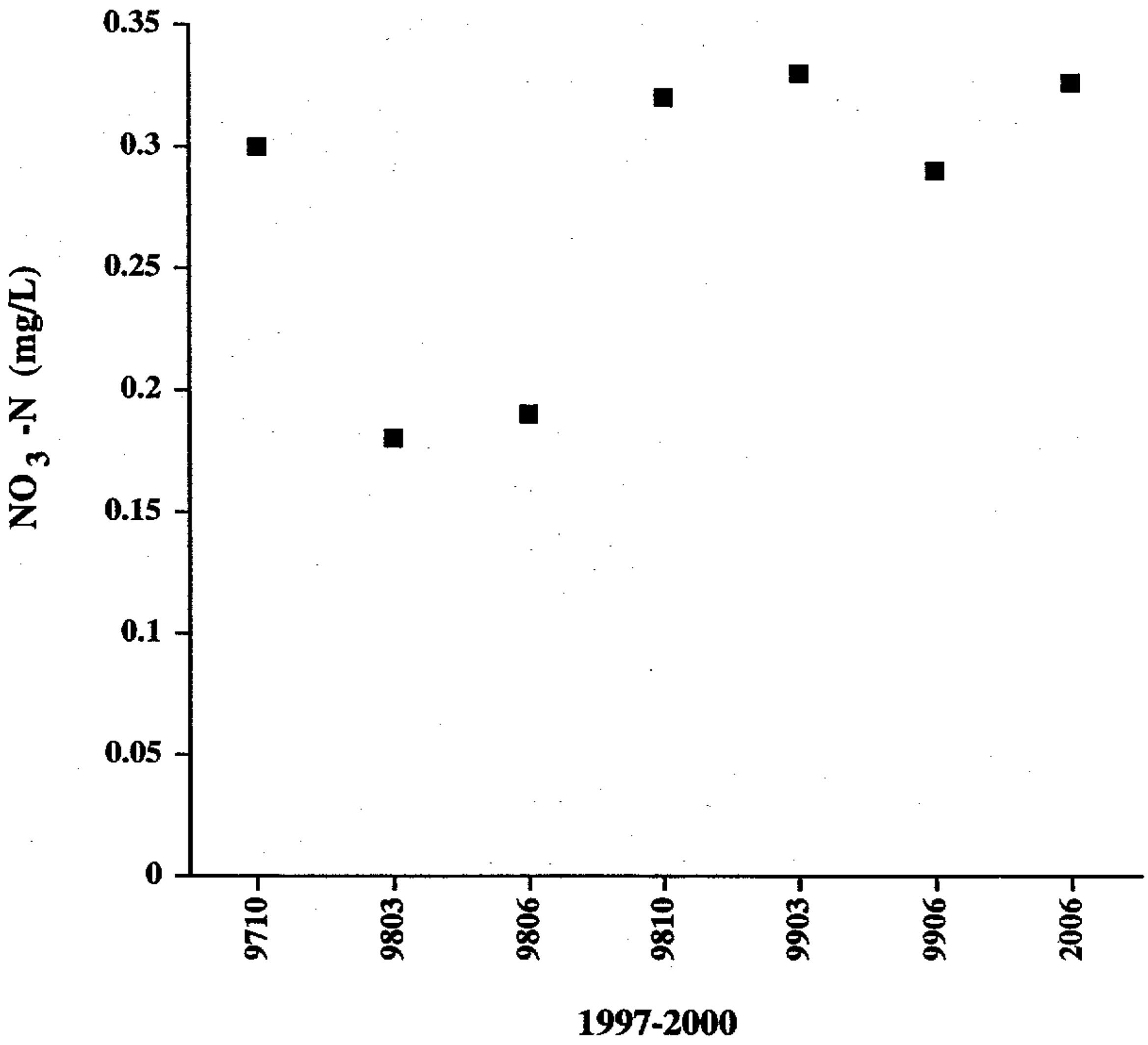

Figure 17. Nitrate-nitrogen (NO_3-N mg/L) collected at Lees Ferry Rkm 0.0 from October 1997 to June 2000.

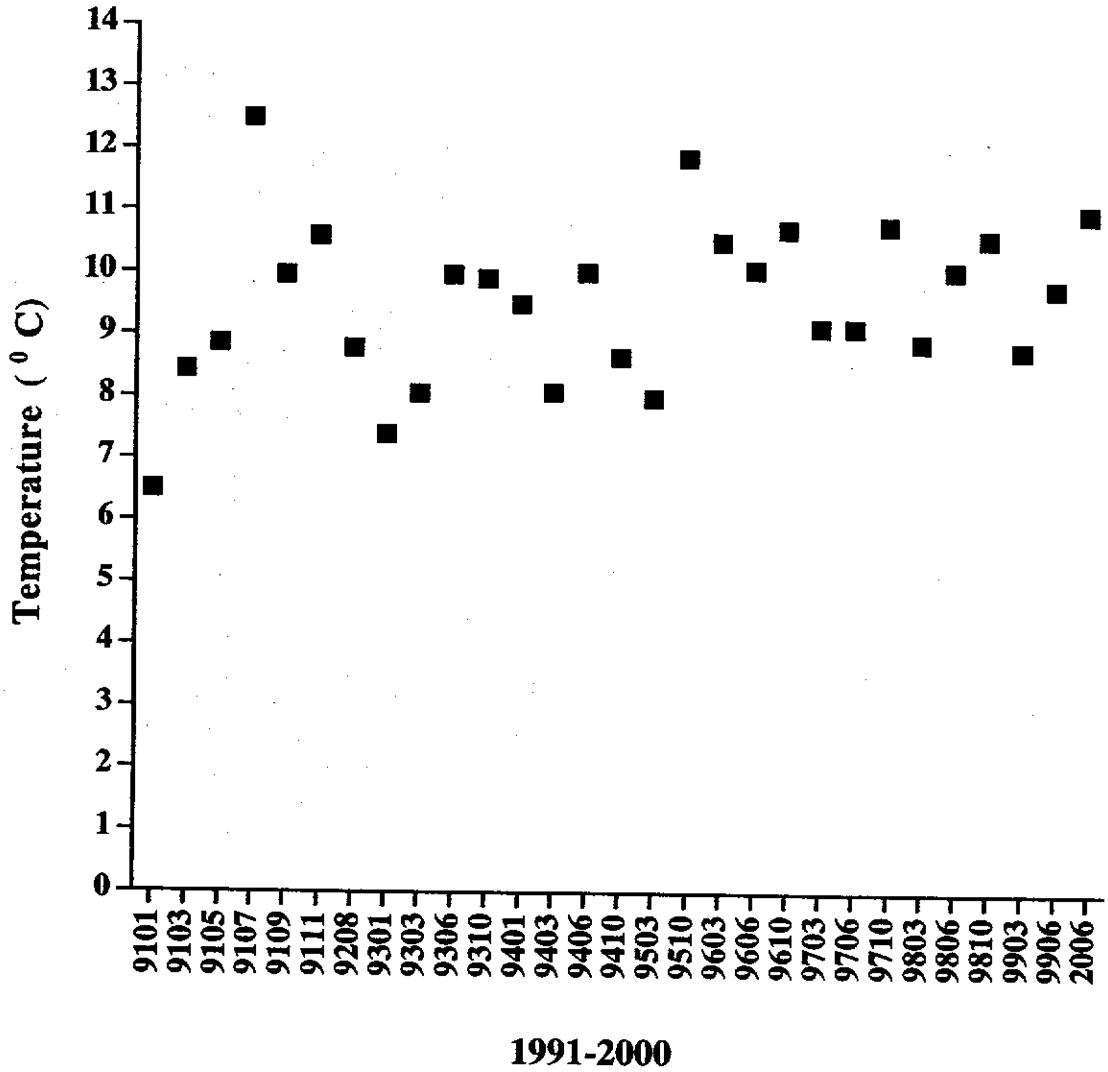

Figure 18. Water temperature (℃) collected at Two-Mile Wash Rkm 3.1 from January 1991 to June 2000.

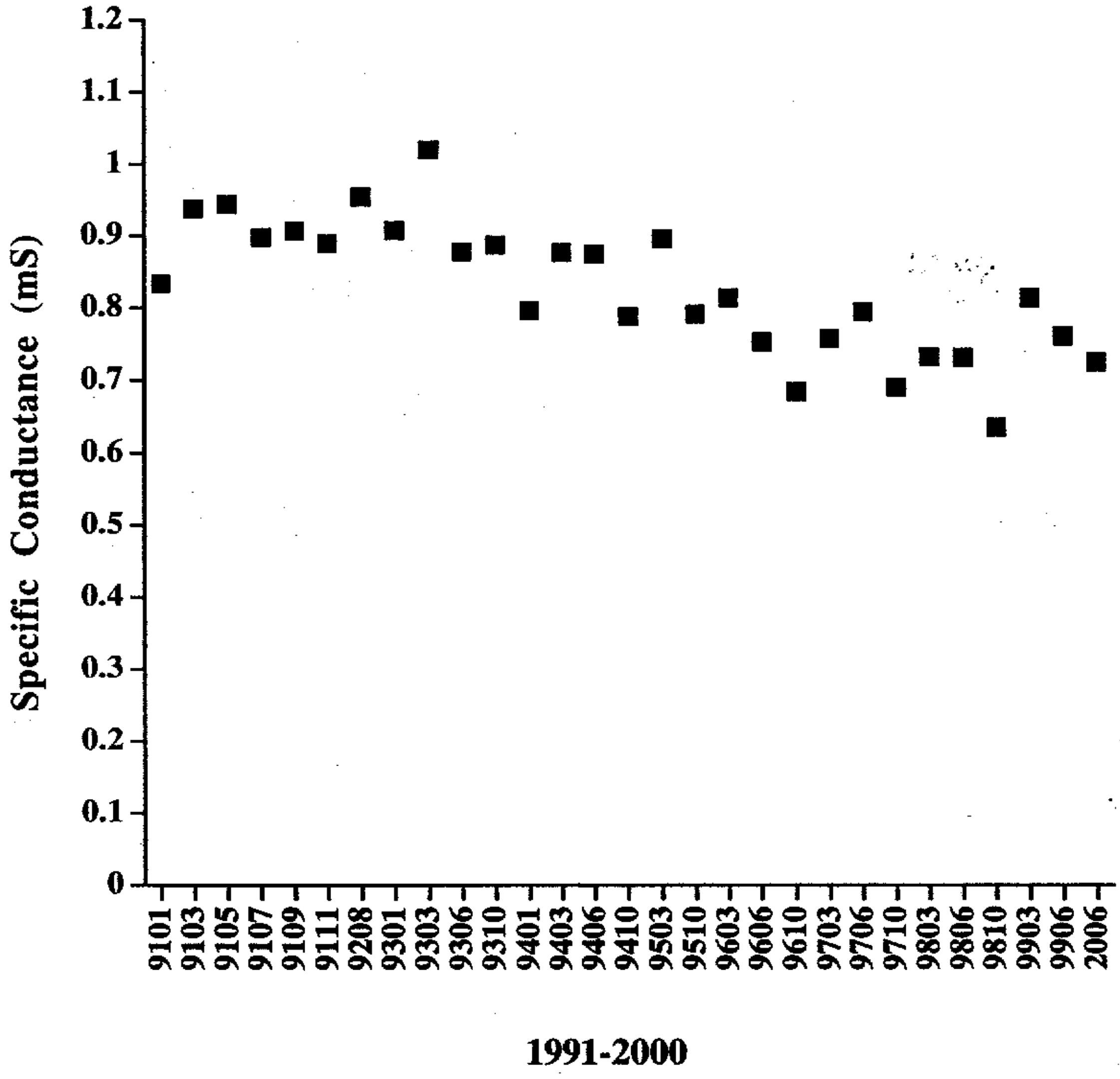

Figure 19. Specific conductance (mS) collected at Two-Mile Wash Rkm 3.1 from January 1991 to June 2000.

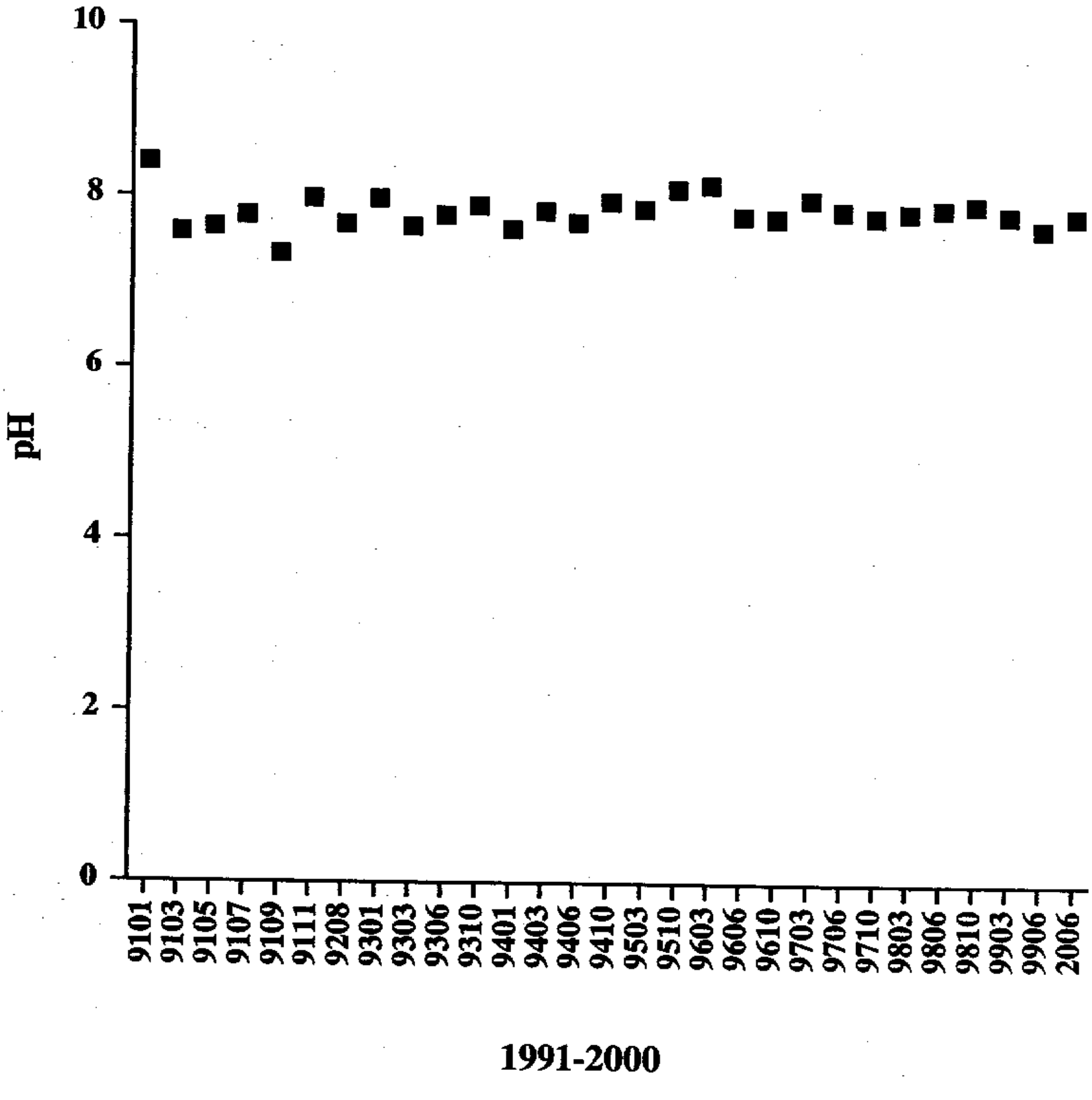

Figure 20. pH collected at Two-Mile Wash Rkm 3.1 from January 1991 to June 2000.

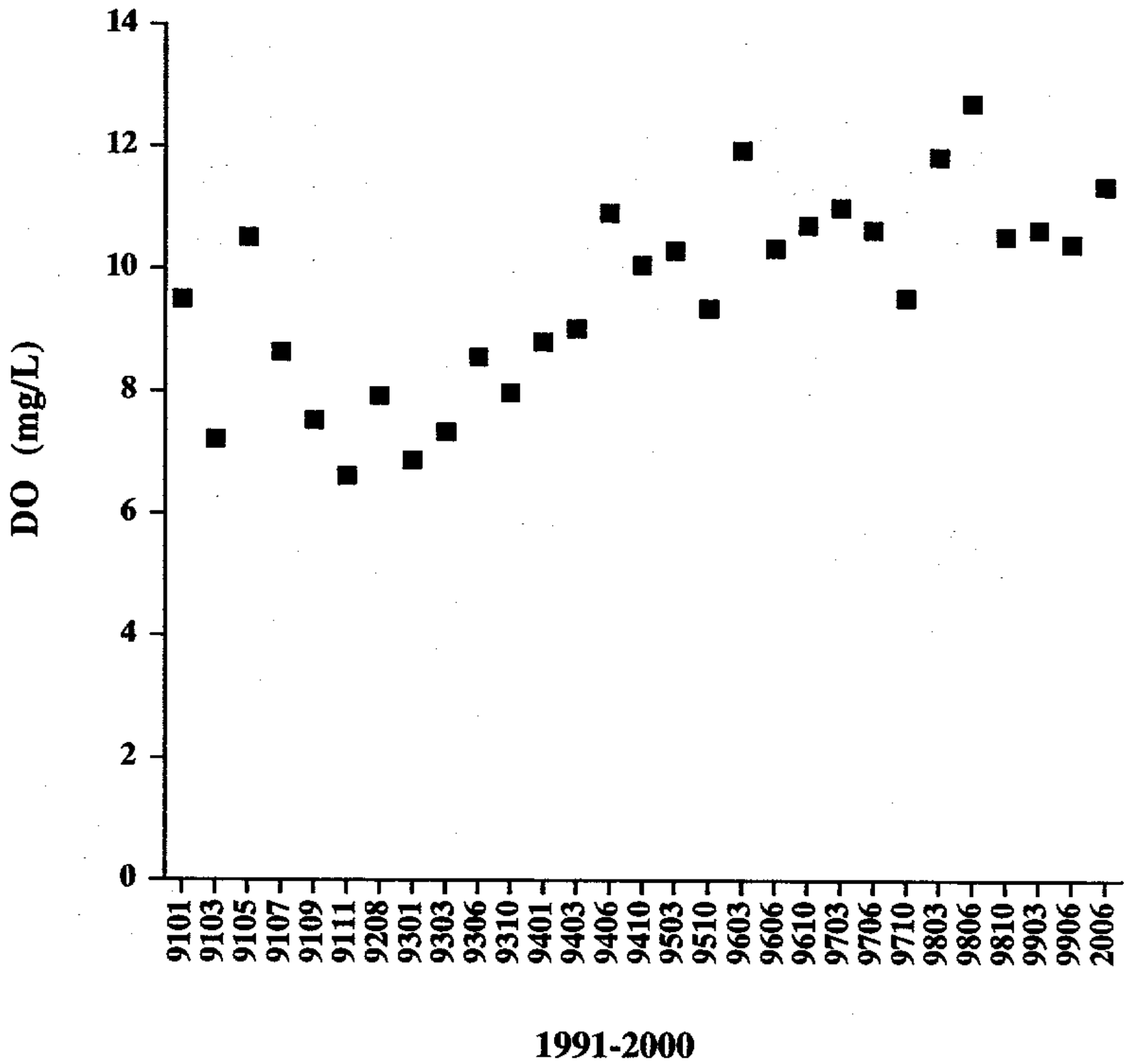

Figure 21. Dissolved oxygen (mg/L) collected at Two-Mile Wash Rkm 3.1 from January 1991 to June 2000.

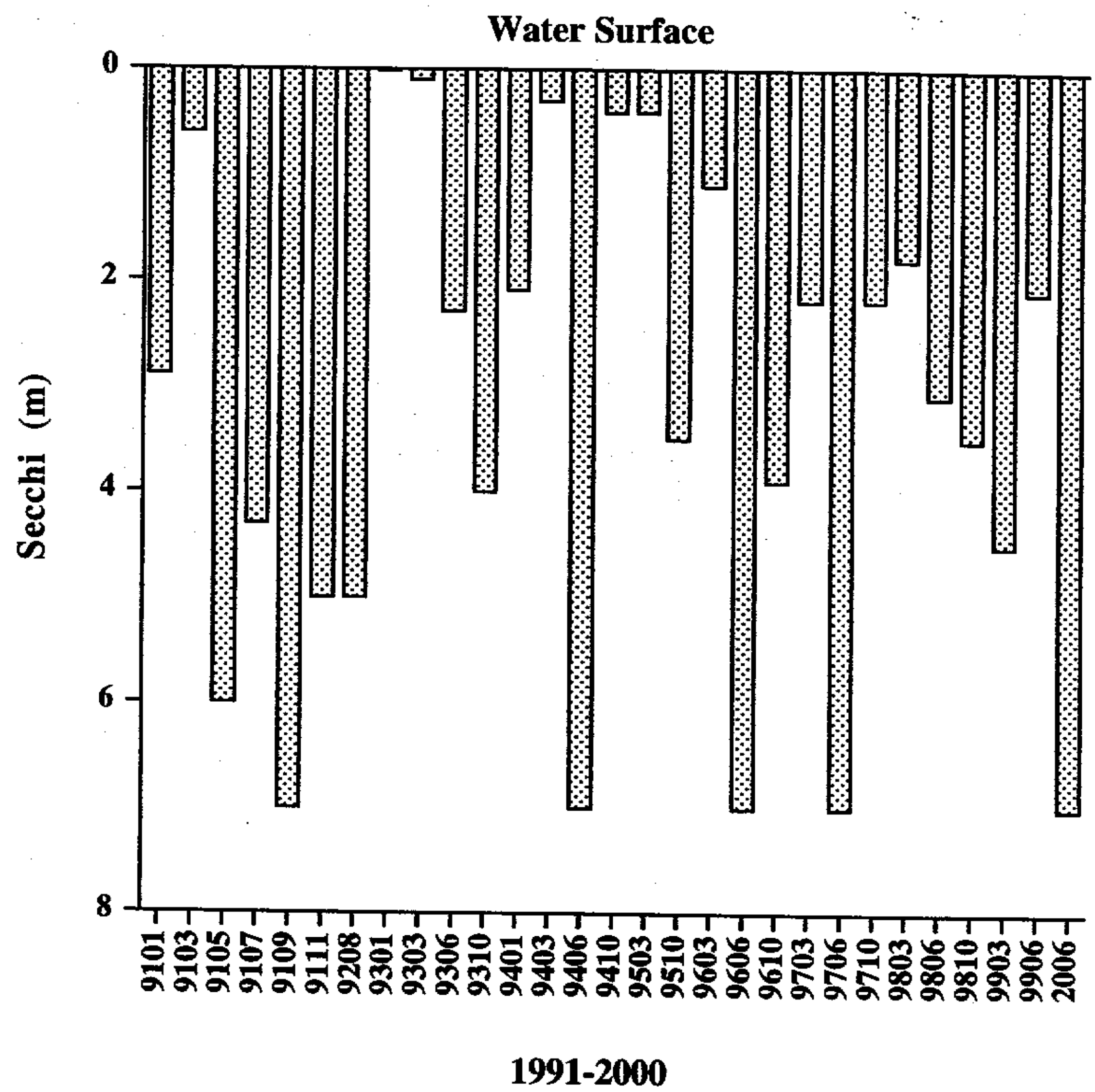

Figure 22. Secchi depth (m) collected at Two-Mile Wash Rkm 3.1 from January 1991 to June 2000.

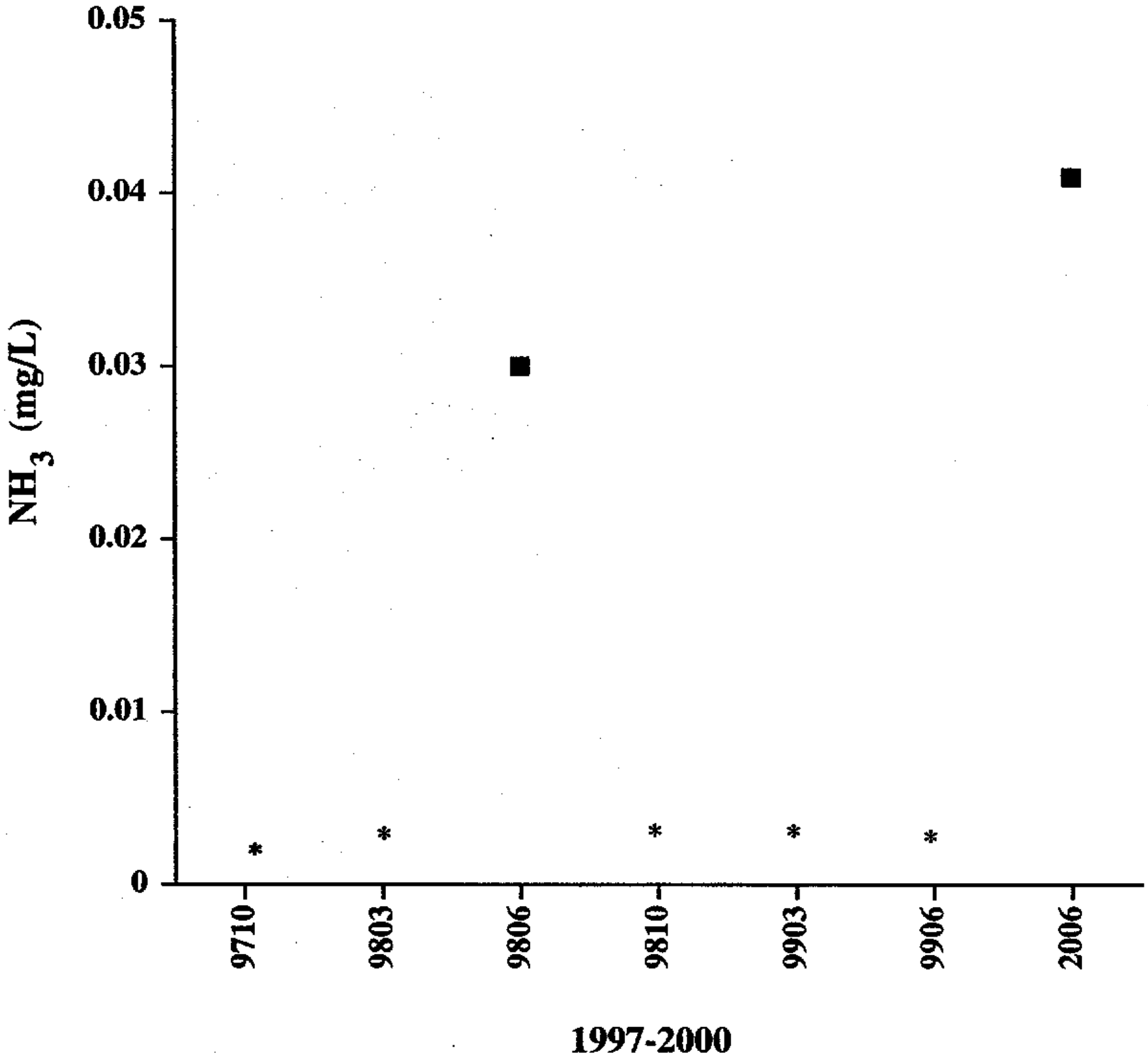

Figure 23. Ammonia (NH_3 mg/L) collected at Two-Mile Wash Rkm 3.1 from October 1997 to June 2000. Samples below detectable levels are represented by a (*).

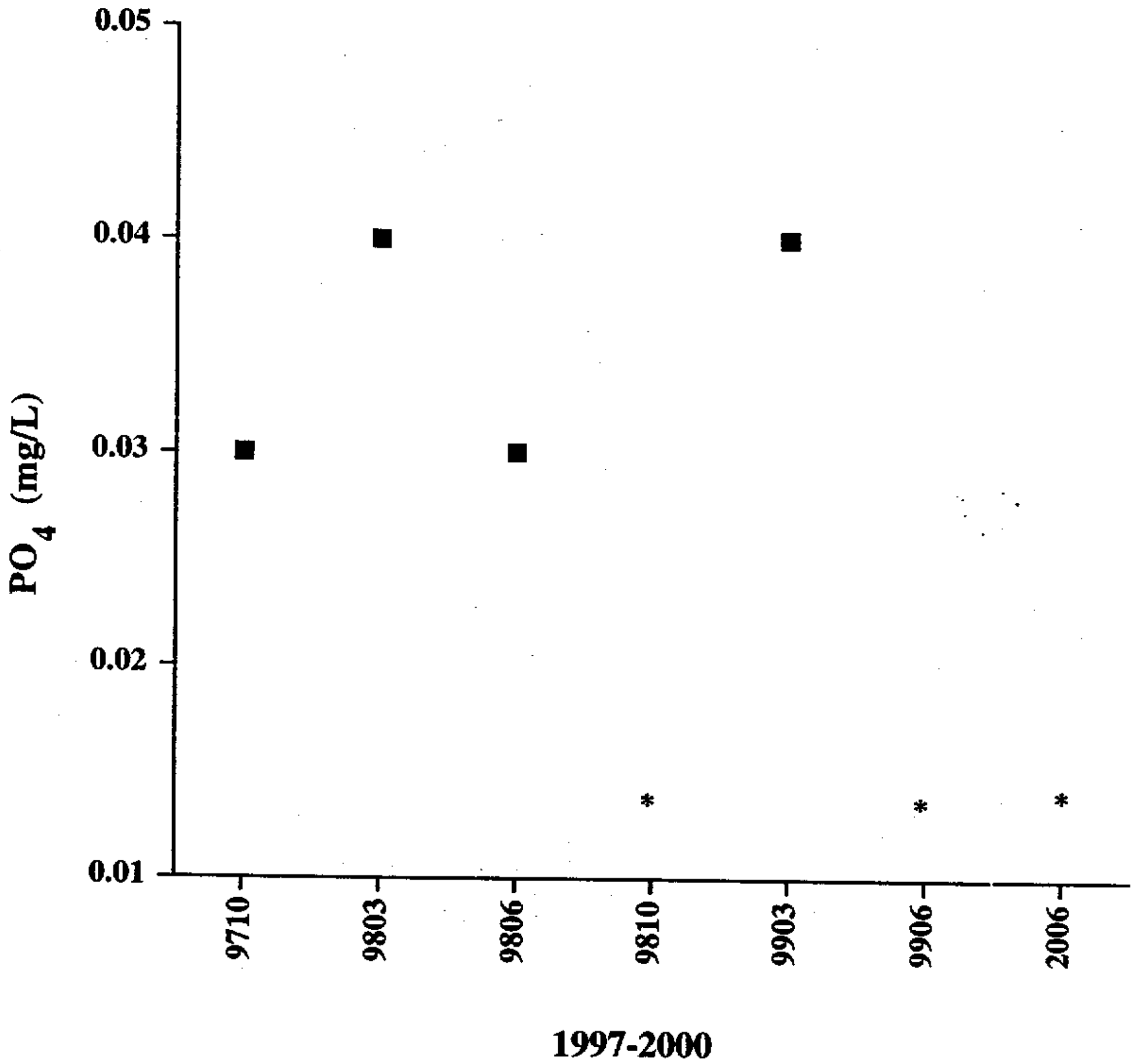

Figure 24. Phosphate (PO_4 mg/L) collected at Two-Mile Wash Rkm 3.1 from October 1997 to June 2000.

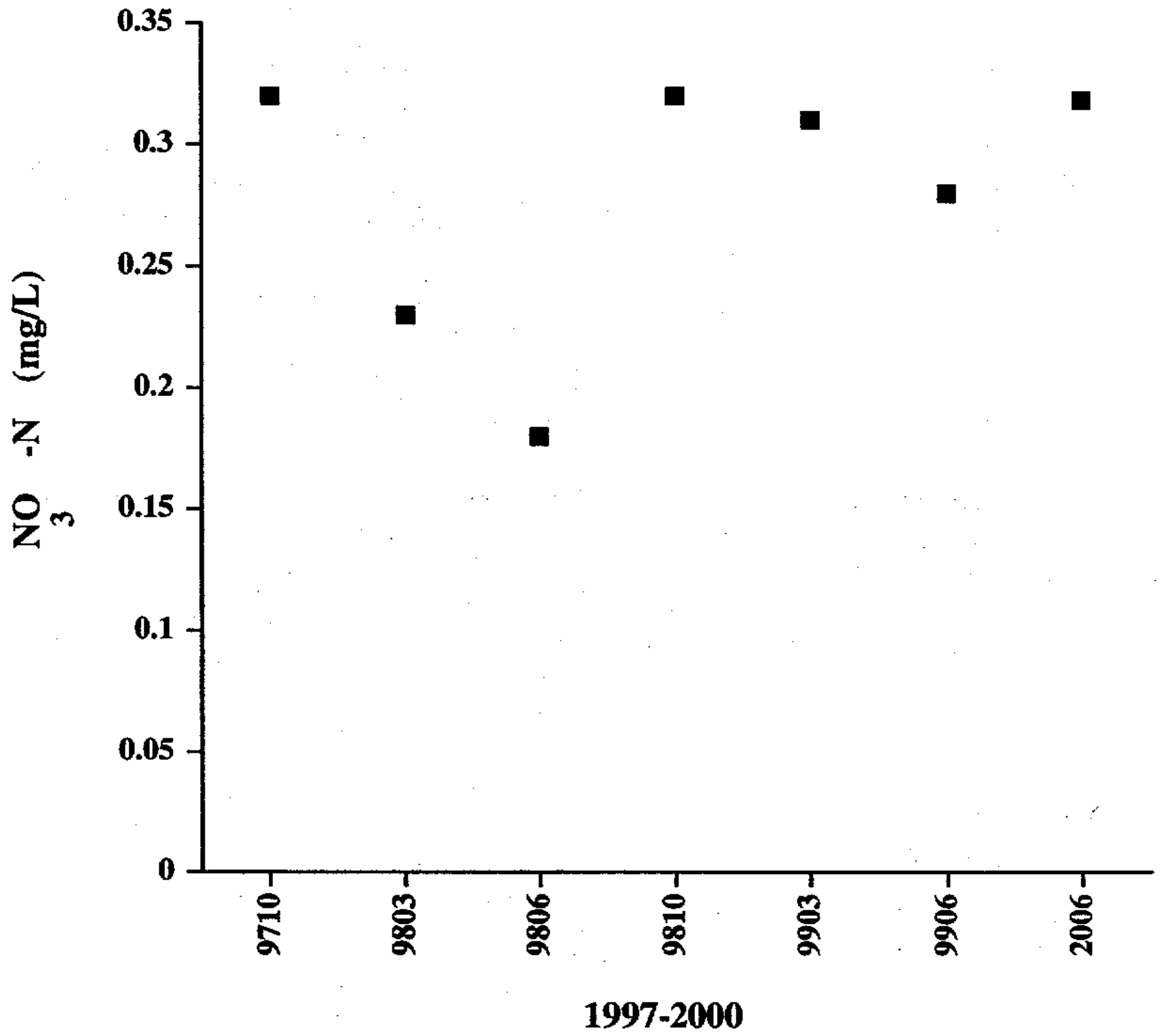

Figure 25. Nitrate-nitrogen (NO_3N mg/L) collected at Two-Mile Wash Rkm 3.1 from October 1997 to June 2000.

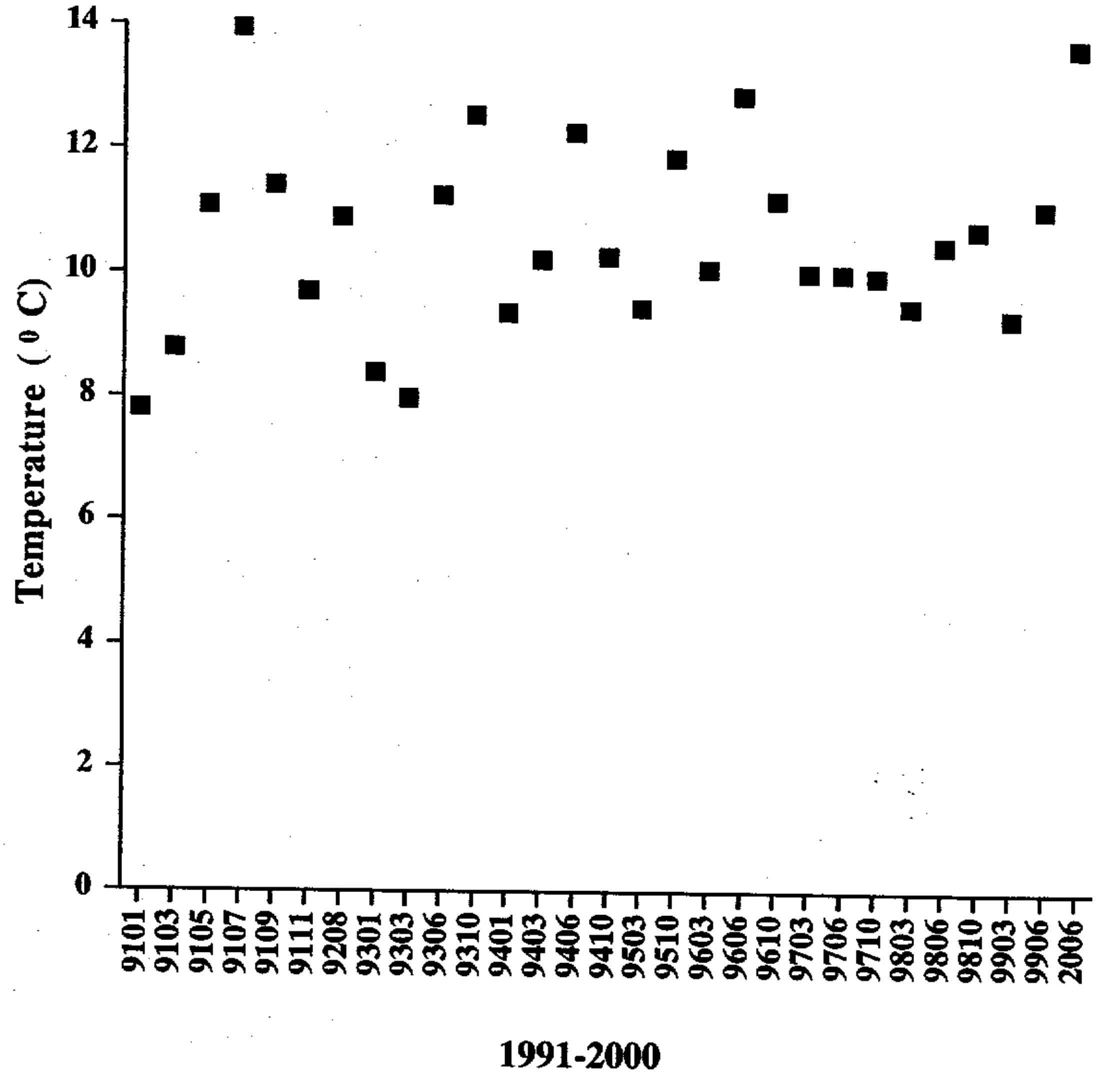

Figure 26. Water temperature (C) collected at the Gauge Above LCR Rkm 98.4 from January 1991 to June 2000.

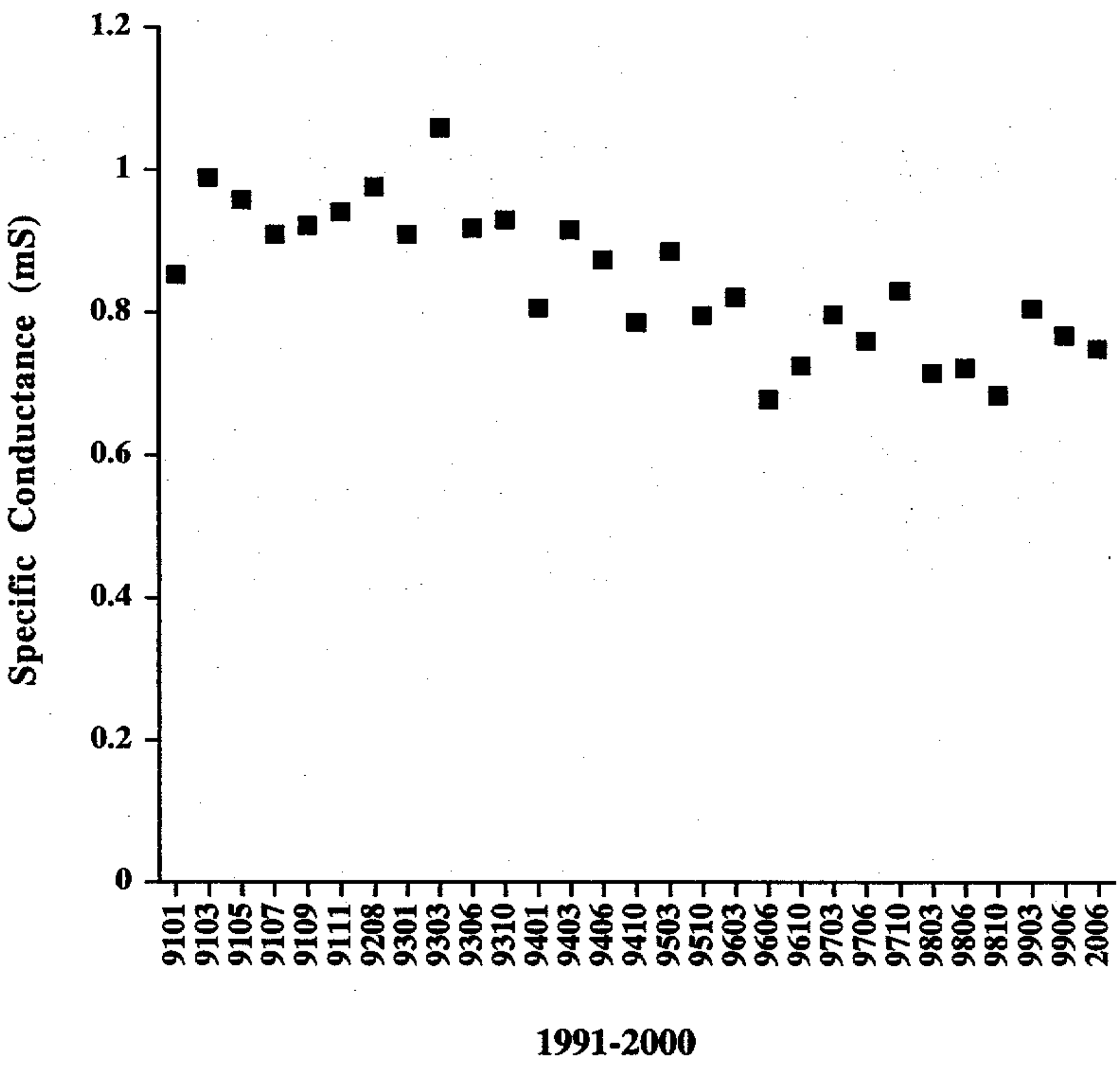

Figure 27. Specific conductance (mS) collected at the Gauge Above LCR Rkm 98.4 from January 1991 to June 2000.

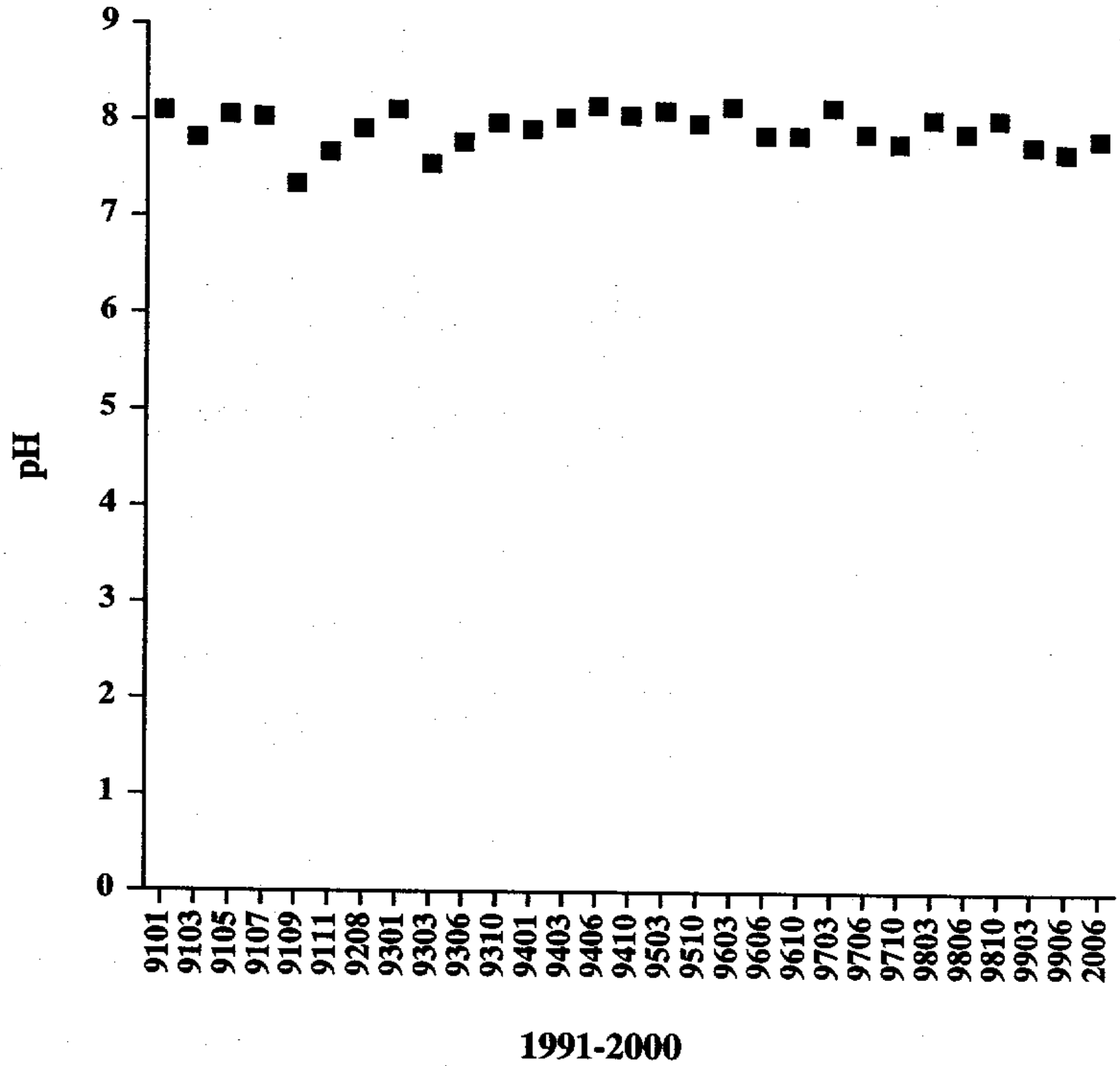

Figure 28. pH collected at the Gauge Above LCR Rkm 98.4 from January 1991 to June 2000.

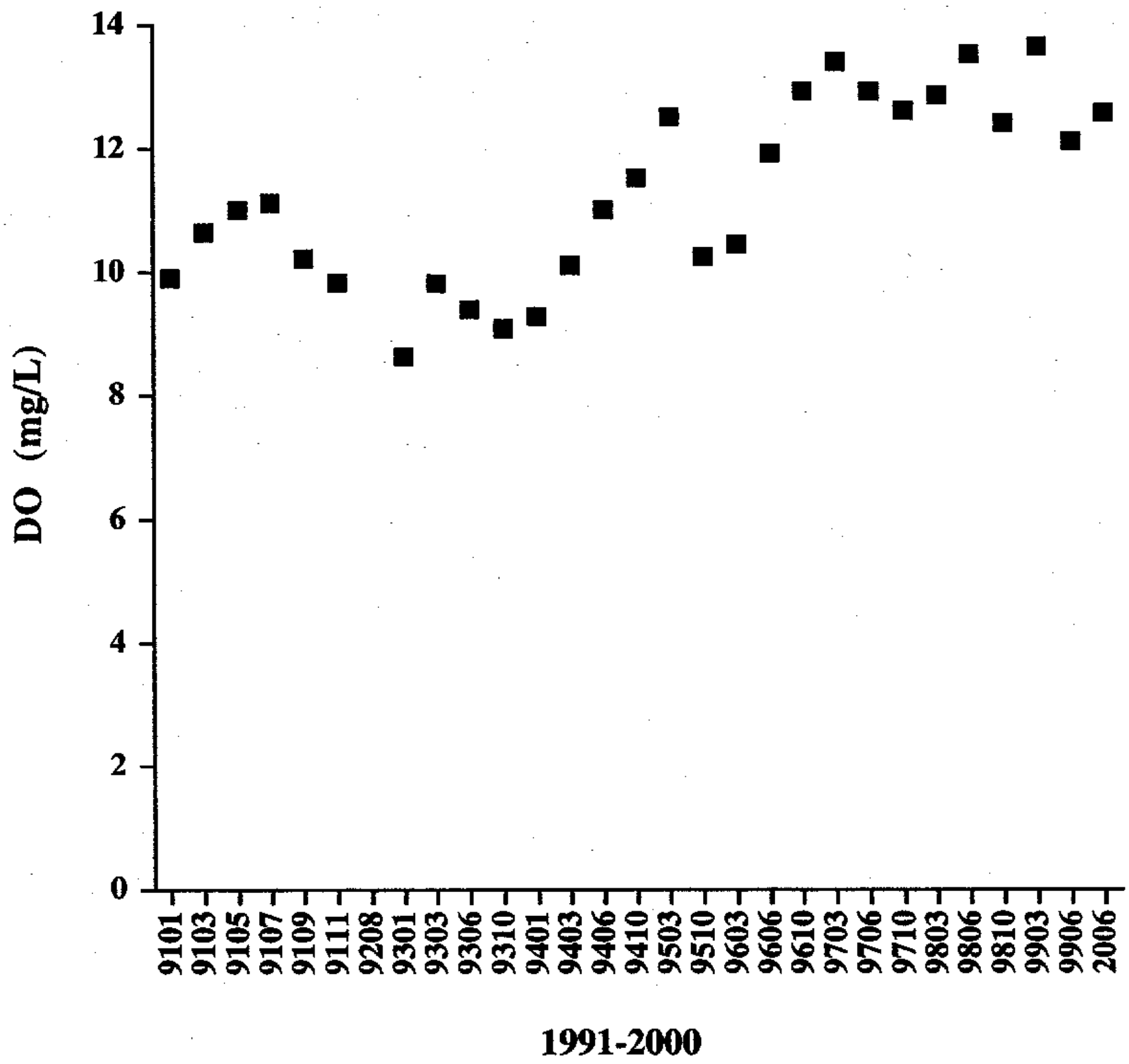

Figure 29. Dissolved oxygen (DO mg/L) collected at the Gauge Above LCR Rkm 98.4 from January 1991 to June 2000.

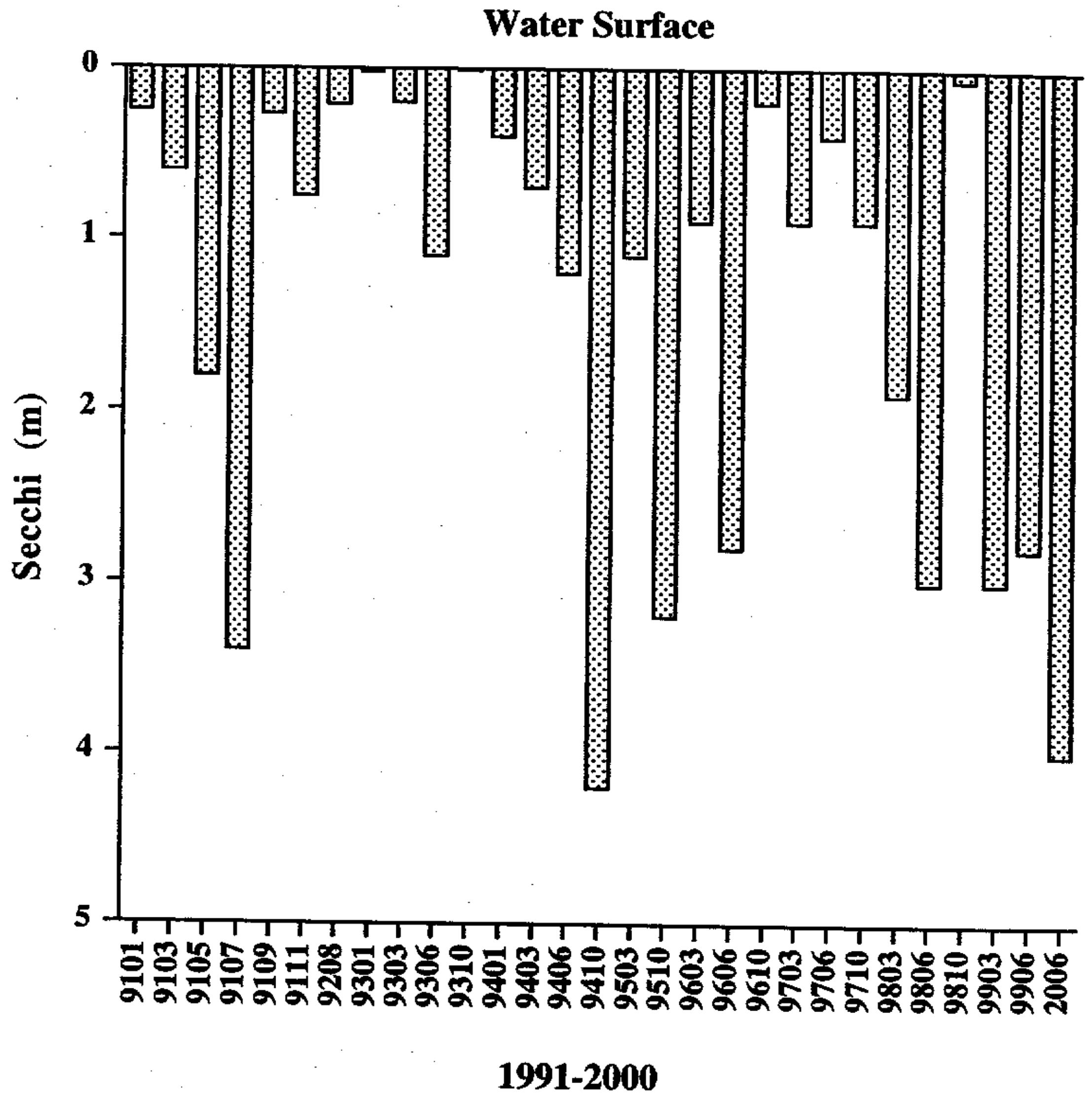

Figure 30. Secchi depth (m) collected at the Gauge Above LCR Rkm 98.4 from January 1991 to June 2000.

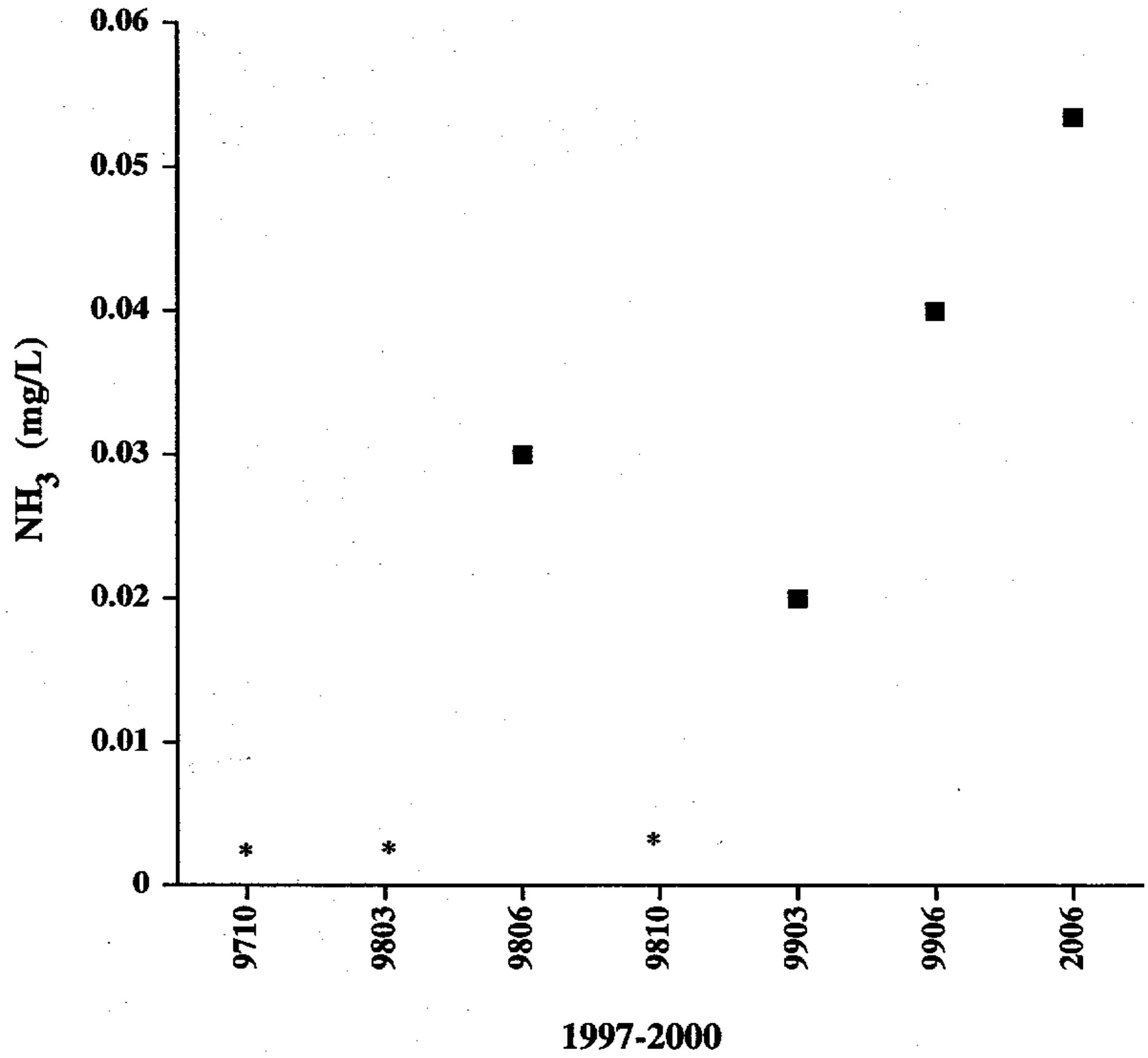

Figure 31. Ammonia (NH_3 mg/L) collected at the Gauge above LCR Rkm 98.4 from October 1997 to June 2000. Samples below detection levels are represented by (*).

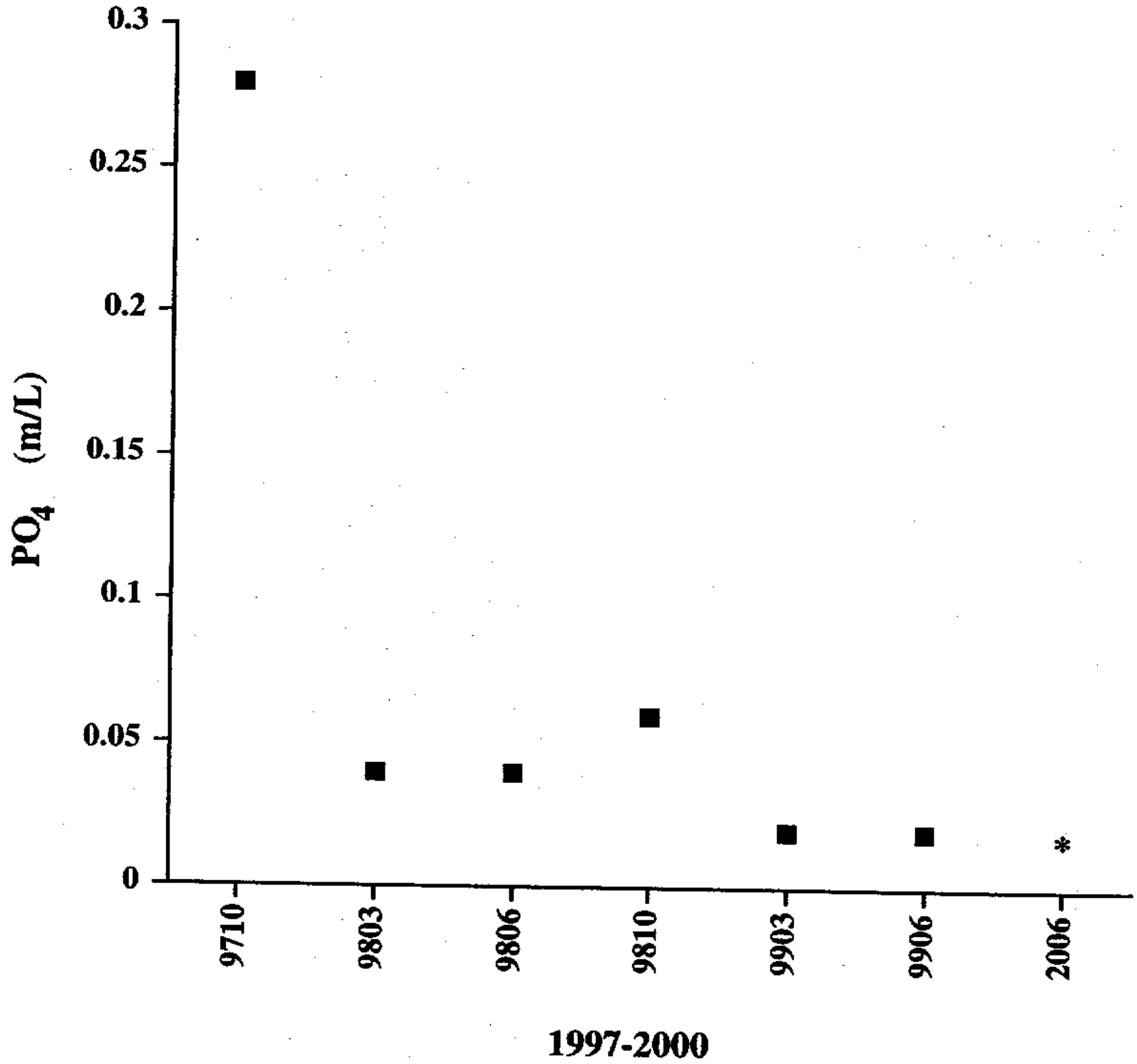

Figure 32. Phosphate (PO_4 mg/L) collected at the Gauge above LCR Rkm 98.4 from October 1997 to June 2000. Samples below detectable limits are represented by a (*).

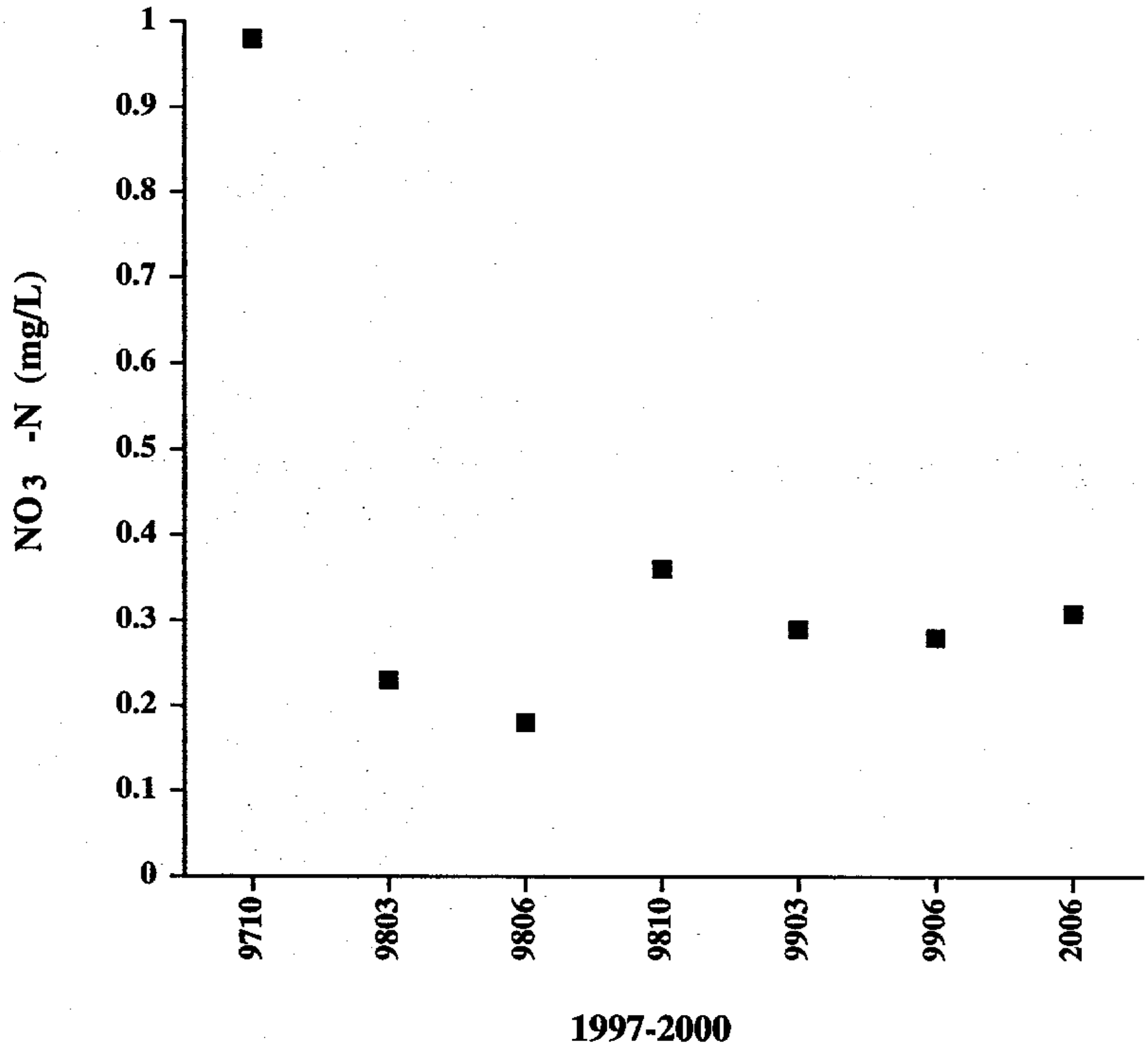

Figure 33. Nitrate-nitrogen (NO_3-N mg/L) collected at the Gauge above LCR Rkm 98.4 from October 1997 to June 2000.

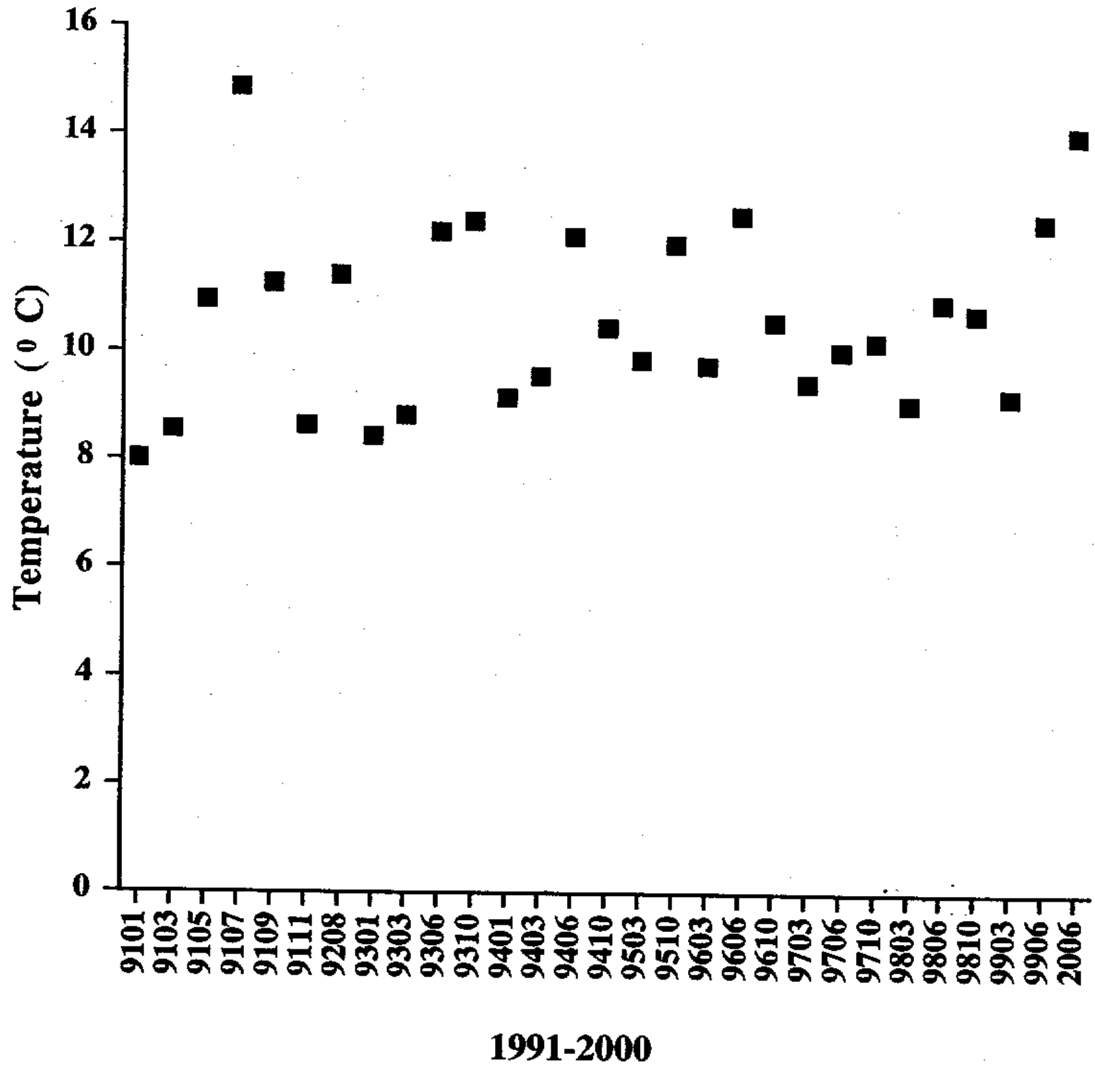

Figure 34. Water temperature (°C) collected at Tanner Canyon Rkm 108.8 from January 1991 to June 2000.

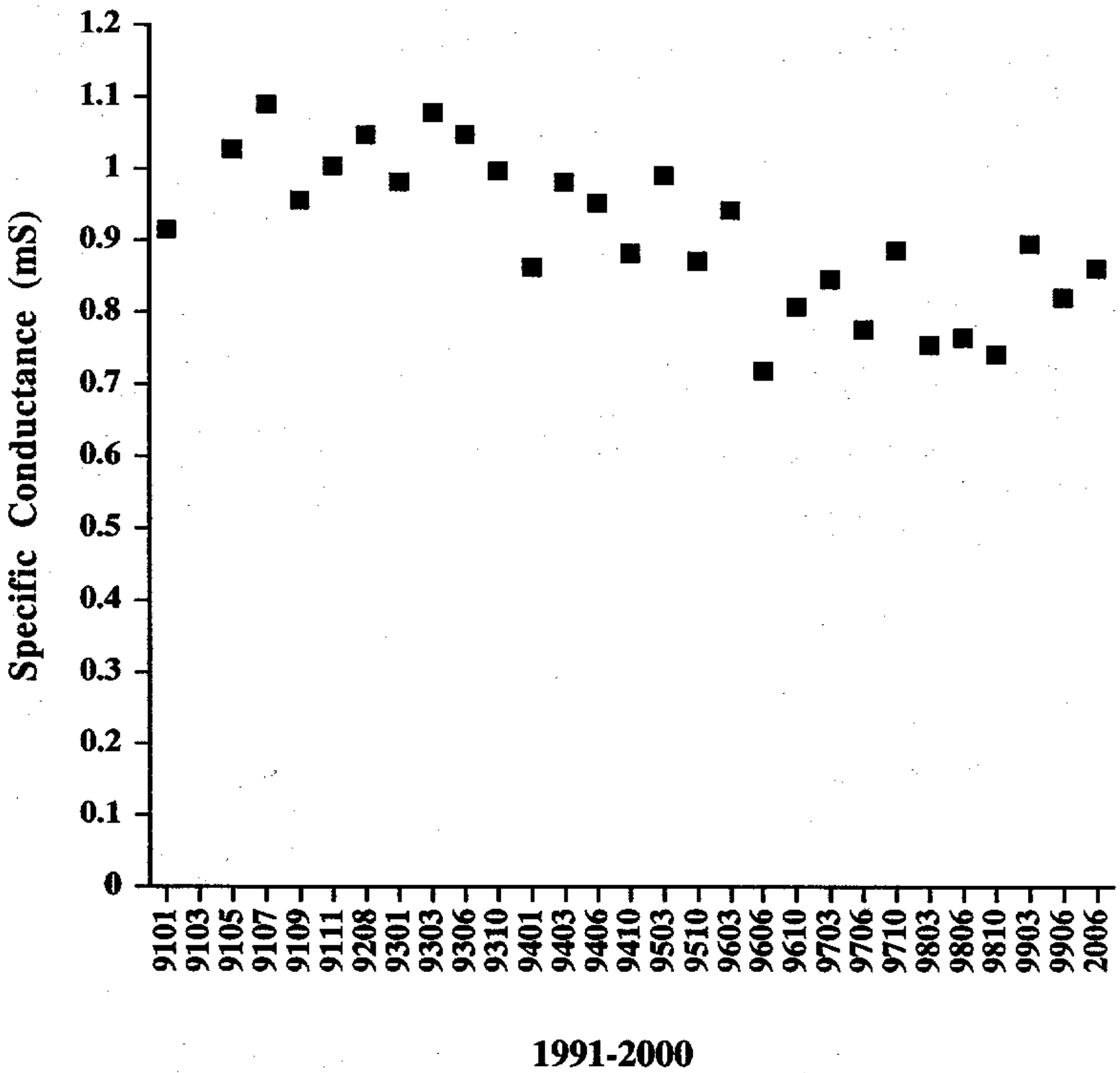

Figure 35. Specific conductance (mS) collected at Tanner Canyon Rkm 108.8 from January 1991 to June 2000.

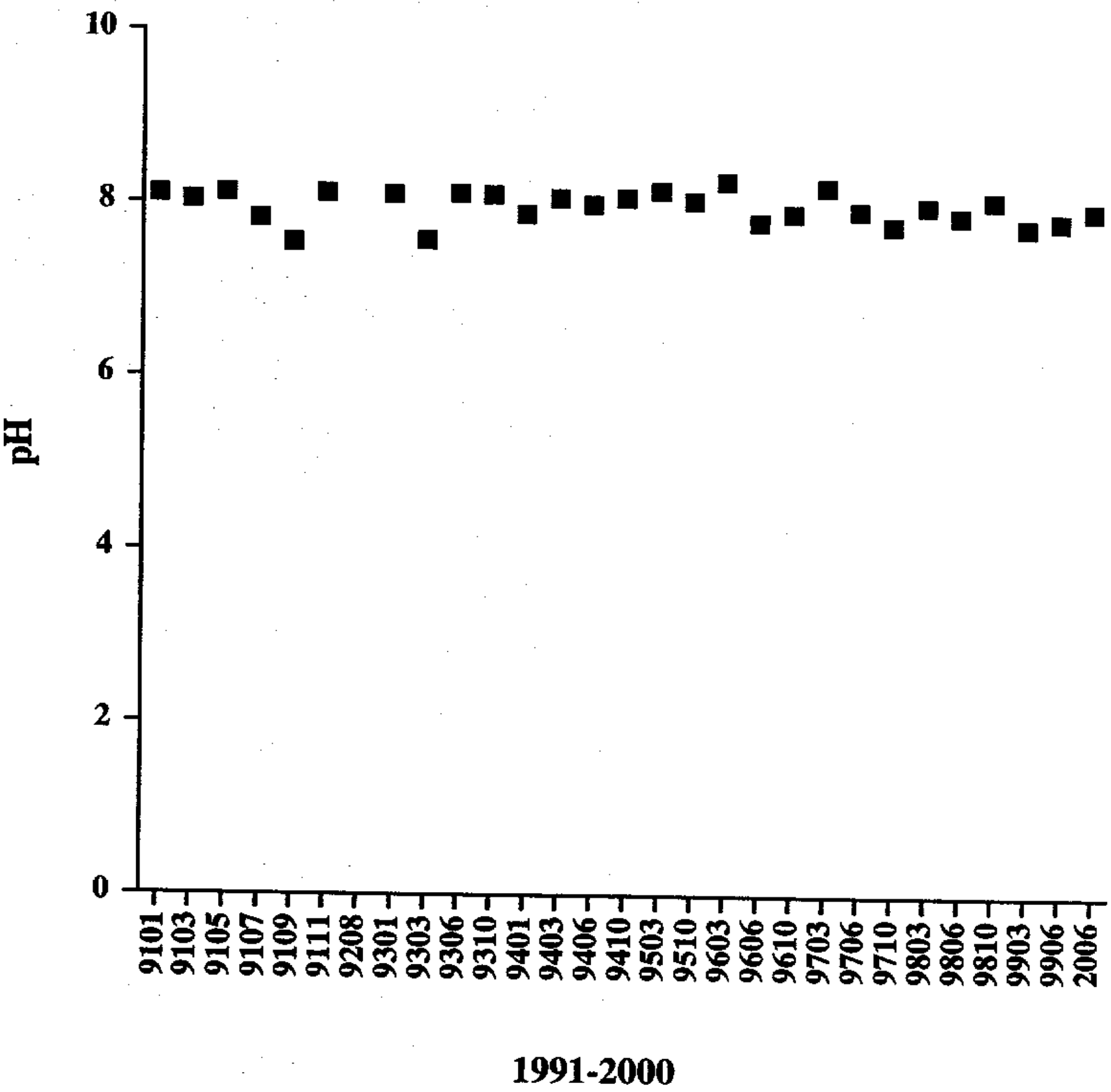

Figure 36. pH collected at Tanner Canyon Rkm 108.8 from January 1991 to June 2000.

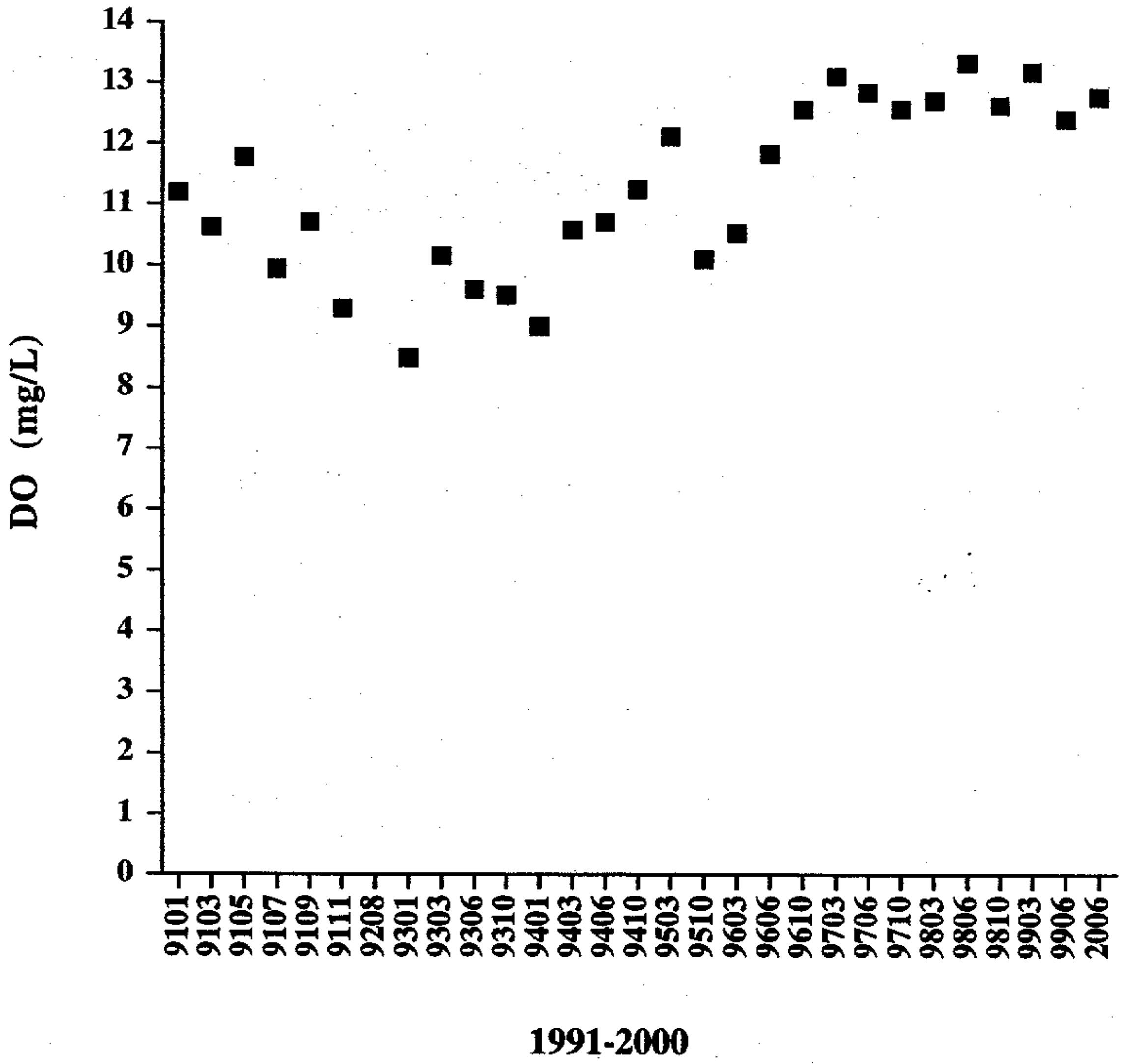

Figure 37. Dissolved oxygen (mg/L) collected at Tanner Canyon Rkm 108.8 from January 1991 to June 2000.

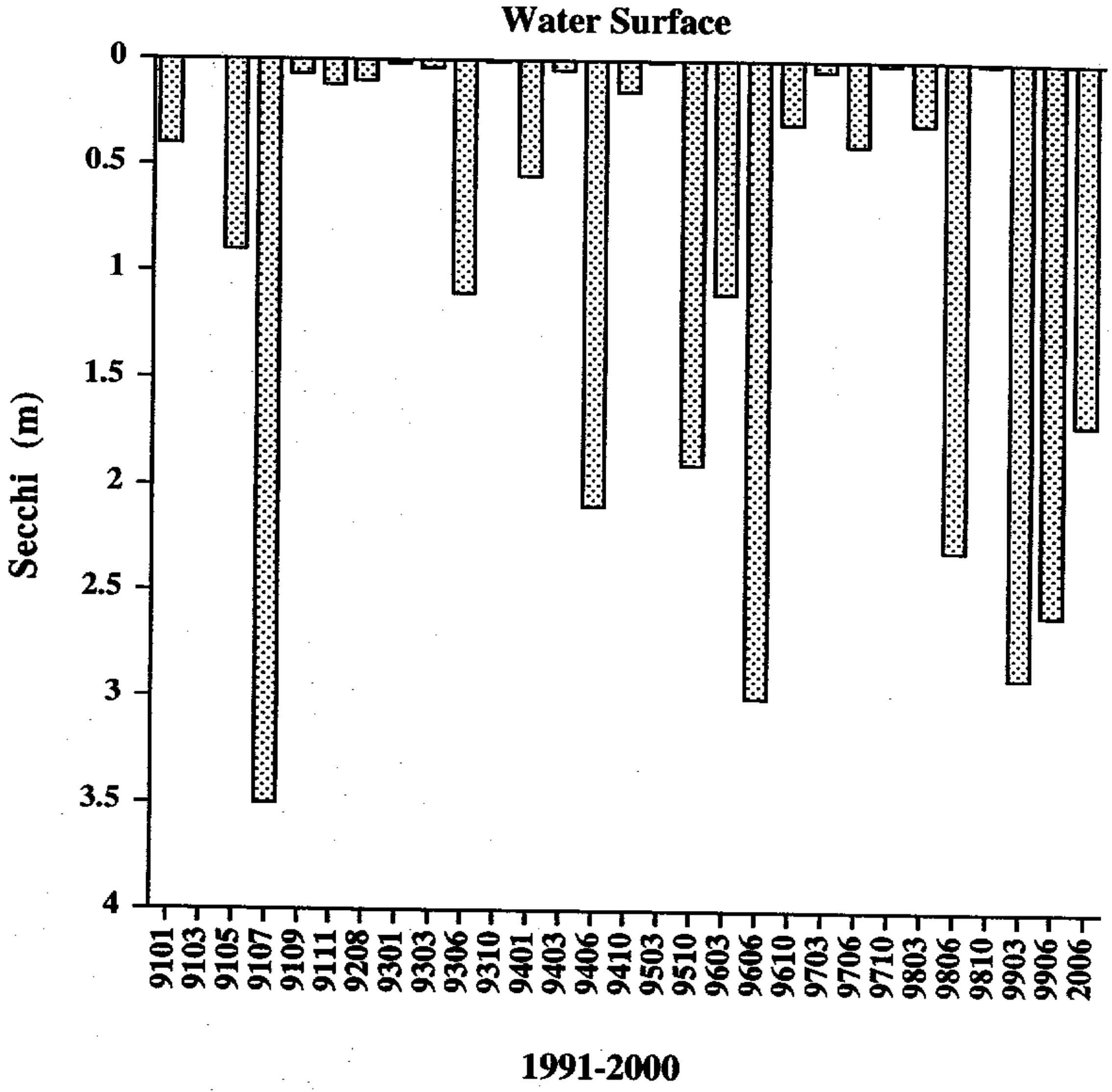

Figure 38. Secchi depth (m) collected at Tanner Canyon Rkm 108.8 from January 1991 to June 2000.

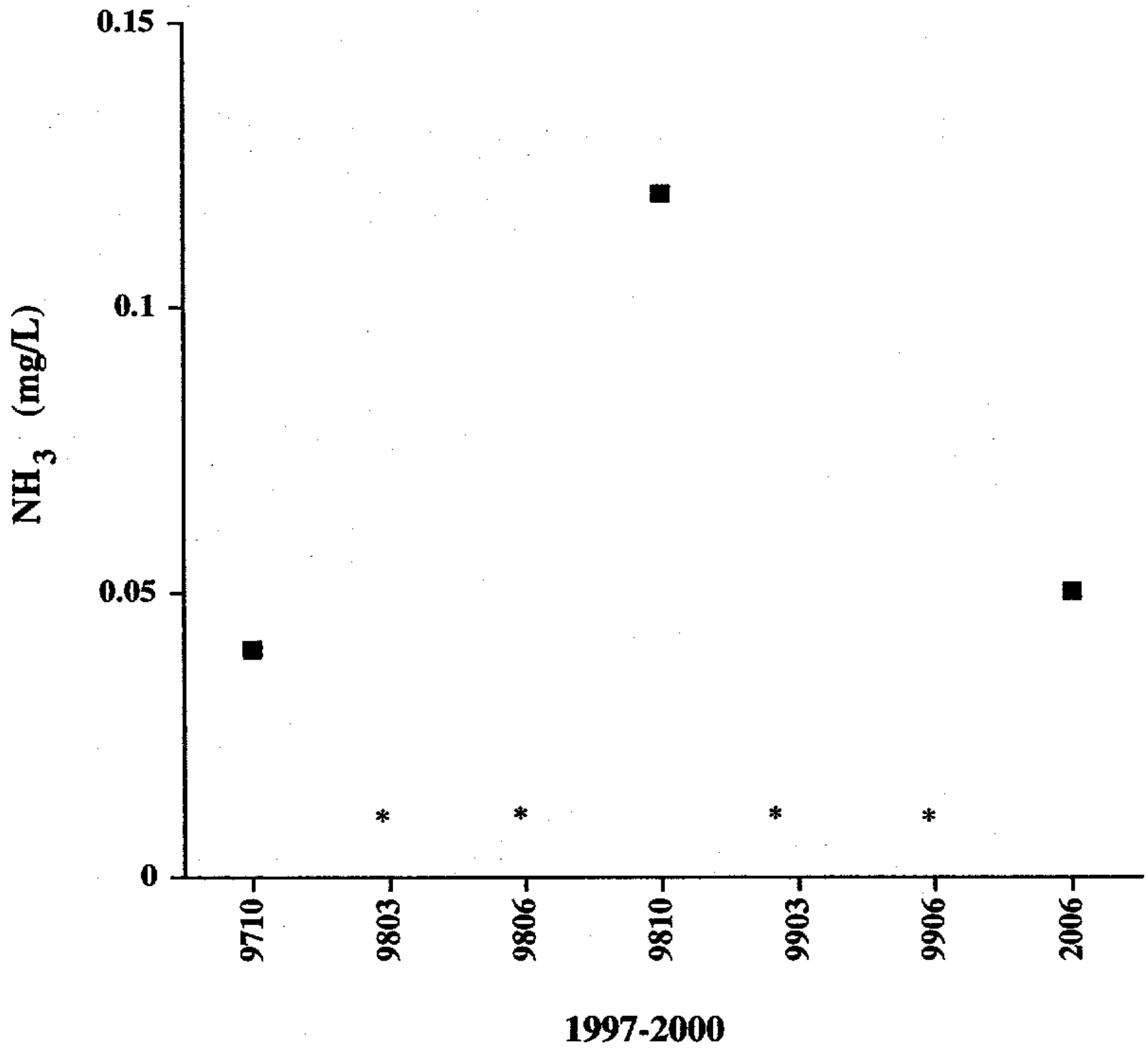

Figure 39. Ammonia (NH_3 mg/L) collected at Tanner Canyon Rkm 108.8 from October 1997 to June 2000. Samples below detectable levels are represented by a (*).

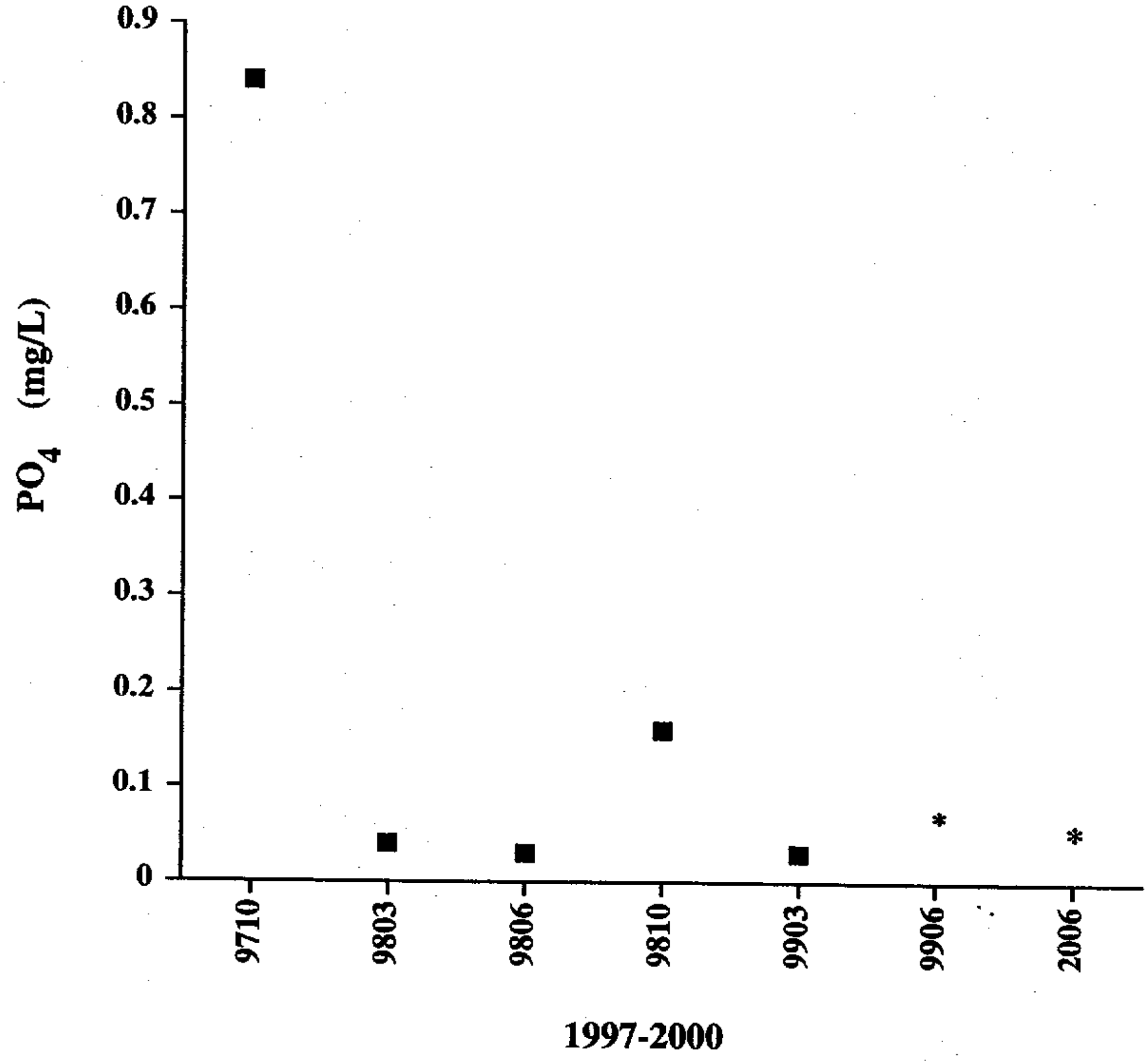

Figure 40. Phosphate (PO_4mg/L) collected at Tanner Canyon Rkm 108.8 from October 1997 to June 2000. Samples below detectable levles are represented by a (*).

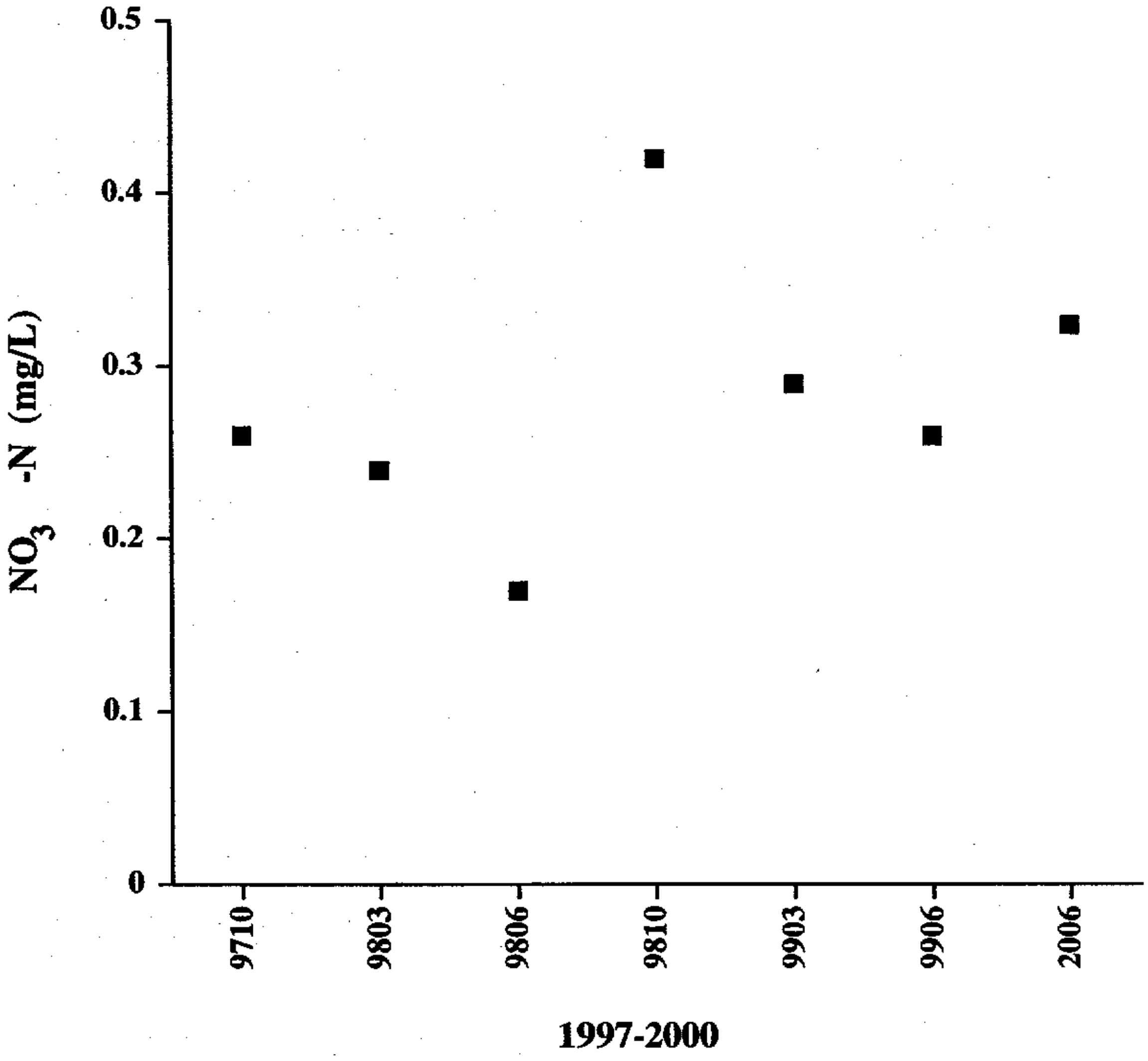

Figure 41. Nitrate-nitrogen (NO_3-N mg/L) collected at Tanner Canyon Rkm 108.8 from October 1997 to June 2000.

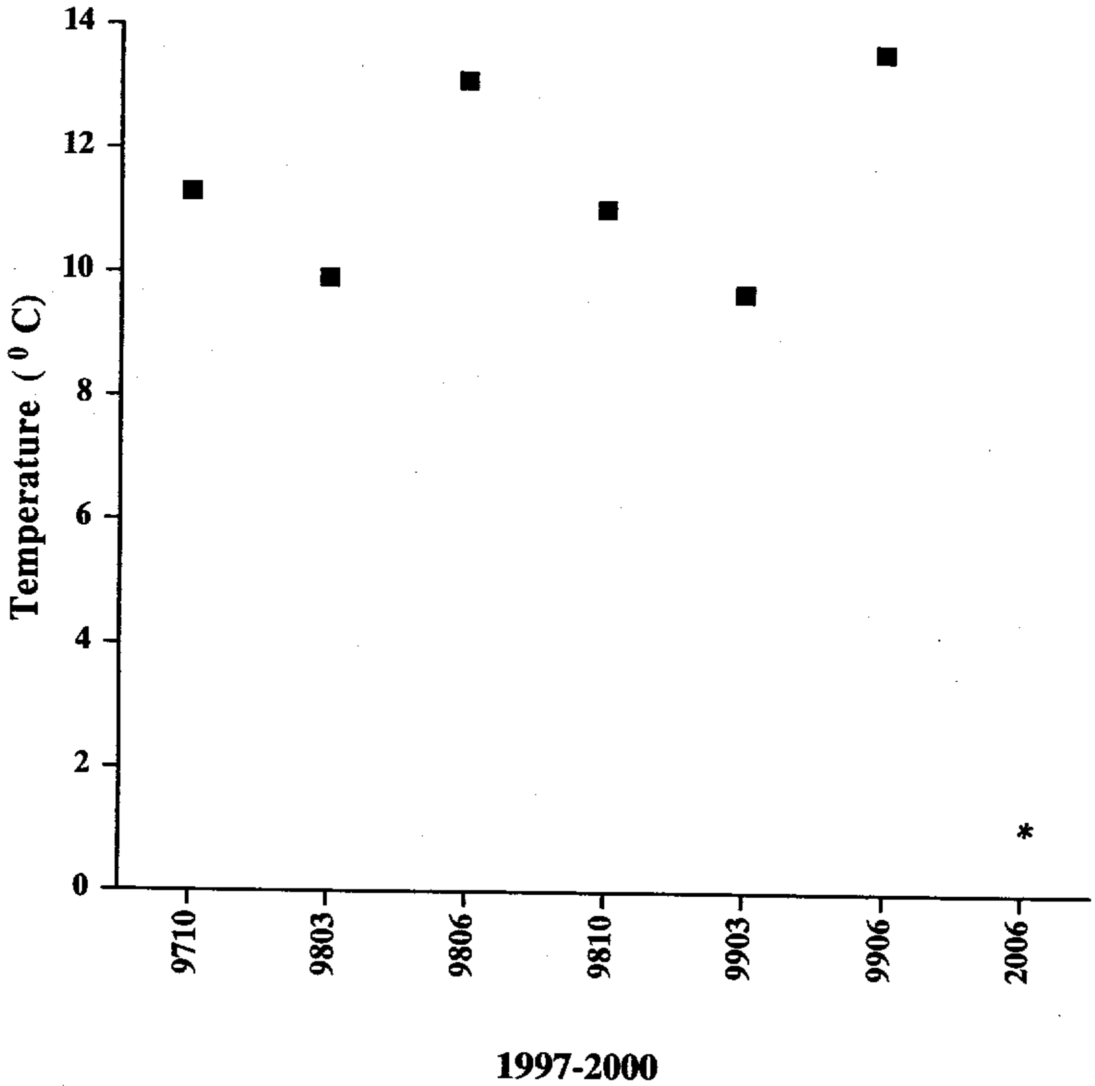

Figure 42. Water temperature (℃) collected at 127 Mile Rkm 202.9 from October 1997 to June 2000.Asterisk (*) represents 15.87.

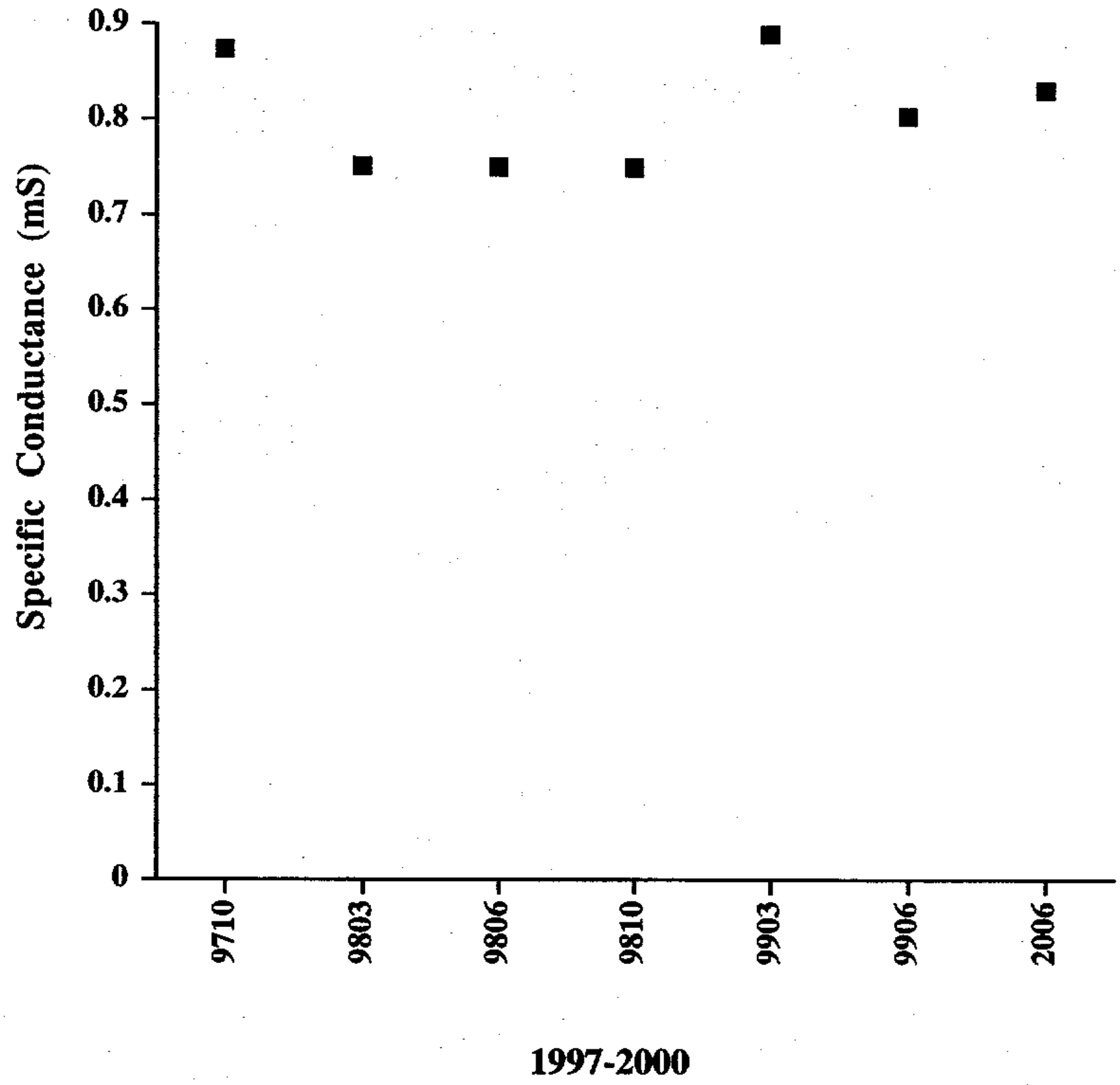

Figure 43. Specific conductance (mS) collected at 127 Mile Rkm 202.9 from October 1997 to June 2000.

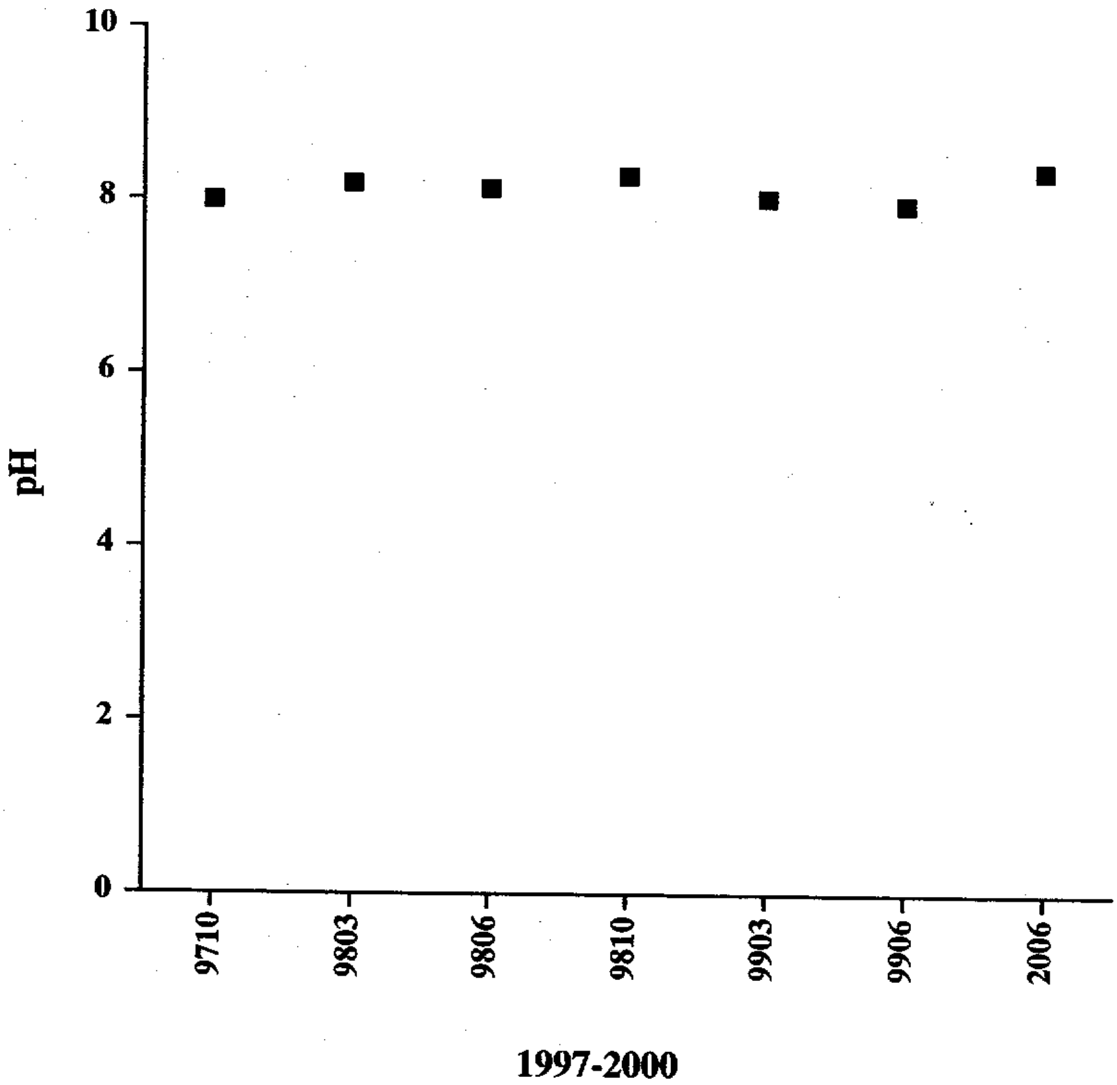

Figure 44. pH collected at 127 Mile Rkm 202.9 from October 1997 to June 2000.

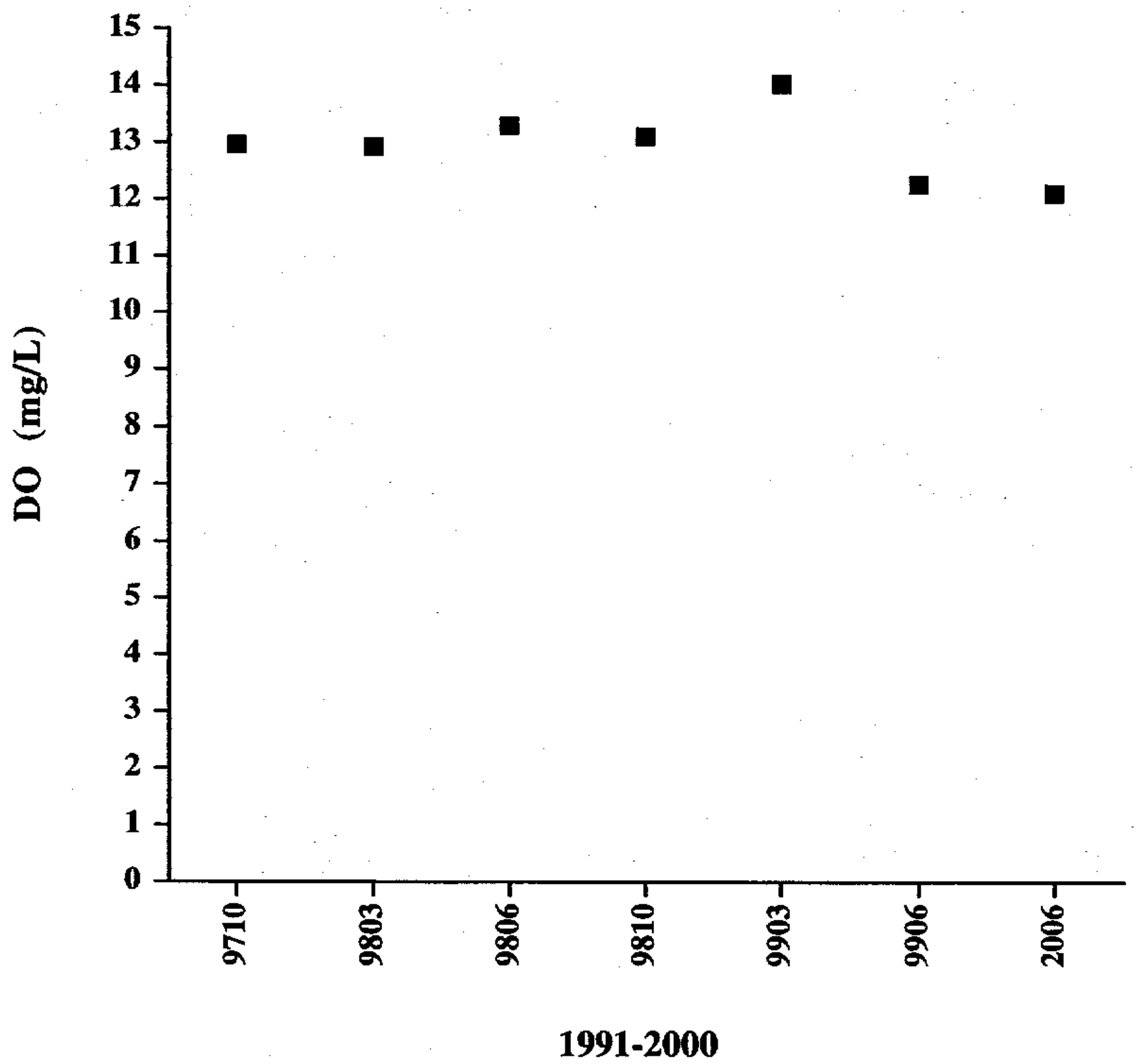

Figure 45. Dissolved oxygen (mg/L) collected at 127 Mile Rkm 202.9 from October 1997 to June 2000.

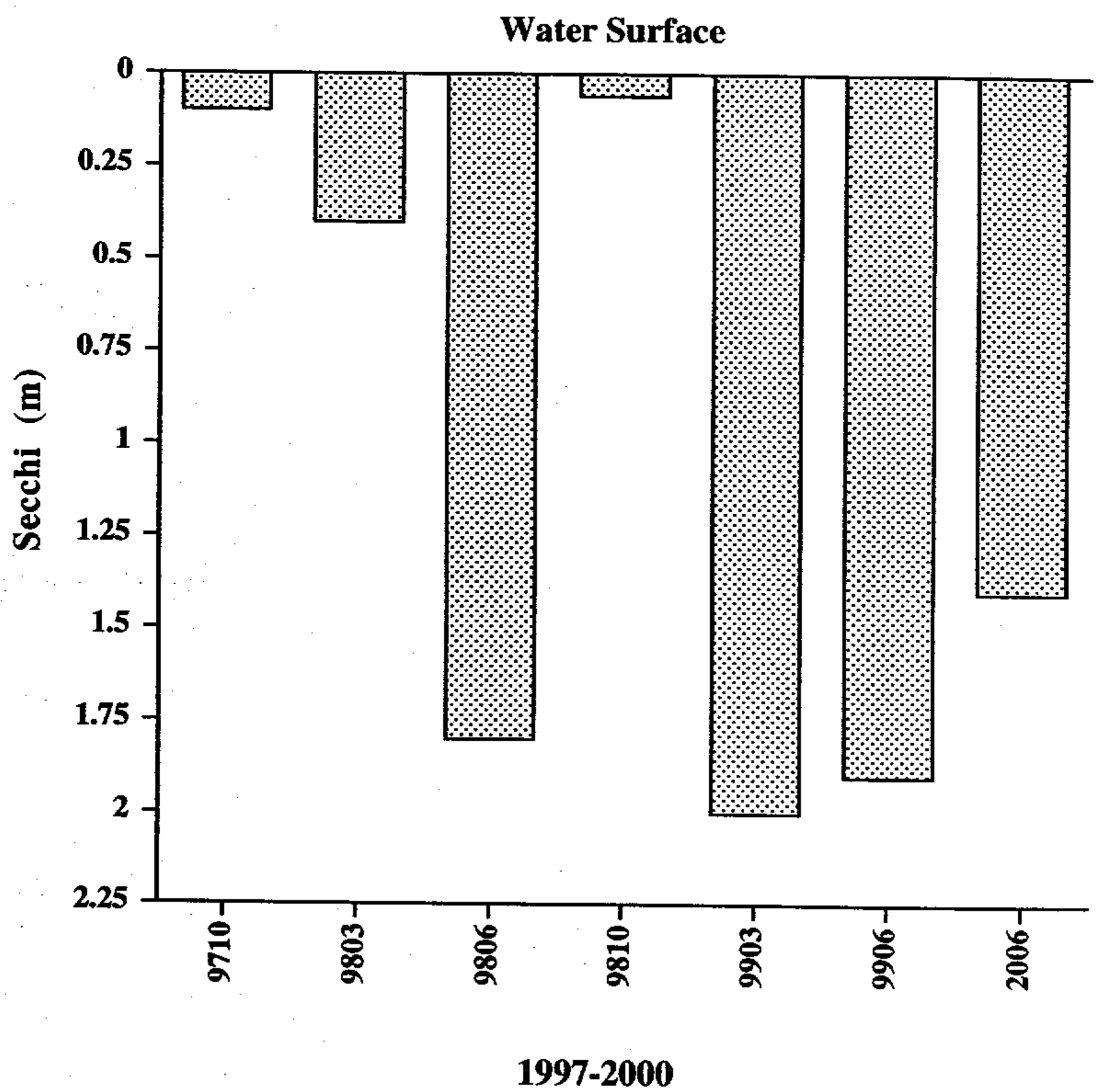

Figure 46. Secchi depth (m) collected at 127 Mile Rkm 202.9 from October 1997 to June 2000.

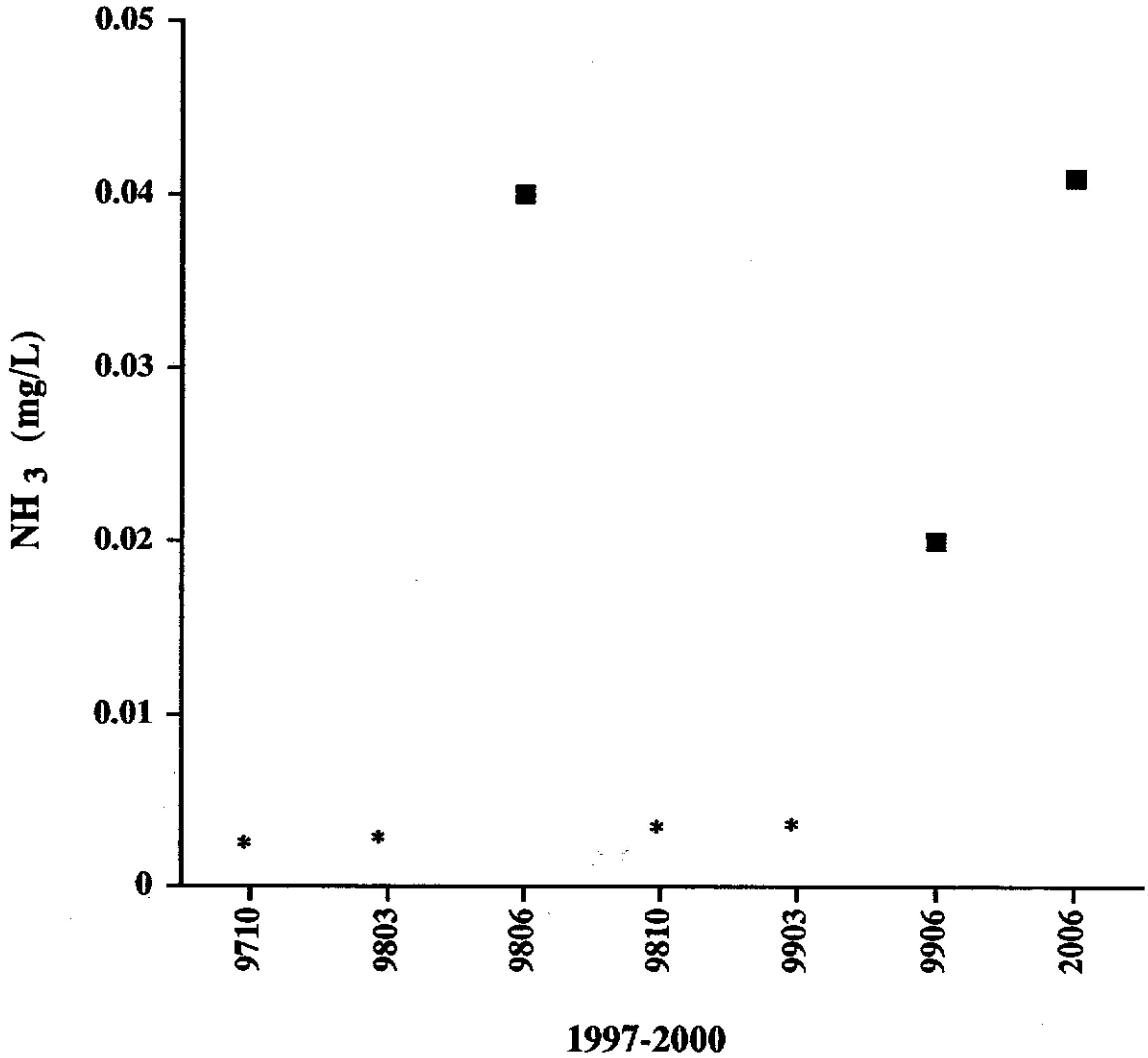

Figure 47. Ammonia (NH_3 mg/L) collected at 127 Mile Rkm 202.9 from October 1997 to June 2000. Samples below detectable levels are represented by a (*).

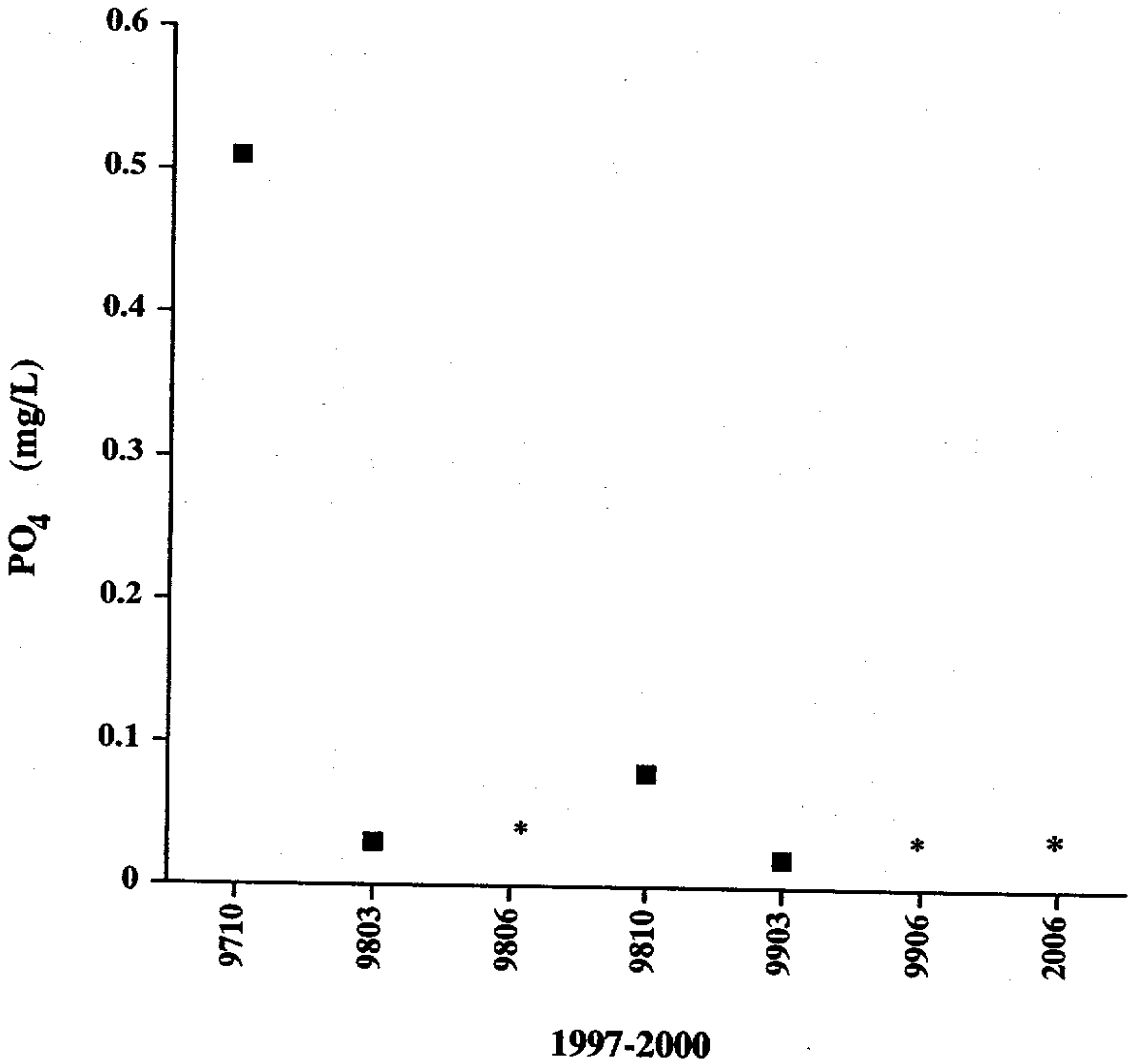

Figure 48. Phosphate (PO_4 mg/L) collected at 127 Mile Rkm 202.9 from October 1997 to June 2000. Samples below detectable levels are represented by a (*).

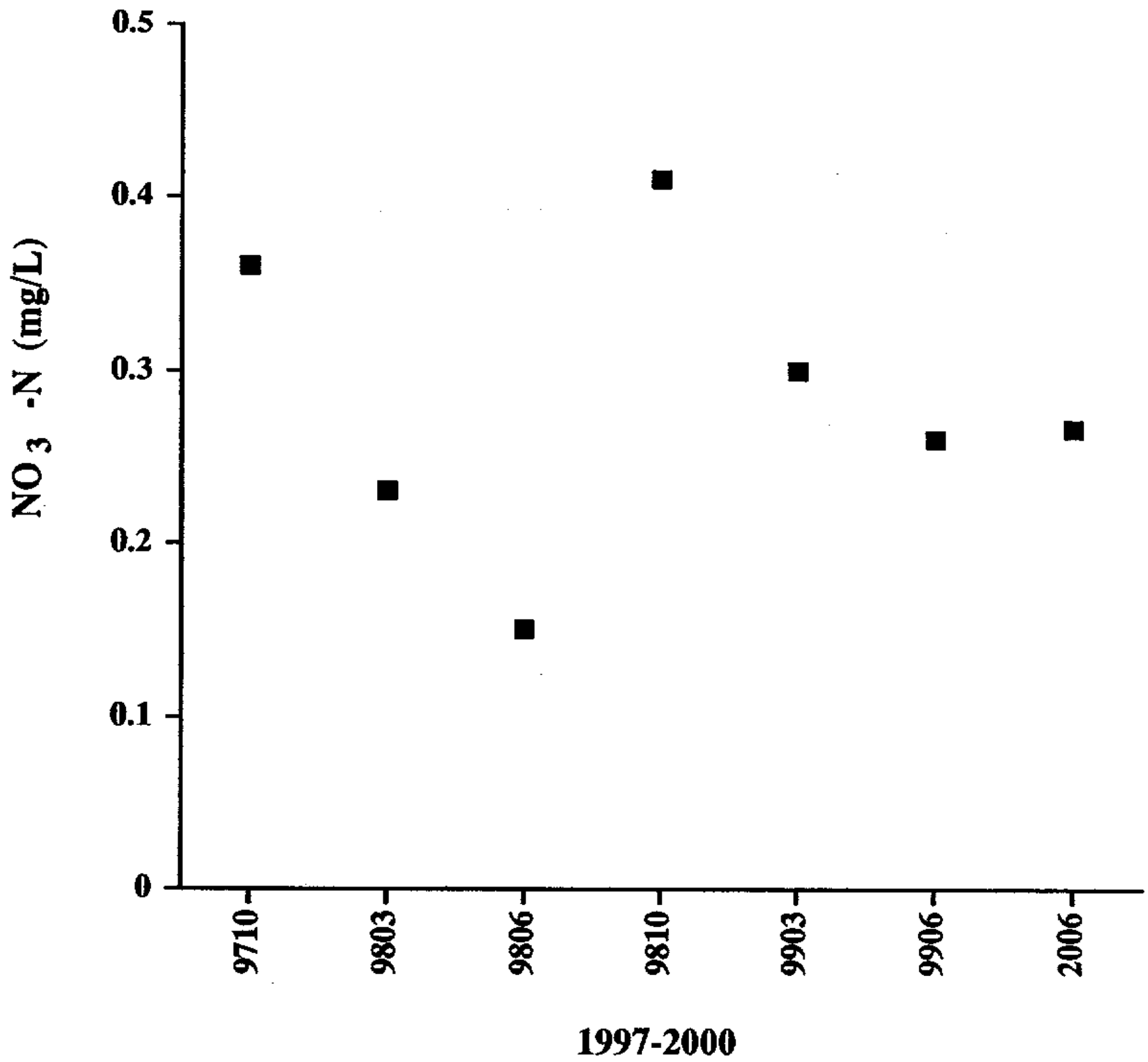

Figure 49. Nitrate-nitrogen (NO_3N mg/L) collected at 127 Mile Rkm 202.9 from October 1997 to June 2000.

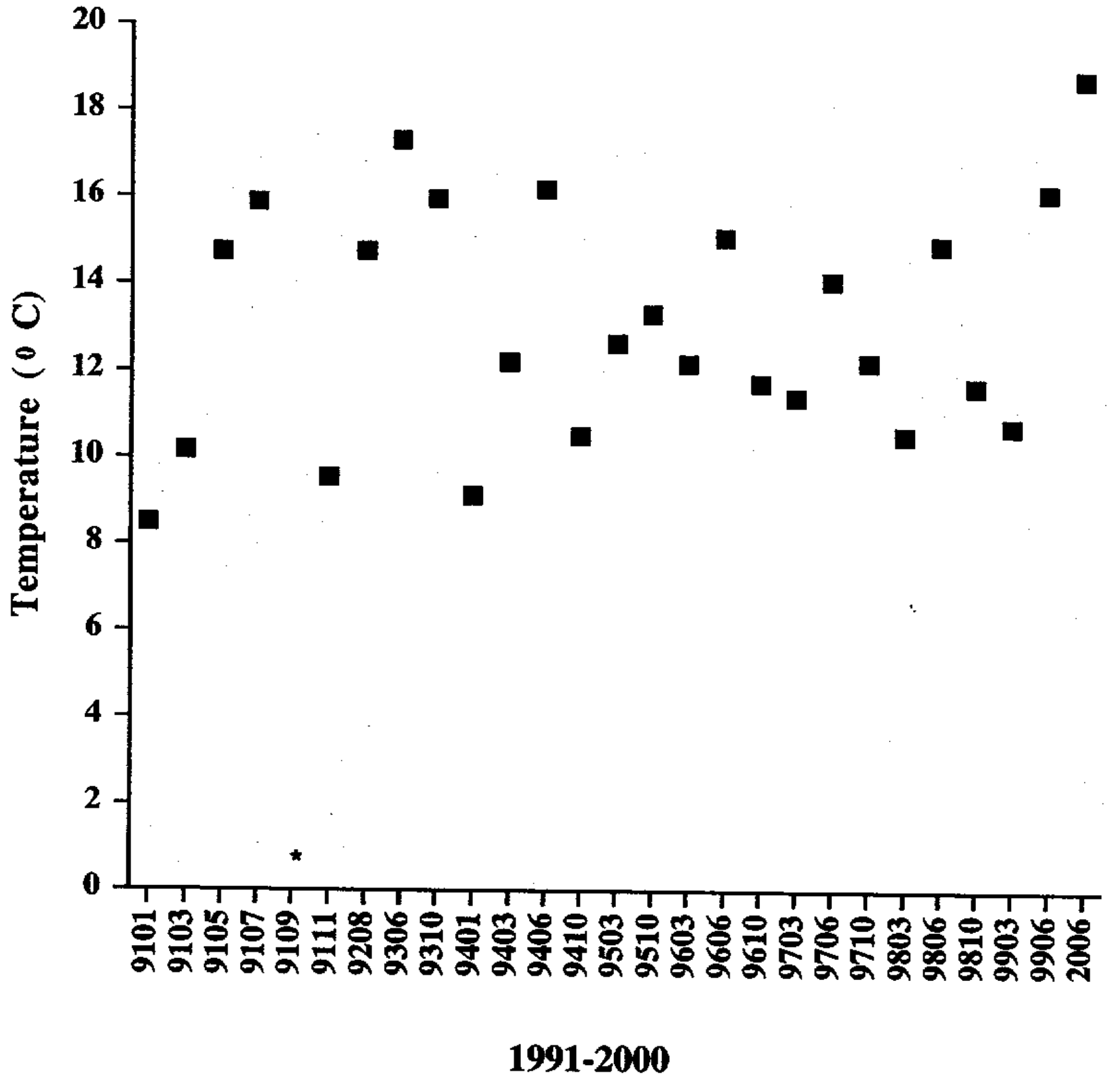

Figure 50. Water temperature (℃) collected at 205 Mile Rkm 328.8 from January 1991 to June 2000. Asterisk (*) represents missing data point.

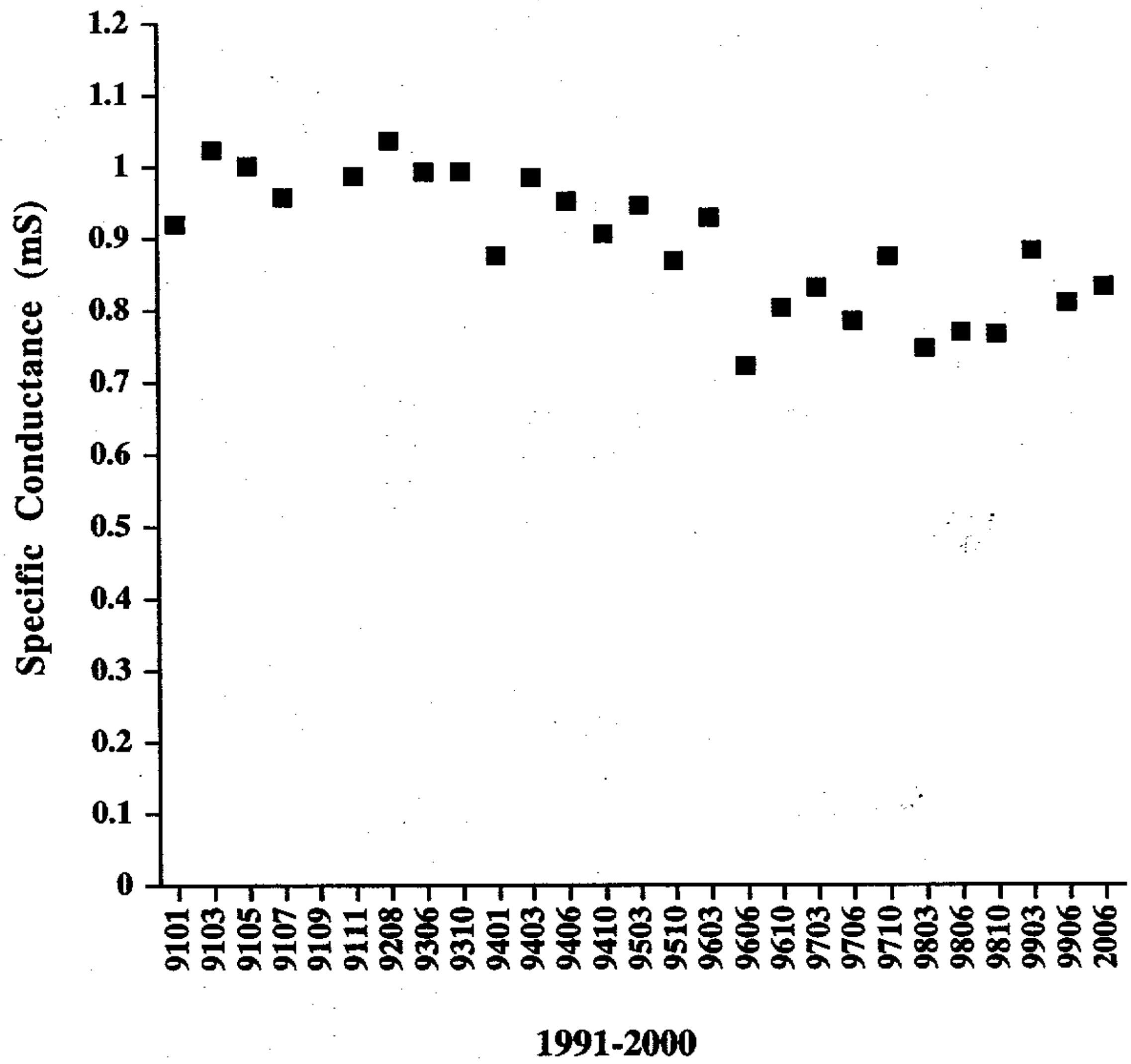

Figure 51. Specific conductance (mS) collected at 205 Mile Rkm 328.8 from January 1991 to June 2000.

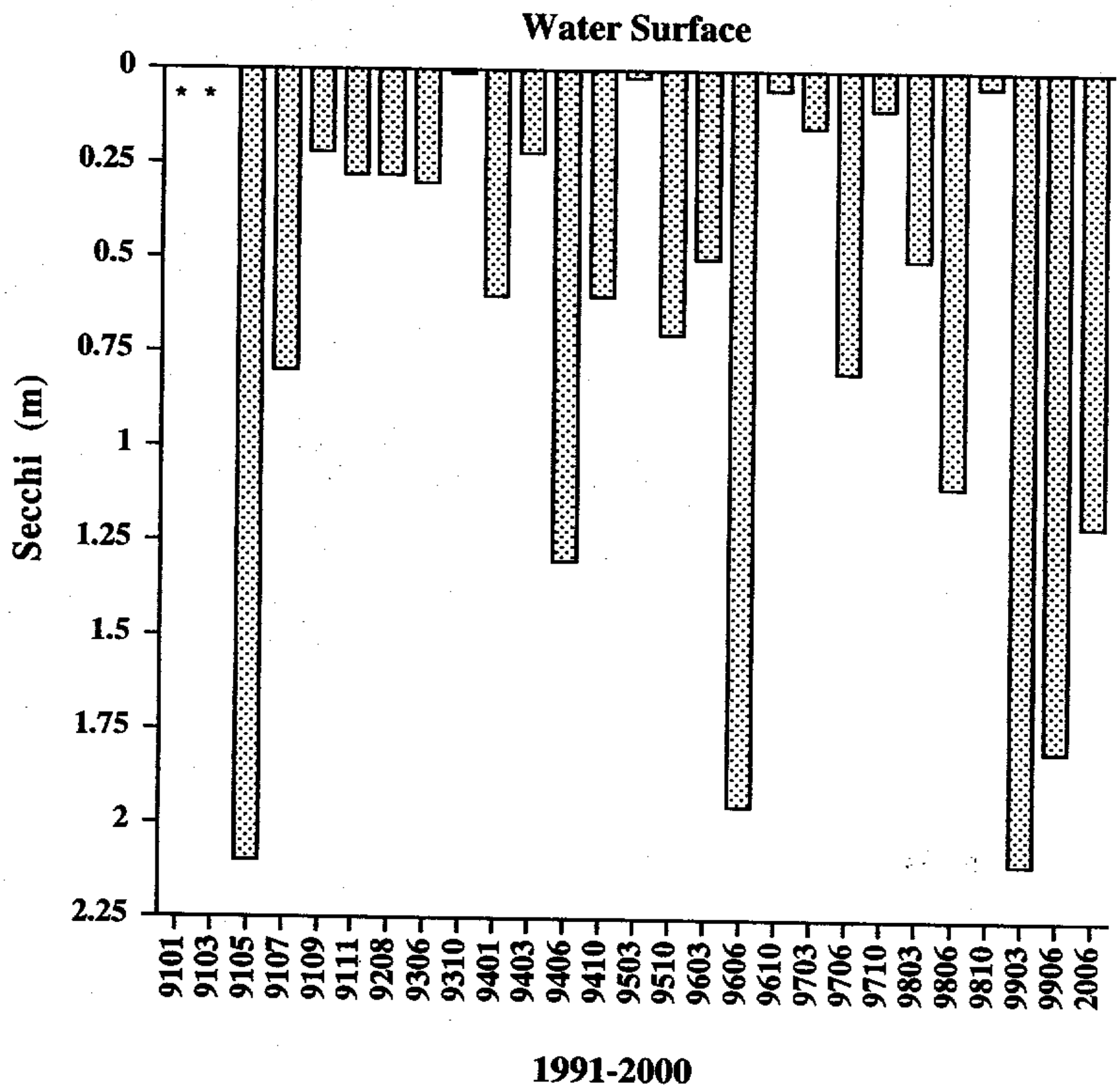

Figure 54. Secchi depth (m) collected at 205 Mile Rkm 328.8 from January 1991 to June 2000. Asterisk (*) represents missing data point.

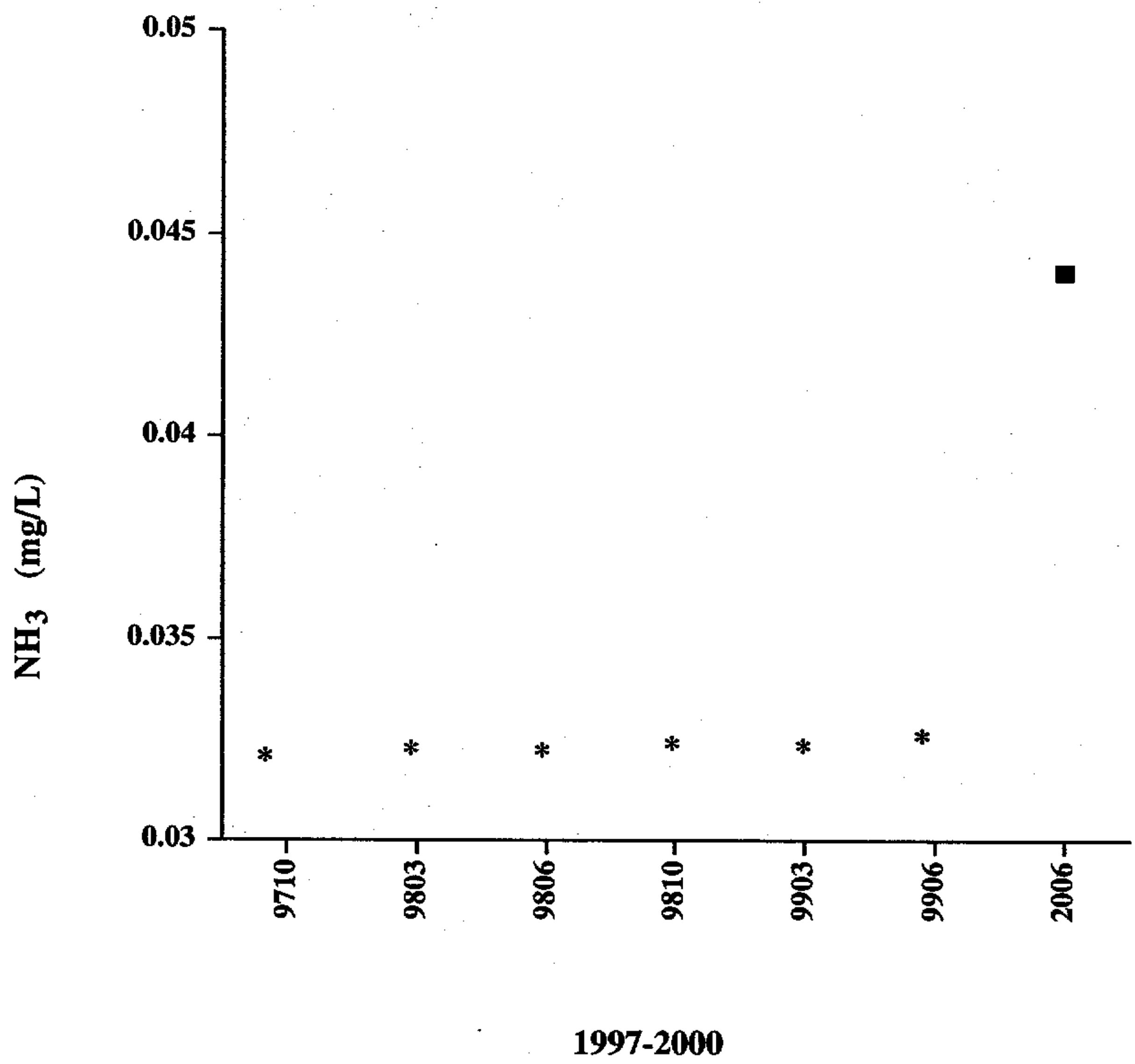

Figure 55. Ammonia (NH_3 mg/L) collected at 205 Mile Rkm 328.8 from October 1997 to June 2000. Samples below detectable levels are represented by (*).

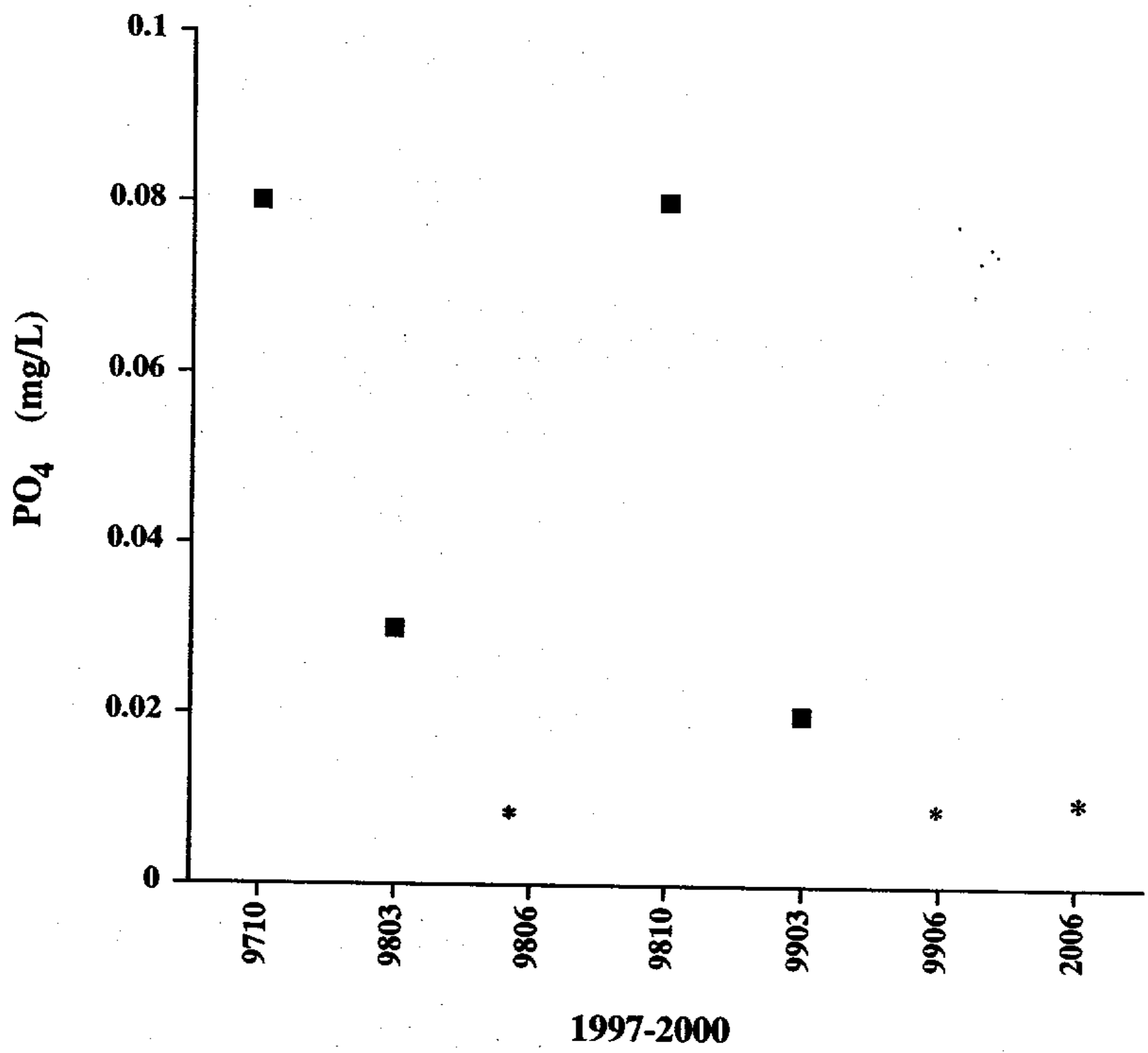

Figure 56. Phosphate (PO_4 mg/L) collected at 205 Mile Rkm 328.8 from October 1997 to June 2000. Samples below detectable levels are represented by a (*).

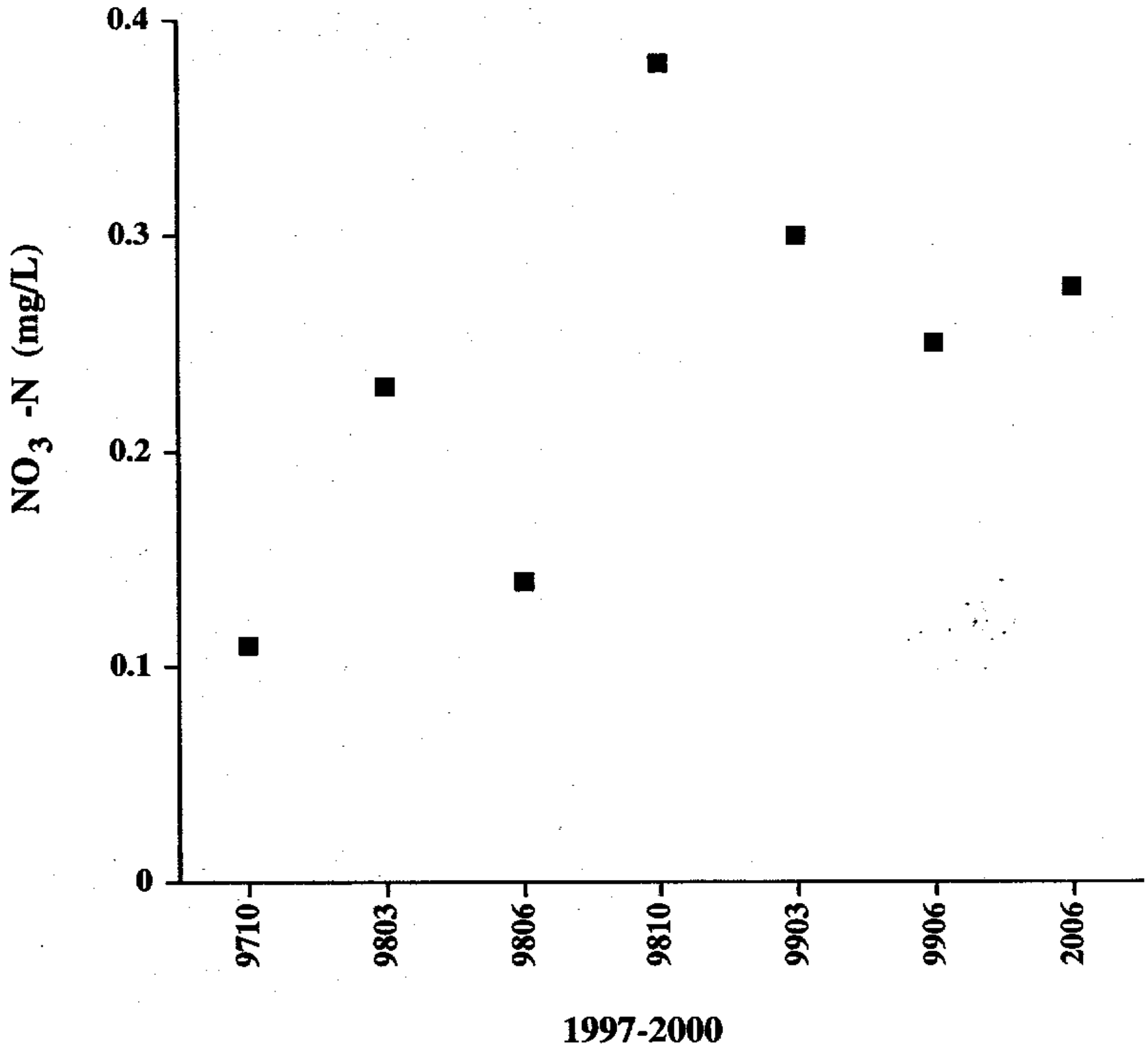

Figure 57. Nitrate-nitrogen (NO_3-N mg/L) collected at 205 Mile Rkm 328.8 from October 1997 to June 2000.

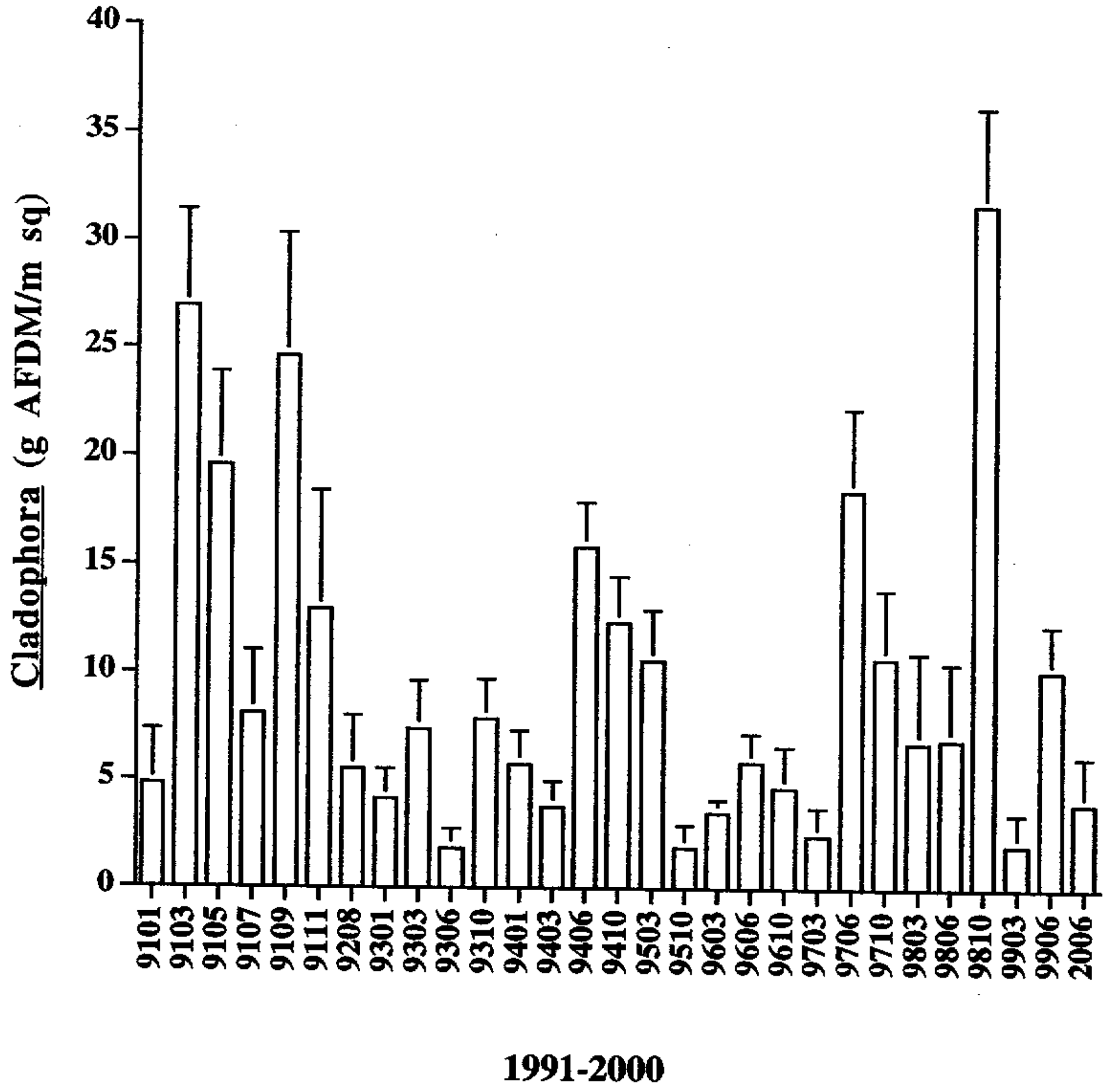

Figure 58. Cladophora biomass estimates (g AFDM/m sq) at Lees Ferry cobble Rkm 0.8 from January 1991 to June 2000. Error bars represent (± 1 SE, n=6).

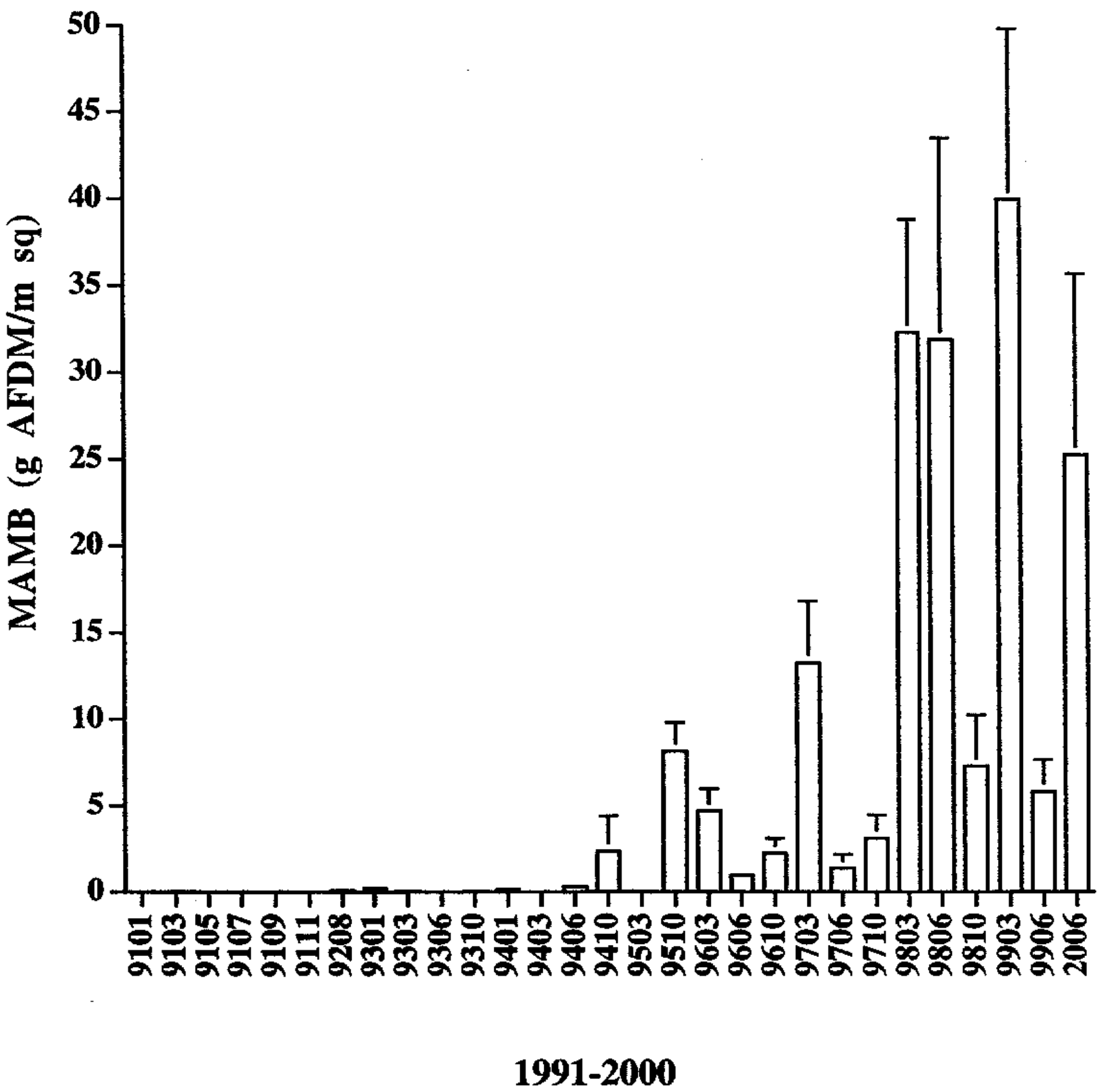

Figure 59. Miscellaneous algae, macrophytes and bryophytes (MAMB) biomass estimates (g AFDM/m sq) at Lees Ferry cobble Rkm 0.8 from January 1991 to June 2000. MAMB was not collected prior to August 1992. Error bars represent (± 1 SE, n=6).

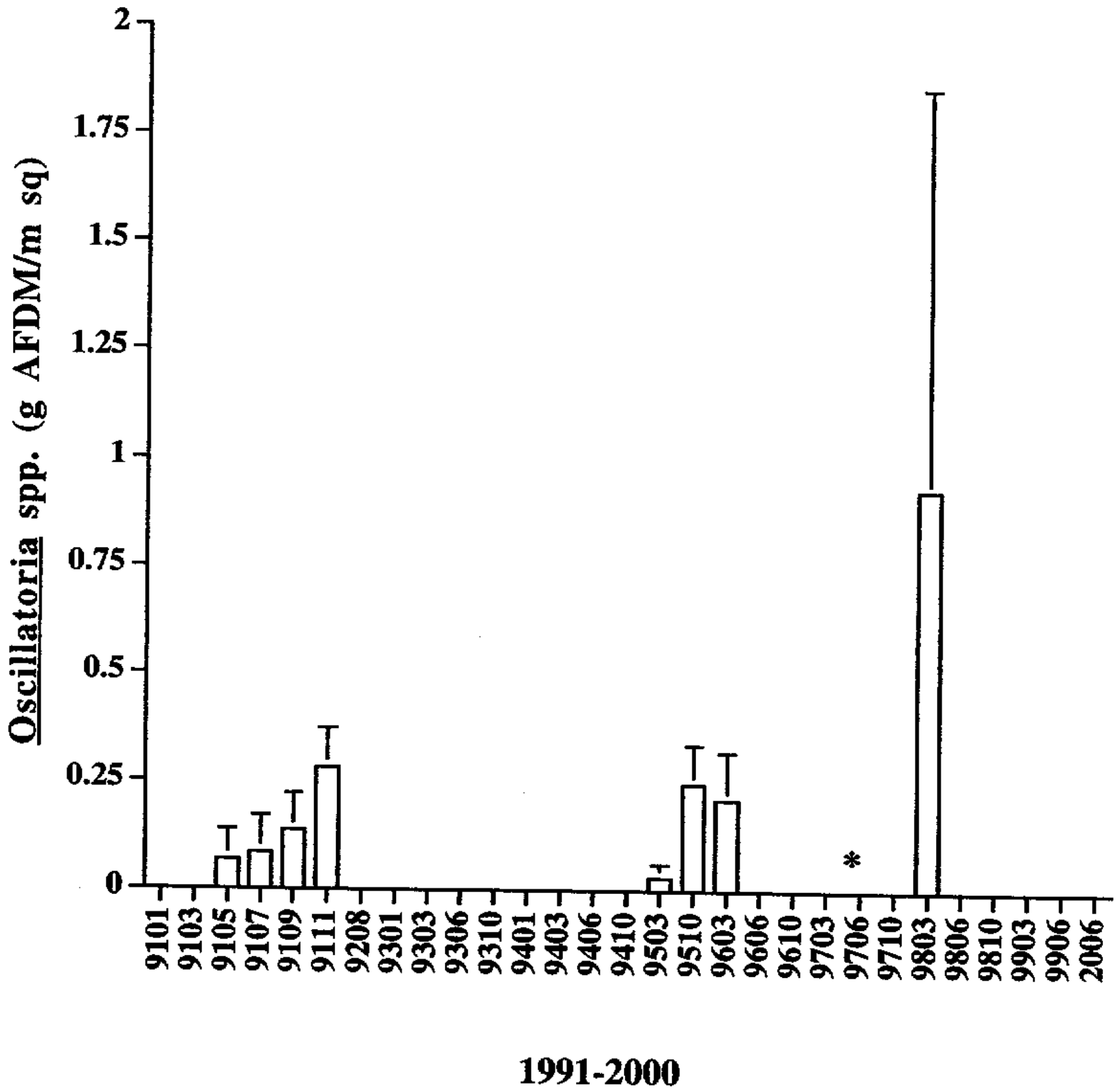

Figure 60. Oscillatoria spp. biomass estimates (g AFDM/m sq) at Lees Ferry cobble Rkm 0.8 from January 1991 to June 2000. Error bars represent (± 1 SE, n=6). Asterisk (*) represents 7 g AFDM/m (± 4 SE).

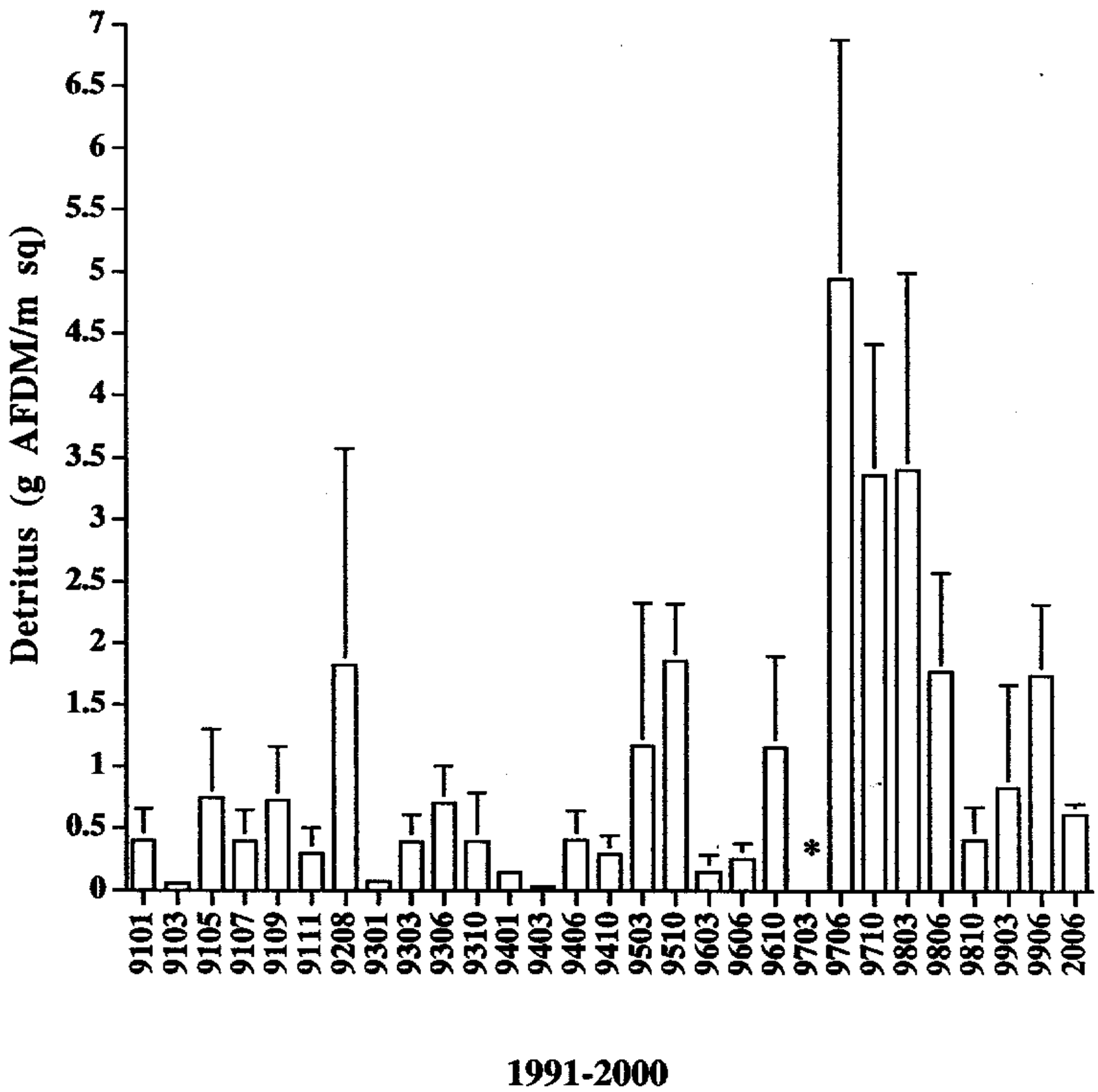

Figure 61. Detritus biomass estimates (g AFDM/m sq) at Lees Ferry cobble Rkm 0.8 from January 1991 to June 2000. Error bars represent (± 1 SE, n=6). Asterisk (*) represents 15 g AFDM/m sq (± 8 SE).

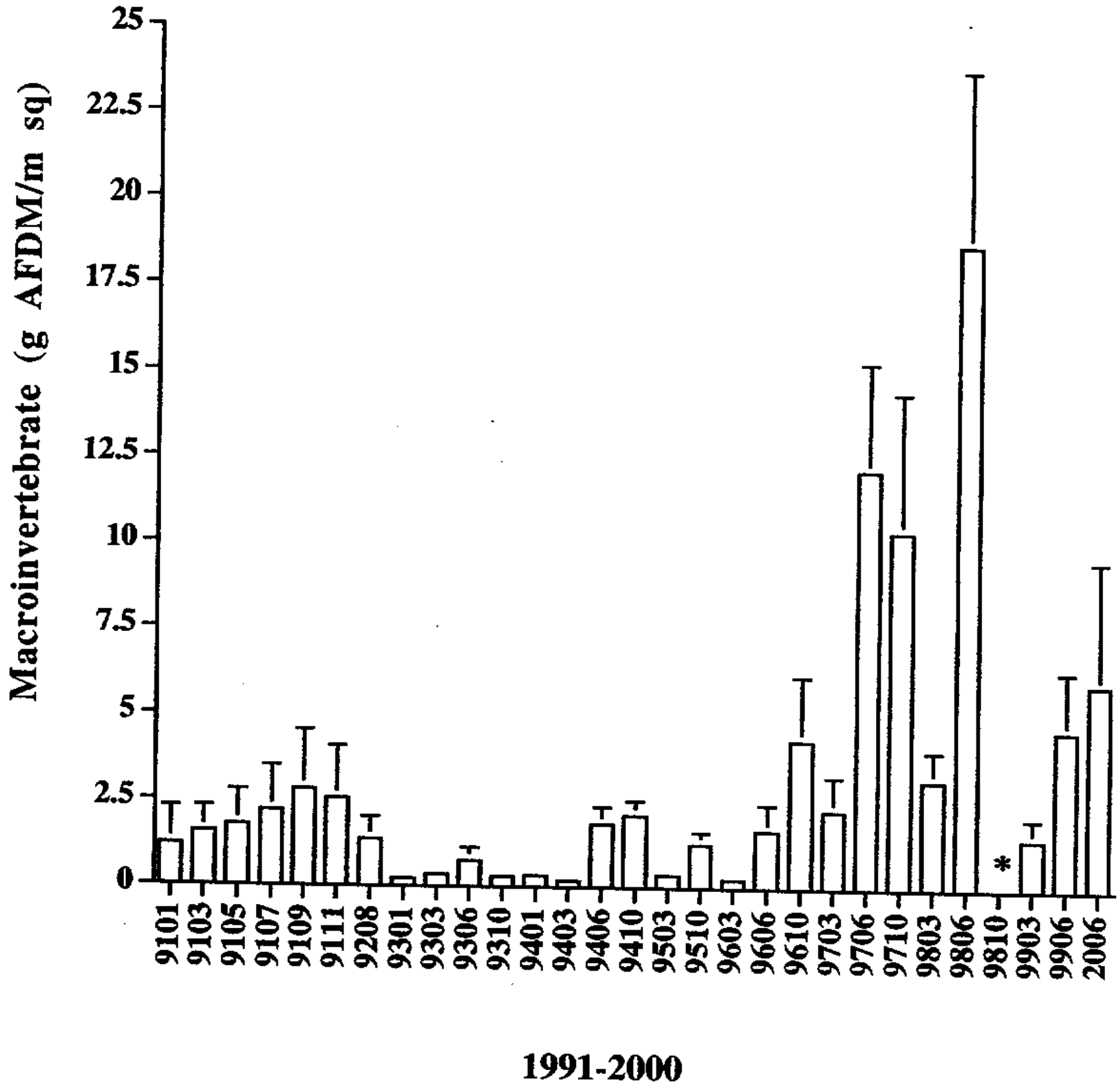

Figure 62. Macroinvertebrate biomass estimates (g AFDM/m sq) at Lees Ferry cobble Rkm 0.8 from January 1991 to June 1999. Error bars represent (± 1 SE, n=6). Asterisk (*) represents 52 g AFDM/m sq (± 7 SE).

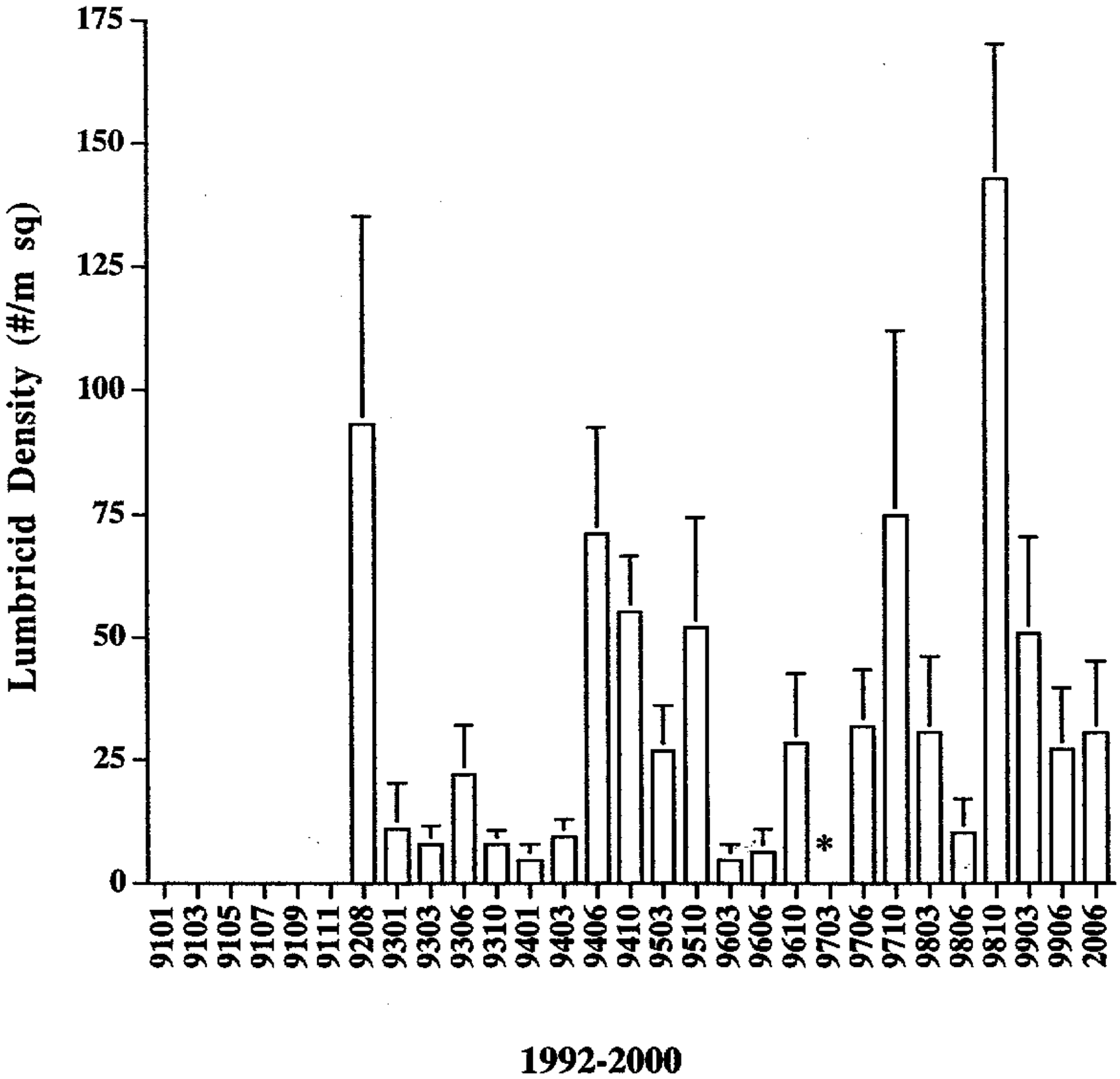

Figure 63. Lumbricid densities (#/m sq) collected at Lees Ferry cobble Rkm 0.8 from August 1992 to June 2000. Error bars represent (± 1 SE, n=6). Asterisk (*) represents 374/m sq (± 269 SE).

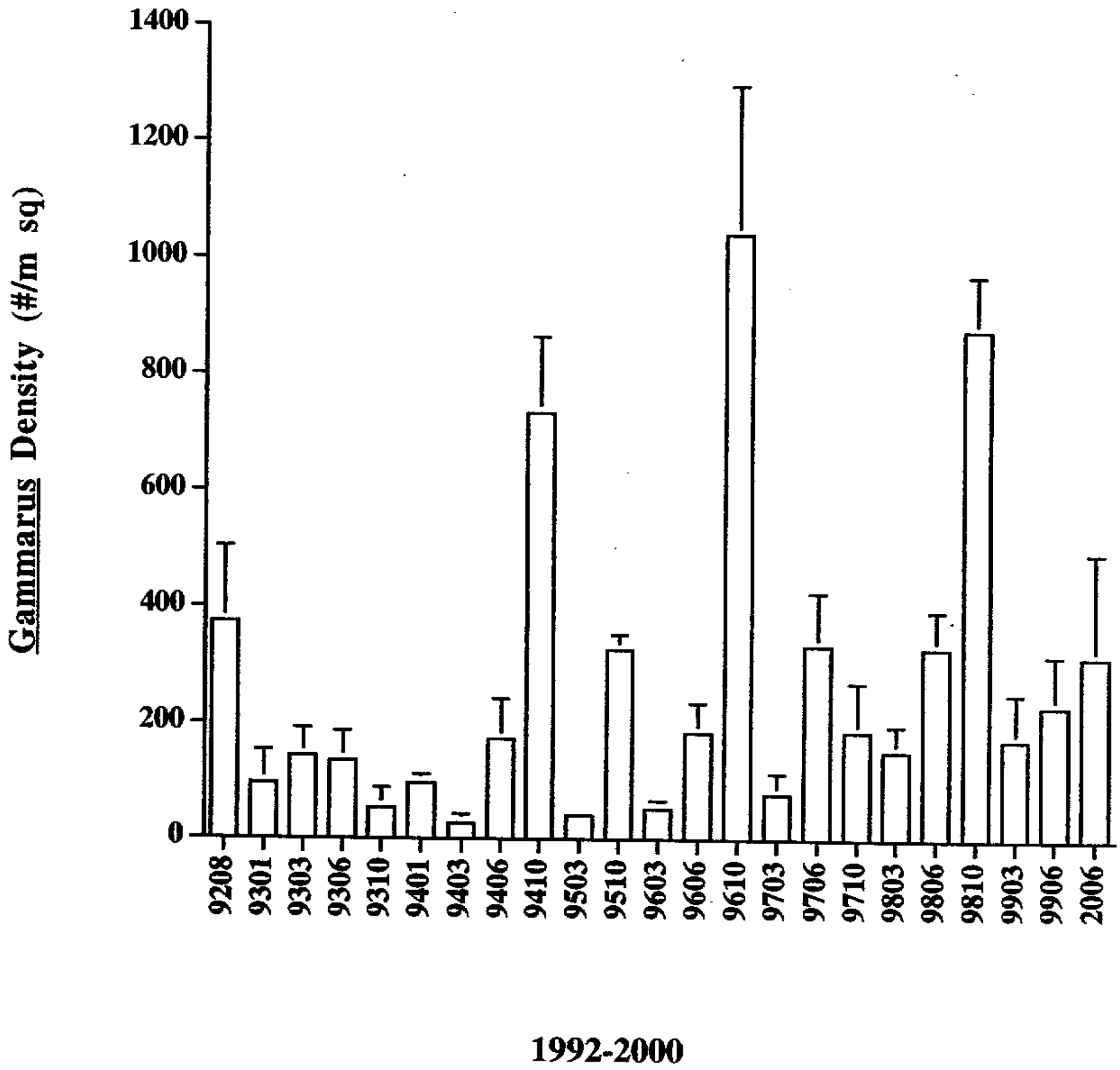

Figure 64. Gammarus densities (#/m sq) collected at Lees Ferry cobble Rkm 0.8 from August 1992 to June 2000. Error bars represent (± 1 SE, n=6).

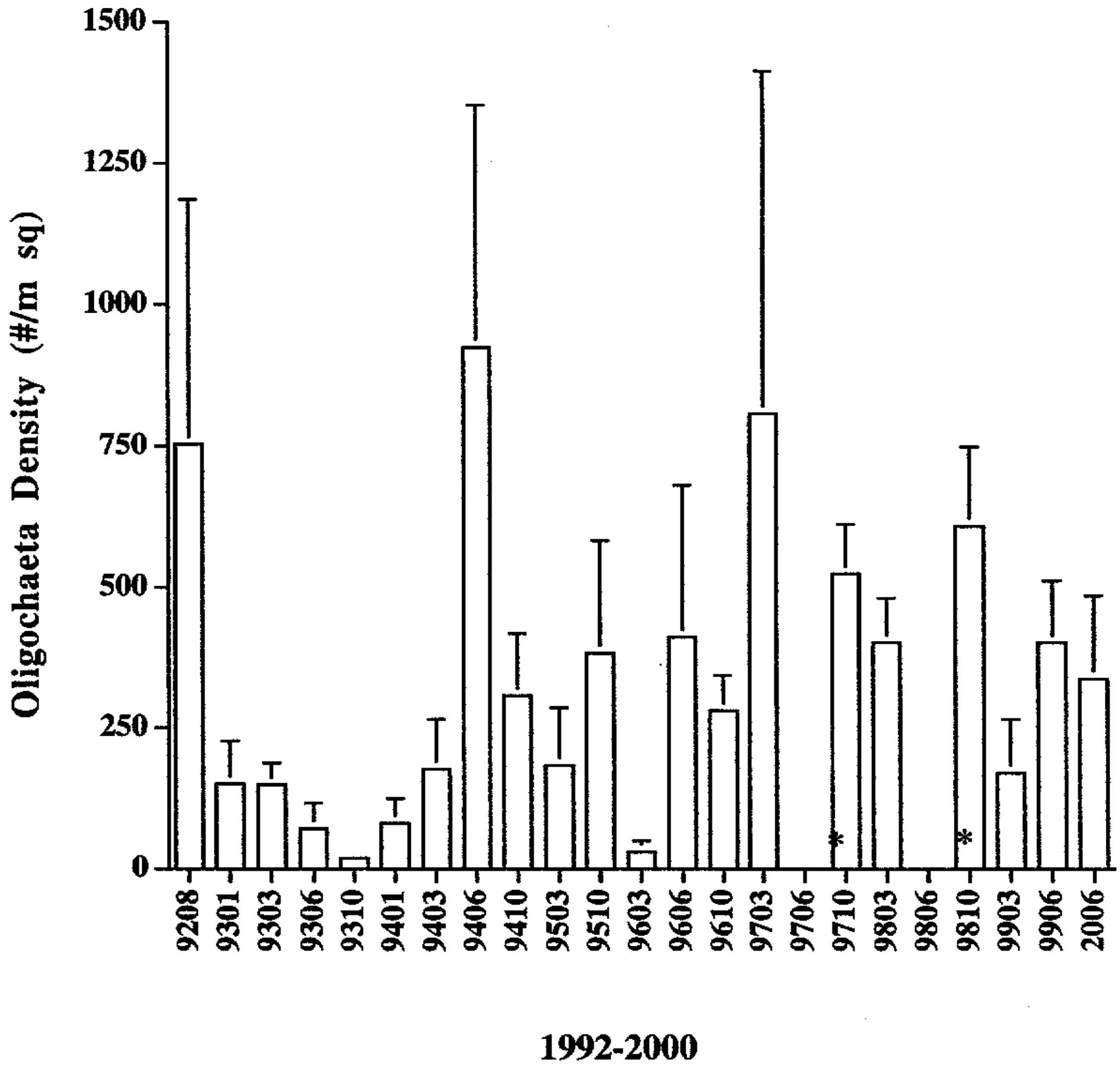

Figure 65. Oligochaeta densities (#/m sq) collected at Lees Ferry cobble Rkm 0.8 from August 1992 to June 2000. Error bars represent (± 1 SE, n=6). Asterisk (*) at 9706 represents 3761/m sq (± 2202 SE) and at 9806 represents 2683/m sq (± 1581 SE).

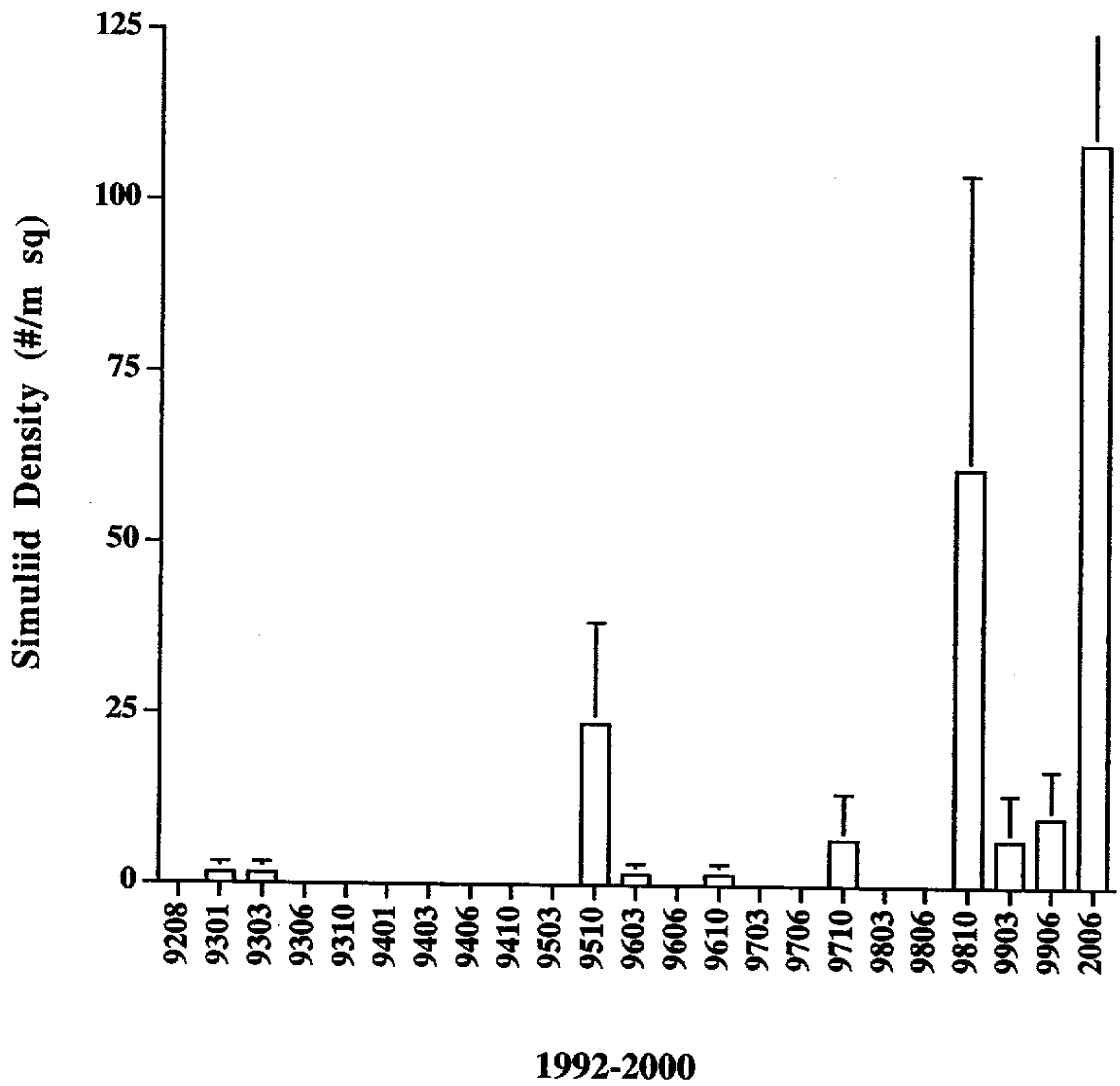

Figure 66. Simuliid densities (#/m sq) collected at Lees Ferry cobble Rkm 0.8 from August 1992 to June 2000. Error bars represent (± 1 SE, n=6).

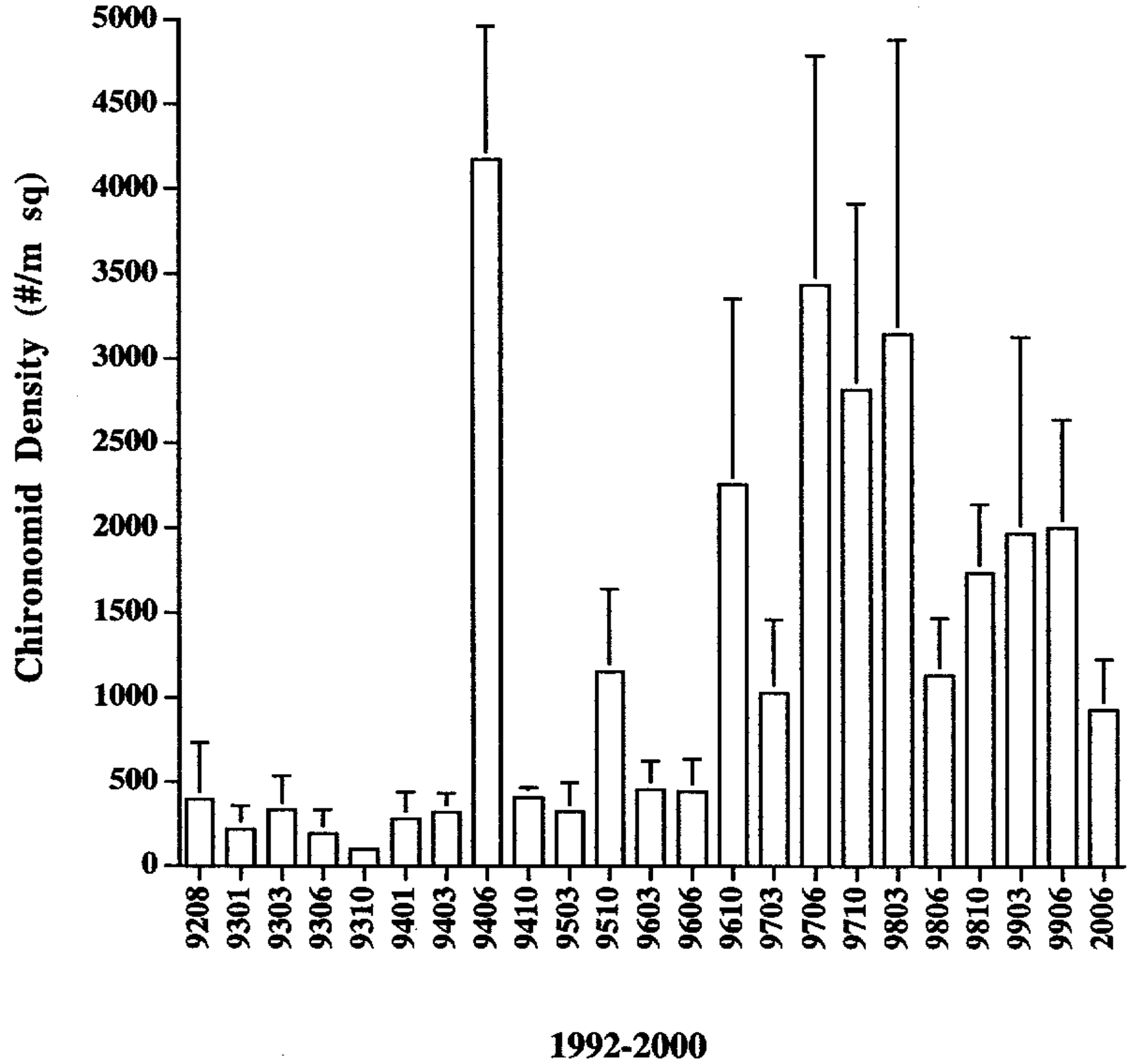

Figure 67. Chironomid densities (#/m sq) collected at Lees Ferry cobble Rkm 0.8 from August 1992 to June 2000. Error bars represent (± 1 SE, n=6).

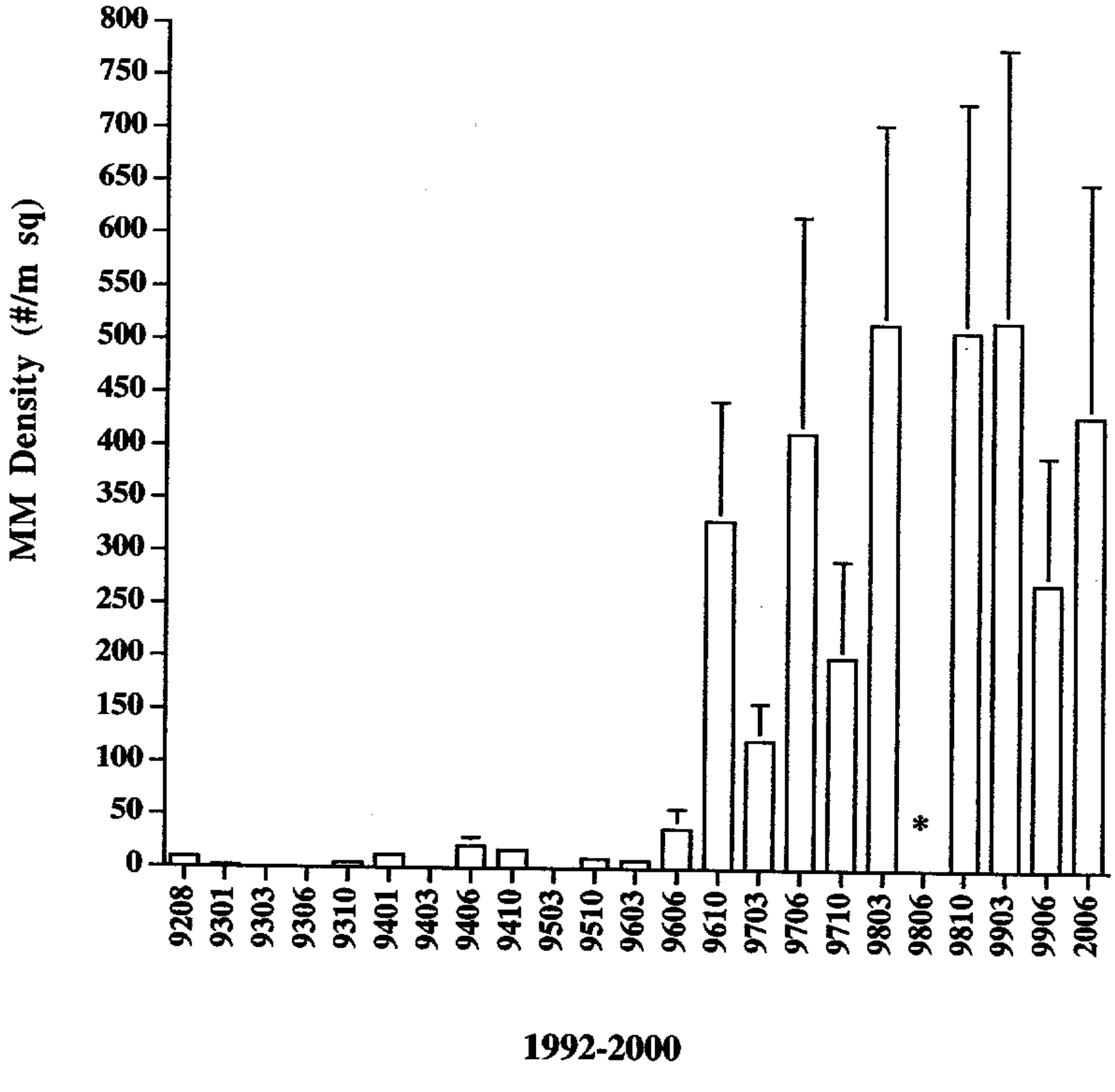

Figure 68. Miscellaneous macroinvertebrate (MM) densities (#/m sq) collected at Lees Ferry cobble Rkm 0.8 from August 1992 to June 2000. Error bars represent (± 1 SE, n=6). Asterisk (*) represents 2013/m sq (± 1560 SE).

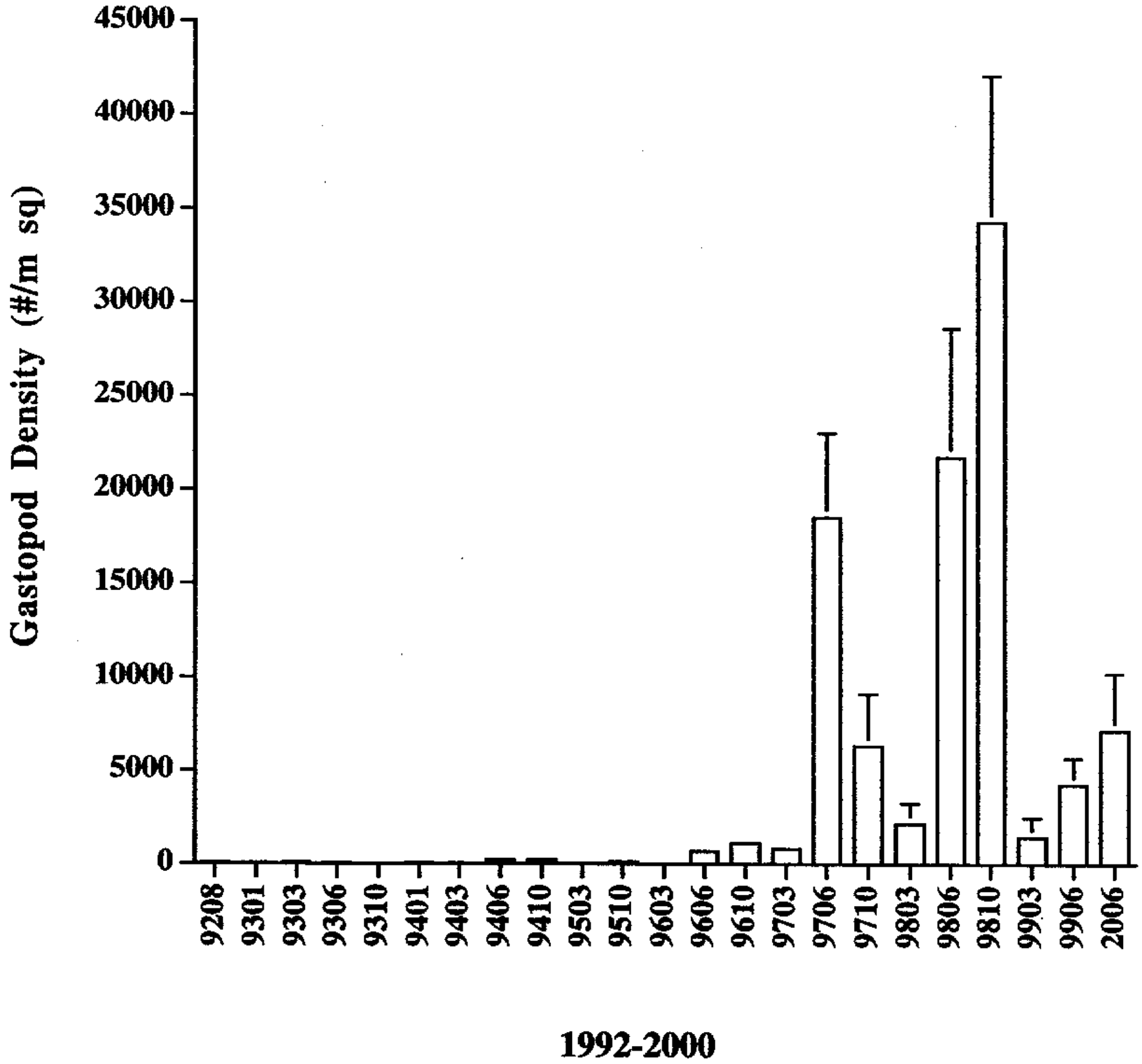

Figure 69. Gastropod densities (#/m sq) collected at Lees Ferry cobble Rkm 0.8 from August 1992 to June 2000. Error bars represent (± 1 SE, n=6).

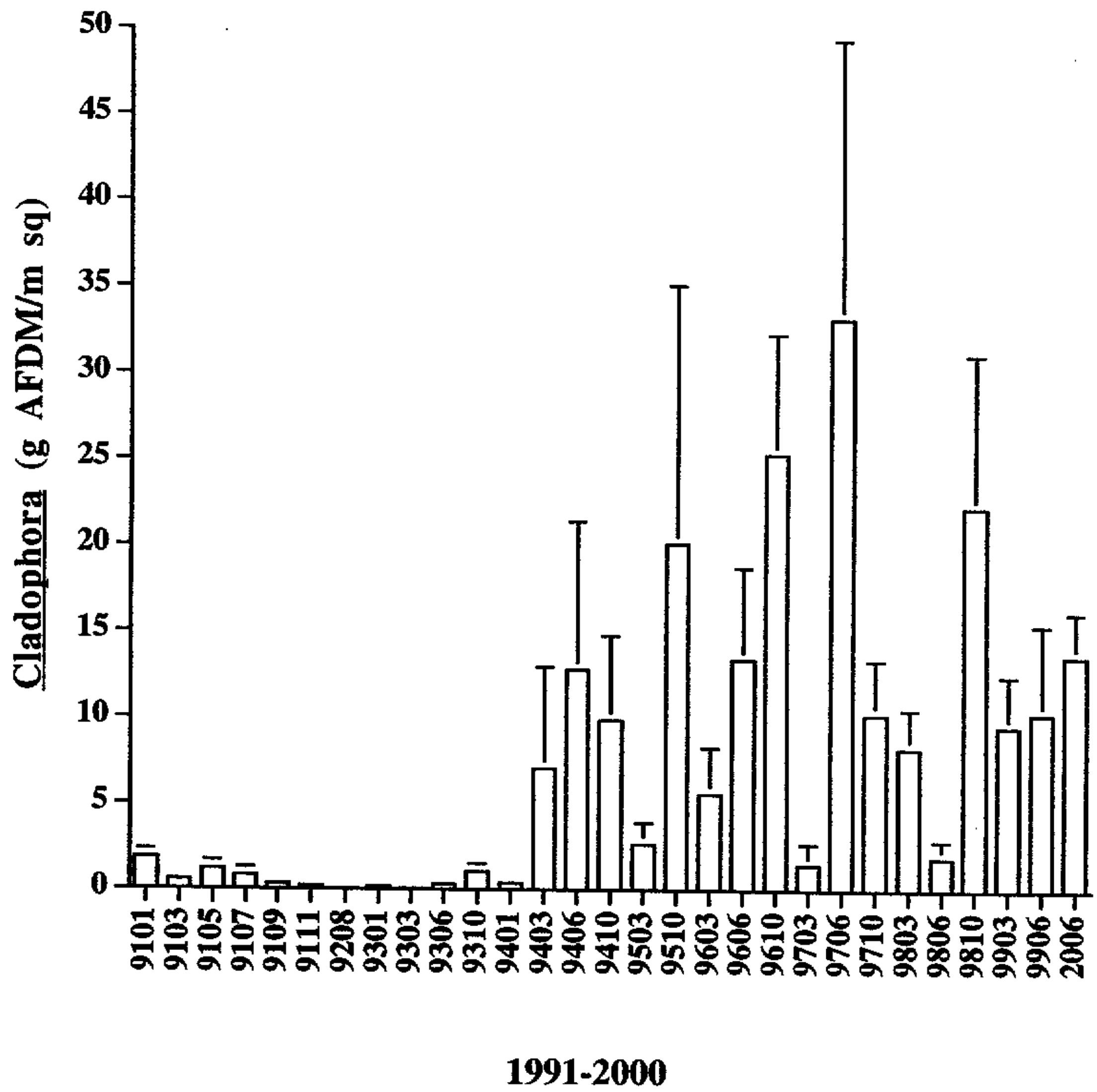

Figure 70. Cladophora biomass estimates (g AFDM/m sq) at Two-Mile Wash cobble Rkm 3.1 from January 1991 to June 2000. Error bars represent (± 1 SE, n=6).

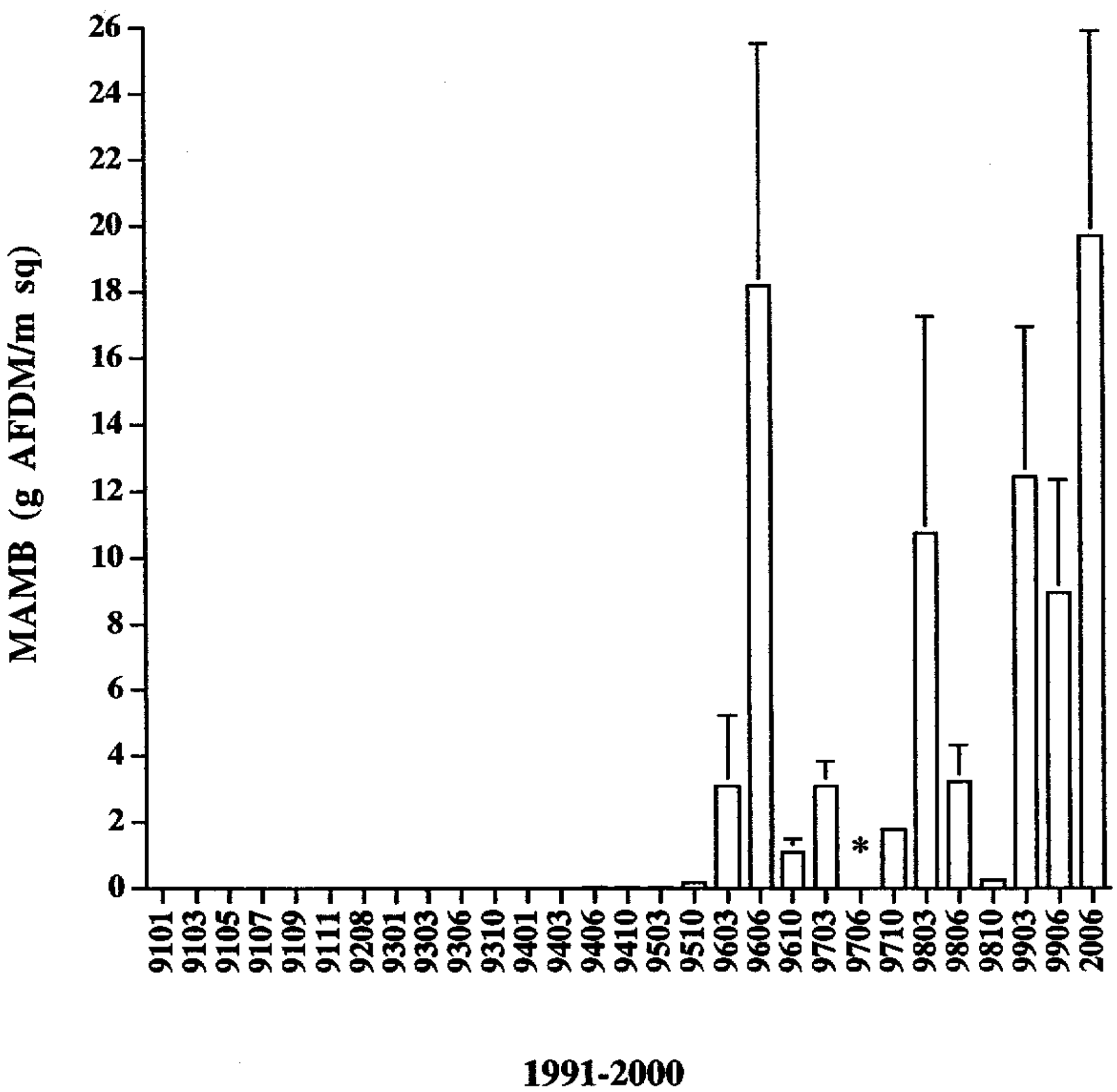

Figure 71. Miscellaneous algae, macrophytes and bryophytes (MAMB) biomass estimates (g AFDM/m sq) at Two-Mile Wash cobble Rkm 3.1 from January 1991 to June 2000. MAMB was not collected prior to August 1992. Error bars represent (± 1 SE, n=6). Asterisk (*) represents 65 g AFDM/m sq (± 23).

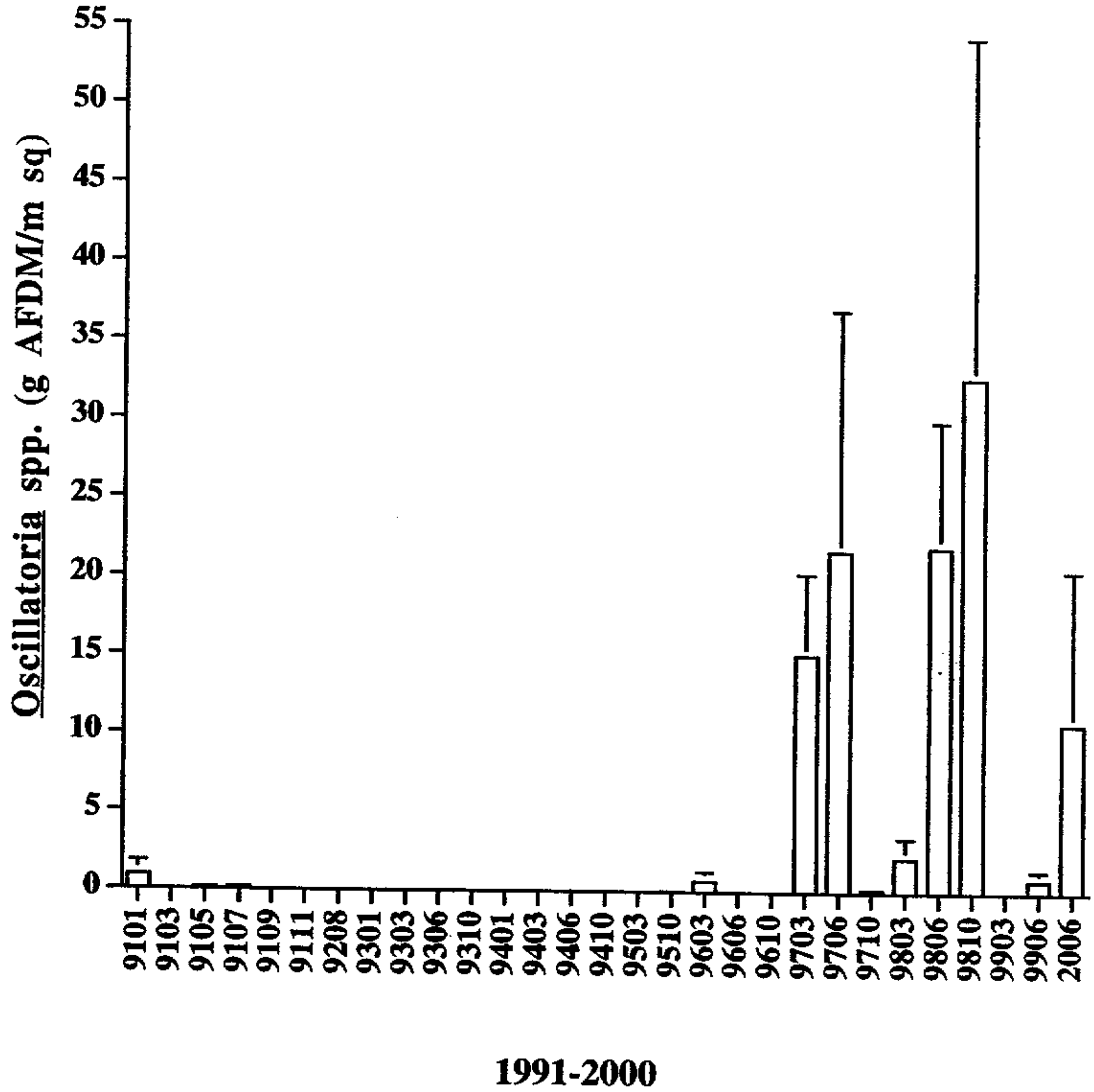

Figure 72. Oscillatoria spp. biomass estimates (g AFDM/m sq) at Two-Mile Wash cobble Rkm 3.1 from January 1991 to June 2000. Error bars represent (± 1 SE, n=6).

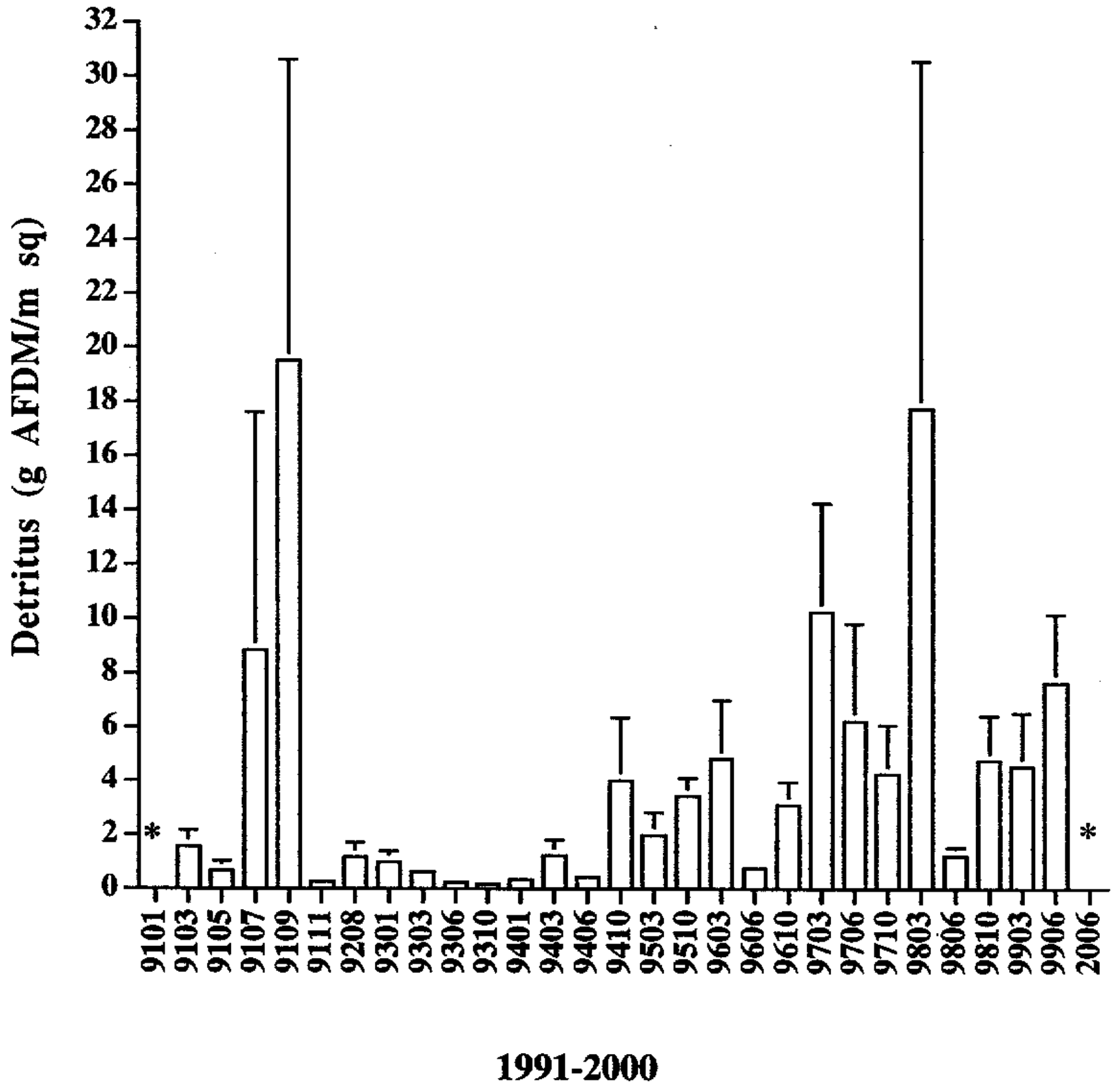

Figure 73. Detritus biomass estimates (g AFDM/m sq) at Two-Mile Wash cobble Rkm 3.1 from January 1991 to June 2000. Error bars represent ($\pm$ 1 SE, n=6). Asterisk (*) at 9101 represents 29 g AFDM/m sq ($\pm$ 25 SE) and at 2006 39 g AFDM/m sq ($\pm$ 31 SE)

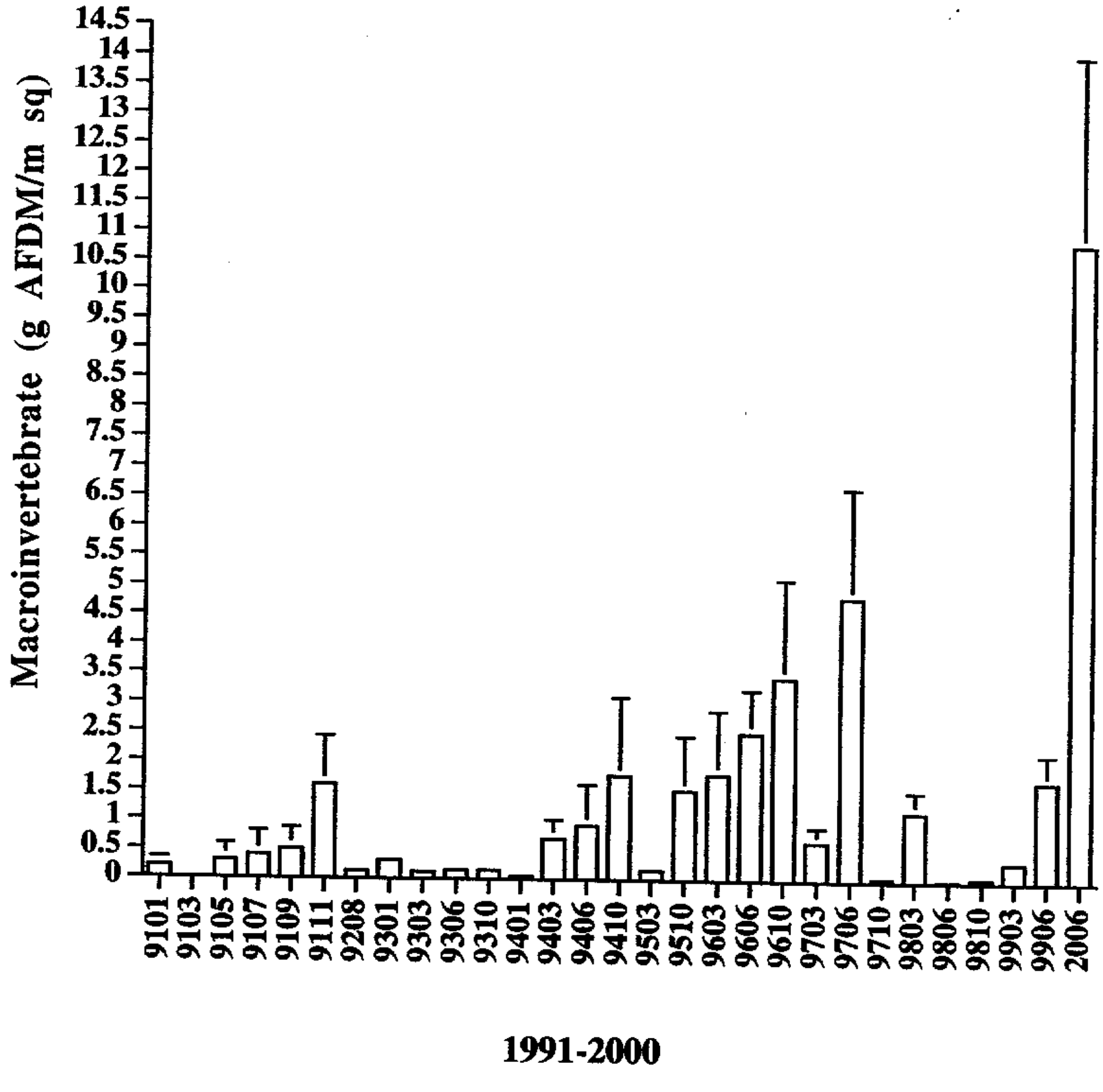

Figure 74. Macroinvertebrate biomass estimates (g AFDM/m sq) at Two-Mile Wash cobble Rkm 3.1 from January 1991 to June 2000. Error bars represent (± 1 SE, n=6).

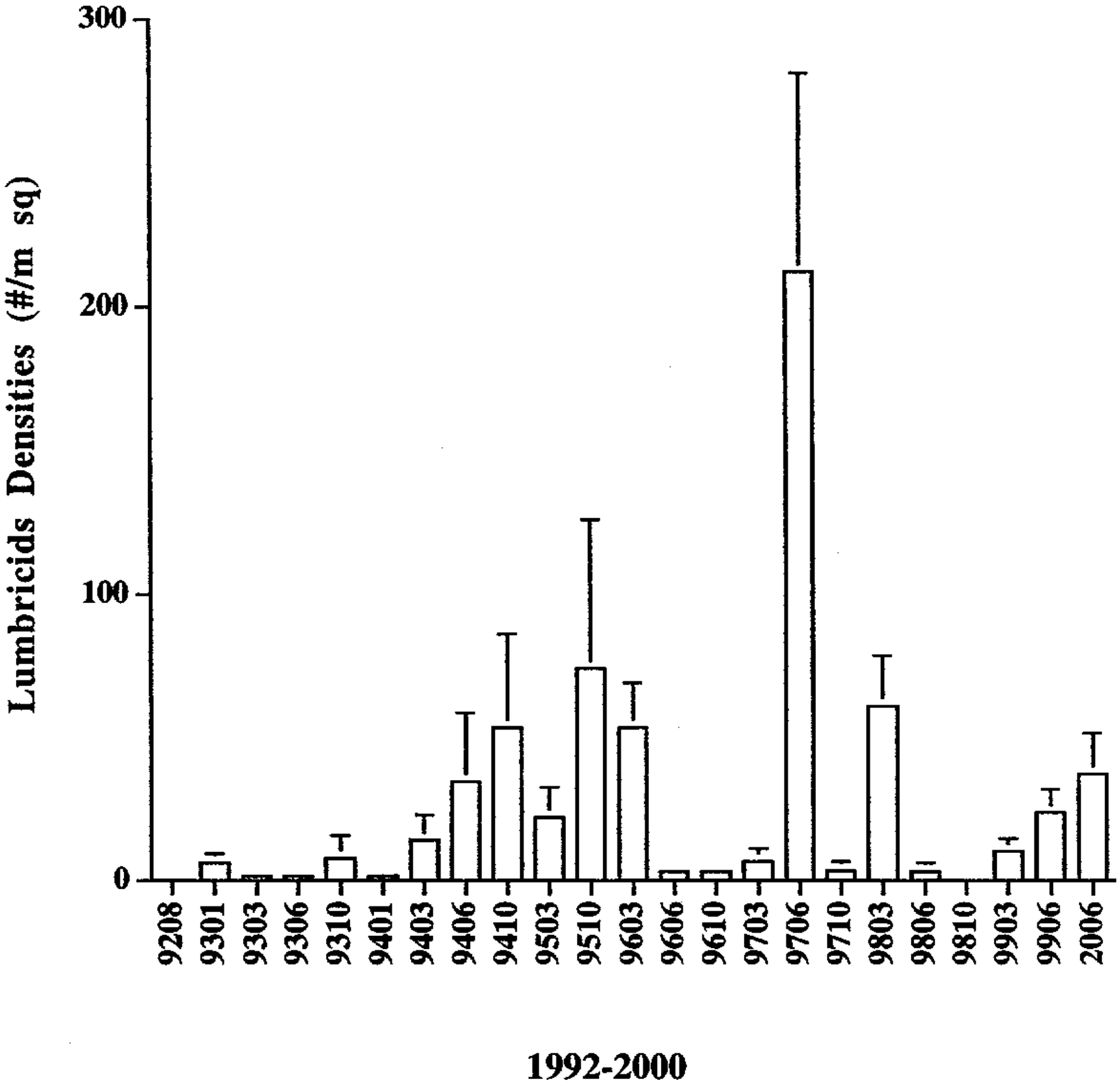

Figure 75. Lumbricid densities (#/m sq) collected at Two-Mile Wash cobble Rkm 3.1 from August 1992 to June 2000. Error bars represent ($\pm$ 1 SE, n=6).

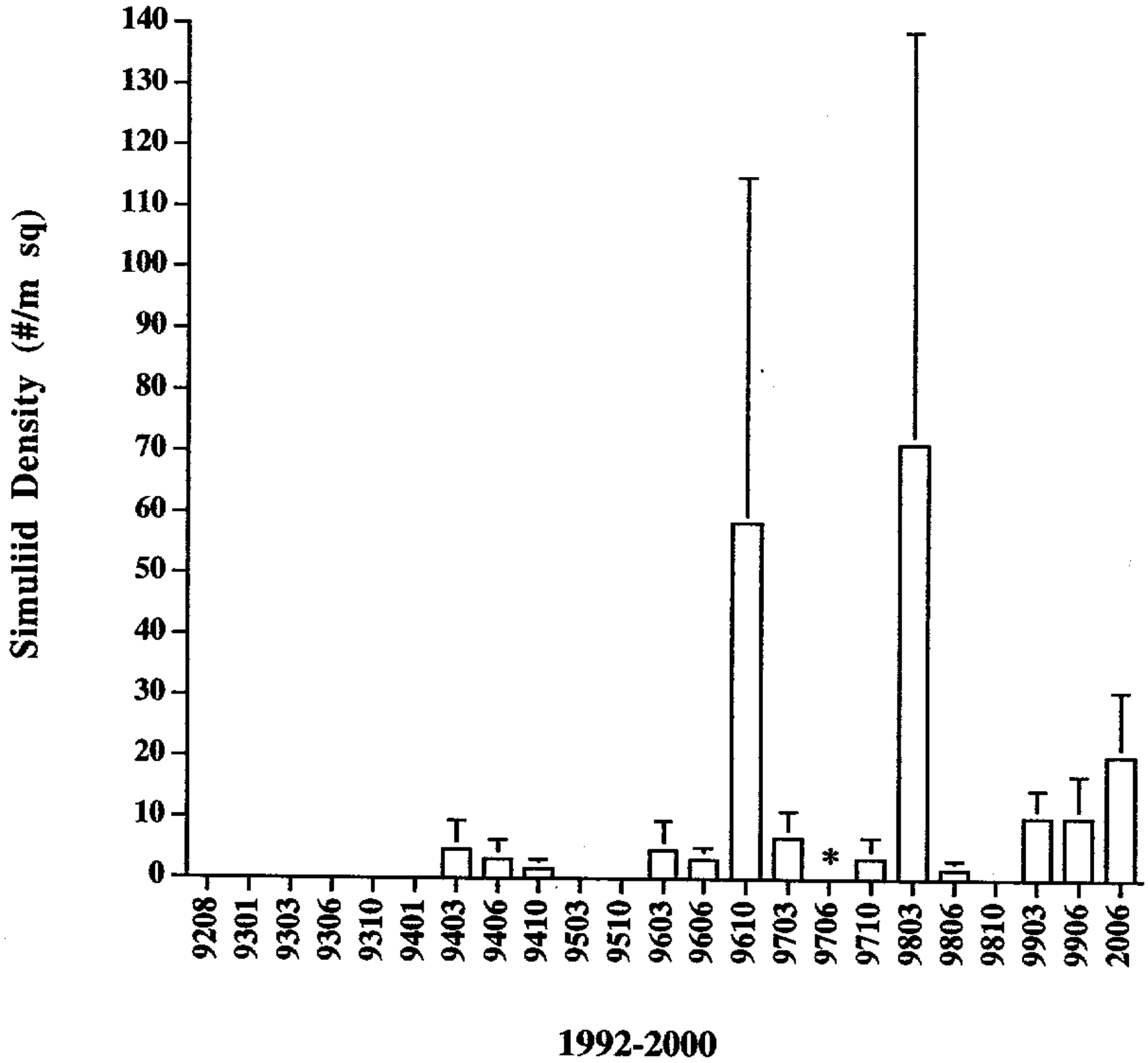

Figure 78. Simuliid densities (#/m sq) at Two-Mile Wash cobble Rkm 3.1 from August 1992 to June 2000. Error bars represent (± 1 SE, n=6). Asterisk (*) represents 753/m sq (± 721 SE).

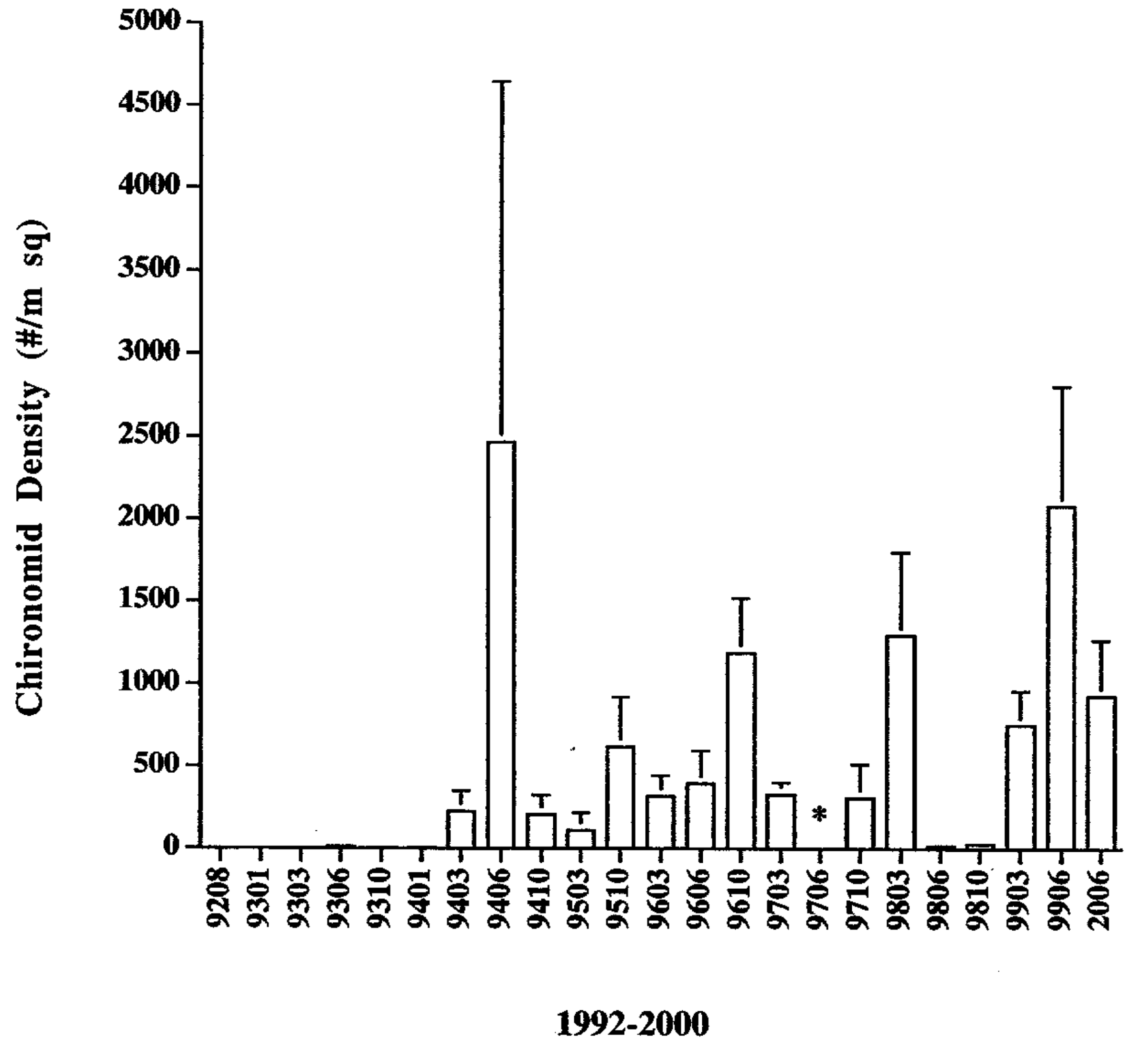

Figure 79. Lumbricid densities (#/m sq) at Two-Mile Wash cobble Rkm 3.1 from August 1992 to June 2000. Error bars represent (± 1 SE, n=6). Asterisk (*) 9628/m sq (± 4184 SE).

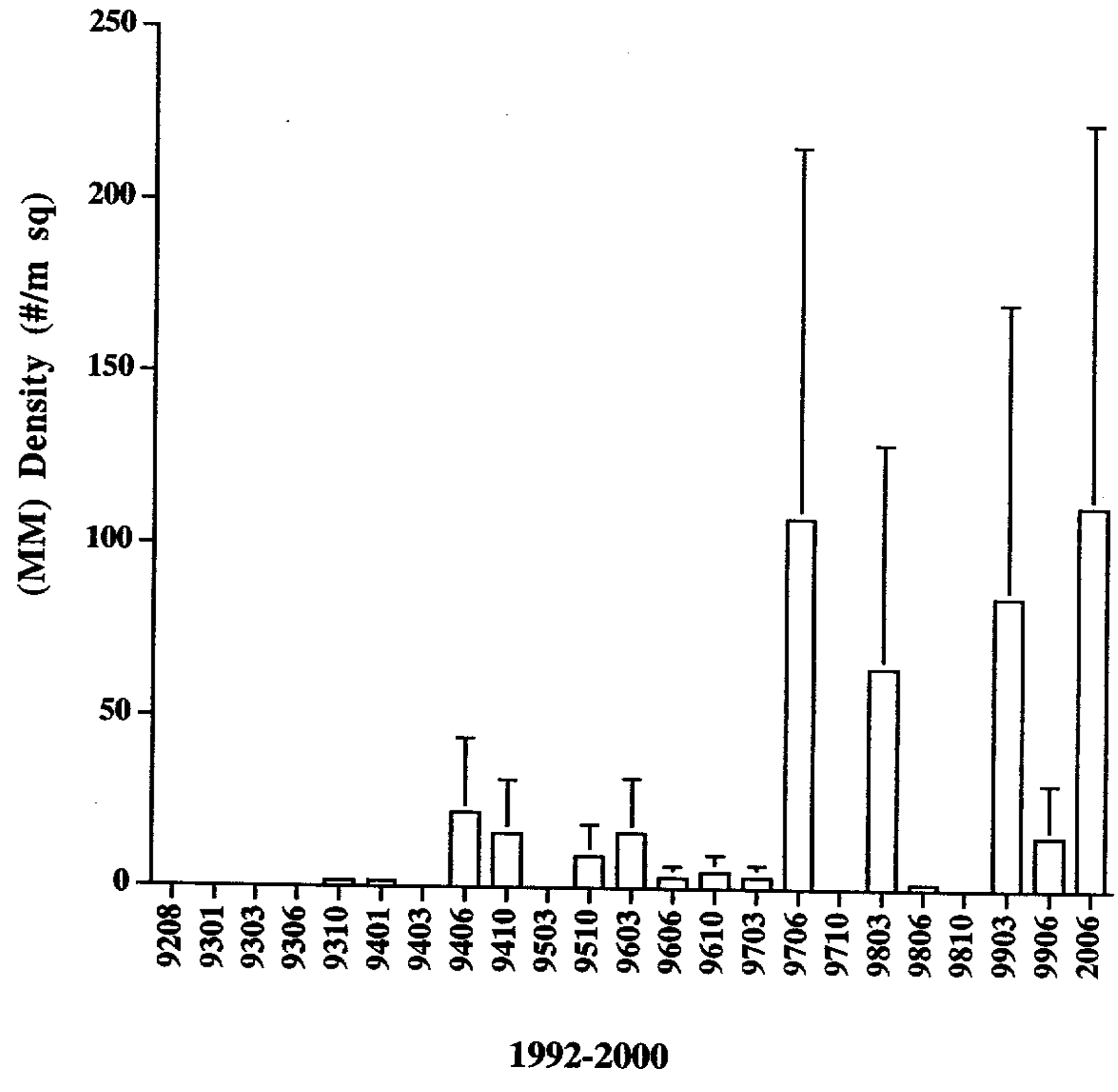

Figure 80. Miscellaneous macroinvertebrate (MM) densities (#/m sq) at Two-Mile Wash cobble Rkm 3.1 from August 1992 to June 2000. Error bars represent (± 1 SE, n=6).

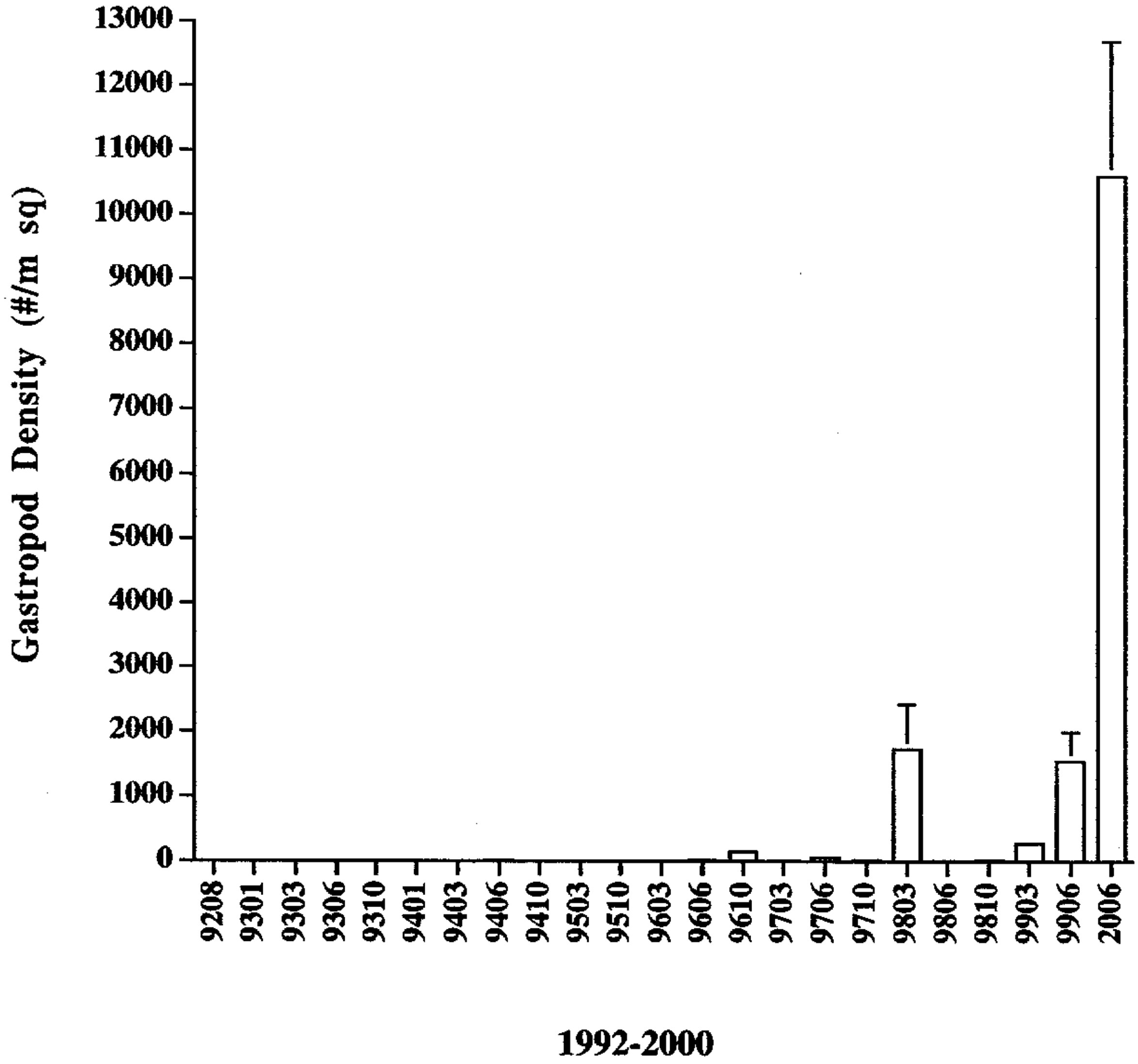

Figure 81. Gastropod densities (#/m sq) at Two-Mile Wash cobble Rkm 3.1 from August 1992 to June 2000. Error bars represent (± 1 SE, n=6).

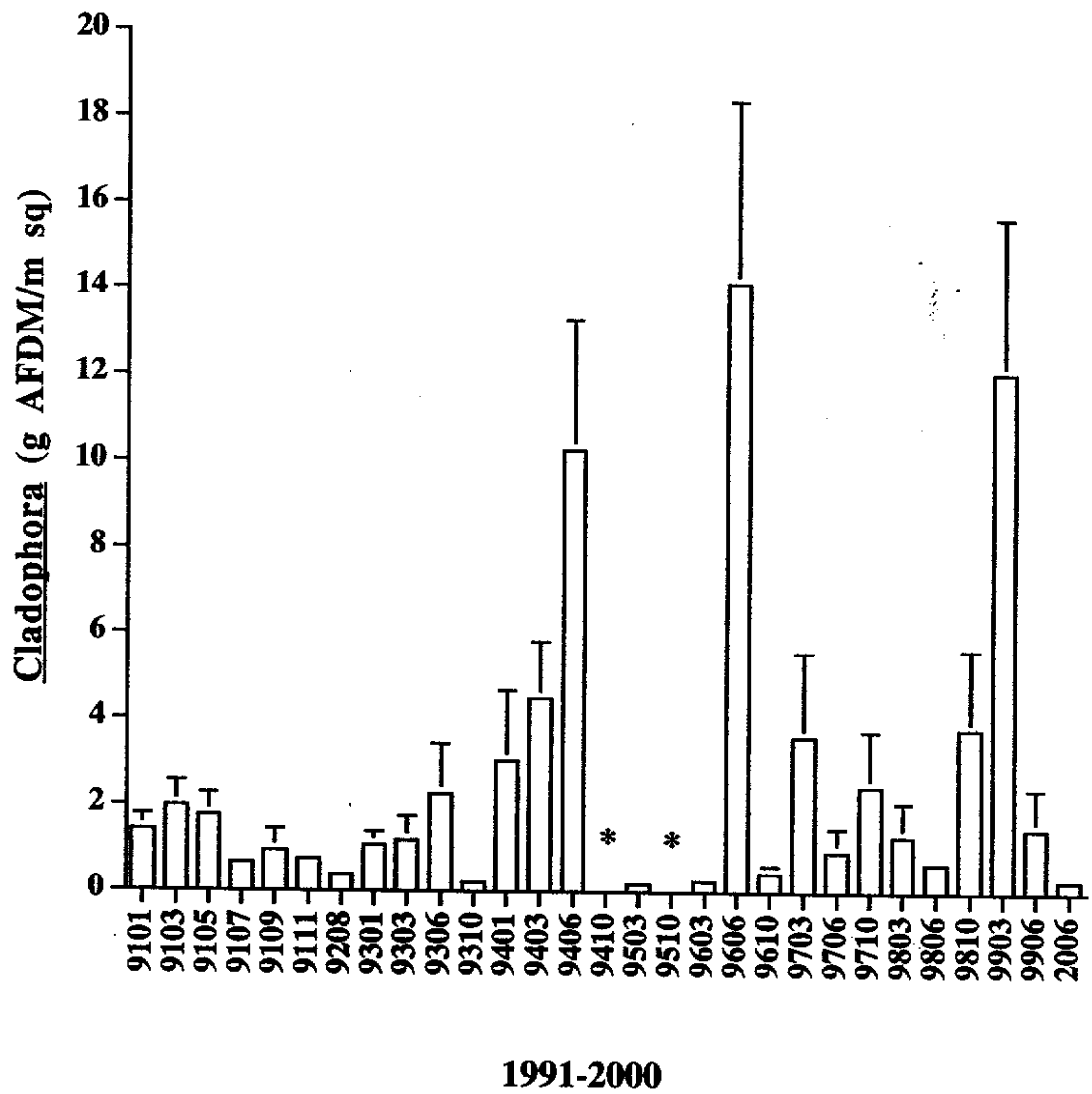

Figure 82. Cladophora biomass estimates (g AFDM/m sq) at LCR Island cobble Rkm 98.6 from January 1991 to June 2000. Error bars represent (± 1 SE, n=6). Asterisk (*) at 9410 represents 32 g AFDM/m sq (± 11 SE) and at 9510 represents 96 g AFDM/m sq (± 38 SE).

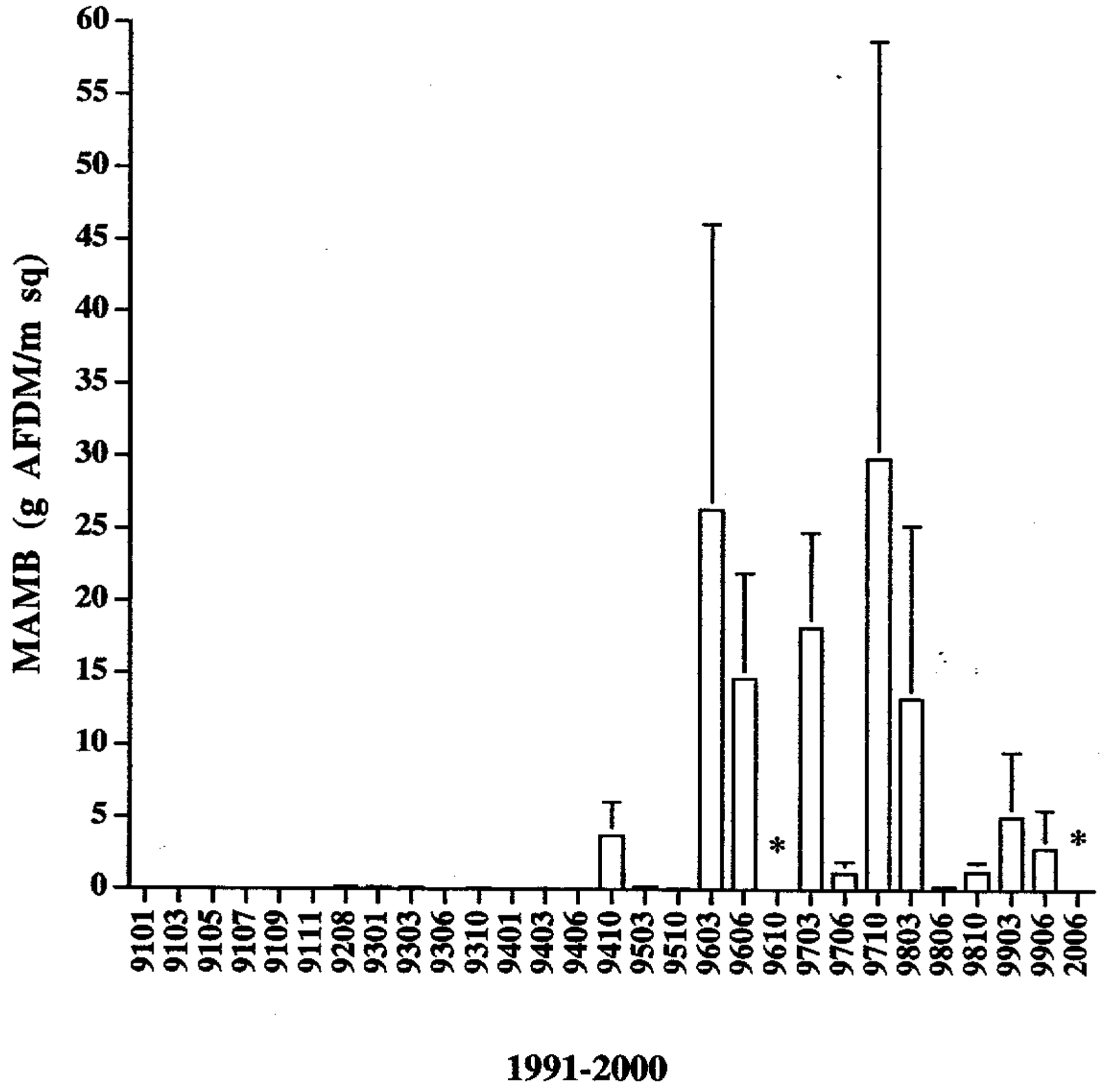

Figure 83. Miscellaneous algae, macrophytes and bryophytes (MAMB) biomass estimates (g AFDM/m sq) at LCR Island cobble Rkm 98.6 from January 1991 to June 2000. MAMB was not collected prior to August 1992. Error bars represent (± 1 SE, n=6). Asterisk (*) at 9610 represents 91 g AFDM/m sq (± 26 SE) and at 2006 198 g AFDM/m sq (± 29 SE).

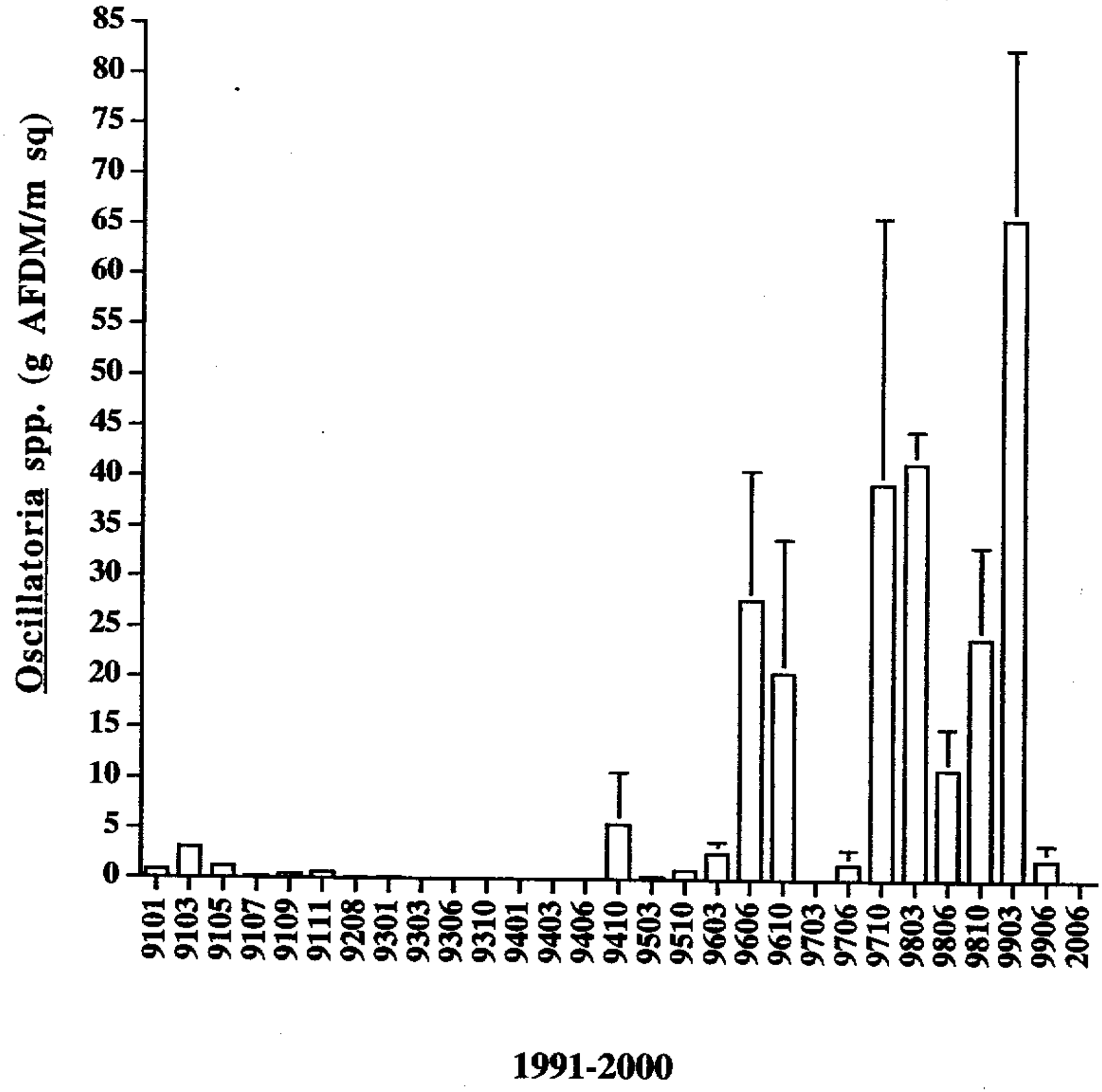

Figure 84. Oscillatoria spp. biomass estimates (g AFDM/m sq) at LCR Island cobble Rkm 98.6 from January 1991 to June 2000. Error bars represent (± 1 SE, n=6).

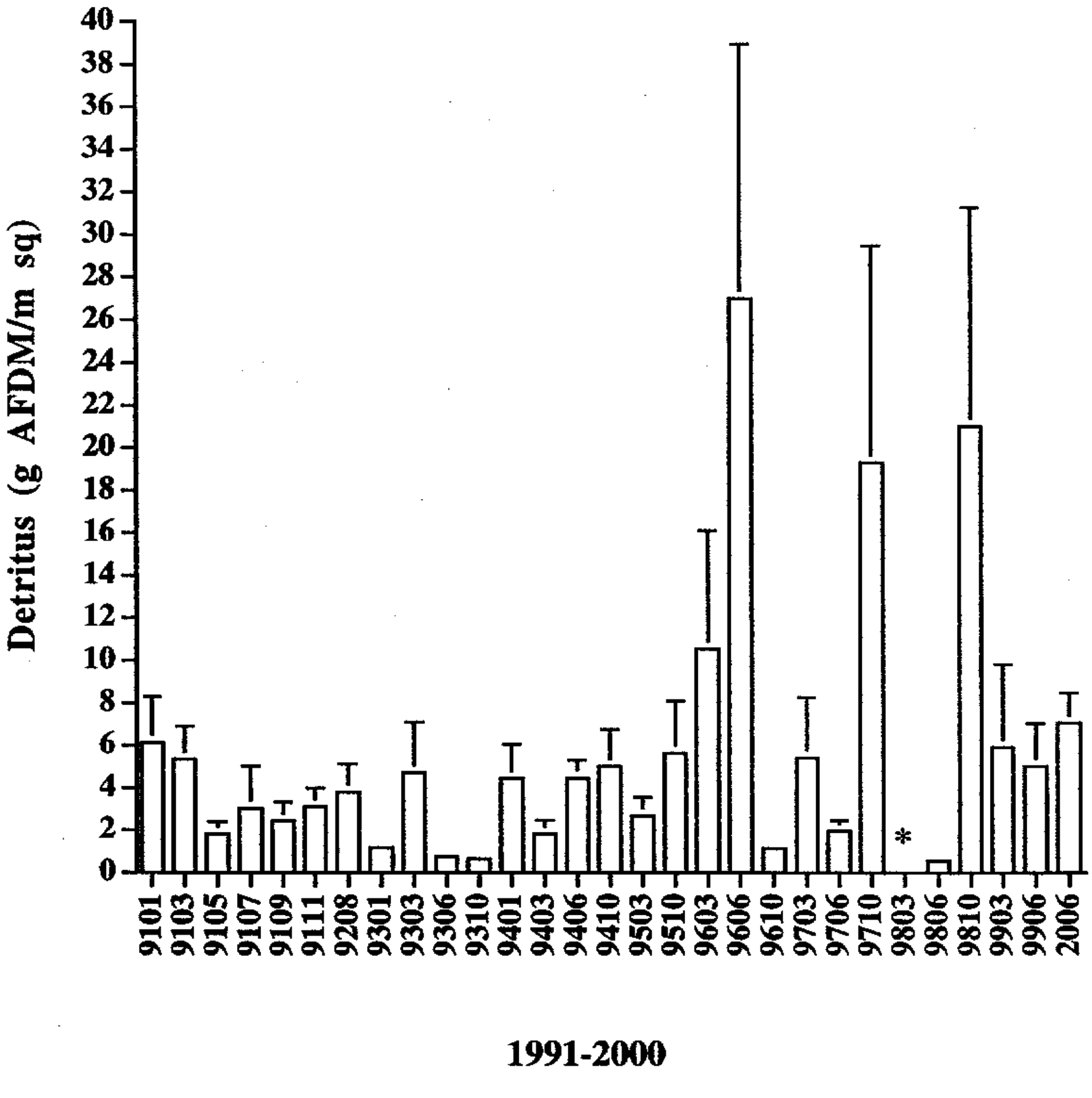

Figure 85. Detritus biomass estimates (g AFDM/m sq) at LCR Island cobble Rkm 98.6 from January 1991 to June 2000. Error bars represent (± 1 SE, n=6). Asterisk (*) represents 39 g AFDM/m sq (± 31 SE).

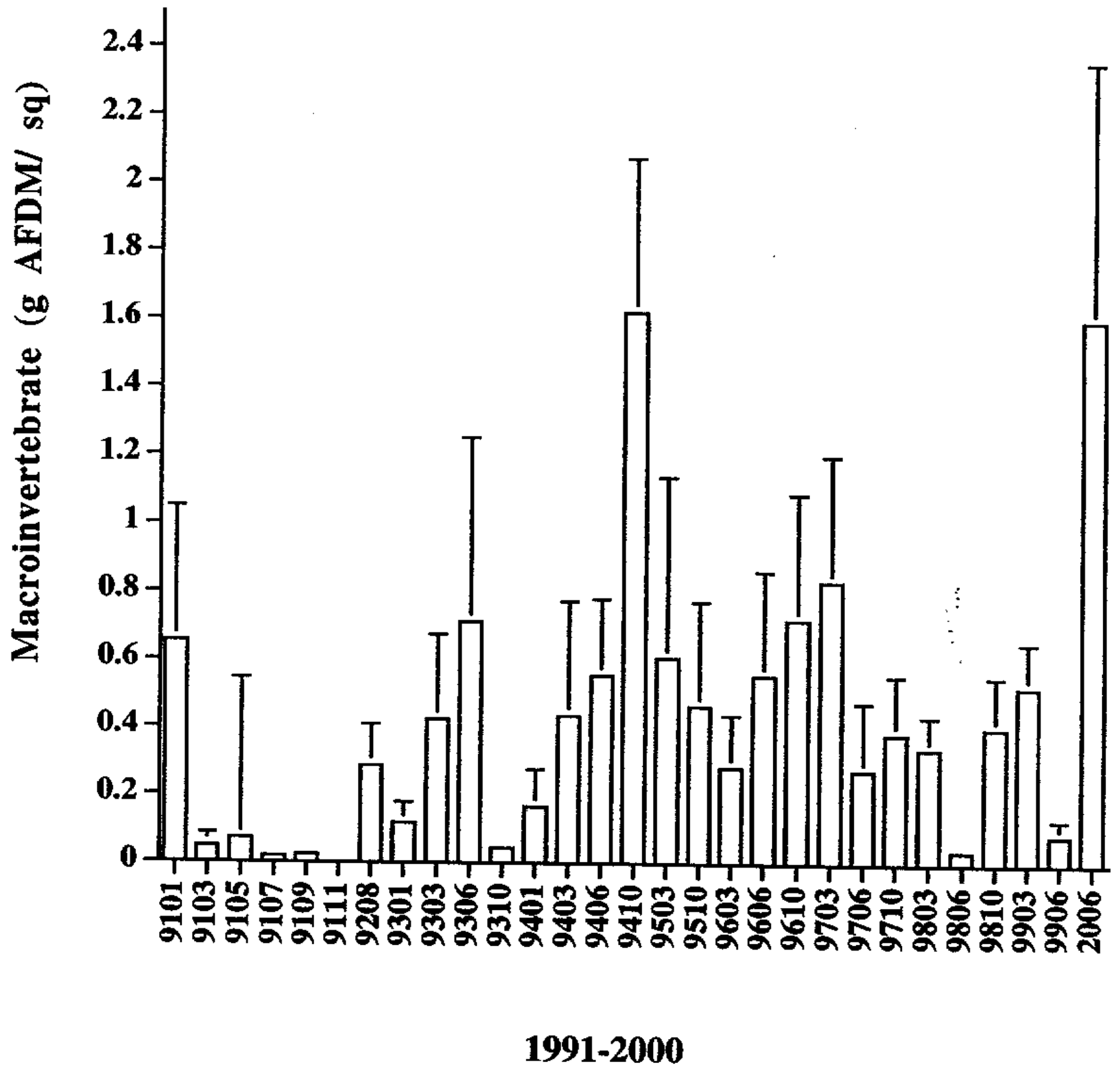

Figure 86. Macroinvertebrate biomass estimates (g AFDM/m sq at LCR Island cobble Rkm 98.6 from January 1991 to June 2000. Error bars represent (± 1 SE, n=6).

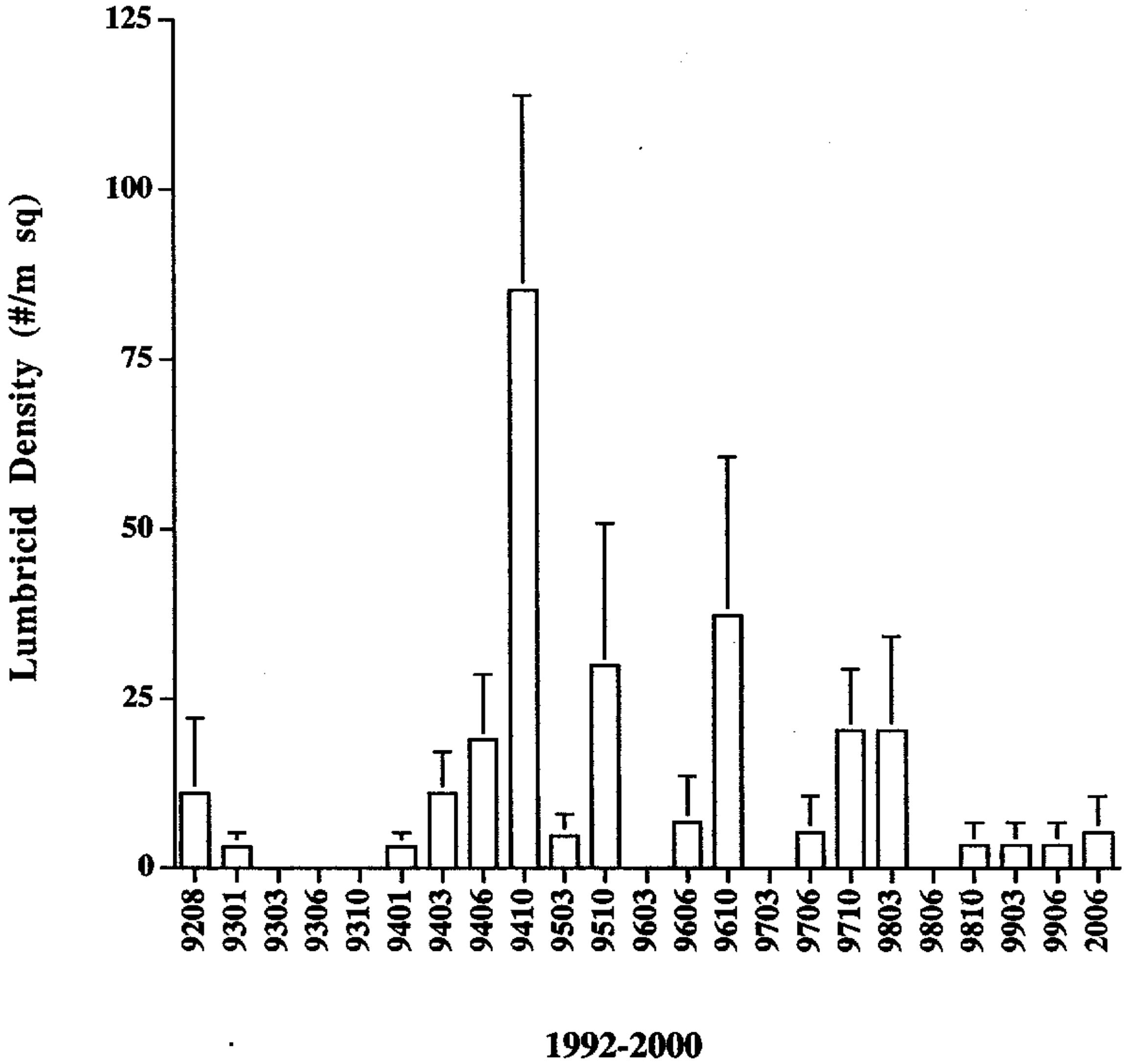

Figure 87. Lumbricid densities (#/m sq) collected at LCR Island cobble Rkm 98.6 from August 1992 to June 2000. Error bars represent (± 1 SE, n=6).

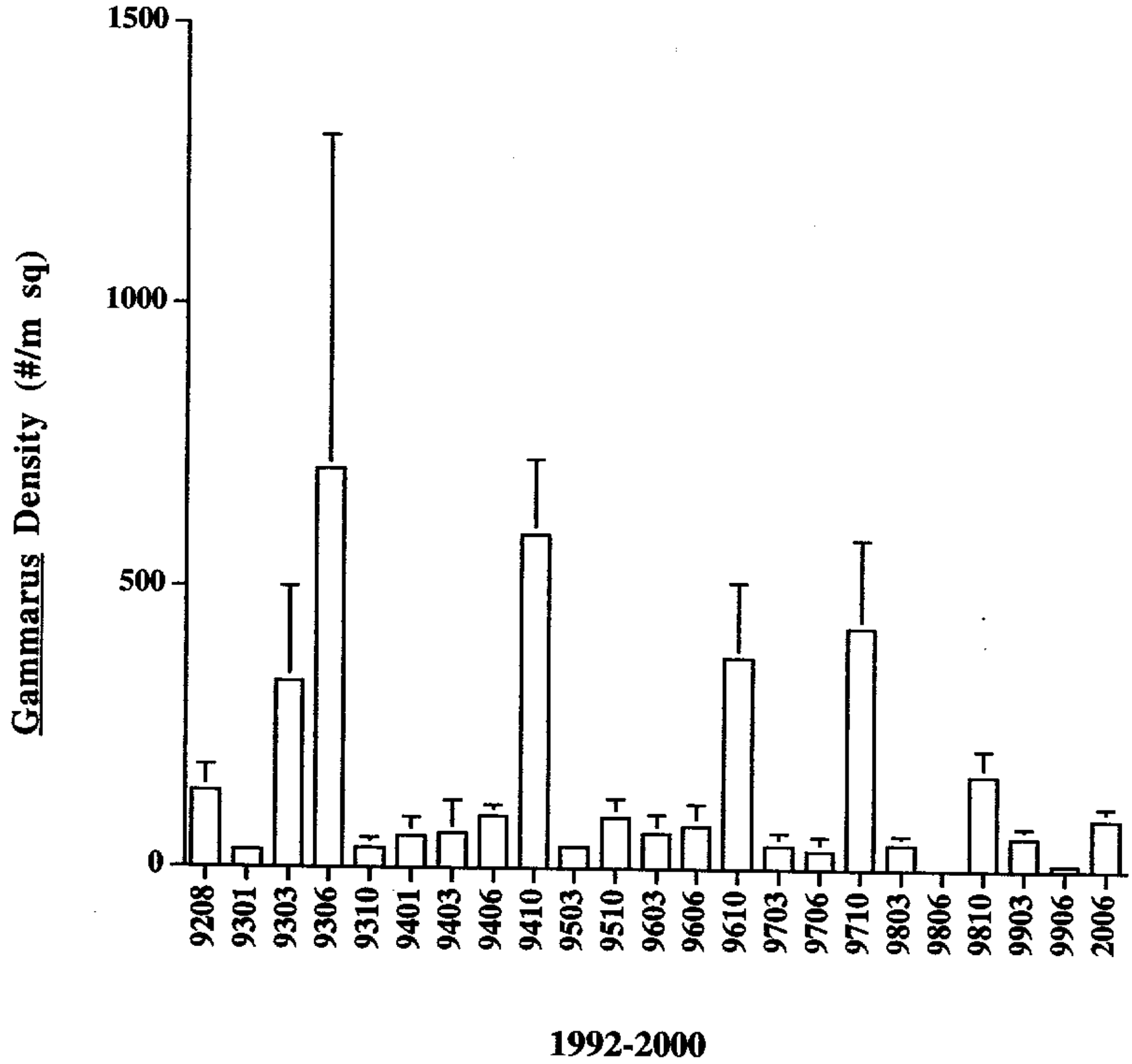

Figure 88. Gammarus densities (#/m sq) collected at LCR Island cobble Rkm 98.6 from August 1992 to June 2000. Error bars represent (± 1 SE, n=6).

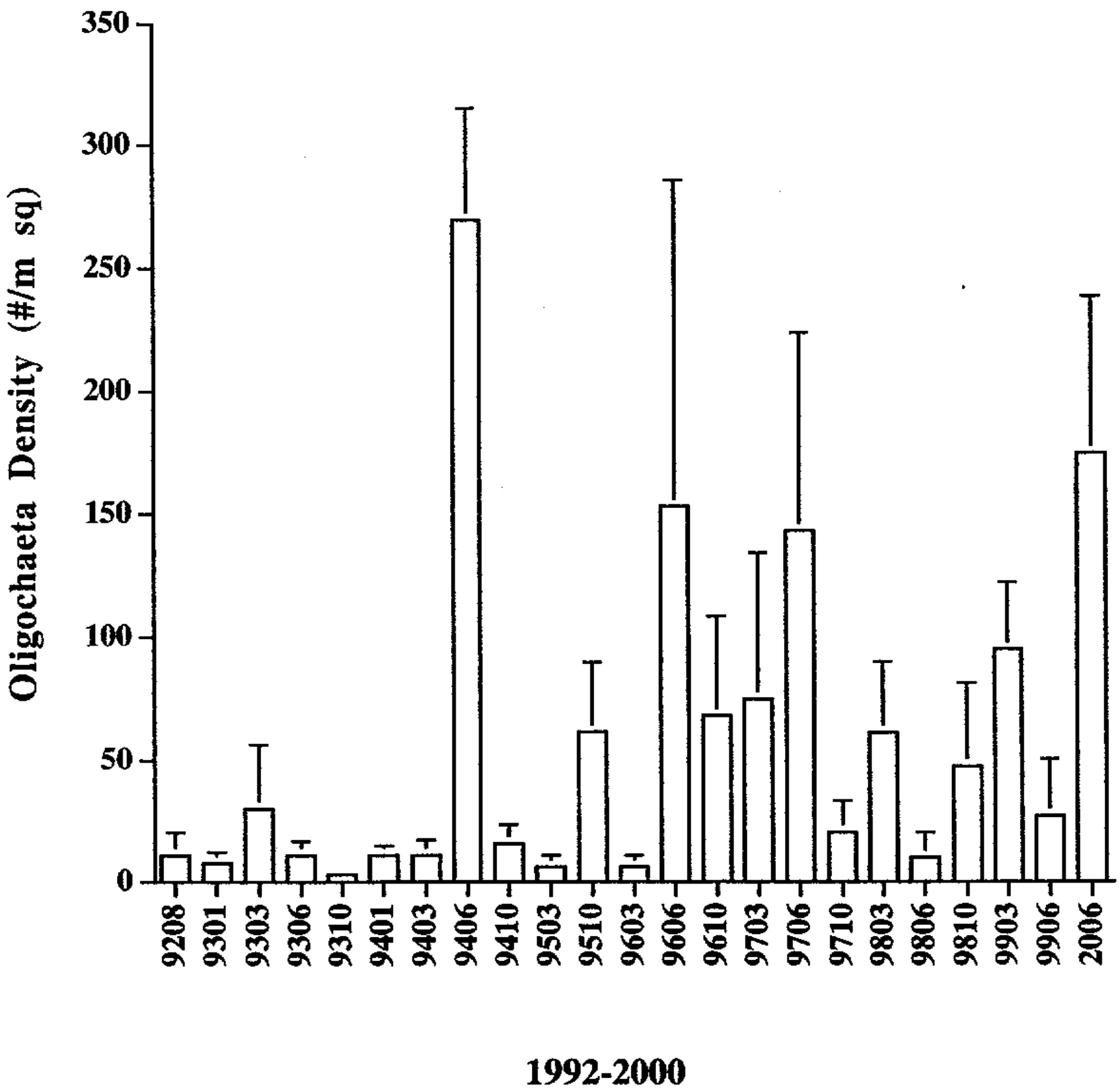

Figure 89. Oligochaeta densities (#/m sq) collected at LCR Island cobble Rkm 98.6 from August 1992 to June 2000. Error bars represent (± 1 SE, n=6).

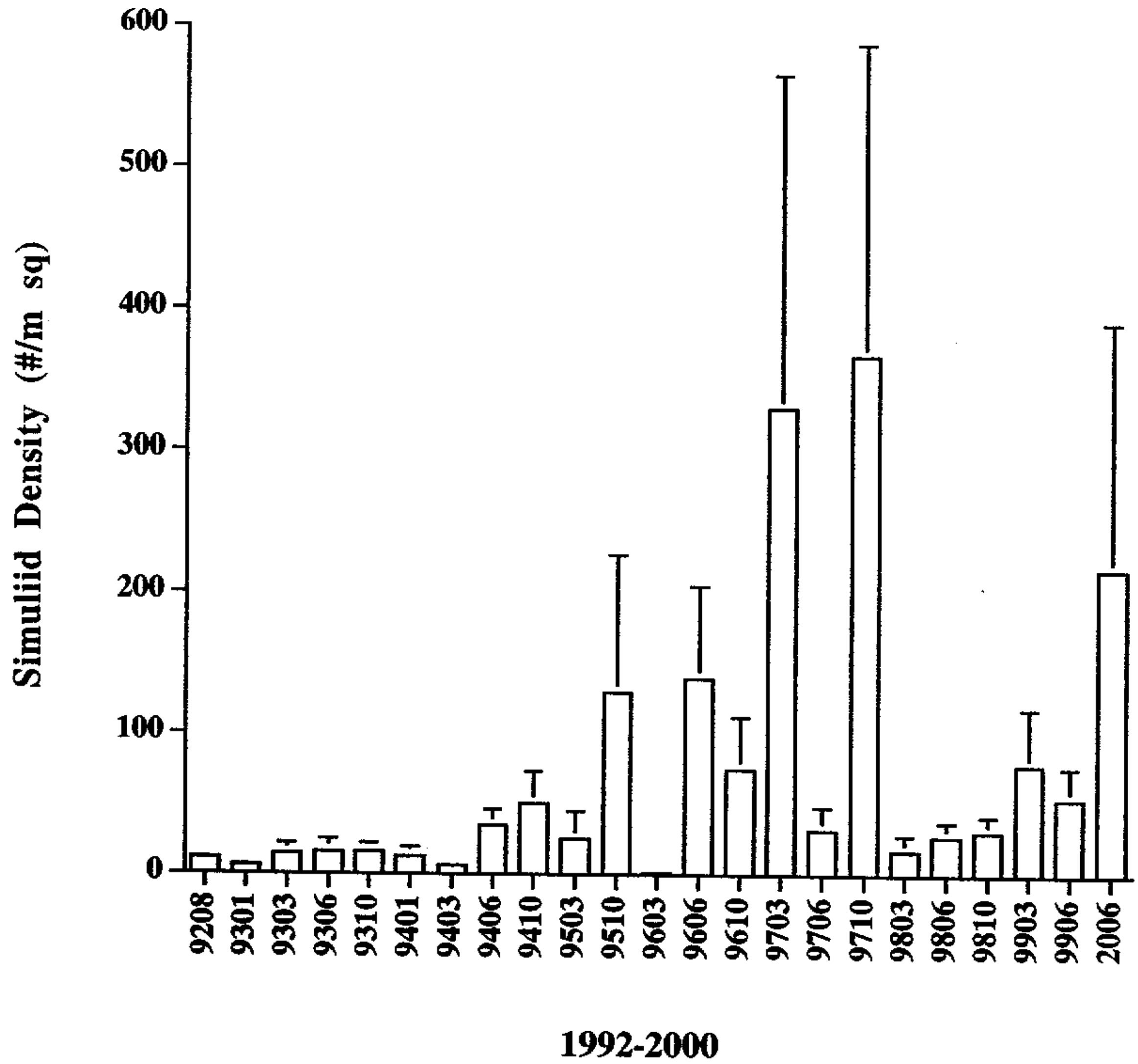

Figure 90. Simuliid densities (#/m sq) collected at LCR Island cobble Rkm 98.6 from August 1992 to June 2000. Error bars represent (± 1 SE, n=6).

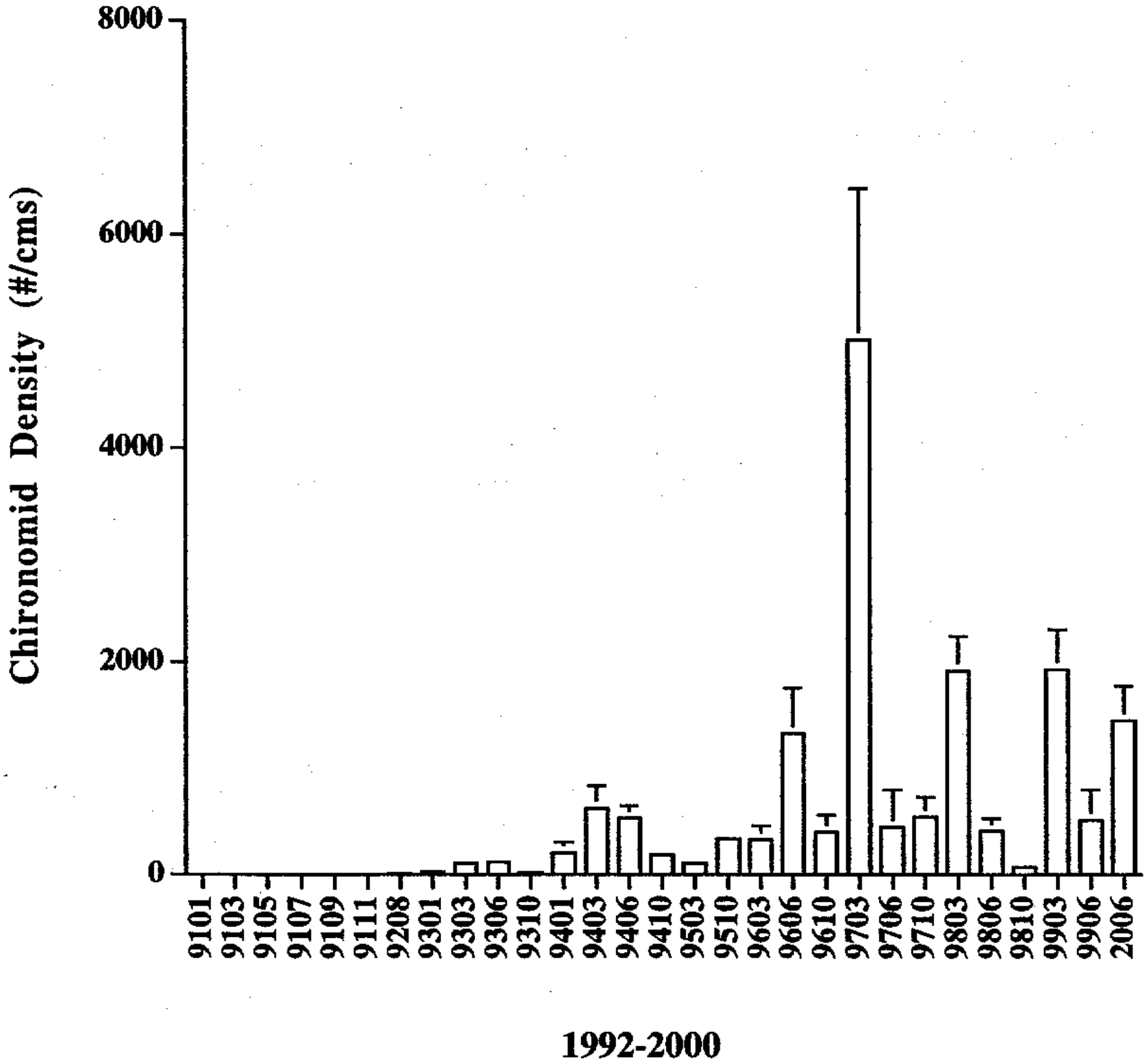

Figure 91. Chironomid densities (#/m sq) collected at LCR Island cobble Rkm 98.6 from August 1992 to June 2000. Error bars represent ($\pm$ 1 SE, n=6).

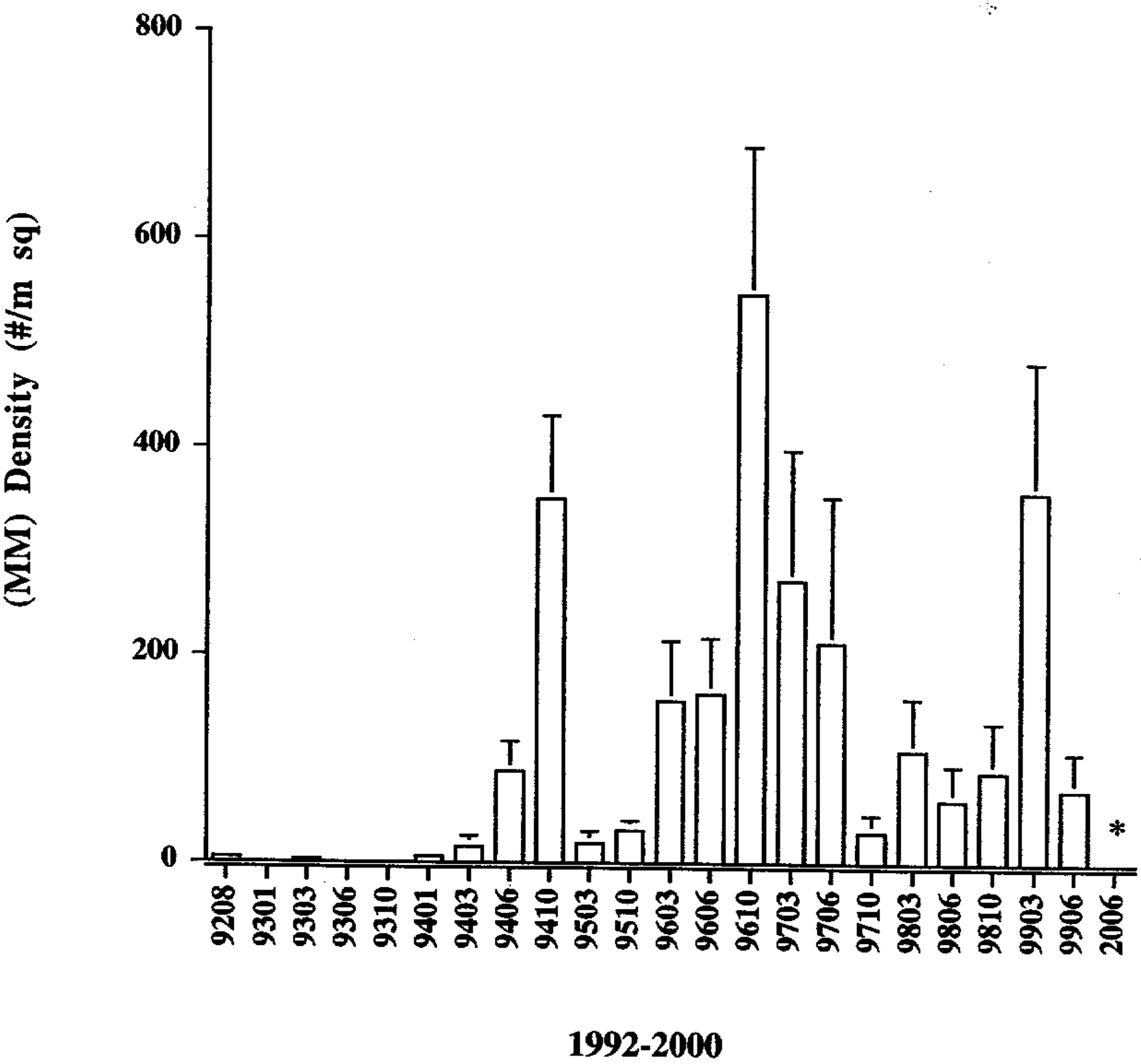

Figure 92. Miscellaneous macroinvertebrate densities (#/m sq) collected at LCR Island cobble Rkm 98.6 from August 1992 to June 2000. Error bars represent ($\pm$ 1 SE, n=6).Asterisk (*) represents 1798 g/m sq ($\pm$ 1373 SE).

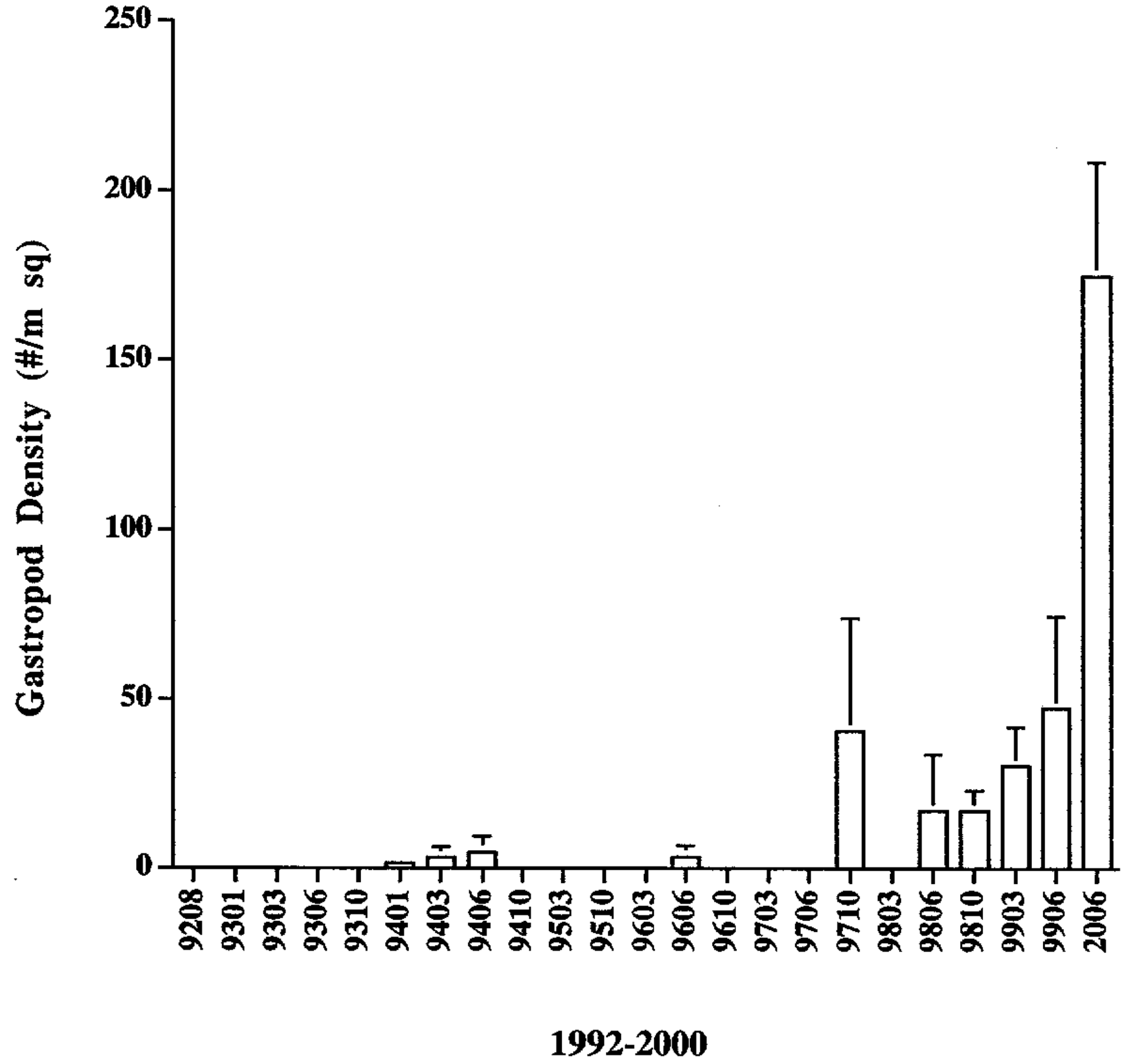

Figure 93. Gastropod densities (#/m sq) collected at LCR Island cobble Rkm 98.6 from August 1992 to June 2000. Error bars represent (± 1 SE, n=6).

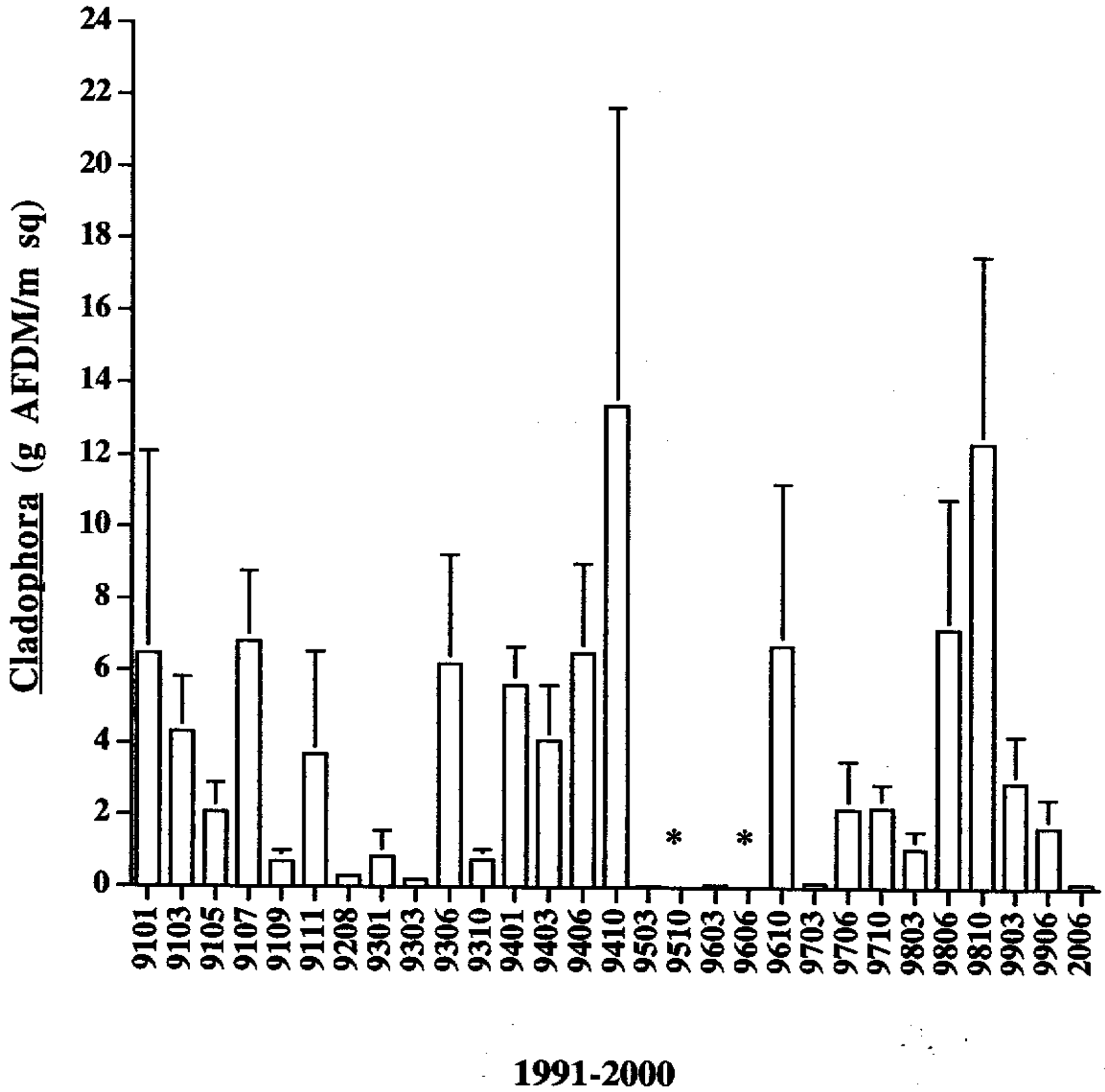

Figure 94. Cladophora biomass estimates (g AFDM/m sq) at Tanner cobble Rkm 109.6 from January 1991 to June 2000. Error bars represent (± 1 SE, n=6). Asterisk (*) at 9510 represents 53 g AFDM/m sq (± 17 SE) and at 9606 represents 75 g AFDM/m sq (± 59 SE).

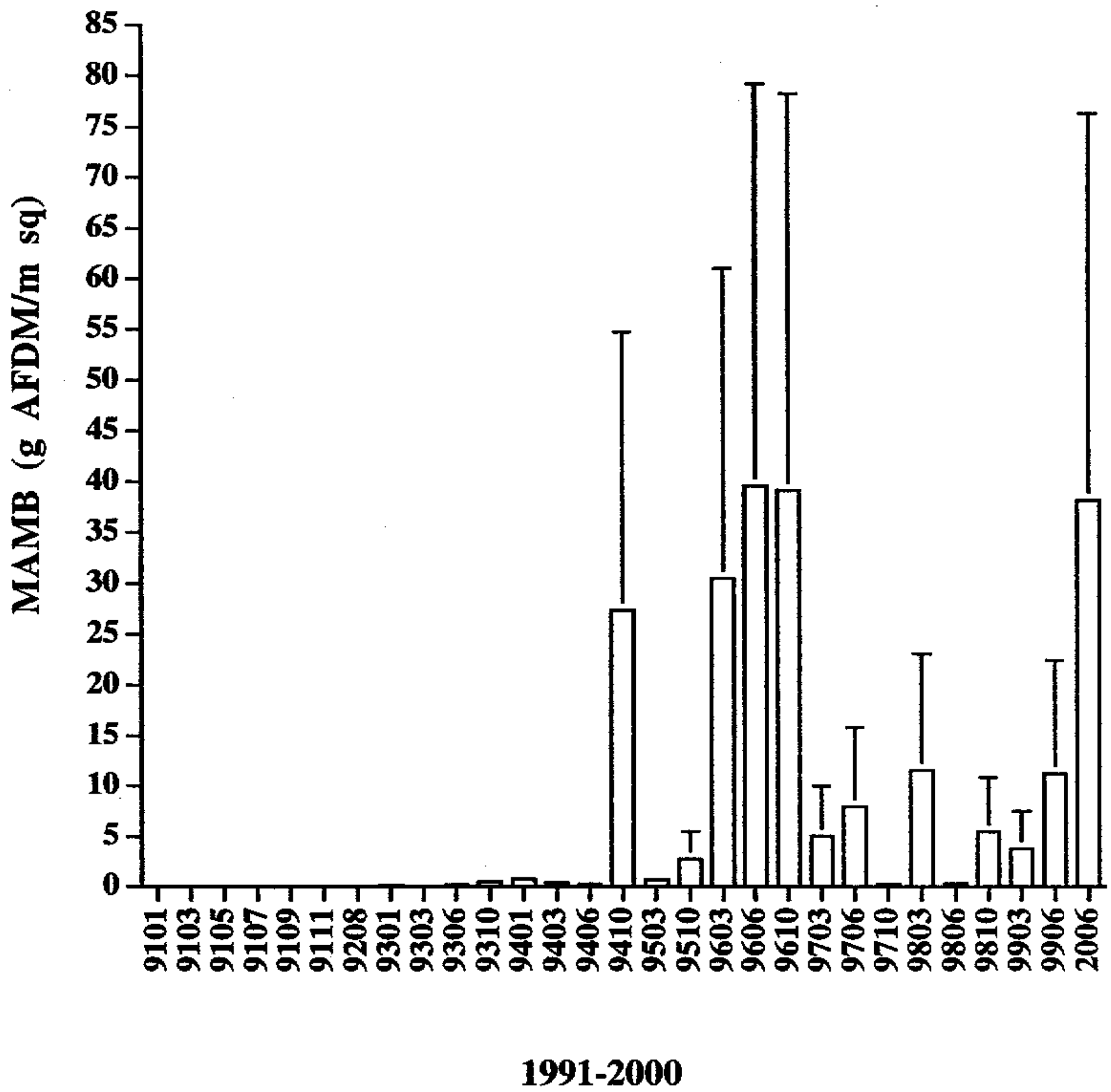

Figure 95. Miscellaneous algae, macrophytes and bryophytes (MAMB) biomass estimates (g AFDM/m sq) at Tanner cobble Rkm 109.6 from January 1991 to June 2000. MAMB was not collected prior to August 1992. Error bars represent (± 1 SE, n=6).

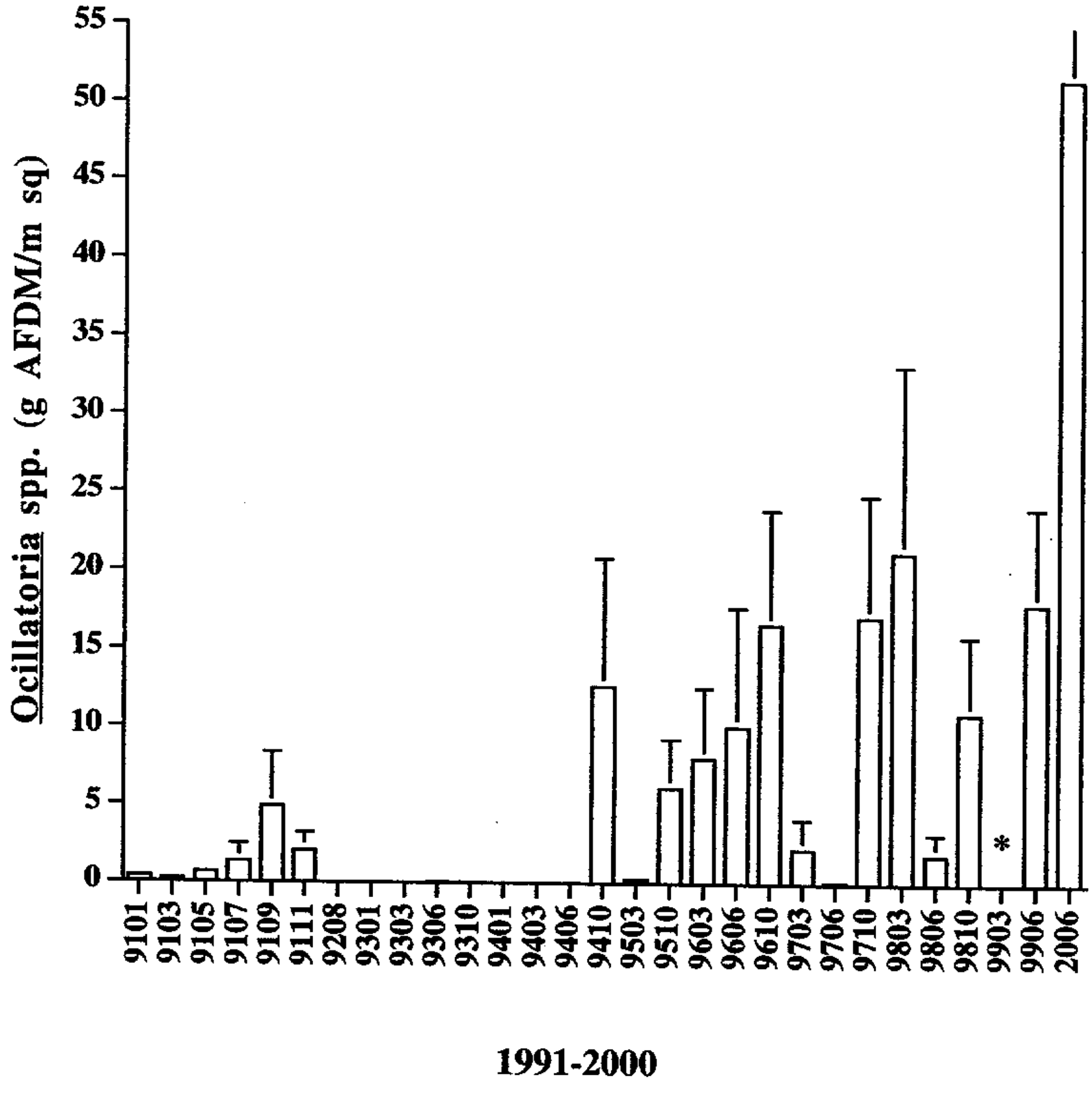

Figure 96. Oscillatoria spp. biomass estimates (g AFDM/m sq) at Tanner cobble Rkm 109.6 from January 1991 to June 2000. Error bars represent (± 1 SE, n=6). Asterisk (*) represents 82 g AFDM/m sq (± 45 SE).

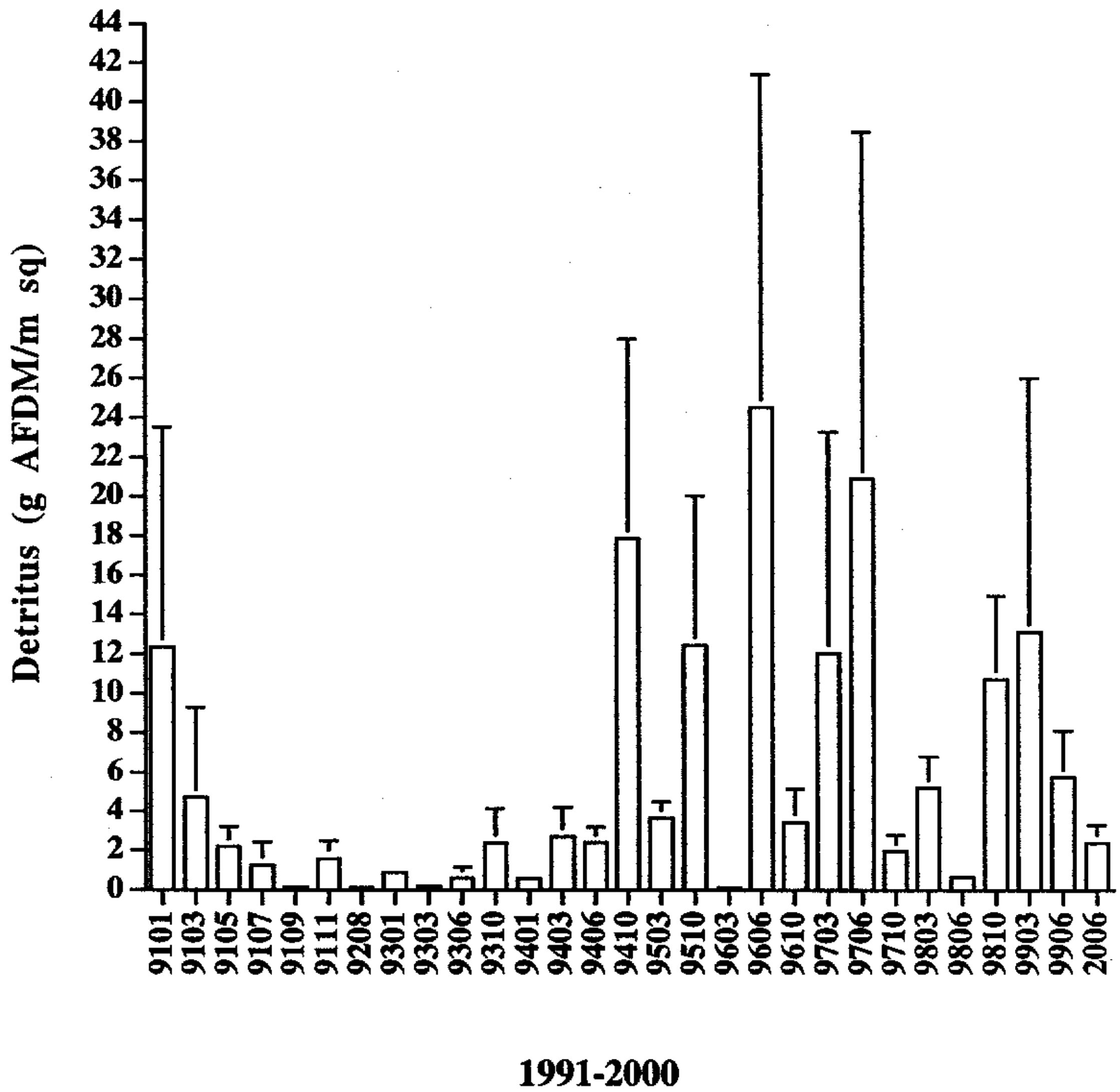

Figure 97. Detritus biomass estimates (g AFDM/m sq) at Tanner cobble Rkm 109.6 from January 1991 to June 2000. Error bars represent (± 1 SE, n=6).

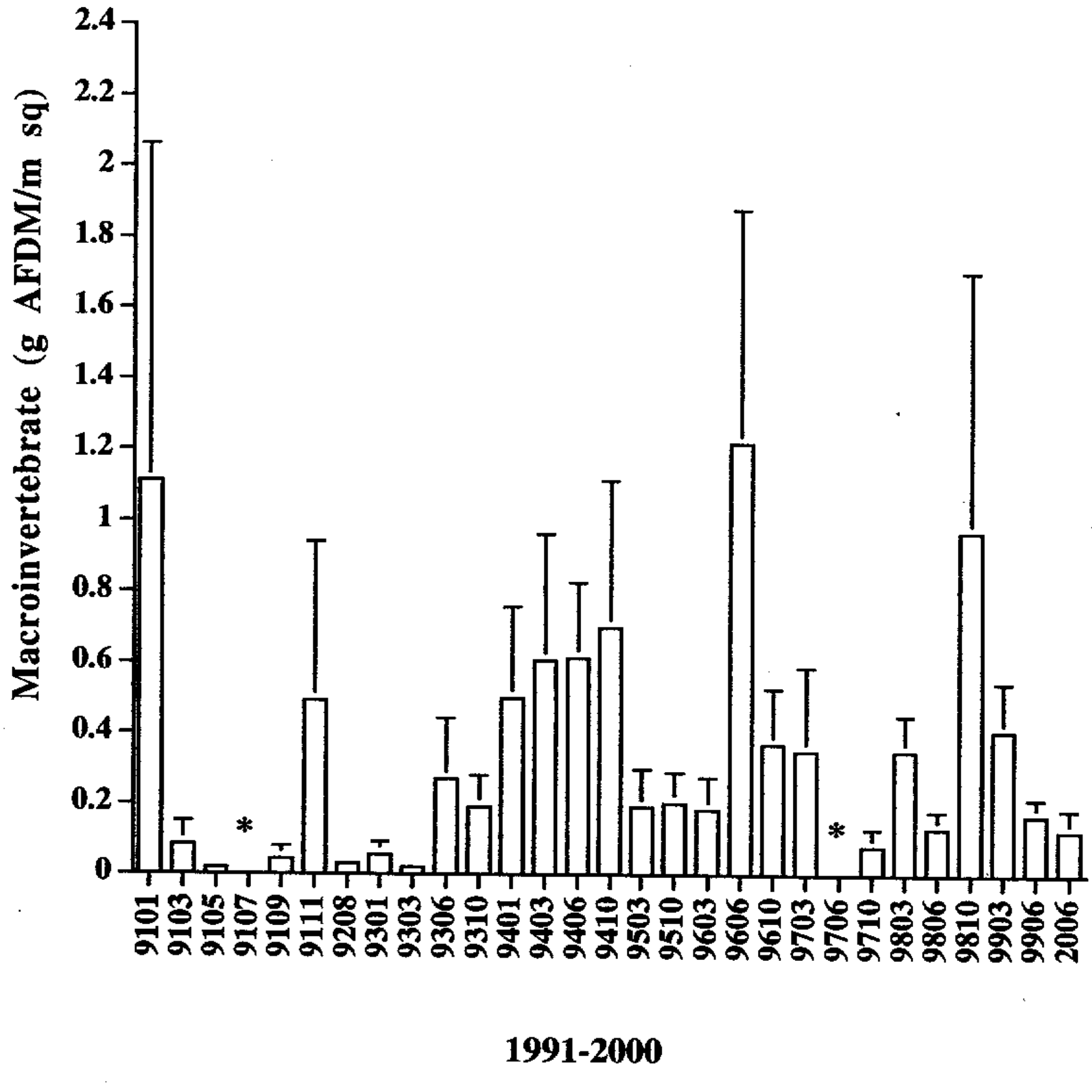

Figure 98. Macroinvertebrate biomass estimates (g AFDM/m sq) at Tanner cobble Rkm 109.6 from January 1991 to June 2000. Error bars represent (± 1 SE, n=6). Asterisk (*) at 9107 represents 7 g AFDM/m sq (± 2 SE) and at 9706 represents 2.5 g AFDM/m sq (± 2 SE).

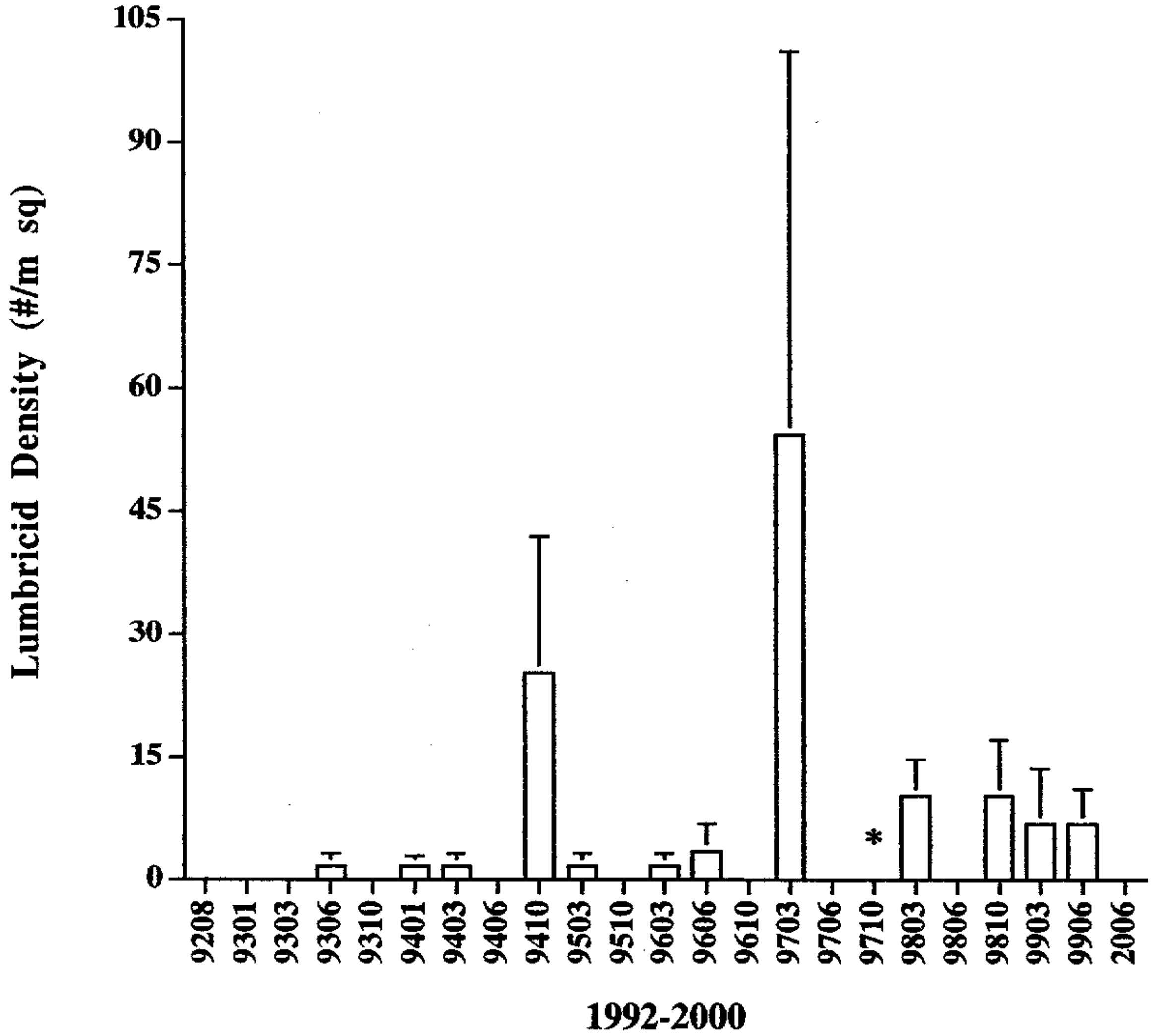

Figure 99. Lumbricid densities (#/m sq) collected at Tanner cobble Rkm 109.6 from August 1992 to June 2000. Error bars represent (± 1 SE, n=6). Asterisk (*) represents 249/m ^{2} sq (± 212 SE).

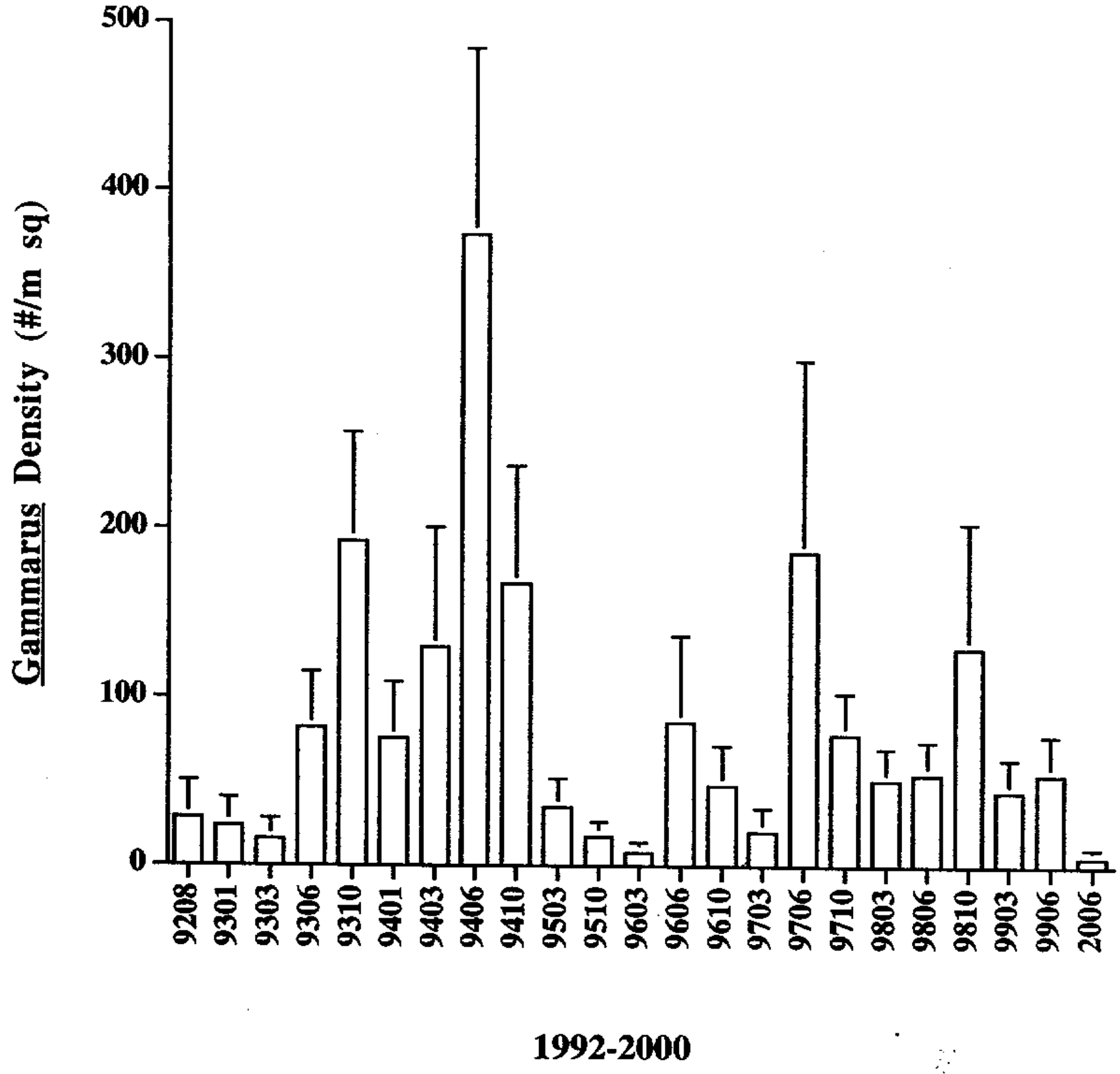

Figure 100. Gammarus densities (#/m sq) collected at Tanner cobble Rkm 109.6 from August 1992 to June 2000. Error bars represent (± 1 SE, n=6).

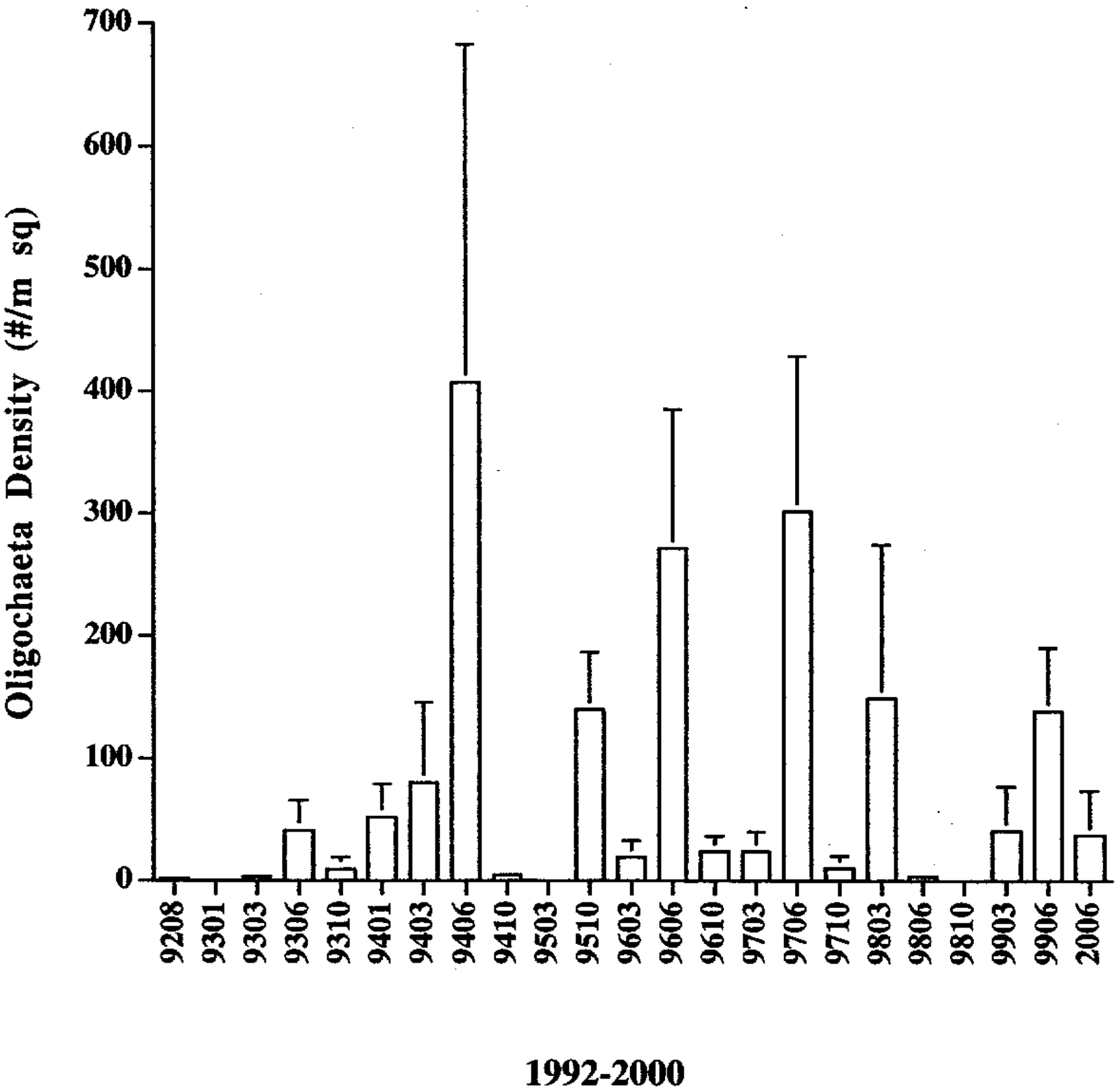

Figure 101. Oligochaeta densities (#/m sq) collected at Tanner cobble Rkm 109.6 from August 1992 to June 2000. Error bars represent (± 1 SE, n=6).

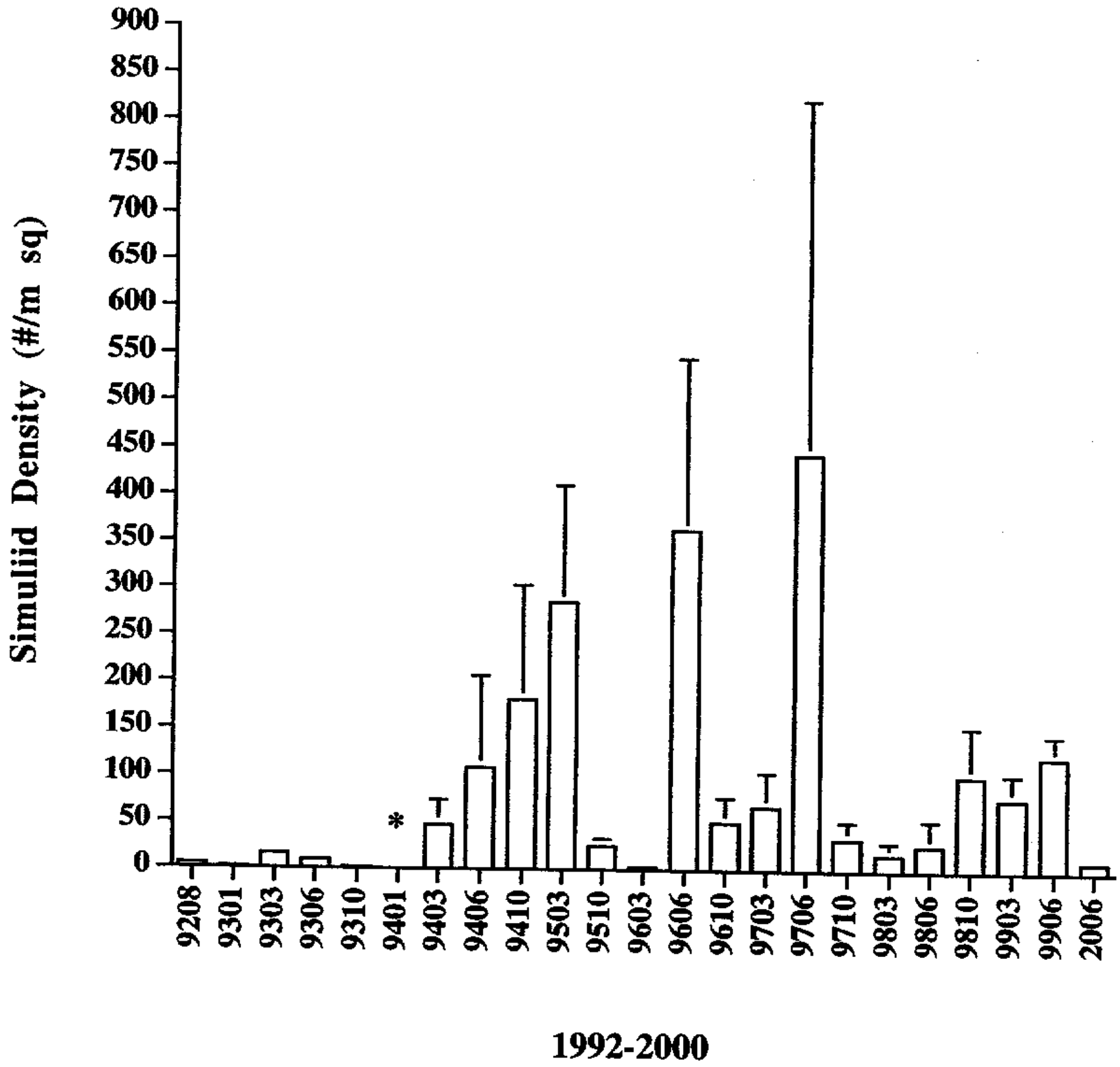

Figure 102. Simuliid densities (#/m sq) at Tanner cobble Rkm 109.6 from August 1992 to June 2000. Error bars represent (± 1 SE, n=6).

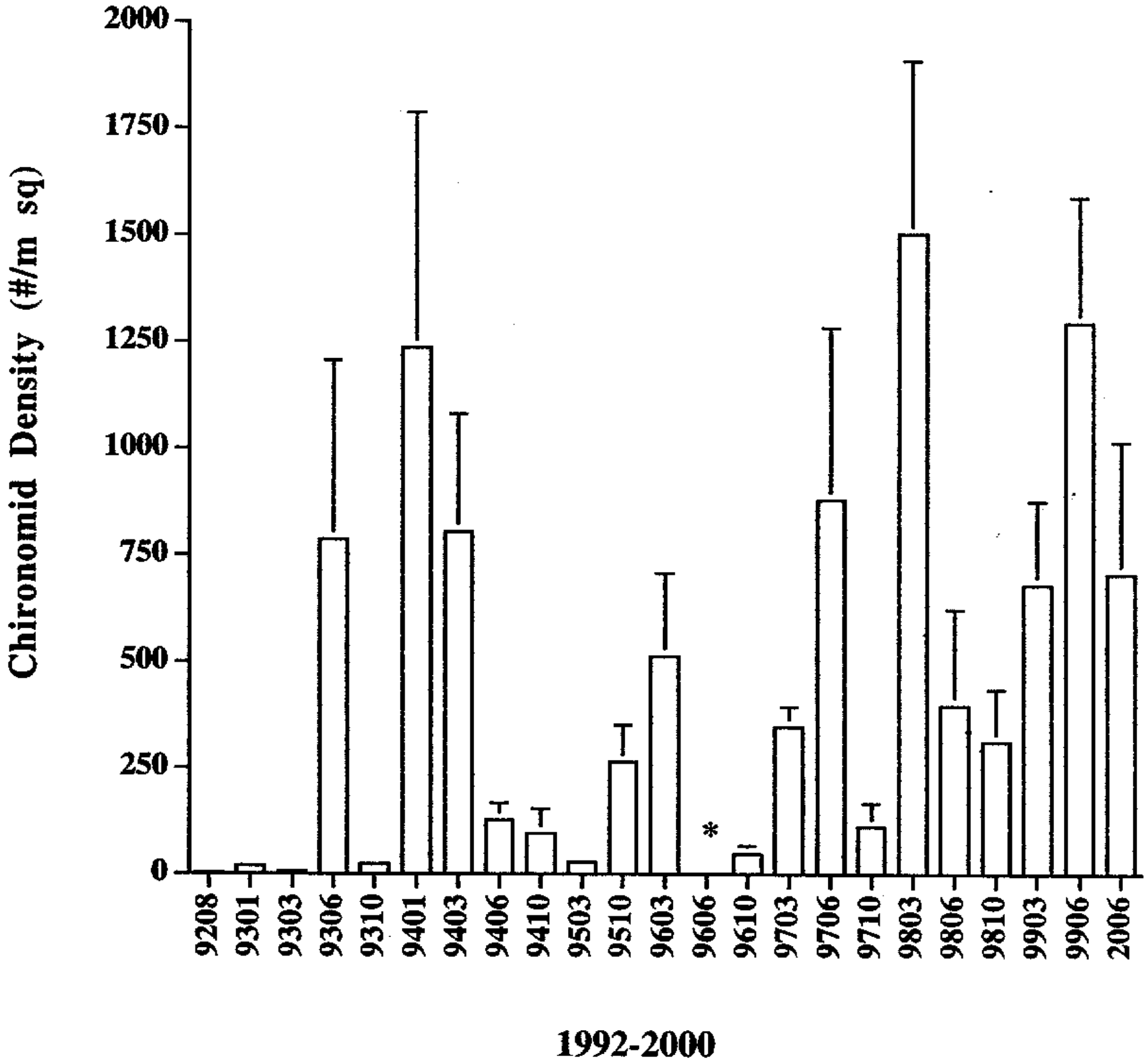

Figure 103. Chironomid densities (#/m sq) collected at Tanner cobble Rkm 109.6 from August 1992 to June 2000. Error bars represent (± 1 SE, n=6).

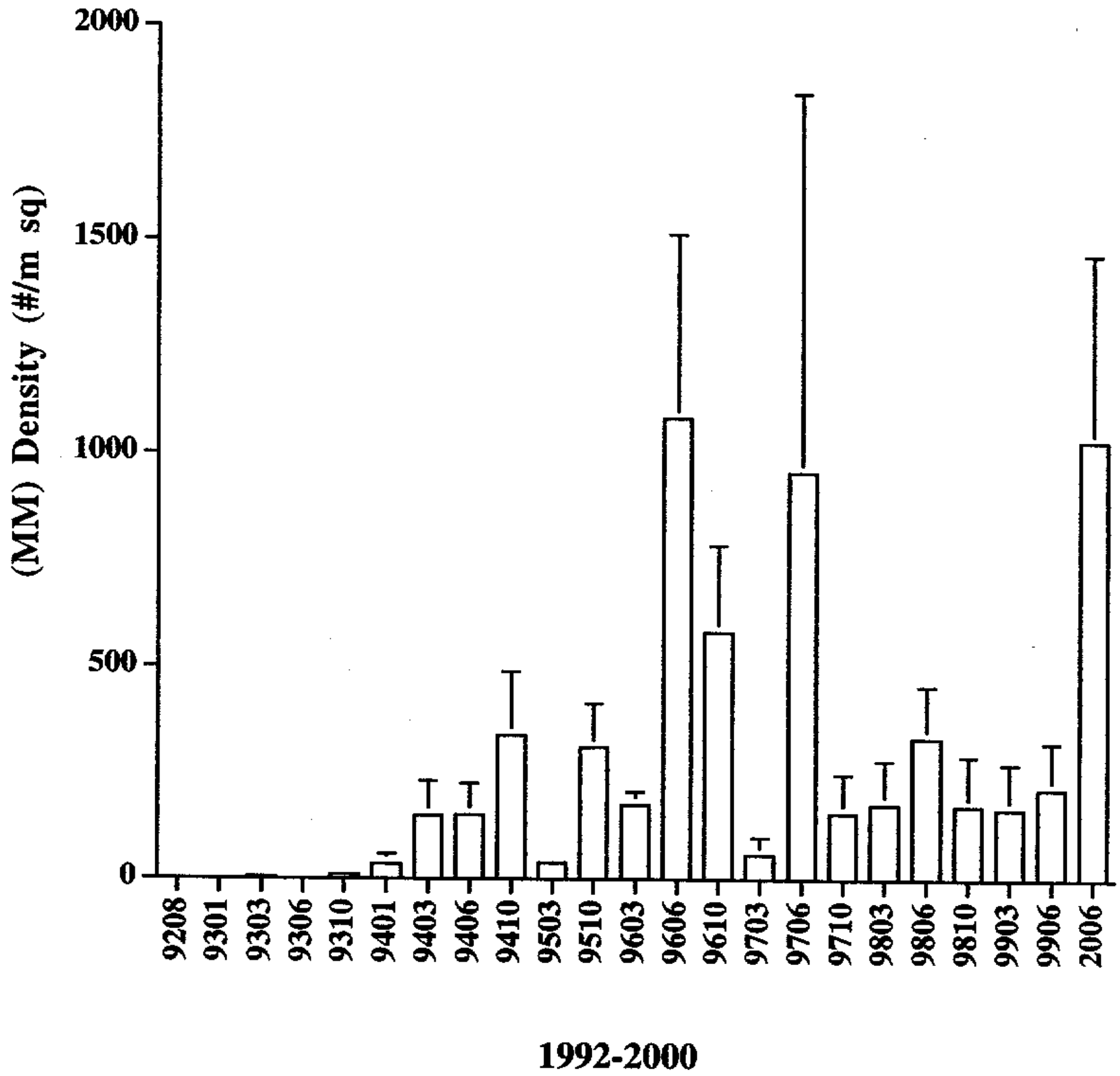

Figure 104. Miscellaneous macroinvertebrate (MM) densities (#/m sq) collected at Tanner cobble Rkm 109.6 from August 1992 to June 2000. Error bars represent (± 1 SE, n=6).

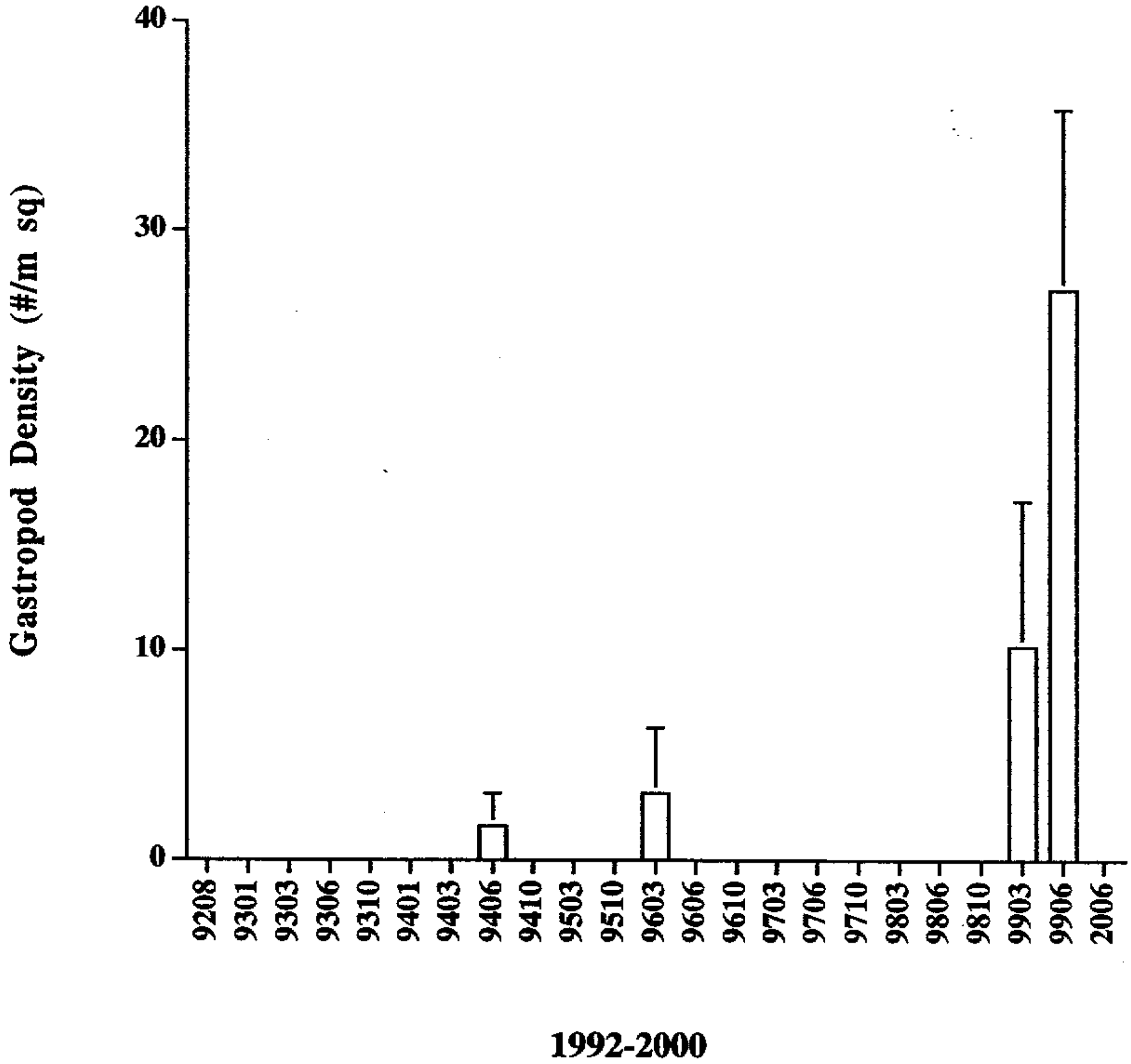

Figure 105. Gastropod densities (#/m sq) collected at Tanner cobble Rkm 109.6 from August 1992 to June 2000. Error bars represent (± 1 SE, n=6).

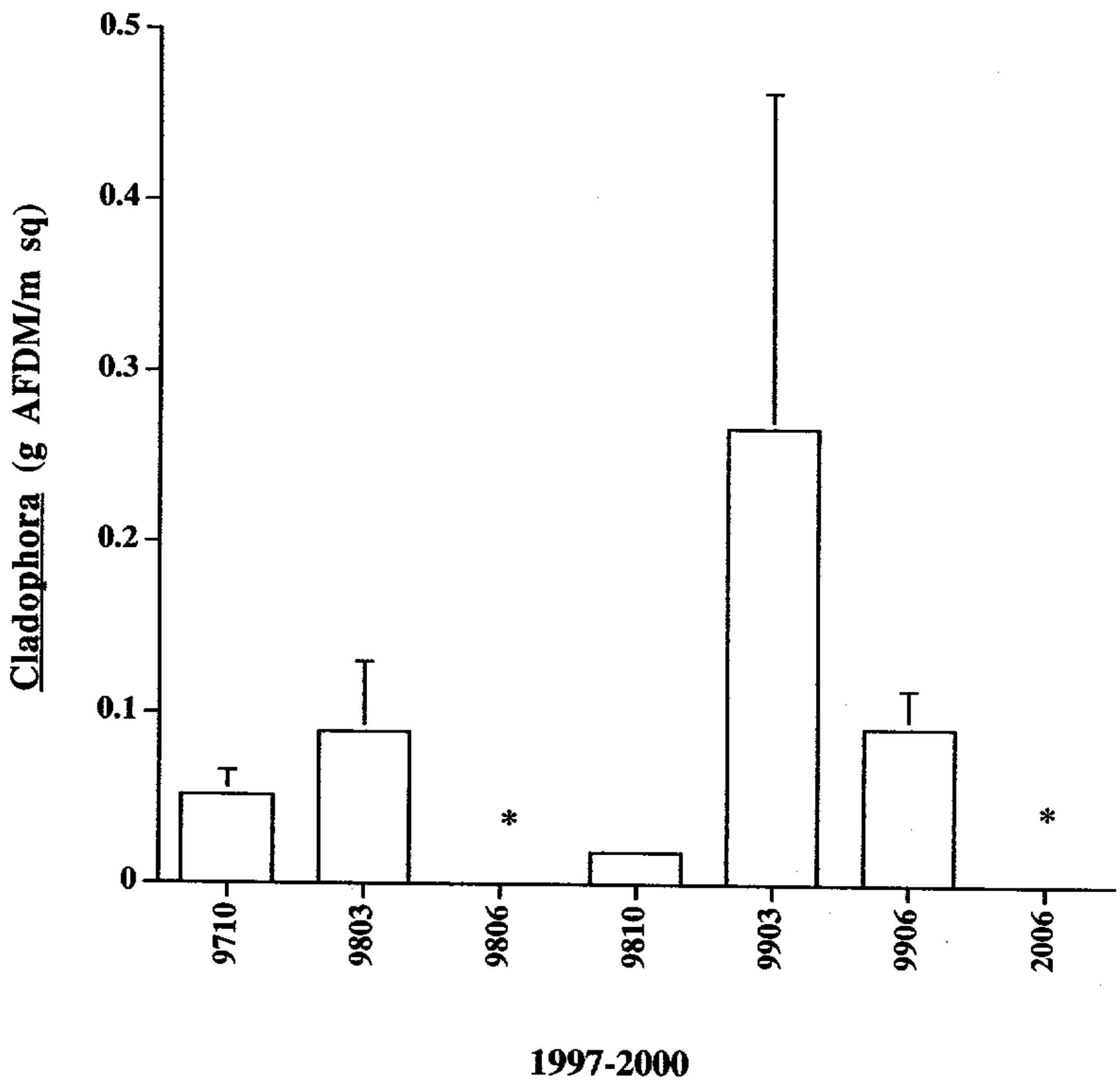

Figure 106. Cladophora biomass estimates (g AFDM/m sq) at 127 Mile Rapid cobble Rkm 202.9 from October 1997 to June 2000. Error bars represent (± 1 SE, n=6). Asterisk (*) repesents 3 g AFDM/m sq(± 1.5 SE) and at 2006 represents 1.0 g AFDM/m sq (± 0.77 SE).

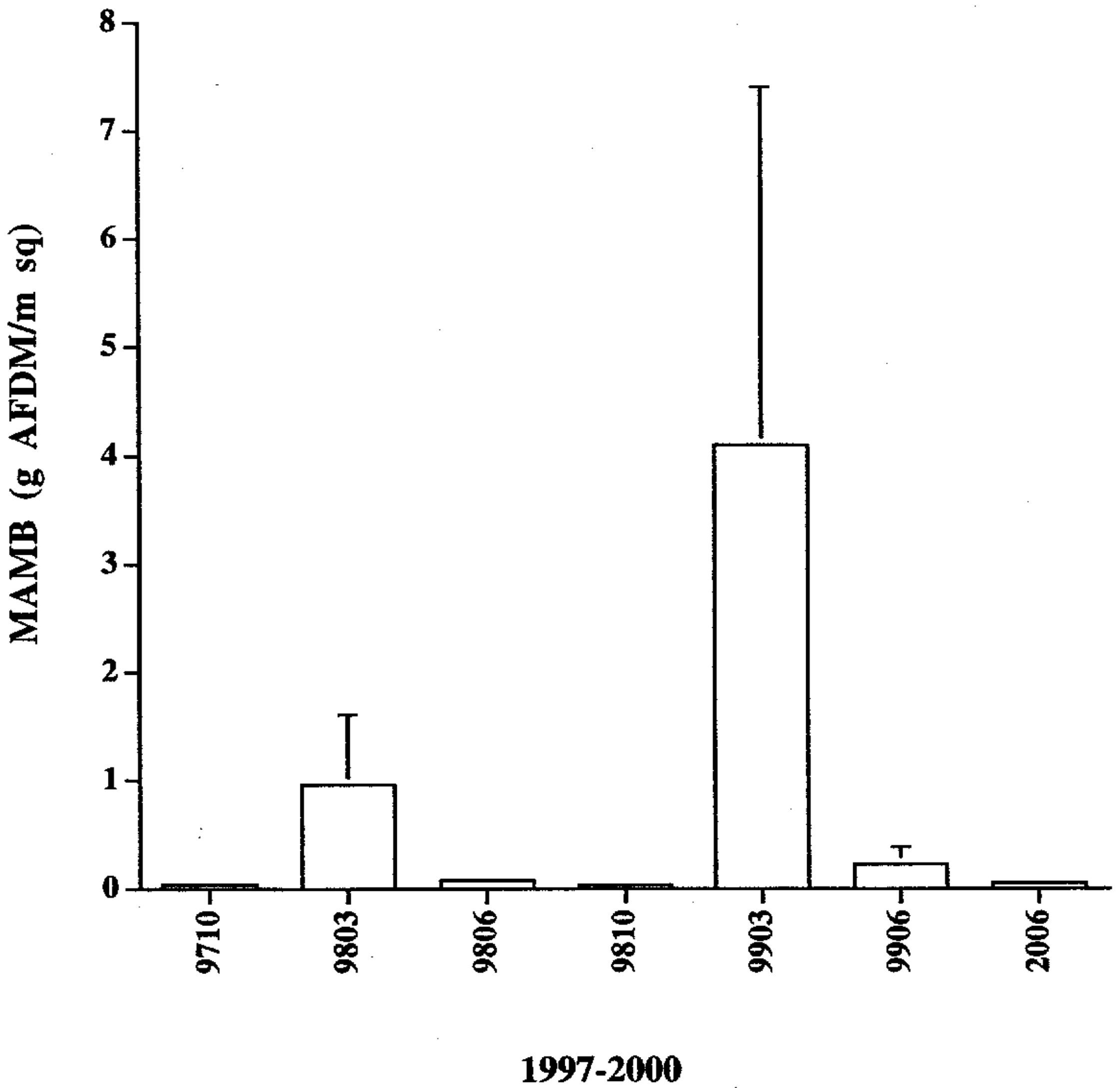

Figure 107. Miscellaneous algae, macrophytes and bryophytes (MAMB) biomass estimates (g AFDM/m sq) at 127 Mile Rapid cobble Rkm 202.9 from October 1997 to June 2000. Error bars represent (± 1 SE, n=6).

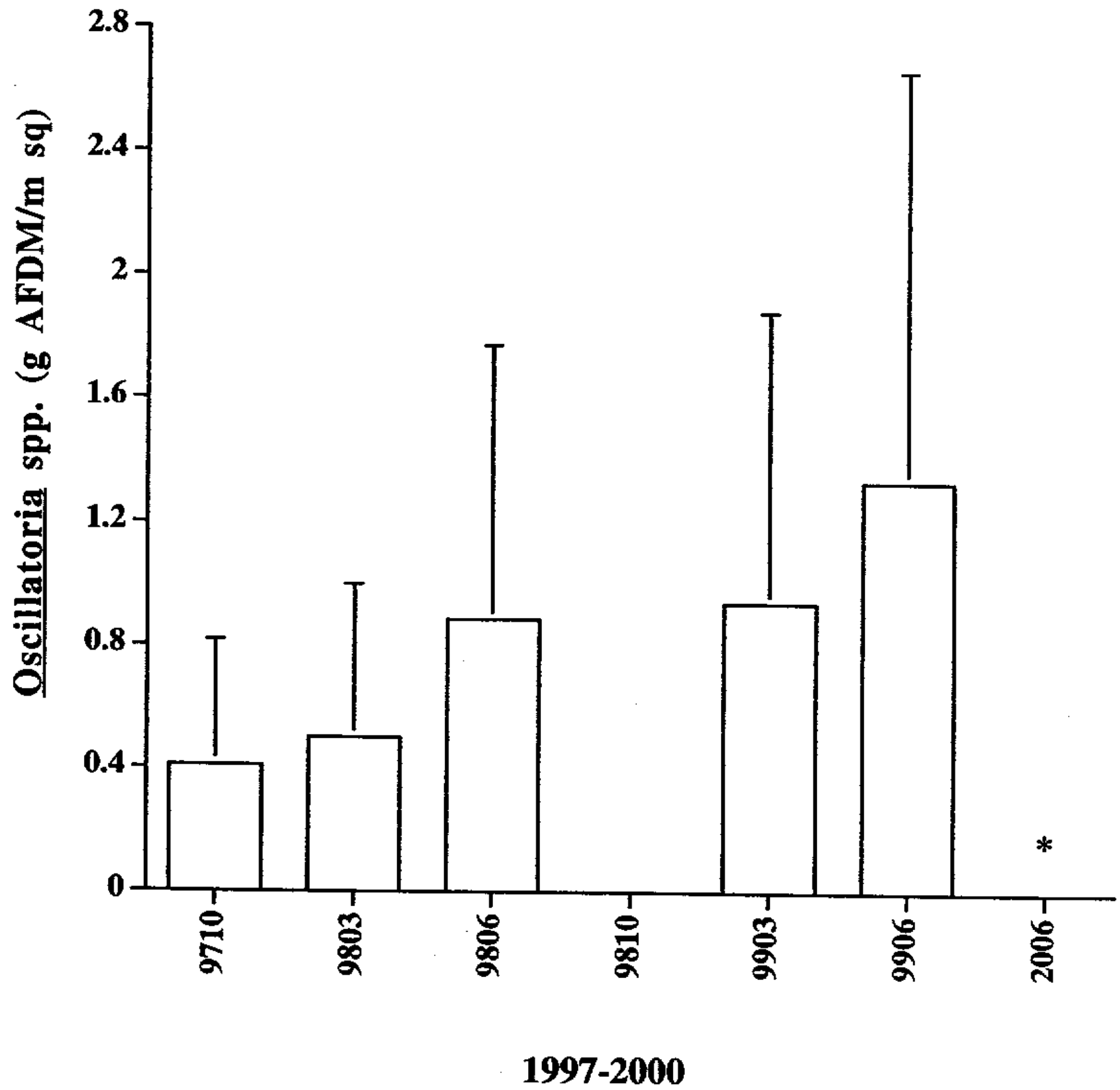

Figure 108. Oscillatoria spp. biomass estimates (g AFDM/m sq) at 127 Mile Rapid cobble Rkm 202.9 from October 1997 to June 2000. Error bars represent (± 1 SE, n=6). Asterisk represents 10 g AFDM/m sq (± 3 SE).

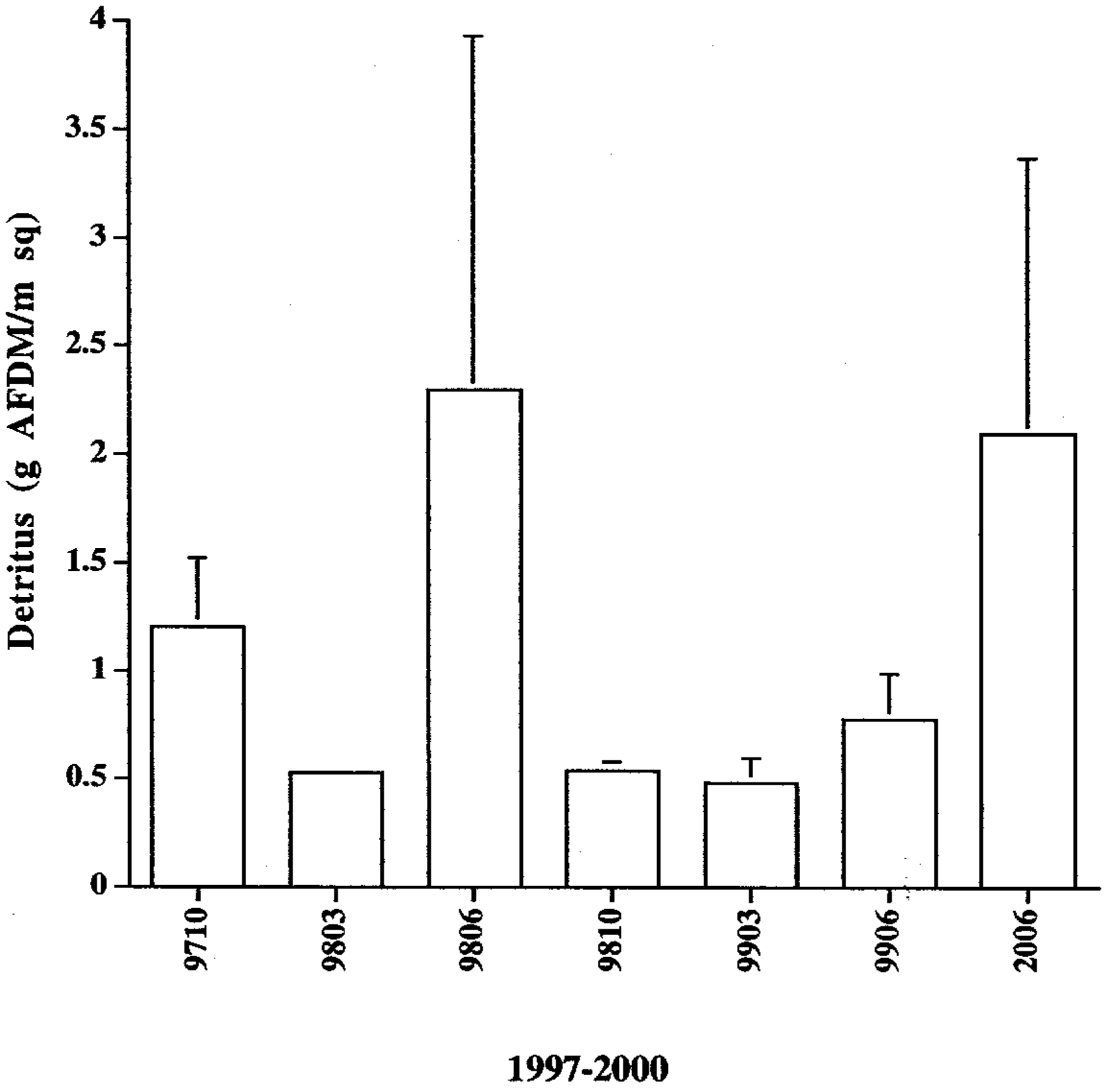

Figure 109. Detritus biomass estimates (g AFDM/m sq) at 127 Mile Rapid cobble Rkm 202.9 from October 1997 to June 2000. Error bars represent (± 1 SE, n=6).

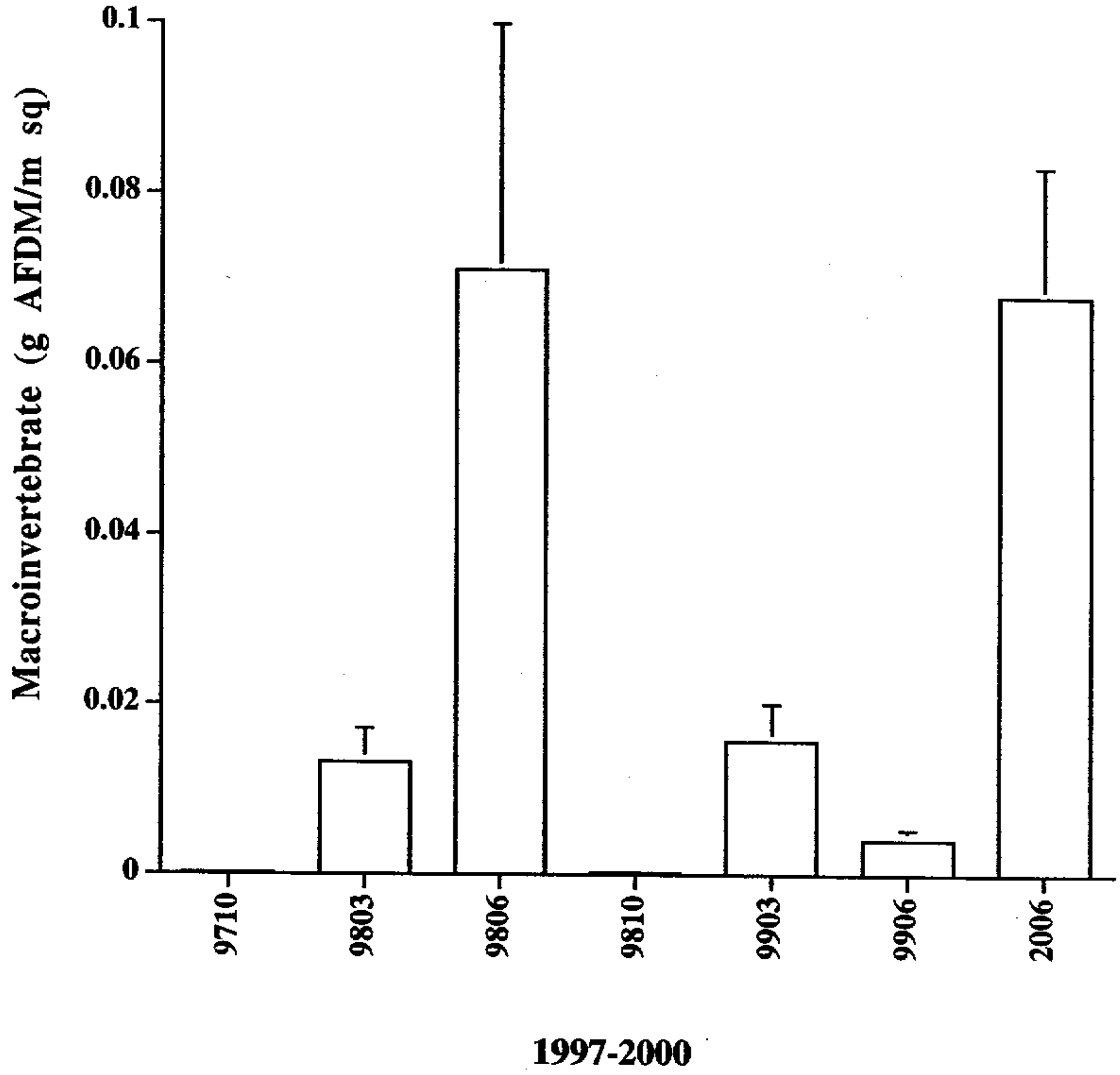

Figure 110. Macroinvertebrate biomass estimates (g AFDM/m sq) at 127 Mile Rapid cobble Rkm 202.9 from October 1997 to June 2000. Error bars represent (± 1 SE, n=6).

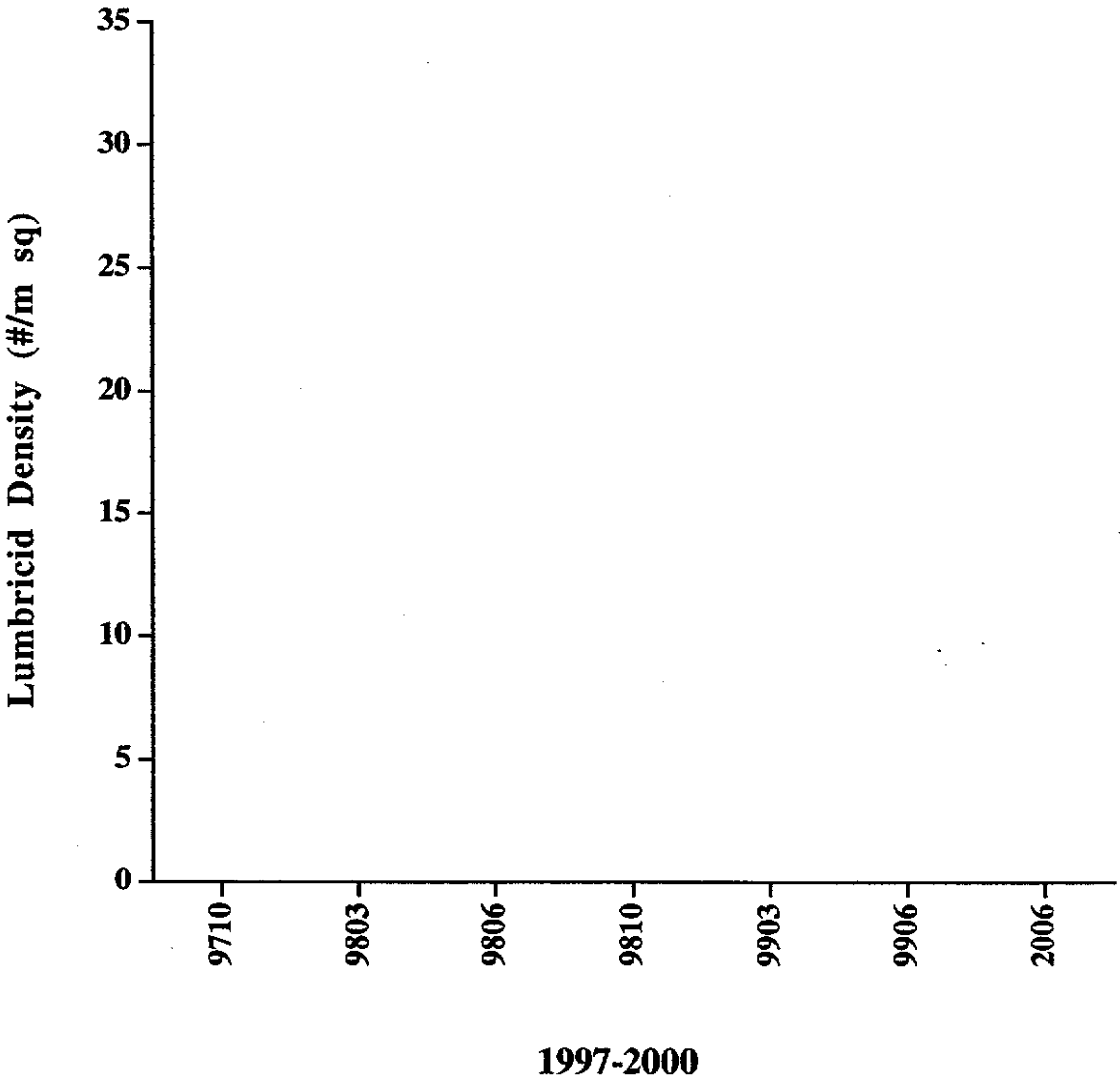

Figure 111. Lumbricid densities (#/m sq) collected at 127 Mile Rapid cobble Rkm 202.9 from October 1997 to June 2000. No Lumbricid abundances were found at this site during our collection dates.

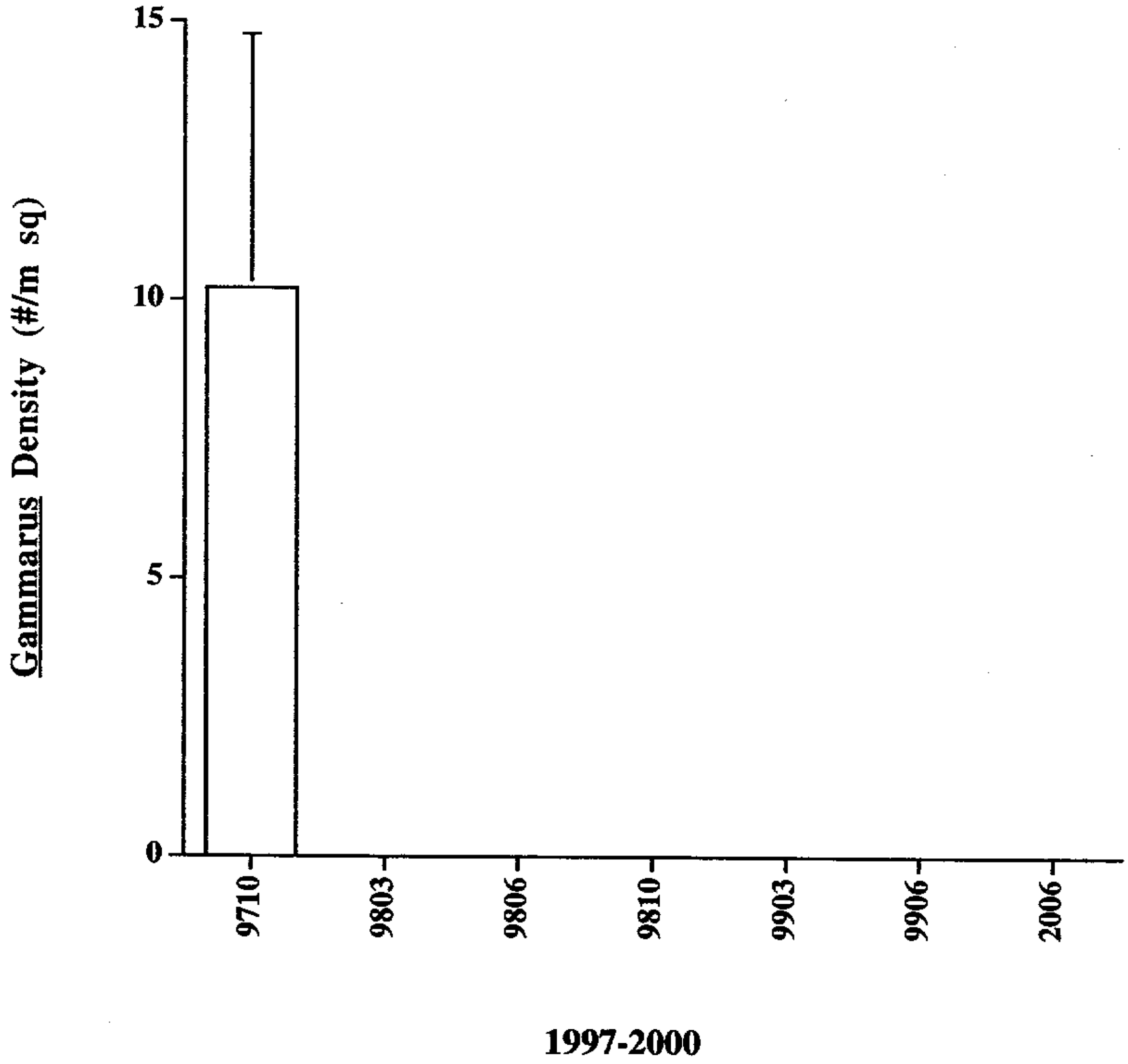

Figure 112. Gammarus densities (#/m /s) collected at 127 Mile Rapid cobble Rkm 202.9 from October 1997 to June 2000. Error bars represent ($\pm$ 1 SE, n=6).

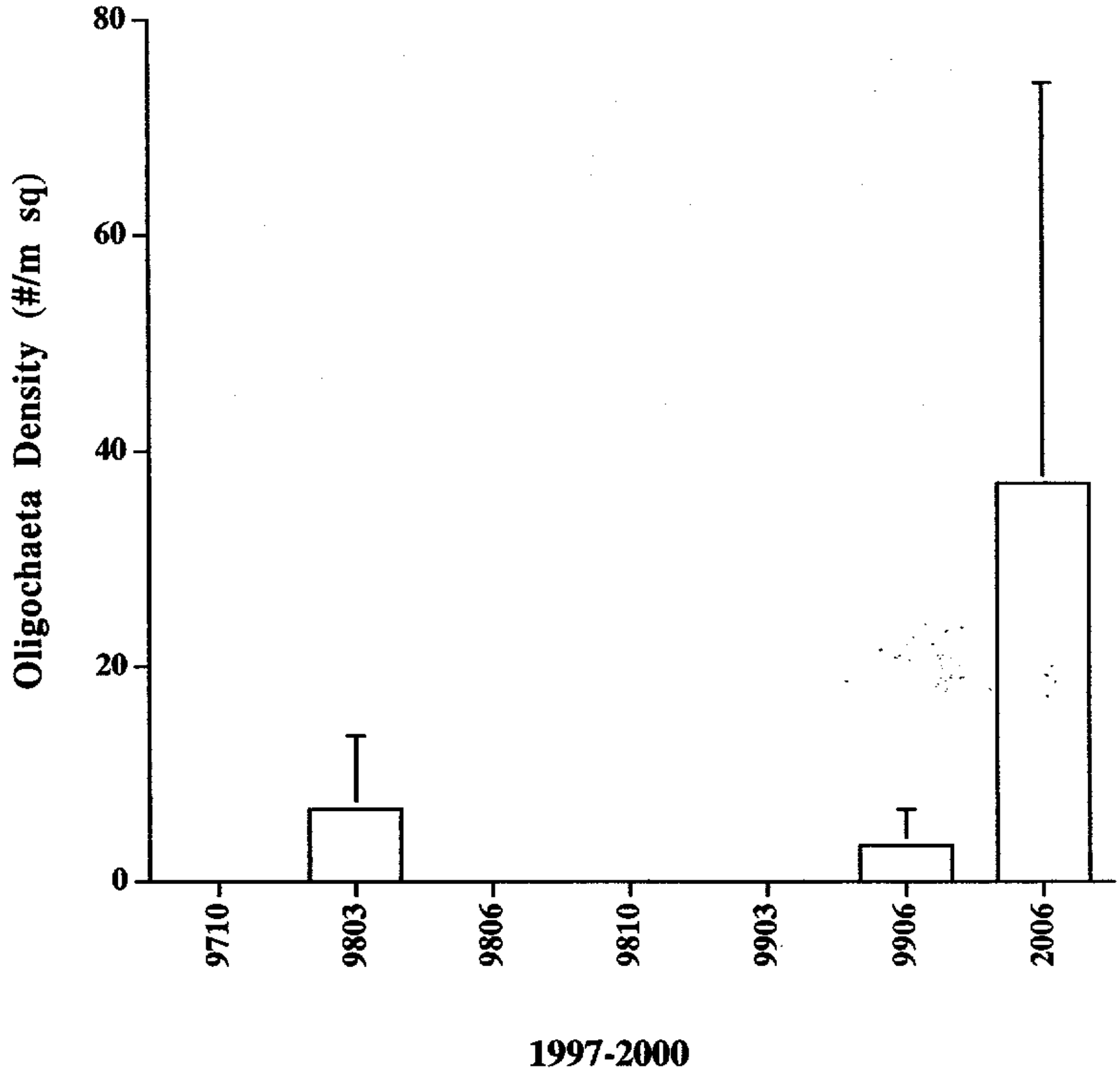

Figure 113. Oligochaeta densities (#/m sq) collected at 127 Mile Rapid cobble Rkm 202.9 from October 1997 to June 2000. Error bars represent (± 1 SE, n=6).

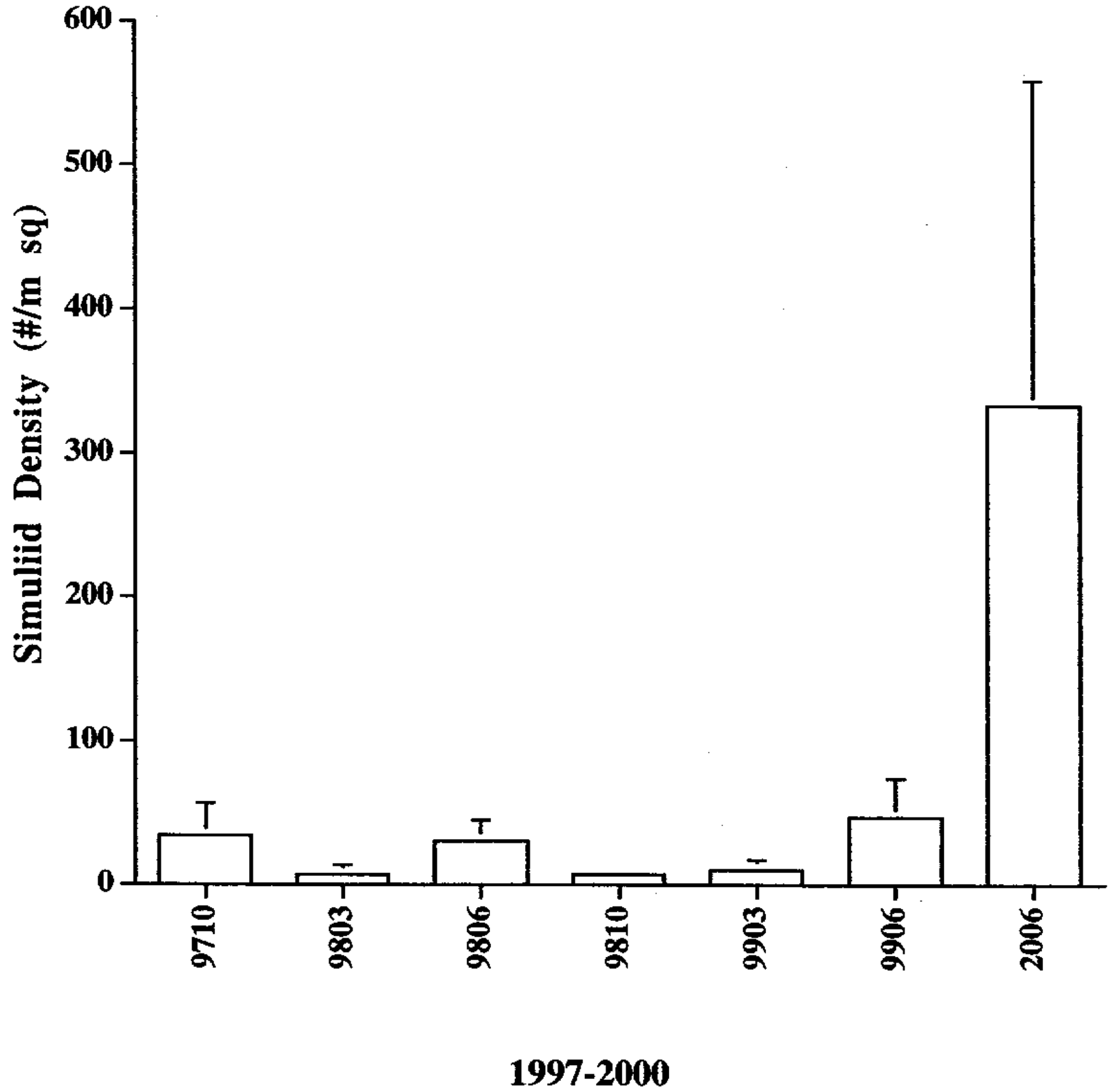

Figure 114. Simuliid densities (#/m sq) collected at 127 Mile Rapid cobble Rkm 202.9 from October 1997 to June 2000. Error bars represent (± 1 SE, n=6).

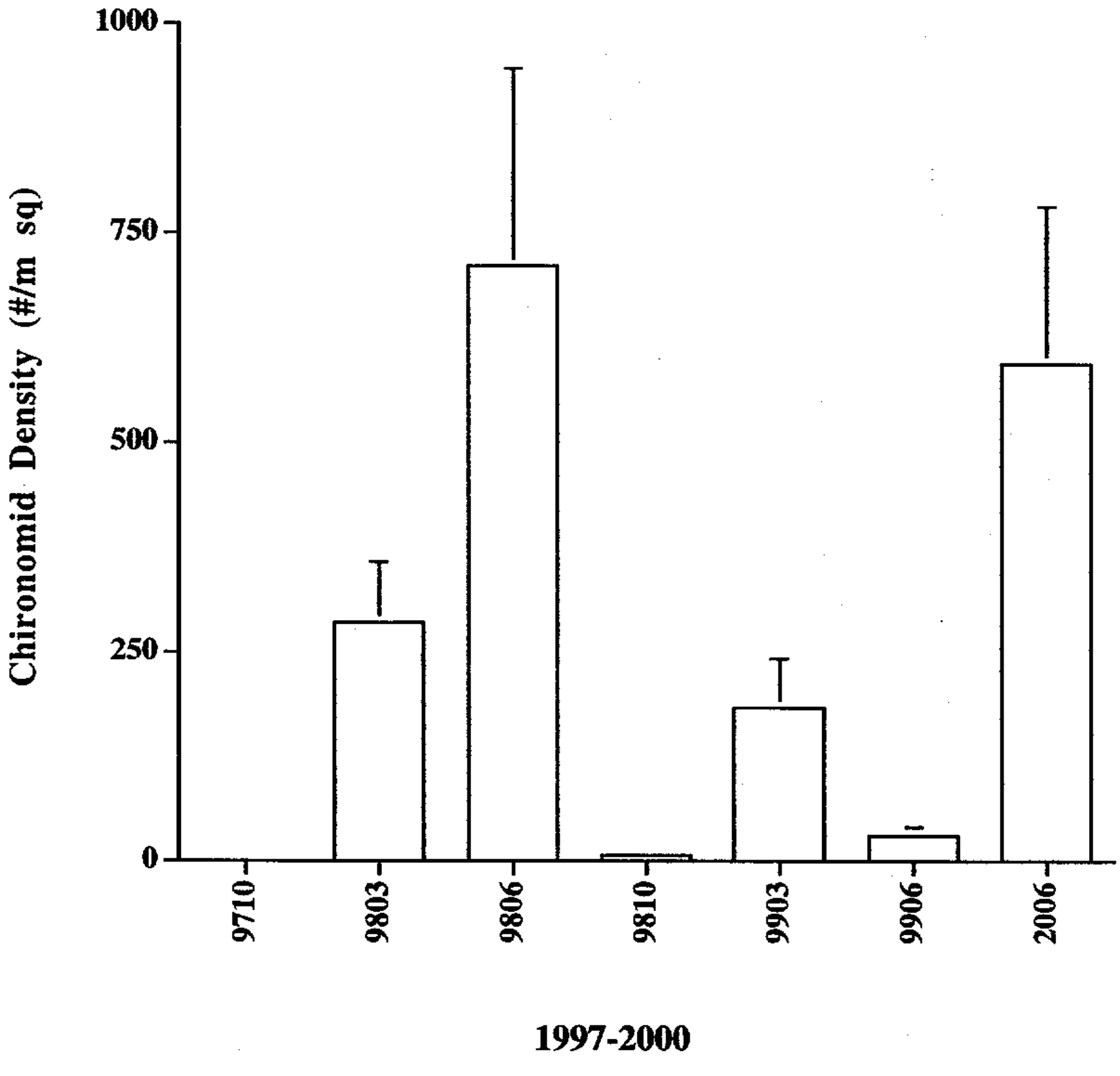

Figure 115. Chironomid densities (#/m sq) collected at 127 Mile Rapid cobble Rkm 202.9 from October 1997 to June 2000. Error bars represent ($\pm$ 1 SE, n=6).

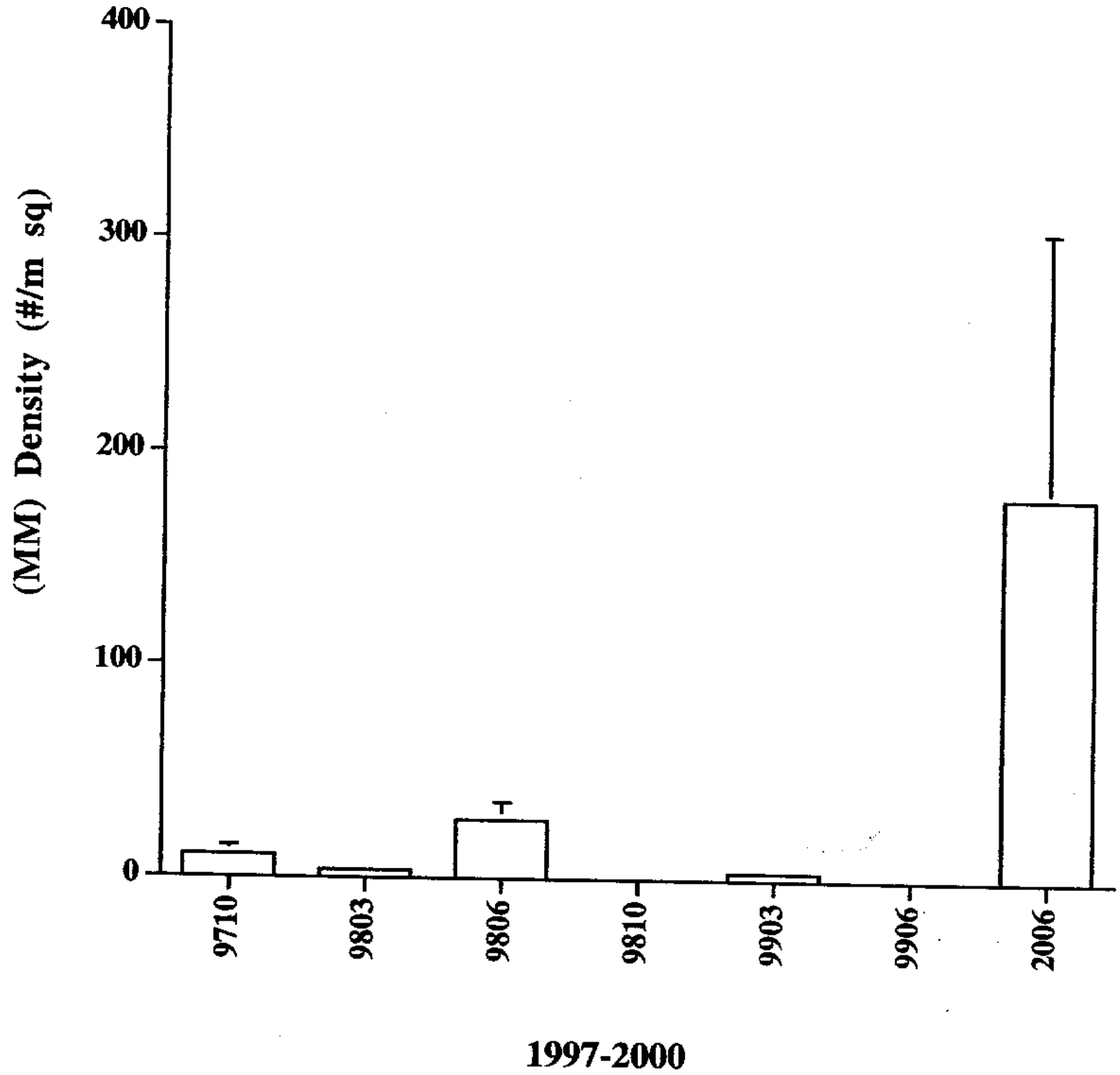

Figure 116. Miscellaneous macroinvertebrate (MM) densities (#/m sq) collected at 127 Mile Rapid cobble Rkm 202.9 from October 1997 to June 2000. Error bars represent (± 1 SE, n=6).

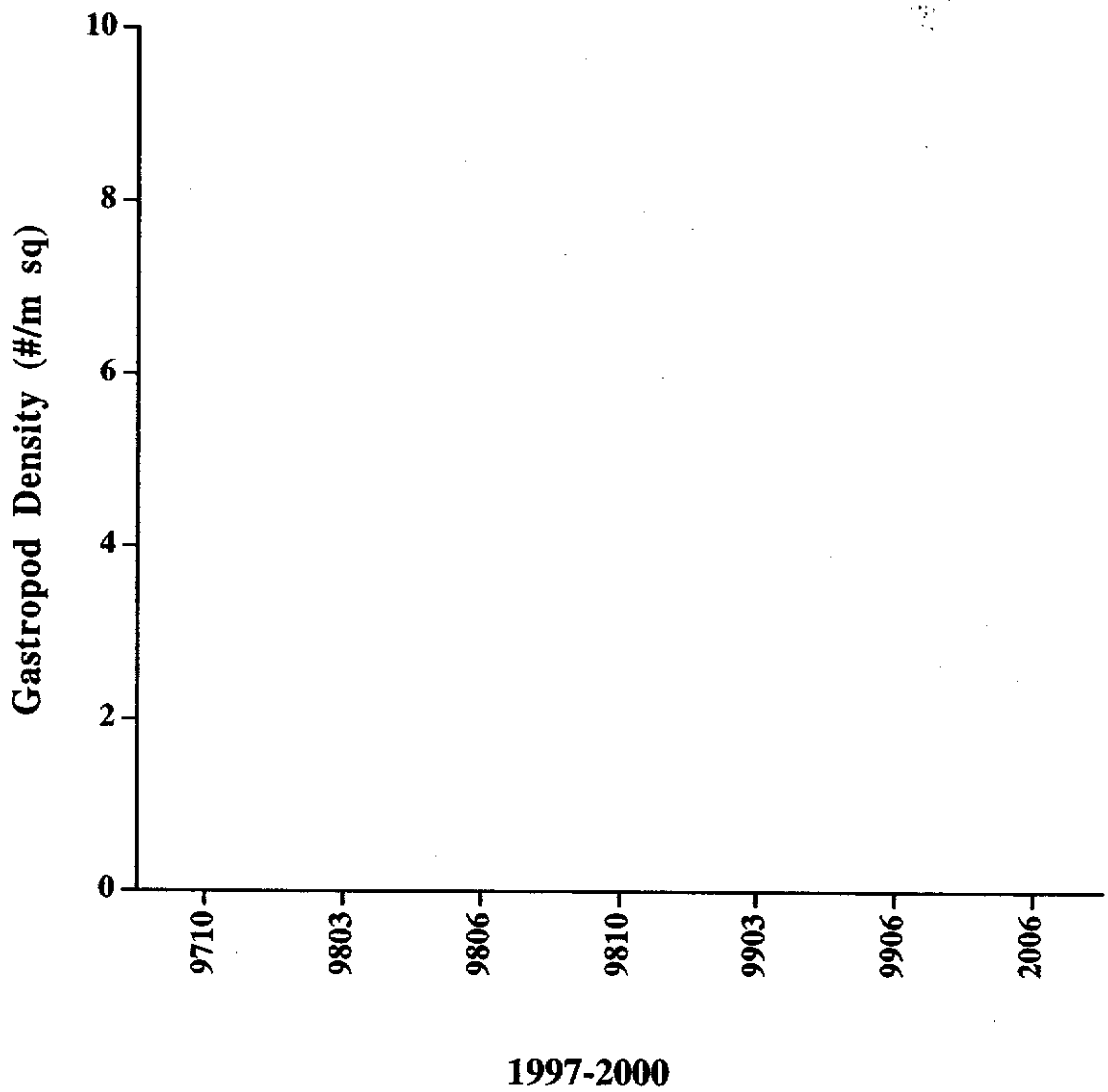

Figure 117. Gastropod densities (#/m sq) collected at 127 Mile Rapid cobble Rkm 202.9 from October 1997 to June 2000. No Gastropod abundances were found at this site during our collection dates.

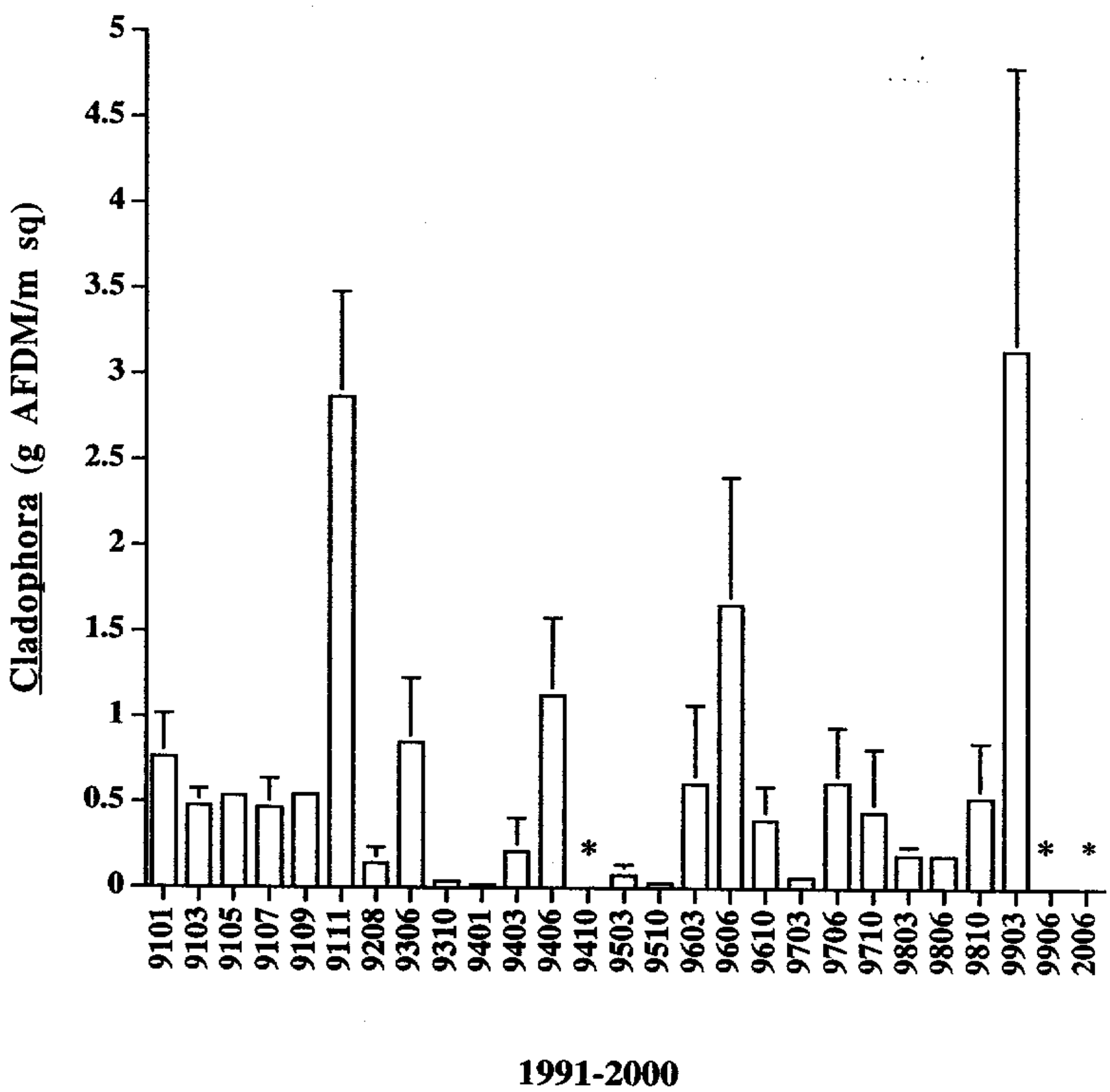

Figure 118. Cladophora biomass estimates (g AFDM/m sq) at 205 Mile rapid Rkm 328.8 from January 1991 to June 2000. Error bars represent (± 1 SE, n=6). Asterisk (*) at 9410 represents 8 g AFDM/m sq (± 4 SE), at 9906 represents 8 g AFDM/m sq (± 2 SE) and at 2006 5 g AFDM/m sq (± 2 SE).

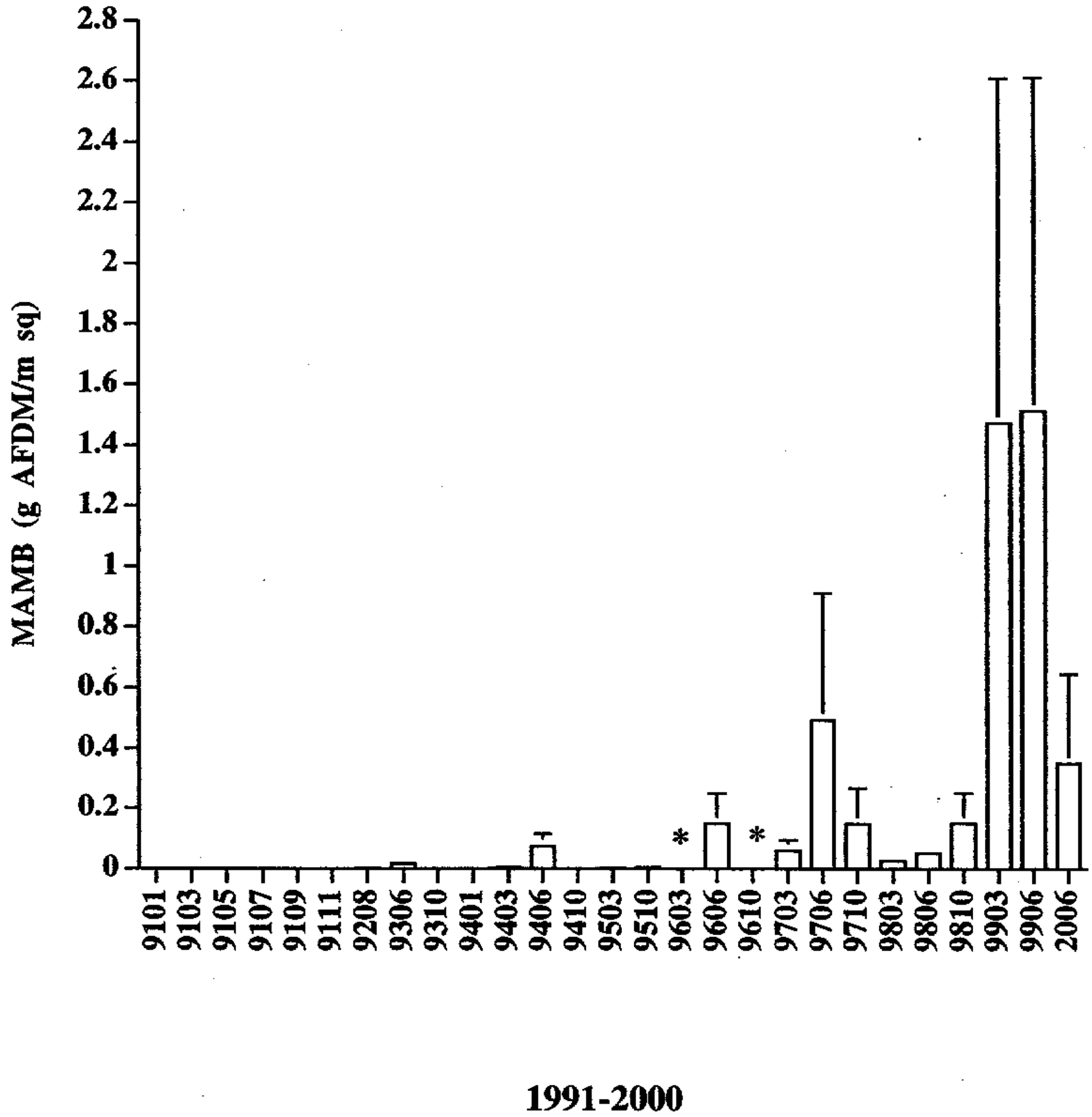

Figure 119. Miscellaneous algae, macrophytes and bryophytes (MAMB) biomass estimates (g AFDM/m sq) at 205 Mile rapid Rkm 328.8 from January 1991 to June 2000. MAMB was not collected prior to August 1992. Error bars represent (± 1 SE, n=6). Asterisk (*) at 9603 represents 8 g AFDM/m sq (± 7 SE) and at 9610 represents 4 g AFDM/m sq(± 2 SE).

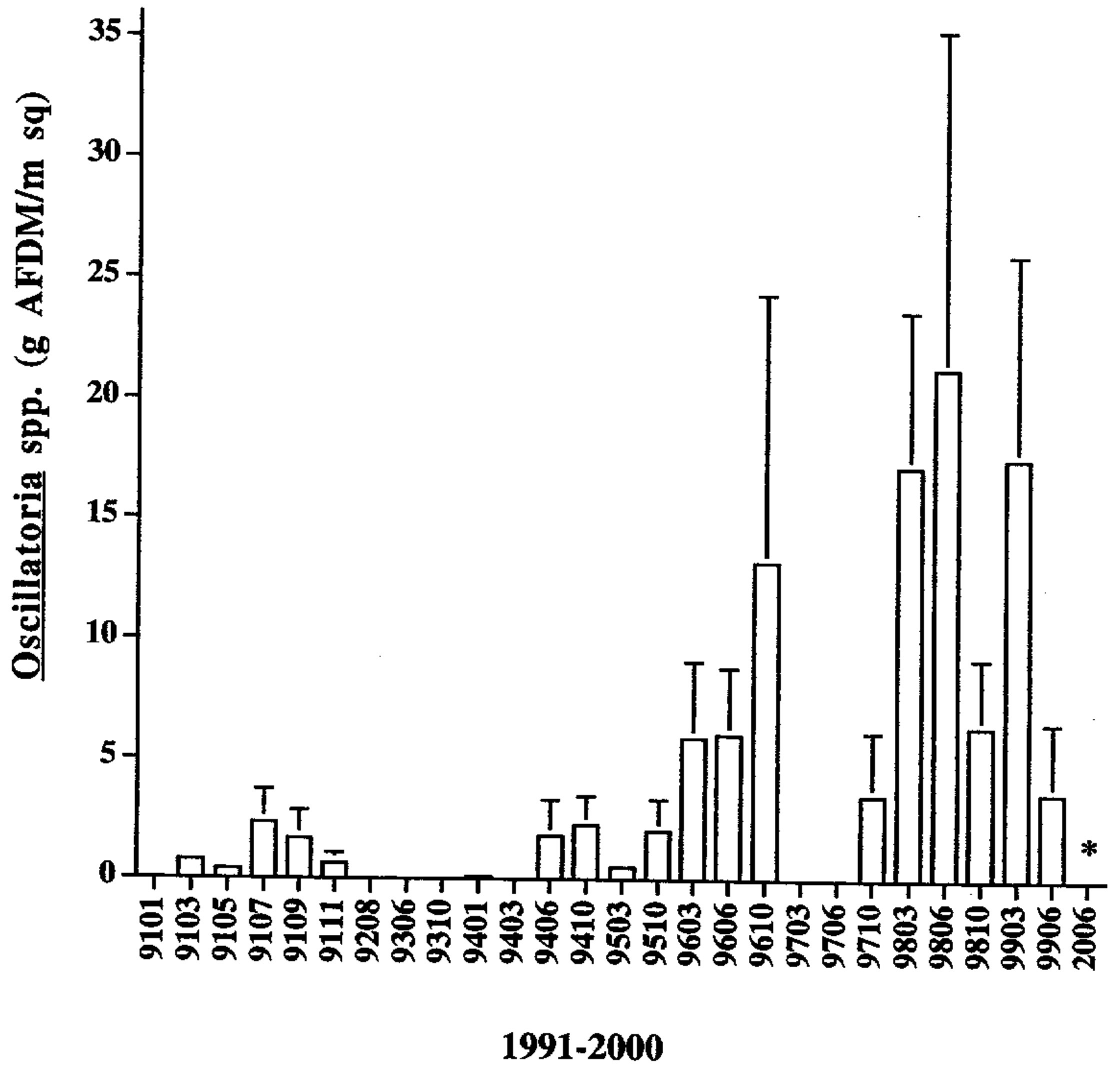

Figure 120. Oscillatoria spp. biomass estimates (g AFDM/m sq) at 205 Mile rapid Rkm 328.8 from January 1991 to June 2000. Error bars represent (± 1 SE, n=6). Asterisk (*) represents 36 g AFDM (± 23 SE).

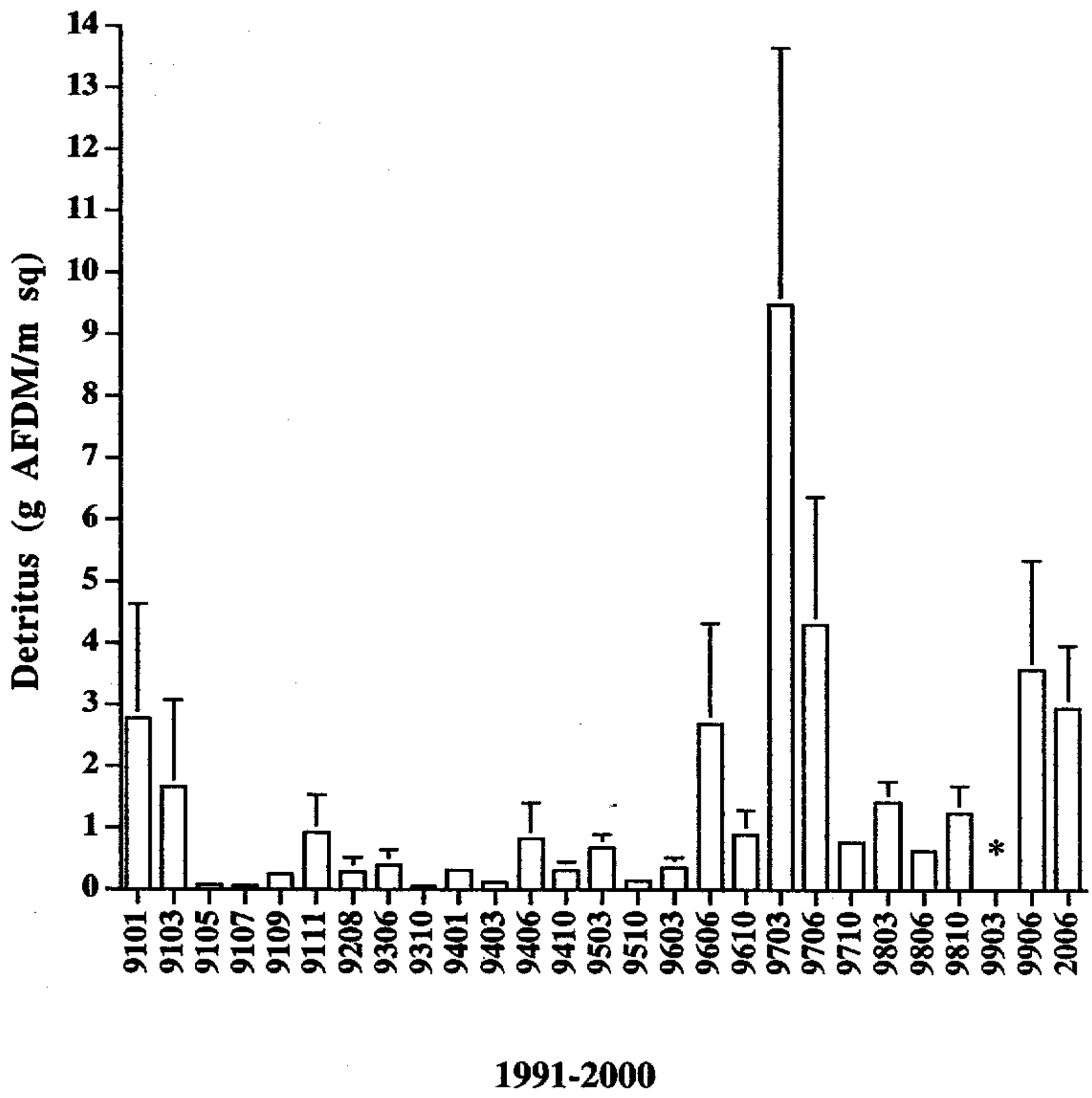

Figure 121. Detritus biomass estimates (g AFDM/m sq) at 205 Mile rapid Rkm 328.8 from January 1991 to June 2000. Error bars represent (± 1 SE, n=6). Asterisk(*) represents 13 g AFDM/m sq (± 12 SE).

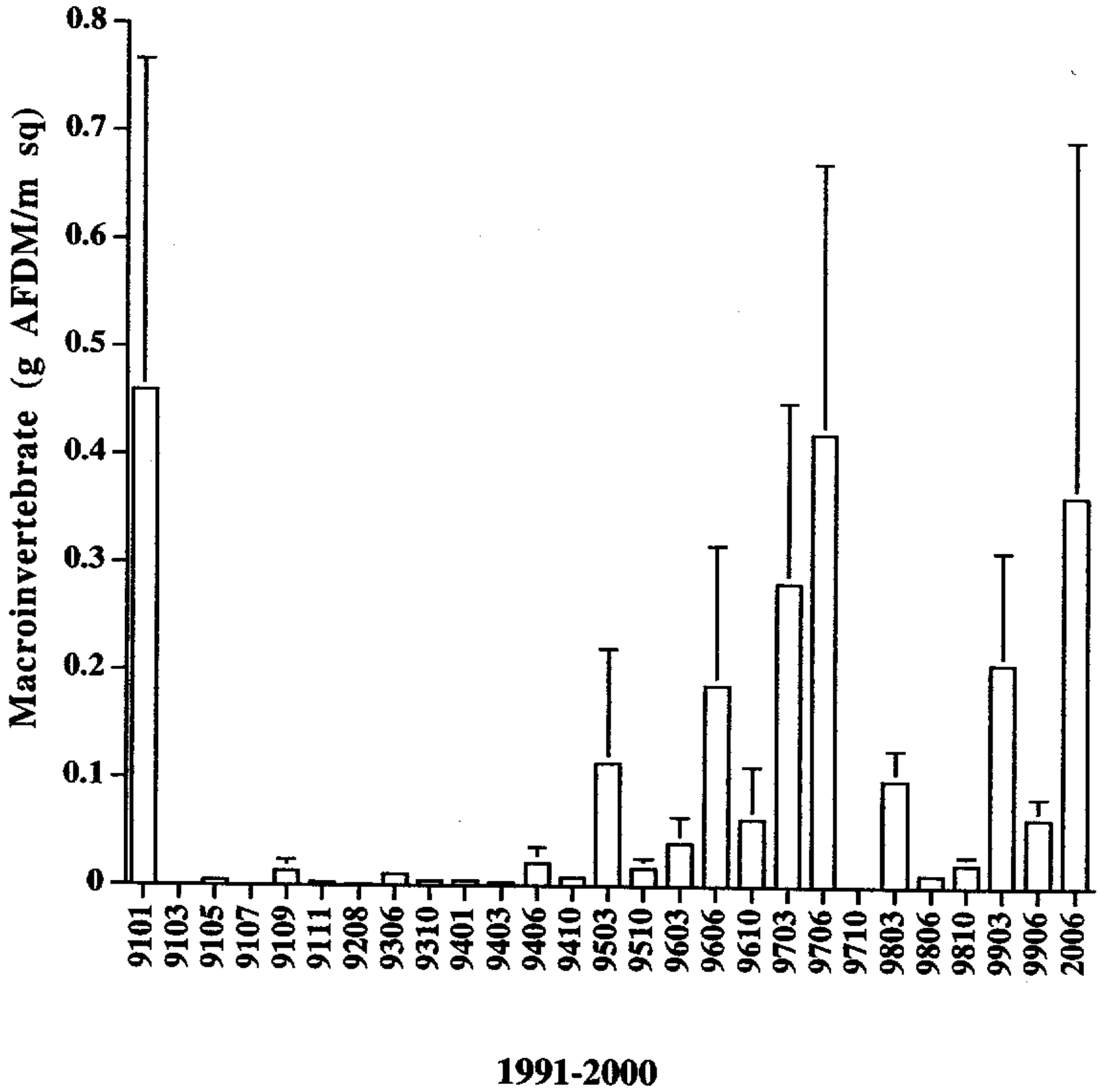

Figure 122. Macroinvertebrate biomass estimates (g AFDM/m sq) at 205 Mile rapid Rkm 328.8 from January 1991 to June 2000. Error bars represent (± 1 SE, n=6).

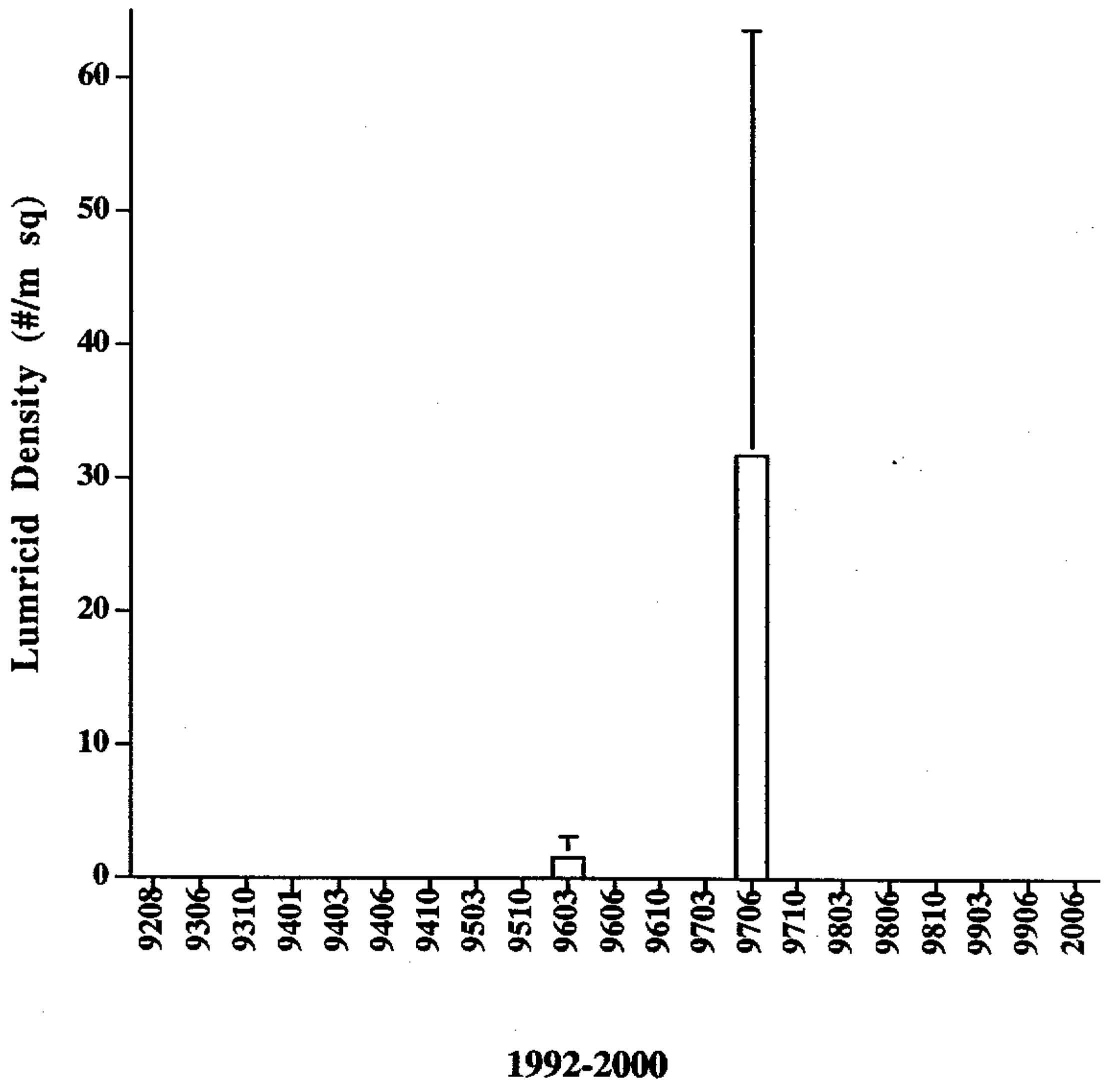

Figure 123. Lumbricid densities (#/m sq) collected at 205 Mile Rapid cobble Rkm 202.9 from August 1992 to June 2000. Error bars represent (± 1 SE, n=6). .

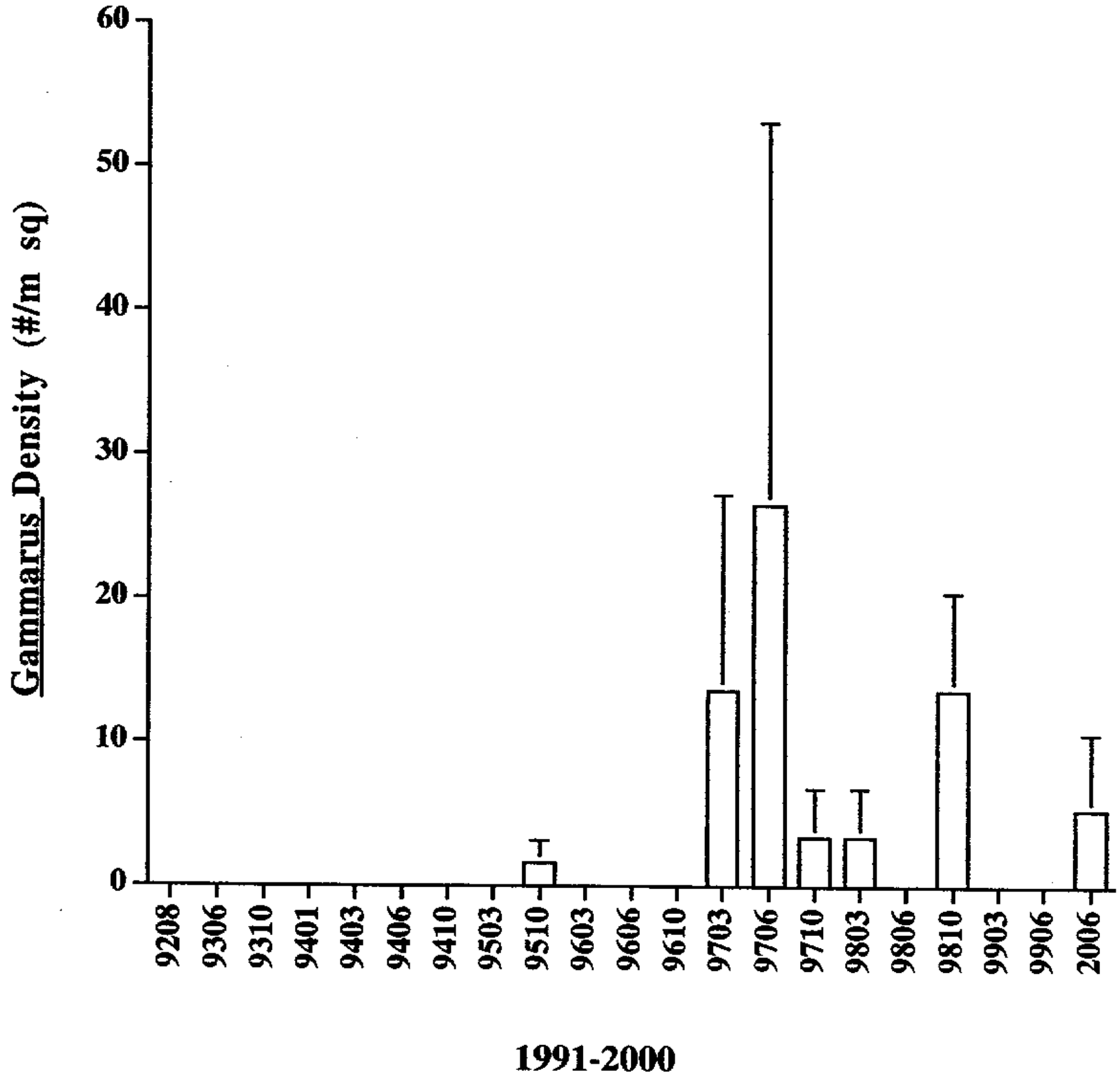

Figure 124. Gammarus densities (#/m sq) collected at 205 Mile Rapid cobble Rkm 202.9 from October 1997 to June 2000. Error bars represent (+ 1 SE, n=6). .

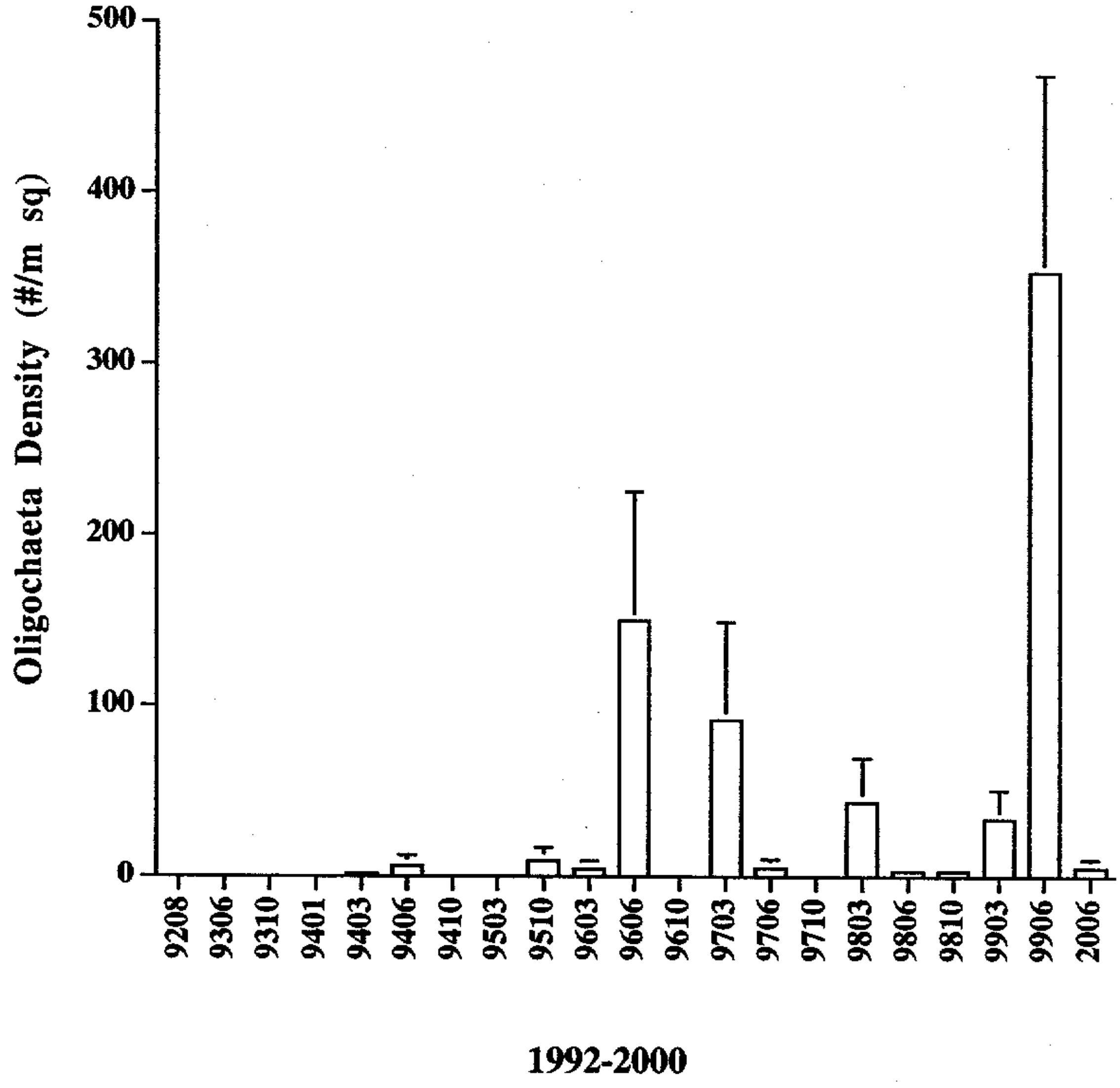

Figure 125. Oligochaeta densities (#/m sq) collected at 205 Mile Rapid cobble Rkm 202.9 from August 1992 to June 2000. Error bars represent (± 1 SE, n=6). .

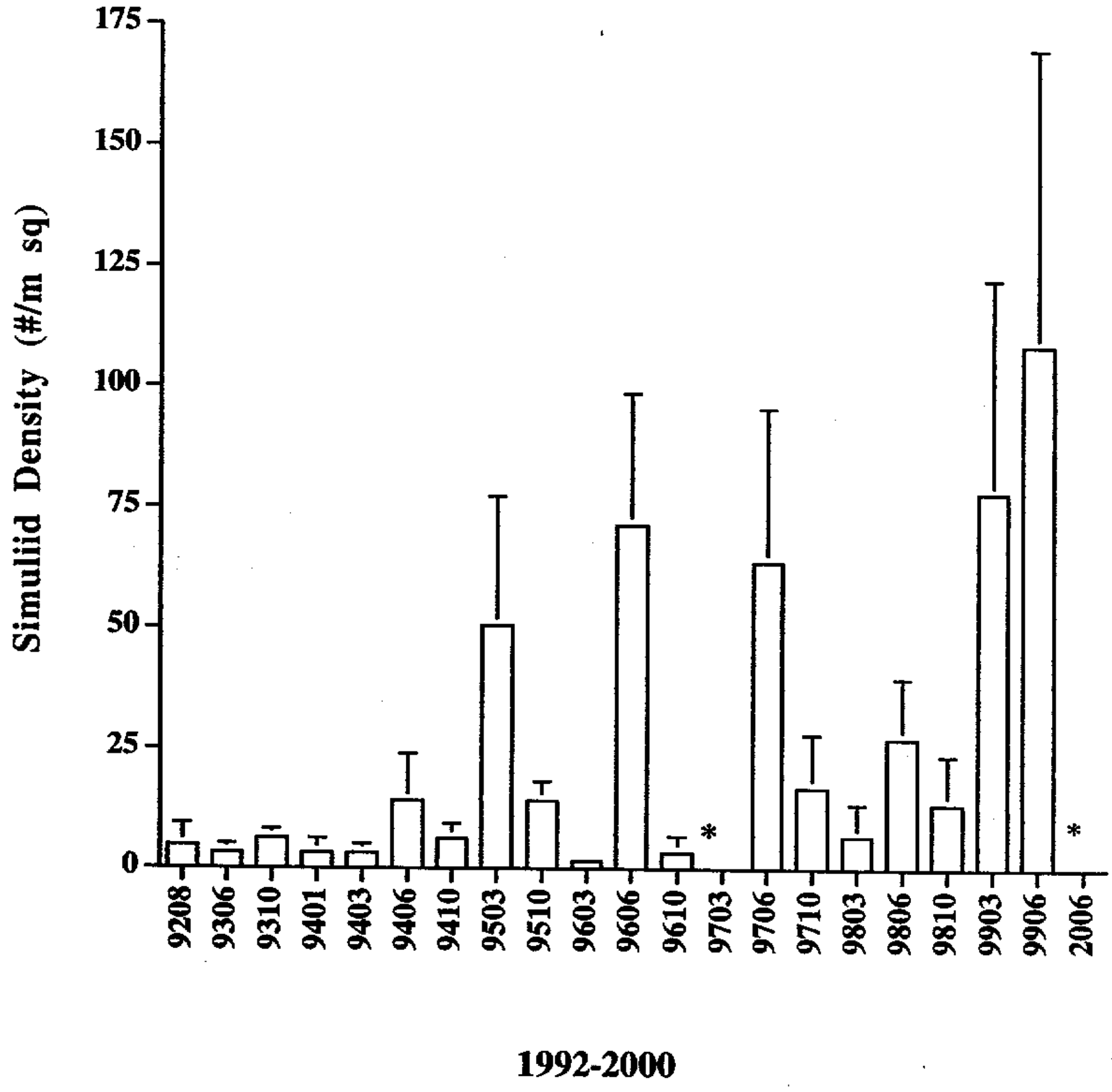

Figure 126. Simuliid densities (#/m sq) collected at 205 Mile Rapid cobble Rkm 202.9 from August 1992 to June 2000. Error bars represent (± 1 SE, n=6). Asterisk (*) represents 350/m sq (± 225 SE) and at 2006 represents 1698/m sq (± 1628 SE).

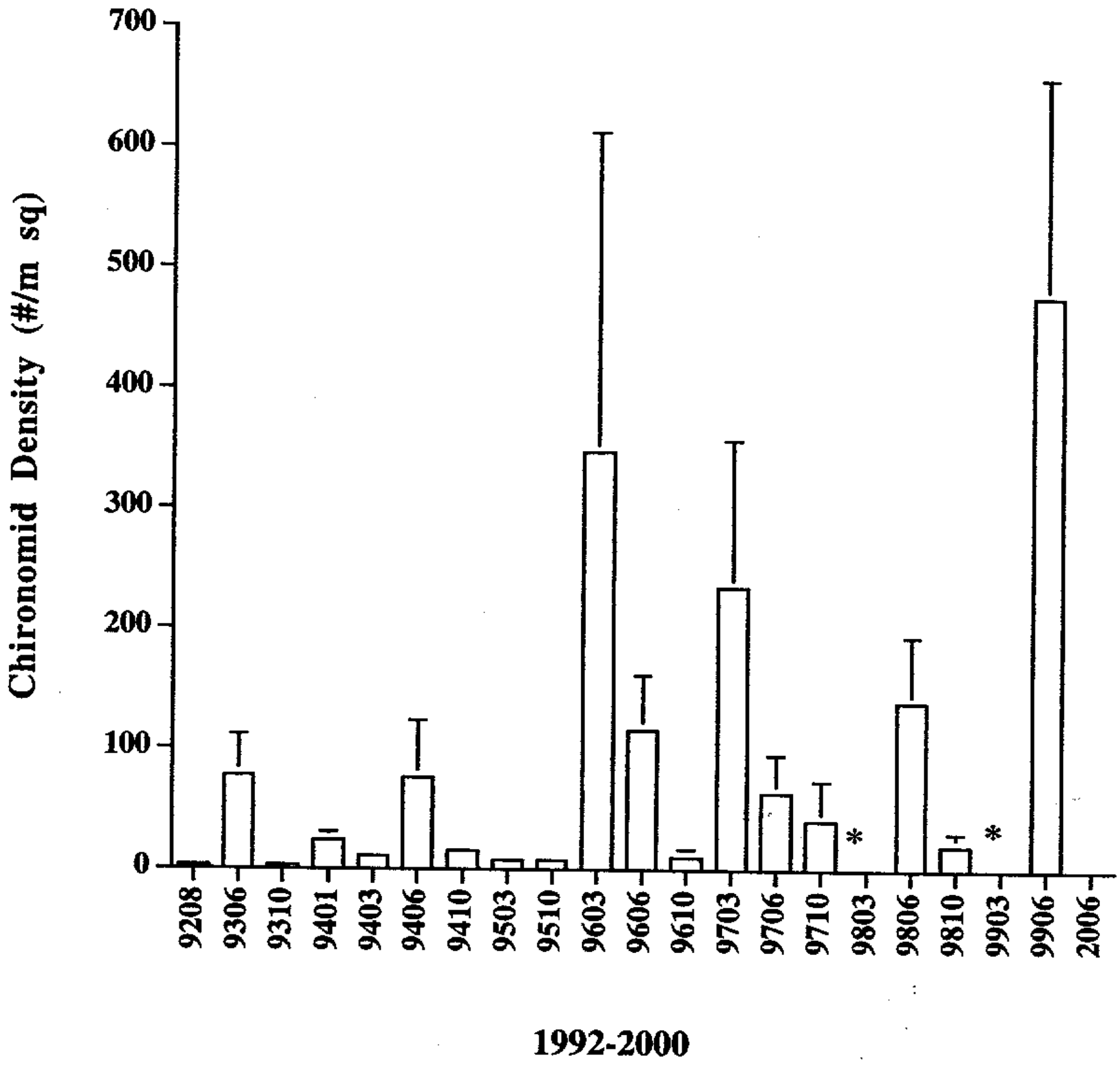

Figure 127. Chirononmid densities (#/m sq) collected at 205 Mile Rapid cobble Rkm 202.9 from August 1992 to June 2000. Error bars represent (± 1 SE, n=6). Asterisk (*) at 9803 represents 15989/m sq (± 855 SE) and at 9903 represents 1098/m sq (± 360 SE).

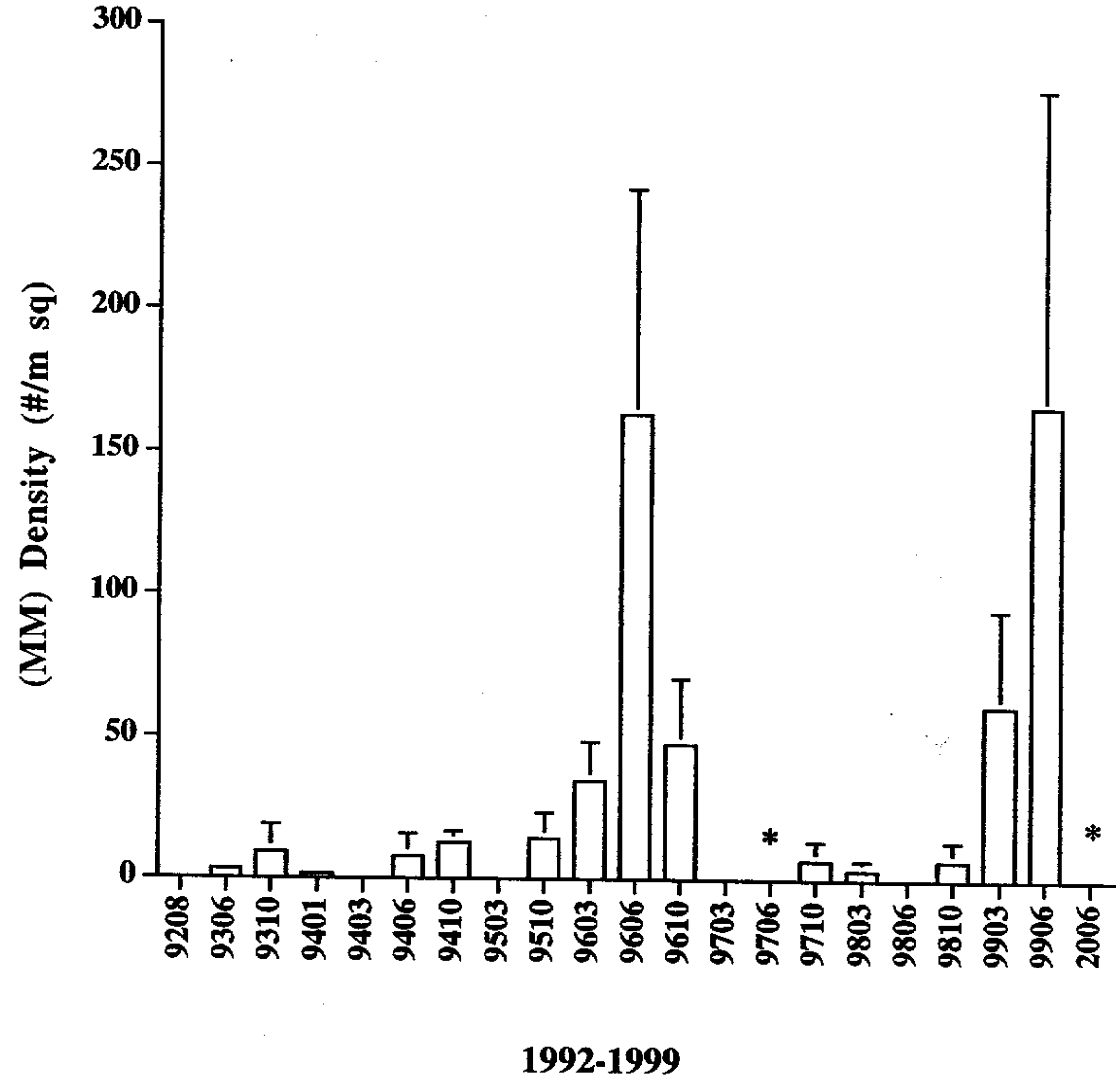

Figure 128. Miscellaneous macroinvertebrate (MM) densities (#/m 2sq) collected at 205 Mile Rapid cobble Rkm 202.9 from October 1997 to June 2000. Error bars represent (± 1 SE, n=6). Asterisk (*) represents 588/m 2sq (± 335 SE) and at 2006 represents 520/m sq (± 221 SE).

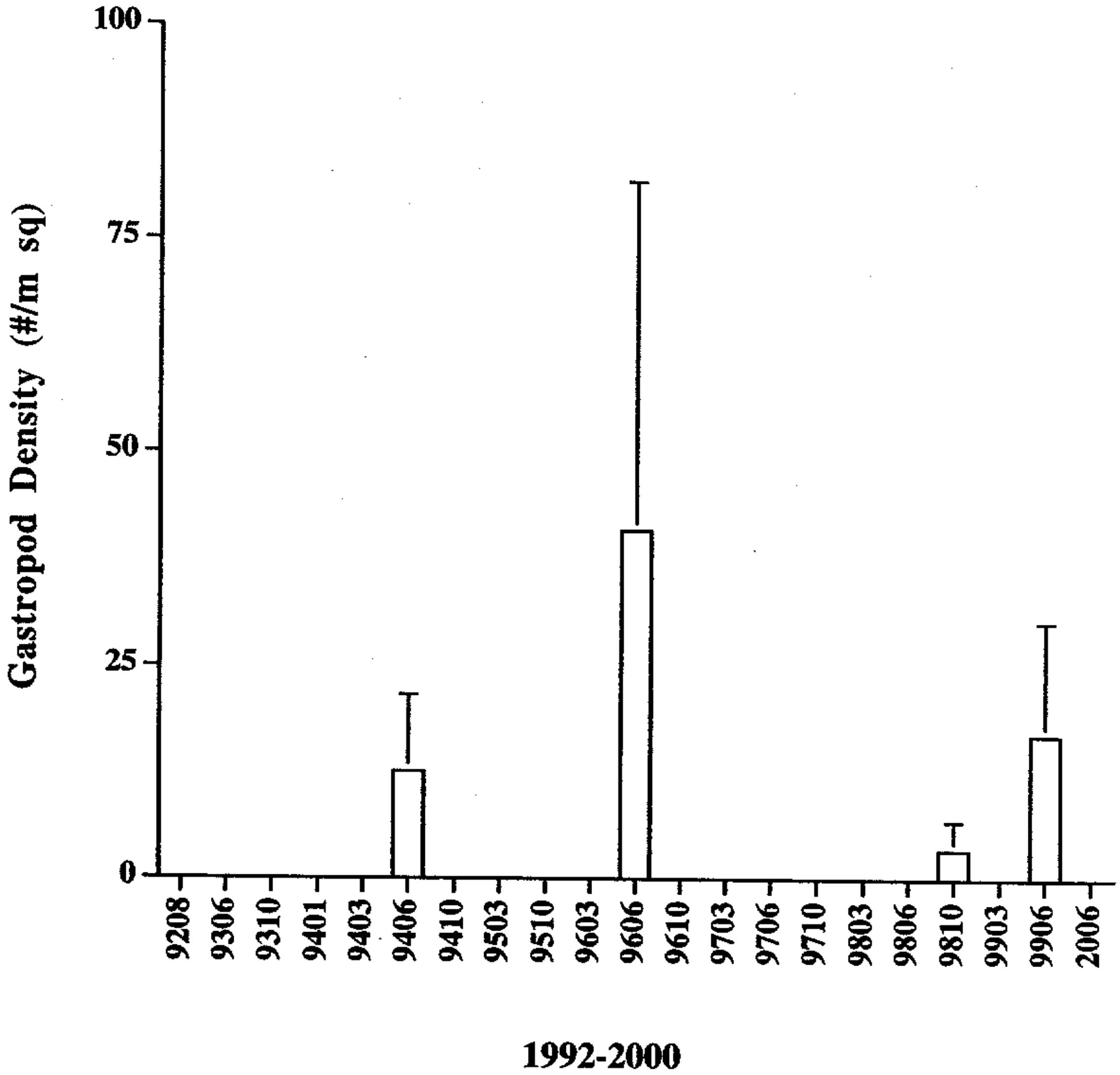

Figure 129. Gastropod densities (#/m sq) collected at 205 Mile Rapid cobble Rkm 202.9 from August 1992 to June 2000. Error bars represent (+ 1 SE, n=6). .

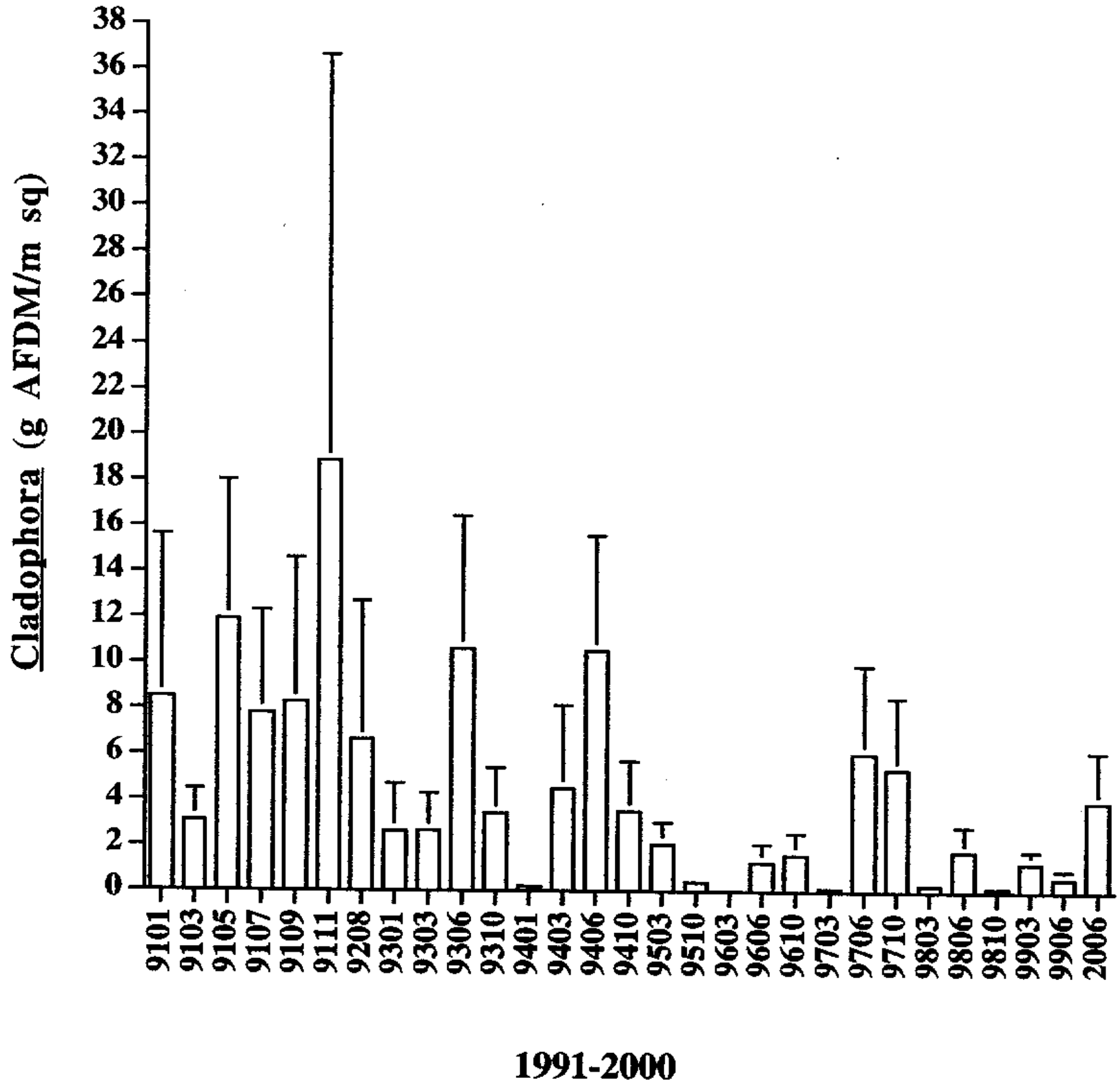

Figure 130. Cladophora biomass estimates (g AFDM/m sq) at Lees Ferry pool Rkm 0.0 from January 1991 to June 2000. Error bars represent ($\pm$ 1 SE, n=12).

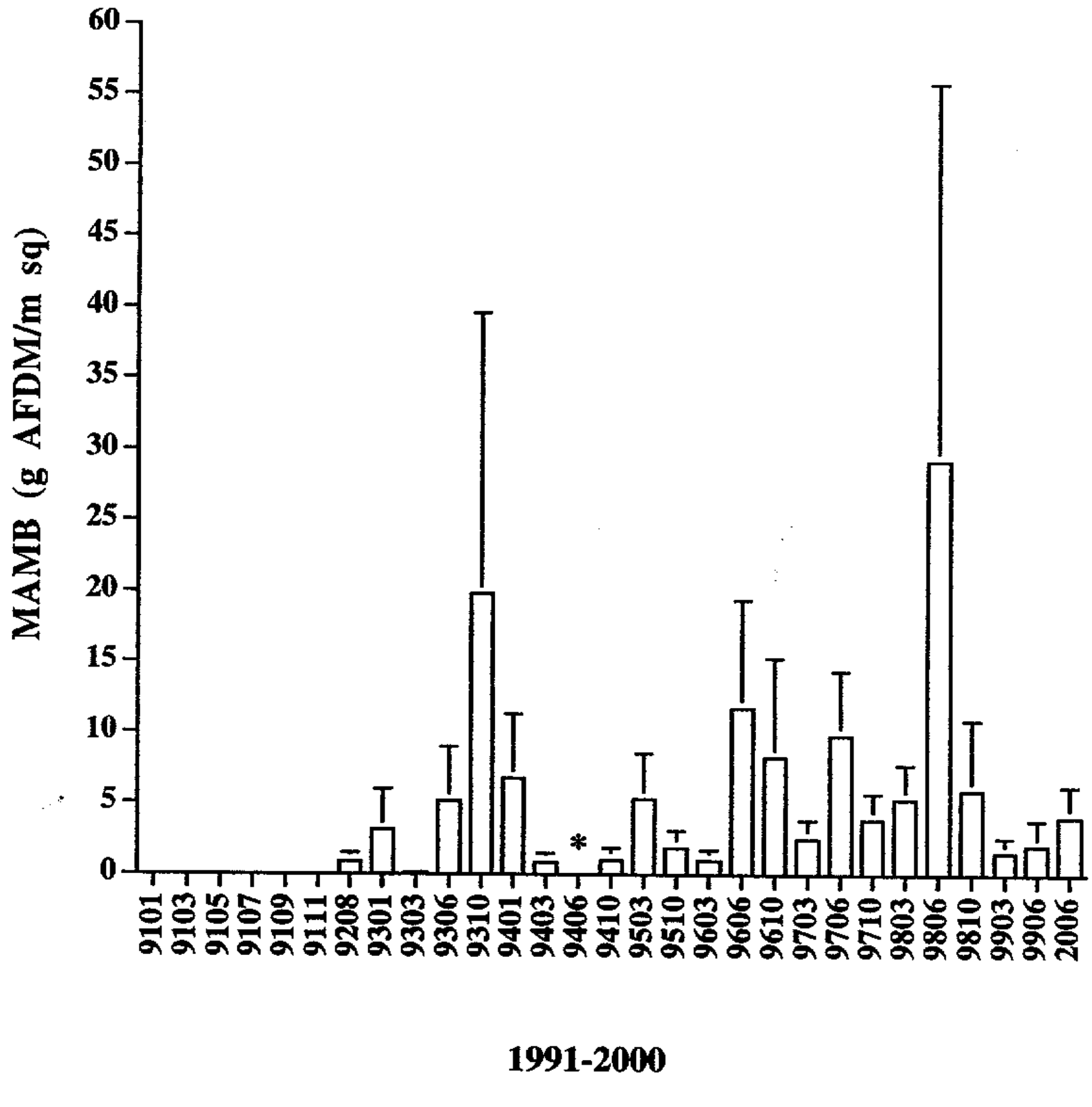

Figure 131. Miscellaneous algae, macrophytes and bryophytes (MAMB) biomass estimates (g AFDM/m sq at Lees Ferry pool Rkm 0.0 from January 1991 to June 2000. MAMB was not collected prior to August 1992. Error bars represent (± 1 SE, n=12). Asterisk (*) represents 50 g AFDM/m sq (± 39 SE).

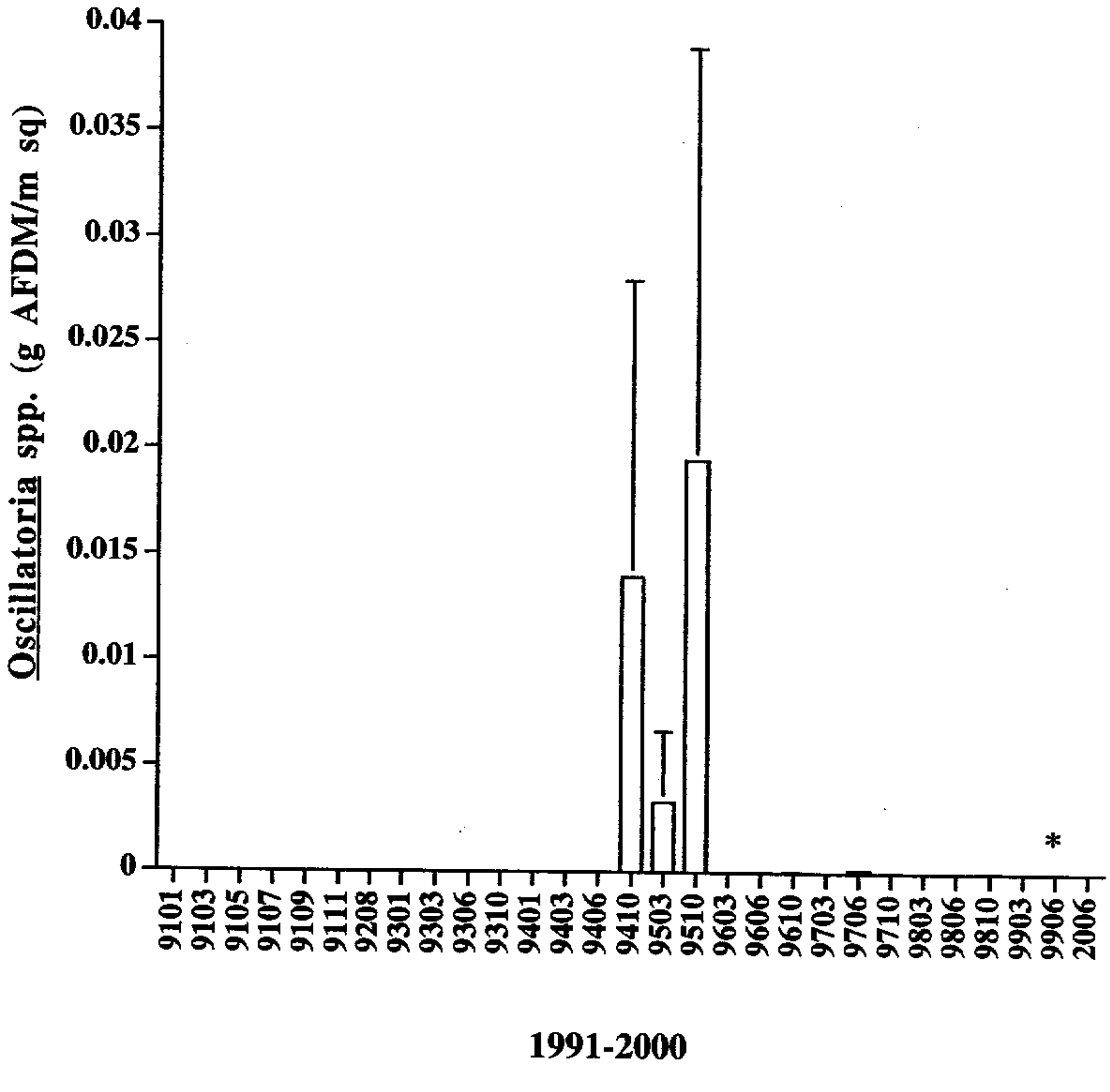

Figure 132. Oscillatoria spp. biomass estimates (g AFDM/m sq) at Lees Ferry pool Rkm 0.0 from January 1991 to June 2000. Error bars represent (± 1 SE, n=12). Asterisk (*) represents 0.73 g AFDM/m sq (± 0.73 SE).

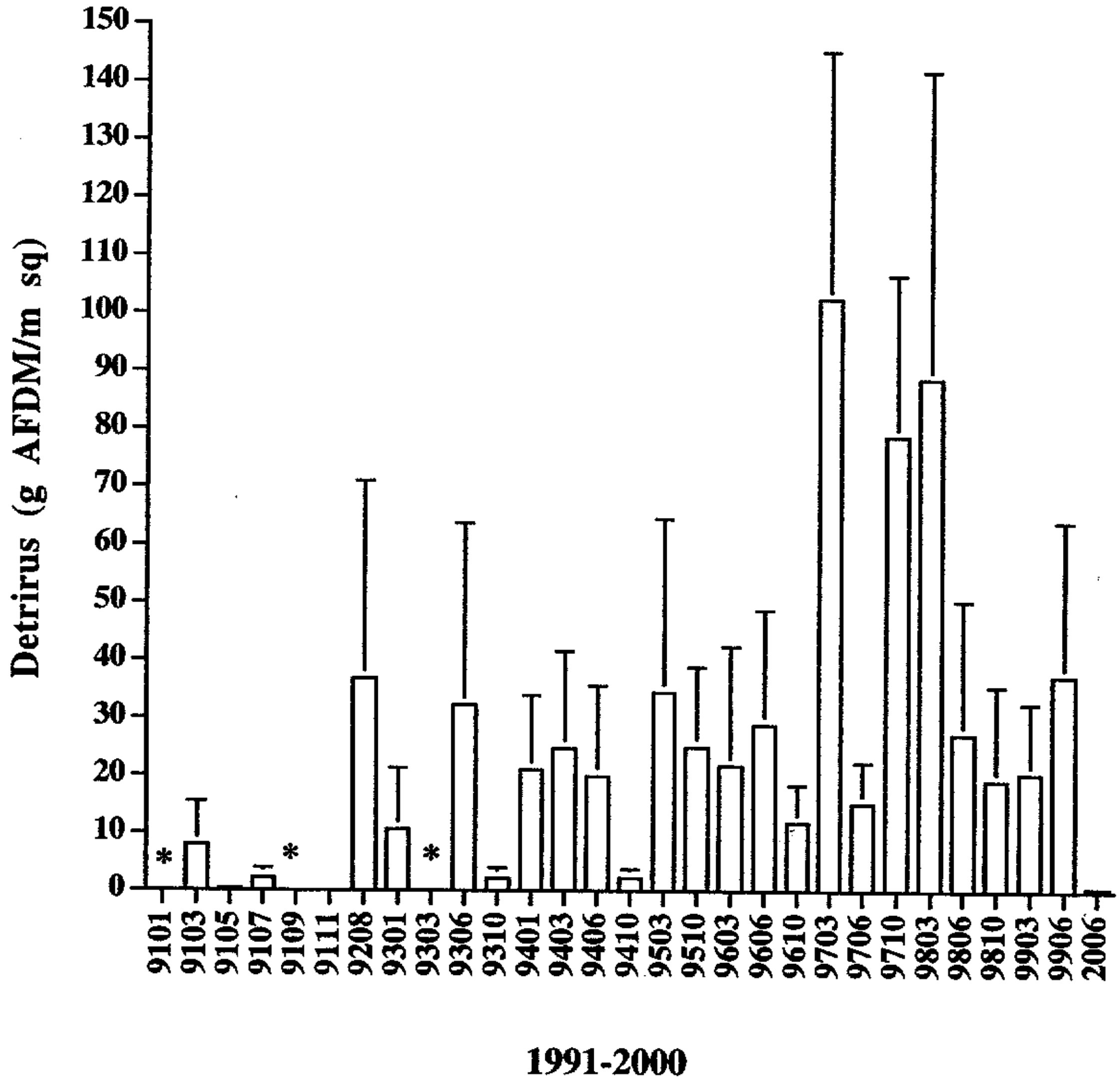

Figure 133. Detritus biomass estimates (g AFDM•m) at Lees Ferry pool Rkm 0.0 from January 1991 to June 2000. Error bars represent (± 1 SE, n=12). Asterisk (*) at 9101 represents 1143 g AFDM/m sq (± 1143 SE), at 9109 represents 523 g AFDM/m sq (± 521 SE) and at 9303 represents 213 g AFDM/m sq (± 175 SE).

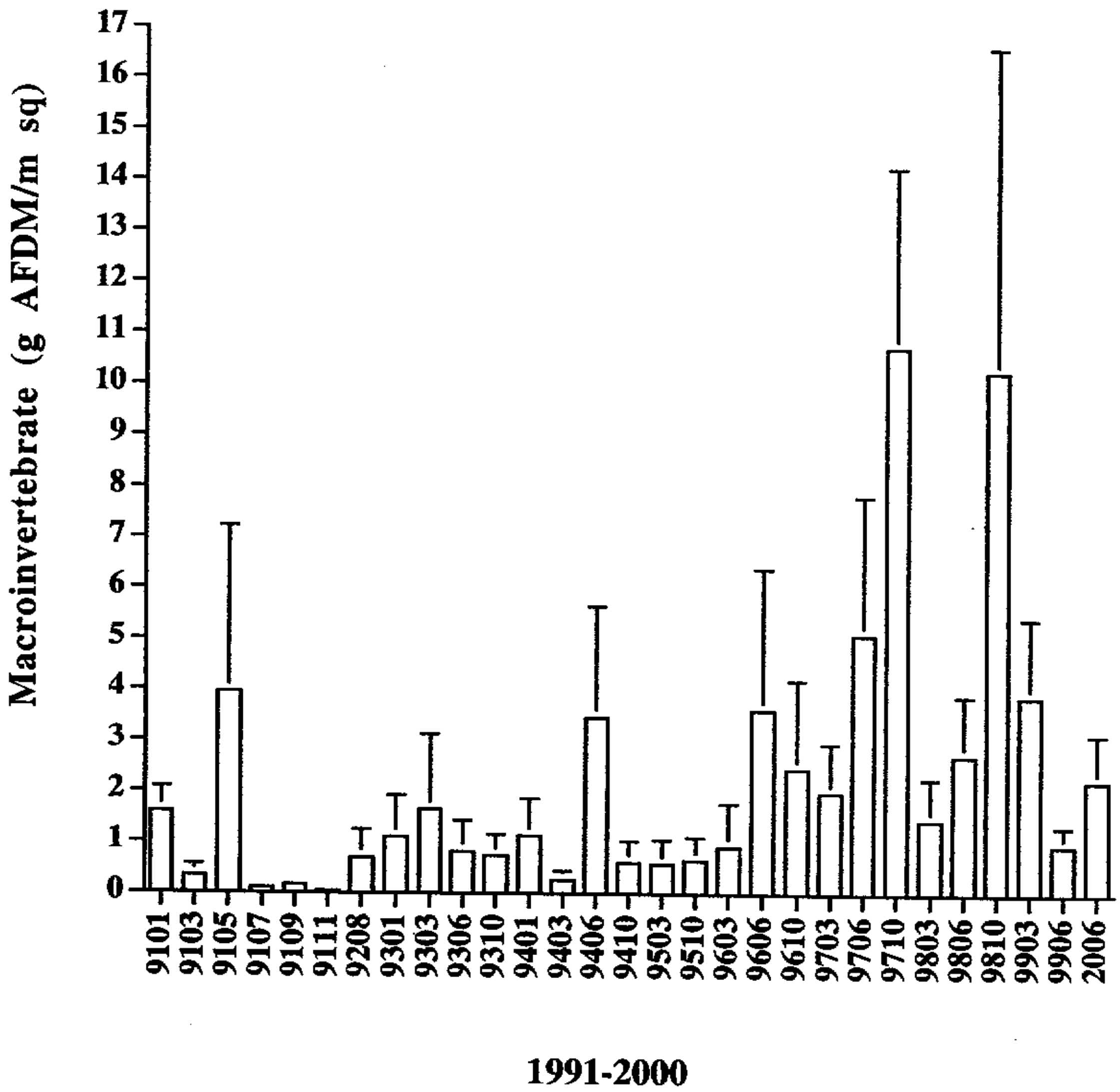

Figure 134. Macroinvertebrate biomass estimates (g AFDM/m sq) at Lees Ferry pool Rkm 0.0 from January 1991 to June 1999. Error bars represent (± 1 SE, n=12).

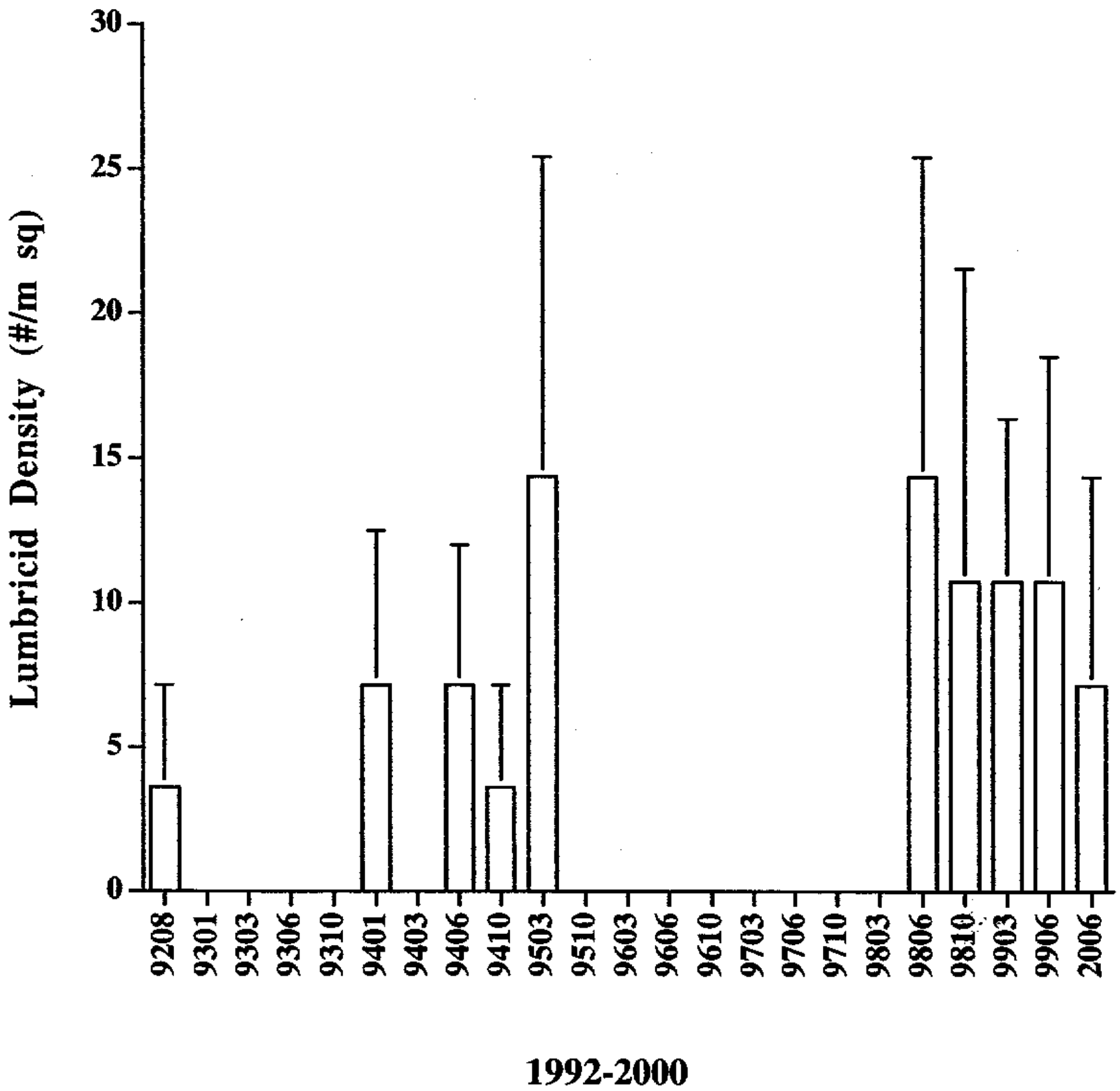

Figure 135. Lumbricid densities (#/m sq) collected at Lees Ferry pool Rkm 0.0 from August 1992 to June 2000. Error bars represent (± 1 SE, n=12).

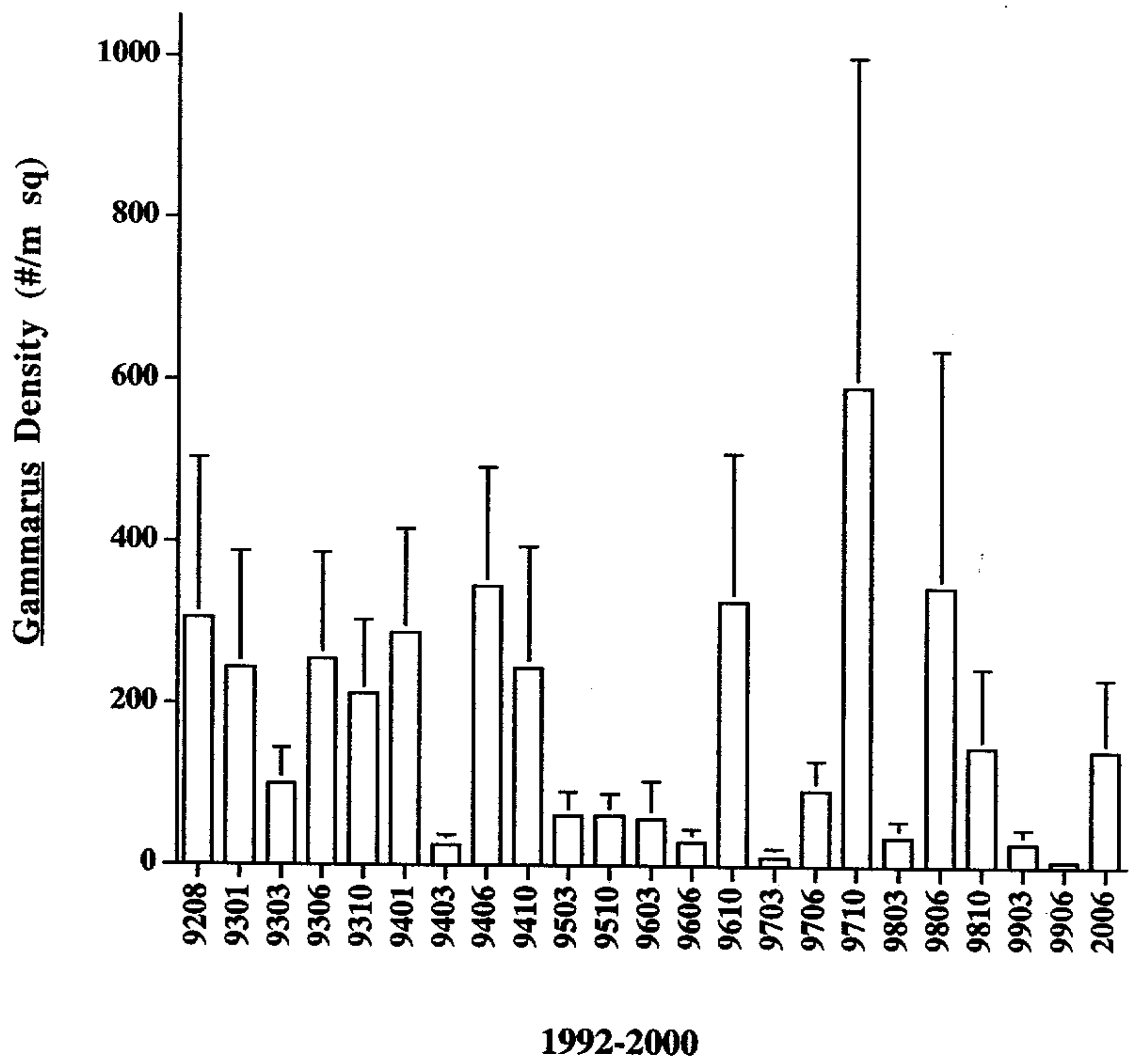

Figure 136. Gammarus densities (#/m sq) collected at Lees Ferry pool Rkm 0.0 from August 1992 to June 2000. Error bars represent (± 1 SE, n=12).

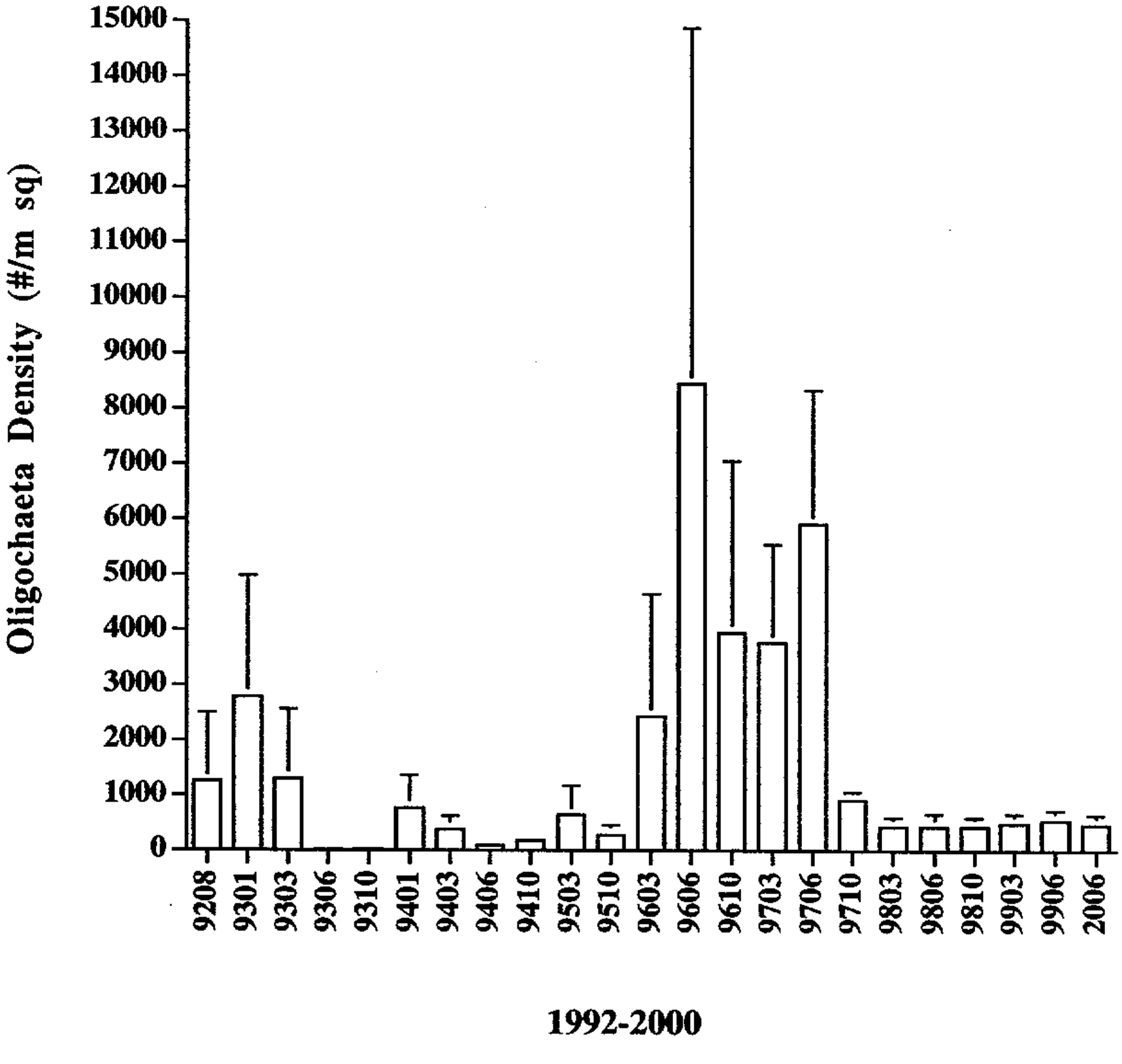

Figure 137. Oligochaeta densities (#/m sq) collected at Lees Ferry pool Rkm 0.0 from August 1992 to June 2000. Error bars represent (± 1 SE, n=12).

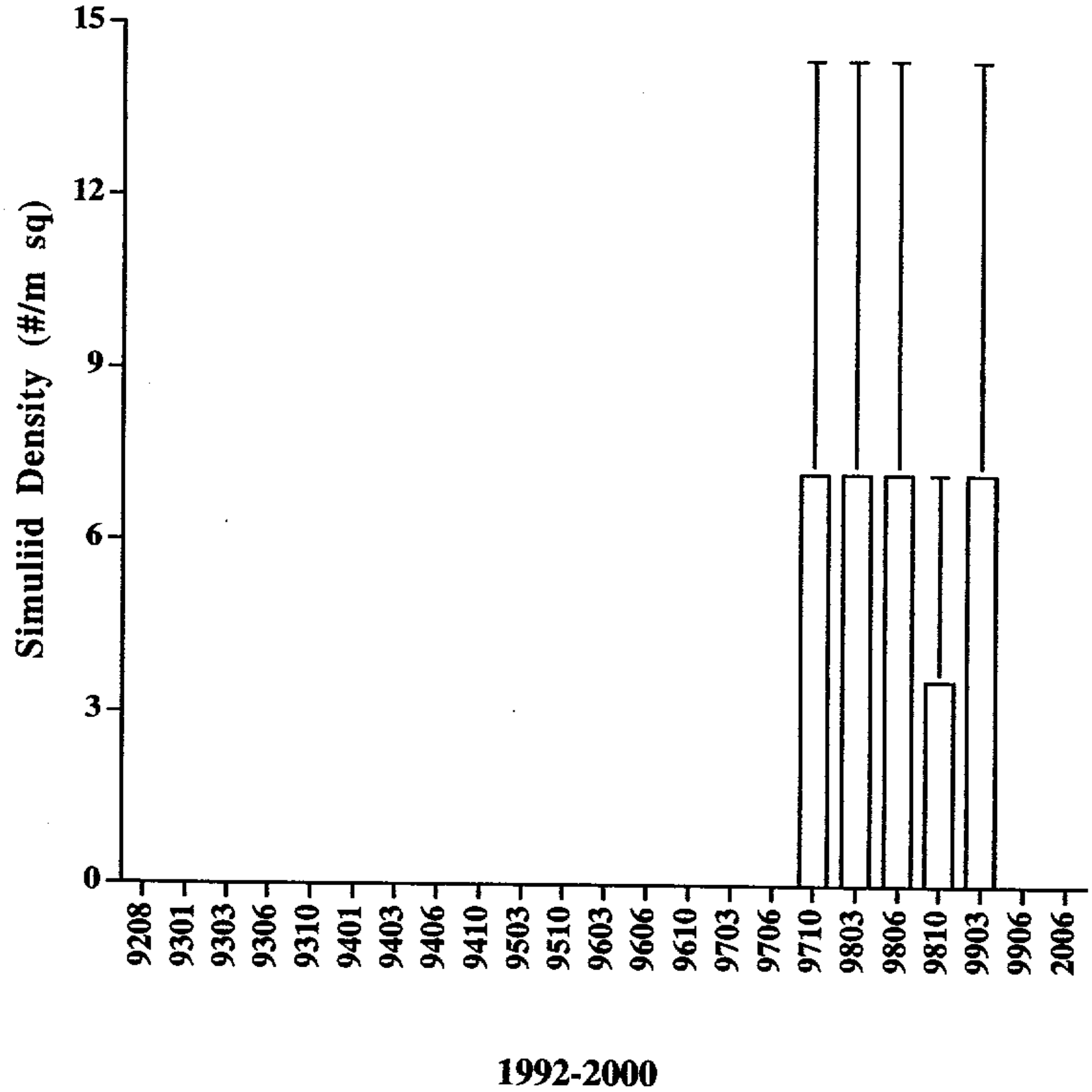

Figure 138. Simuliid densities (#/m sq) collected at Lees Ferry pool Rkm 0.0 from August 1992 to June 2000. Error bars represent (± 1 SE, n=12).

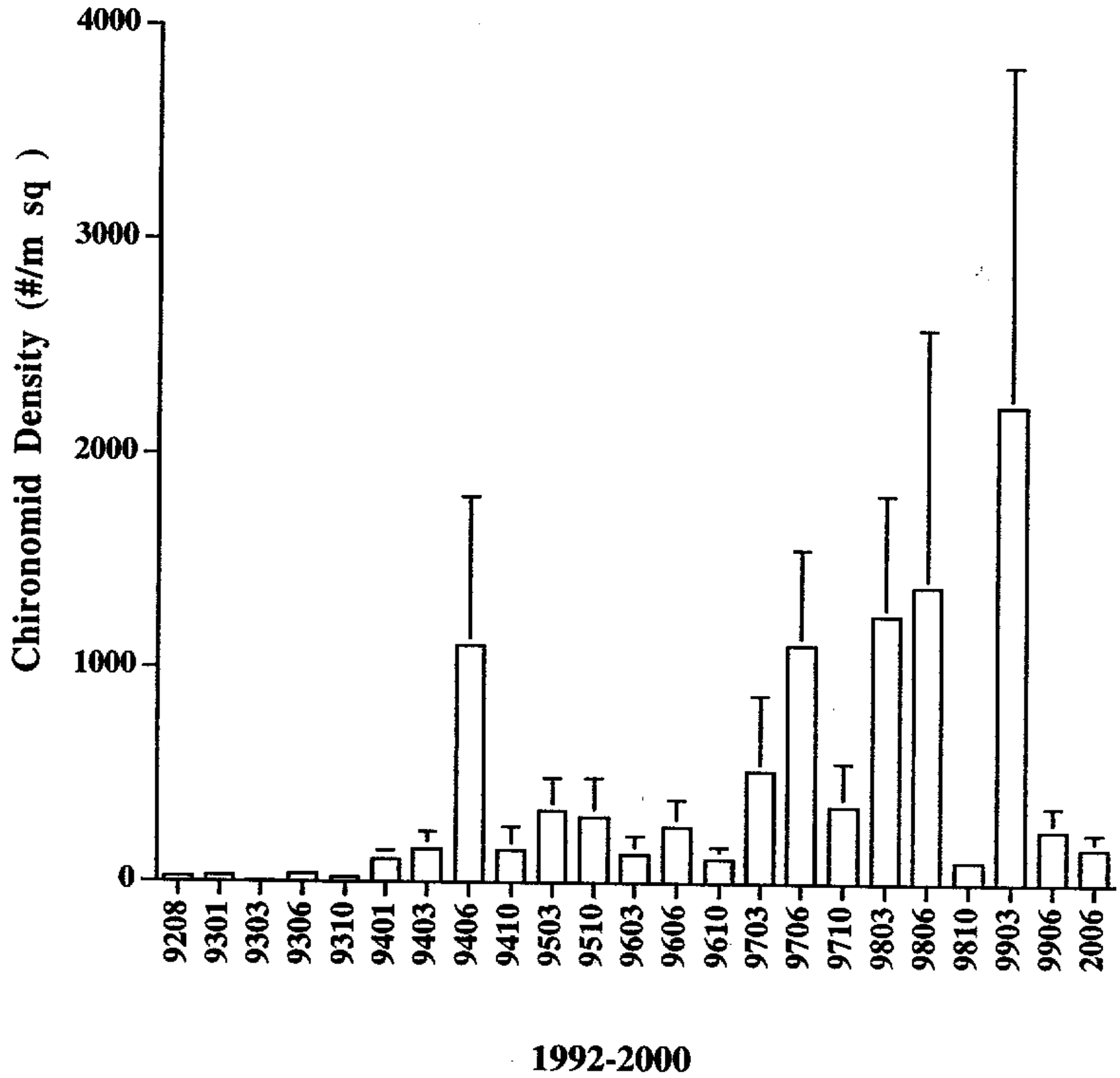

Figure 139. Chironomid densities (#/m sq) collected at Lees Ferry pool Rkm 0.0 from August 1992 to June 2000. Error bars represent (± 1 SE, n=12).

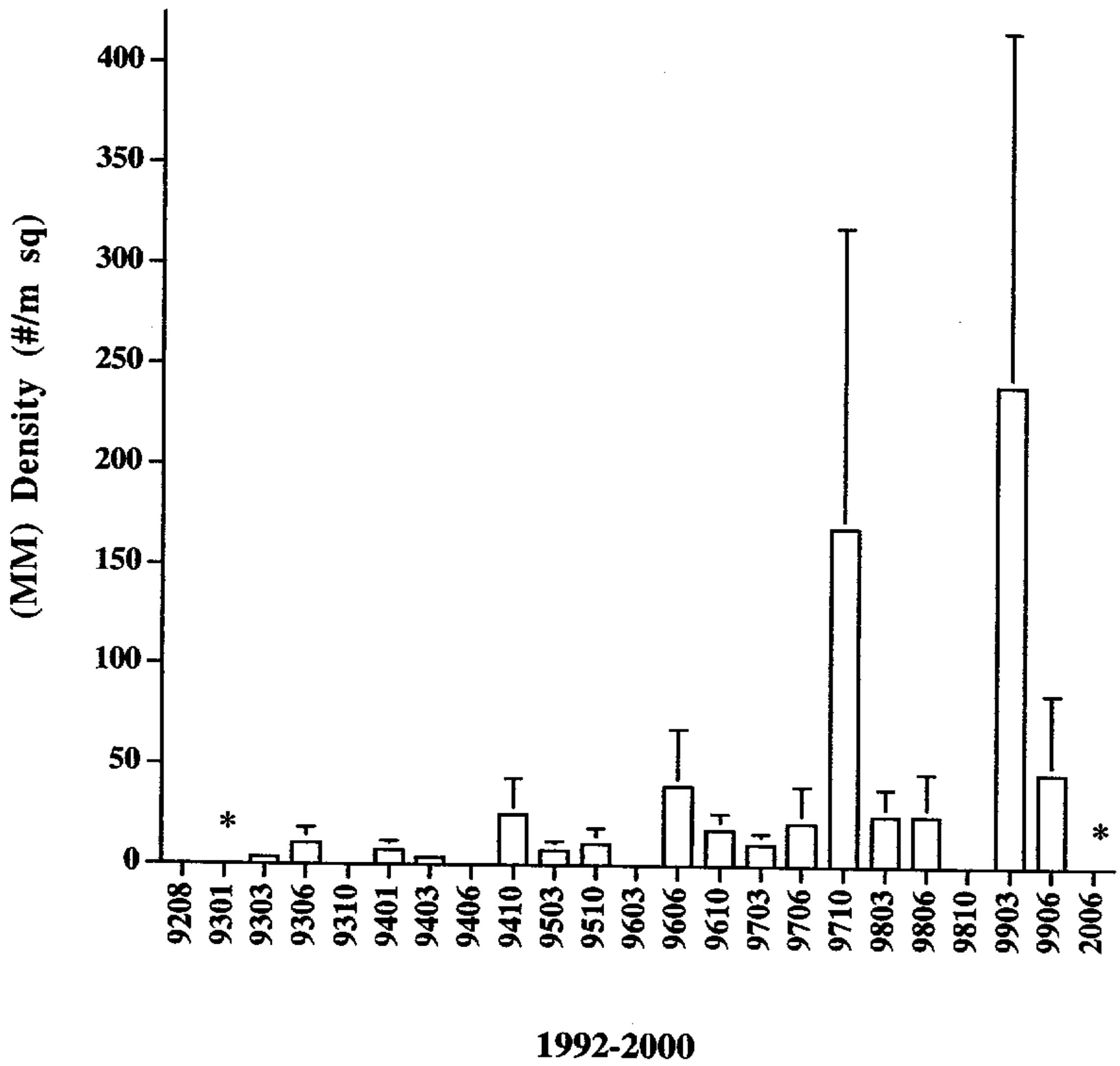

Figure 140. Miscellaneous macroinvertebrate (MM) densities (#/m sq) collected at Lees Ferry pool Rkm 0.0 from August 1992 to June 2000. Error bars represent (± 1 SE, n=12). Asterisk at 9103 (*) represents 581/m sq (± 574 SE) and at 2006 represents 427/m sq (± 218 SE).

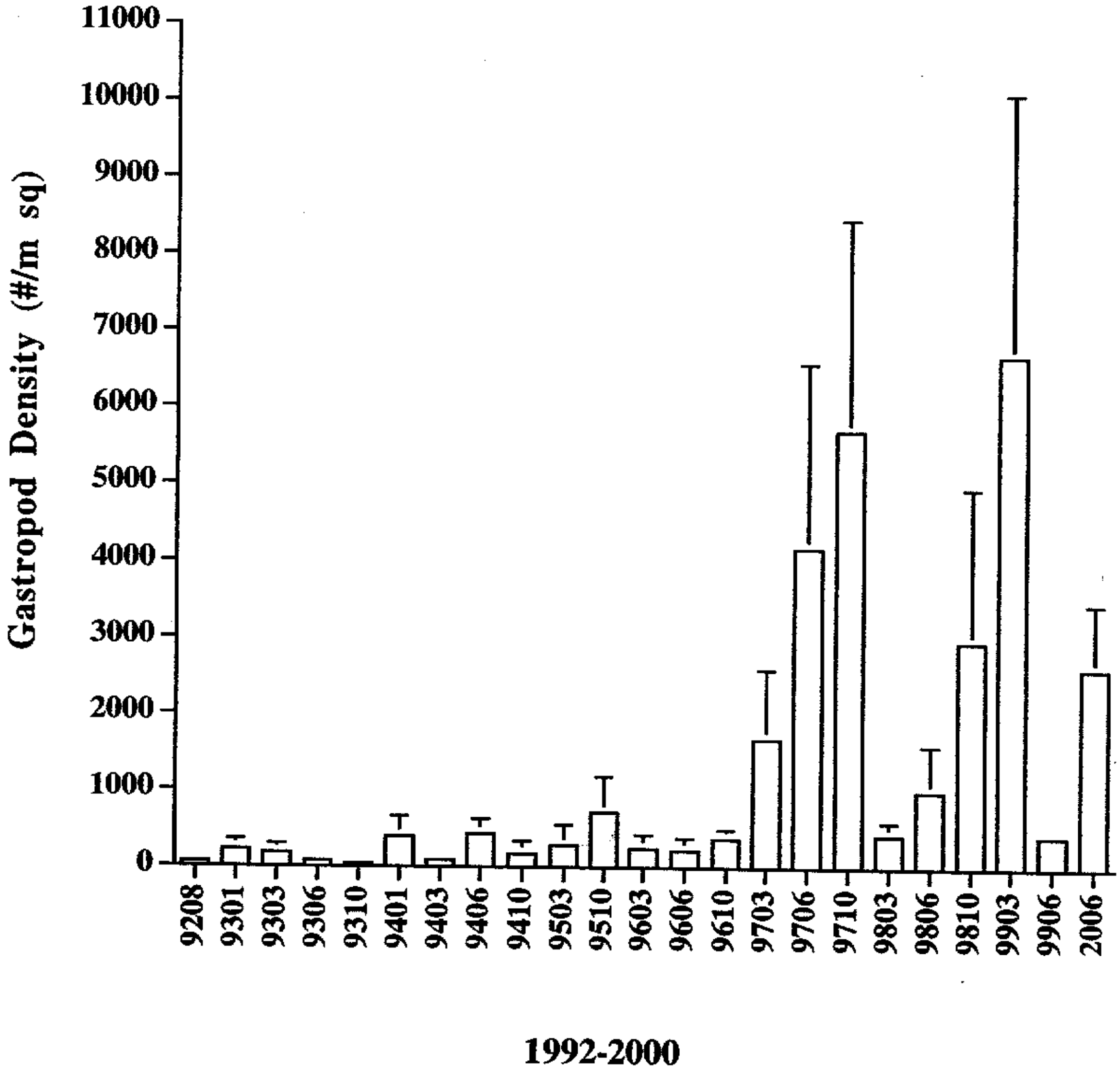

Figure 141. Gastropod densities (#/m sq) collected at Lees Ferry pool Rkm 0.0 from August 1992 to June 2000. Error bars represent (± 1 SE, n=12).

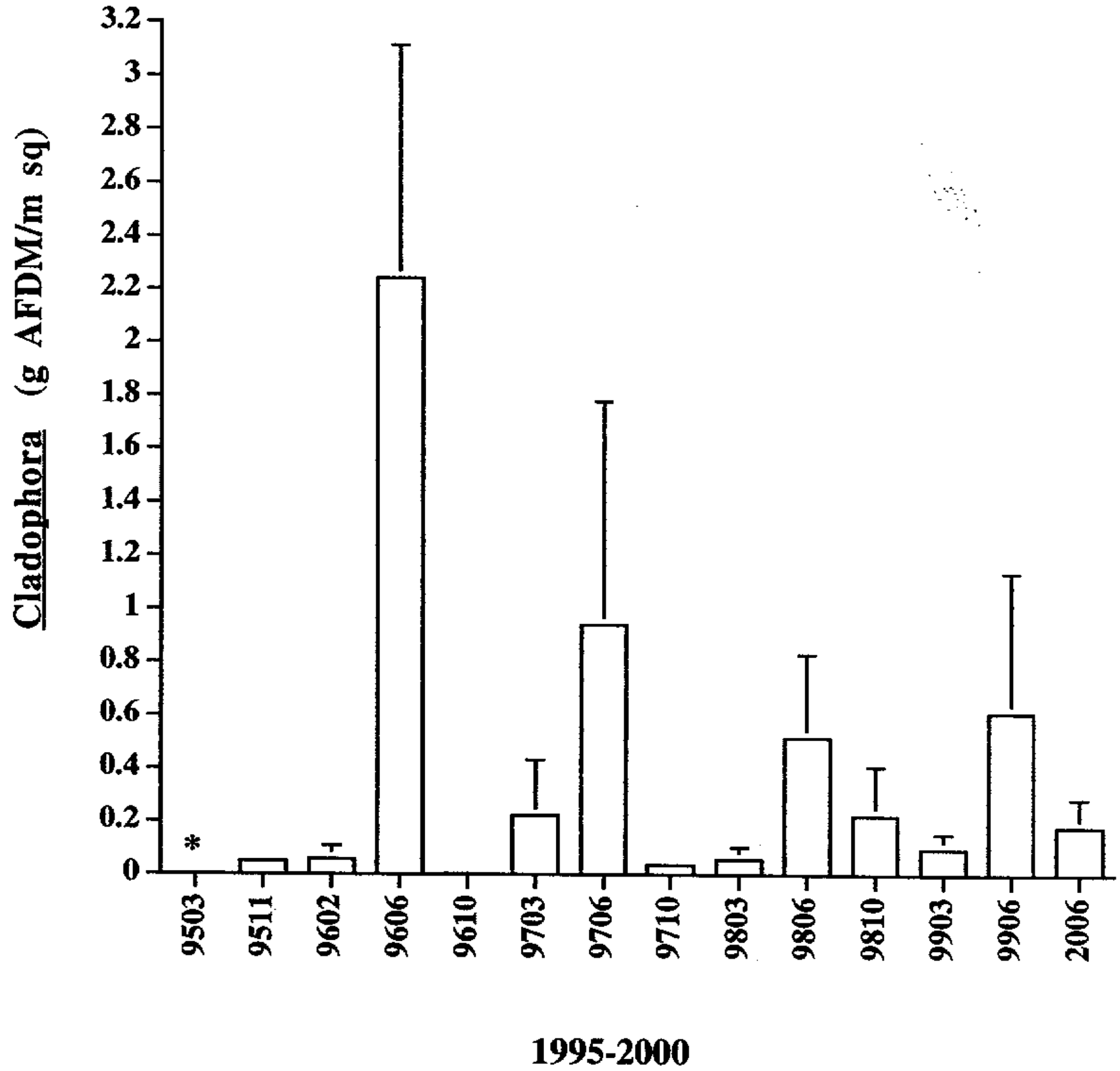

Figure 142. Cladophora biomass estimates (g AFDM/m sq) at Two-Mile pool Rkm 3.1 from March 1995 to June 2000. Error bars represent (± 1 SE, n=12). Asterisk (*) represents 22 g AFDM/m sq (± 22 SE).

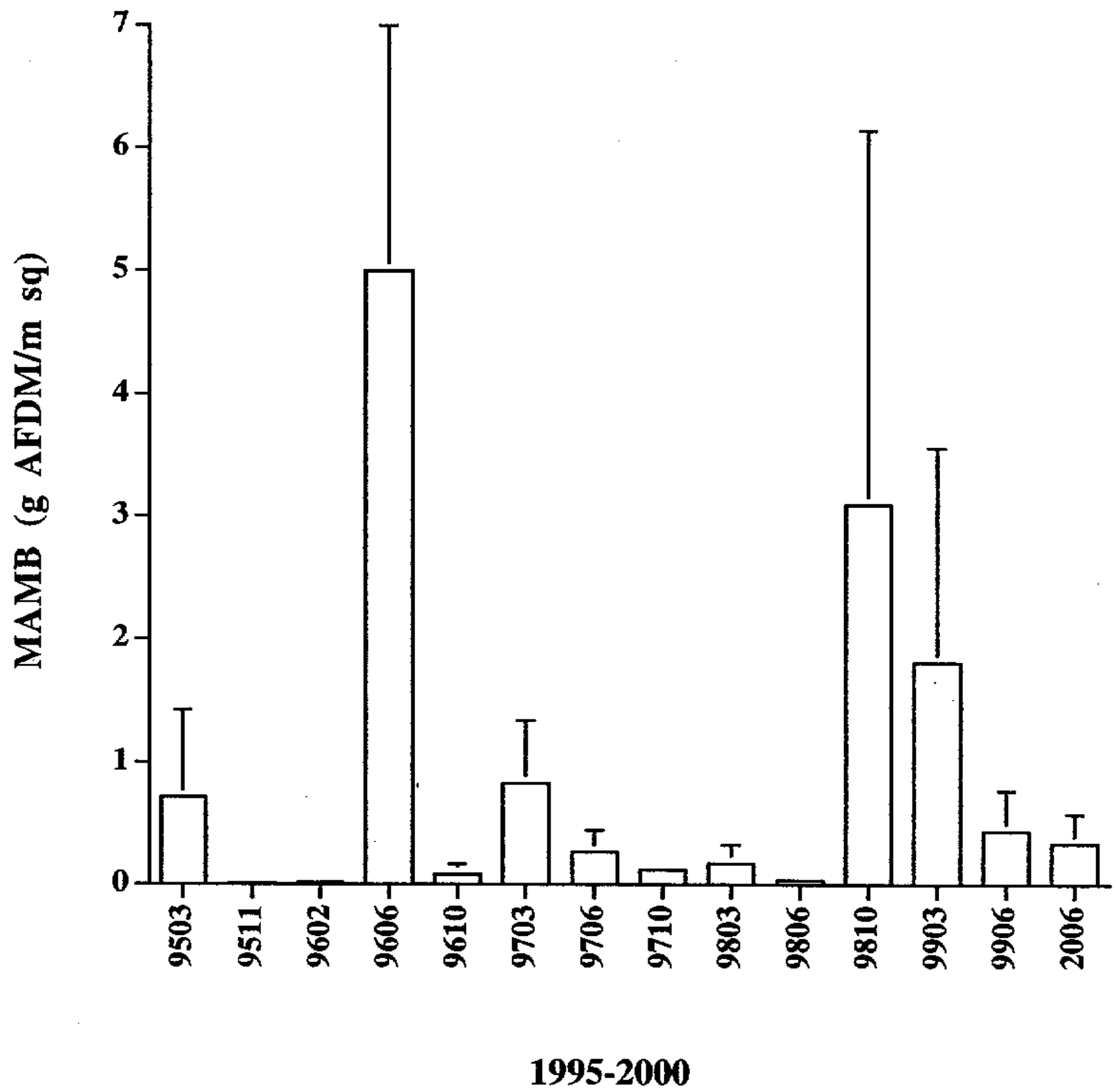

Figure 143. Miscellaneous algae, macrophytes and bryophytes (MAMB) biomass estimates (g AFDM/m sq) at Two-Mile pool Rkm 3.1 from March 1995 to June 2000. MAMB was not collected prior to August 1992. Error bars represent ($\pm$ 1 SE, n=12).

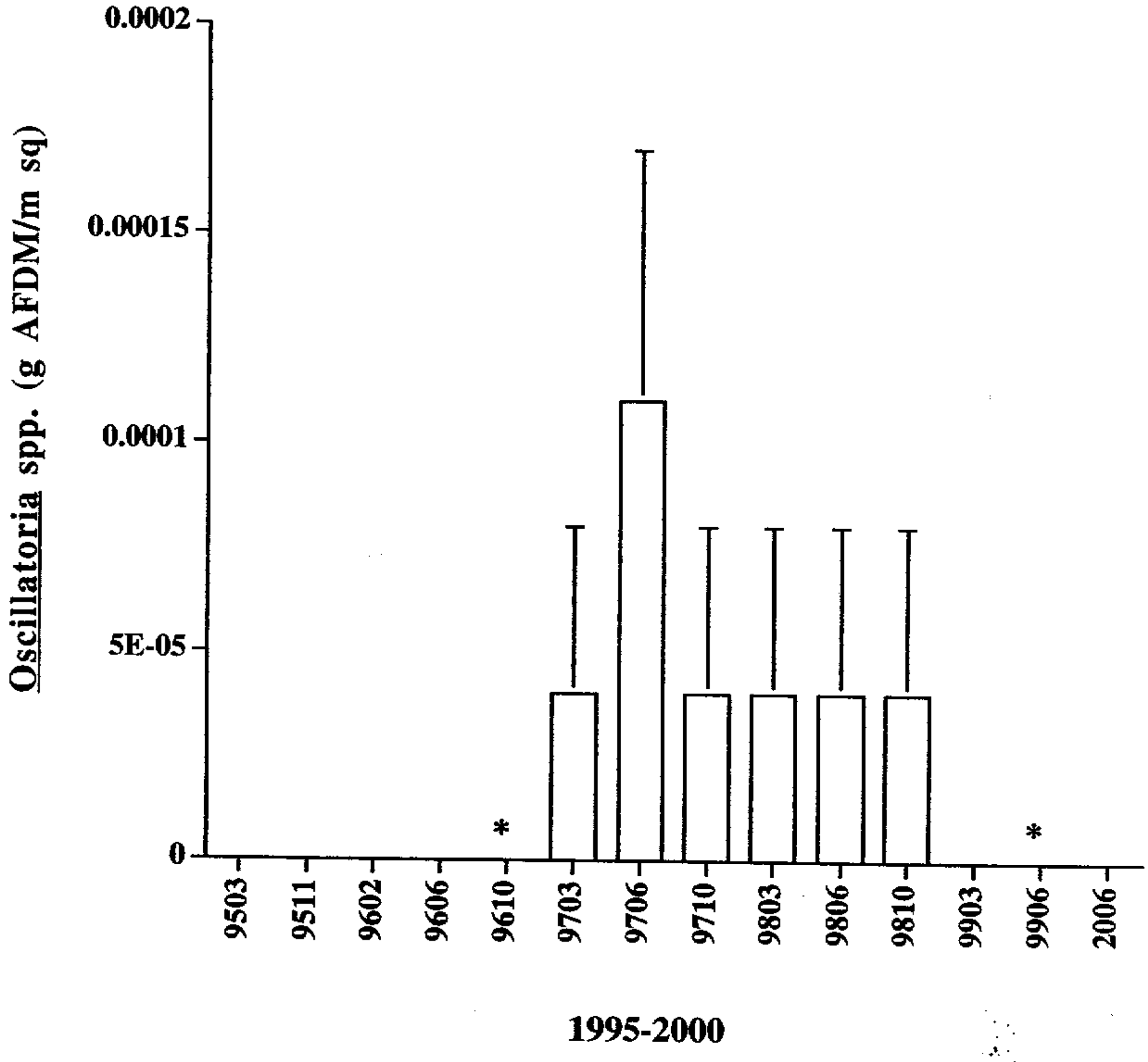

Figure 144. Oscillatoria spp. biomass estimates (g AFDM/m sq) at Two-Mile pool Rkm 3.1 from March 1995 to June 1999. Error bars represent (± 1 SE, n=12). Asterisk (*) at 9610 represents 13 g AFDM/m sq (± 11.5 SE) and at 9903 represents 0.65 g AFDM/m sq (± 0.65 SE).

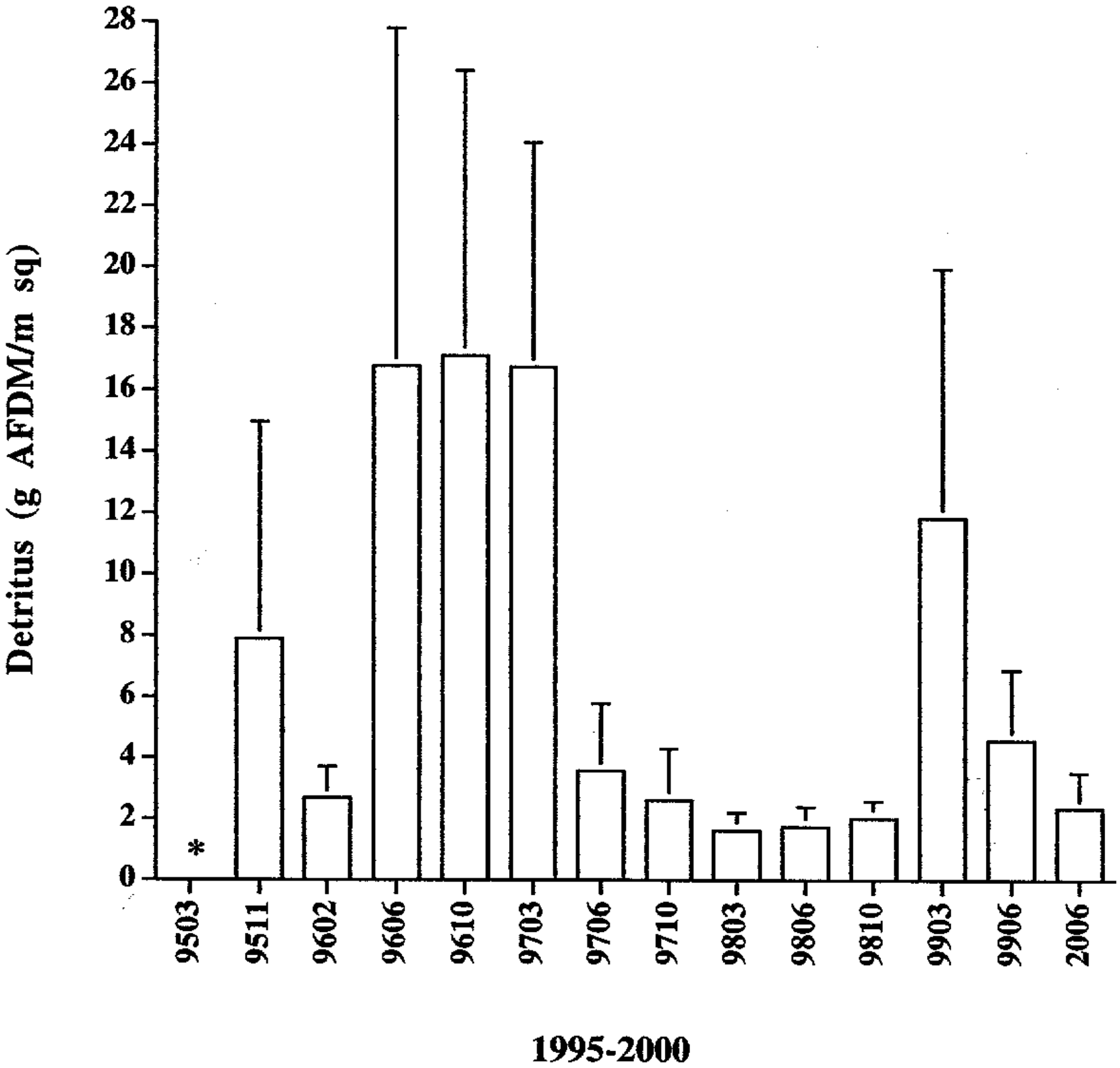

Figure 145. Detritus biomass estimates (g AFDM/m sq) at Two-Mile pool Rkm 3.1 from March 1995 to June 2000. Error bars represent (± 1 SE, n=12). Asterisk (*) represents 822 g AFDM/m sq (± 821 SE).

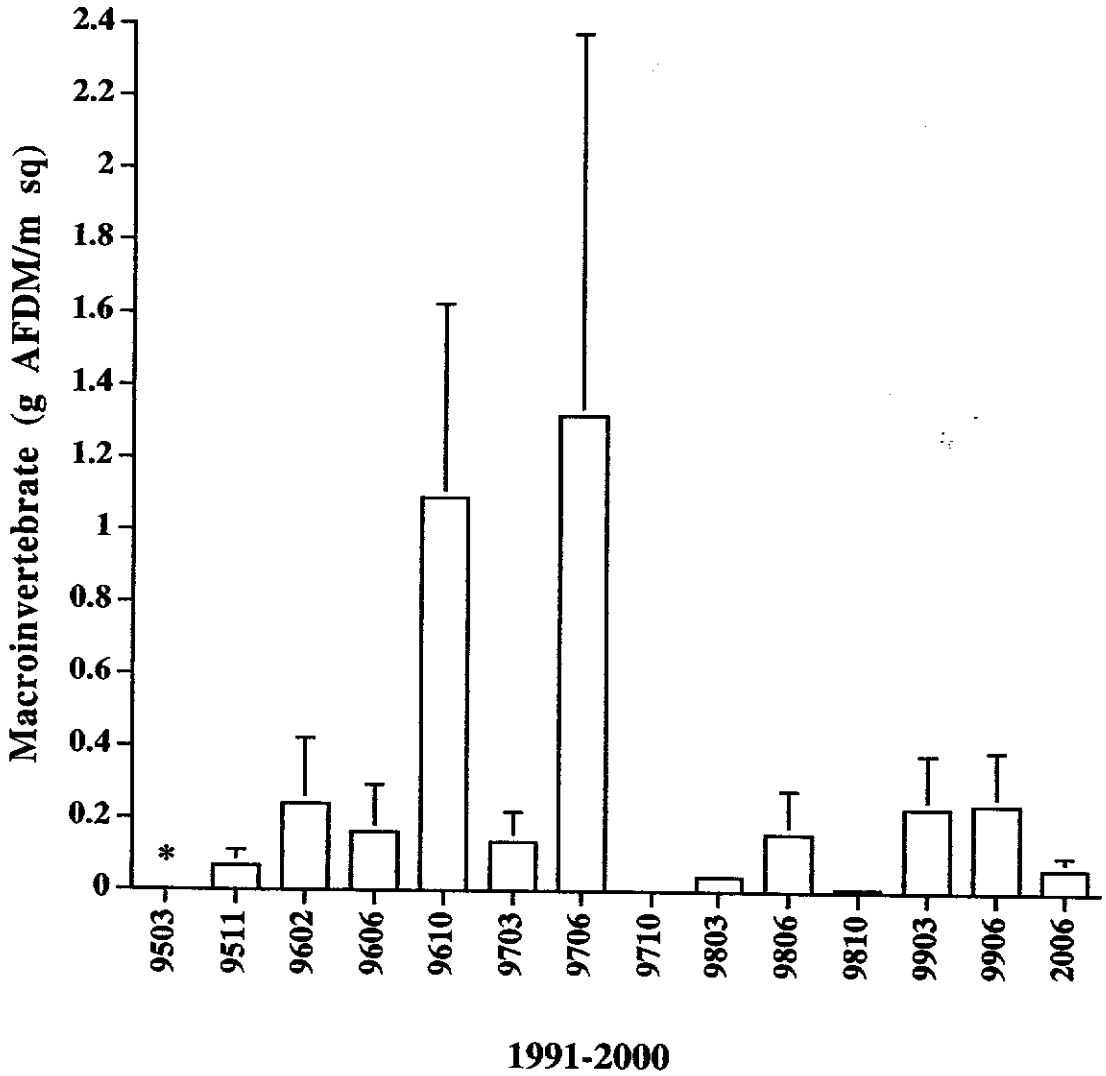

Figure 146. Macroinvertebrate biomass estimates (g AFDM/m sq) at Two-Mile pool Rkm 3.1 from January 1991 to June 2000. Error bars represent (± 1 SE, n=6). Asterisk (*) represents 2 g AFDM/m sq (± 2 SE).

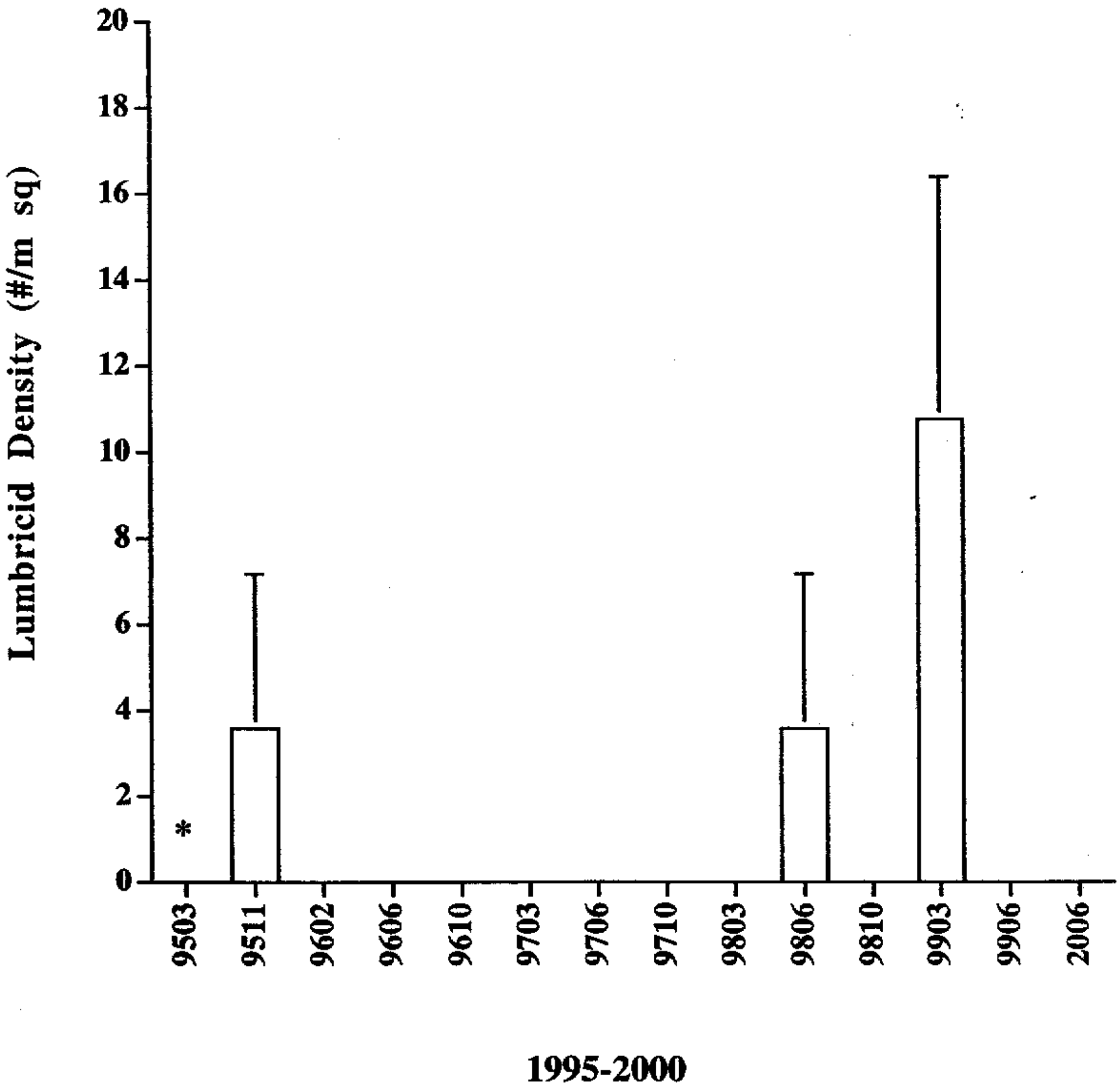

Figure 147. Lumbricid densities (#/m sq) collected at Two-Mile pool Rkm 3.1 pool from March 1995 to June 2000. Error bars represent (± 1 SE, n=12). Asterisk (*) represents 391/m sq (± 383 SE).

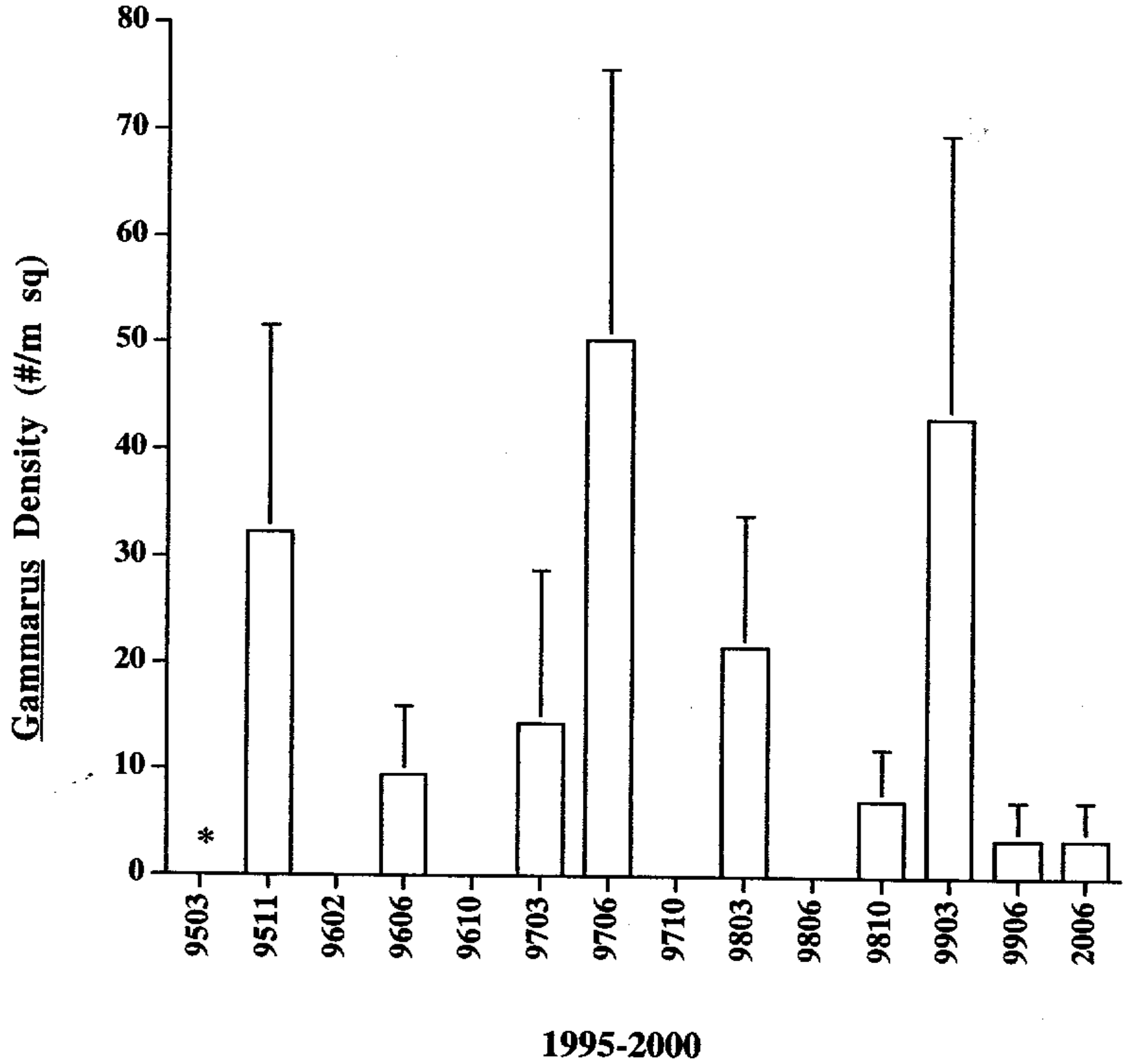

Figure 148. Gammarus densities (#/m sq) collected at Two-Mile pool Rkm 3.1 from March 1995 to June 2000. Error bars represent (± 1 SE, n=12). Asterisk (*) represents 1041/m sq (± 1041 SE).

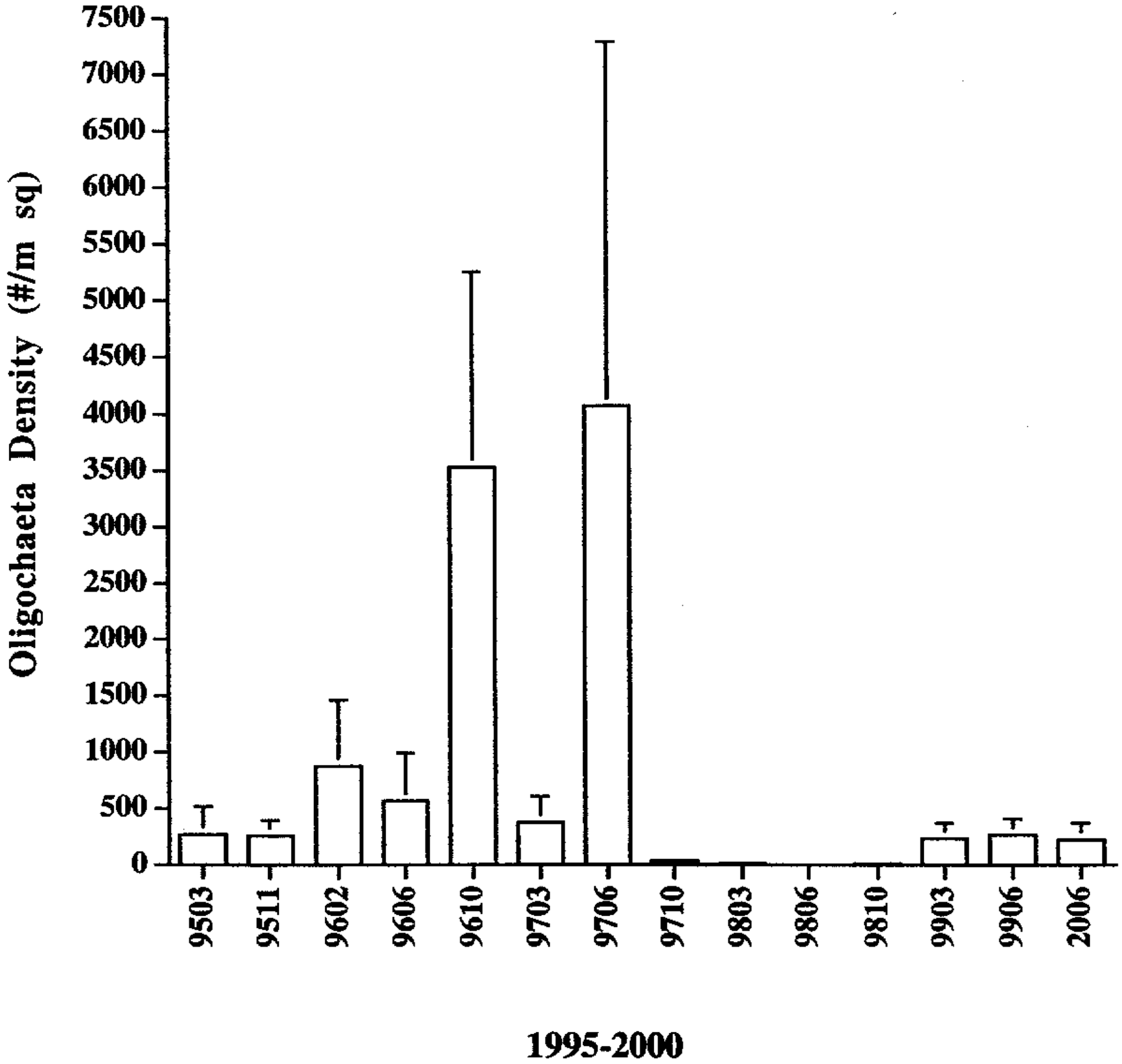

Figure 149. Oligochaeta densities (#/m sq) collected at Two-Mile pool Rkm 3.1 pool Rkm 0.0 from March 1995 to June 2000. Error bars represent (± 1 SE, n=12).

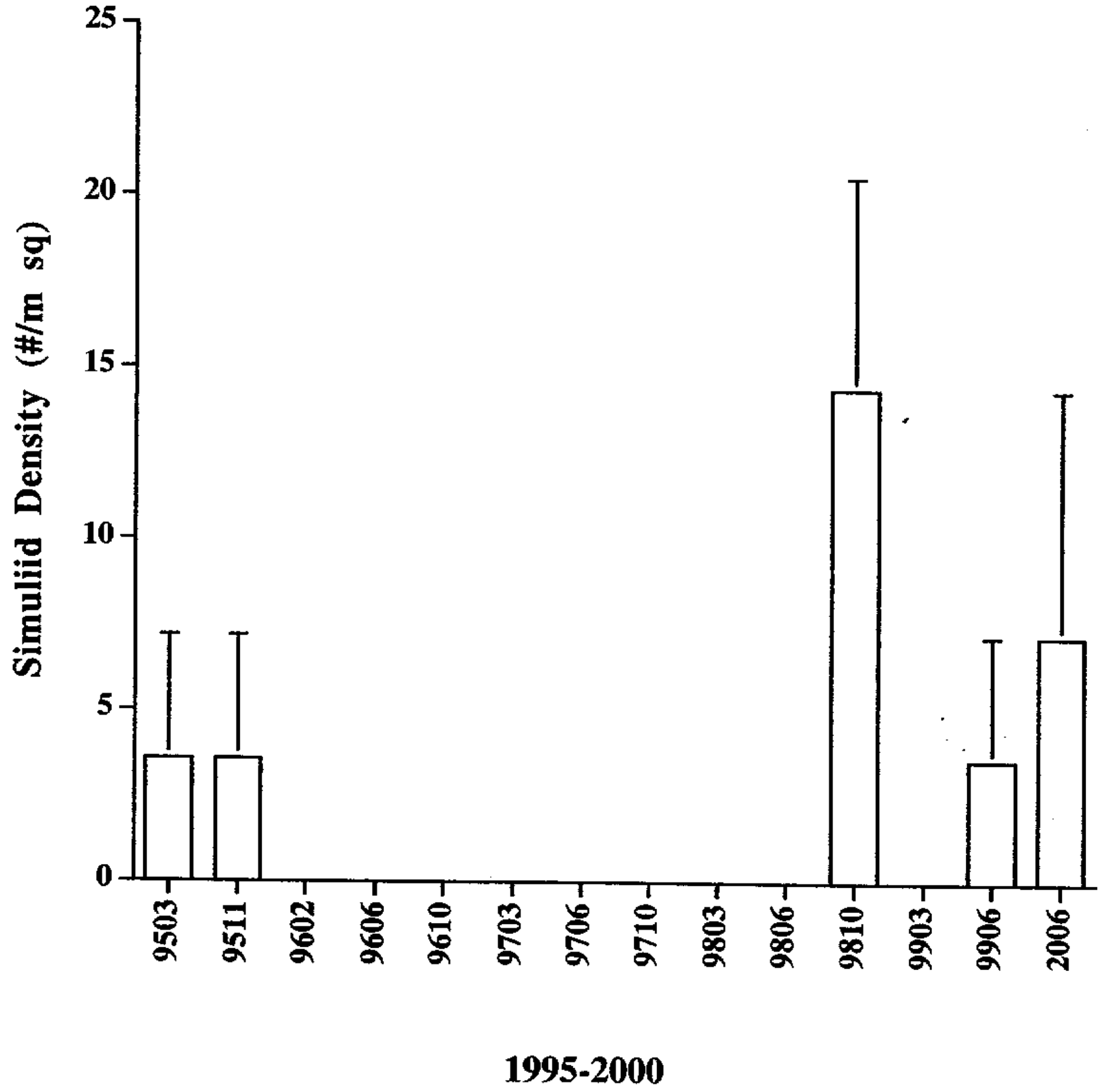

Figure 150. Simuliid densities (#/m sq) collected at Two-Mile pool Rkm 3.1 pool from March 1995 to June 2000. Error bars represent (± 1 SE, n=12).

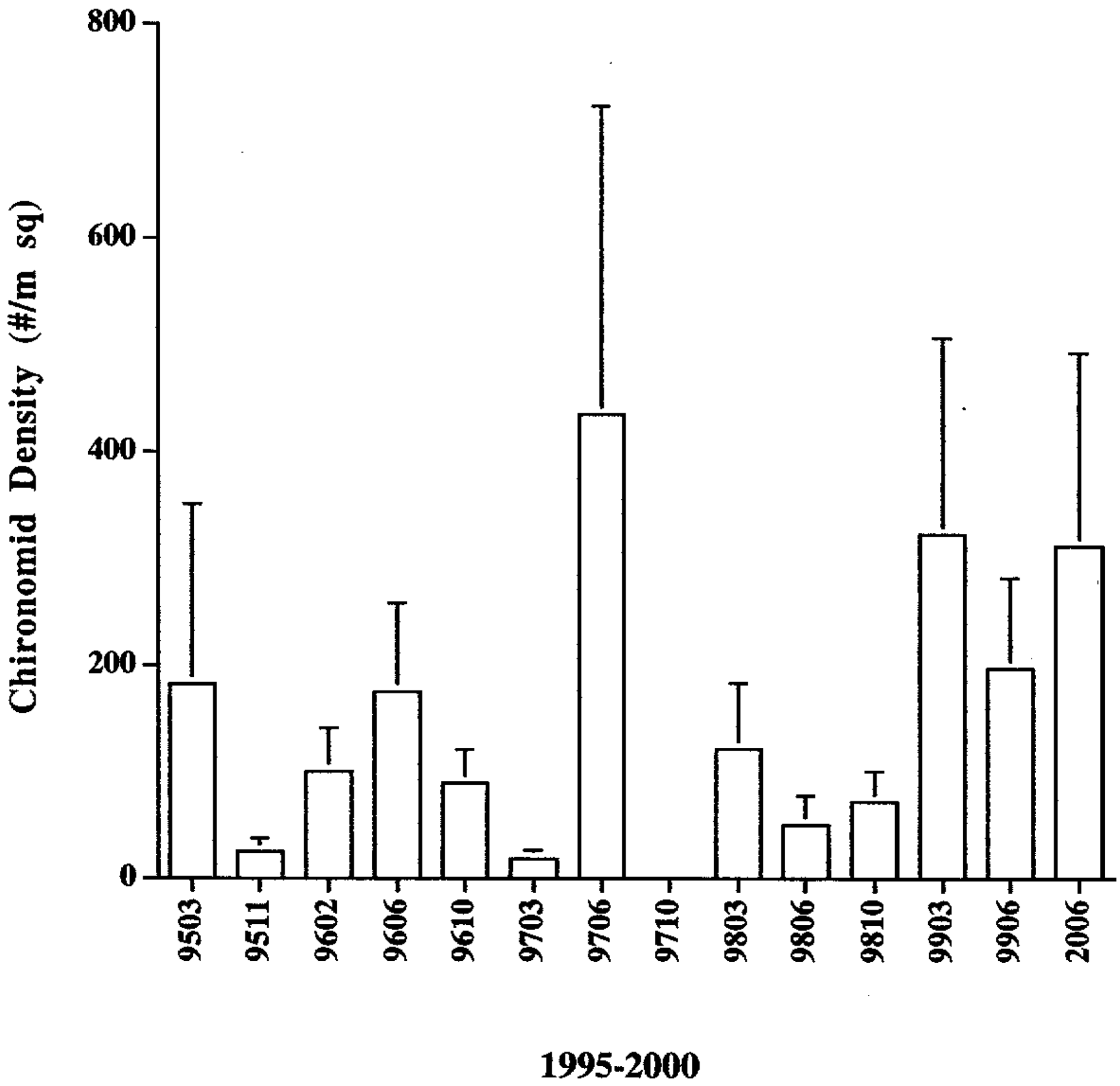

Figure 151. Simuliid densities (#/m sq) collected at Two-Mile pool Rkm 3.1 pool from March 1995 to June 2000. Error bars represent (± 1 SE, n=12).

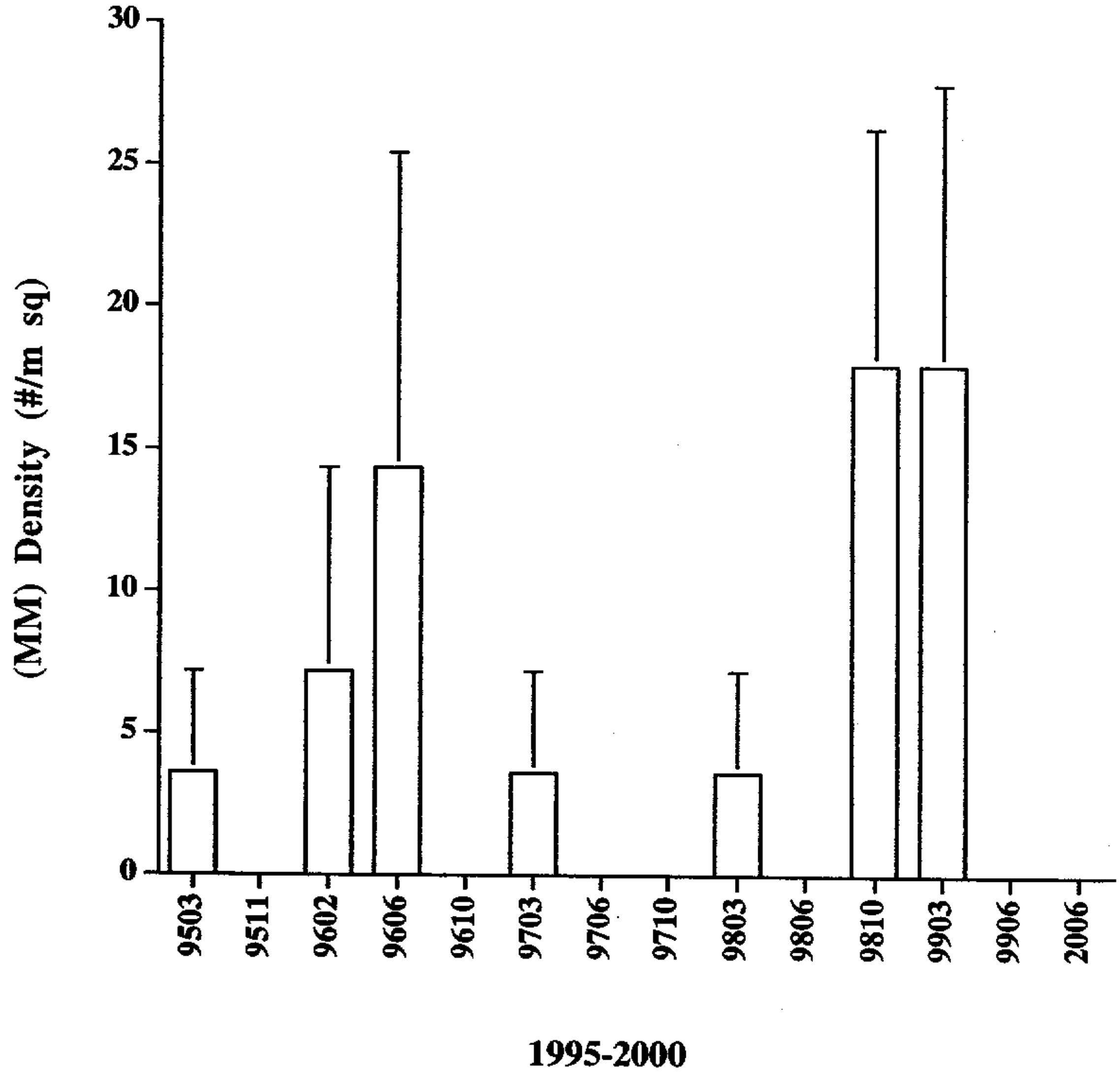

Figure 152. Miscellaneous invertebrate (MM) densities (#/m sq) collected at Two-Mile pool Rkm 3.1 from March 1995 to June 2000. Error bars represent (± 1 SE, n=12).

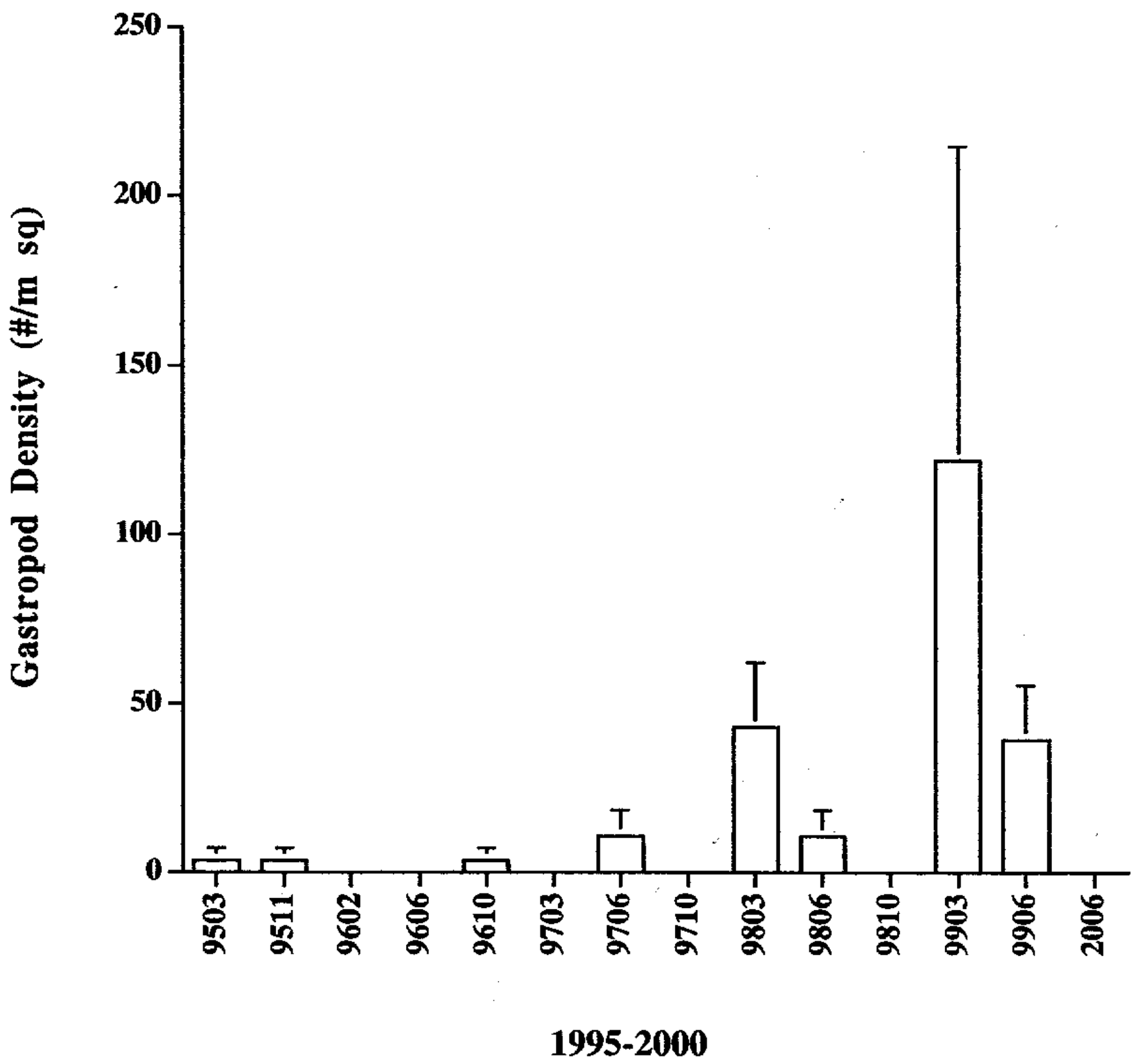

Figure 153. Gastropod densities (#/m sq) collected at Two-Mile pool Rkm 3.1 from March 1995 to June 2000. Error bars represent (± 1 SE, n=12).

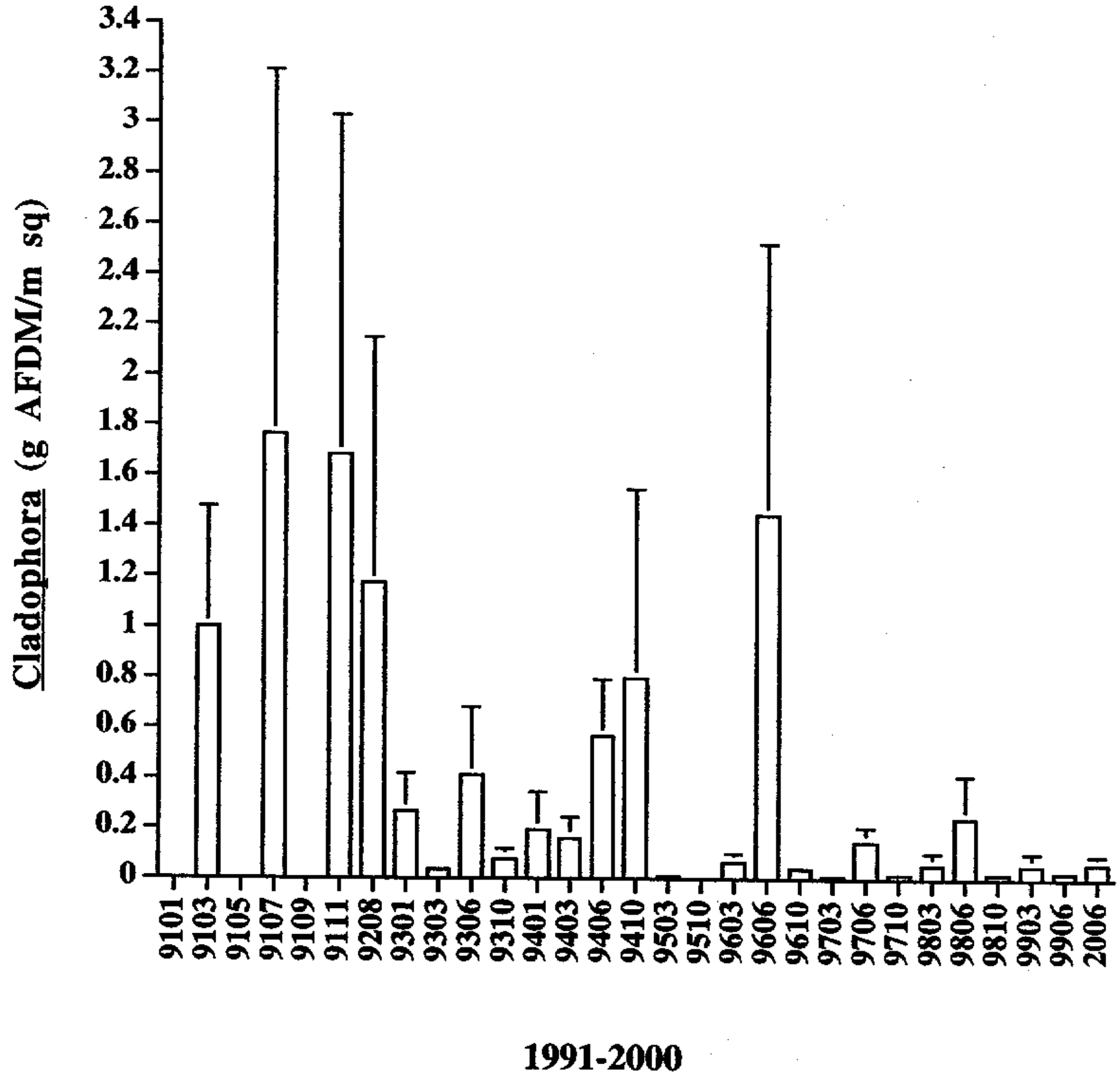

Figure 154. Cladophora biomass estimates (g AFDM/m sq) at 60 Mile rapid pool Rkm 95.7 from January 1991 to June 2000. Error bars represent (± 1 SE, n=12).

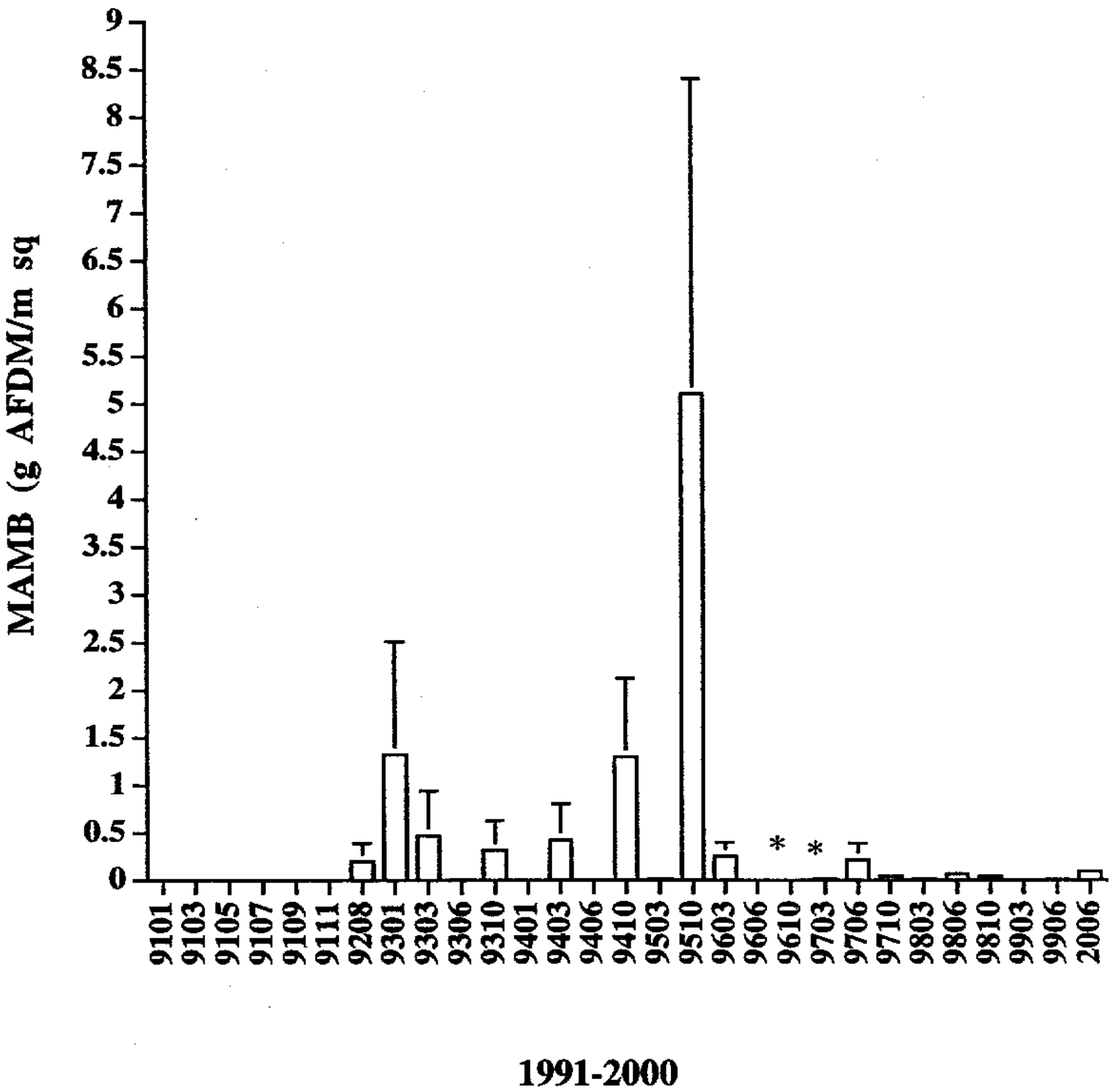

Figure 155. Miscellaneous algae, macrophytes and bryophytes (MAMB) biomass estimates (g AFDM/m sq) at 60 Mile rapid pool Rkm 95.7 from January 1991 to June 2000. MAMB was not collected prior to August 1992. Error bars represent (± 1 SE, n=12). Asterisk (*) at 9606 represents 12 g AFDM/m sq (± 10 SE) and at 9610 represents 9 g AFDM/m sq (± 6 SE).

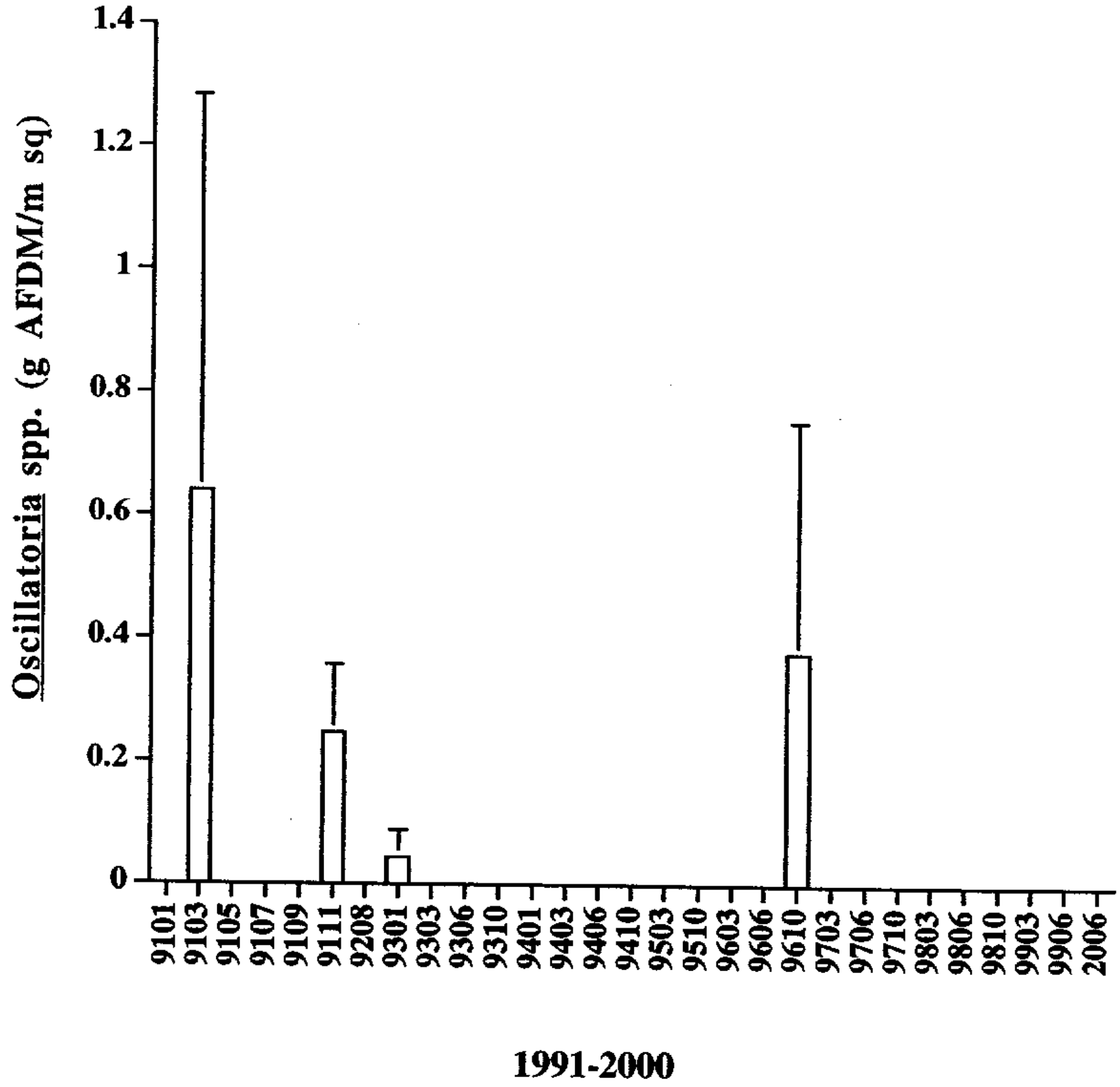

Figure 156. Oscillatoria spp. biomass estimates (g AFDM/m sq) at 60 Mile rapid pool Rkm 95.7 from January 1991 to June 2000. Error bars represent (± 1 SE, n=12).

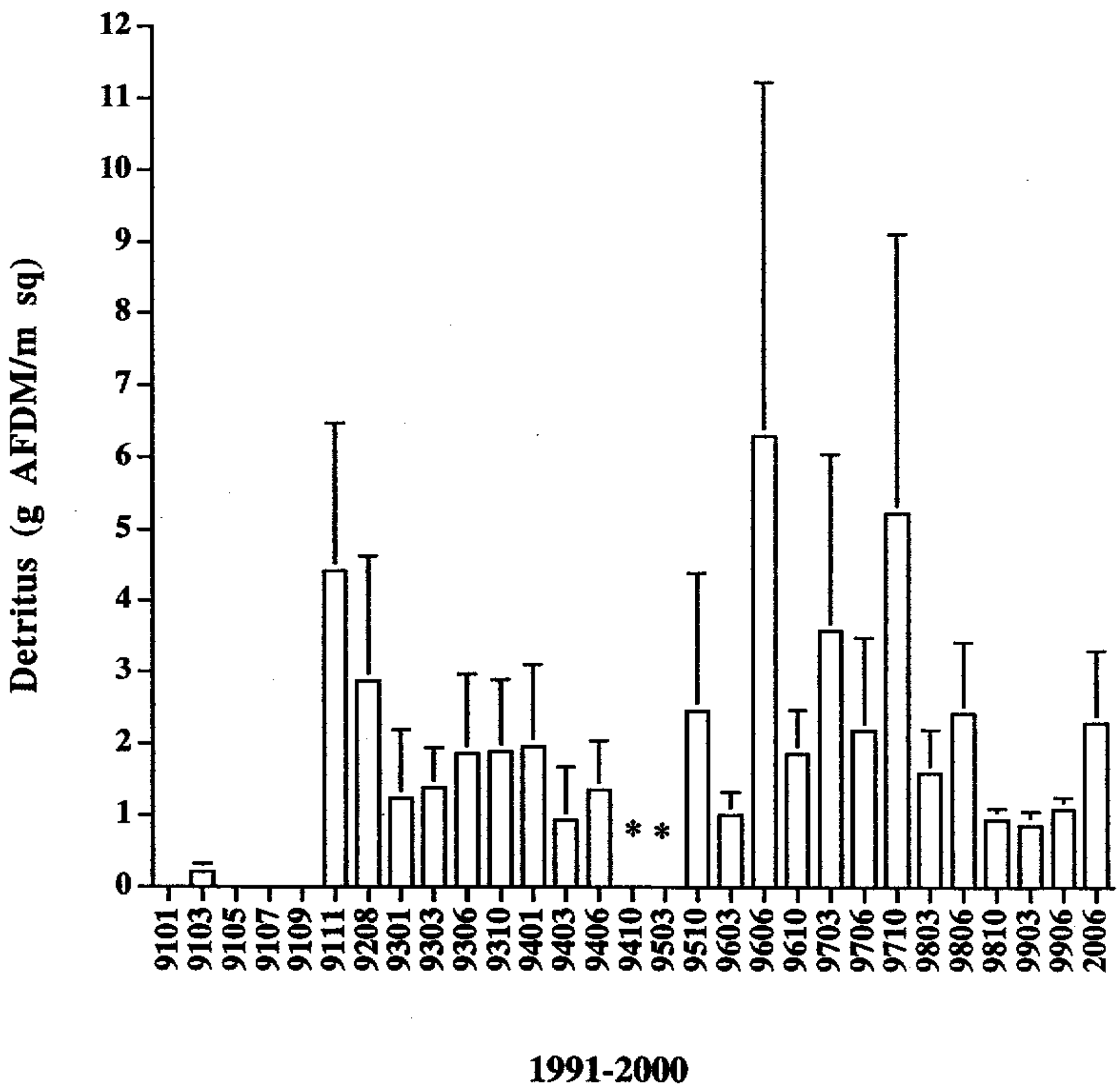

Figure 157. Detritus biomass estimates (g AFDM/m sq) at 60 Mile rapid pool Rkm 95.7 from January 1991 to June 2000. Error bars represent (± 1 SE, n=12). Asterisk (*) at 9410 represents 19 g AFDM/m sq (± 14 SE) and at 9503 represents 49 g AFDM/m sq (± 41 SE).

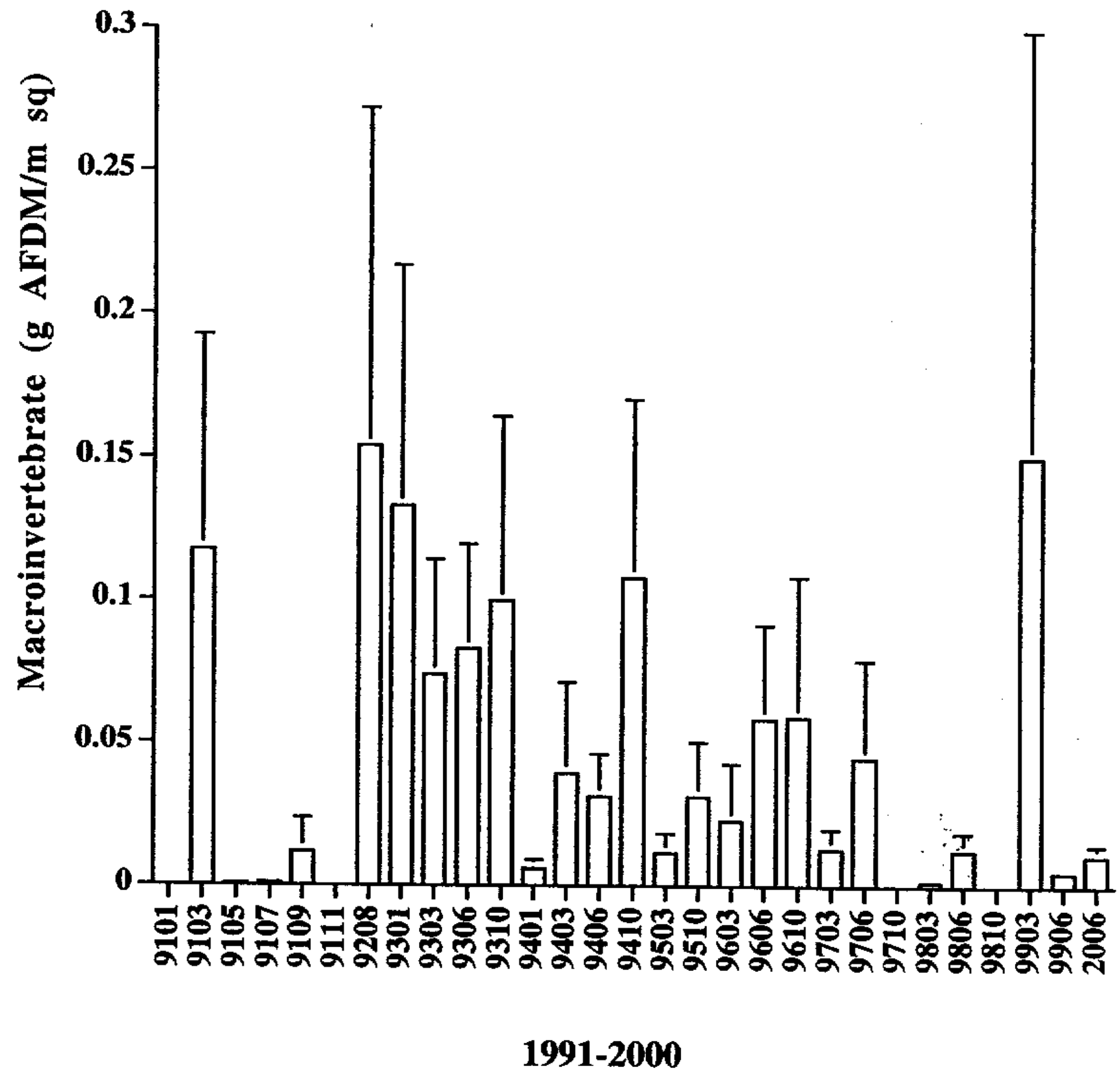

Figure 158. Macroinvertebrate biomass estimates (g AFDM/m sq) at 60 Mile rapid pool Rkm 95.7 from January 1991 to June 2000. Error bars represent (± 1 SE, n=12).

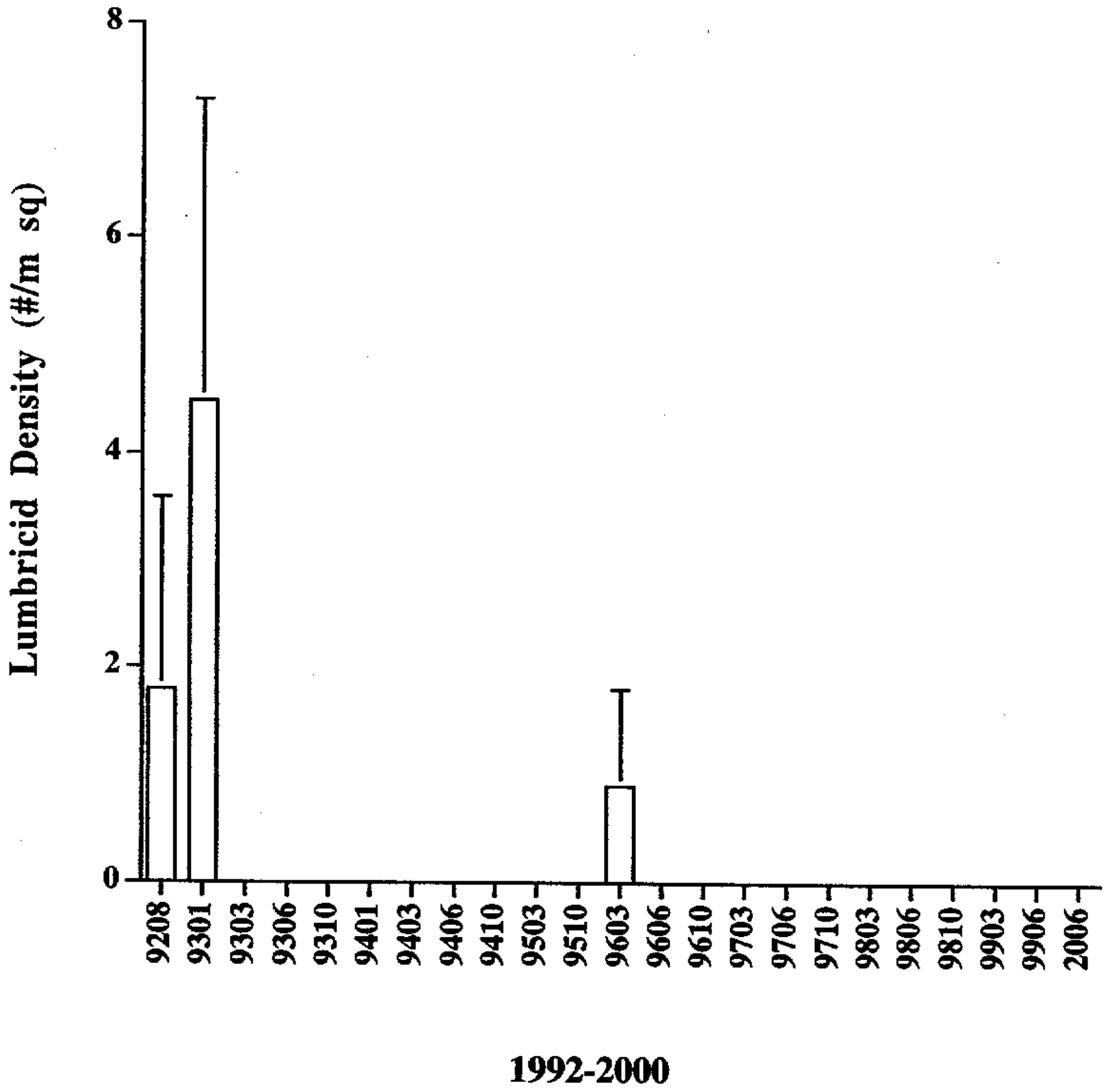

Figure 159. Lumbricid densities (#/m sq) collected at 60 Mile rapid Rkm 95.7 from August 1992 to June 2000. Error bars represent (± 1 SE, n=12).

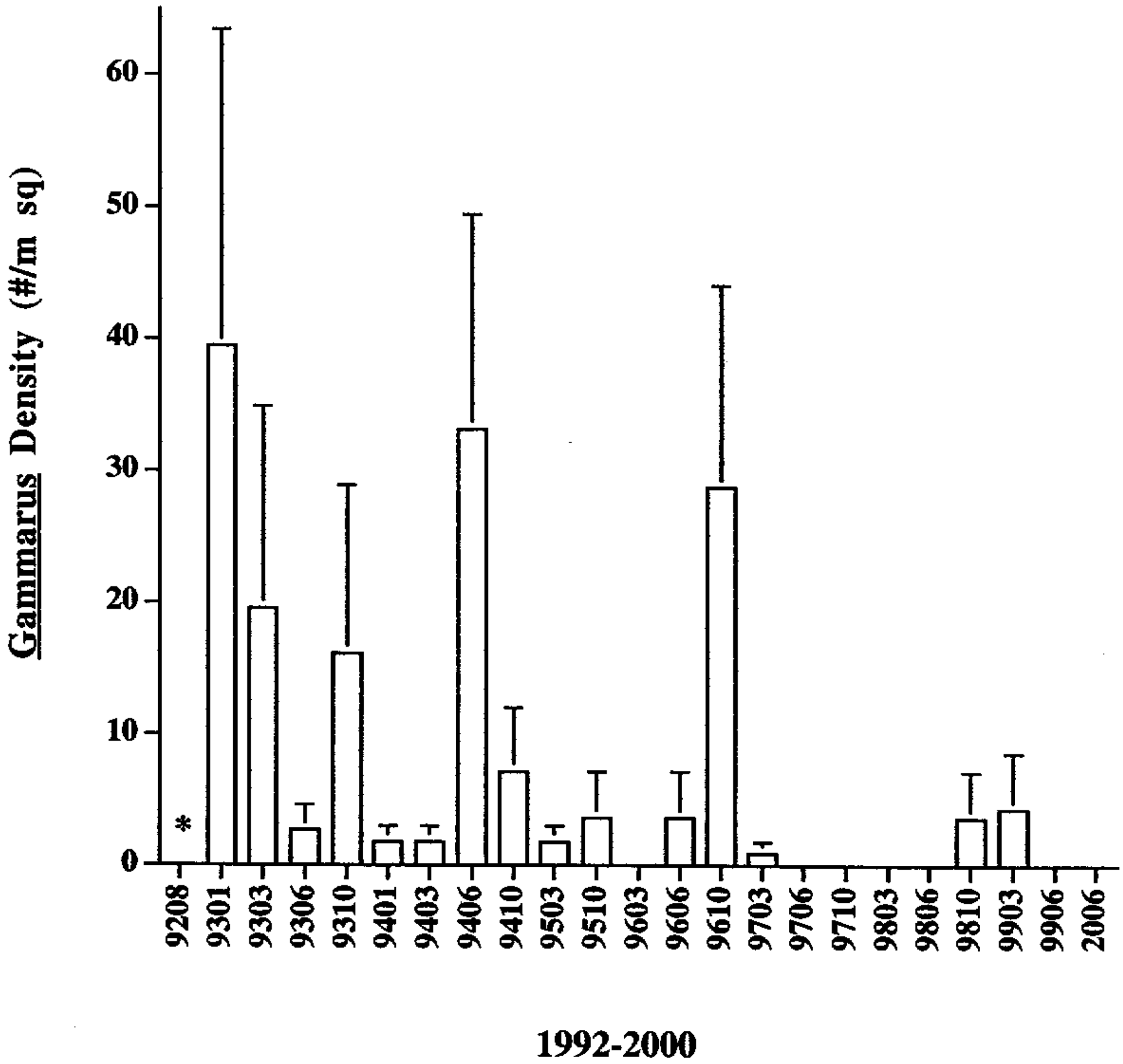

Figure 160. Gammarus densities (#/m sq) collected at 60 Mile rapid Rkm 95.7 from August 1992 to June 2000. Error bars represent (± 1 SE, n=12). Asterisk (*) represents 219/m sq (± 189 SE).

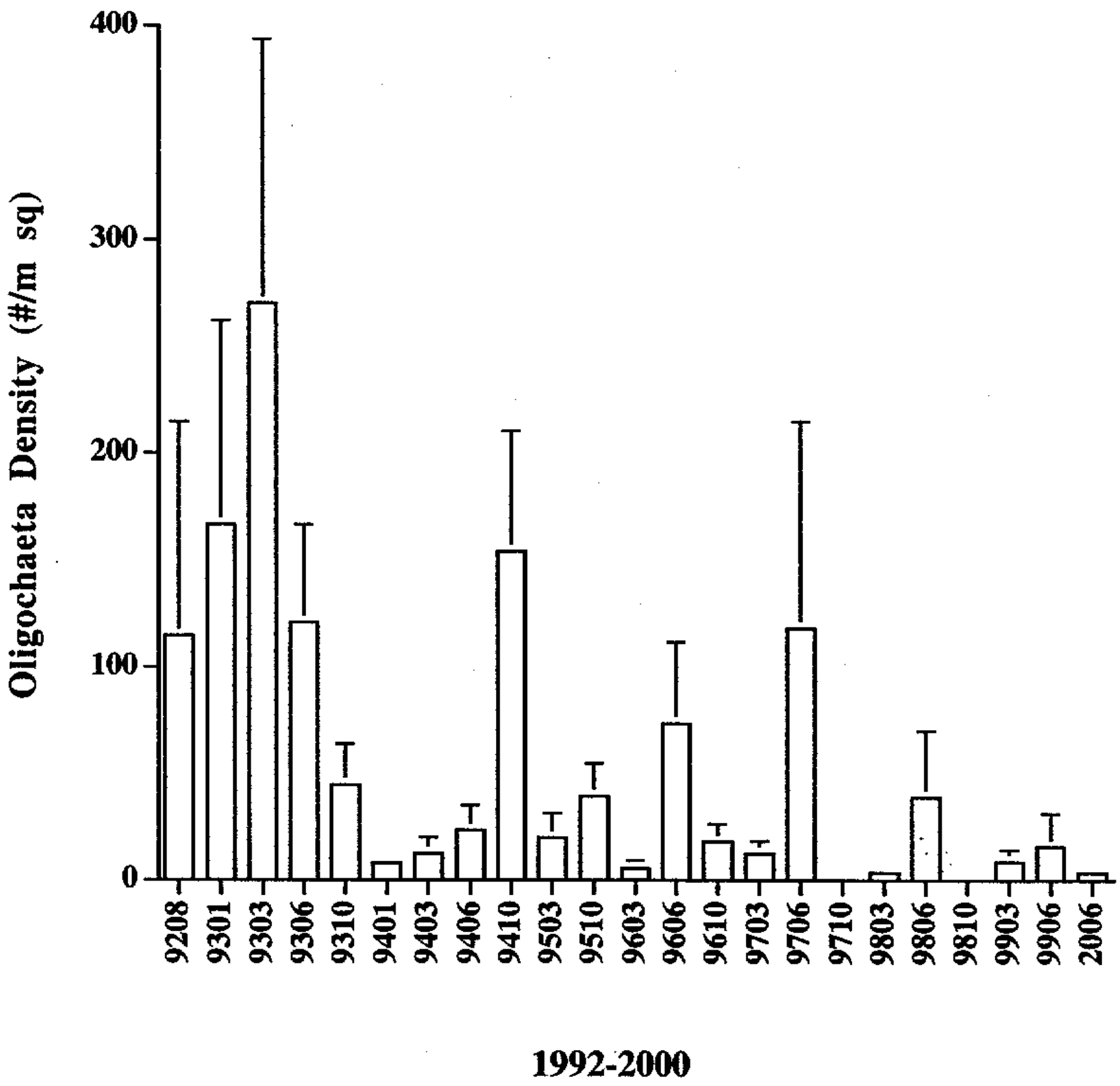

Figure 161. Oligochaeta densities (#/m sq) collected at 60 Mile rapid Rkm 95.7 from August 1992 to June 2000. Error bars represent (± 1 SE, n=12).

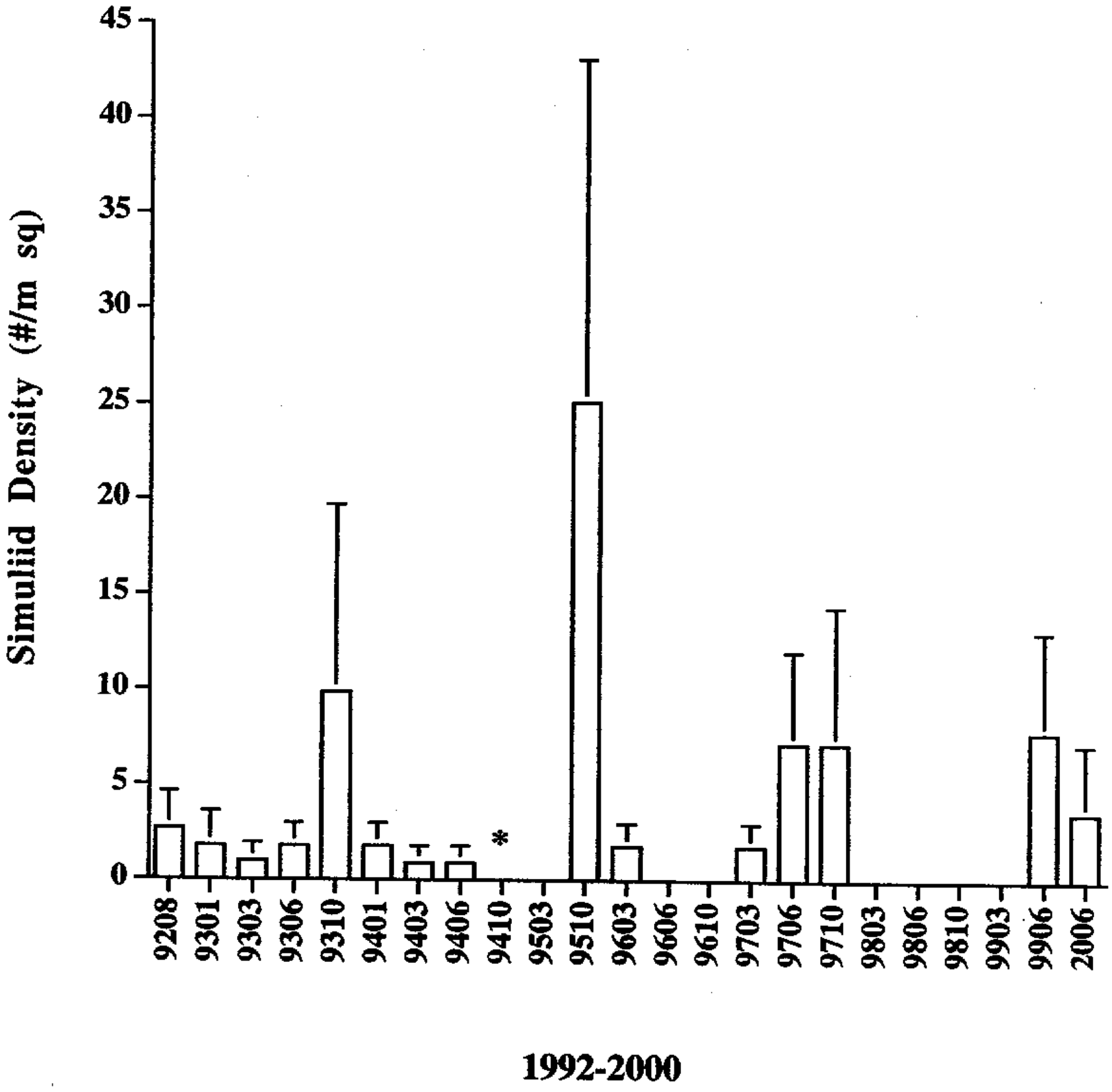

Figure 162. Simuliid densities (#/m sq) collected at 60 Mile rapid Rkm 95.7 from August 1992 to June 2000. Error bars represent (± 1 SE, n=12). Asterisk (*) represents 64/m sq (± 50 SE).

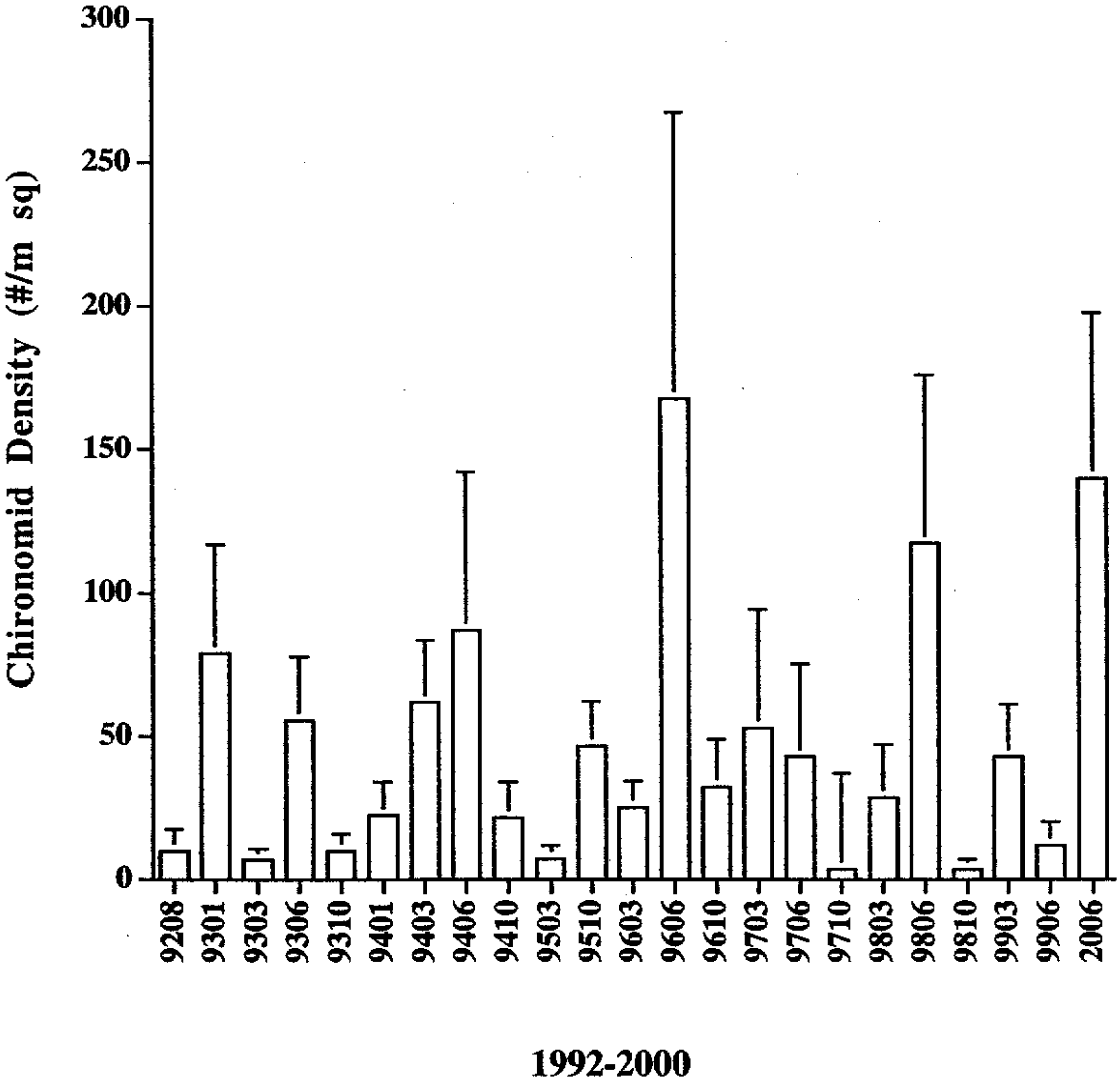

Figure 163. Chironomid densities (#/m sq) collected at 60 Mile rapid Rkm 95.7 from August 1992 to June 2000. Error bars represent (± 1 SE, n=12).

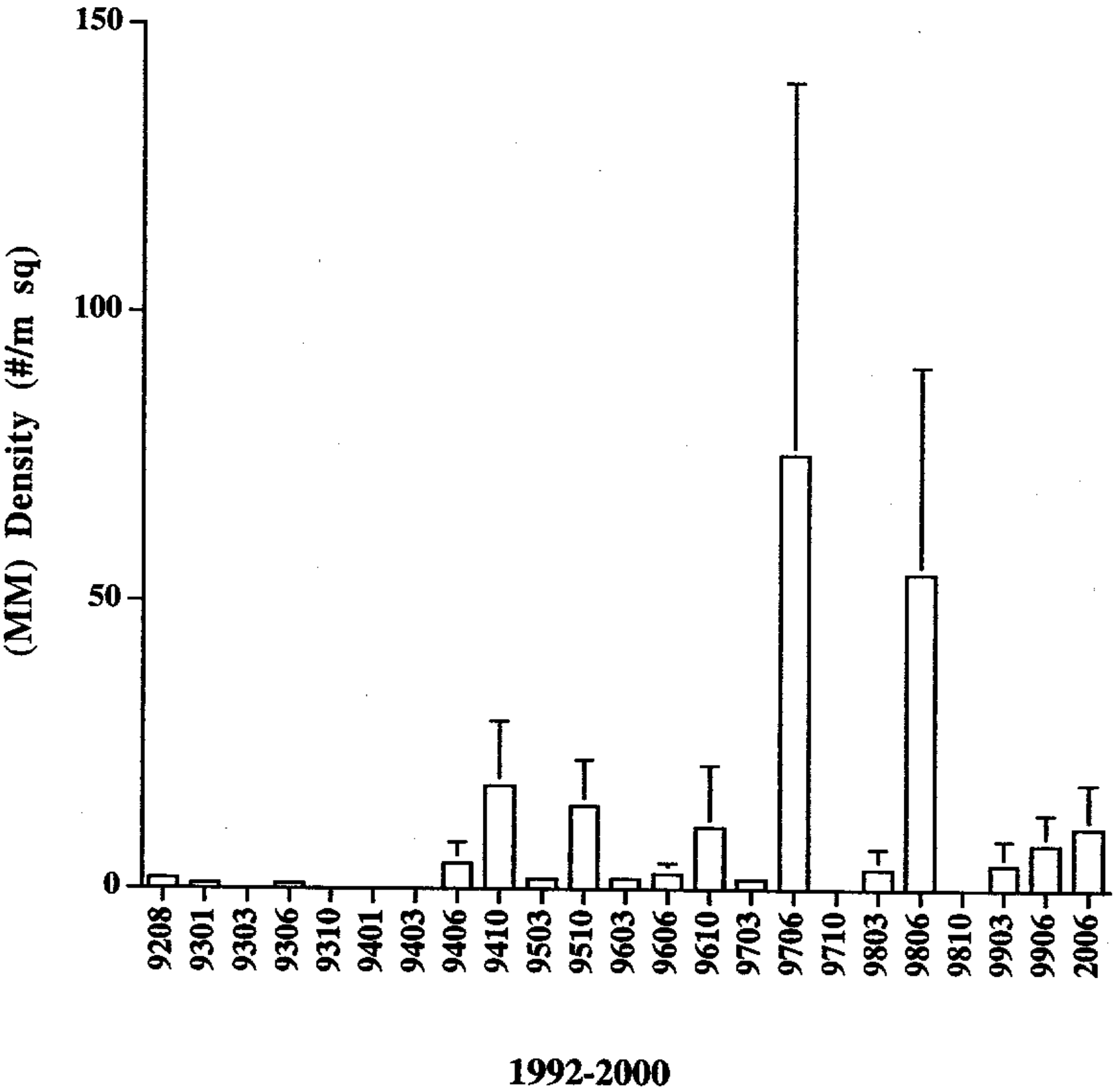

Figure 164. Miscellaneous invertebrate (MM) densities (#/m sq) collected at 60 Mile rapid Rkm 95.7 from August 1992 to June 2000. Error bars represent (± 1 SE, n=12).

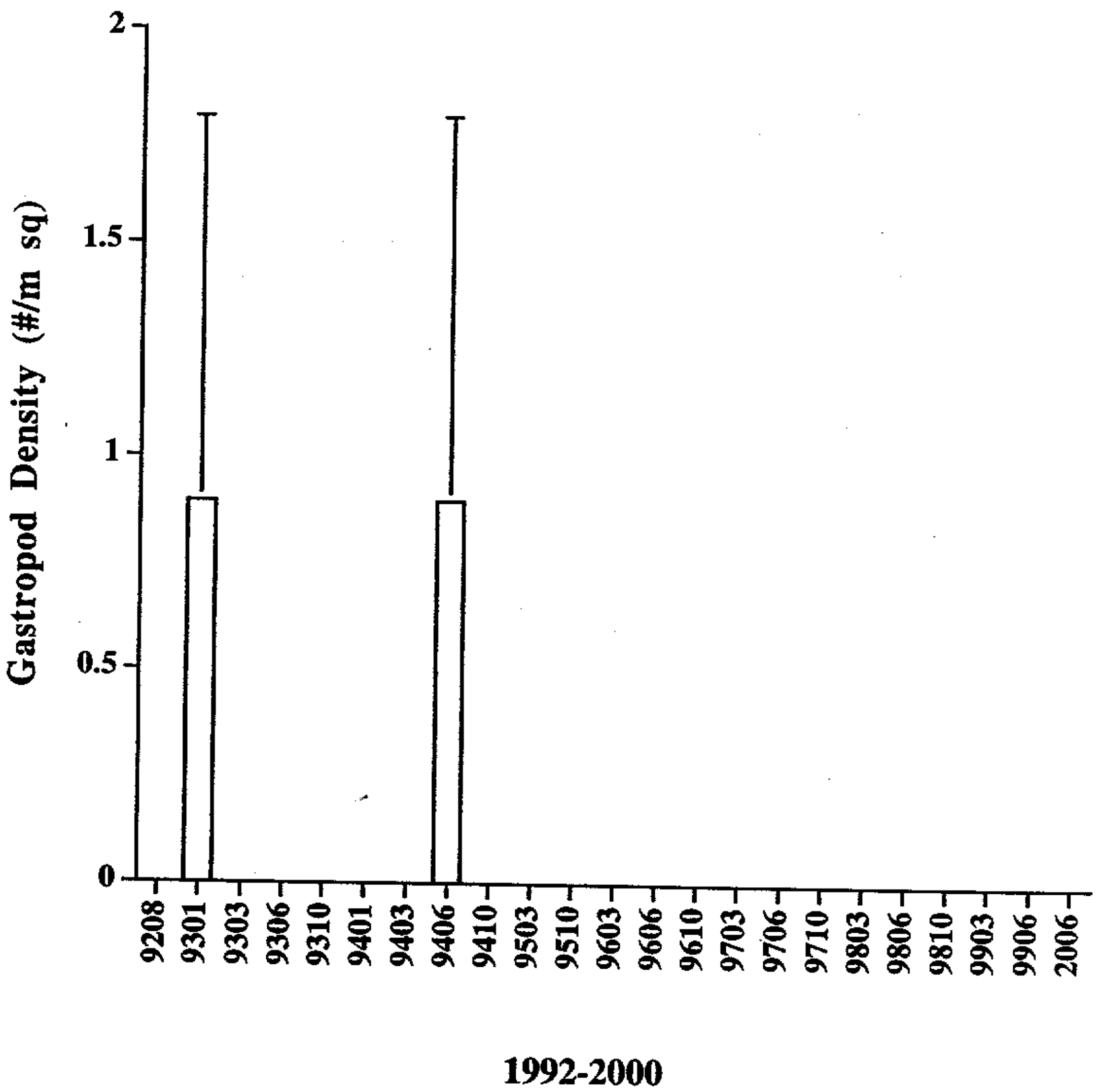

Figure 165. Gastropod densities (#/m sq) collected at 60 Mile rapid Rkm 95.7 from March 1995 to June 2000. Error bars represent (± 1 SE, n=12).

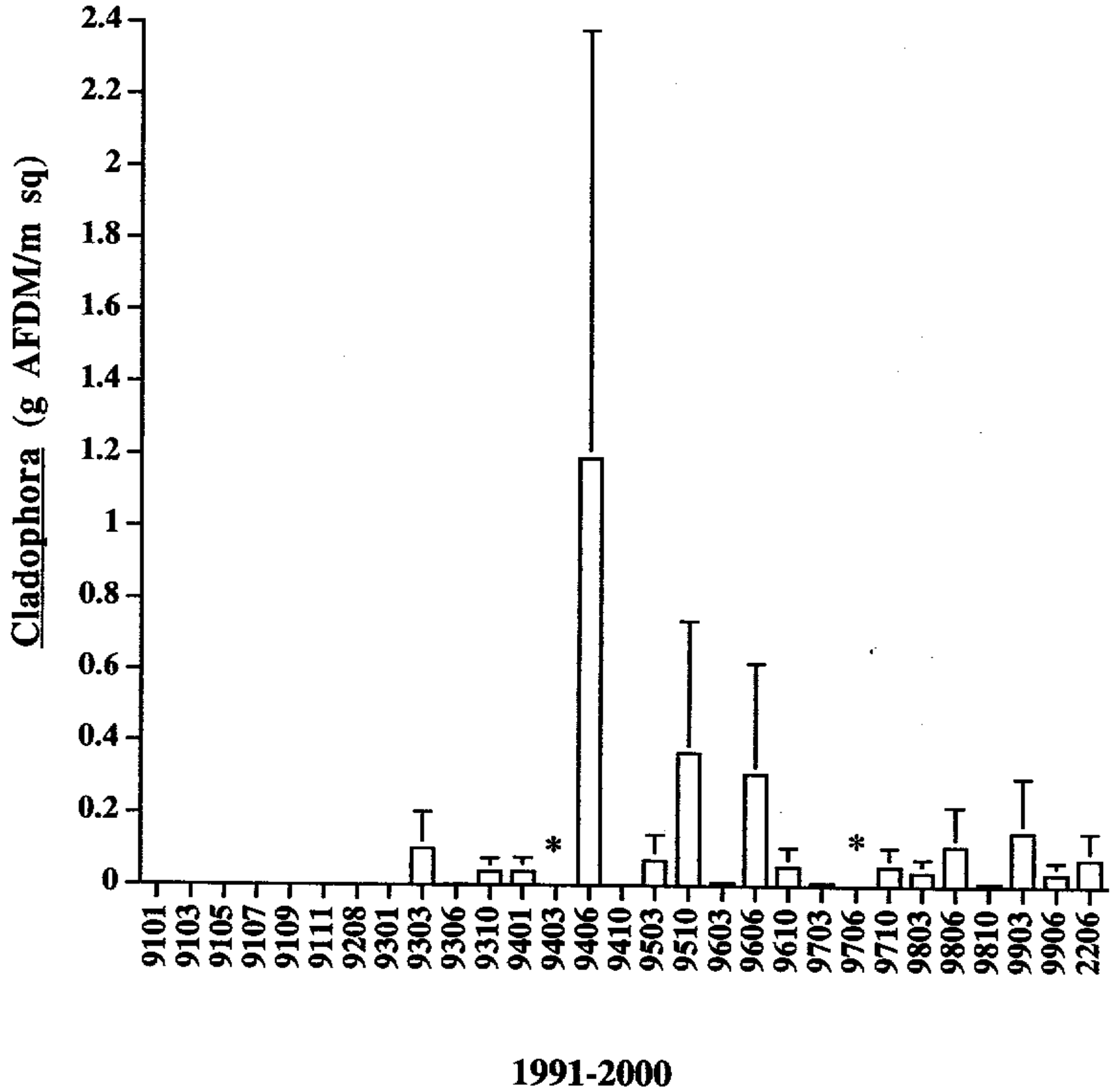

Figure 166. Cladophora biomass estimates (g AFDM/m sq) at Tanner Canyon pool Rkm 108.8 from January 1991 to June 2000. Error bars represent (± 1 SE, n=12). Asterisk (*) at 9403 represents 5.8 g AFDM/m sq (± 5.8 SE) and at 9706 represents 2 g AFDM/m sq (± 2 SE).

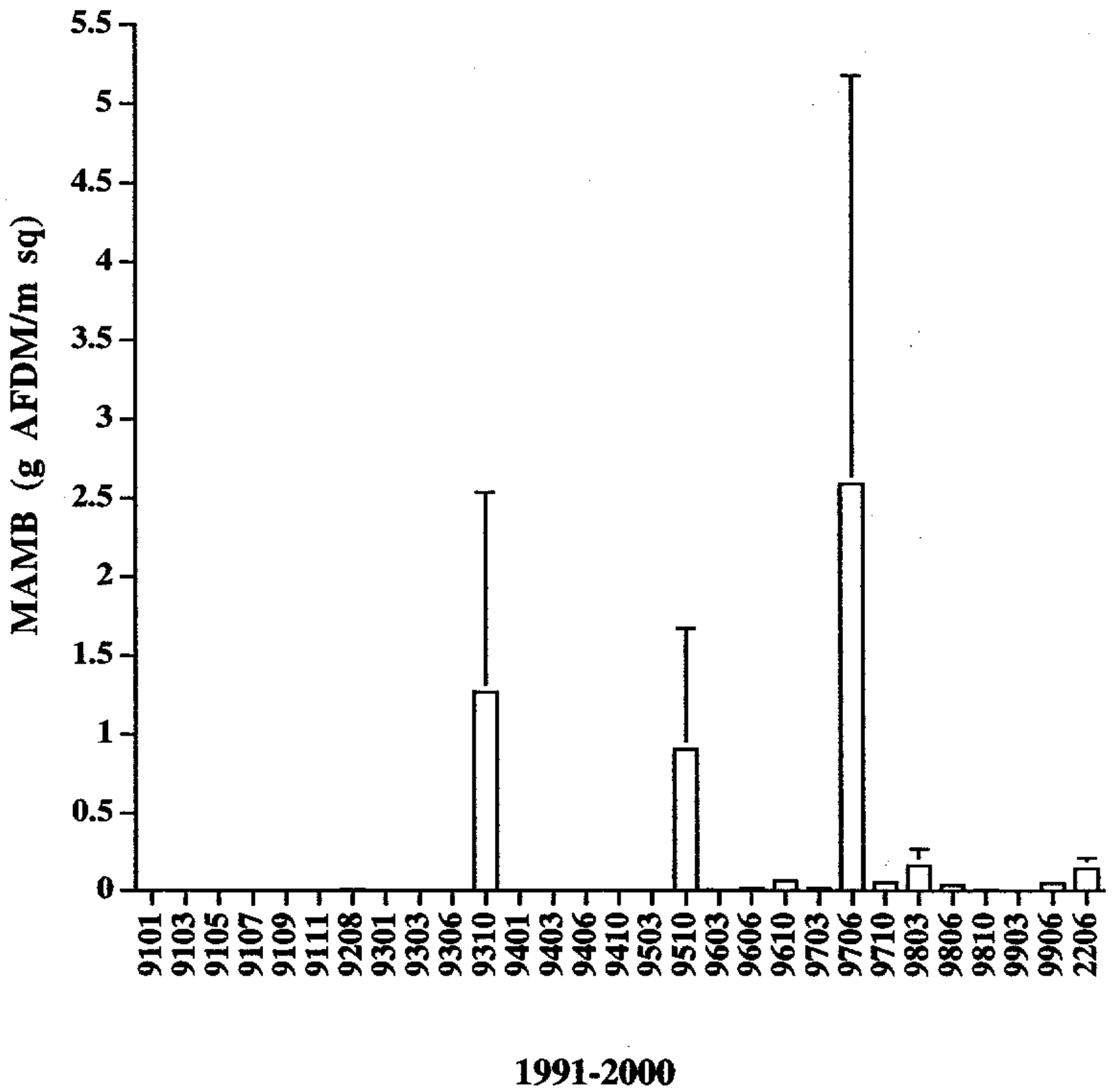

Figure 167. Miscellaneous algae, macrophytes and bryophytes (MAMB) biomass estimates (g AFDM/m sq) at Tanner Canyon pool Rkm 108.8 from January 1991 to June 2000. MAMB was not collected prior to August 1992. Error bars represent (± 1 SE, n=12).

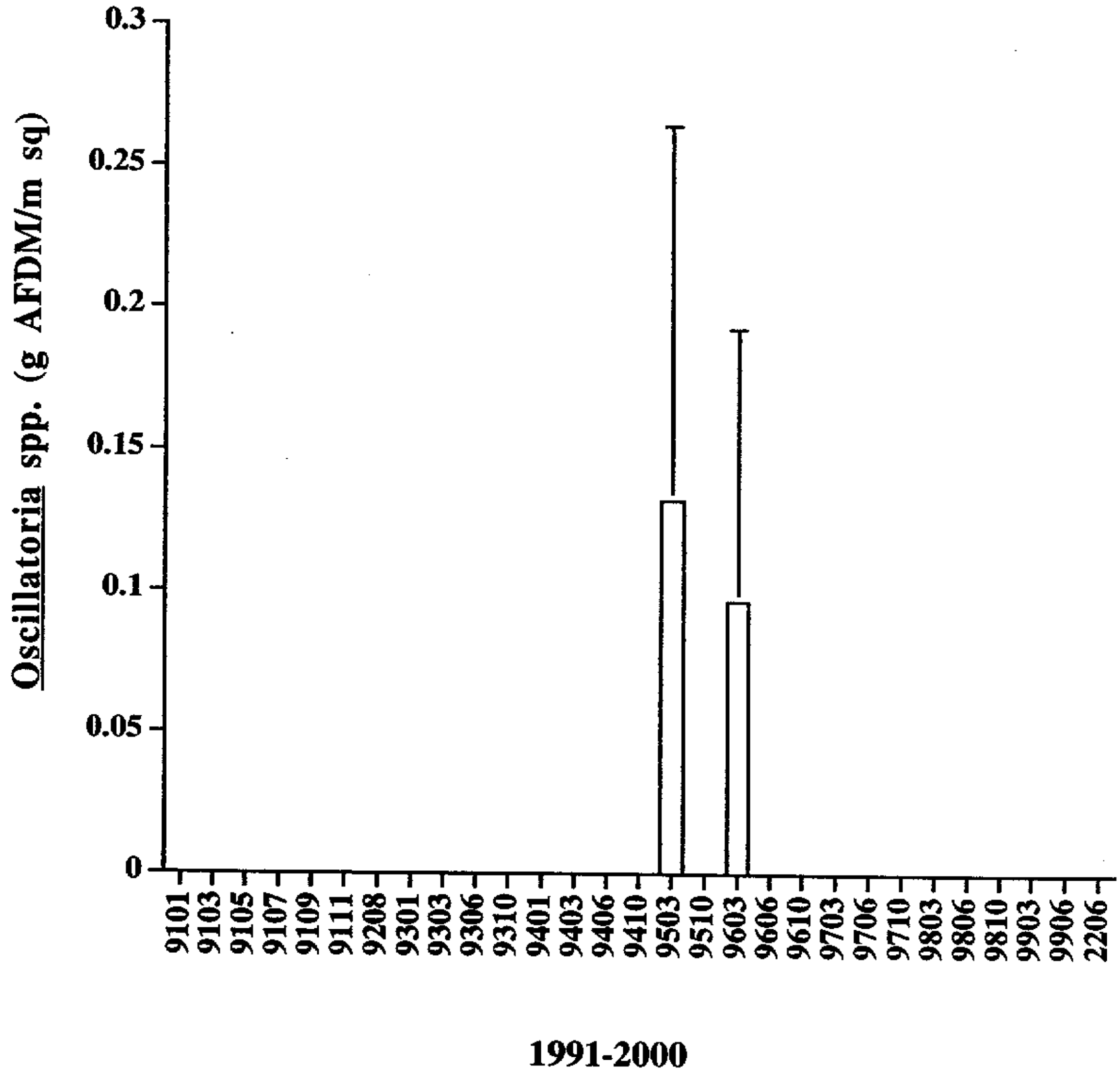

Figure 168. Oscillatoria spp. biomass estimates (g AFDM/m sq) at Tanner Canyon pool Rkm 108.8 from January 1991 to June 1999. Error bars represent (± 1 SE, n=12).

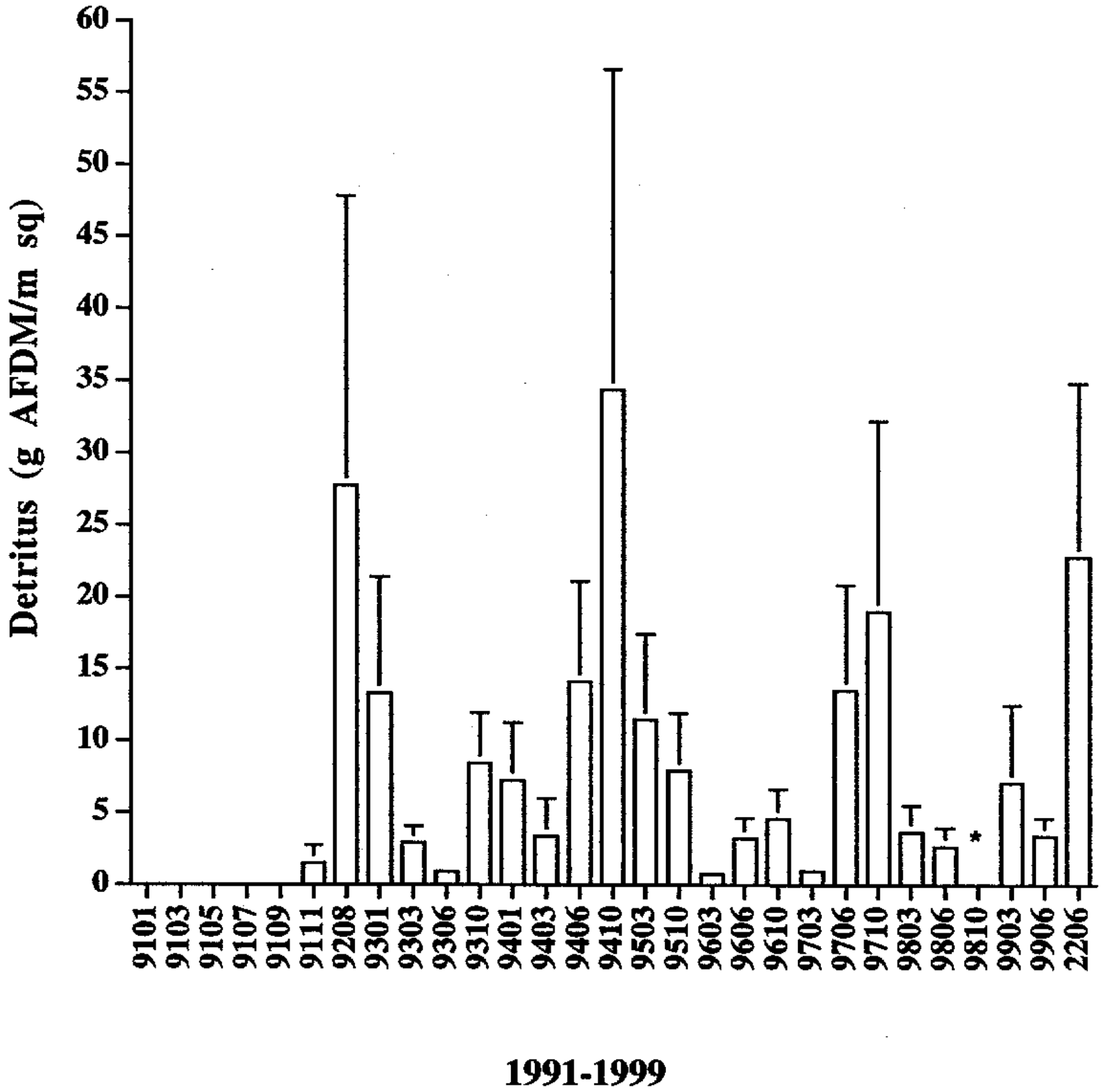

Figure 169. Detritus biomass estimates (g AFDM/m sq) at Tanner Canyon pool Rkm 108.8 from January 1991 to June 2000. Error bars represent (± 1 SE, n=12).Asterisk (*) represents 81/m sq (± 61 SE).

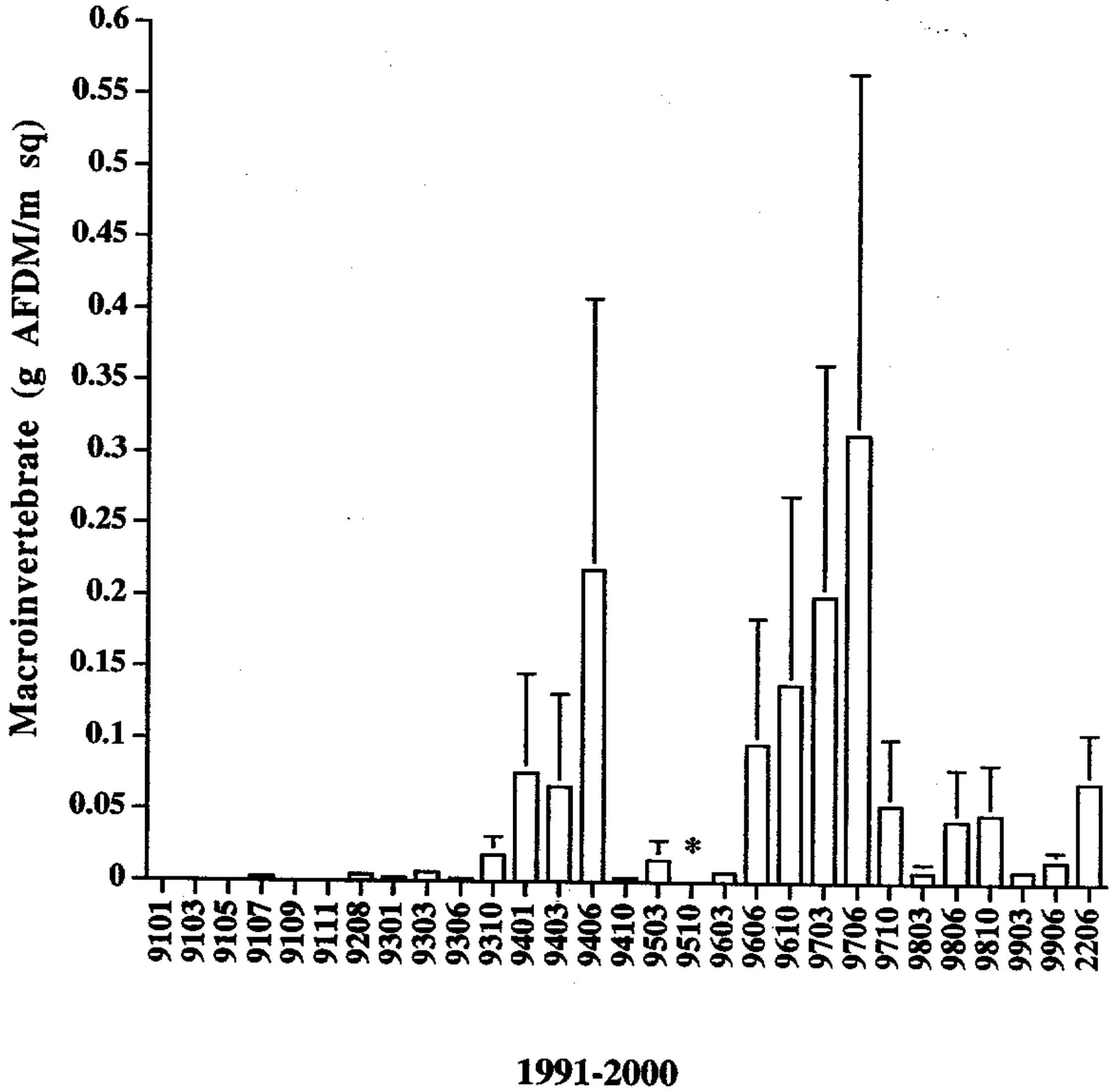

Figure 170. Macroinvertebrate biomass estimates (g AFDM/m sq) at Tanner Canyon pool Rkm 108.8 from January 1991 to June 1999. Error bars represent (± 1 SE, n=12). Asterisk (*) represents 0.5 g AFDM/m sq (± 0.5 SE).

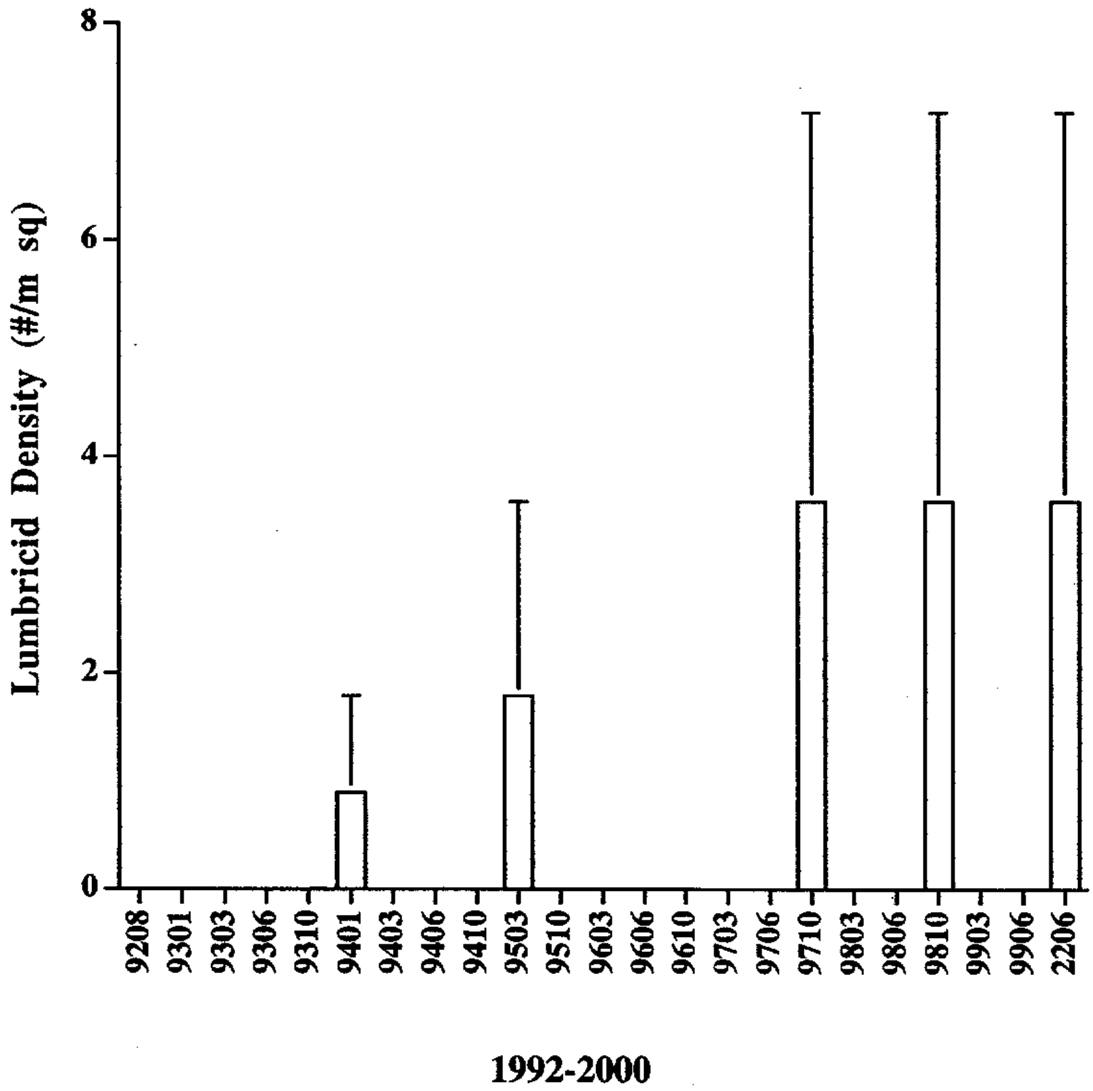

Figure 171. Lumbricid densities (#/m sq) collected at Tanner Canyon pool Rkm 108.8 from August 1992 to June 2000. Error bars represent (± 1 SE, n=12).

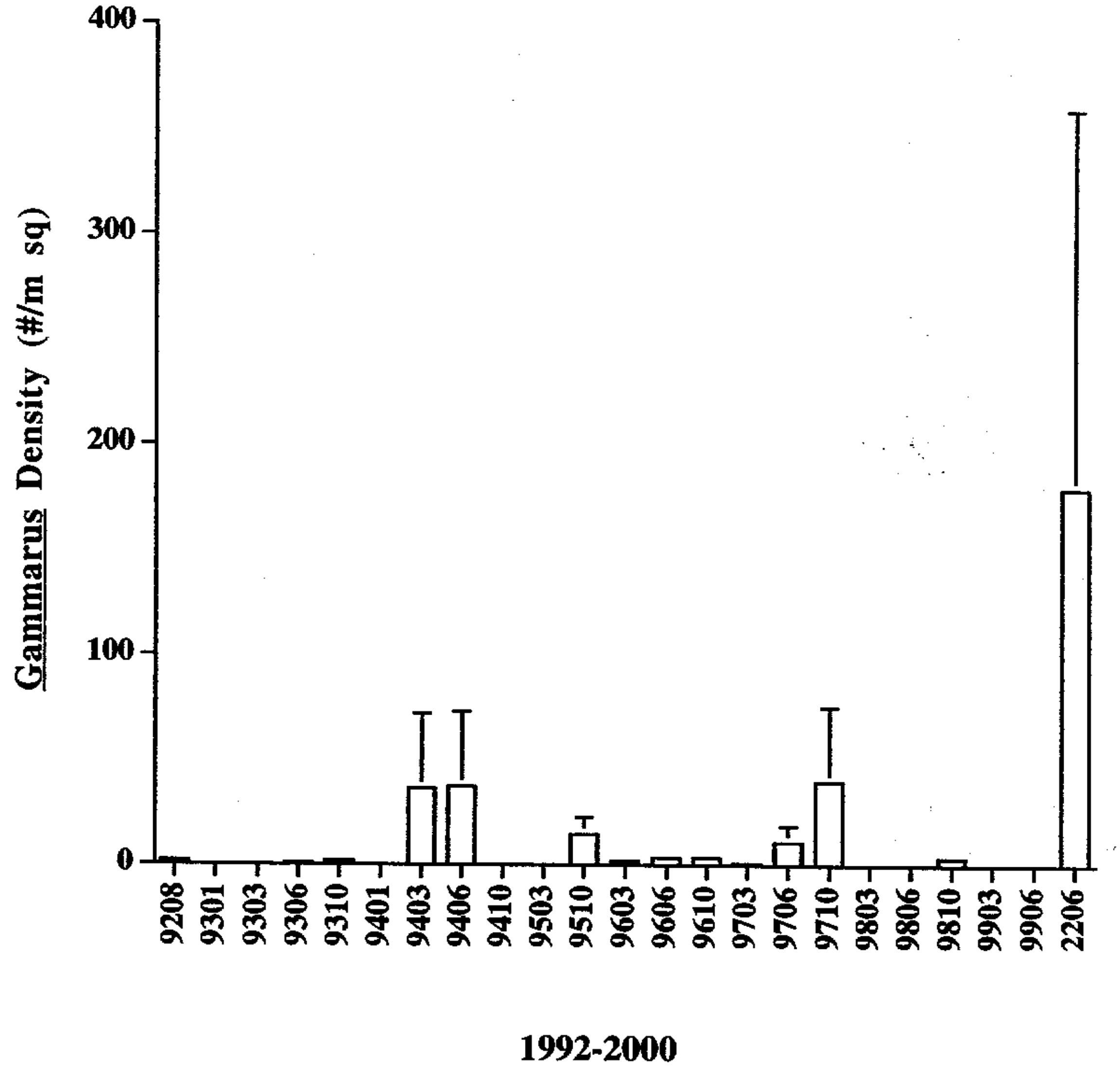

Figure 172. Gammarus densities (#/m /s) collected at Tanner Canyon pool Rkm 108.8 from March 1995 to June 2000. Error bars represent (± 1 SE, n=12).

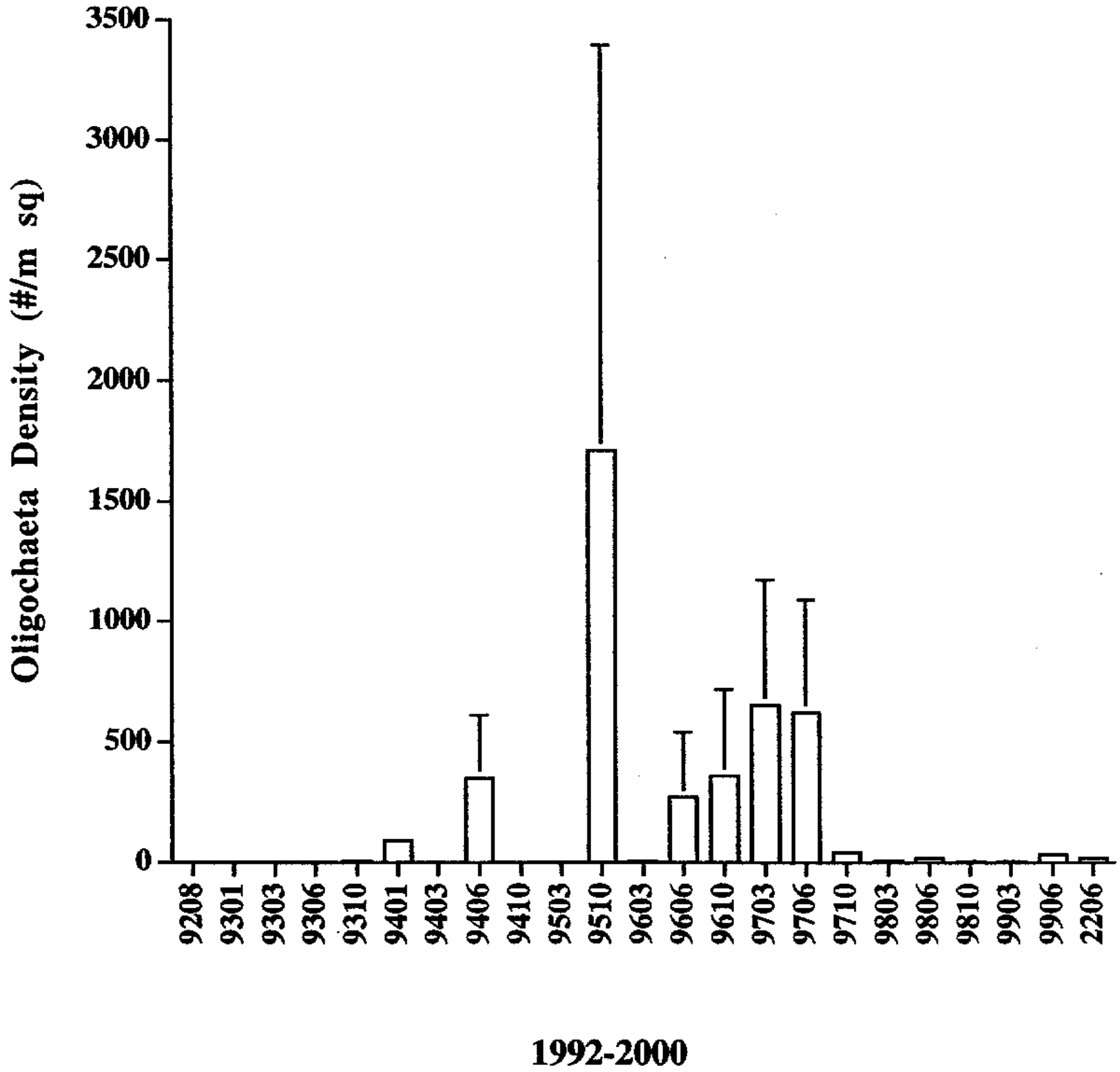

Figure 173. Oligochaeta densities (#/m sq) collected at Tanner Canyon pool Rkm 108.8 from August 1992 to June 2000. Error bars represent (± 1 SE, n=12).

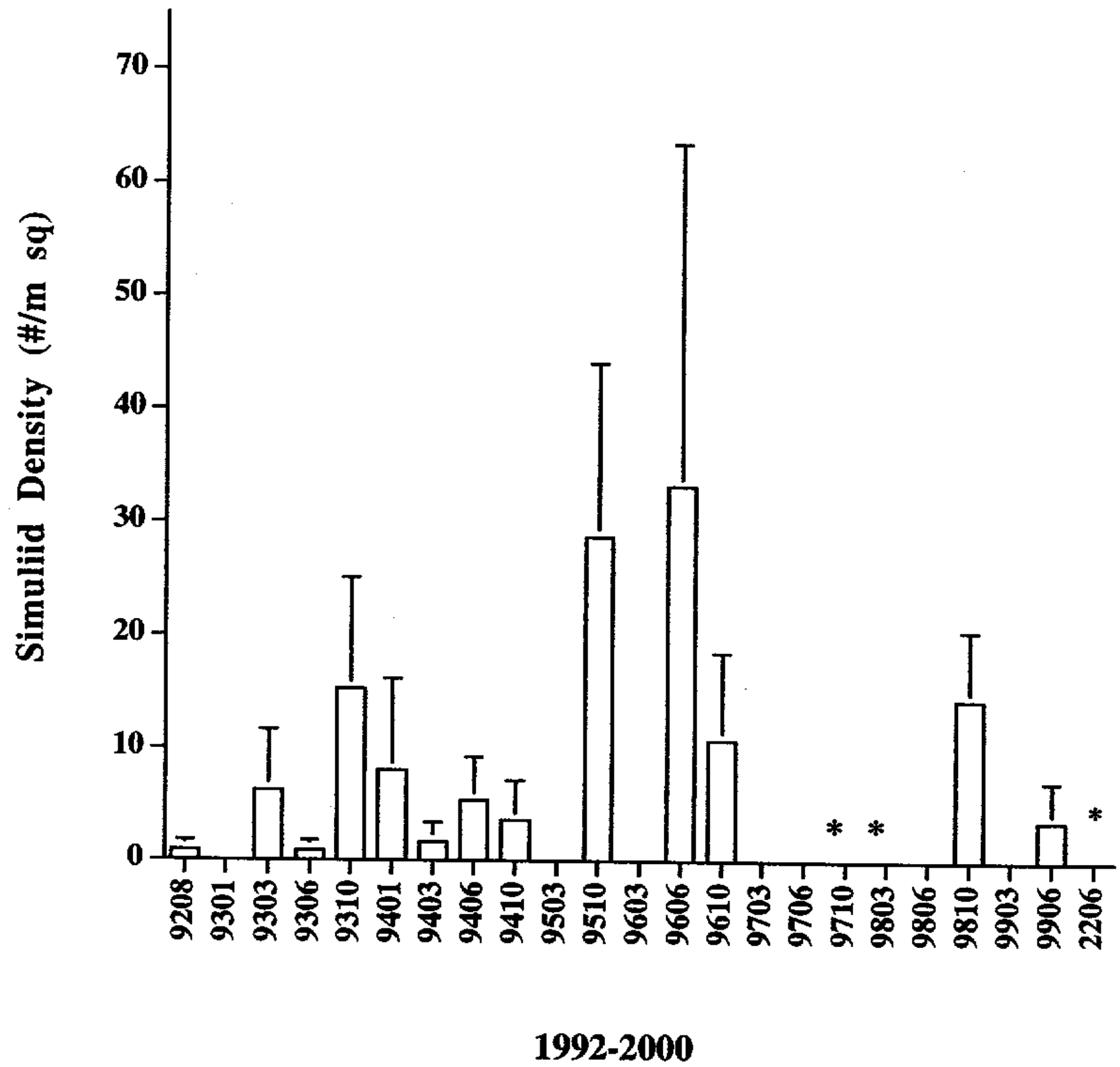

Figure 174. Simuliid densities (#/m sq) collected at Tanner Canyon pool Rkm 108.8 from August 1992 to June 2000. Error bars represent (± 1 SE, n=12). Asterisk (*) at 9706 represents 226/m^{2}sq (± 203 SE) at 9710 represents 129/m sq^2 (± 117 SE) and at 2006 represents 122/m sq (± 69 SE).

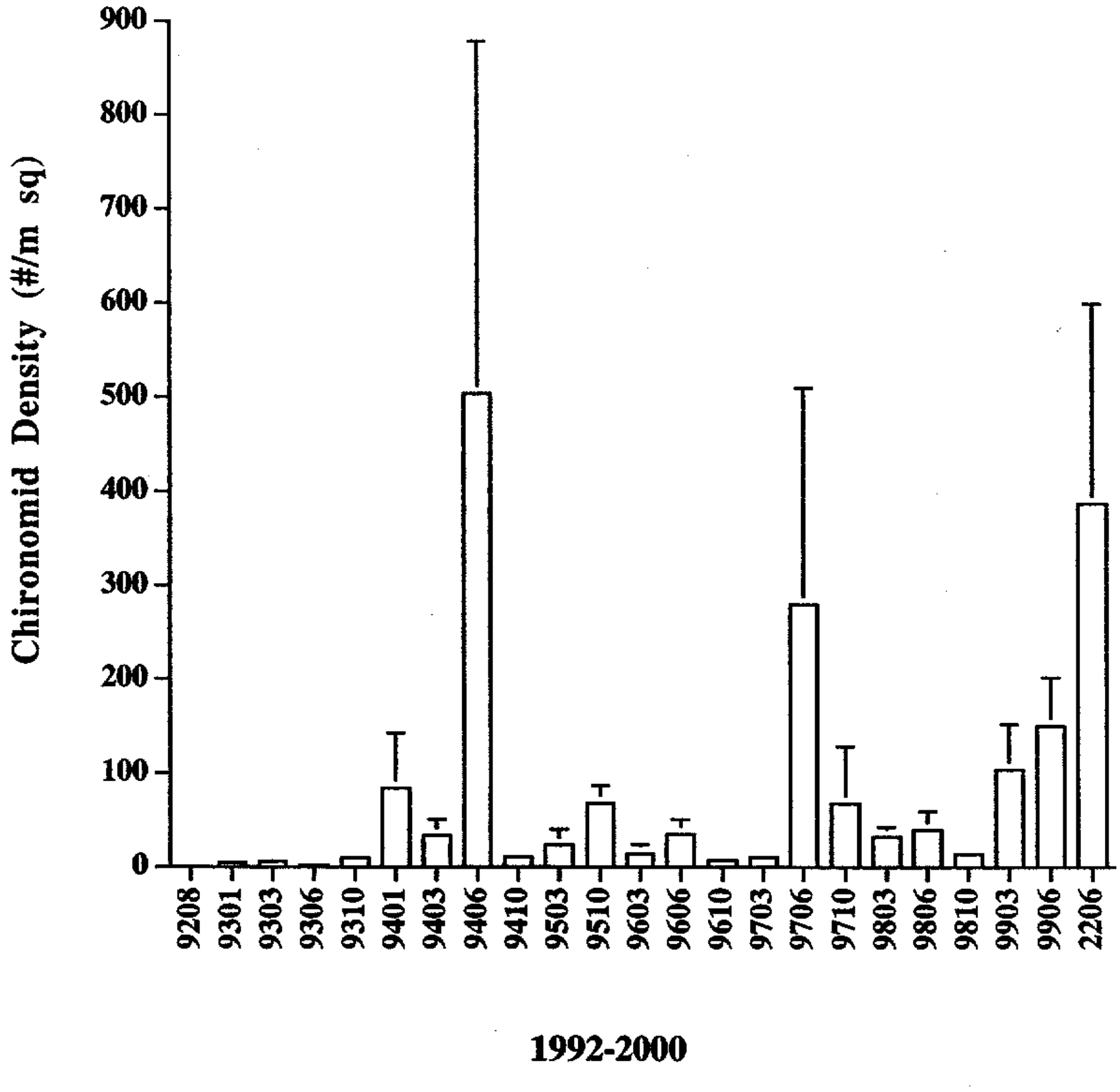

Figure 175. Chironomid densities (#/m sq) collected at Tanner Canyon pool Rkm 108.8 from August 1992 to June 2000. Error bars represent (± 1 SE, n=12).

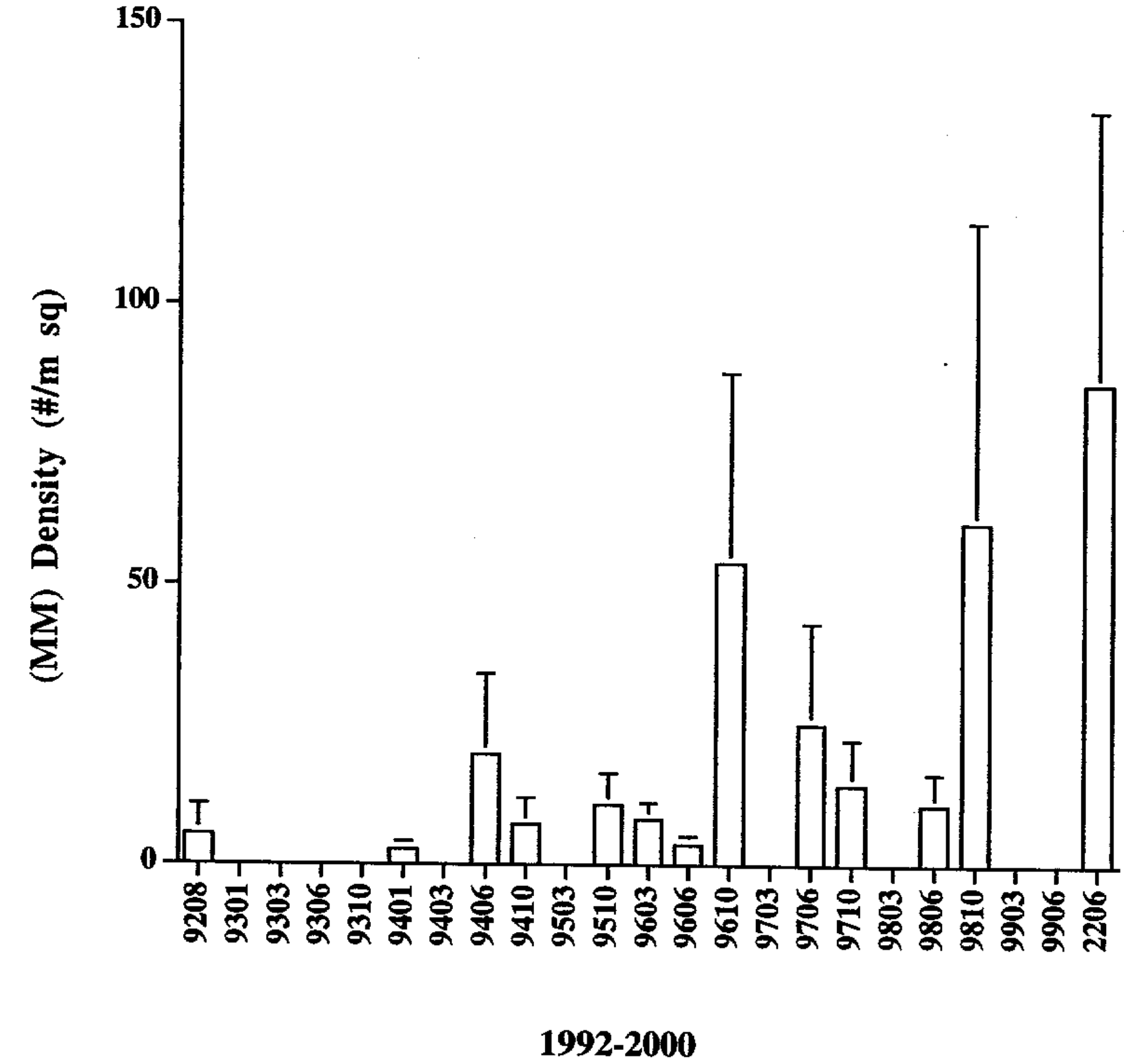

Figure 176. Miscellaneous invertebrate (MM) densities (#/m sq) collected at Tanner Canyon pool Rkm 108.8 from August 1992 to June 2000. Error bars represent (± 1 SE, n=12).

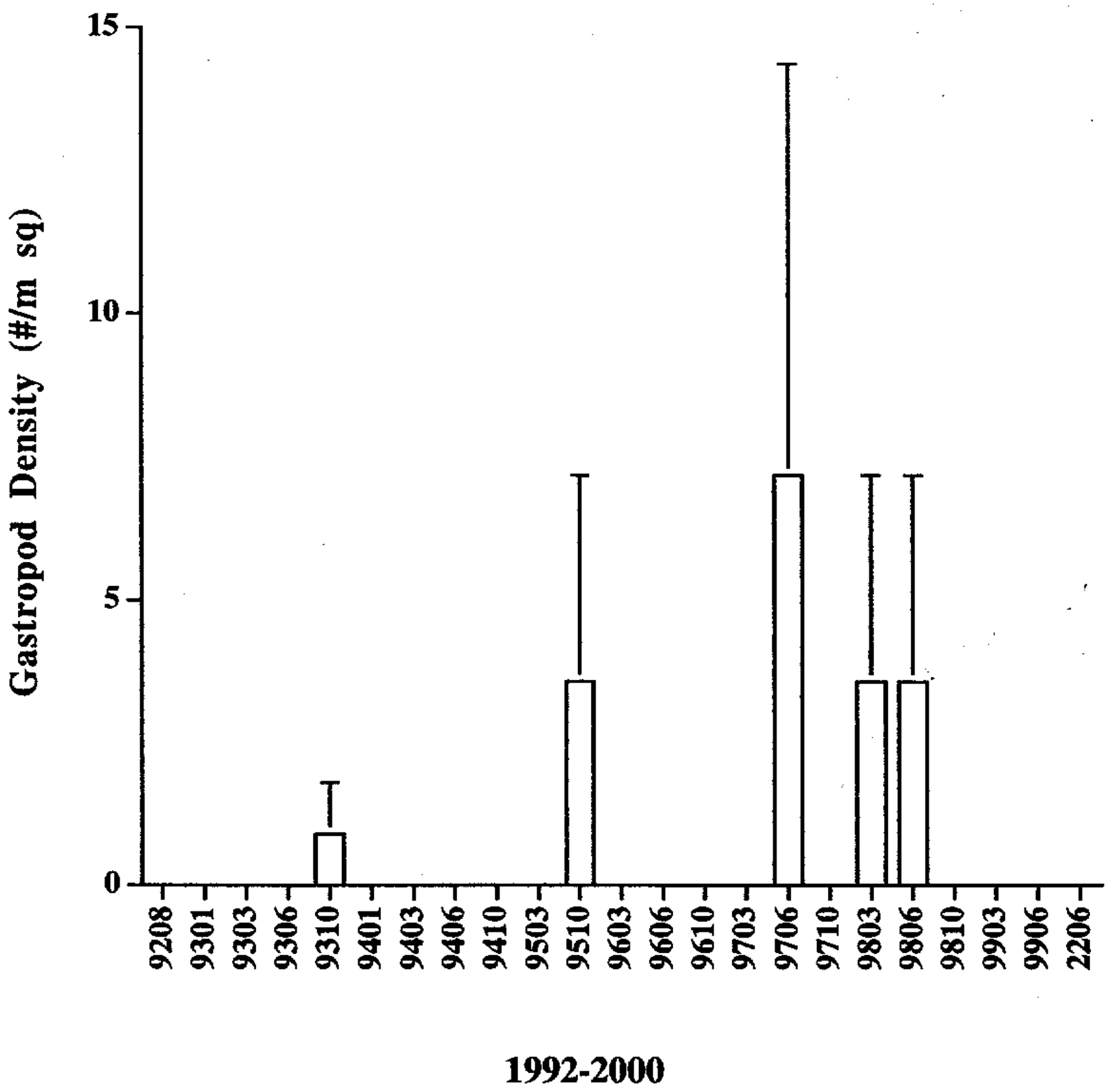

Figure 177. Gastropod densities (#/m sq) collected at Tanner Canyon pool Rkm 108.8 from August 1992 to June 2000. Error bars represent (± 1 SE, n=12).

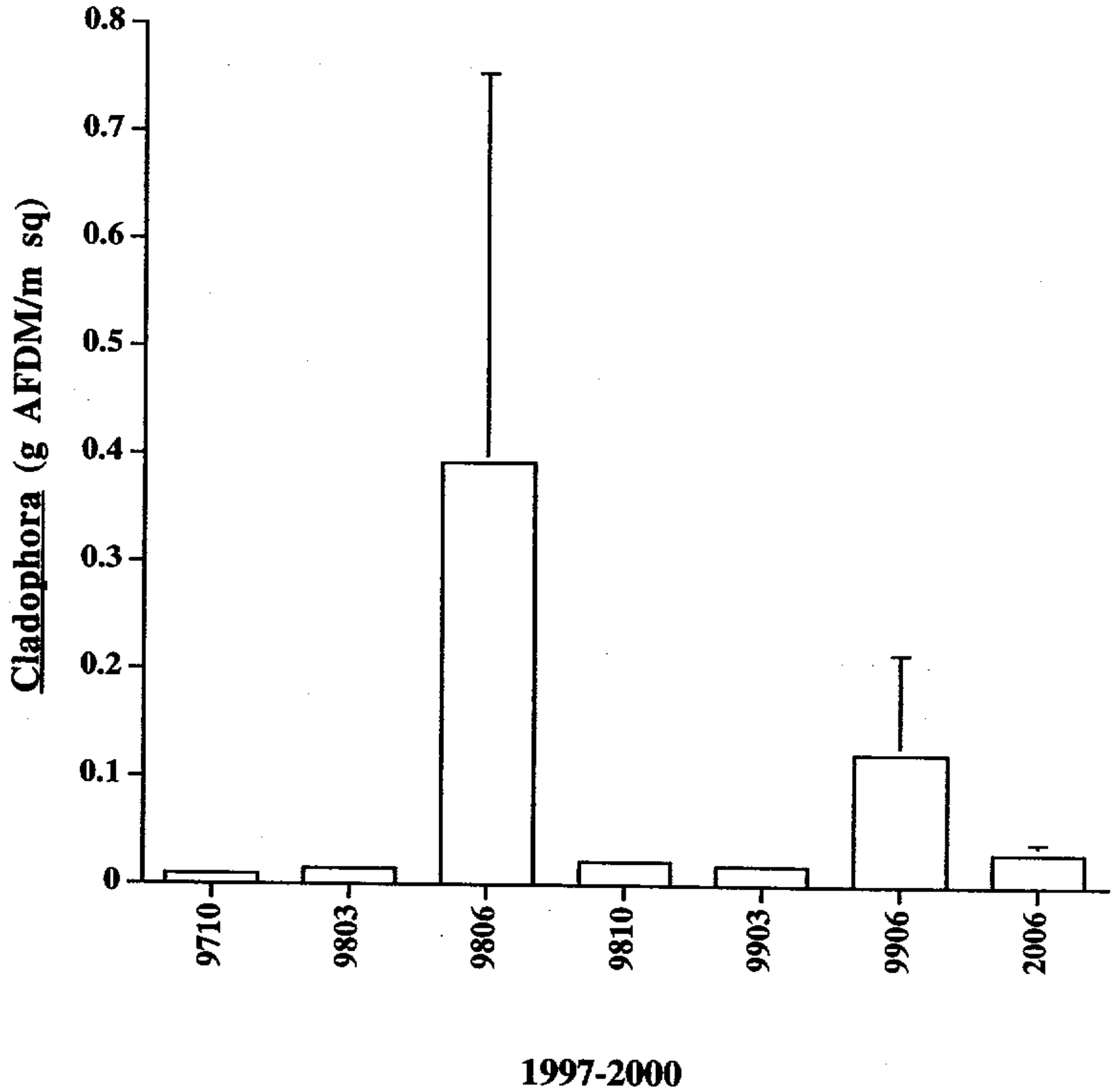

Figure 178. Cladophora biomass estimates (g AFDM/m sq) at Middle Granite Gorge pool Rkm 203.2 from October 1997 to June 2000. Error bars represent (± 1 SE, n=12).

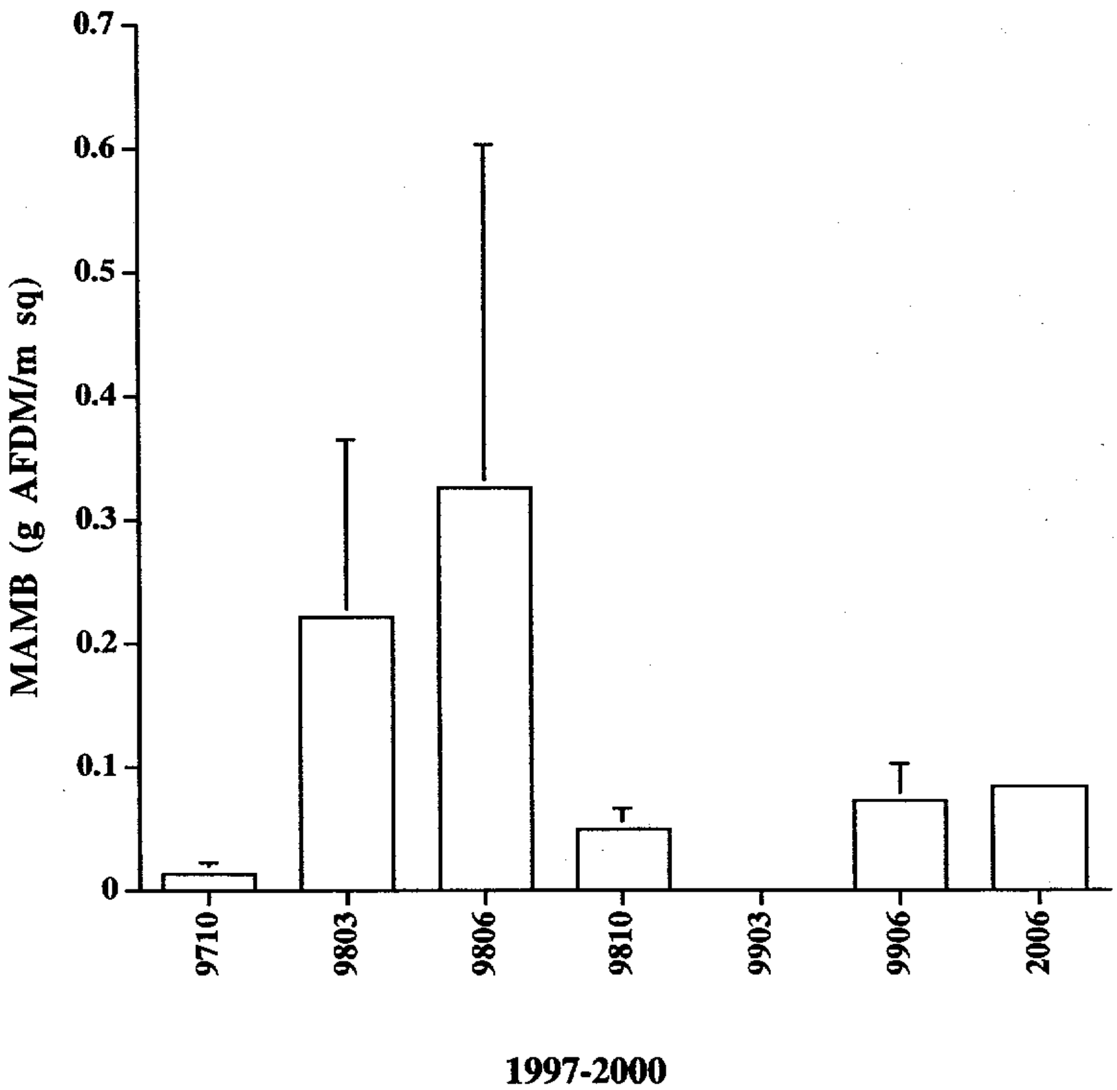

Figure 179. Miscellaneous algae, macrophytes and bryophytes (MAMB) biomass estimates (g AFDM/m sq) at Middle Granite Gorge pool Rkm 203.2 from October 1997 to June 2000. Error bars represent (± 1 SE, n=12).

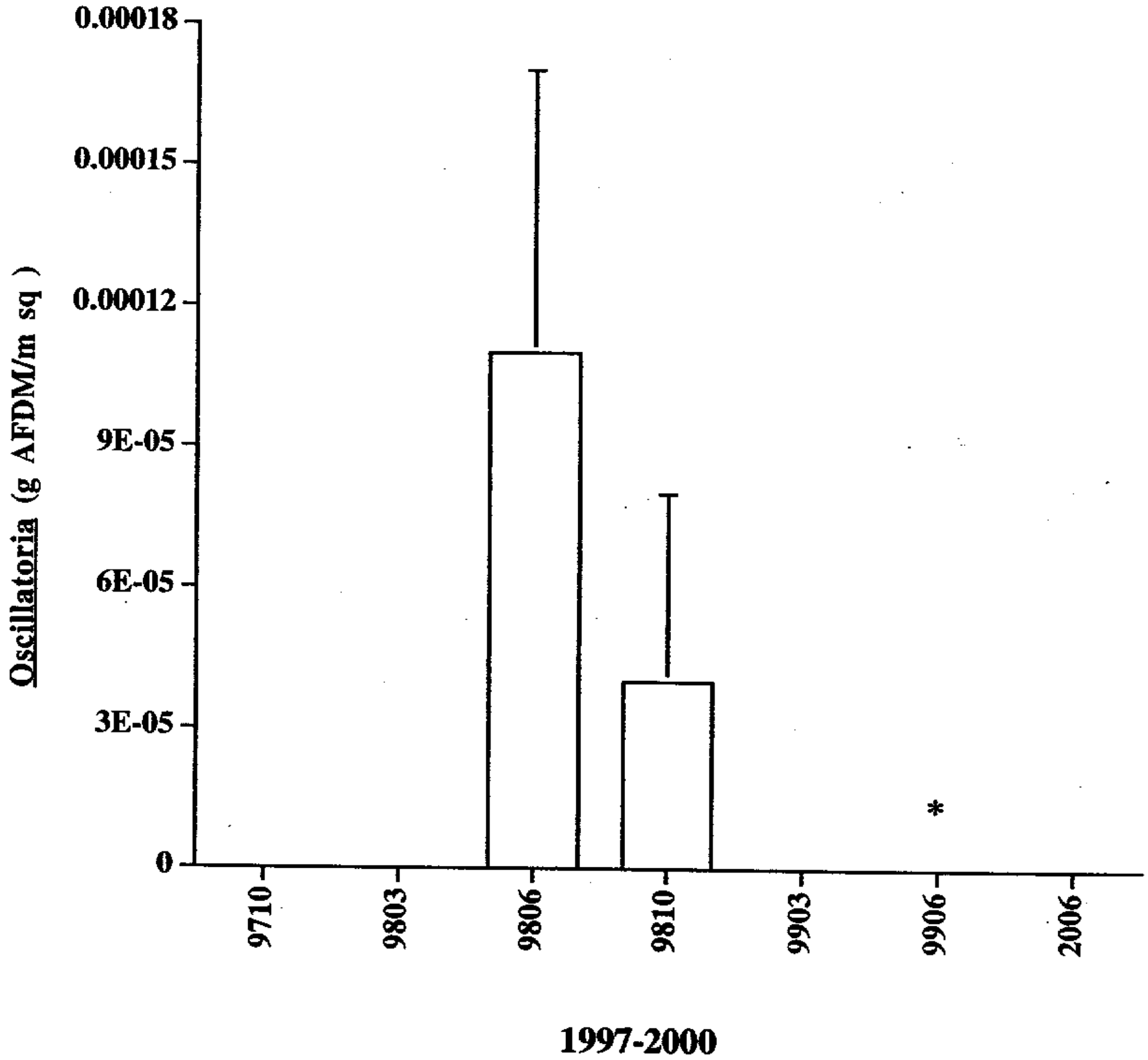

Figure 180. Oscillatoria spp. biomass estimates (g AFDM/m sq) at Middle Granite Gorge pool Rkm 203.2 from October 1997 to June 2000. Error bars represent (± 1 SE, n=12).

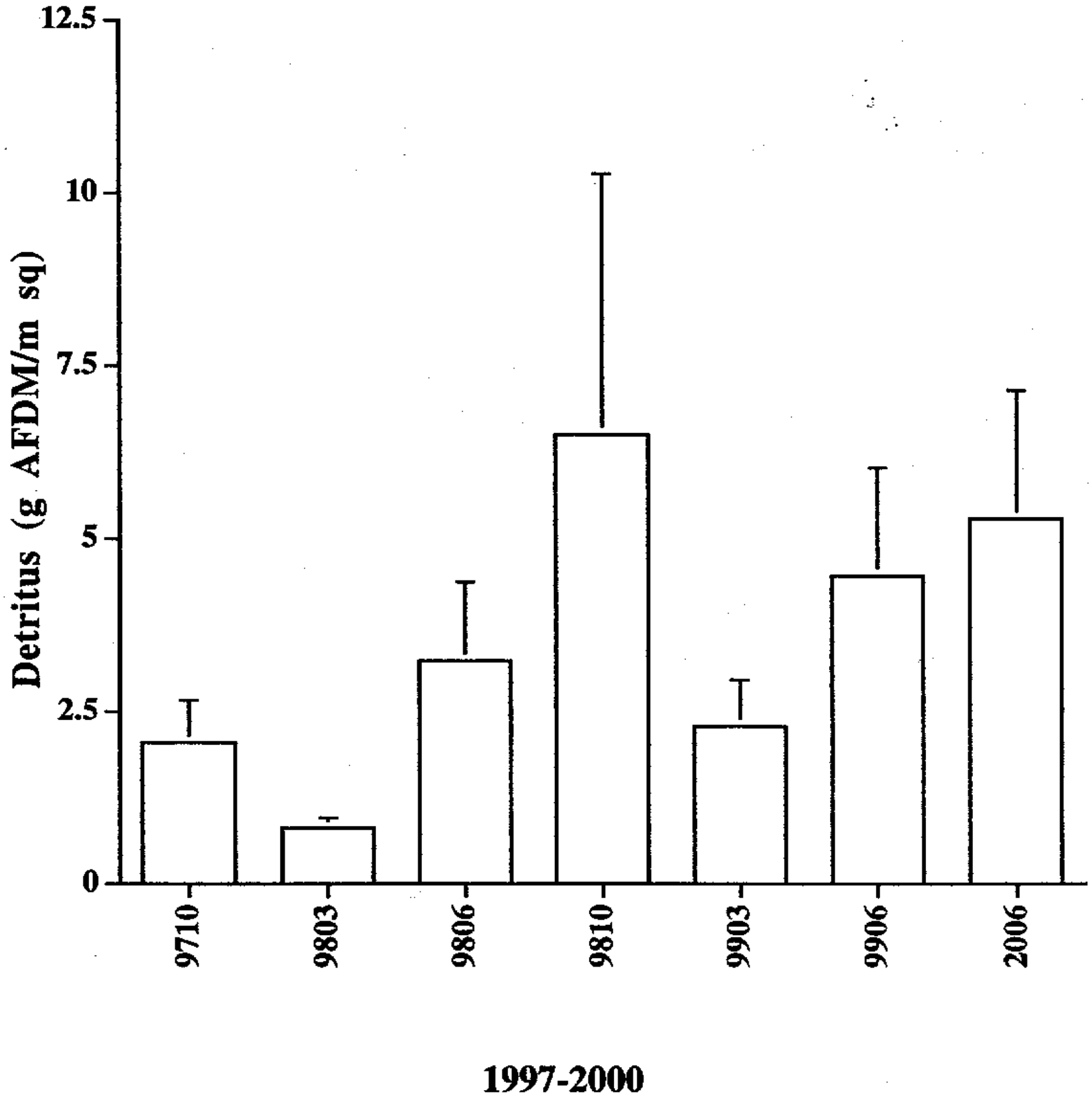

Figure 181. Detritus biomass estimates (g AFDM/m sq) at Middle Granite Gorge pool Rkm 203.2 from October 1997 to June 2000. Error bars represent ($\pm$ 1 SE, n=12).

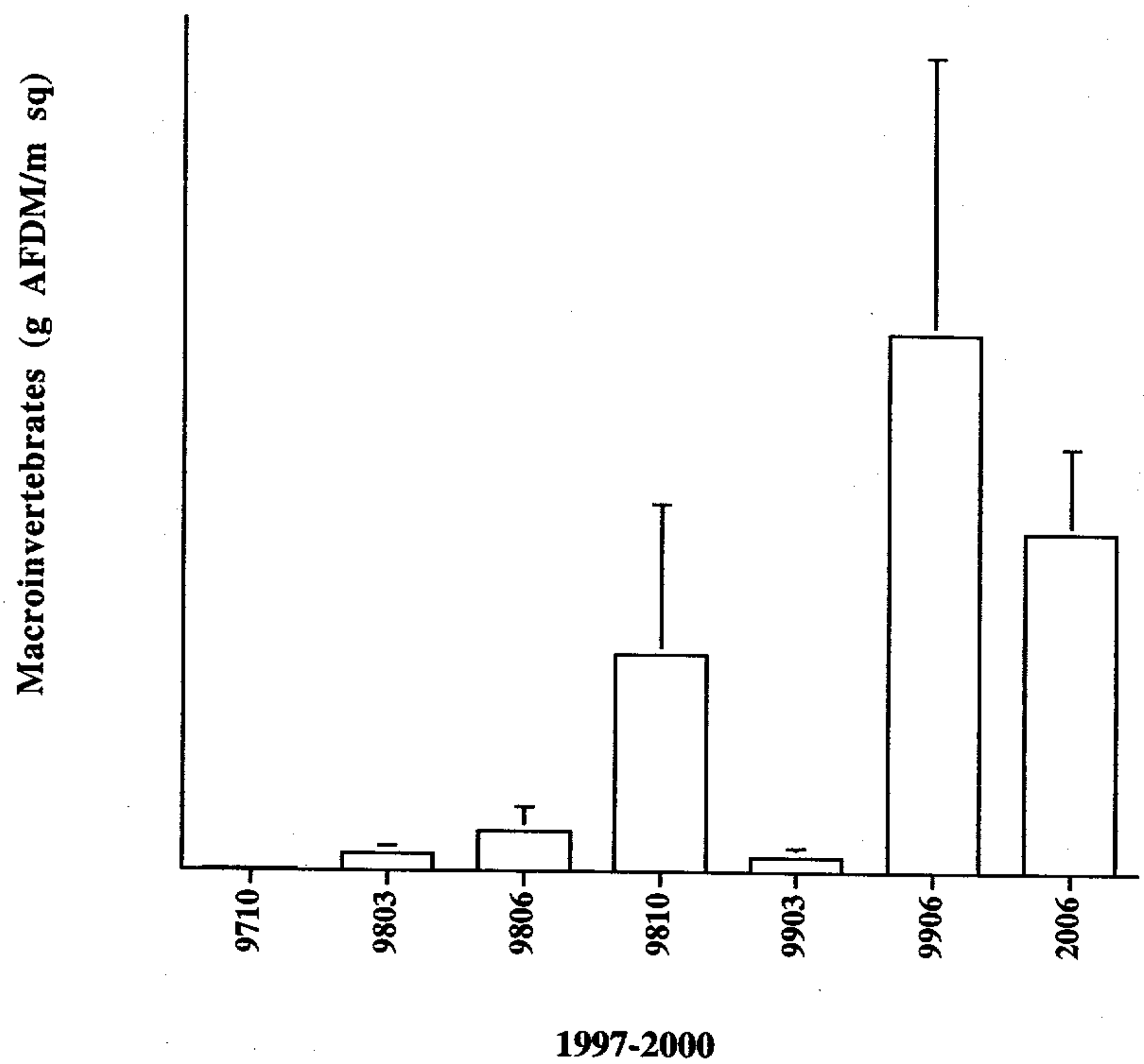

Figure 182. Macroinvertebrate biomass estimates (g AFDM/m sq) at Middle Granite Gorge pool Rkm 203.2 from October 1997 to June 2000. Error bars represent (± 1 SE, n=12).

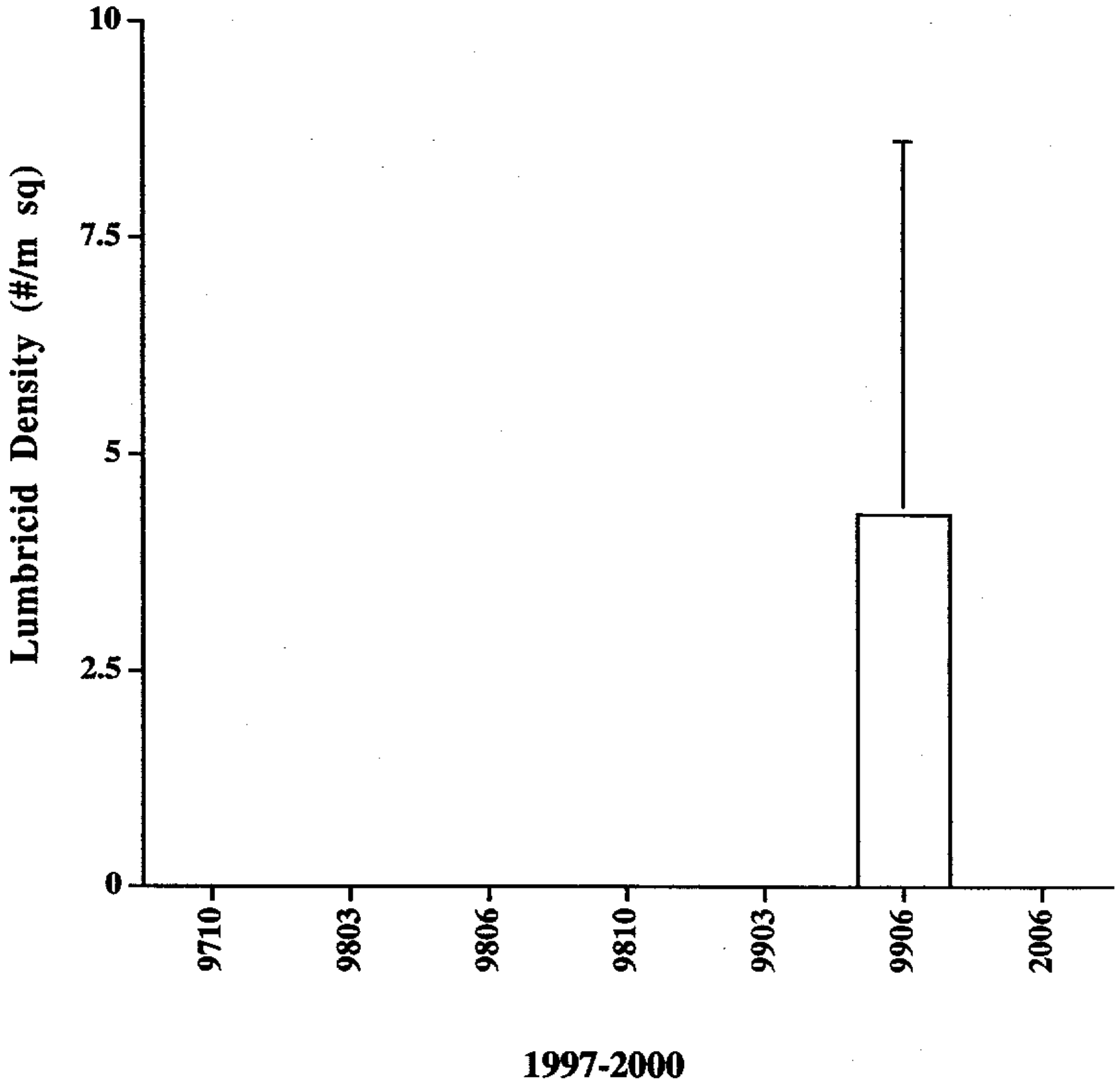

Figure 183. Lumbricid densities (#/m sq) collected at Middle Granite Gorge pool Rkm 203.2 from October 1997 to June 2000. Error bars represent (± 1 SE, n=12).

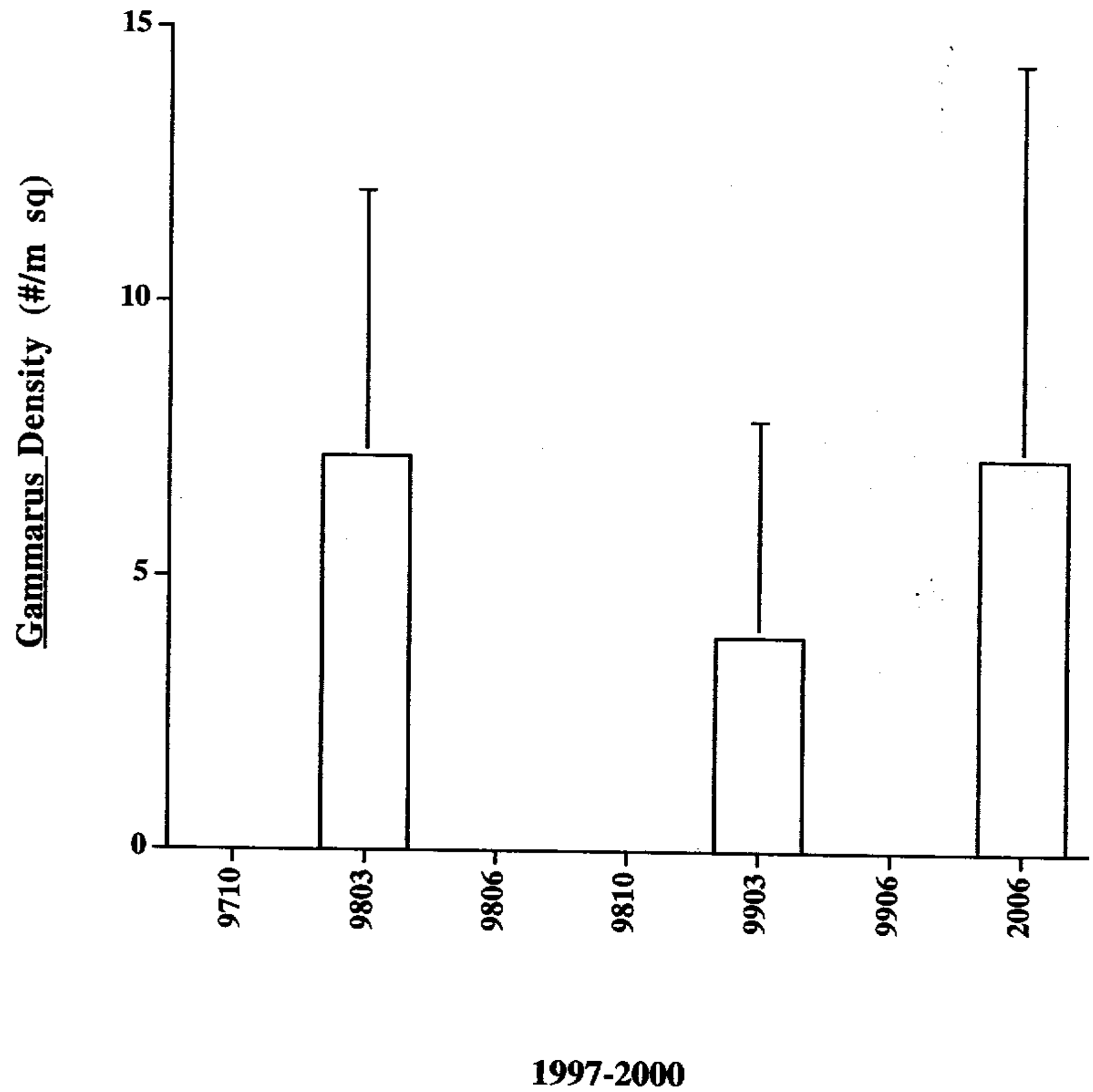

Figure 184. Gammarus densities (#/m sq) collected at Middle Granite Gorge pool Rkm 203.2 from October 1997 to June 2000. Error bars represent (± 1 SE, n=12).

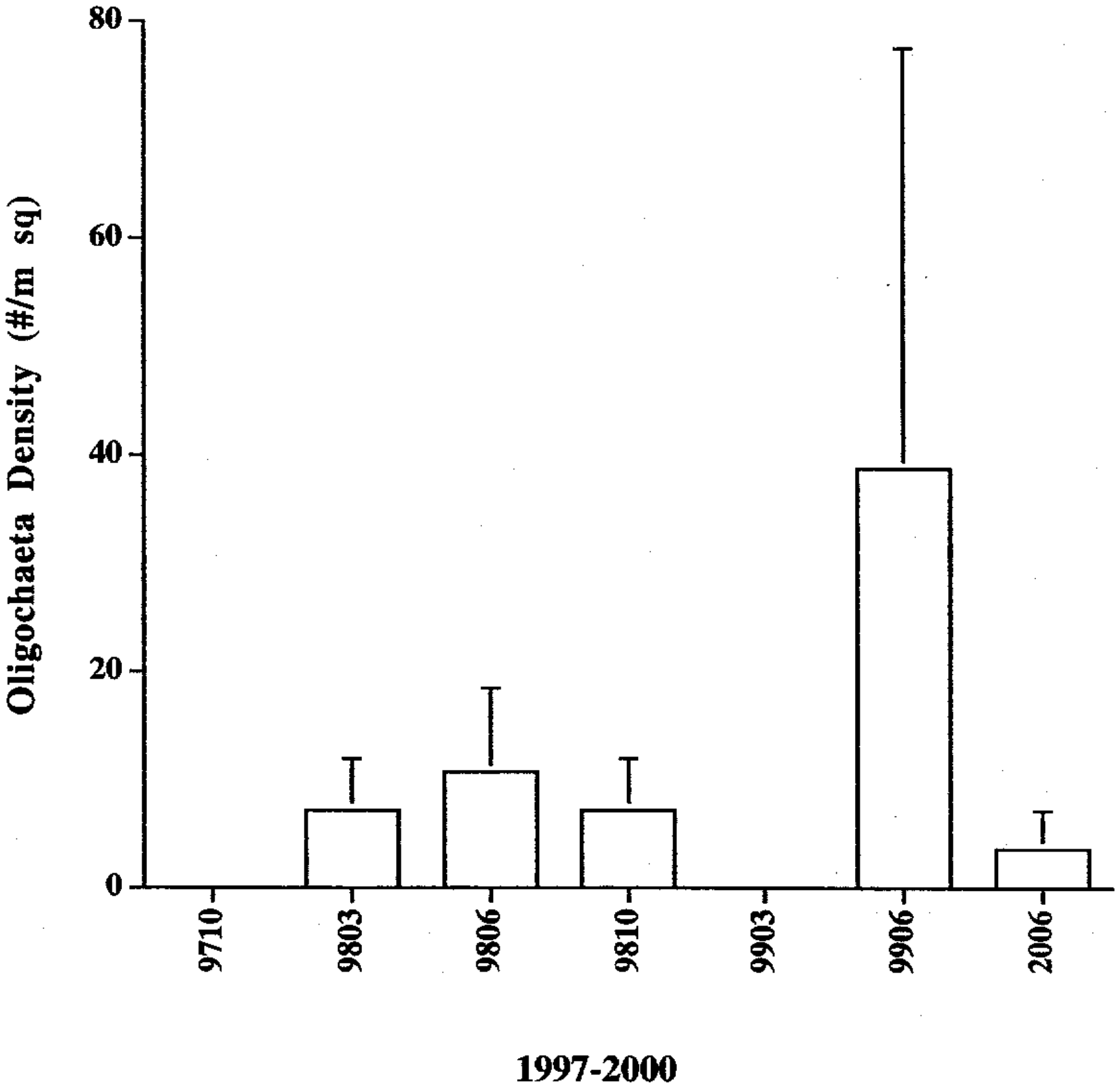

Figure 185. Oligochaeta densities (#/m sq) collected at Middle Granite Gorge pool Rkm 203.2 from October 1997 to June 2000. Error bars represent (± 1 SE, n=12).

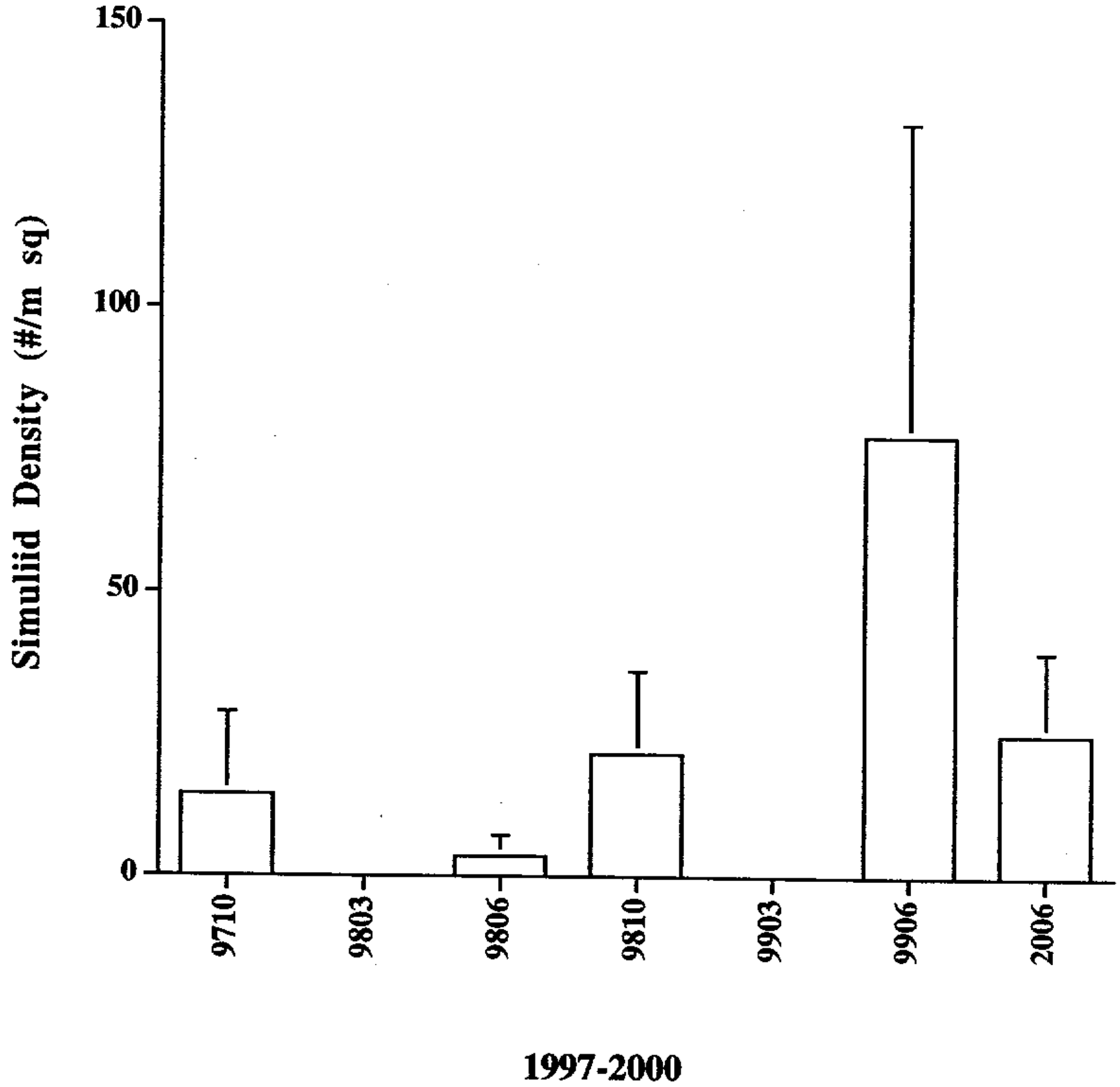

Figure 186. Simuliid densities (#/m sq) collected at Middle Granite Gorge pool Rkm 203.2 from October 1997 to June 2000. Error bars represent (± 1 SE, n=12).

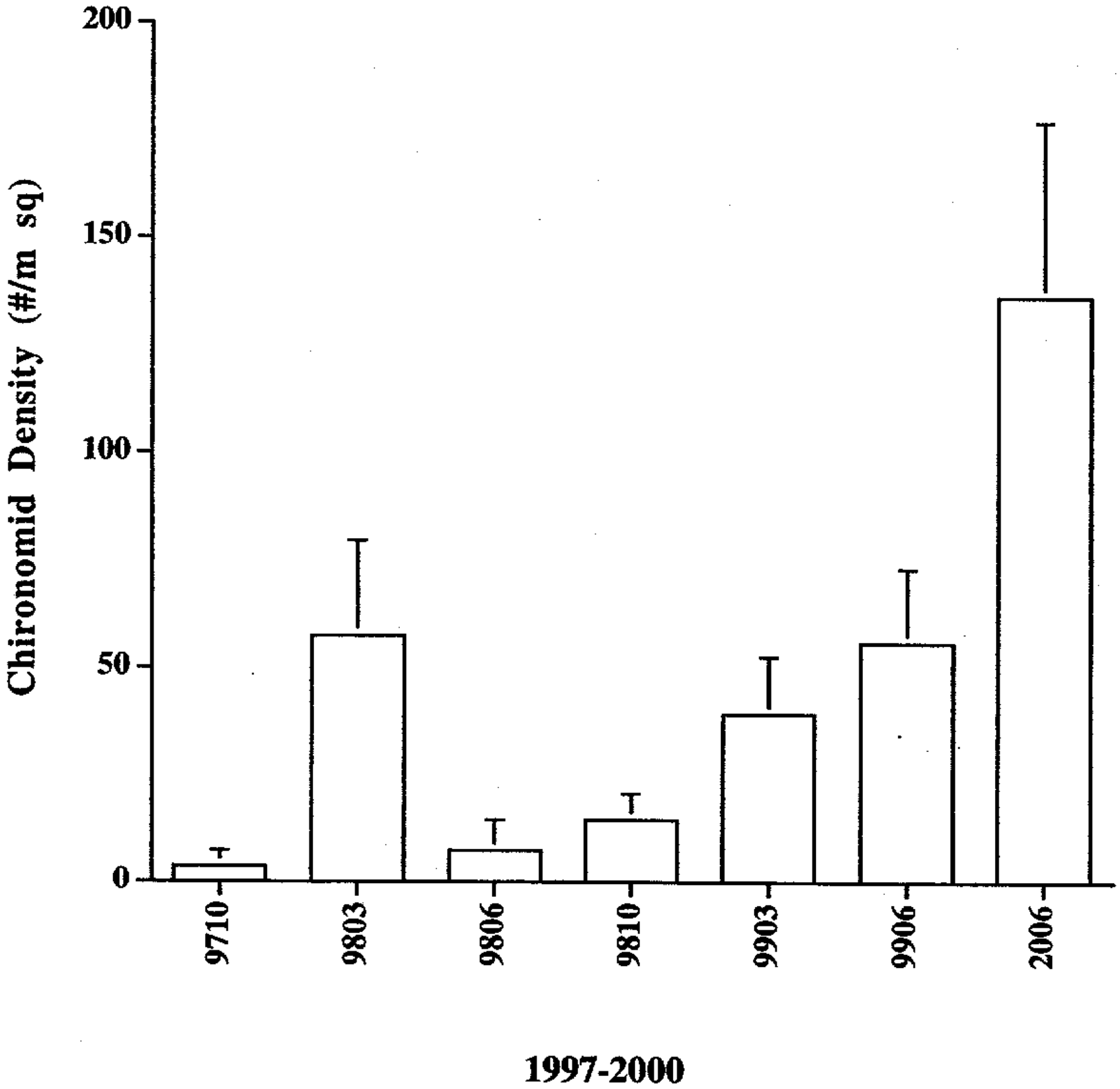

Figure 187. Chironomid densities (#/m sq) collected at Middle Granite Gorge pool Rkm 203.2 from October 1997 to June 2000. Error bars represent (± 1 SE, n=12).

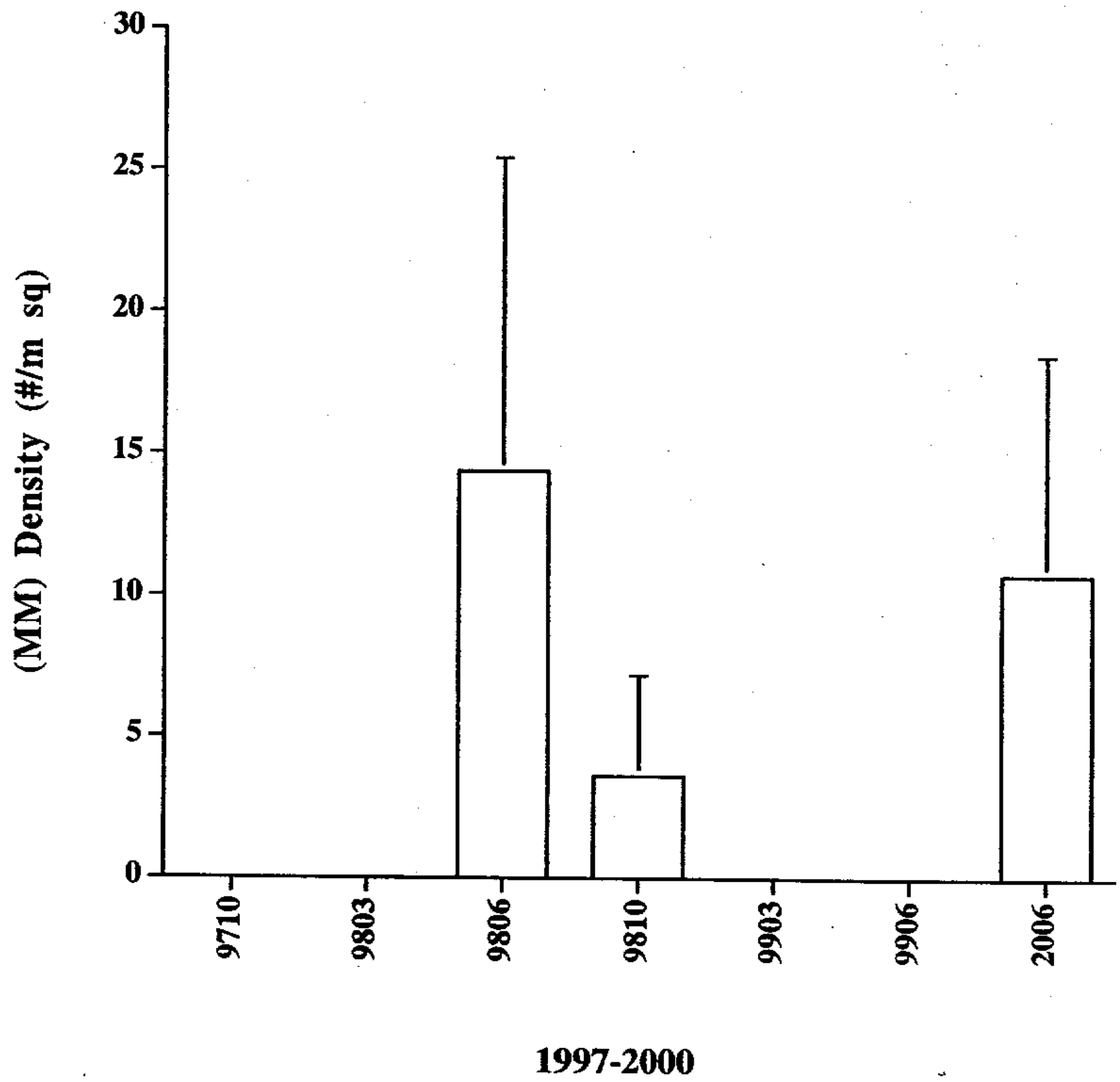

Figure 188. Miscellaneous invertebrate (MM) densities (#/m sq) collected at Middle Granite Gorge pool Rkm 203.2 from October 1997 to June 2000. Error bars represent (± 1 SE, n=12).

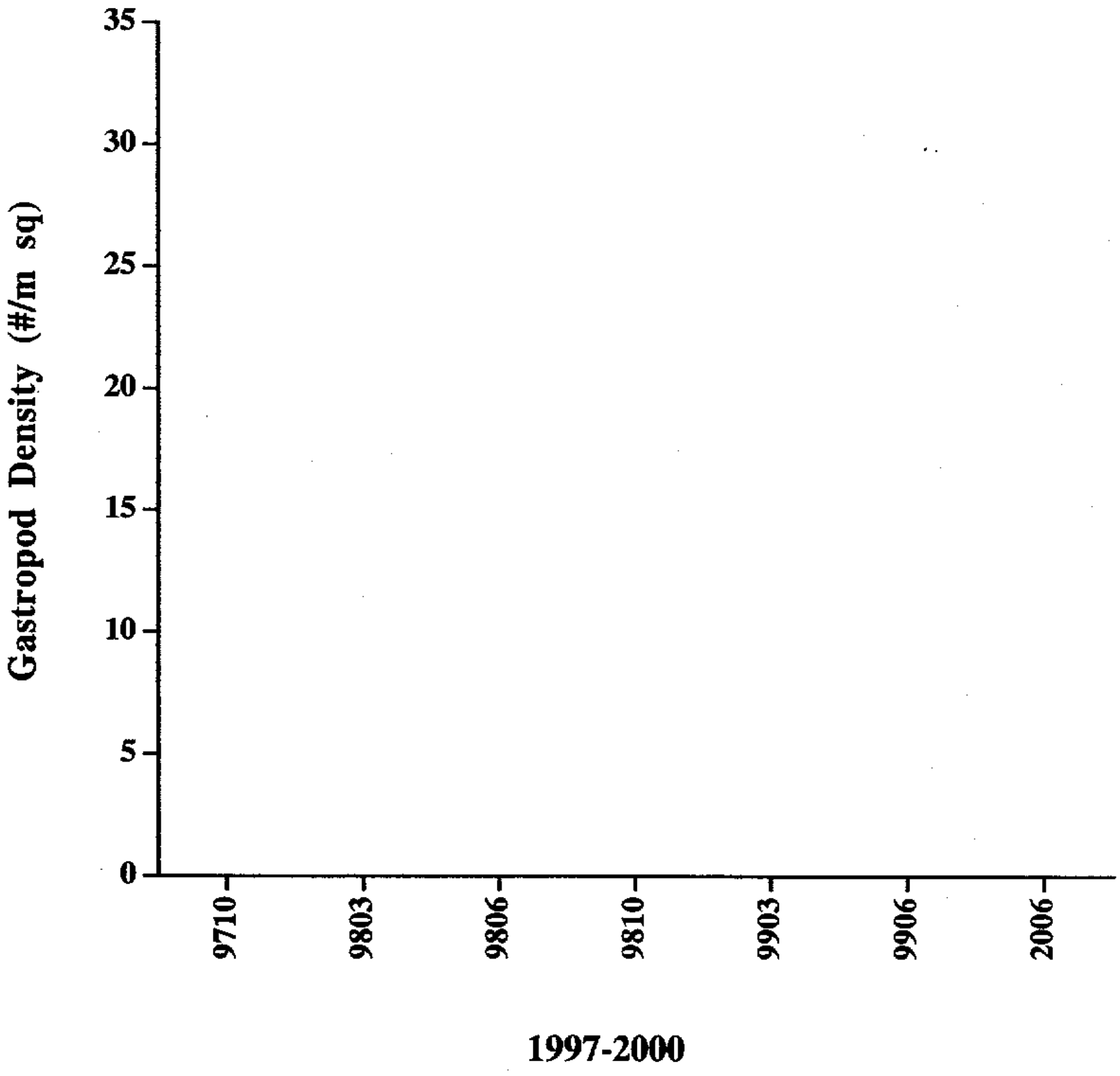

Figure 189. Gastropod densities (#/m sq) collected at Middle Granite Gorge pool Rkm 203.2 from October 1997 to June 2000. No abundances of Gastropods were present during these collection dates.

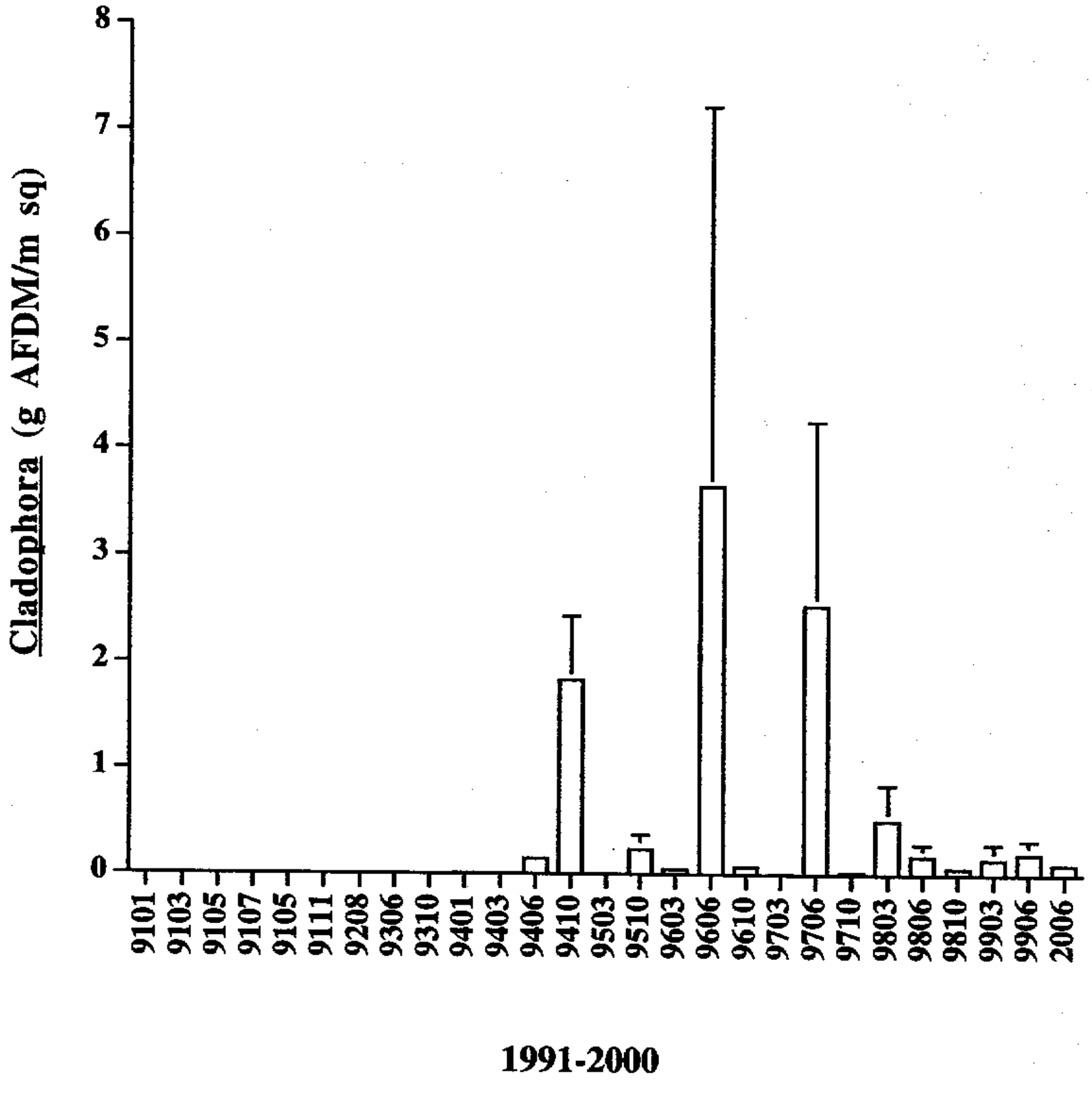

Figure 190. Cladophora biomass estimates (g AFDM/m sq) at Spring Canyon pool Rkm 326.4 from January 1991 to June 2000. Error bars represent (± 1 SE, n=12).

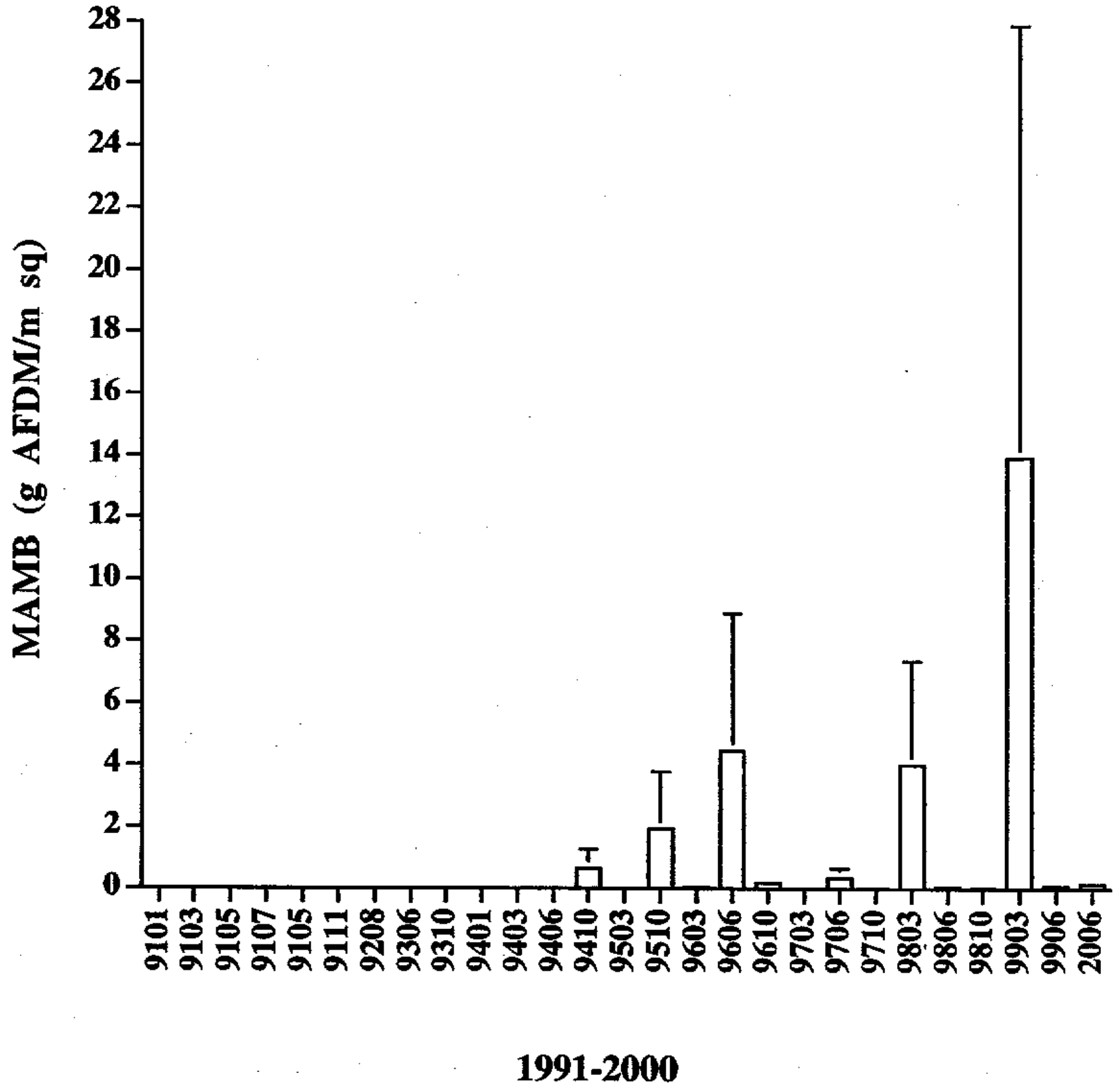

Figure 191. Miscellaneous algae, macrophytes and bryophytes (MAMB) biomass estimates (g AFDM/m sq) at Spring Canyon pool Rkm 326.4 from January 1991 to June 2000. MAMB was not collected prior to August 1992. Error bars represent (± 1 SE, n=12).

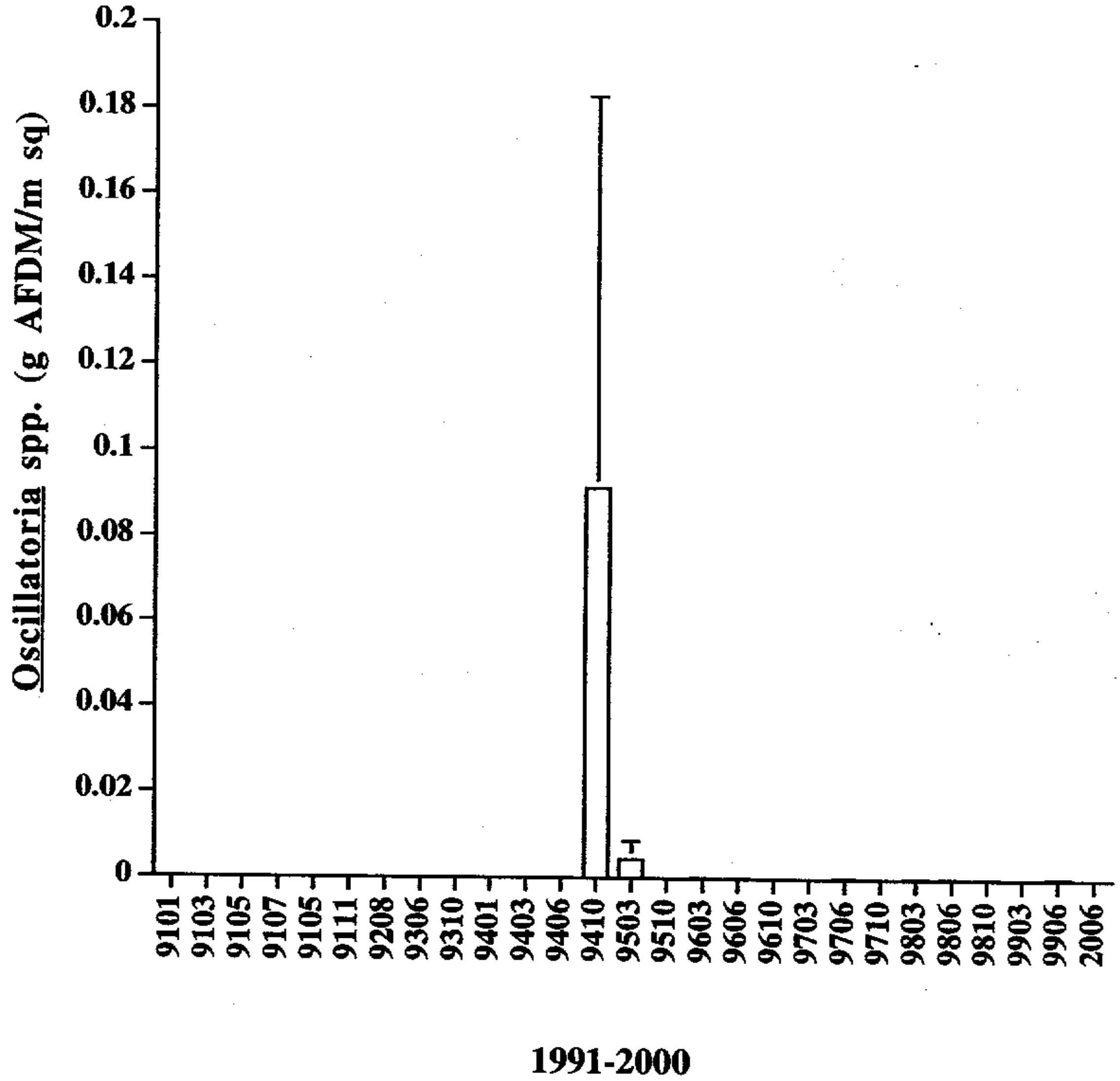

Figure 192. Oscillatoria spp. biomass estimates (g AFDM/m sq) at Spring Canyon pool Rkm 326.4 from January 1991 to June 2000. Error bars represent (± 1 SE, n=12).

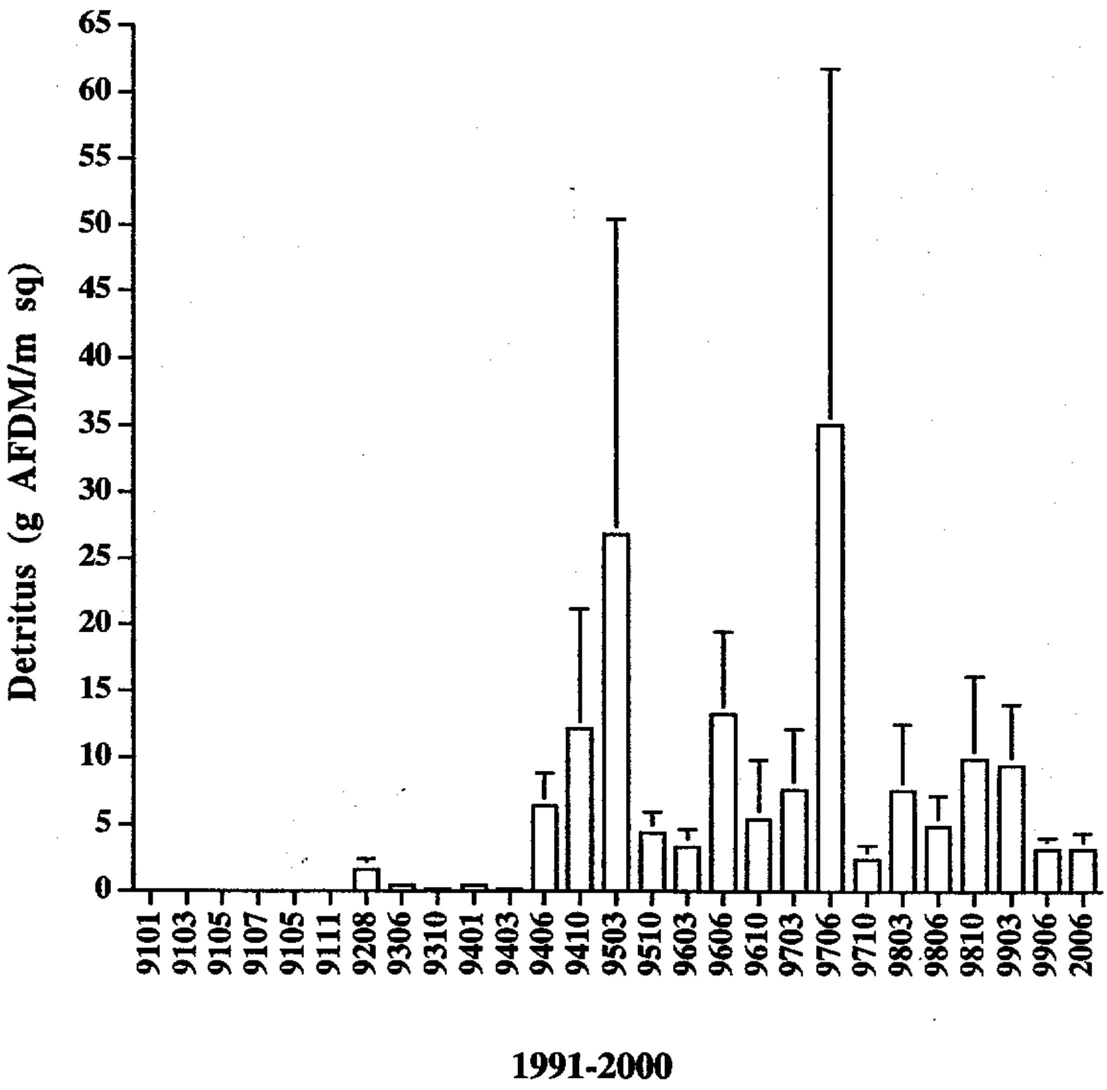

Figure 193. Detritus biomass estimates (g AFDM/m sq) at Spring Canyon pool Rkm 326.4 from January 1991 to June 2000. Error bars represent (± 1 SE, n=12).

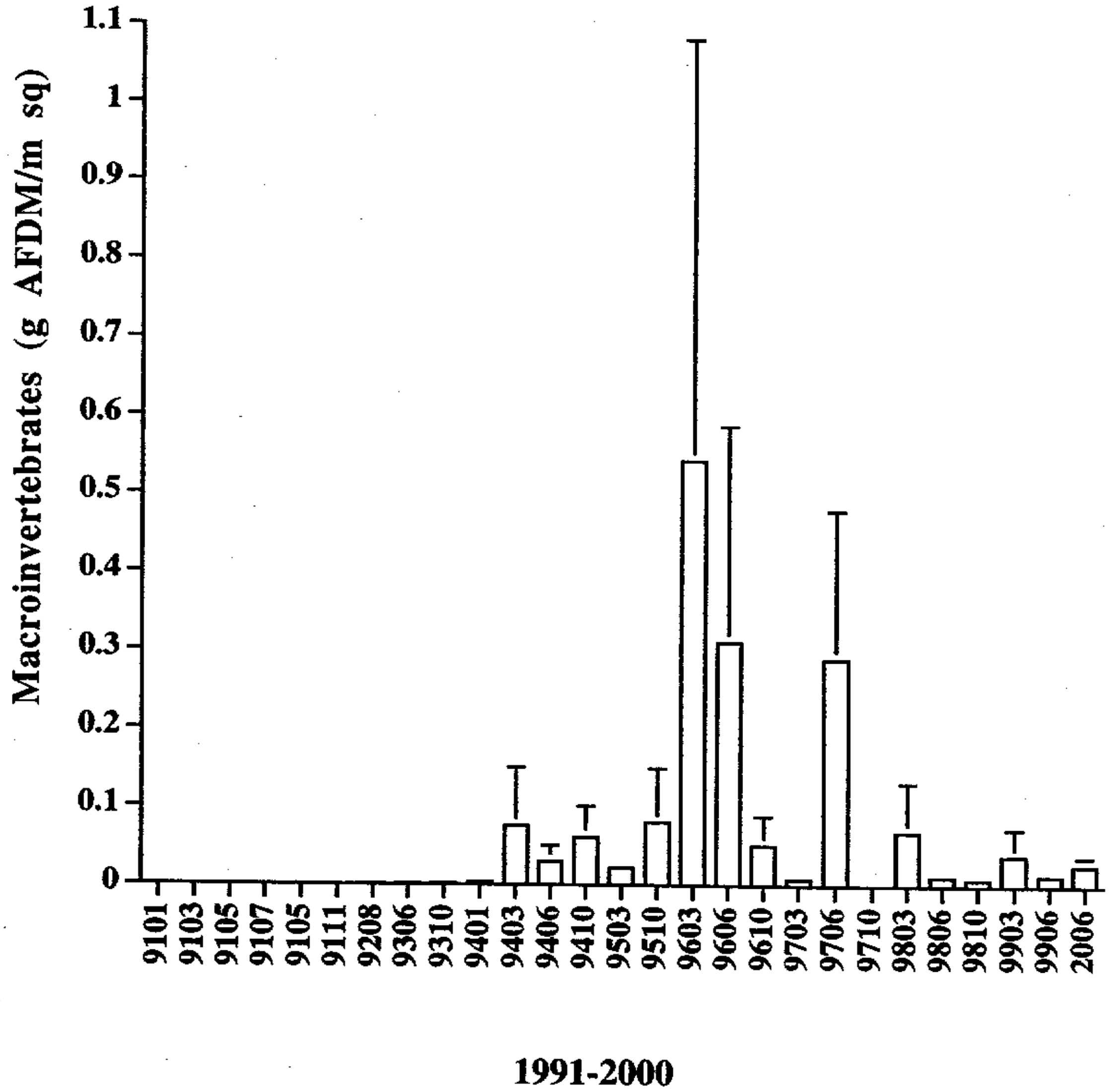

Figure 194. Macroinvertebrate biomass estimates (g AFDM/m sq) at Spring Canyon pool Rkm 326.4 from January 1991 to June 2000. Error bars represent (± 1 SE, n=12).

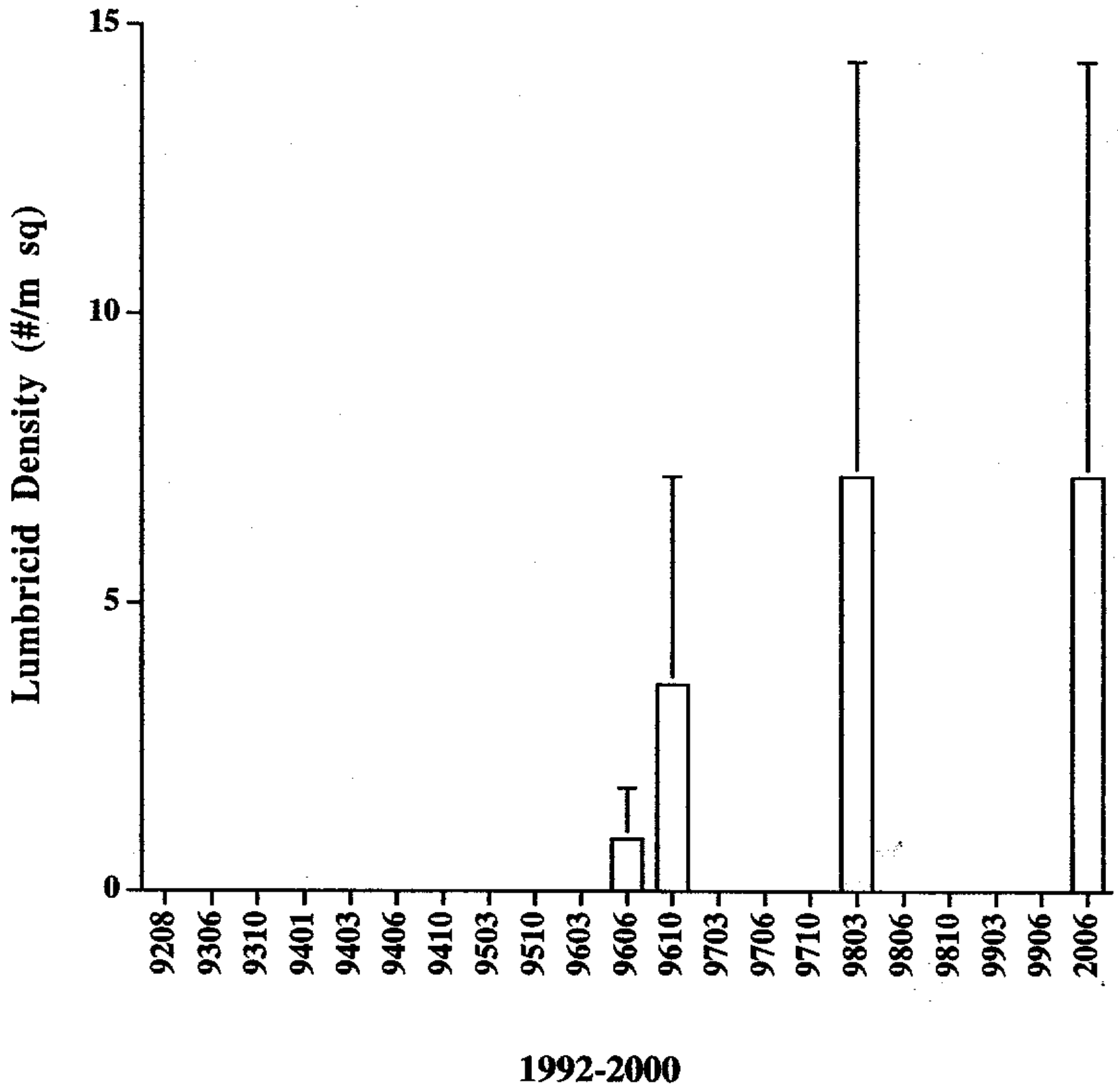

Figure 195. Lumbricid densities (#/m sq) collected at Spring Canyon pool Rkm 326.4 from August 1992 to June 2000. Error bars represent (± 1 SE, n=12).

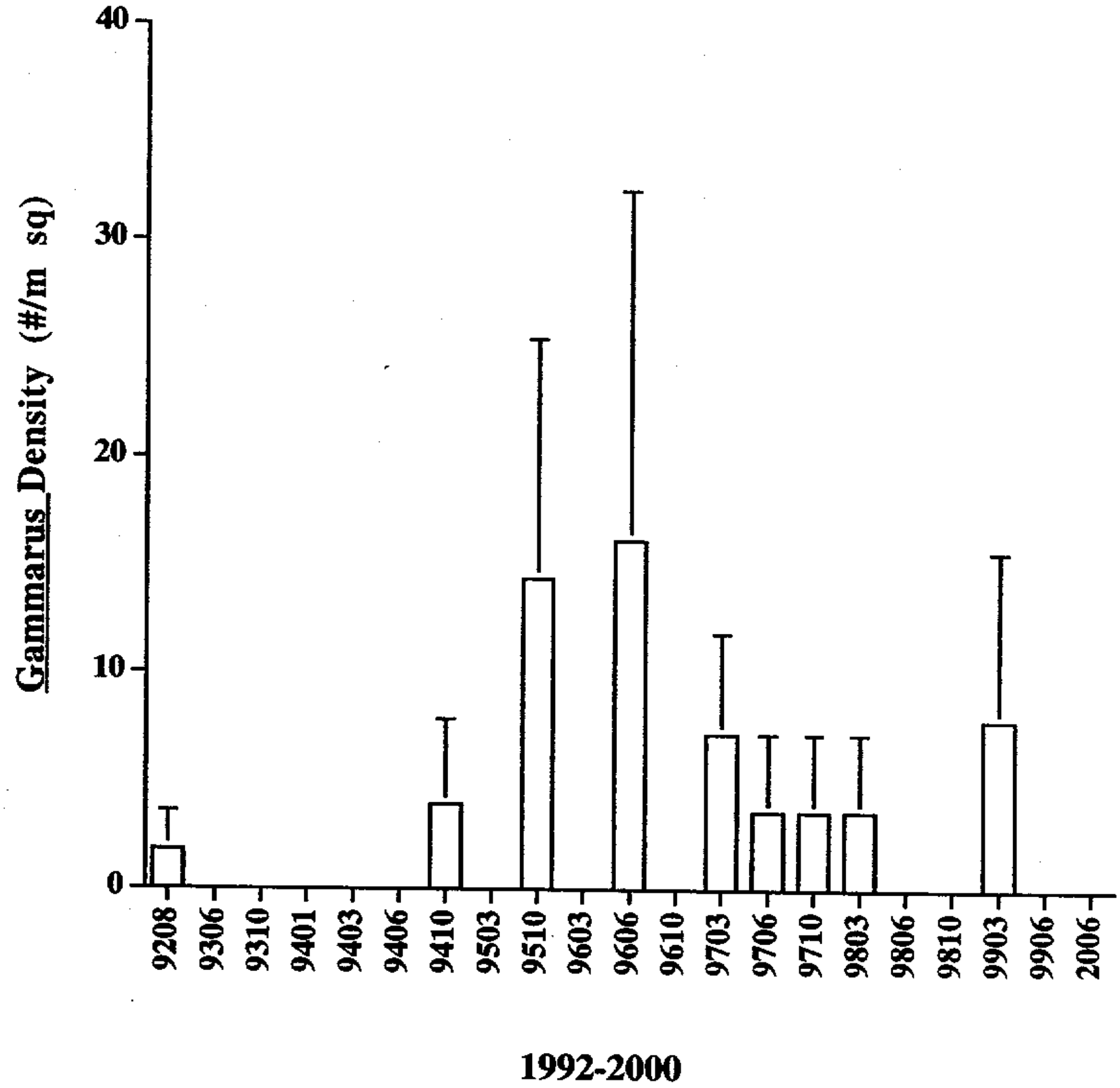

Figure 196. Gammarus densities (#/m sq) collected at Spring Canyon pool Rkm 326.4 from August 1992 to June 2000. Error bars represent (± 1 SE, n=12).

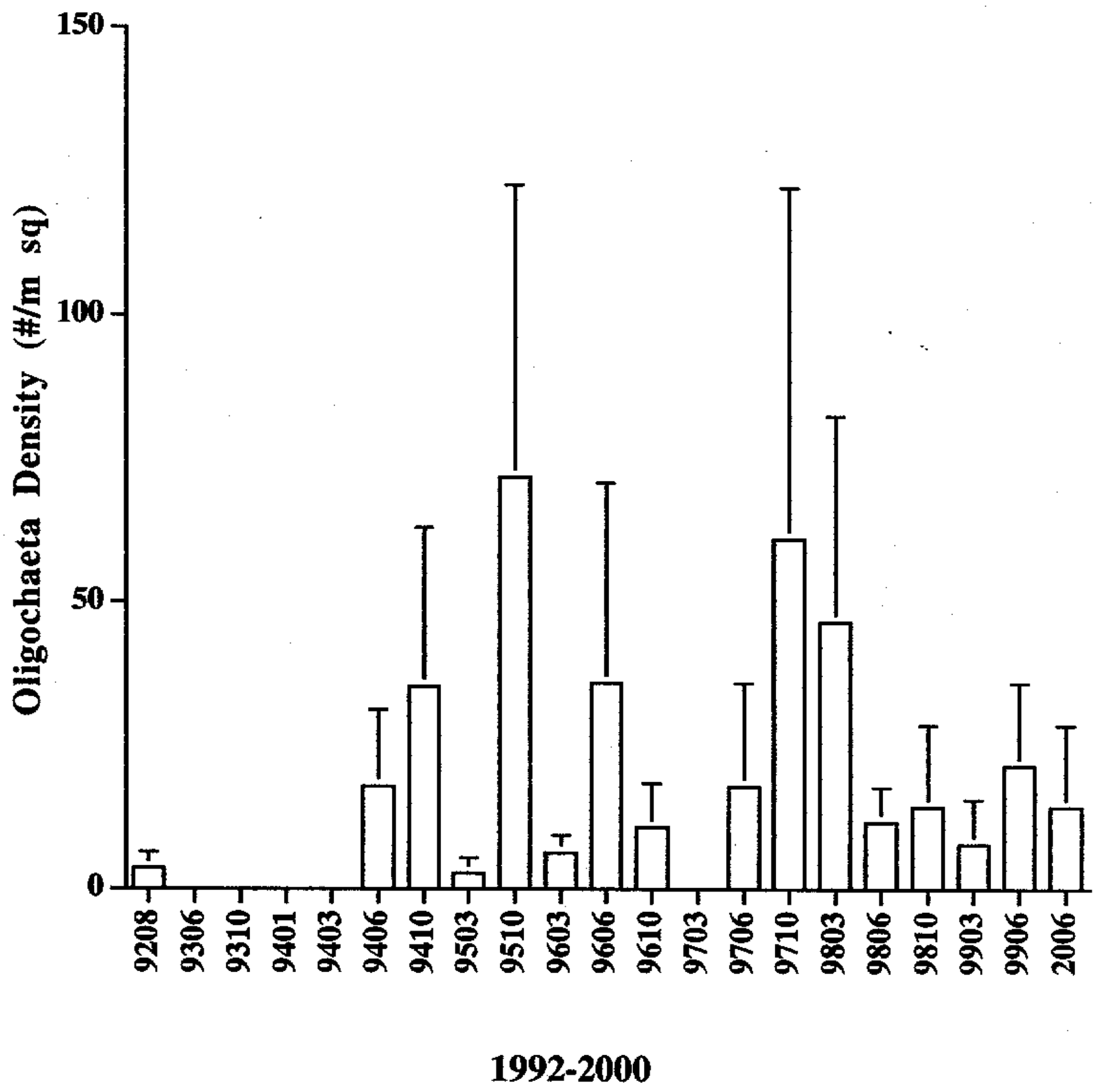

Figure 197. Oligochaeta densities (#/m sq) collected at Spring Canyon pool Rkm 326.4 from August 1992 to June 2000. Error bars represent (± 1 SE, n=12).

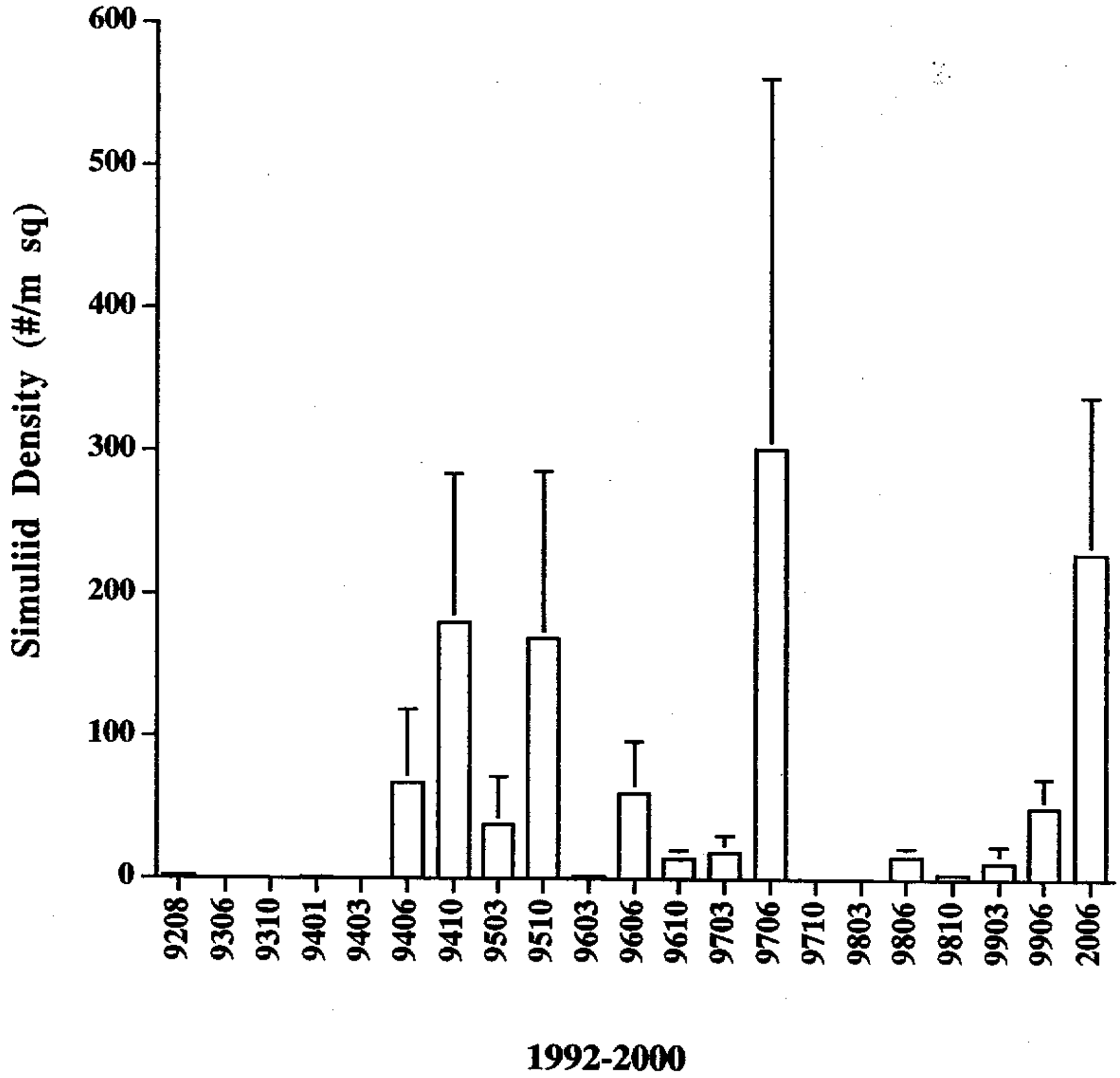

Figure 198. Simuliid densities (#/m sq) collected at Spring Canyon pool Rkm 326.4 from August 1992 to June 2000. Error bars represent (± 1 SE, n=12).

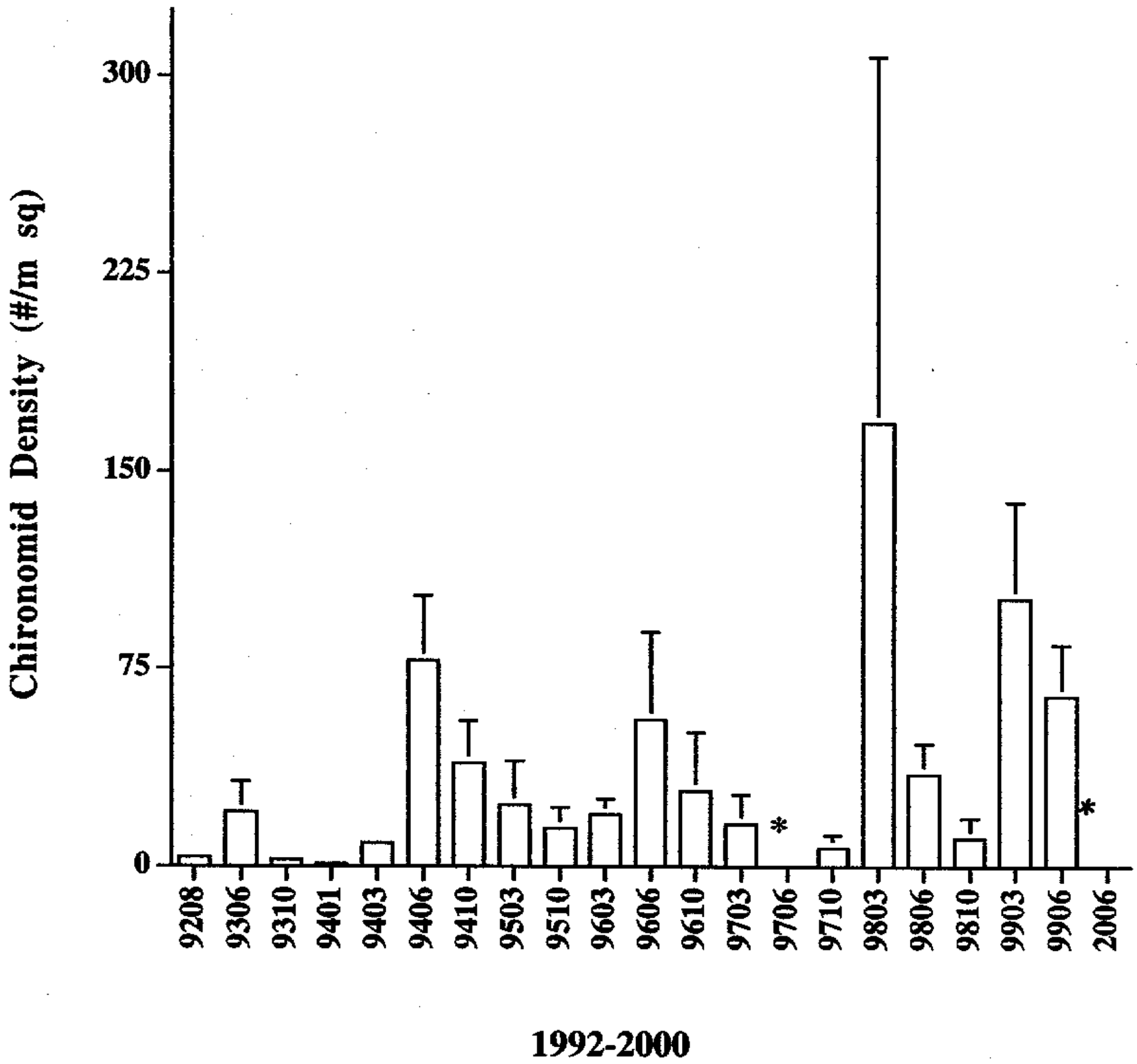

Figure 199. Chironomid densities (#/m ^{2} sq) collected at Spring Canyon pool Rkm 326.4 from August 1992 to June 2000. Error bars represent (± 1 SE, n=12). Asterisk (*) represents 563/m ^{2} sq (± 318 SE) and at 2006 represents 194/m sq (± 134 SE).

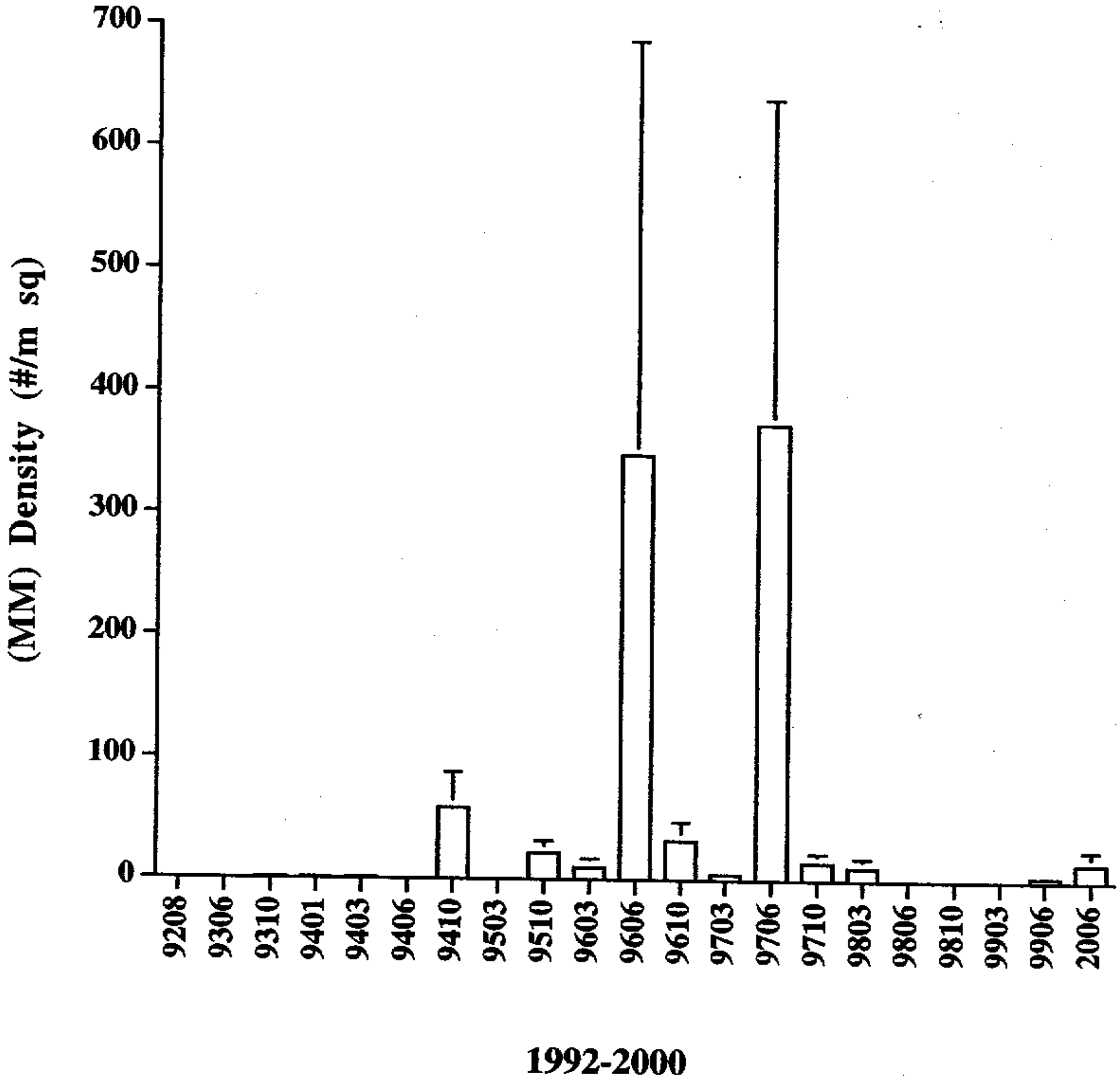

Figure 200. Miscellaneous invertebrate (MM) densities (#/m sq) collected at Spring Canyon pool Rkm 326.4 from August 1992 to June 2000. Error bars represent (± 1 SE, n=12).

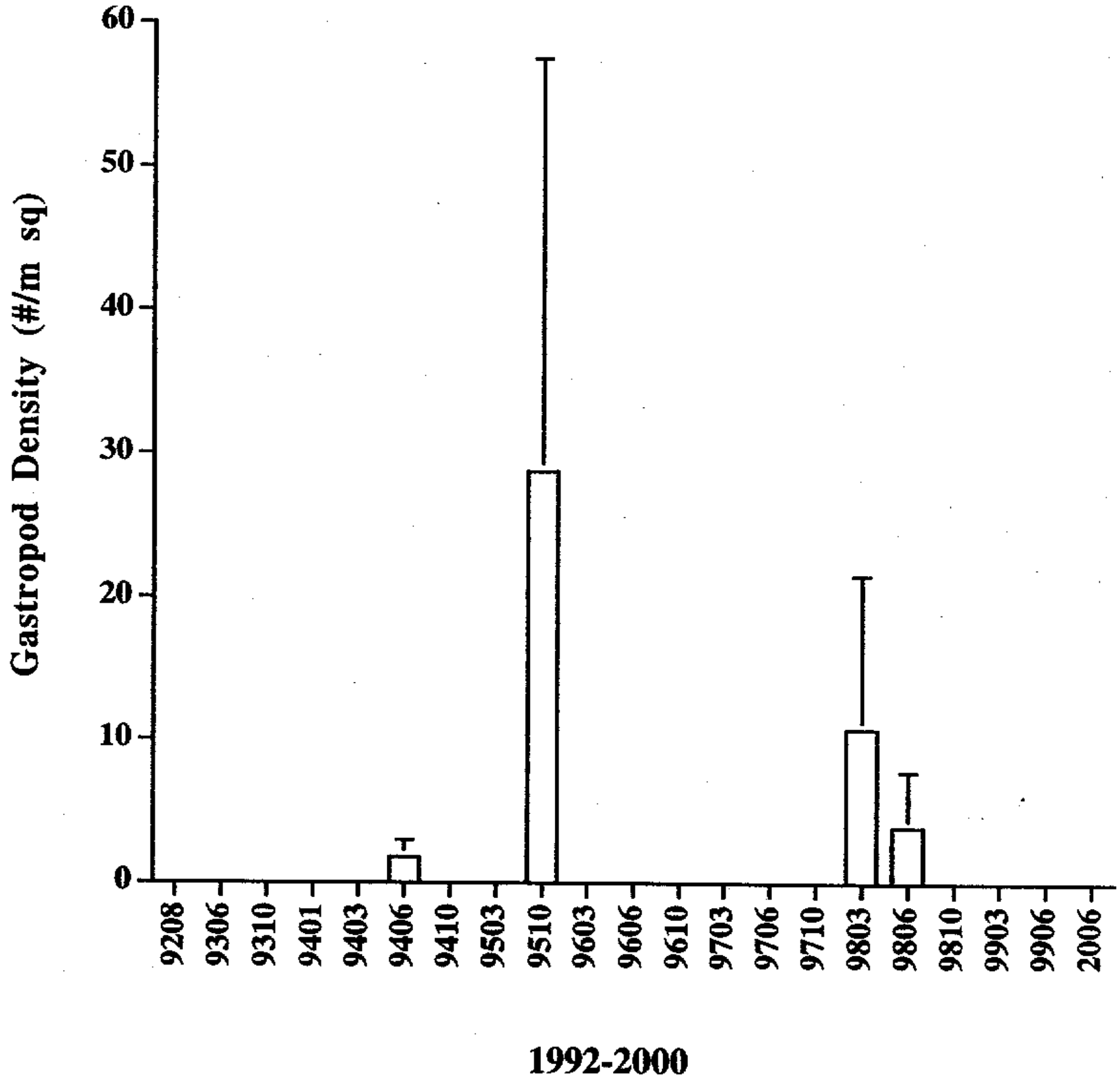

Figure 201. Gastropod densities (#/m sq) collected at Spring Canyon pool Rkm 326.4 from August 1992 to June 2000. Error bars represent (± 1 SE, n=12).

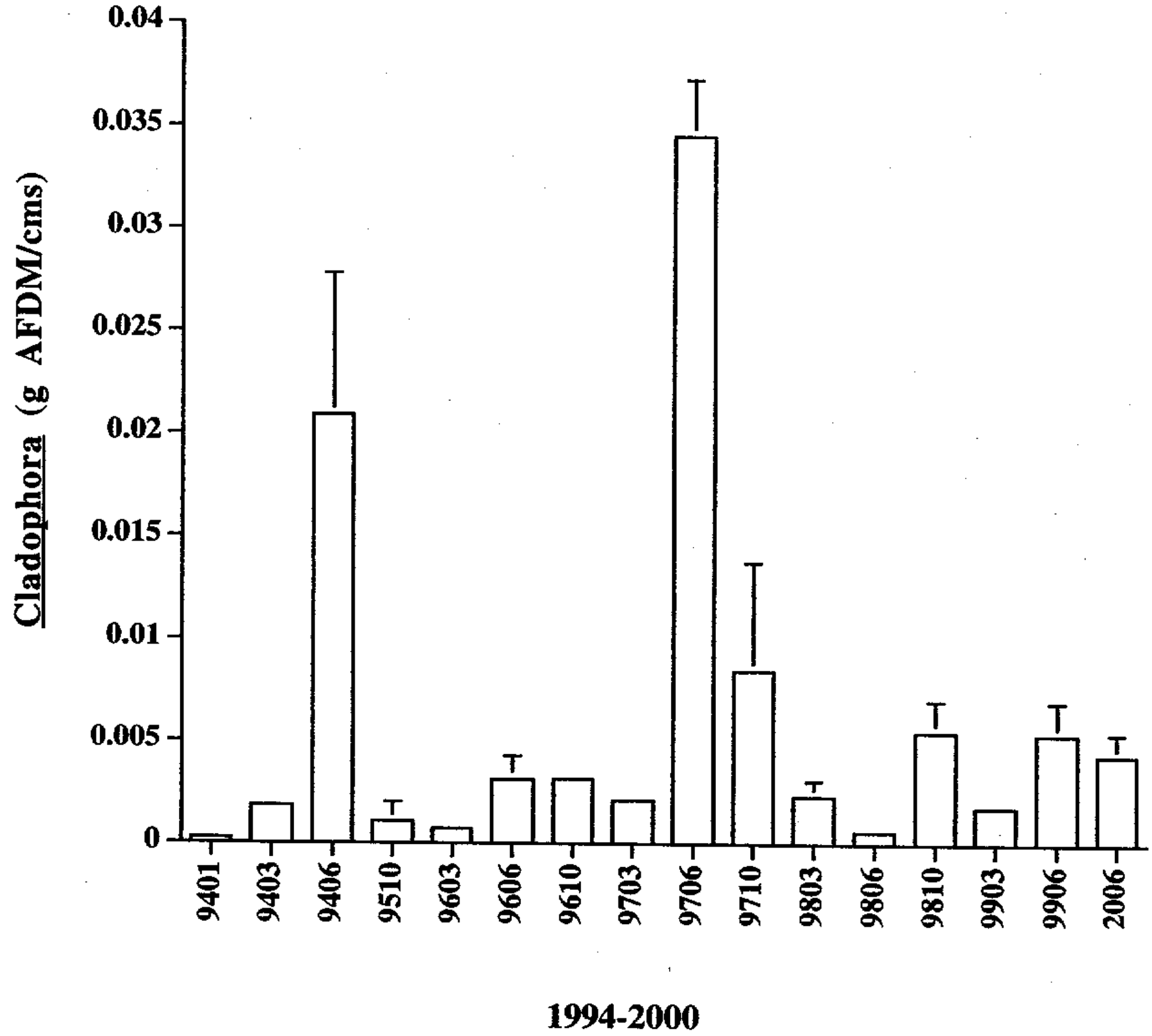

Figure 202. Average CPOM drift mass (g AFDM/cms) of Cladophora collected at Glen Canyon Gauge Rkm -23.2 from January 1994 to June 2000. Error Bars represent (± 1 SE).

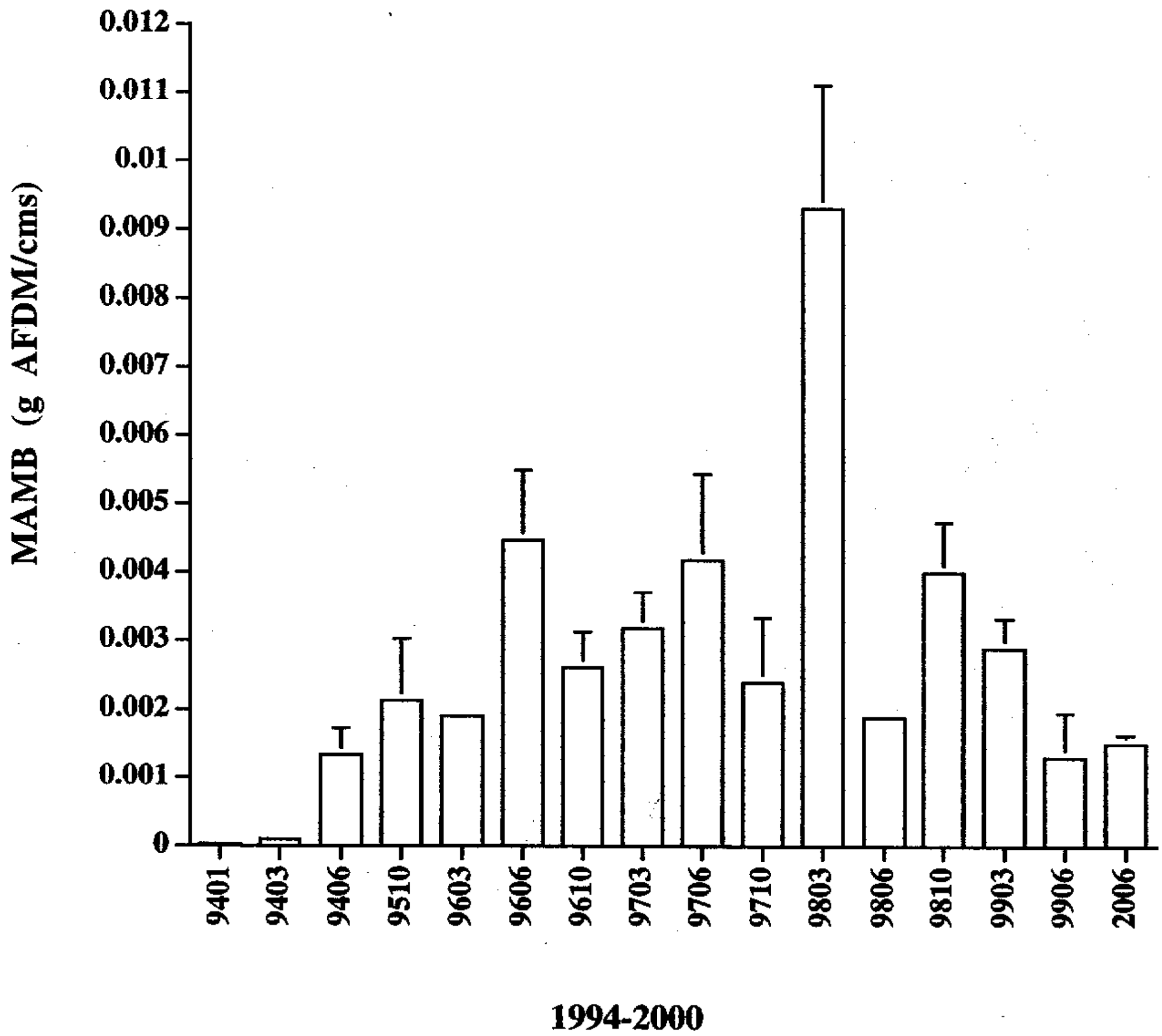

Figure 203. Average CPOM drift mass (g AFDM/cms) of miscellaneous algae, macrophytes, and bryophytes (MAMB) collected at Glen Canyon Gauge Rkm -23.2 from January 1994 to June 2000. Error Bars represent ($\pm$ 1 SE).

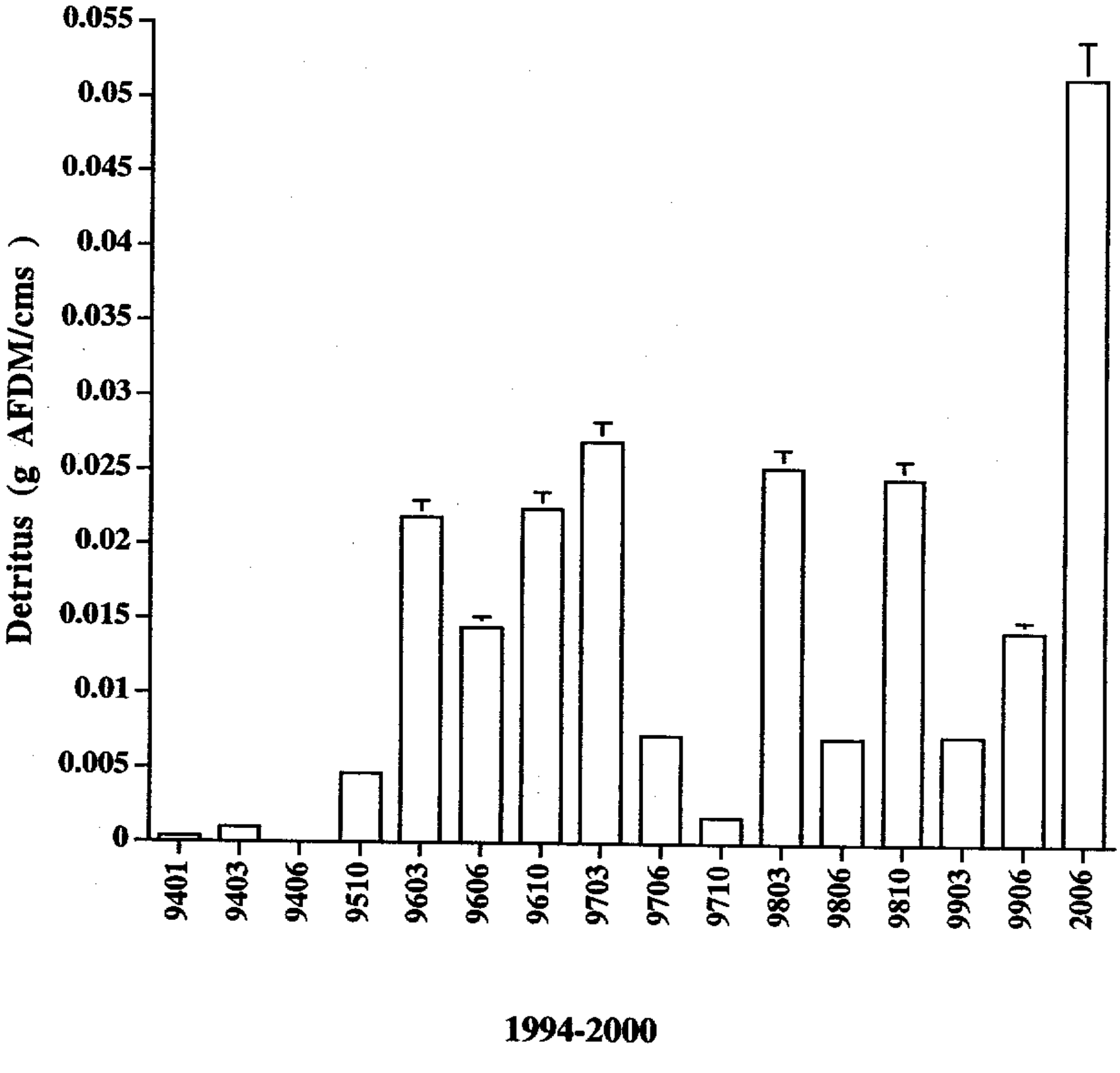

Figure 204. Average CPOM drift mass (g AFDM/cms) for detritus collected at Glen Canyon Gauge Rkm -23.2 from January 1994 to June 2000. Error Bars represent (± 1 SE).

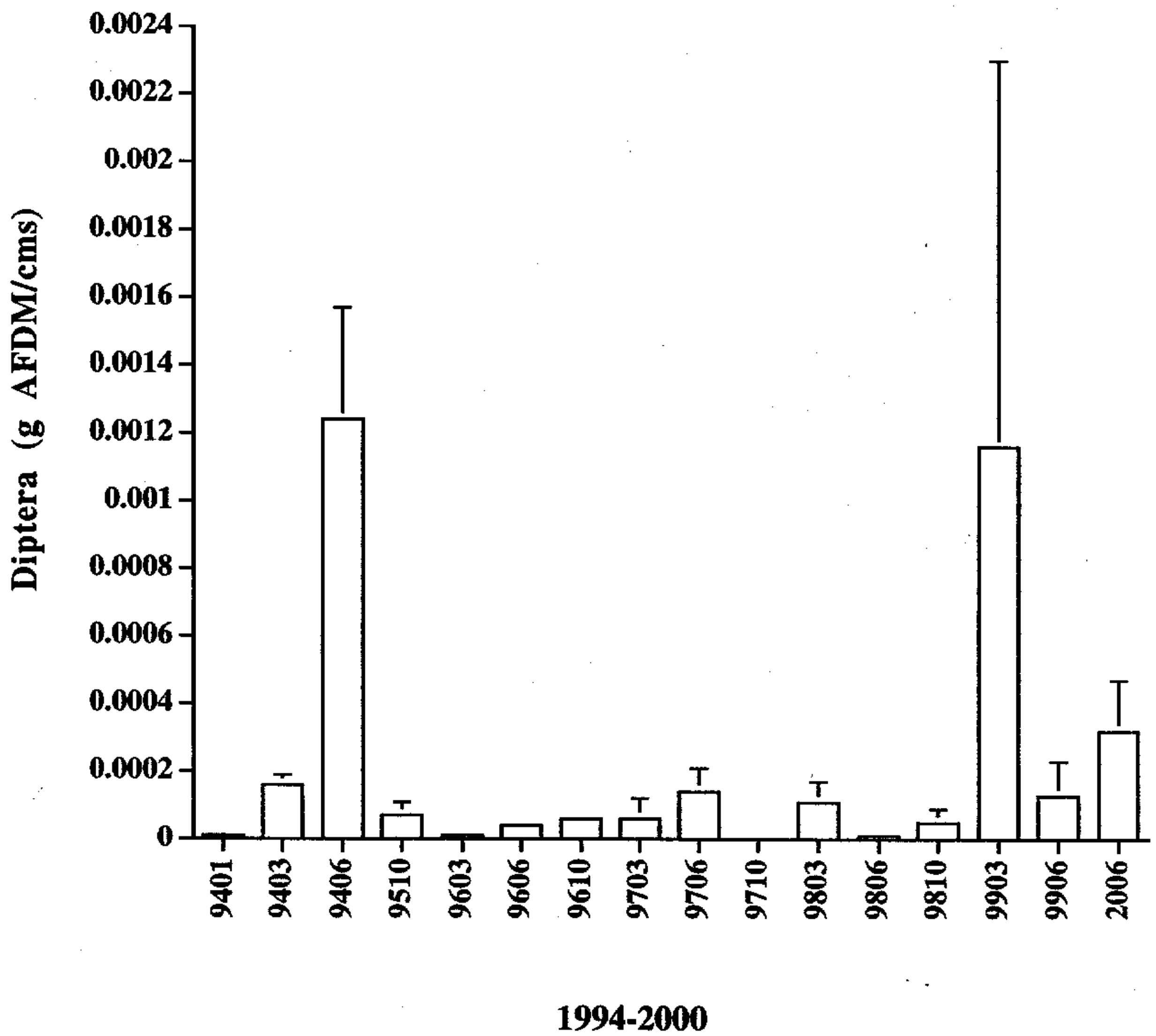

Figure 205. Average CPOM drift mass (g AFDM/cms) for aquatic diptera collected at Glen Canyon Gauge Rkm -23.2 from January 1994 to June 2000. Error Bars represent (± 1 SE).

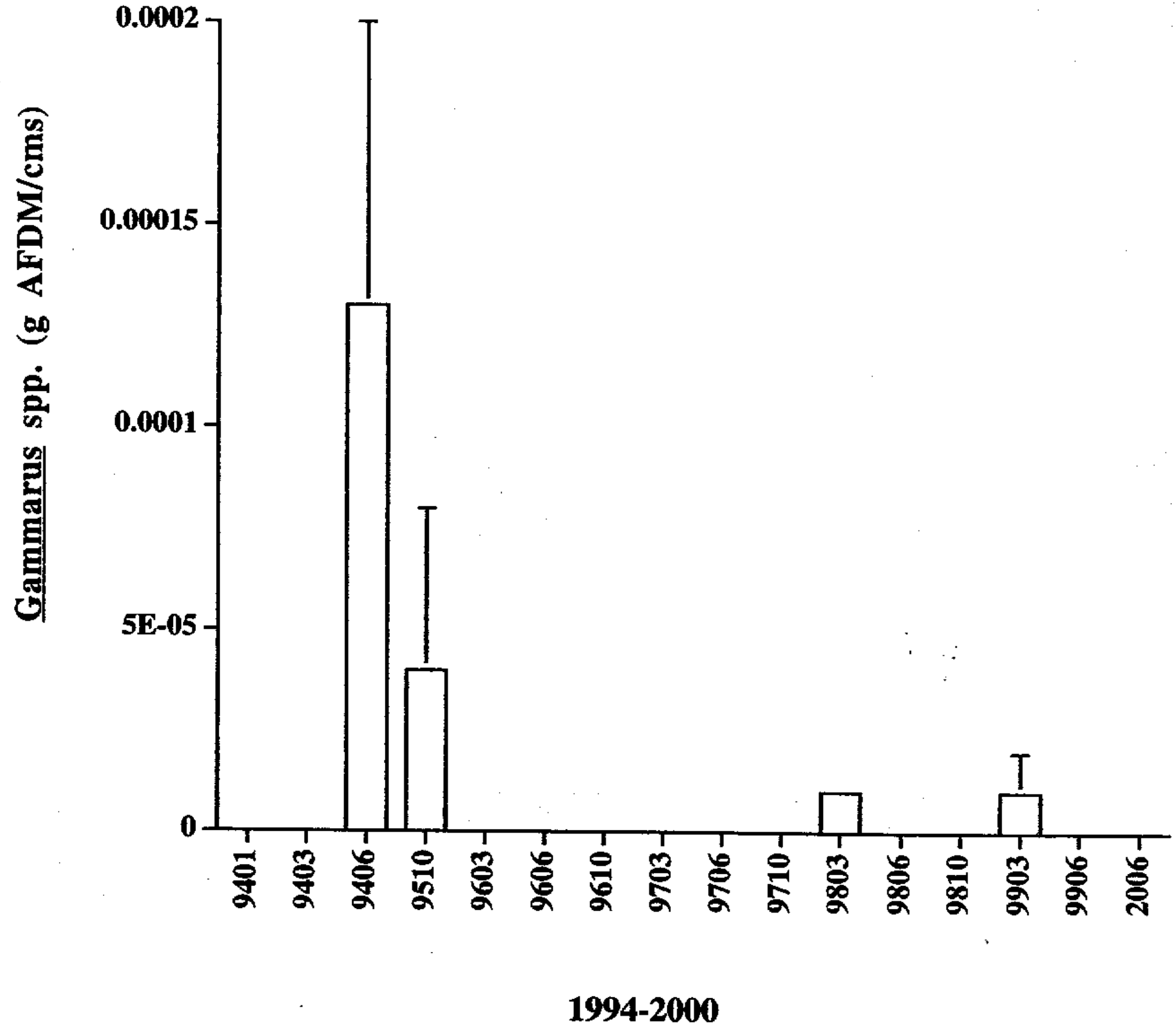

Figure 206. Average CPOM drift mass (g AFDM/cms) for <u>Gammarus</u> spp. collected at Glen Canyon Gauge Rkm -23.2 from January 1994 to June 2000. Error Bars represent (± 1 SE).

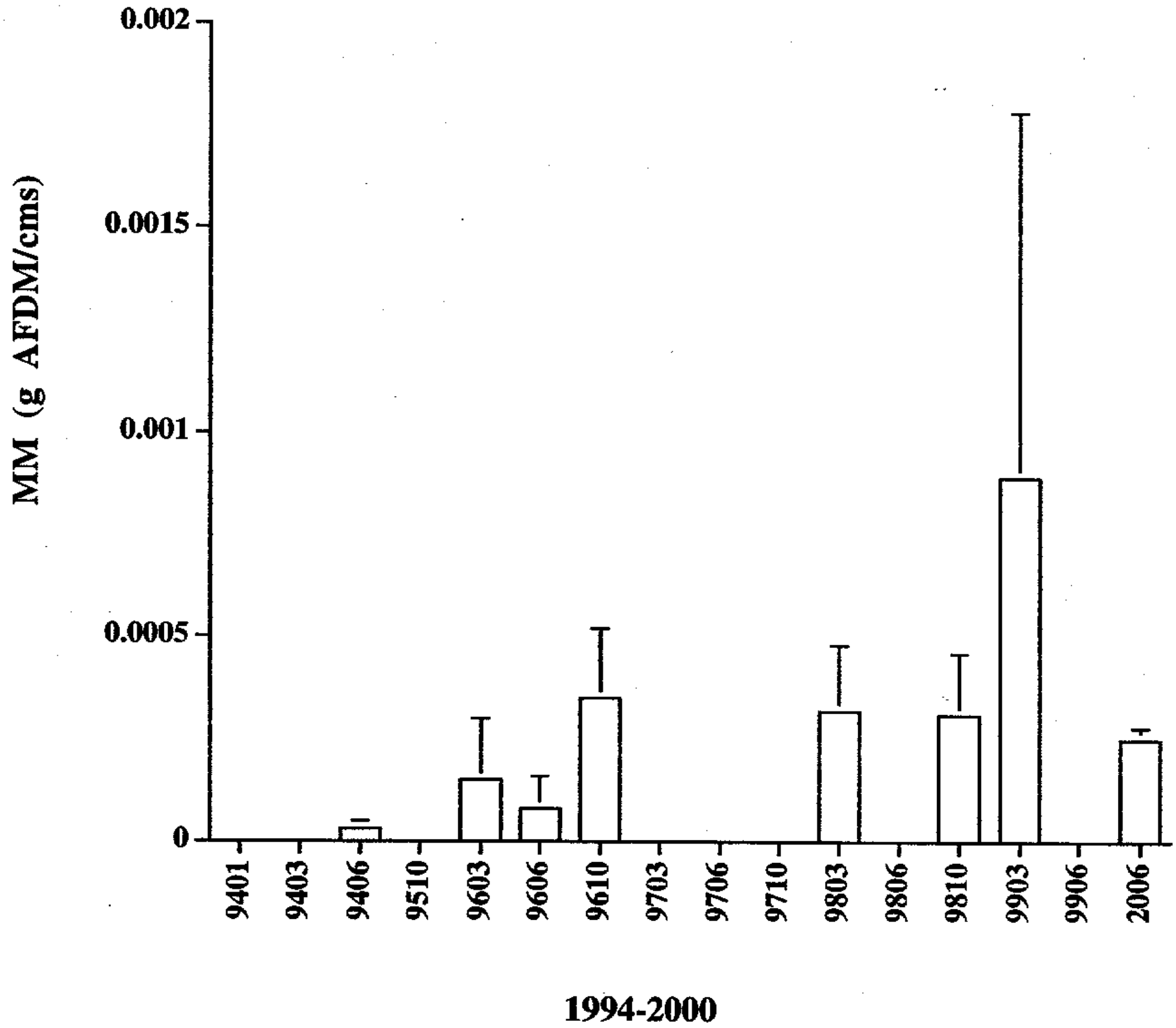

Figure 207. Average CPOM drift mass (g AFDM/cms) for miscellaneous macroinvertebrates (MM) collected at Glen Canyon Gauge Rkm -23.2 from January 1994 to June 2000. Error Bars represent (± 1 SE).

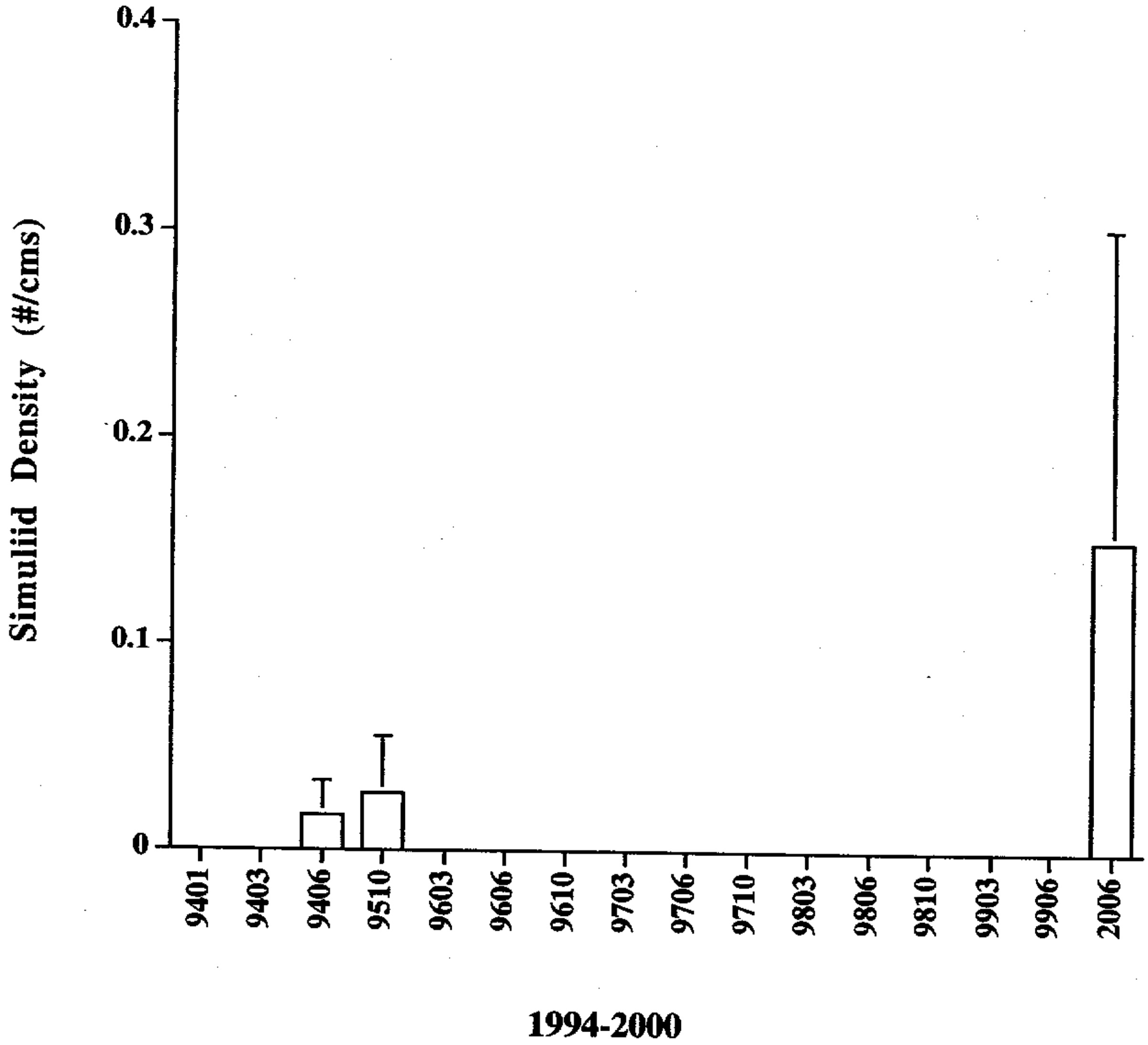

Figure 208. Average CPOM drift densities (#/cms) for Simuliids collected at Glen Canyon Gauge Rkm -23.2 from January 1994 to June 2000. Error Bars represent (± 1 SE).

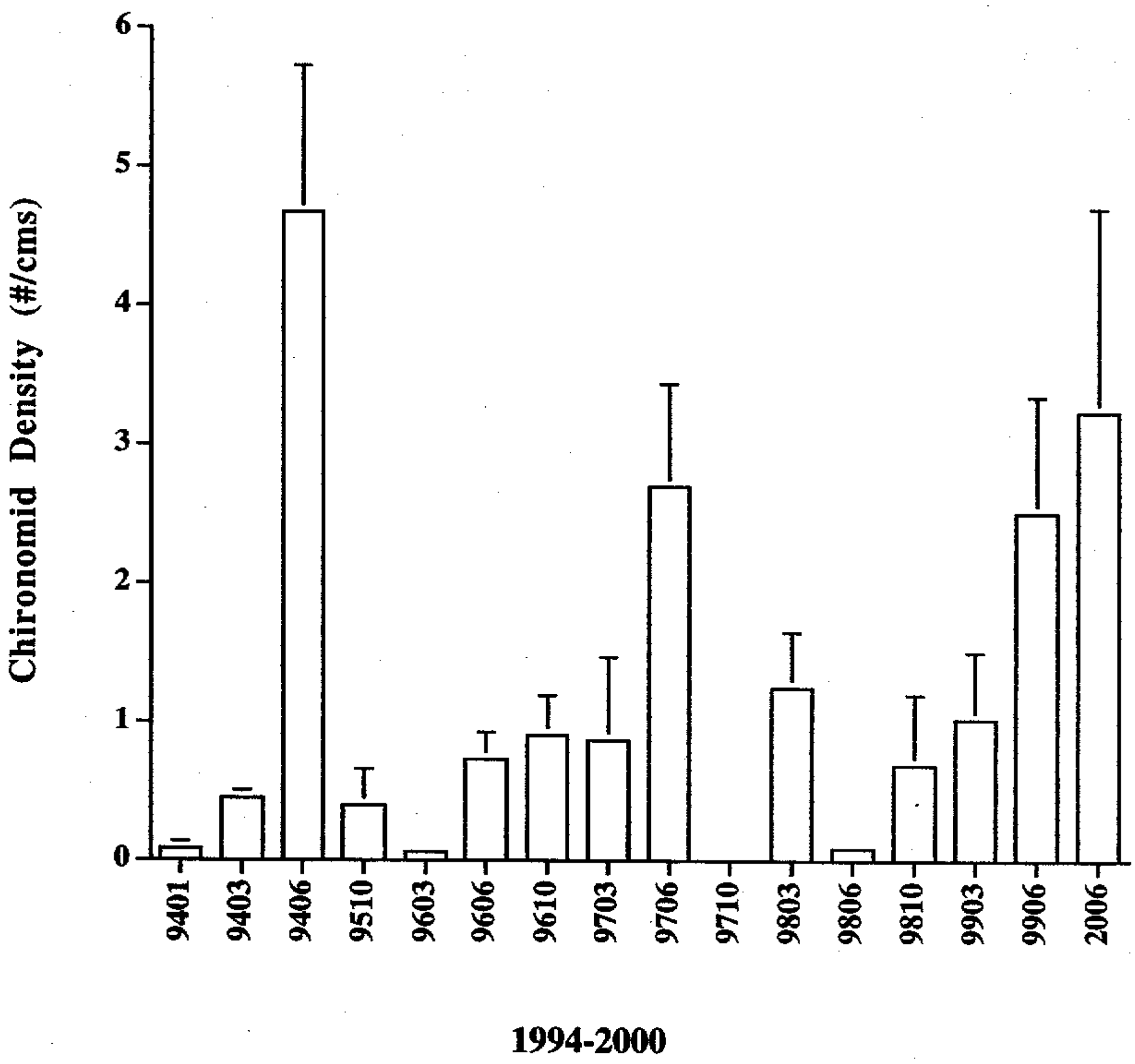

Figure 209. Average CPOM drift densities (#/cms) for Chironomids collected at Glen Canyon Gauge Rkm -23.2 from January 1994 to June 2000. Error Bars represent ($\pm$ 1 SE).

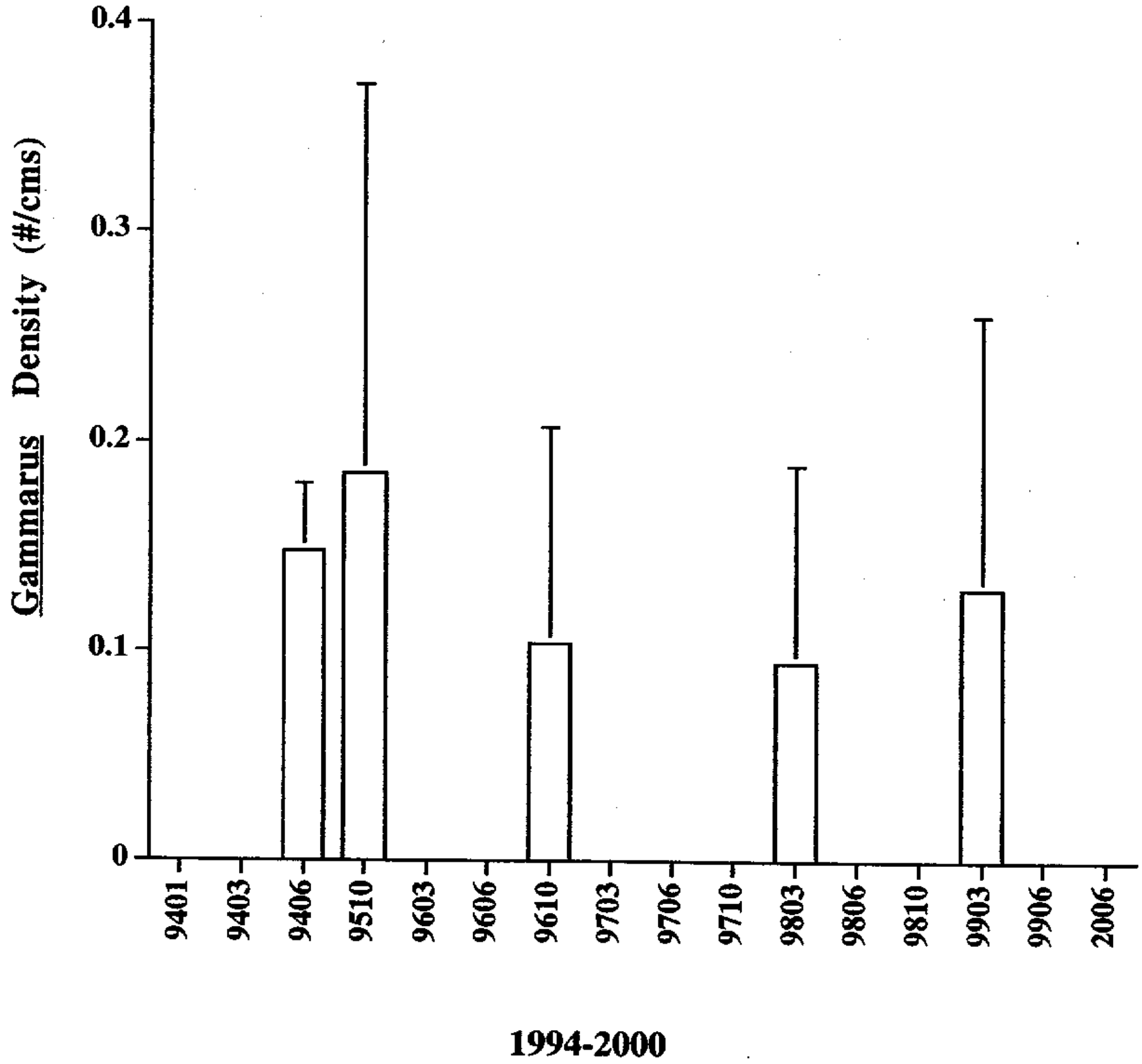

Figure 210. Average CPOM drift densities (#/cms) for Gammarus collected at Glen Canyon Gauge Rkm -23.2 from January 1994 to June 2000. Error Bars represent (± 1 SE).

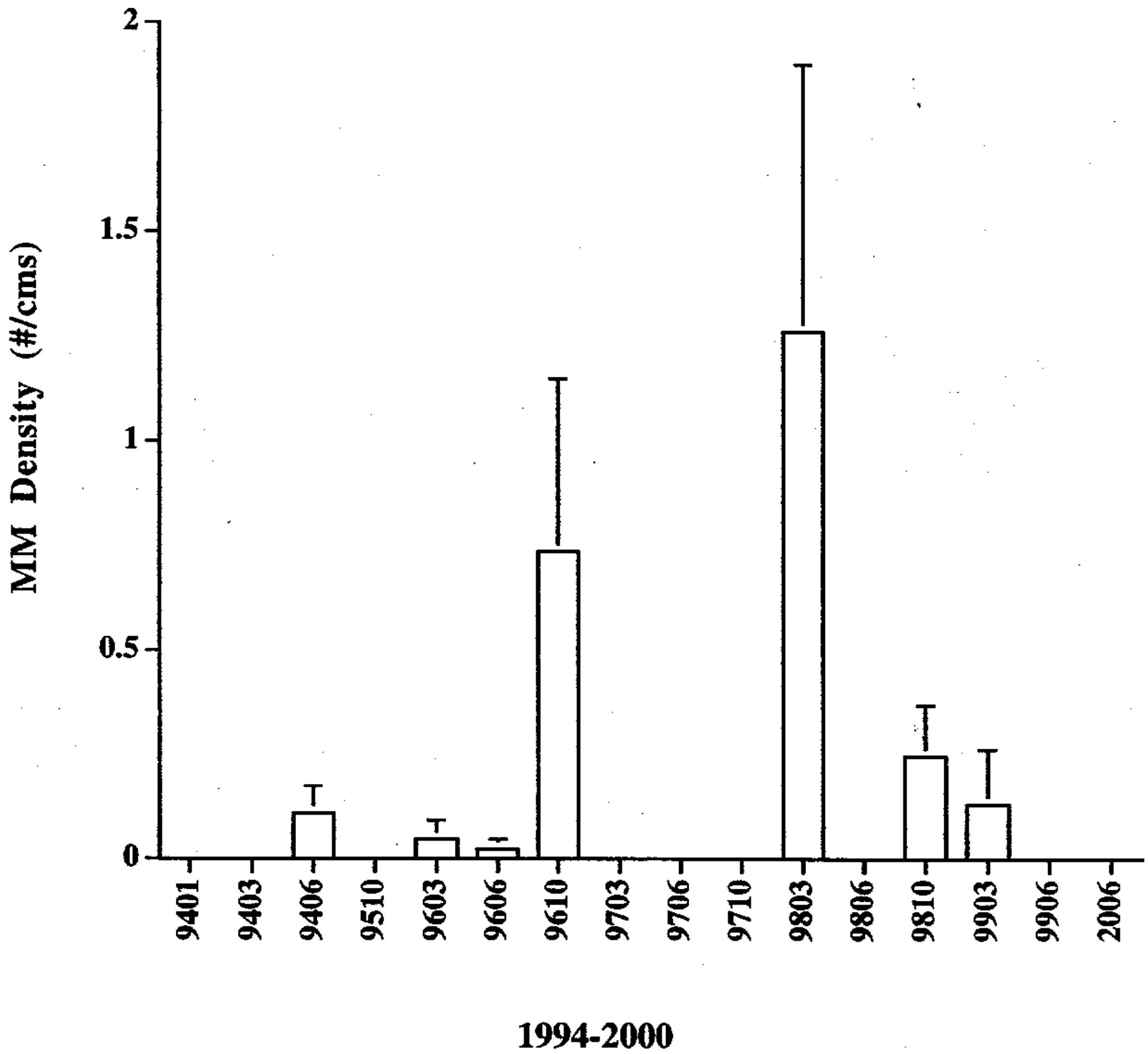

Figure 211. Average CPOM drift densities (#/cms) for miscellaneous macroinvertebrates (MM) collected at Glen Canyon Gauge Rkm -23.2 from January 1994 to June 2000. Error Bars represent (± 1 SE).

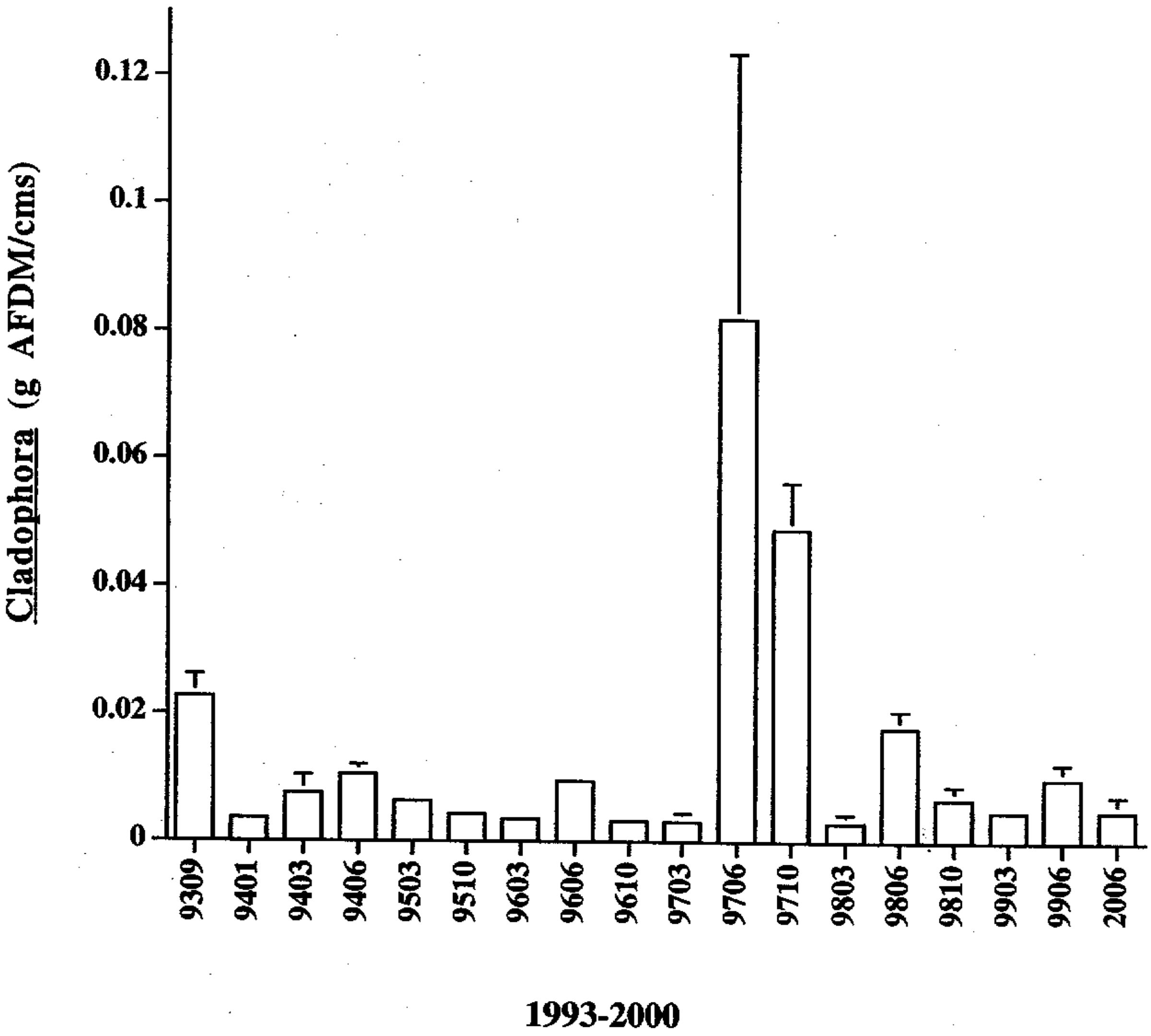

Figure 212. Average CPOM drift mass (g AFDM/cms) for Cladophora collected at Lees Ferry Rkm 0.0 from September 1993 to June 2000. Error Bars represent (± 1 SE).

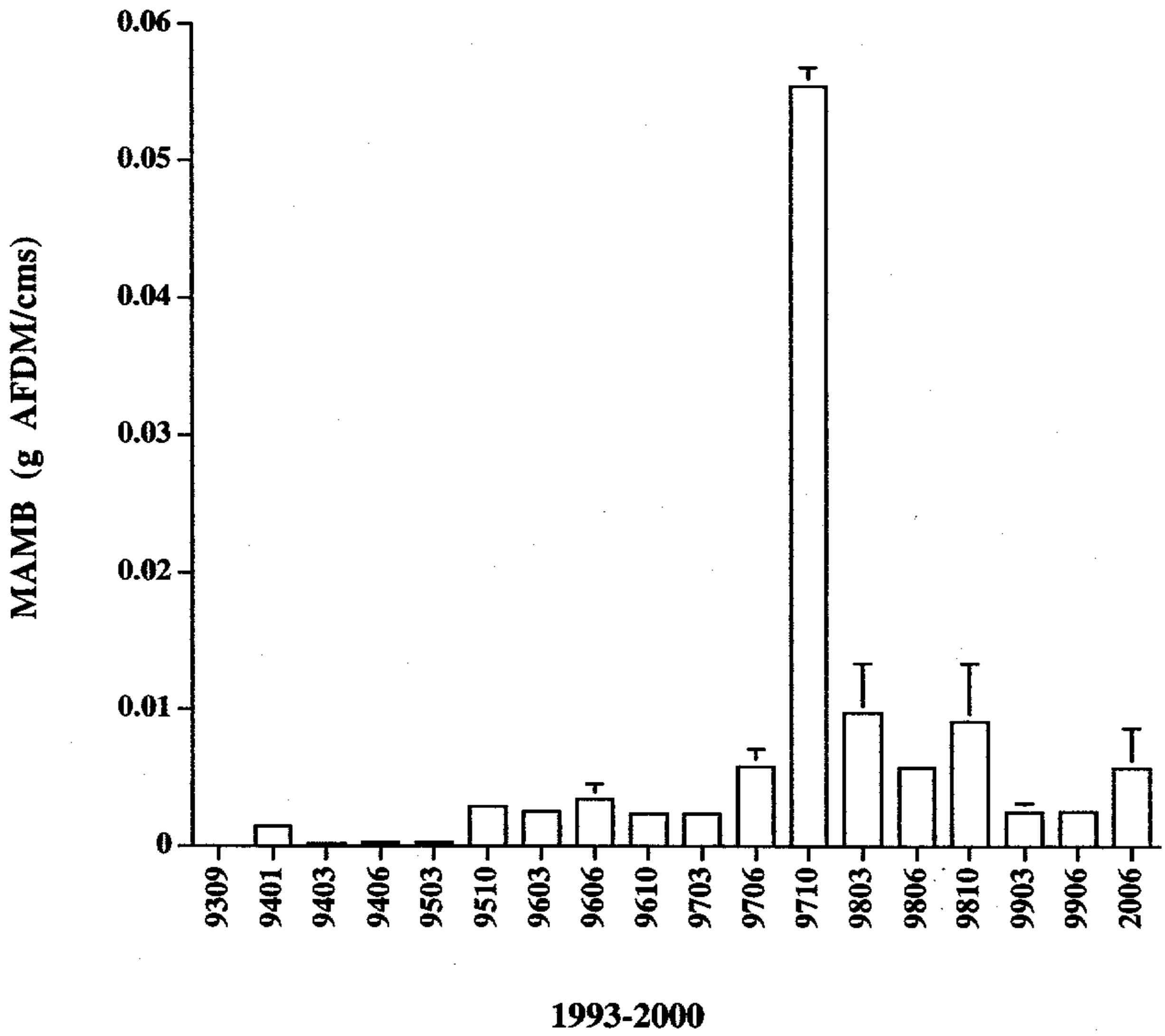

Figure 213. Average CPOM drift mass (g AFDM/cms) for miscellaneous algae, macrophytes and bryophytes (MAMB) collected at Lees Ferry Rkm 0.0 from September 1993 to June 2000. Error Bars represent ($\pm$ 1 SE).

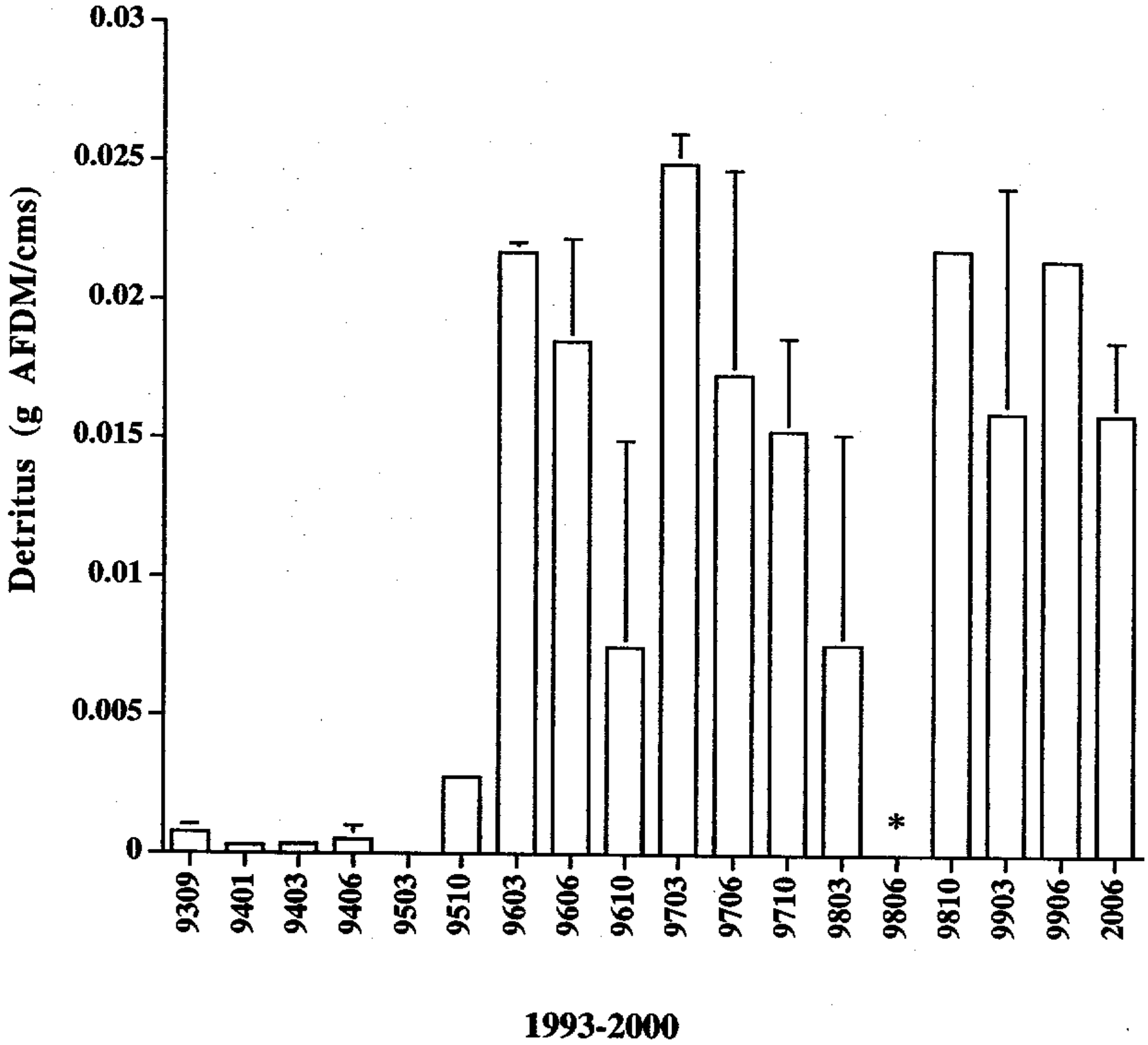

Figure 214. Average CPOM drift mass (g AFDM/cms) for detritus collected at Lees Ferry Rkm 0.0 from September 1993 to June 2000. Error Bars represent (± 1 SE). Asterisk (*) represents 0.15 g AFDM/cms (± 0.12 SE). High values of detritus are due to beaver cuttings.

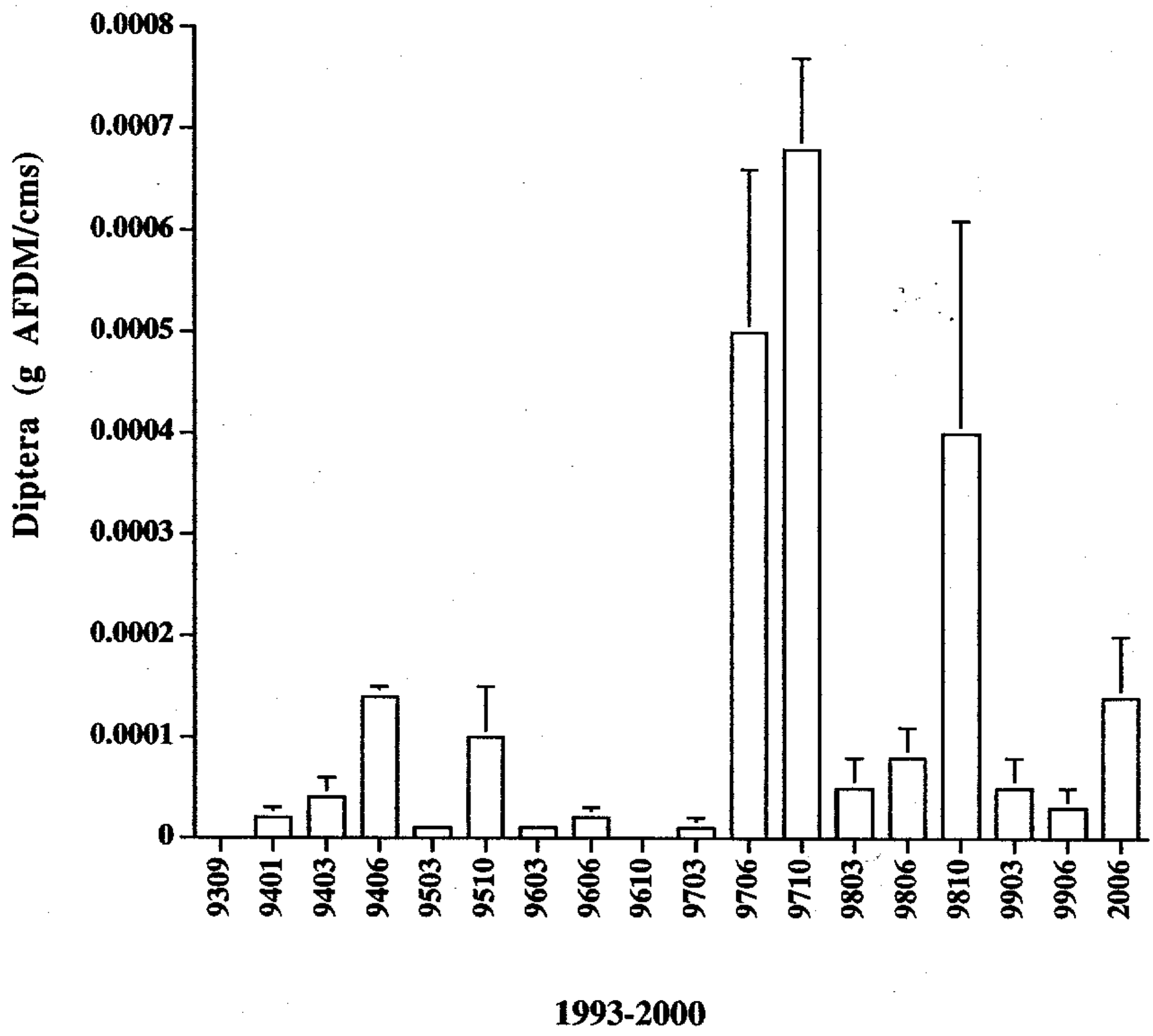

Figure 215. Average CPOM drift mass (g AFDM/cms) for aquatic diptera collected at Lees Ferry Rkm 0.0 from September 1993 to June 2000. Error Bars represent (± 1 SE).

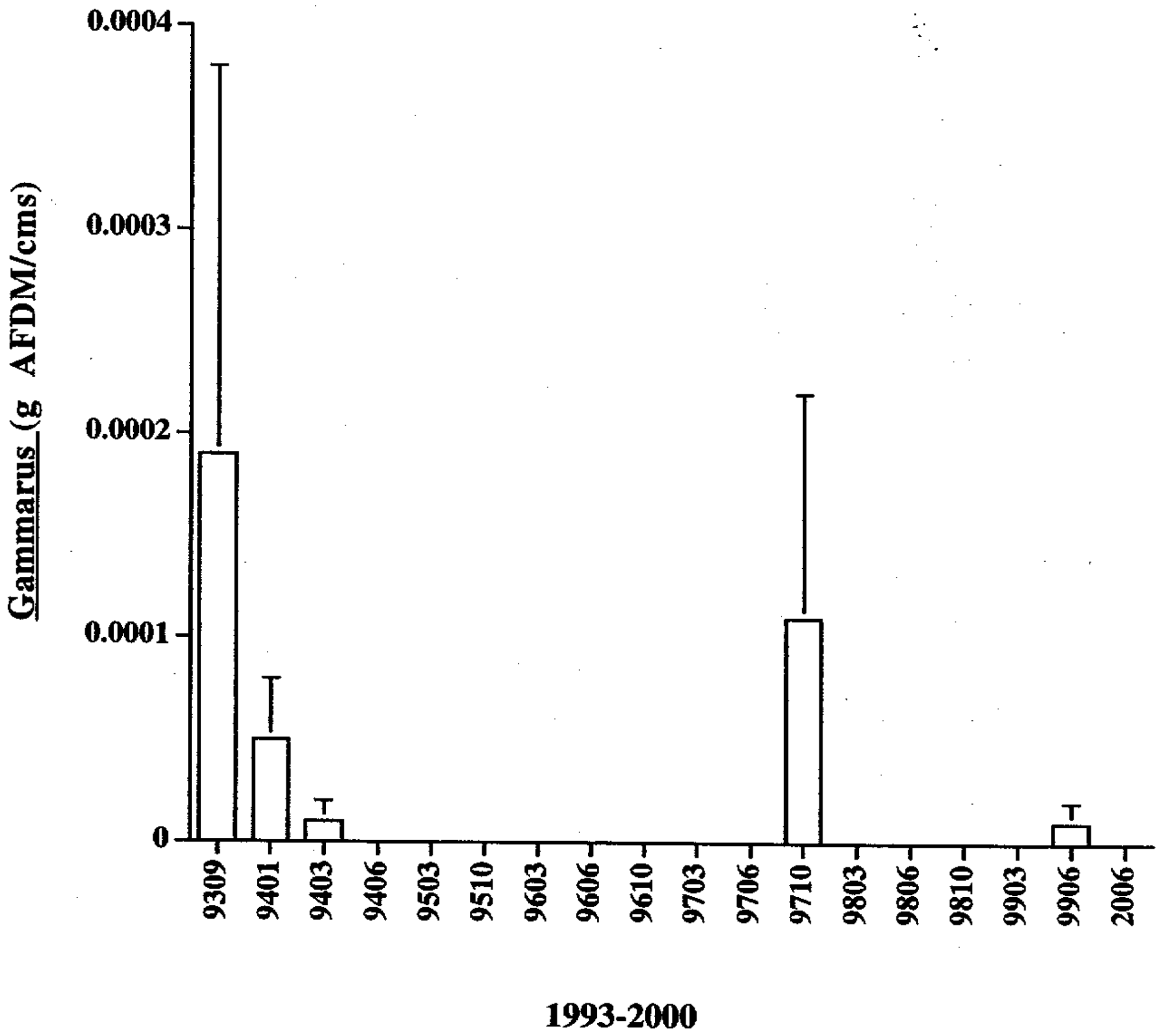

Figure 216. Average CPOM drift mass (g AFDM/cms) for Gammarus collected at Lees Ferry Rkm 0.0 from September 1993 to June 2000. Error Bars represent (± 1 SE).

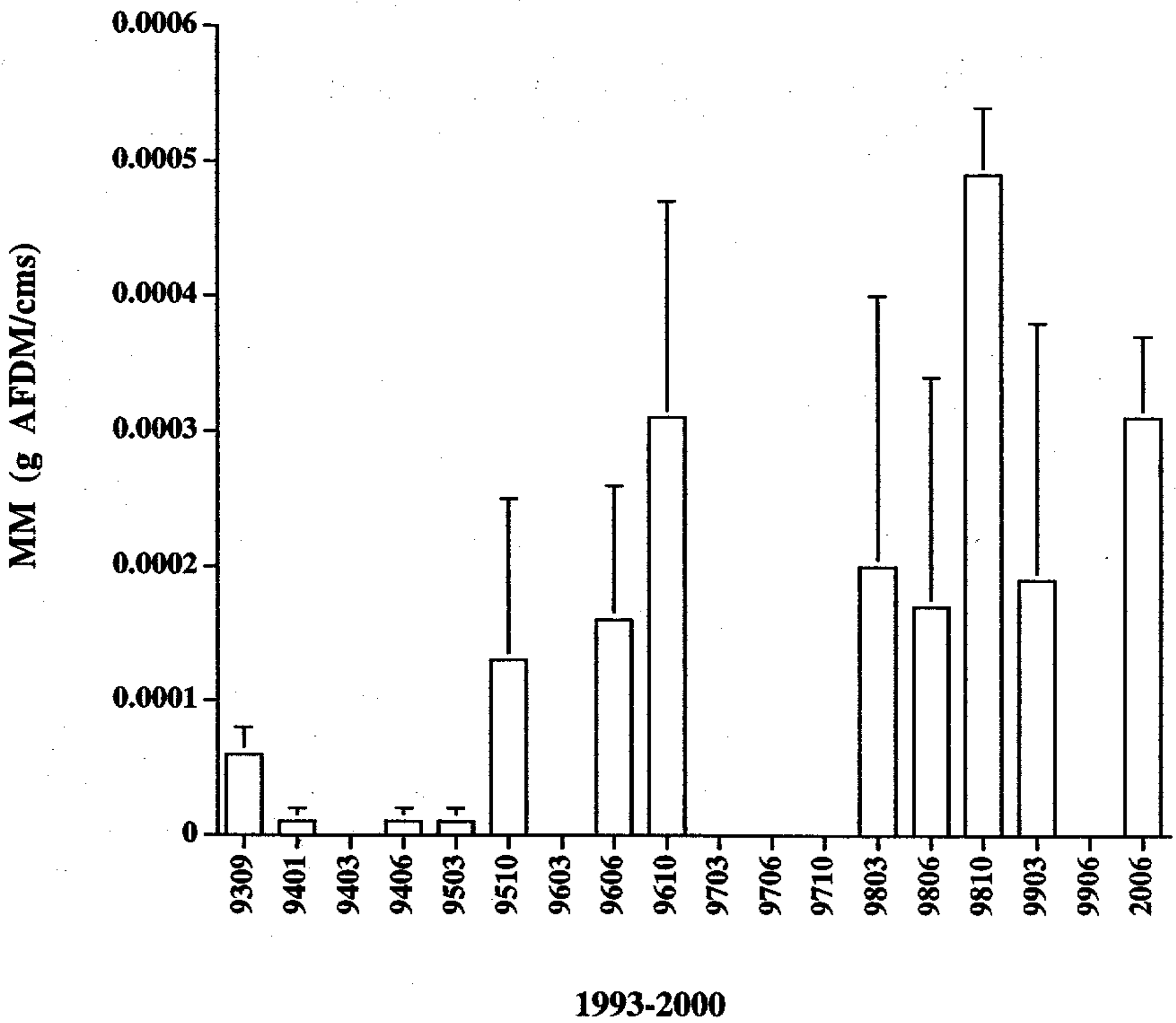

Figure 217. Average CPOM drift mass (g AFDM/cms) for miscellaneous macroinvertebrates (MM) collected at Lees Ferry Rkm 0.0 from September 1993 to June 2000. Error Bars represent (± 1 SE).

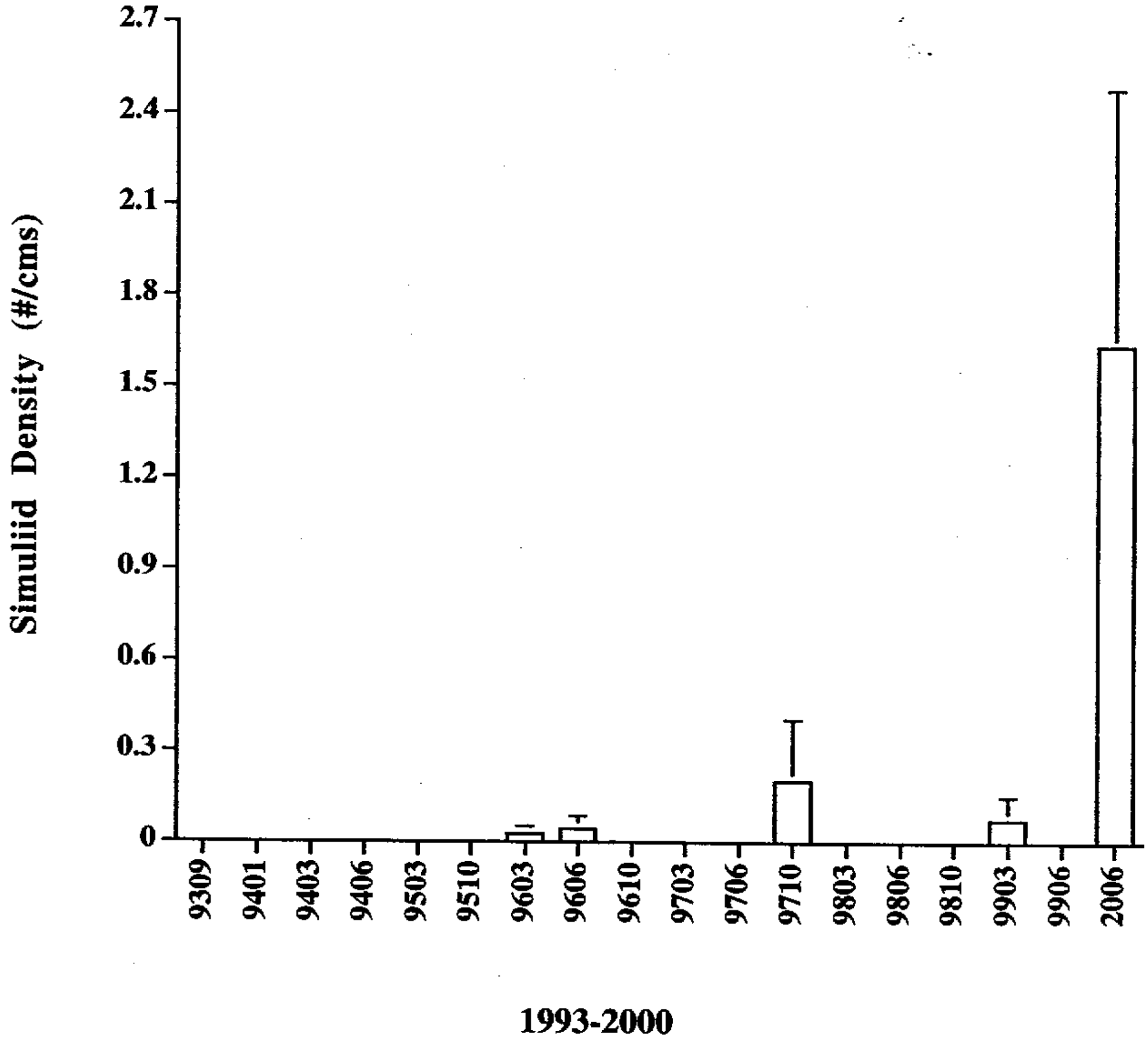

Figure 218. Average CPOM drift densities (#/cms) for Simuliids collected at Lees Ferry Rkm 0.0 from September 1993 to June 2000. Error Bars represent (± 1 SE).

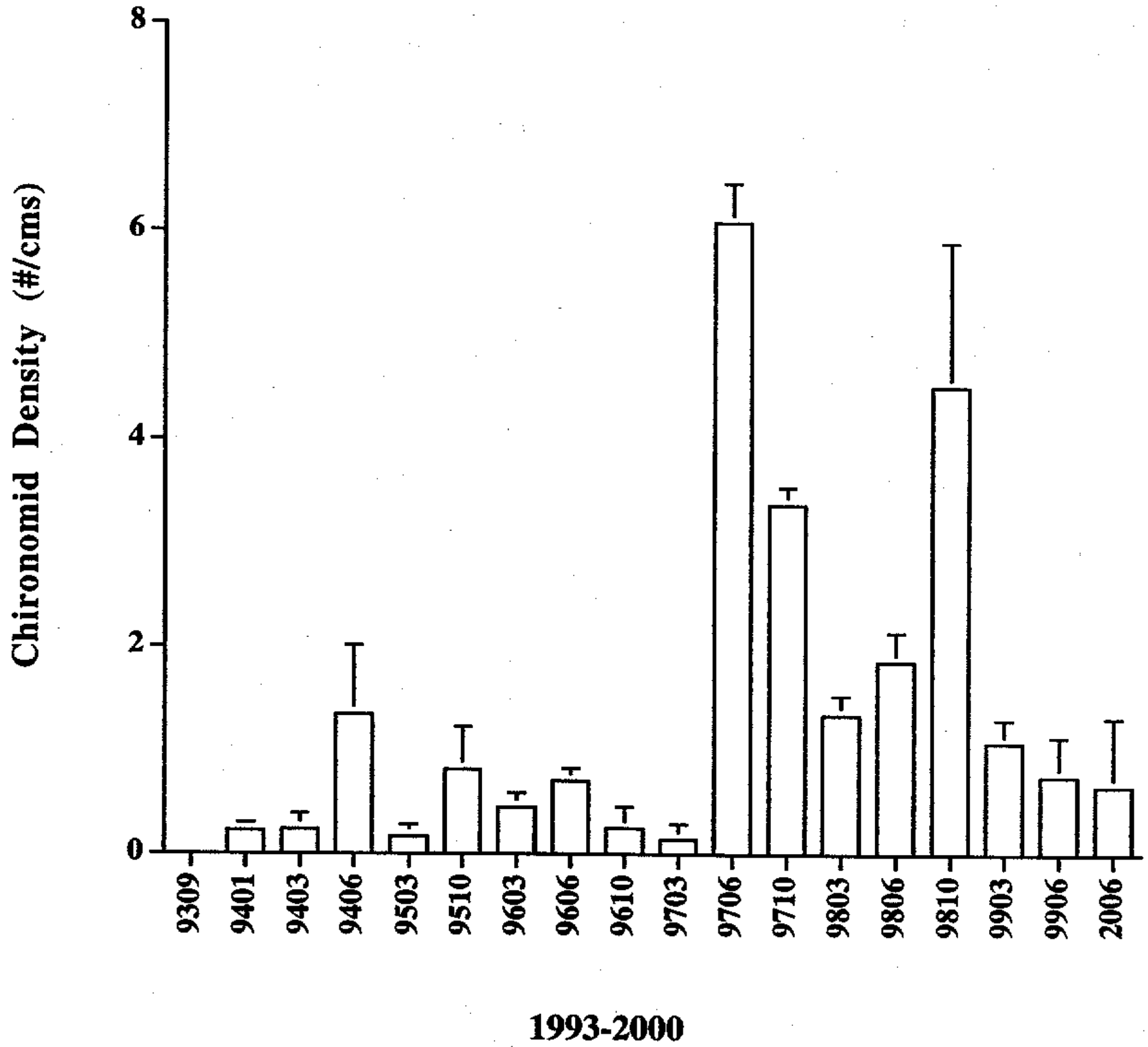

Figure 219. Average CPOM drift densities (#/cms) for Chironomids collected at Lees Ferry Rkm 0.0 from September 1993 to June 2000. Error Bars represent (± 1 SE).

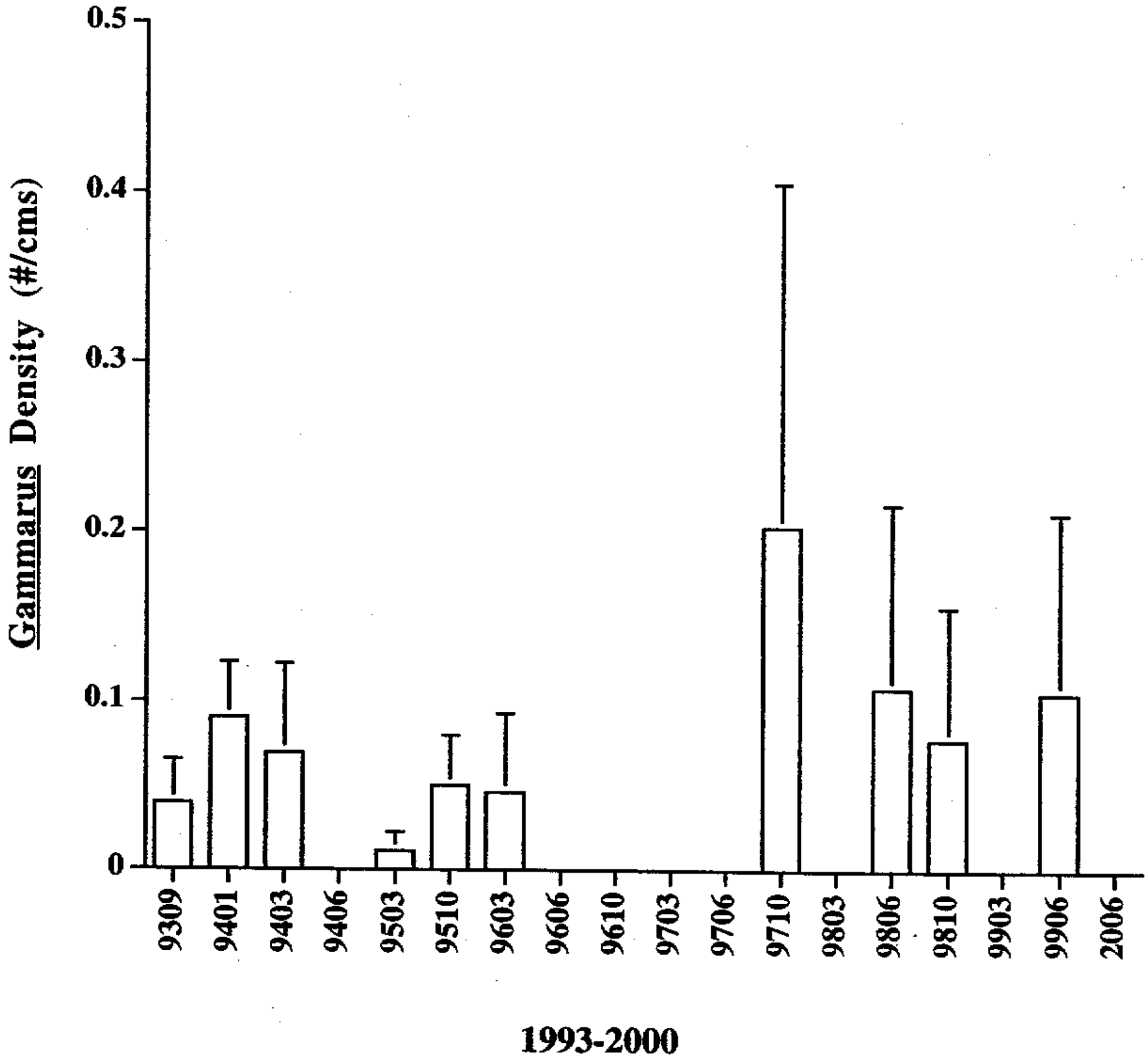

Figure 220. Average CPOM drift densities (#/cms) for <u>Gammarus</u> collected at Lees Ferry Rkm 0.0 from September 1993 to June 2000. Error Bars represent (1 SE) .

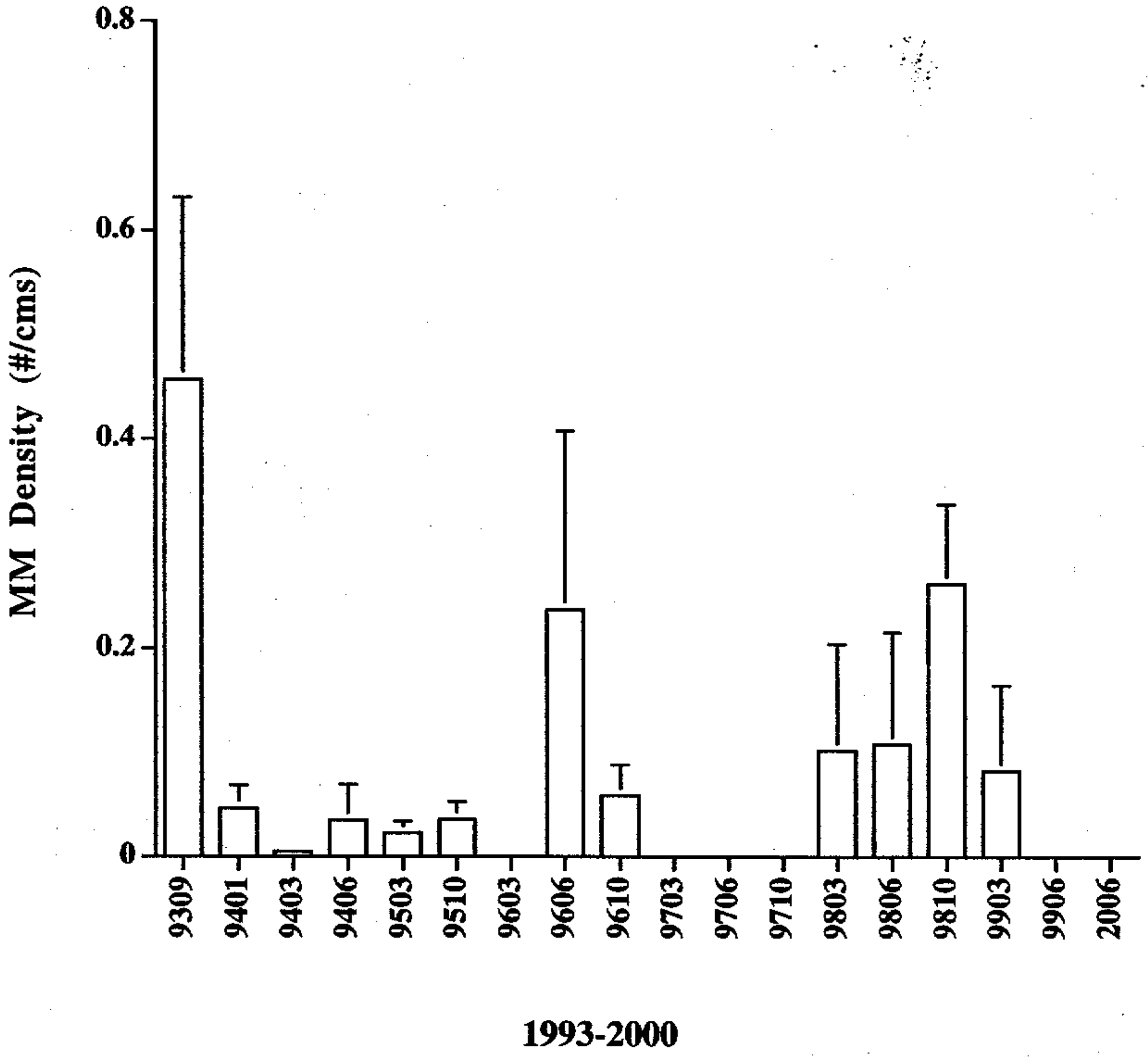

Figure 221. Average CPOM drift densities (#/cms) for miscellaneous macroinvertebrate (MM) collected at Lees Ferry Rkm 0.0 from September 1993 to June 2000. Error Bars represent (± 1 SE).

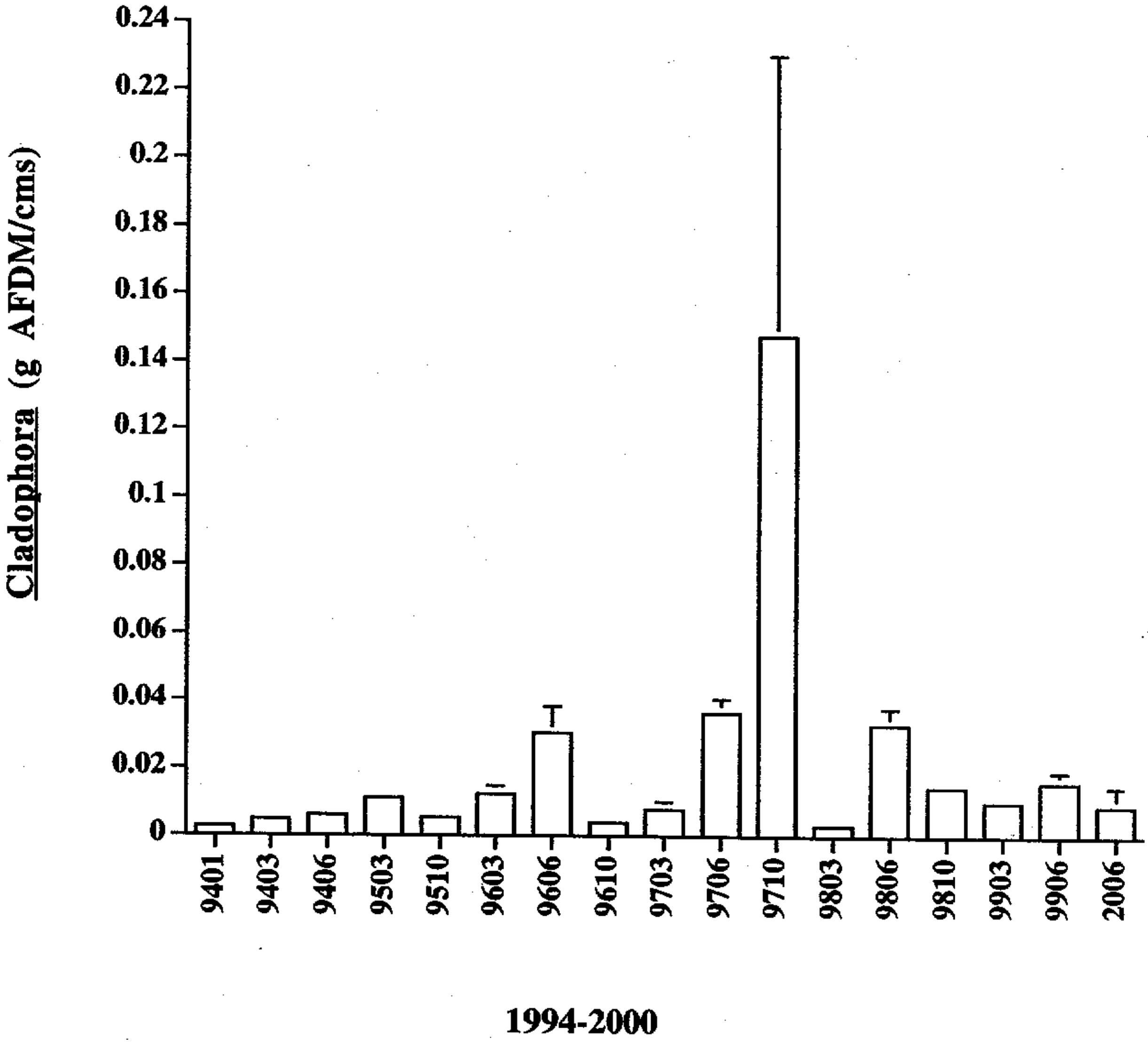

Figure 222. Average CPOM drift mass (g AFDM/cms) for Cladophora collected at Two-Mile Wash Rkm 2.9 from January 1994 to June 2000. Error Bars represent (± 1 SE).

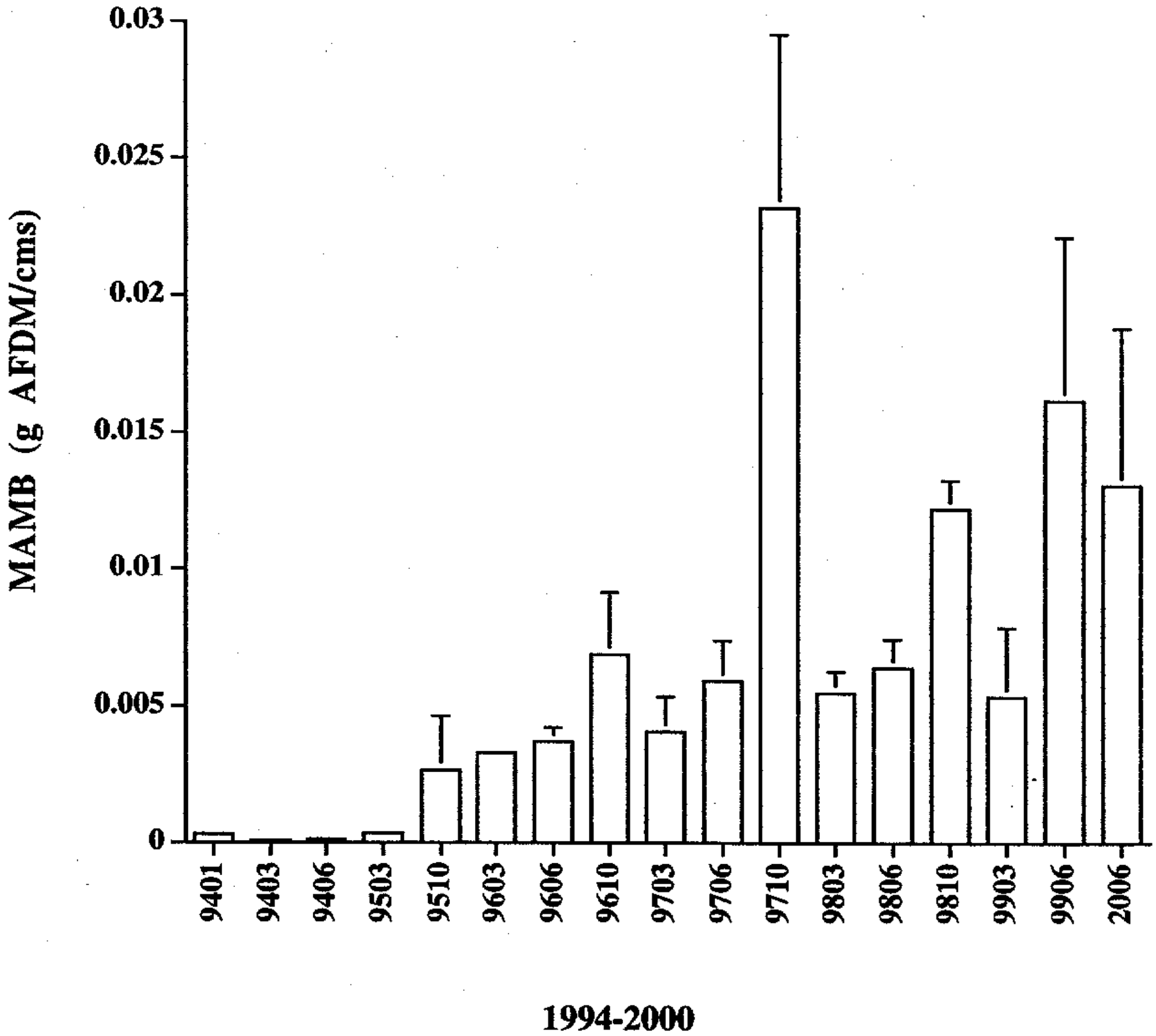

Figure 223. Average CPOM drift mass (g AFDM/cms) for miscellaneous algae, macrophytes and bryophytes (MAMB) collected at Two-Mile Wash Rkm 2.9 from January 1994 to June 2000. Error Bars represent ($\pm$ 1 SE).

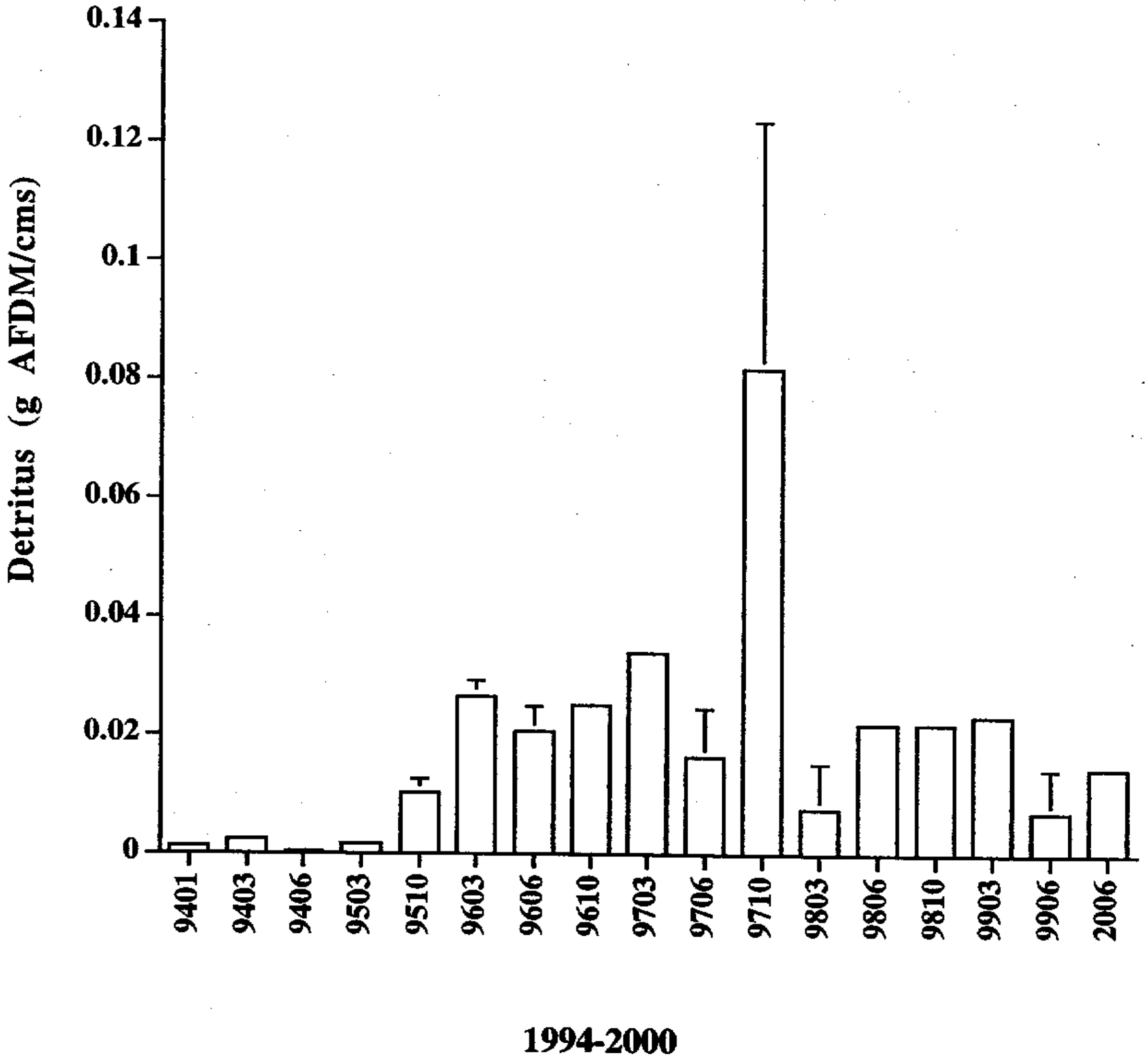

Figure 224. Average CPOM drift mass (g AFDM/cms) for detritus collected at Two-Mile Wash Rkm 2.9 from January 1994 to June 2000. Error Bars represent (± 1 SE).

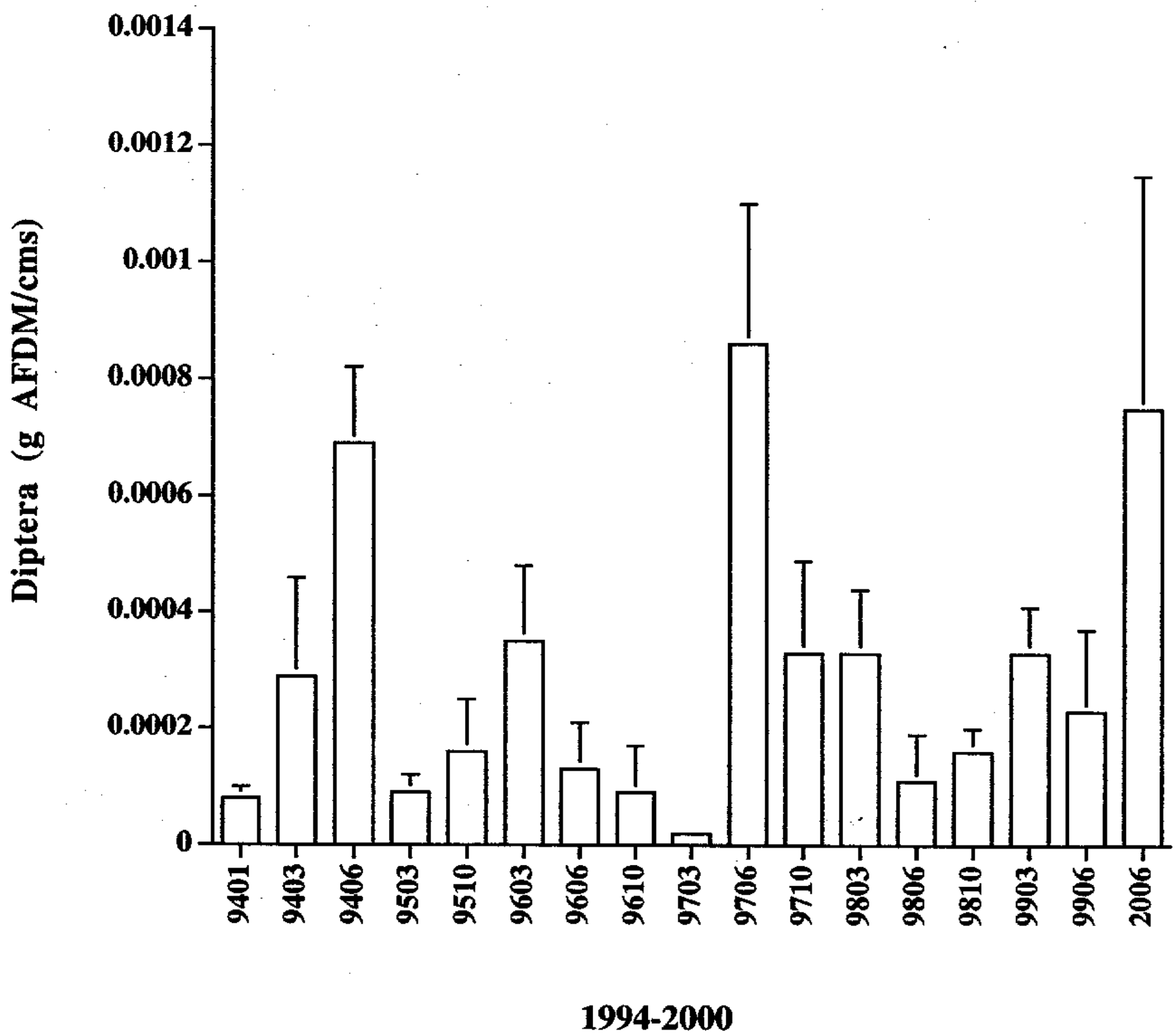

Figure 225. Average CPOM drift mass (g AFDM/cms) for aquatic diptera collected at Two-Mile Wash Rkm 2.9 from January 1994 to June 2000. Error Bars represent (± 1 SE).

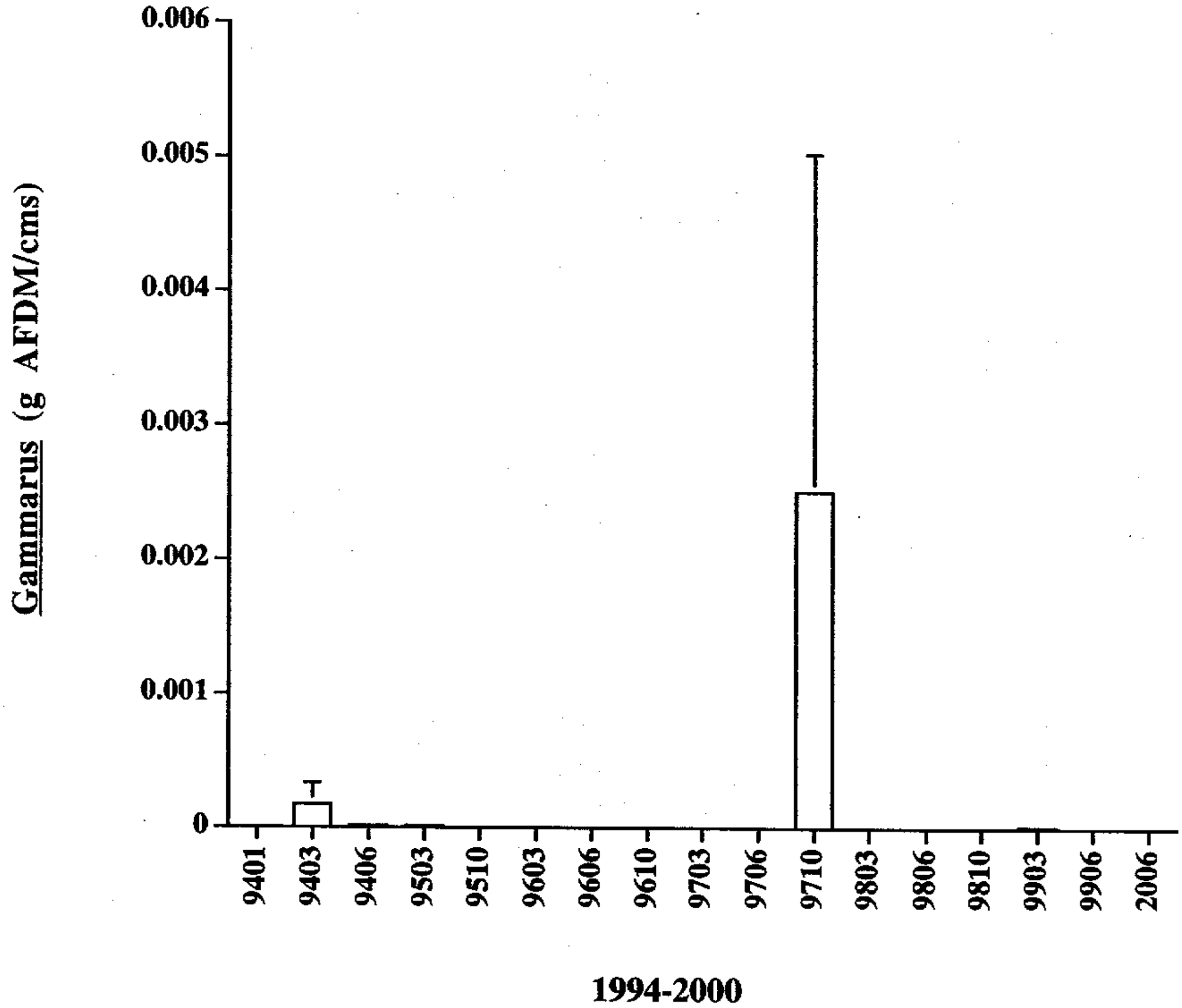

Figure 226. Average CPOM drift mass (g AFDM/cms) for <u>Gammarus</u> collected at Two-Mile Wash Rkm 2.9 from January 1994 to June 2000. Error Bars represent (± 1 SE).

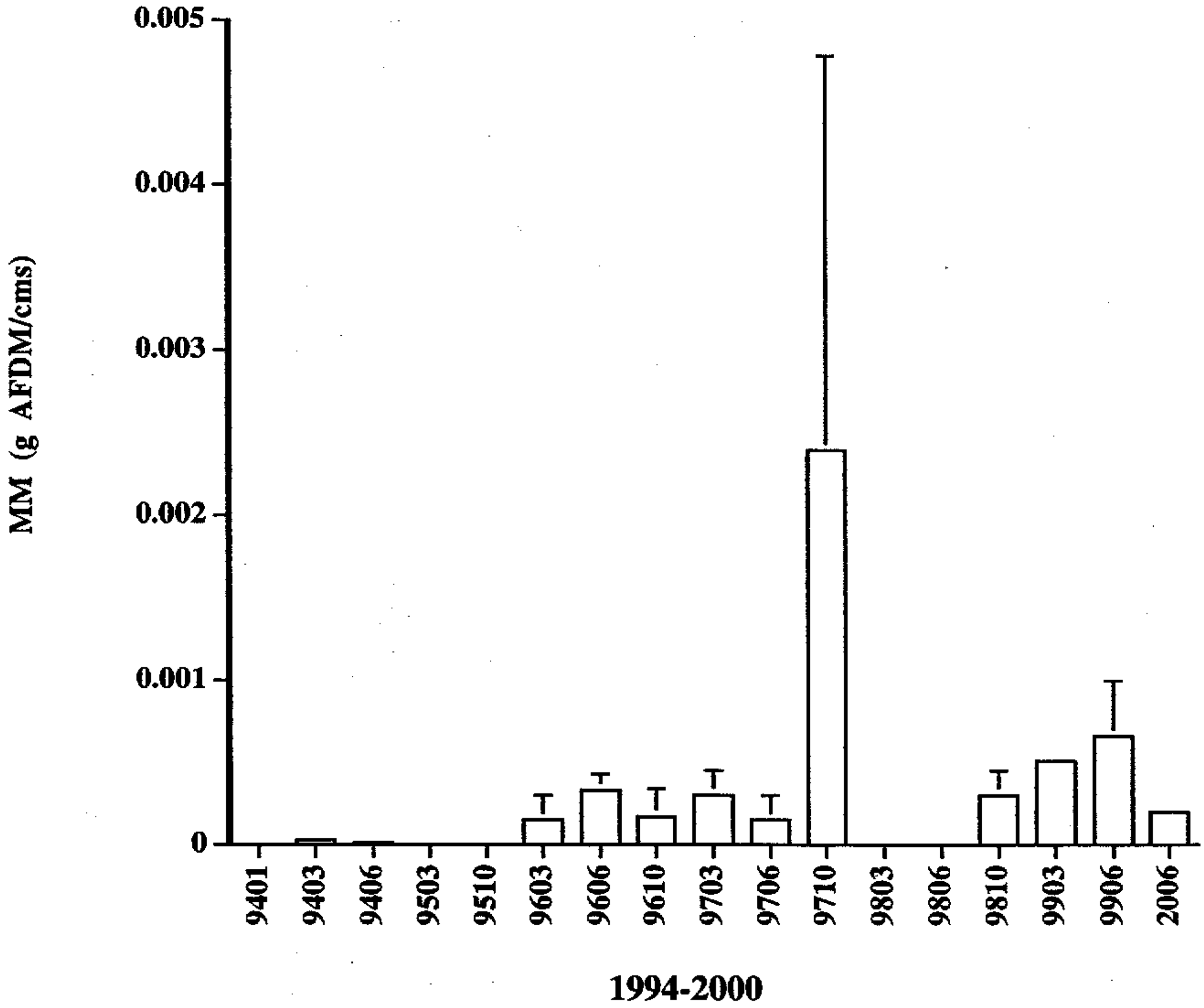

Figure 227. Average CPOM drift mass (g AFDM/cms) for miscellaneous macroinvertebrates (MM) collected at Two-Mile Wash Rkm 2.9 from January 1994 to June 2000. Error Bars represent (± 1 SE).

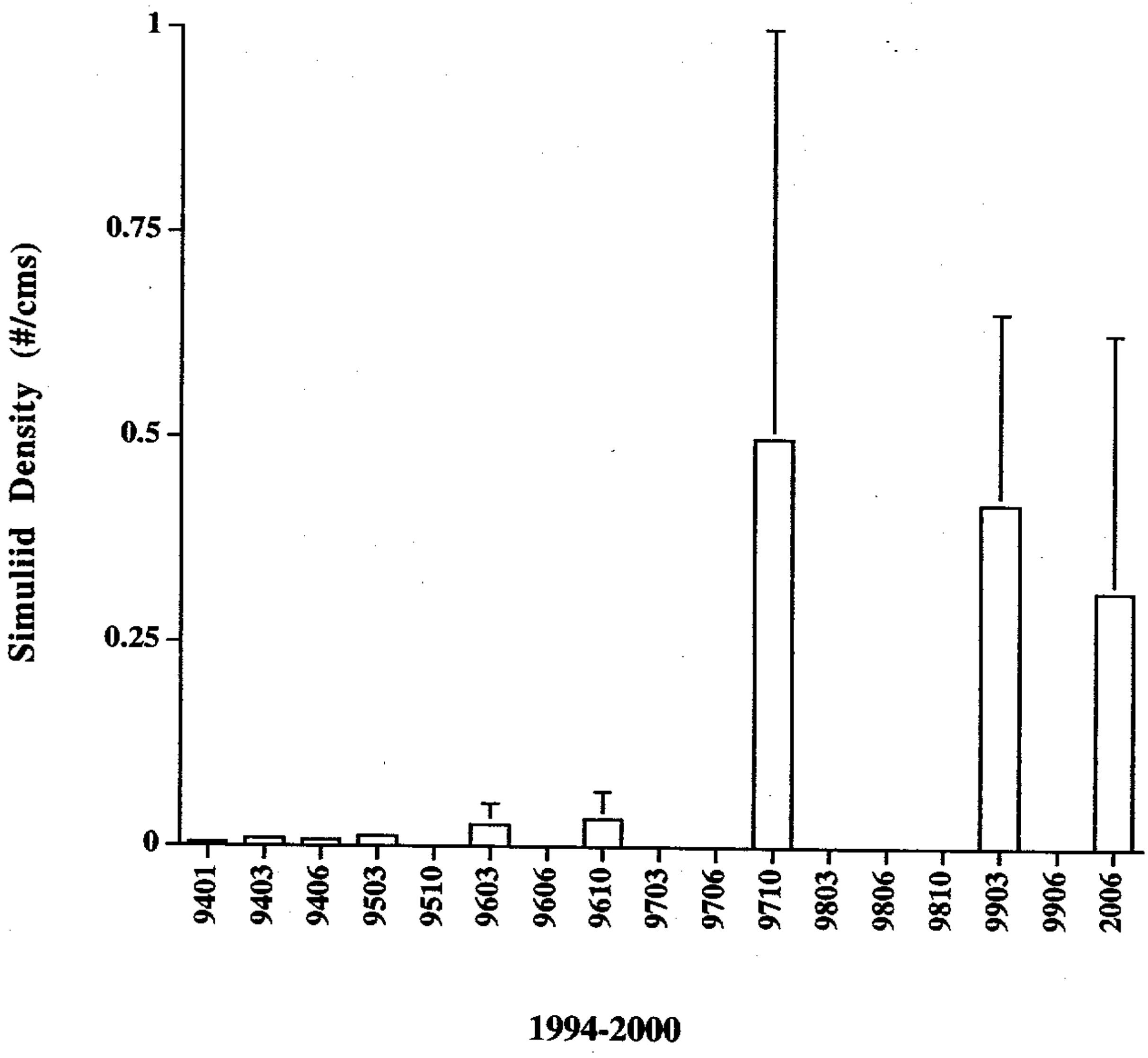

Figure 228. Average CPOM drift densities (#/cms) for Simuliids collected at Two-Mile Wash Rkm 2.9 from January 1994 to June 2000. Error Bars represent (± 1 SE).

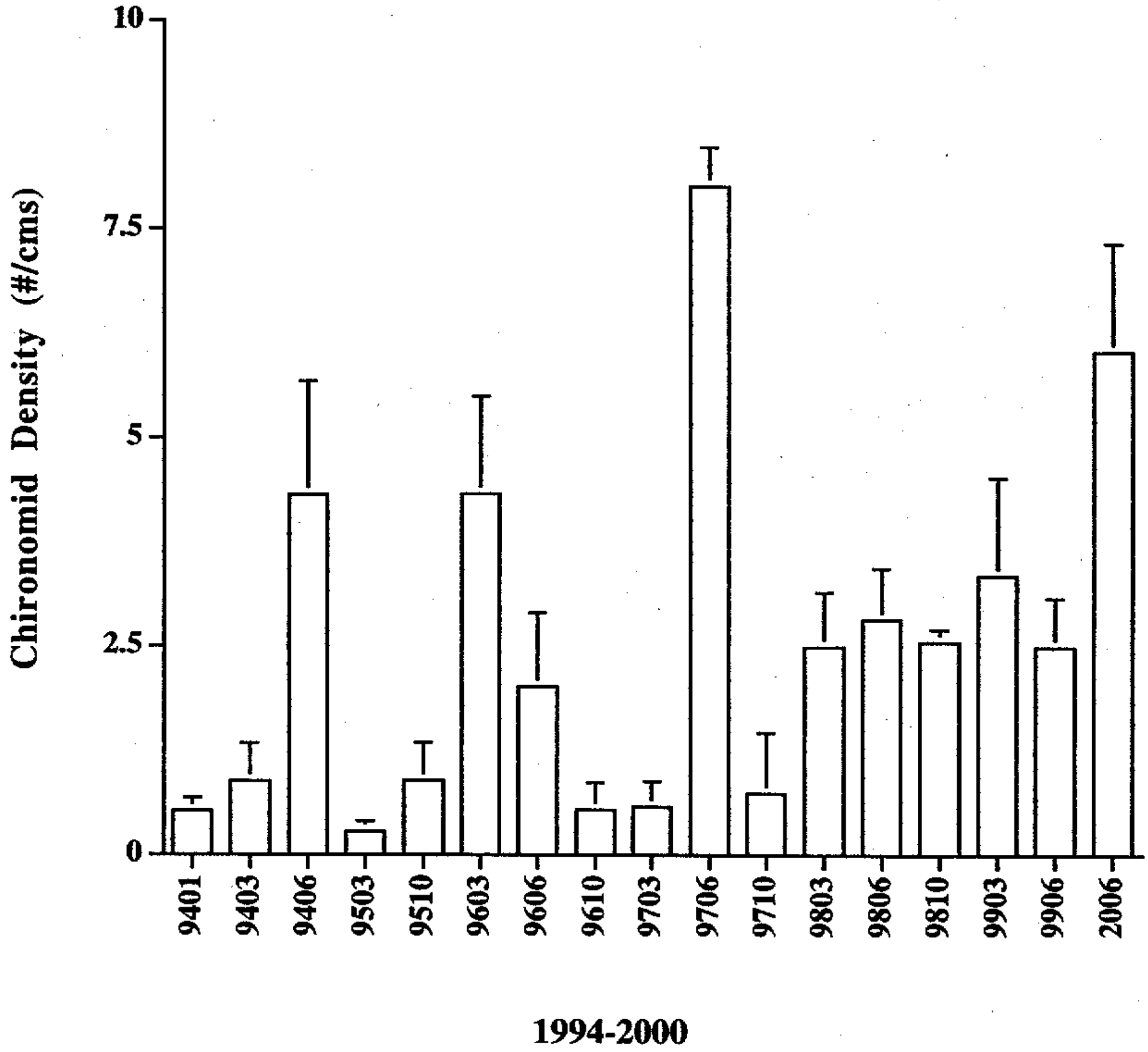

Figure 229. Average CPOM drift densities (#/cms) for Chironomids collected at Two-Mile Wash Rkm 2.9 from January 1994 to June 2000. Error Bars represent (± 1 SE).

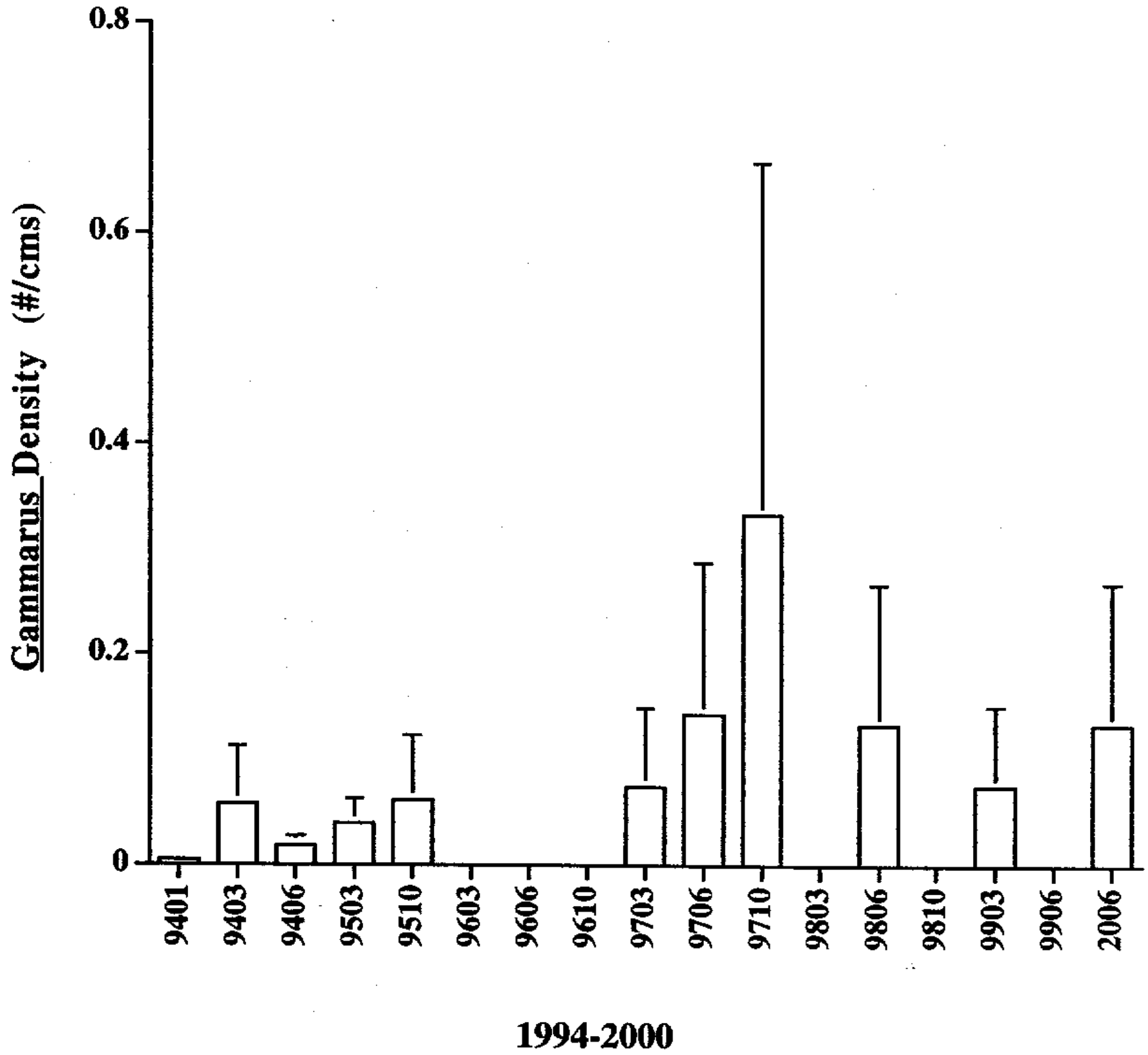

Figure 230. Average CPOM drift densities (#/cms) for <u>Gammarus</u> collected at Two-Mile Wash Rkm 2.9 from January 1994 to June 2000. Error Bars represent (± 1 SE).

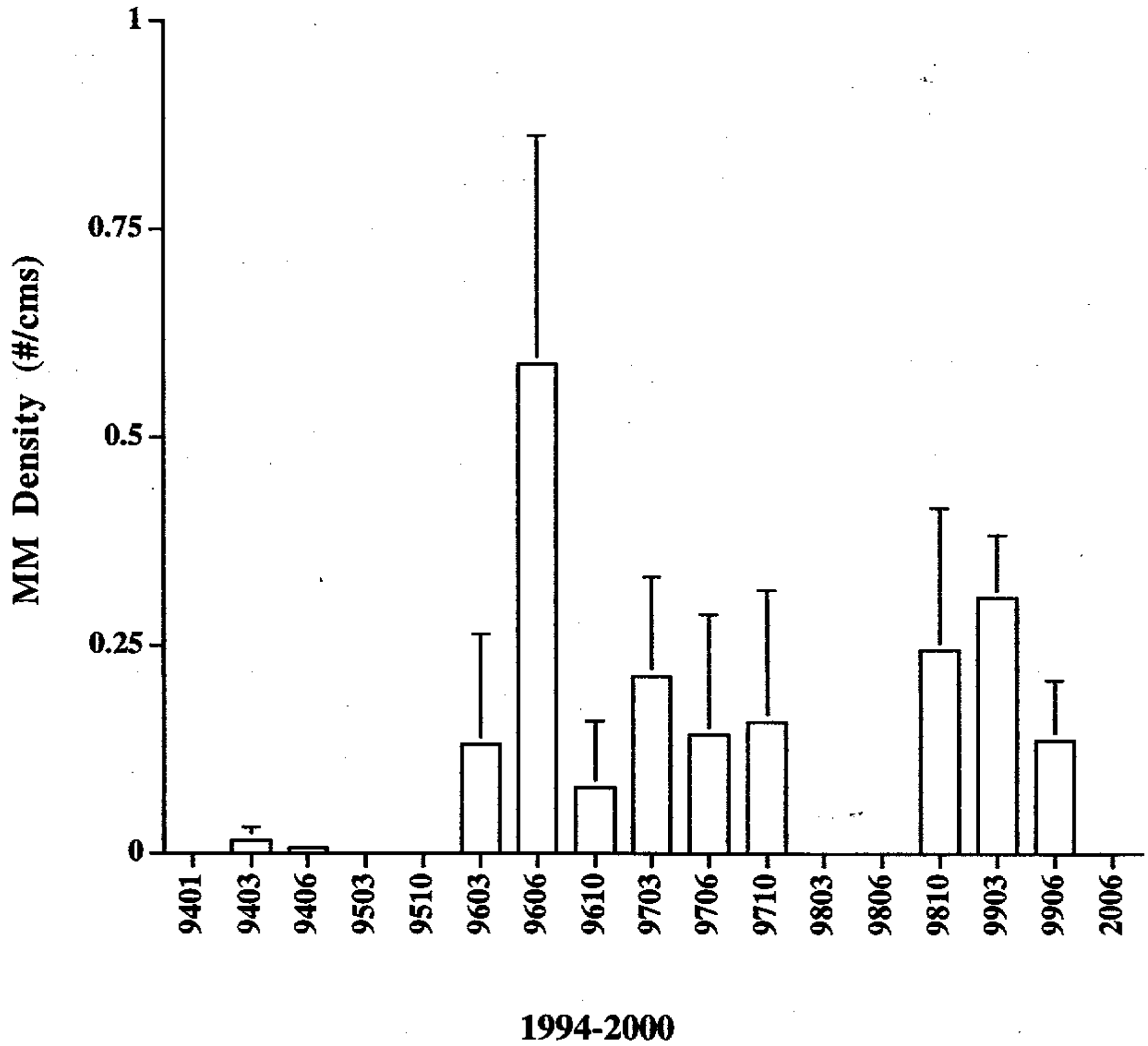

Figure 231. Average CPOM drift densities (#/cms) for miscellaneous macroinvertebrates (MM) collected at Two-Mile Wash Rkm 2.9 from January 1994 to June 2000. Error Bars represent (± 1 SE).

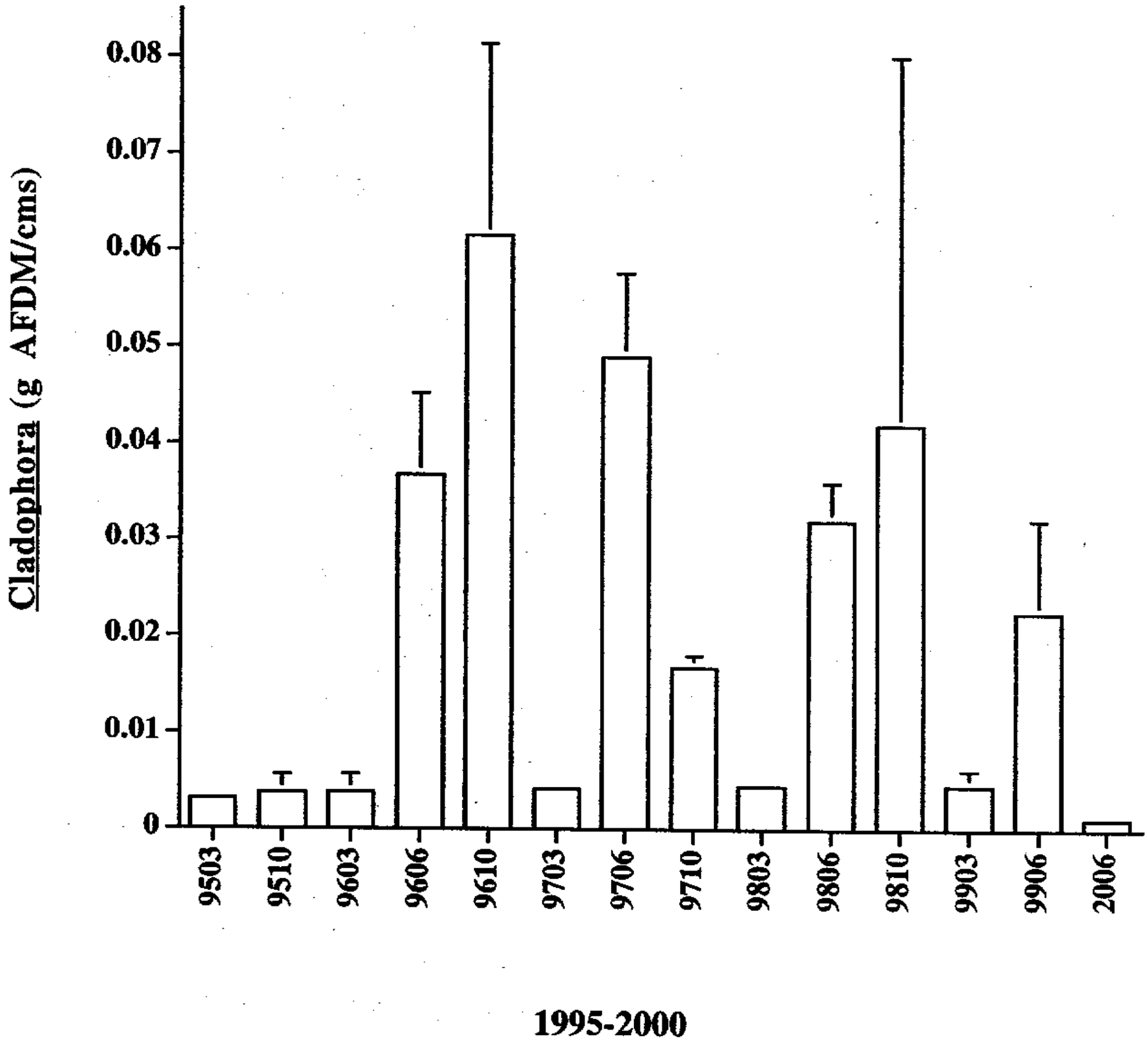

Figure 232. Average CPOM drift mass (g AFDM/cms) for Cladophora collected at the Gauge above LCR Rkm 98.4 from March 1995 to June 2000. Error Bars represent (± 1 SE).

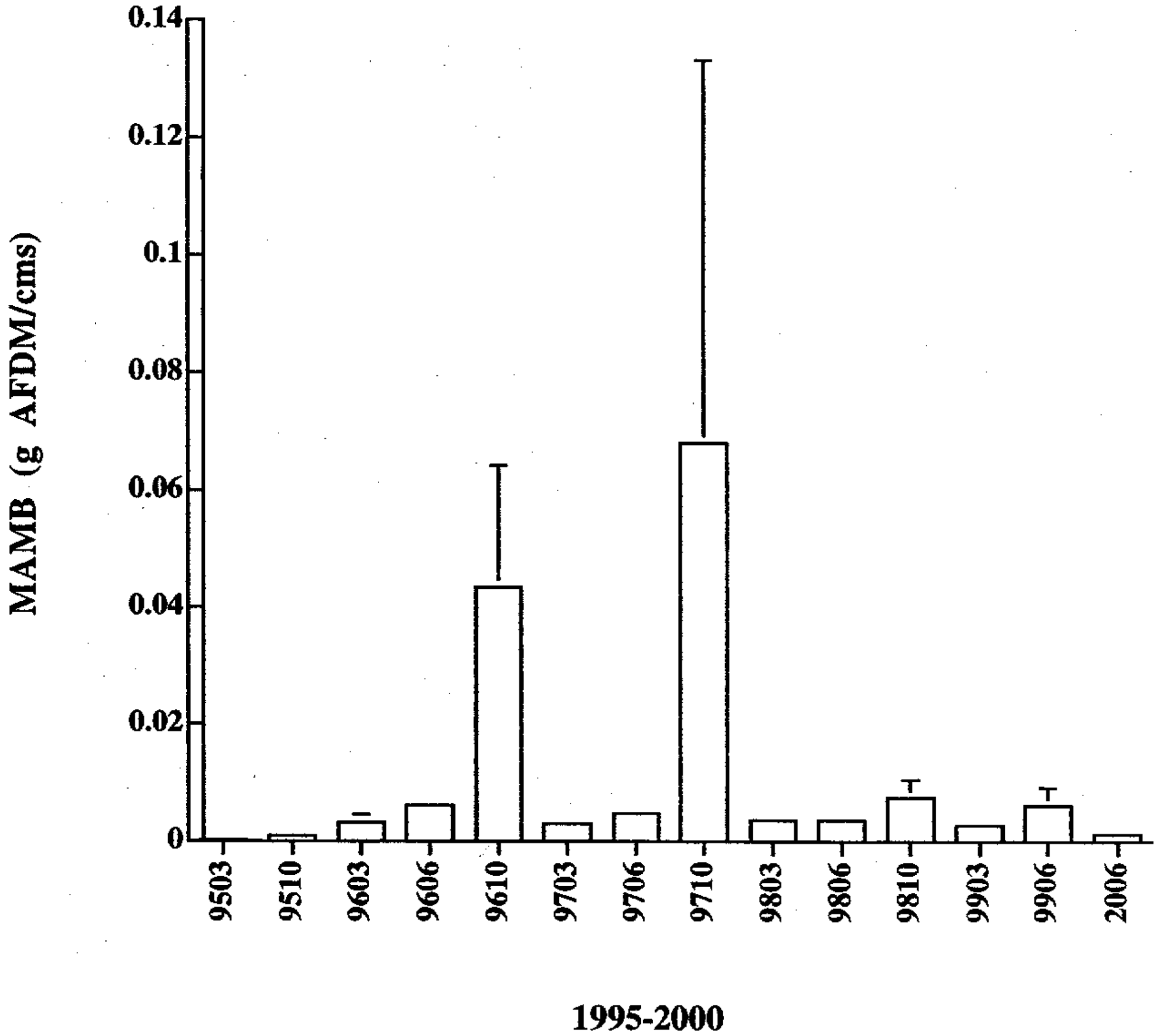

Figure 233. Average CPOM drift mass (g AFDM/cms) for miscellaneous algae, macrophytes and bryophytes (MAMB) collected at Gauge above LCR Rkm 98.4 from March 1995 to June 2000. Error Bars represent (± 1 SE).

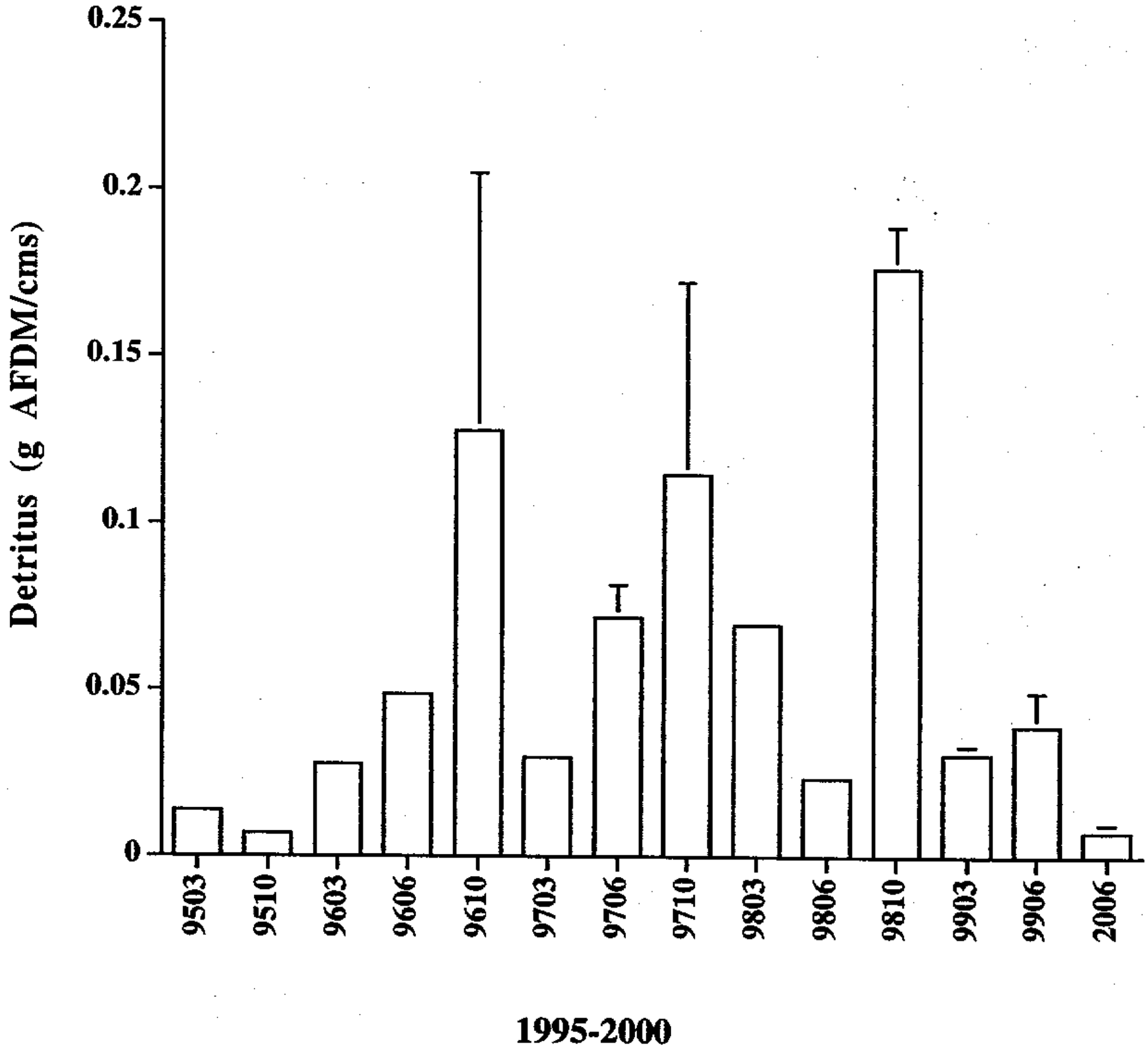

Figure 234. Average CPOM drift mass (g AFDM/cms) for detritus collected at the Gauge above LCR Rkm 98.4 from March 1995 to June 2000. Error Bars represent (± 1 SE).

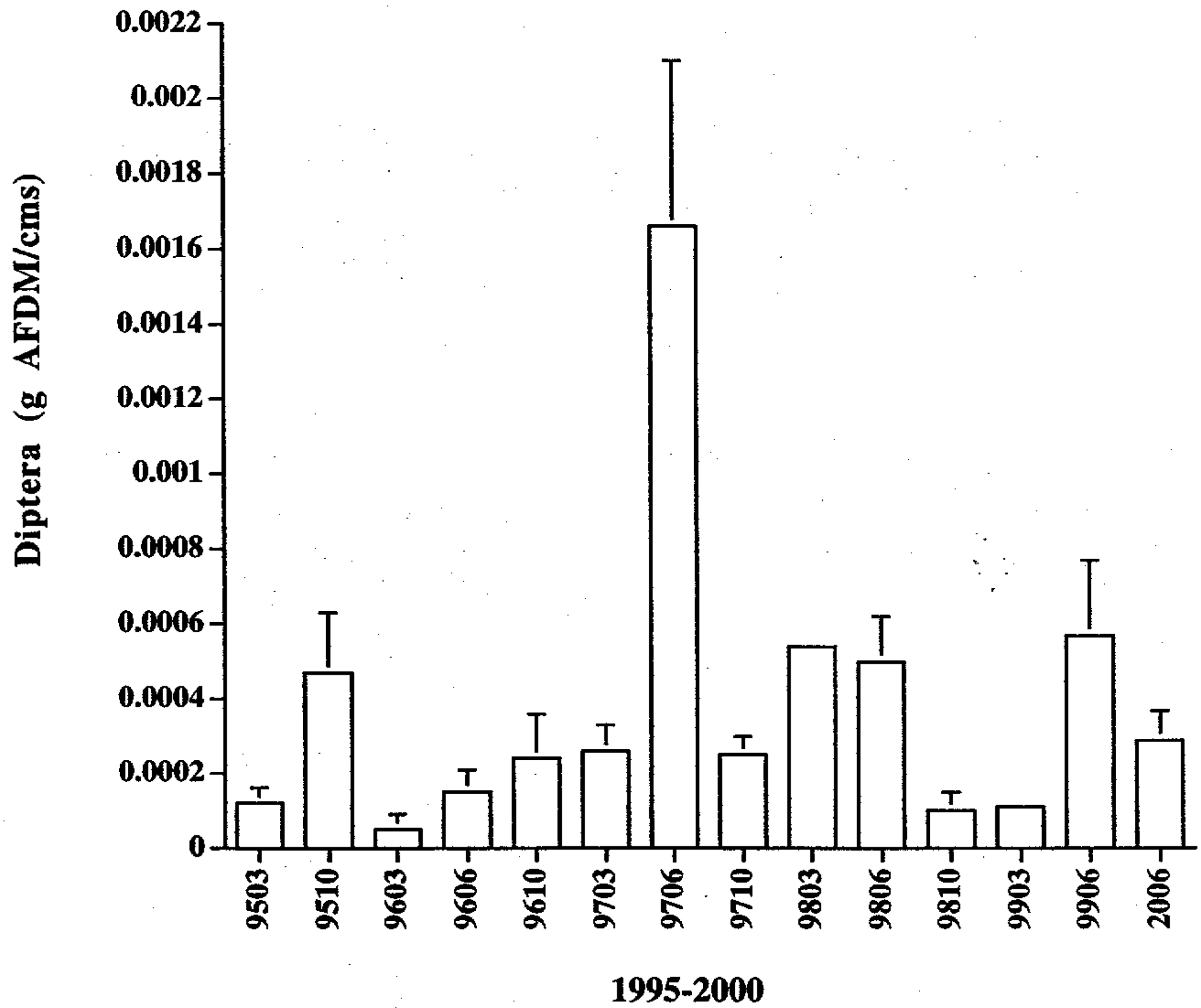

Figure 235. Average CPOM drift mass (g AFDM/cms) for aquatic diptera collected at the Gauge above LCR Rkm 98.4 from March 1995 to June 2000. Error Bars represent (± 1 SE).

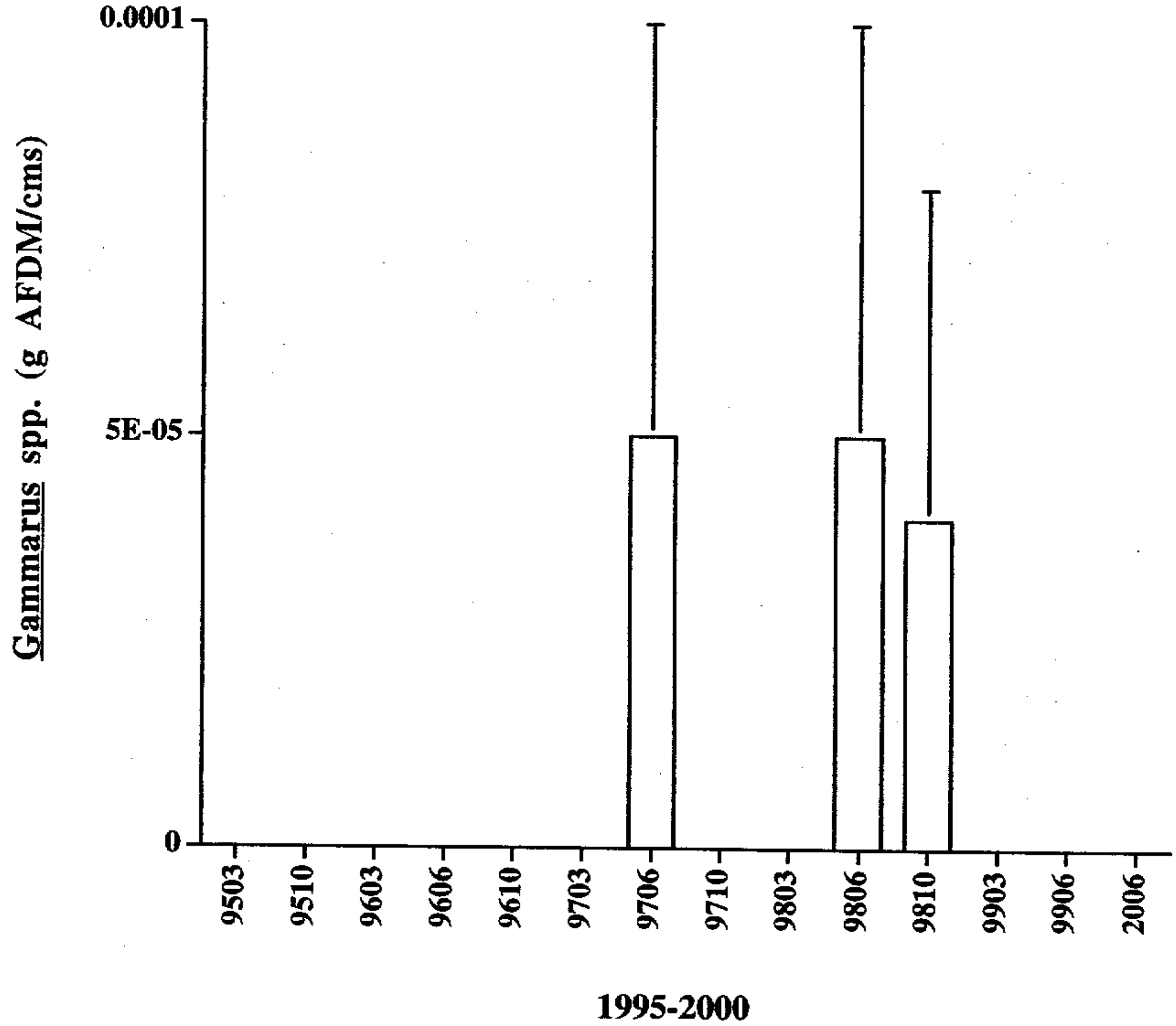

Figure 236. Average CPOM drift mass (g AFDM/cms) for <u>Gammarus</u> collected at the Gauge above LCR Rkm 98.4 from March 1995 to June 2000. Error Bars represent (± 1 SE).

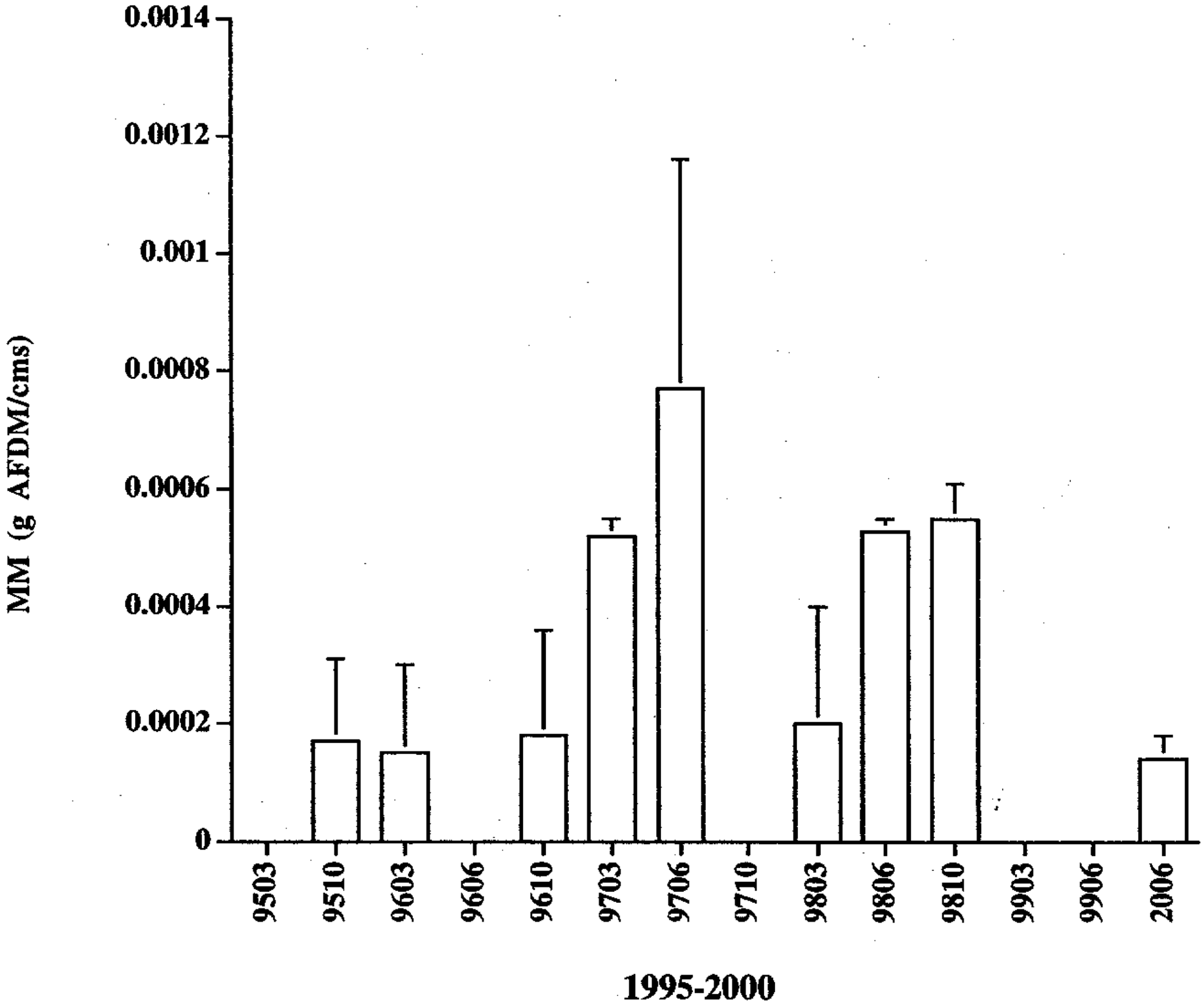

Figure 237. Average CPOM drift mass (g AFDM/cms) for miscellaneous macroinvertebrates (MM) collected at the Gauge above LCR Rkm 98.4 from March 1995 to June 2000. Error Bars represent (± 1 SE).

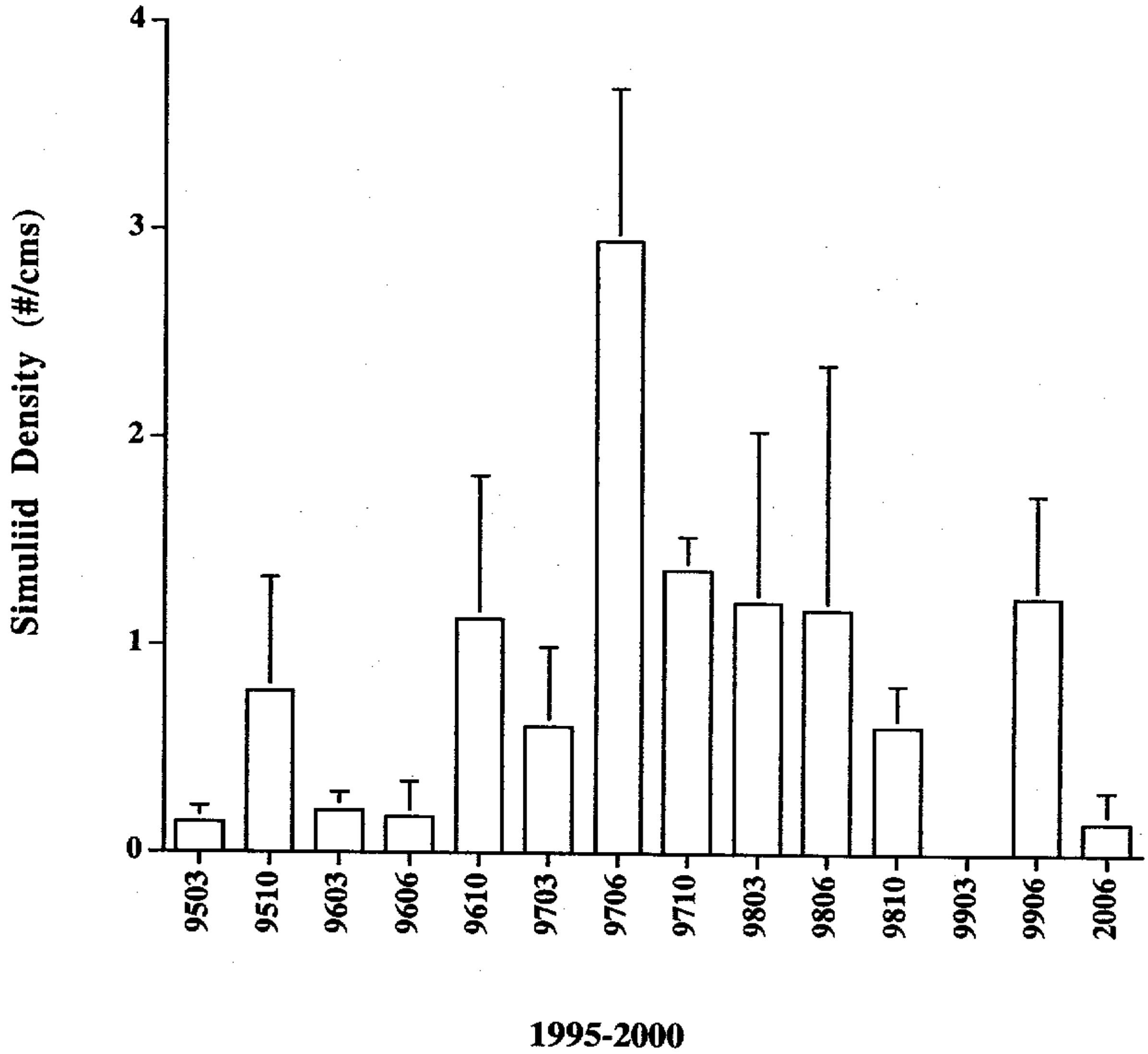

Figure 238. Average CPOM drift densities (#/cms) for Simuliids collected at Gauge above LCR Rkm 98.4 from March 1995 to June 2000. Error Bars represent (± 1 SE).

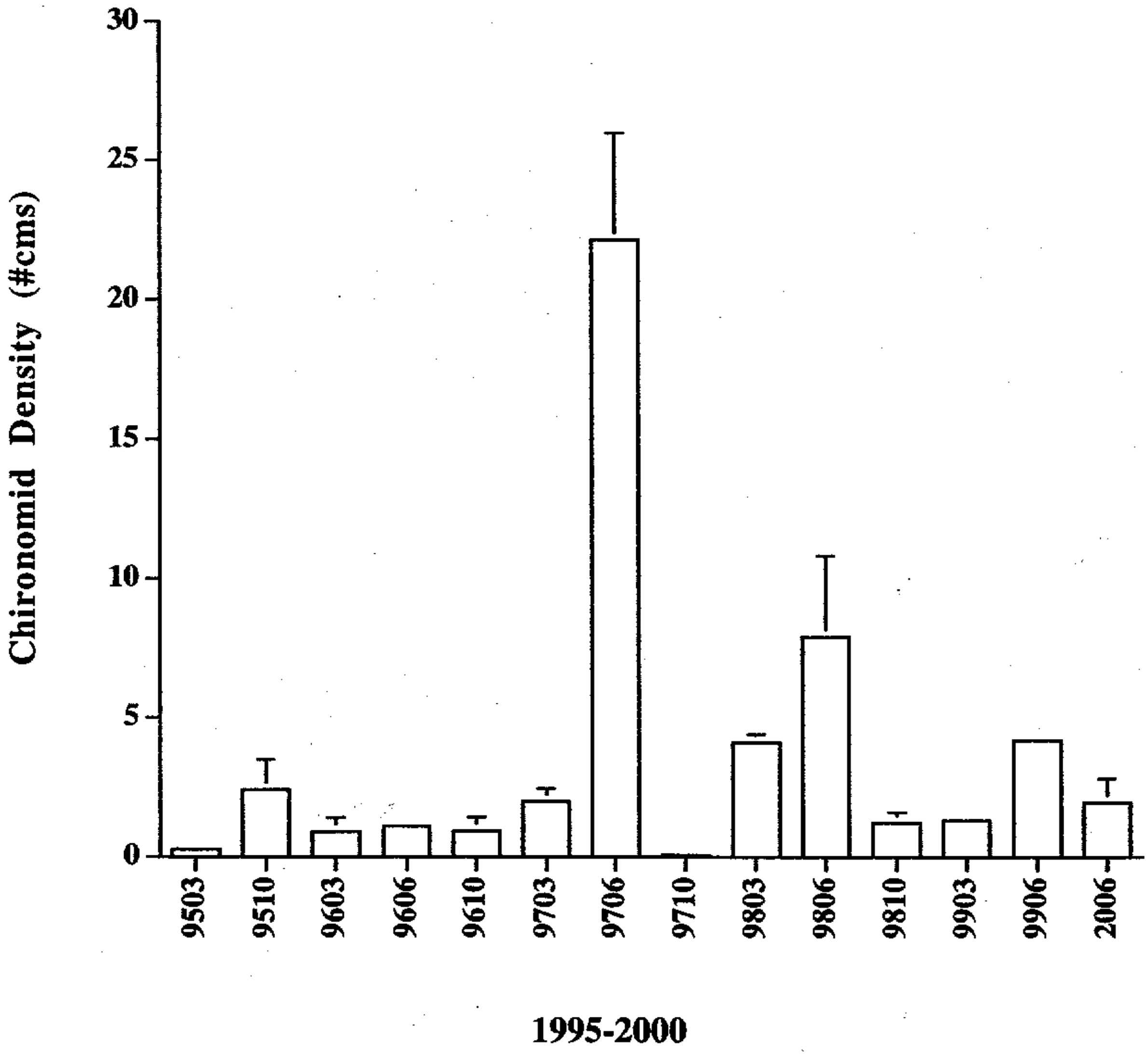

Figure 239. Average CPOM drift densities (#/cms) for Chironomids collected at Gauge above LCR Rkm 98.4 from March 1995 to June 2000. Error Bars represent (± 1 SE).

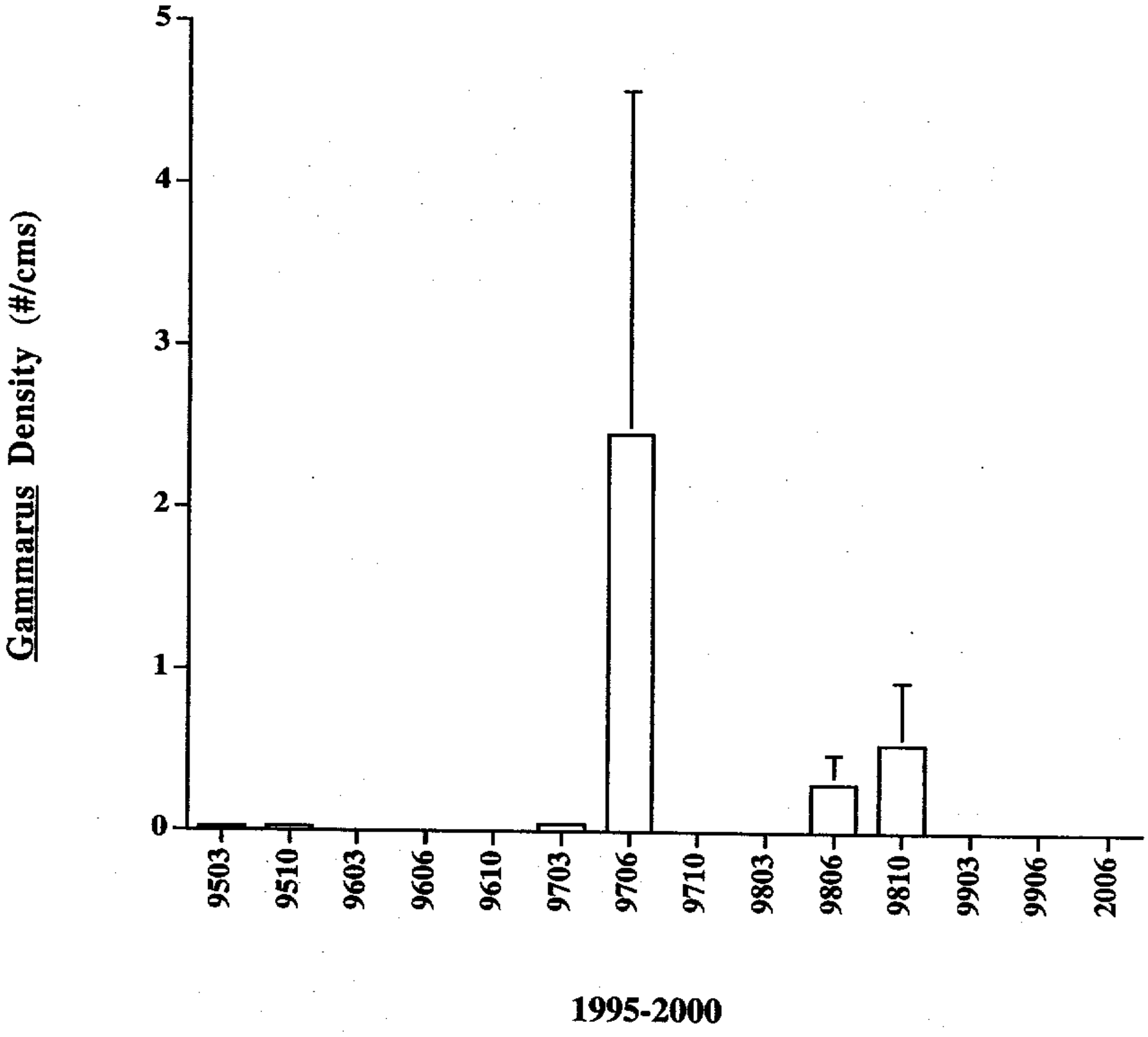

Figure 240. Average CPOM drift densities (#/cms) for Gammarus collected at Gauge above LCR Rkm 98.4 from March 1995 to June 2000. Error Bars represent (± 1 SE).

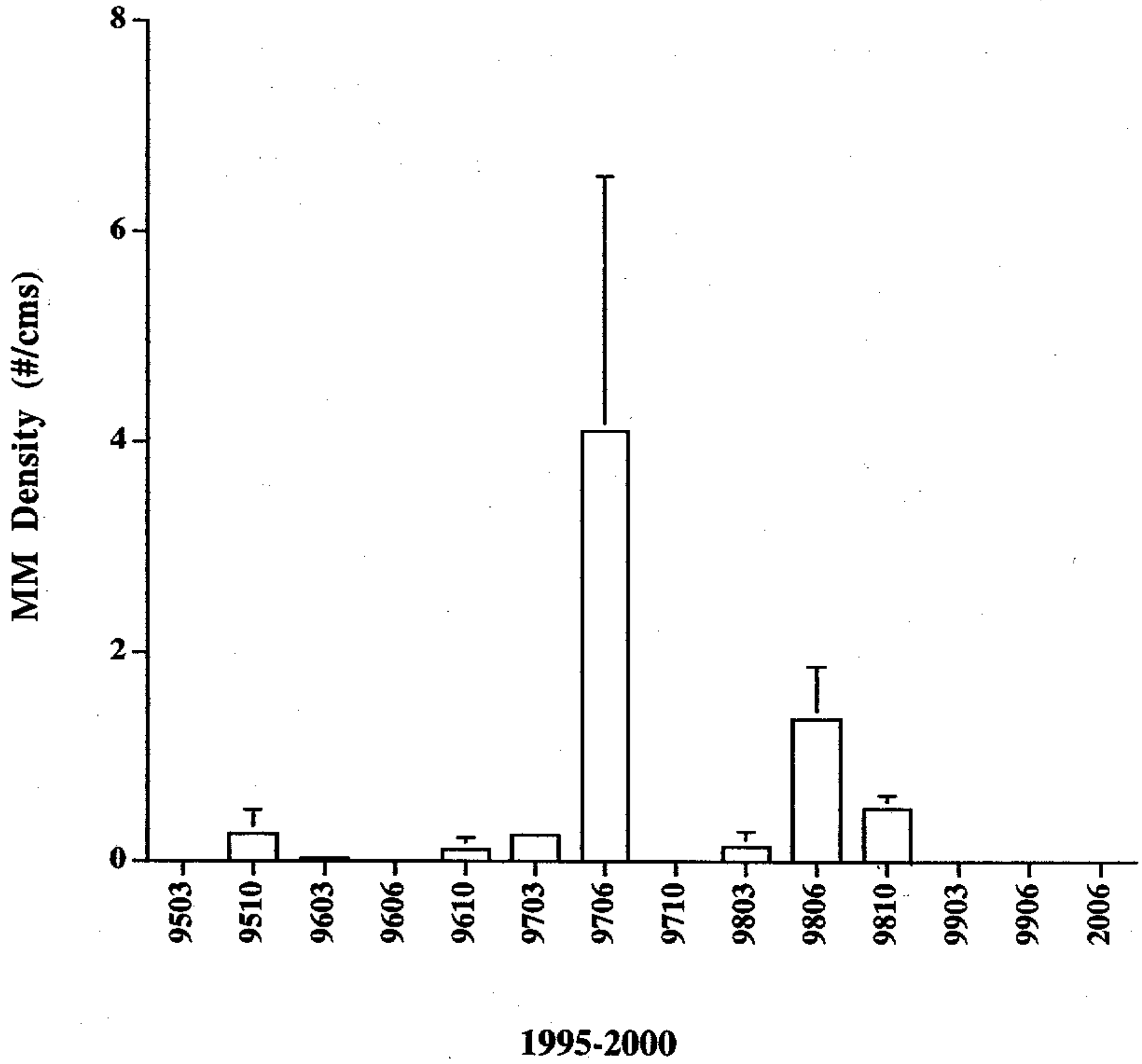

Figure 241. Average CPOM drift densities (#/cms) for miscellaneous macroinvertebrates (MM) collected at Gauge above LCR Rkm 98.4 from March 1995 to June 2000. Error Bars represent (± 1 SE).

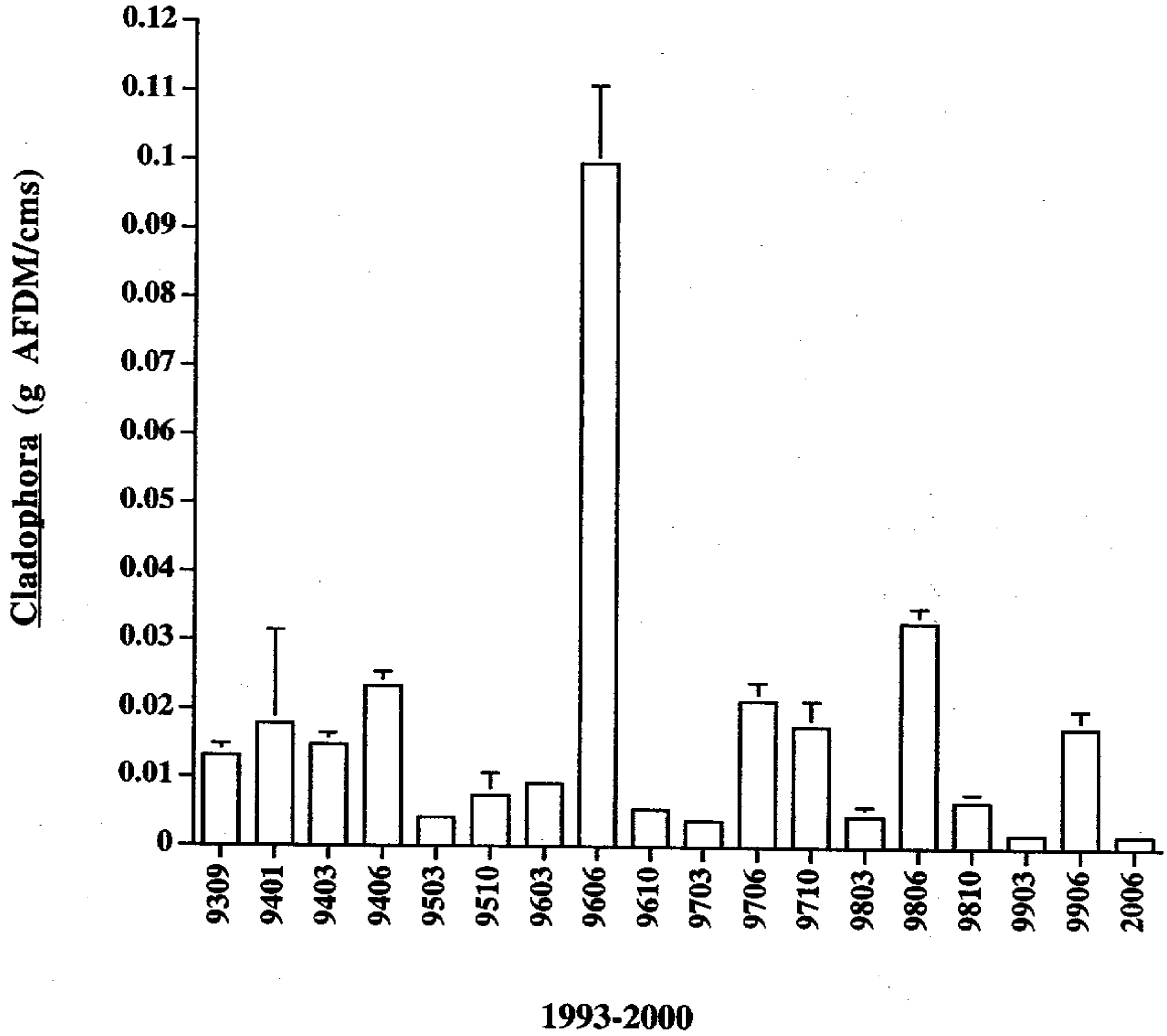

Figure 242. Average CPOM drift mass (g AFDM/cms) for Cladophora collected at Tanner cobble Rkm 109.6 from September 1993 to June 2000. Error Bars represent (± 1 SE).

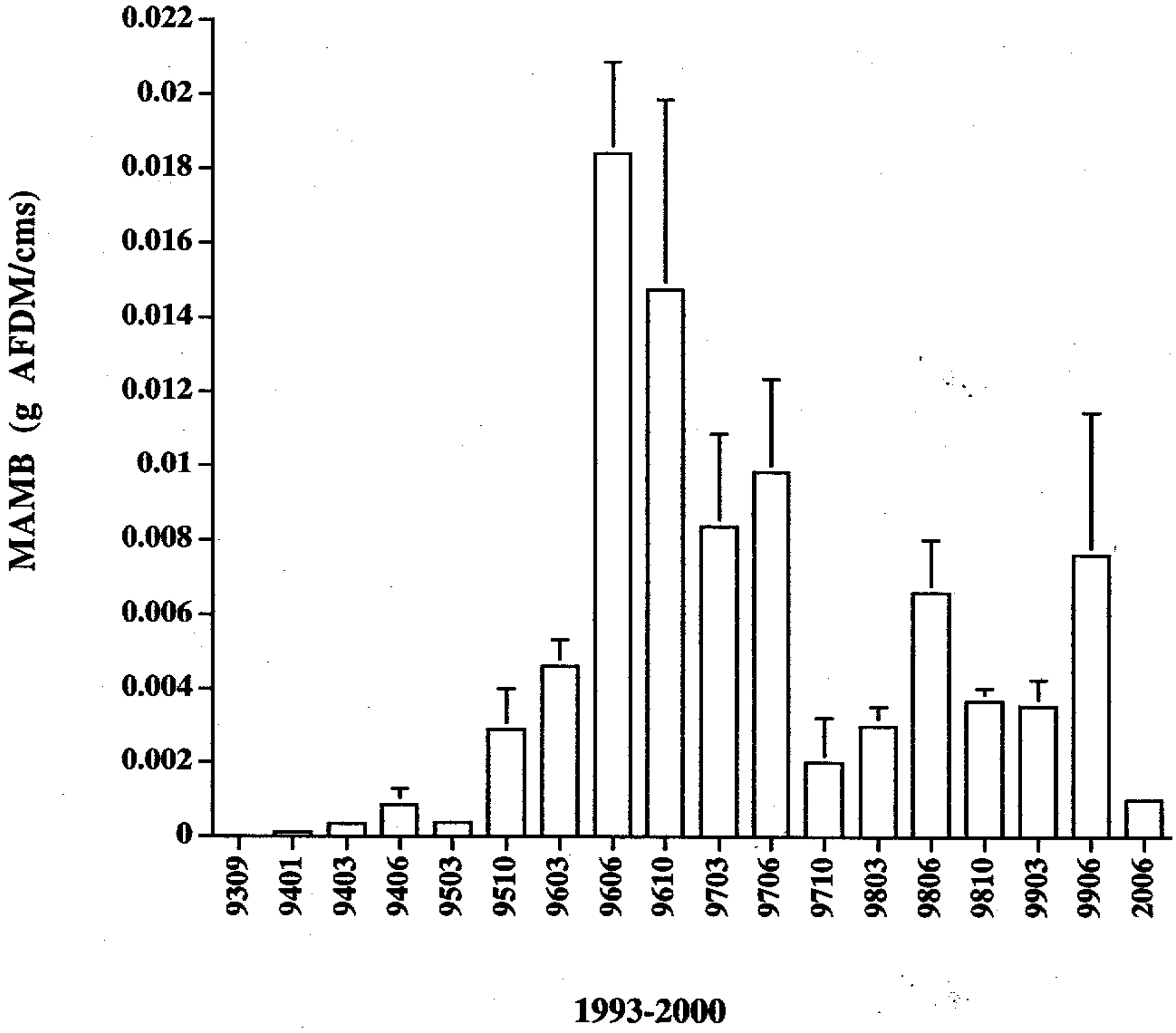

Figure 243. Average CPOM drift mass (g AFDM/cms) for miscellaneous algae, macrophytes and bryophytes (MAMB) collected at Tanner cobble Rkm 109.6 from September 1993 to June 2000. Error Bars represent (± 1 SE).

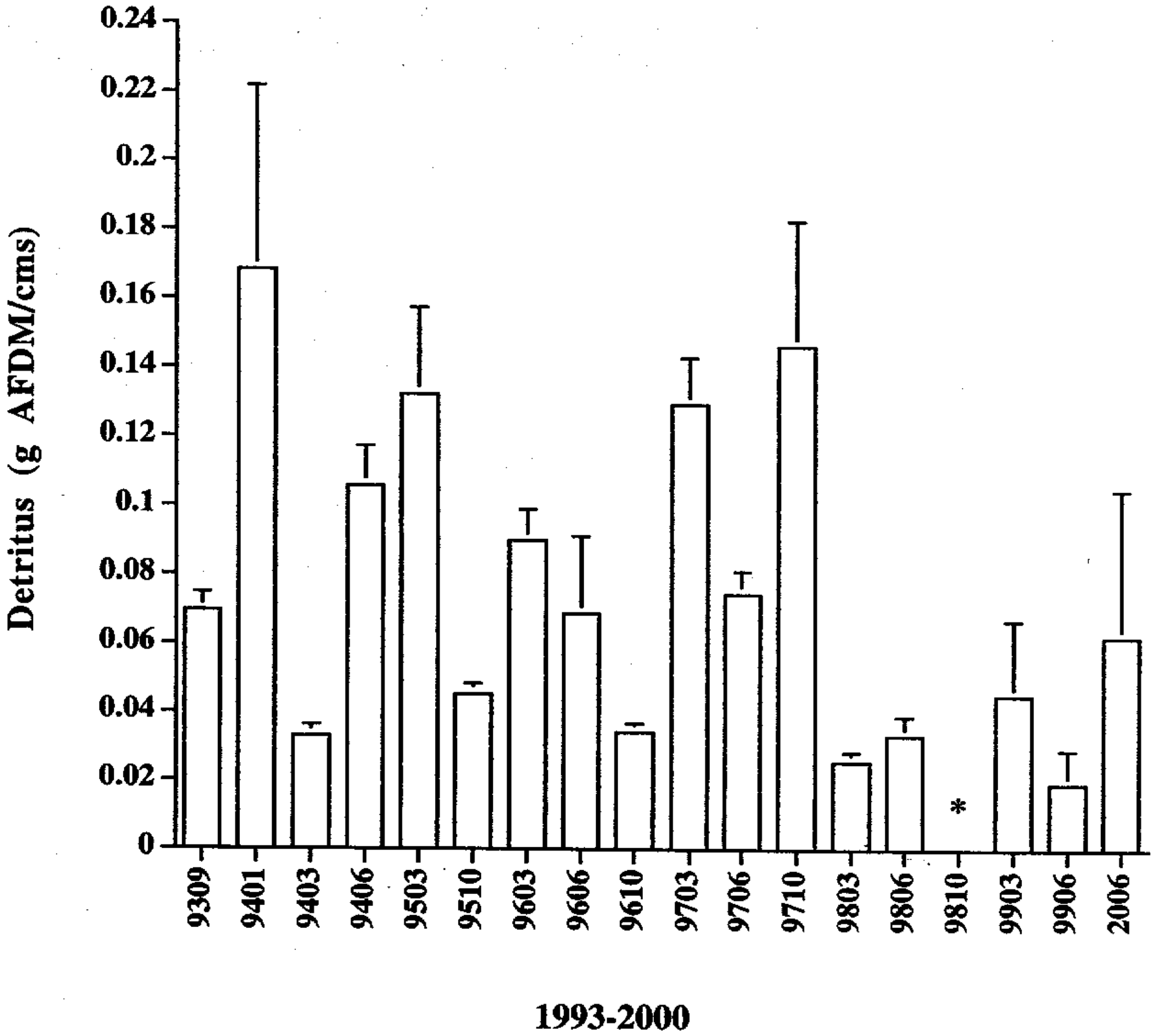

Figure 244. Average CPOM drift mass (g AFDM/cms) for detritus collected at Tanner cobble Rkm 109.6 from September 1993 to June 2000. Error Bars represent ($\pm$ 1 SE). Asterisk (*) represents 0.30 g AFDM/cms ($\pm$ 0.10 SE).

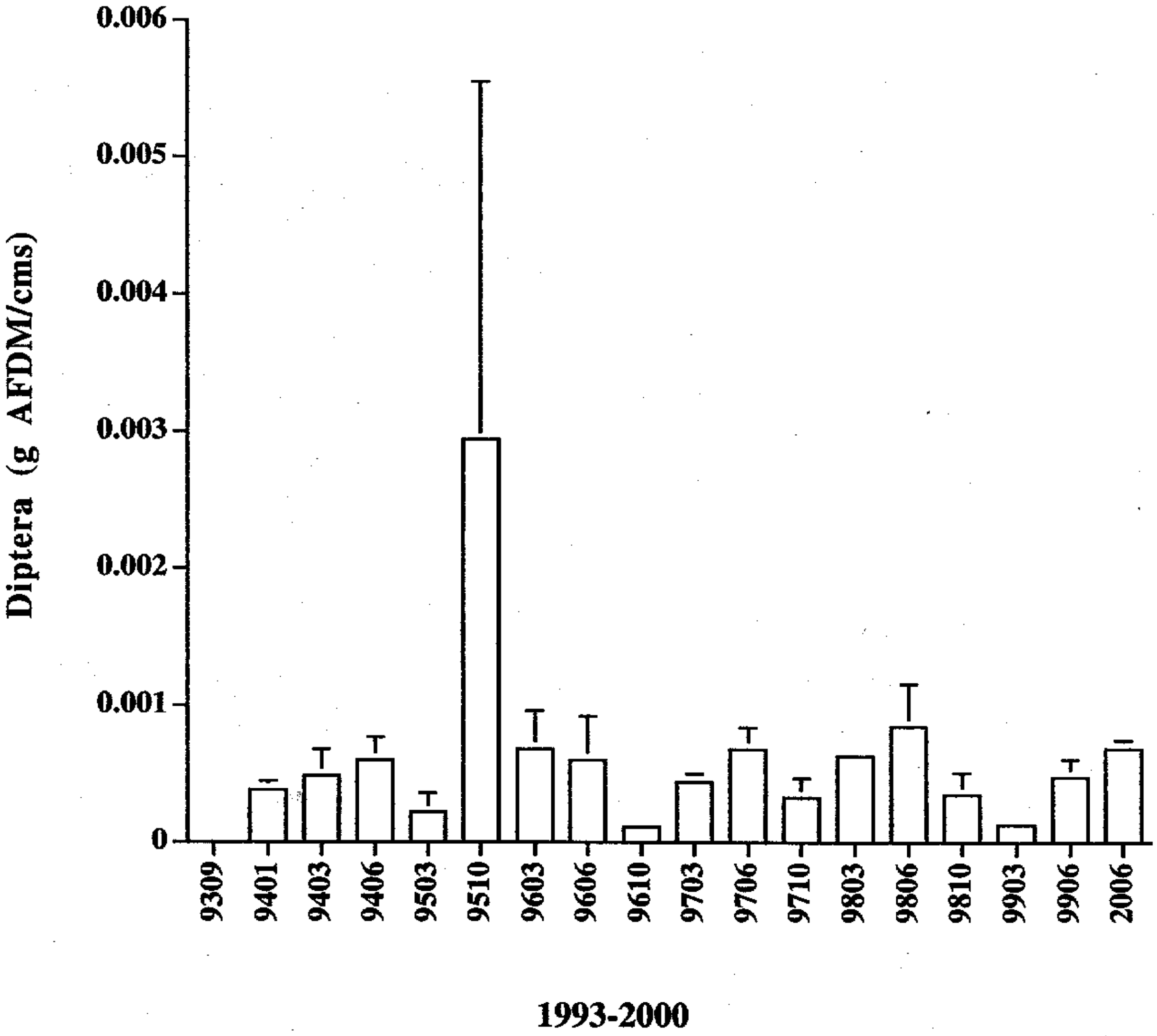

Figure 245. Average CPOM drift mass (g AFDM/cms) for aquatic diptera collected at Tanner cobble Rkm 109.6 from September 1993 to June 2000. Error Bars represent (± 1 SE).

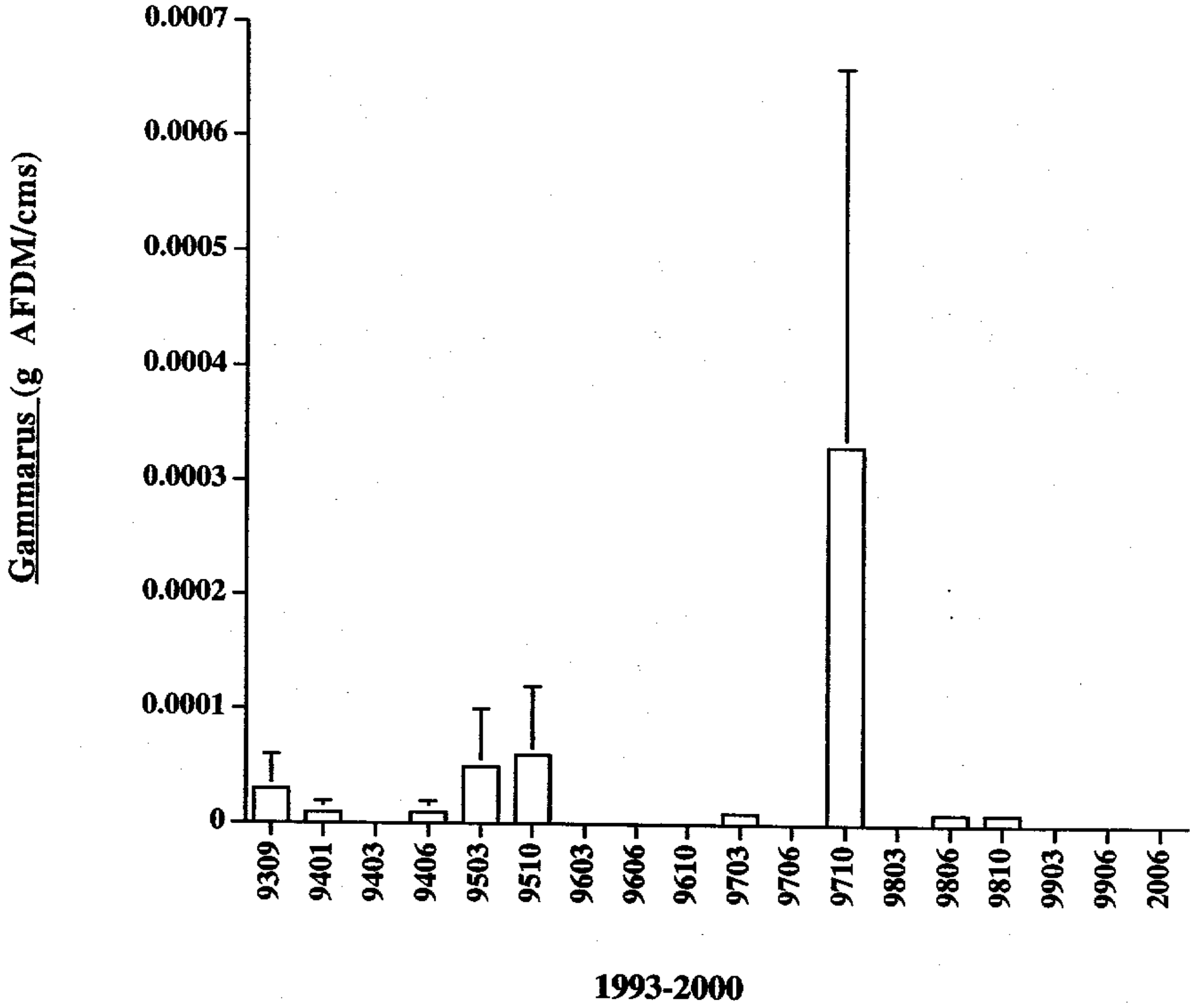

Figure 246. Average CPOM drift mass (g AFDM/cms) for Gammarus collected at Tanner cobble Rkm 109.6 from September 1993 to June 2000. Error Bars represent ($\pm$ 1 SE).

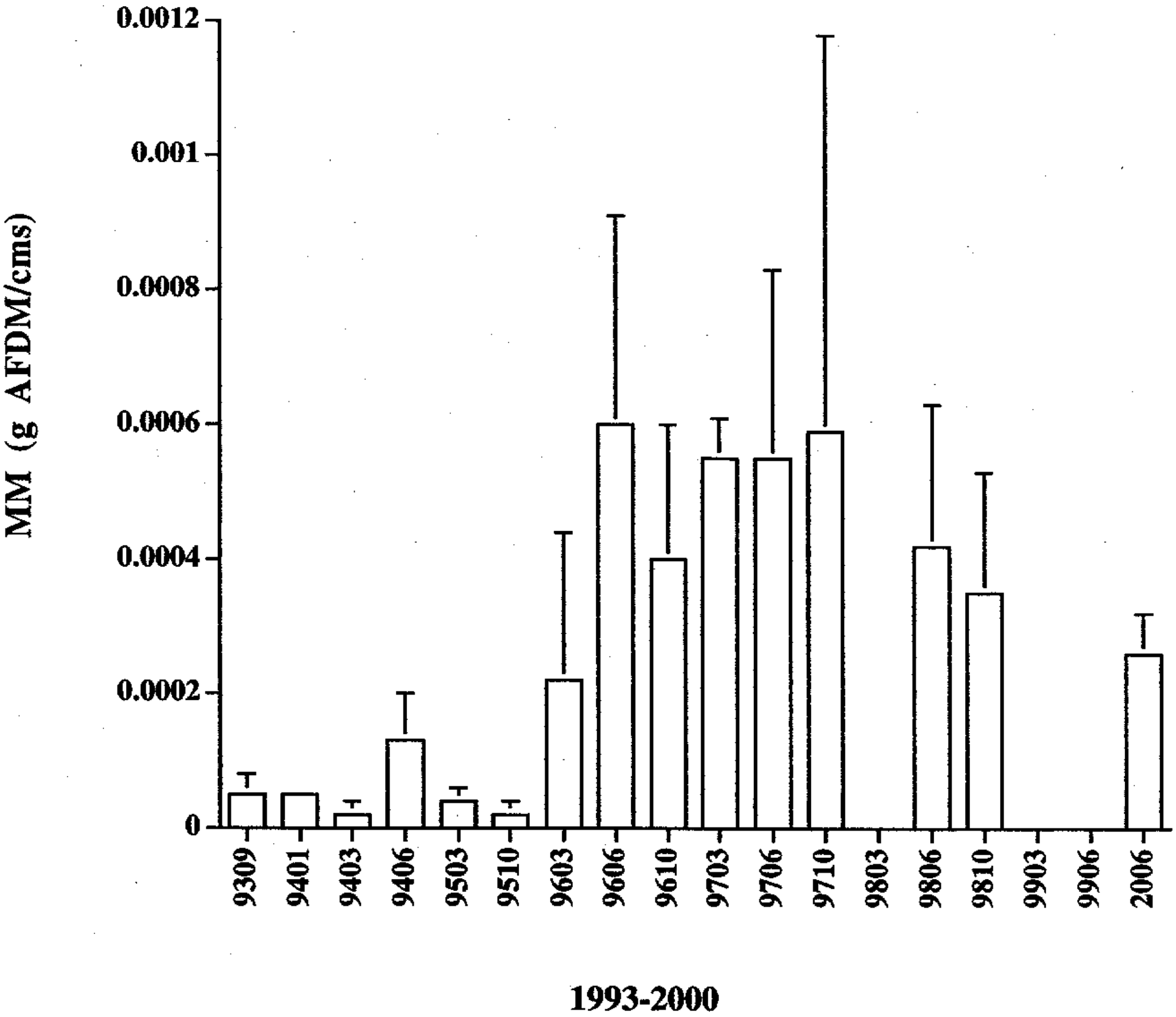

Figure 247. Average CPOM drift mass (g AFDM/cms) for miscellaneous macroinvertebrates (MM) collected at Tanner cobble Rkm 109.6 from September 1993 to June 2000. Error Bars represent (± 1 SE).

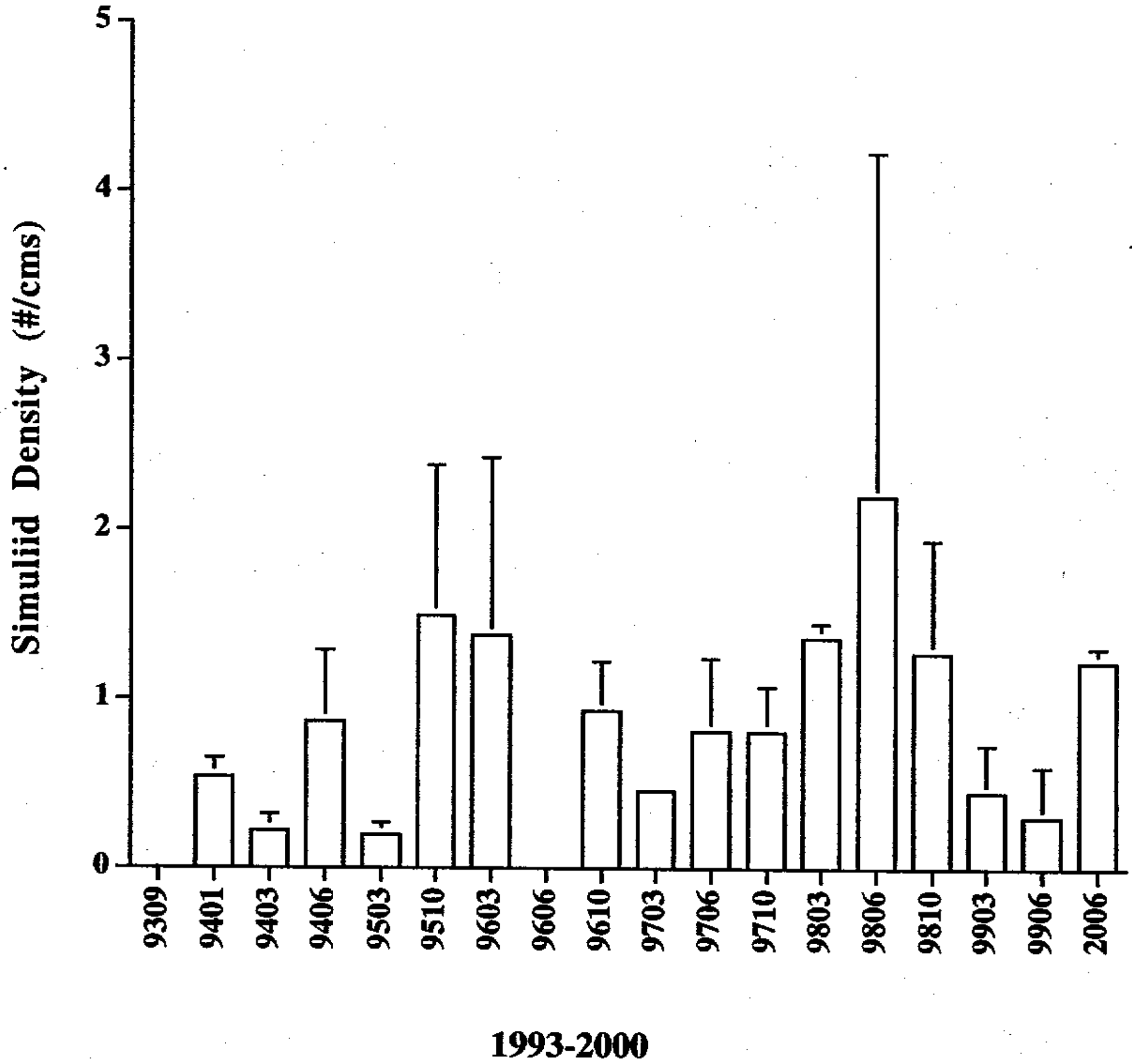

Figure 248. Average CPOM drift densities (#/cms) for Simuliids collected at Tanner cobble Rkm 109.6 from September 1993 to June 2000. Error Bars represent (± 1 SE).

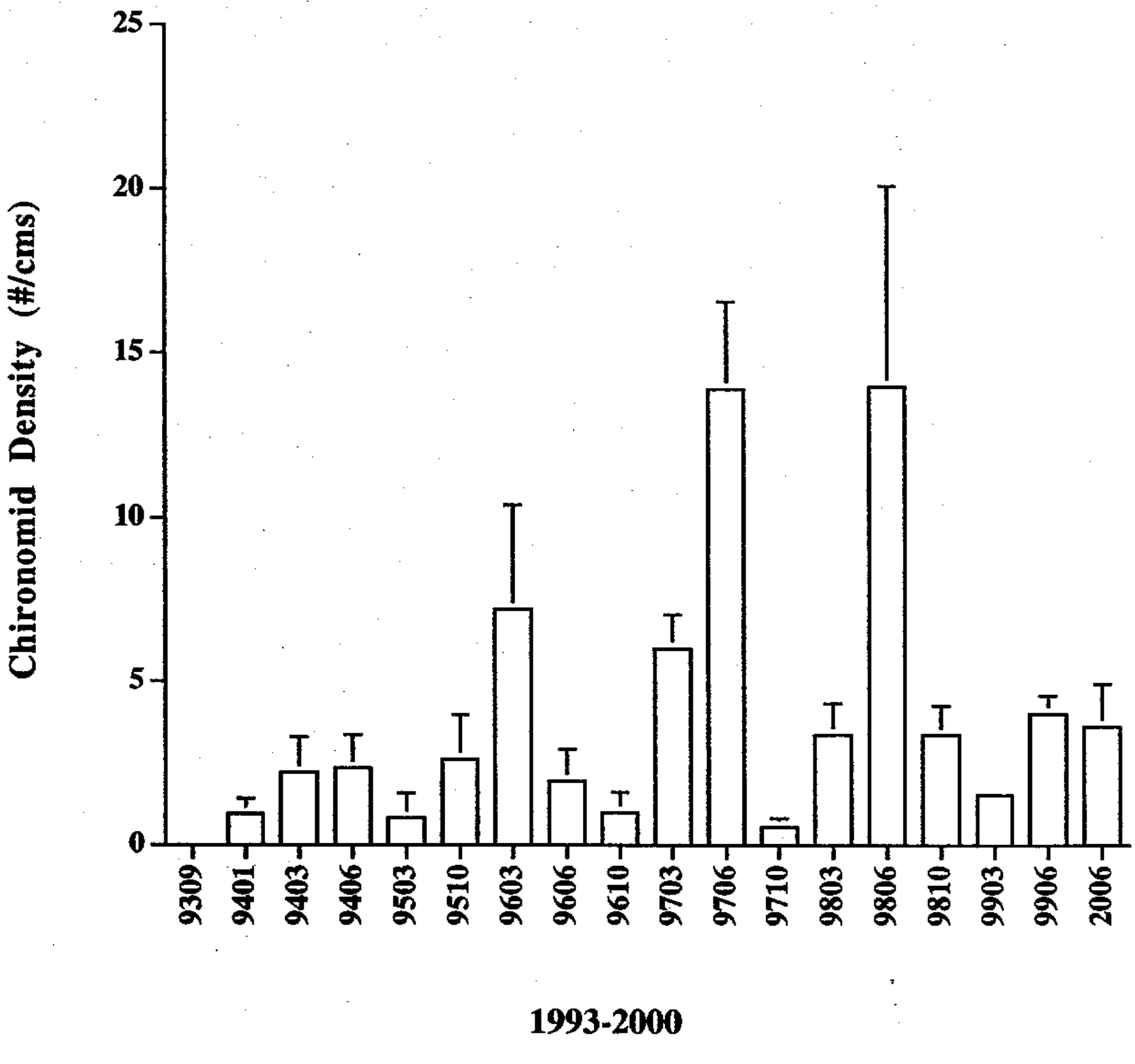

Figure 249. Average CPOM drift densities (#/cms) for Chironomids collected at Tanner cobble Rkm 109.6 from September 1993 to June 2000. Error Bars represent (± 1 SE).

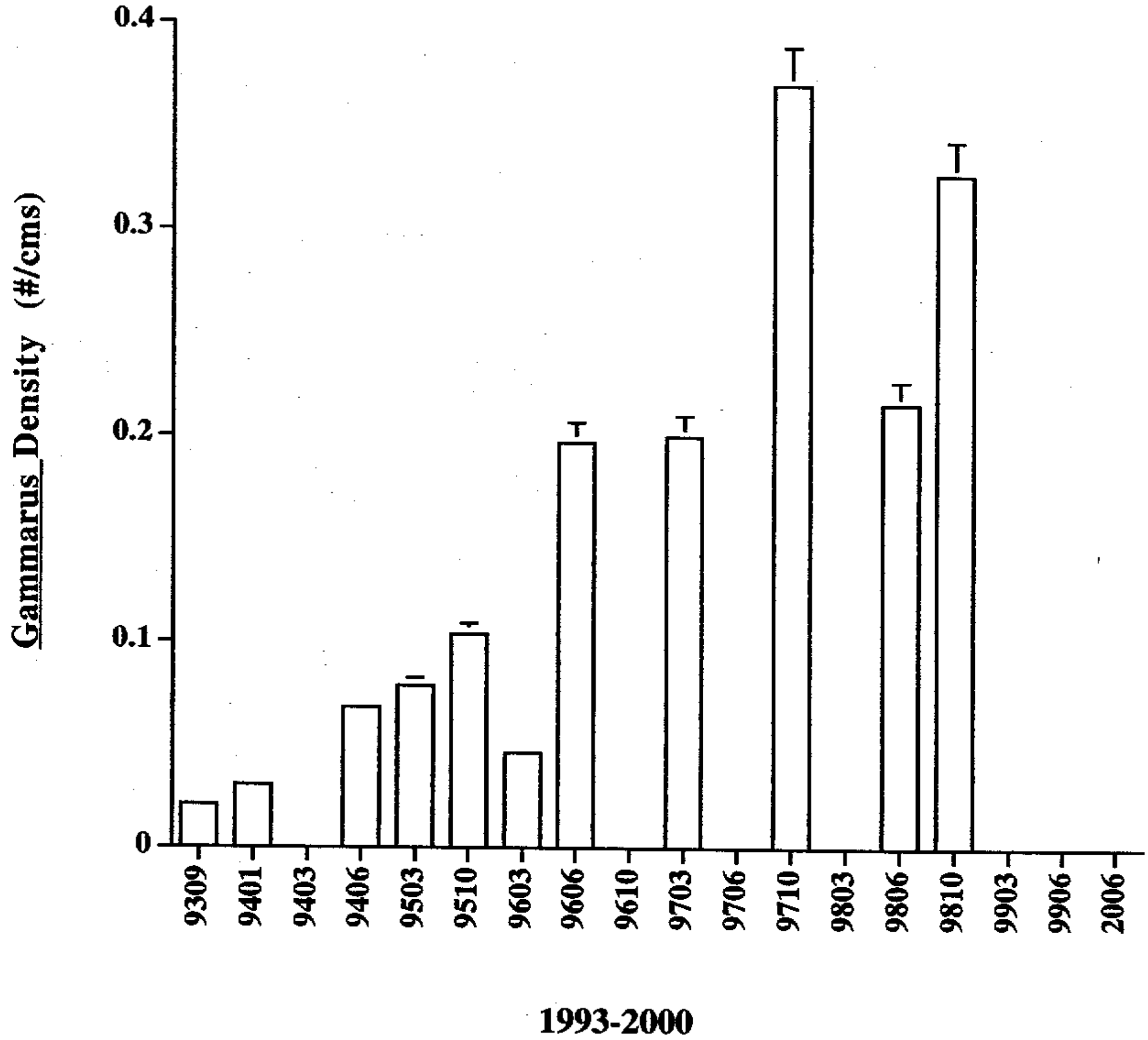

Figure 250. Average CPOM drift densities (#/cms) for Gammarus collected at Tanner cobble Rkm 109.6 from September 1993 to June 2000. Error Bars represent (± 1 SE).

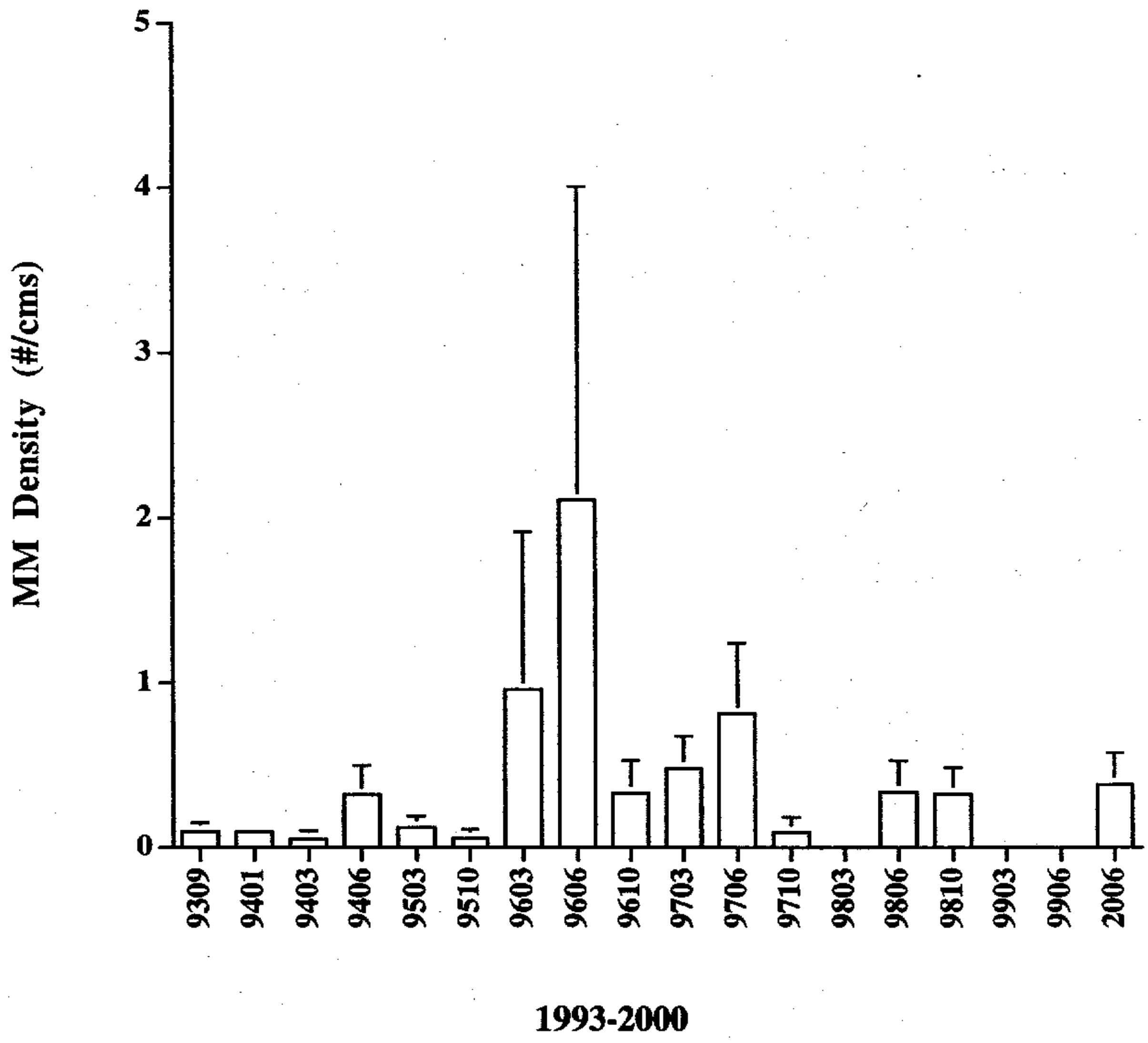

Figure 251. Average CPOM drift densities (#/cms) for miscellaneous macroinvertebrates (MM) collected at Tanner cobble Rkm 109.6 from September 1993 to June 2000. Error Bars represent (± 1 SE).

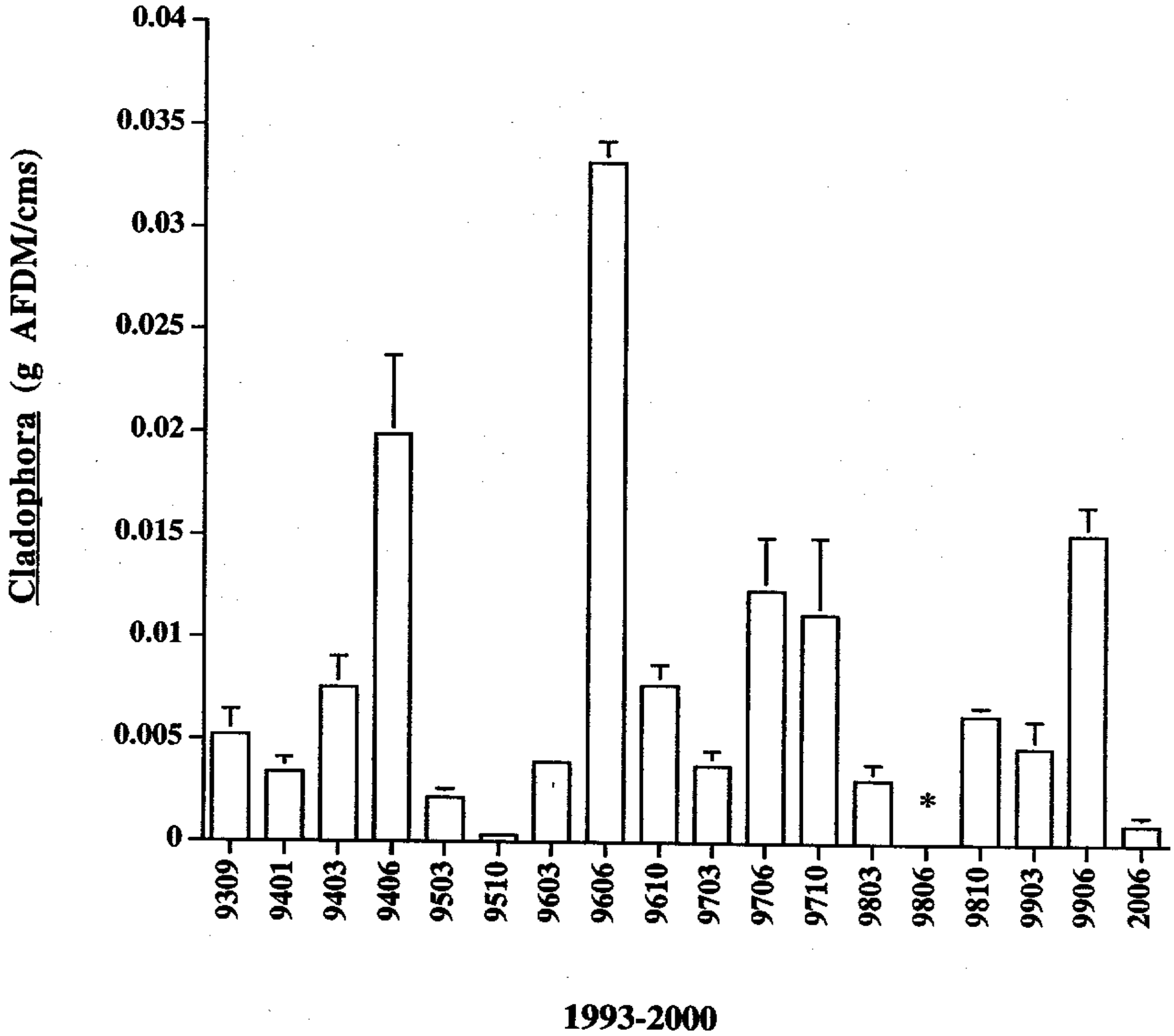

Figure 252. Average CPOM drift mass (g AFDM/cms) for Cladophora collected at 127 Mile rapid Rkm 202.9 from September 1993 to June 2000. Error Bars represent (+ 1 SE). Asterisk (*) represents 0.05 g AFDM/cms (+ 0.02 SE).

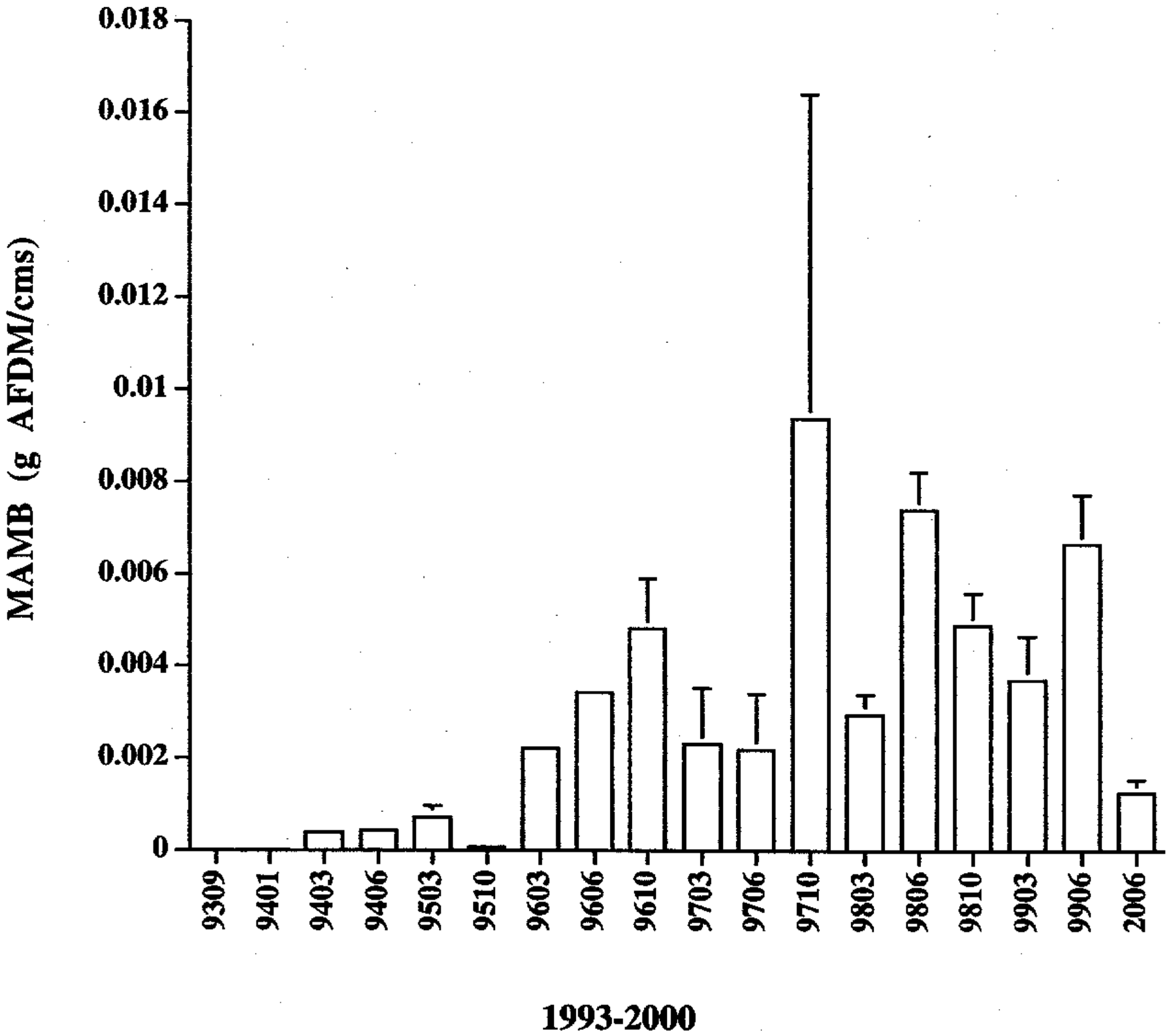

Figure 253. Average CPOM drift mass (g AFDM/cms) for miscellaneous algae, macrophytes and bryophytes (MAMB) collected at 127 Mile rapid Rkm 202.9 from September 1993 to June 2000. Error Bars represent (± 1 SE).

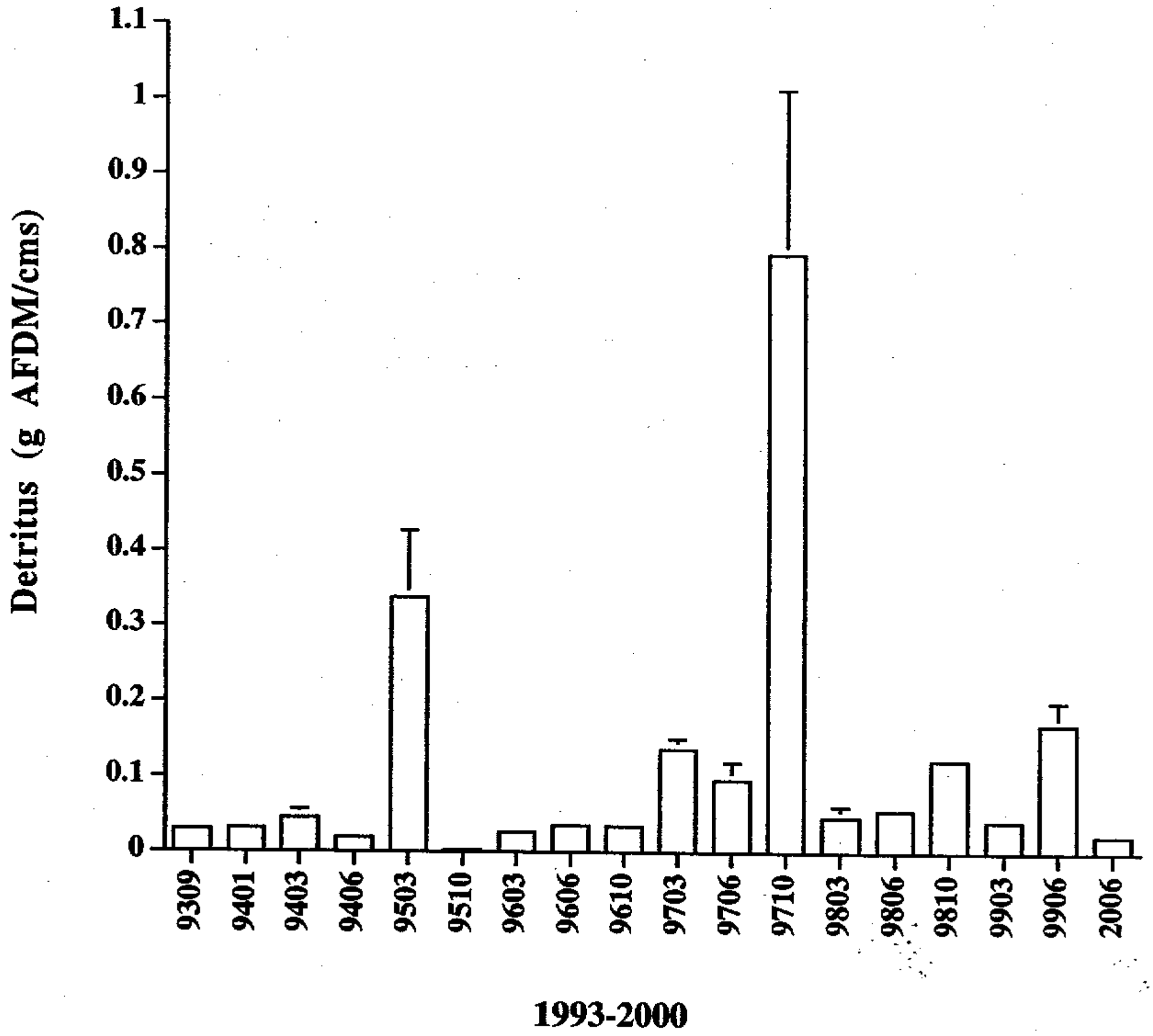

Figure 254. Average CPOM drift mass (g AFDM/cms) for detritus collected at 127 Mile rapid Rkm 202.9 from September 1993 to June 2000. Error Bars represent (± 1 SE).

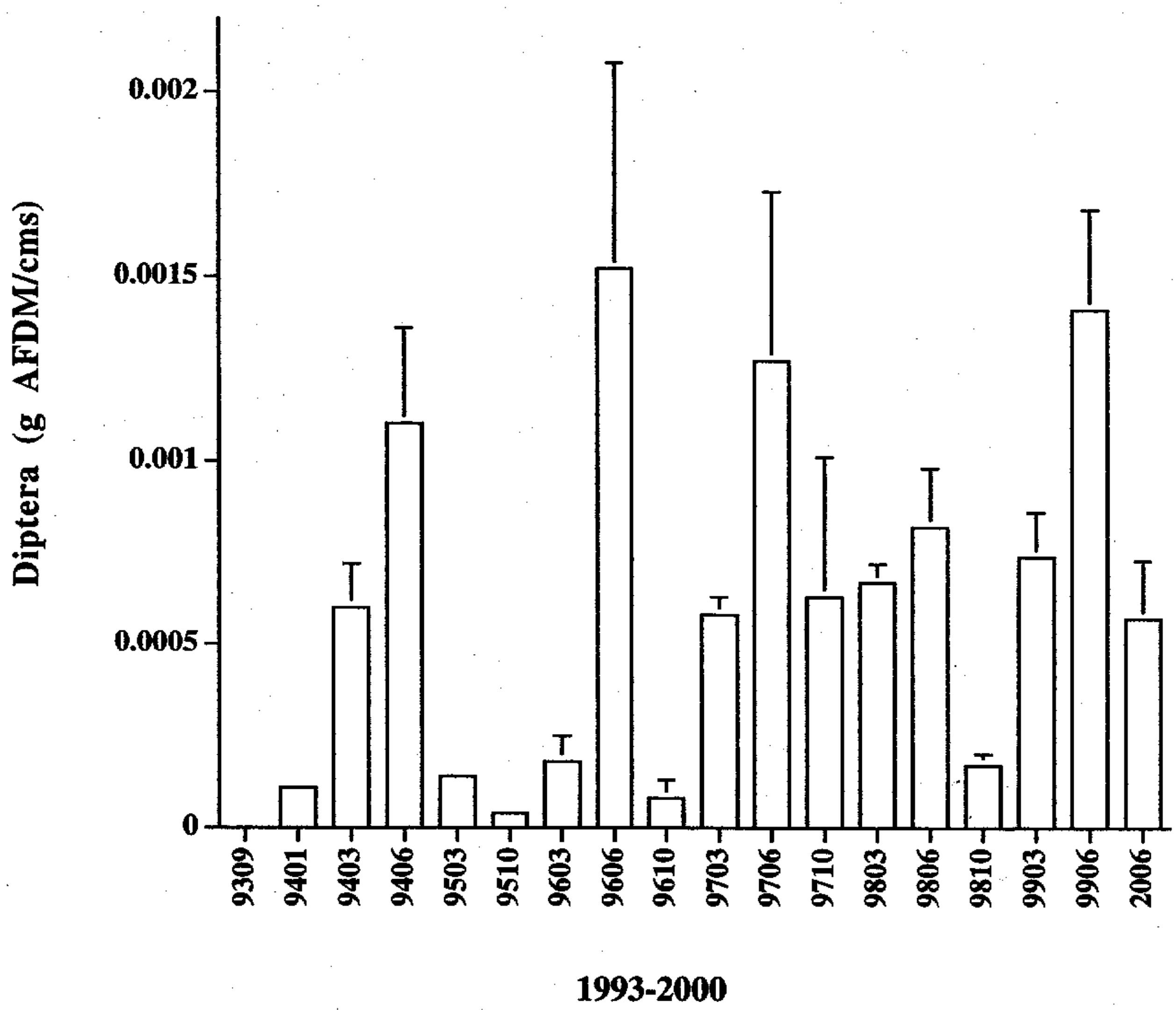

Figure 255. Average CPOM drift mass (g AFDM/cms) for aquatic diptera collected at 127 Mile rapid Rkm 202.9 from September 1993 to June 2000. Error Bars represent (± 1 SE).

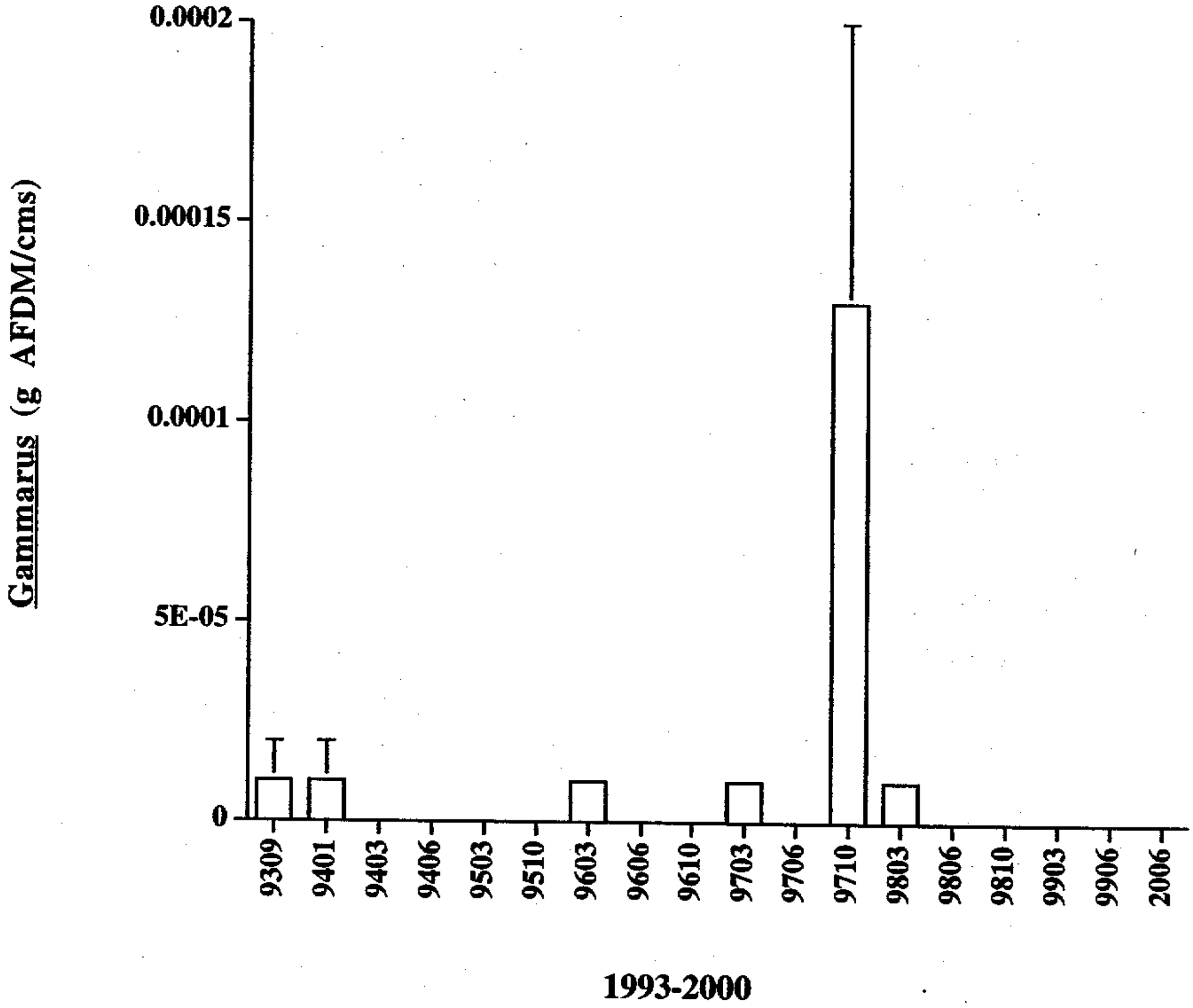

Figure 256. Average CPOM drift mass (g AFDM/cms) for Gammarus collected at 127 Mile rapid Rkm 202.9 from September 1993 to June 2000. Error Bars represent (± 1 SE).

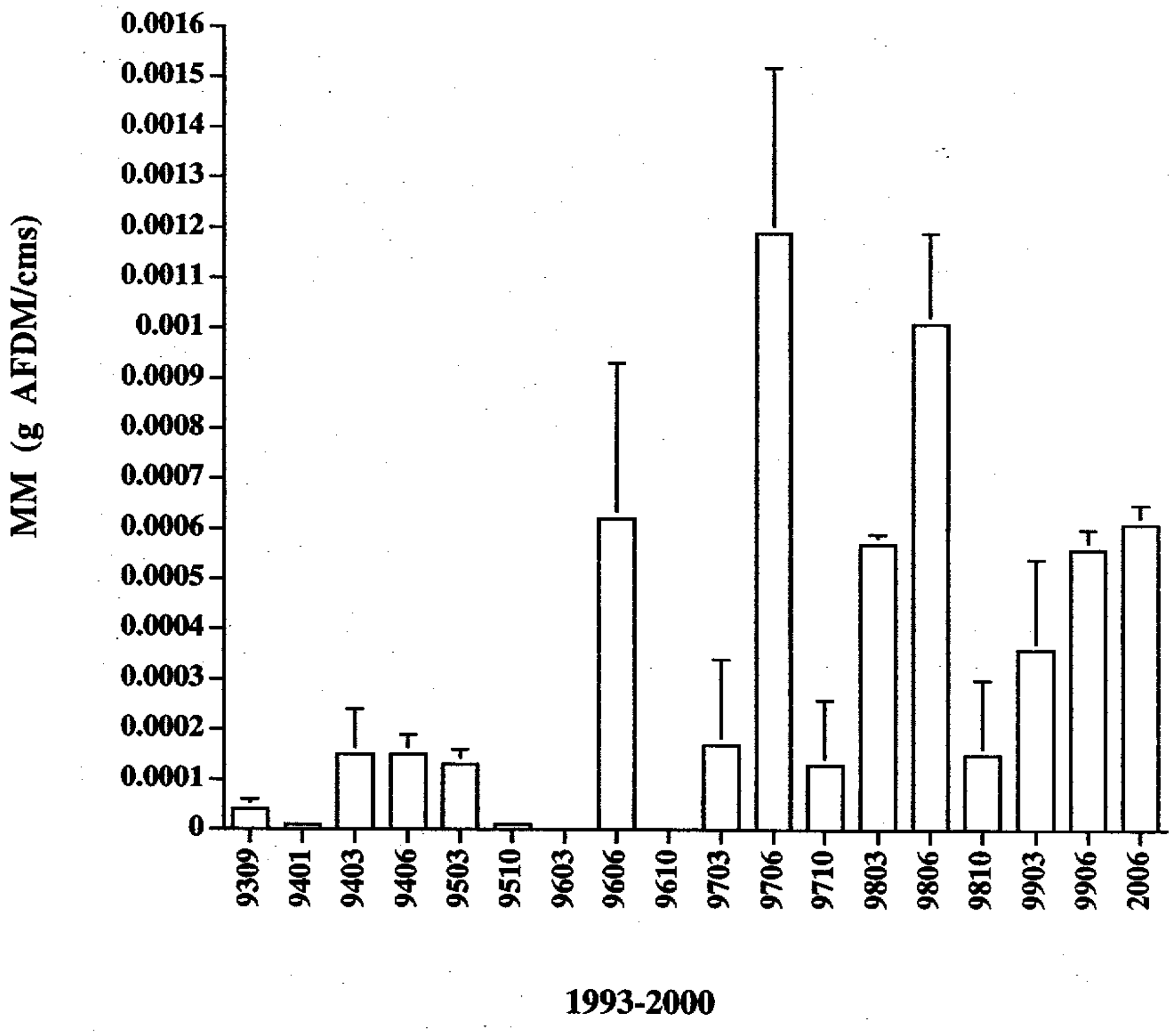

Figure 257. Average CPOM drift mass (g AFDM/cms) for miscellaneous macroinvertebrates (MM) collected at 127 Mile rapid Rkm 202.9 from September 1993 to June 2000. Error Bars represent (± 1 SE).

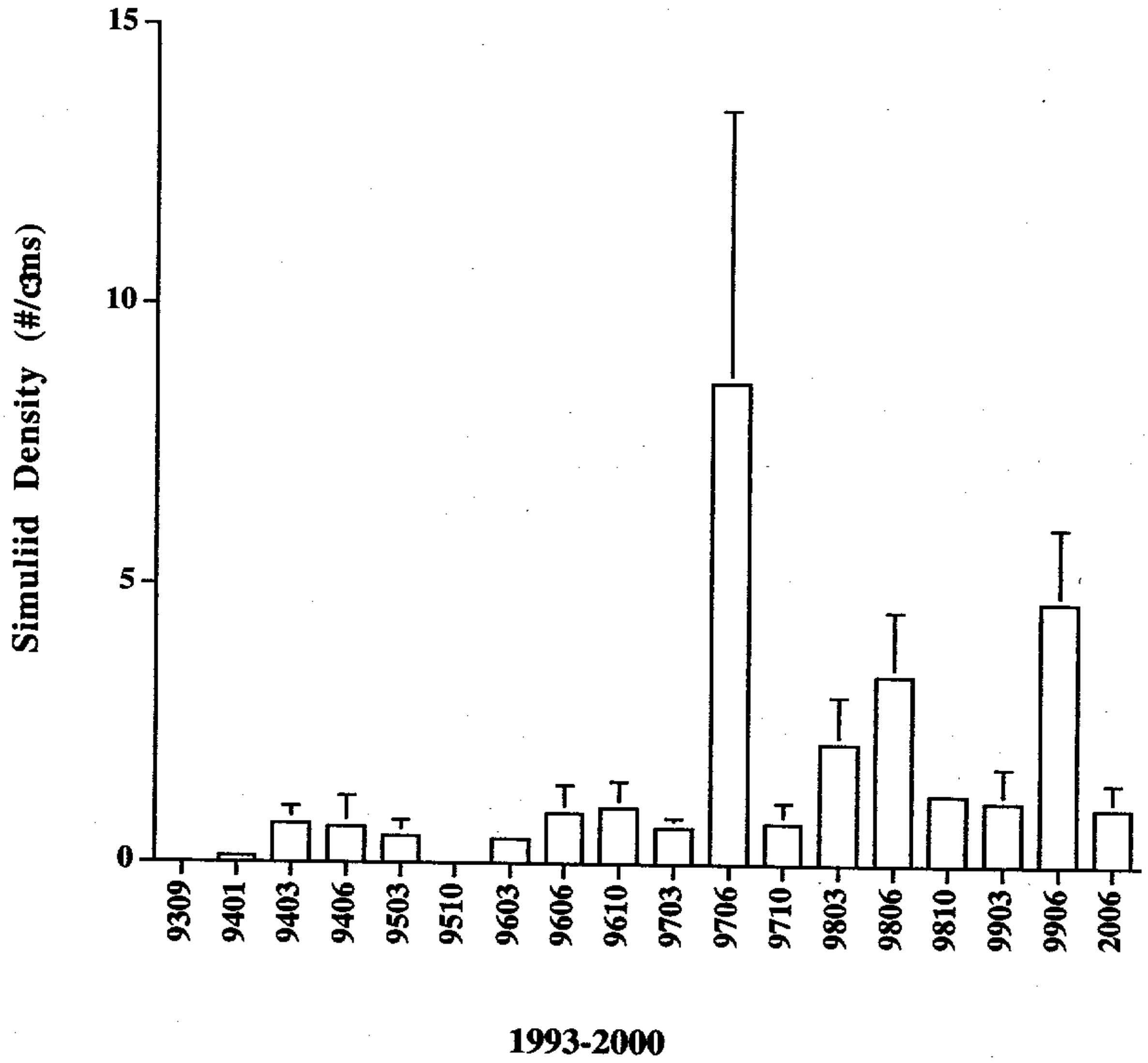

Figure 258. Average CPOM drift densities (#/cms) for Simuliids collected at 127 Mile rapid Rkm 202.9 from September 1993 to June 2000. Error Bars represent (± 1 SE).

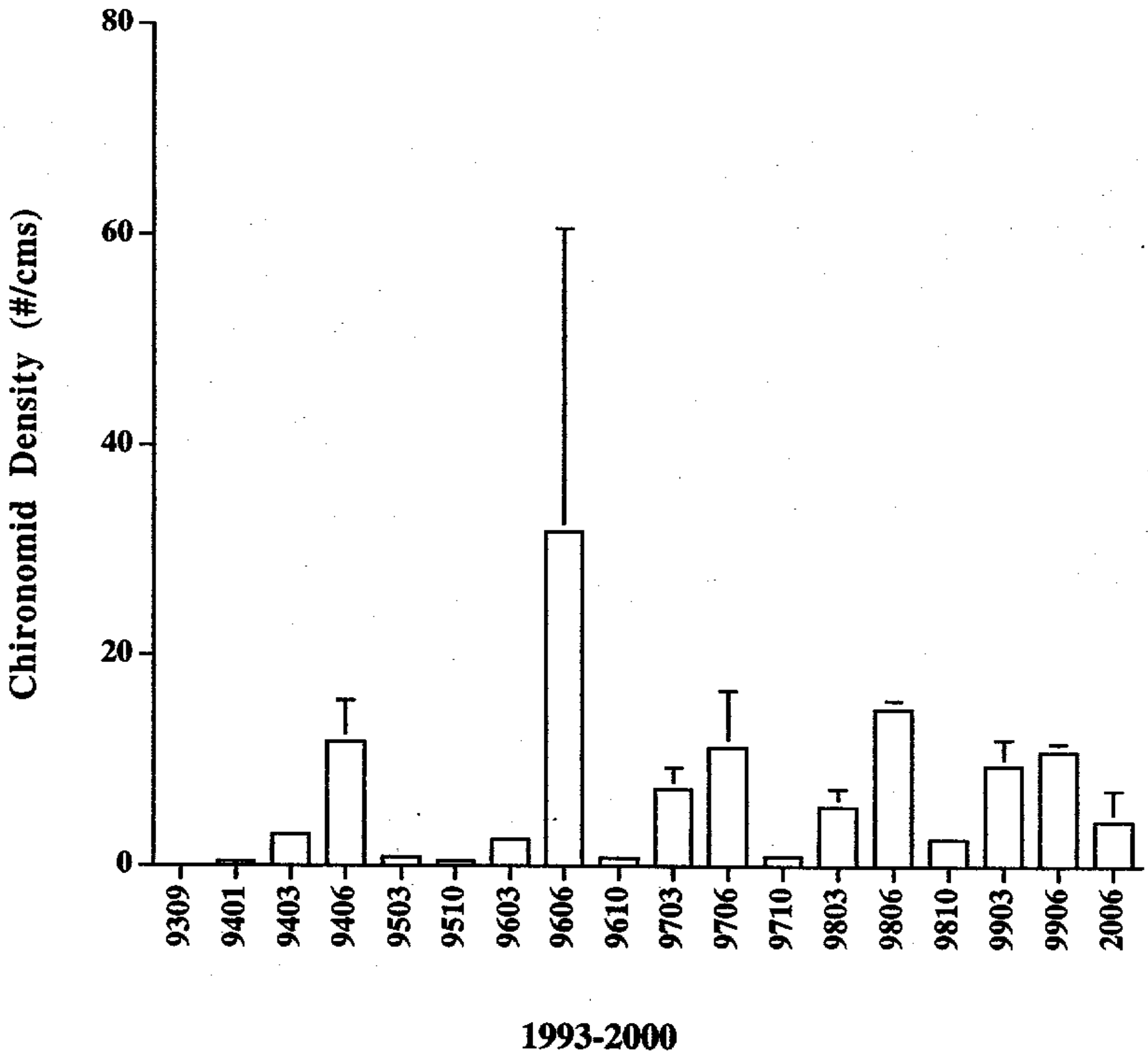

Figure 259. Average CPOM drift densities (#/cms) for Chironomids collected at 127 Mile Rkm 202.9 rapid from September 1993 to June 2000. Error Bars represent ($\pm$ 1 SE).

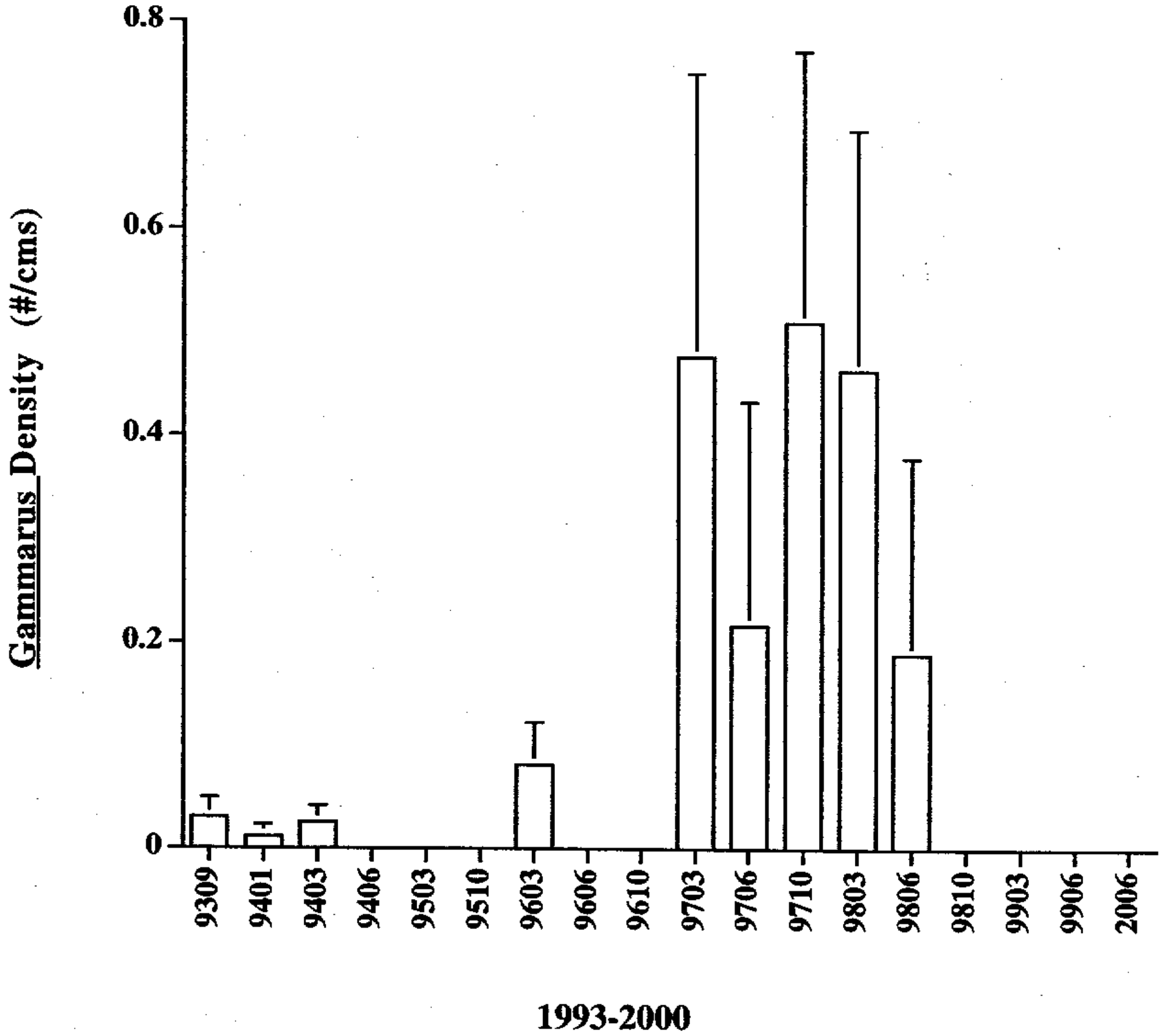

Figure 260. Average CPOM drift densities (#/cms) for Gammarus collected at 127 Mile Rkm 202.9 rapid from September 1993 to June 2000. Error Bars represent (± 1 SE).

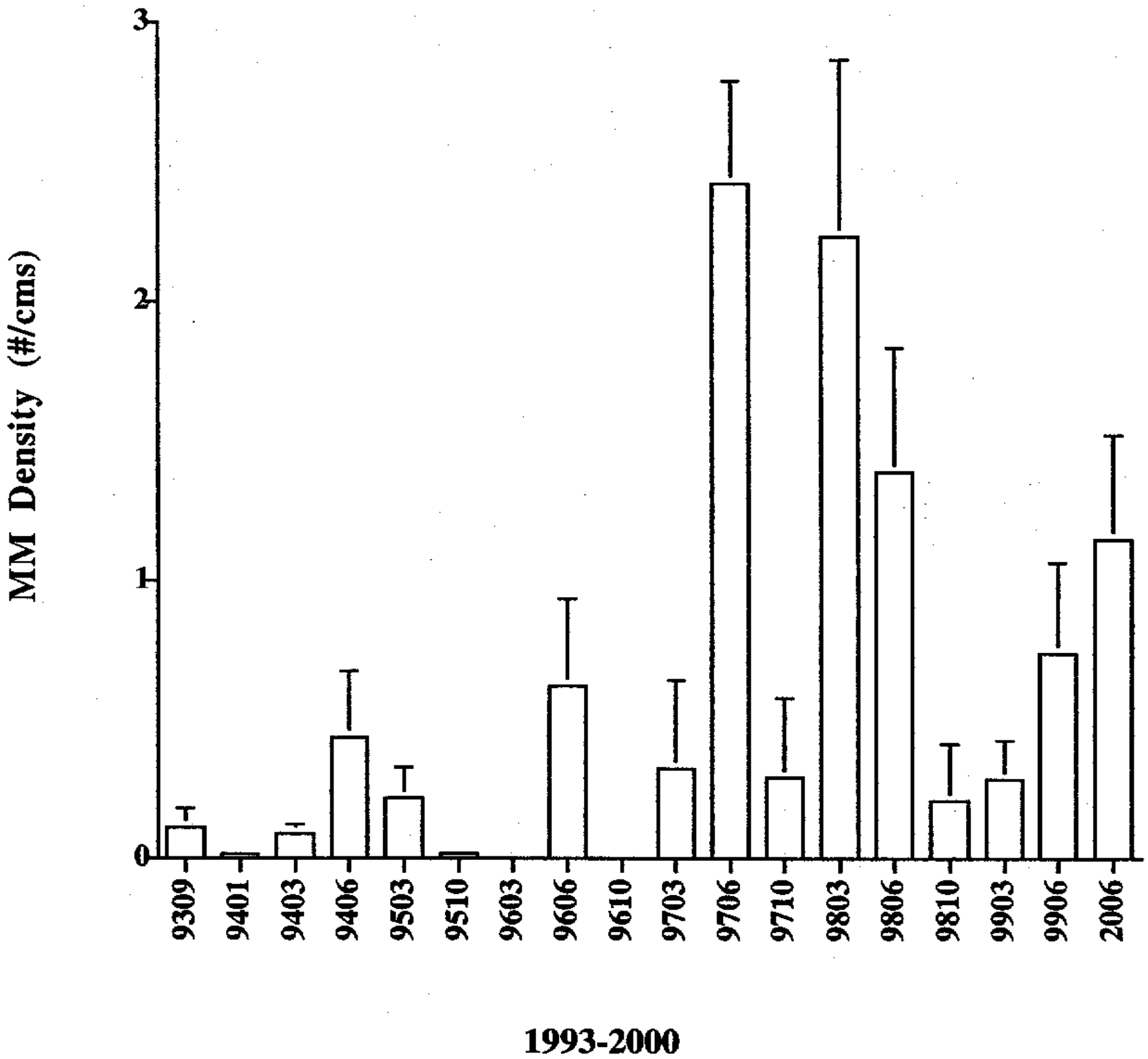

Figure 261. Average CPOM drift densities (#/cms) for miscellaneous macroinvertebrates (MM) collected at 127 Mile rapid Rkm 202.9 from September 1993 to June 2000. Error Bars represent (± 1 SE).

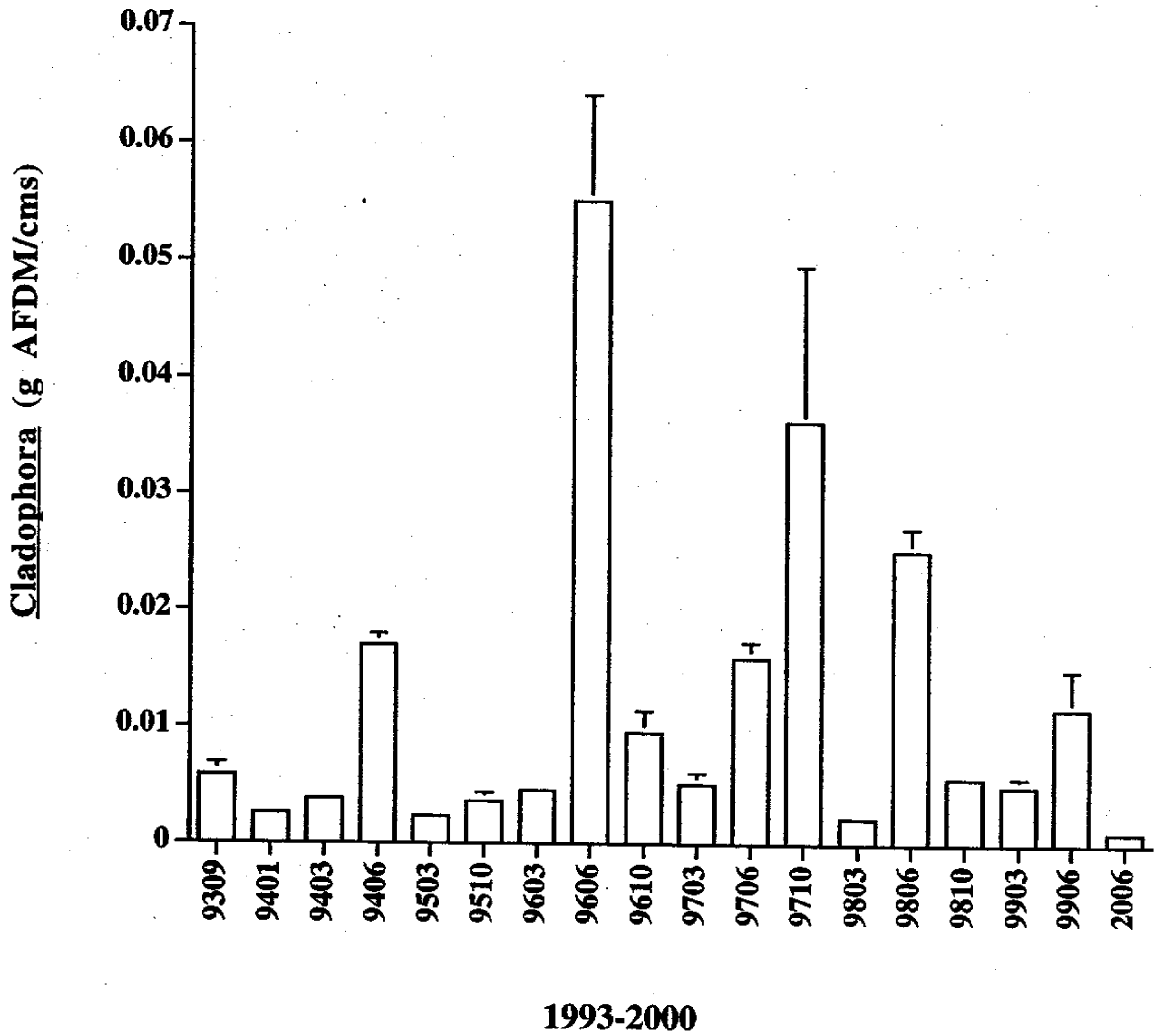

Figure 262. Average CPOM drift mass (g AFDM/cms) for Cladophora collected at 205 Mile rapid Rkm 328.8 from September 1993 to June 2000. Error Bars represent ($\pm$ 1 SE).

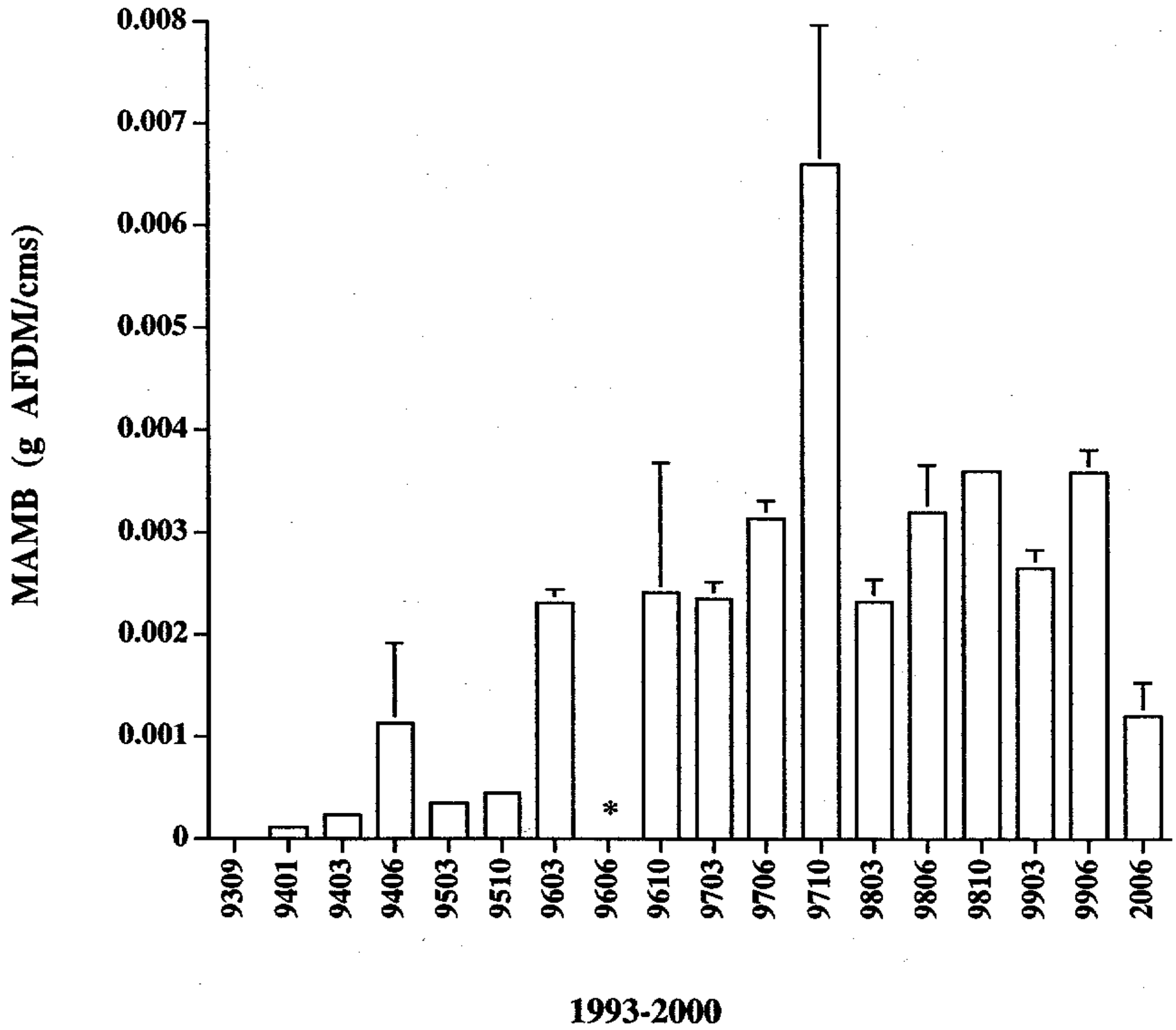

Figure 263. Average CPOM drift mass (g AFDM/cms) for miscellaneous algae, macrophytes and bryophytes (MAMB) collected at 205 Mile rapid Rkm 328.8 from September 1993 to June 2000. Error Bars represent (± 1 SE). Asterisk (*) represents 0.018 g AFDM/cms (± 0.011 SE).

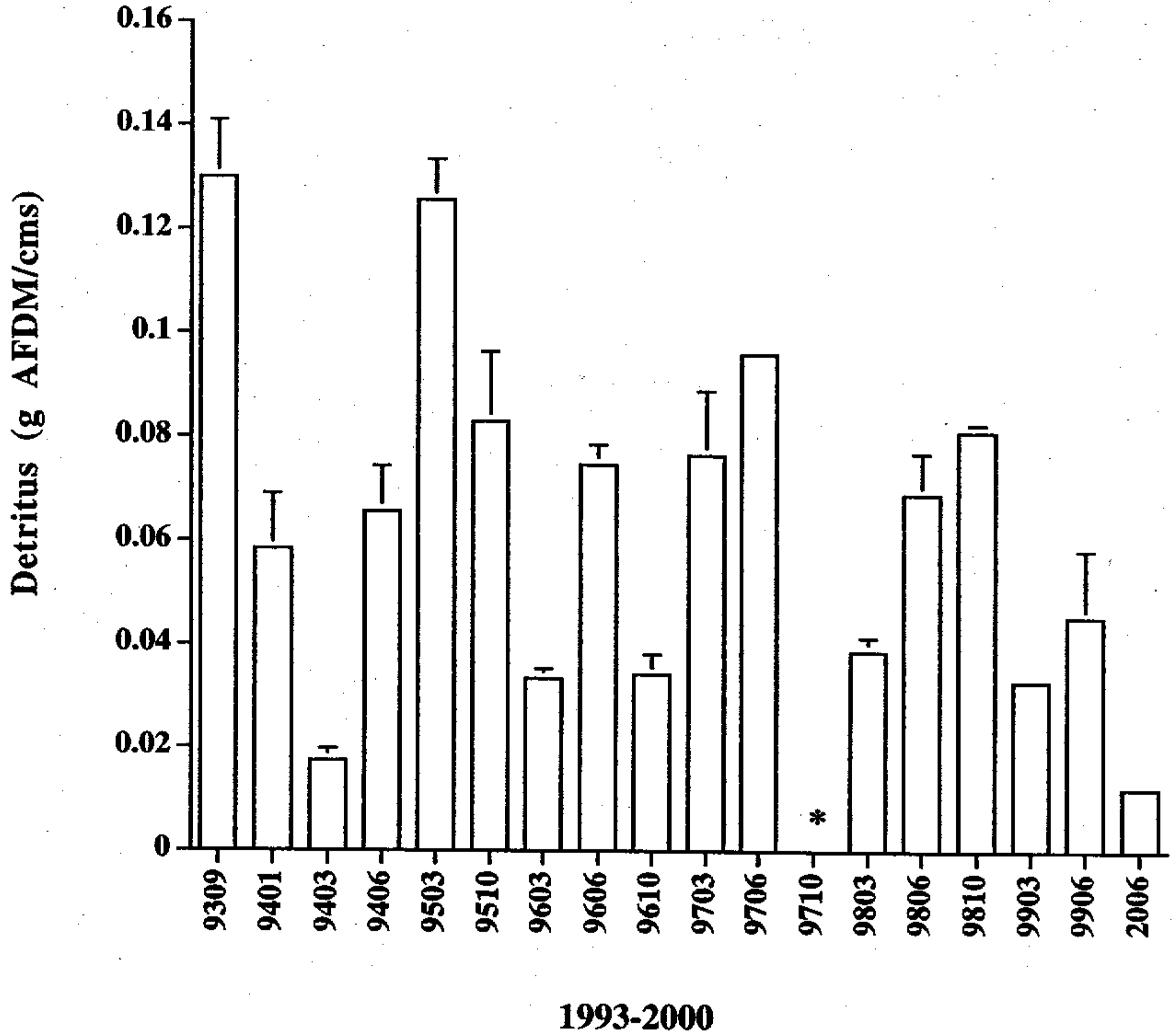

Figure 264. Average CPOM drift mass (g AFDM/cms) for detritus collected at 205 Mile rapid Rkm 328.8 from September 1993 to June 2000. Error Bars represent (± 1 SE). Asterisk (*) represents 0.5 g AFDM/cms(± 0.2 SE).

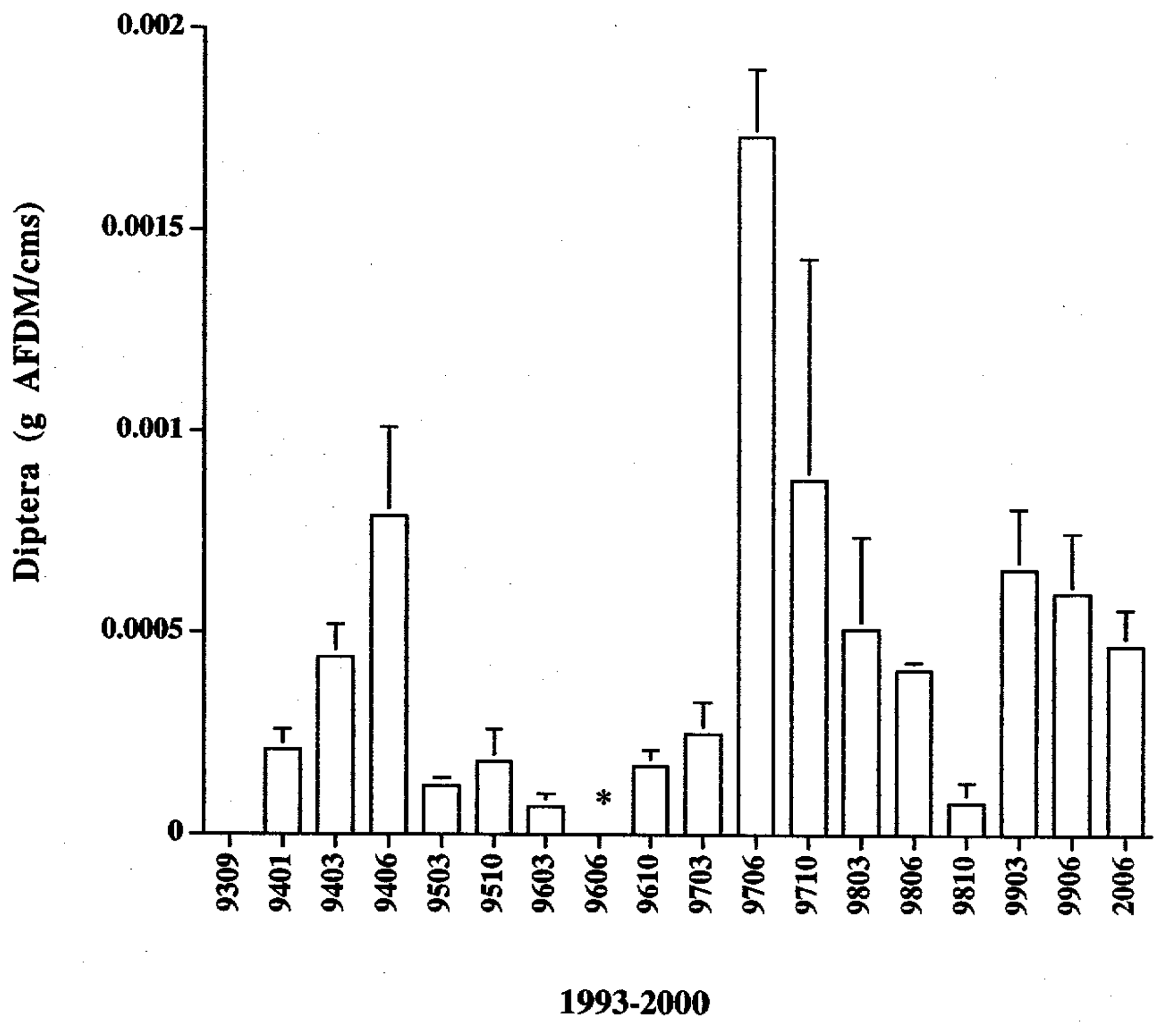

Figure 265. Average CPOM drift mass (g AFDM/cms) for aquatic diptera collected at 205 Mile rapid Rkm 328.8 from September 1993 to June 2000. Error Bars represent (± 1 SE). Asterisk (*) represents 0.005 g AFDM/cms^{-1} (± 0.004 SE).

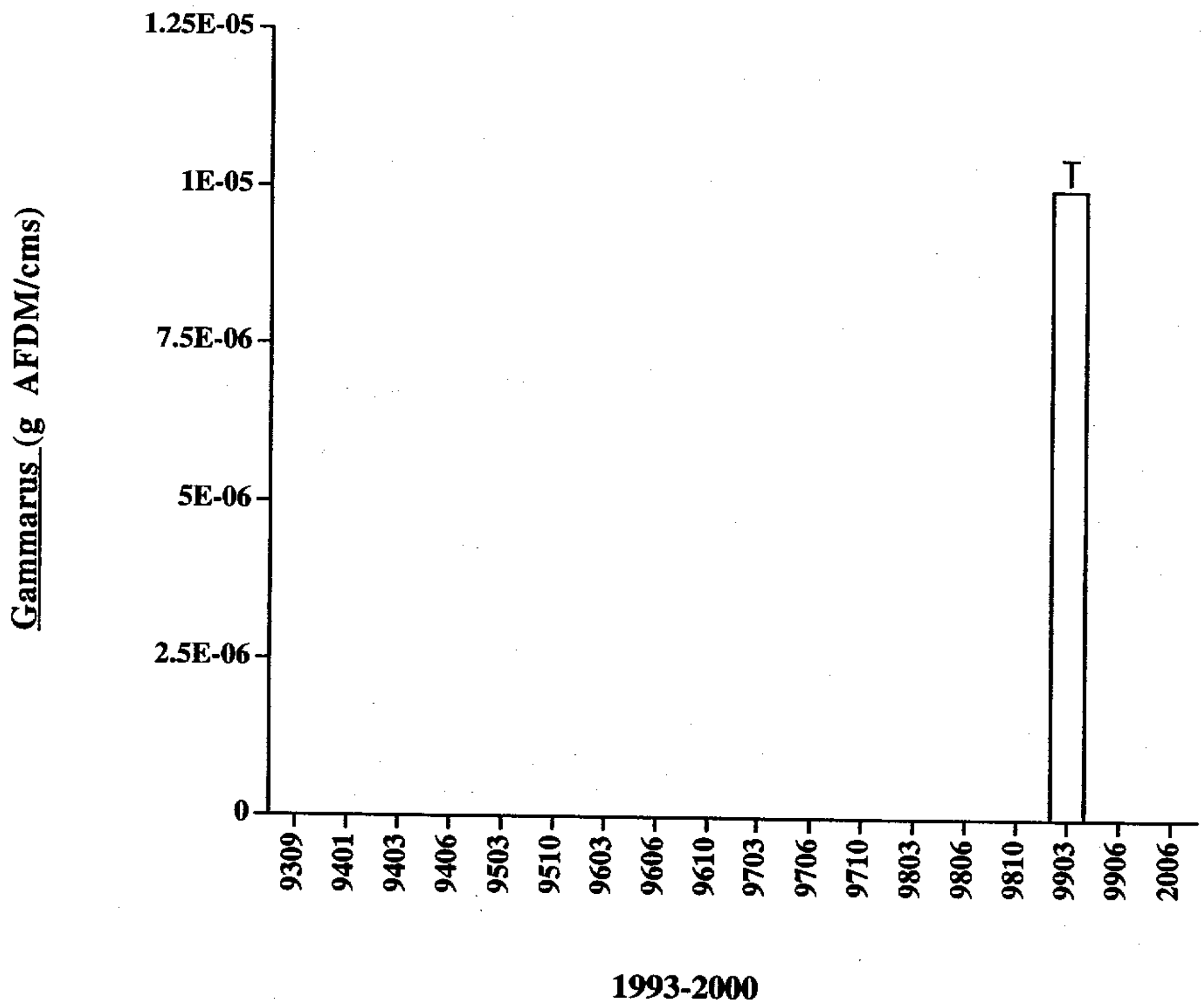

Figure 266. Average CPOM drift mass (g AFDM/cms) for Gammarus collected at 205 Mile rapid Rkm 328.8 from September 1993 to June 2000. Error Bars represent (± 1 SE).

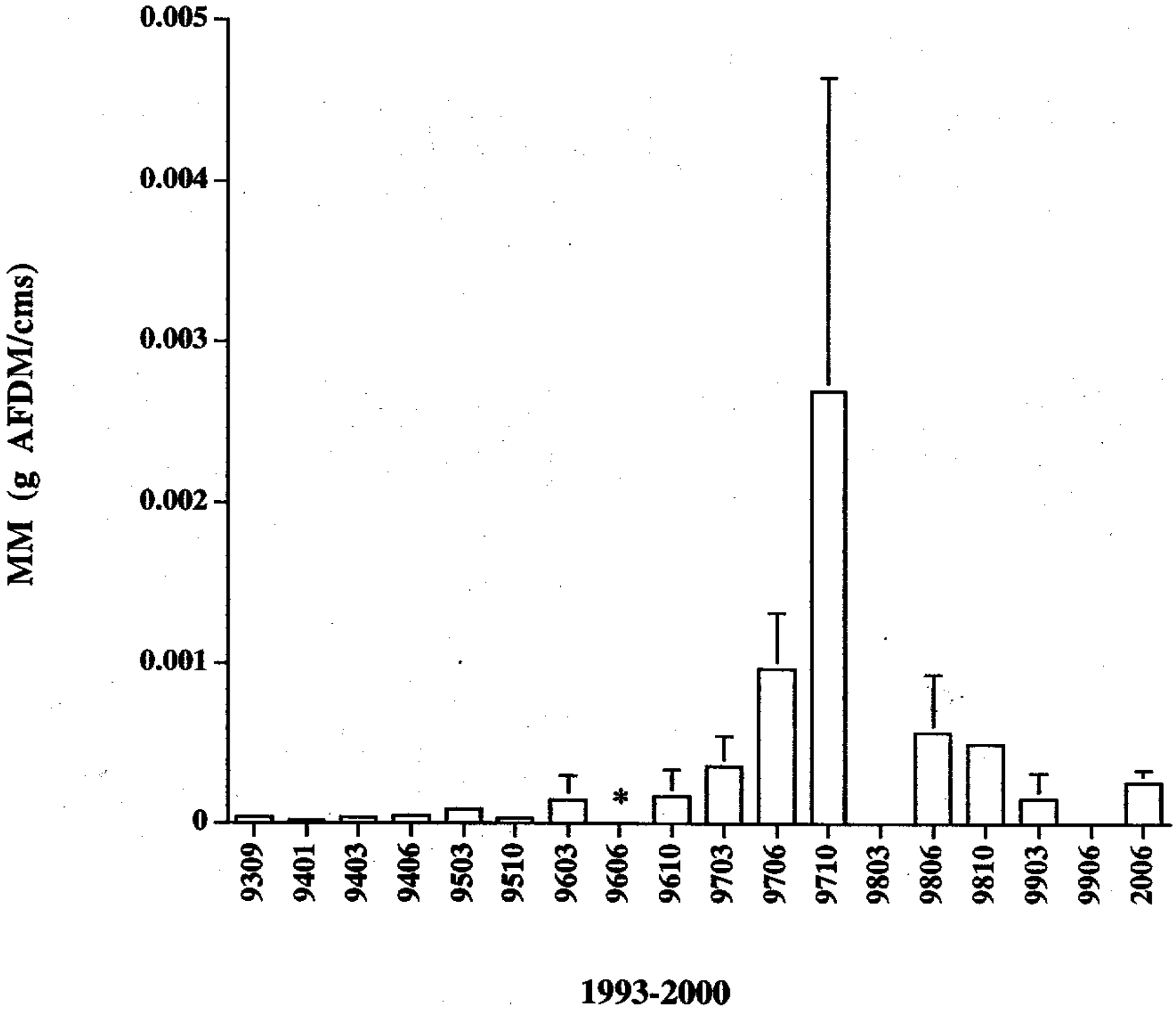

Figure 267. Average CPOM drift mass (g AFDM/cms) for miscellaneous macroinvertebrates (MM) collected at 205 Mile rapid Rkm 328.8 from September 1993 to June 2000. Error Bars represent (± 1 SE). Asterisk (*) represents 0.014 g AFDM/cms (± 0.007).

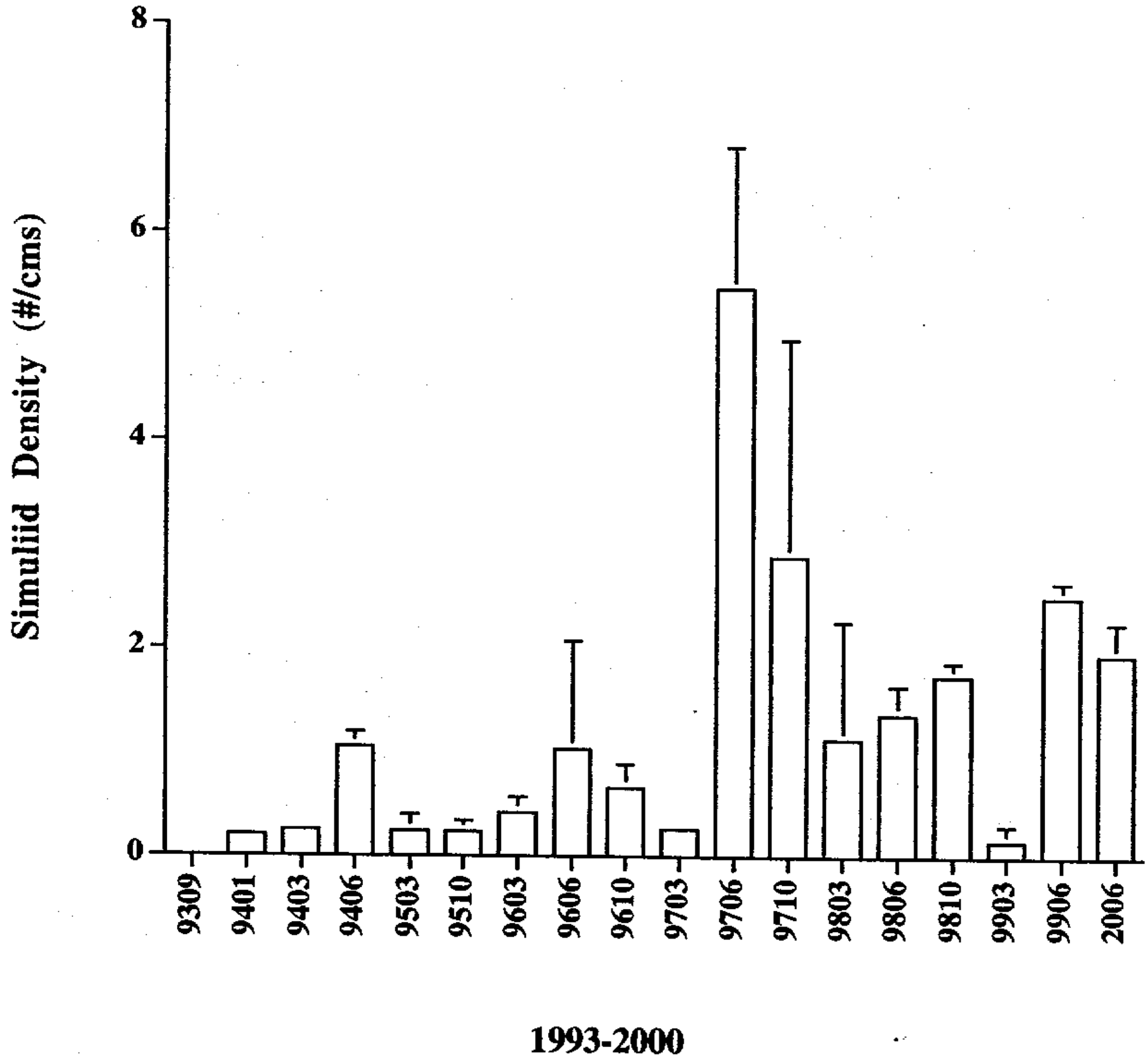

Figure 268. Average CPOM drift densities (#/cms) for Simuliids collected at 205 Mile rapid Rkm 328.8 from September 1993 to June 2000. Error Bars represent ($\pm$ 1 SE).

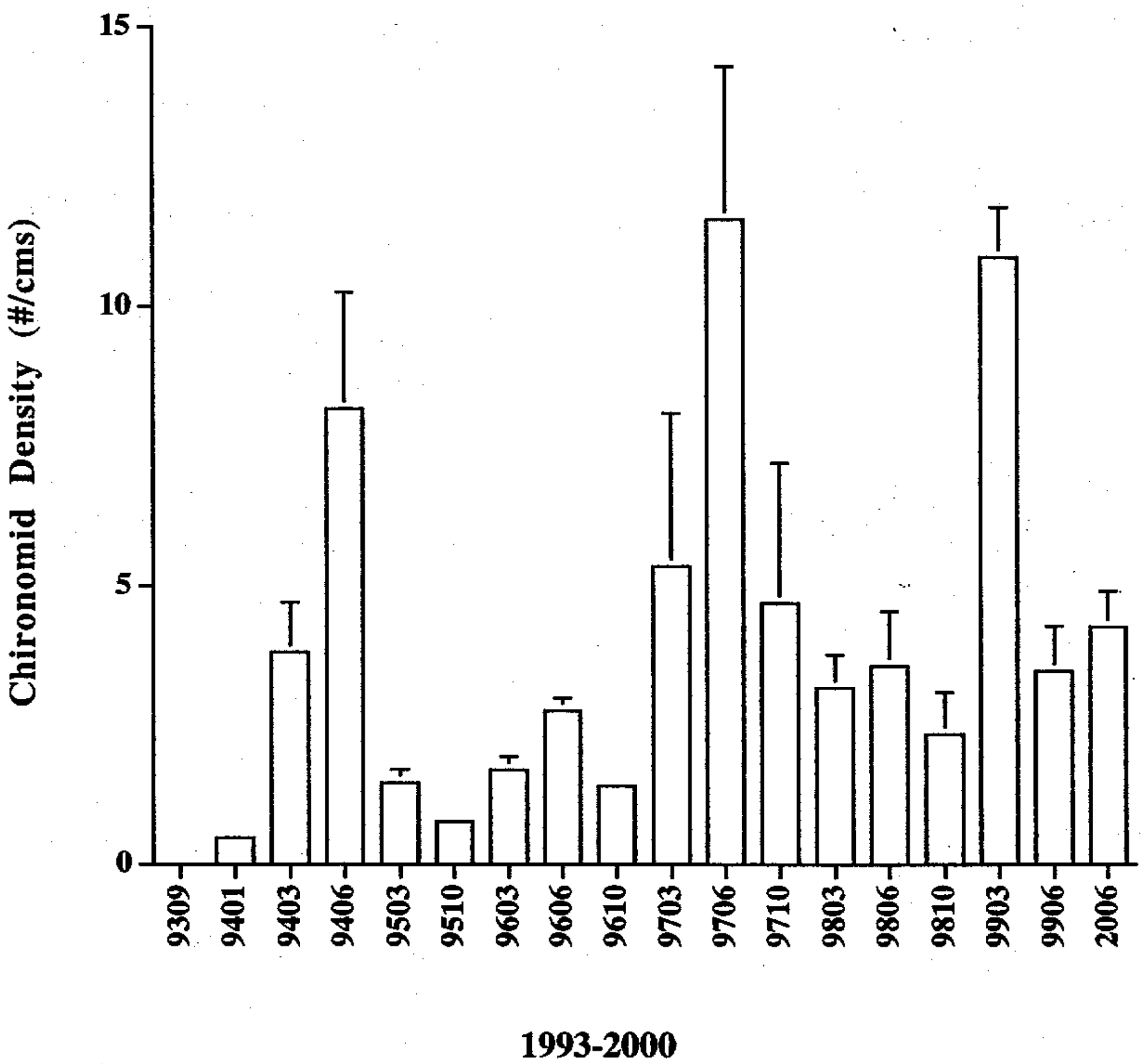

Figure 269. Average CPOM drift densities (#/cms) for Chironomids collected at 205 Mile rapid Rkm 328.8 from September 1993 to June 2000. Error Bars represent (± 1 SE).

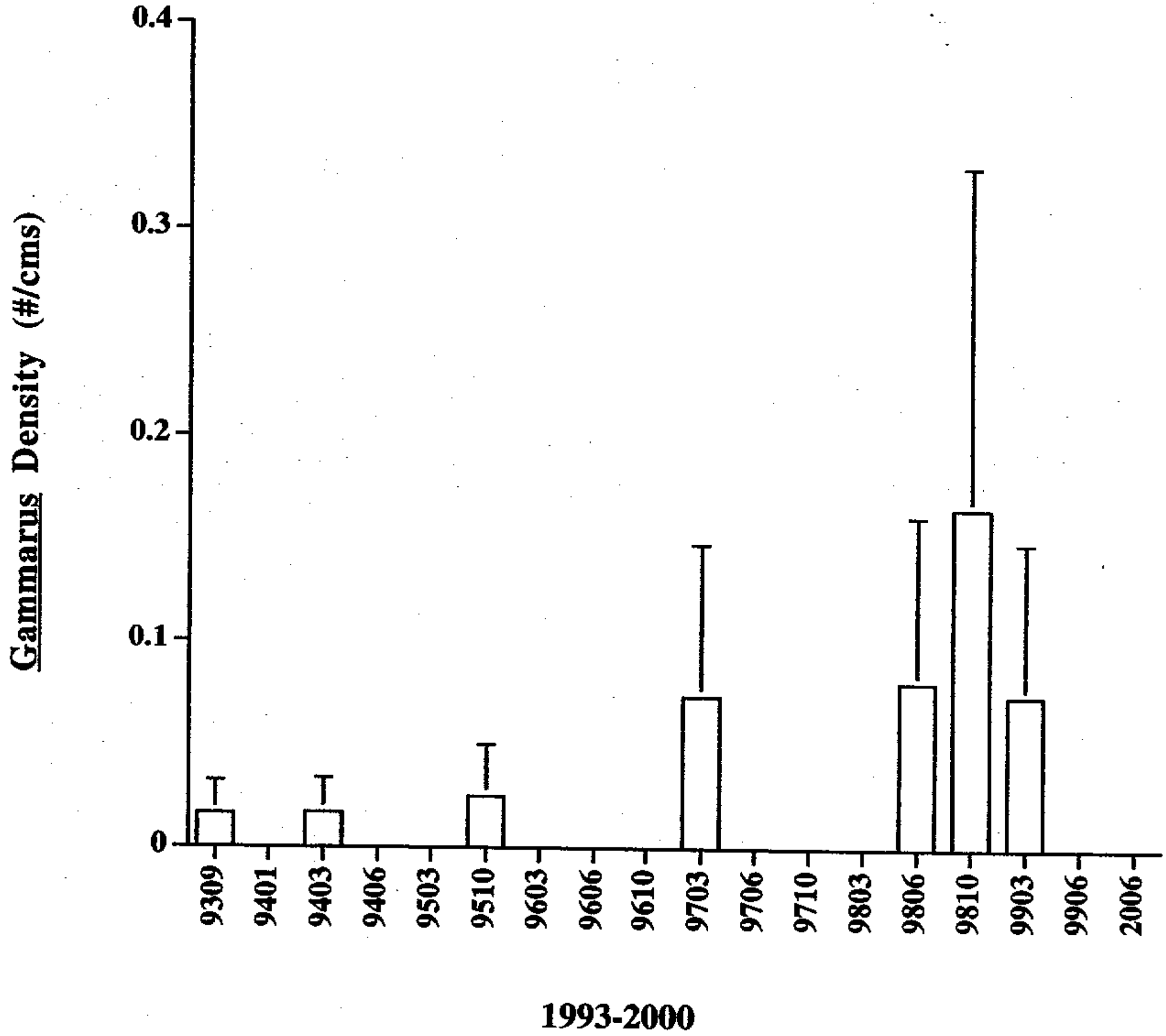

Figure 270. Average CPOM drift densities (#/cms) for <u>Gammarus</u> collected at 205 Mile rapid Rkm 328.8 from September 1993 to June 2000. Error Bars represent (± 1 SE).

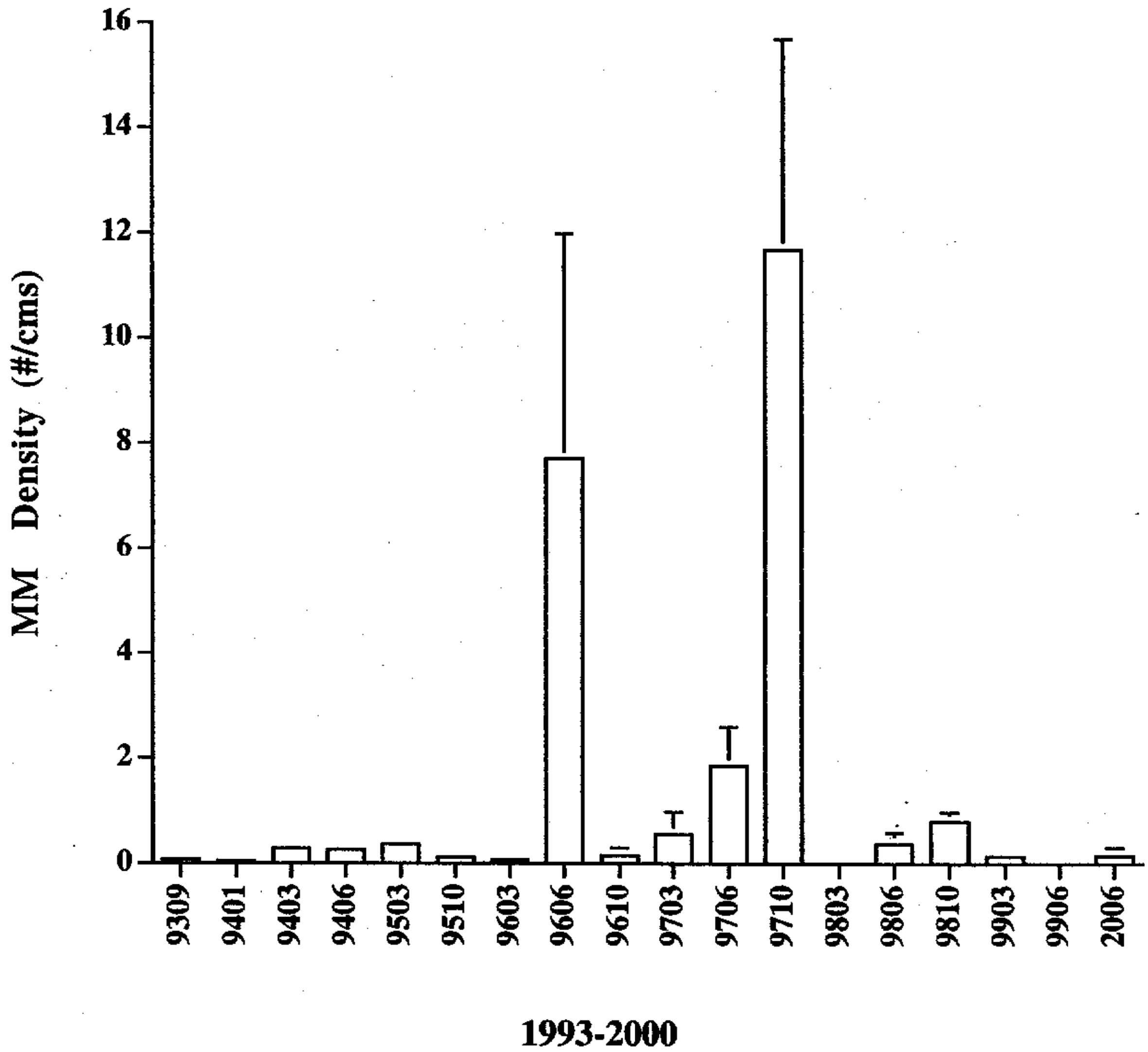

Figure 271. Average CPOM drift densities (#/cms) for miscellaneous macroinvertebrates (MM) collected at 205 Mile rapid Rkm 328.8 from September 1993 to June 2000. Error Bars represent (± 1 SE).

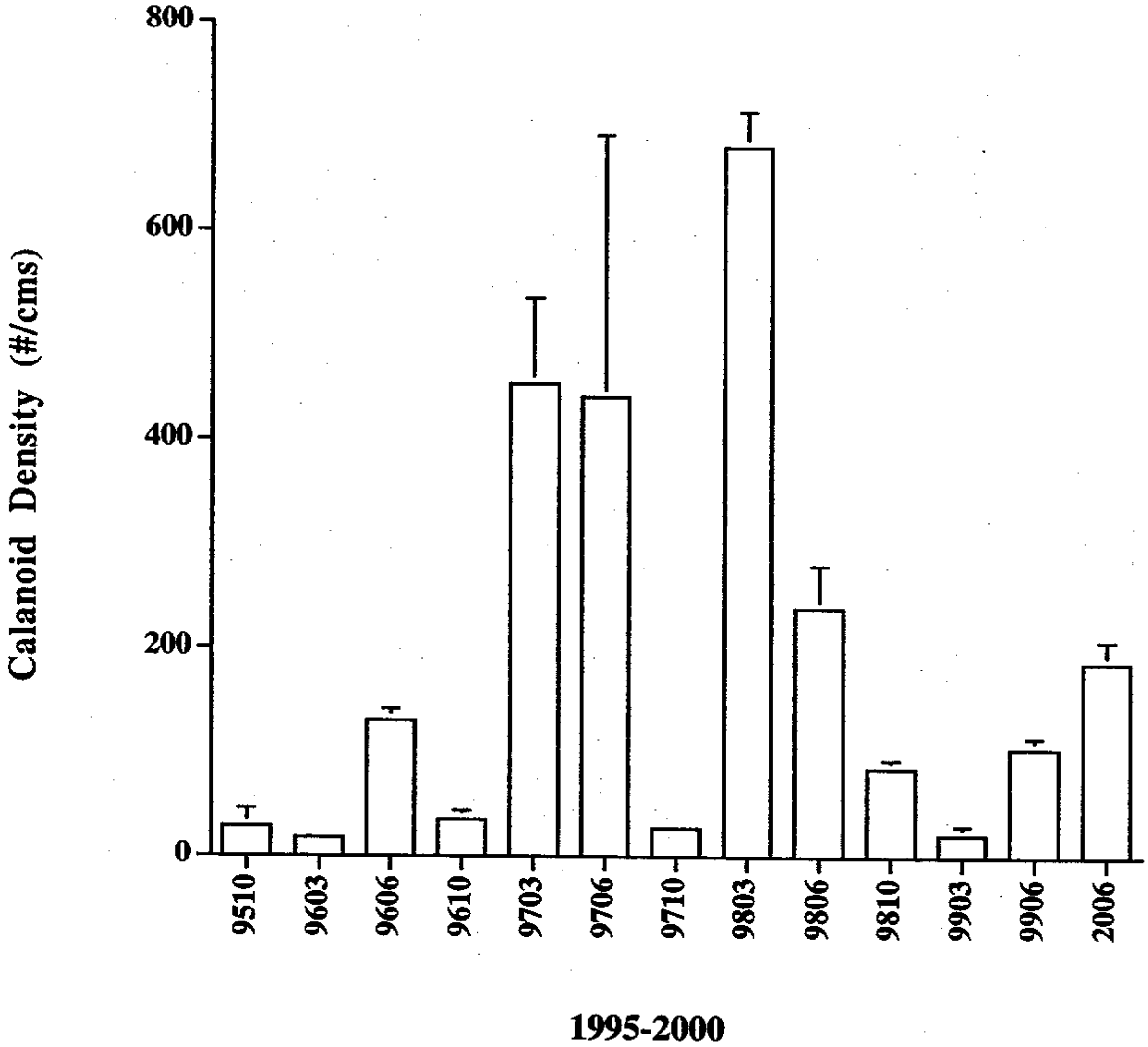

Figure 272. Average FPOM drift densities (#/cms) of Calanoids collected at Glen Canyon Gauge Rkm -23.2 from October 1995 to June 2000.Error bars represent (±1 SE).

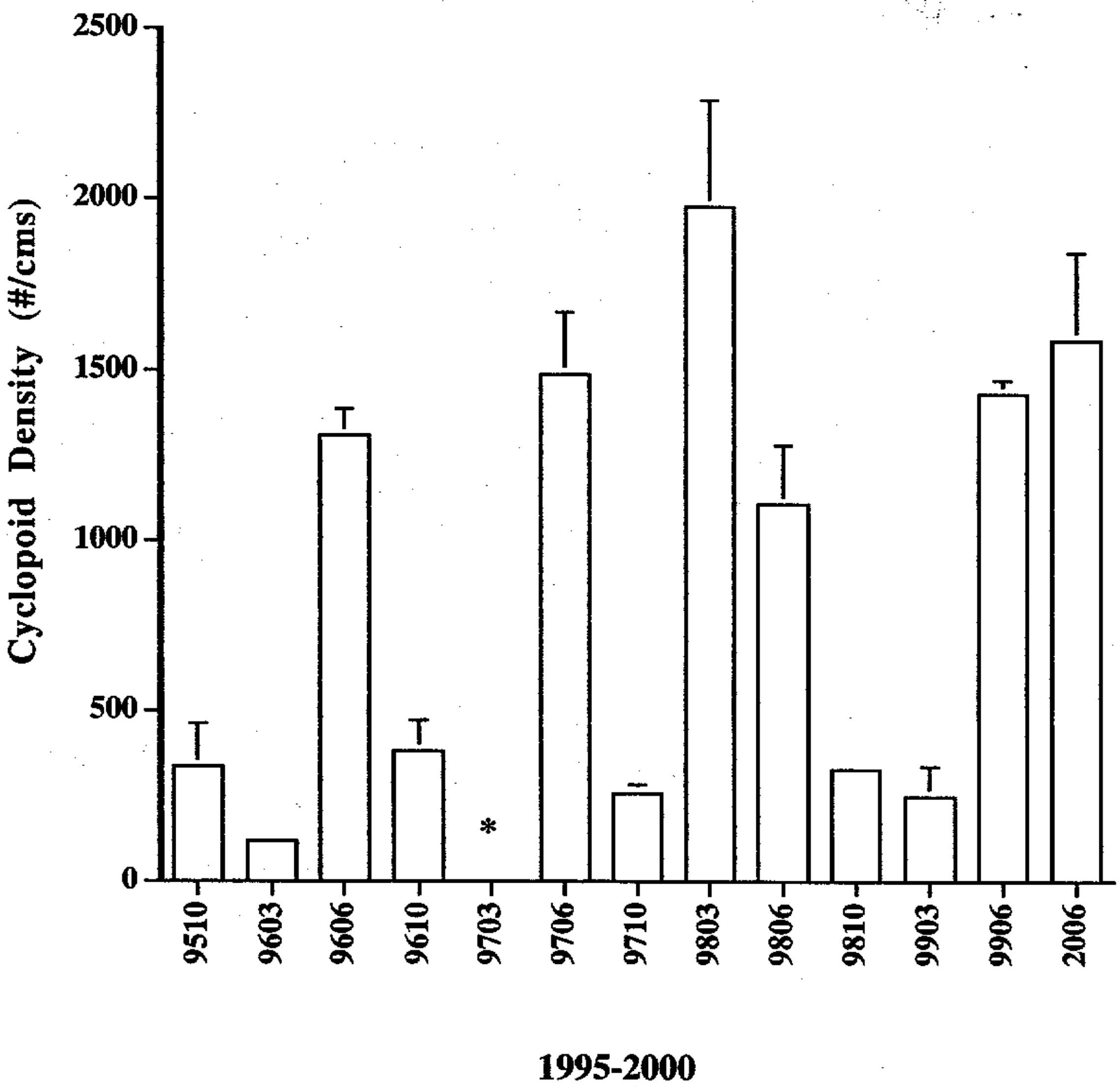

Figure 273. Average FPOM drift densities (#/cms) of Cyclopoids collected at Glen Canyon Gauge Rkm -23.2 from October 1995 to June 2000. Error bars represent (± 1 SE). Asterisk (*) represents 2316/cms (± 277 SE).

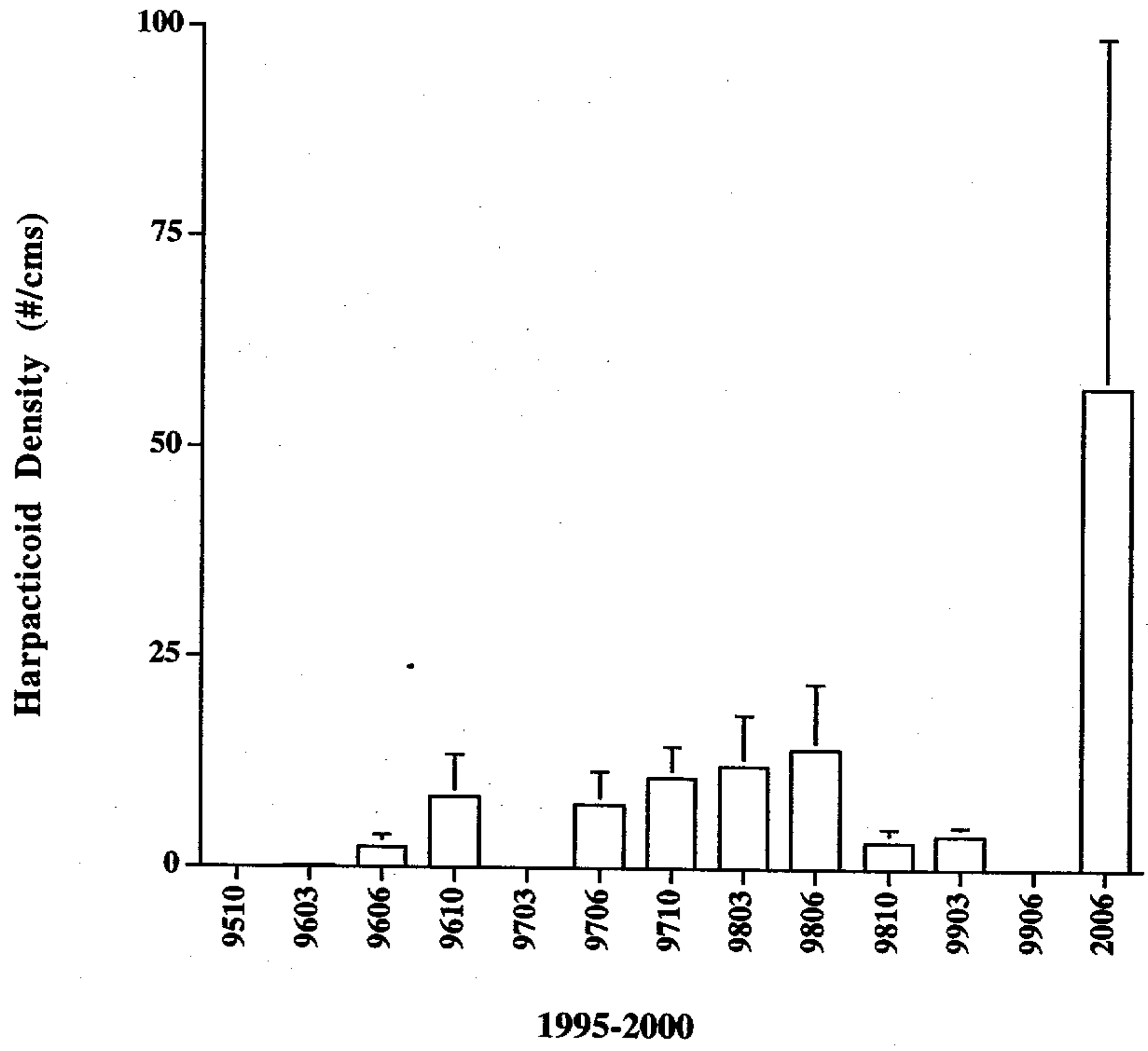

Figure 274. Average FPOM drift densities (#/cms) of Harpacticoids collected at Glen Canyon Gauge Rkm -23.2 from October 1995 to June 2000.

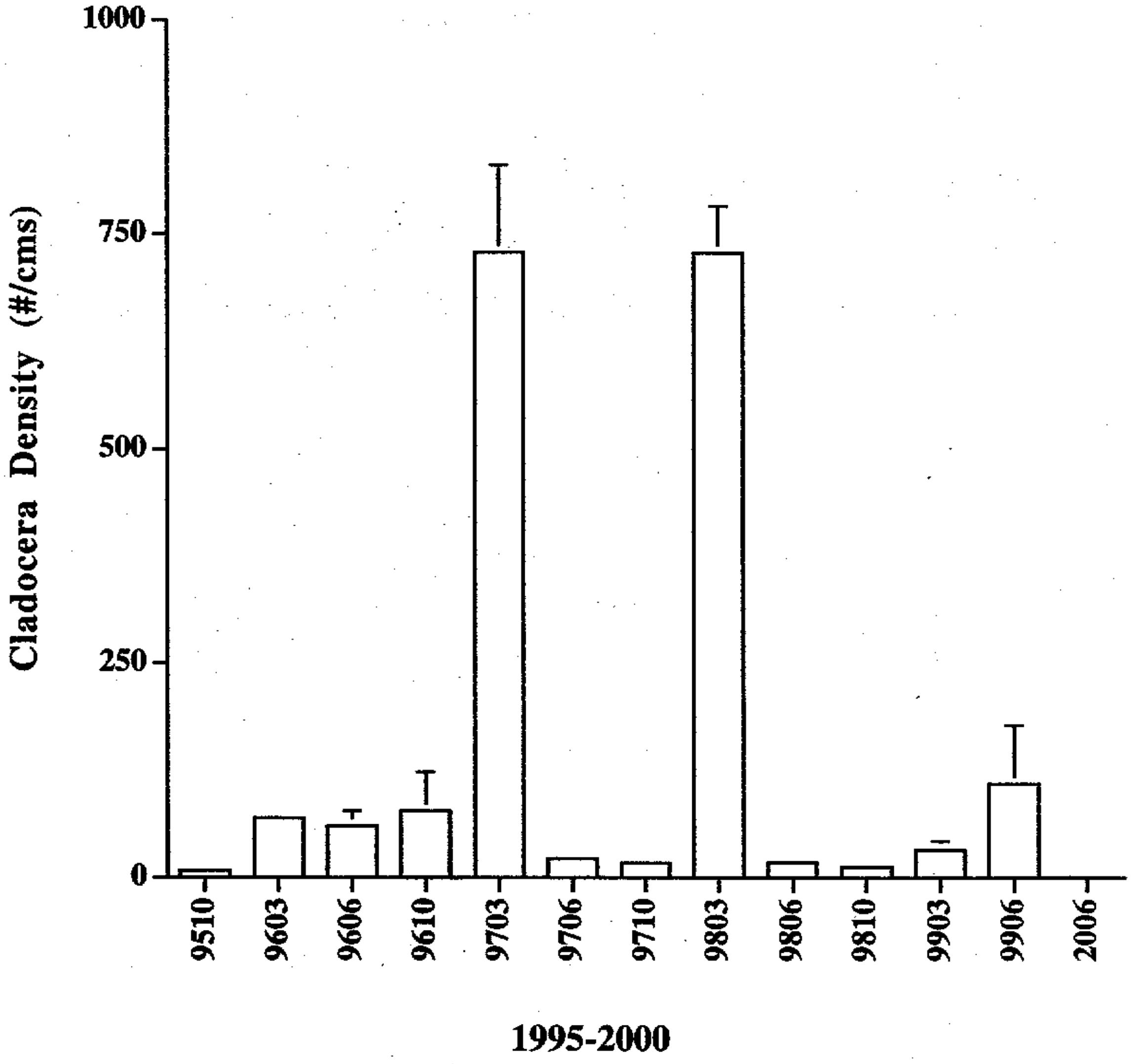

Figure 275. Average FPOM drift densities (#cms) of Cladocera collected at Glen Canyon Rkm -23.2 from October 1995 to June 200.

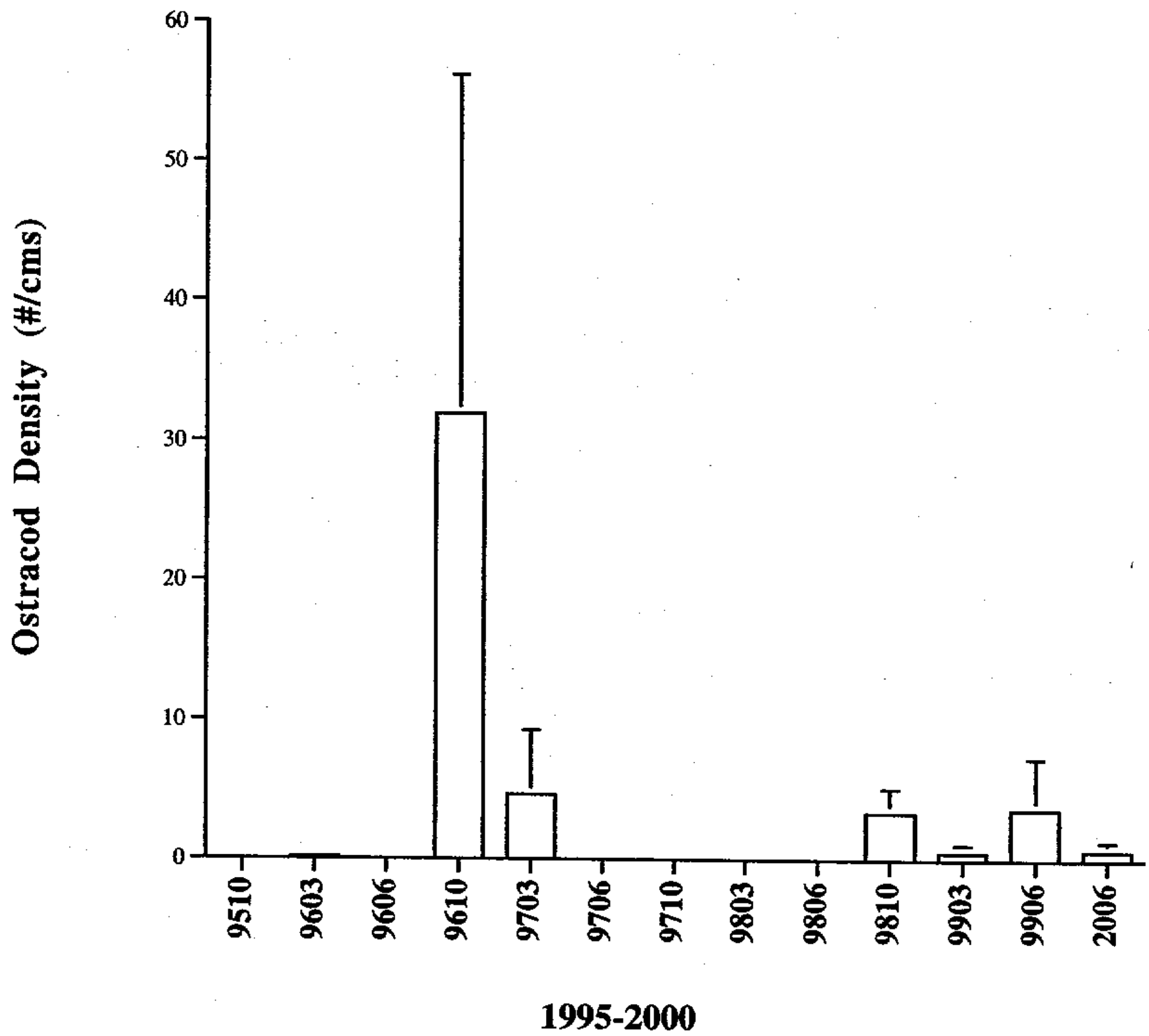

Figure 276. Average FPOM drift densities (#/cms) of Ostracods collected at Glen Canyon Gauge Rkm -23.2 from October 1995 to June 2000.

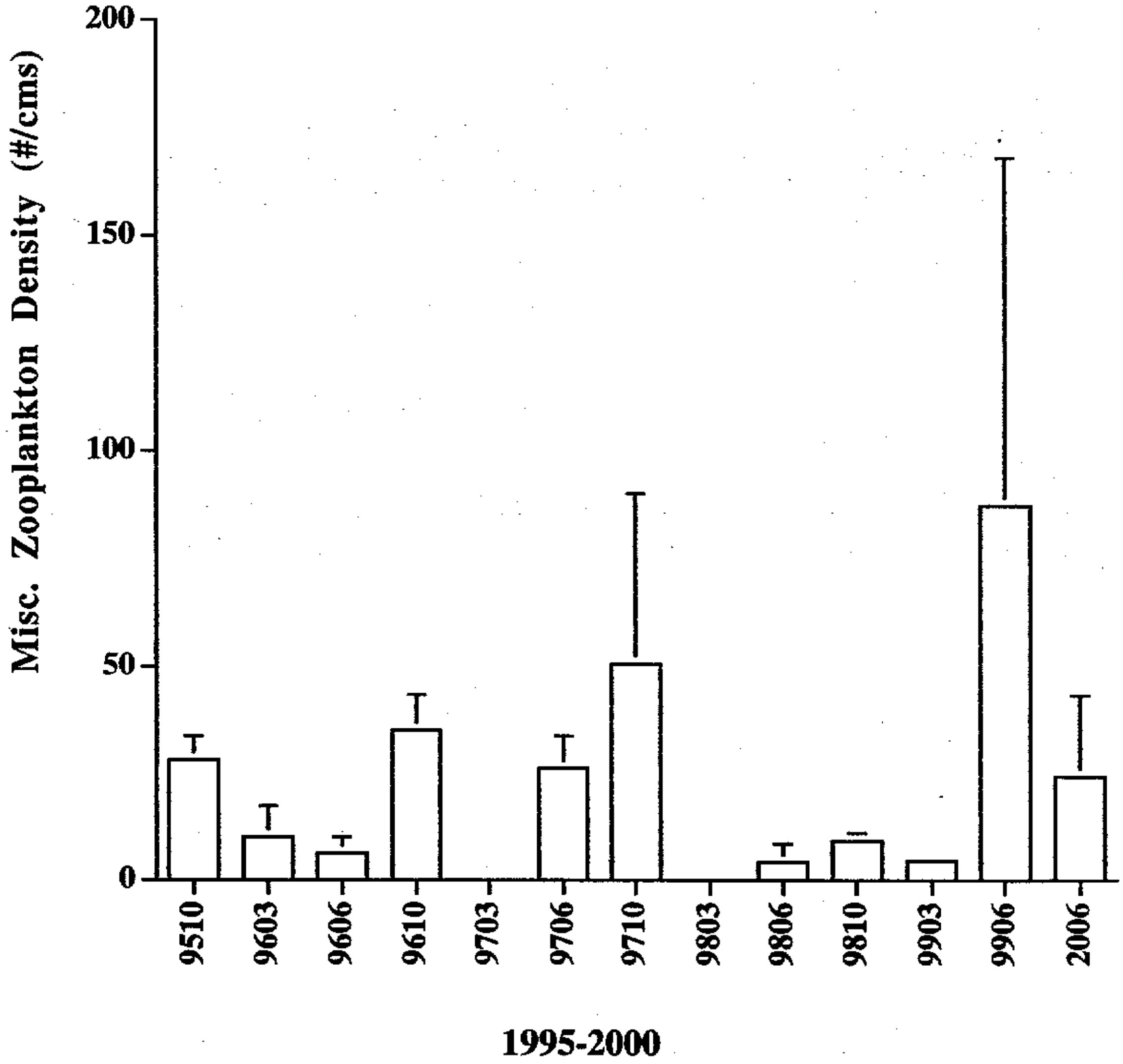

Figure 277. Average FPOM drift densities (#/cms) of miscellaneous zooplankton (benthic origin) collected at Glen Canyon Gauge Rkm -23.2 from October 1995 to June 2000.

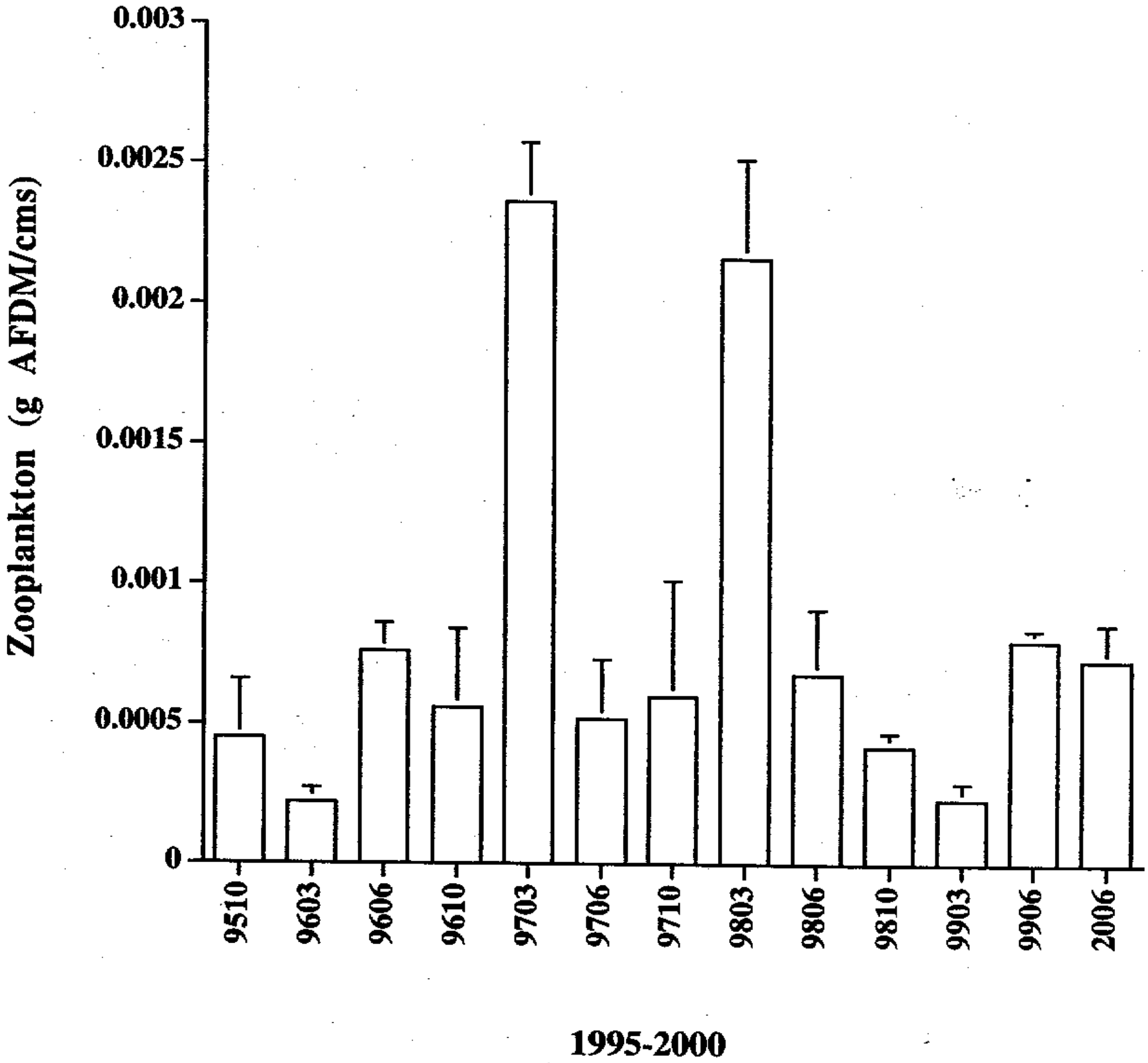

Figure 278. Average zooplankton biomass (g AFDM/cms) of lentic origin for Calanoida, Cyclopoida, Cladocera and Ostracoda collected at Glen Canyon Rkm -23.2 from October 1995 to June 2000.

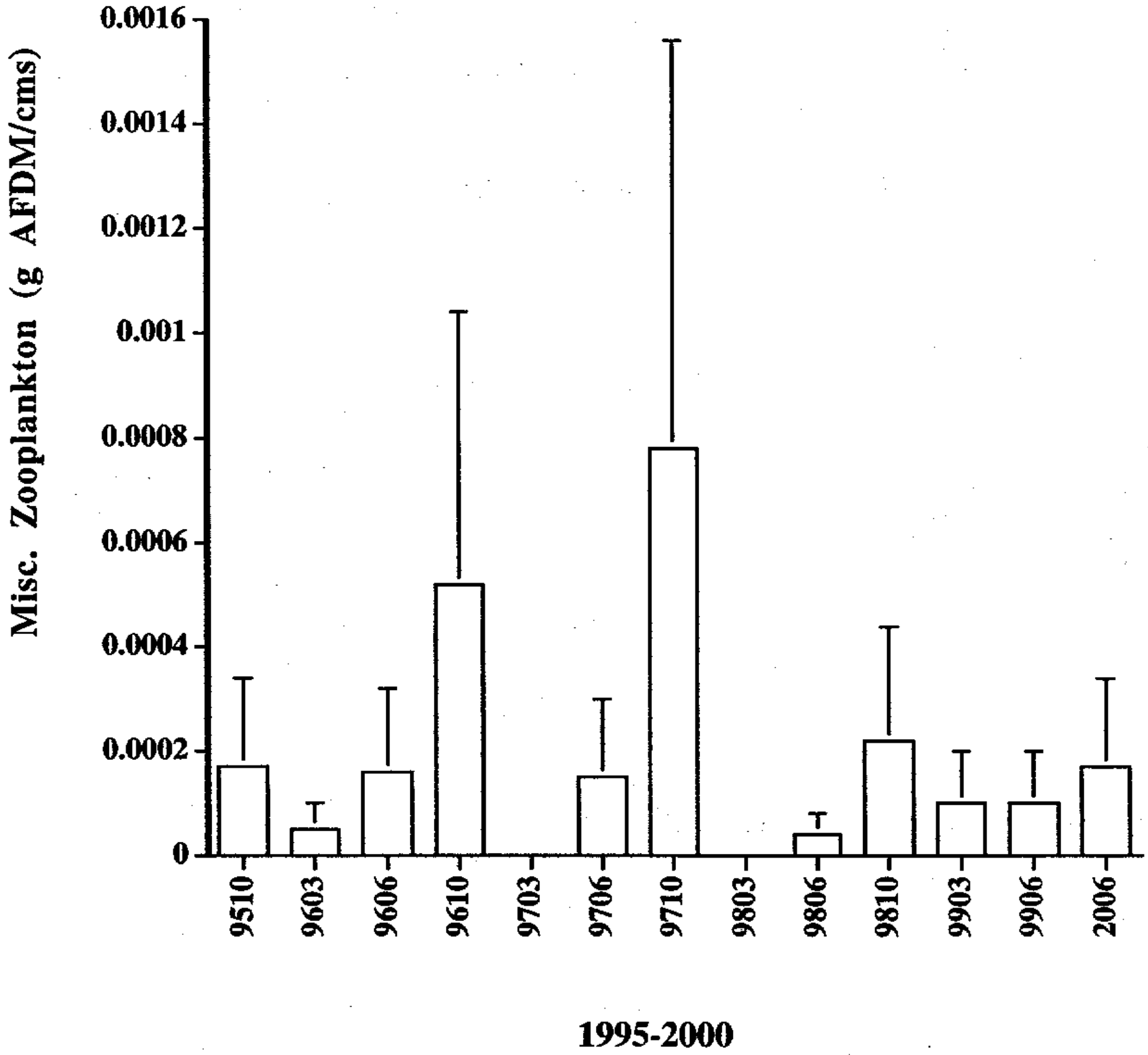

Figure 279. Average miscellaneous zooplankton biomass (g AFDM/cms) of benthic origin collected at Glen Canyon Gauge Rkm -23.2 from October 1995 to June 2000.

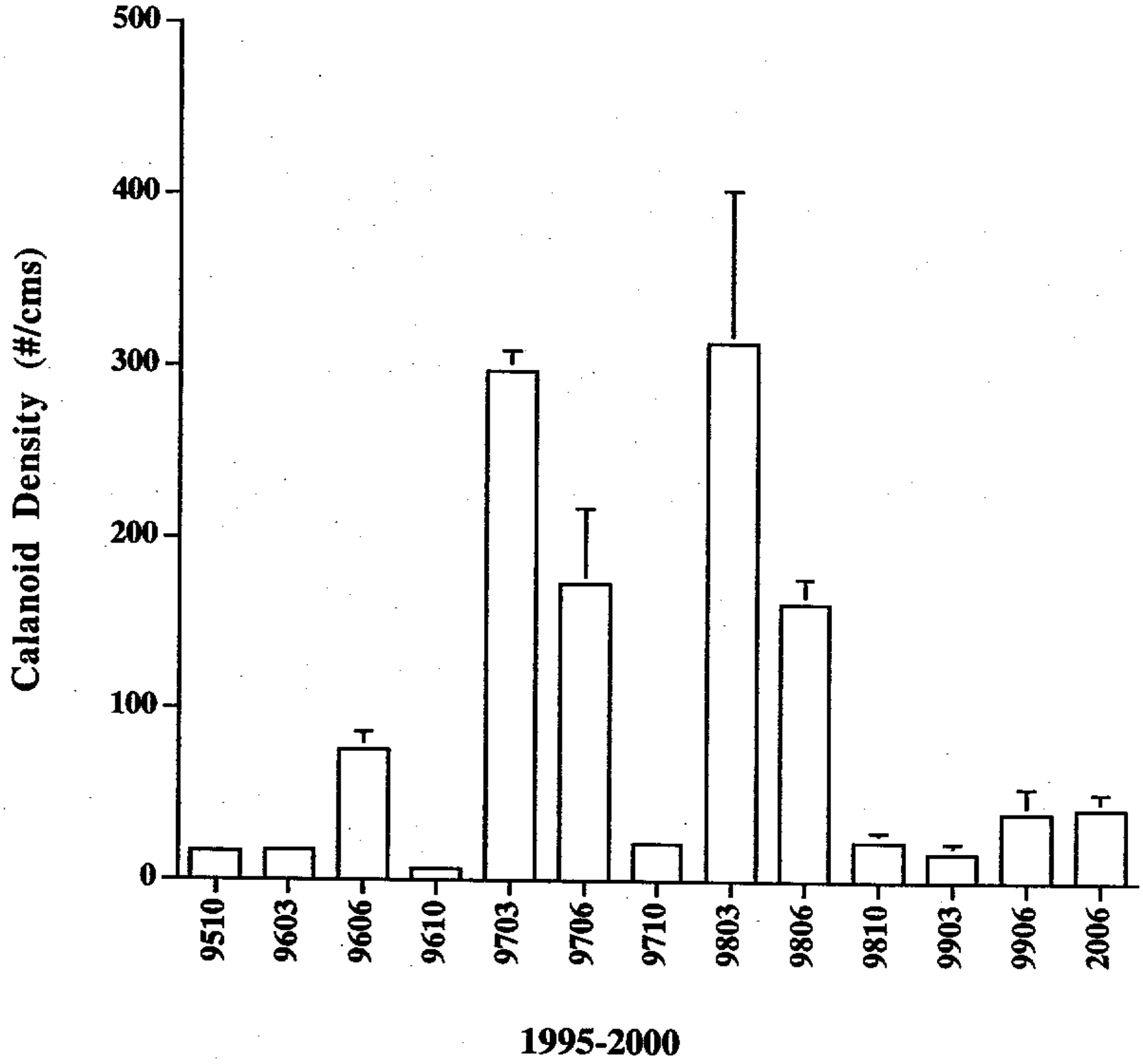

Figure 280. Average FPOM drift densities (#/cms) of Calanoids collected at Lees Ferry Rkm 0.0 from October 1995 to June 2000.

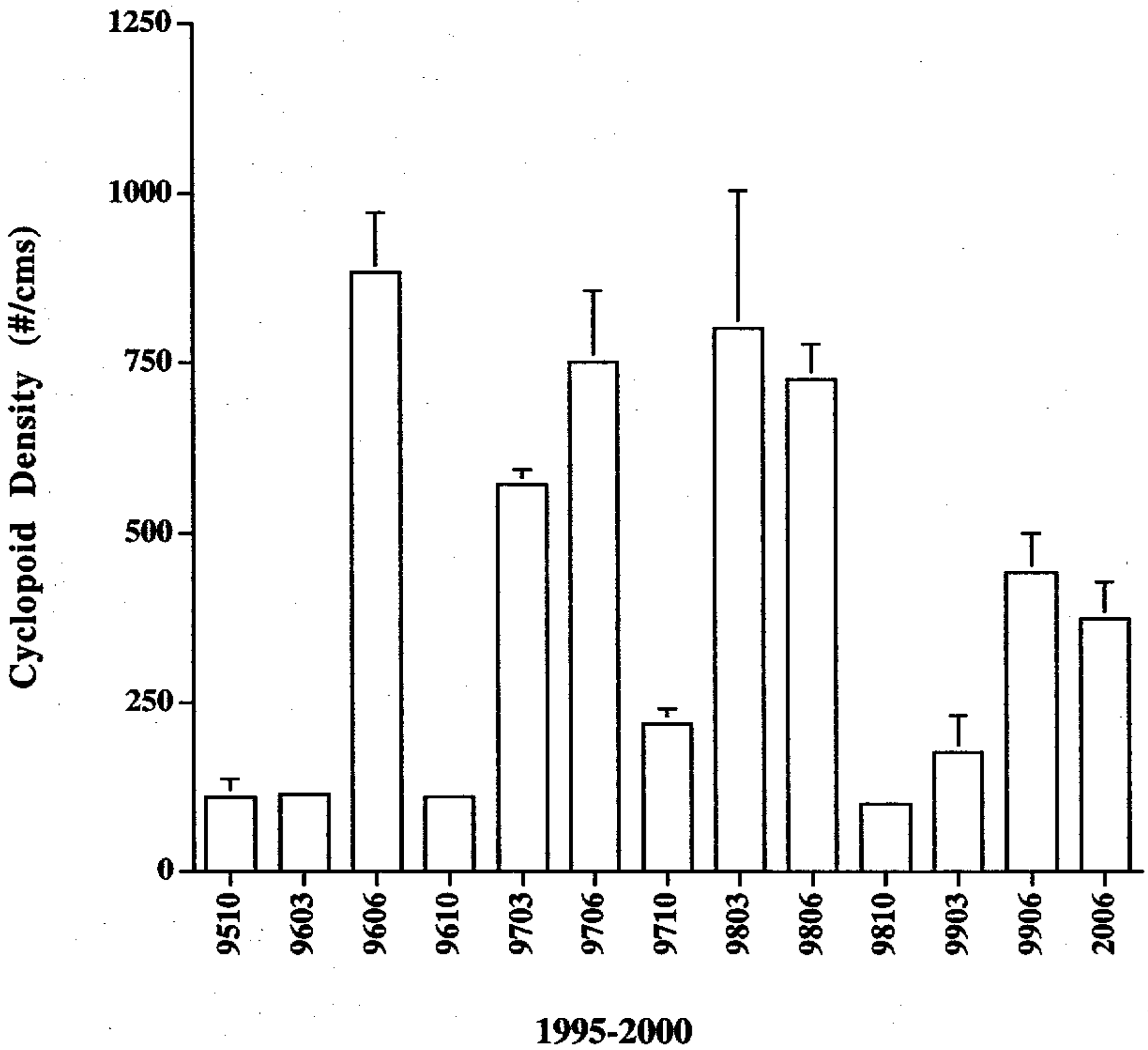

Figure 281. Average FPOM drift densities (#/cms) of Cyclopoids collected at Lees Ferry Rkm 0.0 from October 1995 to June 2000.

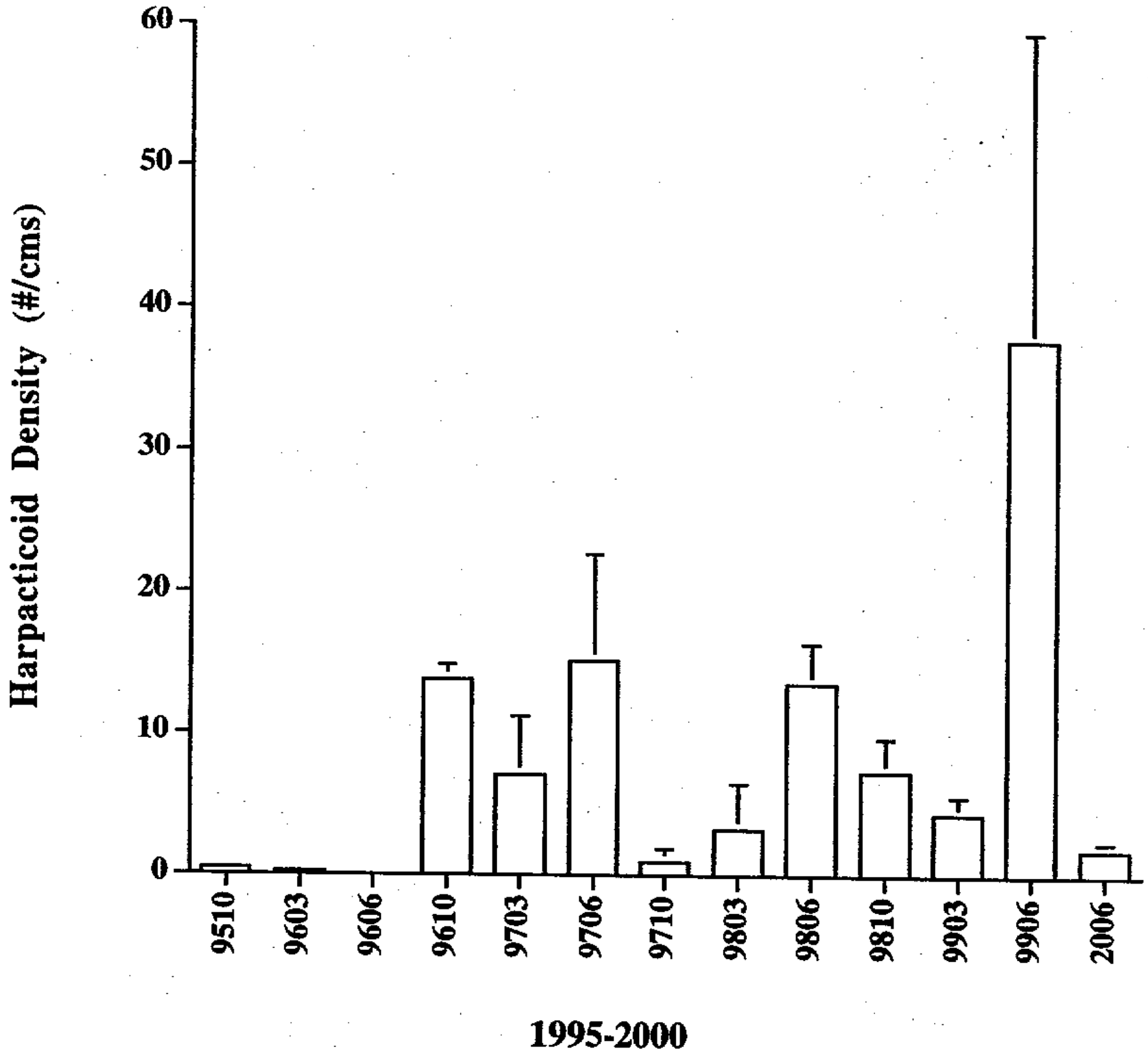

Figure 282. Average FPOM drift densities (#/cms) of Harpacticoids collected at Lees Ferry Rkm 0.0 from October 1995 to June 2000.

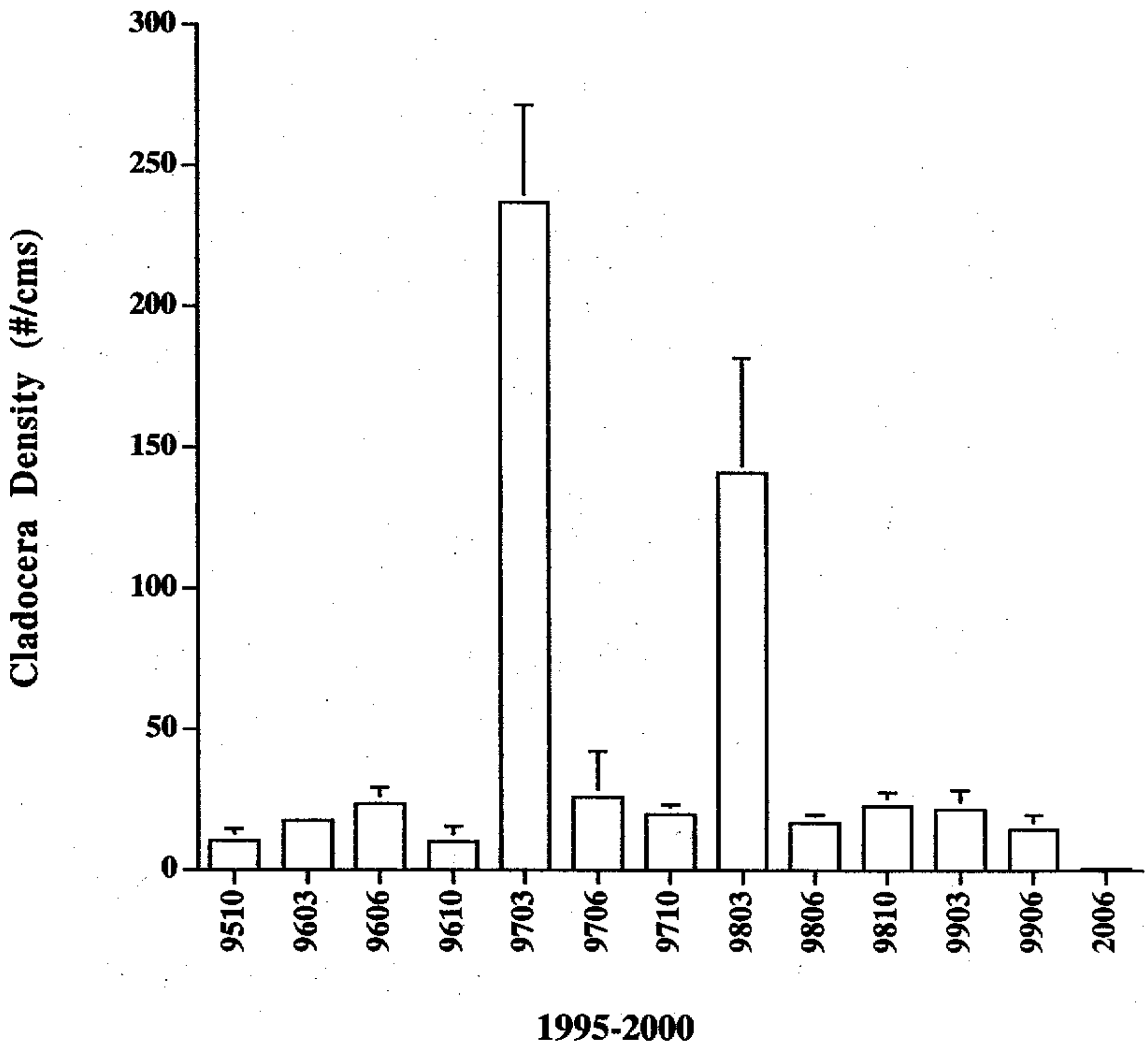

Figure 283. Average FPOM drift densities (#/cms) of Cladocera collected at Lees Ferry Rkm 0.0 from October 1995 to June 2000.

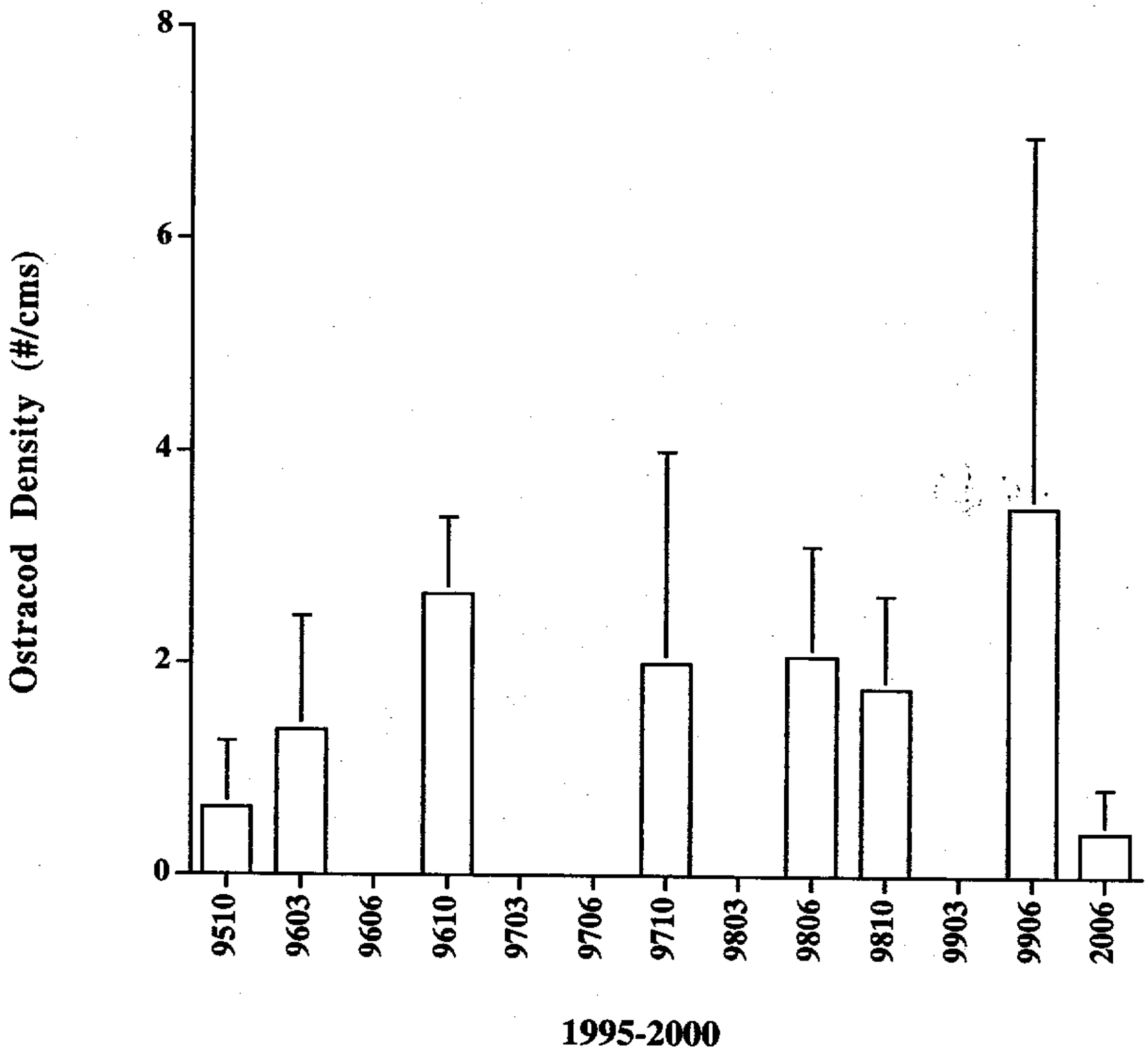

Figure 284. Average FPOM drift densities (#/cms) of Ostracods collected at Lees Ferry Rkm 0.0 from October 1995 to June 2000.

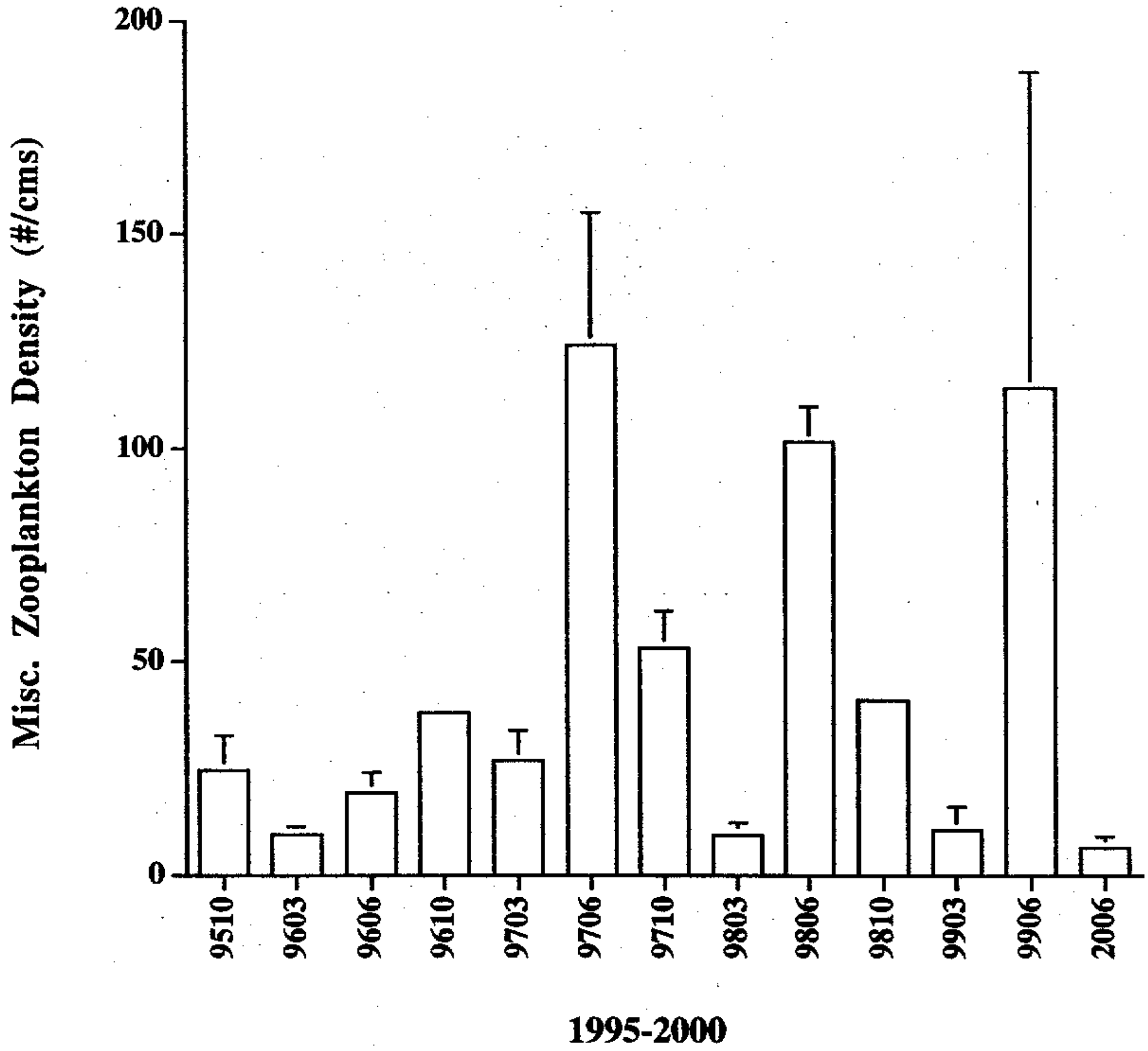

Figure 285. Average FPOM drift densities (#/cms) of miscellaneous zooplankton (benthic origin) collected at Lees Ferry Rkm 0.0 from October 1995 to June 2000.

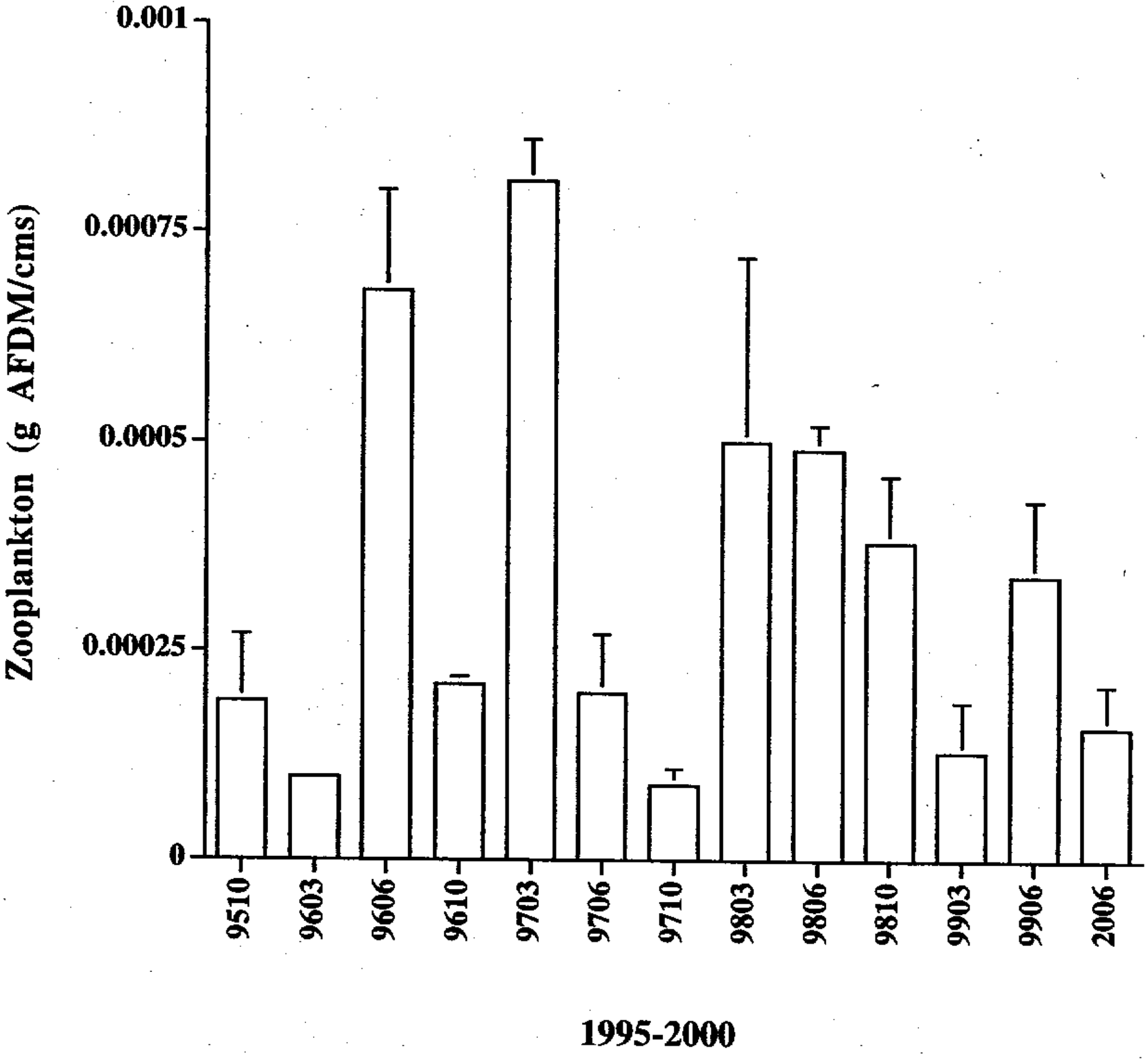

Figure 286. Average zooplankton biomass (g AFDM/cms) of lentic origin for Calanoida, Cyclopoida, Harpactacoida, Cladocera and Ostracoda collected at Lees Ferry Rkm 0.0 from October 1995 to June 2000.

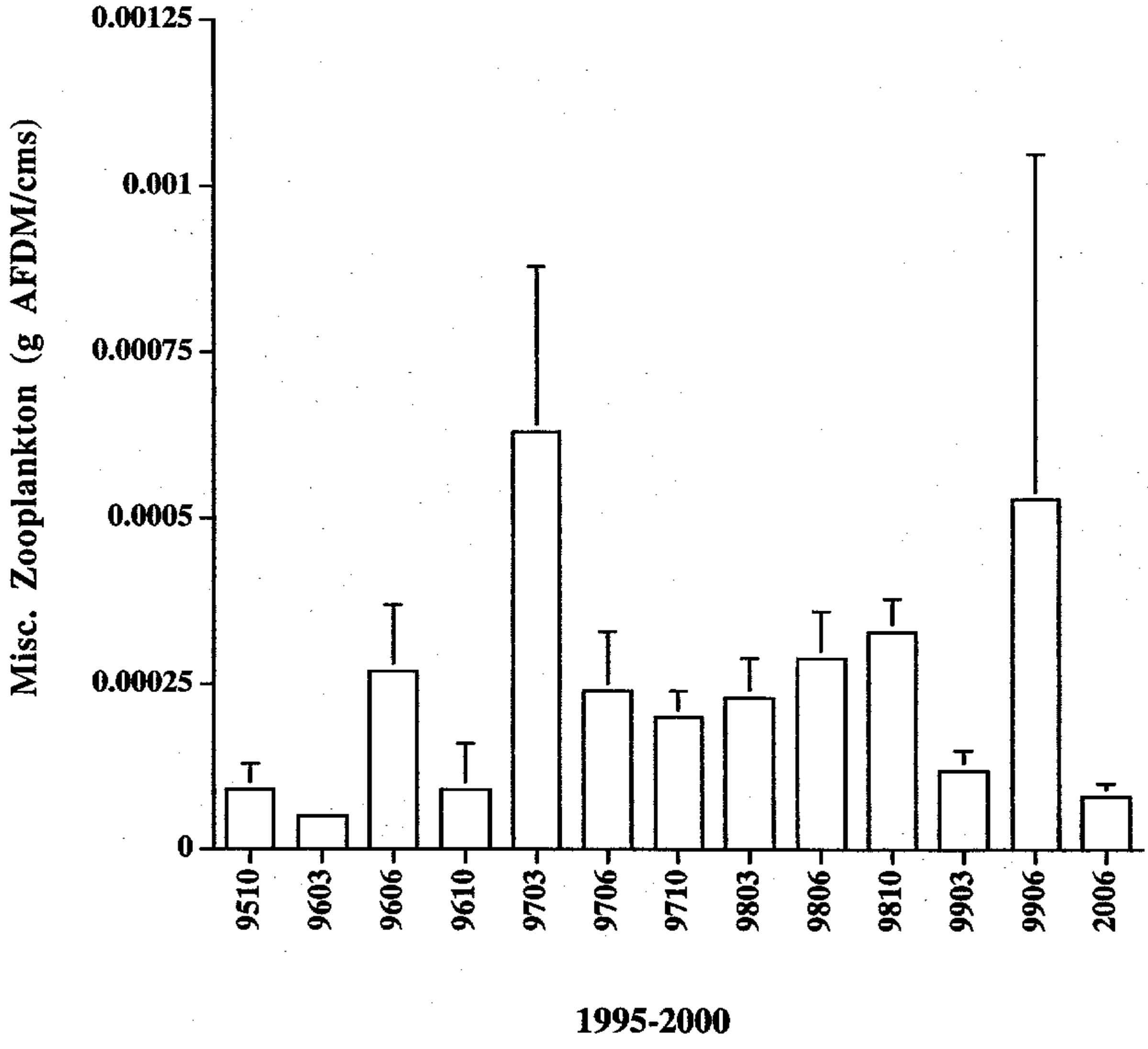

Figure 287. Average miscellaneous zooplankton biomass (g AFDM/cms) of benthic origin collected at Lees Ferry Rkm 0.0 from October 1995 to June 2000.

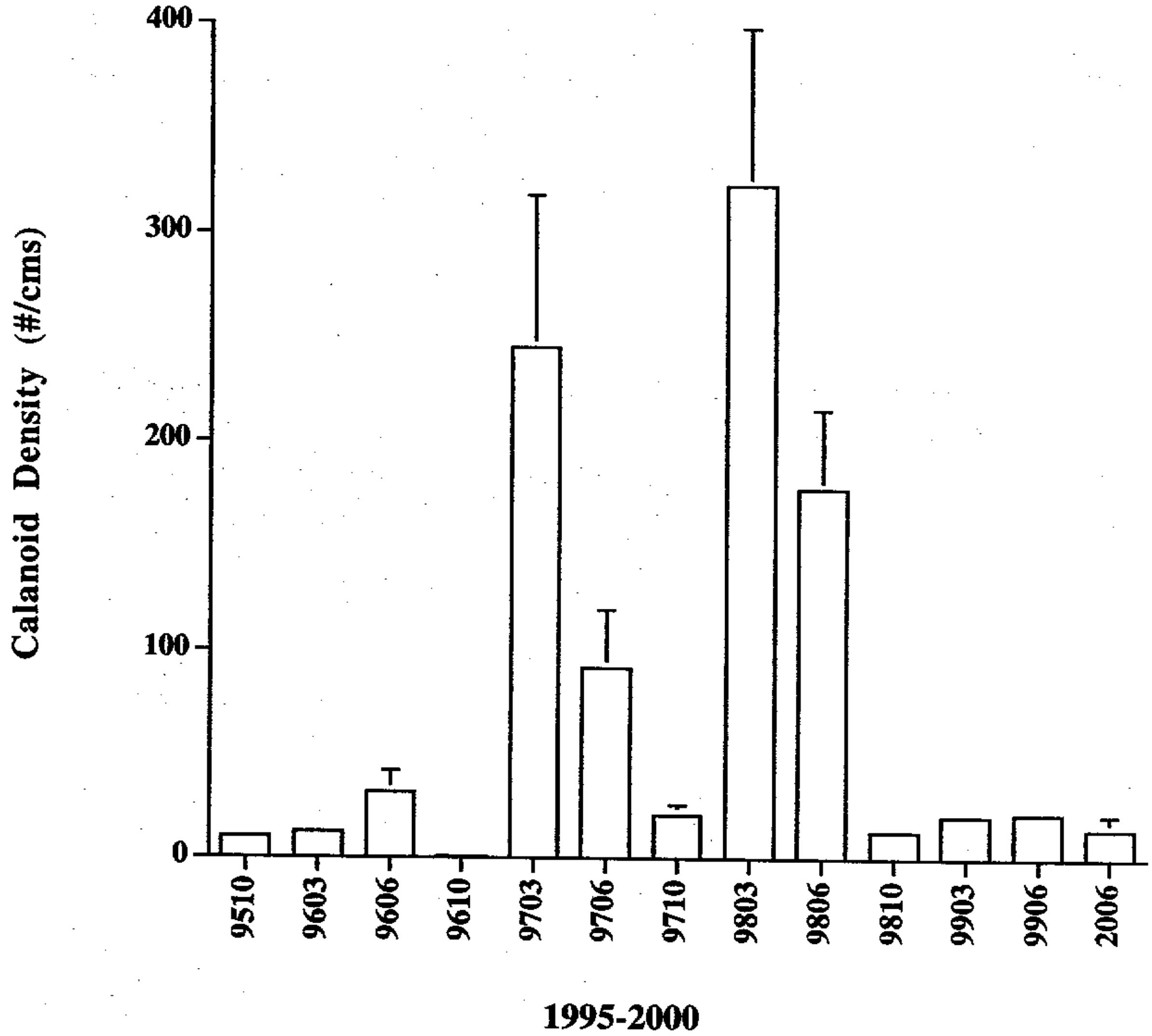

Figure 288. Average FPOM drift densities (#/cms) of Calanoids collected at Two-Mile Wash Rkm 2.9 from October 1995 to June 2000.

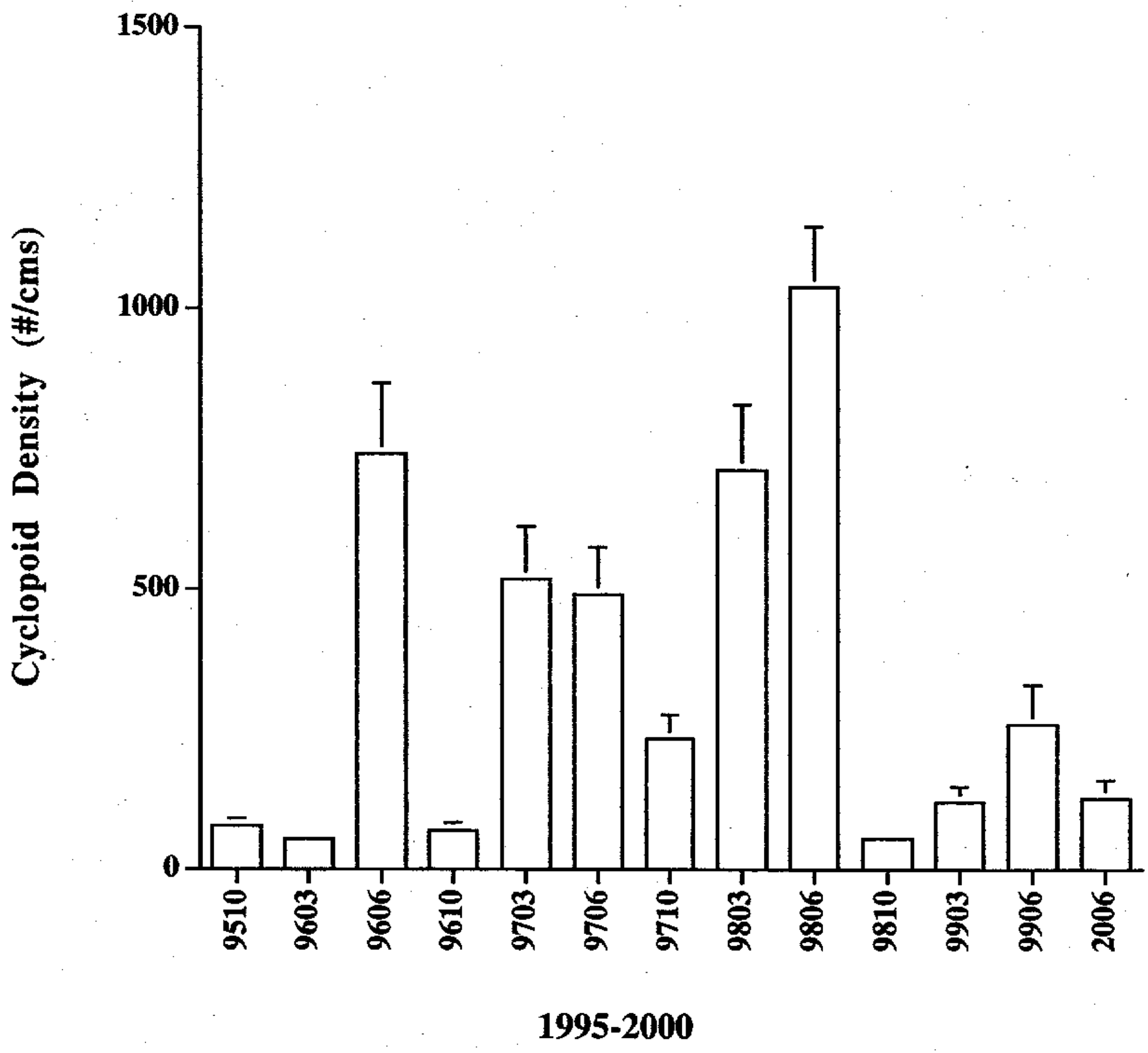

Figure 289. Average FPOM drift densities (#/cms) of Cyclopoids collected at Two-Mile Wash Rkm 2.9 from October 1995 to June 2000.

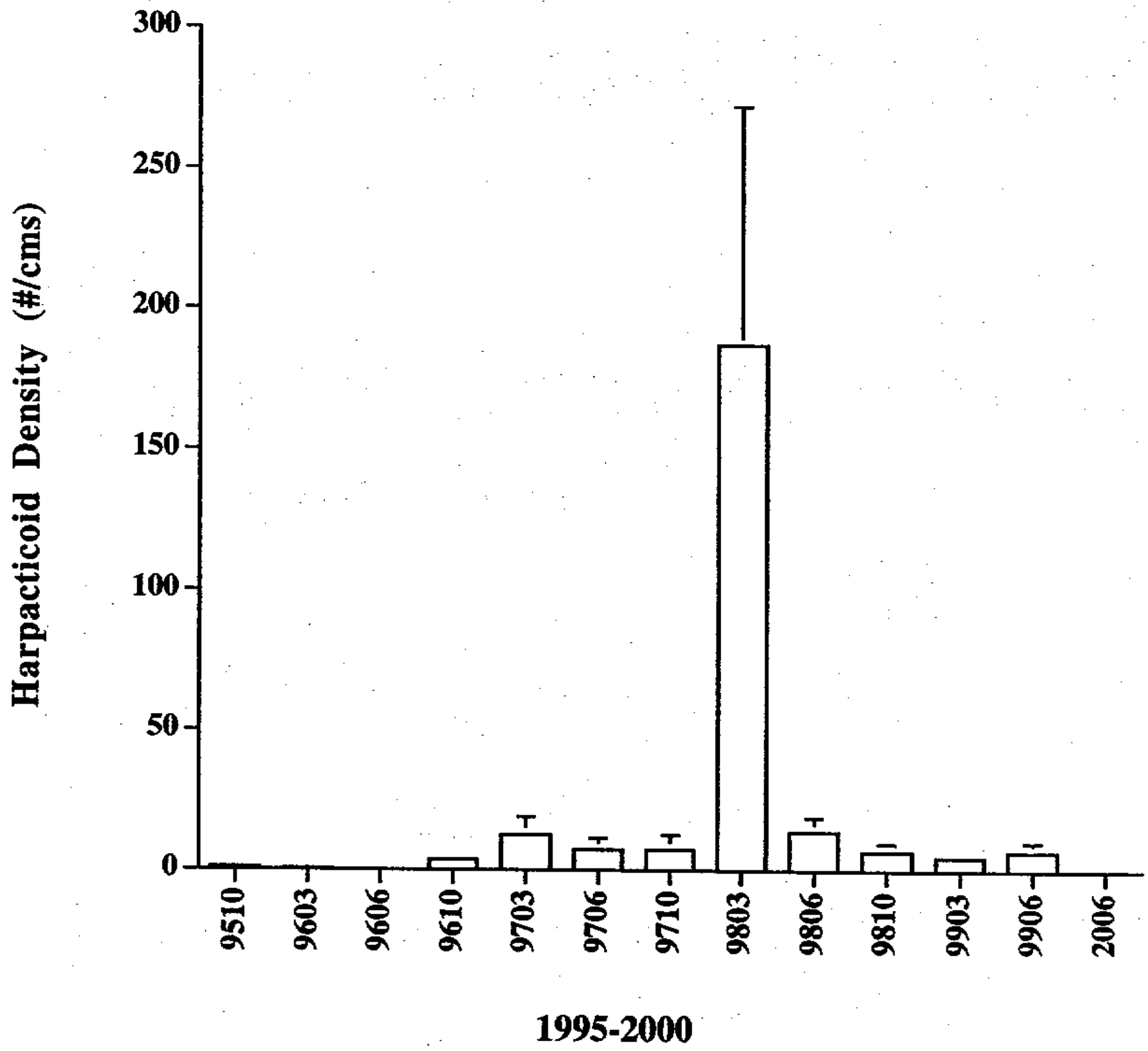

Figure 290. Average FPOM drift densities (#/cms) of Harpacticoids collected at Two-Mile Wash Rkm 2.9 from October 1995 to June 2000.

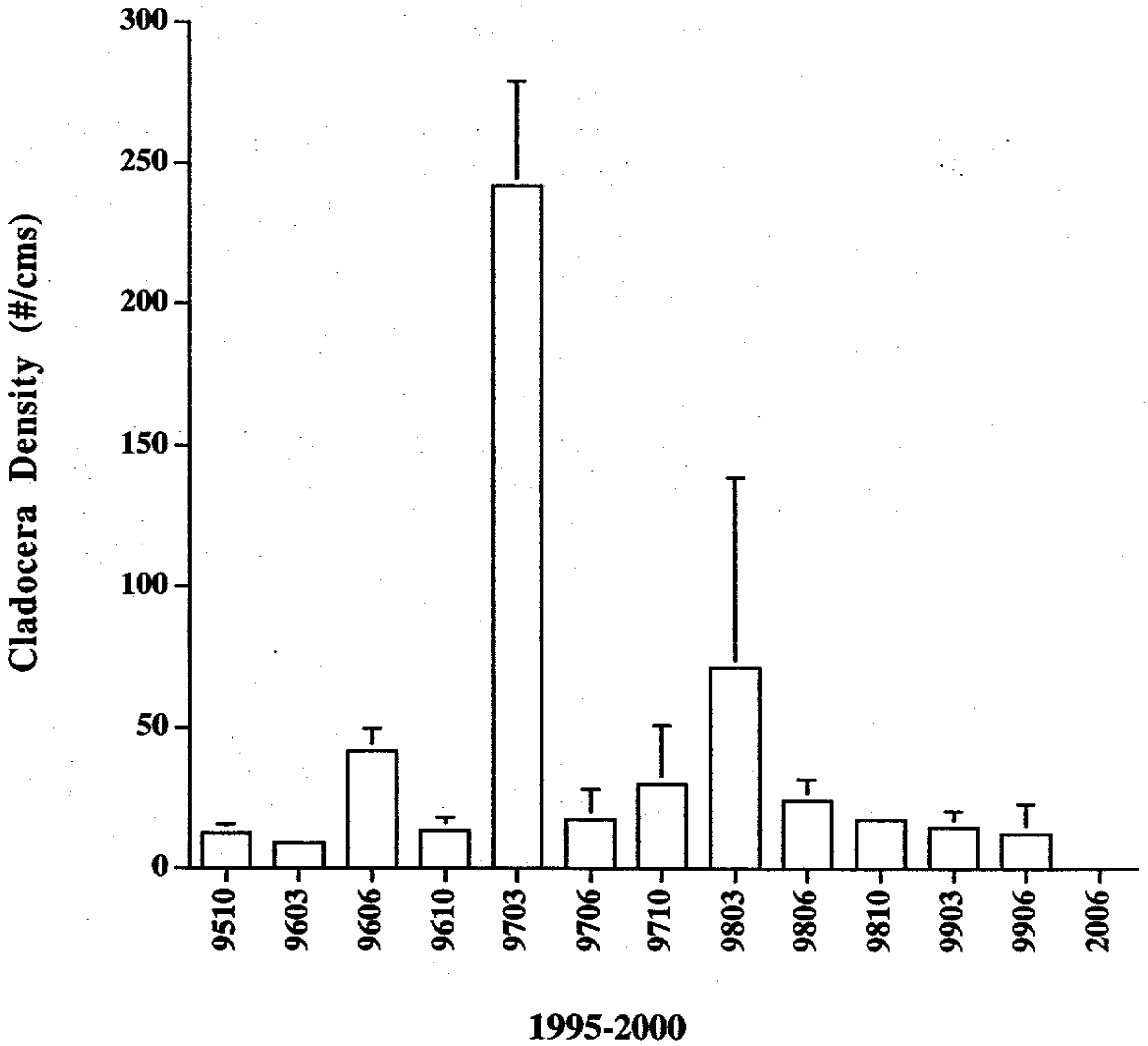

Figure 291. Average FPOM drift densities (#/cms) of Cladocera collected at Two-Mile Wash Rkm 2.9 from October 1995 to June 2000.

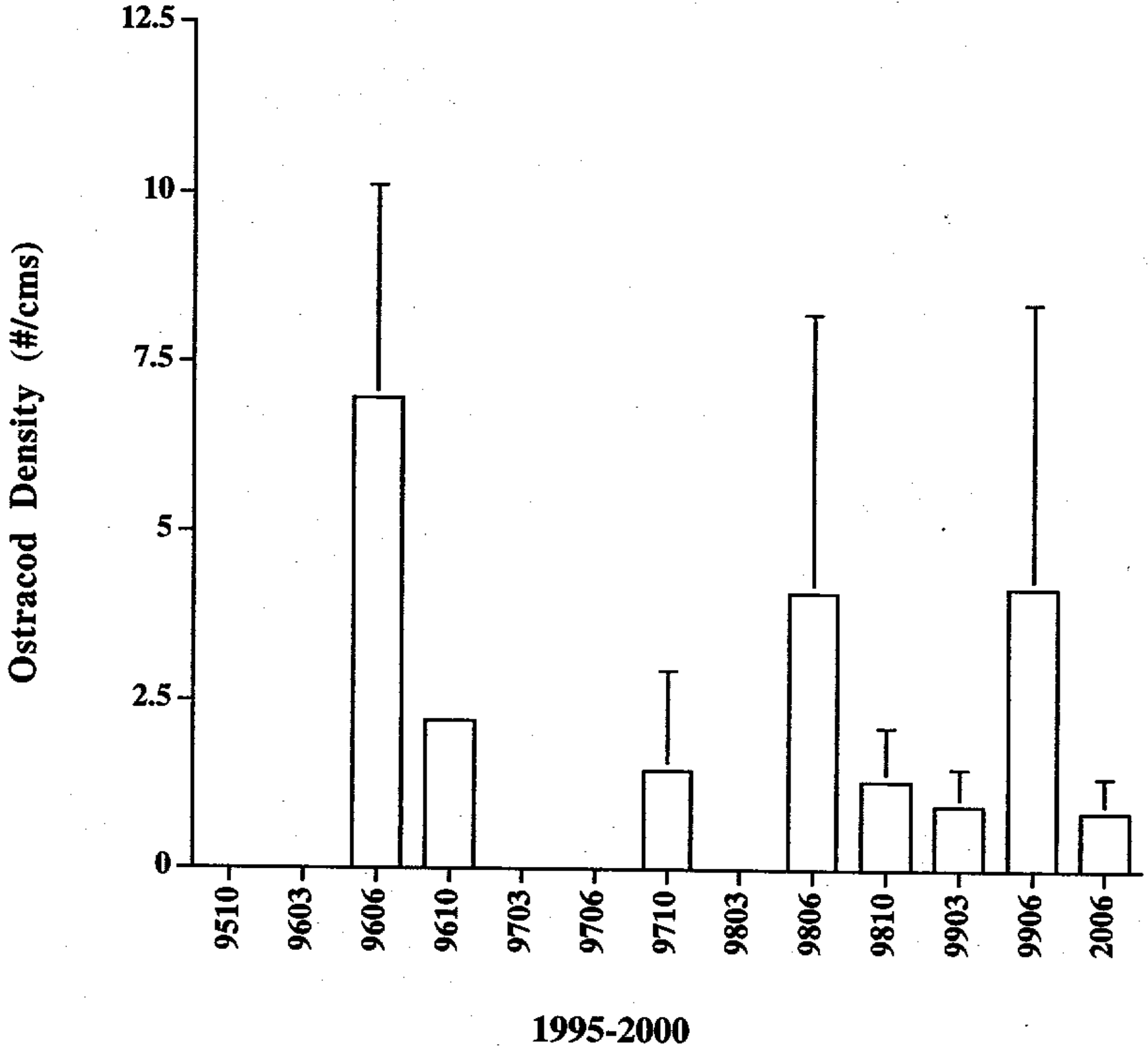

Figure 292. Average FPOM drift densities (#/cms³) of Ostracods collected at Two-Mile Wash Rkm 2.9 from October 1995 to June 2000.

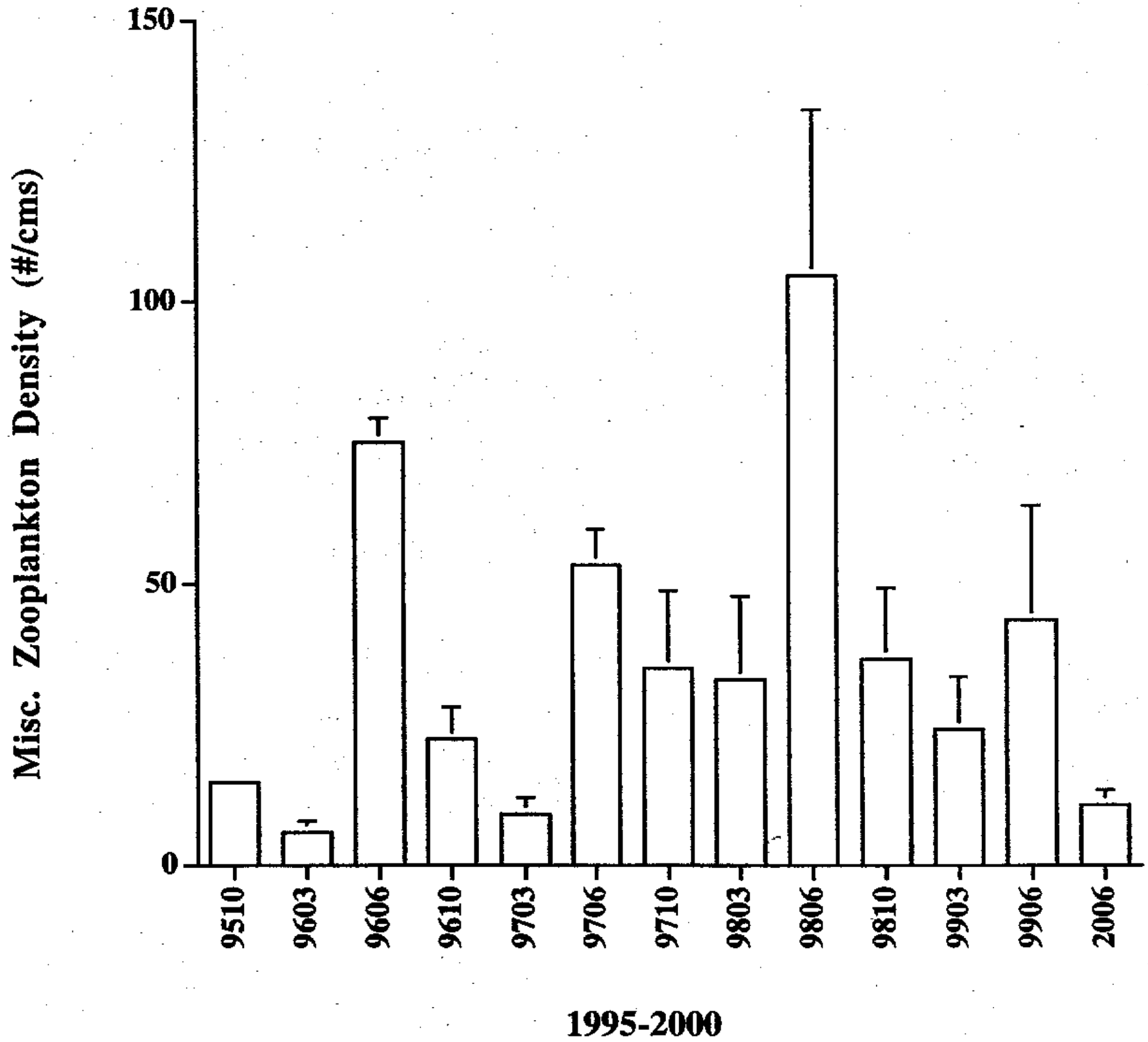

Figure 293. Average FPOM drift densities (#/cms) of miscellaneous zooplankton (benthic origin) collected at Two-Mile Wash Rkm 2.9 from October 1995 to June 2000.

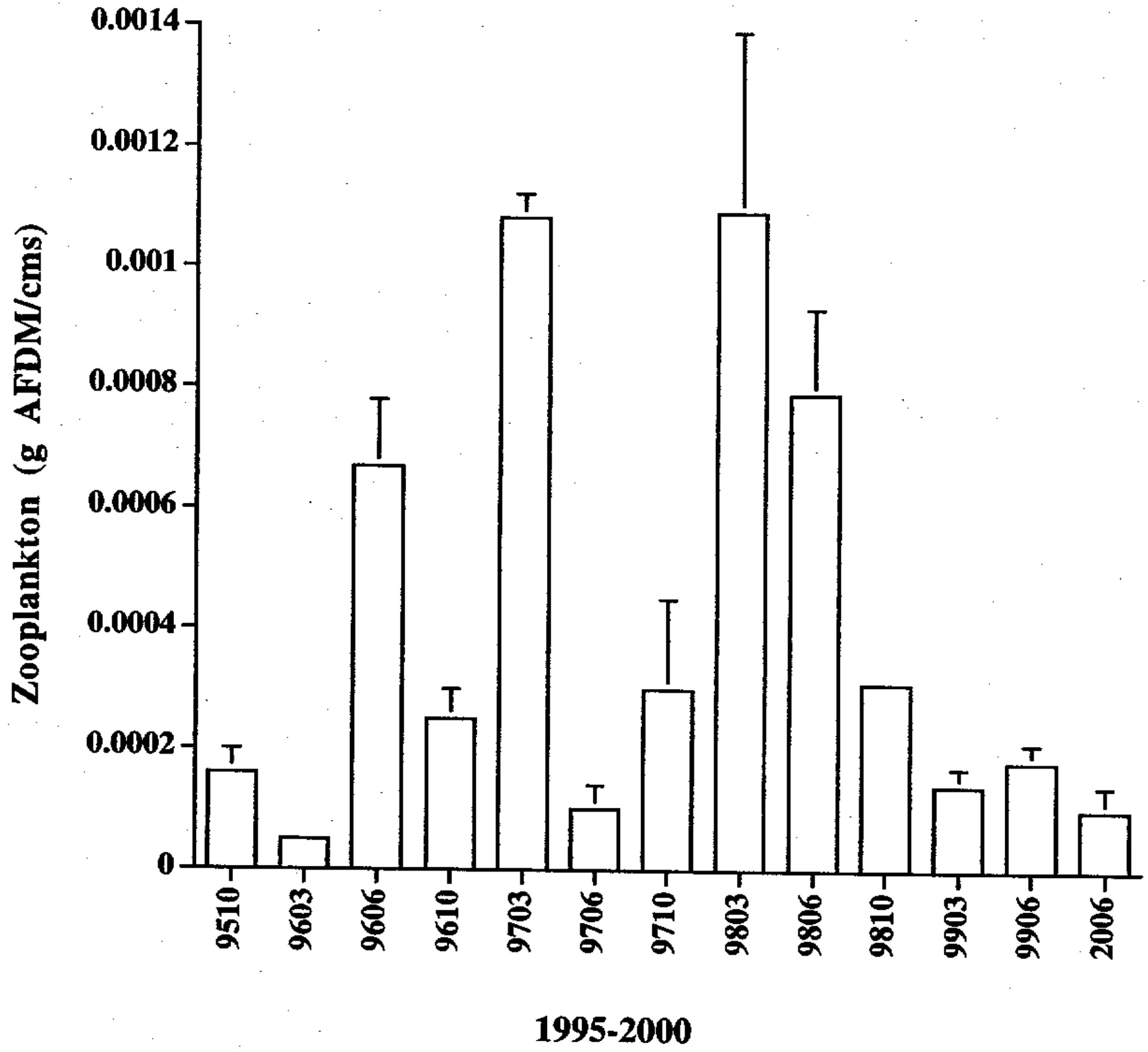

Figure 294. Average zooplankton biomass (g AFDM/cms) of lentic origin for Calanoida, Cyclopoida, Harpactacoida, Cladocera and Ostracoda collected at Two-Mile Wash Rkm 2.9 from October 1995 to June 2000.

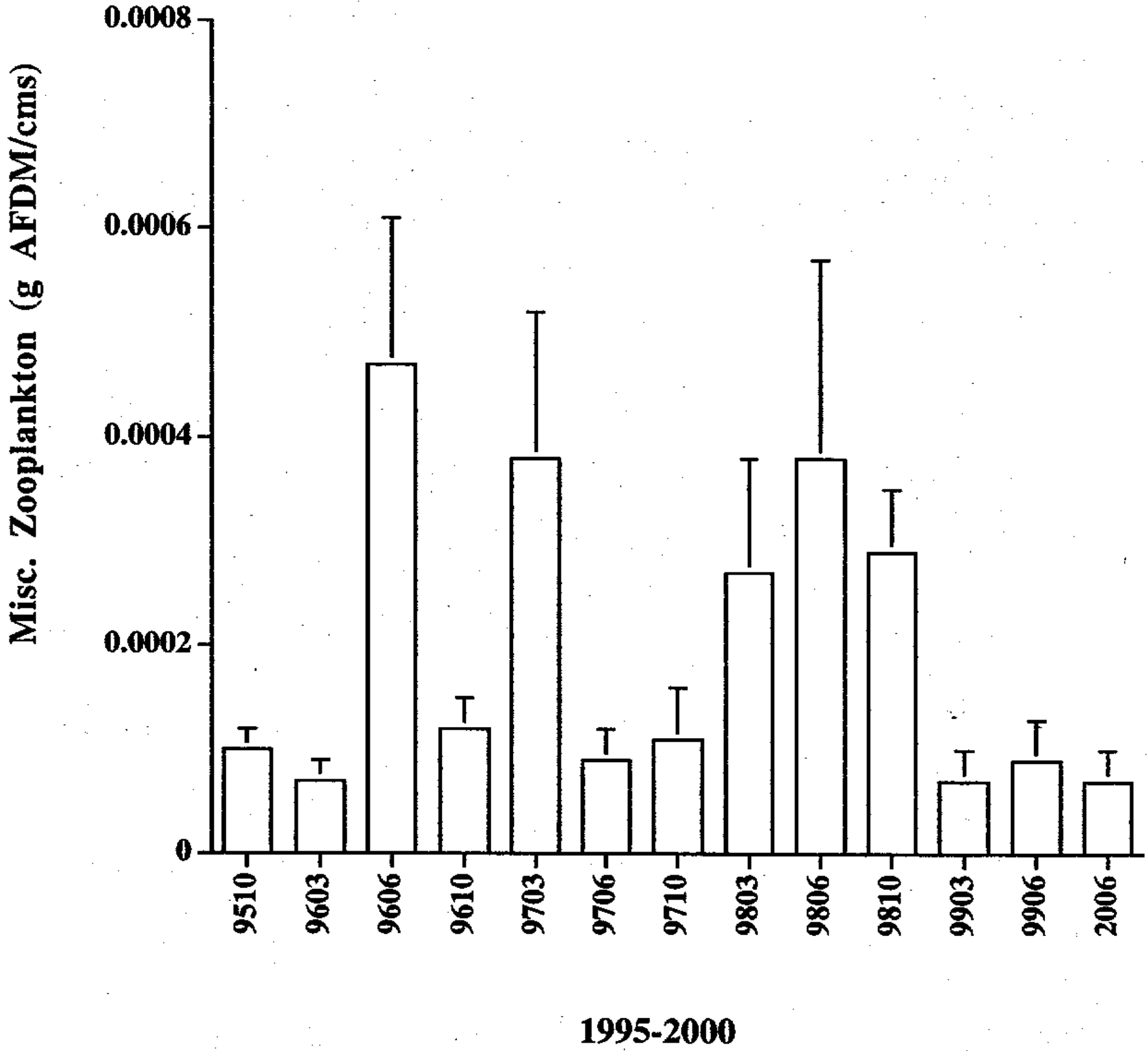

Figure 295. Average miscellaneous zooplankton biomass (g AFDM/cms) of benthic origin collected at Two-Mile Wash Rkm 2.9 from October 1995 to June 2000.

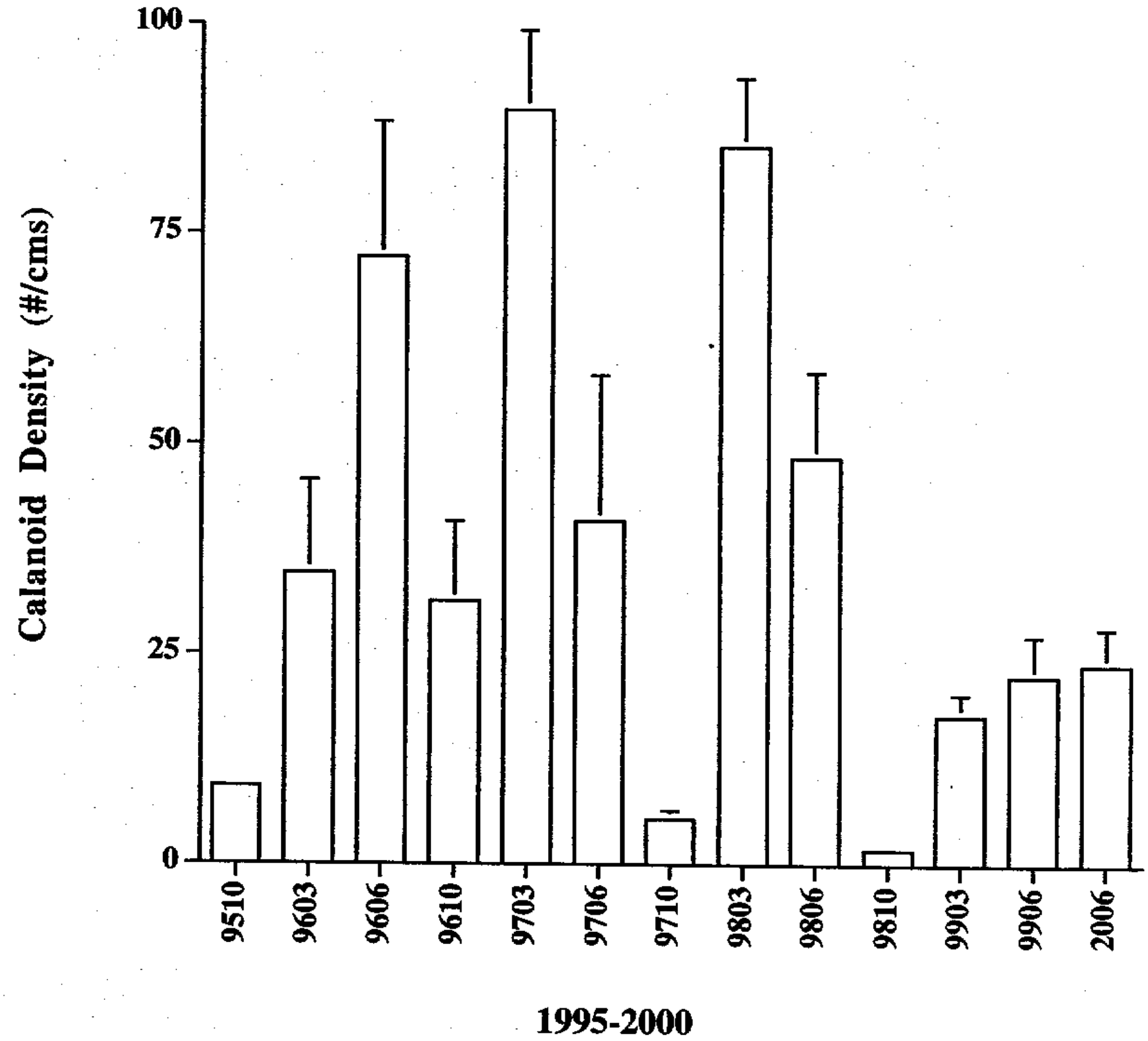

Figure 296. Average FPOM drift densities (#/cms) of Calanoids collected at Guage Above LCR Rkm 98.4 from October 1995 to June 2000.

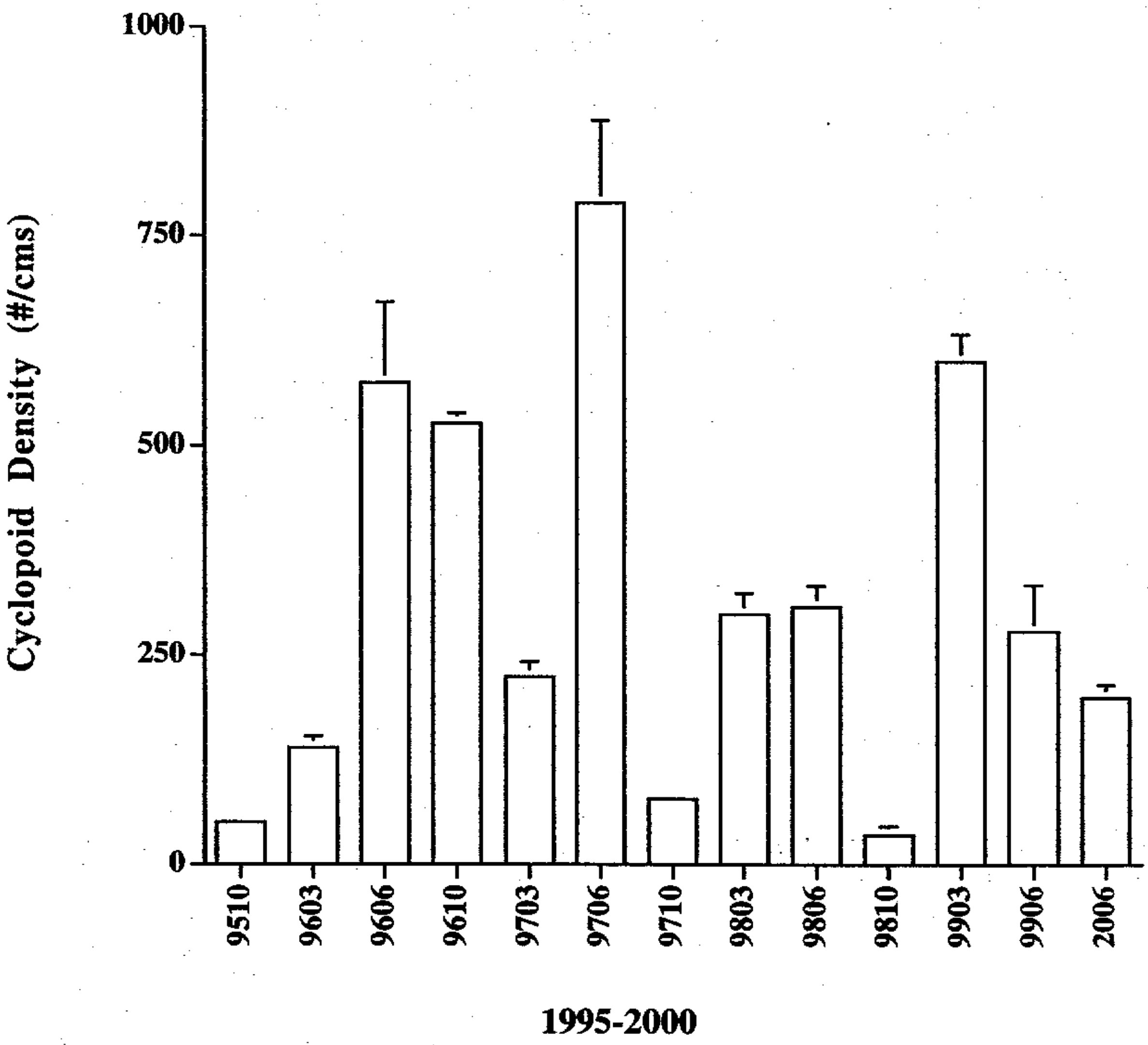

Figure 297. Average FPOM drift densities (#/cms) of Cyclopoids collected at Guage Above LCR Rkm 98.4 from October 1995 to June 2000.

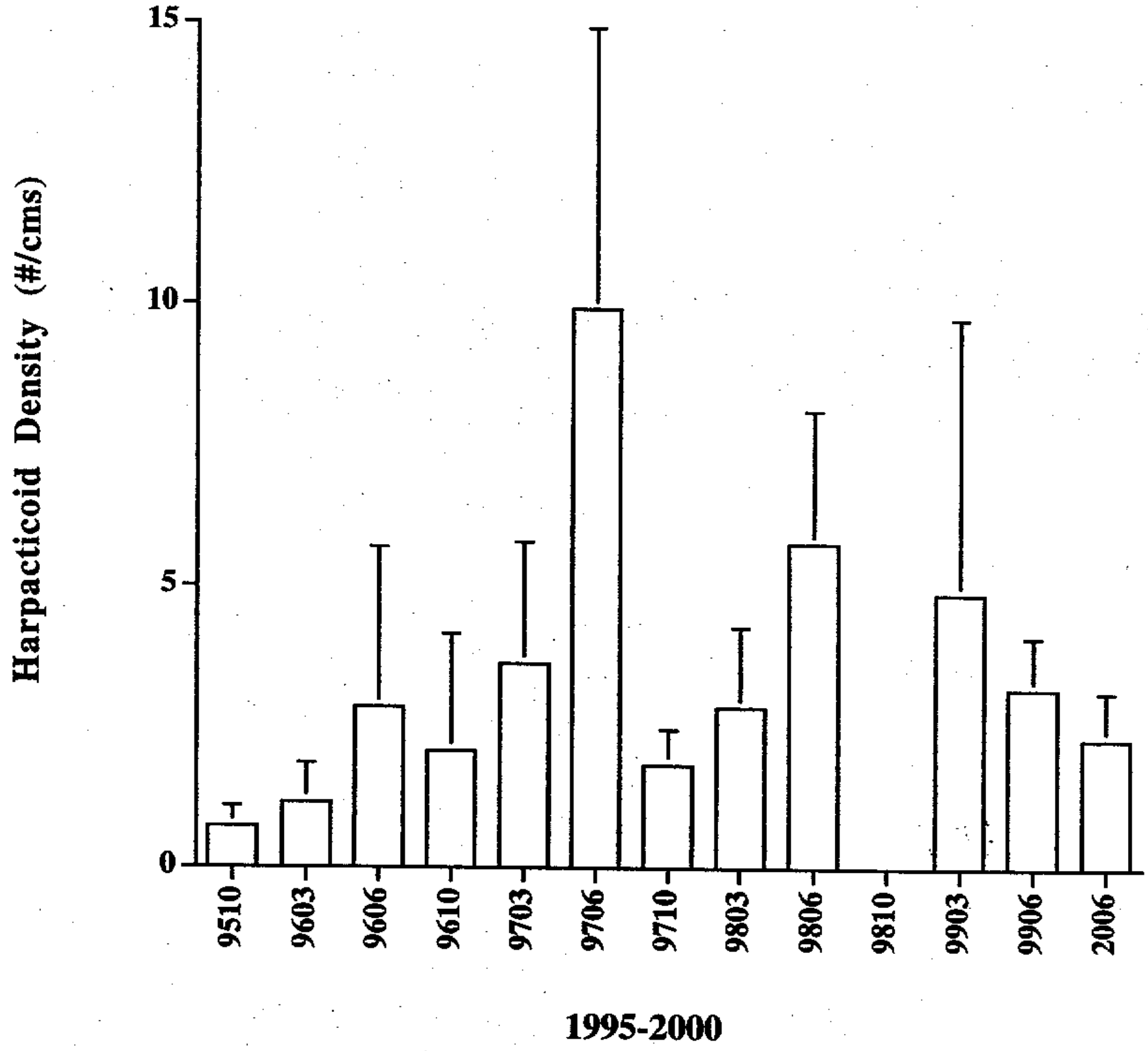

Figure 298. Average FPOM drift densities (#/cms) of Harpacticoids collected at Guage Above LCR Rkm 98.4 from October 1995 to June 2000.

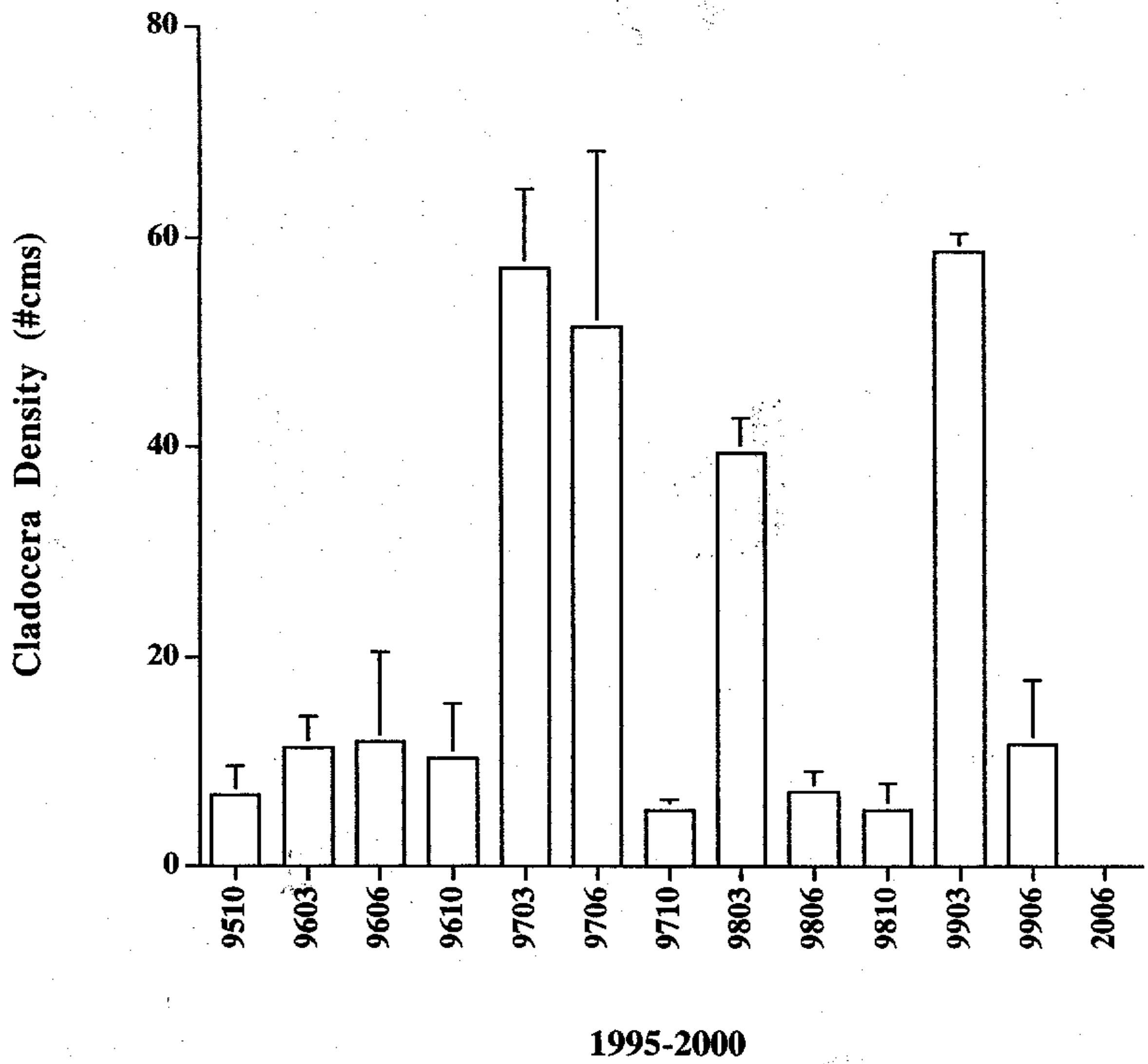

Figure 297. Average FPOM drift densities (#/cms) of Calanoids collected at Guage Above LCR Rkm 98.4 from October 1995 to June 2000.

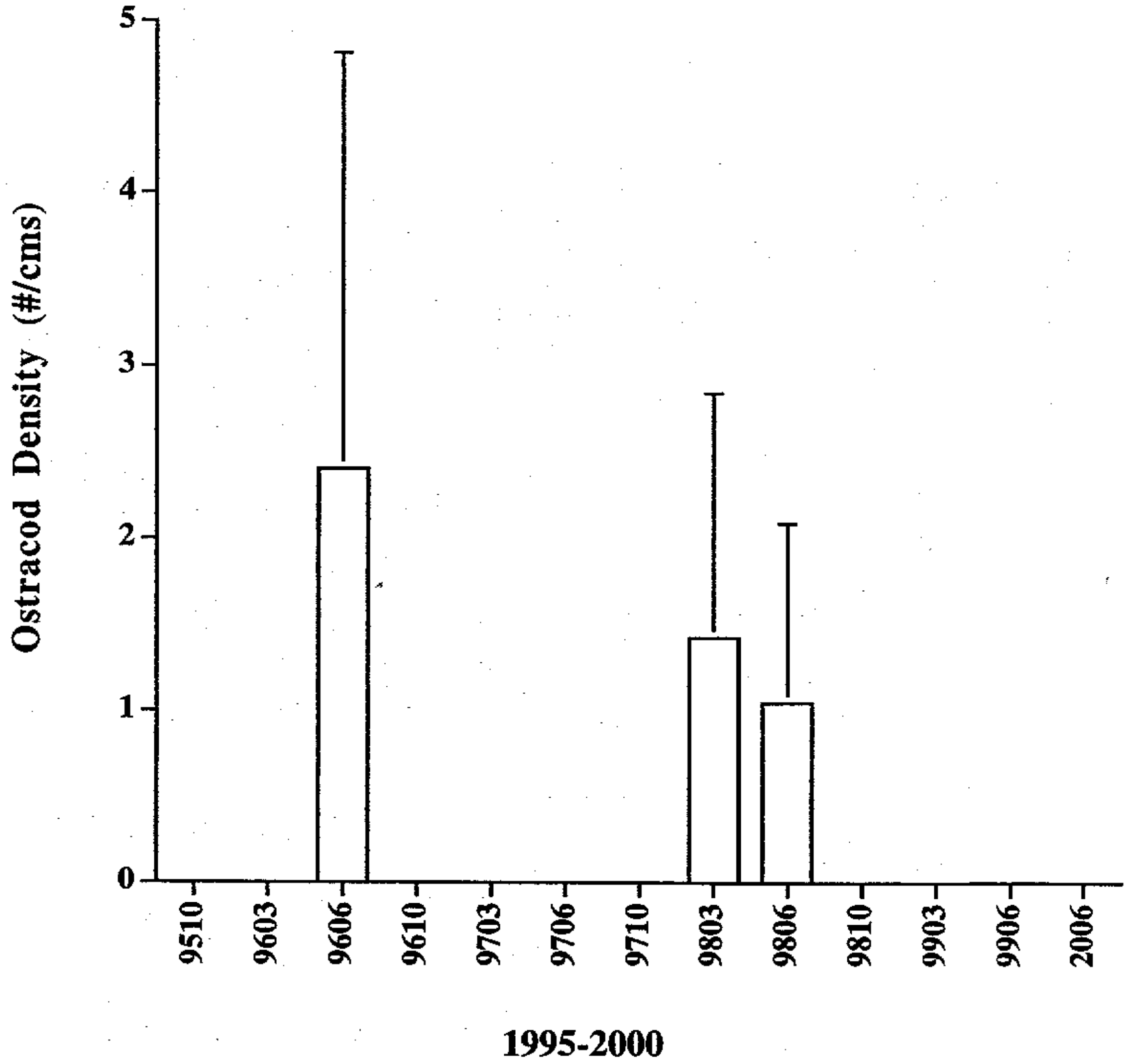

Figure 300. Average FPOM drift densities (#/cms) of Ostracods collected at Guage Above LCR Rkm 98.4 from October 1995 to June 2000.

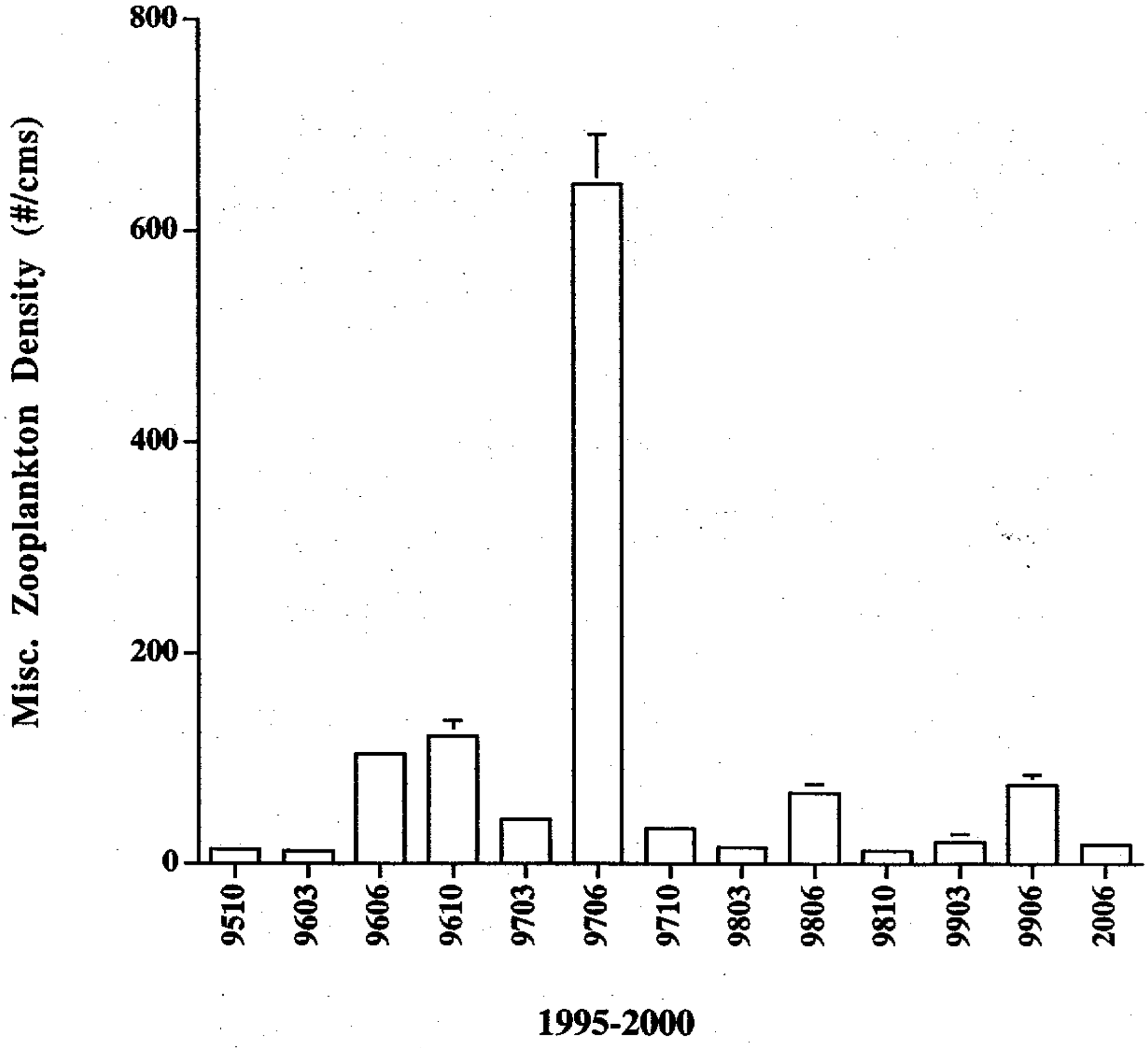

Figure 301. Average FPOM drift densities (#/cms) of miscellaneous zooplankton (benthic origin) collected at Guage Above LCR Rkm 98.4 from October 1995 to June 2000.

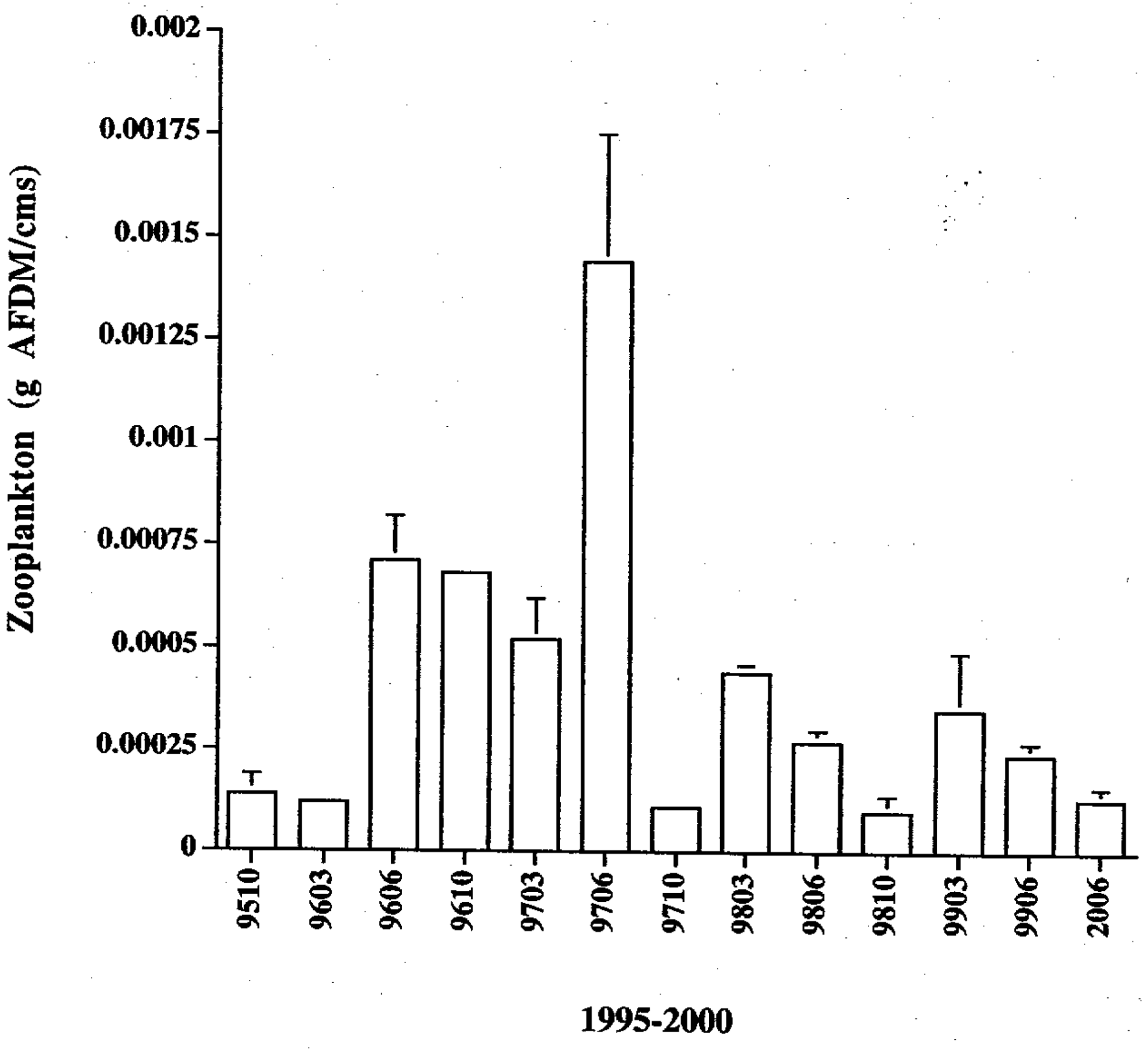

Figure 302. Average zooplankton biomass (g AFDM/cms) of lentic origin for Calanoida, Cyclopoida, Cladocera and Ostracoda collected at Gauge Above LCR Rkm 98.4 from October 1995 to June 2000.

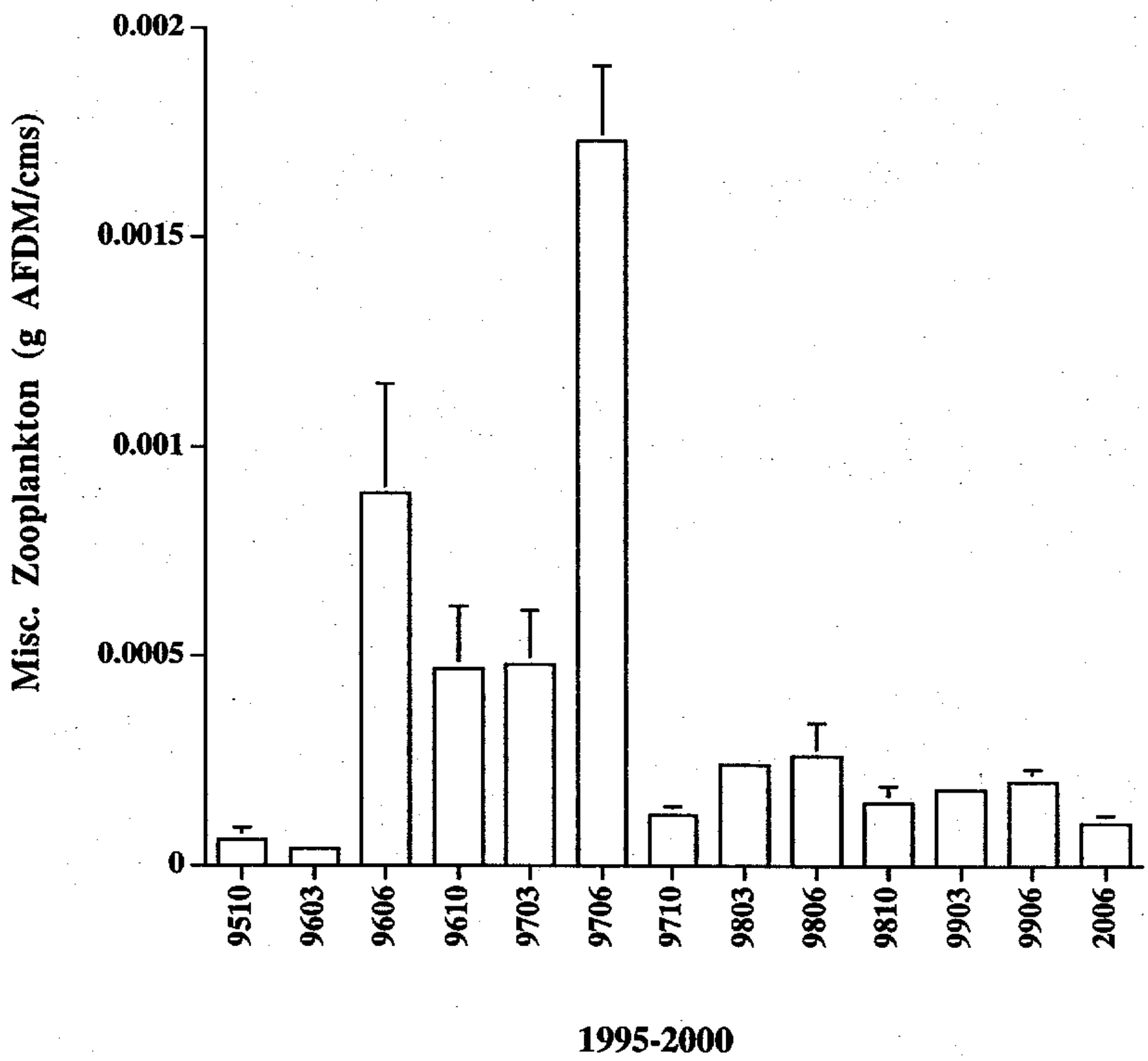

Figure 303. Average miscellaneous zooplankton biomass (g AFDM/cms) of benthic origin collected at Gauge Above LCR Rkm 98.4 from October 1995 to June 2000.

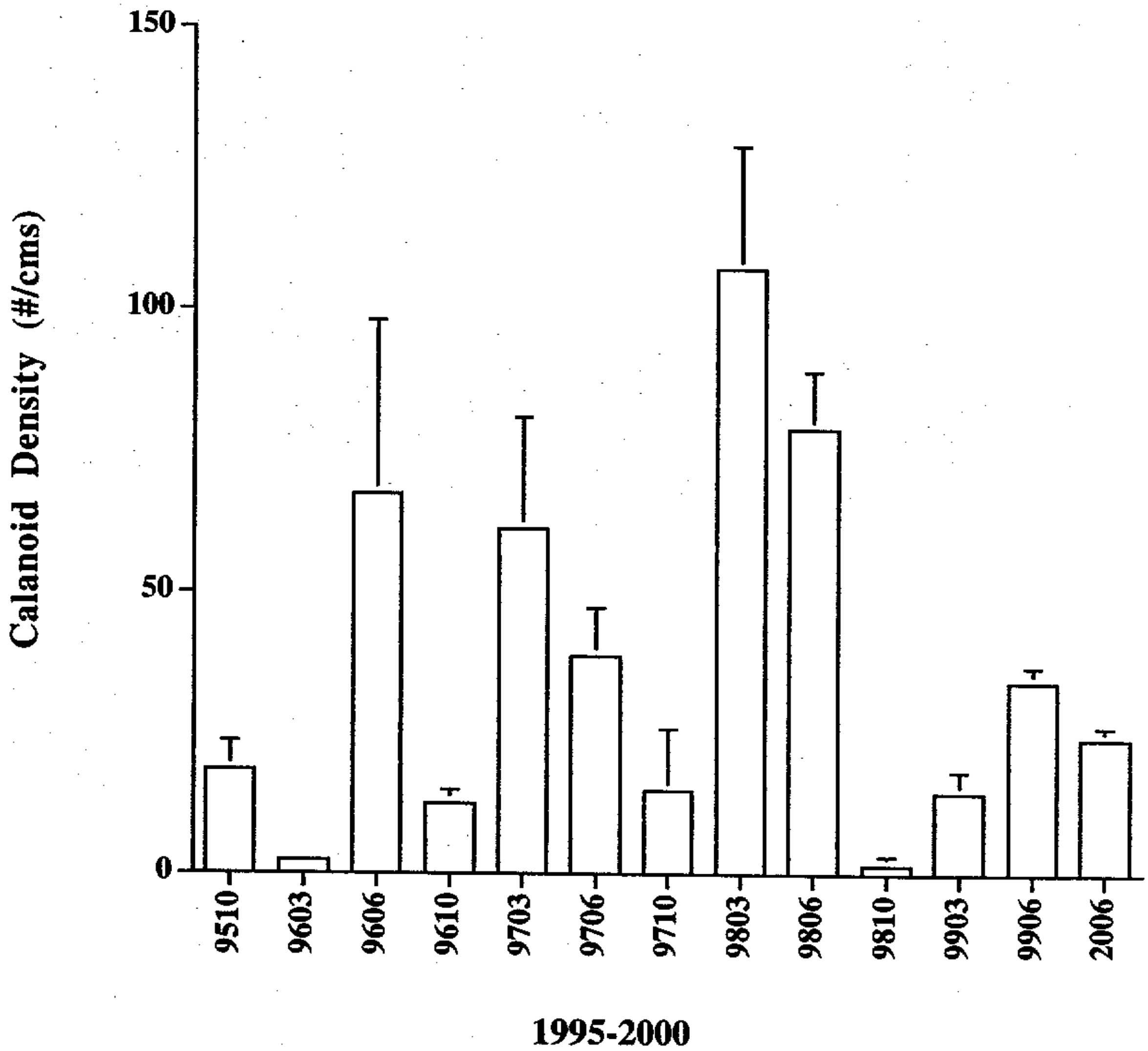

Figure 304. Average FPOM drift densities (#/cms) of Calanoids collected at Tanner Cobble Rkm 109.6 from October 1995 to June 2000.

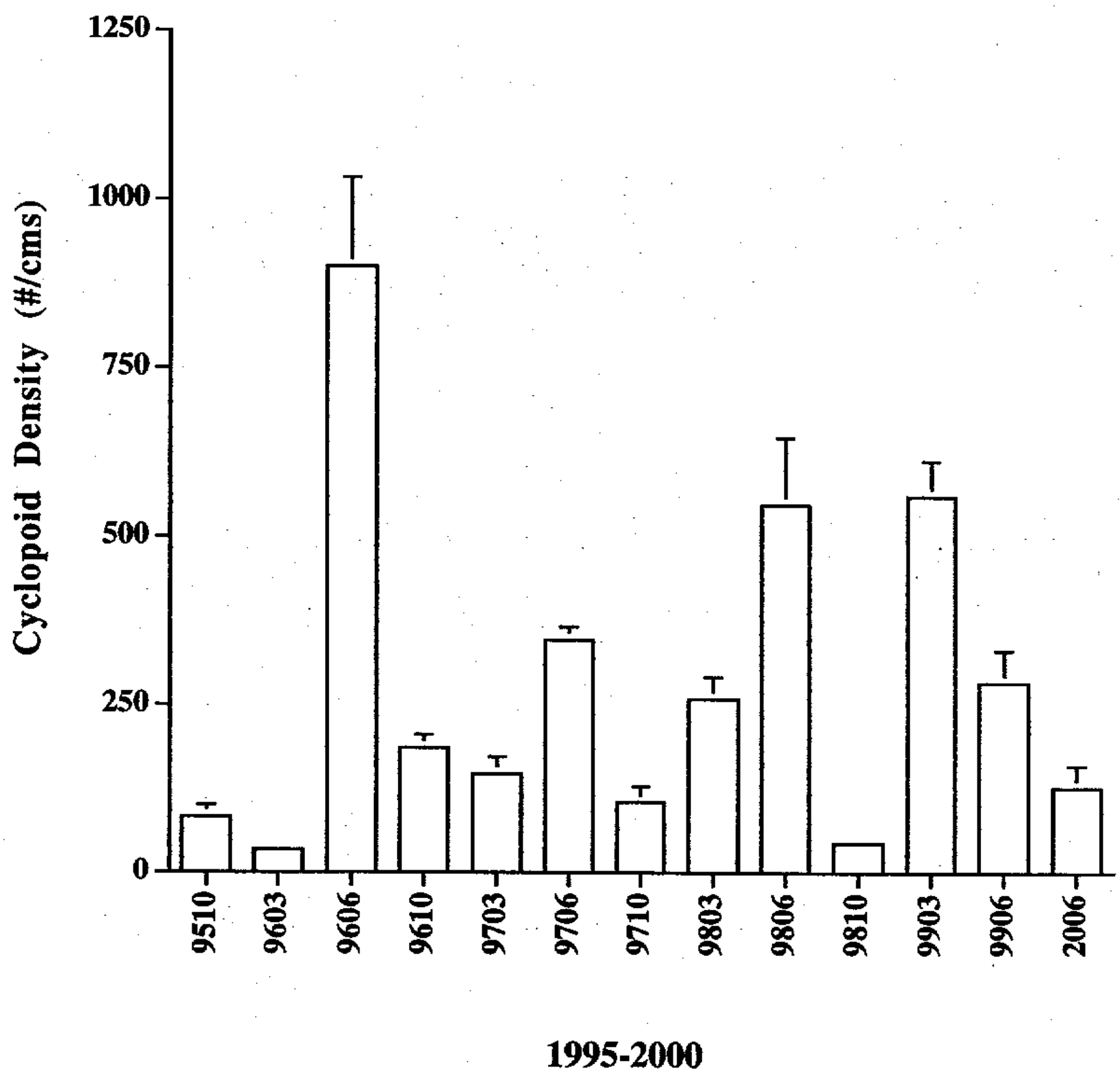

Figure 305. Average FPOM drift densities (#/cms) of Cyclopoids collected at Tanner Cobble Rkm 109.6 from October 1995 to June 2000.

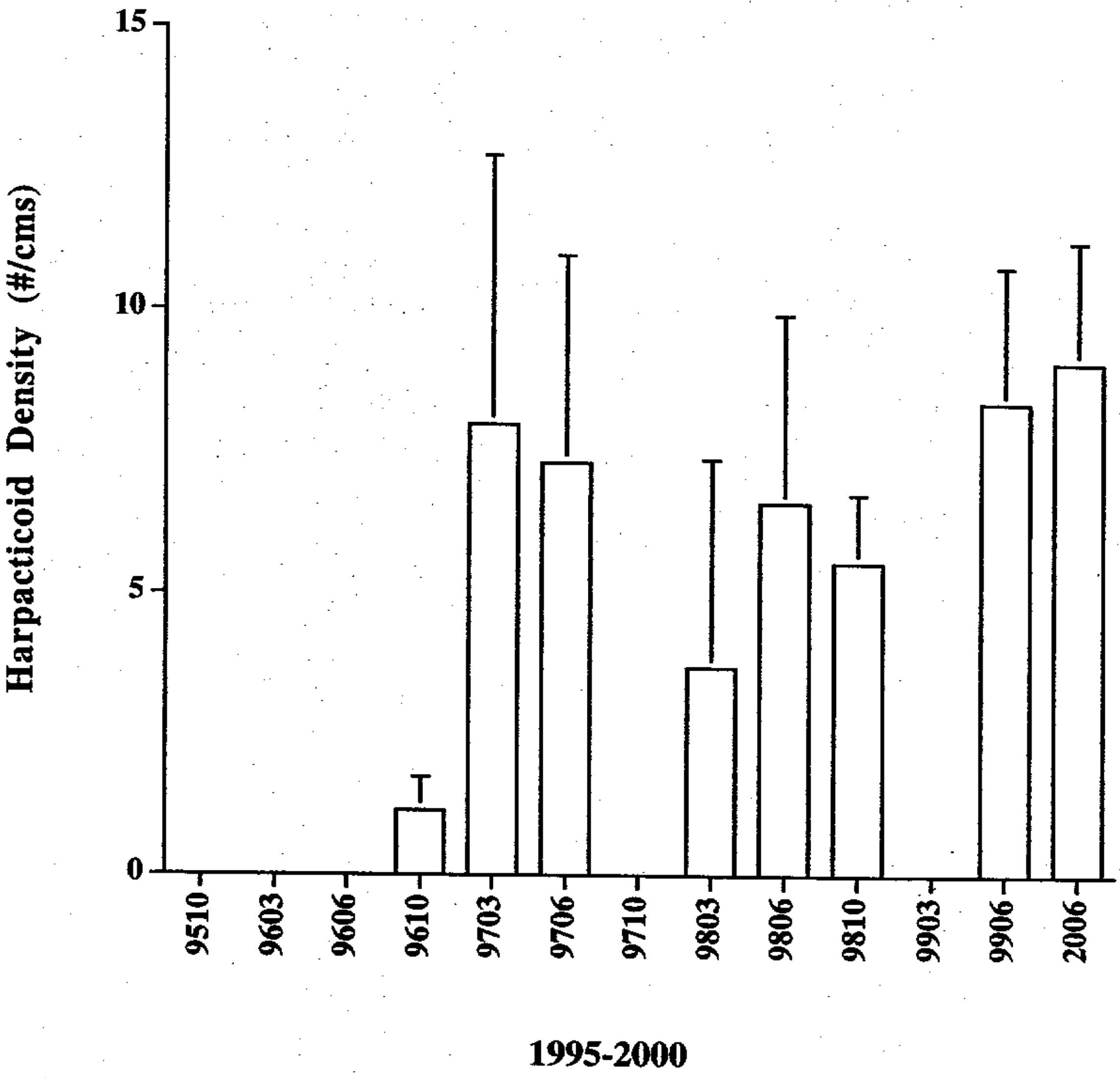

Figure 306. Average FPOM drift densities (#/cms) of Harpacticoids collected at Tanner Cobble Rkm 109.6 from October 1995 to June 2000.

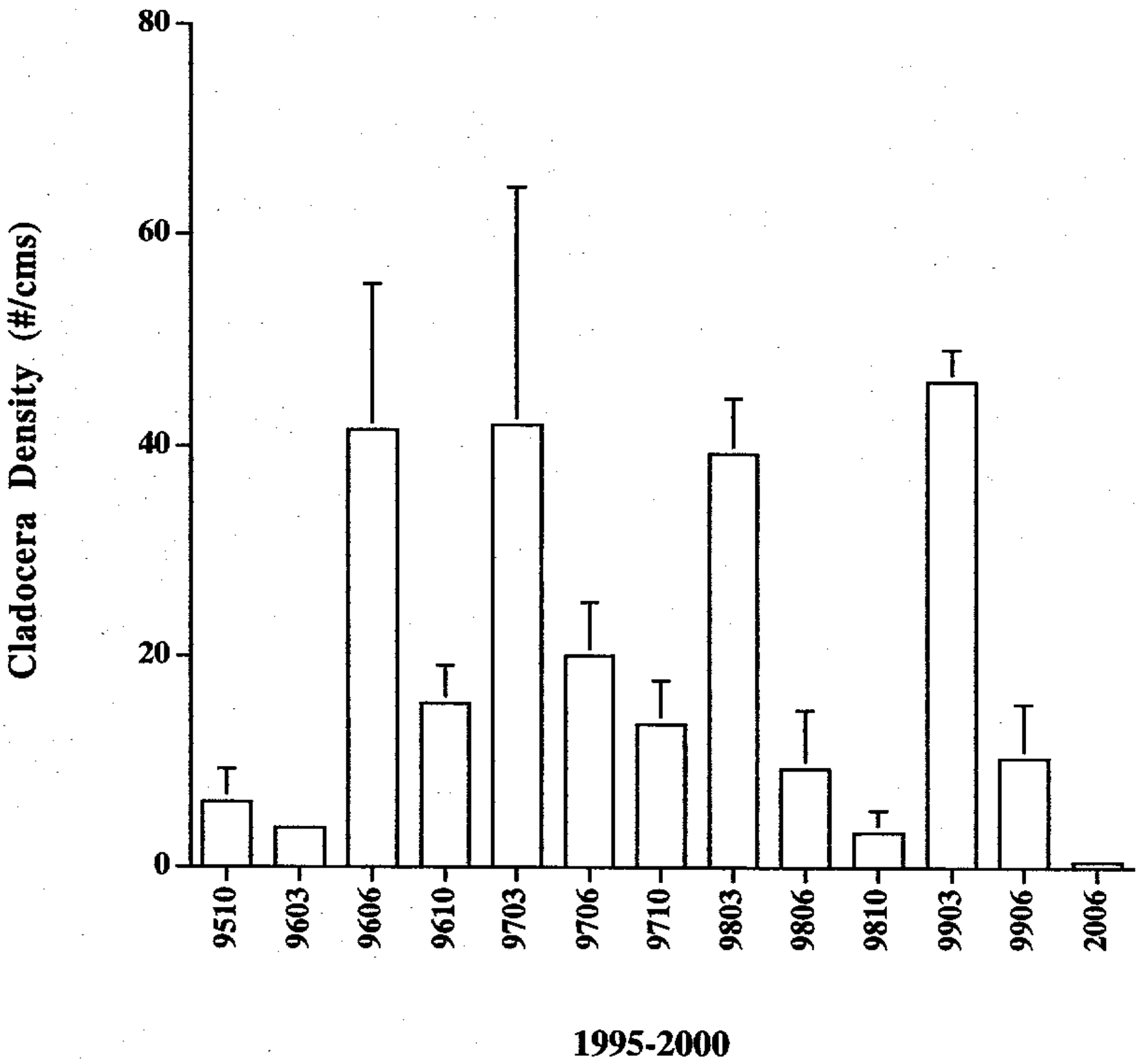

Figure 307. Average FPOM drift densities (#/cms) of Cladocera collected at Tanner Cobble Rkm 109.6 from October 1995 to June 2000.

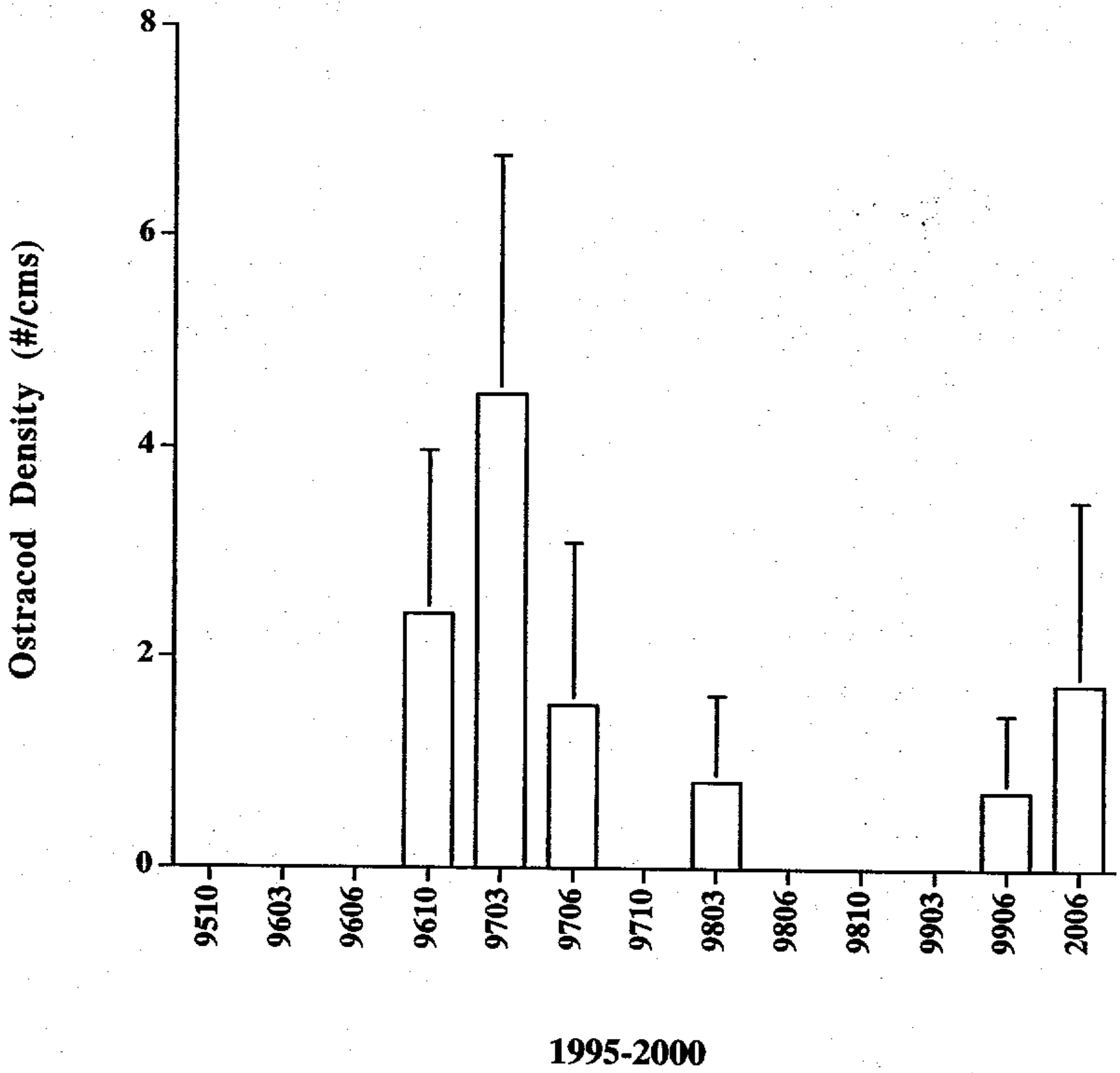

Figure 308. Average FPOM drift densities (#/cms) of Ostracods collected at Tanner Cobble Rkm 109.6 from October 1995 to June 2000.

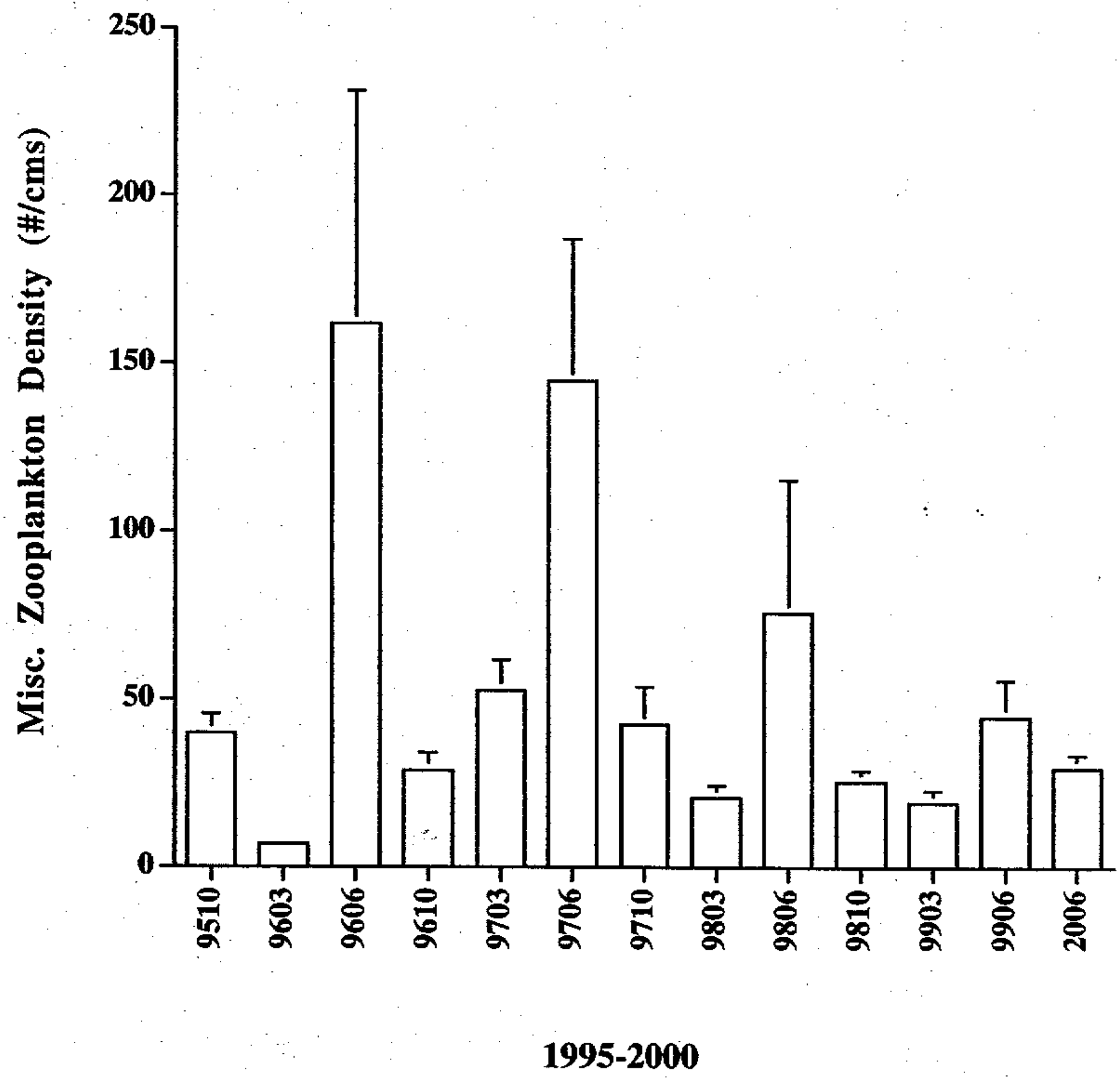

Figure 309. Average FPOM drift densities (#/cms) of miscellaneous zooplankton (benthic origin) collected at Tanner Cobble Rkm 109.6 from October 1995 to June 2000.

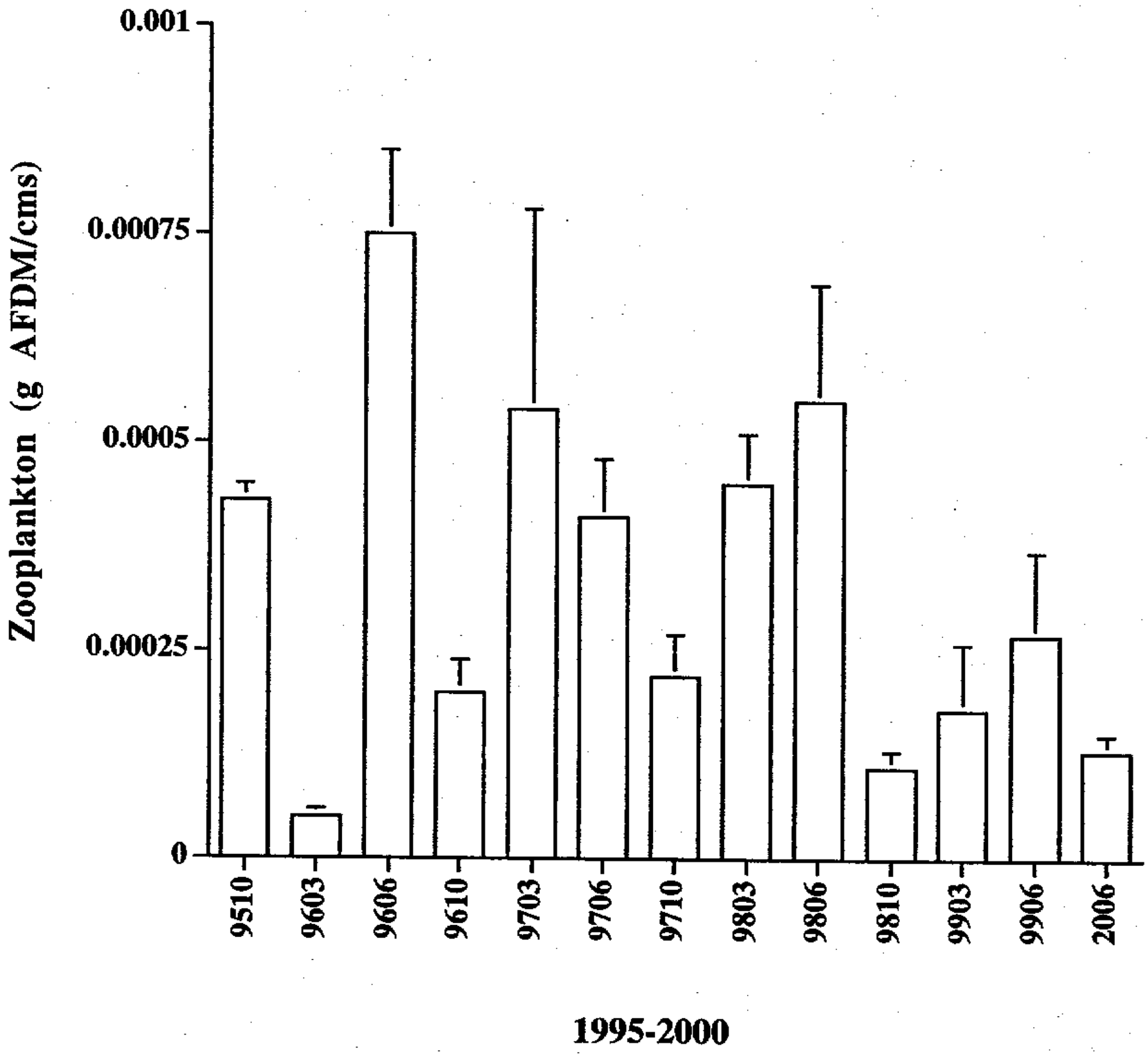

Figure 310. Average zooplankton biomass (g AFDM/cms) of lentic origin for Calanoida, Cyclopoida, Cladocera and Ostracoda collected at Tanner Cobble Rkm 109.6 from October 1995 to June 2000.

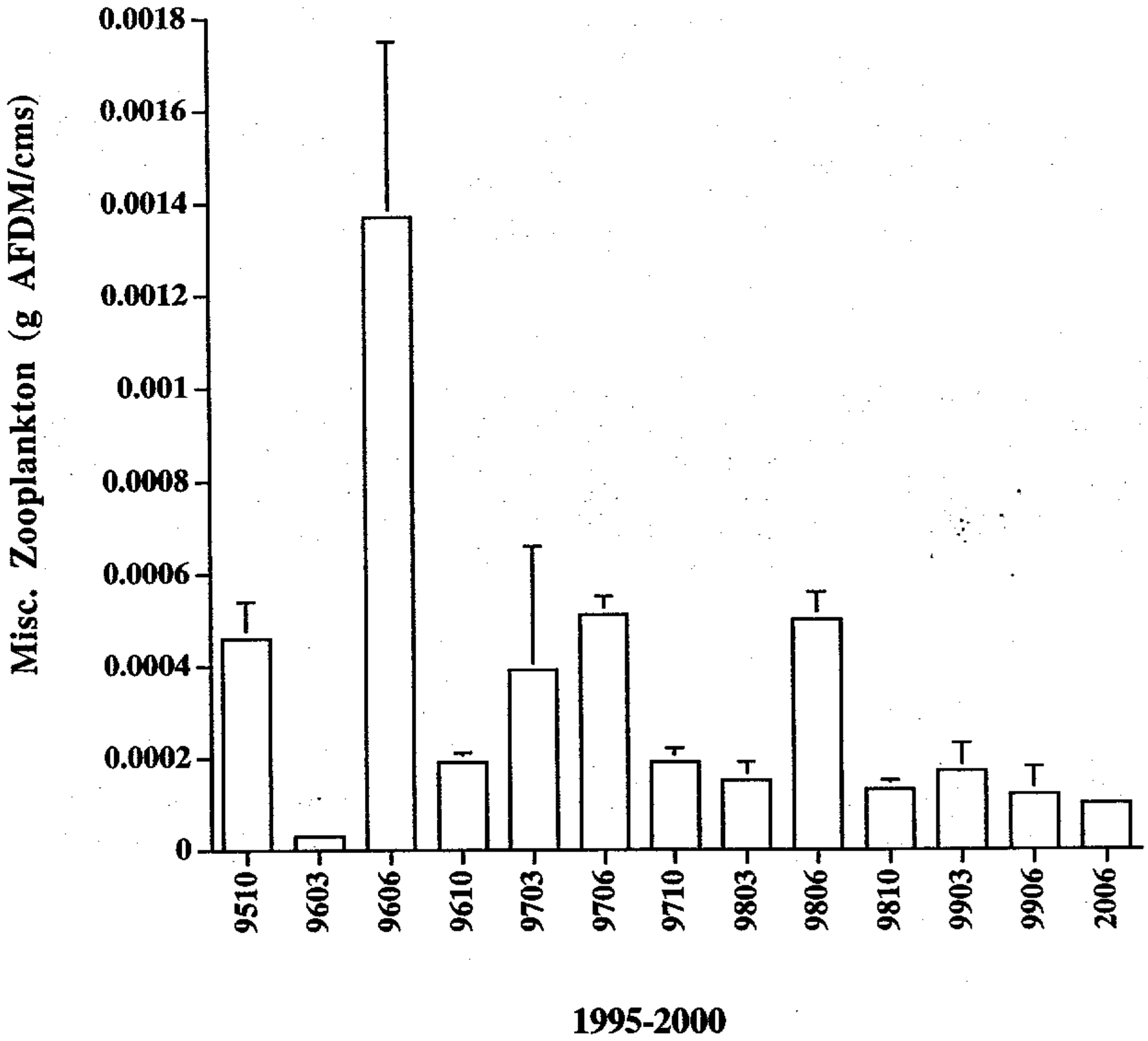

Figure 311. Average miscellaneous zooplankton biomass of benthic origin (g AFDM/cms) collected at Tanner Cobble Rkm 109.6 from October 1995 to June 2000.

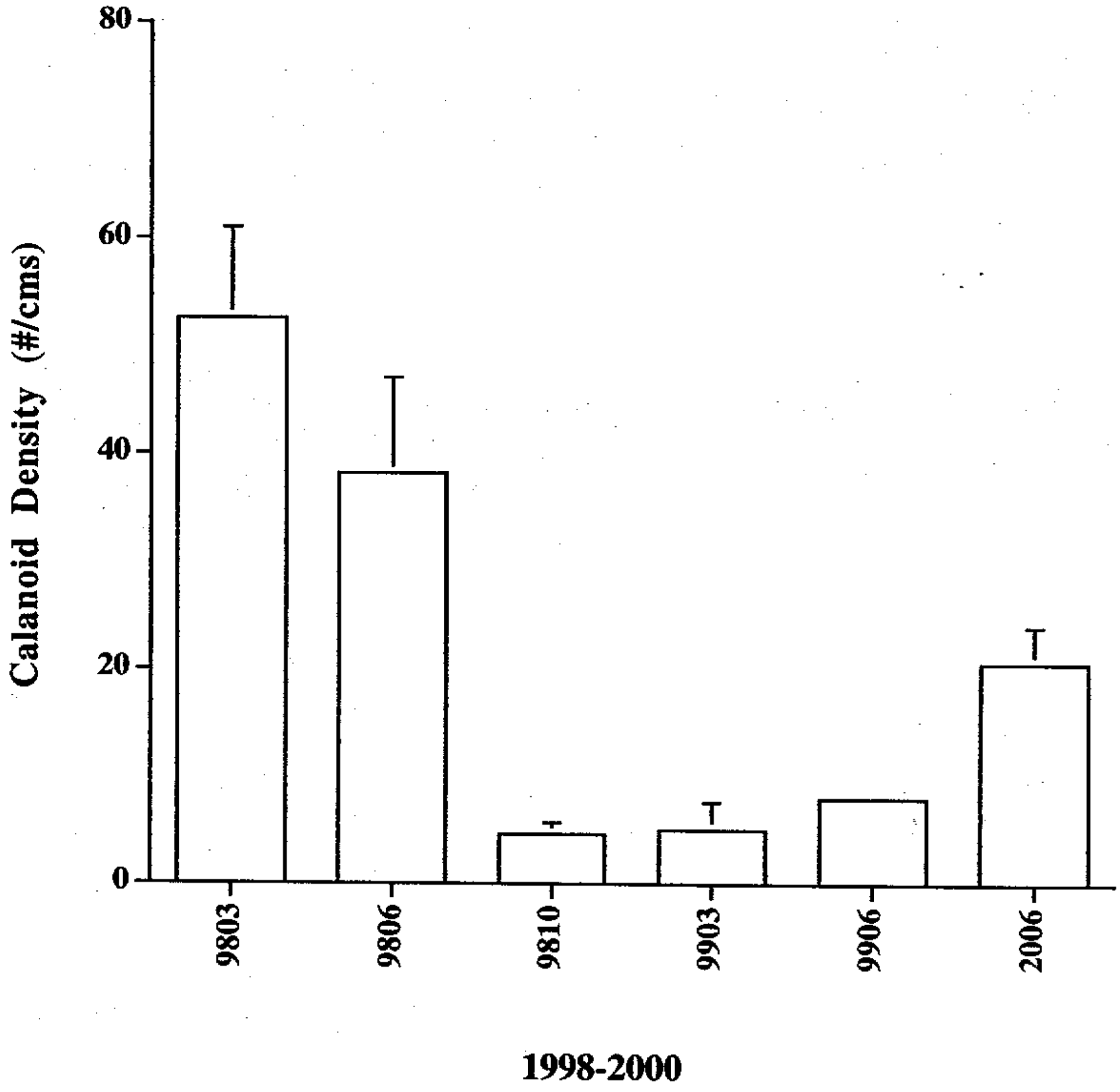

Figure 312. Average FPOM drift densities (#/cms) of Calanoids collected at 127 Mile Rapid Rkm 202.9 from March 1998 to June 2000.

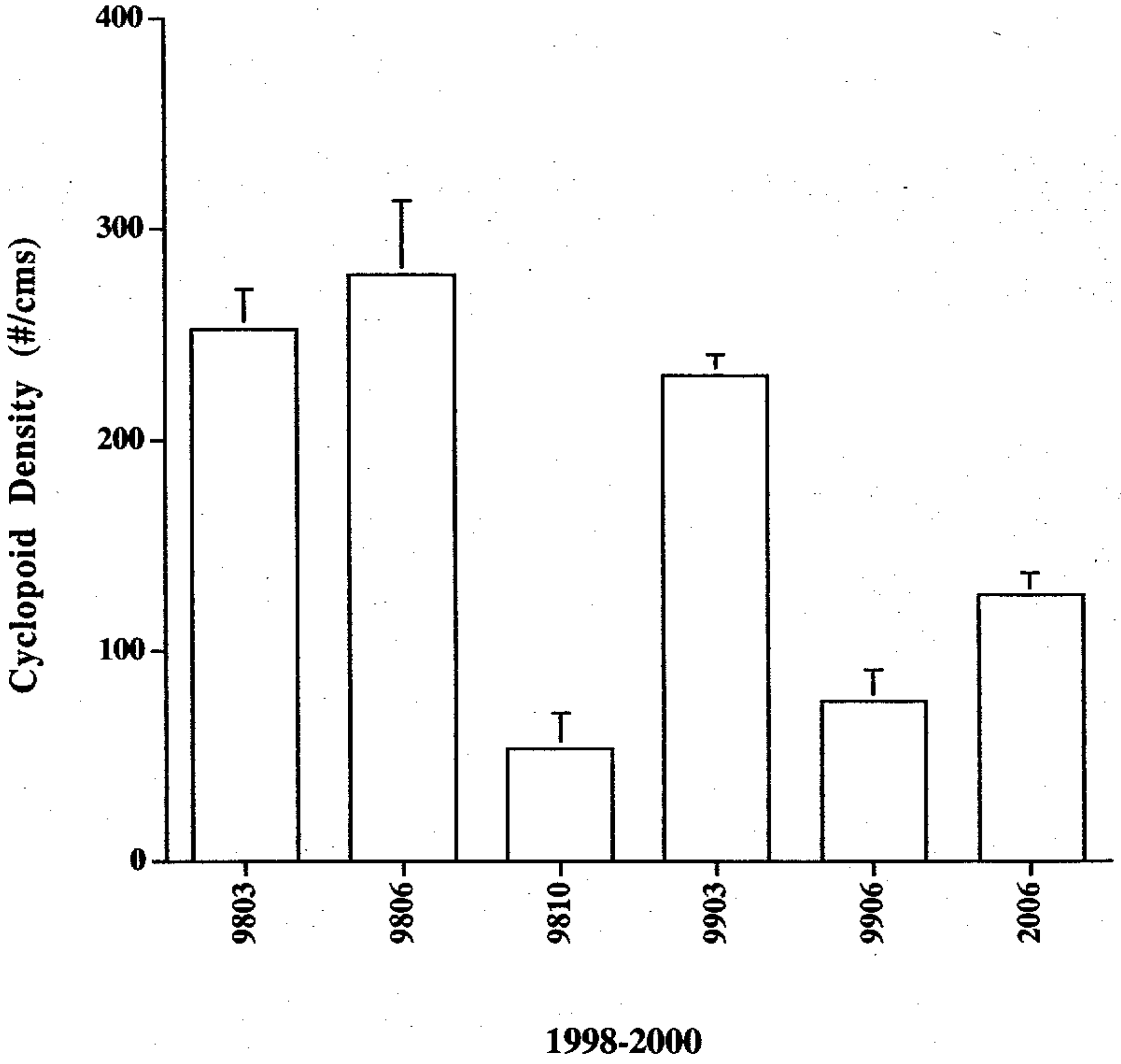

Figure 313. Average FPOM drift densities (#/cms) of Cyclopoids collected at 127 Mile Rapid Rkm 202.9 from March 1998 to June 2000.

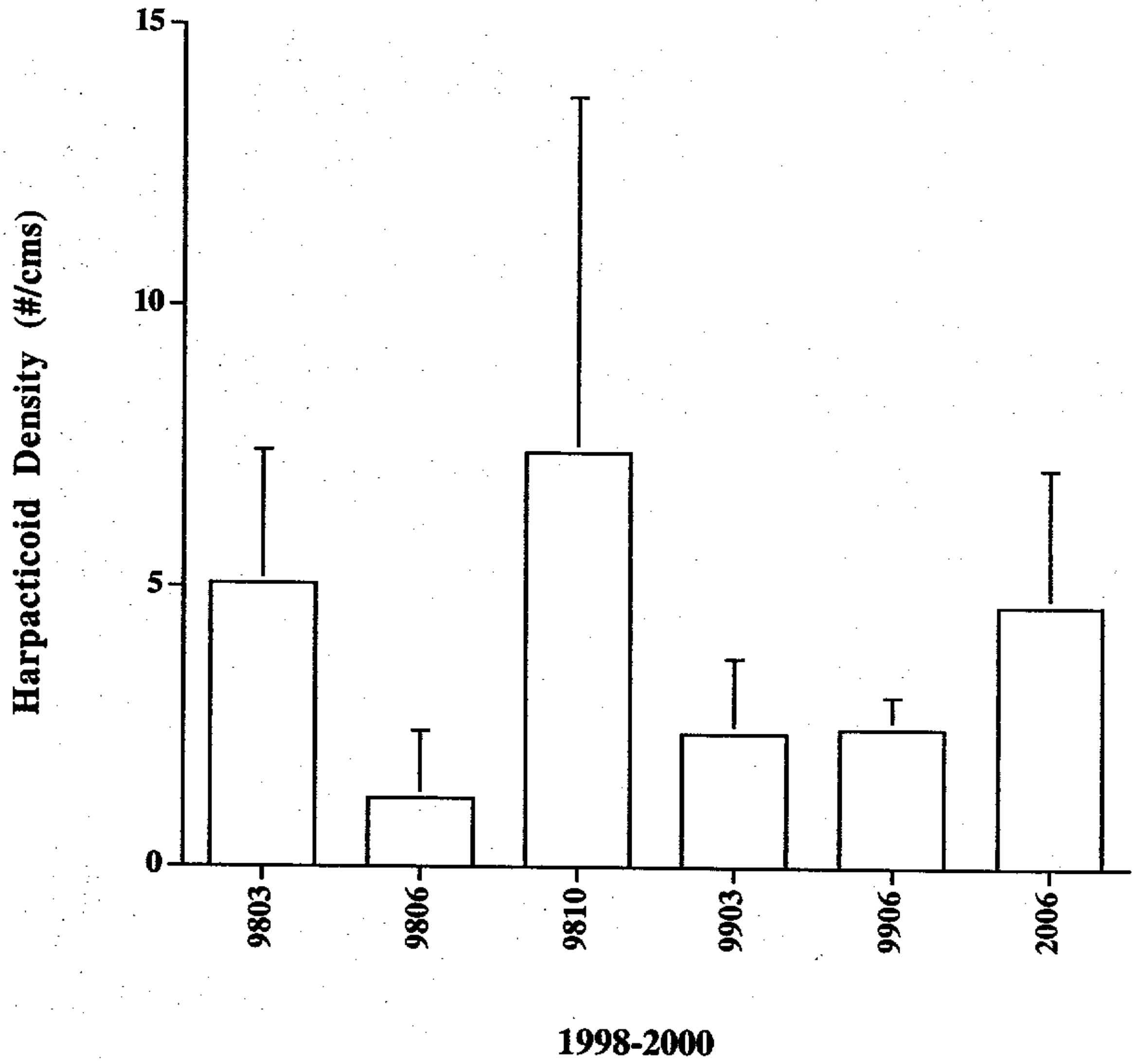

Figure 314. Average FPOM drift densities (#/cms) of Harpacticoids collected at 127 Mile Rapid Rkm 202.9 from March 1998 to June 2000.

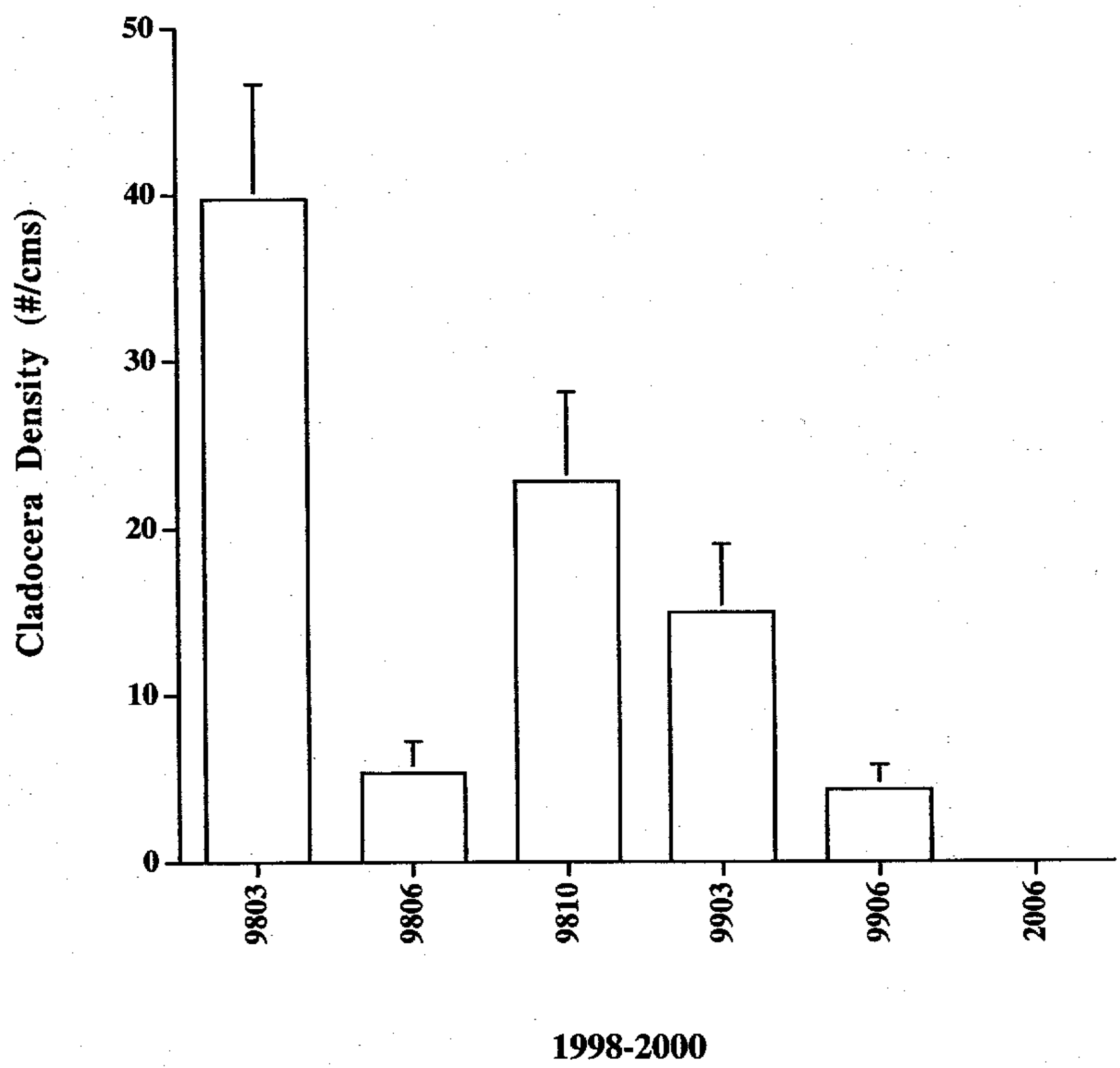

Figure 315. Average FPOM drift densities (#/cms) of Cladocera collected at 127 Mile Rapid Rkm 202.9 from March 1998 to June 2000.

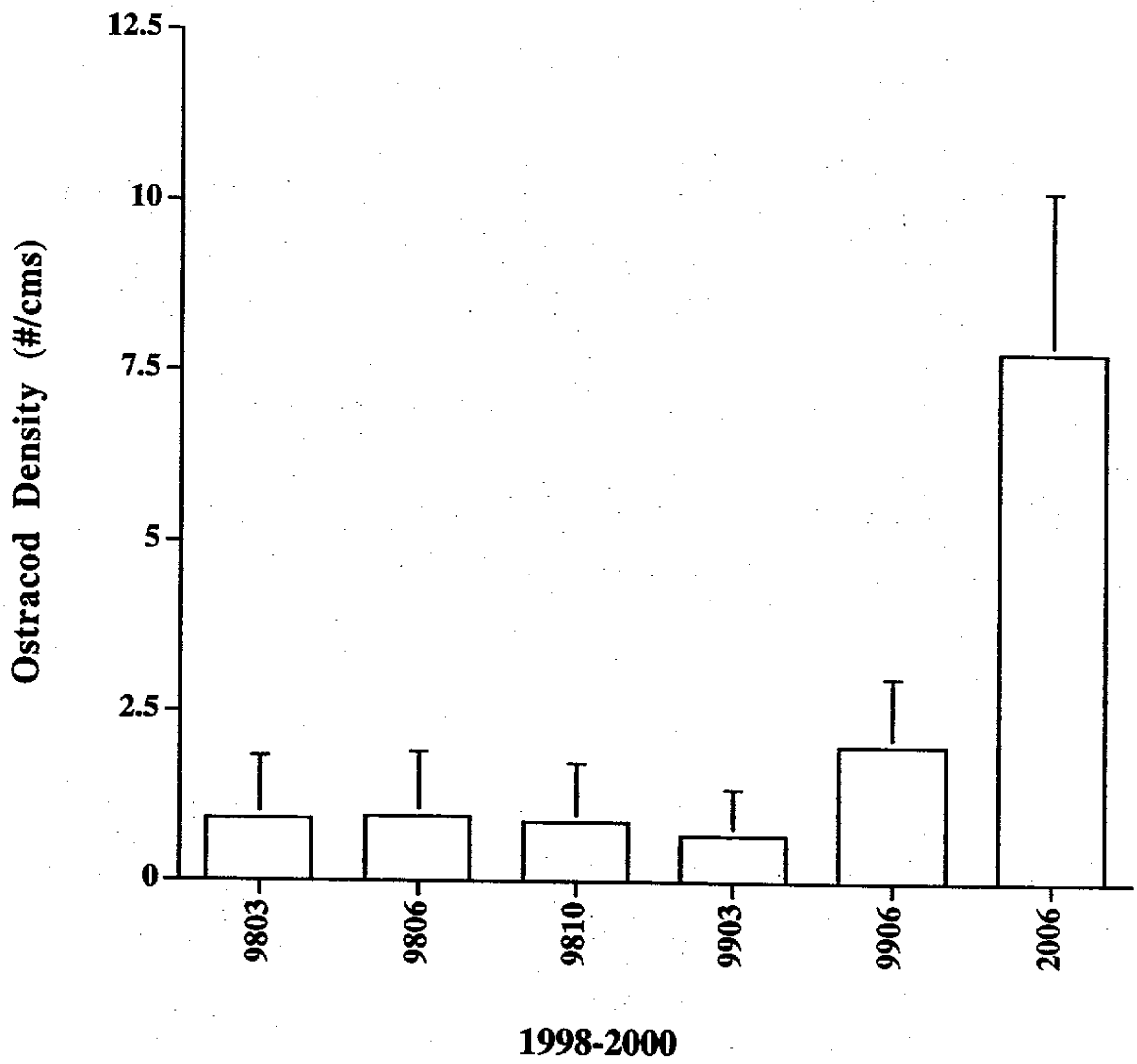

Figure 316. Average FPOM drift densities (#/cms) of Ostracods collected at 127 Mile Rapid Rkm 202.9 from March 1998 to June 2000.

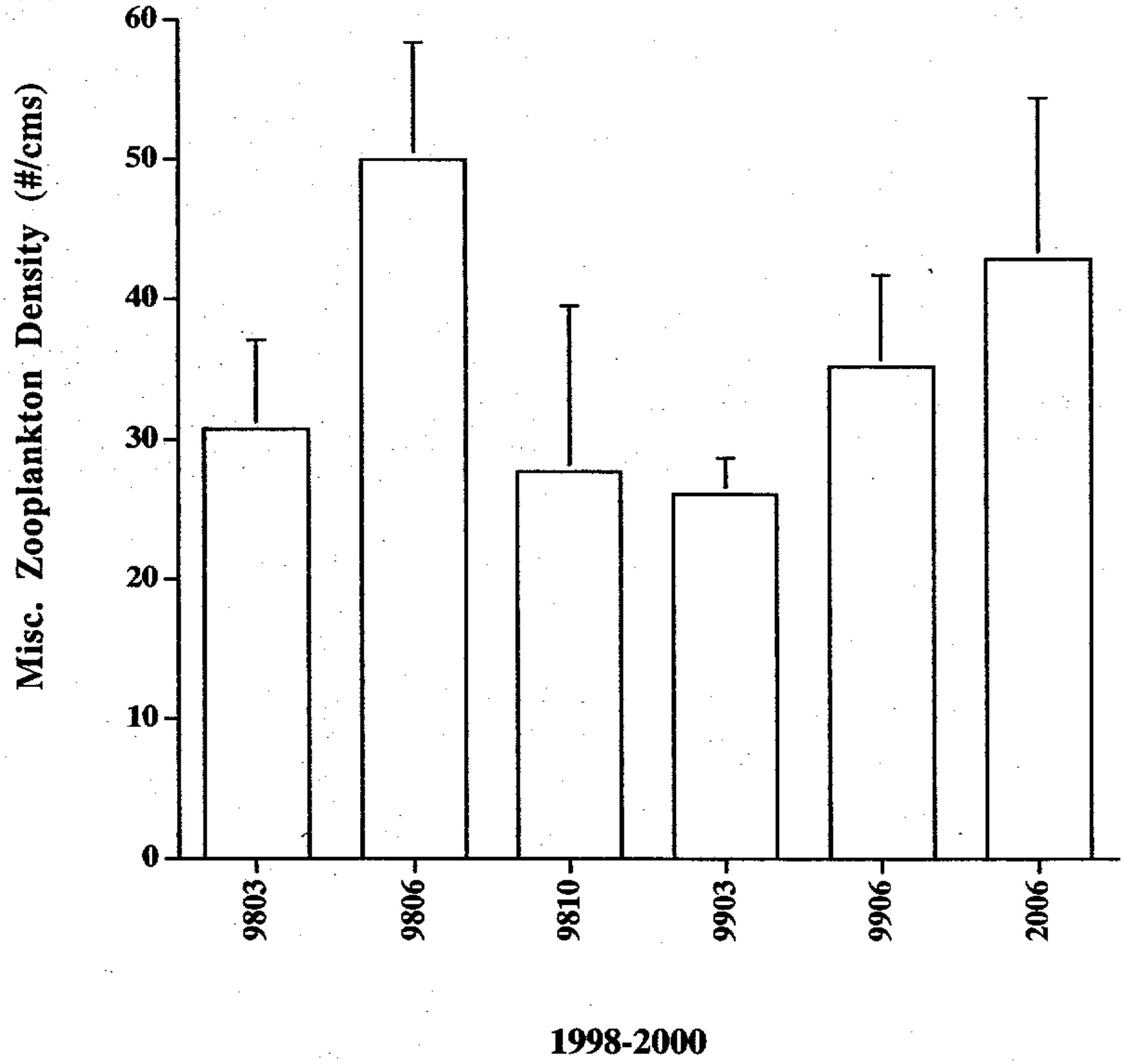

Figure 317. Average FPOM drift densities (#/cms) of miscellaneous zooplankton (benthic origin) collected at 127 Mile Rapid Rkm 202.9 from March 1998 to June 2000.

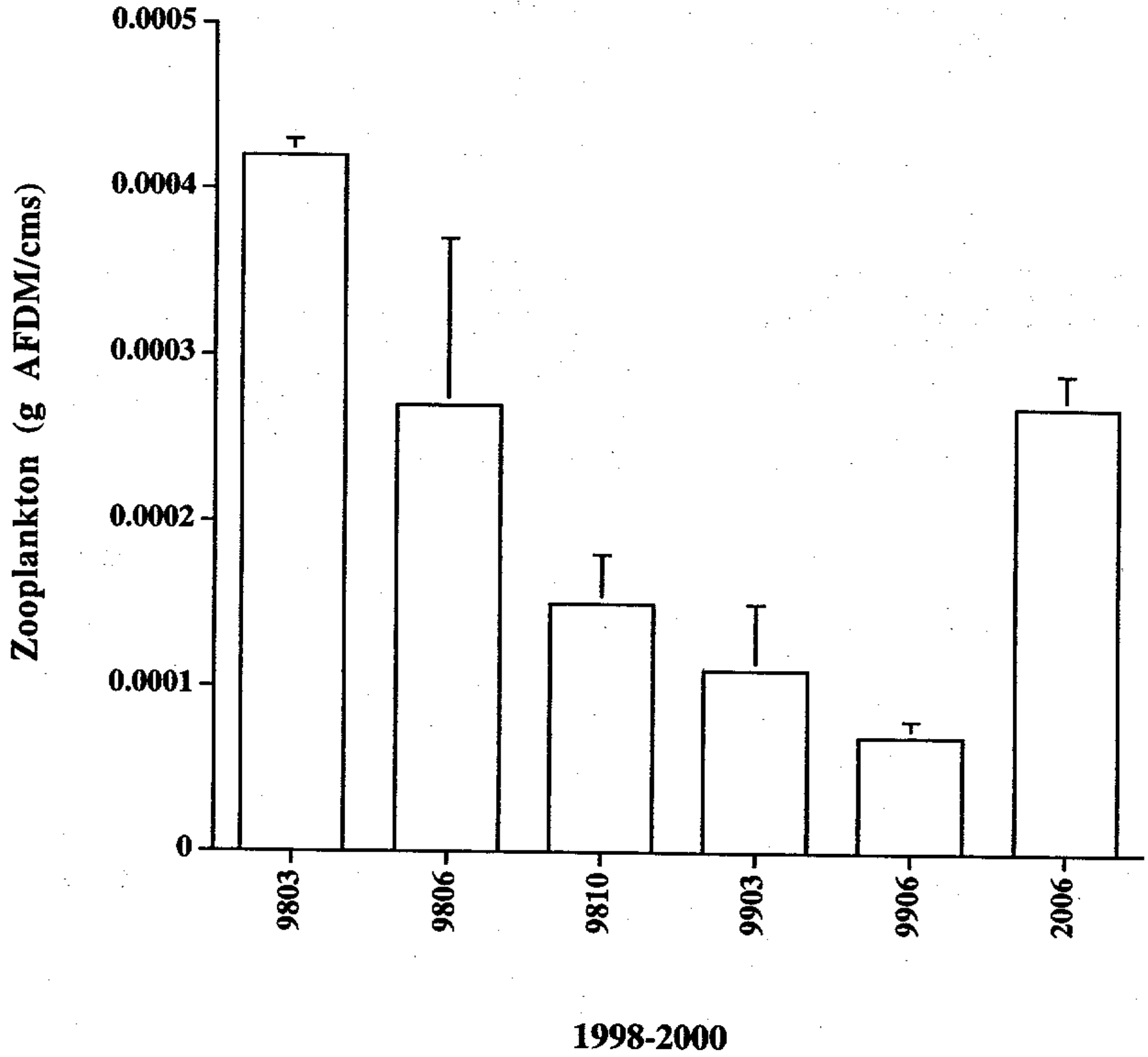

Figure 318. Average zooplankton biomass (g AFDM/cms) of lentic origin for Calanoida, Cyclopoida, Cladocera and Ostracoda collected at 127 Mile Rapid from March 1998 to June 2000.

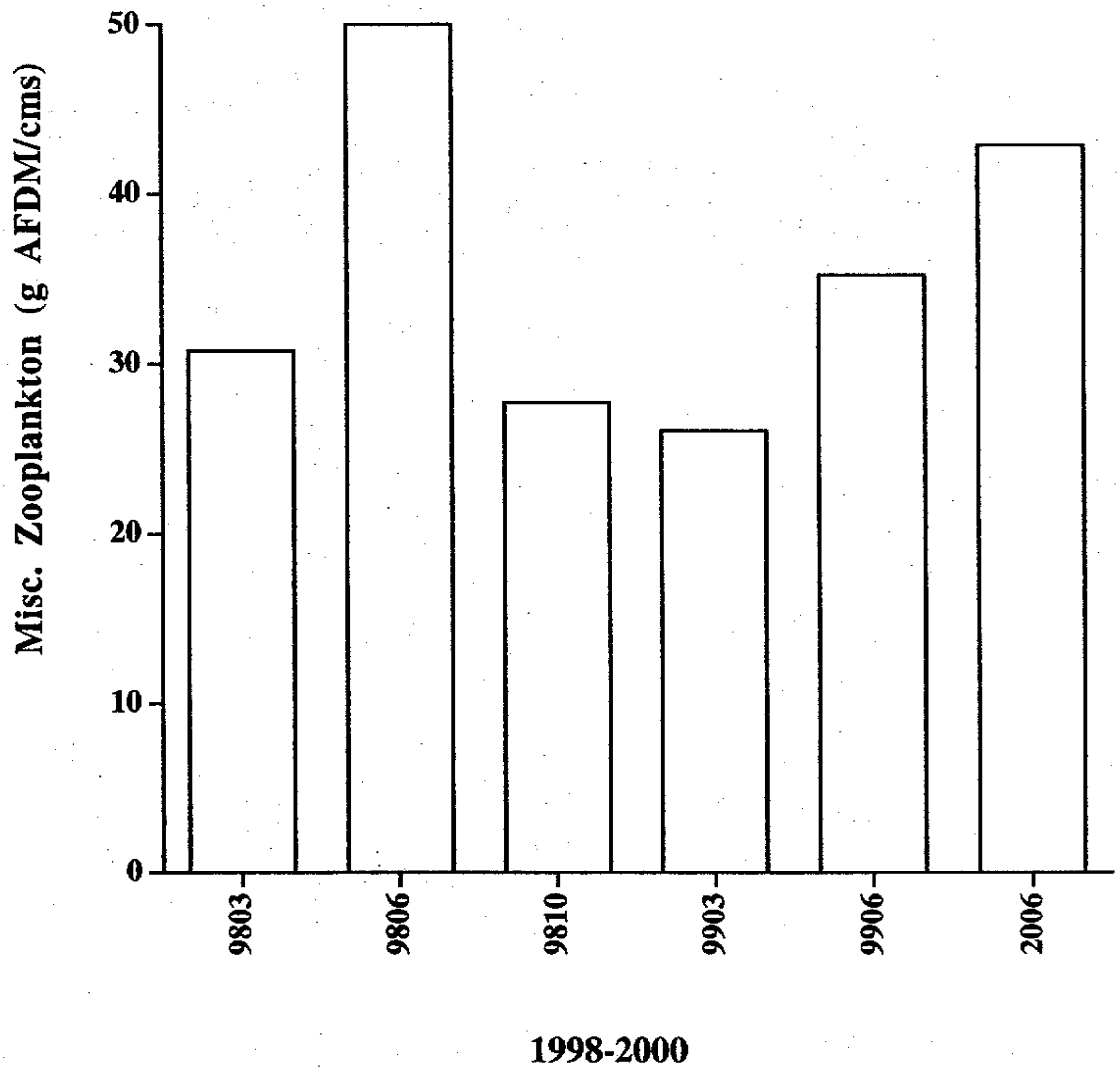

Figure 319. Average miscellaneous zooplankton biomass (g AFDM/cms) of benthic origin collected at 127 Mile Rapid from March 1998 to June 2000.

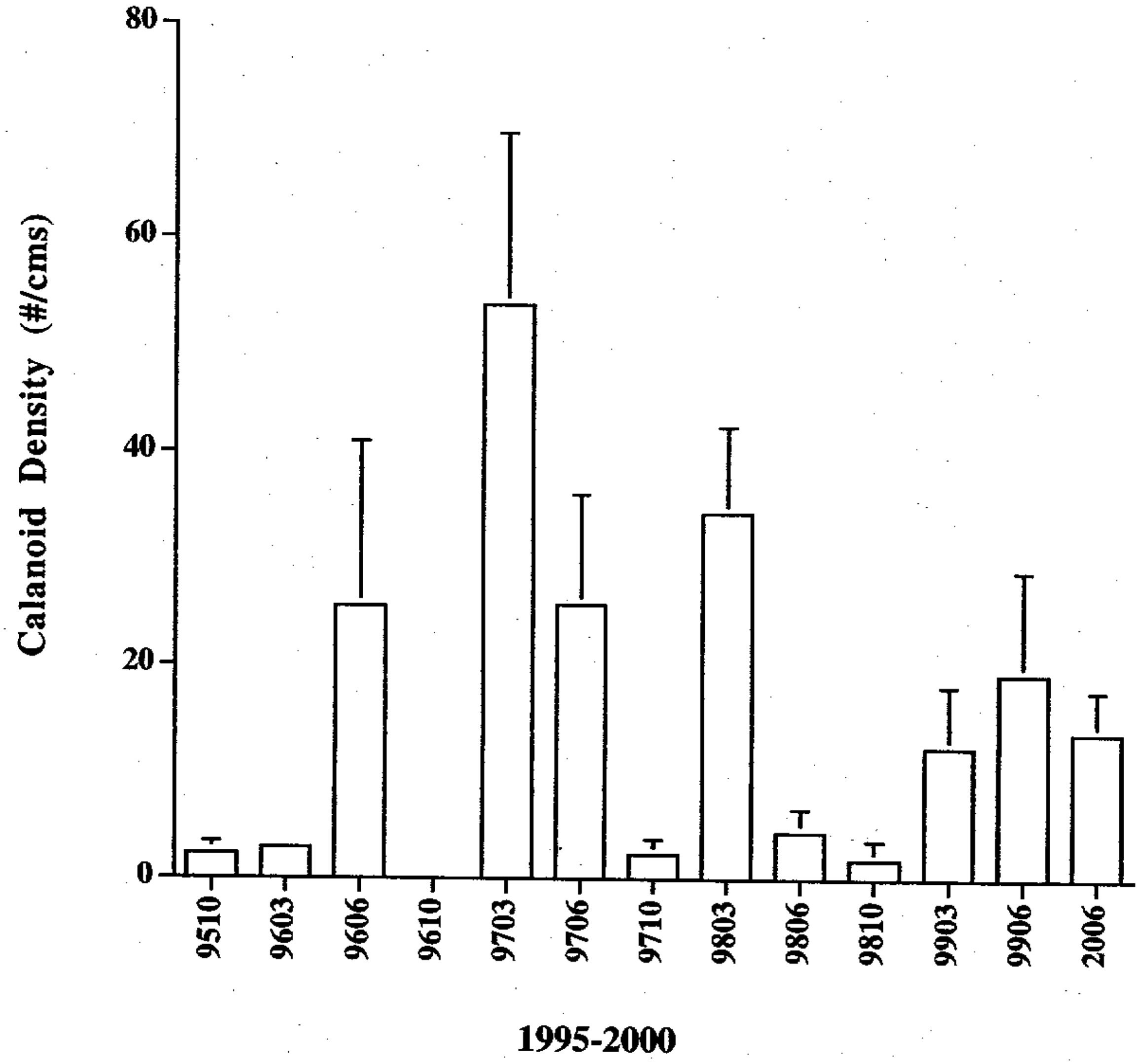

Figure 320. Average FPOM drift densities (#/cms) of Calanoids at 205 Mile Rapid Rkm 328.8 from October 1995 to June 2000.

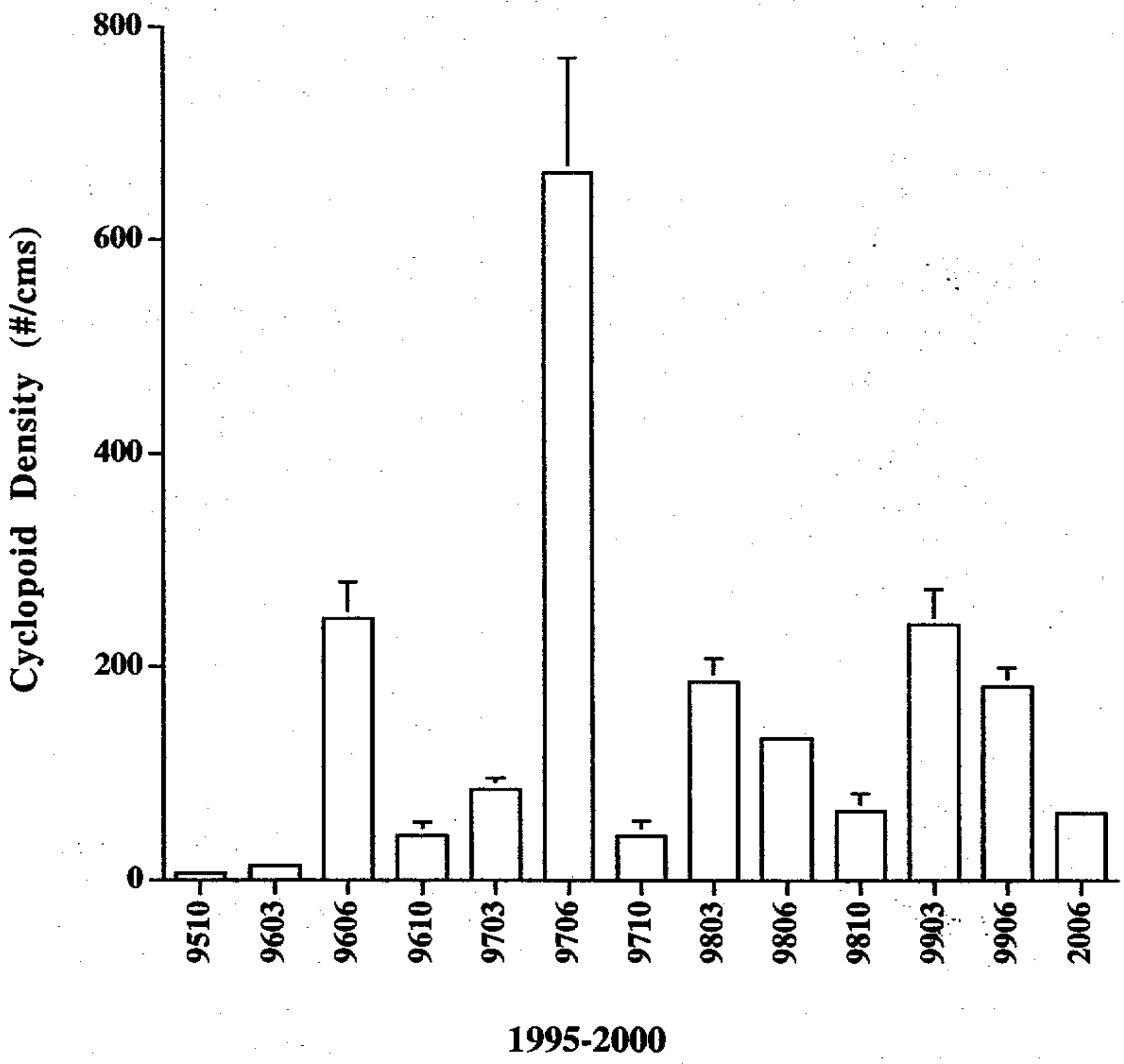

Figure 321. Average FPOM drift densities (#/cms) of Cyclopoids at 205 Mile Rapid Rkm 328.8 from October 1995 to June 2000.

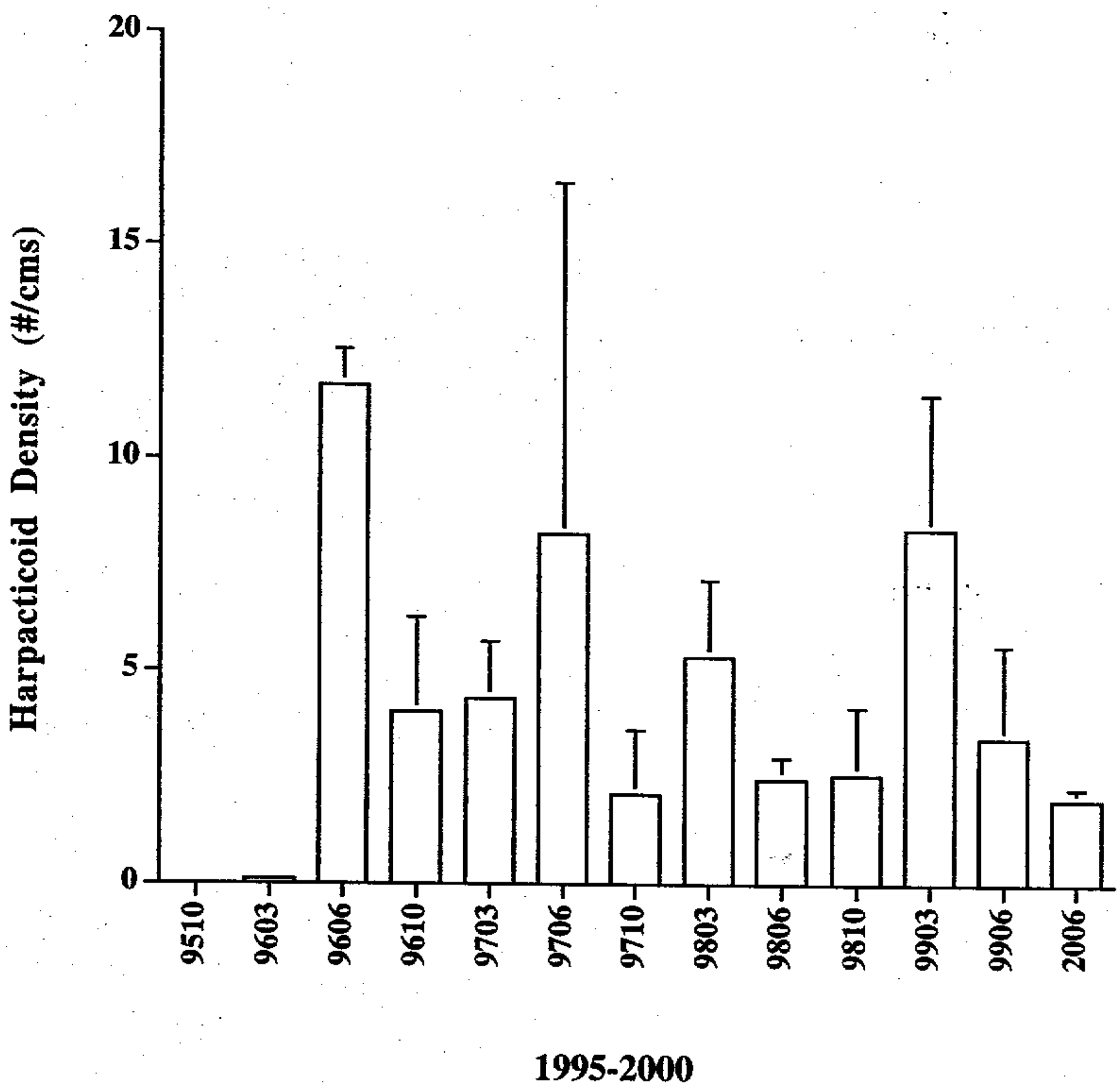

Figure 322. Average FPOM drift densities (#/cms) of Harpacticoids at 205 Mile Rapid Rkm 328.8 from October 1995 to June 2000.

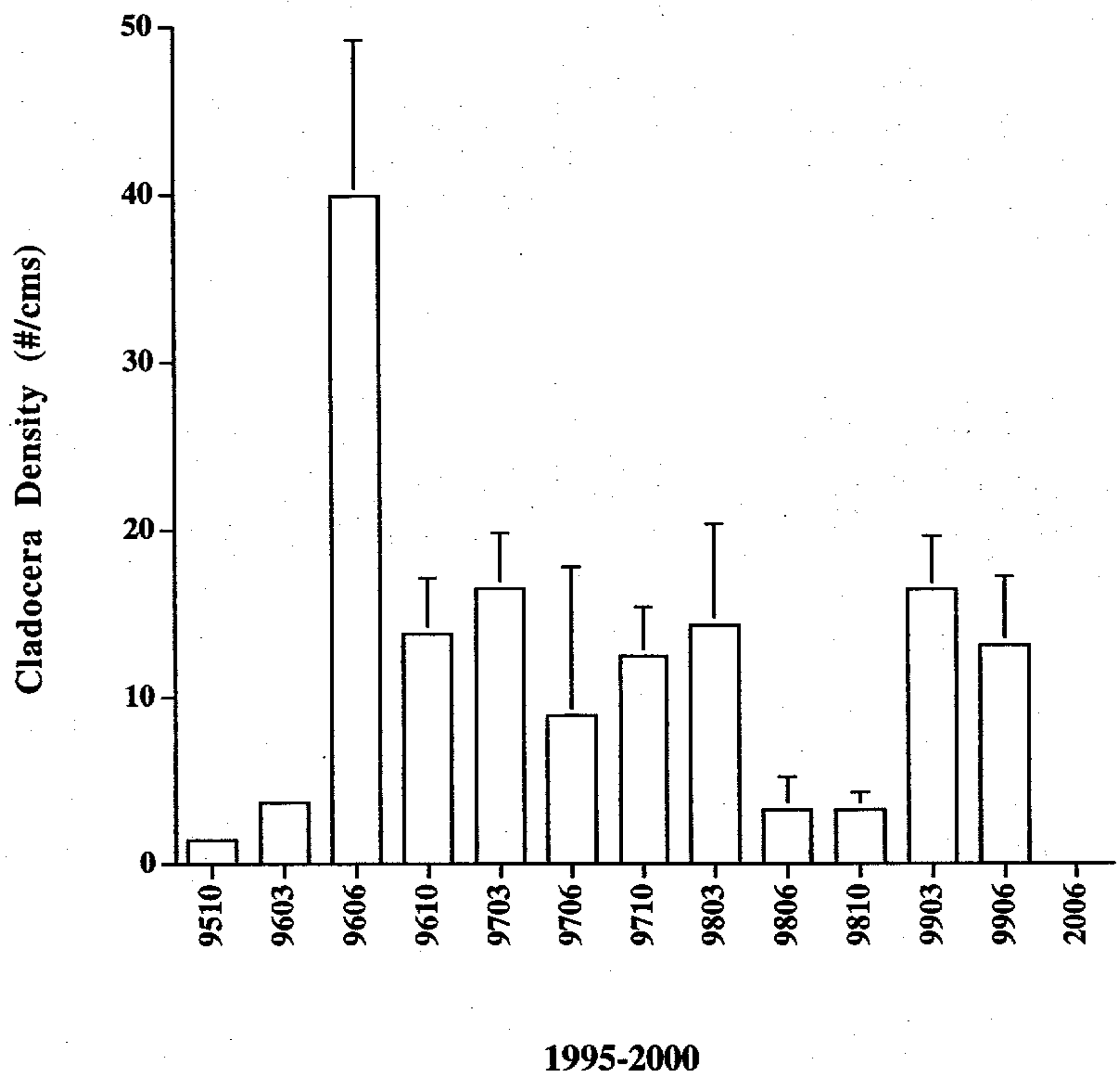

Figure 323. Average FPOM drift densities (#/cms) of Cladocera at 205 Mile Rapid Rkm 328.8 from October 1995 to June 2000.

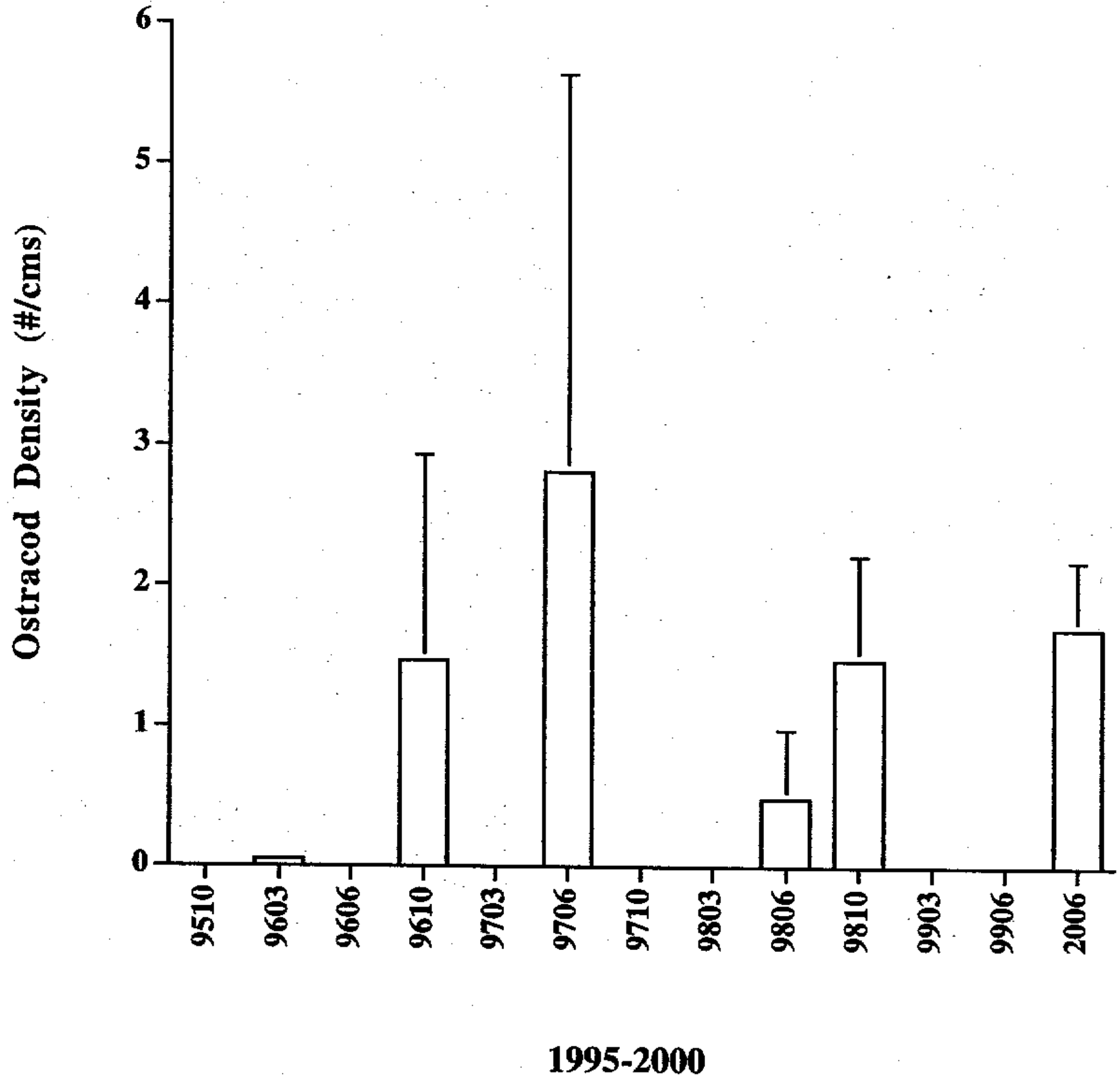

Figure 324. Average FPOM drift densities (#/cms) of Ostracods at 205 Mile Rapid Rkm 328.8 from October 1995 to June 2000.

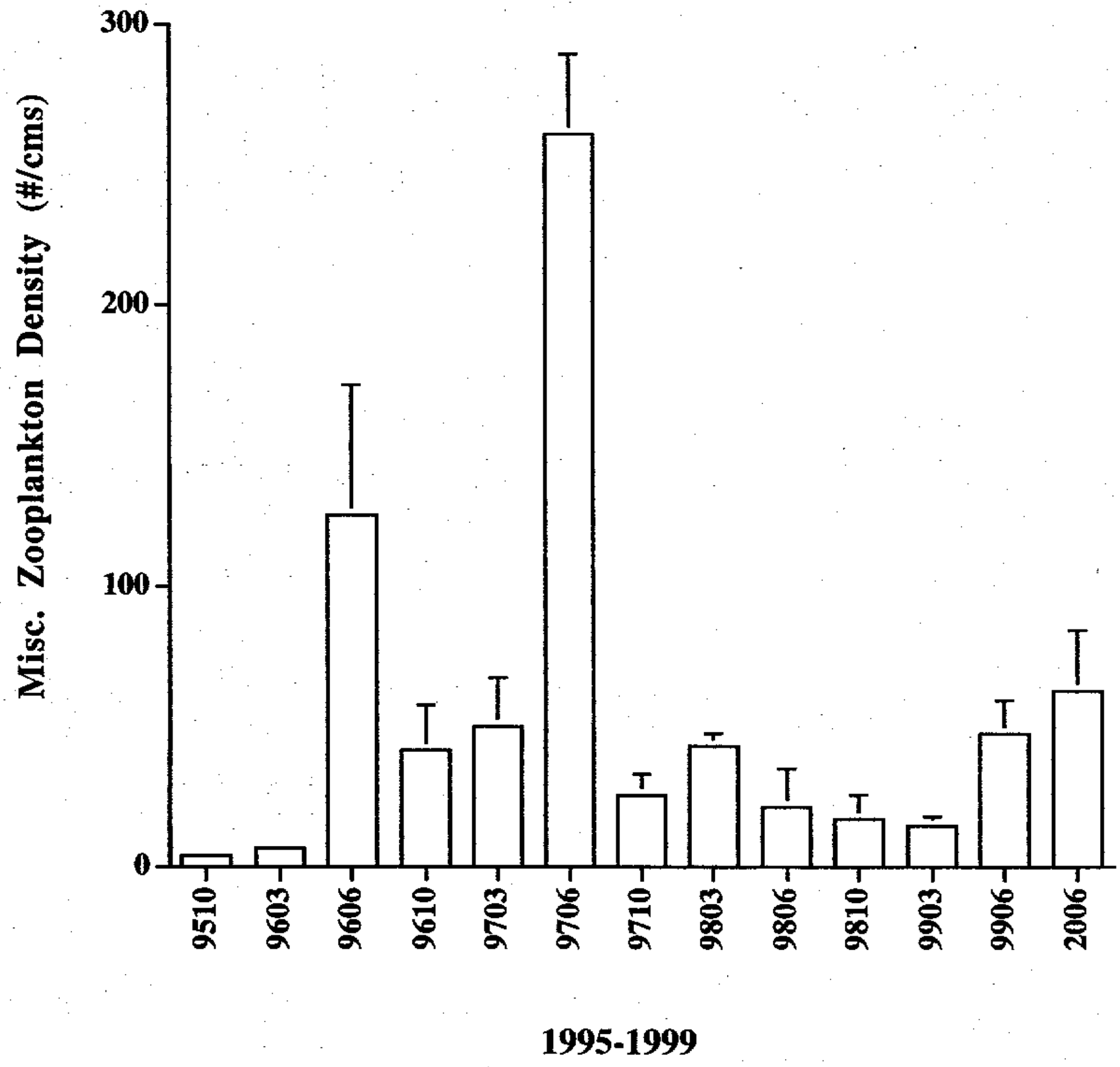

Figure 325. Average FPOM drift densities (#/cms) of miscellaneous zooplankton (benthic origin) at 205 Mile Rapid Rkm 328.8 from October 1995 to June 2000.

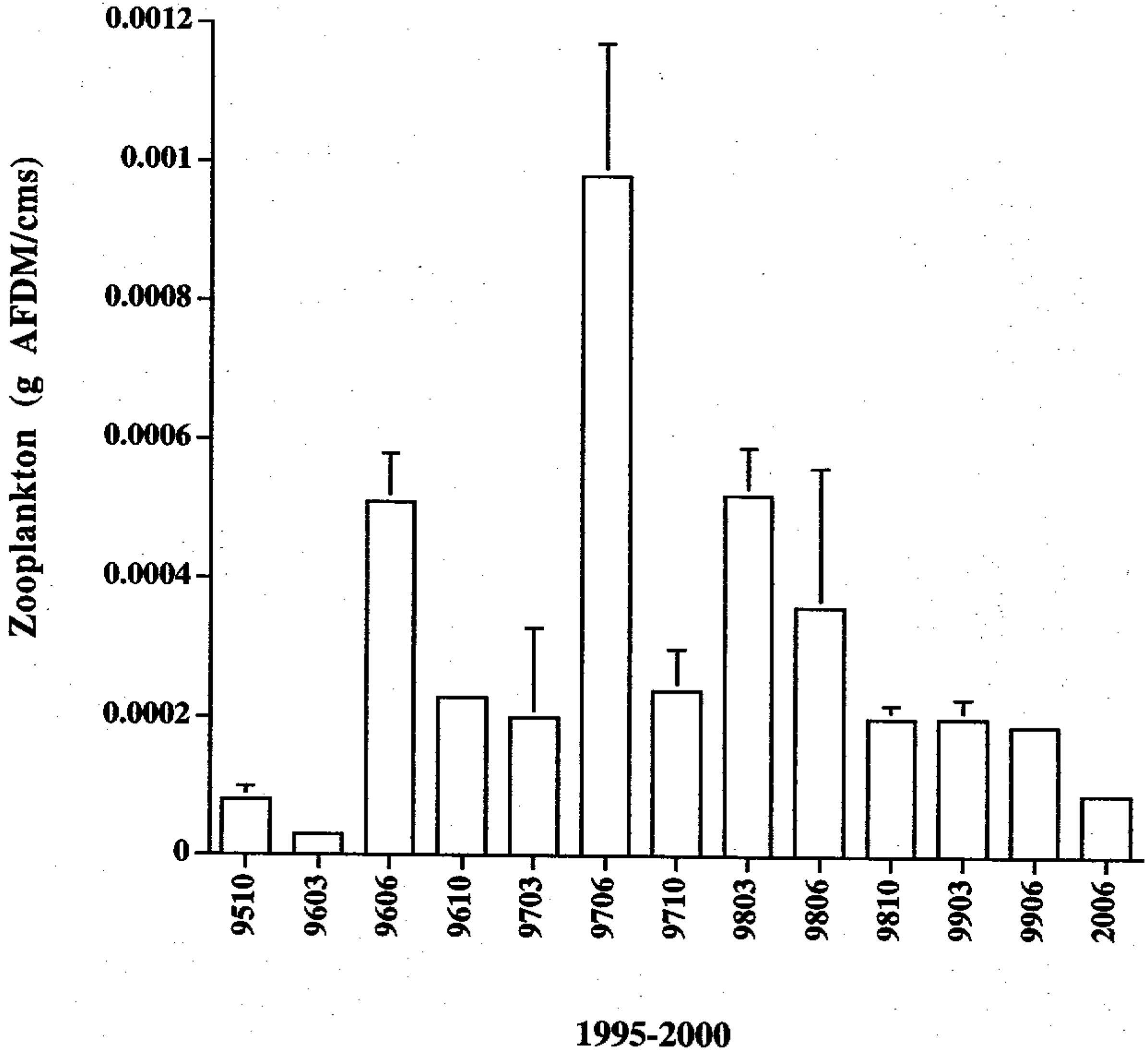

Figure 326. Average zooplankton biomass (g AFDM/cms) of lentic origin for Calanoida, Cyclopoida, Cladocera and Ostracoda collected at 205 Mile Rapid Rkm 328.8 from October 1995 to June 2000.

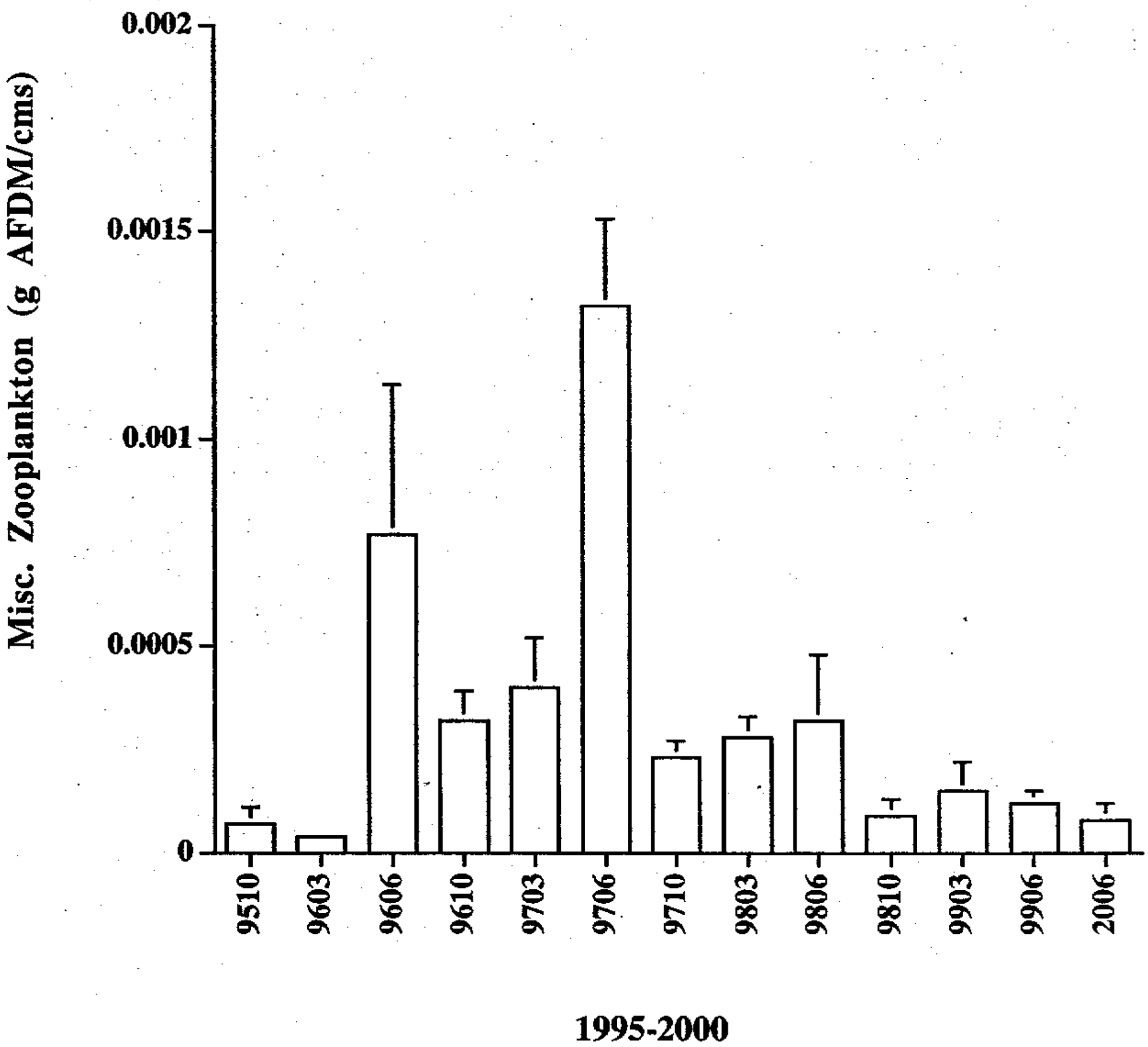

Figure 327. Average miscellaneous zooplankton biomass (g AFDM/cms) of benthic origin collected at 205 Mile Rapid Rkm 328.8 from October 1995 to June 2000.

Table 1A. Comparison of benthic biomass from 1991 reference data to monitoring data collected from October 1998, March 1999 and June 1999 at nine sites in the Colorado River through Grand Canyon. Results of MANOVA are depicted as follows for each biotic factor; (+) resource enhanced significantly, (=) resource maintained, nonsignificant change and (-) resource degraded significantly. Miscellaneous algae, macrophytes and bryophytes are depicted by MAMB. Pool habitats are indicated by P and cobble habitats by C. **<u>Oscillatoria</u> is the only biotic factor that does not enhance the aquatic food base with increasing biomass, therefore a + means reduced <u>Oscillatoria</u> biomass over 1991 reference data.**

Site/Date	<u>Cladophora</u>	<u>Oscillatoria</u>	Detritus	MAMB	Macroinvertebrates
October 1998					
Rkm 0.0 P	–	–	=	=	=
Rkm 0.8 C	=	=	=	=	=
Rkm 3.1 C	=	=	=	=	–
Rkm 95.7 P	–	=	=	=	–
Rkm 98.6 C	=	–	=	=	=
Rkm 108.8 P	=	=	=	=	=
Rkm 109.6 C	=	+	=	=	=
Rkm 326.4 P	=	+	+	=	=
Rkm 328.8 C	=	=	–	=	=
March 1999					
Rkm 0.0 P	=	=	=	=	=
Rkm 0.8 C	=	=	=	+	=
Rkm 3.1 C	+	=	=	+	=
Rkm 95.7 P	–	+	=	=	=
Rkm 98.6 C	+	–	=	=	+
Rkm 108.8 P	=	+	=	=	=
Rkm 109.6 C	=	–	=	=	=
Rkm 326.4 P	=	+	+	=	=
Rkm 328.8 C	=	–	=	=	=

Table 1A continued

Site/Date	Cladophora	Oscillatoria	Detritus	MAMB	Macroinvertebrates
June 1999					
Rkm 0.0 P	–	+	=	=	=
Rkm 0.8 C	+	=	+	–	=
Rkm 3.1 C	+	=	+	+	+
Rkm 95.7 P	–	+	+	=	=
Rkm 98.6 C	=	=	+	=	=
Rkm 108.8 P	+	+	+	+	=
Rkm 109.6 C	=	–	=	+	=
Rkm 326.4 P	=	+	+	=	=
Rkm 328.8 C	+	=	=	=	=

– end of report –