2003 Annual Report:
Aquatic Food Base Response To The 2003 Ecological Restoration Flows

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NAU Aquatic Food Base Project

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Abstract

Flows from Glen Canyon Dam were modified beginning on 1 January 2003 in an attempt to disadvantage alien fish, particularly trout, during their winter spawning period. These 2003 Ecological Restoration Flows (2003 Eco Flows) consisted of daily fluctuations of between 142-566 m^3/s. We monitored the aquatic community structure in Glen Canyon monthly from December 2002 to June 2003 and seasonally through Grand Canyon National Park to October 2003.

Water quality varied during the sampling period in response to a regional drought that reduced the level of Lake Powell Reservoir by approximently 30m resulting in increased variability in the river chemistry. The 2003 Eco-flows did have an influence on the phyto-benthic biomass estimates in Glen Canyon. Cladophora remains inconsistent (since 1995) as the previous dominate primary producer within the study site. Biomass estimates varied significantly both within and between cobble bars in Glen Canyon. Coarse organic drift has decreased while zooplankton drift has increased in compared to past data. New Zealand Mudsnail (Potamopyrgus antipodarum, Gastropoda: Hydrobiidae, NZMS) biomass and densities were not negatively impacted by the 2003 Eco-flows to any substantial degree. Chironomid (midge) larvae were not found at Lees Ferry cobble in October 2003 (Fig. 5); this was the first time that $0/m^2$ chironomid larvae were estimated at this site since our collections began in 1990. Planaria were absent from our 1990 data since 1993 we have documented a steady increase peaking at $9000/m^2$ in 2000, while estimates decreased in 2001 and 2002. However in 2003 estimates increased by two orders of magnitude within one year to over $60{,}000/m^2$.

We recommend continuation of the NAU Aquatic Food Base Monitoring Program to better understand 2004 Eco-Flows. Also, because of continued drought and lowering of Lake Powell with subsequent release of epilimnetic

water, this project will aid in designing monitor protocols in anticipation of the proposed thermal modification of Glen Canyon Dam.

Acknowledgments

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This project could not have been completed without the valuable efforts of our students and volunteers: Emma Benenati, Kasey Gilliland, Ken Colemen, Adam Lockyer, Cecile Walters, Laura Galati, Jessica Charpentier, Nicholas Glidners, Will Fletcher, Doug McCarty, Brian McGinness, Marty Schlien, Suzy Elison, Jennifer Williams,Tonia Haff, John Weisheit, David Haskell, Suzette Weisheit, April Reese, Gerry Barrett, Michelle Harrington, and Tatiane lawson

Table of Contents

Introduction

Flows from Glen Canyon Dam (GCD) were modified beginning 1 January 2003 in an attempt to disadvantage alien fish, particularly trout, during their winter spawning period. These 2003 Ecological Restoration Flows (2003 Eco Flows) consisted of daily fluctuations of between 142-566 m^3/s with the up-ramp starting at 9 am (Figure 1). This flow regime is a departure from the 1996 Glen Canyon Dam Environmental Impact flows (BOR 1996) and were coupled with alien fish killing efforts in the humpback chub (Gila cypha) critical habitat near the confluence of the Little Colorado River (rkm 99.1 L). Humpback chub are listed as an endangered species by the US Fish and Wildlife Service, with total abundance and health declining since the construction of Glen Canyon Dam. The overall objectives of the 2003 Eco Flows were designed to improve the habitat of the chub through both reducing both direct predation by alien fish taxa and indirect competition for food and rearing habitat.

Justification for long term aquatic food base monitoring:

Grand Canyon National Park Colorado River Management Plan (NPS 1989) states that the Park 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 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.

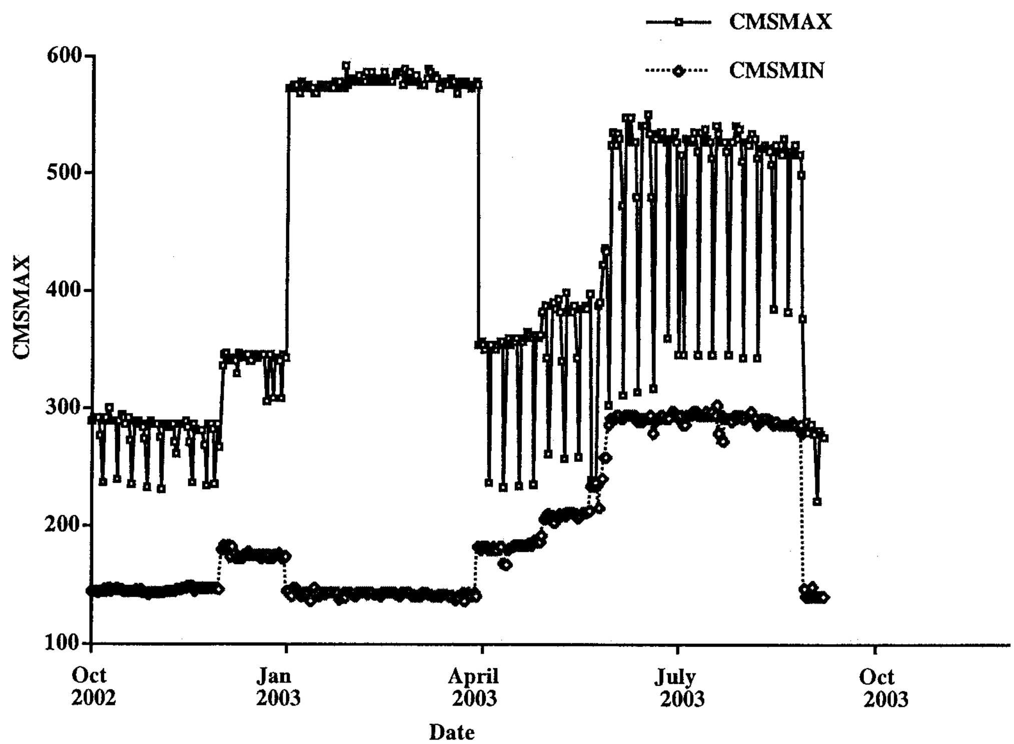

Figure 1. Lees Ferry gauge hydrograph (m^3/s) for FY 2003 showing the 2003 Eco-flows from January through March 2003 that were released from Glen Canyon Dam. Boxes indicate the daily maximum discharge while diamonds indicate daily minimum discharge.

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.

This project also provides data supporting the following Grand Canyon Adaptive Management Program Goals, and Management Objectives (MO)

Goal 1. Protect or improve the aquatic food base so that it will support viable populations of desired species at higher trophic levels.

MO 1.1 Maintain or attain primary producer biomass and composition in the Glen Canyon reach.

MO 1.2 Maintain or attain primary benthic invertebrate biomass and composition in the Glen Canyon reach.

MO 1.3 Maintain or attain primary producer biomass and composition in the Colorado Ecosystem below the Paria River.

MO 1.4 Maintain or attain primary benthic invertebrate biomass and composition in the Colorado Ecosystem below the Paria River.

MO 1.5 Maintain or attain drift biomass and composition in the main stem and tributaries.

The objective of this study was to determine if there was any detectable change in benthic biomass estimates or composition of the phyto-benthic community from the 2003 Eco Flows in the Colorado River below Glen Canyon Dam. Also as part of the Northern Arizona University annual long-term monitoring program 2002 and 2003 June phyto-benthic estimates will be compared for trends.

Methods

The NAU Aquatic Food Base Project collected phyto-benthic material from three cobble bar sites in Glen Canyon monthly from December 2002 through March 2003. We followed the Grand Canyon Monitoring and Research Center (GCMRC) modified collection protocol that NAU established in 1991, which was reviewed in 1997 and reduced in scope because of budget constraints. In 2002, through a Request For Proposal (RFP) process GCMRC further reduced the scope of collecting to a single habitat (cobble bars) from four and increased the number of samples taken from six to 18 in an effort to reduce sampling variability (Table 1). This protocol initiated by the GCMRC biology staff was not supported by the peer-review process,however the GCMRC still directed the NAU Food Base Project to collect as they originally proposed in the RFP. The statistical program MONITOR, which the GCMRC staff directed us to use to analyze data was removed from the USGS web site because of problems with statistical assumptions.

Benthos

Modified Hess substrate samplers were used to collect on cobble/bar riffles (Table 1). Cobble-riffle collections were taken at or below the 142 m^3/s stage which is the minimum flow allowed from GCD. The stage and location of collection was determined using an abney level, a control point, and the distance from the previous days high water in conjunction with USGS STARS Model.

Samples were preserved in 70% ETOH and sorted in the laboratory into six biotic categories: Cladophora glomerata, Oscillatoria spp., detritus, miscellaneous algae and macrophytes (MAMB), New Zealand Mudsnails, and other macroinvertebrates. Animals were numerated into Gammarus lacustris, chironomid larvae, simuliid larvae, snails, and miscellaneous invertebrates categories. Miscellaneous invertebrates included lumbriculids, tubificids, 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.

Table 1. Collection sites: River Kilometer (rkm), Elevation (m), Orientation, and Reach Type in the Colorado River Below Glen Canyon Dam for cobble-riffle habitats in Glen, Marble, and Grand Canyons, Arizona.

Name	RKM	Elevation	Orientation	Reach Type
GLEN CANYON				
1. -9 Mile Bar	-13.8R	950	Southwest	Narrow
2. -3 Mile Bar	-6.8L	949	Southwest	Narrow
3. Lees Ferry Cobble	0.8R	947	Southwest	Wide
MARBLE CANYON				
4. Two-mile Cobble	3.1R	944	South	Wide
5. Vasey's Paradise	50.8C	876	East	Narrow
6. Nankoweap	80.3C	828	South	Wide
GRAND CANYON				
7. Tanner Cobble	109.6L	808	Southwest	Wide
8. 127 Mile Rapid	202.9R	616	Northeast	Narrow
9. 205 Mile Rapid	328.8R	427	South	Narrow

Drift

Coarse particulate organic matter (CPOM) drift samples (0-0.5 m deep) were collected above each cobble site for CPOM during each collection trip. Collections were taken between 1000 h and 1500 h at each site to establish the effects of discharge on drift (n=6). 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 benthic collections. Current velocity was measured with a Marsh-McBirney electronic flow meter at the mouth of the net and collection duration were measured for volumetric calculations (mass/m^3/s).

Triplicate plankton samples (156 μm) were collected simultaneously with CPOM sets. Current velocity was measured with a Marsh-McBirney electronic flow meter at the mouth of the net and collection duration were measured for volumetric calculations (mass/m^3/s). 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 and 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 (Benenati et al., 2000). 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.

New Zealand Mudsnail Research

We surveyed for New Zealand Mudsnail (Potamopyrgus antipodarum, Gray, 1843; NZMS) densities within the varial zone (hydro-power wet/dry area of channel) at six sites: rkm 0.8, 1.0, 44.8, 68.8, 217.6 and 307.2) Three habitats were examined within a circular template (78.6 cm^2): top of cobbles, underside of cobbles, and pools. At each study site a 12m transect was established on the cobble bar within the varial zone within 0.5 m of the daily low flow stage parallel to the channel. To determine varial zone colonization rates transects were sampled near the minimum and maximum discharge during the 12 hour cycle, which was in the evening aftering arriving in camp and before leaving in the morning. Six meters of the same transect were sampled at a time in which the substrata was exposed to dry conditions (min. discharge), and 6 meters were sampled at a time when the transect was inundated (max. discharge). The STARS model (Randle 1998, USGS) was used to determine the stage of the river and the stage where the transects were located.

All NZMS found within the circle template at each meter mark were counted to obtain a density estimate (NZMS/m2). The snails were then stored in labeled bags and returned to the lab to process for biomass estimates. All samples were oven dried for 48hrs (60 °C), and ignited at 500 °C for an hour to obtain AFDM. Abiotic data collected for each site includes air and water temperature, and water depth. A Marsh McBirney electric current meter was used to determine water velocity.

We designed a laboratory desiccation experiment to determine if the varial zone survey data was credible. Three NZMS were placed in a petri dish to mimic varial zone dessication conditions and examined hourly for 1-9 hours and at 14 hours. A continually wet control treatment that was also established. These durations were selected to mimic the probable amount of time NZMS could be stranded due to hydro-power releases from GCD. Snails were re-hydrated after the specified amount of time and were considered living if active after 20 minutes

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Analysis

We used Multiple Analysis of Variance statistical test with categorical biomass estimates (AFDM g/m^2 and) as the response variable, with collection trip and site as the predictor variables. All calculations were performed with SYSTAT ™ Ver. 5.2 computer software (SYSTAT, Inc., 1992) on ln+1 transformed data. This approach was used to determine any changes in the phyto-benthic community within 2003 collections as they pertain to the 2003 Eco-flows and between 2002 and 2003 as a trend analysis.

New Zealand Mudsnail research statistical analyses were performed on ln+1 transformed data to reduce homoscedasticity, and sample estimate variance. Student's T-test was used to compare the average varial zone density with the density in the nearby river channel.

Results and Discussion

River Water quality variability was increased during the sampling period in response to a regional drought that reduced the level of Lake Powell Reservoir by about 30m (Table 2). These river chemistry changes at this time do not appear to be biologically significant, but are more of an indication of potential change that could become biologically significant if the drought continues. Of all measured water quality parameters, river temperture has the the most influence on the aquatic community structure. Our October 2003 monitoring trip showed an autumn increase in water temperature down river with 15°C being reached near Middle Granite Gorge (Fig. 2). This is the critical temperature to trigger life history changes in aquatic insects (Hawkins et al., 2000).

Table 2. Range of water quality comparison between 2000 and 2003 at Lees Ferry Cobble (rkm 0.8).

Parameter	2002	2003
pH	7.6 - 7.9	7.1 - 8.3
Dissolved Oxygen (mg/l)	9.3 - 12.3	7.1 - 10.1
Conductivity (mS)	0.71 - 0.81	0.71 - 0.88
Temperture (C°)	9.1 - 10.2	8.3 - 11.3
Total Dissolved Solids (ppt)	0.41 - 0.42	0.51 - 0.61

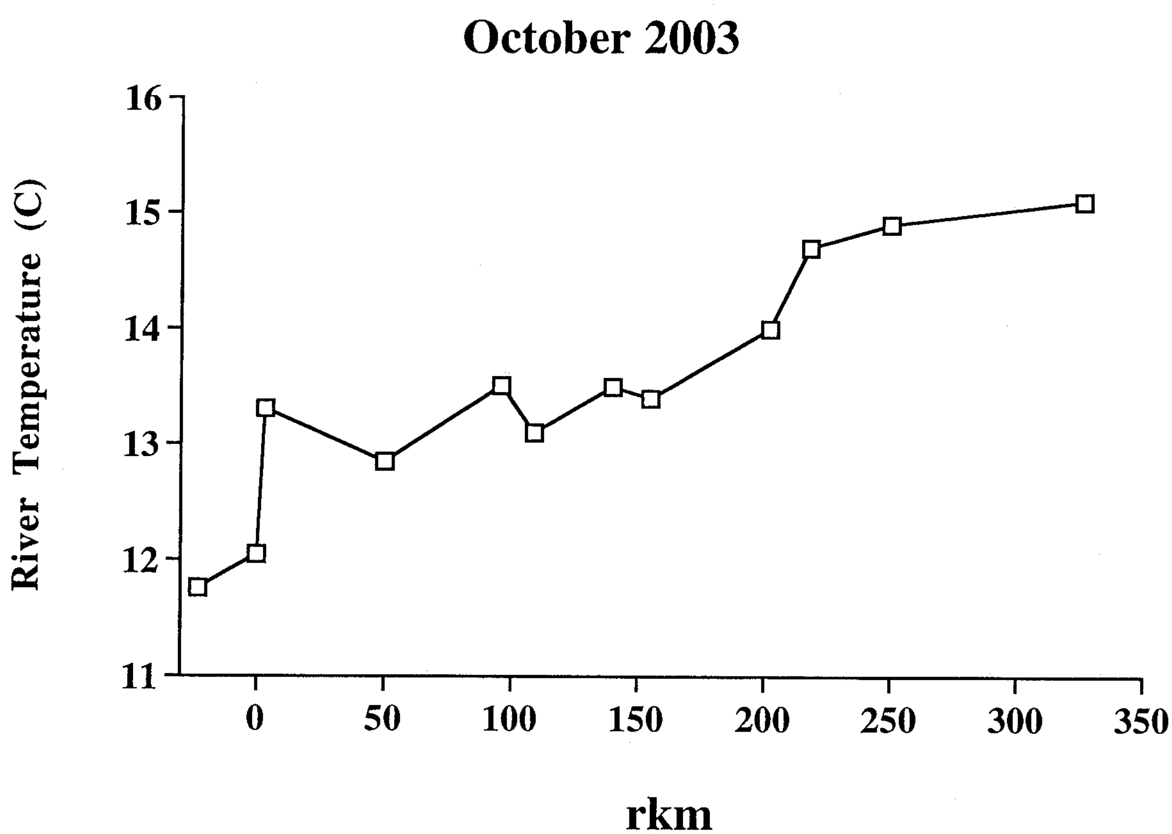

Figure 2. Colorado River temperature collected in the first two weeks of October 2003 with a Hydro-Lab.

The 2003 Eco-flows did have an influence on the phyto-benthic biomass estimates in Glen Canyon. Biomass estimates varied significantly both within and between cobble bars in Glen Canyon (Tables 3 & 4, Figs. 3-5). These differences prevented us from combining sites within Glen Canyon for analysis. Overall there was drop in benthic biomass during the January to March flows followed by recovery through the summer

Cladophora remains inconsistent as the dominate primary producer within the study site (Figs. 2-4). For example, at -8 Mile Bar Cladophora comprised 92% of the primary producer biomass in December 2002, but only 32% in June. Miscellaneous algae, macrophytes and bryophytes (MAMB) replaced Cladophora as the dominate biotic category. A variety of filamentous Chlorophtyes (Ulotrichaceae, Zygnemataceae), bryophyte Fontinalis spp., and diatom mucilage matrix were the major constituents of MAMB. This overall primary producer pattern held for all three collection sites in Glen Canyon.

Macroinvertebrate biomass decreased during the January to March flows with a general recovery by June (Figs. 2-4). New Zealand Mudsnail (Potamopyrgus antipodarum, Gastropoda: Hydrobiidae, NZMS), biomass and densities were not negatively impacted by the 2003 Eco-flows to any substantial degree. For example, at -3 Mile Bar NZMS biomass dropped by 70% between December and January collections after just one month of 127 - 567 m^3/s flows. However, by June NZMS had recovered to 90% of the December estimate. [See Richards et al, 2001 and Schreiber et al, 2003 for a description of these alein invaders.]

Table 3. Results of multiple analysis of variance comparing benthic biomass in the Colorado River through Glen Canyon from three cobble sites: -8 Mile Bar, -3 Mile Bar and Lees Ferry. Collections were taken approximately monthly from December 2002 through June 2003, which included the 2003 Eco-Flows from January through March. Predictor variables of collection month covaried by collection site and were analyzed against response variables of biotic categories (AFDM/m^2 ln+1 transformed data). Biotic categories include: Cladophora (C), miscellaneous algae/macrophytes and bryophytes (M), detritus (D), macroinvertebrates (B) and New Zealand Mudsnails (N) Only significant univariate response variables are listed ($p < 0.05$). Overall Wilks' Lambda, month & site, was significant ($p < 0.0001$).

Source	Wilks' Lambda	Approximate F-Statistic	df	p	Response Variable
Month	0.56	9.9	30,1894	<0.0001	C,M,D,B,N
Site	0.18	17.6	54,2844	<0.001	C,M,D,B,N

Table 4. Results of multiple analysis of variance comparing benthic biomass in the Colorado River through Glen Canyon from three cobble sites; -8 Mile Bar (rkm -23.3), -3 Mile Bar (rkm -6.7) and Lees Ferry (rkm 0.8). Collections were taken approximately monthly from December 2002 through June 2003, which included the 2003 Eco-Flows from January through March. Predictor variables of collection month and were analyzed against response variables of biotic categories (AFDM/m^2 ln+1 transformed data). Biotic categories include: Cladophora (C), miscellaneous algae/macrophytes and bryophytes (M), detritus (D), macroinvertebrates (B) and New Zealand Mudsnails (N) Only significant univariate response variables are listed ($p < 0.05$). Overall Wilks' Lambda, month & site, was significant ($p < 0.001$).

Source Site	Wilks' Lambda	Approximate F-Statistic	df	p	Response Variable
rkm 0.8	0.13	8.9	30,418	<0.001	C,M,D,B,N
rkm -6.7	0.33	4.8	25,354	<0.001	C,M,D,B,N
rkm -23.3	0.08	13.8	25,467	<0.001	C,D,B,N

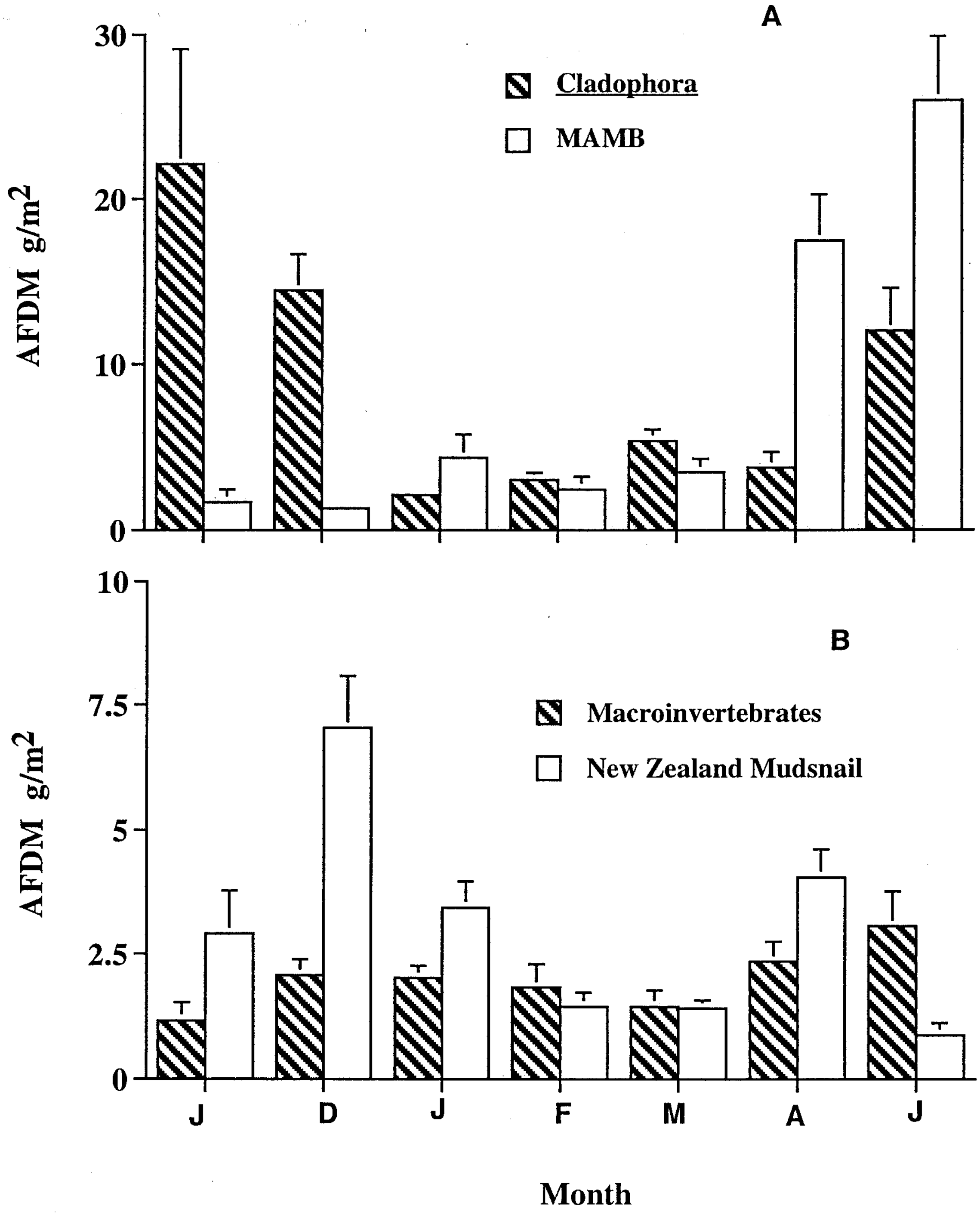

Figure 3. Monthly primary (A) and secondary (B) producer biomass estimates at -8 Mile Bar (rkm -13.9) in Glen Canyon, Colorado River, AZ. Collections occured starting June 2002 and continued through June 2003. MAMB is an abbreviation for miscellanous algae, macrophytes and bryophytes.

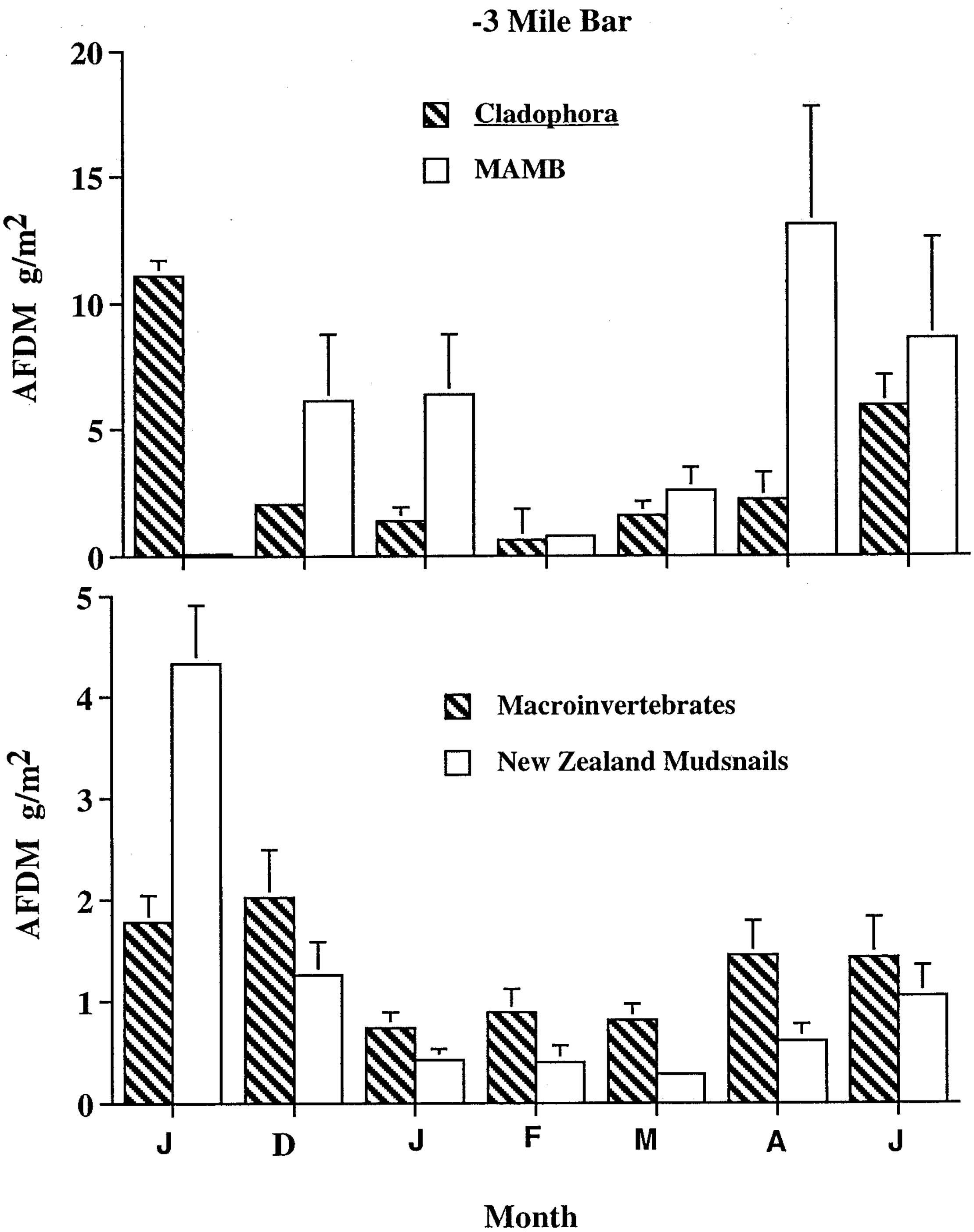

Figure 4. Monthly primary (A) and secondary (B) producer biomass estimates at -3 Mile Bar (rkm -6.7) in Glen Canyon, Colorado River, AZ. Collections occured starting June 2002 and continued through June 2003. MAMB is an abbreviation for miscellanous algae, macrophytes and bryophytes.

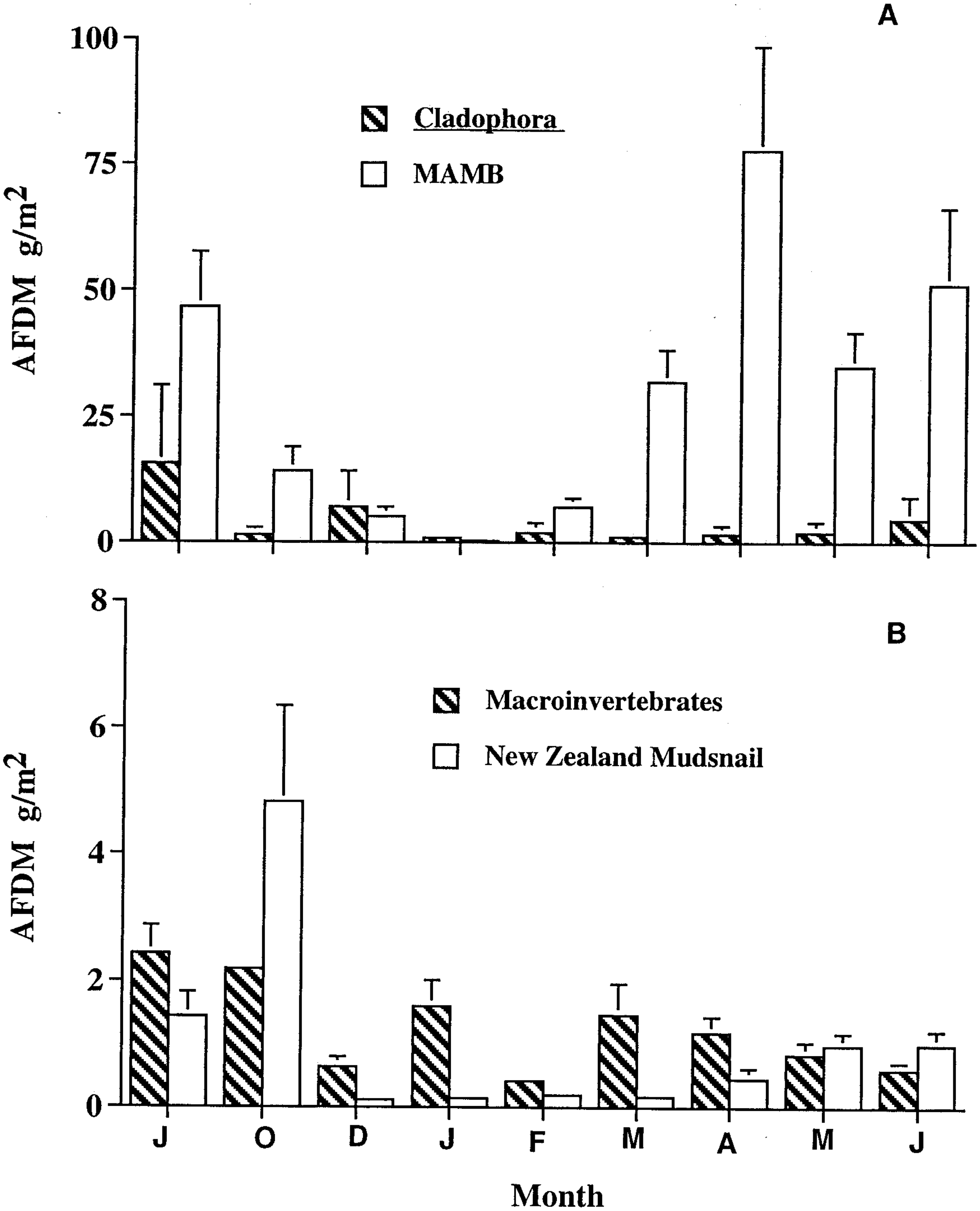

Figure 5. Monthly primary (A) and secondary (B) producer biomass estimates at Lees Ferry Cobble (rkm 0.8) in Glen Canyon, Colorado River, AZ. Collections occured starting June 2002 and continued through June 2003. MAMB is an abbreviation for miscellanous algae, macrophytes and bryophytes.

Chironomid (midge) larvae were not found in our collections at Lees Ferry cobble in October 2003 (Fig. 6); this was the first time that $0/m^2$ chironomid larvae were estimated at this site since 1990. We estimated there were $535/m^2$ (± se 235; n=18) in October 2002 with an average for the December 2002 - June 2003 collection period of $702/m^2$ (± se 92; n=102) at Lees Ferry Cobble. This decline of a primary food base constituent within this aquatic ecosystem (Shannon et al. 2001) could be related to the unusual warming of the river. Glen Canyon Dam has created a habitat that has selected for a near-arctic diptera assemblage (Sublette et al. 1998) because of the normally stenothermic cool water released from GCD. It is logical that Glen Canyon macroinvertebrates would show the first indication of thermal change because this reach has the most consistent thermal regime (Stevens et al. 1997).

Compositional change has also occurred in the benthos with an explosion of planaria; Turbellaria, Tricladia, Dugesia spp. (Thorp and Covich 2001; Fig. 6). We did not collect any planaria in 1990 and documented a steady increase starting in 1993 peaking at $9000/m^2$ in 2000, then dropping until 2003. However, estimates increased by two orders of magnitude within one year to over $60{,}000/m^2$. These flatworms of 6 - 12 mm are predators and may consume isopods, midges, oligochaetes, caddisflis, mayflies, ostracods and cladocerans (Thorp and Covich, 2001). Contribution to the diet of fish is easily under-estimated because of their soft body parts and difficulties to detect in fish gut analysis. Gee and Young (1993) reported these predators are "invasive strong competitors" and may expand with other invasive taxa. It is easy to speculate the increase in Dugesia is related to the NZMS invasion. This is a prime topic for intra-trophic level research. How these compositional changes will affect higher trophic levels of both aquatic and terrestrial consumers is unknown at this time. Vinson (2001) documented multi-decade changes in the aquatic community in the

Green River below Flaming Gorge Dam and he would describe these changes as a "sub-lethal negative influence" that compounds the variability and stress in a regulated river.

Annual June phyto-benthic monitoring revealed significant differences in some biotic categories when sites were grouped by reach (Table 5). Although we detected a significant difference between sites within a reach (MANOVA; $p>0.001$), we combined sites as directed by GCMRC staff. In Glen Canyon Cladophora biomass dropped from 16.02 g/m^2 AFDM (± se 2.4) in 2002 to 7.31 g/m^2 AFDM (± 1.3) in 2003. This reduction in Cladophora biomass was accompanied by a near doubling of MAMB biomass between 2002 and 2003, 16.7 (± 4.8) to 30.0 (± 6.3) g/m^2 AFDM respectively. Cladophora provides a superior substrate compared to MAMB for diatom colonization and therefore grazing consumers such as Gammarus and midge larvae (Shaver et al. 1997; Benenati et al. 2000)

In Marble Canyon detritus increased to 1.04 (± 0.1) g/m^2 AFDM in 2003 from 0.5 (± 0.08) g/m^2 AFDM in 2002. Although this is an order of magnitude increase, the potential relationship to macroinvertebrates is unknown. In Grand Canyon Cladophora biomass increased by 90% in 2003 from 0.14 (± 0.05) g/m^2 AFDM in 2002. Oscillatoria biomass decreased by 60% in 2003 from 1.5 (± 0.1) g/m^2 AFDM in 2002. We would have predicted that this shift to Cladophora would have supported an increase in macroinvertebrate biomass, however our estimates show an order of magnitude drop in 2003 biomass of 0.1 g/m^2 AFDM (± 0.05) in 2002 to 0.01 g/m^2 AFDM (±0.004) in 2003.

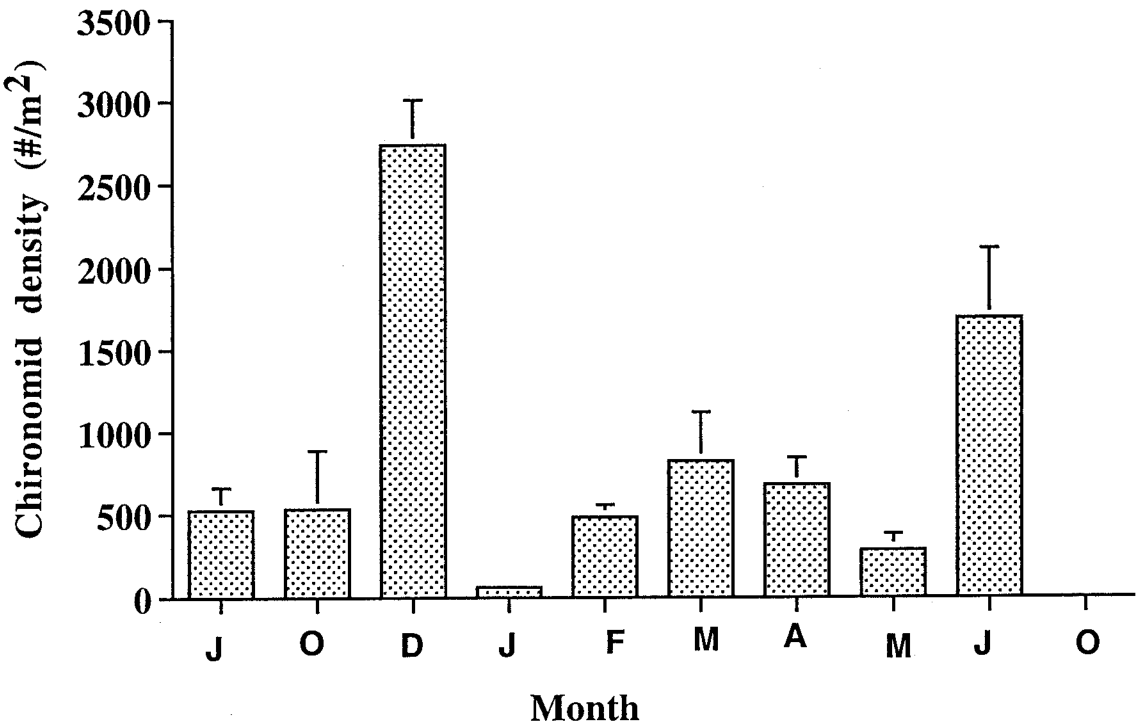

Figure 6. Chironomid larvae density estimates at Lees Ferry Cobble (rkm 0.8) in Glen Canyon, Colorado River, AZ. Collections occured starting June 2002 and continued through October 2003.

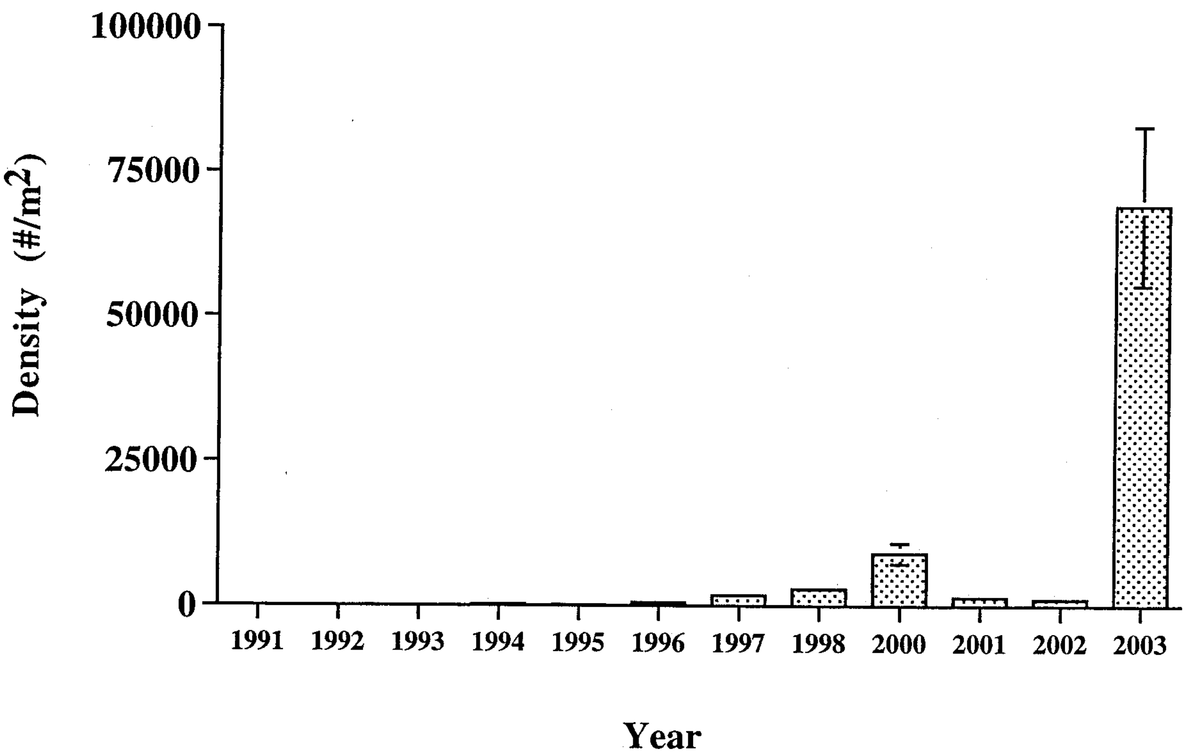

Figure 7. Average planaria density at Lees Ferry Cobble (rkm 0.8) (±se)

Table 5. Multivariate (MANOVA) analysis comparing 2002 and 2003 biomass estimates (AFDM g/m2) collected from cobble bars in the Colorado River below Glen Canyon Dam. Sites were combined into three reaches for trend analyses; Glen Marble and Grand Canyons (Table 1). Only significant univariate response variables are listed (p<0.05). Biotic categories include: Cladophora (C), miscellaneous algae/macrophytes and bryophytes (M), detritus (D), macroinvertebrates (B) and New Zealand Mudsnails (N) Only significant univariate response variables are listed (p <0.05).

Source Site	Wilks' Lambda	df	F-ratio	p	Significant Response Variable
Glen Canyon	0.56	6,93	11.5	<0.001	C,M,N
Marble Canyon	0.73	6,104	6.5	<0.001	D
Grand Canyon	0.83	6,101	6.5	0.003	C,O,B

Drift

Coarse organic drift estimates varied significantly by collection trip and site between October 2002 and 2003 (Table 6). However, of the six biotic categories only midge/blackfly larvae and MAMB varied signficantly between trips (Fig.8 and 9). Only detritus and midge/blackfly larvae varied signficantly between collection sites, indicating some stability during the past year within these categories. In October 2003 chironomid midge larvae and adults were absent in the drift at both Glen Canyon and Lees Ferrys sites. This is a significant departure from typical where midges are the most abundant macroinvertebrate in the drift. Shannon et al. (1996) reported that in 1993 and 1994 chironomids comprised 62% of the drifting invertebrate biomass and Gammarus 33%. Gammarus biomass was also an order of magnitude less in 2002-03 than in 1993-94. Midge numbers were higher down river than in Glen Canyon in 2003-03, which is also a signficant change from the past 10 years ago. The mechanism for these changes are not clear from these monitoring trips but the change in water quality (primarily higher river tempertures) from Lake Powell, increases in NZMS numbers and MAMB biomass could all be contributing factors.

Zooplankton drift abundance estimates varied significantly by collection trip and site between October 2002 and 2003 (Table 7). However, biomass estimates did not ($p > 0.13$). Benenati et al., (2001) reported that zooplankton densities between 1995 and 1999 averaged 106/m^3/s for all collections. In this investigation we averaged 2,734/m^3/s for all collections. This order of magnitude increase correspondes with a large increase in zooplankton being released from Glen Canyon Dam since March of 2003 as a result of the drought conditions in Lake Powell. In October there 34,851/m^3/s ($\pm$ 10.712 se) lentic zooplankton collected at the Glen Canyon Gauge about 1 km below GCD. This

2003 estimate is an order of maganitude higher than Benenati et al., (2001) stated with both time periods dominated by Cyclopoida Copepodes.

Table 6. Multivariate (MANOVA) analysis comparing 2002 and 2003 organic drift estimates (AFDM g/m^3) collected in the Colorado River below Glen Canyon Dam. Only significant univariate response variables are listed ($p<0.05$). Biotic categories include: Gammarus (G), midges and blackflies (MB), other invertebrates (O), Cladophora (C), detritus (D), and MAMB (M). Only significant univariate response variables are listed ($p<0.05$).

Source Site	Wilks' Lambda	df	F-ratio	p	Significant Response Variable
Trip	0.49	12,697	2.7	<0.001	MB, M
Site	0.76	6,148	7.8	<0.001	MB,D

Table 7. Multivariate (MANOVA) analysis comparing 2002 and 2003 zooplankton drift abundance estimates (#/m^3) collected in the Colorado River below Glen Canyon Dam. Only significant univariate response variables are listed ($p<0.05$). Biotic categories include: Copepoda; Calanoida (CA), Cyclopoida (CY), Harpacticoida (HA), Cladocera (CL), Ostracoda (OS), and miscellaneous zooplankton (MZ). Only significant univariate response variables are listed ($p<0.05$).

Source Site	Wilks' Lambda	df	F-ratio	p	Significant Response Variable
Trip	0.21	42,373	3.4	<0.001	CA, CY HA, OS
Site	0.66	6,79	6.7	<0.001	CA, CY,CL

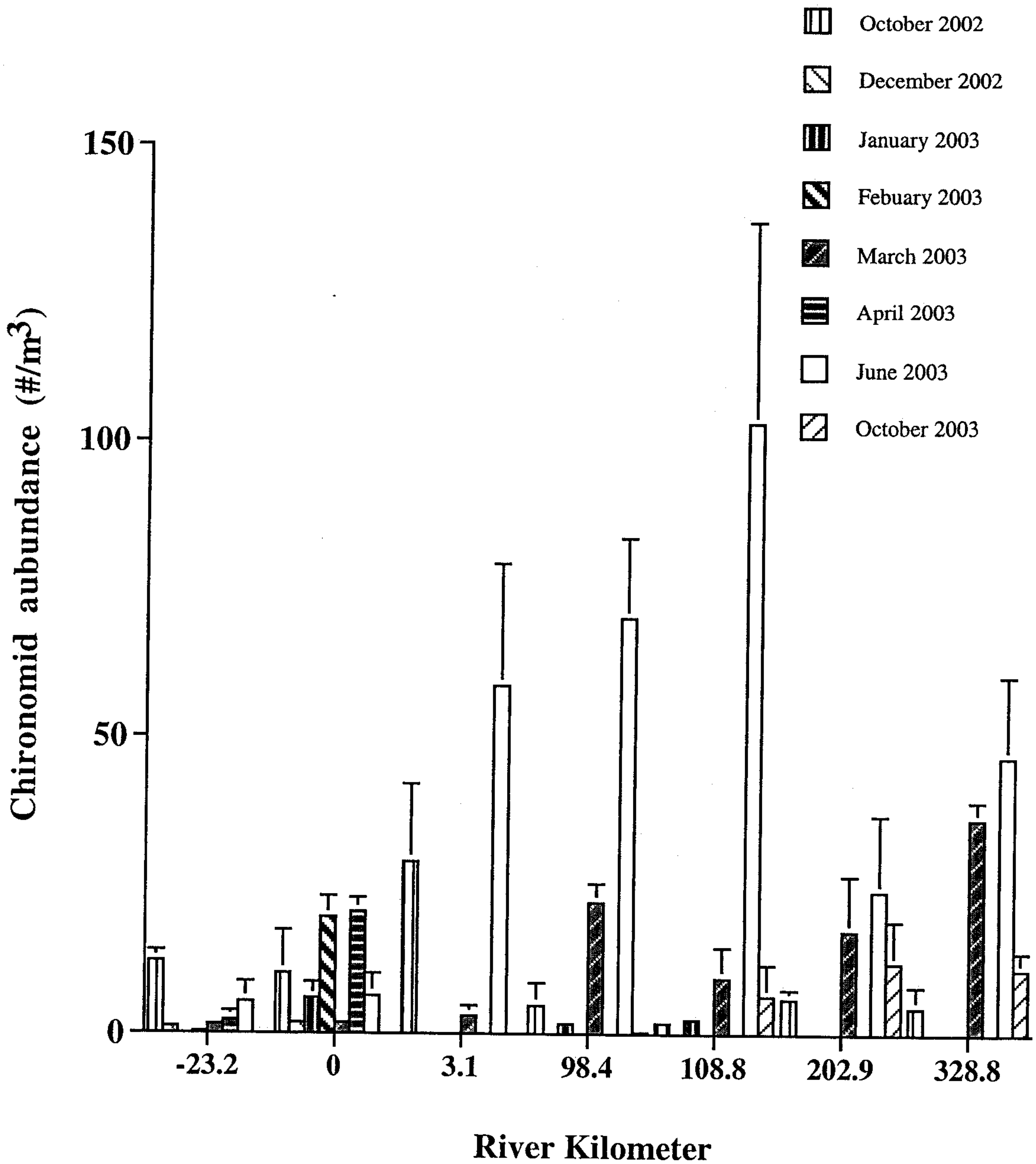

Figure 8. Chironomid drift abundance from October 2002 to October 2003 in the Colorado River through Grand Canyon.

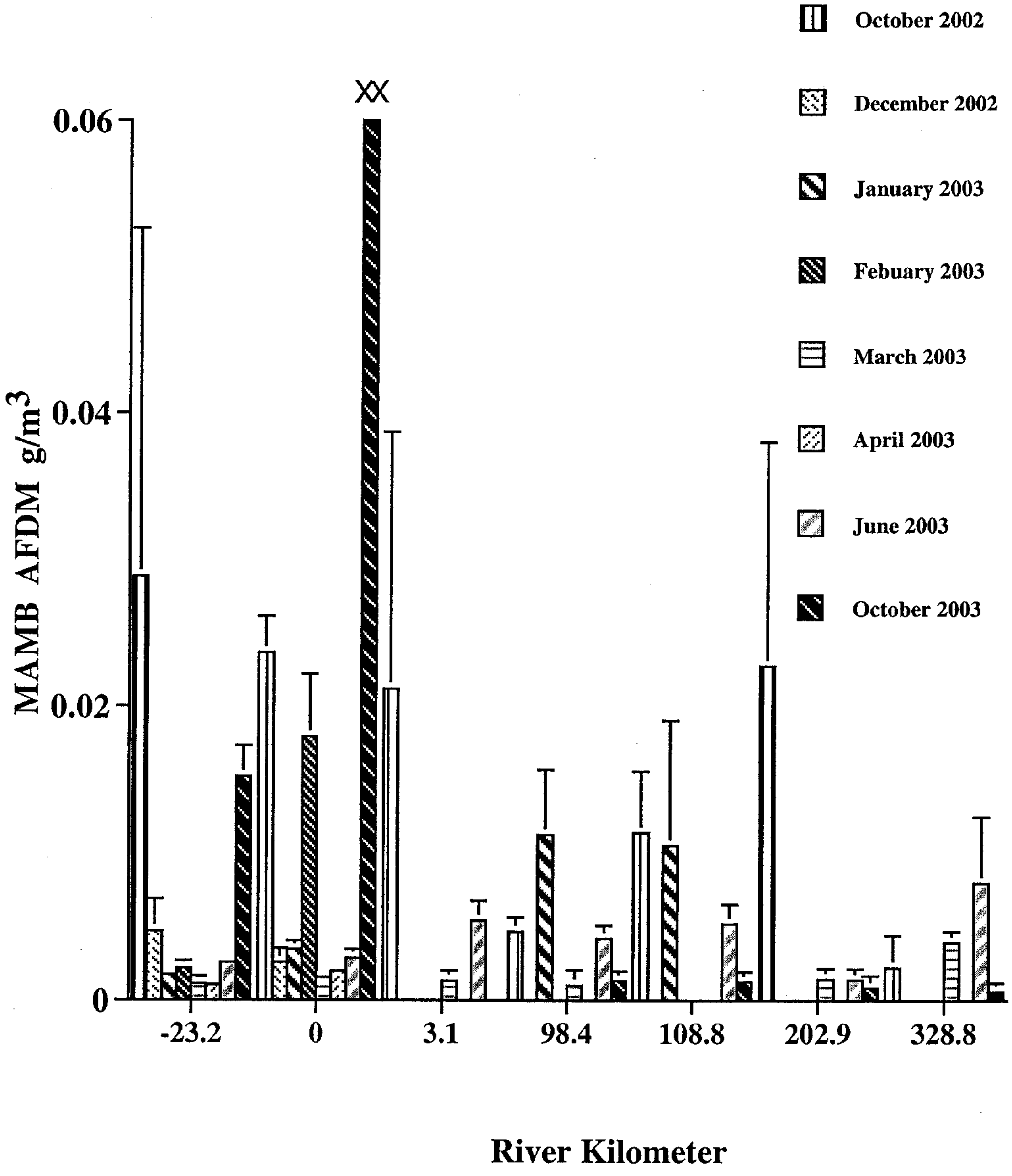

Figure 9. Miscellaneous algae, macrophytes, and bryophtes (MAMB) drift in the Colorado River through Grand Canyon from October 2002 to October 2003. XX = 0.1216 g AFDM (±0.0013 se)

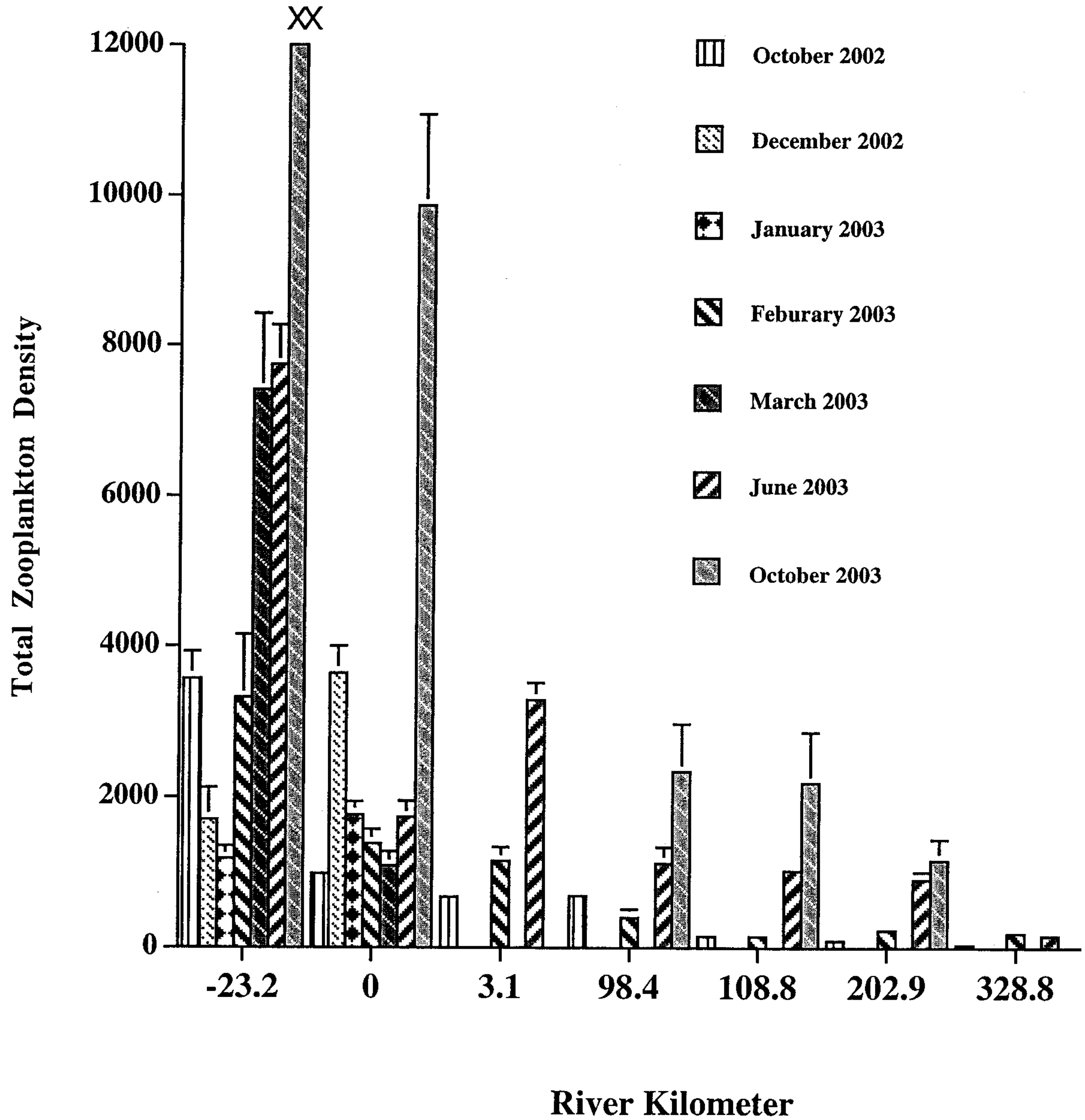

Figure 10. Total zooplankton density estimates (#/m ^{3}) in the Colorado River through Grand Canyon from OCtober 2002 to October 2003. XX=34,851(±=10,712se)

New Zealand Mudsnail Research

New Zealand Mudsnails were found in the varial zone primarily in pools and under cobbles. However, the varial zone habitat contained only an average of 2% of the total density including submerged channel habitats ($p<0.01$). Average study site wide density in the varial zone was 0.9 (±0.2 se) and while the channel estimate was 525 (± 75.2 se). Although these NZMS varial zone densities appear low it does indicate that they can colonize and survive in the varial zone.

Laboratory dessciation experiment results verified that NZMS can survive under cobbles during low flow periods and within varial pools. There was an average 50% survival rate from one to seven h of exposure, while eight and nine h expsoure periods killed an average of 88% of the NZMS. No NZMS survived at 14 h. These data indicate that a single day of varial zone exposure, such as Sunday low flows, may reduce NZMS numbers within the varial zone. Alternatively, pools within the varial zone may provide refugia for these invaders. Through pool warming a nursery habitat may be formed providong the release mechanism for their 20 embryos that they each can carry when the river reaches high flows. These snails probably floated into the varial zone by sealing air within their operculums (Ribi and Arter, 1986). Shannon et al. (2003) reported NZMS densities as high as $297/m^2$(±82 se) in large pools (> $1m^3$) in October 2002 during a low flow period of 142 - 284 m^3/s. This information is supported by Bowler (1991) who observed NZMS survviving along the Snake River during peak drawdown by hydro-electric dams. Schreiber et al., (2003), has related NZMS presence and rapid colonization to flow driven disturbance, suggesting that high fluctuating flows will not reduce but enhance local populations by opening micro-habitats for further colonization.

Aquatic Food Base status and trends

Phyto-benthic patterns in 2003 indicate the aquatic community remains unstable (Benenati et al. 2000, Table 8). Cladophora biomass continues to decline while MAMB increases and changes in dominate taxa throughout the year. New Zealand Mudsnails dominate the macroinvertebrate assemblage and planaria increasing in Glen Canyon. Drought draining Lake Powell have altered the water quality released from GCD, primarily warmer temperatureslevels. Organic drift reflects these patterns with an increase in zooplankton and a decrease in midge biomass. The 2003 Eco-flows designed to reduce alein fish numbers is occuring during an extended drought which will complicate the understanding of this management action. Seperating out the impacts of a changing Lake Powell versus changing in dam operations during the winter will be difficult to evaluate. For example, a reduction in benthic biomass energy by peaking hydro-power flows may be replaced by more lentic zooplankton from Lake Powell, which small fish can thrive on. We recommend continuation of the NAU Aquatic Food Base Monitoring Program to better understand 2004 Eco-Flows. Also, because of drought lowering Lake Powell and subsequent release of epilimnetic water, this project will provide important support in designing monitoring protocols in anticipation of the proposed thermal modification of Glen Canyon Dam.

Table 8. Average biomass and density estimates (± se) in the Colorado River from Lees Ferry (rkm 0.8) to 205 Mile Rapid (rkm 328.8) in June from 1991 - 2003 from cobble/riffle habitats.

Year	Cladophora g/m^2 AFDM		MAMB g/m^2 AFDM		Invertebrates $\#/m^2$		Snails $\#/m^2$	
1991	2.7	(1.0)	0		150	(57)	2	(0.6)
1992	0.7	(0.3)	0.04	(0.01)	191	(72)	4	(1.3)
1993	1.5	(0.6)	0.08	(0.02)	197	(74)	4	(1.1)
1994	5.2	(1.9)	1.5	(0.5)	738	(280)	13	(4.2)
1995	12.0	(4.5)	1.5	(0.6)	427	(162)	6	(1.9)
1996	7.0	(2.6)	15	(5.2)	1160	(440)	58	(19.1)
1997	3.8	(1.4)	6.2	(2.1)	2500	(950)	970	(320)
1998	6.1	(2.3)	6.6	(2.3)	4773	(1813)	3336	(1100)
1999	5.2	(1.8	8.0	(2.8)	2237	(850)	640	(211)
2000	2.0	(0.7)	38.0	(13.3)	1116	(424)	37350	(12k)
2001	6.2	(2.3)	36.1	(12.6)	995	(391)	2624	(865)
2002	5.8	(2.7)	10.9	(5.2)	1224	(469)	1969	(839)
2003	3.1	(.5)	13.4	(2.5	3351	(978)	517	(125)

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Appendix Table 1. Benthic data collected from cobble bars in the Colorado River below Glen Canyon Dam June 2002. River kilometers (rkm). Mean biomass estimates (g/m^2) (±se) or density ($\#/m^2$) (±se). Miscellanous algae, macrophytes, and bryophytes is abbrviated with MAMB.

Biotic Category	Collection Site								
rkm	-13.9	-6.7	0.8	3.1	50.8	80.0	109.6	202.9	328.8
Biomass									
Cladophora	22.1 (7.0)	11.0 (1.8)	15.6 (2.5)	0.8 (0.2)	0.7 (0.2)	2.2 (0.7)	0.3 (0.1)	0.04 (0.008)	0.05 (0.02)
Oscillatoria	0 (0)	0 (0)	0 (0)	0 (0)	1.5 (0.7)	$1x10^{-5}$ ($1x10^{-5}$)	2.9 (1.2)	$1x10^{-5}$ ($1x10^{-5}$)	1.5 (1.0)
MAMB	1.7 (0.8)	0.1 (0.03)	46.7 (10.9)	0.3 (0.1)	24.5 (9.7)	7.9 (4.2)	14.8 (3.4)	0.2 (0.06)	3.1 (0.7)
Detritus	2.8 (0.5)	0.6 (0.1)	4.7 (6.1)	0.6 (0.1)	0.7 (0.2)	0.2 (0.07)	0.8 (0.2)	0.7 (0.06)	2.0 (0.6)
Macroinvertebrates	1.2 (0.4)	1.8 (0.3)	2.4 (0.4)	0.6 (0.1)	0.2 (0.1)	0.08 (0.04)	0.2 (0.1)	0.1 (0.1)	0.02 (0.005)
New Zealand Mudsnails	2.9 (0.9)	4.3 (0.6)	1.4 (0.4)	0.1 (0.04)	0.3 (0.2)	0.3 (0.07)	0.3 (0.08)	0.02 (0.008)	0.04 (0.01)
Density									
Lumbriculids	326 (76)	336 (37)	51 (15)	95 (26)	7 (5)	9 (6)	16 (11)	0 (0)	0 (0)
Gammarus	273 (118)	195 (50)	730 (125)	19 (8)	5.3 (4)	5 (3)	5 (4)	0 (0)	2 (2)
Oligochaeta	201 (92)	347 (84)	580 (115)	0 (0)	0 (0)	2 (2)	4 (4)	0 (0)	9 (2)
Simulids	0 (0)	0 (0)	2 (2)	18 (13)	5 (5)	5 (3)	32 (15)	18 (6)	7 (2)
Chironomids	2483 (721)	492 (117)	523 (139)	136 (61)	649 (313)	184 (50)	225 (75)	25 (10)	28 (11)
Other macroinvertebrates	732 (394)	368 (178)	1056 (278)	129 (78)	394 (305)	81 (21)	196 (90)	5 (3)	9 (6)
Gastropods	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
New Zealand Mudsnails	4816 (1515)	7121 (918)	3197 (632)	431 (127)	624 (452)	813 (230)	525 (153)	71 (33)	127 (44)

Appendix Table 2. Benthic data collected from cobble bars in the Colorado River below Glen Canyon Dam October 2002. River kilometers (rkm). Mean biomass estimates (g/m^2) (±se) or density ($\#/m^2$) (±se). Miscellanous algae, macrophytes, and bryophytes is abbrviated with MAMB.

Biotic Category	rkm	Collection Site 0.8	3.1	98.62	109.6	202.9	328.8
	Biomass						
Cladophora		1.4 (0.8)	5.1 (2.9)	5.2 (1.4)	5.1 (5.0)	1.2 (0.7)	0.2 (0.1)
Oscillatoria		0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0.1 (0.1)
MAMB		14.1 (4.8)	1.6 (0.6)	21.3 (7.7)	8.9 (3.7)	1.9 (0.8)	3.8 (2.7)
Detritus		0.8 (0.3)	1.1 (0.4)	1.6 (0.5)	2.8 (1.4)	0.4 (0.2)	0.3 (0.2)
Macroinvertebrates		2.2 (0.7)	0.5 (0.1)	0.2 (0.03)	0.07 (0.02)	0.01 (0.004)	0 (0)
New Zealand Mudsnails		4.8 (1.5)	3.2 (0.5)	0.2 (0.09)	0.3 (0.2)	0.001 (0.001)	0.003 (0.002)
	Density						
Lumbriculids		159 (80)	69 (32)	48 (36)	0 (0)	0 (0)	0 (0)
Gammarus		546 (128)	74 (13)	53 (24)	0 (0)	0 (0)	0 (0)
Oligochaeta		244 (90)	27 (13)	58 (47)	5 (5)	0 (0)	0 (0)
Simulids		0 (0)	5 (5)	5 (5)	11 (7)	0 (0)	0 (0)
Chironomids		531 (357)	69 (28)	446 (174)	138 (126)	21 (16)	0 (0)
Other macroinvertebrates		806 (313)	53 (20)	111 (57)	159 (140)	5 (5)	0 (0)
Gastropods		0.003 (0.003)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
New Zealand Mudsnails		806 (313)	2430 (762)	950 (642)	987 (685)	5 (5)	11 (0.7)

Appendix Table 2. Benthic data collected from cobble bars in the Colorado River below Glen Canyon Dam December 2002. River kilometers (rkm). Mean biomass estimates (g/m^2) (±se) or density ($\#/m^2$) (±se). Miscellanous algae, macrophytes, and bryophytes is abbrviated with MAMB.

Biotic Category	rkm	Collection Site -13.9	-6.7	0.8	3.1
	Biomass				
Cladophora		14.5 (2.2)	2.0 (0.8)	7.1 (1.2)	3.3 (1.1)
Oscillatoria		0 (0)	0 (0)	0 (0)	0 (0)
MAMB		1.3 (0.3)	6.1 (2.7)	5.1 (2.0)	0.4 (0.2)
Detritus		4.0 (0.4)	0.1 (0.08)	0.5 (0.2)	0.6 (0.1)
Macroinvertebrates		2.1 (0.3)	2.02 (0.5)	0.6 (0.2)	0.1 (0.02)
New Zealand Mudsnails		7.0 (4.5)	1.3 (0.3)	0.1 (0.02)	0.02 (0.01)
	Density				
Lumbriculids		410 (56)	279 (43)	118 (36)	21 (7)
Gammarus		304 (105)	302 (84)	251 (55)	5 (5)
Oligochaeta		336 (104)	$1X10^{-5}$ ($1X10^{-5}$)	536 (191)	0 (0)
Simulids		0 (0)	4 (4)	0 (0)	0 (0)
Chironomids		117 (24)	845 (250)	891 (238)	170 (69)
Other macroinvertebrates		1188 (316)	152 (24)	1008 (242)	21 (16)
Gastropods		0 (0)	0 (0)	0 (0)	0 (0)
New Zealand Mudsnails		11728 (1825)	2151 (576)	782 (173)	32 (20)

Appendix Table 3. Benthic data collected from cobble bars in the Colorado River below Glen Canyon Dam January 2003. River kilometers (rkm). Mean biomass estimates (g/m^2) (±se) or density ($\#/m^2$) (±se). Miscellanous algae, macrophytes, and bryophytes is abbrviated with MAMB.

Biotic Category	rkm	Collection Site -13.9	-6.7	0.8	3.1
Biomass					
Cladophora		2.1 (0.3)	1.4 (0.4)	1.0 (0.3)	11.8 (3.5)
Oscillatoria		0 (0)	0 (0)	0 (0)	0 (0)
MAMB		4.3 (1.4)	6.4 (2.4)	0.4 (0.1)	0.5 (0.2)
Detritus		2.04 (0.4)	0.5 (0.1)	1.5 (0.3)	2.0 (0.6)
Macroinvertebrates		2.006 (0.3)	0.7 (0.2)	0.2 (0.06)	2.2 (0.4)
New Zealand Mudsnails		3.4 (0.5)	0.4 (0.1)	0.1 (0.06)	0.9 (0.3)
Density					
Lumbriculids		318 (46)	232 (80)	21 (9)	202 (40)
Gammarus		435 (78)	111 (37)	23 (9)	249 (45)
Oligochaeta		57 (25)	161 (93)	366 (115)	5 (5)
Simulids		11 (7)	0 (0)	0 (0)	223 (204)
Chironomids		315 (112)	341 (60)	64 (32)	202 (92)
Other macroinvertebrates		113 (21)	94 (35)	39 (19)	74 (62)
Gastropods		0 (0)	0 (0)	0 (0)	0 (0)
New Zealand Mudsnails		7889 (1185)	943 (248)	502 (177)	1093 (406)

Appendix Table 4. Benthic data collected from cobble bars in the Colorado River below Glen Canyon Dam February 2003. River kilometers (rkm). Mean biomass estimates (g/m^2) (±se) or density ($\#/m^2$) (±se). Miscellanous algae, macrophytes, and bryophytes is abbrviated with MAMB.

Biotic Category	rkm	Collection Site -13.9	-6.7	0.8	3.1
Biomass					
Cladophora		3.0 (0.4)	0.6 (0.2)	2.0 (1.0)	6.1 (2.7)
Oscillatoria		0 (0)	0 (0)	0 (0)	$1x10^{-5}$ ($1x10^{-5}$)
MAMB		2.4 (0.8)	0.8 (0.3)	7.1 (1.7)	8.7 (3.7)
Detritus		1.7 (0.5)	1.2 (0.3)	6.9 (2.5)	7.0 (4.6)
Macroinvertebrates		1.8 (0.5)	0.9 (0.2)	0.4 (0.07)	1.8 (0.8)
New Zealand Mudsnails		1.4 (0.3)	0.4 (0.2)	0.2 (0.07)	0.6 (0.3)
Density					
Lumbriculids		313 (76)	159 (46)	35 (11)	239 (115)
Gammarus		212 (45)	69 (17)	44 (11)	233 (65)
Oligochaeta		16 (7)	263 (137)	442 (110)	0 (0)
Simulids		7 (5)	0 (0)	4 (4)	32 (7)
Chironomids		539 (128)	149 (46)	483 (72)	525 (230)
Other macroinvertebrates		46 (20)	42 (12)	136 (38)	58 (29)
Gastropods		0 (0)	0 (0)	0 (0)	0 (0)
New Zealand Mudsnails		3026 (547)	943 (442)	554 (87)	822 (308)

Appendix Table 5. Benthic data collected from cobble bars in the Colorado River below Glen Canyon Dam March 2003. River kilometers (rkm). Mean biomass estimates (g/m^2) (±se) or density ($\#/m^2$) (±se). Miscellanous algae, macrophytes, and bryophytes is abbrviated with MAMB.

Biotic Category		Collection Site						
	rkm	-13.9	-6.7	0.8	3.1	98.6	109.6	202.9
	Biomass							
Cladophora		5.3 (0.7)	1.6 (0.5)	1.2 (0.5)	8.3 (3.2)	2.4 (2.4)	0.006 (0.006)	0.01 (0.005)
Oscillatoria		0 (0)	0 (0)	0 (0)	0 (0)	4.3 (4.1)	$1x10^{-5}$ ($1x10^{-5}$)	0 (0)
MAMB		3.5 (0.8)	2.5 (0.9)	31.9 (6.4)	2.2 (1.0)	3.5 (3.1)	21.02 (5.9)	0.09 (0.03)
Detritus		1.0 (0.2)	0.6 (0.1)	11.3 (4.4)	4.4 (1.5)	12.9 (5.1)	3.04 (1.6)	1.1 (0.3)
Macroinvertebrates		1.4 (0.3)	0.8 (0.2)	0.5 (0.12)	1.2 (0.2)	0.4 (0.3)	0.2 (0.04)	0.03 (0.02)
New Zealand Mudsnails		1.4 (0.2)	0.3 (0.5)	0.2 (0.05)	0.5 (0.1)	0.01 (0.008)	0.1 (0.1)	0.006 (0.006)
	Density							
Lumbriculids		195 (39)	53 (14)	60 (17)	212 (45)	32 (26)	5 (5)	0 (0)
Gammarus		173 (41)	127 (27)	48 (11)	271 (58)	0 (0)	0 (0)	0 (0)
Oligochaeta		7 (4)	$1x10^{-5}$ ($1x10^{-5}$)	468 (103)	5 (5)	11 (11)	11 (7)	0 (0)
Simulids		2 (2)	0 (0)	0 (0)	122 (73)	11 (7)	159 (27)	16 (7)
Chironomids		4425 (300)	697 (179)	821 (296)	955 (407)	143 (119)	780 (210)	32 (16)
Other macroinvertebrates		76 (23)	179 (46)	78 (30)	106 (46)	11 (7)	53 (16)	21 (16)
Gastropods		0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
New Zealand Mudsnails		3190 (434)	1171 (326)	336 (89)	106 (46)	16 (7)	248 (196)	11 (11)

Appendix Table 6. Benthic data collected from cobble bars in the Colorado River below Glen Canyon Dam April 2003. River kilometers (rkm). Mean biomass estimates (g/m^2) (±se) or density ($\#/m^2$) (±se). Miscellanous algae, macrophytes, and bryophytes is abbrviated with MAMB.

Biotic Category	rkm	Collection Site -13.9	-6.7	0.8	3.1
	Biomass				
<u>Cladophora</u>		3.7 (0.9)	2.2 (0.4)	1.7 (1.3)	3.4 (2.5)
<u>Oscillatoria</u>		0 (0)	0 (0)	0 (0)	0 (0)
MAMB		17.4 (2.8)	13.1 (4.7)	77.7 (20.8)	0.6 (0.1)
Detritus		6.6 (4.2)	1.1 (0.3)	1.3 (0.4)	2.2 (0.6)
Macroinvertebrates		2.3 (0.4)	1.4 (0.3)	1.2 (0.3)	1.2 (0.5)
New Zealand Mudsnails		4.0 (0.6)	0.6 (0.2)	0.5 (0.2)	0.5 (0.2)
	Density				
Lumbriculids		531 (85)	255 (55)	286 (101)	74 (31)
<u>Gammarus</u>		343 (64)	290 (125)	149 (29)	111 (47)
Oligochaeta		147 (50)	739 (306)	881 (262)	27 (10)
Simulids		18 (11)	9 (4)	0 (0)	58 (39)
Chironomids		5524 (777)	2518 (1066)	676 (163)	690 (514)
Other macroinvertebrates		1485 (411)	582 (186)	932 (346)	191 (87)
Gastropods		0 (0)	0 (0)	0 (0)	0 (0)
New Zealand Mudsnails		4 (0.6)	1841 (581)	1834 (430)	1570 (565)

Appendix Table 7. Benthic data collected from cobble bars in the Colorado River below Glen Canyon Dam May 2003. River kilometers (rkm). Mean biomass estimates (g/m^2) (±se) or density ($\#/m^2$) (±se). Miscellanous algae, macrophytes, and bryophytes is abbrviated with MAMB.

Biotic Category	rkm	Collection Site 0.8
Biomass		
Cladophora		2.1 (0.7)
Oscillatoria		0 (0)
MAMB		34.9 (6.9)
Detritus		2.2 (0.5)
Macroinvertebrates		0.8 (0.2)
New Zealand Mudsnails		1.0 (0.2)
Density		
Lumbriculids		64 (16)
Gammarus		207 (47)
Oligochaeta		727 (251)
Simulids		0 (0)
Chironomids		284 (95)
Other macroinvertebrates		379 (131)
Gastropods		0 (0)
New Zealand Mudsnails		2446 (477)

Appendix Table 8. Benthic data collected from cobble bars in the Colorado River below Glen Canyon Dam June 2003. River kilometers (rkm). Mean biomass estimates (g/m2) (±se) or density (#/m2) (±se). Miscellanous algae, macrophytes, and bryophytes is abbrviated with MAMB.

Biotic Category		Collection Site									
	rkm	-13.9	-6.7	0.8	3.1	50.8	80.0	98.6	109.6	202.9	328.8
	Biomass										
<u>Cladophora</u>		12.0 (2.6)	5.9 (1.9)	4.6 (2.01)	2.5 (0.8)	2.0 (0.4)	0.4 (0.2)	0.1 (0.05)	0.1 (0.07)	0.04 (0.006)	3.5 (1.06)
<u>Oscillatoria</u>		0 (0)	0 (0)	0.04 (0.04)	0 (0)	0.2 (0.2)	$1x10^{-5}$ (0)	0 (0)	1.0 (1.0)	$1x10^{-5}$ (0)	0.9 (0.7)
MAMB		25.9 (3.9)	8.6 (4.0)	51.2 (15.03)	1.6 (0.6)	1.3 (0.4)	25.4 (10.7)	1.8 (0.5)	7.7 (1.4)	0.7 (0.02)	1.8 (0.6)
Detritus		1.4 (0.2)	1.2 (0.2)	1.6 (0.5)	1.04 (0.1)	1.04 (0.1)	0.6 (0.1)	2.3 (1.0)	0.9 (0.1)	1.2 (0.2)	2.9 (0.7)
Macroinvertebrates		3.1 (0.7)	1.4 (0.4)	0.6 (0.1)	0.6 (0.2)	0.02 (0.005)	0.1 (0.04)	0.1 (0.07)	0.02 (0.01)	0.001 (0.001)	0.009 (0.006)
New Zealand Mudsnails		0.9 (0.2)	1.1 (0.3)	1.0 (0.2)	0.4 (0.09)	0.05 (0.3)	0.08 (0.04)	0.05 (0.03)	0.2 (0.08)	0.002 (0.001)	0.007 (0.003)
	Density										
Lumbriculids		613 (118)	255 (66)	94 (20)	140 (57)	2 (2)	19 (11)	16 (7)	11 (5)	0 (0)	0 (0)
<u>Gammarus</u>		282 (75)	276 (84)	175 (64)	108 (40)	7 (4)	5 (4)	11 (11)	0 (0)	0 (0)	0 (0)
Oligochaeta		34 (19)	140 (45)	509 (161)	53 (26)	4 (2)	44 (23)	16 (11)	14 (8)	18 (9)	4 (2)
Simulids		8 (6)	0 (0)	5 (5)	6 (5)	92 (44)	35 (13)	5 (5)	30 (9)	30 (10)	37 (9)
Chironomids		14335 (3440)	3444 (1359)	1687 (422)	1774 (766)	156 (58)	585 (186)	32 (14)	111 (39)	44 (15)	163 (61)
Other macroinvertebrates		934 (396)	603 (265)	893 (288)	176 (65)	50 (19)	134 (64)	16 (11)	58 (42)	0 (0)	53 (42)
Gastropods		0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
New Zealand Mudsnails		1114 (298)	1282 (305)	1761 (346)	660 (145)	46 (22)	90 (39)	48 (21)	153 (70)	7 (4)	11 (4)