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San Joaquin River
Up-Stream DO TMDL Project
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Task: 9

Deliverable Title: An Analysis Of Grazing And Phytoplankton Communities In The Lower San Joaquin River Above The Stockton Deep Water Ship Channel

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Abstract

As part of a larger study investigating algal dynamics in the San Joaquin River, an analysis of zooplankton and phytoplankton was coordinated with a dye monitoring study during the summers of 2005, 2006, and 2007. During low-flow conditions of 2007, organisms were sampled longitudinally along the river. In 2005, bivalves were also sampled and identified in the study reach. The study reach is a tidal freshwater river spanning 30 miles above the Stockton Deep Water Ship Channel (DWSC). Rotifera comprised the most diverse group with 42 species. Rotifer diversity over the study reach varied greatly with several species exhibiting site preferences. Copepoda followed rotifers in diversity however their biomass was generally higher, especially downstream. Approximately four species of copepods occur; all three major orders are represented. The introduced *Pseudodiaptomus forbesi* was the dominant copepod. Nauplii occur throughout the reach, their numbers increasing downstream. Cladocera are represented by six species, but abundance is low and distribution inconsistent. Peaks in zooplankton biomass occurred sporadically over the study period: in 2005 peaks occurred about 15 miles above the DWSC; in 2006 they occur in the five mile reach above the DWSC. In 2006, peaks are strongly correlated with reversal in flow during flood tides. In August and September 2005 and July and August 2006 zooplankton biomass peaked during night hours. The DWSC maintained a considerably higher biomass than other sites in half of the sample periods. In 2007, net zero flows occurred after the June monitoring. Samples taken in June 2007 showed very high zooplankton levels in the DWSC, but during July, August and September the numbers fell off and peaks occurred 5 – 10 miles above the DWSC and moved longitudinally with the tidal flow. During periods of low flow, a single large zooplankton peak occurs at either river mile 48 or 50. Plots of zooplankton density or biomass with total photosynthetic pigment concentration consistently shows a negative relationship, with pigment generally falling off in the DWSC with zooplankton numbers on the increase. These data suggest that algal dynamics are controlled, in part, by zooplankton grazing. During low flow periods, algal peaks are generally a few miles upstream of the zooplankton peak.

Introduction

The purpose of this task is to investigate the ecological causes for chlorophyll reduction in the San Joaquin River (SJR) between Vernalis and the DWSC, and diel chlorophyll fluctuations. Data from Task 8 indicate that chlorophyll a levels tend to decrease from Mossdale to the DWSC. This pattern is variable from month to month however a trend does exist. To understand this pattern requires an understanding of the abiotic and biotic factors that influence algal population levels. This is difficult in that the segment of the SJR under investigation has a complex flow regime because the reach above Mossdale is not tidally influenced, whereas below Mossdale the river becomes increasingly more tidal, with flow reversals of several miles possible in the lower reach. One effect of this reversal is to pull components of the biotic community present in the DWSC into the upstream areas of the river. Algae, which are likely well mixed throughout the water column during downstream water flow, probably settle during periods of tidal slowing of flow and tidal reversal. Turbidity, which is usually high in the river, and has a shading effect on the algae (Welch, 1952) and therefore likely influences its growth, is also affected by the tidal dynamics. Reductions in turbidity during tidal slowing of flow and reversals is apparent in field observations and in the amount of sediment captured during zooplankton trapping. Another factor in the complexity of this reach is that water depth gradually increases downstream, which likely further reduces availability of light for algae. The settling effect in deeper water could be a significant factor on the growth and size of algal populations, however this effect is not clearly understood. Other factors that could influence algal populations include side-water areas of low flow which could serve as algal breeding grounds, tributary inputs such as French Camp Slough, and outfall pipes for storm water and other discharges, and zooplankton grazing.

The major biotic factor influencing algal standing crop and rate of production is grazing by zooplankton, which is typically described as a producer and consumer relationship (Reid, 1961; Ruttner, 1963). The present investigation seeks to describe the abundance and diversity of zooplankton in the study reach to better understand the effect of grazing on the algal population. Another potentially significant source of grazing is by benthic macroinvertebrates, especially bivalve mollusks. It has been shown that an introduced clam in the San Francisco Bay is the cause of chlorophyll and zooplankton decline (Kimmerer et al., 1994). Therefore, an assessment of the bivalve community is another objective of this study.

The standard method to assess zooplankton in surface water is to collect samples and identify organisms using microscopic analysis. Although this method is invaluable, it is time consuming and requires expert knowledge to identify and separate zooplankton.

Phospholipids, which are the one of the principal chemical constituents of the membrane, can be extracted and used as biomarkers, or specific chemical signatures for a microbial species. They also can be used to estimate biomass. All organisms have a membrane that interfaces with the surrounding environment. The structure and chemical composition of the membrane depends primarily on the microorganism type, age, and environmental conditions. Phospholipid biomarkers have traditionally been used to understand community structure of both bacteria and algae (Napolitano, Pollero et al. 1997; Parrish, Abrajano et al. 2000). However, zooplankton also contains PLFA, from internal cell wall construction and also from algae that was consumed (Desvilettes, Bourdier et al. 1997; Muller-Solger, Jassby et al. 2002).

Some of the lipids from algae are considered essential fatty acids, necessary for zooplankton growth, reproduction, and buoyancy. Lipid dynamics in aquatic ecosystems is driven by the production of these essential fatty acids by the phototrophic organisms (e.g. algae) which are consumed and converted by animal species(Muller-Navarra, Brett et al. 2000; Muller-Navarra, Brett et al. 2003). One of the key lipids, 20:5w3, is a twenty carbon fatty acid with 5 double bonds, also referred to as a poly unsaturated fatty acid (PUFA). This essential fatty acid is synthesized by diatoms and a preferred food to many grazers (Galois, Richard et al. 1996). Therefore the production and loss of certain fatty acids extracted from the water column can give information about zooplankton growth and grazing (Desvilettes, Bourdier et al. 1997).

In this report, lipid analysis is explored as a secondary method for assessing zooplankton biomass. Samples were collected during a float test on the San Joaquin River (SJR) between Mossdale and the Stockton deep water ship channel (DWSC). This section of the SJR is tidal, and samples were collected by placing fluorescent dye in the river and sampling and following this parcel of water until reaching the DWSC. Samples were collected every three hours with a total sampling time of approximately 72 hours, depending on the river flow.

Samples were collected using a zooplankton trap and lipids were analyzed from the bulk sample. To investigate the use of lipid to identify zooplankton, both the whole water and zooplankton sample were extracted and recovered lipids were identified. Recovered lipid peaks from the analysis were correlated to counts from a parallel zooplankton sample that was counted using the traditional counting methods. The results show that eicospentanoic acid, EPA, 20:5w3, an essential fatty acid manufactured primarily by diatoms, is correlated with zooplankton (r^2 = 0.8104). Two other lipids, another 20 carbon lipid with one double bond, 20:1, was correlated with the rotifer density (r^2 = 0.7225) and an unknown lipid of similar molecular weight was correlated with copepod density (r^2 = 0.8040). These lipids could be used in unknown samples to estimate zooplankton biomass.

Field activities of Task 9 will coincide with the dye study of Task 8, providing correlation of biological and water quality data.

Materials and Methods

Plankton sampling dates, locations:

Approximate locations of sample sites can be seen in Figures 1 and 2 in combination with Tables 1, 2, 3 and 4. Unless otherwise noted, zooplankton samples were taken at mid-depth. For Lagrangian sampling, SJR numbers are in time series, and do not refer to specific locations across sampling periods.

13-14 July 2005 sampling: the first data collection event, originally scheduled in June, was delayed until mid-July due to very high flows. For this event, eleven sites were sampled, named SJR1 through SJR12 (Figure 1). Zooplankton sample SJR9 does not exist as the sample was lost. All sites except SJR7 and SJR8 were taken in the dyed water mass of task 8. Sampling times are shown in the figure, and span day and night hours.

16-18 August 2005 sampling: for this event, eighteen sites were sampled, named SJR1 through SJR18 (Figure 1). All samples were taken in the dyed water mass of task 8.

15-17 September 2005 sampling: for this event, 15 sites were sampled, named SJR1 through 23 (Figure 1). All samples were taken in the dyed water mass except for SJR8-

10 and SJR16-20, which were taken at fixed positions for several hours using an Isco portable sampler (Teledyne Isco, Inc.).

13-14 October 2005 sampling: for this event, 12 sites were sampled, named SJR1 through 12, and ISCO7 through 9 (Figure 1). All samples were taken in the dyed water mass except ISCO 7 through 9, which were sampled with a portable sampler as in September.

19-21 July 2006 sampling: for this event, 17 sites were sampled, named SJR1 through 15, and the mouth of French Camp Slough and the Turning Basin of the DWSC (Figure 1). All samples were taken in the dyed water mass except French Camp Slough and the Turning Basin. Sampling at several depths occurred with SJR8 (4 depths), SJR13 (3 depths), SJR15 (2 depths), French Camp Slough (2 depths), and the Turning Basin (2 depths).

9-10 August 2006 sampling: for this event, 13 sites were sampled, named SJR1 through 13 (Figure 1). All samples were taken in the dyed water mass. At each site, samples were taken at the bottom, mid-depth, surface or edge.

12-15 June 2007 sampling: for this event, 27 sites were sampled, which included 23 regular sample locations and three "hole" locations, that is, special sites where a deep depression occurred in the river (Figures 1 and 2). Sampling in these holes took place at bottom, mid-depth, and surface depths, except at site Hole5, where depths were sampled. A depth profile also occurred at site SJR7, where bottom, mid-depth, and surface depths were sampled. In two locations, one of which was a regular sample site (SJR12), effect of sun-lit vs. shady habitat was investigated. At river mile 43.29, only sun vs. shade samples were taken. At SJR12 (river mile 47.09), both a regular sample was taken and sun vs. shade samples. Sun vs. shade samples were taken near the bank with the sampler dropped into shaded water or sun-lit water. Regular samples were taken at mid-depth.

17 July 2007 sampling: for this event, a longitudinal profile was taken starting at Navigation light 48 in the DWSC and ending at the Head of Old River (river mile 53.4), yielding 9 samples taken at two mile intervals (Figures 1 and 2). The transect took place during Low-Low tidal conditions during the day.

24 July 2007 sampling: for this event, a longitudinal profile was taken starting at Navigation light 48 in the DWSC and ending at Mossdale (river mile 56.8), yielding 11 samples per transect (Figures 1 and 2). Sampling took place at 2 mile intervals, and the transect took place at slack tide under High-High and Low-Low tidal conditions. The slack conditions in the DWSC where followed up river as the slack progressed upstream, providing near slack conditions at all sample sites. High-High sampling took place at night, and Low-Low during day.

14-15 August 2007 sampling: for this event, a longitudinal profile was taken, as in the 24 July 2007 sampling. In this period, four tidal events were sampled: Low-High at night, High-Low at night, High-High at day, and Low-Low at day.

23 August 2007 sampling: for this event, a longitudinal profile was taken starting at Navigation light 48 in the DWSC and ending at Mossdale (river mile 56.8), yielding 11 samples taken at two mile intervals (Figures 1 and 2). The transect took place during Low-Low tidal conditions during the day.

6 September 2007 sampling: for this event, a longitudinal profile was taken during Low-Low tide during the day, from river mile 34 near Fourteen Mile Slough in the DWSC to Mossdale (river mile 56.8), yielding 17 samples (Figures 1 and 2).

19-20 September 2007 sampling: for this event, a longitudinal profile was taken during High-High tide during the night from river mile 34 to Mossdale (river mile 56.8). Another transect was taken during Low-Low tide during day, from river mile 40 to Mossdale (Figures 1 and 2). Twenty-three samples were taken.

Benthic macroinvertebrate sampling dates, locations:

Sampling of benthic organisms occurred in 2005 at the following dates and locations:

- 24 May, entrance to Burns Cutoff
- 27 June, Stockton Brick Company, entrance to French Camp Slough
- 1 July, Head of Old River, DWR station
- 13 July, many locations from Vernalis to Burns Cutoff
- 28 July, between Vernalis and Mossdale
- 17 August, approx. 2 mi N of Dos Reis Park dock.
- 15 September, approx. 4 mi S of Mossdale
- 16 September, approx. 4.5 mi N of Mossdale
- 13 October, from Vernalis bridge to 1 mi N of bridge
- 14 October, approx. 4 mi S of DWSC to the DWSC, including all of Burns Cutoff and French Camp Slough

Plankton sampling and preservation:

Phytoplankton were collected by sampling whole water and preserving in Lugol's solution. Zooplankton are collected with a 30 L Schindler-Patalas Trap fitted with a 63 um net (Wildlife Supply Company, Buffalo, NY). Using a power winch, the trap is lowered into the water column to approximately one-half depth or to specific depths depending on the site and date. The 30 L sample is taken at the point in the water column where the trap is pulled upward. The samples are preserved in buffered formalin sucrose (5% final concentration).

In September and October 2005, several samples were taken using a portable Isco sampler. The sampler was fitted with 24 1-liter bottles. Zooplankton volumes varied with the time and location. The date, sites, and volumes sampled (liters) were as follows: 9/16/05, SJR7, 3; 9/16/05, SJR8, 4; 9/16/05, SJR9, 5; 9/16/05, SJR10, 5; 9/17/05, SJR15, 2; 9/17/05, SJR16, 3; 9/17/05, SJR17, 3; 9/17/05, SJR18, 3; 9/17/05, SJR19, 3; 9/17/05, SJR20, 2; 10/14/05, ISCO7, 6; 10/14/05, ISCO8, 6; 10/14/05, ISCO9, 6.

Benthic sampling involved different methods for mid-channel and near-bank locations. A winch-mounted standard Ponar dredge with an 8 L capacity (Wildlife Supply Company, Buffalo, NY) is used to take mid-channel samples. Dredge contents are rinsed into a bucket, mixed with water, and poured into a 500 um mesh sorting frame. A stream of water is used to rinse away all fine sediments. The remaining material is transferred into a 500 mL bottle with buffered formalin sucrose (5% final concentration). For near-bank sampling, hand-digging is performed down to approximately 30 cm depth. Bivalves are placed in 37% buffered formalin for preservation.

Plankton concentration and analysis:

Phytoplankton analysis follows U.S. EPA LG401 with modifications. Briefly, samples taken in July and August 2005 were settled in a settling apparatus (Standard Utermohl Chamber, Aquatic Research Instruments, Lemhi ID) prior to microscopic analysis. For samples collected in September and October 2005 and in 2006, 2 mL of well mixed sample was filtered through 1 µm Nuclepore filters (Whatman), and the filters were then inverted on microscope slides and frozen. Frozen filters were peeled off of the slides, thereby transferring the sample to the slide. Phytoplankton were then mounted in 50% glycerol and examined under fluorescence microscopy to reveal phytoplankton (Hewes and Holm-Hansen, 1983).

Zooplankton analysis follows U.S. EPA LG403. Briefly, zooplankton samples are thoroughly mixed by inversion and a 5 - 20 mL subsample is taken from each using a Stempel pipette (volume adjusted for sediment amount in sample). The subsamples are added to a settling apparatus, and settled for 5 – 20 hrs depending on volume. Prior to settling, 100 uL of 1% rose Bengal dye is added to facilitate counting of zooplankton.

Examination of phytoplankton took place with a Leica DM-IRE inverted fluorescence microscope, and examination of zooplankton took place with a Leica DM-IL inverted microscope fitted with a Canon 350D digital camera. Identification of species follows standard texts (Balcer et al. 1984; Chengalath et al. 1971; Pennak 1989; Pontin 1978; Prescott 1951; Smith 1950; Wallace 1991; Wehr and Sheath 2002). All species encountered are photo- and specimen-vouchered, and all counted samples are stored for future reference.

For phytoplankton counts on the settled samples, enough 0.25 mm^2 fields were examined to count at least 400 natural counting units. For the filtered samples, a single 22 mm long x 0.1 mm wide strip was examined. Biovolume estimates were calculated with formulae contained in U.S. EPA LG403. For 2005, 2006, and 12-15 June 2007 zooplankton counts, the entire chamber floor is examined. For biomass estimates, body measurements are taken from a maximum of twenty individuals of each species using a calibrated ocular Whipple Grid. Conversion of body measurements into biomass follows U.S. EPA publication LG403. Following publication L403, a minimum of 200 individual organisms are counted for each sample. To encounter that many individuals requires the settling of up to 450 mL of sample volume, depending on the amount of sediment in the samples. For 24 July 2007 and 14-15 August 2007 samples, 1 mL of sample was settled and organisms were counted and assigned to rotifer, copepod, and cladoceran groups. Biomass for each group was estimated from mean biomass values averaged over all of 2005, 2006, and 12-15 June 2007 data. For 17 July 2007, 23 August 2007, 6 September 2007, and 19-20 September 2007 samples, 10 mL of sample was settled and the full species identification and biomass estimates were performed.

Benthic macroinvertebrate species identifications:

Bivalve mollusks are identified using standard texts (Burch 1972, 1973).

PLFA sampling and analysis:

The lipid study included samples collected in the SJR on four sampling events: September 15, 2005, July 19, 2006, August 9, 2006, July 14, 2007. Samples from the SJR were collected using a 30 liter zooplankton sampler (Schindler-Patalas Plankton Trap from Wildlife Supply Company, New York, NY). The water trapped by the sampler is passed through 63 um filter. All particulate matter, which contains zooplankton and other organic debris, was rinsed from the filter, placed in a HDPE bottle, and preserved with 3% formalin until analysis.

To extract PLFA from the sample, the sample was filtered through a Whatman GF/F glass fiber filter. After filtration, the filter is placed in a 25 mm glass tube and stored at -20°C until extraction. The total lipids were extracted from the filter with a modified Bligh-Dyer solution which consists of 5 ml of chloroform, 10 ml of methanol, and 4 ml of phosphate buffer. The extract is used to estimate chlorophyll concentration by measuring absorbance at 435 and 665 nm on a UV/Vis spectrometer. The phospholipids are methylated and subsequently analyzed on an Agilent 6890N Gas Chromatograph (GC) equipped with a Flame Ionization Detector. Peak confirmation is accomplished on an Agilent 5972A mass spectrometer and double bond position confirmed with a dimethyl disulfide derivation. Peak quantification was accomplished by use of an internal 19:0 phospholipid standard (1,2-Dinonadecanoyl-sn-Glycero-3-phophocholine) (Avanti, Alabaster, AL) which is added immediately prior to extraction, and an external 11:0 carbon fatty acid methyl ester standard (methyl decanoate) (Matreya, Pleasant Gap, GA) which is added immediately before analysis on the GC. (Nichols, Guckert et al. 1986; White and Ringelberg 1998)

Lipids classes recovered from the samples were assigned to different groups of organisms. Fatty acids can be characterized by the shorthand X:YwZ, where X equals the number of carbon atoms, Y equals the number of double bonds, and Z equals the position of the first double bond counting from the methyl end (White and Ringelberg 1998; Brepohl 2005). In Table 5 are listed several sources in the literature that identify specific lipids for various types of algae.

Results

Zooplankton microscopic analysis:

Table 6 lists the zooplankton taxa identified in the six sampling periods. Zooplankton consist of rotifers, cladocerans, and copepods, both as nauplii (larvae) and adults. These taxa are common constituents of the limnetic environment in rivers (Reid, 1961; Wetzel 1983). In general, the data indicate that rotifers are common throughout the study reach however their biomass is low in comparison to non-rotifer animals. Dominant rotifer taxa shift across months. Three species of Copepoda occur in the river, where two are planktonic and one largely benthic. The benthic species (Harpacticoida) was probably trapped by the plankton sampler because suspension of sediments by high water flow places benthic forms into the water column. The two planktonic species occur in patches, often with large populations.

Copepods are usually most abundant in the lower half of the study reach (Tables 7 – 20, Figures 3 – 16). In general, the alien copepod *Pseudodiaptomus forbesii* (pforb) occurs largely in downstream areas, and the native species *Microcyclops rubellus* (mrubel) generally occurs further upriver, although the two species can overlap their distributions greatly in certain months. In July 2005, pforb was absent from the study reach, with mrubel occurring largely in the downstream half of the reach. In August 2005, pforb occupied most downstream sites below the Head of Old River and mrubel occupied the upstream half of the reach, with co-occurrence in the upstream sites SJR2 and Dos Reis Dock. In September 2005, the pattern was similar to August 2005 however mrubel had shifted downstream as far as SJR14 (just upstream of Garwood Bridge), where it co-occurred with pforb. Below SJR14 only pforb was present. In October 2005, the two species only co-occur at SJR10 (near Stockton Brick Company Stack), with mrubel common in sites upstream and with pforb only occurring at SJR10 and SJR5 (near Mossdale). In July 2006, mrubel was absent from the reach, and pforb occupied most downstream sites below Brandt Bridge. In that month, depth profiling showed that the highest biomass of copepods was near the bottom. In August 2006, the two species were very mixed among sites, with co-occurrence at four sites (SJR7, SJR8, SJR9, and SJR11), although pforb dominated near the DWSC and mrubel was the sole species at the most upstream site. Depth profiling in August 2006 showed that highest copepod biomass was at the bottom in the upstream sites, then more downstream the pattern shifts to mid- or surface depths harboring the most copepods.

Copepod larvae (nauplii) are usually widespread in the river and their density generally increases with water age. Cladocerans are less abundant than either rotifers or copepods, and their distribution is usually patchy, although the pelagic *Bosmina longirostris* is widespread in the river. The other cladoceran species are largely confined to the DWSC or to littoral areas scattered throughout the reach.

Figures 3 – 16 show the relationship between zooplankton biomass and total photosynthetic pigment over all sampling periods and sites. In general, zooplankton biomass increases with the age of the water, with the highest levels generally occurring between the Stockton Wastewater Treatment Facility outfall pipe and the DWSC. Also, zooplankton tend to increase during night hours, and in 2006 this increase is usually associated with tidal reversal. Large zooplankton populations are also commonly seen near Mossdale. Above Mossdale, rotifers generally dominate the fauna.

In all sampling periods where night and day were sampled, except July and October 2005, there are population spikes in zooplankton during night hours, with subsequent sharp population decreases. Population spikes in general are associated with particular areas of the reach, especially the vicinity of Mossdale and the Wastewater Outfall and DWSC. In half of the sample periods, the DWSC maintains a very high biomass of zooplankton, with several species characteristic of that site. The highest biomass seen in the study, 414 ug/L, occurred at mid-depth of the DWSC in June 2007. In July 2006 the Turning Basin and French Camp Slough were sampled. They are most similar in zooplankton diversity and abundance to the other sites closest to them. The Turning Basin maintains the second highest level of organisms seen in the study, with a biomass of 282 ug/L at the bottom in July 2006.

Relationship to pigment concentration is varied with the month. In some periods little relationship is seen, and in others the correlation is strongly positive or negative depending on the position along the reach. There are instances where a negative correlation occurs in the upper reach and then a strongly positive correlation downstream, or the reverse relationship. In general, however, the relationship is negative especially in the vicinity of the DWSC.

In July and August 2006, and in June 2007, many sites were sampled at two or three depths. Collectively for all zooplankton, biomass generally differs by depth, with the highest biomass usually occurring at mid-depth. Samples taken along the edge of the channel had the lowest biomass.

Benthic macroinvertebrates:

Three species of bivalve mollusks have been found. Two native clams, *Anodonta* sp. (California Floater) and *Pisidium* sp. (Pea Mussel), and one introduced clam, *Corbicula fluminea* (Asian Clam), are found discontinuously throughout the river. Anodonta and Corbicula are in highly clustered positions, largely in shallow water near the banks. Pisidium has only been found in the mid-channel position. In general, density of these organisms is extremely low and the exact density and distribution is not known. Future work will improve our understanding of their importance in grazing. Figure 18 provides a summary of the species present at various locations in the river.

Phytoplankton analysis:

Tables 21 – 26 and Figures 17 – 22 show phytoplankton data from the microscopic analysis. In general, the patterns are similar to the pigment patterns revealed in Task 8. The trend is generally one of a decrease in algae as the water moves into the DWSC.

There are often erratic biovolume peaks upstream. It can be seen in the figures that as phytoplankton falls off near the DWSC, zooplankton generally show a marked increase.

PLFA results:

Biomass composition from whole water sample

Using the lipids as described in Table 5 the algal community composition of the algae in the parcel of water that was followed down the river was determined. For three of sampling dates the community was dominated by lipids that are produced by diatom algae (Figure 24), which is consistent with previous monitoring on this section of the river (Lehman 2001; Lehman, Sevier et al. 2004; IEP 2006). For the 2005 sampling date there was a large population of green algae and terrestrial derived biomass. Each of the sampling event occurred in different months, so causes between variations in the composition between sampling could either be seasonal or due to the different flow regimes. 2005 was a moderate flow year, 2006 was a high flow year and 2007 was a relatively low flow year. During sampling SJR flows at Mossdale were 2400 cfs for 9/15/05, flows for 7/19/096 and 8/9/06 sampling dates were both around 3200 cfs, while the flow during the 6/14/07 was around 1350 cfs.

The total biomass (algal, bacterial, terrestrial) as determined by total lipid recovery is shown in Figure 25 for each sampling event. The total lipids show some oscillation due to diurnal cycling, and a sharp decline in total biomass as the water enters the DWSC.

Zooplankton Trap sample

The zooplankton trap sample taken from this section of the river shows a high concentration of EPA. As stated above EPA is the main biomarker lipid found in diatoms and is an essential fatty acid required by zooplankton for growth. Since the zooplankton in the SJR feed on algae, this lipid can be used to quantify zooplankton biomass. Figure 26 shows the correlation ($r^2 = 0.8104$) between EPA (20:5w3) extracted from the zooplankton sample and the total zooplankton mass quantified by standard methods. In contrast the correlation between total zooplankton plankton mass and EPA recovered from a whole water sample shows a negative correlation between EPA and zooplankton, indicating that the presence of zooplankton reduces the algae biomass in the whole water (data not shown). However, there are some samples that have both low zooplankton and low algae indicating there may be other factors that reduce algae biomass in addition to zooplankton grazing.

For rotifer mass, the best fit was found with the lipid 20:1 (retention time 36.6 minutes). This lipid has unknown function, but may be a metabolite of 20:5w3 (EPA) (Figure 27). Copepods demonstrated the best correlation with a lipid peak with retention time 45.4 minutes, which has been identified as squalene. However, the correlation plot shows that this positive correlation is predominantly driven by a high level of copepods in one sample, as most of the samples have low counts. Subsequent analysis on other zooplankton samples has shown that this is not a good biomarker for copepods. The lipid at retention time 37.9, which has not yet been identified but is an unsaturated 22 carbon lipid, has demonstrated a better correlation with copepod mass. Shown in Figure 28 is a correlation between this biomarker lipid and copepod mass.

Using data from the SJR sampling the following relationships were developed.

$$\text{Zoo}_{\text{total mass}} = 5.06\ (\text{20:5w3 lipid, pm/g}) + 11.0$$

$$\text{Rotifer}_{\text{total mass}} = 12.9\ (\text{20:1 lipid, pm/g}) + 0.215$$

$$\text{Copepod}_{\text{total mass}} = 114.2\ (\text{37.9 lipid, pm/g}) - 8.22$$

These equations were applied to samples collected in the SJR on 8/9/06 and 7/19/06 to see if they predicted observed zooplankton concentrations as measured by standard methods. Figure 29 shows the results of these calculations. For total zooplankton, the 20:5w3 lipid was able to predict both the magnitude of the zooplankton biomass and also closely matched the maximum peaks observed at around 20 hours on 7/19/06 and 32 hours on 8/9/06. The rotifer peak observed in the 2007 samples only was able to predict the approximate magnitude of the rotifer biomass but was not able match the trends observed.

Conclusions

The data strongly indicate that the zooplankton community in the SJR is of normal structure and composition, and that zooplankton biomass increases as the water flows downstream during high to normal flow conditions, and during low flow conditions the zooplankton community is centered at either river mile 50 or 48 and is pushed up or down river by tidal flow. Variation in species composition and biomass varies greatly between sampling periods, and species-specific distributions vary over time, but general trends do exist. Strong peaks in zooplankton abundance occur in some sampling periods, but do not in others. In general, the major contributors to biomass are copepods, and the largest populations of these organisms are seen downstream in the last few miles of the study reach.

The results of this study do not differ markedly from studies of other large river systems. As an example, the zooplankton taxa found in a recent study of the Danube River in Austria (Baranyi et al., 2002) are very similar to those found in the SJR. The Danube supports 43 species of rotifers whereas the SJR supports 42 species with very similar species composition. For copepods, both systems support two major copepod species, although the species identities differ. The major cladocerans in both systems are *Bosmina longirostris* and one *Daphnia* species, with a few other species scattered in various locations, and these few others are in similar or the same taxonomic families. They also found a strong positive correlation between water age (i.e., travel time) and zooplankton biomass, and that rotifer species dominate in younger water and crustaceans (copepods and cladocerans) dominate in older waters. These results are consistent with the concept that rotifers should be better able to dominate younger waters rather than crustaceans because of their shorter development time (Ecker and Walz, 1998; Townsend et al., 1997). Because of their longer development time, crustaceans should dominate in slower, older waters, such as is the case in SJR downstream areas influenced by tides. Furthermore, the influence of the sluggishly-flowing Turning Basin and the DWSC, which support high levels of crustaceans, likely have a biotic influence on the SJR when tides reverse.

Diel vertical migration (DVM) has been studied extensively in the past (Dini and Carpenter, 1992) and is a well known phenomenon that characterizes many crustacean zooplankton species. A typical pattern is for animals to ascend to the surface waters during the night hours to feed, and then to descend to the bottom during the day. It is believed that this behavior is a predator-avoidance mechanism. DVM is known to occur in some species at certain times but not at other times, and other species do not have this behavior. In the present study, the data from August 2006 do indicate a movement of copepods from the bottom to the mid-depths during night hours, however the surface depths do not support the highest biomass. There is, however, a large increase in total non-rotifer biomass during night hours for that sampling period and in July 2006, but that increase is not strongly associated with a vertical movement, with the largest increases occurring in the species pforb at mid- and bottom depths.

Bivalves are present in the river however their abundance is low and their distribution is very patchy. Very little suitable habitat exists in the lower reach for these organisms. There is evidence that high flows scour out the sediments and sweep away these organisms. Until flows subside for long periods it is unlikely that these organisms will contribute significantly to grazing in the study reach.

The PLFA study has had mixed results. It is clear that the lipid quantities do somewhat reflect biomass values derived from the microscopic analysis, however the correspondence is not very high in many samples. There are distinct lipids recovered from zooplankton trap samples that can be correlated to zooplankton biomass. It is suggested that future investigations focus on improving the detection and complete the identification of these lipids. In addition, to test the validity of the method more samples are needed to calibrate the zooplankton – lipid relationships. Suggested future studies should re-analyze the samples after concentration to improve the signal to noise ratio of these peaks and to finalize the lipid identification.

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Table 1: Locations of samples sites studied in 2005. All UTM coordinates are zone 10s.

Date	Site	Time	UTM E	UTM N	River Mile
7/13/05	SJR1	13:00	652223	4173775	68.4
7/13/05	SJR2	15:20	652357	4176211	65.8
7/13/05	SJR3	17:48	650436	4178792	61.4
7/13/05	SJR4	19:55	648967	4181216	58.9
7/13/05	SJR5	23:45	648395	4184400	55.6
7/14/05	SJR6	3:00	647882	4186581	53.1
7/14/05	SJR7	4:55	648577	4188381	51.1
7/14/05	SJR8	8:00	648577	4188381	51.1
7/14/05	SJR9	10:04	646723	4193468	46.6
7/14/05	SJR10	14:05	647255	4196951	44.1
7/14/05	SJR11	16:00	647537	4198421	42.9
7/14/05	SJR12	18:30	645377	4200753	40.6
8/16/05	SJR1	13:00	653188	4171792	71.5
8/16/05	SJR2	15:00	652085	4172472	69.5
8/16/05	SJR3	16:50	652432	4174971	66.8
8/16/05	SJR4	18:40	651433	4175343	64.3
8/16/05	SJR5	20:20	650028	4177294	62.4
8/17/05	SJR6	0:50	649722	4182490	57.6
8/17/05	SJR7	3:30	648977	4183679	56.6
8/17/05	SJR8	5:49	648886	4184477	56
8/17/05	SJR9	9:30	647345	4186006	53.8
8/17/05	SJR10	12:00	648650	4188143	52.2
8/17/05	SJR11	15:00	647925	4191647	48.2
8/17/05	SJR12	17:50	647790	4191657	48.1
8/17/05	SJR13	21:11	646713	4193505	46.7
8/17/05	SJR14	0:00	647144	4195953	44.8
8/18/05	SJR15	7:05	646875	4192940	47
8/18/05	SJR16	9:00	646632	4193209	46.7
8/18/05	SJR17	12:30	647297	4198787	42.6
8/18/05	SJR18	13:55	646203	4201546	39.8

Date	Site	Time	UTM E	UTM N	River Mile
9/15/05	SJR1	9:45	653350	4171894	71.7
9/15/05	SJR2	12:30	652238	4174326	67.9
9/15/05	SJR3	14:30	651580	4175195	64.3
9/15/05	SJR4	17:40	649968	4179550	60.5
9/15/05	SJR5	19:50	649286	4181425	58.6
9/15/05	SJR6	22:50	648974	4183649	56.7
9/16/05	SJR7-10	0 – 6	648938	4184425	56
9/16/05	SJR11	9:07	648719	4187971	52.1
9/16/05	SJR12	13:10	647444	4190427	46.8
9/16/05	SJR13	12:15	646766	4193097	49.3
9/17/05	SJR14	0:45	647272	4198822	43
9/17/05	SJR15-20	2 - 7	647064	4199074	42.4
9/17/05	SJR21	7:56	647256	4197009	44.2
9/17/05	SJR22	11:00	645589	4200326	40.9
9/17/05	SJR23	12:00	646114	4201393	39.9
10/13/05	SJR1	9:35	653019	4171635	71.9
10/13/05	SJR2	12:00	652080	4174114	68.1
10/13/05	SJR3	15:15	650745	4175572	64.3
10/13/05	SJR4	18:45	649518	4179404	60.2
10/13/05	SJR5	22:00	649577	4182750	57.5
10/14/05	SJR6	1:10	648461	4184151	55.8
10/14/05	ISCO 7-9	2-6	648515	4184153	55.8
10/14/05	SJR7	8:05	648579	4188385	51.1
10/14/05	SJR8	11:05	647387	4192136	47.7
10/14/05	SJR9	14:00	646984	4195588	45
10/14/05	SJR10	17:00	646984	4195588	45
10/14/05	SJR11	20:35	647396	4196591	44.1
10/14/05	SJR12	23:55	646036	4201295	40

Table 2: Locations of samples sites studied in 2006. All UTM coordinates are zone 10s.

Date	Site	Time	UTM E	UTM N	River Mile
7/19/06	SJR1	18:05	653006	4171662	71.9
7/19/06	SJR2	21:00	652557	4175246	67.3
7/20/06	SJR3	0:00	650542	4176237	63.3
7/20/06	SJR4	3:00	649110	4180517	59.4
7/20/06	SJR5	6:00	648386	4184288	55.7
7/20/06	SJR6	9:00	648326	4186883	52.7
7/20/06	SJR7	12:35	647562	4190066	49.7
7/20/06	SJR8	15:00	647734	4191731	48.1
7/20/06	SJR9	19:20	646622	4193758	46.3
7/20/06	SJR10	21:00	647380	4196694	44.3
7/21/06	SJR11	0:55	646949	4195392	45.2
7/21/06	SJR12	3:30	646678	4194110	46.1
7/21/06	SJR13	6:50	647426	4196610	44.3
7/21/06	SJR14	9:40	645816	4200353	41.1
7/21/06	FRENCH	8:11	647828	4198268	
7/21/06	DWSC	11:20	646227	4201651	39.7
7/21/06	TURNB	11:40	647900	4201836	

Date	Site	Time	UTM E	UTM N	River Mile
8/9/06	SJR1	8:20	647659	4186161	53.6
8/9/06	SJR2	11:00	648710	4187979	51.3
8/9/06	SJR3	14:00	647588	4192038	47.8
8/9/06	SJR4	15:50	646696	4194301	46
8/9/06	SJR5	17:50	647009	4195250	45.3
8/9/06	SJR6	20:15	647163	4196294	44.6
8/9/06	SJR7	21:55	647274	4197257	43.9
8/9/06	SJR8	23:55	646621	4199980	41.7
8/10/06	SJR9	1:55	645687	4200935	40.3
8/10/06	SJR10	5:35	647101	4199067	42.4
8/10/06	SJR11	7:50	647240	4198922	42.6
8/10/06	SJR12	10:05	645911	4201210	40.1
8/10/06	SJR13	10:50	646213	4201695	39.7

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Table 3: Locations of samples sites studied in June, July, and August 2007. All UTM coordinates are zone 10s.

Date	Site	Time	UTM E	UTM N	River Mile
6/12/07	SJR1	8:39	653041	4171679	71.9
6/12/07	Hole1	10:50	652049	4173919	68.2
6/12/07	SJR2	11:32	652416	4174837	67.6
6/12/07	Hole2	13:30	651781	4175938	65.3
6/12/07	Hole3	14:30	651712	4174959	64.5
6/12/07	SJR4	17:30	650380	4179382	60.9
6/12/07	Hole4	18:05	650176	4179639	60.6
6/12/07	SJR5/ Hole5	18:05	649386	4181998	58.1
6/12/07	SJR6	23:35	649032	4184032	56.5
6/13/07	SJR7	3:15	648366	4184343	55.6
6/13/07	SJR8	6:19	648523	4185059	55.2
6/13/07	SJR9	9:12	647434	4186077	53.8
6/13/07	SJR10	12:20	648578	4188380	51.1
6/13/07	SJR11	15:10	647447	4192108	47.7
6/13/07	SJR12	18:10	646942	4192757	47.1
6/13/07	SJR13	21:10	646860	4193016	46.9
6/14/07	SJR14	0:20	647174	4196130	44.7
6/14/07	SJR15	3:10	646660	4193612	46.4
6/14/07	SJR16	6:15	647582	4190676	49.1
6/14/07	SJR17	9:14	647465	4192091	47.7
6/14/07	SJR18	12:07	647253	4196894	44.1
6/14/07	SJR19	15:08	646976	4199377	42.2
6/14/07	SJR20	18:15	647717	4198158	43.2
6/14/07	sunshd	20:05	647577	4198066	43.3
6/14/07	SJR21	21:09	647312	4197428	43.8
6/15/07	SJR22	0:10	646290	4200250	41.4
6/15/07	SJR23	1:54	646123	4201377	39.9

24 July 2007					
Site	UTM E	UTM N	River Mile	Time Run1	Time Run2
LT48	646169	4201742	39.6	1:30	10:30
RM40	646033	4201268	40		10:50
RM42	646973	4199391	42	2:30	11:00
RM44	647385	4196702	44	2:55	11:15
RM46	646658	4193939	46	3:10	11:30
RM48	647894	4191666	48	3:30	11:50
RM50	648044	4189342	50	3:50	12:10
RM52	648059	4187020	52	4:05	12:25
HOR	647270	4185829	53.4	4:20	12:45
RM56	648983	4183749	56		13:05
MSD	649043	4183441	56.2	4:50	13:15

14-15 August 2007					
Site	UTM E	UTM N	River Mile	Time Run1	Time Run2
LT48	646169	4201742	39.6	21:05	1:00
RM40	646033	4201268	40	21:20	1:15
RM42	646973	4199391	42	21:40	1:25
RM44	647385	4196702	44	21:55	1:35
RM46	646658	4193939	46	22:15	1:50
RM48	647894	4191666	48	22:25	2:00
RM50	648044	4189342	50	22:45	2:15
RM52	648059	4187020	52	23:00	2:30
HOR	647270	4185829	53.4	23:20	2:45
RM56	648983	4183749	56	23:30	3:00
MSD	649043	4183441	56.8	23:45	3:10

17 July 2007				
Site	UTM E	UTM N	River Mile	Time Run
LT48	646169	4201742	39.6	15:25
RM40	646033	4201268	40	15:45
RM42	646973	4199391	42	16:00
RM44	647385	4196702	44	16:15
RM46	646658	4193939	46	16:45
RM48	647894	4191666	48	16:50
RM50	648044	4189342	50	17:15
RM52	648059	4187020	52	17:30
HOR	647270	4185829	53.4	17:50

23 Aug 2007				
Site	UTM E	UTM N	River Mile	Time Run
LT48	646169	4201742	39.6	8:45
RM40	646033	4201268	40	9:30
RM42	646973	4199391	42	9:45
RM44	647385	4196702	44	10:15
RM46	646658	4193939	46	10:30
RM48	647894	4191666	48	10:35
RM50	648044	4189342	50	11:00
RM52	648059	4187020	52	11:05
HOR	647270	4185829	53.4	11:30
RM56	648983	4183749	56	11:40
MSD	649043	4183441	56.8	11:45

Table 4: Locations of samples sites studied in September 2007. All UTM coordinates are zone 10s.

6 September 2007				
Site	UTM E	UTM N	River Mile	Time Run
RM34	638801	4206486	34	8:10
RM35	640314	4205898	35	8:35
RM36	641652	4205059	36	8:45
RM37	642685	4204024	37	9:00
RM38	643741	4202871	38	9:10
RM39	645122	4202109	39	9:15
LT48	646169	4201742	39.6	9:15
RM40	646033	4201268	40	9:40
RM42	646973	4199391	42	9:50
RM44	647385	4196702	44	10:00
RM46	646658	4193939	46	10:10
RM48	647894	4191666	48	10:20
RM50	648044	4189342	50	10:30
RM52	648059	4187020	52	10:45
HOR	647270	4185829	53.4	11:00
RM56	648983	4183749	56	11:10
MSD	649043	4183441	56.8	11:20

19-20 September 2007					
Site	UTM E	UTM N	River Mile	Time Run1	Time Run2
RM34	638801	4206486	34	21:20	
RM36	641652	4205059	36	21:45	
RM38	643741	4202871	38	22:15	
RM40	646033	4201268	40	22:50	8:00
RM42	646973	4199391	42	23:15	8:30
RM44	647385	4196702	44	23:30	8:30
RM46	646658	4193939	46	23:45	8:50
RM48	647894	4191666	48	0:15	9:05
RM50	648044	4189342	50	0:30	9:25
RM52	648059	4187020	52	0:55	9:45
HOR	647270	4185829	53.4	1:15	10:00
RM56	648983	4183749	56	1:30	10:20
MSD	649043	4183441	56.8	1:45	10:30

Table 5: Identification of Lipid biomarkers used for community composition

Algal type	Biomarker/characteristic Fatty acid	References
Diatoms	16:3w3 20:5w3 (EPA, eicosapentaenoic acid)	(Galois, Richard et al. 1996; Desvilettes, Bourdier et al. 1997; Parrish 1998; Pond, Bellb et al. 1998; Parrish, Abrajano et al. 2000; Muller-Solger, Jassby et al. 2002; Boschker, Kromkamp et al. 2005; Brepohl 2005)
Dinoflagellates	22:6w3 (DHA, docosahexaenoic acid)	(Galois, Richard et al. 1996; Desvilettes, Bourdier et al. 1997; Parrish, Abrajano et al. 2000; Brepohl 2005)
Green Algae	18:3w3 (ALA, α-linolenic acid)	(Naploitano 1994; Napolitano, Polerro et al. 1997)
Bacteria	i15:0 a15:0	(Desvilettes, Bourdier et al. 1997; Parrish, Abrajano et al. 2000; Boschker, Kromkamp et al. 2005)
Terrestrial	25:0 26:0	(Galois, Richard et al. 1996; Napolitano, Polerro et al. 1997)

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Table 6: Zooplankton taxa identified and enumerated.

ROTIFERA
Asplanchnidae
Asplanchna priodonta Gosse, 1850
Asplanchnopus multiceps (Schrank, 1793)

Brachionidae
Anuraeopsis fissa (Gosse, 1851)
Brachionus angularis Gosse, 1851
B. budapestinensis Daday, 1885
B. calyciflorus Pallas, 1776
B. caudatus Barrois & Daday, 1894
B. havanaensis Rousselet, 1911
B. quadridentatus Hermann, 1783
B. rubens Ehrenberg, 1838
B. urceolaris Müller, 1773
Kellicottia longispina (Kellicott, 1879)
Keratella cochlearis (Gosse, 1851)
K. tropica (Apstein, 1907)
Notholca acuminata (Ehrenberg, 1832)
Platyias quadricornis (Ehrenberg, 1832)

Collothecidae
Collotheca pelagica (Rousselet, 1893)

Conochilidae
Conochilus dossuarius (Hudson, 1875)
Conochilus hippocrepis (Schrank, 1830)

Epiphanidae
Epiphanes senta (Müller, 1773)

Euchlanidae
Euchlanis dilatata Ehrenberg, 1832

Filiniidae
Filinia longiseta (Ehrenberg, 1834)

Gastropodidae
Ascomorpha saltans Bartsch, 1870

Hexarthridae
Hexarthra mira (Hudson, 1871)

Lecanidae
L. bulla (Gosse, 1851)
L. dysorata Myers, 1942
L. luna (Müller, 1776)
L. quadridentata (Ehrenberg, 1832)

Lepadellidae
Colurella adriatica Ehrenberg, 1831
Lepadella ovalis (Müller, 1786)
Squatinella mutica (Ehrenberg, 1832)

Mytilinidae
Lophocharis salpina (Ehrenberg, 1834)

Notommatidae
Cephalodella gibba (Ehrenberg, 1832)
Unidentified *Notomatta*

Synchaetidae
Ploesoma truncatum (Levander, 1894)
Polyarthra remata (Skorikov, 1896)
Synchaeta longipes Gosse, 1887

Testudinellidae
Pompholyx sulcata (Hudson, 1885)
Testudinella patina (Hermann, 1783)

Trichocercidae
Trichocerca similis (Wierzejski, 1893)
T. rousseleti (Voigt, 1901)

Trichotriidae
Trichotria longipedis Myers, 1942

CLADOCERA
Bosminidae
Bosmina longirostris (O. F. Müller, 1776)

Chydoridae
Disparalona dadayi (Birge, 1910)
Monospilus dispar G. O. Sars, 1861

Daphniidae
Ceriodaphnia lacustris Birge, 1893
Daphnia parvula Fordyce, 1901

Macrothricidae
Macrothrix laticornis (Jurine, 1820)

Sididae
Diaphanosoma brachyurum (Liévin, 1848)

COPEPODA
Calanoida: Pseudodiaptomidae
Pseudodiaptomus forbesi (Poppe & Richard, 1890)

Calanoida: Temoridae
Eurytemora affinis (Poppe, 1880)

Cyclopoida: Cyclopidae
Microcyclops rubellus (Lilljeborg, 1901)

Harpacticoida
Unidentified Harpacticoid species

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Table 7: Zooplankton data for July 2005. Density = individuals/L. Biomass = dry weight ug/L.

	Total Zooplankton		Rotifera		Copepoda		Cladocera	
	density	biomass	density	biomass	density	biomass	density	biomass
SJR 1	70.3	4.2	64.4	1.2	5.86	3.07	0.00	0.00
SJR 2	77.9	2.6	74.0	1.1	3.68	1.47	0.28	0.12
SJR 3	64.0	3.0	59.2	1.1	4.88	1.95	0.00	0.00
SJR 4	109.3	4.1	103.5	1.7	5.37	2.15	0.38	0.23
SJR 5	90.9	3.0	87.0	1.4	3.83	1.53	0.00	0.00
SJR 6	92.7	2.7	91.0	1.7	1.72	1.00	0.00	0.00
SJR 7	109.7	5.3	107.3	1.7	2.33	3.61	0.00	0.00
SJR 8	90.7	2.7	88.0	1.7	2.64	1.06	0.00	0.00
SJR 10	32.9	2.2	29.2	0.9	3.70	1.36	0.00	0.00
SJR 11	30.8	1.8	28.4	0.8	2.17	0.80	0.26	0.13
SJR 12	53.5	5.5	44.4	1.9	9.09	3.56	0.00	0.00

Table 8: Zooplankton data for August 2005. Density = individuals/L. Biomass = dry weight ug/L.

	Total Zooplankton		Rotifera		Copepoda		Cladocera	
	density	biomass	density	biomass	density	biomass	density	biomass
SJR 1	48.81	1.71	46.7	0.85	2.14	0.86	0.00	0.00
SJR 2	52.86	2.61	48.6	0.92	4.05	1.63	0.24	0.07
SJR 3	34.39	1.50	31.8	0.51	2.58	0.98	0.00	0.00
SJR 4	38.79	1.64	36.4	0.67	2.42	0.97	0.00	0.00
SJR 5	44.63	1.70	42.4	0.86	2.22	0.84	0.00	0.00
SJR 6	125.71	23.28	79.5	2.74	28.57	10.54	17.62	10.00
SJR 7	66.39	4.37	60.6	1.85	5.00	2.19	0.83	0.33
SJR 8	39.26	2.23	35.7	0.89	3.52	1.34	0.00	0.00
SJR 9	36.30	3.14	30.2	0.73	6.11	2.41	0.00	0.00
SJR 10	56.11	5.00	46.1	1.00	10.00	4.00	0.00	0.00
SJR 11	48.52	8.66	30.4	0.60	17.96	7.74	0.19	0.32
SJR 12	94.00	15.39	59.0	1.42	34.67	13.87	0.33	0.11
SJR 13	48.52	11.72	22.8	0.60	25.74	11.12	0.00	0.00
SJR 14	83.33	43.77	33.7	1.14	49.67	42.63	0.00	0.00
SJR 15	65.24	18.51	26.2	0.75	39.05	17.76	0.00	0.00
SJR 16	89.67	27.37	28.0	0.62	61.67	26.75	0.00	0.00
SJR 17	60.95	14.68	25.2	0.44	35.71	14.24	0.00	0.00
SJR 18	102.33	23.65	47.0	1.52	55.33	22.13	0.00	0.00

Table 9: Zooplankton data for September 2005. Density = individuals/L. Biomass = dry weight ug/L.

	Total Zooplankton		Rotifera		Copepoda		Cladocera	
	density	biomass	density	biomass	density	biomass	density	biomass
SJR1	31.3	2.56	27.2	0.74	3.85	1.70	0.26	0.11
SJR2	24.6	2.05	21.1	0.69	3.33	1.33	0.11	0.03
SJR3	26.0	2.64	21.3	0.75	4.62	1.76	0.13	0.14
SJR4	19.8	1.90	16.7	0.65	3.14	1.25	0.00	0.00
SJR5	29.4	3.29	24.2	1.23	5.14	2.02	0.14	0.03
SJR6	33.6	3.35	27.4	1.04	5.77	2.24	0.38	0.07
SJR7	73.6	4.69	65.0	1.28	8.54	3.41	0.00	0.00
SJR8	66.2	4.05	59.5	1.48	6.76	2.57	0.00	0.00
SJR9	76.3	5.99	70.3	1.46	5.63	2.52	0.31	2.01
SJR10	78.1	4.31	71.9	1.81	6.25	2.50	0.00	0.00
SJR11	30.3	4.33	23.2	0.76	6.79	2.70	0.26	0.87
SJR12	23.0	3.26	16.8	0.57	6.11	2.41	0.08	0.28
SJR13	23.0	4.33	13.0	0.32	9.91	3.95	0.09	0.06
SJR14	11.8	3.91	5.8	0.21	5.92	3.70	0.00	0.00
SJR15	37.2	5.03	26.7	0.81	10.56	4.22	0.00	0.00
SJR16	40.1	7.86	27.8	0.99	12.30	6.87	0.00	0.00
SJR17	40.2	5.75	28.0	0.86	12.20	4.89	0.00	0.00
SJR18	186.4	16.20	161.4	4.12	25.00	12.09	0.00	0.00
SJR19	197.6	14.89	171.4	4.42	26.19	10.48	0.00	0.00
SJR20	131.8	10.39	112.5	2.66	19.32	7.73	0.00	0.00
SJR21	14.4	3.92	5.5	0.15	8.79	3.72	0.06	0.05
SJR22	25.4	6.48	10.1	0.36	15.00	6.01	0.26	0.11
SJR23	51.5	8.38	34.6	1.25	16.48	6.87	0.37	0.27

Table 10: Zooplankton data for October 2005. Density = individuals/L. Biomass = dry weight ug/L.

	Total Zooplankton		Rotifera		Copepoda		Cladocera	
	density	biomass	density	biomass	density	biomass	density	biomass
SJR1	14.3	1.8	10.7	0.2	3.57	1.53	0.12	0.06
SJR2	14.5	2.0	10.1	0.2	4.47	1.72	0.00	0.00
SJR3	16.4	2.2	11.5	0.2	4.80	1.85	0.13	0.10
SJR4	12.7	2.3	7.4	0.2	5.19	2.03	0.12	0.11
SJR5	15.0	2.3	10.8	0.4	4.06	1.76	0.14	0.08
SJR6	40.0	1.9	37.4	0.8	2.41	0.90	0.19	0.22
Isco7	33.5	1.4	31.1	0.5	2.44	0.87	0.00	0.00
Isco8	30.1	1.3	28.0	0.5	2.03	0.81	0.00	0.00
SJR7	55.2	3.4	49.0	1.0	5.95	2.37	0.24	0.08
SJR8	24.7	1.1	22.9	0.4	1.78	0.67	0.00	0.00
SJR9	16.5	0.9	15.1	0.3	1.43	0.59	0.00	0.00
SJR10	9.0	0.5	8.2	0.2	0.77	0.30	0.00	0.00
SJR11	11.0	0.8	9.4	0.2	1.56	0.62	0.00	0.00
SJR12	91.7	7.9	89.0	6.7	2.33	0.93	0.33	0.22

Table 11: Zooplankton data for July 2006. Density = individuals/L. Biomass = dry weight ug/L.

	Total Zooplankton		Rotifera		Copepoda		Cladocera	
	density	biomass	density	biomass	density	biomass	density	biomass
SJR1 3'	223.3	6.38	217.50	3.95	4.17	1.67	1.67	0.76
SJR2 4'	185.0	5.71	182.50	4.83	0.83	0.33	1.67	0.54
SJR3 8'	242.5	5.34	240.83	4.67	1.67	0.67	0.00	0.00
SJR4	270.0	6.40	266.67	5.18	2.50	1.00	0.83	0.21
SJR5	271.7	4.78	270.00	4.11	1.67	0.67	0.00	0.00
SJR6	210.0	4.37	208.33	3.70	1.67	0.67	0.00	0.00
SJR7	342.2	6.71	341.11	6.27	1.11	0.44	0.00	0.00
SJR8surf	361.7	36.25	321.67	5.14	40.00	31.11	0.00	0.00
SJR8mid	398.3	40.07	330.00	5.03	66.67	33.40	1.67	1.64
SJR8bot5'	297.5	55.50	241.67	4.37	55.83	51.13	0.00	0.00
SJR8bot16'	293.3	59.85	242.50	4.85	50.83	54.99	0.00	0.00
SJR9 13'	320.8	45.71	244.17	5.10	76.67	40.61	0.00	0.00
SJR10	370.0	35.22	295.00	5.39	75.00	29.83	0.00	0.00
SJR11	438.9	166.08	270.00	5.65	168.89	160.43	0.00	0.00
SJR12 15'	554.4	154.21	342.22	7.19	212.22	147.02	0.00	0.00
SJR13surf	375.6	48.44	265.56	4.44	110.00	44.00	0.00	0.00
SJR13mid6'	627.8	67.71	478.89	8.16	148.89	59.56	0.00	0.00
SJR13 14'	423.3	41.30	336.67	6.64	86.67	34.67	0.00	0.00
SJR14 20'	515.0	67.08	365.00	7.08	150.00	60.00	0.00	0.00
DWSC surf	900.0	202.94	461.67	19.59	431.67	172.67	6.67	10.68
DWSC 35'	828.3	192.11	435.00	13.52	371.67	167.21	21.67	11.37
TBsurf	1021.7	44.02	963.33	14.17	48.33	19.17	10.00	10.68
TB34'	1215.0	281.65	805.00	31.48	268.33	118.22	141.67	131.95
FCSsurf	289.2	71.9	115.8	2.2	172.5	69.0	0.83	0.70
FCSbot10'	448.3	105.2	195.0	3.9	253.3	101.3	0.00	0.00

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Table 12: Zooplankton data for August 2006. Density = individuals/L. Biomass = dry weight ug/L.

	Total Zooplankton		Rotifera		Copepoda		Cladocera	
	density	biomass	density	biomass	density	biomass	density	biomass
SJR1surf	191.7	8.32	178.33	3.30	12.50	5.00	0.83	0.02
SJR1edge	111.1	6.15	101.67	2.37	9.44	3.78	0.00	0.00
SJR1bot7'	150.6	7.05	141.67	3.13	8.33	3.33	0.56	0.59
SJR2surf	146.7	8.38	132.22	2.74	14.44	5.63	0.00	0.00
SJR2edge	90.4	5.09	82.92	2.09	7.50	3.00	0.00	0.00
SJR2bot7'	168.3	7.80	156.67	3.14	11.67	4.67	0.00	0.00
SJR3surf	157.2	9.12	141.11	2.72	15.56	6.22	0.56	0.18
SJR3edge	105.0	10.70	86.25	2.15	18.75	8.55	0.00	0.00
SJR3bot9'	200.8	13.60	175.83	3.60	25.00	10.00	0.00	0.00
SJR4surf	203.3	11.55	180.83	2.55	22.50	9.00	0.00	0.00
SJR4mid6'	250.0	16.97	220.00	4.54	29.17	11.52	0.83	0.92
SJR4bot12'	180.0	13.78	155.00	2.86	24.17	10.13	0.83	0.79
SJR5surf	265.0	12.97	242.50	3.22	21.67	8.67	0.83	1.09
SJR5mid8'	199.2	12.90	175.00	3.23	24.17	9.67	0.00	0.00
SJR5bot11'	195.8	19.39	160.83	4.51	34.17	13.45	0.83	1.42
SJR6surf	174.2	8.17	162.50	3.50	11.67	4.67	0.00	0.00
SJR6mid10'	275.8	14.63	250.83	4.63	25.00	10.00	0.00	0.00
SJR6bot15'	159.4	9.49	142.78	2.93	16.67	6.56	0.00	0.00
SJR7surf	132.2	9.70	117.22	2.95	15.00	6.75	0.00	0.00
SJR7mid9'	225.8	19.23	192.50	4.38	32.50	14.48	0.83	0.38
SJR7bot14'	249.2	15.63	227.50	5.20	21.67	10.43	0.00	0.00
SJR8surf	166.7	14.96	140.00	3.09	25.83	10.33	0.83	1.54
SJR8mid6'	238.3	23.81	196.67	4.54	41.67	19.28	0.00	0.00
SJR8bot13'	188.3	18.1	151.67	3.43	36.67	14.67	0.00	0.00
SJR9surf	201.7	35.8	159.17	3.95	42.50	31.89	0.00	0.00
SJR9mid8'	240.8	81.55	165.00	3.62	75.83	77.93	0.00	0.00
SJR9bot13'	241.7	41.95	188.33	4.33	53.33	37.62	0.00	0.00
SJR10surf	229.2	47.42	151.67	2.97	77.50	44.45	0.00	0.00
SJR10mid7'	343.3	59.75	220.00	4.40	123.33	55.35	0.00	0.00
SJR10bot13'	297.5	66.11	204.17	3.88	93.33	62.23	0.00	0.00
SJR11surf	244.2	32.69	170.83	3.36	73.33	29.33	0.00	0.00
SJR11mid8'	294.2	39.53	214.17	4.86	80.00	34.68	0.00	0.00
SJR11bot20'	348.3	41.72	260.00	5.90	88.33	35.82	0.00	0.00
SJR12surf	287.5	41.59	207.50	5.50	80.00	36.08	0.00	0.00
SJR12mid12'	380.0	48.96	273.33	6.30	106.67	42.67	0.00	0.00
SJR12bot22'	273.3	33.51	200.00	4.07	73.33	29.43	0.00	0.00
SJR13surf	336.7	26.06	293.33	6.21	41.67	16.67	1.67	3.18
SJR13mid14'	513.3	47.28	421.67	10.01	90.00	35.69	1.67	1.58
SJR13bot32'	400.0	46.61	303.33	7.16	95.00	38.00	1.67	1.45

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Table 13: Zooplankton data for June 2007. Density = individuals/L. Biomass = dry weight ug/L.

	Total Zooplankton		Rotifera		Copepoda		Cladocera	
	density	biomass	density	biomass	density	biomass	density	biomass
S1	40.9	1.46	38.89	0.64	1.85	0.74	0.19	0.08
Hole#1 surf	84.3	3.73	77.67	1.07	6.33	2.53	0.33	0.14
Hole#1 mid7'	137.2	5.15	128.89	1.96	8.33	3.20	0.00	0.00
Hole#1 bot15'	118.3	3.8	112.78	1.75	5.00	1.86	0.56	0.16
S2	95.8	2.6	92.50	1.28	3.33	1.33	0.00	0.00
Hole#2surf	85.8	4.1	80.83	1.56	4.17	2.30	0.83	0.22
Hole#2mid8'	131.7	5.8	122.78	1.99	8.89	3.77	0.00	0.00
Hole#2bot16'	160.0	5.4	154.44	1.99	5.00	1.76	0.56	1.69
Hole#3=S3 surf	85.0	3.4	80.00	1.41	5.00	2.00	0.00	0.00
Hole#3=S3mid12'	120.0	4.2	115.00	1.89	3.89	1.56	1.11	0.77
Hole#3=S3bot23'	148.3	7.1	139.44	3.15	7.78	2.69	1.11	1.24
S4	119.4	3.9	116.67	2.84	2.78	1.11	0.00	0.00
Hole#4 surf	111.1	2.8	107.78	1.43	3.33	1.33	0.00	0.00
Hole#4 mid20'	123.3	6.5	112.78	2.03	10.00	4.07	0.56	0.37
Hole#4 bot40'	152.2	4.6	146.67	2.43	5.56	2.16	0.00	0.00
Hole#5=S5 surf	177.5	5.0	172.50	2.55	5.00	2.41	0.00	0.00
Hole#5=S5 mid19'	164.4	11.9	156.11	2.66	6.11	2.44	2.22	6.84
Hole#5=S5bot36'	164.4	10.5	154.44	2.98	8.89	5.82	1.11	1.65
S6	152.8	8.7	146.11	3.30	6.67	5.36	0.00	0.00
S7 surf	203.3	15.3	190.83	4.47	7.50	4.07	5.00	6.73
S7 mid6'	262.5	24.1	244.17	6.54	10.00	4.08	8.33	13.52
S7 bot12'	176.7	15.9	164.17	4.70	8.33	3.08	4.17	8.15
S8	240.8	37.4	212.50	5.65	16.67	6.40	11.67	25.39
S9	240.0	29.4	217.50	6.67	13.33	8.01	9.17	14.67
S10	216.7	21.0	185.83	4.88	25.83	10.33	5.00	5.80
S11	232.5	32.0	168.33	4.34	63.33	27.64	0.83	0.00
S12_shade	408.9	64.8	314.44	8.47	87.22	38.70	7.22	17.65
S12_sun	290.0	48.0	202.22	5.78	83.89	34.25	3.89	7.98
S13	496.7	78.3	341.67	8.29	151.67	60.16	3.33	9.83
S14	638.3	161.4	383.33	12.02	255.00	149.39	0.00	0.00
S15	528.3	130.5	335.00	12.05	190.00	115.25	3.33	3.15
S16	435.0	173.3	258.33	8.37	168.33	158.09	8.33	6.83
S17	646.7	101.0	436.67	14.93	206.67	82.05	3.33	3.96
S18	701.7	132.8	396.67	10.25	300.00	120.00	5.00	2.53
S19	610.0	133.1	326.67	12.63	280.00	117.35	3.33	3.15
S20	553.3	128.1	363.33	11.81	190.00	116.25	0.00	0.00
Shade_rm43.29	1191.1	242.7	635.56	20.45	554.44	222.03	1.11	0.18
Sun_rm43.29	1416.7	215.2	944.44	22.84	455.56	182.22	16.67	10.10
S21	698.3	100.9	495.00	19.39	201.67	80.14	1.67	1.41
S22	938.3	134.1	651.67	20.50	281.67	110.81	5.00	2.81
S23	1290.0	414.1	498.33	12.72	650.00	305.09	141.67	96.34

Table 14: Zooplankton data for 17 July 2007. Density = individuals/L. Biomass = dry weight ug/L.

	Total Zooplankton		Rotifera		Copepoda		Cladocera	
	density	biomass	density	biomass	density	biomass	density	biomass
Lt48	185.0	40.60	90.00	0.79	90.00	36.69	5.00	3.13
rm40	140.0	47.61	40.00	0.48	95.00	37.83	5.00	9.30
rm42	128.3	38.14	46.67	0.27	75.00	32.44	6.67	5.43
rm44	256.7	66.5	108.33	0.77	146.67	57.62	1.67	8.08
rm46	321.7	75.8	160.00	1.61	161.67	74.14	0.00	0.00
rm48	391.7	112.1	141.67	2.37	245.00	107.78	5.00	1.97
rm50	1100.0	93.5	955.00	28.80	131.67	54.67	13.33	9.98
rm52	623.3	41.0	583.33	15.98	36.67	20.57	3.33	4.49
rm54	741.7	57.6	663.33	20.57	66.67	29.83	11.67	7.25

Table 15: Zooplankton data for 24 July 2007. Density = individuals/L. Biomass = dry weight ug/L.

	Rotifera		Nauplii		Copepoda		Cladocera		Total Zoo
Night	density	biomass	density	biomass	density	biomass	density	biomass	biomass
Lt48	50.0	2.5	16.7	6.7	33.3	43	0.0	0	52.1
Rm40	116.7	5.7	16.7	6.7	33.3	43	0.0	0	55.4
Rm42	100.0	4.9	16.7	6.7	0.0	0	0.0	0	11.6
Rm44	133.3	6.5	33.3	13.3	0.0	0	0.0	0	19.9
Rm46	50.0	2.5	116.7	46.7	0.0	0	0.0	0	49.1
Rm48	150.0	7.4	83.3	33.3	16.7	21.5	0.0	0	62.2
Rm50	816.7	40.0	150.0	60.0	16.7	21.5	0.0	0	121.5
Rm52	2050.0	100.5	166.7	66.7	16.7	21.5	0.0	0	188.6
Rm54	2566.7	125.8	33.3	13.3	0.0	0	0.0	0	139.1
Rm56	983.3	48.2	0.0	0.0	16.7	21.5	0.0	0	69.7
rm56.8	933.3	45.7	33.3	13.3	33.3	43	16.7	30.83	132.9
Day									
Lt48	100.0	4.9	16.7	6.7	16.7	21.5	0.0	0	33.1
rm40	50.0	2.5	100.0	40.0	16.7	21.5	0.0	0	64.0
rm42	83.3	4.1	0.0	0.0	0.0	0	0.0	0	4.1
rm44	383.3	18.8	116.7	46.7	0.0	0	0.0	0	65.5
rm46	1650.0	80.9	200.0	80.0	16.7	21.5	16.7	30.83	213.2
rm48	3233.3	158.4	316.7	126.7	33.3	43	0.0	0	328.1
rm50	1733.3	84.9	116.7	46.7	0.0	0	0.0	0	131.6
rm52	1850.0	90.7	66.7	26.7	0.0	0	0.0	0	117.3
rm54	1666.7	81.7	50.0	20.0	0.0	0	0.0	0	101.7
rm56	866.7	42.5	33.3	13.3	0.0	0	0.0	0	55.8
rm56.8	783.3	38.4	16.7	6.7	16.7	21.5	0.0	0	66.6

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Table 16: Zooplankton data for night samples collected on 14-15 August 2007. Density = individuals/L. Biomass = dry weight ug/L.

Low-High	Rotifera		Nauplii		Copepoda		Cladocera		Total Zoo
Night	density	biomass	density	biomass	density	biomass	density	biomass	biomass
Lt48	166.7	8.2	100.0	40.0	33.3	43	0.0	0	91.2
Rm40	83.3	4.1	66.7	26.7	16.7	21.5	0.0	0	52.3
Rm42	150.0	7.4	66.7	26.7	0.0	0	0.0	0	34.0
Rm44	66.7	3.3	16.7	6.7	16.7	21.5	0.0	0	31.4
Rm46	233.3	11.4	150.0	60.0	33.3	43	16.7	30.8	145.3
Rm48	383.3	18.8	83.3	33.3	83.3	107.5	0.0	0	159.6
Rm50	466.7	22.9	0.0	0.0	0.0	0	0.0	0	22.9
Rm52	1116.7	54.7	50.0	20.0	33.3	43	0.0	0	117.7
Rm54	616.7	30.2	50.0	20.0	0.0	0	0.0	0	50.2
Rm56	300.0	14.7	16.7	6.7	0.0	0	0.0	0	21.4
rm56.8	666.7	32.7	100.0	40.0	0.0	0	0.0	0	72.7
High-Low									
Night									
Lt48	133.3	6.5	33.3	13.3	0.0	0	0.0	0	19.9
rm40	166.7	8.2	50.0	20.0	0.0	0	0.0	0	28.2
rm42	83.3	4.1	50.0	20.0	0.0	0	0.0	0	24.1
rm44	166.7	8.2	33.3	13.3	33.3	43	0.0	0	64.5
rm46	200.0	9.8	100.0	40.0	0.0	0	0.0	0	49.8
rm48	350.0	17.2	33.3	13.3	0.0	0	0.0	0	30.5
rm50	500.0	24.5	66.7	26.7	0.0	0	0.0	0	51.2
rm52	1233.3	60.4	83.3	33.3	16.7	21.5	0.0	0	115.3
rm54	483.3	23.7	16.7	6.7	0.0	0	0.0	0	30.4
rm56	350.0	17.2	16.7	6.7	0.0	0	0.0	0	23.8
rm56.8	483.3	23.7	16.7	6.7	0.0	0	0.0	0	30.4

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Table 17: Zooplankton data for day samples collected on 14-15 August 2007. Density = individuals/L. Biomass = dry weight ug/L.

High-High	Rotifera		Nauplii		Copepoda		Cladocera		Total Zoo
Day	density	biomass	density	biomass	density	biomass	density	biomass	biomass
Lt48	83.3	4.1	33.3	13.3	33.3	43	0.0	0	60.4
Rm40	216.7	10.6	0.0	0.0	0.0	0	0.0	0	10.6
Rm42	116.7	5.7	50.0	20.0	0.0	0	0.0	0	25.7
Rm44	83.3	4.1	16.7	6.7	16.7	21.5	16.7	30.83	63.1
Rm46	16.7	0.8	33.3	13.3	0.0	0	0.0	0	14.2
Rm48	266.7	13.1	0.0	0.0	0.0	0	0.0	0	13.1
Rm50	166.7	8.2	50.0	20.0	16.7	21.5	0.0	0	49.7
Rm52	266.7	13.1	50.0	20.0	0.0	0	0.0	0	33.1
Rm54	950.0	46.6	33.3	13.3	0.0	0	0.0	0	59.9
Rm56	633.3	31.0	16.7	6.7	0.0	0	0.0	0	37.7
rm56.8	366.7	18.0	0.0	0.0	16.7	21.5	0.0	0	39.5
Low-Low									
Day									
Lt48	183.3	9.0	16.7	6.7	0.0	0	0.0	0	15.7
rm40	116.7	5.7	66.7	26.7	0.0	0	0.0	0	32.4
rm42	116.7	5.7	50.0	20.0	16.7	21.5	0.0	0	47.2
rm44	283.3	13.9	33.3	13.3	0.0	0	0.0	0	27.2
rm46	200.0	9.8	116.7	46.7	0.0	0	0.0	0	56.5
rm48	200.0	9.8	50.0	20.0	0.0	0	0.0	0	29.8
rm50	633.3	31.0	33.3	13.3	0.0	0	0.0	0	44.4
rm52	600.0	29.4	0.0	0.0	0.0	0	0.0	0	29.4
rm54	666.7	32.7	0.0	0.0	33.3	43	0.0	0	75.7
rm56	583.3	28.6	0.0	0.0	0.0	0	0.0	0	28.6
rm56.8	333.3	16.3	0.0	0.0	0.0	0	0.0	0	16.3

Table 18: Zooplankton data for 23 August 2007. Density = individuals/L. Biomass = dry weight ug/L.

	Total Zooplankton		Rotifera		Copepoda		Cladocera	
	density	biomass	density	biomass	density	biomass	density	biomass
Lt48	220.0	11.82	196.67	2.60	21.67	8.67	1.67	0.54
rm40	193.3	22.37	148.33	1.87	45.00	20.50	0.00	0.00
rm42	203.3	22.72	161.67	2.01	41.67	20.71	0.00	0.00
rm44	61.7	28.2	16.67	0.10	41.67	25.27	3.33	2.80
rm46	21.7	7.5	8.33	0.16	13.33	7.31	0.00	0.00
rm48	248.3	38.3	175.00	3.15	73.33	35.18	0.00	0.00
rm50	2666.7	106.5	2650.00	99.85	16.67	6.67	0.00	0.00
rm52	1950.0	88.5	1883.33	61.82	66.67	26.67	0.00	0.00
rm54	1135.0	44.7	1123.33	40.63	11.67	4.07	0.00	0.00
rm56	1216.7	70.0	1183.33	56.65	33.33	13.33	0.00	0.00
rm56.8	1125.0	51.6	1100.00	43.32	16.67	6.67	8.33	1.60

Table 19: Zooplankton data for 6 September 2007. Density = individuals/L. Biomass = dry weight ug/L.

	Total Zooplankton		Rotifera		Copepoda		Cladocera	
	density	biomass	density	biomass	density	biomass	density	biomass
rm34	105.0	31.79	15.00	0.28	85.00	28.33	5.00	3.18
rm35	143.3	47.24	20.00	0.19	116.67	43.05	6.67	4.00
rm36	170.0	35.49	76.67	0.92	81.67	28.84	11.67	5.73
rm37	158.3	38.5	63.33	0.56	60.00	22.34	35.00	15.64
rm38	88.8	13.8	55.83	1.16	28.33	10.04	4.58	2.60
rm39	298.3	38.7	210.00	4.00	75.00	27.83	13.33	6.86
Lt49	200.0	30.0	133.33	2.64	56.67	22.43	10.00	4.91
rm40	145.0	30.1	81.67	2.27	53.33	22.18	10.00	5.63
rm42	213.3	49.2	106.67	6.78	100.00	39.42	6.67	2.95
rm44	275.0	64.6	138.33	7.68	135.00	56.47	1.67	0.46
rm46	313.3	98.2	123.33	4.30	190.00	93.90	0.00	0.00
rm48	1008.3	105.2	796.67	21.05	210.00	83.61	1.67	0.54
rm50	530.0	32.3	495.00	18.32	35.00	14.00	0.00	0.00
rm52	208.3	12.5	191.67	5.79	16.67	6.67	0.00	0.00
rm54	110.0	4.6	105.00	2.62	5.00	2.00	0.00	0.00
rm56	105.0	3.9	101.67	2.57	1.67	0.67	1.67	0.70
rm56.8	203.3	6.4	201.67	5.71	1.67	0.67	0.00	0.00

Table 20: Zooplankton data for 19-20 September 2007. Density = individuals/L. Biomass = dry weight ug/L.

High-High	Total Zooplankton		Rotifera		Copepoda		Cladocera	
Night	density	biomass	density	biomass	density	biomass	density	biomass
rm34	48.3	54.96	3.33	1.62	40.00	48.34	5.00	5.00
rm36	55.0	24.67	0.00	0.00	55.00	24.67	0.00	0.00
rm38	111.7	62.07	33.33	0.58	73.33	59.59	5.00	1.91
rm40	256.7	40.2	173.33	3.86	81.67	34.56	1.67	1.76
rm42	271.7	46.0	173.33	5.60	95.00	39.26	3.33	1.16
rm44	333.3	136.7	230.00	66.58	96.67	68.56	6.67	1.59
rm46	836.7	127.1	671.67	28.30	165.00	98.79	0.00	0.00
rm48	1420.0	181.6	1161.67	57.81	258.33	123.81	0.00	0.00
rm50	906.7	155.8	625.00	28.78	281.67	127.03	0.00	0.00
rm52	441.7	110.8	201.67	8.14	240.00	102.65	0.00	0.00
rm54	146.7	38.4	61.67	2.66	81.67	33.15	3.33	2.59
rm56	33.3	1.7	33.33	1.70	0.00	0.00	0.00	0.00
rm56.8	63.3	5.2	56.67	2.24	5.00	2.00	1.67	1.00
Low-Low Day								
rm40	371.7	61.8	251.67	8.90	120.00	52.88	0.00	0.00
rm42	855.0	80.9	741.67	30.75	113.33	50.17	0.00	0.00
rm44	1261.7	166.0	936.67	36.90	323.33	128.70	1.67	0.43
rm46	513.3	99.8	305.00	10.62	208.33	89.13	0.00	0.00
rm48	258.3	53.6	140.00	4.89	118.33	48.71	0.00	0.00
rm50	75.0	12.0	46.67	1.32	28.33	10.67	0.00	0.00
rm52	65.0	8.7	46.67	1.82	18.33	6.90	0.00	0.00
rm54	35.0	3.2	28.33	0.96	6.67	2.23	0.00	0.00
rm56	20.0	1.9	16.67	0.61	3.33	1.33	0.00	0.00
rm56.8	28.3	2.4	23.33	0.39	5.00	2.00	0.00	0.00

Table 21: Phytoplankton data for July 2005. Bv = biovolme = μm^3 cell volume. Density = individuals/L.

	Total bv/mL	Total density	Diatom density	Diatom bv	Green density	Green bv
Sjr1	1247209.4	6307.5	4473.4	706953.6	1610.4	222000.7
Sjr2	2811205.7	15287.3	12016.2	1872836.8	2670.3	362885.8
Sjr3	2788710.0	18758.0	15277.6	2334768.6	2892.8	342847.9
Sjr4	2614920.7	13821.2	11330.1	1587534.2	1848.2	294645.4
Sjr5	2574508.6	17085.6	14780.4	2170589.1	1808.0	187885.5
Sjr6	2970328.4	19616.8	17628.0	2313659.8	1672.4	423693.5
Sjr8	1980301.7	17085.6	14825.6	1775041.7	1988.8	177485.8
Sjr9	1570516.0	9444.1	7742.5	1198617.4	1446.4	260263.4
Sjr10	4111835.7	33719.2	27300.8	3109924.9	5830.8	524963.1
Sjr11	1446602.2	12832.2	8863.8	927251.5	3412.0	251361.7
Sjr12	1258719.0	11915.6	8196.3	967522.3	2927.2	193273.7

	Cryptomonad density	Cryptomonad bv	Blue-Green density	Blue-Green bv
Sjr1	14.9	249842.5	208.8	68412.6
Sjr2	66.8	36806.5	511.8	486245.8
Sjr3	180.8	66645.5	361.6	8948.0
Sjr4	40.2	7573.4	602.7	725167.7
Sjr5	22.6	14200.0	429.4	69122.8
Sjr6	45.2	85200.2	180.8	55001.5
Sjr8	0.0	0.0	271.2	27774.3
Sjr9	28.4	9503.8	226.9	102131.4
Sjr10	271.2	22436.1	271.2	4654.6
Sjr11	148.3	45090.6	333.8	51624.3
Sjr12	241.1	59865.5	551.0	38057.5

Table 22: Phytoplankton data for August 2005. Bv = biovolme = µm^3 cell volume. Density = individuals/L.

	Total bv/mL	Total density	Diatom density	Diatom bv	Green density	Green bv
Sjr1	684776.0	5094.5	2764.2	536257.1	1687.5	63137.5
Sjr2	1687763.9	13419.4	6950.8	1310089.5	5584.7	220652.6
Sjr3	3151070.1	16708.4	8628.5	1710036.6	6733.2	172241.5
Sjr4	1702481.0	10282.0	5534.1	1147391.4	3804.7	273853.1
Sjr5	1080253.7	12560.8	5747.5	884175.9	4910.1	124751.0
Sjr6	1178946.5	10157.7	5654.1	1036548.8	3616.0	58908.6
Sjr7	1195339.1	9180.2	4900.0	670327.7	3424.1	30884.6
Sjr8	2391678.5	26200.5	9133.0	1258363.3	15621.1	244727.4
Sjr9	1485176.7	26713.2	7638.8	1177983.7	18260.8	258156.6
Sjr10	1772400.1	12113.6	5930.2	1400006.5	4375.4	151239.8
Sjr11	1369545.8	11979.2	4673.0	714624.1	5859.8	228314.7
Sjr12	1897993.2	19061.5	9556.6	1606333.3	8058.5	210566.4
Sjr13	1347578.4	14174.7	5124.4	909133.3	7314.7	202359.9
Sjr14	1780147.3	20370.1	8557.9	1399067.5	9281.1	236193.9
Sjr15	894133.6	15331.8	4532.1	572569.8	8292.7	176228.7
Sjr16	1026462.2	17690.6	4061.0	688434.5	12238.8	200184.0
Sjr17	674167.4	24893.3	2283.8	450964.1	16138.8	156887.9
Sjr18	637971.6	24664.9	2664.4	545833.1	13169.9	89883.7

	Cryptomonad density	Cryptomonad bv	Blue-Green density	Blue-Green bv
Sjr1	225.0	39987.3	417.8	45394.0
Sjr2	482.1	68202.2	361.6	63575.1
Sjr3	299.3	99400.2	997.5	761344.9
Sjr4	62.9	94979.7	880.4	186256.9
Sjr5	38.1	797.2	1865.1	70529.6
Sjr6	32.9	688.5	854.7	82800.5
Sjr7	0.0	0.0	856.0	494126.8
Sjr8	289.3	153111.5	1115.8	562371.2
Sjr9	90.4	33322.7	723.2	15713.7
Sjr10	72.3	16798.6	1735.7	204355.2
Sjr11	222.5	74568.4	1112.6	148140.7
Sjr12	51.7	2197.6	1394.7	78895.9
Sjr13	206.6	66861.9	1529.1	169223.3
Sjr14	120.5	42537.0	2350.4	47820.9
Sjr15	289.3	97847.7	2217.8	47487.4
Sjr16	166.9	23186.1	1168.2	16349.7
Sjr17	456.8	50621.9	6014.0	15693.4
Sjr18	0.0	0.0	8830.7	2254.9

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Table 23: Phytoplankton data for September 2005. Bv = biovolme = µm^3 cell volume. Density = individuals/L.

	Total bv/mL	Total density	Diatom density	Diatom bv	Green density	Green bv
Sjr1	696221.6	21780.0	4400.0	531668.7	15290.0	150841.2
Sjr2	207000.0	11220.0	3410.0	150325.6	7260.0	50914.9
Sjr3	445631.1	17160.0	5280.0	323631.9	11440.0	71649.4
Sjr4	941305.8	19360.0	7040.0	715687.9	11660.0	171708.1
Sjr5	1474284.8	18700.0	6380.0	833702.1	11770.0	587133.6
Sjr6	1173777.7	34540.0	9350.0	840052.1	23540.0	201470.8
Sjr7	962789.1	24860.0	5280.0	548774.7	18810.0	400695.4
Sjr8	681936.6	36300.0	6050.0	356634.4	28270.0	177626.1
Sjr9	11165330.2	30910.0	6820.0	10995796.4	21890.0	137539.2
Sjr10	615744.4	26840.0	7040.0	536938.7	17710.0	15550.9
Sjr11	164782.2	10560.0	1320.0	68769.6	9020.0	7084.3
Sjr12	703319.2	40810.0	6490.0	452704.6	31790.0	25486.2
Sjr13	566543.1	22770.0	3410.0	342811.4	16830.0	124407.4
Sjr14	427549.5	16830.0	1210.0	71275.1	13640.0	86394.0
Sjr15	147215.4	23210.0	1430.0	61253.3	20350.0	15982.9
Sjr20	320924.9	15510.0	660.0	57970.4	14080.0	37322.2
Sjr21	2219591.5	16720.0	880.0	2179893.4	14630.0	26868.5
Sjr22	198000.6	13970.0	330.0	117971.0	12320.0	9676.1
Sjr23	936655.0	11550.0	880.0	742772.4	8910.0	55983.3

	Cryptomonad density	Cryptomonad bv	Blue-Green density	Blue-Green bv
Sjr1	880.0	8351.4	1210.0	5360.2
Sjr2	330.0	4636.5	220.0	1123.1
Sjr3	440.0	50349.7	0.0	0.0
Sjr4	550.0	53449.1	110.0	460.8
Sjr5	550.0	53449.1	0.0	0.0
Sjr6	1210.0	102650.5	440.0	29604.3
Sjr7	660.0	13088.7	110.0	230.4
Sjr8	1650.0	141225.4	330.0	6450.8
Sjr9	1760.0	18661.1	440.0	13333.5
Sjr10	1540.0	46206.4	550.0	17048.4
Sjr11	220.0	88928.2	0.0	0.0
Sjr12	2200.0	220232.7	220.0	4031.7
Sjr13	1650.0	56876.1	880.0	42448.3
Sjr14	1430.0	248973.1	550.0	20907.3
Sjr15	1430.0	69979.1	0.0	0.0
Sjr20	550.0	39021.3	220.0	186611.0
Sjr21	1210.0	12829.5	0.0	0.0
Sjr22	1210.0	62981.2	110.0	7372.3
Sjr23	1430.0	123385.0	330.0	14514.2

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Table 24: Phytoplankton data for October 2005. Bv = biovolme = μm^3 cell volume. Density = individuals/L.

	Total bv/mL	Total density	Diatom density	Diatom bv	Green density	Green bv
Sjr1	230902.4	21340.0	1650.0	103759.2	18810.0	117553.4
Sjr2	911562.8	35310.0	6820.0	544109.4	25300.0	157561.1
Sjr3	1021724.2	25960.0	4840.0	879145.3	20240.0	18574.7
Sjr4	501675.6	33880.0	5170.0	380263.2	27500.0	43197.0
Sjr5	897413.8	33660.0	6600.0	796423.1	26290.0	53459.6
Sjr6	532885.4	29810.0	5830.0	431602.8	22220.0	36947.8
Isco7	294367.2	21890.0	3080.0	125098.5	17930.0	14082.2
Isco8	347836.6	19470.0	2530.0	245013.4	15730.0	14571.8
Isco9	422322.7	17930.0	2090.0	170887.3	14520.0	11404.0
Sjr7	324366.3	13640.0	1320.0	128727.1	11550.0	15205.3
Sjr8	344582.5	14740.0	660.0	108467.7	13090.0	10280.9
Sjr9	375036.4	16170.0	2530.0	176934.9	12100.0	9503.3
Sjr10	737963.1	23650.0	3850.0	326223.7	17490.0	76314.7
Sjr11	52873.1	20020.0	770.0	27214.1	18480.0	14514.2
Sjr12	116617.5	15180.0	660.0	32829.7	14080.0	19640.2

	Cryptomonad density	Cryptomonad bv	Blue-Green density	Blue-Green bv
Sjr1	660.0	6997.9	220.0	2591.8
Sjr2	1430.0	165617.3	1760.0	44275.0
Sjr3	550.0	119857.3	330.0	4146.9
Sjr4	440.0	4665.3	770.0	73550.1
Sjr5	660.0	46379.2	110.0	1151.9
Sjr6	1320.0	55464.9	440.0	8869.8
Isco7	770.0	137366.5	110.0	17820.0
Isco8	1210.0	88251.5	0.0	0.0
Isco9	770.0	228080.2	550.0	11951.2
Sjr7	770.0	180433.9	0.0	0.0
Sjr8	990.0	225833.9	0.0	0.0
Sjr9	1540.0	188598.1	0.0	0.0
Sjr10	2090.0	209174.3	220.0	126250.4
Sjr11	770.0	11144.8	0.0	0.0
Sjr12	440.0	64147.5	0.0	0.0

Table 25: Phytoplankton data for July 2006. Bv = biovolme = µm^3 cell volume. Density = individuals/L.

	Total bv/mL	Total density	Diatom density	Diatom bv	Green density	Green bv
Sjr1	4084793.1	26290.0	10780.0	2935419.7	13970.0	44521.7
Sjr2	5496415.1	28930.0	12210.0	5005841.1	15070.0	97222.0
Sjr3	2297713.2	25740.0	12210.0	1936413.5	11990.0	46825.5
Sjr4	3739794.7	30250.0	22000.0	3448848.5	7480.0	35248.8
Sjr5	9134149.6	20240.0	13860.0	6404387.2	5610.0	23556.8
Sjr6	2647356.9	30580.0	22110.0	2424042.9	7810.0	23556.8
Sjr7	450177.5	13310.0	9130.0	360003.8	3850.0	3023.8
Sjr8	863594.4	19580.0	12100.0	693398.2	6930.0	53564.3
Sjr9	1959084.7	40260.0	17160.0	1802870.0	22880.0	22059.3
Sjr10	899807.9	14960.0	7260.0	776034.1	6930.0	20216.2
Sjr11	2069634.9	17380.0	12980.0	1656173.0	2970.0	65601.8
Sjr12	640859.6	14960.0	9240.0	579876.5	5060.0	3974.1
Sjr13	592144.5	15730.0	7040.0	427909.5	8140.0	8034.6
Sjr14	1012926.5	28490.0	9240.0	555513.4	18040.0	14168.6
DWSC	67387.3	22880.0	880.0	50108.5	22000.0	17278.8

	Cryptomonad density	Cryptomonad bv	Blue-Green density	Blue-Green bv
Sjr1	770.0	137366.5	770.0	967485.2
Sjr2	880.0	49619.0	770.0	343732.9
Sjr3	1210.0	238058.7	330.0	76415.5
Sjr4	440.0	62894.8	330.0	192802.6
Sjr5	330.0	66696.2	440.0	2639509.5
Sjr6	110.0	47919.9	550.0	151837.5
Sjr7	0.0	0.0	330.0	87149.9
Sjr8	0.0	0.0	550.0	116631.9
Sjr9	0.0	0.0	220.0	134155.5
Sjr10	110.0	17509.2	660.0	86048.4
Sjr11	110.0	44233.7	1320.0	303626.3
Sjr12	0.0	0.0	660.0	57009.0
Sjr13	110.0	44233.7	440.0	111966.6
Sjr14	550.0	169332.2	660.0	273912.2
DWSC	0.0	0.0	0.0	0.0

Table 26: Phytoplankton data for August 2006. Bv = biovolme = μm^3 cell volume. Density = individuals/L.

	Total bv/mL	Total density	Diatom density	Diatom bv	Green density	Green bv
Sjr1	1596791.5	20900.0	8690.0	507996.7	11000.0	9935.3
Sjr2	2253880.5	51150.0	10670.0	1878162.4	34980.0	124810.5
Sjr3	1109860.5	11880.0	6050.0	1073704.6	5720.0	35939.9
Sjr4	12665169.6	29260.0	11880.0	2382919.3	15620.0	10181759.7
Sjr5	2182893.9	30580.0	6270.0	859965.9	21670.0	51764.4
Sjr6	1052914.7	26730.0	9350.0	827827.3	15950.0	174400.7
Sjr7	12185054.6	34540.0	15510.0	1840451.4	18040.0	10210042.9
Sjr8	352334.7	9130.0	5830.0	266439.1	3080.0	31101.8
Sjr9	2495057.6	13640.0	4400.0	2261881.3	8690.0	62894.8
Sjr10	2978404.4	20790.0	6270.0	2771865.1	14080.0	97682.8
Sjr11	1679349.5	21230.0	6270.0	1438632.9	14520.0	101829.7
Sjr12	1214256.9	8470.0	3410.0	1194915.4	5060.0	19341.5
Sjr13	1025607.5	25190.0	11770.0	871931.4	11770.0	105199.1

	Cryptomonad density	Cryptomonad bv	Blue-Green density	Blue-Green bv
Sjr1	550.0	41209.9	660.0	1037649.5
Sjr2	990.0	133737.9	4510.0	117169.6
Sjr3	0.0	0.0	110.0	216.0
Sjr4	660.0	77985.0	1100.0	22505.6
Sjr5	880.0	103672.8	1760.0	1167490.8
Sjr6	0.0	0.0	1430.0	50686.7
Sjr7	660.0	10583.3	330.0	123977.0
Sjr8	110.0	44233.7	110.0	10560.0
Sjr9	220.0	66480.2	330.0	103801.3
Sjr10	110.0	16587.6	330.0	92268.8
Sjr11	220.0	112355.4	220.0	26531.5
Sjr12	0.0	0.0	0.0	0.0
Sjr13	110.0	16587.6	1540.0	31889.4

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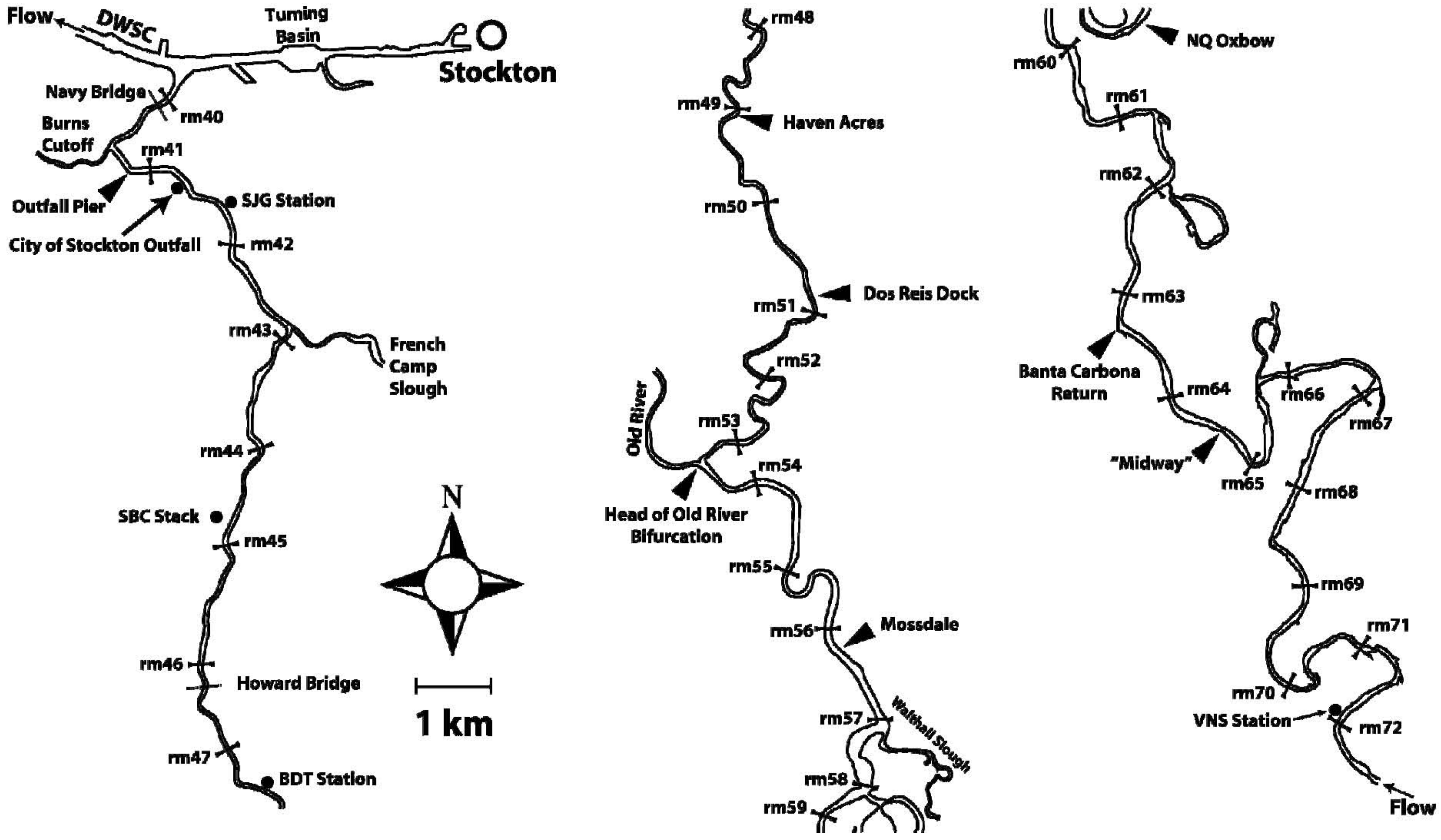

Figure 1. Map of the study reach.

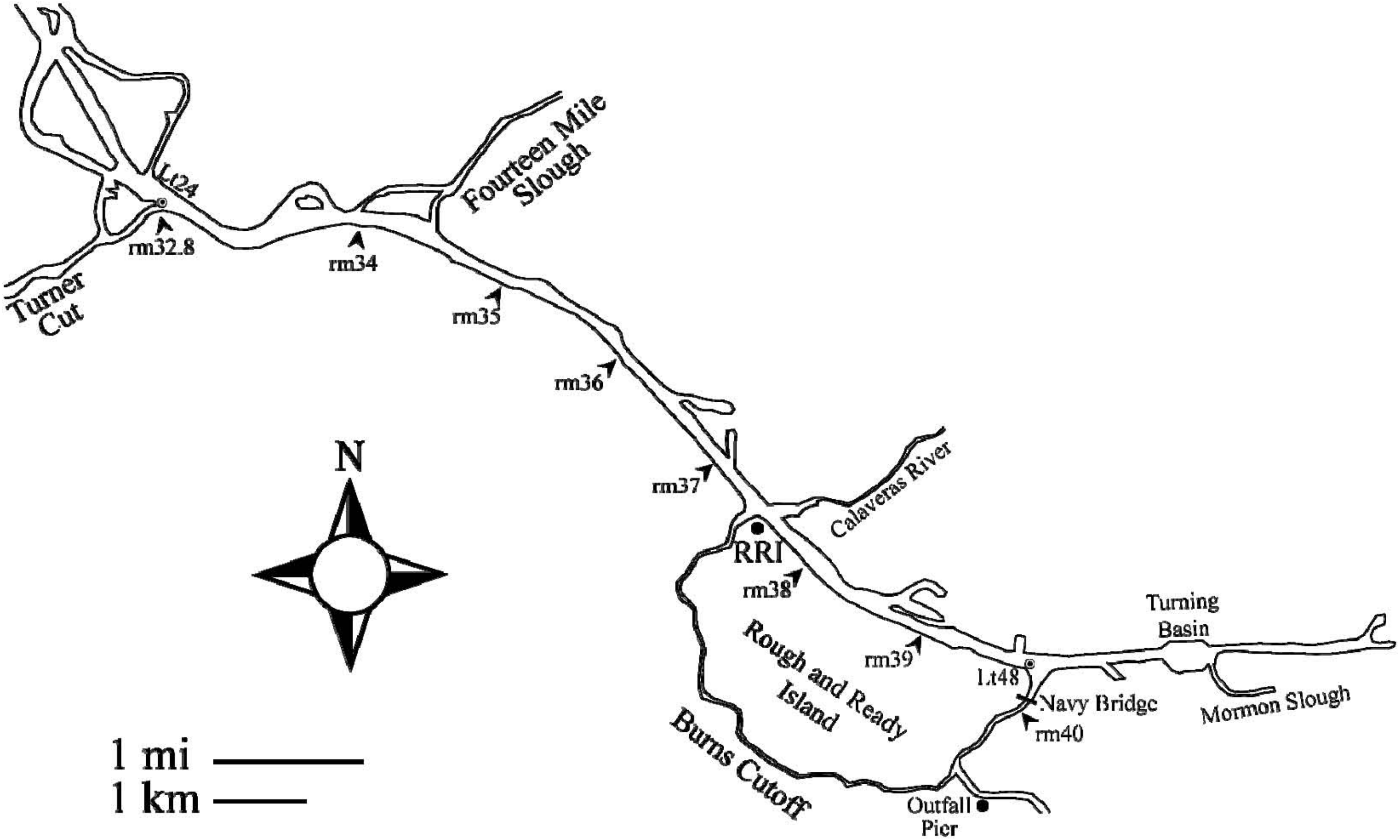

Figure 2. Map of sample sites in the DWSC.

Figure 3: July 2005 relationships between zooplankton and total photosynthetic pigment (chlorophyll a and pheophytin).

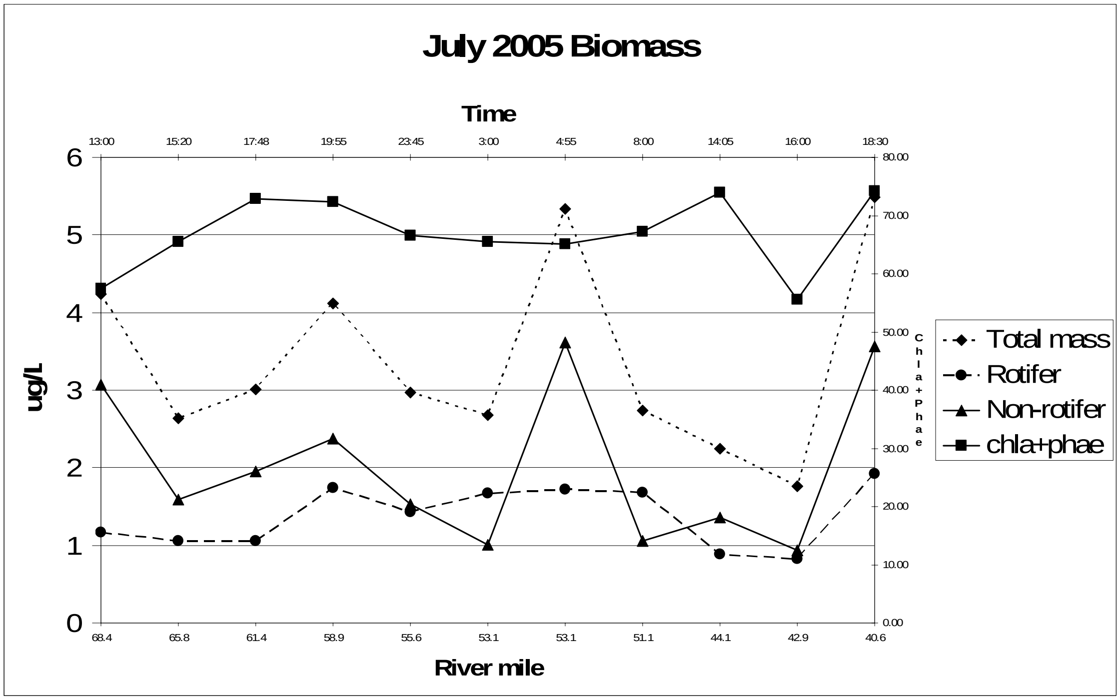

Figure 4: August 2005 relationships between zooplankton and total photosynthetic pigment (chlorophyll a and pheophytin).

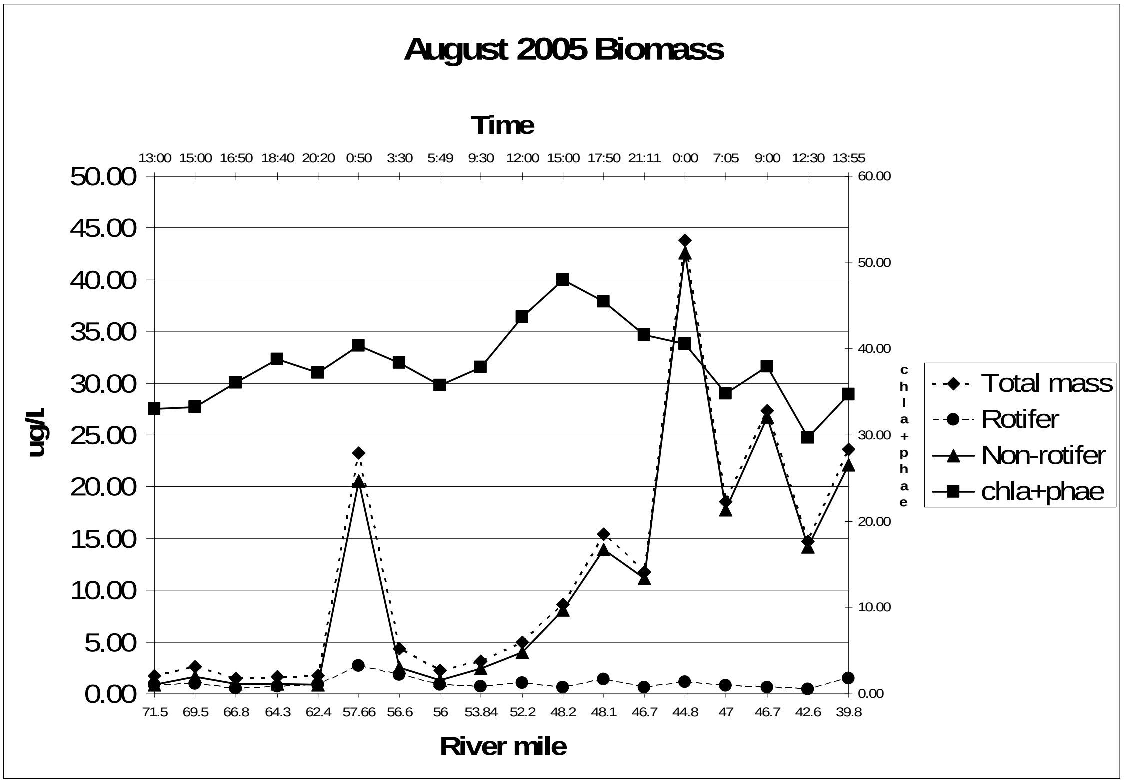

Figure 5: September 2005 relationships between zooplankton and total photosynthetic pigment (chlorophyll a and pheophytin).

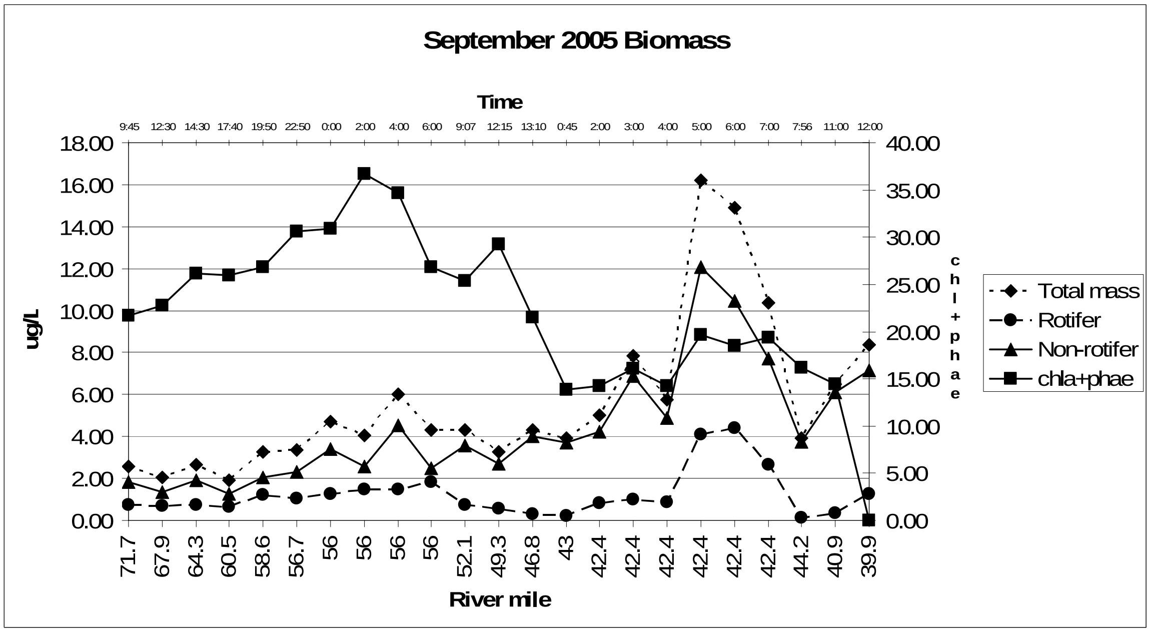

Figure 6: October 2005 relationships between zooplankton and total photosynthetic pigment (chlorophyll a and pheophytin).

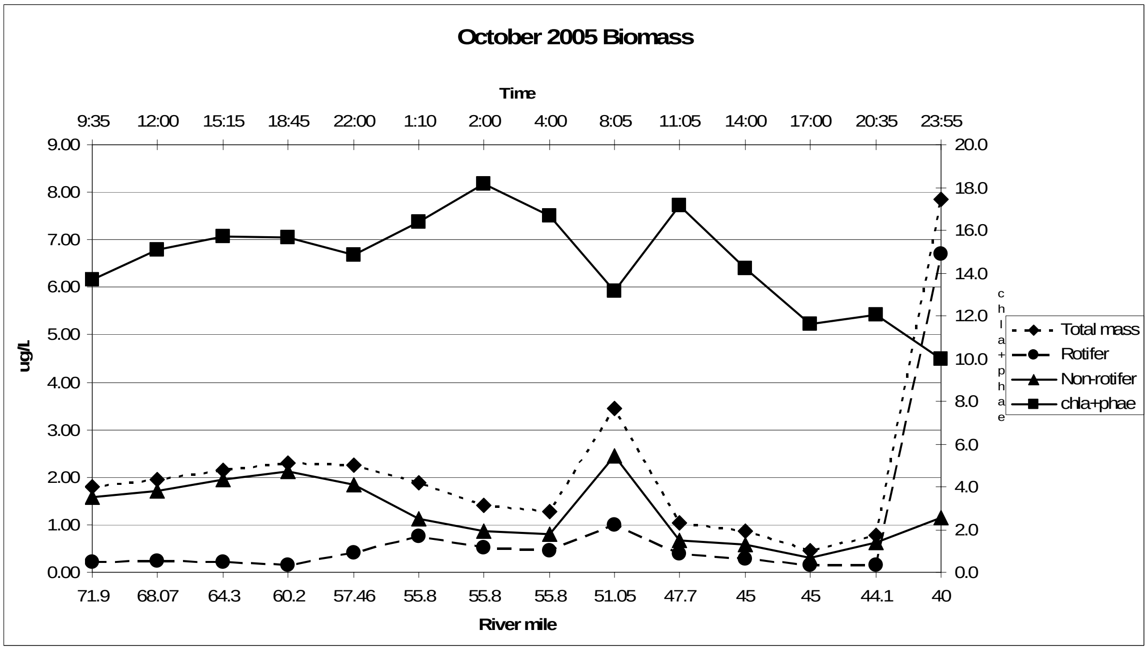

Figure 7: July 2006 relationships between zooplankton and total photosynthetic pigment (chlorophyll a and pheophytin).

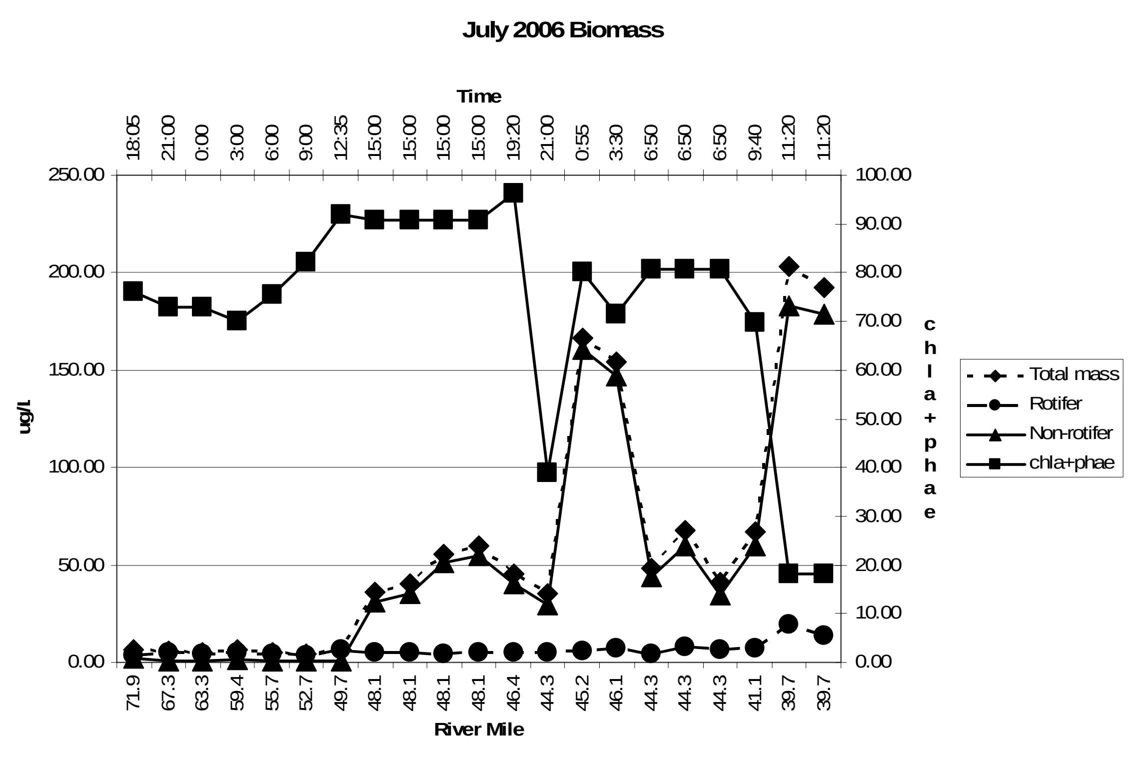

Figure 8: August 2006 relationships between zooplankton and total photosynthetic pigment (chlorophyll a and pheophytin).

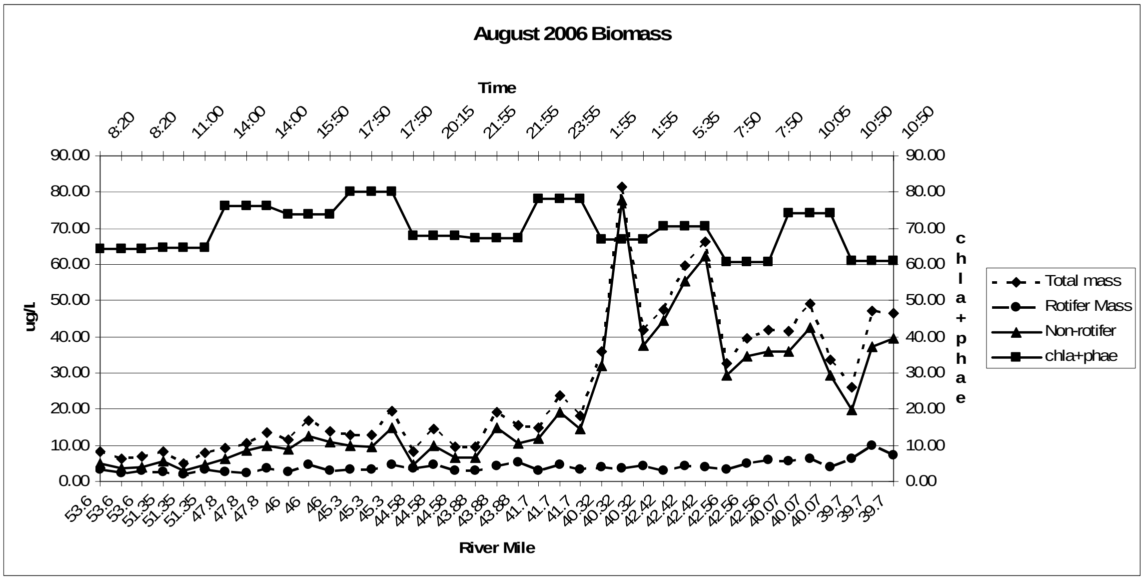

Figure 9: June 2007 relationships between zooplankton and total photosynthetic pigment (chlorophyll a and pheophytin).

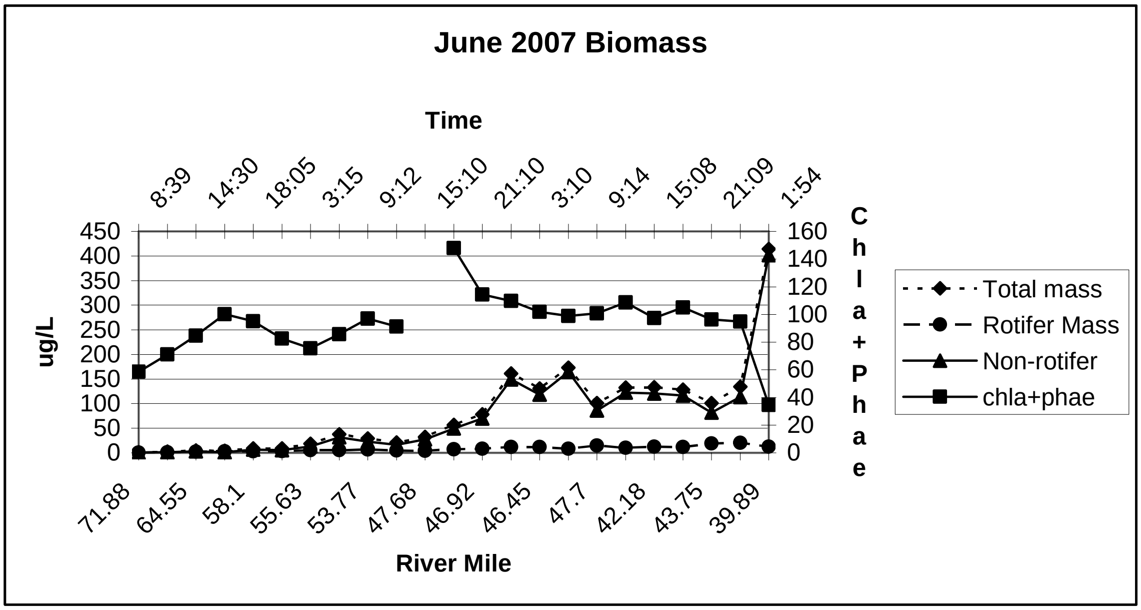

Figure 10: 17 July 2007 relationships between zooplankton and total photosynthetic pigment (chlorophyll a and pheophytin).

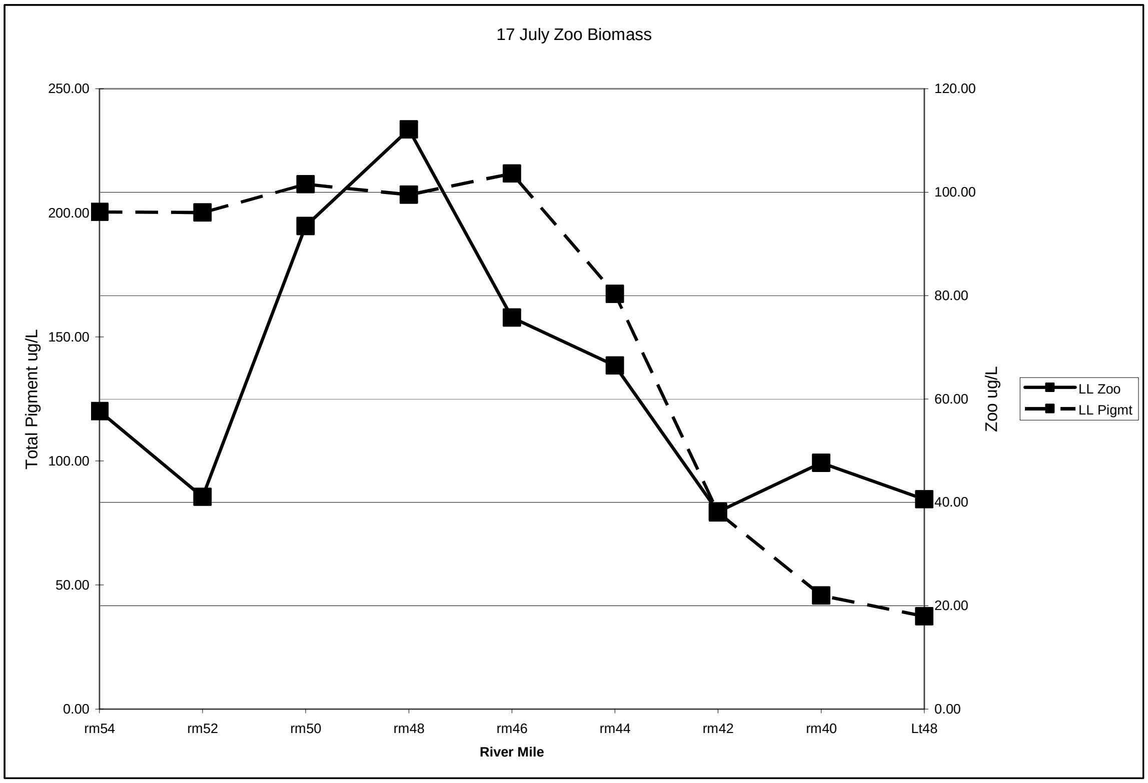

Figure 11: Relationships between zooplankton and total photosynthetic pigment (chlorophyll a and pheophytin) for samples taken 24 July 2007.

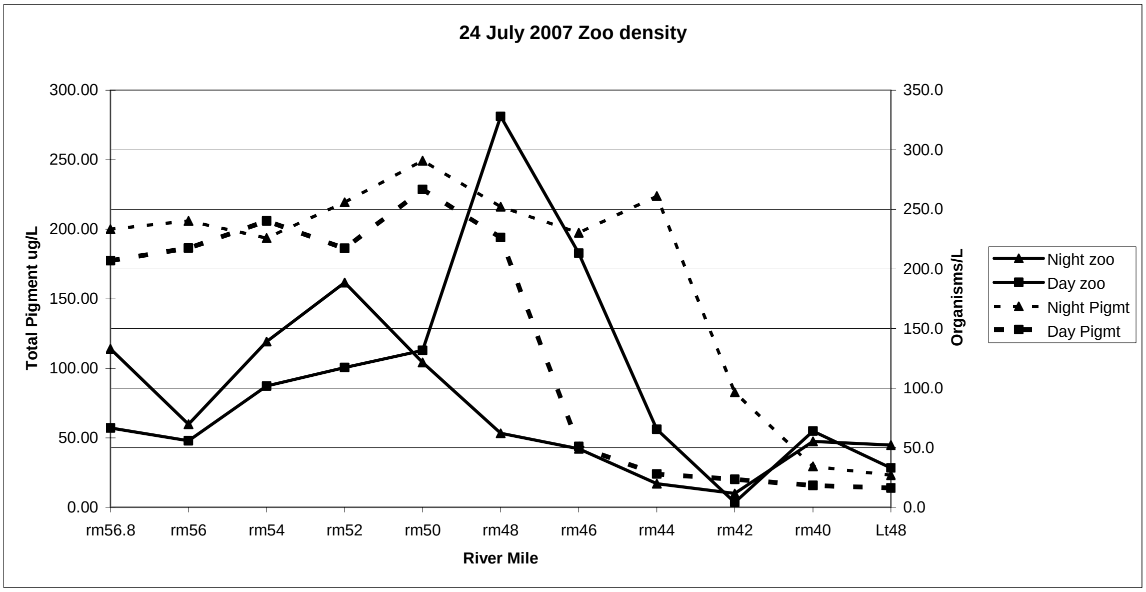

Figure 12: Relationships between zooplankton and total photosynthetic pigment (chlorophyll a and pheophytin) for night samples collected 14-15 August 2007. LH = Low-High tide, HL = High-Low tide.

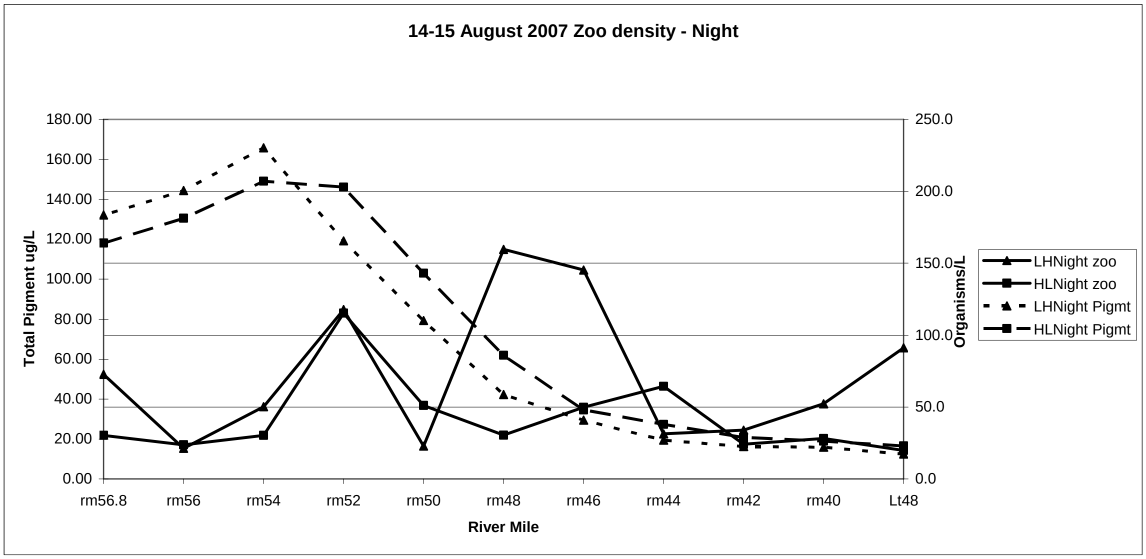

Figure 13: Relationships between zooplankton and total photosynthetic pigment (chlorophyll a and pheophytin) for day samples collected 14-15 August 2007. HH = High-High tide, LL = Low-Low tide.

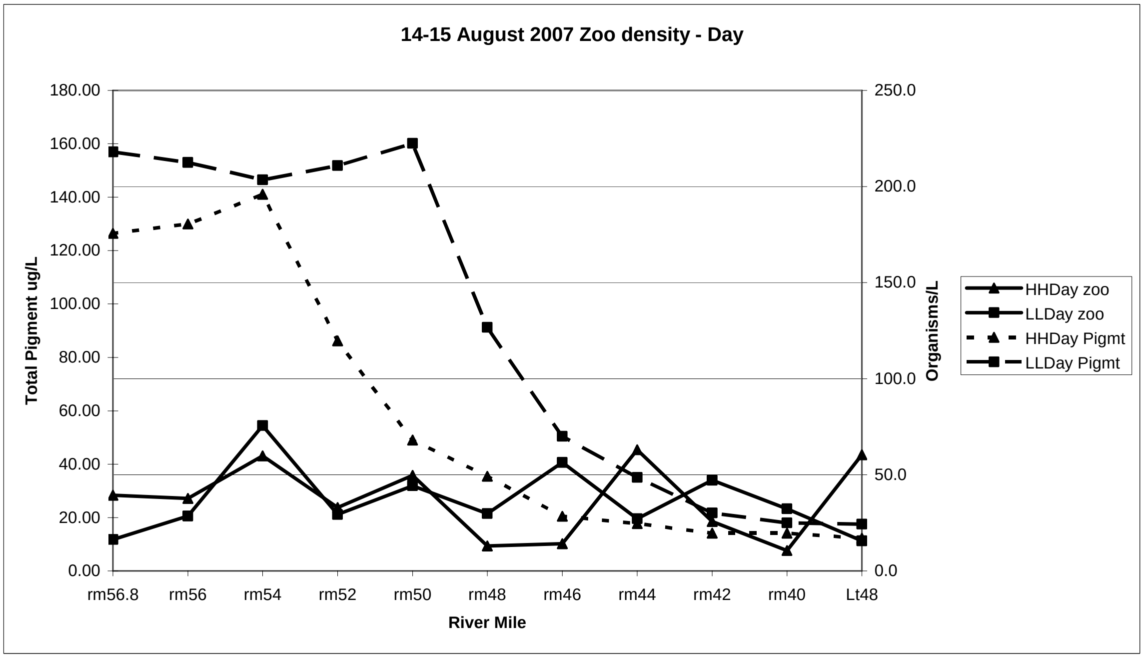

Figure 14: 23 August 2007 relationships between zooplankton and total photosynthetic pigment (chlorophyll a and pheophytin).

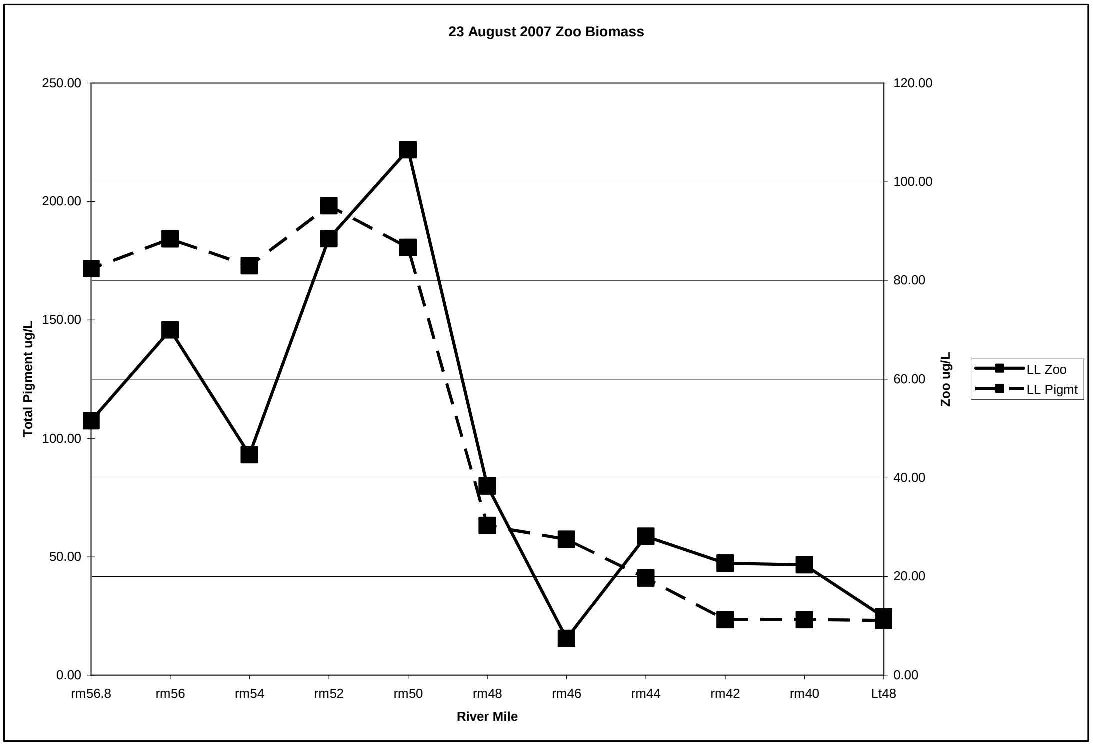

Figure 15: 6 September 2007 relationships between zooplankton and total photosynthetic pigment (chlorophyll a and pheophytin).

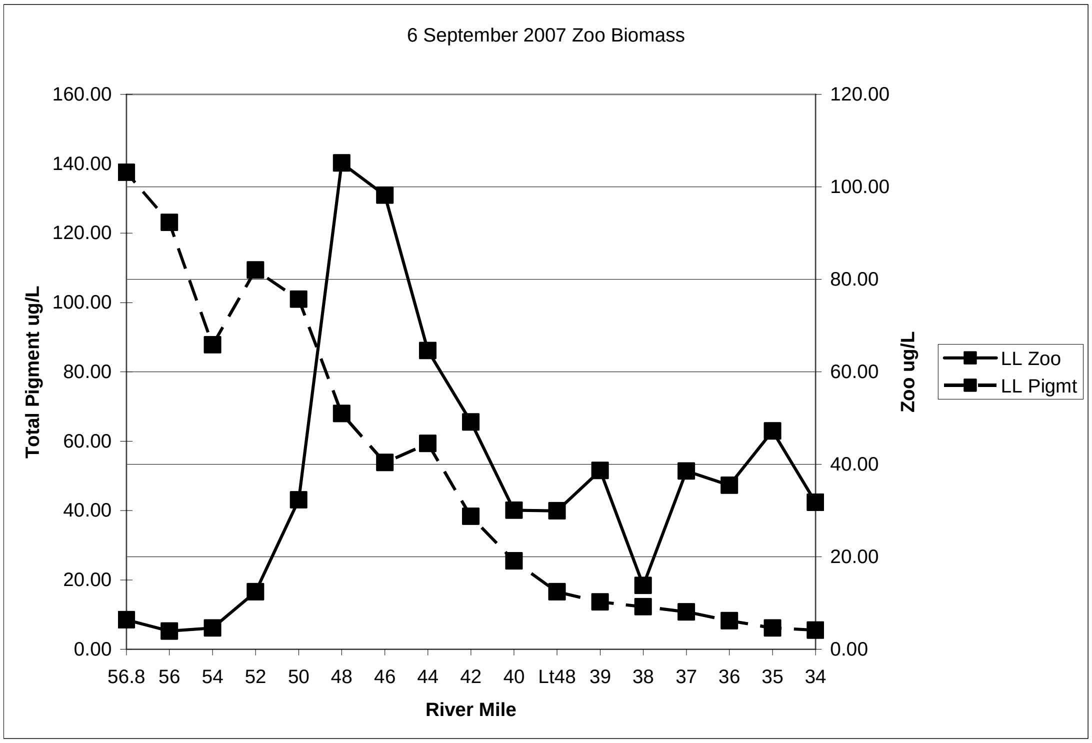

Figure 16: 19-20 September 2007 relationships between zooplankton and total photosynthetic pigment (chlorophyll a and pheophytin).

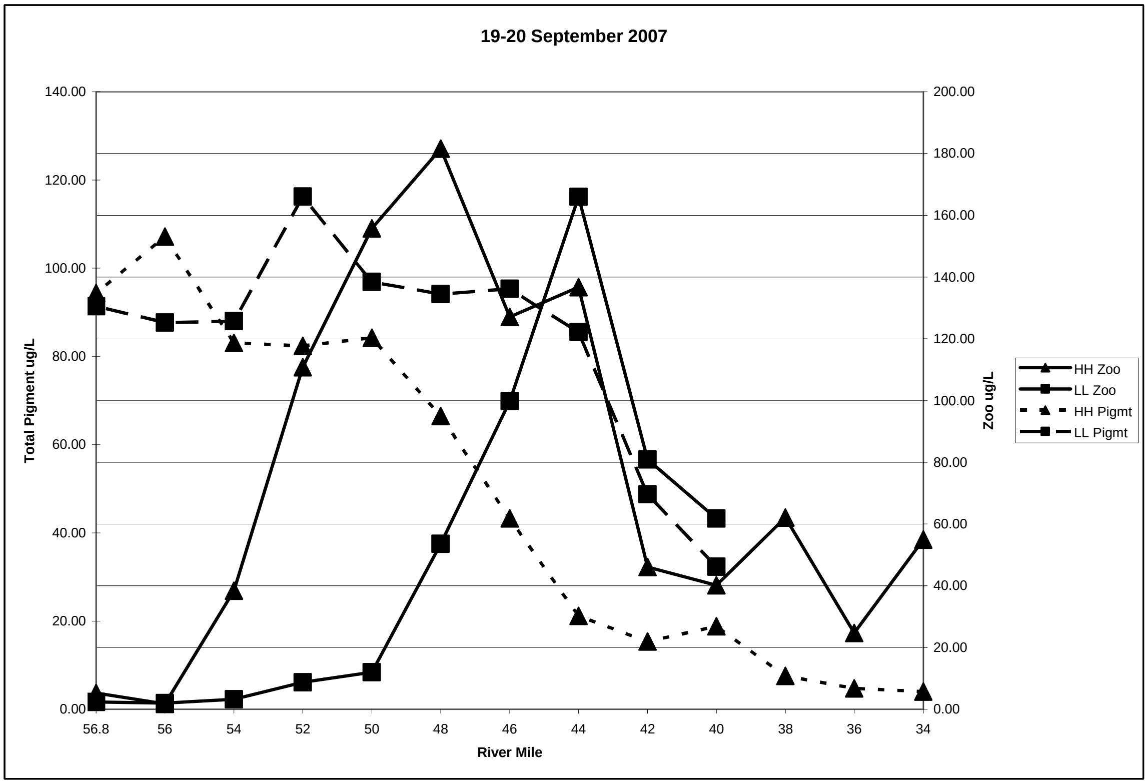

Figure 17: Phytoplankton biovolume relationship to zooplankton biomass for July 2005.

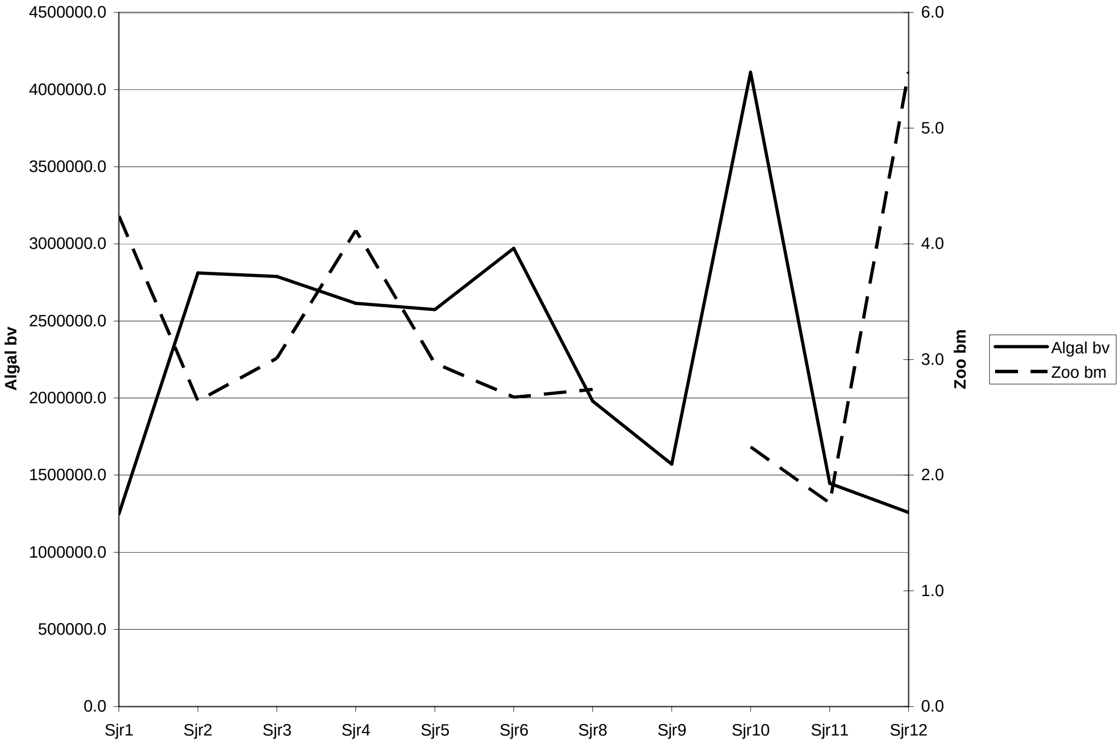

Figure 18: Phytoplankton biovolume relationship to zooplankton biomass for August 2005.

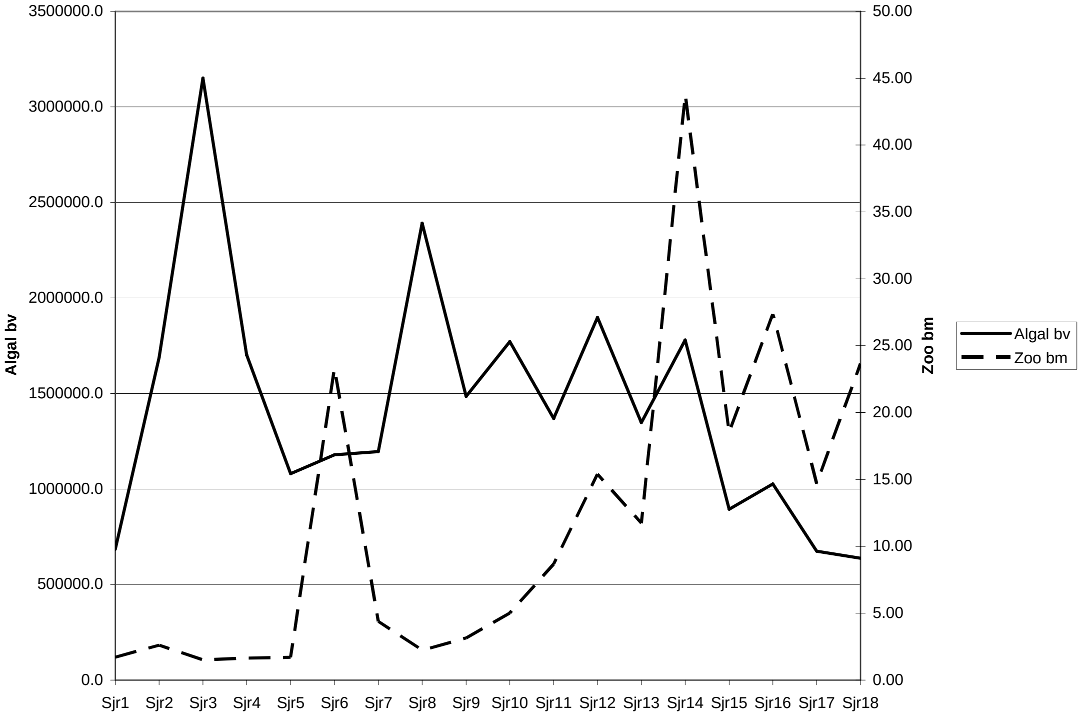

Figure 19: Phytoplankton biovolume relationship to zooplankton biomass for September 2005.

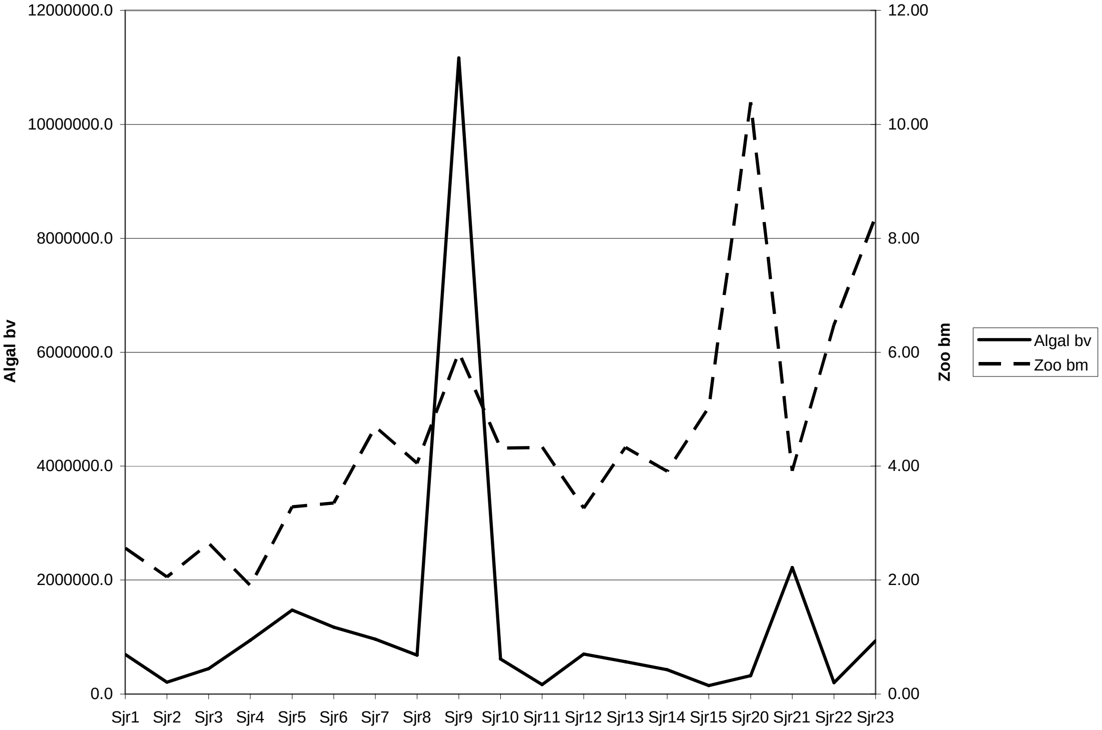

Figure 20: Phytoplankton biovolume relationship to zooplankton biomass for October 2005.

Figure 21: Phytoplankton biovolume relationship to zooplankton biomass for July 2006.

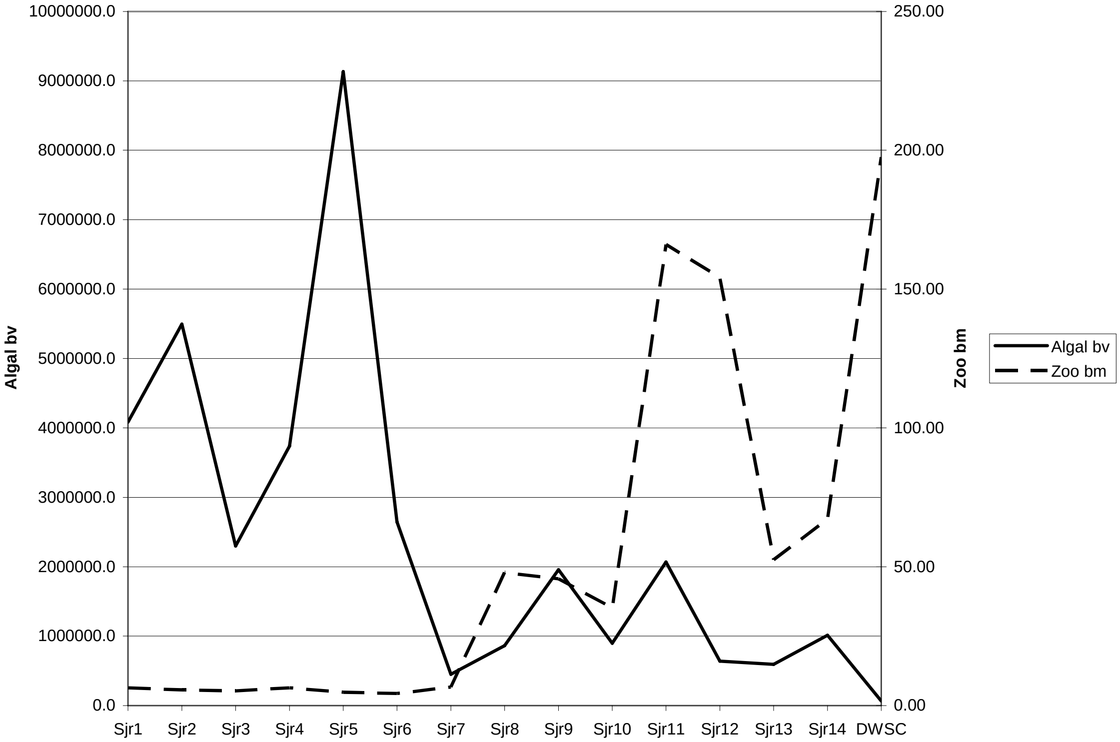

Figure 22: Phytoplankton biovolume relationship to zooplankton biomass for August 2006.

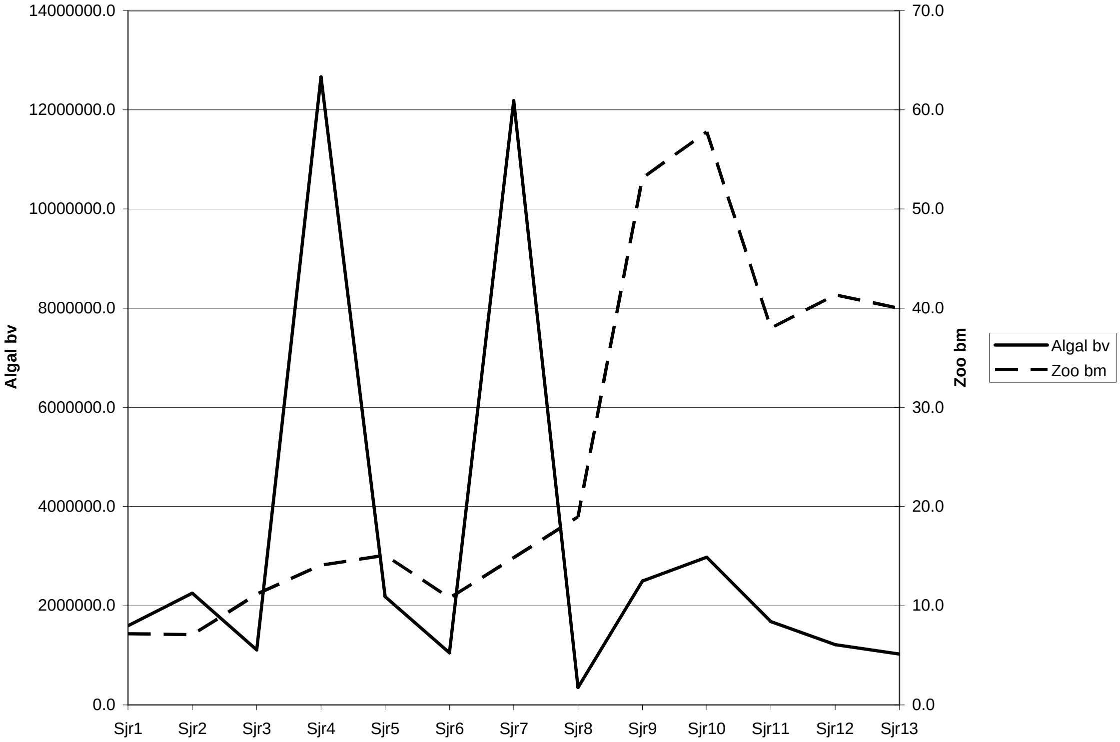

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Figure 23: Bivalve sightings for 2005 plotted by UTM coordinates

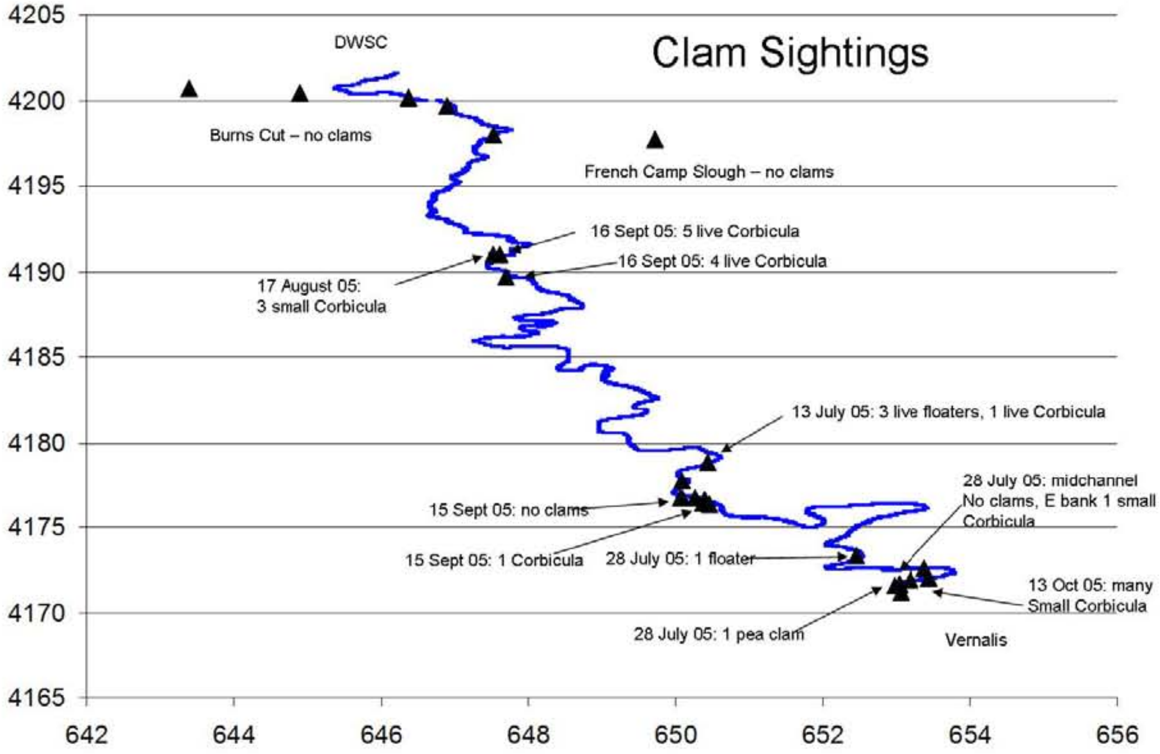

Figure 24: Average algae community composition in the San Joaquin River between Mossdale and the DWSC

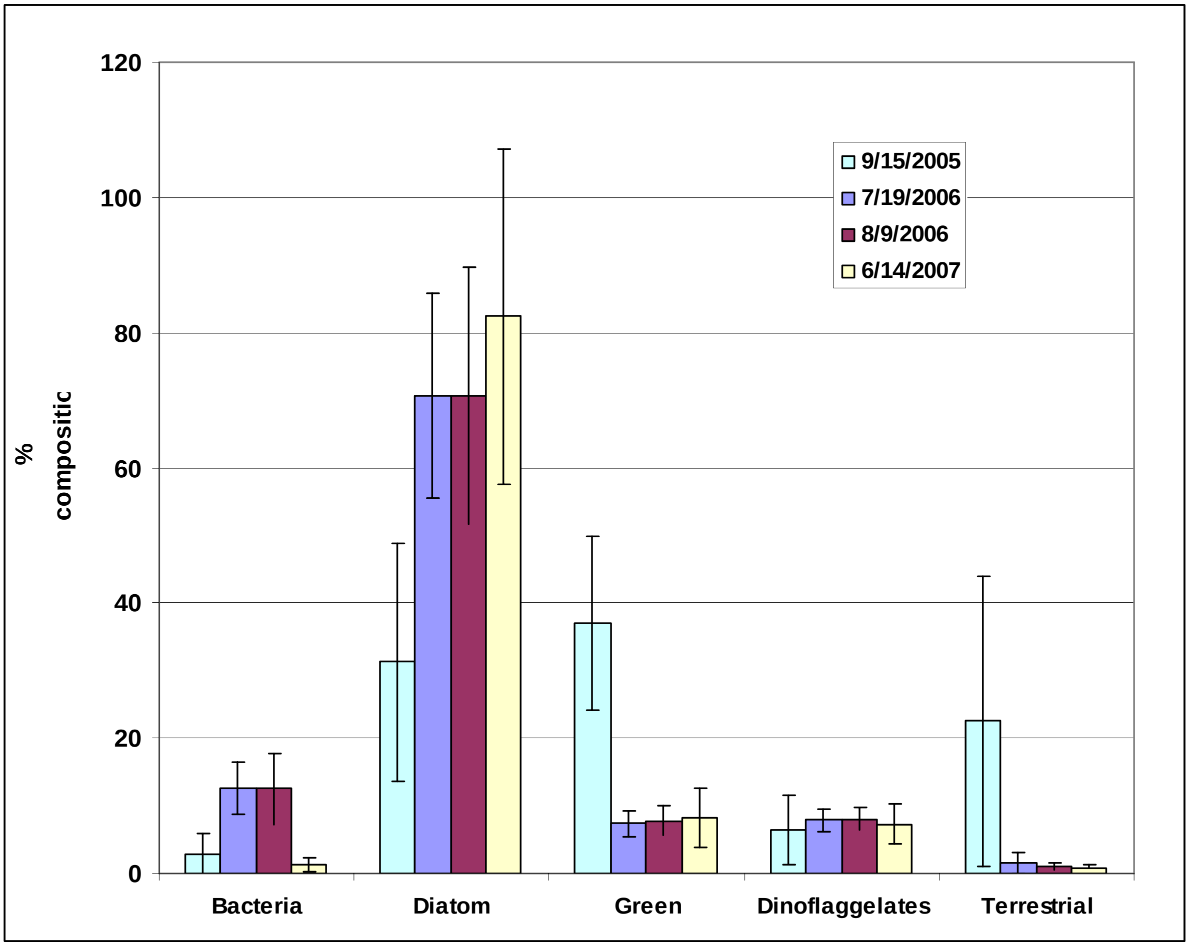

Figure 25: Total biomass concentration the San Joaquin River between Mossdale and the DWSC as determined by total lipid recovery.

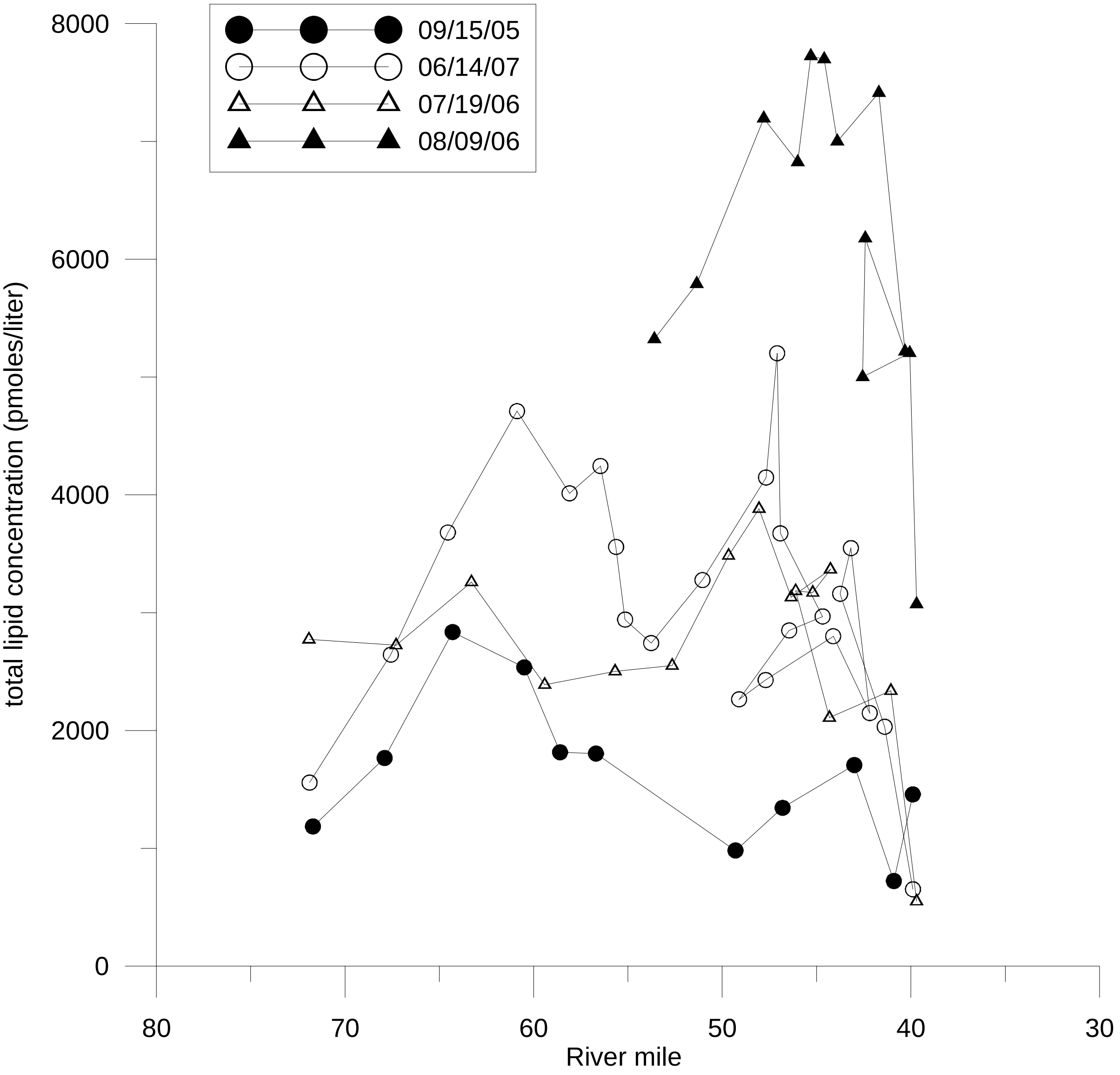

Figure 26: San Joaquin River zooplankton samples -- correlation between total zooplankton mass and 20:5w3, EPA.

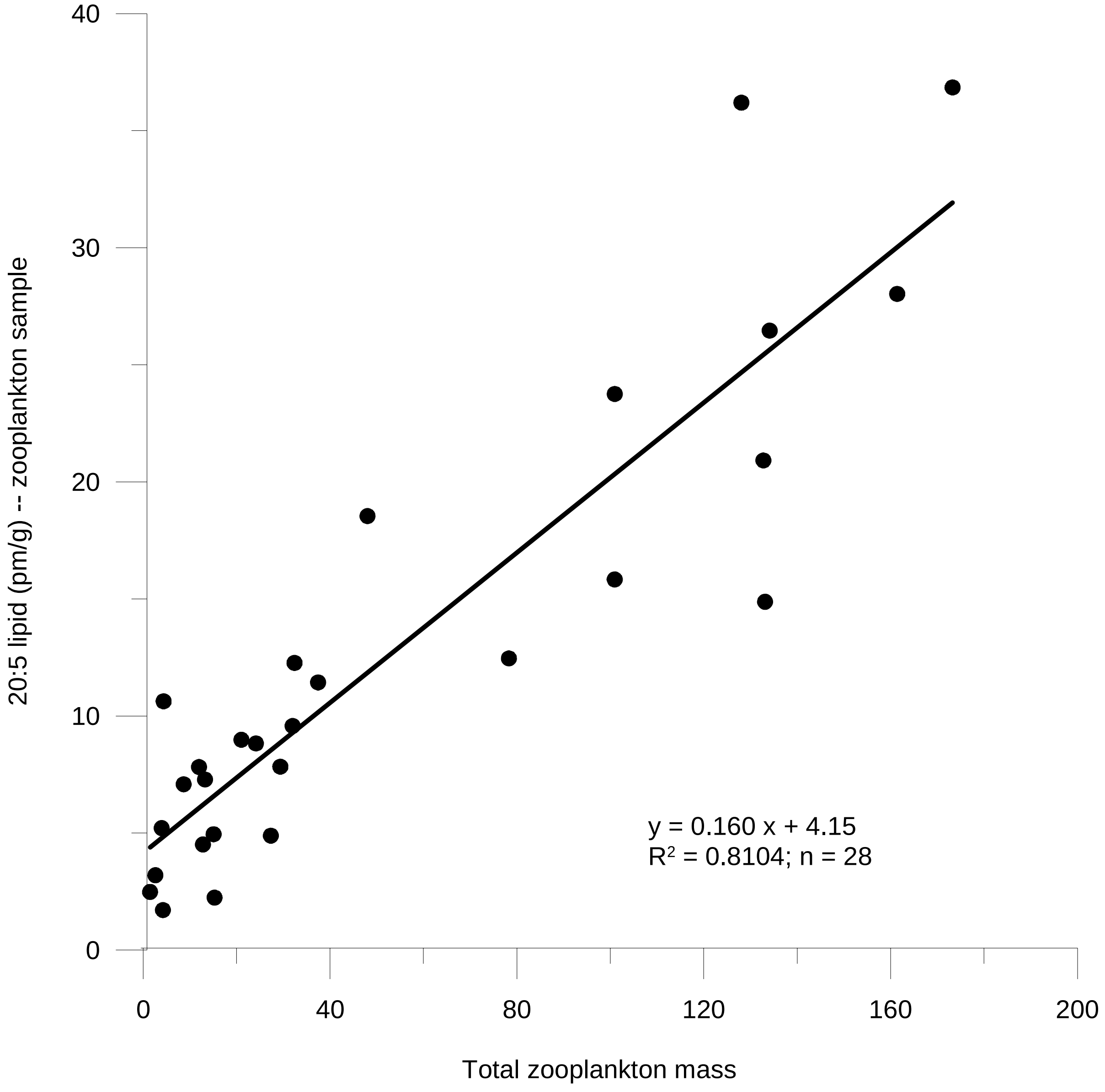

Figure 27: San Joaquin River zooplankton samples -- correlation between rotifer density and mass of 20:1 lipid.

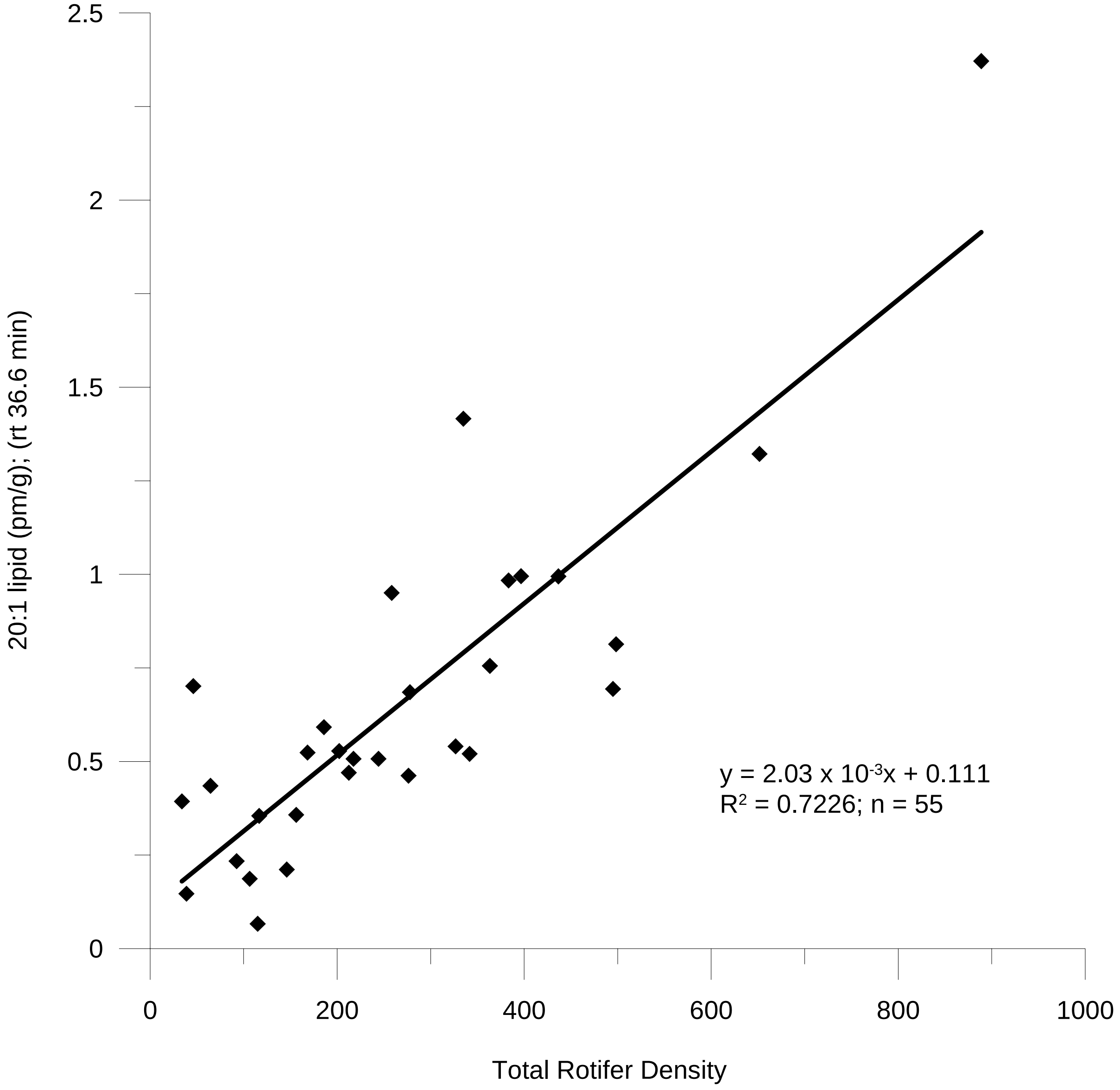

Figure 28: San Joaquin River zooplankton sample (7/14/07) -- correlation between copepod density and lipid 37.9 min (lipid identification pending further analysis).

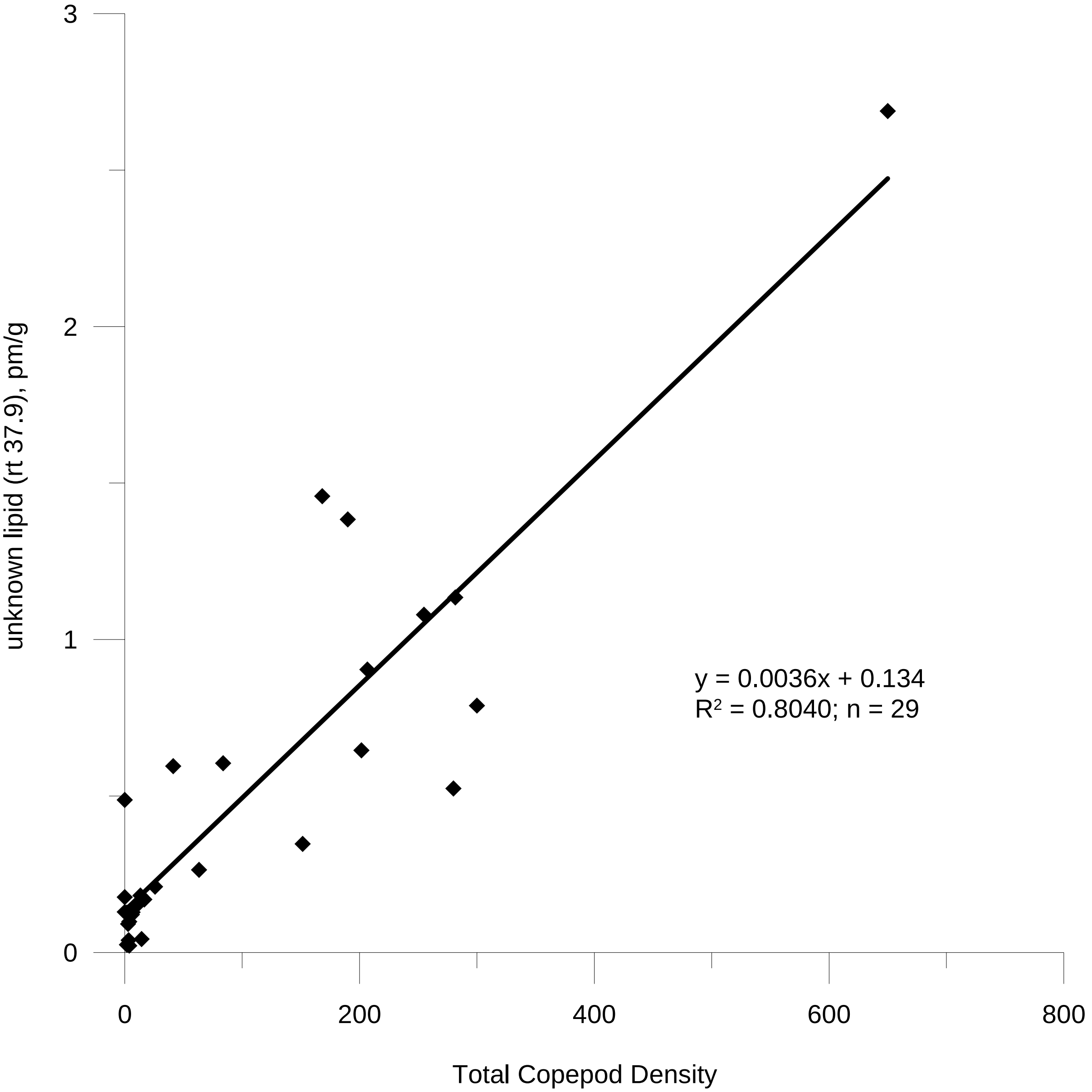

Figure 29: Predicted values of total, rotifer, and non-rotifer (copepod) mass as compared to zooplankton biomass measured by standard methods