Montana Creek Fecal Coliform and Water Quality Assessment

August 2008 – June 2009

Final Report to the Alaska Department of Environmental Conservation

prepared by

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Figure 1. Project volunteers collect water samples and record data in Montana Creek.

Introduction

Montana Creek is a clear-water tributary to the Susitna River in southcentral Alaska. It is an important spawning and rearing stream for chinook, coho, pink, and chum salmon and also supports healthy trout populations. Its 157-square-mile basin is largely undeveloped, although the lower part of the basin downstream from the Yoder Road bridge receives development and recreation pressure. Salmon fishing is open from ¼ mile above the Parks Highway bridge to its mouth, while the upper part of the river is managed as a popular catch-and-release rainbow trout fishery.

Montana Creek receives intense recreational pressure especially during the Chinook and coho salmon fishing seasons. The associated foot traffic and undeveloped camping in the riparian area has resulted in degraded habitat, increased sediment loads, elevated fecal bacteria levels, and biological impairment (Davis and Davis 2006). Additional recreation pressure comes from ATV traffic in the area. These activities contribute to riparian habitat loss and increased sediment loads and may cause creek temperatures to rise. Many of these recreational activities are popular both near the Yoder Road bridge and along the Old Montana Creek Road.

This study was designed to investigate the ecological impacts of recreational activities on Montana Creek To accomplish this, we monitored water quality at strategic locations in the lower part of Montana Creek, building on the work of Davis and Davis (2006) through the analysis of additional water quality data to assess existing conditions and track environmental changes over time. Parameters measured included fecal coliform bacteria, turbidity/sediment and temperature in addition to biological assessments made usingboth benthic macroinvertebrates and algae.

Methods

Sample site location

The sampling locations closely matched those of Davis and Davis (2006) and were initially selected to describe, moving from upstream to downstream, the reference, potentially impacted, and presumed impacted condition. The upstream site (MC-Yoder) was just downstream of the Yoder Road bridge is just downstream from the confluence with the South Fork. Notable channel and riparian disturbances were associated with the bridge, and an extensive gravel bar adjacent to the sampling reach serves as a popular undeveloped camping site during the summer months. As such, there was no true reference site above all human impacts on the mainstem Montana Creek. Most of the residential development is between the Yoder Road and the Parks Highway bridges, with additional recreational and commercial impacts at the Parks Highway and downstream. The middle site (MC-Mid) was situated above the commercial development, but below most residential development, just upstream of where old Montana Creek Road approaches the creek. This site was moved several miles downstream from the previous study (Davis and Davis 2006) for ease of access due to tight holding time requirements for fecal coliform analysis. The most downstream site (MC-Parks) was below the Parks Highway and above the railroad crossing where the south bank riparian vegetation has been removed at a private campground. A map of the sampling locations can be found in Figure 2.

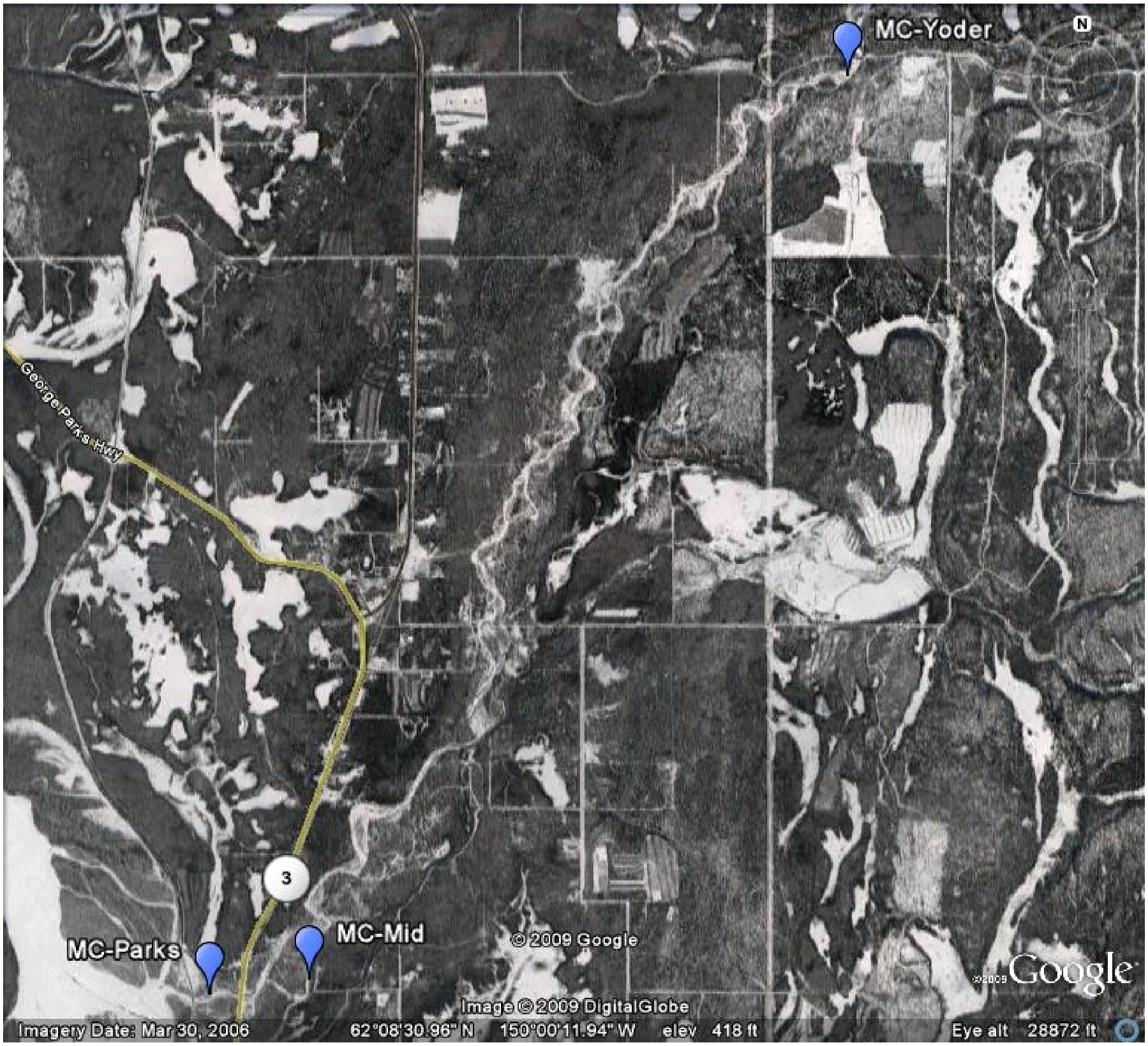

Figure 2. The three main study sites on lower Montana Creek.

Field sampling

Each of the three sample sites had a total of 3 sampling stations located along a cross section of the creek for a total of nine stations. At each cross section, sampling stations were located 0.5 meters from each bank and one was located in the thalweg. A calibrated Hydrolab minisonde 4 was used to collect *in situ* dissolved oxygen, pH, and specific conductance data near one of the banks at each of the three sampling locations on each sampling date.

Fecal coliform (FC), total suspended solids (TSS), and turbidity samples were collected at each of the nine sampling stations. All samples were collected in sterilized containers at mid-depth at each station, or at elbow depth if the depth at the site was greater than one meter. If the water at the thalweg site(s) was too deep to safely collect samples, the thalweg samples were collected from a section of the stream as close to the thalweg as could safely be sampled. A target of five samples was collected during each of three 30-day sampling periods: August 2008, September 2008, and June 2009.

The sampling team conducted a Wolman pebble count in the late summer to determine any differences in substrate size and embeddedness between sites. One hundred particles were selected systematically along diagonal cross-channel transects. Particles were measured for b-axis length, and particle embeddedness was estimated as percent embedded in fine substrates.

Temperature data loggers were deployed at each of the three sites following the methods of Mauger (2008). Temperature loggers were deployed from August 2 to October 22 in 2008 and again from May 16 to July 31 in 2009.

Macroinvertebrates and diatoms were collected in early August 2008, and again in May 2009 following methods developed by the University of Alaska Anchorage's Environment and Natural Resources Institute (Major 2001, ENRI 2004). Macroinvertebrate samples were collected with a 350-µm mesh D-frame net from 100-meter reaches that included each of the three sampling sites. Benthic diatoms were collected by scrubbing a standardized area from a random selection of 16 rocks spread throughout the 100-meter reaches.

Laboratory analysis

FC and TSS analyses followed procedures described in Standard Methods (APHA 1998; SM 9222D and SM 2540D, respectively). FC samples were first passed through a membrane filter. Then, the filter was incubated in contact with culture medium for 24 hours after which the resulting colonies were counted and verified to indicate the total number of coliform bacteria in the filtered sample. TSS samples were passed through a pre-weighed glass-fiber filter disc, and the disc was then oven-dried to a constant weight. The increase in weight due to residue on the disc indicates the total suspended solids in the filtered sample.

Macroinvertebrate and diatom analyses followed ENRI protocols (Major 2001, ENRI 2004). Macroinvertebrate sample processing followed a standard 2-phase subsampling technique. For each sample, a 300-organism fixed count was set aside and the remaining sample was then visually scanned for 5 minutes in order to select any large and/or rare taxa that may have been missed in the fixed count. Organisms selected in the fixed count and the 5-minute visual scan were then identified to the lowest practical level (generally genus). Diatom samples were acid digested to clear specimens for easier identification and then mounted on microscope slides. Identifications were made on a 600-valve count to the lowest practical level (generally species). Additional details about sampling and laboratory procedures and parameters can be found in the ADEC-approved QAPP for this project.

Data management

Field data sheets were printed on Rite in the Rain paper and used to record field measurements and observations. Data sheets were reviewed in the field to insure completeness before moving on to the next site. Once back in Anchorage, data and observations were entered into an Excel spreadsheet. The project coordinator reviewed all the data to insure its accuracy. Data not meeting data quality objectives outlined in the QAPP were flagged in the spreadsheet. Laboratory data were reviewed upon receipt from the lab and also entered into an Excel spreadsheet for data analysis.

Macroinvertebrate data was entered into ENRI's Ecological Data Application System (EDAS) database. Macroinvertebrate data analysis was also accomplished in EDAS. Diatom data was entered into ENRI MS Access database for storage and analysis.

Data quality assurance

The Quality Assurance Project Plan (QAPP) for this project was approved by ADEC prior to any data collection. The QAPP outlines data quality assurance measures in more detail, and is available from the author upon request. The Hydrolab minisonde 4a unit calibrated prior to sampling events. Ten percent of all fecal coliform, turbidity, and TSS samples processed in the lab were sterile deionized water. After FC and TSS samples were collected, they were stored in a cooler with blue ice until they arrived at the lab. Two (2) bottles of sterile de-ionized water travelled in the cooler and were processed and analyzed with the FC and TSS samples for QA purposes. Ten percent of the FC and TSS samples analyzed were sterile de-ionized water blanks.

Results and Discussion

Water temperature

The temperature of the water influences both the chemistry and biology in any aquatic system. Water temperature, along with barometric pressure, determines the amount of dissolved oxygen the water can hold in solution when at equilibrium with the atmosphere. The colder the water, the more dissolved oxygen it can hold in solution. Water temperature also affects the metabolic and growth rates of fish and their susceptibility to some diseases. The state of Alaska sets the upper limit for water temperature in waters at 20°C for aquatic life; for waters that are migration routes and rearing areas for anadromous fish the upper limit is set at 15°C; for waters that serve as spawning and incubating areas for anadromous fish the upper limit is 13°C.

At no time while temperature data loggers were deployed did water temperature measurements exceed 20°C. The warmest temperatures were measured in July 2009, when maximum temperatures exceeded 19°C on 6 days at the MC-Parks site, exceeded 15°C at every site on 19 days, and exceeded 13°C at every site on 30 out of 31 days. Daily average temperatures during this month exceeded 15°C at all sites on 7 days and exceeded 13°C on 22 of 31 days. By comparison, in August 2008 and June 2009, daily average temperatures did not exceed 13°C on any day. (Table 1)

Table 1. The number of days the mean and maximum temperatures exceeded 13°C and 15°C in the months of August 2008, June 2009, and July 2009 at each of the sampling locations.

Temperature	August 2008			June 2009			July 2009		
	MC-Yoder	MC-Mid	MC-Parks	MC-Yoder	MC-Mid	MC-Parks	MC-Yoder	MC-Mid	MC-Parks
Mean >13°C	0	0	0	0	0	0	22	23	29
Mean >15°C	0	0	0	0	0	0	9	7	11
Max >13°C	1	4	5	13	11	4	30	30	31
Max >15°C	0	0	0	1	1	0	19	20	23

Dissolved oxygen

The dissolved oxygen content in a river is controlled by several factors, including water temperature, atmospheric pressure, hydraulics, and rates of photosynthesis and respiration. All fish living in Montana Creek, and especially salmon, require well-oxygenated water throughout their entire life cycle. Dissolved oxygen was measured as a concentration (mg/L) and as a percentage of its maximum value (% saturation). Alaska state water quality standards set a lower limit of 7 mg/L of dissolved oxygen for waters that support anadromous fish.

At no time during our sampling did the dissolved oxygen levels approach the lower limit of 7 mg/L; the lowest recorded value for dissolved oxygen was on August 2, 2008 when values ranged from 9.75 to 9.87mg/L at the three sites. All measurements throughout the sampling period ranged from 88 to 100% saturated, indicating healthy levels of dissolved oxygen for the creek (Table 2).

pH

pH is a measure of the hydrogen ion activity, or acidity, of the water. Neutral waters have a value of pH 7; pH values below 7 indicate acidic conditions, while values above 7 indicate basic conditions. Natural waters typically have a pH between 6.5 and 8.0 standard units (Hem 1985). Alaska state water quality standards use this range as the acceptable pH range for natural waters, and also state that they should not vary more than 0.5 pH units from their natural background condition.

The pH values in Montana Creek ranged from 6.7 to 7.2 (Table 2), within the typical range for healthy fish. These circum-neutral values for pH are similar to those measured by Davis and Davis (2006).

Specific Conductance

Specific conductance is a measure of the water's ability to conduct an electric current and values increase with concentrations of dissolved ions. During low-flow conditions, the river's specific conductance will typically be at its highest, indicating a larger proportion of ion-rich groundwater in the river's makeup. Conversely, during high flow periods, specific conductance values tend to be lower, indicating a higher proportion of runoff (from rainfall or snowmelt) which typically has lower ion concentrations.

Specific conductance measured values in Montana Creek tended to follow this pattern, with values dropping from near 40µS/cm in the summer and fall months to around 20µS/cm during the May sampling events, when the river stage was at its highest for the study period. As the river level dropped in June, the specific conductance came back up to near 40µS/cm (Table 2).

Table 2. Water quality parameters measured *in situ* with a Hydrolab Minisonde 4a. Blanks represent equipment failure or data that did not meet QA/QC standards.

	Specific Conductance (µS/cm)			pH			Dissolved Oxygen (mg/L)			Dissolved Oxygen (% sat)		
Date	MC-Parks	MC-Mid	MC-Yoder	MC-Parks	MC-Mid	MC-Yoder	MC-Parks	MC-Mid	MC-Yoder	MC-Parks	MC-Mid	MC-Yoder
8.2.08	28	31	30	7.0	7.1	7.1	9.8	9.8	9.9	88.9	88.1	88.8
8.8.08	36	36	33	7.2		7.2	10.0	10.0	10.2	92.8	93.0	93.6
8.15.08	37	38	35	7.2	7.0	7.1	10.0	10.5	10.3	89.5	94.4	91.7
8.18.08	36	39	39	7.3	7.1	7.2	10.2	9.9	9.9	92.8	92.1	92.7
8.23.08	41	39	39	7.0	7.0	7.1	10.3	10.1	10.4	93.6	90.8	92.5
8.30.08	36	36	34									
9.4.08	39	39	39									
9.16.08	40	40	39	7.1	7.1	7.0	11.8	11.5	11.1	99.6	96.5	93.6
9.25.08	32		31	7.1	7.1	7.2	12.1	11.9	12.1	97.1	94.1	93.8
10.02.08			38						12.5			88.0
10.04.08	39	38	37	7.1	7.1	7.2	12.8	12.7	12.7	93.6	92.7	91.1
05.03.09	25	26	25	7.0	6.9	7.1	13.2	13.0	13.8	92.4	91.2	94.3
05.11.09	23	24	20	7.1	7.0	7.4	11.7	11.4	12.1	95.2	92.4	94.5
05.15.09	22	22	19	7.2	7.1	7.2	12.2	12.1	12.4	93.5	92.8	92.7
05.19.09	20	19	18	7.0	7.0	7.0	10.5	10.5	10.8	95.3	95.4	95.5
05.23.09	21	21	19	7.0	7.0	7.0	10.0	10.0	10.1	98.0	97.8	97.7
05.29.09	20	21	19	7.1	7.0	7.1	10.0	9.9	10.2	96.8	96.6	96.5
06.05.09	35	36	36	6.9	6.9	6.9	10.4	9.9	10.4	90.7	88.5	91.4
06.09.09	35	36	36	7.2		7.2	9.9	10.3	10.6	91.2	94.5	93.6
06.24.09	33	34	32	6.8	6.7	6.7	10.6	10.8	11.1	92.8	94.6	94.5
06.26.09	38	38	37	6.7	6.6	6.7	10.2	10.5	10.6	91.7	93.4	93.1

Turbidity

Turbidity is a measure of water's cloudiness due to suspended particles that are generally too small to see with the unaided eye. Turbidity tends to increase during high flow conditions, due to the runoff from rainfall or snowmelt carrying particles from the land into the creek. Turbidity levels were generally low during the ten sampling events in 2008 (August through early October), with measurements between 0.46 and 1.28 NTUs at all sites. During the first May sampling event, turbidity measurements rose to over 9 NTUs at the two downstream sites, an over seven-fold increase over the highest readings in 2008. As the water level dropped in June, so did the turbidity, with measurements returning to below 2 NTUs. The Alaska state water quality standard for turbidity requires natural running waters not exceed an increase of 25 NTUs above natural conditions.

At no time did turbidity exceed the state water quality standard, although turbidity was consistently and significantly lower at the Yoder Road (upstream) site than both the middle site and the Parks Highway site (*p*<0.001; Repeated Measures ANOVA; SPSS v.17) (Figure 3). Turbidity readings for deionized water trip blanks averaged 0.1 NTUs, and was never greater than 0.3 NTUs.

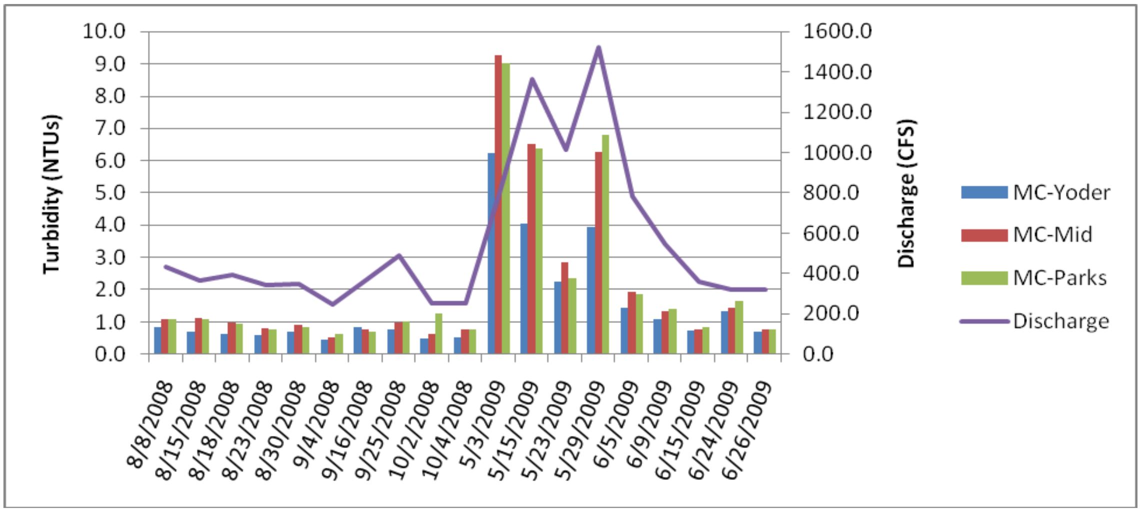

Figure 3. Mean turbidity measurements for the near right bank, near left bank, and thalweg from each of the three sampling sites on Montana Creek in relation to stream discharge.

Total Suspended Solids

TSS is a direct measure of the concentration of particulate material suspended in water. TSS measurements will frequently correlate with turbidity measurements and, as with the turbidity data, TSS levels spiked during the higher flows in May and dropped with falling water levels. Among-site differences in TSS were not as obvious as for turbidity, but during higher flows the upstream site below Yoder Road consistently had lower TSS than the two lower sites (Figure 4).

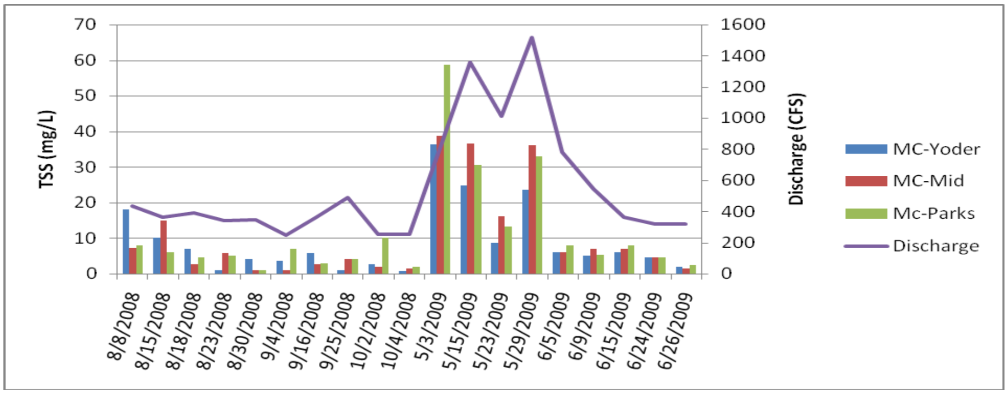

Figure 4. Mean total suspended solids measurements for the near right bank, near left bank, and thalweg from each of the three sampling sites on Montana Creek in relation to stream discharge.

Fecal coliform bacteria

Fecal coliform bacteria (FC) are used as indicators of possible sewage contamination, as they are found in human and other animal feces. The Alaska state water quality standards for FC (drinking water) state that the geometric mean for a 30-day period should not exceed 20 fecal colonies/100mL, with no more than 10% of the samples exceeding 40 fecal colonies/100mL.

FC concentrations were highest during the first half of August, with another spike in FC on October 4, 2008 (Figure 5). FC concentrations exceeded 40 fc/100ml in fewer than 10% of all samples, and geometric means did not exceed 20 fc/100ml in any of the three 30-day periods when sampling was completed (Table 3). There was no pattern associated with sampling site, nor was there a consistent pattern associated with sampling stations, therefore values for near right bank, near left bank and thalweg were averaged for each site (Figure 5). Results from May 11, 15, and 19, 2009 either failed to meet holding requirements or were lost due to lab errors, resulting in an incomplete data set for the May 30-day period. Samples were not collected from near the right bank at site 2 in 2009 due to unsafe wading conditions in the creek.

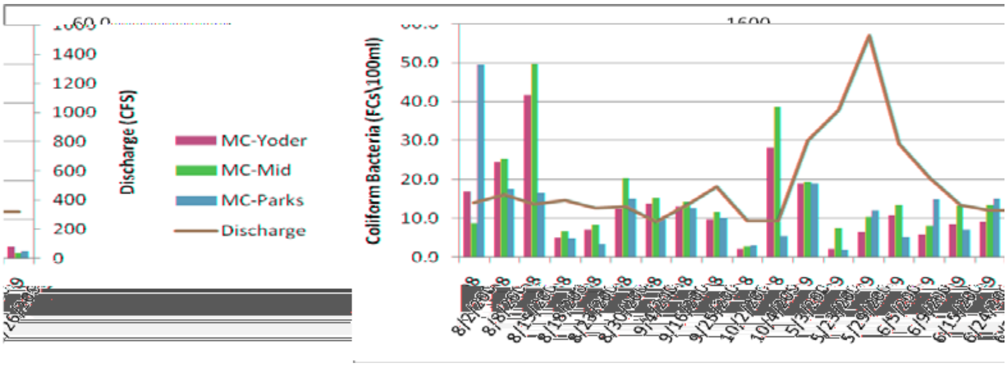

Figure 5. Mean of near right bank, near left bank and thalweg fecal coliform bacteria measurements from each of the three sampling sites on Montana Creek in relation to stream discharge.

Table 3. Geometric means of fecal coliform colonies (fc/100ml) at each of the three study sites for samples taken from the near left bank, thalweg, and near right bank. Right bank samples at the middle site were not collected due to high stream flows.

	MC-Yoder			MC-Mid			MC-Parks		
	Left Bank	Thalweg	Right Bank	Left Bank	Thalweg	Right Bank	Left Bank	Thalweg	Right Bank
August 2008	7.4	11.9	10.4	16.3	18.0	10.7	12.7	14.7	12.5
Sept. 2008	6.9	3.9	13.0	10.1	3.9	8.5	7.6	3.9	13.0
June 2009	7.4	6.3	6.9	7.5	7.7		7.3	6.9	5.6

Substrate characteristics

Substrate size and percent embeddedness from the three sites are shown in figures 6 and 7. MC-Mid had a higher composition of gravel sized substrate, with 87% measuring less than 64 mm along the b-axis. By comparison, 49% of substrate from the MC-Parks site and 64% from the MC-Yoder site were greater than 64mm along the b-axis. Sand deposits were most noticeable at the MC-Yoder site, along the gravel bar on the right bank, but only accounted for 4% of the substrate at that site. Substrate at all sites was relatively unembedded. No pebble count was conducted in the spring of 2009 due to high water and swift flows which made wading across the channel unsafe.

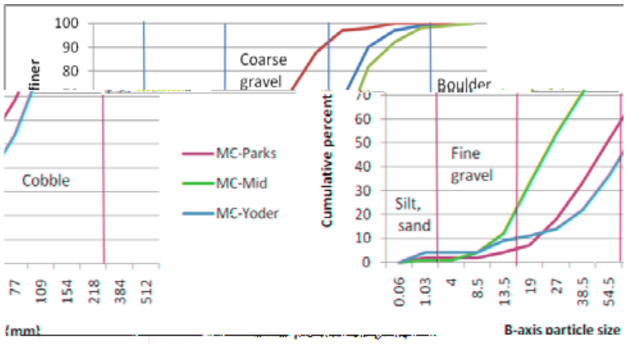

Figure 6. Substrate size distribution at the three Montana Creek sampling reaches.

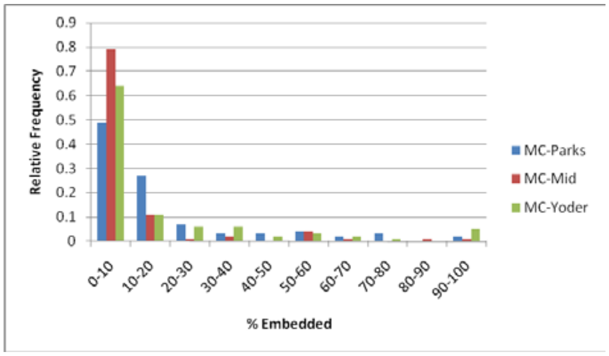

Figure 7. Percentatage of substrate embedded in fine sediments at the three Montana Creek sampling reaches.

Biota

One of the most effective ways to determine a stream's ecological integrity is through the investigation of its living systems. Resident stream biota function as continual natural monitors of water quality, responding to the effects of both episodic and cumulative pollution and habitat alteration.ENRI has developed standard methods to assess stream condition based on both the benthic macroinvertebrate and benthic diatom communities. A macroinvertebrate multi-metric index of biotic integrity has been developed for clear-water streams in the Cook Inlet Ecoregion, known originally as the Alaska Stream Condition Index (ASCI). This index, created in 2001 and revised and renamed to the Cook Inlet Index in 2007, utilizes 6 metrics based on the macroinvertebrate assemblage to calculate an overall score which represents the stream's relative biological health (Rinella and Bogan 2007)(Table 4). The Cook Inlet Diatom Index was developed in 2007, and utilizes 5 metrics based on the diatom assemblage to calculate an index score that is useful in assessing the stream's biological health (Rinella and Bogan 2007)(Table 5).

Macroinvertebrates were collected at all three sites in early August 2008 and again in mid to late May 2009. The index scores from August 2008 showed a decrease in stream health from the uppermost site at Yoder Road (CIMI = 94.8), to MC-Mid (CIMI=79.2), to the lowest site below the Parks Highway (CIMI=53.8). There were no discernible differences between sites from May 2009, with scores in the 90s (Table 4). For a complete list of taxa and abundances see Table A1.

Table 4. Scores for the Cook Inlet Macroinvertebrate Index (2007) and its constituent metrics for the three Montana Creek sample sites. (Raw scores/scaled scores).

Metric/Scaled score	**MC-Yoder Aug 2008**	**MC-Yoder May 2009**	**MC-Mid Aug 2008**	**MC-Mid May 2009**	**MC-Parks Aug 2008**	**MC-Parks May 2009**
# of EPT taxa	12/90.8	12/90.8	9/63.3	12/90.8	11/81.7	11/81.7
# of mayfly taxa	4/77.8	5/100	3/55.6	5/100	3/55.6	4/77.8
Shannon's Diversity Index	2.24/100	1.95/87.9	2.05/95.0	2.18/100	1.17/32.1	2.13/100
% mayflies	43.6/94.2	71.5/100	28.5/61.3	71.3/100	4.8/9.7	48.0/100
% non-insects	1.6/100	0/100	0.5/100	0.4/100	0.9/100	0/100
% scrapers	20.4/100	48.3/100	16.8/100	17.8/100	6.0/43.8	31.9/100
CIMI Score	**94.8**	**96.5**	**79.2**	**98.5**	**53.8**	**93.3**

Diatoms were collected concurrently with the macroinvertebrates. Metrics for motility and organic nitrogen tolerance scored consistently high for all sites in both seasons, indicating good water quality. The saprobity metric, which is a measure of organic pollution, also failed to discriminate between sites. Taxa richness was greater at all sites in the May 2009 sampling, but this metric also did not discriminate between sites. The trophic state metric affected the difference between the multimetric index scores the most (Table 5), and was driven primarily by variations in the abundance of *Achnanthidium minutissimum*, the most abundant diatom in Montana Creek (Table A2).

Table 5. Scores for the Cook Inlet Diatom Index and its constituent metrics for the three Montana Creek sample sites. (Raw scores/scaled scores)

Metric/Scaled score	**MC-Yoder Aug 2008**	**MC-Yoder May 2009**	**MC-Mid Aug 2008**	**MC-Mid May 2009**	**MC-Parks Aug 2008**	**MC-Parks May 2009**
% Motile	0.3/98.6	1.0/94.3	0.7/96.5	0.7/96.5	0.3/98.6	1.0/94.3
Organic Nitrogen Tolerance	1.49/91.2	1.79/89.3	1.69/89.9	1.56/90.8	1.52/91.0	1.65/90.2
Saprobity	1.99/63.8	1.97/65.4	2.05/58.2	1.96/66.7	2.04/58.9	2.01/62.0
Taxa Richness	22/91.9	28/78.3	25/85.1	28/78.3	19/98.6	32/69.3
Trophic state	4.17/66.5	5.62/19.8	4.93/41.9	4.06/70.1	4.20/65.4	4.77/46.9
CIDI Score	**82.4**	**69.4**	**74.3**	**80.5**	**82.5**	**72.5**

Conclusions and Recommendations

The study design of this project allowed for analysis of water quality along a longitudinal section of stream, and across-channel variation that may be due to riparian activity along each bank. While some of the data suggest possible downstream impairment during certain parts of the year, no consistent across-channel differences were discernable. The results of this assessment showed inconsistent and inconclusive evidence of water quality impairment in Montana Creek as it relates to recreational activity.

Turbidity and TSS sampling showed that sediment loads in the creek spiked during times of increased runoff, but were not necessarily elevated during times of increased recreational activity. During the May 2009 sampling, both TSS and turbidity measurements were considerably higher than in August, September, and early October 2008, mostly attributable to increased stream discharge from melting snow. A sampling event occurred on May 23, 2009, which was the Saturday of Memorial Day weekend, a recreational high use time at Montana Creek (Figure 8). On this day TSS and turbidity measurements were relatively low across sampling locations, and again appeared to be more closely related to stream discharge (Figures 3-4). Fecal coliform bacteria concentrations in the creek were also low on this day at all sites.

Figure 8. Camping and recreational activity along the left bank at an organized campground below the Parks Highway bridge on August 1, 2008 (left); and below the Yoder Road bridge on the gravel bar along the northwest bank of Montana Creek on August 2, 2008 (center), and on May 23, 2009 (Saturday of Memorial Day weekend) (right).

Turbidity was the one physicochemical parameter that showed consistent and significant differences between the MC-Yoder and MC-Parks sites. On all but one occasion, turbidity was higher at MC-Parks, suggesting an increase in suspended sediment. TSS data did not bear out these same differences, although quantities of TSS were typically so low, that differences were smaller than the potential error. During May 2009, when values were higher, a consistent pattern emerges that corroborates the turbidity trend of increased sediment at the downstream MC-Parks site.

Our data did not show that FC concentrations in Montana Creek were correlated with stream discharge. FC concentrations above 20 fc/100ml occurred in three sampling events in early to mid-August and once in early October (Figure 5). Human activity in the riparian zone of the creek was high at these times, with many people camping on the gravel bar below the Yoder Road bridge and at the commercial campgrounds along the Parks Highway, yet at other times when human activity was high, FC concentrations were relatively low (eg. August 23, 2008 and May 23, 2009) (Figure 5).

Water temperature was consistently higher at MC-Parks than at MC-Yoder, although temperature differences rarely exceeded 1°C at any given time. The temperature differences are consistent with the findings of Davis and Davis (2006). Temperature data loggers were left in the creek through July 2009—water temperatures during this month were consistently higher than those of August 2008 and June 2009. Future temperature monitoring in Montana Creek should be done so that continuous readings can be recorded throughout the summer months.

Our study design enabled us to investigate across channel differences in TSS, turbidity, and FC bacteria at our three sample sites. No site showed a consistent pattern or discernible differences in trends for any parameter associated with cross-channel location. On occasion, cross-channel differences were pronounced, but no pattern emerged when viewed over a longer temporal scale. The greatest difference in our data set occurred on October 2, 2008, when turbidity from the near left bank sample station at MC- Parks was more than three times greater than the turbidity from any other station on that day. There was a correspondingly high TSS measured from the same station (six times greater than any other sample station that day). FC concentrations from that station were measured at less than one fc/100ml. Two days later, there was a spike in FC concentrations (that was true for all locations), but turbidity and TSS measurements were virtually the same across the channel.

Bioassessment data for macroinvertebrates collected in August 2008 suggested impairment at the downstream MC-Parks site, and was consistent with the findings of Davis and Davis (2006)(Table 6). An abundance of Chironomidae (midge) larvae drove the index score down at the MC-Parks site (Table A1). The May 2009 macroinvertebrate bioassessment data indicated excellent stream health at all three sites, suggesting that the lower site recovered over the winter. Since the bioassessment index for Cook Inlet macroinvertebrates was developed with an index period of mid-May through June, scores from dates outside that period should be interpreted with caution. Those dates were intentionally chosen to avoid complications associated with natural disruption of the macroinvertebrate assemblage by spawning salmon and recreational fishermen.

Table 6. Cook Inlet Index scores for macroinvertebrates in Montana Creek.

	MC-Yoder	MC-Mid	MC-Parks
May 2009	96.5	98.5	93.3
August 2008	94.8	79.2	53.8
August 2005[1,2]	56.3	74.4	45.7
July 2001[1,3]		68.0	

[1] Converted to the recalibrated Cook Inlet Ecoregion Index (Rinella and Bogan 2007)
[2] Data from Davis and Davis 2006
[3] Data from Major et. al. 2002

Cook Inlet Index scores for macroinvertebrates in Montana Creek show an improvement in stream health over the past 8 years (Table 6). We would recommend that subsequent macroinvertebrate sampling be conducted in the spring, to coincide with the Cook Inlet Index period.

Diatom bioassessment data showed similar results at all sites during both August 2008 and May 2009 sampling events. Diatoms have rapid reproduction rates and short life cycles and therefore respond quickly to perturbation (Stevenson and Lowe, 1986). Therefore, stresses may be reflected in the macroinvertebrate community over a longer period of time, while the diatom community is quick to recover from periodic periods of perturbation that could be caused by spawning salmon and/or recreational fishing pressure.

While it is clear that Montana Creek is receiving seasonal recreational camping, ATV, and fishing pressure, it is less clear what short and long-term effects these activities are having on stream health. Future monitoring efforts should continue to investigate the apparent seasonal biological impairment of the lower part of the creek and allow for water quality monitoring during the month of July, when there is much recreational activity in the riparian zone and creek temperatures are at their highest.

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Appendix A—Water quality data

Table A1. Montana Creek Macroinvertebrate taxa .

Class	Order	Family	Genus	MC-Yoder 2008	MC-Yoder 2009	MC-Mid 2008	MC-Mid 2009	MC-Parks 2008	MC-Parks 2009
Insecta	Ephemeroptera	Baetidae	Baetis	64	58	35	131	11	82
		Ephemerellidae	Drunella	21	59	1	5		8
			Ephemerella	12	6		24	2	7
		Heptageniidae	Cinygmula	13	67	25	40	3	22
			Epeorus		1		4		
	Plecoptera	Chloroperlidae		1		1		1	5
			Alaskaperla		1				
			Alloperla				0		
			Suwallia	1	5	5	6	3	6
		Nemouridae		1				2	
			Amphinemura	1			1		
		Perlodidae	Isoperla		2	1	24	1	5
		Leuctridae			0				
	Trichoptera	Apataniidae	Apatania	3		4		14	
		Brachycentridae	Brachycentrus	5	11		5	11	2
		Glossosomatidae	Glossosoma	15	2	6	2	3	49
		Hydropsychidae	Arctopsyche			0	0		0
		Limnephilidae	Ecclisocosmoecus	1					
			Ecclisomyia	1		2			1
			Onocosmoecus				4	1	1
			Psychoglypha	0				3	
		Rhyachophilidae	Rhyacophila		1				
	Diptera	Chironomidae		51	41	73	29	251	51
		Ceratopogoniidae	Probezzia			1	1	1	
		Empididae	Chelifera			2		2	
		Simuliidae	Prosimulium		2		4		1
			Simulium	54		40		2	
		Tipulidae	Dicranota	2	2	3	3	1	5
			Hexatoma	1	9	14	2	18	3
Arachnoidea	Hydracarina			4		1		2	
Oligochaeta								1	
Turbellaria							1		

Total organisms (subsample) 251 267 214 286 333 248

0 denotes taxa present in sample, but not in subsample

Table A2. Montana Creek diatom taxa.

Taxon	MC-Yoder 2008	MC-Yoder 2009	MC-Mid 2008	MC-Mid 2009	MC-Parks 2008	MC-Parks 2009
Achnanthidium minutissimum	191	381	273	151	185	254
A. pyrenaicum	6	6	14	0	23	6
Aulacoseira ambigua	0	0	8	6	12	8
A. canadensis	0	0	0	4	0	0
Brachysira brebisonii	4	4	0	0	0	0
B. neoexilis	0	0	0	2	0	6
Cavinula pseudoscutiformis	0	4	0	0	0	0
Chamaepinnularia soehrensis	0	0	0	2	0	2
Cyclotella meneghiniana	0	0	0	2	0	6
Cymbella cistula	2	0	0	0	0	0
C. gracilis	0	2	0	0	0	0
Diatoma mesodon	2	4	2	4	0	4
D. tenuis	0	2	2	2	0	4
Didymosphenia geminata	0	0	14	0	16	2
Encyonema gaeumanii	0	2	0	0	0	0
E. minutum	8	6	14	10	10	8
E. silesiacum	29	18	48	53	40	41
Encyonopsis cesatii	0	0	5	0	0	0
Eucocconeis flexella	0	0	4	0	2	0
E. laevis	6	12	14	14	12	22
Eunotia bilunaris	0	2	0	2	0	2
E. exigua	0	4	0	0	0	0
E. incisa	0	2	0	0	0	0
E. praerupta	2	0	2	0	2	2
E. subarcuatoides	0	2	0	4	0	4
Fragilaria capucina	54	25	44	27	33	8
F. vaucheriae	0	0	0	9	0	4
Frustulia rhomboides	0	0	0	0	0	2
Gomphonema olivaceum	2	12	0	4	0	0
G. olivaceum var. olivaceoides	2	0	2	3	2	2
G. parvulum	0	4	0	0	0	2
Hannea arcus	206	25	61	90	155	86
Hantzschia amphioxys	0	0	2	0	0	0
Meridion circulare	4	0	2	0	0	0
Navicula gregaria	2	2	0	0	0	0
Neidium bisulcatum	0	2	0	0	0	0
Nitzschia fonticola	0	2	0	0	0	0
N. perminuta	4	6	8	6	0	0
Pinnularia borealis	0	0	2	2	0	0
P. subcapitata	0	0	0	0	0	2
Placoneis elginensis	0	0	0	0	2	0
Planothidium haynaldii	2	0	0	0	0	2
Psammothidium bioreti	4	0	0	0	0	0
P. subatomoides	0	6	2	55	6	21
Pseudostaurosira brevistriata	0	0	0	0	0	2

Reimeria sinuata	29	6	12	66	16	18
Rossithidium pusillum	2	8	2	4	0	10
Staurosira construens	0	0	19	2	17	0
S. construens var. venter	0	0	0	8	0	6
Staurosirella pinnata	0	6	0	2	6	6
Stenopterobia curvula	0	0	0	0	0	2
Synedra ulna	2	0	9	0	4	6
Tabellaria flocculosa	34	45	39	63	53	49
Tetracyclus glans	0	0	0	2	0	0

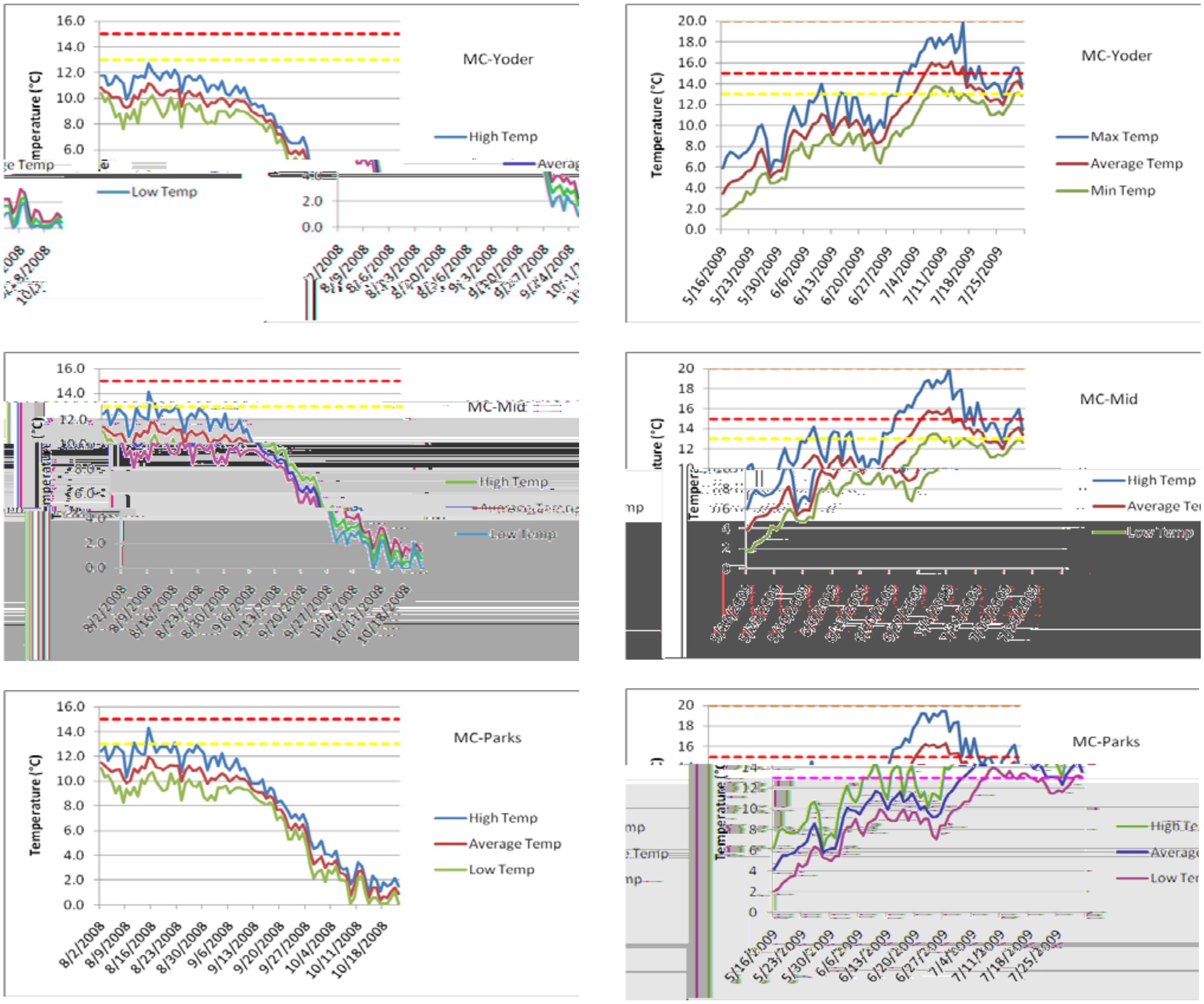

Figure A1. Daily water temperature data for the three Montana Creek sites. Dashed lines represent Alaska Water Quality Standards.

Table A3. Montana Creek FC bacteria concentrations (fc/100ml) by sampling station for each sampling date.

	MC-Yoder			MC-Mid			MC-Parks		
Date	Left Bank	Thalweg	Right Bank	Left Bank	Thalweg	Right Bank	Left Bank	Thalweg	Right Bank
8.2.08	60	58	30	7.6	10.6	8.2	8.2	28	14.7
8.8.08	25	18.2	9.4	29	25	22	31	13.5	28.8
8.15.08	14.1	3.5	32	63.5	63.5	21.8	32	47	46
8.18.08	5.9	5.9	2.9	8.8	8.8	2.9	5.9	4.1	5.3
8.23.08	0.1	5.9	4.7	8.2	10.6	6.5	10	6.5	4.7
8.30.08	13.3	22	10	18.6	22	20.6	8.6	21	8
9.4.08	11.3	9.3	10	10.7	15.3	20	25	8.7	8
9.16.08	14	14	10	10	16	16.6	13.3	14	12
9.25.08	9.3	10	11.3	10.6	10	14	5.3	12	12
10.02.08	2	0.1	7.3	2.7	4	2	0.67	4	2
10.04.08	5.3	6	5.3	35	40.6	40	22	32	30.6
05.03.09	21	17.6	18.2	23	15.9		20	14.7	22
05.23.09	4	0	2	7.3	8		0	2.7	4
05.29.09	10.7	11.3	14	8	12.7		4	9.3	6
06.05.09	4.1	7.6	4.1	14.1	12.9		11.8	9.4	11.2
06.09.09	20	11.8	12.9	4.7	11.8		8.3	2.9	6.5
06.15.09	8	6.7	6.7	16	10.7		8.7	13.3	4
06.24.09	11.7	14.1	19.4	12.9	14.1		10.6	10.6	6.5
06.26.09	2.9	1.2	2.3	1.7	1.2		2.3	4.1	2.9