Dynamics of Fine Particulate Organic Matter in a Phosphorus Fertilized Tundra Stream

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December 10, 1995

* Myron Mitchell Final Copy

* NOT Revised According to Bruce's comments

Abstract

The dynamics of benthic fine particulate organic matter (FPOM) were analyzed for a fourth order river fertilized with phosphorus on the North Slope of Alaska. Standing stock values obtained on 10 July 1995 and 7 August 1995 were significantly higher, in both pool and riffle environments, than samples taken from the unfertilized control reach: 18.5±14.1g/m^2 was collected in fertilized pools and 435.3±769.7g/m^2 was collected in fertilized riffles; control values were 13.7±8.5g/m^2 for pools and 0.6±0.3g/m^2 for riffles. Standing stock results were positively correlated to phosphorus concentrations (r=.92 and r=.63, n=5). Nitrogen isotope results (^{15}N) for standing stock experiments showed higher δ^{15}N in riffles. High δ^{15}N were recorded on 7 August 1995 for subsurface biofilm uptake indicating FPOM exchange between the channel and hyporheic zone.

Turnover experiments showed that FPOM settled at 1.47±1.43g/m^2/d in pools and at 1.93±1.53g/m^2/d in riffle environments. Bare white porcelain tiles revealed that 16% of the material settling in pools remained after one day while only 2% of the material remained in riffles. "Astro turf" covered tiles simulated moss covered rocks that are present due to phosphorus fertilization. Moss tiles retained 88% of the FPOM that had settled within 24 hours. Isotope results obtained for day 5 of the turnover series indicated higher δ^{15}N for riffles than pools. Riffle δ^{15}N did not seem to decline to ambient levels in the control reach, and probably could have been traced further downstream.

It appears that moss communities established because of phosphorus fertilization are significantly affecting the transport of FPOM. Tile experiments indicate that phosphorus is probably not increasing the production of FPOM, rather moss communities are trapping FPOM and slowing down turnover rates.

Introduction

Nutrient load and the potential for its associated "bottom-up" control plays a pivotal role in aquatic ecosystems. Not only do nutrients have the capacity to limit ecosystem production, they also may contribute to altering community structure (Pomeroy 1989). Phosphorus has long been recognized as a limiting nutrient for primary production in almost all freshwater environments (Dillon and Rigler 1974; Schindler 1978; Newbold et al. 1983). Phosphorus availability in turn can affect production at trophic levels throughout a food web (Johnston et al. 1990; Peterson et al. 1993).

In order to monitor the long term effects of nutrient disturbance in a pristine lotic ecosystem, phosphoric acid has been dripped into the Kuparuk River for 13 consecutive summers. Dramatic biological effects have been recorded since fertilization began on the Kuparuk in 1983. In the first two years of fertilization, a ten fold increase of chlorophyll *a* was observed in a the form of epilithic filamentous algae (Peterson et al. 1993). As a result of the epilithon blooms, densities of the caddisfly *Brachycentrus americanus* increased and displaced communities of black flies *Prosimulium martini* and *Stegopterna mutata* (Hershey and Hiltner 1988). Increased densities of *Brachycentrus* and *Baetis* contributed to the "bottom up" effect that eventually stimulated the growth of the Arctic Grayling (*Thymallus arcticus*) (Deegan and Peterson 1993). Seven years after fertilization began, bryophytes, *Hygrohypnum* spp., began to dominate the stream bed of the Kuparuk, especially in riffle habitats (Bowden et al. 1990). Less has been reported concerning the dynamics of organic matter associated with fertilization, including the fate of fine particulate organic matter (FPOM).

The production and processing of FPOM in a river plays a vital role in supporting ecosystem metabolism (Minshall 1966; Sedell et al. 1978; Cummins et al. 1983; Cushing et al. 1993). FPOM acts as a reserve for carbon and nutrient assimilation, whether as benthic or sestonic, especially as stream order increases (Vannote et al. 1980; Minshall et al. 1983). The quality, quantity, size, transport, and storage of FPOM is directly influenced by biological and physical activity, which in turn dictates the distribution of organisms in a stream (Wallace et al. 1982, 1991; Petersen et al. 1989). Thus there is great need, in theory and application, to understand the mechanics and characteristics of FPOM transport along a continuum.

The purpose of this experiment was to investigate the dynamics and characteristics of detrital FPOM (<1mm) transport in a tundra stream. Special attention is being given to the potential effects of phosphorus fertilization concerning FPOM flux. In order to accomplish these objectives, two series of tests were conducted:

1. Standing stock samples of benthic FPOM were collected from the surface and hyporheic zones of both pool and riffles along the experimental reach (consisting of a fertilized and control regions) of the Kuparuk River. A stable isotopic tracer (^{15}N) was used to determine uptake by biota associated with the particulate organic matter. Consideration was given to $\delta^{15}N$ values with

reference to longitude, habitat (pool/riffle), and "subhabitats" (hyporheic/surface) of the stream.

2. Fine Particulate Organic Matter turnover rates were estimated for pools and riffles. Funnels were used to determine gross FPOM settling while tiles were used to simulate "net" FPOM. The isotopic tracer, ^{15}N, was used here to interpret rates at which labeled particles traveled.

I am hypothesizing that bryophyte communities, which were present due to phosphorus fertilization, were acting as a substrate for storage, which interfered with the transport of fine particulate organic matter in the Kuparuk River.

Site Description

The Kuparuk River is located on the North Slope of Alaska. The Kuparuk is a meandering stream of alternating pools and riffles that originates in the foothills of the Brooks Range and drains into the Arctic Ocean (figure 1). It is frozen from late September until late May when there is high discharge due to snowmelt. Average discharge ranges between 1-3 m^3/sec at base flow conditions (Peterson et al. 1993). The Kuparuk is oligotrophic and non-glacial fed which is classified by Craig and McCart (1975) as a clearwater river.

The riparian vegetation, underlain by permafrost, consists of dwarf willows and birches which, on average, reach a height of 0.5 m. This vegetation accounts for only a small portion of the allochthonous input. Most of the allocthonous input is in the form of peat which erodes from the banks (Peterson et al. 1986).

At the study site, the Kuparuk is a fourth order river which is located at approximately 63° 38′N and 149° 24′W. The rocky cobble bottom of the Kuparuk is colonized by filamentous algae, diatoms, aquatic bryophytes, and bacteria. None of the photosynthetic organisms are limited by light due to the extended 24 hour photoperiod during the summer months.

Insect populations include filter feeding blackflies (*Prosimulium martini* and *Stegopterna mutata*). The caddisfly, *Brachycentrus americanus*, is a filter feeder, but occasionally, it will graze on epilithon. The mayfly *Baetis* and chironomid *Orthocladius* are grazing insects (Peterson et al. 1993).

Thymallus articus, the Arctic Grayling, is the sole species of fish in the Kuparuk River (Deegan and Peterson 1992).

Methods

Fertilization and Isotope addition

The experimental site consisted of a four kilometer stream reach. Phosphorus was added from 24 June to August 16, 1995 as phosphoric acid. Fertilizer was dripped continuously by solar power peristaltic pumps until phosphorus concentration in the stream reached 0.32 μmol/L (at mean discharge of 2 m^3/s) (Peterson et al. 1993). Phosphorus addition took place at approximately 0.5 K km of the four kilometer study reach; the upstream reach served as a control. One liter samples of stream water were taken weekly along the experimental transect to obtain phosphorus levels. Soluble reactive phosphorus (SRP) concentrations were determined on a Alpkem autoanalyzer.

A stable isotopic tracer (^{15}N) was added at 1.7K of the four kilometer reach in the form of NH_4Cl (13% ^{15}N). The solution was also dripped by solar power peristaltic pumps, and was fixed at a rate that simulated ammonia seepage from land to stream (Peterson et al. unpublished). Isotope solution, consisting of $^{15}NH_4Cl$ (13% ^{15}N), was added at 0.045g/L/d which contributes only a small fraction of the total estimated 500 g of nitrogen entering the Kuparuk per day (Wollheim pers. comm.). The isotope tracer was added from 1 July to 5 August, 1995.

Standing Stock

Standing stock samples of benthic fine particulate organic matter were sampled with a large Rubbermaid® cylinder with a thick foam collar attached. The foam collar was used to prevent leaks at the uneven rocky stream bottom in order to isolate and contain the sample material in the cylinder. The diameter of the sampling chamber was 30 cm. Standing stock samples were taken on July 10, 1995 and August 7, 1995. Collections were taken at five stations along the study site. Three of the sample sites were taken in the fertilized reach with isotope present, one site was located in the fertilized stretch without isotope, and one site was a control having neither fertilizer or isotope present (figure 2). Four "sub-habitats" were sampled at each location in both pools and riffles to examine FPOM accumulation and isotope labeling:

1. *Loose Surface FPOM.* Loose surface FPOM consisted of unattached flocculant FPOM which can easily be removed from the rock surface layer. The sampling chamber was placed firmly on the stream bed, and the water depth was recorded to determine the total volume contained in the cylinder. For pool samples, a paddle was used to resuspend FPOM. A one liter subsample was then taken of the solution. A different approach was taken when sampling loosely attached FPOM in the riffles. Almost all of the rocks in the riffles of the phosphorus fertilized zone are covered densely with moss. In order to recover all of the FPOM which gets trapped in the moss, these rocks were carefully removed from the area within the sampling chamber and brought to shore. The moss covered rocks were then rinsed thoroughly in a dishpan with one liter of stream water.

2. *Surface Biofilm.* Surface biofilm was FPOM which became associated with periphyton and bacteria assemblages which could not be removed without scrubbing. A rock was taken from the stream bottom where the loose surface sample had already been obtained. A 2"X2" scrub was taken of the surface portion of this rock with a steel bristle brush. Surface biofilm samples were stored in 60 ml centrifuge vials. Surface biofilm samples in the fertilized riffles were unattainable due to the moss coverage.

3. *Loose Subsurface (hyporheic) FPOM.* A portion of particulate organic matter (POM) that settles on the stream bed becomes lodged in interstitial spaces beneath the surface of the rocks - the hyporheic zone. Again, the sampling

chamber was set over a section of stream bottom. Approximately 10 cm of surface rocks were carefully removed until the hyporheic zone had been reached. I then vigorously stirred the subsurface region to suspend loose particulate matter. The sample was stored in a one liter bottle.

4. *Subsurface (hyorheic) Biofilm.* Like the surface biolfilm layer, I was collecting FPOM associated with epilithic communities; mostly bacteria in this case. Similar to the surface biofilm sampling, I would take a rock from the subsurface region and do a 2"X2" rock scrub to remove any FPOM that was associated with the hyporheic biofilm layer.

Turnover

In this series of experiments tiles and funnels were used to assess the sinking and resuspension of FPOM. The experiments were conducted in the same locations as the standing stock tests, but were run at a later date from July 29 to August 4, 1995. Samples were collected on days 1, 3, 5, and 7.

Funnels. Funnels with a mouth diameter of 7 cm were fixed to 500 ml small mouth plastic jars. Funnels were then attached to rebar and pounded into the stream bottom. The concept behind the funnel system is that particular matter could settle, but could not become resuspended. Thus, the funnel accumulation represents "gross" or total FPOM settling (figure 3a).

Tiles. Porcelain tiles (white tiles) and porcelain tiles covered with "astro turf" (moss tiles), both having a surface dimension of 119.68 cm^2, were secured to a 1"X4" wooden board with nails. Tiles could be easily removed on sampling days by simply sliding them out in the direction of the stream flow where I left a nail out. The flow of water secured the tiles against the nails. Four white tiles were placed in both the fertilized and control pools to be collected on days 1, 3, 5, and 7. (figure 3b)

Trial runs of white tiles placed in the Kuparuk indicated that little accumulation was occurring on the bare porcelain substrate in riffles habitats. Therefore, tiles were only placed out for collection on days 3 and 7.

Moss analog tiles were set out in the riffles in addition to the white tiles. The moss analog tiles consisted of "astro turf" siliconed to the porcelain tiles. These were also sampled on days 3 and 7.

On collection days, the funnel sampling units were removed from the stream. The actual funnel was detached, and the 500 ml jar with the FPOM sample was capped. Tiles were carefully removed from their holding apparatus and were stored in 15 cm X 15 cm Tupperware® containers (470 ml volume). The tiles were then scrubbed with a steel bristle brush to remove any POM that had stuck to the tile. In addition, depths and local velocities were recorded at each site. Velocity was measured with a General Oceanics velocity meter.

The samples obtained from the standing stock and turnover experiments were brought back to the laboratory at the Toolik Field Station for immediate processing. Samples were first size fractionated through a 1 mm sieve and then vacuum filtered onto precombusted Whatman GF/F glass fiber filters. Dry weight data were obtained by drying the samples at 50°C for 24 hours. To obtain ash free dry mass (AFDM), samples were placed in an ashing oven at 550°C for four hours. All samples were weighed on a Cahn C-33 Microbalance. Isotope samples were prepared by size fractionating (1 mm sieve) the field samples and vacuum filtering onto Whatman GF/F glass fiber filters. The samples were then dried for 24 hours at 50°C. Isotope ratios were measured at the Ecosystems Center in Woods Hole, Ma on a Finnigan Delta S mass spectrometer.

Results and Discussion

Standing Stock

Figure 4 shows a prominent phosphorus concentration peak at 1K. A major reason for the diminishing concentration of phosphorus with distance thereafter is due to the active uptake of this nutrient by primary producers. During the first two seasons of phosphorus enrichment on the Kuparuk, epilithic algae densities (chlorophyll *a*) increased according to the elevated phosphorus concentrations. In 1990, producer communities had shifted, and bryophytes took over the riffle habitat of the previously dominant epilithic algae. It has been shown that these bryophyte communities are limited by phosphorus availability, and that they would not be present without nutrient enrichment (Bowden et al. 1994). *Hygrophypnum*, a dominant moss taxon in the fertilized reach of the Kuparuk, may account for nearly 67% of the phosphorus uptake. In addition to acting as a phosphorus sink, *Hygrohypnum*'s complex surface area may be acting to trap and disrupt the transport of bedload and sestonic FPOM.

Results of the benthic FPOM show a distinct trend related to manipulated phosphorus concentrations. The distribution of FPOM collected on 10 July 1995 has a positive correlation with phosphorus concentrations (p=.92, n=5); a weaker correlation exists for 7 July 1995 results (r=.63, n=5) (figure 4). Paired student t-tests showed that there was significantly more benthic FPOM in the fertilized reach of the Kuparuk than in the control reach (p=.0097 for pools, p=.0038 for riffles) (figure 5).

Mean estimates of benthic fine particulate organic matter in the control reach of the Kuparuk were $13.7\pm8.5 g/m^2$ for pools and $4.3\pm2.4 g/m^2$ in riffles (mean±S.D.). These results were higher than estimates made in 1979 where pools reportedly had $3.9\pm2.3 g/m^2$ of benthic FPOM and riffles had $0.6\pm0.3 g/m^2$ of benthic FPOM (Peterson et al. 1986). Mean fertilized standing stock values were much higher than control values and previous FPOM estimates: pools had $18.5\pm14.1 g/m^2$ of benthic FPOM and riffles had $435.3\pm769.7 g/m^2$ of benthic FPOM. The results for these standing stock measurements comprise only loose surface and loose subsurface FPOM, and do not include biofilm layer FPOM.

Subhabitat analysis showed large differences when comparing biofilm accumulation between control and enriched environments. A summary of subhabitat FPOM standing stocks is listed in table 1.

Standing Stock estimates made for 10 July 1995 differed from those recorded on 7 August 1995. I believe these differences can be attributed primarily to a flood event occurring on July 20, 1995 that raised discharge levels from an average of $2m^3$/sec to a peak level of $33m^3$/sec. This flood event likely removed loose surface and loose subsurface (hyporheic) FPOM downstream. It has been documented that extreme discharge events are strongly related to the export of benthic FPOM, especially on the rising portion of the hydrograph (figure 6) (Webster et al. 1987; Wallace et al. 1991).

Prior to fertilization, it was common to find higher standing stocks of benthic FPOM in pools than in riffles. Riffles have faster currents and have shallower depths than pools. These factors produce a higher sheer stress which prevents accumulation of fine particles on bare riffle rocks. On average, only riffle rocks are colonized with moss in the fertilized Kuparuk, and pool rocks are left bare of moss being covered with only diatoms and/or detritus. Finlay and Bowden (1994) suggest that the absence of moss in fertilized pools is due to a higher rate of FPOM deposition, and that higher sheer stress prevents accumulation in riffles so moss communities can flourish. This explanation contradicts results I obtained from my standing stock experiments, and leads me to believe that other factors besides FPOM depositions are controlling the distribution of aquatic bryophytes. As I previously discussed, riffle rocks with a moss substrate trap relatively large amounts of FPOM. At every test location, I recovered much more loose surface FPOM in riffle habitats than in corresponding pool habitats. This demonstrates that FPOM settling does not interfere with the survival of moss, and that one or more alternative factors are responsible for moss-free rocks in pools such as: 1) lower gas exchange with the surface, 2) greater light attenuation (Glime 1984) and/or 3) slower currents (Glime 1987).

Standing Stock - Isotope

In order for fine particulate organic matter to become labeled with ^{15}N, nitrogen must be assimilated by the biota or FPOM must be excreted by an already labeled organism. To recover labeled material downstream, FPOM must be either transported as labeled FPOM or FPOM must come in direct contact with ^{15}N in the water column for uptake. Labeled subsurface and subsurface biofilm FPOM is present most likely because of particle deposition into interstitial spaces or by water exchange with the hypoheic zone.

The first set of data on 7/10/95 revealed that loose surface FPOM was becoming the most enriched material at 2.4K in riffles and pools. Loose subsurface $\delta^{15}N$ were higher in riffle habitats, and subsurface $\delta^{15}N$ were similar in riffles and pools (figure 7a). Thus the loose surface material was the most biologically active FPOM that was sampled

Data for 7 August 1995 differed from that on 10 July 1995. The most dramatic change was seen at the subsurface film riffle location at 2.4K. In one month the $\delta^{15}N$ increased from 1.7 to 8.2 (figure 7a and 7b). This shows that within a relatively short period of time, labeled particles in stream flow can become found later at up to 10 cm below the stream bed. However, subsurface film pool $\delta^{15}N$ at the same locations (2.4K and 3K) were almost at control levels. This demonstrates that there maybe more hyporheic water exchange in riffle habitats in the Kuparuk than in pools.

When comparing data between sites only 600m away, $\delta^{15}N$ were much higher at 2.4K than at 3K (figure 7a and 7b). One could assume from this data that there would be a loss of the ^{15}N signal for detrital FPOM only a short distance downstream.

Turnover

Sheer stress is the underlying concept allowing for the transport of fine particles in lotic ecosystems. In order for deposited material to become suspended, a critical bottom shear stress needs to be exceeded (Fisher et al 1979). Velocity of the stream water needs to surpass the gravity of a specific particle. The complexity of the particle's shape, and possibly even more importantly, the substrate roughness both play critical roles in determining whether fine particles will be transported (Webster et al. 1987).

In this experiment funnels served to sample all of the FPOM settling. Thus, I am referring to funnel values as "gross" FPOM deposition. On average, pools collected $1.47\pm1.43 g/m^2$ of FPOM per day, and riffles collected $1.93\pm1.53 g/m^2$ of FPOM per day. Significantly more FPOM settled in riffle funnels than in pool funnels (p=.0092). Figure 8 shows time cumulative curves for FPOM funnel accumulation in pools and riffles.

Tiles were used to collect "net" FPOM remaining after resuspension had occurred. White tiles placed in pools collected $0.24\pm0.26 g/m^2$ of FPOM per day, and white tiles in riffles collected $0.04\pm0.02 g/m^2$ of FPOM per day. Moss tiles were also placed in riffle habitats. Moss tiles collected, on average, $1.78\pm1.19 g/m^2$ of FPOM per day. Moss tiles accumulated statistically more FPOM than both riffle white tiles (p=.0007) and pool white tiles (p=.002).

I was able to roughly determine rates of resuspension by subtracting funnel settling values (gross) from tile settling values (net). In pool habitats, 1.23g out of 1.47g of FPOM was becoming resuspended per day leaving 16% percent of the original material that had settled in 24 hours. In riffles, 2.10g out of 2.14g was being exported; only 2% of the gross settled material remained. Moss tiles retained 88% of the total FPOM deposited per day (values consistent with funnel or gross deposition, see figure 9) leaving only 0.37g out of 2.14g for resuspension. These results enforce the ideas of critical shear stress where increased velocity of riffles and reduced substrate complexity of white tiles increased fine particle transport. In addition, the 88% retention by moss tiles in faster moving riffles suggests that substrate complexity may be more important than local velocity.

The following are mean local velocities and depth, and how they relate to FPOM deposition on funnels and tiles. Mean velocities were 21.2 cm/sec for pools and 61.6 cm/sec for riffles. Velocity was positively correlated with the amount of FPOM settling in funnels per day (r=.65 for pools, n=20 , r=.75 for riffles, n=20), but velocity was not correlated with FPOM settling on tiles.

Mean depths were 43.4 cm for pools and 28.5 cm for riffles. Depth was positively correlated with mass settling in riffle funnels (r=.76, n=20) and on riffle moss tiles (r=.69, n=20). Depth was negatively correlated to FPOM settling on white tiles in riffles (r=-.08, n=20)

My standing stock results established that phosphorus has significantly increased benthic FPOM in both pools and riffles in the fertilized reach of the Kuparuk. A question that needs to be addressed is whether phosphorus fertilization increased the production of FPOM or is FPOM simply being retained from downstream transport by moss communities (present as a result of fertilization)? Some FPOM may originate due to moss fragmentation; however, my results comparing accumulation over time on control tiles and fertilized tiles show only small differences (figure 10). The slope for accumulation on moss tiles for days three and seven is 2.89 in the fertilized reach and 2.08 in the control. White tiles sampled at the same locations also show similarities between control and fertilized sites. Overtime, fertilized white tiles had a slope for accumulation of -0.01 and the control tiles had a slope of -0.025 (see figure 10). These results indicate that the same amount of FROM is settling per day on a given substrate type regardless of phosphorus fertilization. Assuming this is true, along with my standing stock data, I can deduce that 1) phosphorus is initiating moss colonization which is retaining higher amounts of FPOM, and that 2) phosphorus is responsible for a negligible portion of FPOM production.

Turnover - Isotope

Isotope data for day five (July 29, 1995) turnover had high $\delta^{15}N$ for flocculant FPOM that had settled in funnels (figure 11). Del values for riffles were high with a smaller amount of FPOM settling than the lower $\delta^{15}N$ for pool funnel samples where more material was settling. There was no declining trend in the high riffle $\delta^{15}N$ which suggests that labeled particles may have been recovered much further downstream. Pool $\delta^{15}N$ were much lower and appeared to be diminishing with distance.

Del values obtained from white tiles on day five were higher than those obtained from funnels (figure 9). Del values peeked at 2.4K on the tile samples while $\delta^{15}N$ for funnel samples peeked at 2K. Tile values may have peeked further downstream because of resuspension; whereas funnel values peeked sooner due to the "capture - no release" design.

Overall, the turnover isotope data shows that in five days particles had been labeled, and had been transported more than a kilometer downstream. These results are well within estimate traveling ranges for fine particulate organic matter. Cushing et al. (1993) investigated FPOM transport in 2nd and 3rd order streams in Idaho (mean discharge was $0.68m^3/sec$ and $0.25m^3/sec$ respectively). FPOM was labeled with ^{14}C and approximately 99% of this material had been exported from the one kilometer experimental reach within 24 hours. Additional samples stations at 4K and 5K on the Kuparuk would more accurately determine the total travel distance of fine particulate organic matter.

It is clear that the additions of phosphorus to the Kuparuk River have had dramatic biological effects on the ecosystem. Not only has the emergence of aquatic bryophytes been a sink for phosphorus, it also appears that their surfaces served to interfere with the transport of fine particulate organic matter.

In laboratory flume experiments, Webster et al. (1987) demonstrated the importance of substrate characteristics with regard to the transport of fine particles. Roughness and substrate complexity significantly increased retention of FPOM. From my experiments, I have observed that moss communities and moss analog tiles are both accumulating significantly more FPOM than bare rock surfaces. Vannote et al. (1980) discussed the importance of FPOM transport in relation to the zonations of animal communities, especially macroinvertebrates. Organisms downstream are strategically located to capitalize on upstream "inefficiencies" i.e. POM transport. In the case of the fertilized Kuparuk River, turnover rates are much slower, and there are significantly higher amounts of organic matter accumulating as a result of moss communities present.

Knowing the importance of FPOM transport, the next experimental step would be to investigate FPOM distribution with regard to insect communities. Some of the highlight changes that have occurred on the Kuparuk since fertilization deal with the altered densities and growth rates of filter feeding insects. The disturbed transport of FPOM may very well be a cause for these ecosystem shifts.

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Webster, J. R., E. F. Benfield, S. W. Golladay, B. H. Hill, L. E. Hornick, R. F. Kazmierczak, W. B. Perry. 1987. Experimental studies of physical factors affecting seston transport in streams. Limnology and Oceanography 32: 848-863.

Vannote, R. L., G. W. Minshall, K. W. Cummins, J. R. Sedell, C. E. Cushing. 1980. The river continuum concept. Canadian Journal of Fisheries and Aquatic Sciences 37: 130-137.

Figure 1

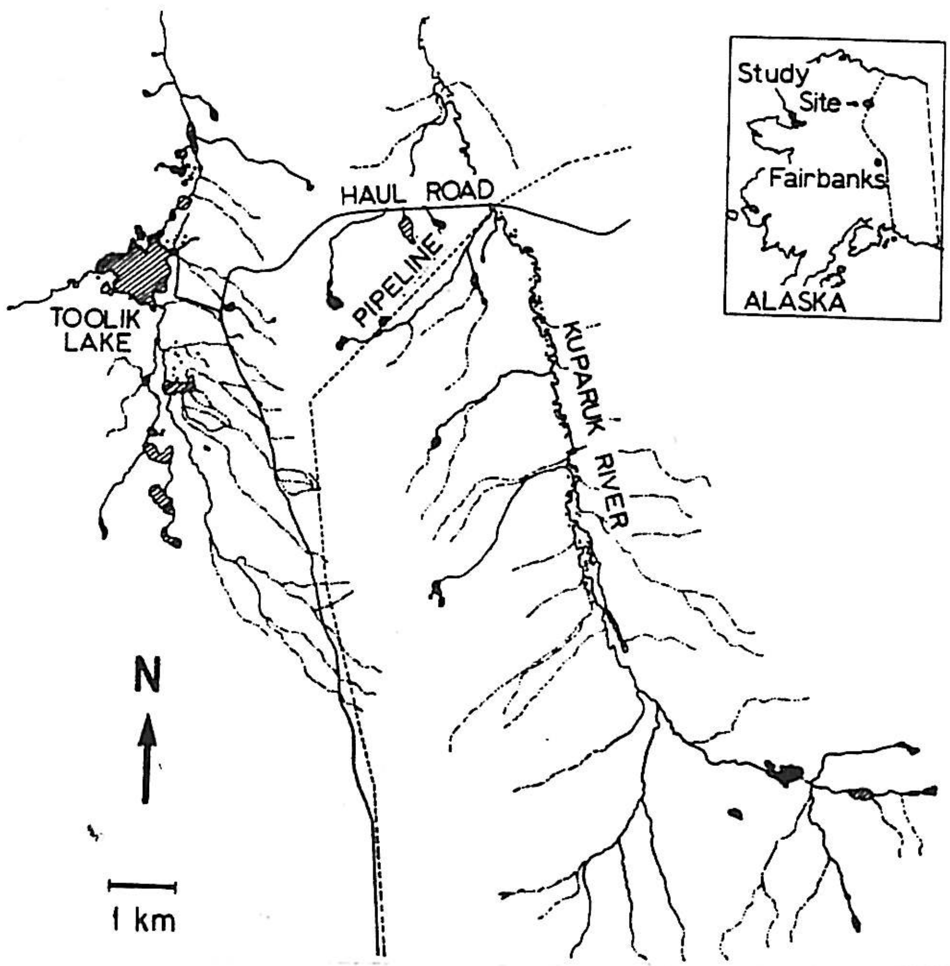

HAUL ROAD
PIPELINE
TOOLIK
LAKE
KUPARUK RIVER
N
1 km
Study
Site
Fairbanks
ALASKA

Figure 2

Sampling stations along the experimental reach of the Kuparuk River

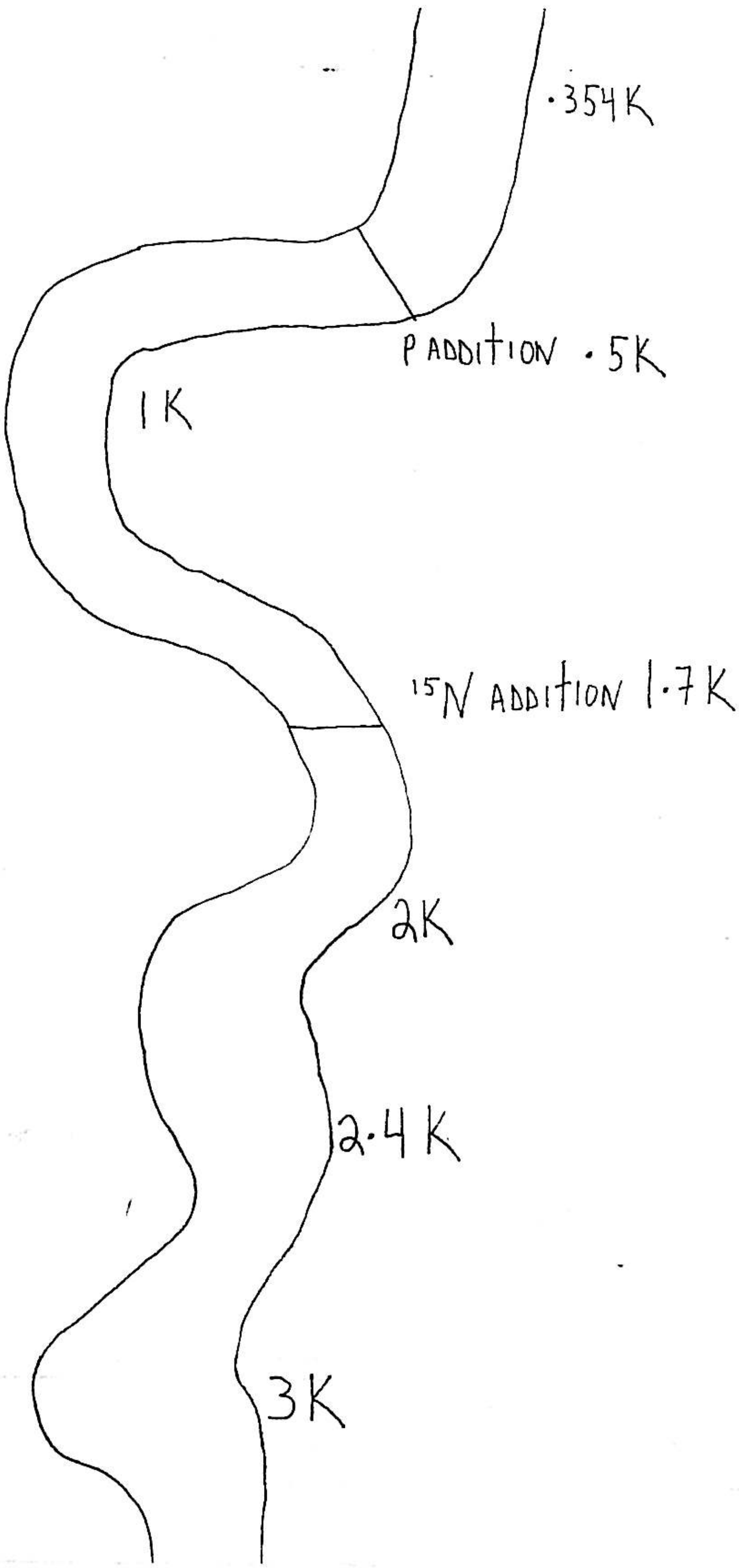


Figure 3a

diagram of the funnel sampling apparatus

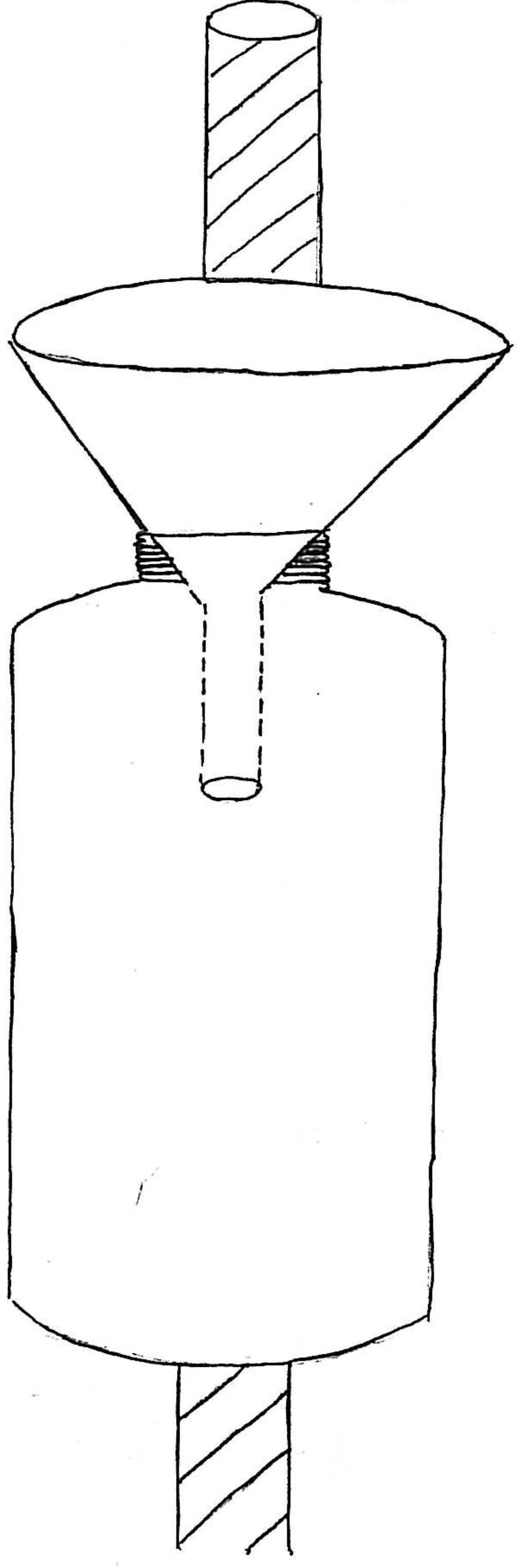


Figure 3b

diagram of the tile sampling apparatus

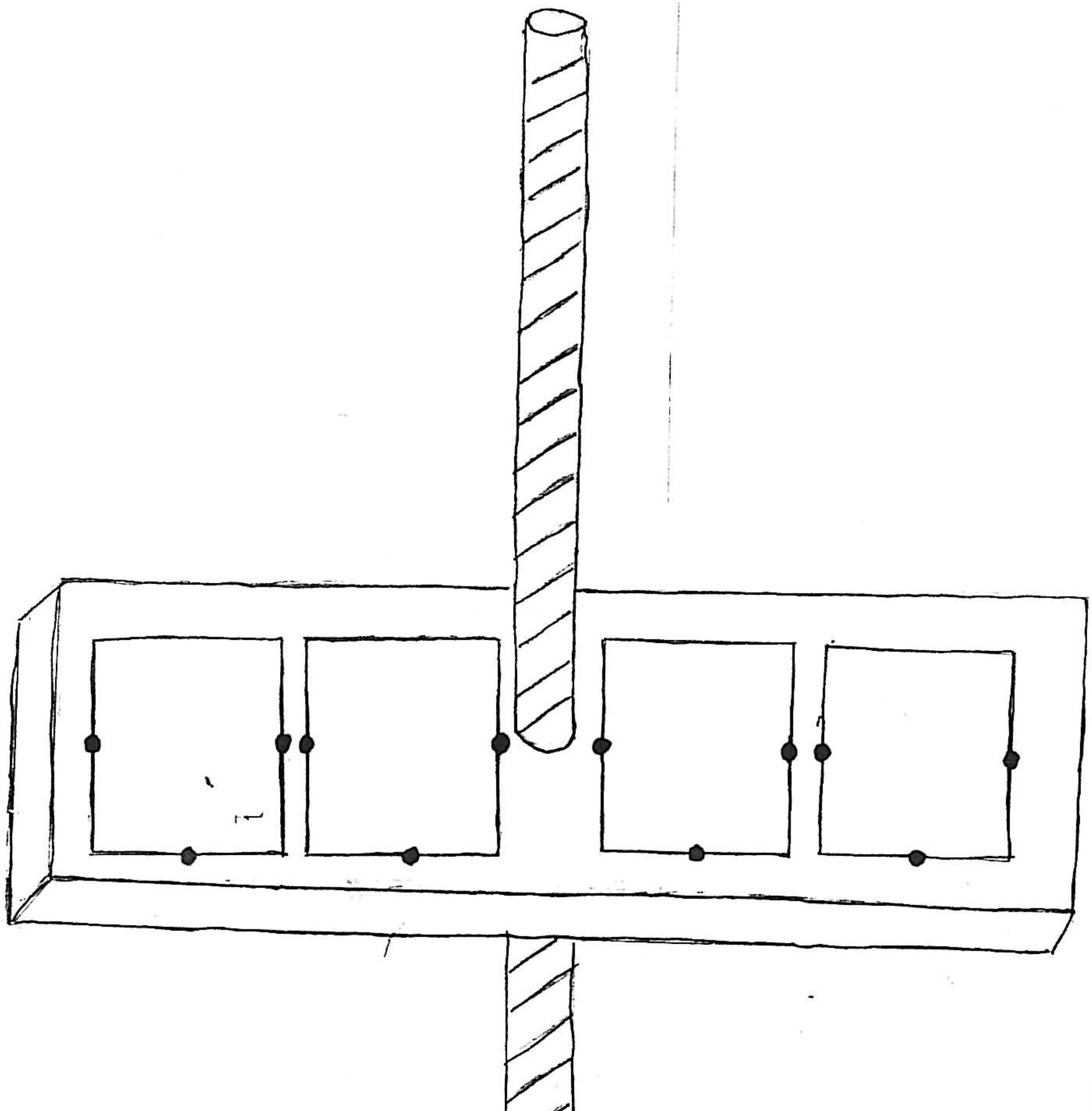
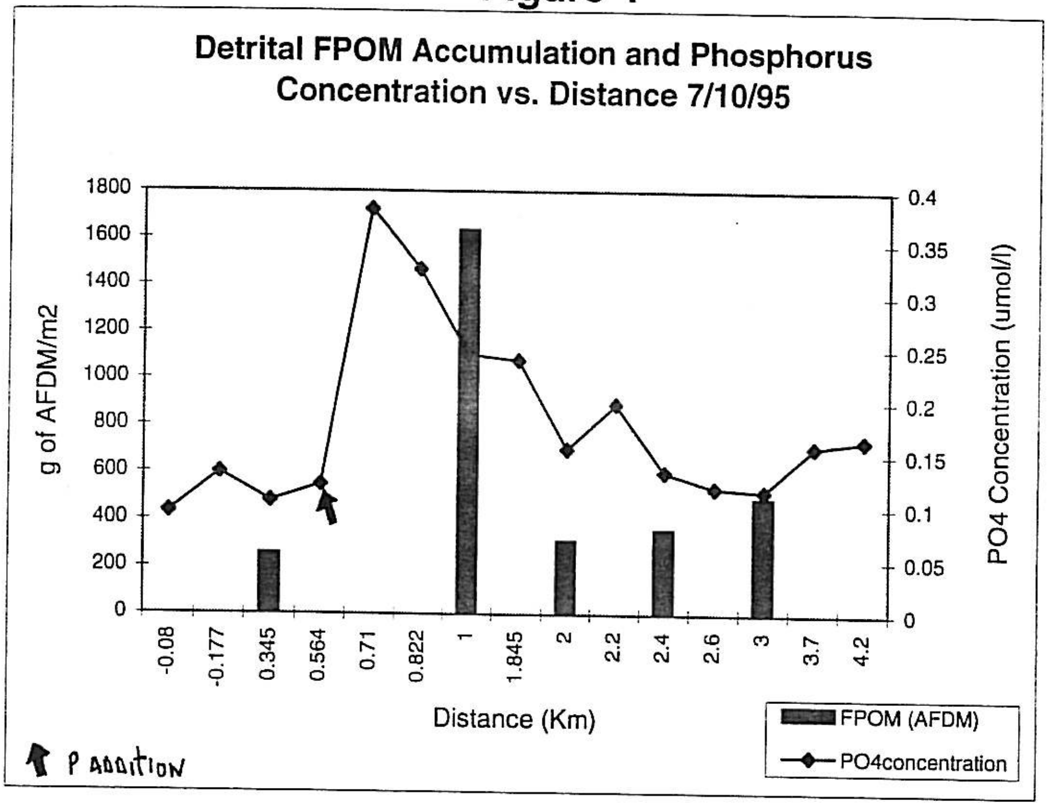
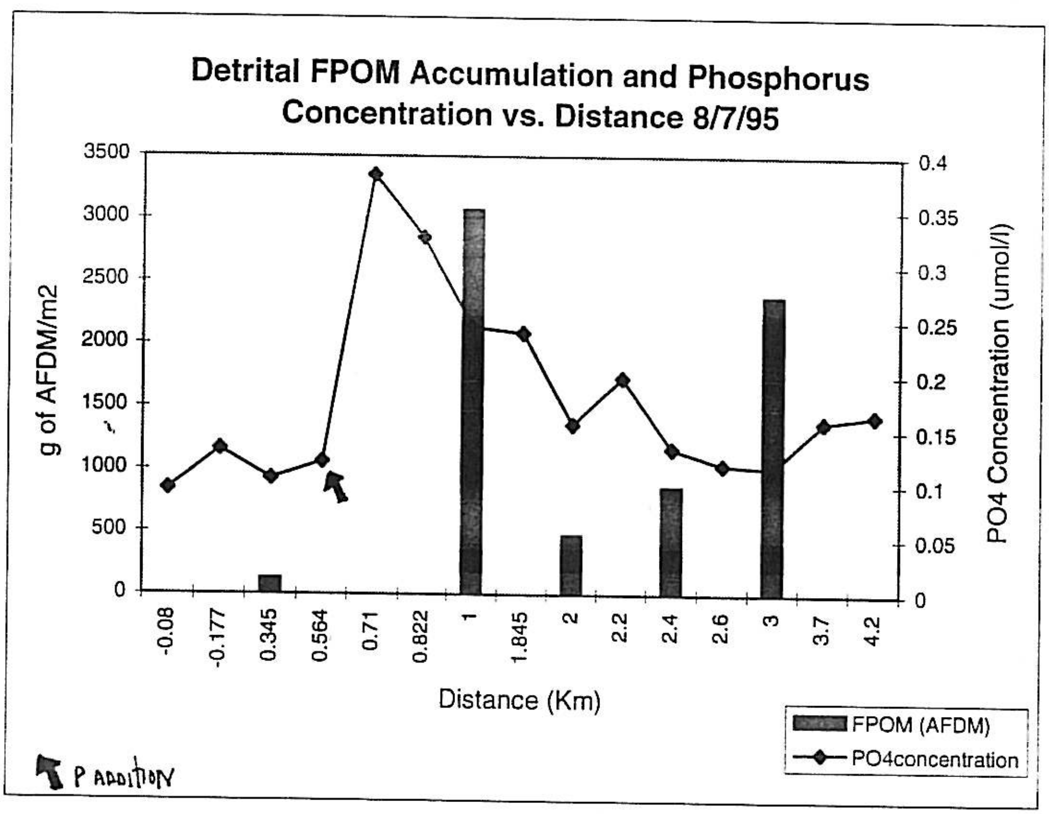


Figure 4

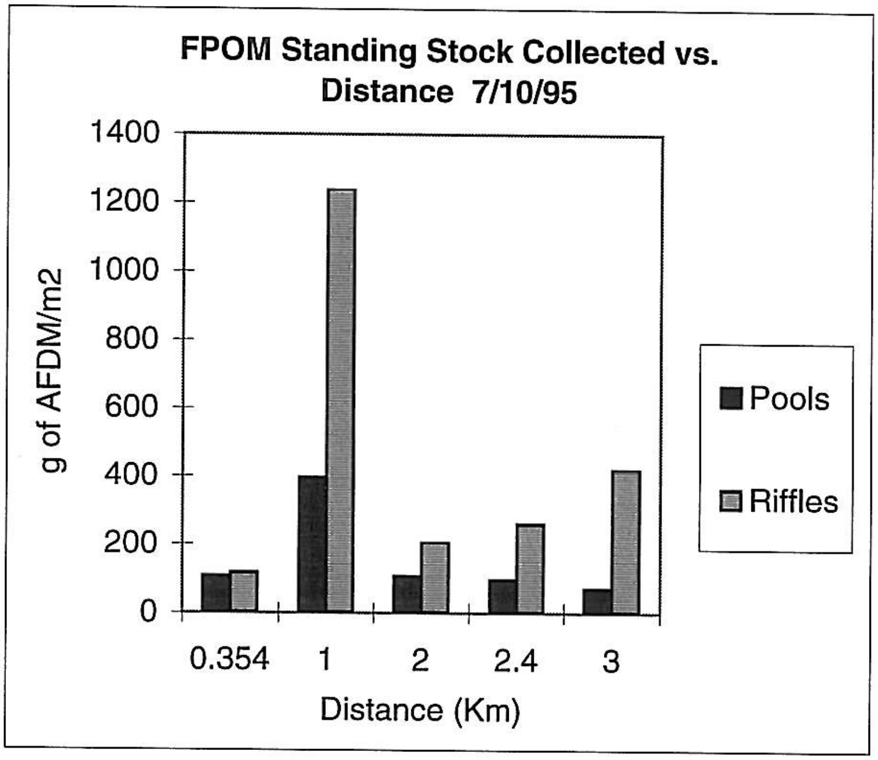


Detrital FPOM Accumulation and Phosphorus Concentration vs. Distance 7/10/95
g of AFDM/m2
1800
1600
1400
1200
1000
800
600
400
200
0
PO4 Concentration (umol/l)
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
-0.08
-0.177
0.345
0.564
0.71
0.822
1
1.845
2
2.2
2.4
2.6
3
3.7
4.2
Distance (Km)
FPOM (AFDM)
PO4concentration
P ADDITION



Detrital FPOM Accumulation and Phosphorus Concentration vs. Distance 8/7/95
g of AFDM/m2
3500
3000
2500
2000
1500
1000
500
0
PO4 Concentration (umol/l)
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
-0.08
-0.177
0.345
0.564
0.71
0.822
1
1.845
2
2.2
2.4
2.6
3
3.7
4.2
Distance (Km)
FPOM (AFDM)
PO4concentration
P ADDITION

Figure 5


FPOM Standing Stock Collected vs. Distance 7/10/95
1400
1200
1000
800
600
400
200
0
g of AFDM/m2
0.354
1
2
2.4
3
Distance (Km)
Pools
Riffles

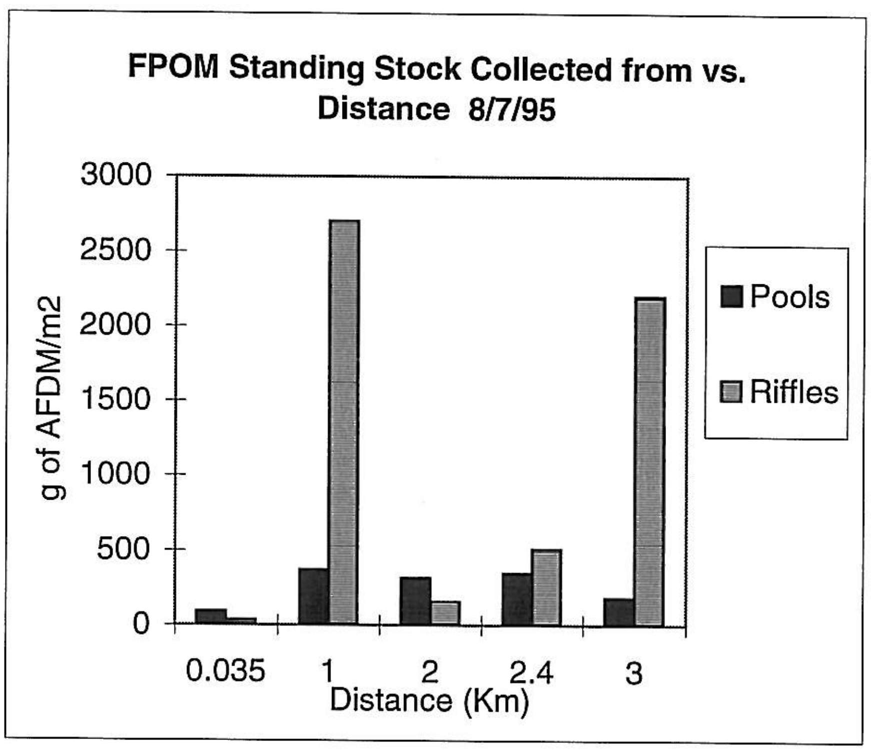

FPOM Standing Stock Collected from vs. Distance 8/7/95
3000
2500
2000
1500
1000
500
0
g of AFDM/m2
0.035
1
2
2.4
3
Distance (Km)
Pools
Riffles

Figure 6

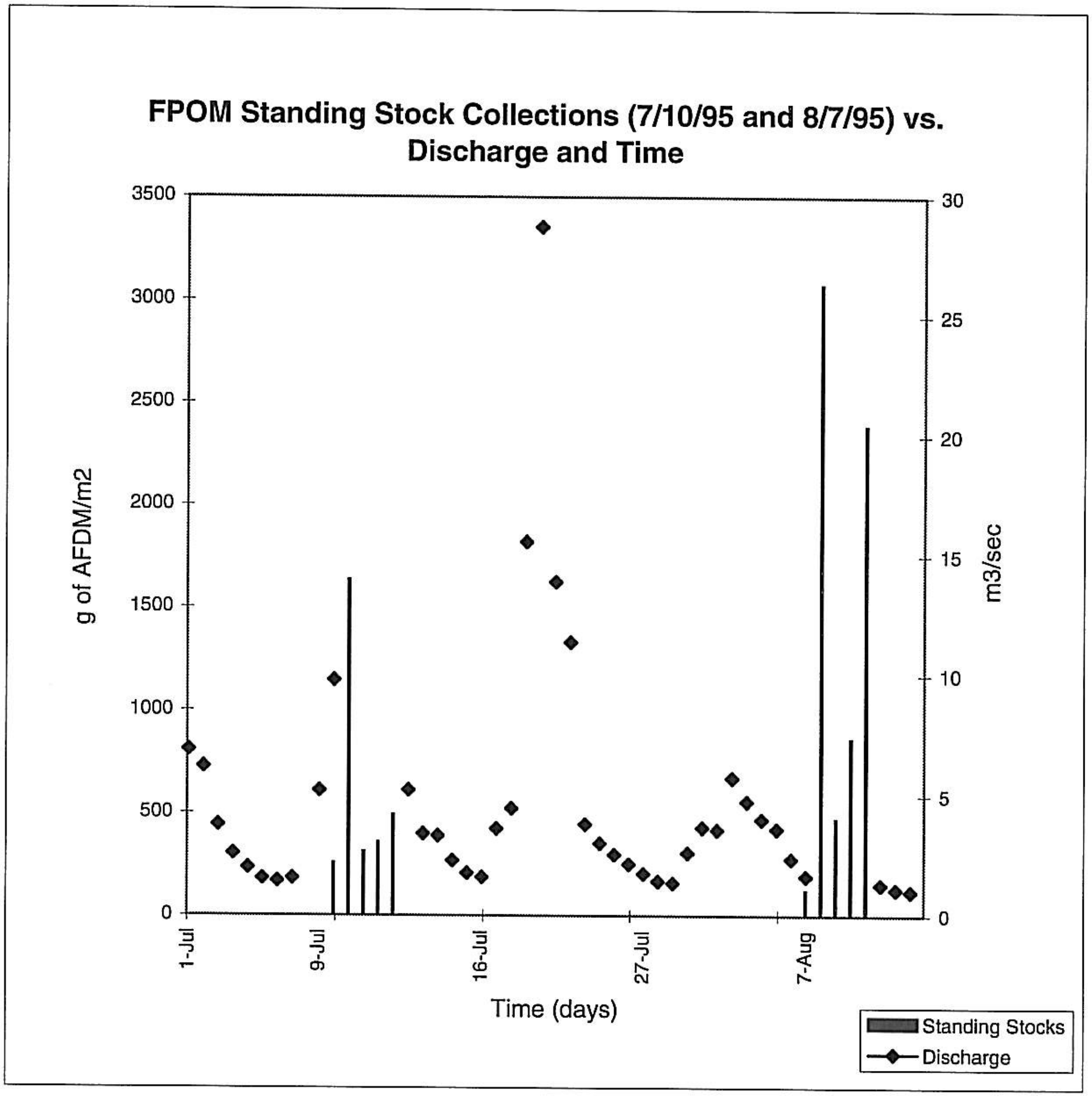
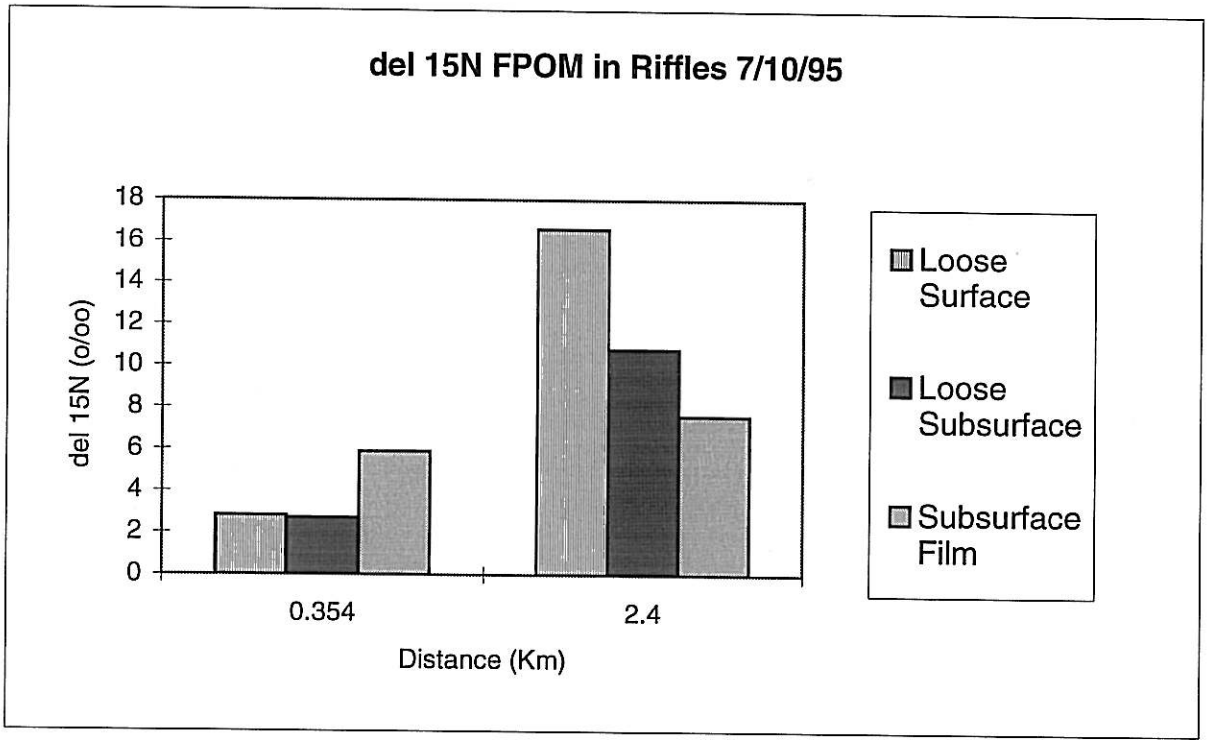

FPOM Standing Stock Collections (7/10/95 and 8/7/95) vs. Discharge and Time
g of AFDM/m2
3500
3000
2500
2000
1500
1000
500
0
m3/sec
30
25
20
15
10
5
0
1-Jul
9-Jul
16-Jul
27-Jul
7-Aug
Time (days)
Standing Stocks
Discharge

Figure 7a


del 15N FPOM in Riffles 7/10/95
18
16
14
12
10
8
6
4
2
0
del 15N (o/oo)
0.354
2.4
Distance (Km)
Loose Surface
Loose Subsurface
Subsurface Film

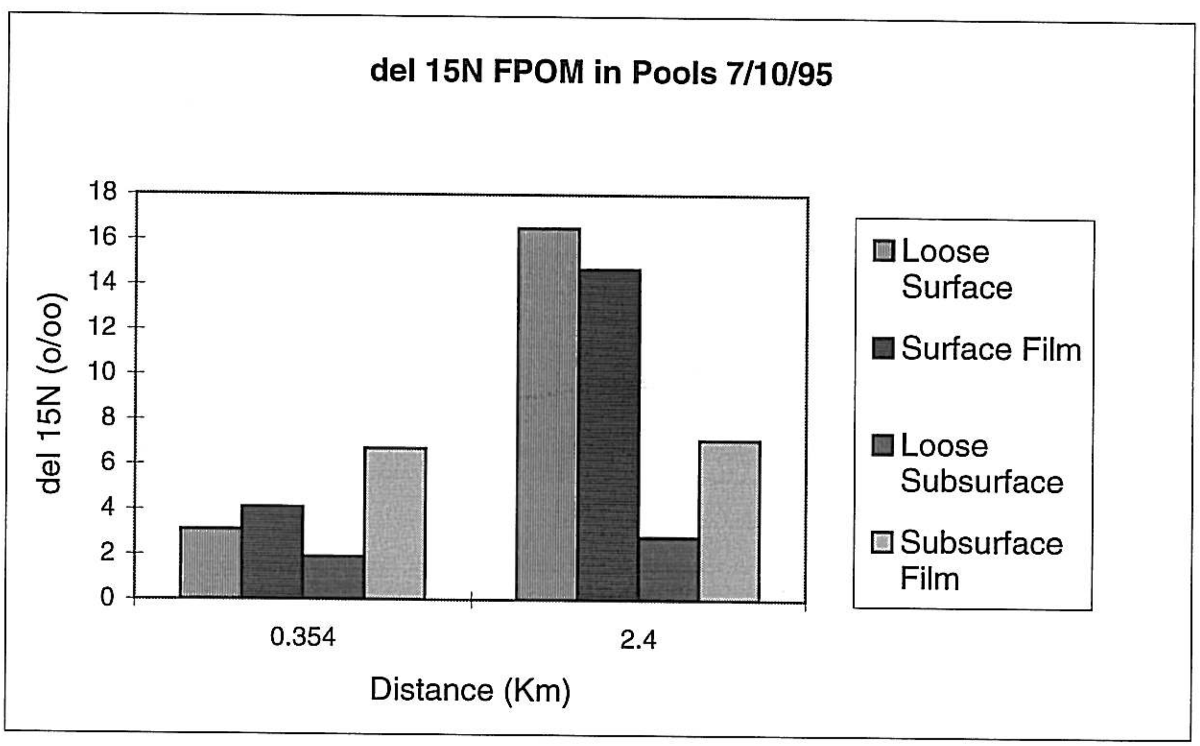
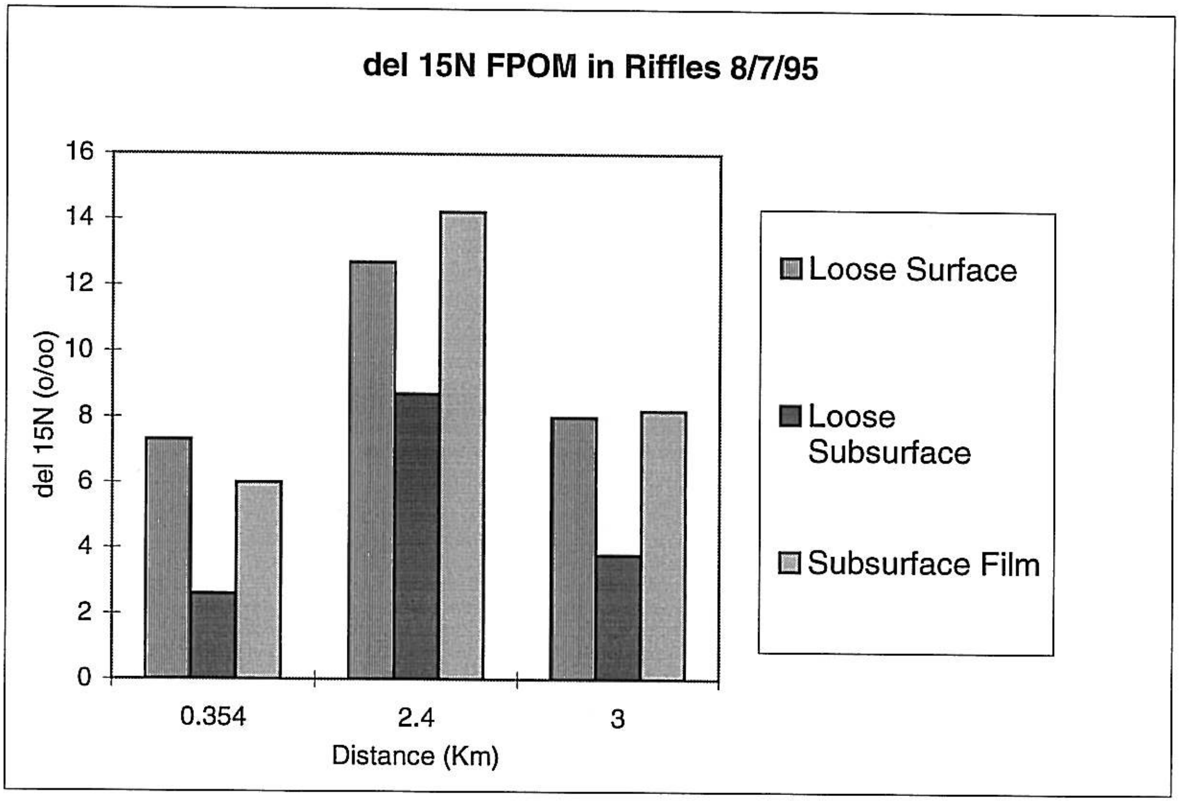

del 15N FPOM in Pools 7/10/95
18
16
14
12
10
8
6
4
2
0
del 15N (o/oo)
0.354
2.4
Distance (Km)
Loose Surface
Surface Film
Loose Subsurface
Subsurface Film

Figure 7b


del 15N FPOM in Riffles 8/7/95
16
14
12
10
8
6
4
2
0
del 15N (o/oo)
0.354
2.4
3
Distance (Km)
Loose Surface
Loose Subsurface
Subsurface Film

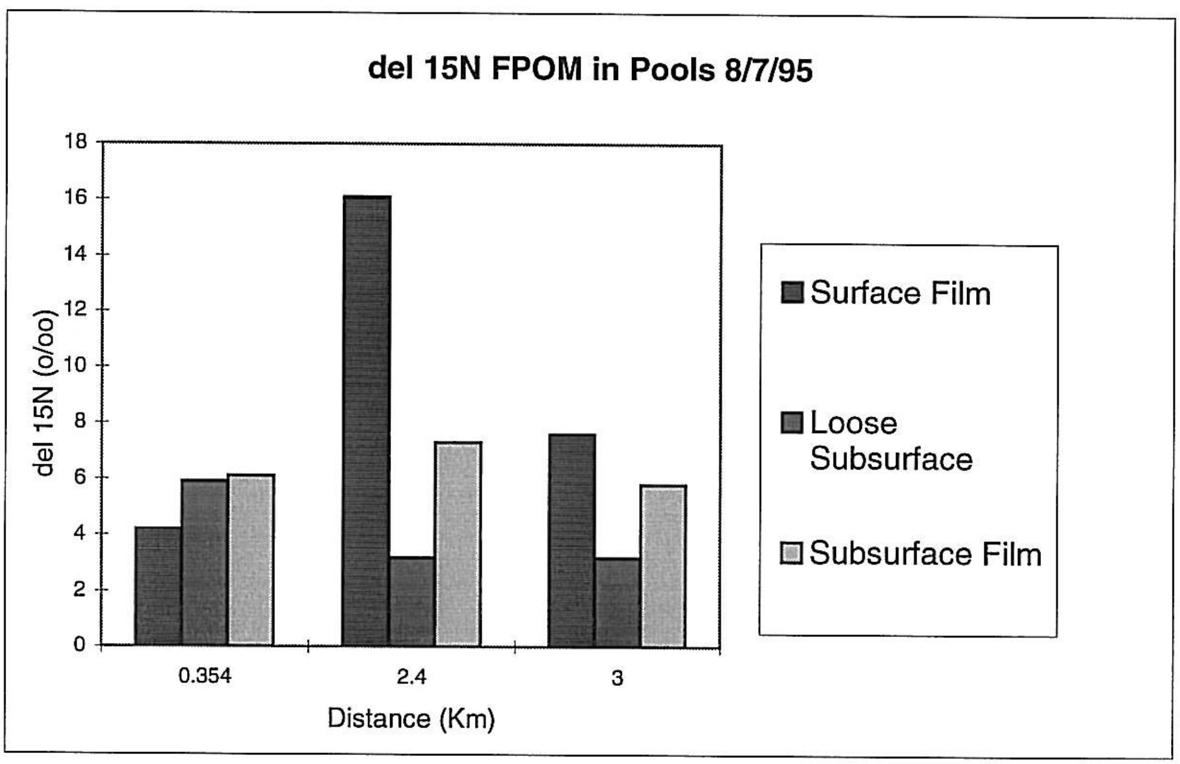
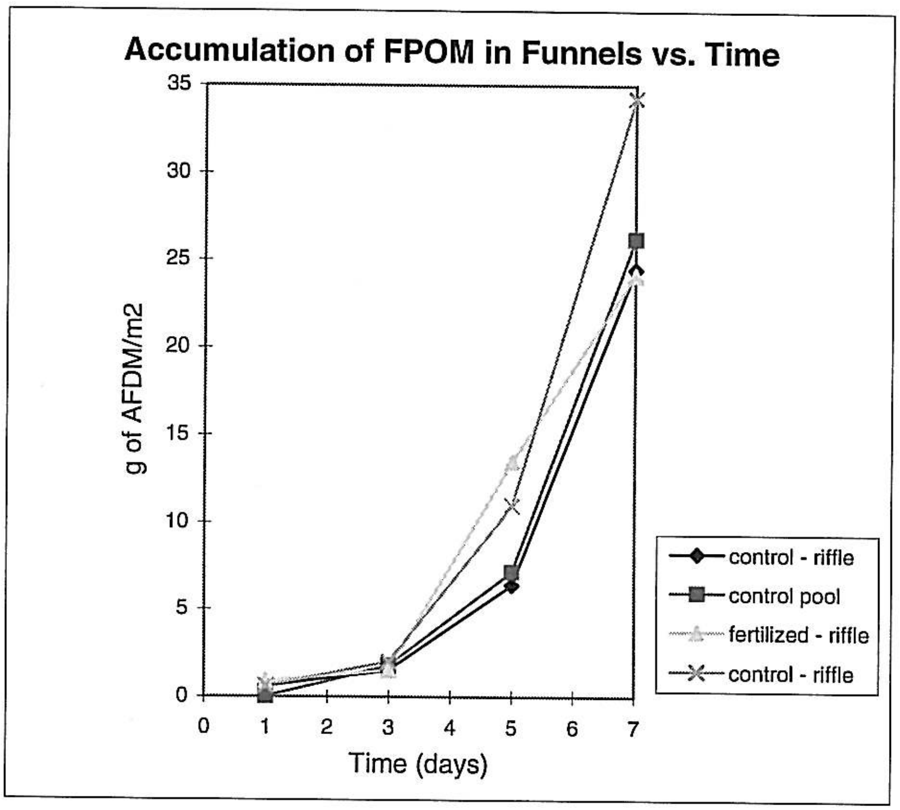

del 15N FPOM in Pools 8/7/95
18
16
14
12
10
8
6
4
2
0
del 15N (o/oo)
0.354
2.4
3
Distance (Km)
Surface Film
Loose Subsurface
Subsurface Film

Figure 8



Accumulation of FPOM in Funnels vs. Time
g of AFDM/m2
35
30
25
20
15
10
5
0
0
1
2
3
4
5
6
7
Time (days)
control - riffle
control pool
fertilized - riffle
control - riffle

Figure 9

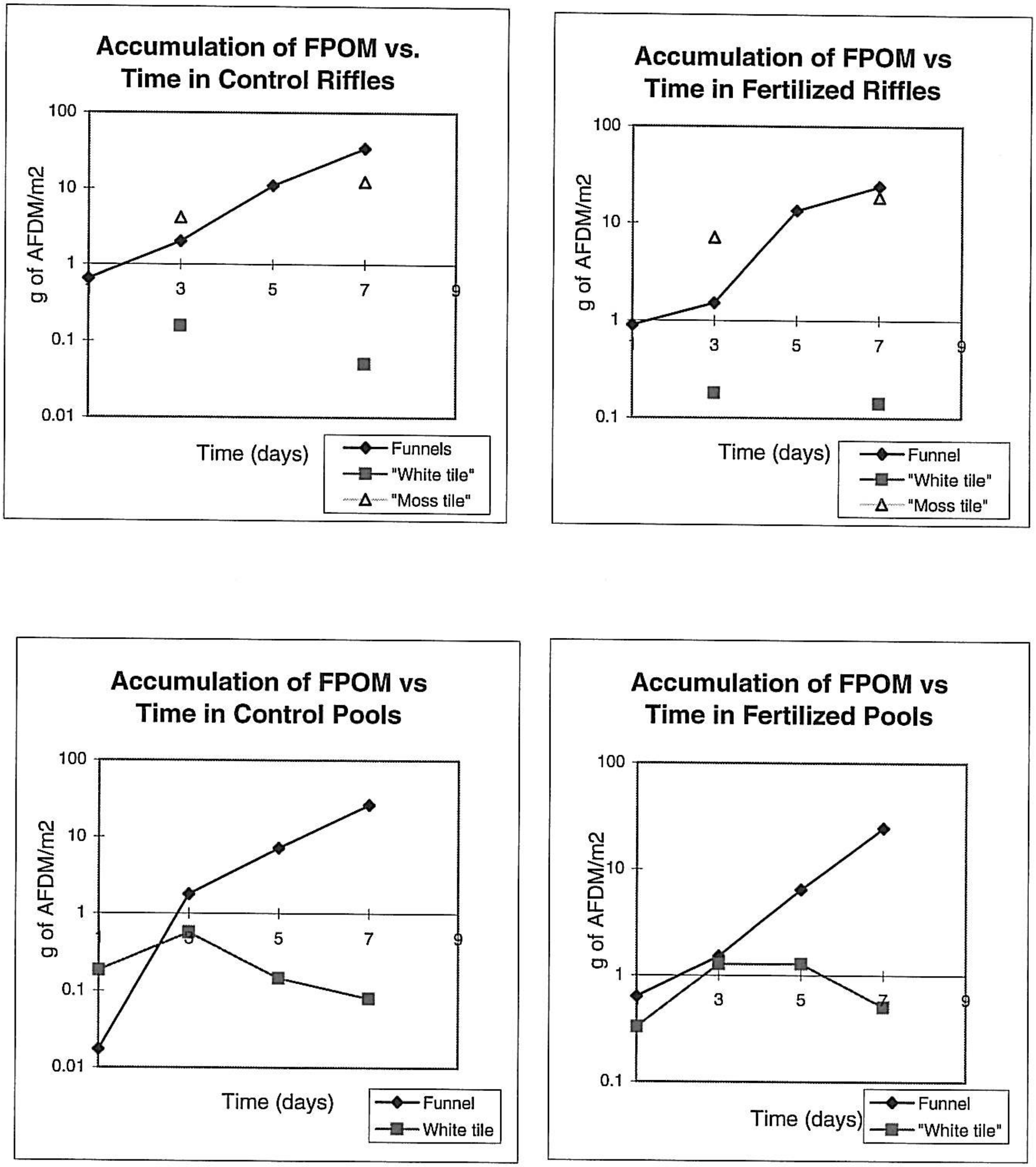
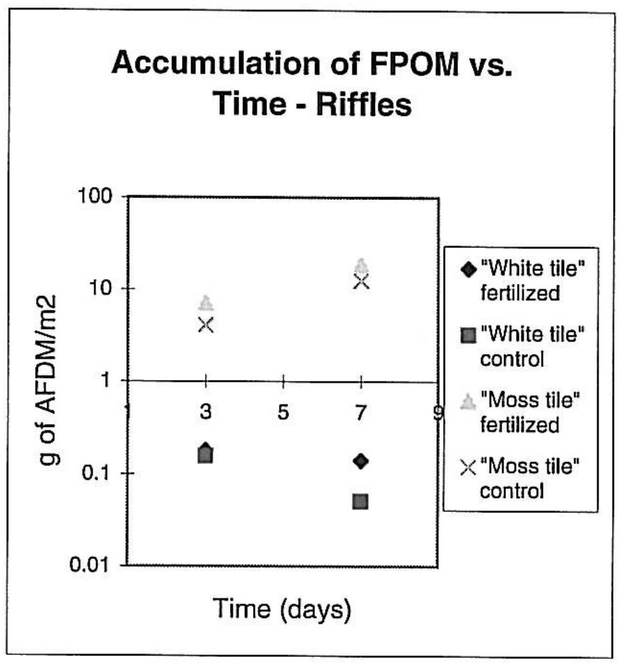
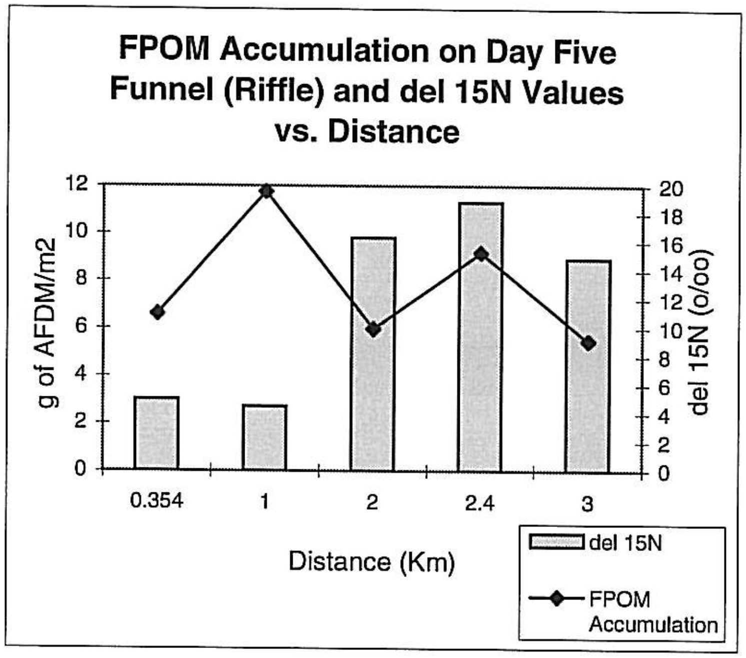

Accumulation of FPOM vs. Time in Control Riffles
100
10
1
0.1
0.01
g of AFDM/m2
3
5
7
9
Time (days)
Funnels
"White tile"
"Moss tile"
Accumulation of FPOM vs Time in Fertilized Riffles
100
10
1
0.1
g of AFDM/m2
3
5
7
9
Time (days)
Funnel
"White tile"
"Moss tile"
Accumulation of FPOM vs Time in Control Pools
100
10
1
0.1
0.01
g of AFDM/m2
5
7
9
Time (days)
Funnel
White tile
Accumulation of FPOM vs Time in Fertilized Pools
100
10
1
0.1
g of AFDM/m2
3
5
9
Time (days)
Funnel
"White tile"

Figure 10

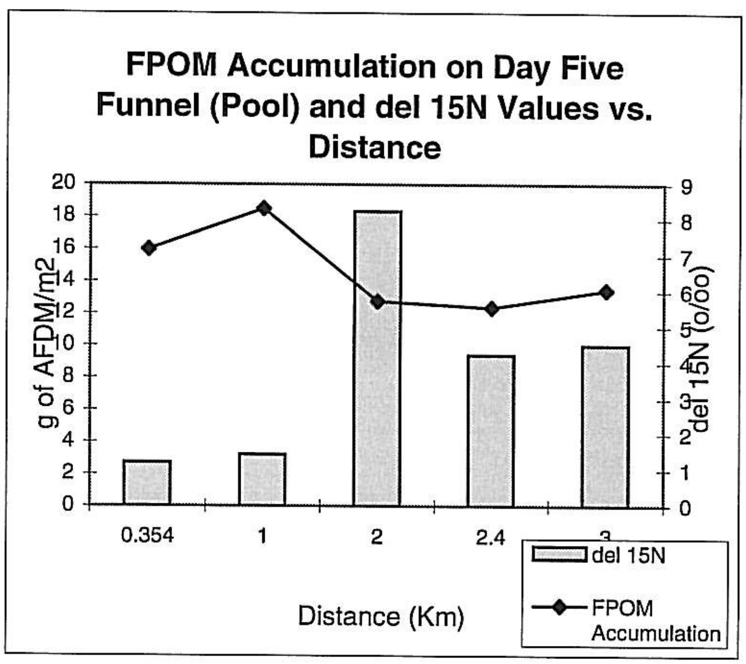


Accumulation of FPOM vs. Time - Riffles
100
10
1
0.1
0.01
g of AFDM/m2
1
3
5
7
9
Time (days)
"White tile" fertilized
"White tile" control
"Moss tile" fertilized
"Moss tile" control

Figure 11

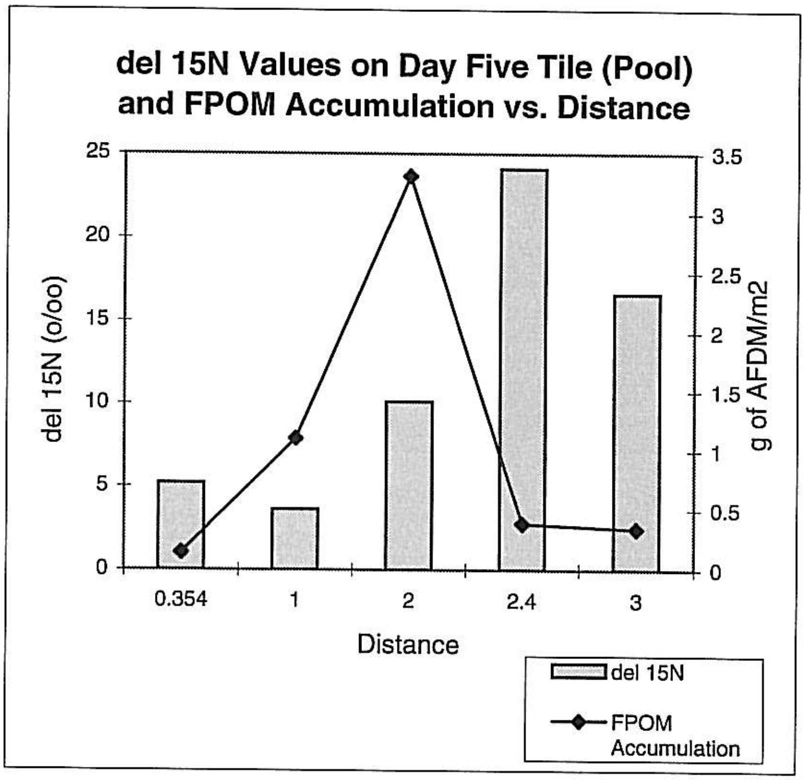


FPOM Accumulation on Day Five Funnel (Riffle) and del 15N Values vs. Distance
g of AFDM/m2
del 15N (o/oo)
0.354
1
2
2.4
3
Distance (Km)
del 15N
FPOM Accumulation

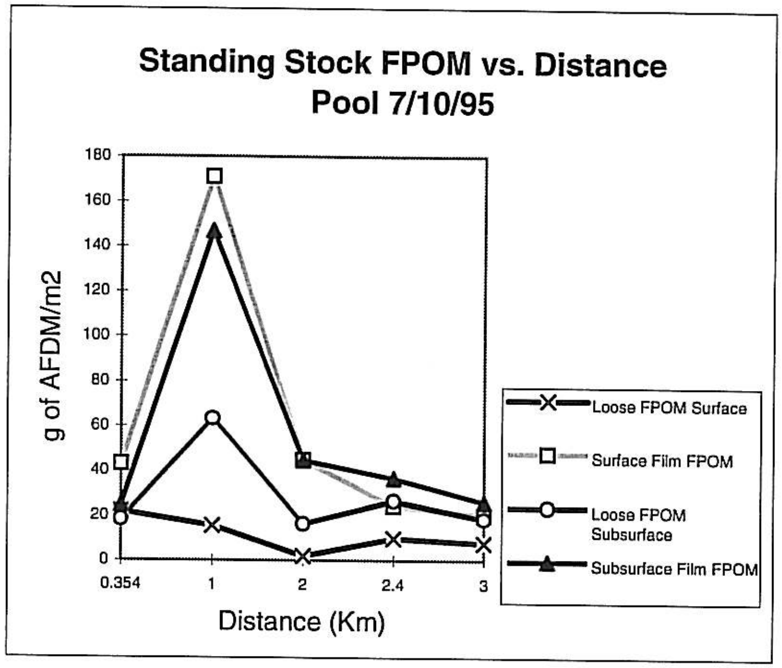


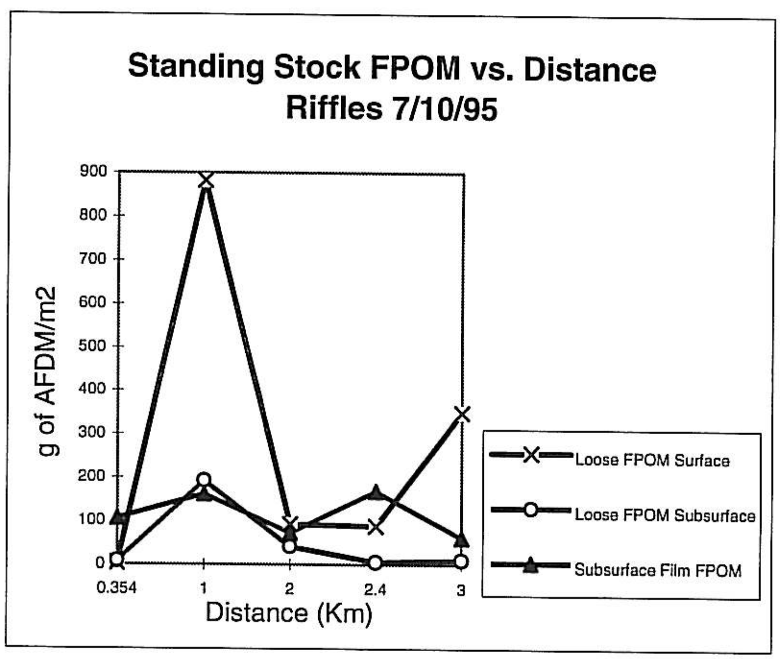
FPOM Accumulation on Day Five Funnel (Pool) and del 15N Values vs. Distance
g of AFDM/m2
del 15N (o/oo)
0.354
1
2
2.4
Distance (Km)
del 15N
FPOM Accumulation

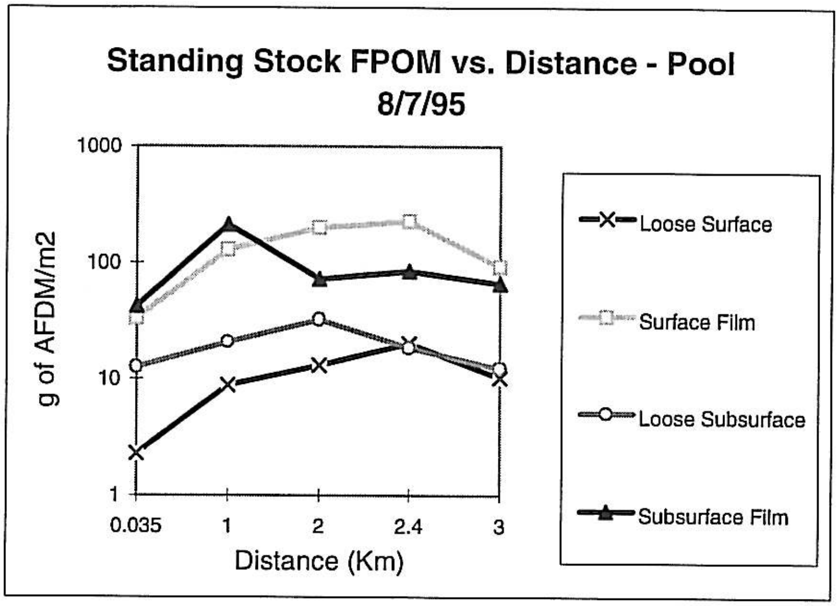
Figure 12

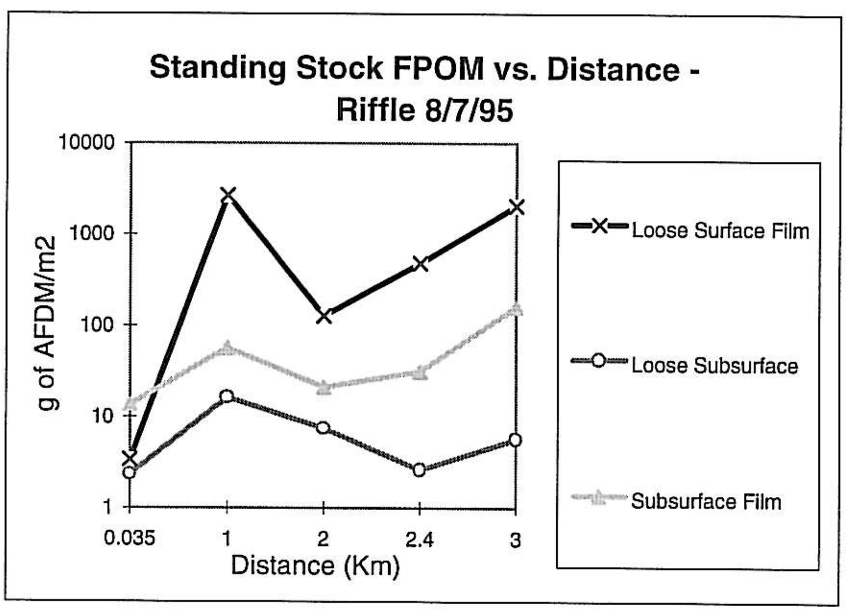

del 15N Values on Day Five Tile (Pool)
and FPOM Accumulation vs. Distance
25
20
15
10
5
0
del 15N (o/oo)
3.5
3
2.5
2
1.5
1
0.5
0
g of AFDM/m2
0.354
1
2
2.4
3
Distance
del 15N
FPOM
Accumulation

Appendix: the following two graphs show the standing stock results with sub-habitat analysis for 10 July 1995 and 7 August 1995.


Standing Stock FPOM vs. Distance
Pool 7/10/95
g of AFDM/m2
180
160
140
120
100
80
60
40
20
0
0.354
1
2
2.4
3
Distance (Km)
Loose FPOM Surface
Surface Film FPOM
Loose FPOM Subsurface
Subsurface Film FPOM


Standing Stock FPOM vs. Distance
Riffles 7/10/95
g of AFDM/m2
900
800
700
600
500
400
300
200
100
0
0.354
1
2
2.4
3
Distance (Km)
Loose FPOM Surface
Loose FPOM Subsurface
Subsurface Film FPOM


Standing Stock FPOM vs. Distance - Pool 8/7/95
1000
100
10
1
g of AFDM/m2
0.035
1
2
2.4
3
Distance (Km)
Loose Surface
Surface Film
Loose Subsurface
Subsurface Film


Standing Stock FPOM vs. Distance - Riffle 8/7/95
10000
1000
100
10
1
g of AFDM/m2
0.035
1
2
2.4
3
Distance (Km)
Loose Surface Film
Loose Subsurface
Subsurface Film