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June 28, 1985

Dr. Larry Gilbertson
Aquatic Group Leader
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Dear Larry:

Enclosed find a draft report discussing the results of AEIDC's efforts to obtain information on seasonal rates of primary production in the Susitna River. This is in fulfillment of Task 31 in our contract with Harza-Ebasco. I would appreciate a rapid review by you and your staff so that we can schedule a technical review of this task and can agree on a scope of work and budget for this effort in fiscal year 1986.

Sincerely,

William J. Wilson

William J. Wilson
Principal Investigator

WJW:jlh
33A-092

Enclosure

TECHNICAL MEMORANDUM

SUMMARY OF PRELIMINARY RESULTS: TASK 31 PRIMARY PRODUCTION MONITORING EFFORT

INTRODUCTION

The purpose of the Task 31 monitoring effect is to document seasonal baseline patterns of primary production in the middle Susitna River and to collect the data necessary to quantitatively predict how these patterns might be altered after impoundment. The justification for this work rests on the assumption that juvenile salmonid growth is substantially limited by food availability and that fish food production in the uncanopied middle river is based primarily on benthic algae production. The results of this effort, combined with those concerning another major factor regulating fish production (mainstem discharge), will provide a powerful tool for understanding middle river ecosystem processes under natural conditions and for predicting how those processes would likely be altered under with-project conditions.

Thus, the major objectives of Task 31 are to fill the following information gaps.

1) documented seasonal patterns of benthic algae biomass, community structure, and productivity in the middle Susitna River and other glacial systems;

2) documented seasonal patterns of benthic macroinvertebrate densities and community composition in the middle Susitna River and other glacial systems;

3) a reliable quantitative model relating primary production rate to relevant limiting factors (e.g. light at depth, temperature, photoperiod) for glacial systems; and

4) a comprehensive, quantitative comparison of baseline and forecasted with-project trophic status conditions in the middle river and objective prediction of associated impacts on salmonid production.

This technical memo addresses the first two information needs and presents some preliminary results and analysis based on data collected during the winter and spring of 1985.

APPROACH

The annual pattern of flow, temperature, and suspended sediment transport displayed by the middle Susitna River exerts a powerful influence on the timing of food production in the system and hence its ability to support fish production (EWT&A and WCC 1985, Van Nieuwenhuyse 1985). Any study addressing the trophic status of the middle river must therefore document conditions during the entire annual cycle. Field data collection for Task 31 thus began in March 1985 when most of the river was still frozen and covered with snow and continued through the spring transition period before breakup in late May. If allowed to continue, the monitoring effort will proceed through the summer period of relatively high flow, temperature, and turbidity, through the fall transition period (when most of the annual autochthonous production occurs) until early November when freeze up is well under way. Unless the 1985 water year is very unusual, the resulting information will provide a solid basis for understanding the essential processes regulating middle river fish production under natural conditions.

In order to predict how these processes will be expressed under with-project conditions, however, requires the formulation of a model. For this purpose it is not sufficient merely to describe baseline patterns of productivity, but to measure the most important factors that make them possible. For that reason, part of the Task 31 data collection effort includes measurements of discharge, water quality and temperature, extinction coefficient, and incident photosynthetically active radiation (PAR), in addition to the biological parameters (i.e., algal biomass, productivity, and community composition).

In order to calibrate the model derived for the middle Susitna River, it is necessary to collect data on the same parameters for as many other glacial systems as possible. Given the constraints of time, money, and manpower, the approach used in Task 31 was to focus attention on systems draining large glacial lakes, thus representing as closely as possible many of the physical conditions anticipated for the middle river under with-project conditions. Two systems were selected for this purpose: the Kasilof River and the Kenai River. If possible, measurements will also be made in the Talkeetna River during the summer and fall of 1985.

Finally, in order to determine whether or not primary production is important to fish production in the middle river, it is necessary to document annual patterns of secondary production as well. The approach used in Task 31 to address this question was to couple measurements of primary productivity and/or benthic algae biomass with simultaneous estimates of macroinvertebrate densities and community composition. In light of the data presented later in this memorandum, linking this information with what is already known about the food habits of middle river juvenile salmonids (ADF&G/Su-Hydro 1982, 1985) should provide a straightforward means for predicting any impacts on fish production resulting from major changes in primary production.

PRELIMINARY RESULTS

SUSITNA RIVER

SKULL CREEK SIDE CHANNEL (RM 125)

The first sampling period at this site occurred during winter conditions (March 30 - April 7, 1985. Snow depths exceeded 10 ft, air temperatures during the day never exceeded 5 C and occasionally fell to -32 C at night. The photoperiod was approximately 13 h long providing a total of 1,615 kcal/m^2 of incident PAR energy on clear days and about 40% less than that on cloudy days. Mean water temperature in this side channel was <1 C at a constant discharge of about 6 cfs. Alkalinity, hardness, conductivity and pH averaged 63±1, 71±2 mg/l, 205 µmhos/cm, and 6.7 respectively. Riffle and run areas remained ice free throughout this period, while much of the surface water in pools froze during the night and then thawed by mid-afternoon. Presumably, the source of the water flowing through this channel was groundwater upwelling and drainage from Slough 8A. The mouth of Slough 8A during the open water season is located less than a mile upstream of the study site and could be recognized by the dune-like appearance of its silt substrate. Much of Slough 8A was still covered by ice and snow during the sampling period. Open areas presented substrate conditions and benthic communities very similar in appearance to those further downstream in the side channel. Substrate in the side channel and slough was predominately cobble-sized with about 10-20% sedimentation in riffles and runs and >50% in slack water stretches. Riffles and runs characterized about 10-20% of the habitat in this roughly 2-mile long stretch of open water; slackwater occupied the remainder. Overturning a rock or otherwise disturbing the substrate anywhere in the channel usually generated a cloud of turbidity downstream. No fish were observed during this sampling period.

Despite the relatively cold water temperatures and less than perfect substrate quality, a well established benthic community thrived in the side channel. Chlorophyll a densities ranged from 0.4 - 12 mg/ft^2 with an overall mean for the site of 3.2±4.2 mg/ft^2 (table 1). The macroinvertebrate community was dominated by chironomid larvae and showed a very strong positive association with algal growth. Chironomid densities ranged from 318-3100 $individuals/ft^2$. The overall site mean for all benthic insects was 1596 ± 476 $insects/ft^2$ (table 2). The distribution of chironomids was fairly uniform throughout the side channel, but was most conspicuous in riffle and run areas supporting large (50 ft^2) mats of a stalked, brown colored algae tentatively identified as Hydrurus foetides. The surfaces of rocks in the slackwater areas were coated with a layer of pennate diatoms and silt which displayed a characteristic vermiform pattern as a result of chironomid grazing.

A comparison of the optical densities of chl a samples before and after acidification revealed that the algal community in the slackwater area was less vigorous than the communities supported by riffle and run habitats. As one would expect, the riffle and run habitats supported higher densities of plecopteran, ephemeropteran, and trichopteran nymphs.

Analysis of the dissolved oxygen and temperature data is not yet complete, but preliminary figures indicate that primary productivity during this winter period was low averaging about 0.5 $g\text{-}O_2/m^2/d$ while respiration was about 3.0 $g\text{-}O_2/m^2/d$.

Returning to this site during the spring transition, we found that considerable snow and ice had melted, but flow through the channel was still about 6 cfs. During this second visit (April 27 - May 5), maximum air

Table 1. Density (mg/ft^2) of chlorophyll _a_ and phaeophytin in benthic algae samples collected in Skull Creek side channel, April 4-5, 1985.

Sampling Area	Depth (ft)	Velocity (ft/s)	Chl _a_ (mg/ft^2)	Phaeophytin (mg/ft^2)
1. Slack Water	0.26	0.15	12.30	2.12
	0.95	0.20	0.37	0.12
	1.00	0.20	3.12	1.48
	0.20	0.00	0.71	0.09
	0.95	0.20	0.49	0.18
2. Riffle	0.23	0.25	0.82	0.00
	0.15	0.20	0.43	0.00
	0.25	1.4	0.63	0.00
	0.15	0.25	0.64	0.10
	0.25	0.65	12.23	0.00
3. Run	0.40	0.30	4.94	0.00
	0.20	0.00	0.47	0.01
	0.50	0.30	7.53	3.70
	0.60	0.30	1.69	0.02
	0.20	0.00	1.69	0.00

Table __. Composition and density of benthic macroinvertebrates sampled at Skull Creek side channel, April 4-5, 1985.

Order	Family	Genus	Sampling Area #1 x Insects/ft^2	Sampling Area #2 x Insects/ft^2	Sampling Area #3 x Insects/ft^2	Combined Sampling Areas X Insects/ft^2
Diptera	Chironomidae		1824	1455	1407	1562 ± 481*
Plecoptera	Capniidae	Allocapnia sp.	12	17	36	22 ± 12
Ephemeroptera	Baetidae	Baetis sp.	1	11	7	6 ± 6
	Ephemerellidae	Ephemerella sp.		5		2 ± 3
		Rhithrogena sp.			1	1 ± .19
	Siphlonuridae	Ameletus sp.			2	1 ± .88
Trichoptera	Hydropsychidae	Arctopsyche sp.		4	5	3 ± 4
						SITE MEAN: 1596 ± 476 insects/ft^2

* 95% confidence limits.

Table 3. Density (mg/ft^2) of chlorophyll a and phaeophytin in benthic algae samples collected in Slough 8A, May 4, 1985.

Sampling Area	Depth (ft)	Velocity (ft/s)	Chl a (mg/ft^2)	Phaeophytin (mg/ft^2)
1. Run	0.36	0.15	3.53	0.88
	0.35	0.20	9.77	1.54
	0.42	0.15	7.06	1.17
	0.25	0.40	8.62	1.94
	0.41	0.30	33.00	21.94
2. Riffle	0.10	0.50	0.78	0.07
	0.15	0.35	0.57	0.06
	0.35	1.55	0.32	0.02
	0.40	1.00	0.20	0.08
	0.15	1.20	0.14	0.09

Table 4. Density of chlorophyll a and phaeophytin in benthic algae samples collected in mainstem habitats, May 3 and 14, 1985.

Sampling Area	Depth (ft)	Velocity (ft/s)	Chl a (mg/ft²)	Phaeophytin (mg/ft²)
RM 127.8				
Riffle	0.20	1.30	0.01	0.02
	0.40	2.10	<0.01	<0.01
	0.25	1.50	<0.01	<0.01
	0.50	1.60	<0.01	<0.01
	0.45	2.00	<0.01	<0.01
Run	0.60	0.85	0.08	0.00
	0.80	1.15	<0.01	<0.01
	0.61	1.10	<0.01	0.01
	0.58	1.00	0.04	0.28
	0.65	1.15	<0.01	<0.01
Riffle	1.55	2.10	0.29	0.05
	1.70	2.30	0.52	0.05
	1.30	3.90	0.15	0.05
	1.80	4.50	0.04	0.02
	1.70	4.00	0.05	0.12
RM 138.7	0.80	1.60	0.05	<0.01
	0.85	1.50	<0.01	<0.01
	1.10	2.40	<0.01	<0.01
	1.50	2.20	<0.01	<0.01
	1.25	2.60	0.11	0.00
	0.60	1.40	0.25	0.00
	0.95	0.70	0.25	0.00
	0.80	0.85	24.80	5.42
	0.80	1.30	0.19	0.00
	1.00	1.05	0.20	0.00
RM 117.0	0.70	0.45	0.06	0.00
	0.85	0.65	<0.01	<0.01
	1.10	0.80	0.06	0.00
	1.00	1.00	0.23	0.00
	1.30	0.90	0.11	0.00
RM 114.5	0.90	2.30	0.15	0.00
	1.00	2.00	<0.01	<0.01
	0.80	1.90	0.09	0.00
	0.50	2.00	0.16	0.00
	0.75	0.90	0.08	0.00

Table 4. Density of chlorophyll a and phaeophytin in benthic algae samples collected in main stem habitats, May 3 and 14, 1985.
(cont'd)

Sampling Area	Depth (ft)	Velocity (ft/s)	Chl a (mg/ft^2)	Phaeophytin (mg/ft^2)
RM 101.8	1.10	0.00	1.49	0.00
	1.10	0.00	1.20	0.00
	1.20	0.00	1.60	0.00
	1.10	0.00	1.15	0.00
	1.10	0.00	3.97	0.00

temperatures were about 15 C while night time lows averaged about -5 C. The photoperiod had increased by 1.5 h supplying as much as 2,658 kcal/m^2 of PAR per day. Mean water temperature was now about 4 C and alkalinity and hardness averaged 61 ±2 and 70 ± 3 mg/l, respectively. Turbidity was <1 NTU.

Chlorophyll a densities in Slough 8A ranged from 0.1 - 33 mg/ft^2, with an overall mean of 6.4 ± 10 mg/ft^2 (table 3). Large numbers of adult stoneflies and chironomids were observed along the banks. Schools of chum salmon juveniles and individual 1+ chinook juveniles were also observed. Benthic macroinvertebrate samples were taken, but have yet been classified and enumerated. Primary productivity levels were considerably higher; preliminary calculations place the average at about 2.0g - O_2/m^2/d. There is evidence that photoinhibition occurred shortly before noon on most clear days.

MAINSTEM HABITATS

A survey of mainstem habitats was conducted in May before breakup when turbidity levels were <2 NTU. Sample sites included a large side channel downstream of Slough 9 (RM 127.8), two areas along the left bank a few hundred feet upstream of the Indian River confluence (RM 138.7), a large side channel at RM 117.0, a channel near the mouth of Mainstem II side channel (RM 114.5), and Whiskers West side channel (RM 101.8) which resembled a large pool. The Indian River and Whiskers West sites were influenced by groundwater upwelling, while the remaining sites represented predominant mainstem habitat conditions. Chlorophyll a densities at all sites not receiving groundwater upwelling were low, while those in the Indian River and Whiskers West sites were comparable to levels observed in sloughs (table 4). Macroinvertebrate densities were correspondingly low as well and displayed a higher percentage of plecopterans and trichopterans than in upwelling areas.

An attempt to estimate primary productivity in the mainstem itself (RM 124) was not successful because the dissolved oxygen concentration never dropped below saturation.

KASILOF RIVER

The first field trip to the Kasilof River occurred April 14-19, 1985 when discharge was low (500 cfs) and large ice shelves extended from both banks. Sampling took place near the Sterling Highway bridge where a USGS gauge has been in place since 1949. Turbidity remained fairly constant between 60-65 NTU compared to <2 NTU in the mainstem Susitna River during this time. Water temperature fluctuated between 0 and 3 C and averaged about 1 C. Mean alkalinity and hardness were 18.4 ± 0.3 and 18.1 ± 0.06 mg/l respectively. The photoperiod was about 13.5 hours long and the maximum daily total PAR measured was 24.69 $E/m^2/d$ or 1291 $kcal/m^2/d$.

The substrate was made up of cobble-sized material and was lightly infiltrated with fine sediment. Little benthic algal growth was evident and pigment analysis indicated that much of the growth present was in poor physiological condition (table 5). The relatively high chlorophyll a densities observed in a slackwater area downstream from the bridge may have resulted from runoff draining a nearby lodge. Primary productivity was low, averaging <0.5 $g - O_2/m^2/d$.

Benthic macroinvertebrate densities were also low dominated, as in the Susitna River, by chironomid larvae (table 6). Species composition was basically similar to communities in the Susitna River with the exception of the Hydrocarina. Copepods displaced from Tustamena Lake (located about 12 miles upstream) were also present in some samples. Some adult stoneflies were observed along the banks during this period.

The second monitoring period began on May 20. By this time, most of the shelf ice along the banks had melted and large mats of green filamentous algae (*Zygnema*) had become established. This growth extended out from the banks

Table 5. Density (mg/ft^2) of chlorophyll *a* and phaeophytin in benthic algae samples collected in the Kasilof River, April 16, 1985.

Sampling Area	Depth (ft)	Velocity (ft/s)	Chl *a* (mg/ft^2)	Phaeophytin (mg/ft^2)
1. Riffle	0.90	0.60	0.65	0.39
	0.45	0.70	0.43	0.82
	0.55	0.80	0.00	2.51
	0.45	0.40	0.36	0.00
	0.25	0.30	1.51	0.0
2. Run	0.60	0.30	1.41	0.00
	0.70	0.35	1.46	0.00
	0.80	0.40	0.00	2.74
	1.10	0.50	0.00	1.44
	1.30	0.50	0.18	0.14
3. Slack Water	0.30	0.15	3.52	0.00
	0.60	0.20	3.75	0.18
	0.50	0.30	4.93	0.00
	0.80	0.60	4.82	0.00
	0.90	1.00	2.82	1.47

Table __. Composition and density of benthic macroinvertebrates sampled at Kasilof River Bridge, April 16, 1985.

Order or Class*	Family	Genus	Sampling Area #1 x Insects/ft^2	Sampling Area #2 x Insects/ft^2	Sampling Area #3 x Insects/ft^2	Combined Sampling Areas X Insects/ft^2
Diptera	Chironomidae		249	112	689	350 ± 188*
	Empedidae				2	1 ± 1
Plecoptera	Capniidae	Allocapnia sp.	3			1 ± 2
	Chloroperlidae	Alloperla sp.	2	1		1 ± 1
Ephemeroptera	Baetidae	Baetis sp.	6	3		3 ± 3
	Heptageniidae	Heptagenia sp.			5	2 ± 3
Trichoptera	Hydropsychidae	Arctopsyche sp.		5	3	3 ± 3
	Brachycentridae	Brachycentrus sp.			3	1 ± 1
	Limnephilidae				3	1 ± 2
Class* Arachnoidea	Hydracarina		18	9	19	12 ± 8
						SITE MEAN: 378 ± 194 insects/ft^2

* 95% confidence limits.

beyond safe wading distance and presumably covered most of the river's benthic surface area for at least 13 miles downstream from the lake outlet. Flow had increased slightly to about 550 cfs, while turbidity remained a constant 59 NTU. Turbidity in the mainstem Susitna River at this time (May 17) was 5.8 NTU.

Chlorophyll a densities increased substantially and represented largely new growth (table 7). Values ranged from 1.15 to 7.97 mg/ft^2 with an overall mean of 4.4 ± 2.0 mg chl a/ft^2. This increase in benthic algae biomass corresponded to an even more substantial increase in production rate which now averaged almost 3g $-O_2/m^2/d$; a 500% increase over previous levels!

Macroinvertebrate samples were also collected, but have not yet been analyzed. Densities did not appear to be much greater than previous levels however. Observations made in early June, however, indicate that chironomid larvae densities at least may have been increasing by that time.

Large hatches of caddisflies have recently been observed in both the Kenai and Kasilof Rivers (Jeff Koenings, ADF&G, FRED, personal communication).

Table 7. Density (mg/ft^2) of chlorophyll a and phaeophytin in benthic algae samples collected in the Kasilof River, May 22, 1985.

Sampling Area	Depth (ft)	Velocity (ft/s)	Chl a (mg/ft^2)	Phaeophytin (mg/ft^2)
1. Slack Water	0.15	0.00	7.97	0.08
	0.40	0.05	5.03	0.31
	0.50	0.15	4.79	0.29
	0.63	0.10	6.91	0.86
	0.62	0.20	2.87	0.32
2. Run	1.00	0.25	1.15	0.07
	1.34	0.45	3.58	0.40
	1.75	0.55	3.30	0.39
	1.26	0.80	3.97	0.32
	2.15	1.00	4.03	0.01

DISCUSSION

BASELINE CONDITIONS

Based on available data and observations, a tentative scenario can be formulated regarding the natural seasonal pattern of food production in the middle river and its relationship to fish production. The summer (June-August), characterized by high flows and turbidities, is a period of low primary production. Productivity is limited by the lack of sufficient light intensity and the scouring action of suspended sediment and bedload transport. Benthic macroinvertebrate biomass is low and consequently the amount of food available to juvenile salmonids as drift is minimal. Given the relatively low water temperature regime of the system, it is reasonable to assume that most aquatic insects in the middle river produce only a single generation each year. If this is so, it is also reasonable to assume that most of the macroinvertebrate biomass of the system during summer is in the form of eggs or very early instars (too small to be caught in drift nets) or is deep within the substrate beyond the harmful effects of flow and suspended sediment. In terms of fish production then, the summer period seems to be devoted primarily to facilitating outmigration of smolts and the inmigration of adult salmon spawners. Summer flows, however, also act to flush out mainstem peripheral channels, inundate adjacent wetlands and riparian vegetation, and hence to liberate nutrients from the terrestrial environment. Fresh glacial silt deposited in peripheral channels may also provide additional nutrients by way of microbial action.

As discussed in previous reports, (EWTA and WCC 1985; Van Nieuwenhuyse 1985; AEIDC 1985, Milner 1985), the major period of organic carbon production clearly takes place during the fall (September and October) when mainstem flows are generally below 12,000 cfs, rarely greater than 22,000 cfs, and turbidity levels decline to less than 50 NTU following the cessation of glacial wasting. Without data for this period, it is impossible to accurately estimate this amount, but its magnitude is very likely on the order of hundreds or even thousands of tons. If our assumption about macroinvertebrate life cycles is correct, this pulse of primary production is ideally timed to support the growth of insect larvae during the cold months to follow.

It is also during the fall that many rearing juvenile salmonids begin to congregate in sloughs and tributary mouths where they will spend the winter and spring. Chinook juveniles overwintering in groundwater fed habitats associated with the mainstem come from both the tributaries themselves (where all of them were born), as well as the turbid side channels where many of them reared during part of the summer.

During the winter (November-February) suitable habitat (which is probably <5% of available habitat) for juvenile salmonids is at a premium. What makes groundwater fed habitats so suitable is their relative warmth, stability, and the abundant food they will offer when it is needed most, i.e., during the months preceding outmigration.

As the results of the Task 31 monitoring effort have already shown, by March, macroinvertebrate densities in these habitats are already very high and individual insects are of sufficient size to sample and to constitute an abundant food source both for 1+ chinook juveniles and recently emerged chum fry. By mid-summer, most of these fish have become smolts and have left the system making room for the cohorts to follow. It is also during the spring that most of the aquatic insects inhabiting the middle river begin emerging, mating, and laying their eggs. Since many species make up the aquatic insect community, the precise timing of their emergence may well extend throughout the summer, but it seems clear that on a system wide basis most insect reproduction is taking place in the spring.