TECHNICAL MEMORANDUM

SUMMARY OF RESULTS: TASK 71 PRIMARY PRODUCTION MONITORING EFFORT

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INTRODUCTION

This technical memorandum presents a summary of baseline field data collected during 1985 on the distribution, timing, and relative abundance of benthic primary and secondary production in the middle Susitna River and the Kasilof River. It also briefly discusses these results and their likely implications regarding the "fish food" production of the middle river under anticipated with-project conditions of flow, temperature, and turbidity.

The strong positive correlation between fish production and lower trophic level production in aquatic systems in general is well established (Wetzel 1975, LeCren 1972). The quantitative details of this relationship are well on their way to being worked out for lentic systems, but are only just beginning to be studied seriously in lotic systems. Data on this subject for glacial rivers in particular cannot be found in the literature. At any rate, given a certain basic macronutrient influx from its watershed, the flow, temperature, and suspended sediment/turbidity regimes of a stream are known to exert a powerful influence on its production of "fish food," and hence its ability to support healthy fish populations (Hynes 1972).

Comparing plots of these three regimes for the middle Susitna River under anticipated with-project conditions and under "normal" baseline conditions (Harza-Ebasco 1985) (figure 1) reveals the magnitude of the downstream environmental changes impoundment would produce. The chemically similar Kasilof River, with a gradient (10 ft/mi) and substrate composition very much like the middle Susitna River and a nearly constant year round turbidity level

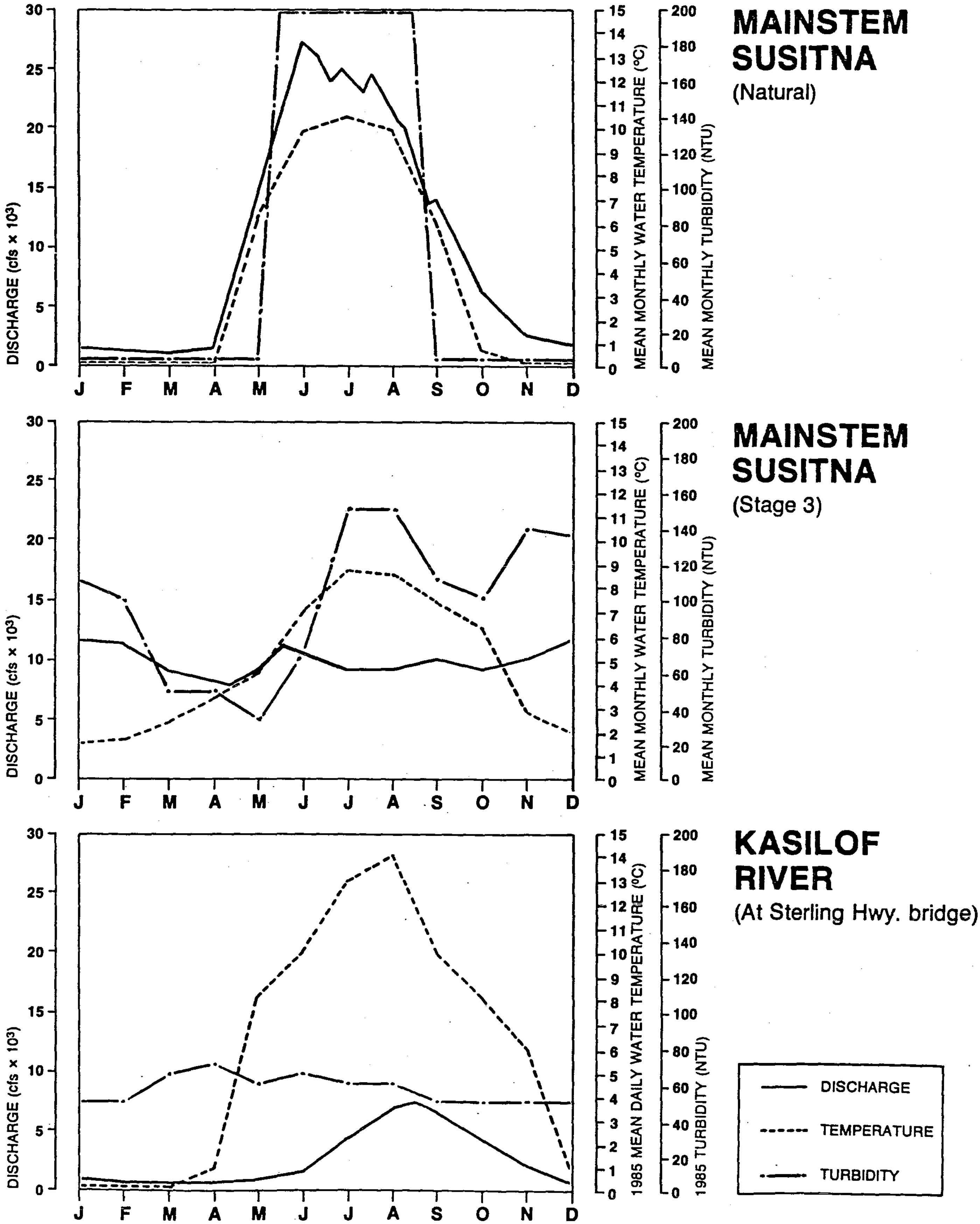

Figure 1. Mean monthly discharge (50% exceedence), temperature, and turbidity for: the Susitna River at Gold Creek (a) under natural conditions, (b) projected under Stage 3, E-VI scenario; and (c) the Kasilof River.

(figure 1), offers a unique opportunity to study the interaction and relative magnitude of these density-independent regulating factors and provides useful information for predicting the likely with-project productivity and fish rearing potential of the middle Susitna River.

MATERIALS AND METHODS

FIELD METHODS

Both rivers were sampled on roughly a monthly basis from early April to late October, 1985. The field schedule was designed to provide information on benthic algal standing crop (mg-chlorophyll *a* m^{-2}) and productivity (g-O_2 $m^{-2}d^{-1}$); benthic macroinvertebrate standing crop (g wet weight m^{-2}) and density (number of individuals m^{-2}); as well as data on water quality and incident photosynthetically active radiation (PAR) for all four seasons. Study sites in the middle Susitna River were selected to represent both mainstem and side slough habitat conditions and, with the exception of the Susitna Side Channel site (RM 121.7R), have been modelled hydraulically. A given study site was represented by one or more (usually 3) "sampling areas" depending on the heterogeneity of substrate and hydraulic conditions. A sampling area consisted of a 10 ft x 15 ft grid subdivided into five 2 ft x 15 ft strips running parallel to the bank. Within each strip, three locations were selected at random for epilithic algae sample collection and one location for macroinvertebrate sampling. Depth and mean velocity were measured before each rock was removed. Sampling the rock for benthic fauna required that a 250 u mesh net be held immediately downstream to catch any dislodged insects and then scraping the rock bare into the same net. The long and short axes of the rock were then measured to provide an estimate of the surface area sampled. Insects and debris trapped by the net were transferred to 100% isopropyl alcohol for subsequent identification and enumeration.

A cylindrical masonite template circumscribing an area of 0.0027 m^2 was placed on a relatively flat surface of the rocks collected for chl *a* samples. The circumscribed area was then scraped bare of algae and other material and filtered onto a 0.45 μ glass fiber filter. Several drops of saturated magnesium carbonate solution were added before the sample was frozen for subsequent laboratory analysis.

Estimates of gross primary productivity were made using the single-station diel oxygen curve method of Odum (APHA 1980). Photosynthetically active radiation (PAR) was monitored more or less continuously using a LI-COR 1776 solar monitor set on a 0.5 h integrating interval. Turbidity was measured using a HACH "Portalab" field turbidimeter. Flow (cfs) in the Kasilof River was estimated using the Type A wire weight gage installed on the highway bridge by the USGS in 1949. Mainstem flows (cfs) in the middle river referred to in this memo are taken from provisional USGS records for its Gold Creek station. Flows, depths, and velocities reported for other locations were measured using a top-set wading rod and a Marsh-McBirney velocity meter.

LABORATORY METHODS

Pigment analyses of benthic algae samples were performed using the standard trichromatic method (APHA 1980). Samples were ground in 90% acetone solution, centifuged and immediately read on a Bausch & Lombe Spec 2000 spectrophotometer. The conversion of chl *a* densities to algae biomass values (i.e., multiply the former by 67 to obtain the latter) is recommended in APHA (1980) and is included in the tables of the results section as a convenience for people who are unaccustomed to dealing with chlorophyll *a* values.

Macroinvertebrates were enumerated and identified to the generic level, except for chironomids which were just grouped by family. Densities (no. m^{-2}) for each genus or group were converted to biomass (g m^{-2}) on the basis of mean length using the length-weight relationships published in Edmondson and Winberg (1971).

RESULTS

SUSITNA RIVER

SPRING (MARCH-BREAKUP)

Spring breakup in the middle river occurred approximately May 23-24. At this time, the ice jams which began forming in open leads by late April had succumbed to warmer air temperatures and a mean daily mainstem flow at Gold Creek which increased from its typical winter level of about 1,800 cfs on May 11 to 18,000 cfs by May 24. Sediment-laden, brown colored mainstem water began inundating peripheral shoreline areas and side channels that had lain follow under an insulating layer of ice and snow for over six months. By May 25, the mean daily flow at Gold Creek of 29,200 cfs was sufficient to flood most of the peripheral side slough habitats that since the previous fall had provided rearing habitat for overwintering juvenile salmonids and more recently, for newly emerged chum salmon fry.

In terms of middle river primary and especially secondary production, breakup marked the beginning of a summer period of low production and provided a sharp contrast to the relatively high productivity (on a per unit area basis) observed both in mainstem and spring-fed peripheral channels during the two months prior. Epilithic algal biomass and community composition in open water channels along the entire length of the middle river before breakup displayed considerable variation depending on a variety of factors, principal among which seemed to be: substrate quality, water velocity, and water temperature.

Thus, highly sedimented cobble streambeds in slackwater reaches of side sloughs (e.g., Slough 8A), supported benthic communities dominated by pennate diatoms and chironomid larvae and were characterized by high densities and standing crops. Chlorophyll *a* densities ranged from 4.0 to 132.4 mg m^{-2}, averaging 36.4 ± 53.5 mg m^{-2}. Pigment analysis revealed that much of this growth was not recent (table 1). Chironomid larvae dominated the aquatic insect community both numerically (>99%) and in terms of biomass (84 ± 20%). Total macroinvertebrate densities in the Slough 8A pool ranged from about 10,000 to 26,000 individuals m^{-2} with an overall standing crop of 7.85 ± 7.40 g m^{-2} (of which 80 ± 20% consisted of late instar chironomid larvae) (table 2). Pool habitat of this character was the most (about 80%) prevalent kind of groundwater-fed habitat open during much of the winter and spring (roughly, from mid-February to breakup). The remaining stretches of locally spring-fed peripheral open water channels consisted of riffles and runs.

Riffle and run habitats supported about the same amount of epilithic algal growth as in the slackwater reaches but offered greater biological diversity. Riffles were dominated by the heavily stalked, brown colored filamentous alga *Hydrurus foetidis*, while runs tended to support a mixture of *Zygnema* and *Spriogyra* along the margins and *Hydrurus* and a variety of pennate diatom in the higher velocity regions. Chlorophyll *a* densities in the Slough 8A riffle ranged from 4.6 to 132 mg m^{-2} and in the run from 5.1 to 81 mg m^{-2}. Pigment analyses showed that riffle/run algal communities contained less phaeophytin and were thus "younger" than those in pools (table 1). Ranges for total macroinvertebrate densities in riffles and runs, respectively, were 4,700 to 28,000 m^{-2} and 7,000 to 33,000 m^{-2}. The average macroinvertebrate standing crop for the riffle was about 10.8 ± 5.0 g m^{-2} and for the run 22 ± 17 g m^{-2}. In both cases chironomids made up 63% of the total biomass and as one would expect, the riffle and run habitats supported higher densities of plecopteran (stonefly), ephemeropteran (mayfly), and trichopteran (caddisfly) nymphs than the slackwater habitat (table 2). The overall mean

Table 1. Mean (±S.D.) chlorophyll a density, estimated biomass, vitality[1], and selected environmental parameters for epilithic algae sample areas, middle Susitna River, April-May[2] 1985 (n = 15).

DATE	SAMPLE SITE AND AREA	WATER TEMP (C)	TURBIDITY (NTU)	MEAN(±S.D.)[3] DEPTH (ft)	MEAN(±S.D.)[3] VELOCITY (ft)	CHL a. DENSITY (mg m^{-2})	ALGAL BIOMASS (g-AFW m^{-2})	VITALITY
04/05/85	Slough 8A							
	I (pool)	1.2	0.7	0.67 ± 0.40	0.15 ± 0.09	36.4 ± 53.5	2.44 ± 3.58	1.50 ± 0.07
	II (riffle)	1.3	0.7	0.21 ± 0.05	0.55 ± 0.51	9.3 ± 4.4	0.62 ± 0.29	1.67 ± 0.11
	III(run)	1.3	0.7	0.38 ± 0.18	0.18 ± 0.16	35.3 ± 31.4	2.37 ± 2.10	1.58 ± 0.10
05/04/85	IV (run)[4]	6.5	0.8	0.36 ± 0.07	0.24 ± 0.11	140.3 ± 132.6	9.40 ± 8.88	1.47 ± 0.04
	V (riffle)[4]	6.5	0.8	0.23 ± 0.14	0.92 ± 0.50	4.8 ± 3.1	0.32 ± 0.01	1.44 ± 0.21
05/03/85	128.3R[5]							
	I (riffle)	1.2	1.5	0.36 ± 0.13	1.70 ± 0.34	0.18 ± 0.07	0.01 ± 0.005	1.70 ± 0
	II (run)	1.2	1.5	0.65 ± 0.09	1.05 ± 0.13	0.35 ± 0.29	0.02 ± 0.02	1.70 ± 0
	III(riffle)	1.2	1.5	1.61 ± 0.19	3.36 ± 1.09	2.54 ± 2.23	0.17 ± 0.15	1.37 ± 0.20
05/14/85	138.8 L							
	IV (mainstem margin)	1.8	5.7	1.10 ± 0.29	2.06 ± 0.49	0.51 ± 0.31	0.03 ± 0.02	1.70 ± 0
	V (mainstem margin	1.8	5.7	0.79 ± 0.14	1.06 ± 0.34	2.11 ± 0.33	0.14 ± 0.02	1.70 ± 0.01
	117.0 L	0.5	5.7	0.99 ± 0.23	0.76 ± 0.22	1.48 ± 0.80	0.10 ± 0.05	1.70 ± 0
	114.0 R	7.8	5.7	0.79 ± 0.19	1.82 ± 0.54	1.47 ± 0.52	0.10 ± 0.03	1.70 ± 0
	101.5 L (pool)	10.0	2.0	1.10 ± 0.05	0.00	20.26 ± 12.73	1.36 ± 0.85	1.70 ± 0

1. Before-to-after acidification absorption peak ratio (1.0 = all phaeophytin, 1.7 = all chl a).
2. Summer and fall samples were collected, but have yet to be analyzed.
3. Mean of depths and mean velocities where samples were randomly selected, not of the channel in which the sample area was located.
4. Completely ice/snow covered less than three weeks prior to sampling.
5. EWT&A/AEIDC habitat inventory reconnaissance site numbers (EWT&A 1985) or river mile.

Table 2. Mean (±S.D.) macroinvertebrate density and biomass (indicating percent chironomid) and selected environmental parameters for sample areas in Slough 8A, April-October, 1985 (n=5).

DATE	SAMPLE AREA	WATER TEMP (C)	TURBIDITY (NTU)	MEAN(±S.D.)[1] DEPTH (ft)	MEAN(±S.D.)[1] VELOCITY ($ft\ s^{-1}$)	MACROINVERT DENSITY ($No.\ m^{-2}$)	MACROINVERT BIOMASS ($g\text{-}WW\ m^{-2}$)
04/05/85	I (pool)	1.2	0.7	0.74 ± 0.34	0.15 ± 0.08	19,519 ± 6,743 (>99%)[2]	7.85 ± 7.40 (84 ± 20%)[2]
	II (riffle)	1.3	0.7	0.21 ± 0.05	0.55 ± 0.51	16,519 ± 10,604 (92 ± 12%)	10.79 ± 5.03 (63 ± 42%)
	III (run)	1.3	0.7	0.34 ± 0.24	0.18 ± 0.16	16,656 ± 10,266 (95 ± 3%)	22.17 ± 17.47 (63 ± 17%)
05/04/85	IV (run)[3]	6.5	0.8	0.36 ± 0.07	0.24 ± 0.11	3,748 ± 1,624 (100%)	1.79 ± 0.98 (100%)
	V (riffle)[3]	6.5	0.8	0.23 ± 0.14	0.92 ± 0.50	2,151 ± 558 (98 ± 3%)	1.46 ± 1.26 (84 ± 25%)
08/15/85	VI (riffle)	8.0	1.5	0.56 ± 0.17	1.64 ± 0.61	3,812 ± 1,803 (76 ± 21%)	1.06 ± 0.73 (53 ± 32%)
	VII (pool)	9.0	1.5	0.53 ± 0.20	0.00	1,891 ± 2,017 (91 ± 17%)	0.28 ± 0.39 (89 ± 23%)
09/19/85	VI (riffle)	4.5	1.2	0.53 ± 0.22	1.94 ± 0.47	13,964 ± 9,818 (85 ± 9%)	10.56 ± 10.12 (73 ± 12%)
10/16/85	VI (riffle)	2.5	0.6	0.38 ± 0.03	2.17 ± 0.32	7,011 ± 4,973 (56 ± 16%)	5.86 ± 2.39 (7 ± 4%)
	VIII (pool)	2.6	0.6	0.33 ± 0.10	0.10	2,327 ± 245 (87 ± 3%)	2.71 ± 0.87 (52 ± 21%)

1. Mean of depths and mean velocities where samples were randomly selected, not of the channel in which the sample area was located.
2. Percent of total comprised of chironomid larvae or pupae (species undetermined).
3. Completely ice/snow covered less than three weeks prior to sampling.

values for chl a density, macroinvertebrate density, and macroinvertebrate standing crop for all three sample areas at the Slough 8A site were 34.4 ± 45.2 mg chl a m^{-2}, 17,600 ± 8,800 m^{-2}, and 13.6 ± 12.3 g m^{-2}, respectively.

Primary productivity estimates made between April 28 and May 4 averaged 1.1 ± 0.2 g-O_2 m^{-2} d^{-1}, with a corresponding mean respiration rate of 3.0 ± 0.5 g^{-2} d^{-1}.

A riffle and run section of Slough 8A sampled in early May had been totally ice covered only three weeks prior to sampling and thus provided some indication of trophic conditions under the ice. As the moderately low before-to-after acidification absorption peak ratios indicate, the algal community in these recently exposed reaches contained a considerable amount of "old growth." Nevertheless, the amount of algal material sampled here was as high as 355 mg chl a m^{-2}, dominated by a brown, filamentous form, probably diatomaceous. Taxonomic samples were collected, but have yet to be analyzed. The "true" mean chl a density for the run was probably closer to 78 ± 29 mg chl a m^{-2} rather than the 140 mg m^{-2} reported in table 1. The macroinvertebrate community of the run was made up entirely of chironomid larvae and numbered from 1,700 to 5,500 m^{-2}, averaging 3,700 ± 1,600 m^{-2}; biomass ranged from 0.72 to 3.20 g m^{-2} and averaged 1.8 ± 1 g m^{-2} (table 2). Chlorophyll a and aquatic insect densities in the recently exposed riffle reach were lower averaging 4.8 ± 3.1 mg m^{-2} and 1,151 ± 558 m^{-2}, respectively, but the presence of plecopteran nymphs yielded a mean biomass estimate comparable to the run (table 2). Overall site means for chl a (excluding the outlier), insect density, and insect biomass were 37 ± 43 mg chl a m^{-2}, 2,851 ± 2,068 m^{-2}, and 0.67 ± 0.69 g m^{-2}, respectively.

In sharp contrast to the relatively warm, somnolent streamflows of side sloughs and other peripheral spring-fed habitats, the open water stretches of true middle river mainstem habitats prior to breakup generally offered excellent substrate quality (i.e., armored cobble/rubble with silt-free interstitial spaces), deep, fast, crystal clear (but cold) water, and (like the sloughs) a moderately high level of plant macronutrients (20 $\mu g\ l^{-1}$ of dissolved ortho-phosphate and 120 $\mu g\ l^{-1}$ nitrate-nitrogen). Many open leads (some created by high velocities, others by the warmth of groundwater upwelling) were well developed by the time of our helicopter reconnaissance flight (March 20) and had presumably begun forming weeks before that. An estimate of light transmittance under an ice/snow cover of 0.66 m thickness (comprised of a 0.20 m layer of "new snow" with a mean density of 0.21 g cm^{-3}; 0.38 m of older, compacted snow with a mean density of 0.31 g cm^{-3}; and an 8 cm thick layer of clear-as-glass ice), in near zero turbidity water and about 1,350 $\mu E\ m^{-2}\ s^{-1}$ incident light intensity, indicated that diffraction within the water column can transmit light energy adequate for photosynthesis to substrate at least 1 to 1.5 m beyond the edge of an open lead.

Several clear, deep (typically 3.5 - 5.0 ft deep) backwater areas developed at the downstream ends of slough/side channel complexes (e.g., Slough 8B/Susitna side channel, Slough 8A/Skull Creek side channel, Slough 9/unnamed side channel, Slough 21/Slough 21 side channel) several weeks before breakup and were still intact by May 14. On April 28, several individual 1+ chinook, one dead rainbow(?) juvenile (80 mm fork length), and one adult salmonid (about 350 mm long) were observed in such a backwater area near the frozen mouth of Skull Creek.

With its near zero turbidity, sufficient light for photosynthesis is easily able to penetrate to the greatest depth of any mainstem lead prior to breakup. Substrate viewed at an angle from an overhanging bank through more than 15 ft of water appeared dark green with diatomaceous-looking growth.

Unfortunately, rocks from such depths could not be sampled. The deepest mainstem epilithic algae samples were collected on May 3, from the "Slough 9 side channel" site (RM 128.3R) at a depth of 1.80 ft and mean column velocity of 4.5 ft/s. The chl a density at this depth was 0.54 mg m^{-2} and had a proportionately high level of phaeophytin (0.03 mg m^{-2}). For all three sample areas studied at this site--shallow and deep--chl a densities were relatively low, ranging from 0.09 to 6.0 mg m^{-2} and few filamentous forms were observed. Sample areas I (shallow riffle) and II (run) had phaeophytin-free growth, while the deeper samples, with one exception, indicated either old growth (i.e., from earlier in the winter or more likely from the previous fall) or severe stress. The overall site mean for this channel was 1.02 ± 1.64 mg chl a m^{-2} (table 1).

The aquatic insect community at this site displayed a slightly greater species diversity than the exclusively spring-fed peripheral sites and a much lower proportional representation by chironomid larvae (which accounted for 53 ± 21% of the density, but only 8 ± 12% of the biomass for all three sample areas combined) (table 3). The chironomids present were small, early instar individuals indicating that perhaps the early February "mosquito hatch" mentioned by helicopter pilots in March, may instead have been the emergence of adult chironomids. At any rate, Simulidae dominated the aquatic insect standing crop in the riffle areas of this site (ranging from 0.6 to 27.6 g m^{-2}), while plecopteran and ephemeropteran standing crops ranged from 0.24 to 5.1 and 0.01 to 1.0 g m^{-2}, respectively. Only two samples from the run sample area yielded caddisfly nymphs which "weighed in" at 0.3 and 2.3 g m^{-2}. The site means for insect density and biomass were 1,514 ± 1.775 m^{-2} and 4.9 ± 8.1 g m^{-2}, respectively.

Table 3. Mean (±S.D.) macroinvertebrate density and biomass (indicating percent chironomid) and selected environmental parameters for Susitna River mainstem and side channel locations, May-October, 1985 (n=5).

DATE	SAMPLE SITE AND AREA	WATER TEMP (C)	TURBIDITY (NTU)	MEAN(±S.D.)[1] DEPTH (ft)	MEAN(±S.D.)[1] VELOCITY (ft s^{-1})	MACROINVERT DENSITY (No. m^{-2})	MACROINVERT BIOMASS (g-WW m^{-2})
05/03/85	128.3R[3]						
	I (riffle)	1.2	1.5	0.36 ± 0.13	1.70 ± 0.34	869 ± 820 (44 ± 21%)[2]	3.77 ± 4.08 (8 ± 18%)[2]
	II (run)	1.2	1.5	0.65 ± 0.09	1.05 ± 0.13	1,204 ± 457 (61 ± 14%)	1.99 ± 1.71 (7 ± 6%)
	III(riffle)	1.2	1.5	1.61 ± 0.19	3.36 ± 1.09	2,491 ± 2,869 (54 ± 27%)	9.00 ± 13.40 (10 ± 13%)
05/14/85	138.8 L						
	IV[4]	1.8	5.7	1.10 ± 0.29	2.06 ± 0.49	909 ± 884 (64 ± 7%)	1.36 ± 1.21 (9 ± 11%)
	V	1.8	5.7	0.79 ± 0.14	1.06 ± 0.34	4,182 ± 2,363 (96 ± 3%)	1.58 ± 0.76 (45 ± 38%)
	117.0 L[4]	0.5	5.7	0.99 ± 0.23	0.76 ± 0.22	8,820 ± 3,454 (98 ± 1%)	4.07 ± 2.45 (67 ± 33%)

1. Mean of depths and mean velocities where samples were randomly selected, not of the channel in which the sample area was located.
2. Percent of total comprised of chironomid larvae or pupae (species undetermined).
3. EWT&A/AEIDC habitat inventory reconnaissance site numbers (SUS 412) or river mile.
4. Mainstem margin.

Table 3 Cont'd. Mean (±S.D.) macroinvertebrate density and biomass (indicating percent chironomid) and selected environmental parameters for Susitna River mainstem and side channel locations, May-October, 1985 (n=5).

DATE	SAMPLE SITE AND AREA	WATER TEMP (C)	TURBIDITY (NTU)	MEAN(±S.D.)[1] DEPTH (ft)	MEAN(±S.D.)[1] VELOCITY (ft s^{-1})	MACROINVERT DENSITY[2] (No. m^{-2})	MACROINVERT BIOMASS (g-WW m^{-2})
05/14/85	114.0 R (riffle)	7.8	5.7	0.79 ± 0.19	1.82 ± 0.54	393 ± 179 (54 ± 26%)	1.49 ± 1.50 (4 ± 3%)
	101.5 L[3] (pool)	10.0		1.10 ± 0.05	0.00	1,910 ± 754 (100%)	1.70 ± 0.67 (100%)
08/14/85	138.8 L IV	-	116	1.80 ± 0.45	1.31 ± 0.08	57 ± 114 (0%)	0.001 ± 0.002 (0%)
	125.2 R VI[4]	-	120	1.02 ± 0.45	1.70 ± 0.37	164 ± 171 (67 ± 58%)	0.013 ± 0.018 (67 ± 58%)
	101.5 L VII[4]	10.0	120	1.18 ± 0.44	1.86 ± 0.24	44 ± 61 (33%)	0.003 ± 0.004 (99%)

1. Mean of depths and mean velocities where samples were randomly selected, not of the channel in which the sample area was located.
2. Percent of total comprised of chironomid larvae or pupae (species undetermined).
3. Channel was not breached.
4. Side channel margin.

Table 3 Cont'd. Mean (±S.D.) macroinvertebrate density and biomass (indicating percent chironomid) and selected environmental parameters for Susitna River mainstem and side channel locations, May-October, 1985 (n=5).

DATE	SAMPLE SITE AND AREA	WATER TEMP (C)	TURBIDITY (NTU)	MEAN(±S.D.)[1] DEPTH (ft)	MEAN(±S.D.)[1] VELOCITY (ft s^{-1})	MACROINVERT DENSITY (No. m^{-2})	MACROINVERT BIOMASS (g-WW m^{-2})
09/11/85	138.8 L (IV)	-	58	1.16 ± 0.65	1.52 ± 0.55	69 ± 154 (0%)[2]	0.013 ± 0.029 (0%)[2]
	101.5 L (VII)	-	64	1.57 ± 0.23	2.07 ± 0.06	0	0
10/15/85	138.8 L (IV)	1.0	2.8	0.67 ± 0.54	0.98 ± 1.1	5,556 ± 3,621 (81 ± 23%)	1.55 ± 1.01 (53 ± 47%)
	125.2 R (VI)	1.6	2.8	0.84 ± 0.30	1.75 ± 0.97	1,729 ± 1,277 (71 ± 22%)	0.22 ± 0.21 (22 ± 23%)
	121.7 R[3]	1.6	3.0	0.95	1.80	7,109 (74%)	5.43 (63%)
10/17/85	101.5 L[3] (VII)	0.2	3.2	0.88	1.00	1,569 (100%)	1.40 (100%)

1. Mean of depths and mean velocities where samples were randomly selected, not of the channel in which the sample area was located.
2. Percent of total comprised of chironomid larvae or pupae (species undetermined).
3. Only one sample analyzed to date.

Other sample locations dominated by pre-breakup mainstem flow (i.e., 138.8 L, transects IV and V, 117.0 L, and 114.0 R) supported similar benthic communities with about the same order of magnitude chl a density and aquatic insect standing crop (tables 1 and 3).

The Whisker's West site (105.5L) is a large side channel during the open water season and during the previous fall supported heavy periphytic growth. Prior to breakup, however, the upstream end was essentially a long (about 100 m), moderately deep pool bearing warm groundwater and a dense layer of fresh brown and green epilithic/epipsammic growth (table 1). As one might expect from the previous physical description of peripheral slackwater habitats further upstream along the middle river, the aquatic insect community at the 101.5 L site was dominated by chironomids (100%) and averaged about 1.7 ± 0.7 g m^{-2} in standing crop (table 3).

To summarize then, for those organisms that are not destroyed by its formation, the ice and snow cover of the middle river in winter might be viewed as a protective, insulating shell which effectively conceals growing communities of aquatic insects for at least three months (December-February) and then gradually "cracks open" during the spring, creating well lit open water for fresh food production (primarily epihithic algae) for late instar insects and steadily releasing millions of adult aquatic insects. The latter generally live only for a brief time; just long enough to find mates and lay their eggs. The amount of open water is maximal during the last weeks before breakup and in terms of lower trophic level production is probably best represented in the peripheral channels by the slackwater habitat of Slough 8A. Thus, average values of benthic algae and aquatic insect standing crop for this kind of habitat are about 2.5 g m^{-2} (ash free dry weight) and about 8 g m^{-2} (wet weight), respectively. The latter figure (which is probably a liberal estimate) would consist primarily (about 85%) of mid- and late instar chironomid larvae.

On a system-wide basis, the standing crop of algae in spring is dominated by pennote diatoms. Mainstem benthic communities in spring appeared fairly similar in terms of species composition and standing crop. A "typical" value for benthic algal biomass would be about 0.1 g m^{-2} (AFDW) and for the benthic fauna, on the order of 2 g m^{-2} (wet wt).

Using these approximate figures then, a crude estimate of pre-breakup middle river lower trophic level production can be made by assuming (a) that the maximum amount of peripheral groundwater-fed habitat available in spring is approximated by the surface area of "side slough habitat" quantified for middle river aerial photographs taken at a mainstem flow (at Gold Creek) of 5,100 cfs (EWT&A 1985), and (b) that the maximum amount of mainstem water supporting benthic production between freezeup and breakup is roughly equal to the "side channel" surface area delineated in the same aerial photos. Thus, peripheral habitat covers about 121 acres or 48.97 ha and supports roughly 1,200 kg (ash free weight) of benthic algae and 4,000 kg (wet weight) of benthic aquatic insects of which 3,400 kg is chironomid larvae, the "preferred" food of rearing salmonids in the Susitna (ADF&G 1985).

Under the above assumptions, middle river mainstem habitat would cover about 700 acres (283 ha) and support an algal standing crop of roughly 280 kg ash free dry weight and a benthic macroinvertebrate biomass of 5,700 kg wet weight. The average ratio of substrate surface area to water surface area measured at 7 sites was about 1.5. Adjusting the above estimates by this factor yields a total spring middle river algal standing crop of 2,220 kg (AFDW) and a total macroinvertebrate standing crop of 14,550 kg (wet weight). These crude estimates, of course, do not take into account production rate (i.e., productivity), but at least for the aquatic insects at this time of year, this may not be important since most, if not all, species probably produce only a single generation each year.

SUMMER (JUNE-AUGUST)

Summer in the middle Susitna River is characterized by high, erratic flows that transport millions of tons of suspended sediment (Knott and Lipscomb 1983) and usually race through all peripheral channels at least once during the season. Although summer flows may serve to "flush out" the system and import macronutrients (especially phosphorus) from the terrestial environment (e.g., on the surface of silt particles) and, of course, generally assist fish in migrating into, within, or out of the system; the suspended sediment load they transport degrades substrate quality in peripheral channels, causes scour, and most of all generates higher turbidity levels. These characteristics render the entire length of the middle river a poor place in which to grow benthic organisms.

All chl a samples collected after May have yet to be analyzed, but little growth was apparent except along the margins. How much of this growth was diatomaceous and how much bacterial is not yet known, but the resulting matrix served to trap small sediment particles forming a slippery coating on cobble-sized substrate material along the banks. Mainstem habitat macroinvertebrate densities were extremely low and consisted mainly of very small, white, early instar individuals. Most samples yielded no insects at all as late as mid-September (table 3).

Conditions in peripheral habitats varied considerably depending for the most part on the frequency and duration of overtopping. Slough 8A was sampled August 15 under non-breached conditions. Its lower portion (where most salmon spawning takes place) overtopped several times prior to sampling: from May 25 through May 31, again from June 3-7, June 13-17, June 26 - July 9, and finally July 21-24. Compared to most side sloughs, Slough 8A breaches at a fairly high mainstem discharge. Despite all this flooding with mainstem water, substrate quality appeared about the same as before breakup. For the most part, chironomid larvae still dominated the benthic fauna, especially in the slackwater reaches, and total macroinvertebrate standing crop estimates ranged from 0.03 to 2.11 g-WW m^{-2}. The average total density and biomass for the site was 2,851 ± 2,068 (83 ± 19% chironomid) and 0.67 ± 0.69 g-WW m^{-2} (71 ± 32%) chironomid), respectively.

Primary productivity was monitored from August 17 to August 25, 1985, and averaged 1.3 ± 0.2 g^{-O_2} m^{-2} d^{-1} at mean water temperature of 7.0 ± 0.4 C

FALL (SEPTEMBER-OCTOBER)

Mainstem discharge generally declined after mid-August (with the exception of one storm in mid-September) and turbidity levels dropped from about 75-100 NTU in early September to less than 5 NTU by mid-October. This fall was cooler (on average ______ C) and cloudier than the previous fall and the contrast in system-wide benthic algal production between the two years was blatant. While the fall bloom of 1984 was characterized by dense mats of Zygnema and Spirogyra waving filaments typically five or more feet long, algal growth this fall, although clearly much greater than summer levels, was much less dense in most channels and not quite as widely distributed. These statements are made on the basis of low altitude helicopter overflights of the entire length of the middle river made on October 2, 1984 and October 16, 1985 during which the distribution of algal mats was delineated on aerial photos.

With the passage of time and the general improvement of environmental conditions, macroinvertebrate densities and biomass levels had increased at mainstem sampling sites from near zero in mid-September to several thousands of individuals and as much as 3.5 g per square meter by mid-October (table 3). With the cessation of overtopping in Slough 8A (except for one event on September 16), noticeably more benthic production was able to take place there than in typical mainstem margin habitat. As in the mainstem channels, benthic algae production in Slough 8A (and in most side sloughs generally) appeared much less extensive than during the fall of 1984. Nevertheless, macroinvertebrate production on average increased from a summer value of 2,851 ± 2,068 m^{-2} and 0.67 ± 0.69 g m^{-2} to 13,964 ± 9,818 m^{-2} and 10.6 ± 10.1 g m^{-2} by mid-September (table 3). Not all of the samples collected in October have been analyzed yet, but those that have been examined indicate a similar order of magnitude. Although with such small sample sizes (n=5) and inadequate time and money to perform size-frequency or cohort analyses, formal secondary productivity estimates are impossible, it seems clear that within one month, a roughly one order of magnitude increase in insect biomass occurred. To what extent this increase should be attributed to actual growth versus migration up from the hyporheic zone is unknown at this time. Both processes are undoubtedly involved.

KASILOF RIVER

SPRING (MARCH-MAY)

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 65-70

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^{-1} respectively. The photoperiod was about 13.5 hours long and the maximum daily total PAR measured was 24.69 E m^{-2} d^{-1} or 1291 kcal m^{-2} d^{-1}.

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 4). The average for all three sample areas was 18.6 ± 21.4 mg chl a m^{-2}. 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 less than 0.7 g-O_2 m^{-2} d^{-1}.

Benthic macroinvertebrate densities were also relatively low (x = 4,000 ± 3,900), dominated (88 ± 13%), as in the Susitna River, by chironomid larvae. Biomass was generally less than 0.2 g m^{-2}; the large sample area means are due to the presence of large trichopteran nymphs. The overall site mean was 1.6 ± 3.0 g m^{-2} of which 50 ± 43% consisted of small chironomid larvae (table 5). Species composition was basically similar to communities in the Susitna River with the exception of the presence of Hydrocarina and a filter-feeding genus of chirononid. 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 melted and large mats of green filamentous algae (Zygnema) had become established. This growth extended out from the banks beyond safe wading distance and presumably covered most of the river's benthic

Table 4. Mean (±S.D.) chlorophyll a density, estimated biomass, vitality[1], and selected environmental parameters for epilithic algae sample areas (n = 15), Kasilof River, April-July[2], 1985.

DATE	SAMPLE AREA	WATER TEMP (C)	TURBIDITY (NTU)	MEAN(±S.D.) DEPTH (ft)	MEAN(±S.D.) VELOCITY (ft)	CHL a. DENSITY (mg m^{-2})	ALGAL BIOMASS (g-AFW m^{-2})	VITALITY
04/16/85	I[3]	0.8	70	0.52 ± 0.24	0.56 ± 0.21	6.8 ± 6.4	0.46 ± 0.43	1.43 ± 0.25
	II	0.8	70	0.90 ± 0.29	0.41 ± 0.09	6.2 ± 7.6	0.42 ± 0.51	1.24 ± 0.51
	III	0.8	70	0.62 ± 0.23	0.45 ± 0.35	46.3 ± 10.0	3.10 ± 0.67	1.64 ± 0.09
05/22/85	IVa	9.6	59	0.46 ± 0.20	0.10 ± 0.08	61.9 ± 22.3	4.15 ± 1.49	1.55 ± 0.07
	IVb	9.6	59	1.50 ± 0.45	0.61 ± 0.29	35.9 ± 13.2	2.41 ± 0.88	1.52 ± 0.08
07/25/85	V	11.0	58	1.73 ± 0.33	1.54 ± 0.52	68.7 ± 28.9	4.60 ± 1.94	1.69 ± 0.02
	VI	11.0	58	1.71 ± 0.31	1.58 ± 0.74	79.5 ± 30.4	5.33 ± 2.04	1.69 ± 0.01

1. Before-to-after acidification absorption peak ratio (1.0 = all phaeophytin, 1.7 = all chl a).
2. Samples collected in September and October have yet to be analyzed.
3. Roman numerals denote specific transects; all sample areas are mainstem margin.

Table 5. Mean (±S.D.) macroinvertebrate density and biomass (indicating percent chironomid) and selected environmental parameters for sample areas in the Kasilof River (near Sterling Highway bridge) April-October, 1985) (n=5).

DATE	SAMPLE AREA	WATER TEMP (C)	TURBIDITY (NTU)	MEAN(±S.D.)[1] DEPTH (ft)	MEAN(±S.D.)[1] VELOCITY (ft s^{-1})	MACROINVERT DENSITY (No. m^{-2})	MACROINVERT BIOMASS (g-WW m^{-2})
04/16/85	I[3]	0.8	70	0.52 ± 0.24	0.56 ± 0.21	2,948 ± 2,930 (80 ± 19%)[2]	0.047 ± 0.051 (69 ± 40%)[2]
	II	0.8	70	0.90 ± 0.29	0.41 ± 0.09	1,423 ± 711 (87 ± 9%)	1.13 ± 1.75 (28 ± 41%)
	III	0.8	70	0.62 ± 0.23	0.45 ± 0.35	7,686 ± 4,185 (97 ± 4%)	3.64 ± 4.52 (51 ± 47%)
05/22/85	IVa	9.6	59	0.46 ± 0.20	0.10 ±0.08	34,685 ± 20,986 (97 ± 3%)	19.15 ± 10.71 (89 ± 9%)
	IVb	9.6	59	1.50 ± 0.45	0.61 ± 0.29	15,442 ± 2,866 (98 ± 1%)	10.33 ± 3.90 (83 ± 18%)
07/25/85	V	11.0	58	1.67 ± 0.42	1.61 ± 0.59	5,144 ± 3,081 (87 ± 6%)	1.93 ± 1.89 (46 ± 21%)
	VI	11.0	58	1.68 ± 0.22	1.98 ± 0.29	5,330 ± c,478 (86 ± 6%)	1.21 ± 0.86 (63 ± 22%)

1. Mean of depths and mean velocities where samples (n=5) were randomly selected, not of the channel in which the sample area was located.
2. Percent of total comprised of chironomid larvae or pupae (species undetermined).
3. Roman numerals denote specific transects; all sample areas are mainstem margin.

Table 5 Cont'd. Mean (±S.D.) macroinvertebrate density and biomass (indicating percent chironomid) and selected environmental parameters for sample areas in the Kasilof River (near Sterling Highway bridge) April-October, 1985 (n=5).

DATE	SAMPLE SITE AND AREA	WATER TEMP (C)	TURBIDITY (NTU)	MEAN(±S.D.)[1] DEPTH (ft)	MEAN(±S.D.)[1] VELOCITY (ft s^{-1})	MACROINVERT DENSITY (No. m^{-2})	MACROINVERT BIOMASS (g-WW m^{-2})
09/05/85	V	10.1	51	1.51 ± 0.50	1.38 ± 0.22	585 ± 378 (62 ± 26%)[2]	0.38 ± 0.40 (43 ± 40%)[2]
	VI	10.1	51	1.58 ± 0.38	1.16 ± 1.08	397 ± 243 (71 ± 25%)	1.09 ± 1.84 (35 ± 40%)
10/02/85	VII	7.0	53	1.70 ± 0.28	1.90 ± 0.46	5,011 ± 1,608 (77 ± 20%)	0.20 ± 0.16 (22 ± 12%)
	V	7.0	53	1.44 ± 0.59	0.96 ± 0.44	5,057 ± 3,241 (73 ± 10%)	0.18 ± 0.11 (24 ± 16%)
10/23/85	V	3.0	55	1.55	0.28	3,194 (85%)	0.17 (33%)
	II	3.5	55	0.20	0.15	7,231 (88%)	3.46 (95%)

1. Mean of depths and mean velocities where samples (n=5) were randomly selected, not of the channel in which the sample area was located.
2. Percent of total comprised of chironomid larvae or pupae (species undetermined).
3. Only two samples analyzed to date.

surface area for at least 13 miles downstream from the lake outlet. Flow had had increased slightly to about 550 cfs, while turbidity remained a constant 59 NTU. The compensation depth was about 2.6 ft, while the mean depth of the channel was less than 2 ft. Turbidity in the mainstem Susitna River at this time (May 17) was 5.8 NTU.

Chlorophyll a densities had increased substantially and represented a mixture of new and old growth (table 4). Values ranged from 13 to 90 mg m^{-2} with an overall mean of 48.9 ± 22.1 mg m^{-2}. This increase in benthic algae biomass corresponded to an even more substantial increase in productivity which between May 21 and June 10 averaged 2.2 ± 0.5 g-O_2 m^{-2} d^{-1}.

Accompanying this substantial increase in primary production was a similar order of magnitude increase in aquatic insect density and biomass (table 5). Densities ranged from 12,000 to over 66,000 m^{-2}, while estimated biomass ranged from 6.7 to 35.6 g m^{-2} wet weight. Species diversity seemed to increase and the average size of chironomid larvae had roughly doubled in just over one month. The overall mean insect density was 25,063 ± 17,385 m^{-2} (98 ± 2% chironomid) and mean biomass was 14.7 ± 8.9 g m^{-2} (86 ± 14% chironomid). Some of the chironomids were very near emergence and most insects appeared to be in late instar phases.

SUMMER (JUNE-SEPTEMBER)

By late May, discharge began increasing rapidly and by mid-June the mean depth of the channel exceeded the compensation depth. This mean depth appeared to fluctuate relatively little throughout the summer and was sufficiently high up along the banks to flood riparian grasses in some areas. Benthic samples under these flow conditions could only be collected near the shoreline since the depth increased rapidly within a few feet of both wetted edges. Apparently this channel geometry is fairly uniform along the entire 19-mile length of the river except at its mouth, near its origin at Tustamena Lake ("Slackwater"), and within two large riffle areas five miles ("Moosehead Rapids") and seven miles ("Silver Salmon Rapids") upstream from the Sterling Highway Bridge at RM 7.5.

Nearshore benthic samples collected at depths ranging from 1.0 to 2.2 ft contained relatively high chl a levels despite the prevailing turbidity of 58 NTU (table 4). Values ranged from 20 - 141 mg m^{-2} (or 1.3 - 9.4 g-AFDW m^{-2}) and seemed to consist primarily of pennate diatoms (taxonomic analyses are pending). Benthic invertebrate densities had fallen off steeply, however. Informal reports of caddisfly and other aquatic insect hatches in both the Kasilof and Kenai Rivers are substantiated by the much reduced overall site mean of 5,237 ± 3,099 insects m^2 (87 ± 5% chironomids) and the much lower mean biomass of 1.6 ± 1.4 g m^{-2} (55 ± 22% chironomid). This decline in insect biomass continued through early September until early October (table 5). By this time, macroinvertebrate densities had increased to an average of about 5,000 ± 2,400 (75% ± 15% chironomid), while biomass averaged less 0.2 g m^{-2} (23 ± 13% chironomid). Almost all the insects were small, early instar individuals.

Another important event was the decline of gross productivity to levels below detection (<0.4 g-O_2 m^{-2} d^{-1}). Presumably, this happened because most of the streambed was now beyond the reach of the incident PAR.

FALL (OCTOBER-NOVEMBER)

When last sampled (10/23/85), the Kasilof River water level was still high and "steaming" because its temperature was 13.5 C warmer than the surrounding air. No ice had yet formed, turbidity was a consistent 55 NTU, and both the benthic flora and fauna seemed little changed from their appearance during our previous visit (table 5).

Inquiries made of personnel at the ADF&G Crooked Creek hatchery by phone indicate that ice was beginning to jam up at the Sterling Highway bridge site by mid-December.

DISCUSSION

The general pattern of "fish food" production in the middle Susitna and Kasilof Rivers appears to conform to the pattern observed in most temperate streams, i.e., minimal biomass in summer, followed by growth and mortality in winter, and a biomass peak in spring just prior to adult emergence (see p. 298, Hynes 1970).

The main "fuel" for this secondary production in the middle Susitna is probably derived from autochthonous sources, although this assumption might well merit a field study of its own. We have seen that the bulk of this instream primary production is generated during the fall, but may vary considerably from year-to-year depending on the duration of stable, relatively low, non-turbid autumn mainstem flows and, of course, on the amount of available sunshine. At any rate the pulse of algal production which occurred during the fall of 1984 (and probably amounted to several hundred tons or more) was no doubt to a large (but unknown) extent the main food source for the roughly 15 tons of "fish food" calculated to be present in the middle reach during the pre-breakup period of 1985.

To place these numbers in perhaps a more pragmatic context, assume 1) that the average annual middle river production of chum salmon outmigrants is about 3.0×10^6 (WCC 1985); 2) that 57% (or 2.6×10^6) of these fry emerged from side slough or mainstem natal areas; 3) that about 85% of these fry spend at least two weeks rearing near their natal areas before outmigrating; 4) that the mean increase in length for chum fry rearing in mainstem-affected habitats for 11-15 days is 12 mm (ADF&G 1985); and 5) that the length-weight regression derived for sockeye fry (ADF&G 1985) may also be used for chum fry; then the average amount of chum fry flesh produced by the mainstem/side slough habitats of the middle river is: $(2.6 \times 10^6) \times (0.85) \times (0.70\ g - 0.28\ g)$ or approximately 975 kg.

Using a weight-fed-to-weight-gained ratio of 4.9:1 for salmonids which is fairly typical for "natural foods" (Bell 1973), 975 kg of side slough-born chum fry growth would require nearly 4,800 kg of "natural food" (i.e., in our case chironomids). The estimated total maximum standing crop of chironomids in side slough habitats of the middle river prior to breakup was only 3,400 kg and for all open water in the system only 12,400 kg.

These calculations are crude approximations at best, but serve to illustrate first of all that the fish production of the middle Susitna River is very likely food-limited and secondly, that what relatively little fish production that is able to take place in habitats associated with the mainstem must (very likely) depend on the benthic production of the mainstem itself for "fuel" and not just that of the side sloughs. With these observations in mind, let us consider the potential middle river primary and secondary production under the long-term water quality and flow conditions created by impoundment.

Perhaps the most obvious impact will be a change in the timing of maximal primary production. The combination of low flows, relatively low turbidities, and warmer-than-natural water temperatures (figure 1) should provide conditions in the middle river resembling in may ways those observed in the Kasilof River during May. It is not known whether the Kasilof River produces a "fall" bloom, but, given the high projected turbidities, it is very unlikely that the with-project middle Susitna River ever will. What this could mean in terms of middle river "fish food" production is difficult to predict (especially with only one field season of data to go on). It is unlikely that aquatic insects will change their basic life cycles to accommodate a man-made water quality regime, so insect biomass will probably still peak in spring. What could happen at the community level is change in "life-style", e.g., a shift in community composition from grazer/collector-gatherers to a preponderance of filter-feeding forms, probably mostly chironomids. Whether such a community could effectively harvest and convert into "fish food" the relatively meager amount of organic carbon expected to be released from the upstream reservoirs (Harza-Ebasco 1985) is unknown, but these and other questions relating to project effects on trophic status surely merit further monitoring.

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