GEORGIA INSTITUTE OF TECHNOLOGY OFFICE OF CONTRACT ADMINISTRATION

PROJECT ADMINISTRATION DATA SHEET

[x] ORIGINAL
[ ] REVISION NO. ______

Project No. G-32-667 DATE: 6/12/81

Project Director: Dr. Arthur C. Benke School/~~Lab~~ Biology

Sponsor: National Science Foundation; Washington, D.C. 20550

Type Agreement: Grant No. DEB-8104427 dated 5/15/81

Award Period: From 7/1/81 To ~~12/31/82*~~ ~~12/31/82~~ 12/31/84 (Performance) -- (Reports)

Sponsor Amount: $216,051 Contracted through:

Cost Sharing: $12,000 (G-32-334) GTRI/~~GIT~~

Title: The Biological Basis of Production in Subtropical Blackwater Rivers

ADMINISTRATIVE DATA OCA CONTACT Faith G. Costello x4820

1) Sponsor Technical Contact: James T. Callahan, NSF Program Officer; Ecosystems Studies Program; Division of Environmental Biology (DEB); Directorate for Biological, Behavorial, Social Studies; NSF; Washington, D.C. 20550; (202) 357-9656

2) Sponsor Admin./Contractual Contact: James R. Bottum, Jr; NSF Grants Official; Section XI, BBS/SE Branch; Division of Grants & Contracts; Directorate for Administration; National Science Foundation; Washington, DC 20550 (202) 357-9843

Reports: See Deliverable Schedule Security Classification: None

Defense Priority Rating: None

RESTRICTIONS

See Attached NSF Supplemental Information Sheet for Additional Requirement

Travel: Foreign travel must have prior approval - Contact OCA in each case. Domestic travel requires sponsor approval where total will exceed greater of $500 or 125% of approved proposal budget category.

Equipment: Title vests with GIT

COMMENTS: *Includes the usual six (6) month unfunded flexibility period.

JUN 1981
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GEORGIA INSTITUTE OF TECHNOLOGY OFFICE OF CONTRACT ADMINISTRATION

SPONSORED PROJECT TERMINATION/CLOSEOUT SHEET

Date 4/22/85

Project No. G-32-667

School/~~Lab~~ Biology

Includes Subproject No.(s) N/A

Project Director(s) Dr. Arthur C. Benke GTRC / ~~GIT~~

Sponsor National Science Foundation

Title The Biological Basis of Production in Subtropical Blackwater Rivers

Effective Completion Date: 12/31/84 (Performance) 3/31/85 (Reports)

Grant/Contract Closeout Actions Remaining:

- [ ] None
- [ ] Final Invoice or Final Fiscal Report
- [ ] Closing Documents
- [x] Final Report of Inventions For our records
- [ ] Govt. Property Inventory & Related Certificate
- [ ] Classified Material Certificate
- [ ] Other

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10 March 1982

Dr. James T. Callahan, Associate Program Director
Ecosystem Studies Program
Division of Environmental Biology
Directorate for Biological, Behavioral, and Social Sciences
National Science Foundation
Washington, DC 20550

Subject: Research Proposal for Continuation of NSF Grant No. DEB-8104427

Gentlemen:

In accordance with NSF requirements, we are pleased to submit herewith the subject continuation proposal. This is a request for the second year of support under NSF Grant No. DEB-8104427.

No more than $6,000 will remain from the 1981-82 budget year. We anticipate that these residual funds will be spent during the Summer Quarter, 1982.

If anything additional is needed, please do not hesitate to contact either Dr. Arthur C. Benke at 404/894-3700 or the undersigned at 404/894-4814.

Sincerely,

Duane Hutchison
GEORGIA TECH RESEARCH INSTITUTE

DH/pb

Addressee: In duplicate
Enclosures: Proposal - in duplicate
Budget - in triplicate

Annual Progress Report

to

National Science Foundation

The Biological Basis of Production in Subtropical Blackwater Rivers

(NSF Grant No. DEB-8104427)

Principal Investigator: Arthur C. Benke

Co-Investigators

E. Lloyd Dunn	July L. Meyer	J. Bruce Wallace
	(Univ. of Georgia)	(Univ. of Georgia)

Georgia Tech Research Institute

Georgia Institute of Technology

Contents

1. Annual Progress Report

2. Budget for FY82

3. Current and Pending Support for Investigators

4. Residual Funds (see cover letter by Duane Hutchison)

Introduction

Our progress on research of subtropical blackwater rivers has coincided fairly closely with our anticipated "schedule of progress" (p. 26 of proposal). We had about a 1-mo delay in starting to set up our on-site field laboratory on the Ogeechee River due to problems in reaching an agreement with the previously contacted property owner. After an intensive search for a new field lab, we located an even better site, about 8 km downstream of our original location. We now lease a cottage adjacent to the Ogeechee River, accessible by a private road or from the river. We also have virtually exclusive use of a boat ramp and lighted outdoor work areas. Georgia Tech provides matching funds for lease of the laboratory.

The only significant alteration in our work plan was a change of location from the Canoochee River to Black Creek as our "blackwater" field site. The reasons for this change are discussed in detail in a letter (8 Oct. 1981), and primarily involve: (1) the discovery of extensive human influences on the Canoochee of which we were previously unaware, and (2) the suitability of Black Creek as a comparable substitute, and its improved logistics(see Fig. 1). All of our Ogeechee sampling is done within 0.5 km of our field site; the Black Creek sampling involves about a 2-km boat trip.

Analyses are proceeding at the habitat level with primary production, secondary production and microbial production being considered in sand, mud, and snag habitats, and in the water column of both streams. Analyses of carbon flows are proceeding simultaneously at the ecosystem level, including estimates of total community production and respiration,

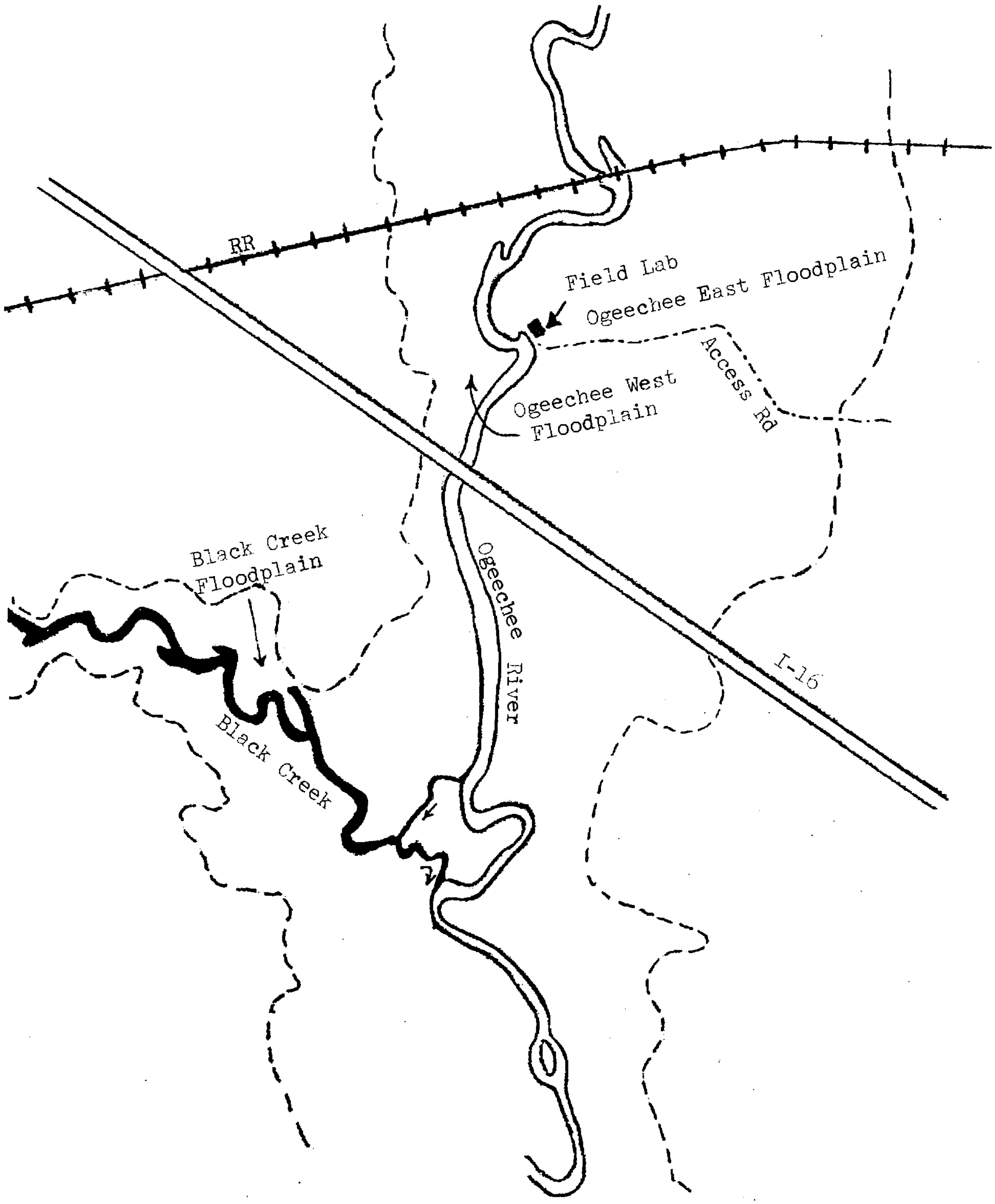

Fig. 1. Location of field laboratory and floodplain study sites on the Ogeechee River and Black Creek.

seston flows, DOC flows, litter fall and decomposition, and hydrodynamic behavior.

Aquatic Primary Production and Respiration

We have assembled an automatic sampling and data recording module, which interfaces with a Tektronix computer for use in determining ecosystem production and respiration from diurnal O_2 curves. This system was first operational during low flow conditions in December on the Ogeechee. These data can be compared with a diurnal O_2 curve from low flow conditions in July. During July, P/R was >1, whereas P/R was <1 in December. Clearly, the autotrophic component in the riverine ecosystem is reduced in importance during the winter. During year 2, we plan flood-related and seasonal determinations of ecosystem production and respiration in both rivers.

Habitat-specific measurements of primary productivity are proceeding more or less on schedule. A summary of the seasonal changes in water column photosynthesis and associated environmental parameters is shown in Table 1. In Black Creek, the pH and inorganic carbon is lower and light extinction, higher, resulting in much lower rates of photosynthesis than in the Ogeechee. Using a channel profile determined at low water in late fall, daily rates of photosynthesis per m^2 of river surface were estimated to range from 2 to 68 and from 1 to 5 mg C $m^{-2}d^{-1}$ for Ogeechee River and Black Creek respectively.

It is evident from preliminary snag samples at high water this winter that the vertical stems of almost all shrubs and trees that are flooded have photosynthetically active periphyton. An extensive sample

Table 1. Water column photosynthesis and associated environmental parameters.

	Temp	pH	Inorg. Carbon	Light Extinct.	Mean Photosyn.	Daily Photosyn.
	^{o}C		mg C/l	k/m	mg C $m^{-3}h^{-1}$	mg C $m^{-2}d^{-1}$
Ogeechee River						
Aug 1981	26	7.3	8.4	1.93	5.0	40
Oct 1981	21	7.7	12.3	--	9.7	68
Nov 1981	11	7.5	7.4	1.47	0.4	2
Feb 1982	11	6.8	3.6	1.52	1.6	11
Black Creek						
Sept 1981	22	4.6	3.5	--	--	--
Oct 1981	25	6.8	4.0	--	0.2	1
Nov 1981	11	6.6	3.3	3.04	0.2	1
Feb 1982	11	4.6	3.0	4.37	0.8	5

Table 2. Preliminary information on microbial production and standing stock from all benthic habitats in the Ogeechee River (OR) and Black Creek (BC).

	OR Sand	OR Backwater	OR Snag	BC Sand	BC Backwater	BC Snag
Production						
mg C m^{-2} hr^{-1}	5.6 [1]	2.4 [2]	0.097 [2,3]	5.3 [1]	5.6 [2]	0.077 [2,3]
Biomass [1]						
gC m^{-2}	0.02	0.07	0.004	0.016	0.05	0.001
no. cm^{-2} [4]	$1.8x10^{8}$	$7.0x10^{8}$	$3.8x10^{7}$	$1.6x10^{8}$	$5.2x10^{8}$	$1.0x10^{7}$

[1] November 1981; water temperature = 17 C; production in top 1 cm only.

[2] December 1981; water temperature = 10 C; production in top 1 cm only.

[3] Assumes no dilution of ^{3}H-Tdr; therefore these figures probably underestimate production.

[4] Acridine-orange direct counts of top 1 cm sediment for sand and mud.

of area and standing biomass of this periphyton will be necessary at low water as well as detailed photosynthesis measurements as a function of tissue water content in order to evaluate the contribution of this component adequately.

We have developed techniques to measure benthic photosynthesis during low water, but we have been unable to test these further due to high water this winter. We also have initiated algal biomass assessments from chlorophyll measurements. Chlorophyll concentration has been below detection limits.

Microbial Production

After considerable work on methods development, the use of the ^{3}H-thymidine (^{3}H-Tdr) technique to measure microbial production is approaching the point where it can be routinely applied to both benthic habitats and snags. Preliminary data on microbial production and standing stock are presented in Table 2. These results agree well with the only other reported rates of benthic microbial production (Moriarty and Pollard 1981).

We are currently optimizing our recovery of ^{3}H-DNA from sediments, using exogenous ^{3}H-DNA to check various steps in the procedure. We plan to routinely check DNA recovery efficiency because separation of DNA from sediments is not straight-forward (Lorenz et al. 1981). We are also using an isotope dilution technique (Moriarty and Pollard 1981) to ascertain the degree of dilution of added ^{3}H-Tdr by exogenous Tdr in the sediment and Tdr synthesized by the cells. There are large pools of Tdr in these habitats, which must be accounted for when calculating production from the apparent rate of ^{3}H-Tdr incorporation.

The preliminary data (Table 2) indicate comparable bacterial standing crops in both rivers, with highest numbers in the backwater habitat and lowest on the snags. Microbial production in sand and backwater habitats is the same in Black Creek, whereas in the Ogeechee the sand habitat is more productive. The low standing stock and production on snags lends support to the idea that insect production in this habitat is dependent on suspended material. By year 2, the few remaining methodological difficulties will be eliminated and we plan routine monitoring of bacterial production in all habitats and in the different seston size fractions.

Dissolved Organic Carbon

The more pertinent DOC data are summarized in Table 3. There is a clear increase in DOC concentration as the Ogeechee River enters the Coastal Plain. During these summertime low flow conditions, the diel and horizontal variation in DOC concentration at the main sampling site was <0.75 mg C/l and showed no consistent pattern. Hence the river appears well mixed, and the time of day at which samples are taken is not critical. During winter low flow conditions, most of the DOC was in the high molecular weight fractions in the Ogeechee, whereas most of Black Creek DOC was in the low molecular weight fraction. As the rivers rose during the first flood after a prolonged drought, all sites showed a doubling in DOC concentrations. In addition, there was a marked increase in the low molecular weight size fraction such that it became the dominant fraction in the Ogeechee. The relative importance of low molecular weight DOC also increased in Black Creek, but to a much lesser

Table 3. DOC concentrations in the Ogeechee River and Black Creek.

Date	Condition	Station	mg C / l	% of DOC in < 10,000 MW fraction
July 1981	Low flow	Ogeechee River on the Piedmont	7.57	---
July 1981	Low flow	Ogeechee River on the Coastal Plain	10.28	---
Nov. 1981	Low flow	Ogeechee River	8.13	14
		Black Creek	8.70	48
Dec. 1981	Low flow	Ogeechee River	9.69	27
		Black Creek	14.75	76
		Black Creek backwater	20.75	56
Jan. 1982	River rising	Ogeechee River	13.00	88
		Black Creek	31.45	65
Jan. 1982	River rising	Ogeechee River	17.38	78
		Ogeechee backwater	15.00	84
		Black Creek	30.58	65
		Black Creek backwater	34.52	63
Jan. 1982	River over bank	Ogeechee River	18.53	75
		Black Creek backwater	37.05	66
Jan. 1982	River receding, but on flood-plain	Ogeechee River	13.72	69
		Ogeechee floodplain	13.34	76
		Black Creek	25.18	80

degree. These differences suggest that under low-flow conditions, much of the Black Creek DOC is originating from within the floodplain, while much of the Ogeechee River DOC is more refractory DOC from upstream sources. During year 2 we will continue to measure DOC concentrations and molecular weight composition at Ogeechee River and Black Creek mainstream and backwater sites to determine seasonal and flood-related patterns.

Litter Fall and Litter Decomposition

Litter studies are being conducted in 3 distinct floodplain habitats (Fig. 1): a permanent lentic habitat on the Ogeechee East floodplain, a temporary lentic habitat on the Black Creek floodplain, and the Ogeechee West floodplain which alternates between a lentic and lotic system as discharge changes. Twenty high and 20 low litterfall samplers were installed at each site. In addition, initial standing crop of litter and twig fall are being estimated from 10 (4 m^2) plots at each site. These latter plots indicate that the lowest floodplain (Ogeechee West), most subject to flooding, had lower standing crops of litter. We will expand this phase of the work during the coming year. Likewise, initial soil cores from each site suggest less organic matter in storage on the low floodplain site.

Twelve hundred leaf bags have been installed (9 Dec 1981) at 13 sites (high, low and wet in each floodplain, and two stream sites in each stream) to study litter decomposition. We are using replicate (5) samples of two leaf species (Sweetgum and Water Oak) for these studies. To date, litter bags have been collected three times. All invertebrates have been removed from the latter and this phase of the project is progressing on schedule. Preliminary data suggests that few macroinvertebrates inhabitat the Ogeechee East sites and decomposition is slow. Litter decomposition is faster on Ogeechee West and Black Creek and is dominated by Isopods. Extensive investigation of physical and chemical changes in these habitats through an annual discharge cycle is planned with parallel investigation of changes in associated fauna.

Litterbags with macrophytes *Hydrolea quadrivalvis* Walt. and *Alternanthera philoxeroides* (MART.) Griseh. (alligator weed) were placed in our Ogeechee backwater site on 9 Nov 1981. To date, three collections have been made - 11 Dec 1981, 5 Jan 1982, and 7 Feb 1982, and initial results are very different than expected. Studies in more temperate climates indicate rapid macrophyte decomposition with autumn senescence. However, at least for the two species in this study, those placed in the Ogeechee are not decomposing rapidly. In fact, they appear viable and dormant.

Stream Seston

Stream seston sampling was initiated in December 1981 on both streams. Initially we attempted 8 seston size classes (Table 4). The 4 μm screen had to be replaced with a 12 μm size due to difficulty in cleaning. We also encountered sampling problems with the coarse size fractions due to high variability, but this has been solved by sampling larger volumes of water with Miller nets.

Results indicate that in both the Ogeechee (OR) and Black Creek (BC), organic seston is heavily skewed toward the smaller size classes

Table 4. Seston concentration (Ash Free Dry Wt, AFDW) and its % distribution across size classes on various dates in the Ogeechee River (OR), and Ogeechee River floodplain channel (OFP) 470 m from the river, and Black Creek (BC). Bacterial counts in seston size fractions and presented for 11-12 Jan 1982, the first flood of the year (in Box). All units under sieve sizes are %'s except for cells per mg AFDW, which are densities.

Date	Site	Total	Sieve Size (μm)(% of total) 5000	864	234	106	50	25	12	.45
			COARSE	LARGE	MED LARGE	MED	FINE	VERY FINE	V.V. FINE	ULTRA FINE
16 Dec 81										
AFDW (mg/1)	OR	.72	0.0	9.0	6.6	10.2	10.0	7.1	*	57.1
	BC	.96	18.0	2.6	1.5	1.8	1.9	2.8	*	71.3
17 Dec 81										
AFDW (mg/1)	OR	.49	0.0	1.2	3.2	3.6	6.3	4.8	*	80.8
11-12 Jan 82										
AFDW (mg/1)	OR	1.68	-	0.7	0.5	6.0	8.3	6.0	6.0	72.6
	BC	.98	-	2.0	1.0	13.2	12.2	14.2	16.3	43.7
Bacterial Cells($x10^9$)/1	OR	1.87	-	.02	.02	.20	.30	.20	.30	98.9
	BC	1.49	-	0.0	0.0	.10	.10	.10	.10	99.6
Cells ($x10^7$) per mg AFDW	OR		-	2.6	5.7	3.7	3.8	4.5	5.4	152**
	BC		-	1.7	2.3	0.9	1.0	0.7	0.8	344**
22-23 Jan 82										
AFDW(mg/1)	OR	.53	1.1	0.4	0.9	4.9	4.9	4.9	4.8	79.0
	OFP	.65	0.5	0.2	0.1	5.2	5.1	5.0	4.6	79.4
	BC	.55	11.2	0.8	0.5	5.1	3.4	5.0	4.1	69.9

* The 4 μm sieve size used for very very fine (VVF) size class in December proved unsatisfactory and VVF is combined with ultra fine. A 12 μm sieve was used for VVF thereafter.

** Note that these are actual numbers, not %'s. Also, the smallest size fraction includes all cells in water passing a 12 μm sieve. Consequently, this fraction includes cells associated with 12 μm and smaller particles, as well as free bacteria.

(Table 4), typical of a wide variety of streams. On 16 Dec 1981, and later during high water on 22-23 Jan 1982, coarse material made a large contribution to the seston in Black Creek, but was low or unmeasurable in the Ogeechee River. The difference in concentration and particle size distributions between 16 and 17 Dec 1981 in the Ogeechee suggests that changes in seston concentration may occur rapidly, depending on the hydrograph, which was rapidly rising. On 22 Jan 1982, during flood stage, the organic seston concentration was only slightly higher in a floodplain channel (OFP) 470 m from the river, than found in the Ogeechee, with little difference in particle size distribution (Table 4). This similarity emphasizes the mixing and interchange of the river with its floodplain during flood stage.

The distribution of bacterial cells among the seston size classes was calculated for the first flood of the year in early January, 1982 (Table 4). The rivers were sampled about two days before peak discharge. Seston concentrations were higher than those measured in preceeding low-water conditions and in later high-water samples, indicating that stored particulate matter was flushed during the rising limb of the first flood. Total seston concentrations and cell counts were slightly higher in the Ogeechee. In both rivers, the majority of bacterial cells were in the particle fraction passing through a 12 μm sieve. The number of cells per mg AFDW in each fraction indicates little difference in bacterial colonization among particle sizes, except for the smallest size. This fraction includes particles and associated bacteria as well as free bacteria. Even though most of the total AFDW is in this size range, the concentration of cells per mg of seston is also much higher than the other fractions. Future sampling will attempt to more finely resolve the less than 12 μm fraction and determine the relative concentration of unattached bacteria.

Invertebrate Studies

Based upon preliminary sampling, we have decided to use a 2-level sampling strategy for bottom habitats. A ponar grab is used for molluscs (especially *Corbicula fluminea*, the Asiatic clam) and any other large animals, which are separated into size classes by a sieve series down to 2 mm. For small molluscs, arthropod and oligochaetes, we decided a core sampler (20 cm^2) was preferable, but the commercially built corers on hand (e.g., K-B corer) proved unsuitable. Therefore, a pole-corer was designed by D. M. Gillespie which has worked extremely well for macroinvertebrate sampling (down to a 5 m water depth) as well as proven useful for microbial analyses (see above). We have used a stratified sampling design which involves 12 core samples and 6 ponar samples from each of 3 transects on the Ogeechee and 12 core samples from each of 3 transects on Black Creek. Molluscs have not been found in Black Creek.

Table 5 shows the results of preliminary core samples in the Ogeechee taken to assess depth distribution of animals. Most of the major taxa (as well as animal biomass) are concentrated in the upper 8 cm. Pole-corer sampling usually includes the upper 12-16 cm. Densities are comparable to those found in the Satilla River (Benke et al. 1979), and the fauna is dominated by dipterans, oligochaetes, molluscs, beetle larvae, and mayflies. Ponar samples for *Corbicula* can be processed and enumerated much faster than core samples, and the densities and size distributions are presented in Table 6. Large *Corbicula* pre-

Table 5. Depth distribution based upon 5 core samples from the Ogeechee River in October 1981. Units are N/m^2.

Taxa	Depth (cm) 0-8	8-12	12-16
Chironomidae	26,462	230	538
Ceratopogonidae	998	384	0
Trichoptera	230	0	0
Ephemeroptera	4,000	0	0
Coleoptera	2,382	0	0
Oligochaeta	6,538	1,308	2,078
Mollusca	998	384	0
Total	41,608	2,306	1,616

Table 6. Size distributions and densities of <u>Corbicula fluminea</u> in three benthic habitats of the Ogeechee. Samples taken with Ponar grab. n = 6 for each mean density (N/m^2).

Habitat-Date	Sieve Size (mm) 2.0	2.8	4.0	5.6	8.0	12.5	16.0	>19.0	Total
Riffle									
Dec 1981	458.7	437.2	207.8	121.8	7.2		7.2		1239.9
Jan 1982	7.2	21.5	0	7.2					43.1
Deep Run									
Dec 1981	266.6	524.6	172.0	77.4	25.8	17.2			1083.6
Jan 1982	64.5	107.5	14.3	14.3	7.2	7.2			215.0
Backwater									
Dec 1981	7.2	21.5	7.2	21.5	57.3	93.2	21.5		229.4
Jan 1982			28.7	35.8	28.7	100.3	57.3		250.8

dominate in the backwater (mud) and numbers seem stable under different flow regimes; whereas, the two main channel (sand) habitats (riffle and deep run) are dominated by small size classes which were greatly reduced (mortality or redistribution?) from 17 Dec to 23 Jan, when discharge increased from about 14 m^3/s to about 150 m^3/s.

Snag samples (20/stream/date) are being collected and processed as described in the proposal. Densities for some preliminary samples are presented in Table 7. The diversity of taxa is higher on snags than in bottom habitats, as expected, and densities on Ogeechee snags are comparable to those previously found in the Satilla and Savannah Rivers. Snag densities based upon preliminary samples are notably lower in Black Creek, but the lack of certain taxa is an artifact due to small sample size.

Animals collected from preliminary sampling of benthic and snag habitats during the summer and fall have been identified to at least the genus level, and often the species level. Thus, we now have a reasonably good reference collection to begin detailed counting and identification of quantitative samples. Our quantitative sampling of habitats began in mid-December, somewhat sooner than promised in our original Schedule of Progress. Species-specific and size-specific dry wt determinations are underway, and they will ultimately enable us to translate our numbers data into standing stock and production. Separate invertebrate samples are being taken monthly for stomach analyses and eventual determination of the biological basis of animal productions, but results are not yet available.

Preliminary drift samples were taken with paired Miller nets in December 1981 (Table 7). Densities seemed particularly high, and the abundance of stoneflies was surprising. A full set of paired samples

Table 7. Snag densities and drift densities (Ogeechee only). Snags from late summer. Drift from December.

Taxa	Snag Densities ($\bar{N}/m^2$)		Drift Densities ($\bar{N}/10m^3$)
	Ogeechee	Black	Ogeechee
Diptera			
Simuliidae	1048	17	7
Chironomidae	6654	1369	72
Ephemeroptera	2011	17	63
Trichoptera	5905	584	9
Coleoptera (elmids)			
Adults	751	0	
Larvae	2641	185	4
Plecoptera	370	0	31
Odonata	25	0	0
Megaloptera	113	50	0
Microcrustaceans	-	-	191
Misc.	-	-	6
Total	19518	2222	383

(each for 2 hr periods every 2 hr) over a 24-hr period was taken in the Ogeechee in mid-January 1982, and processing is underway. We retain all coarse particulate matter from these faunal samples to increase our data base for seston analysis.

We have made considerable progress in developing simulated lotic systems at the on-site laboratory for invertebrate growth studies. A new design in laboratory streams by Peter W. Larson was on display at the 1981 meeting of the North America Benthological Society, and we have constructed 12 such systems. They consist of plexiglass inserts which fit into a 20 gal aquarium, and are air-powered. We have constructed an ambient temperature bath (with water continuously pumped from the river) so that the experiments can be conducted outdoors. The streams are powered by a portable Conde air pump, and the entire system has now been field-tested on the river bank at our field laboratory. We anticipate growth studies beginning in the spring, on schedule. Other growth chambers are currently being designed for specific situations.

Synthesis

A variety of ecosystem-level parameters are currently or will soon be measured in order that we may translate habitat-specific productivity measures and trophic relationships into ecosystem level flows. We have begun to assemble an environmental monitoring station at the field site on the Ogeechee River. When complete early this Spring, the following data will be recorded on a daily basis: total photosynthetically active radiation (PAR), total solar radiation, mean river temperature, maximum, minimum and mean air and dew point temperatures,PAR at 30 cm depth, mean river height, wind speed and direction. These sensors will be recorded on a portable data acquisition system (Campbell Sci., Model CR21) and will provide background environmental information for several of the studies in the project. Discharge is monitored continuously by the U.S.G.S., and we receive provisional data from them periodically. River stage height information (as well as a 5-day forecast) is obtained from the National Weather Service weekly, in order to respond to flood events.

A major task remaining for the second year is habitat quantification at various water levels. This will involve: a series of depth profiles across the streams for use in benthic habitat and water column analyses (first profile with current velocities done Nov 1981); snag quantification along river banks, possibly using aerial photography; and quantification of live-tree stems in the swamp (high water "snags"). Some of these analyses are best done at low water which we anticipate during the summer/autumn 1982.

Analyses of hydrodynamic behavior have begun and will provide ecosystem information from a variety of standpoints. These include preliminary studies with aerial photography and dye releases to find the gross circulation patterns, diffusion characteristics, and transport rates between the main river channel and swamp. The first dye releases were made on 19 and 20 Feb 1982, following some overview flights earlier in the autumn and winter. It was decided that nearly continuous ground dye releases were necessary, and releases were made from three different locations on the Ogeechee River on 20 Feb, when water was at flood stage. Aerial photographs were taken using natural color and infrared film, and results will be obtained shortly. We anticipate that aerial photography will also provide information on the extent of floodplain inundation at various water levels. Also, in our particular study location on the Ogeechee East (Fig. 1), an Interstate highway, our access road, and the railroad line each tend to funnel floodplain flows through confined areas in which total flows can be approximated at high water. These, and a variety of other hydrodynamic analyses will be continuing through the spring and into the second year of study.

Annual Progress Report

to

National Science Foundation

The Biological Basis of Production in Subtropical Blackwater Rivers

(NSF Grant No. DEB-8104427)

Principal Investigator: Arthur C. Benke

Co-Investigators

E. Lloyd Dunn

Judy L. Meyer
(Univ. of Georgia)

J. Bruce Wallace
(Univ. of Georgia)

Georgia Tech Research Institute

Georgia Institute of Technology

March 1983

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	b. University of Georgia (subcontract)	28
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4.	Residual Funds (see cover letter by Linda H. Bowman)	

Introduction

We have made significant progress in our research on subtropical blackwater rivers after approximately 20 months of study. On most aspects of habitat-specific and ecosystem analyses, we have collected a full year's data for both the Ogeechee River and Black Creek. This has included habitat-specific plant, animal and microbial production; ecosystem metabolism; DOC, seston and drift dynamics; litterfall and habitat-specific decomposition rates; identification of trophic pathways; and hydrodynamic behavior. In some cases, the data have been processed and analyzed. In other cases, such as invertebrate studies which require labor-intensive sorting and identification, quantitative results are not available. In the third year of this project, we will continue our quantitative field studies. However, we now have a much better understanding of our systems, and more emphasis will be placed on experimental studies aimed at factors affecting production processes. The remainder of this report summarizes some of our more significant findings to date, and our plans for the third year of study.

Dissolved Organic Carbon

Dissolved organic carbon (DOC) concentration is consistently higher in Black Creek than in the Ogeechee River (Fig. 1). Although most of the DOC is between 1000 and 10000 molecular weights in both rivers, the high molecular weight fraction (< 10000 MW) is a greater proportion of the total DOC in Black Creek (35% vs 25% in the Ogeechee). Low molecular weight DOC (< 1000 MW) remains consistently below 5 mg/l in both rivers. Total DOC concentration fluctuates seasonally, with higher concentrations when the rivers are on their floodplains.

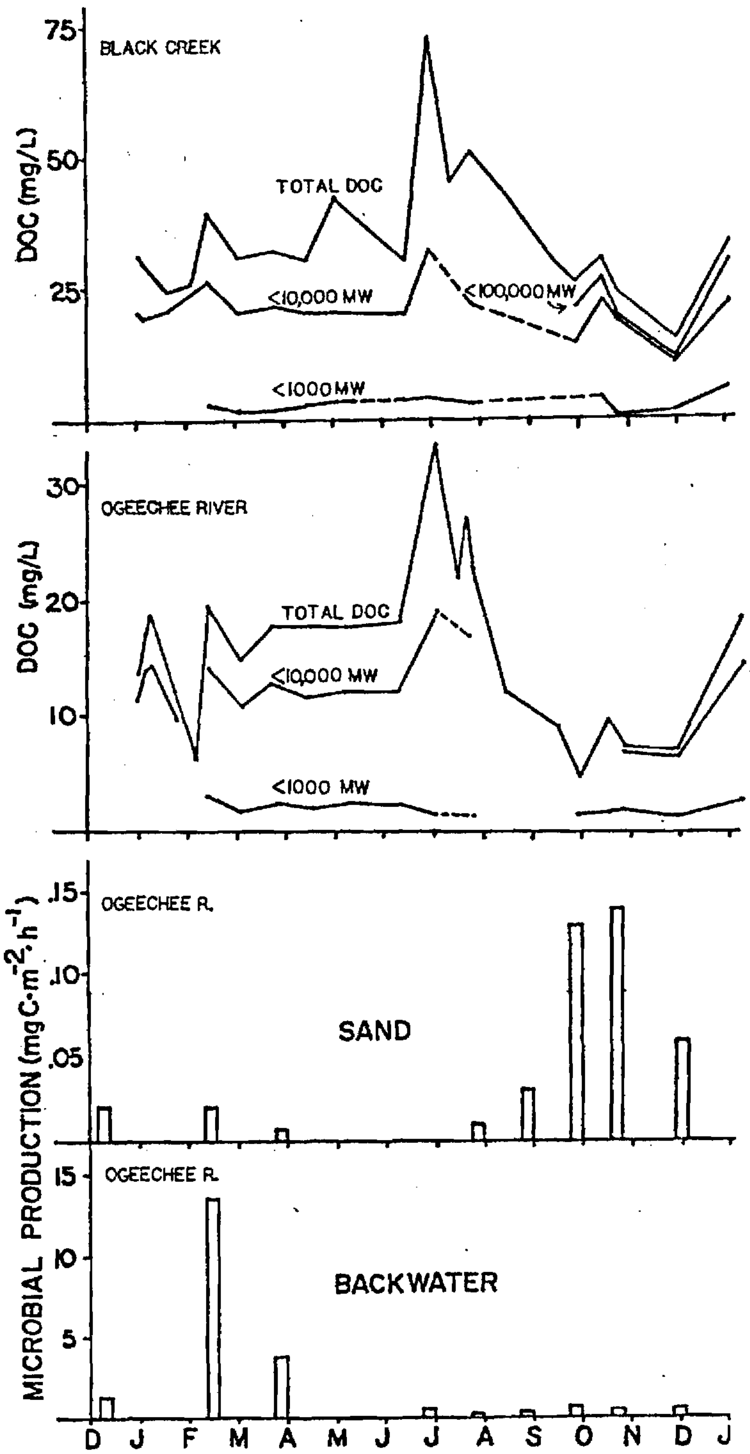

Figure 1: Seasonal variation in DOC concentration in Black Creek and the Ogeechee River, and seasonal variation in microbial production in backwater and sand habitats in the Ogeechee River.

Most of the bacteria in the seston are not attached to particles and hence must be utilizing DOC as their carbon source. However, the prevalent view of DOC in blackwater rivers is that it is refractory and not a good carbon source for bacterial growth. To resolve this conflict we did a pilot experiment on DOC availability to suspended bacteria in Black Creek. One container was enriched with DOC ($>$ 1000 MW) from Black Creek. Bacterial incorporation of ^{3}H-thymidine was greater in this container than in the unenriched control, suggesting that they were able to utilize supposedly refractory DOC. We are encouraged by these results and plan further experiments along these lines.

Benthic microbial production

From our first year's data on benthic bacterial production, it is apparent that the magnitude of production changes markedly through the year (Fig. 1). In the sandy sediments of the Ogeechee River there was a large increase in production in the fall, corresponding with an increase in the organic content of the sediment. This organic matter was carried into the river from the floodplain by floodwaters in August 1982. High water conditions prevailed throughout December and the organic content of the sediments continued to rise. Bacterial production, however, decreased over this period; this appears to be due to falling temperatures. In the backwater areas of the Ogeechee there was a large spring peak in production which also corresponded with an increase in sediment organic matter following a flood. There was only a small rise in production in fall despite a large increase in organic matter. This weak response could be due either to the temperature decline or a change in the quality of the organic matter. Production in the backwater habitats is consistently greater than in the sandy habitat, presumably because of higher organic content of backwater sediments.

The biomass data (acridine-orange direct counts) also showed seasonal changes which related to hydrologic conditions. The fall peak seen in both the sand and backwater cannot be accounted for by *in situ* production. We believe these increases are due to input of organic matter and the associated bacteria from the floodplain. Bacterial production and biomass in Black Creek is similar in magnitude and pattern. The same processes appear to be responsible for the observed pattern.

Ecosystem metabolism

A major determinant of community photosynthesis and respiration appears to be river discharge (Fig. 2). Rates of primary productivity, as measured with the diel oxygen curve method, were high during low water conditions in summer 1980 and 1981. These high rates of production continued through Dec. 1981, despite the cooler water temperatures. After the first invasion of the floodplain in January 1982, little or no primary productivity was recorded. During summer 1982, there were no long periods of low water as in previous summers and we measured little primary productivity. These seasonal trends suggest that water level is a more important determinant of primary productivity than is temperature. During low water conditions the ecosystem has a strong autotrophic component, whereas during periods of higher discharge it a strongly heterotrophic ecosystem.

Habitat-specific metabolism

Habitat-specific measurements of primary productivity have continued during the second year in order to provide a complete seasonal pattern in water column photosynthesis. It is evident that gross primary production in the water column is low in general, but it does show some variations in response to seasonal and water level changes. Monthly values of water

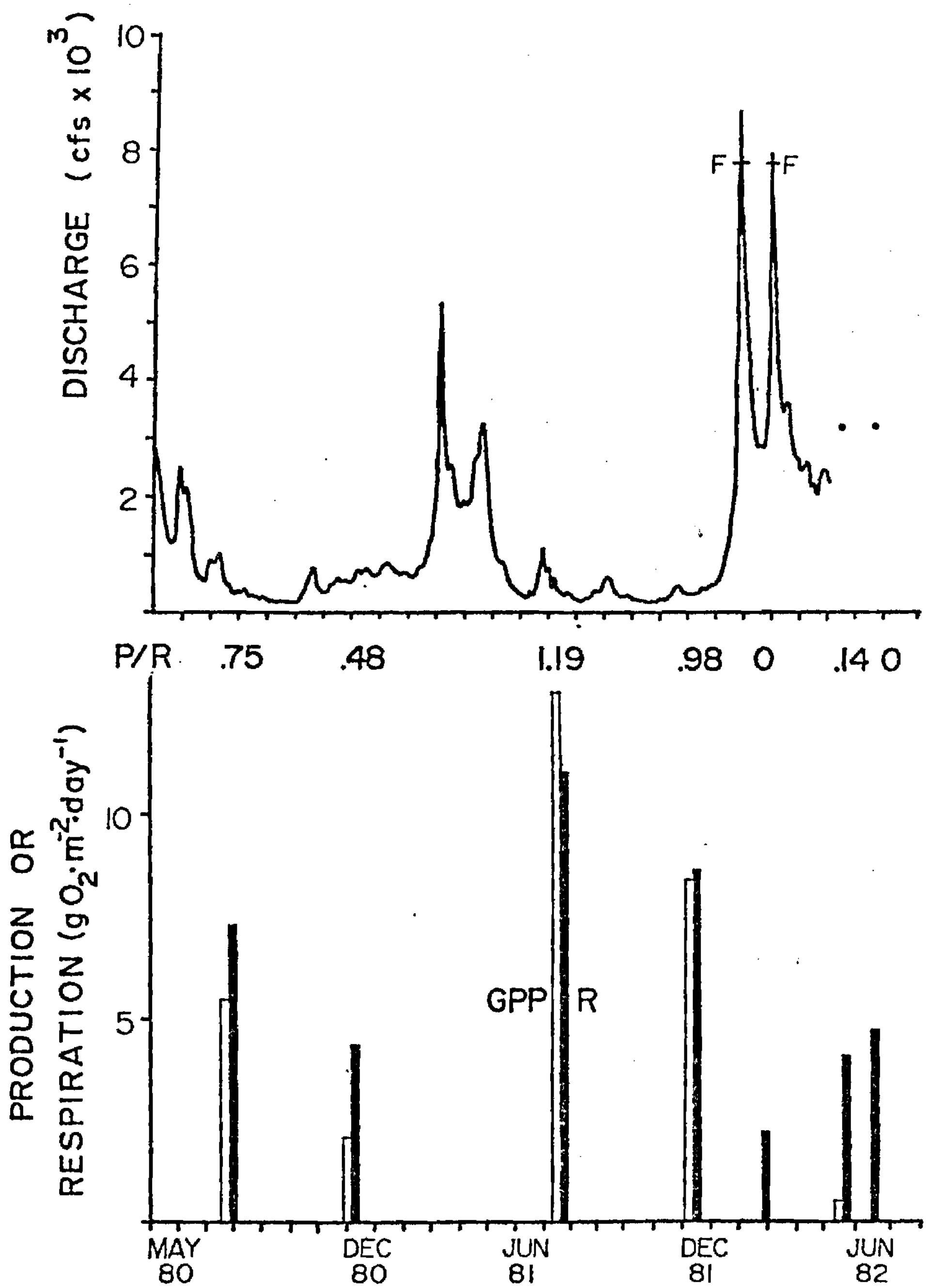

Figure 2: Seasonal variation in ecosystem metabolism in the Ogeechee River compared with river dischar ge.

column photosynthesis and associated environmental variables are given in Table 1 and Fig. 3, and are generally consistent with diel oxygen curve patterns.

Measurements of photosynthesis in benthic samples was not continued until early fall 1982 due to higher than normal summer water levels. Rates of gross photosynthesis are higher in mud than sand but are low in general (Table 1). The area of different benthic habitats needs to be measured from aerial photographs at extremely low water levels this summer and fall, and additional measurements of C-14 photosynthesis need to be done in order to calculate the significance of this source of carbon input to the river.

Efforts to evaluate the significance of photosynthesis in snag macrophytes as a carbon input to the river have continued during the second year. Measurements of photosynthesis using both C-14 and gas exchange techniques are being made under a variety of submerged and exposed conditions on two common snag species, Brachelyma subulatum and Porella pinnata. Rates of photosynthesis are about an order or magnitude higher under exposed than submerged conditions (Table 2), but photosynthetic rates in air are significantly affected by tissue water content and desiccation (Fig. 4). Photosynthetic responses to light and temperature are similar in both species.

Water-column bacteria

We have been counting the number of bacteria associated with different seston size fractions in samples collected monthly in each river. In all seasons and in both rivers $>90\%$ of the bacteria (in most cases $>98\%$) are free-living and not associated with particles. This finding has two important implications: (1) The abundant free-living bacteria appear to be able to utilize DOC as a carbon source, and (2) the greatest amount of bacterial carbon available to filter-feeding invertebrates is in the smallest size fractions.

Table 1. Monthly net photosynthesis and associated variables in the water column and benthic habitats.

Date		pH	Ci mg C/l	Tit. Alk. meq/l	Photosyn. mg C m^{-3} hr^{-1}	Daily Photosyn. mg C m^{-2} day^{-1}
OGEECHEE RIVER						
Jan.	1982	6.38	3.74	0.13	0.74	4.9
"	1983	6.25	4.81	0.17	0.76	5.1
Feb.	1982	6.81	4.81	0.26	1.61	11.8
"	1983	6.33	2.87	0.12	2.85	20.8
March	1983	6.32	2.89	0.11	4.90	37.2
May	1982	7.01	5.53	0.37	1.77	14.7
June	1982	7.14	4.92	0.34	1.13	10.0
July	1982	6.78	6.75	0.39	1.04	9.3
"	"	7.01	5.80	0.40	1.81	15.1
Aug.	1982	7.20	8.74	0.63	0.80	6.3
"	"	6.98	5.70	0.39	0.68	5.4
Sept.	1982	7.17	8.84	0.65	5.36	40.8
"	"	7.22	8.04	0.60	6.35	48.3
Oct.	1981	7.72	12.30	0.98	9.70	70.8
"	1982	7.41	8.66	0.67	6.22	45.4
"	"	7.45	7.10	0.55	2.21	16.1
Nov.	1981	7.54	7.41	0.57	0.38	2.6
"	1982	7.51	7.10	0.55	0.42	2.9
Dec.	1982	6.63	10.27	0.56	2.57	17.2
OGEECHEE SWAMP						
Feb.	1982	6.13	3.91	0.12	5.08	37.1
OGEECHEE BENTHIC						
Mud						
Oct.	1982	7.60	8.63	0.69	12.14	88.6
Nov.	1982	7.60	8.80	0.70	2.86	20.0
Sand						
Oct.	1982	7.60	8.63	0.69	2.27	16.6
Nov.	1982	7.60	8.80	0.70	6.59	46.1

Table 2. Comparison of snag macrophyte photosynthetic rates under submerged and exposed conditions measured with ^{14}C and gas exchange methods. (units are mg C g DW^{-1} hr^{-1})

	Net Photosyn.-^{14}C		Net Photosyn.-IRGA	
	Air	Submerged	Air	Submerged
Brachelyma	0.19	0.004	0.25	--
Porella	0.05	0.004	0.53	--

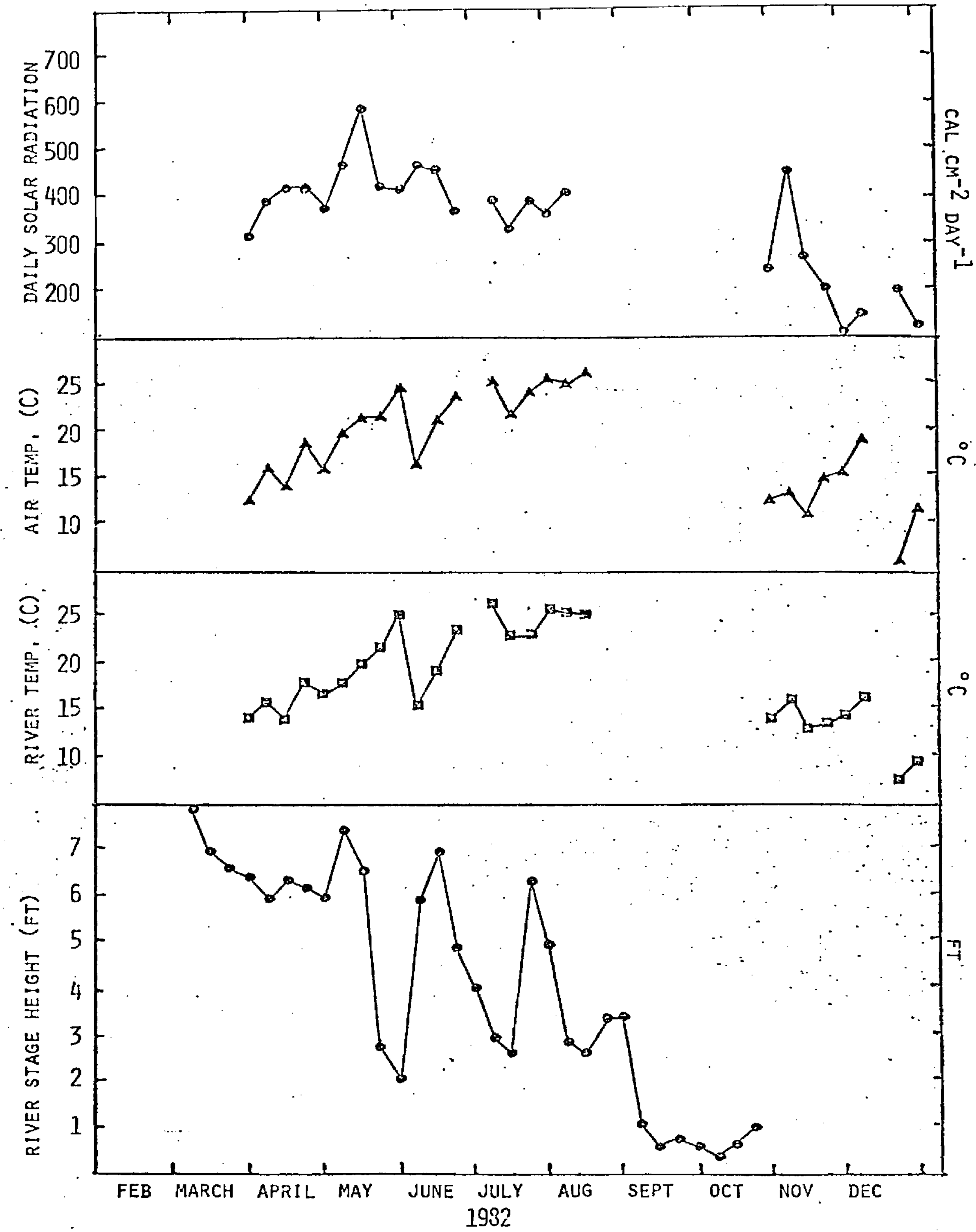

Fig. 3. Weekly mean values of river stage height (ft), river temperature (°C), air temperature (°C) and total daily solar radiation (cal cm^{-2} day^{-1}).

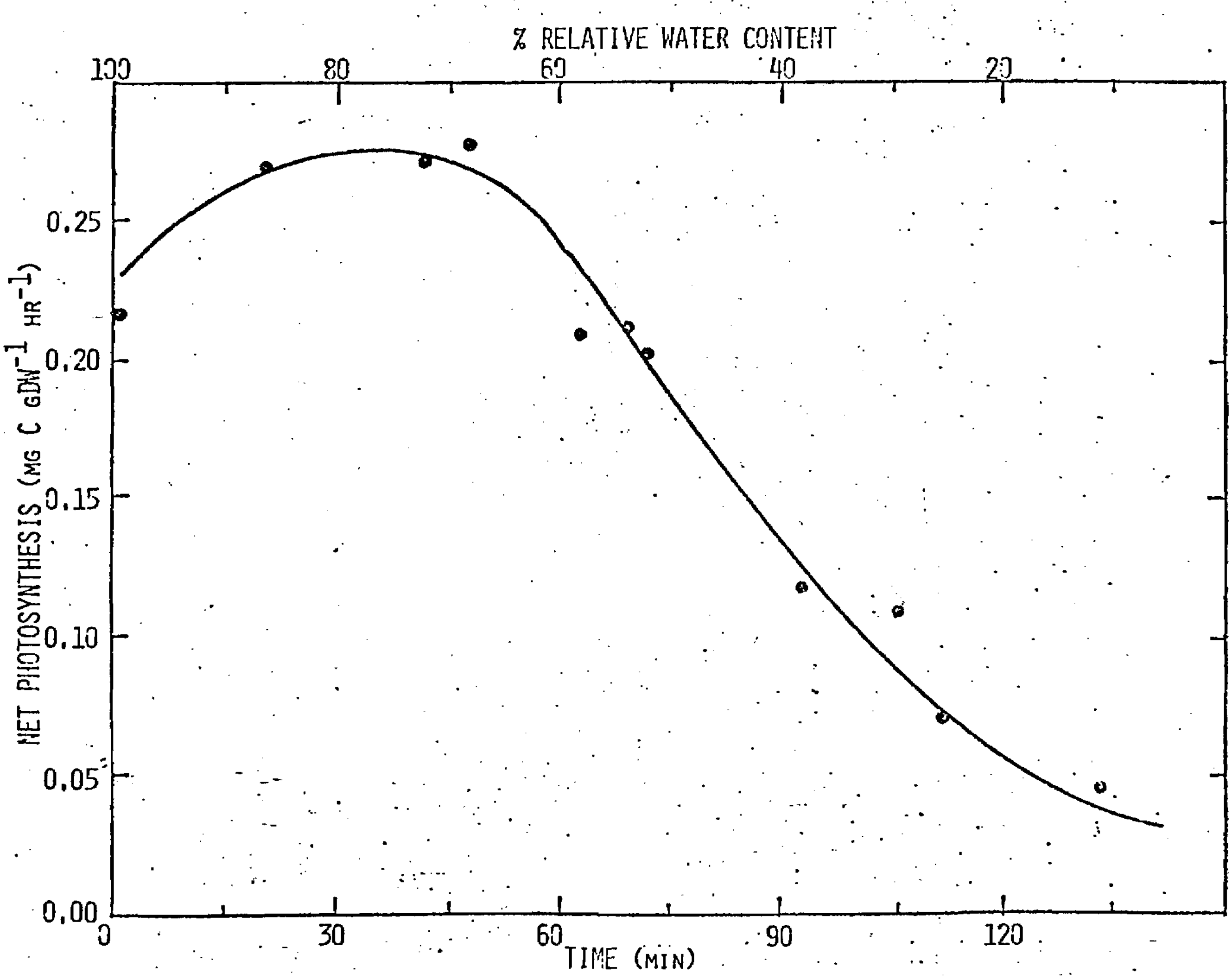

Fig. 4. Response of net photosynthesis (mg C g DW^{-1} hr^{-1}) in a snag macrophyte, Brachelyma subulatum, to dessication expressed as percent relative water content.

Total cell counts in the Ogeechee ranged from 4.4×10^9 to 1.2×10^9 cells/l. In Black Creek the counts range from 2.7×10^9 to 1.2×10^{11} cells/l. Ogeechee River counts are higher during winter and summer, but counts are higher in Black Creek in the fall. In both rivers there is little difference in number of bacteria per mg AFDW of particles ranging in size from 105 to 12 μm. Cell counts in these fractions are on the order of 10^8-10^9 cells/mg AFDW.

Production of bacterial carbon has been determined for water-column bacteria using the ^{3}H-thymidine technique. Values range from 1.32 mg C $m^{-3}hr^{-1}$ in Black Creek in July to a low of 0.028 mg C $m^{-3}hr^{-1}$ in the Ogeechee in December. Production was generally higher in Black Creek than in the Ogeechee. Production rates appear to be temperature sensitive with the highest rates observed during the summer.

Although particle-bound bacteria account for $<10\%$ of the total bacteria, the production attributable to them ranges from 24-58%. A similar phenomenon has been observed in marine ecosystems. The percent of bacterial production attributable to attached bacteria is greater in the Ogeechee than in Black Creek. This may be a consequence of the greater concentration of DOC available in Black Creek.

Bacterial production rates can be expressed per m^2 of water surface to compare the relative contribution of water comumn and sediment bacteria to total bacterial production in the ecosystem. During July, production of water-column bacteria was comparable to rates measured in backwater sediments, whereas during fall and winter, water column rates were 0.04 mg C $m^{-2}hr^{-1}$; i.e. less than the rates observed in the sandy habitat. Because of the relatively small area of the river in backwater habitats, this suggests that the water column is the dominant source of bacterial carbon during the summer, whereas the sediments are more important during fall and winter.

Stream seston

Seston concentrations (organic and inorganic) for Black Creek and the Ogeechee River for 1982 are shown in Table 3. Organic seston concentrations (AFDW) are generally higher in Black Creek than the Ogeechee. The August 11 date is most interesting since recent rains had resulted in a larger proportional increase in flow in Black Creek than the Ogeechee. The seston concentration in Black Creek was much higher on this date than any other observation to date. The percent organic matter in Black Creek is higher than the Ogeechee River on most dates. We will continue to take seston samples on each visit to the streams with the eventual goal of developing a better relationship between stream hydrograph and seston concentrations. Although there is a poor correlation between AFDW of seston in the Ogeechee and Black Creek, these results are not surprising since there is a large difference in the size of the two drainage basins and similar hydrograph responses to meteorological events would not be expected. As seen in several seston studies to date, there is a fairly high correlation between the ash and AFDW of the seston within a given stream. Although the overall seston concentration in the Ogeechee River is well within the range of that seen in most streams, the concentration is somewhat low for most large streams, for which data are available, in the eastern U.S.

As typically found in most streams the distribution of the particulate organic matter in the seston is strongly skewed toward the smaller size fractions. The less than 12 μm to 0.45 μm fraction of the particulate organic seston contains over 50 to 80+ percent of the total AFDW of the organic particles on a given date (Table 3). Based on unattached bacteria counts (see above), a sizable fraction of this material may be attributed to bacterial biomass. This material may prove to be a relatively rich food resource to a number of filter-feeding organisms adapted to fine particle feeding(e.g. Simulium, Rheotanytarsus, Chimarra, Macronema and Corbicula).

Table 3 . Concentration (mg/L) of organic (Ash Free Dry Wt) and inorganic seston (Ash) (mg/L) in the Ogeechee River and Black Ck. on various sampling dates during 1982. Note proportion of total organic seston less than 12 µm and larger than .45 µm.

ORGANIC SESTON (AFDW)

	Ogeechee Riv.				Black Ck.			
Date	n=	$\bar{X}$ conc. mg/L	(±s.e.)	.45<%<12µm	n=	$\bar{X}$ conc. mg/L	(±s.e.)	.45<%<12µm
22 Jan	8	0.5347	(0.0248)	79.0	7	0.550	(0.04)	69.9
6-7 Feb	4	0.4784	(0.0632)	57.4	4	0.94	(0.28)	67.4
3-4 Mar	6	0.6288	(0.0124)	82.7	6	0.3574	(0.0103)	80.0
16 April	4	1.2372	(0.0429)	83.1	2	1.0010	(0.2268)	82.1
15 June	5	0.9778	(0.0393)	60.8	7	1.8376	(0.1790)	83.6
13 July	8	1.2233	(0.0265)		8	2.4313	(0.0260)	
30 July	7	1.3421	(0.0460)		7	2.5383	(0.1051)	
11 Aug	6	1.7486	(0.0886)	51.2	7	4.7407	(0.3381)	52.4
2 Sept	7	1.0457	(0.0306)		7	2.9943	(0.0451)	
9 Oct	7	1.1007	(0.0416)		4	2.4416	(0.0502)	
10 Nov	6	0.3717	(0.0098)		6	0.9117	(0.0232)	
15 Dec	6	0.9550	(0.0169)		7	1.4014	(0.0126)	

INORGANIC SESTON (ASH)

Date	n=	$\bar{X}$ conc. mg/L	(±s.e.)	n=	$\bar{X}$ conc. mg/L	(±s.e.)
22 Jan	8	1.2404	(0.1440)	7	0.550	(0.040)
6-7 Feb	4	1.0948	(0.0607)	4	0.9306	(0.1618)
3-4 Mar	6	1.2908	(0.0362)	6	0.4473	(0.0385)
16 April	4	2.5334	(0.1760)	2	0.7908	(0.3410)
15 June	5	1.5991	(0.0392)	7	0.9398	(0.1059)
13 July	8	2.6213	(0.0842)	8	3.4519	(0.0461)
30 July	7	2.375	(0.0377)	7	2.6779	(0.1095)
11 Aug	6	3.5421	(0.1662)	7	8.108	(0.6605)
2 Sept	7	2.6271	(0.0949)	7	2.990	(0.1011)
9 Oct	7	1.6736	(0.0395)	6	2.5599	(0.0402)
10 Nov	6	0.905	(0.0415)	6	0.795	(0.0312)
15 Dec	7	2.205	(0.0362)	7	1.084	(0.0414)

Table 4. Predicted time (in days) for 95% loss of sweetgum and water oak leaf litter in various habitats in the Ogeechee River and Black Creek. Data based on regression equation lnY= a+bx where Y=% remaining and x=elasped time in days.

STREAM HABITATS

	Ogeechee River		Black Creek	
Species	Riffle Area	Backwater	Riffle Area	Backwater
Sweetgum	146	341	260	415
Water Oak	367	722	581	1066

FLOODPLAIN HABITATS

	Ogeechee River						Black Creek	
	Eastside			Westside				
Species	Wet	Low	High	Wet	Low	High	Low Site	High Site
Sweetgum	948	1214	862	322	804	819	581	1314
Water Oak	2163	1890	934	979	1865	1038	1216	1740

Leaf litter decomposition

Preliminary data on leaf litter decomposition rates of two leaf species at 12 sites are shown in Table 4. These data have been corrected for AFDW; however, no corrections have been made for day degrees, percent moisture, or percent time covered by water (in floodplain sites).

At each site sweetgum leaves are processed faster than water oak. However, there are differences in processing rates among the 12 sites. The processing rates for each leaf species were fastest in the riffle (fast velocity) area of each stream. The fastest rates by far were in the Ogeechee River riffle area where the model also resulted in the poorest fit to the data. This is primarily attributed to physical processing over-riding biological processing in this area.

The magnitude of the difference in breakdown rates between leaf species is smallest at the high floodplain sites. There appears to be a tendency for processing rates to differ more between species among lower floodplain sites (i.e. low or wet). Although our data are preliminary, the differences in processing rates observed between the Ogeechee and Black Creek floodplain sites may be due to higher levels of organic matter and soil moisture at the Black Creek sites as compared to the Ogeechee East or West sites. We have put in additional litter bags at each site this year and are looking at the following parameters: respiration rates, fungi, bacteria and qualitative SEM examination of leaf discs.

Aquatic Macrophytes

At least three species of aquatic macrophytes, *Alternanthera philoxeroides* (Mart.) Griseh. (alligator weed), *Hydrolea quadrivalvis* Walt., and *Nuphar luteum* (L) (water lily or cow lily), are found along the margins or backwater areas of the Ogeechee. The common view is that macrophyte production is seldom used in large quantities by grazing organisms and dies at the end of the growing season to enter detritus food chains. However, we have observed at least two species of emergent macrophytes that are heavily grazed by two species of chrysomelid beetles, Nuphar by Pyrrhalta (G) nymphaeae and alligator weed by Agasicles hydrophila, the latter an introduced species from S. America for biological control of alligator weed.

During the period of late spring to mid-autumn 1982, we sampled Nuphar leaves and the Pyrrhalta population biweekly. Up to 60% of the leaf surface is grazed by the beetles (larvae and adults), and standing stock densities of larvae in excess of $500/m^2$ of water lily surface were common. Preliminary estimates of Pyrrhalta secondary production are in excess of 25 g $AFDW/m^2$ of water lily surface area per year for this multivoltine species. Furthermore, alligator weed appears to be devastated by Agasicles during late June-August. The latter observation is most interesting since submerged litter bags filled with stems and leaves of alligator weed decomposed very little during the period of November 1981 to spring 1982. The plants actually started growing within and through the litter bags by mid-spring 1982! Feces generated by these two beetles are probably a source of rich detrital inputs to the Ogeechee and are potentially important in nutrient cycling regimes within the macrophyte beds. Additional work on this aspect is planned for the coming summer.

Aquatic Invertebrate Productivity

Thirty-six core samples for estimating production of small benthic fauna have been taken monthly in both the Ogeechee River and Black Creek. Our specially designed pole corer has worked extremely well and core depths averaged about 27 cm. Since previous animal depth analyses showed most animals are in the top 4 cm, we feel we are obtaining very good samples. Median sand grain size has ranged from 2 mm to 0.5 mm (-1 to 1.05 Phi scale). Although faunal analyses from core samples are not yet available, the situation in the Ogeechee appears very similar to that found in our Satilla River study. Orthcladiinae midges and oligochaetes predominate numerically, the former being more abundant in colder months and the latter being more abundant in the warmer months. Black Creek, with its lower discharge and slower velocity, contains more benthic organic matter and appears to have larger benthic species and a greater benthic diversity than the Ogeechee.

Molluscs appear to be absent from Black Creek, but they are quite abundant in the Ogeechee. The predominant mollusc species is the introduced Asiatic clam, Corbicula fluminea. Eighteen ponar samples have been taken montly from the Ogeechee, and because our ponar samples can be processed rapidly, we have made a preliminary estimate of Corbicula productivity. Production statistics based upon samples collected from December 1981 to December 1982 are presented in Table 5. We used the size-frequency method for this preliminary estimate and have assumed a 2 yr life span until our growth studies are completed. The Corbicula standing stock biomass of almost 2 g DW/m^2 is lower than has been reported in other rivers where Corbicula is considered a pest, but this biomass will probably be higher than we will obtain for insects and oligochaetes in this habitat. However, the smaller insects and oligochaetes will probably have a much higher biomass turnover rate (annual P/B) and thus a higher production.

We now have a complete year of snag samples from both the Ogeechee River and Black Creek. Twenty snag samples per stream were collected every four weeks during colder months and every two weeks during warmer months (total of 19 sample dates for the year). Invertebrates, attached macrophytes (see

Table 5. Production statistics for Corbicula fluminea from the benthic habitats of the Ogeechee River, 1982. Production was calculated with the size-frequency method assuming a cohort production interval of 2 yr. The size-frequency distribution was determined after weighting the muddy benthic and sandy benthic habitats according to their relative abundance.

Size Class (mm)	2.0–2.8	2.8–4.0	4.0–5.6	5.6–8.0	8.0–12.5	12.5–16.0	16.0–19.0	19.0+	SUM
Mean Individual DW Biomass (mg)	.59	1.10	2.23	4.59	10.3	29.3	53.2	80.9	
No./m^2	24.9	66.0	45.9	27.5	15.9	28.7	8.9	0.6	218.4/m^2
Standing Stock	14.7	72.3	102.6	126.2	163.2	841.4	471.1	47.7	1.8 g/m^2
						Annual Production		=	5.4g/m^2
						Annual P/B		=	2.9

Table 6 . Mean annual standing stock values for attached macrophytes, Detritus, and adventitious roots on snags. Units are mg DW/m^2 of snag surface. n = 380 for each stream.

Stream	Macrophytes	Detritus	Roots
Ogeechee River	51.5	59.2	18.5
Black Creek	14.0	34.0	6.3

Table 7. Mean Daily DW biomass of major faunal groups in Ogeechee River drift (mg DW/100 m^3) on two dates in 1982 (n = 24 for each date). Dip = Diptera, Eph = Ephemeroptera, Tri = Trichoptera, Col = Coleoptera, Cru = Crustacea, Mol = Mollusca. See also Fig. 6.

Date	Dip	Eph	Ple	Tri	Col	Cru	Mol	Total
23 Jan 1982	11.16	7.83	1.02	2.57	2.49	2.56	7.42	38.42
16 Apr 1982	0.84	63.82	32.53	4.82	12.88	0.74	3.48	120.74

above), detritus, and adventitious roots were removed from all snags, and surface area of snags was measured. We also collected an extremely large number of invertebrates for dry weight analyses, and some preliminary length-weight regressions are now available. These have been utilized in the drift analyses below. Although much processing of quantitative snag samples remains to be done, observations of our preliminary data indicates a much higher diversity and productivity on Ogeechee snags than on Black Creek snags. The much more variable discharge and current velocities seem to restrict Black Creek to fine-particle filter-feeders such as Macronema (Hydropsychidae), Rheotanytarsus (Chironomidae), and black flies. The Ogeechee, on the other hand, appears to have a much higher diversity of filter-feeding caddisflies, grazing or gathering mayflies, and stoneflies.

Macrophyte biomass, detritus, and roots from each snag were dried and weighed and amount per snag surface area determined. Mean values from all dates are presented in Table 6, and annual patterns for plant biomass are shown in Fig. 5. Standard errors are extremely high on most dates and there appears to be no obvious annual trend. The same is true for snag detritus. Attached macrophytes are significantly higher in the Ogeechee than in Black Creek. These standing stock biomass estimates for macrophytes will be combined with snag photosynthesis (above) in estimating primary production per surface area of snag. Detrital biomass is somewhat lower in Black Creek than in the Ogeechee, although we expect to find that the total amount of wood surface will be greater in Black Creek and this may result in an overall higher detritus content.

We have had mixed success with our growth studies in air-powered aquarium streams for snag species and smaller benthic chambers for midges and oligochaetes. In spite of some technical difficulties, we were able to obtain

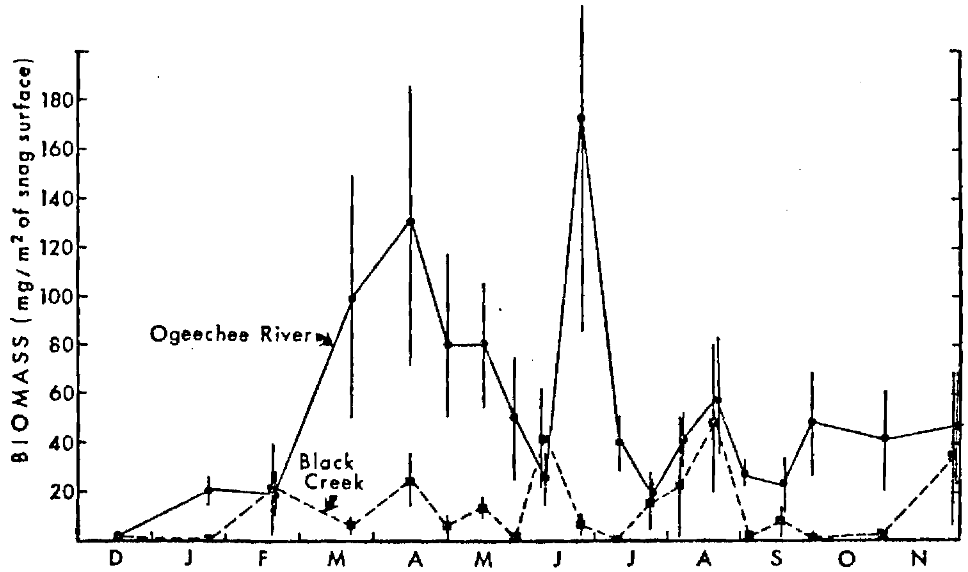

Fig.5. Mean standing stock biomass of macrophytes attached to snag surfaces in the Ogeechee River and Black Creek from Dec. 1981 to Dec. 1982.

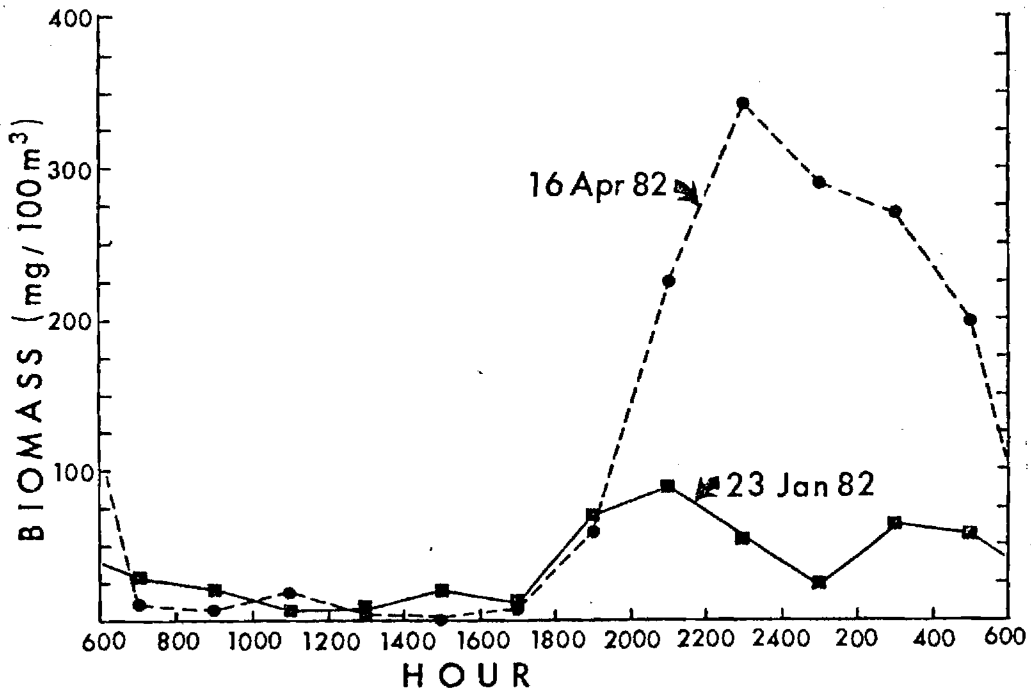

Fig.6. 24-hr pattern of drift biomass (dry wt) in the Ogeechee River in Winter and Spring 1982.

summer development times of about two weeks for Simulium taxodium (black fly), and an even shorter development time for an as yet unidentified midge species. Our on-site growth facility has been considerably expanded this winter and is now capable of handling at least 12 aquarium streams and many benthic chambers simultaneously. This spring and summer, we will continue our black fly and midge studies, and we will also concentrate on the growth of several mayfly species as well. These growth studies provide the important documentation that is necessary in determining the turnover rates (P/B) of fast growing species. We have also been attempting to measure Corbicula growth rates with animals suspended in chambers in the Ogeechee. These chambers have been suspended in the river for several months and survival has been good, but it is too early to know if we will obtain reasonable growth rates.

Drift dynamics

Post-dusk drift samples have been collected during every regular sampling period on the Ogeechee River to assess annual trends in taxonomic and habitat contributions to the drift. Full 24-hr sampling has been done seasonally on the Ogeechee, but only twice on Black Creek due to periodic reduced velocities in the latter which prevent drift from being collected. The biomass concentrations of drift on two dates in the Ogeechee show a distinct diel pattern (Fig. 6) as is common in smaller streams. Drift numbers and biomass are high in comparison to smaller streams. Figure 6 illustrates that a complete 24-hr sampling is necessary in order to assess the faunal contribution to total sestonic biomass. Drift was considerably higher in April due to the high abundance of late instars of mayflies (especially Isonychia) and stoneflies (especially Perlesta) appearing after dark. Table 7 illustrates the large contribution of these two orders to total drift biomass in April, whereas dipterans (Chironomidae) predominate in January. At least in April, the major contribution to drift biomass is comprised of animals from the snag habitat. Interestingly, benthic molluscs make a significant contribution to drift, especially in January. Faunal biomass represents about 0.3% of seston above the 240 μm size class in January and about 0.6% in April. However, during peak drift at night, the faunal contribution to seston above 240 μm reached almost 2%.

Invertebrate feeding

Some preliminary gut analyses of the dominant snag organisms from the Ogeechee River and Black Creek are shown in Table 8. Among the hydropsychid caddisflies from each stream both *Hydropsyche* and *Cheumatopsyche* from the Ogeechee have a higher proportion of animal material in their foreguts than those from Black Creek. The *Hydropsyche* spp. from the Ogeechee also appear to have a larger proportion of algal material in their gut. However, this is somewhat misleading since 98% of the algae in the guts of these animals between December 1981 and April 1982 was found in larvae from December 1981. This latter date also corresponds closely with algae in the stream seston and ecosystem metabolism measurements. These data also suggest that with the exceptions of the larger hydropsychids, the organisms are primarily detritus feeders. Analyses of guts for other organisms and seasons are in progress.

Ecosystem level synthesis

Several ecosystem level parameters have been measured in order that we may translate habitat-specific productivity and trophic level measurements into ecosystem level processes. Daily measurements of several basic environmental parameters are being recorded continuously at the Ogeechee River field site. Some of these parameters have been summarized in Fig. 3 (above).

Table 8. Gut contents for some "snag" inhabiting animals in Black Creek (BC) and the Ogeechee River (OR) between December, 1981, and April, 1982. The proportions are based on percent projected area of each food category as analyzed with a HP-9825 minicomputer interfaced with an HP-9864A digitizer.

Organism	Location	n=[1/]	Food Type as % by Projected Area				
			Animal	Amorphous Detritus	Plant Detritus	Fungi	Algae
Hydropsyche	O.R.	4,020	58.7	18.83	5.1	0.48	16.90[2/]
Hydropsyche	B.C.	537	21.5	68.46	7.4	___	2.6
Cheumatopsyche	B.C.	680	10.87	77.1	1.5		10.5
Cheumatopsyche	O.R.	614	24.7	55.2	18.36	1.3	0.4
Macronema	B.C.	1,349	10.14[3/]	88.15	___	0.1	1.6
Chimarra	B.C.	536	___	89.8	___	___	10.2
Baetis	O.R.	834	___	86.32	4.4	4.4	4.8
Ephemerella	O.R.	2,663	2.4	73.58	22.6	0.5	0.5
Ephemerella	B.C.	475	0.7	95.9	1.4	0.7	1.3
Isonychia	O.R.	138	0.3	99.7	___	___	___
Heptagenia	B.C.	738	0.1	95.13	3.3	0.2	1.3

1/ = total # particles measured

2/ = 98% of total from one date (December 1981)

3/ = 1 large piece on one date

Table 9. Quantification of snag habitat, Ogeechee River. Based upon samples taken 13 November 1982. Average water depth at time of sampling was about 1.7 m. Annual mean water depth is about 2.7 m. Macrophyte and detritus biomass per m^2 of snag surface (Table 6) are converted below to biomass per m^2 of river surface.

	Height of Transect			Amount submerged at mean depth
	Below water surface	0-1 m above water surface	1-2 m above water surface	
Wood Volume (cm^3/m^2)	6702	3078	866	9780
Snag surface Area (m^2/m^2)	.2136	.1038	.0045	.317
Plants on snags (g DW/m^2 river)		5.6		5.6
Detritus on snags (g DW/m^2 river)	12.65	6.14		18.8

Knowledge of water depth is essential for many analyses, especially those concerned with primary production. Therefore, in October 1982, depth profiles were determined for about 35 transects on the Ogeechee and 39 transects on Black Creek. The depth profiles will be useful in determining mean depth at different discharges for 24-hr diel oxygen curves. They will also provide information on the percentages of benthic substrates at various depths for assessing benthic primary production. Furthermore, depth information is useful in estimating the amount of snag material inundated at various water depths.

In order to assess the contributions of snag habitat processes to the total ecosystem, it is necessary to quantify the snag habitat. This can only be done at low water levels. Although the water did not drop as low as we would have liked, we did obtain what we feel are some good preliminary estimates of snag habitat on the Ogeechee on 13 November 1982. We plan to do considerably more quantification in both the Ogeechee and Black Creek during the next dry season. We used the line intersect method developed by foresters for estimating logging residue, and we modified the basic equations for estimating snag surface area. We made estimates along 4 separate transects on the Ogeechee River, taking measurements of stem diameters below water, 0-1 m above the water surface, and 1-2 m above the surface. Mean values for wood volume (in cm^3 of wood/m^2 of river surface) and snag surface area (in m^2 of snag surface/m^2 of river surface) are presented in Table 9. If these preliminary estimates are reasonably accurate, it indicates that the snag surface areas are considerably higher than we expected (i.e. 0.3 m^2 of snag surface per m^2 of river surface seems very high). This is about 5 times higher than our estimates for snag habitat in the Satilla River, and we considered those estimates to be quite significant.

Using our estimate for macrophyte and detrital material from Table 6, we also calculated the average amount of submerged macrophyte and detrital material per m^2 of river surface occurring at a mean depth of about 2.7 m (Table 9). Plant material does not appear to occur in the lowest 1.7 m of depth, so this was not included in the summation in the right hand column.

In the hydrodynamic analyses, we have achieved our greatest success with dye release experiments using a fluorescent dye (Rhodamine WT or Hidacid Uranine). The dye is released upstream and water samples are collected at several sites downstream for extended periods of time. It was found that velocity increases with discharge when the flow is entirely within the main channel. As the banks overflow, however, the added frictional resistance to flow caused by the wide floodplain causes the average velocity to drop sharply. The maximum average velocity of about 2.4 ft/s occurs at an Eden (U.S.G.S. station) Stage of about 7 feet when the main channel is full. At an Eden stage of 10 feet, when the floodplain is extensively inundated, the average velocity drops by half, to about 1.2 ft/s. Considerable variation in velocity was found along the river, depending on the local sinuosity, and criteria were developed for minimum sampling reach lengths to obtain representative velocities.

Dye release experiments to obtain mixing characteristics were conducted both in the main channel and in the swamp. An experiment was performed at high flood stage with release in the main channel, but with sampling in the main channel and along a transect through the swamp. This showed the dye cloud to pass almost simultaneously within the swamp and main channel, suggesting fairly rapid and efficient mixing between them. At a lower stage, however, separate releases in the swamp and main channel showed the dye clouds to remain there for a considerable distance. This is because, at the lower stages, the swamp flow consists of fairly well defined channels, the flow remaining in the swamp for several miles. These experiments will continue in order to quantify the transport rates between the swamp and main channel and to characterize the river hydrodynamics over a wide range of hydrological conditions.

Summary

Our first 20 months of study has resulted in a fairly consistent picture of the blackwater river ecosystems. While some of our results have been consistent with our original hypotheses, there have been some major surprises. Algal primary production can be fairly high at low water, but most of the time it seems very low, suggesting the importance of allochthonous energy sources in these middle-order Coastal Plain streams. Low primary production is consistent with the low amount of algae found in guts of snag invertebrates. A very abundant and diverse community of primary consumers on the snag habitat seems largely dependent upon amorphous detritus, possibly with a high bacterial contribution. However, some of the filter-feeders consume substantial amounts of drifting animals. The snag habitat on which these animals are found appears to be an even more significant habitat type than we had originally believed in these Coastal Plain streams. Furthermore, significant amounts of macrophytes are attached to snags, but they do not seem heavily grazed by invertebrates. Complicating the picture is the occurrence of macrophyte beds which are heavily grazed by herbivores, which in turn contribute an unknown amount of fecal detritus to the system.

The Asiatic clam is abundant and reasonably productive in benthic habitats of the Ogeechee, but the smaller midges and oligochaetes will probably be the most productive benthic fauna. Since microbial production in sandy substrates is rather low, the trophic basis of sand fauna (except for filter-feeding Corbicula) is still a major question. Most of the seston is in the small particle range and may consist largely of unattached bacteria which have been found in high densities. The bacteria in turn appear capable of utilizing the high amounts of DOC measured in both the Ogeechee and Black Creek. These bacteria may serve as a major food source for fine-particle filter-feeding insects on snags. Furthermore, benthic secondary production could also be supported by this seston/bacterial component in transport as it mixes with the shifting sandy substrate community.

Manuscripts and presentations supported by NSF Grant

Manuscripts

Benke, A.C., T.C. Van Arsdall, Jr., D.M. Gillespie, and F.K. Parrish. In Press. Invertebrate productivity in a subtropical blackwater river: the importance of habitat and life history. Ecological Monographs.

Benke, A. C. In Press. Secondary production of aquatic insects. In: V.H. Resh and D.M. Rosenberg (ed) Ecology of aquatic insects: a life history and habitat approach. Praeger.

Findley, S.E.G., J.L. Meyer and R.T. Edwards. Measuring bacterial production *via* rate of incorporation in ^{3}H-thymidine into DNA. Under review by Journal of Microbiological Methods.

Paper presentations

Benke, A. 1982. The invertebrate communities of snags and feeding ecology of fish in southeastern streams. Invited paper in Symposium: Streams and trees-large organic debris in streams and the effect on fish habitat. American Fisheries Society Annual Meeting, Hilton Head, SC.

Benke, A. C. 1983. Secondary production of aquatic insects. Invited paper, Plenary Session. North American Benthological Society Annual Meeting, April 1983.

Dunn, E.L., and T.J. Fitzpatrick. 1983. Photosynthesis of snag macrophytes in southeastern blackwater rivers. Abstract submitted for presentation at AIBS meeting in August 1983.

Edwards, R. T. 1983. The dynamics of seston-associated bacterial biomass in subtropical blackwater rivers. Abstract accepted for presentation at North American Benthological Society Annual Meeting, April 1983.

Findley, S., and J.L. Meyer. 1983. Bacterial biomass and production in sediments of two blackwater rivers. Accepted for presentation at North American Benthological Society Annual Meeting, April 1983.

Meyer, J.L., S. Findley, and R.T. Edwards. 1982. Organic carbon dynamics of a subtropical blackwater river, Bull. Ecol. Soc. Am. 63: 175. Paper presented at ESA-AIBS Annual Meeting at Penn State University, August 1982.

Mizner, J.H., and A.C. Benke. 1983. Estimating the cohort production interval in production studies of fast-growing insects. Abstract accepted for presentation at North American Benthological Society Annual Meeting, April 1983.

Stites, D.L., D.M. Gillespie, and A.C. Benke. 1983. An inexpensive core sampler for use in sandy substrates. Abstract accepted for presentation at North American Benthological Society Annual Meeting, April 1983.

THE UNIVERSITY OF ALABAMA
College of Arts and Sciences

Department of Biology

March 21, 1985

National Science Foundation
Division of Grants and Contracts
Post-Award Projects Branch
1800 G Street, N.W.
Washington, D.C. 20550

Dear Sir:

On behalf of Georgia Institute of Technology, I am submitting two copies of the Final Project Report (NSF Form 98A) for Grant No. DEB-8104427, "The Biological Basis of Production in Subtropical Blackwater Rivers."

I believe this satisfies all technical report requirements of NSF. Final expenditure information will be supplied by Georgia Institute of Technology.

Please note that I am now employed by The University of Alabama, and any questions regarding technical matters should be directed to me at this address, or by calling me at (205) 348-5960.

Sincerely yours,

Arthur C. Benke
Professor

ACB:jr

Enclosure

2 Copies of Final Report to:
Corinne Cown
School of Biology
Georgia Institute of Technology
Atlanta, GA 30332

319 BIOLOGY 205/348-5960 POST OFFICE BOX 1927 UNIVERSITY, ALABAMA 35486

APPENDIX VI

NATIONAL SCIENCE FOUNDATION Washington, D.C. 20550	FINAL PROJECT REPORT NSF FORM 98A	
PLEASE READ INSTRUCTIONS ON REVERSE BEFORE COMPLETING		
PART I—PROJECT IDENTIFICATION INFORMATION		
1. Institution and Address Georgia Tech Research Institute Georgia Institute of Technology Atlanta, GA 30332	2. NSF Program Ecosystems Studies 4. Award Period From 7/1/81 To 12/31/84	3. NSF Award Number DEB-8104427 5. Cumulative Award Amount $599,997
6. Project Title The Biological Basis of Production in Subtropical Blackwater Rivers		

PART II—SUMMARY OF COMPLETED PROJECT *(FOR PUBLIC USE)*

Subtropical blackwater rivers are a major type of river in the Coastal Plain of the southeastern U.S. that have been previously believed to be relatively unproductive. Our initial studies in these systems suggested that wood substrates provided a major habitat for invertebrate consumers, and that animal productivity was quite high. The principal objective of this research was to quantify the major pathways and mechanisms involved in organic matter production and processing in these blackwater river systems. Our approach involved a three-level hierarchy of understanding: (1) total river metabolism and measurement of organic matter flows between major habitats; (2) metabolism within each habitat and measurement of flows among compartments within each habitat; and (3) the measurement of flows between invertebrate functional groups within each habitat-specific invertebrate community. Our results have shown that these middle-order (4th-6th) Coastal Plain streams are strongly heterotrophic with system metabolism regulated by river discharge. Primary production and microbial production are usually quite low in all benthic habitats and in the water column. However, bacterial densities in the water column are extremely high. Submerged woody substrate is a major habitat type and invertebrate production on this substrate is higher than in benthic substrates. This high production is primarily supported by fine particulate organic matter rather than algae, as has been predicted from other stream studies. Much of this fine particulate organic matter appears to be bacteria that are flushed from the broad floodplain swamps during high discharge. Furthermore, our initial investigations on floodplain processes indicate that in general there is a substantial organic matter subsidy from the swamps to the stream. Our findings support the need for further study on the critical linkages of the river with floodplain swamps and upstream tributaries.

PART III—TECHNICAL INFORMATION *(FOR PROGRAM MANAGEMENT USES)*

1. ITEM *(Check appropriate blocks)*	NONE	ATTACHED	PREVIOUSLY FURNISHED	TO BE FURNISHED SEPARATELY TO PROGRAM: Check (√)	Approx. Date
a. Abstracts of Theses		X		X	12/31/85
b. Publication Citations			X		
c. Data on Scientific Collaborators		X			
d. Information on Inventions	X				
e. Technical Description of Project and Results			X		
f. Other *(specify)*					

2. Principal Investigator/Project Director Name *(Typed)*	3. Principal Investigator/Project Director Signature	4. Date
Arthur C. Benke		3/21/85

PART III - TECHNICAL INFORMATION (explanatory notes)

a. Abstracts of Theses - One Ph.D. dissertation has been completed to date (T. F. Cuffney, Abstract attached). We anticipate that the following students will complete their degree on or before December 1985: Jack H. Mizner (M.S.), David I. Jacobi (M.S.), D. L. Stites (Ph.D.), M. Pernik (M.S.), R. T. Edwards (Ph.D.).

b. Publication Citations - The most updated list of papers supported on this grant (DEB-8104427, through December 1984) were furnished to the Ecosystem Program in our Annual Progress Report for BSR-8406630 and BSR-8406631, submitted March 6, 1985. The latter two award numbers represent the renewal awards to DEB-8104427.

c. Data on Scientific Collaborators

1. Georgia Institute of Technology

Arthur C. Benke (Principal Investigator), Associate Professor of Biology (currently Professor of Biology, University of Alabama)

E. Lloyd Dunn (Coinvestigator), Associate Professor of Biology

Philip J. W. Roberts (Research Associate), Assistant Professor of Civil Engineering

David M. Gillespie (Research Associate) Adjunct Assistant Professor of Biology

Keith A. Parsons, Technician

Jack H. Mizner, Jr., Graduate Student

Ann Mizner, Graduate Student

David L. Stites, Graduate Student (Emory University)

Maribeth Pernik, Graduate Student

David I. Jacobi, Graduate Student

2. University of Georgia

Judy L. Meyer (Coinvestigator), Associate Professor of Zoology

J. Bruce Wallace (Coinvestigator), Professor of Entomology

Stuart Findley, Post-doctoral Fellow

Arnold H. Lingle, Jr., Technician

Rebecca Risley, Technician

Richard T. Edwards, Graduate Student

Thomas F. Cuffney, Graduate Student

Joe O'Hop, Graduate Student

d. Inventions - None

e. Technical Description of Project and Results -

This was furnished to the Program as part of our renewal proposal, "Low-gradient Coastal Plain Streams: Trophic Linkages with Floodplain Swamps and Tributaries." This renewal was awarded as a collaborative proposal to The University of Alabama (BSR-8406630) and The University of Georgia (BSR-8406631).

CHARACTERISTICS OF RIPARIAN FLOODING AND AND ITS IMPACT UPON THE PROCESSING AND EXCHANGE OF ORGANIC MATTER IN COASTAL PLAIN STREAMS OF GEORGIA

by

THOMAS F. CUFFNEY

B.Sc, SUNY College of Environmental Science and Forestry, 1974

M.Sc., Idaho State University, 1980

A Dissertation Submitted to the Graduate Faculty

of the University of Georgia in Partial Fulfillment

of the

Requirements for the Degree

DOCTOR OF PHILOSOPHY

ATHENS, GEORGIA

1984

THOMAS F. CUFFNEY
Characteristics of Riparian Flooding and Its Impact Upon the Processing and Exchange of Organic Matter in Coastal Plain Streams of Georgia.
(Under the direction of J. BRUCE WALLACE)

The influence of floods on physical and biological characteristics of two southeastern Georgia Coastal Plain streams, the Ogeechee River and Black Creek, were studied over a two year period (1982 - 1983). Organic matter processing rates, macroinvertebrate community structure and development, and organic matter exchange between rivers and floodplains were quantified and examined with respect to flood duration, intensity, and flood history. The objectives of this study were to compare streams which have extensive floodplains with those with little or no floodplains (e.g. headwater streams) and to examine how current concepts of stream ecosystem structure and function are affected by considerations of floodplain - riverine interactions.

Extent and duration of flooding differed between the two study years (WY 1982 > WY 1982). Floodplains were inundated more frequently and at lower river stages than indicated by USGS flood stage criteria. Elevation of floodplain water tables caused flooding well before natural stream bank levees were overtopped. Characteristics of floodplain flooding (i.e. depth and % inundation) were related to river stage height in a simple linear fashion.

Annual litter fall was significantly greater on the high elevation floodplain (902 g/m^2) than on lower elevation floodplains (ca. 750 g/m^2). Leaf litter processing rates were very slow in floodplain and riverine habitats (range: .0011 - .0596 %/d). Processing rates were fastest in rapidly flowing river sites and slowest in floodplain ponds with low oxygen contents. Macroinvertebrate communities associated with leaf litter bags were dominated by collector-gatherers and contained very few insect shredders (<1 per leaf bag). Processing rates and macroinvertebrate communities of these Coastal Plain habitats resemble those of a insecticide treated headwater stream.

Low-lying floodplains lost more (80 - 90%) of their annual litter inputs (ca. 620 g/m^2) through flood transport into the river than did higher elevation floodplains (ca. 20%, 180 g/m^2). The annual amount of organic matter lost from Ogeechee River floodplains exceeds total annual export losses from the river indicating that these streams are retaining organic matter. Floodplain organic matter represents a substantial organic matter subsidy to Coastal Plain streams which is not recognized by current conceptualizations of riverine structure and function.

INDEX WORDS: Floodplains, flooding, coastal plain, blackwater streams, litter fall, litter processing, organic matter budgets