A SURVEY OF BENTHIC INVERTEBRATES IN THE SUWANNEE RIVER, FLORIDA

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Abstract. Benthic invertebrate communities were surveyed in a 233 km reach of the middle and lower Suwannee River in Northwestern Florida in the winter 1987 and early summer 1988 to determine their abundance and distribution as potential foods of the Gulf sturgeon, *Acipenser oxyrhynchus desotoi*, and to determine the effects of possible natural and human-induced disturbances to the communities. In substrates of the tidal oligohaline to mesohaline lower reach of the East Pass site I (km 2) and site II West Pass (km 5) near the Gulf of Mexico, densities of tube dwelling and free swimming amphipods, polychaetes, oligochaetes, and dipterans in the PONAR grabs were moderate (100–999 $\bar{x}$ individuals/m^2) to abundant (1000–9999 $\bar{x}$ individuals m^{-2}). Also, at sites I and II, low (10–99 $\bar{x}$ individuals m^{-2}) to moderate densities of dipteran Chironomidae and olive nerite snail were collected in hardboard multiplate artificial substrate samplers. Diversities of benthic invertebrates in both grabs and hardboard multiplates were relatively low. Baetid mayflies were moderately abundant in the dip net samples. Upriver from sites I and II, the transition of an oligohaline tolerant benthic community to a freshwater one was abrupt due to strong freshwater flow. At sites III (km 48) and IV (km 89), benthic invertebrate populations were low to moderate in hardboard multiplate and dip net samples. In the middle reach (km 101 to km 233), aquatic insects were predominant and included; chironomids, mayflies, and beetles, and also, freshwater gammarid amphipods, gastropods, and the Asian clam. In winter, the bottom substrates at sites VII (km 153) and VIII (km 205) contained diverse and dense populations of Chironomidae (5932 m^{-2}), – the greatest density for a major taxonomic group recorded in this survey. Crayfish were collected in low densities only in artificial substrate samplers from sites IV to IX. Leeches were widespread in the study area. Empirical Biotic Index values that reflect impacts of organic wastes on benthic invertebrate communities were within a narrow range, 3.16 to 6.38, and indicated 'slightly enriched' to 'enriched' water. Of the total 186 benthic invertebrate taxa, 82% had quality values 0 to 5 that indicate overall 'clean water' conditions. The predominant benthic invertebrates in the Suwannee River were detritivorous and the communities reflected oligotrophic to mesotrophic waters.

1. Introduction

In 1982 the Endangered Species Program of the U. S. Fish and Wildlife Service placed the anadromous Gulf of Mexico subspecies of the Atlantic sturgeon, *Acipenser oxyrhynchus desotoi*, in Federal Category 2 status, i.e., 'taxa for which information now in possession of the Service indicates that proposing to list as endangered and threatened is possibly appropriate, but for which conclusive data on biological vulnerability and threat are not currently available to support proposed rules' (U. S. Fish and Wildlife Service, 1982). Unusually small catches of the Gulf sturgeon in the past decade prompted the State of Florida in 1984 to ban the capture and sale of the subspecies. Unusually small catches of the Gulf sturgeon in the past decade prompted the State of Florida in 1984 to ban the capture and sale of the subspecies. In 1987 the U. S. Fish and Wildlife Service initiated a comprehensive study, including food resources, on the Gulf sturgeon in coastal streams of the Eastern Gulf of Mexico region.

Benthic invertebrates were surveyed in a 233 km reach of the Suwannee River, Florida (Figure 1) in the winter 1987 and early summer 1988 to gather information on the taxonomic composition, abundance, and distribution of potential foods for the Gulf sturgeon. Also, the survey focused on potential impacts of natural and human-induced disturbances to benthic invertebrate communities. Lastly, methods for surveillance of benthic invertebrates in the Suwannee River needed to be tested and improved where necessary.

Huff (1975), who investigated the life history of Gulf sturgeon in the Suwannee River, including foods, reported that in Suwannee Sound migratory adults ate blue crab and other marine crustaceans, and worms (principally polychaetes) and that freshwater-dwelling juveniles ate crustaceans, aquatic insects, and oligochaetes. However, he did not provide quantitative estimates of the benthic invertebrate foods of Gulf sturgeon nor the benthic invertebrate standing crop and diversity in the Suwannee River. The Quebec

Fig. 1. Benthic invertebrate sampling sites, Suwannee River, Florida, 1987-1988.

Department of Fisheries (1948) investigated foods of the Atlantic sturgeon, *A. oxyrhynchus*, in the St. Lawrence River, and found sturgeon guts contained crustaceans (amphipods, decapods, and isopods), gastropods, polychaetes, and bottom substrate and plant materials.

In the past two decades, the benthic ecology of the Suwannee River was studied by state and regional agencies as part of comprehensive limnological and aquatic life surveys (Bass and Hitt 1973; Florida Department of Environmental Regulation 1985). Also, some species of benthic invertebrates have been studied independently, e.g., a survey of the Asian clam *Corbicula fluminea* (Bass and Hitt 1974). Results of these surveys were either unpublished, did not cover the geographical areas of known Gulf sturgeon activity, or did not address fish food aspects of benthic invertebrate communities.

2. Survey Area Description

2.1.1. *General Topography and Hydrology*

The Suwannee River originates in the Okefenokee Swamp area of southern Georgia and is one of the longest coastal streams in the southeastern United States. It flows a distance of about 400 km, from an elevation of 36.6 m above mean sea level, and the drainage area, 28500 km^2, is divided almost evenly between Florida and Georgia (Florida Board of Conservation 1966).

The survey area in northcentral Florida (Figure 1, Table I) is mostly rural and occupies all or part of 15 countries. The basin is divided into two major subbasins, each with distinctive geological features. The Lowlands, referred to here as 'lower reach' from km 101 to the river's mouth at the Gulf of Mexico, and the Northern Highlands is termed the 'middle reach' from km 101 to km 233.

From km 101 to the Gulf of Mexico, the river banks become progressively less steep, and by km 48, the typical coastal floodplain exists. Dense stands of hardwoods extend far into the coastal plain to within 2 km of the river's mouth. Dominant hardwoods include; baldcypress *Taxodium distichum*, Ogeechee tupelo *Nyssa ogeche*, water tupelo *N. aquatica*, southern red cedar *Juniperus silicicola*, and sweet bay *Magnolia virginiana* (Wharton *et al.*, 1982). Roots of these trees form a tangled web that extends 1 m from the bank, forming a canopy for aquatic organisms and a nearly perpendicular transition to the streambed. At site I and throughout most of the middle reach, holes and caverns 6 m deep are common.

The delta lowlands are covered with sedges, rushes, grasses, and cabbage palms. Emergent vegetation line the banks in the lower Suwannee River including: saw grass *Cladium*, cattail *Typha*, pickerel weed *Pontideria*, spatterdock *Nuphar*, rush *Juncus*, and cord grass *Spartina*. Predominant submerged aquatic vegetation is pondweed *Potamogeton*, fish grass *Cabomba caroliniana*, watermilfoil *Myriophyllum*, eelgrass *Vallisneria*, and coontail *Ceratophyllum*, and *Hydrilla* (Bass and Hitt 1973).

In the middle reach of the Suwannee River, limestone of the Miocene Hawthorn Formation is the primary bedrock and occupies about 25% of the Basin (Florida Board of Conservation, 1966). Downriver from the site IX, the banks are partly exposed Ocala

TABLE I

Benthic invertebrate survey program for the Suwannee River, Florida, 1987–1988

	Sampling device	PONAR Grab		Artificial Substrate Sampler[a]	Dip Net	
	Collection date	Nov. 1987	May 1988	May 1988	May 1988	
	Replicates/site	6	6	2	1	Total
Sites	reach km					
I	East Pass 2		×	M	×	9
II	West Pass 5	×	×	M	×	15
III	Fanning Springs 48	×	×	M	×	15
IV	Rock Bluff 89		×	M	×	9
V	Fort White-Santa Fe R. 101.018	×[b]	×	B	×	10
VI	Branford 118	×	×	B	×	15
VII	Luraville 153	×	×	B	×	15
VIII	Ellaville 205	×	×	B	×	15
IX	Suwannee Springs 233		×	B	×	9
Total samples		30	54	18	9	112

[a] M = Multiplate sampler; B = Basket sampler.
[b] Single PONAR grab at site V.

Limestone interspersed with pockets of fine 'sugar' sand. From this area to site VI (km 118) at Branford, Florida, swift currents scour the channel bedrock and prevent sand and other detritus from forming thick deposits. Deciduous hardwood forests provide organic materials to this reach.

Near site VIII (km 205), two major tributaries; the Alapaha River and Withlacoochee River, enter the Suwannee River (Figure 1). In the past, these streams, and other smaller tributaries in the area, have contributed significant amounts of sediment and wastes to the mainstem Suwannee River (Florida Department of Environmental Regulation 1985). The Santa Fe River (drainage area 4212 km^2) enters the Suwannee River at km 101, and contributes about 15% of the Suwannee River's flow volume at site III (km 48).

2.1.2. *Physicochemical Conditions*

A detailed limnological assessment of the survey area to site III (Figure 1) was conducted in 1982–1983 by the Florida Department of Environmental Regulation (1985). Selected physicochemical data covering 1982 to early 1988 are summarized below to aid in evaluation of major environmental effects on the benthic biota. Also, these data will provide benchmarks for comparison with future evaluations of the physicochemical conditions in the Suwannee River.

Physicochemical data for sampling sites III, VI, and IX in late 1982 to early 1988 provide a general picture of water quality in the freshwater reaches (Figures 2, 3 and 4).

Flows of the Suwannee River were highly variable by year and season (Figure 2). In 1984, the spring high flow increase at km 118 (site VI) was 10 fold, while in 1985, the high flow increase was three fold and did not occur until summer. In February-March, spring river stages at km 118 normally increased 6–8 m over summer low water, and summer storm episodes in southern Georgia, lasting two weeks, caused the river level at this site to rise by 4–5 m.

The flow of the Suwannee River in the middle and lower reaches is augmented throughout the year by 52 artesian springs, including 22 subsurface upwellings. Flows from individual springs are estimated to be 25 to 66 million gallons (0.095 to 0.25 million m^3) per day (Council, 1976). Ambient water temperatures of these springs are nearly constant at 20–22 °C throughout the year.

Surface water temperatures at site VI peaked at 26–27 °C during June and July 1987, and the minimum water temperature was 11 °C in most years (Figure 3). Conductivity was directly correlated with flow and highly variable (60 to 315 μmhos/cm–25 °C during 1987–1988). Calcium carbonate alkalinity at site VI fluctuated widely in 1987 and levels indicated low buffering potential of the water.

The Suwannee River is brown, dystrophic, and acidic as it enters Florida. The pH fluctuated widely at site IX during 1982–1988 and, except in 1985–1986, low pHs, of 4–5 SU existed in this reach (Figure 4). By comparison during this same period at site VI, pH levels fluctuated within two units and pH values < 6 SU were not recorded.

Nutrient levels for the Suwannee River in 1982–1988 (Figure 3) indicated that

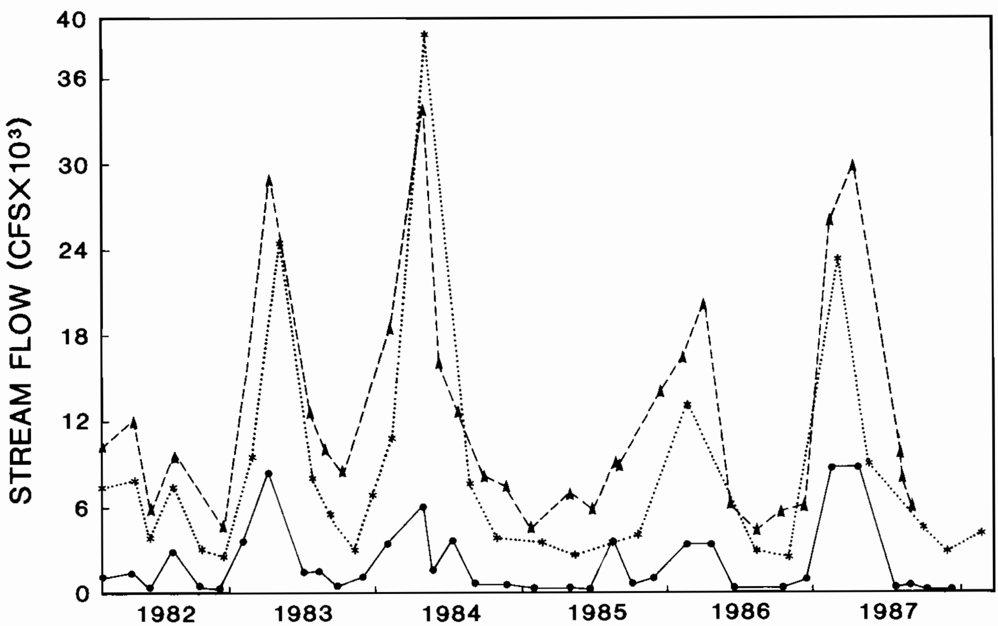


Fig. 2. Flows (cfs) 1982-1987, Suwannee River, Florida, sites III (dashed line), VI (dotted line), and IX (solid line). Data source: U.S. Geological Survey, Reston, Virginia.

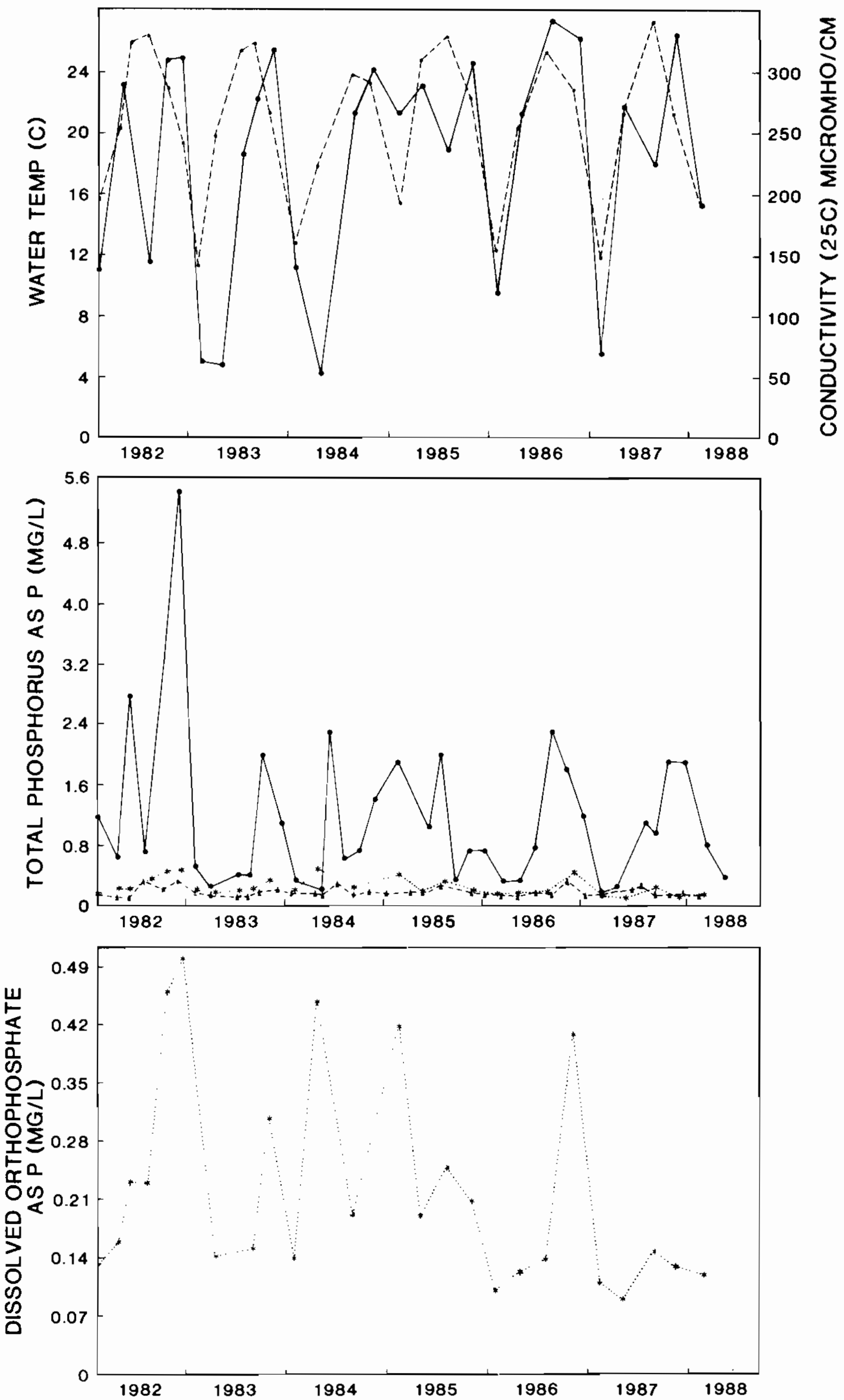
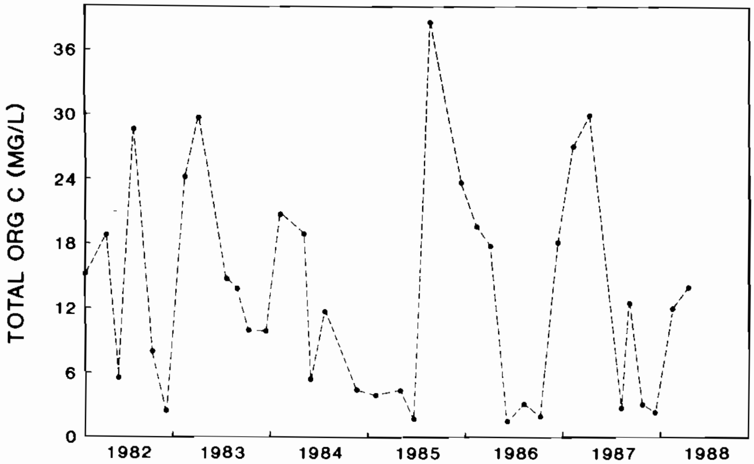
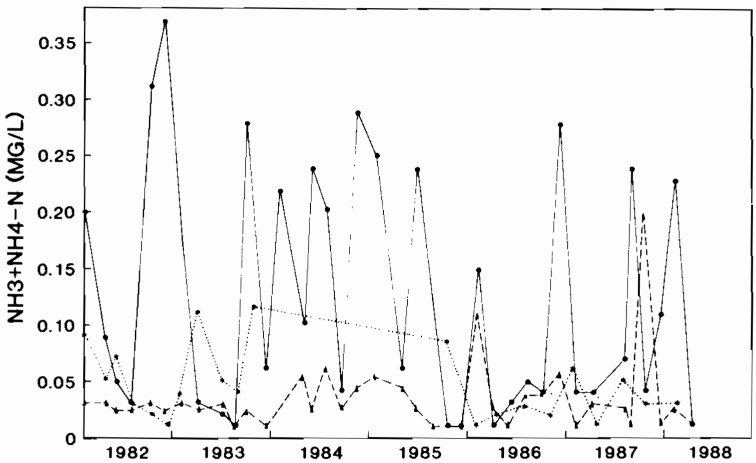


Fig. 3. Selected physicochemical data 1982-1988, Suwannee River, Florida, sites III (dashed line), VI (dotted lines), and IX (solid line). Data source: Florida Department of Environmental Regulation, Tallahassee.


TOTAL ORG C (MG/L)
0
6
12
18
24
30
36
1982
1983
1984
1985
1986
1987
1988


NH3+NH4-N (MG/L)
0
0.05
0.10
0.15
0.20
0.25
0.30
0.35
1982
1983
1984
1985
1986
1987
1988

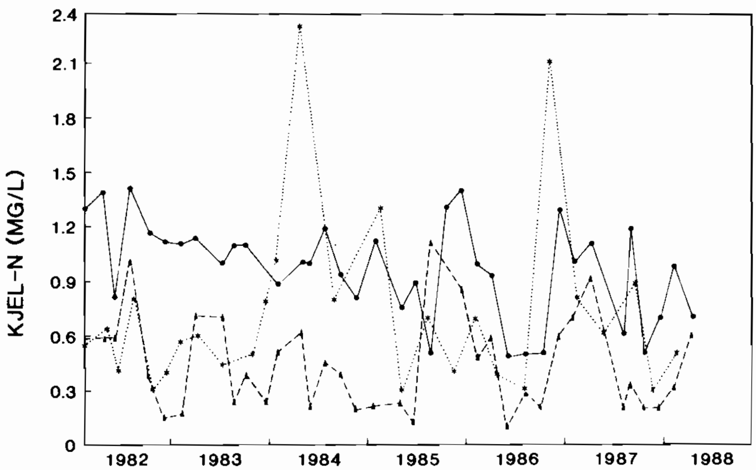

KJEL-N (MG/L)
0
0.3
0.6
0.9
1.2
1.5
1.8
2.1
2.4
1982
1983
1984
1985
1986
1987
1988

Fig. 3 (cont.).

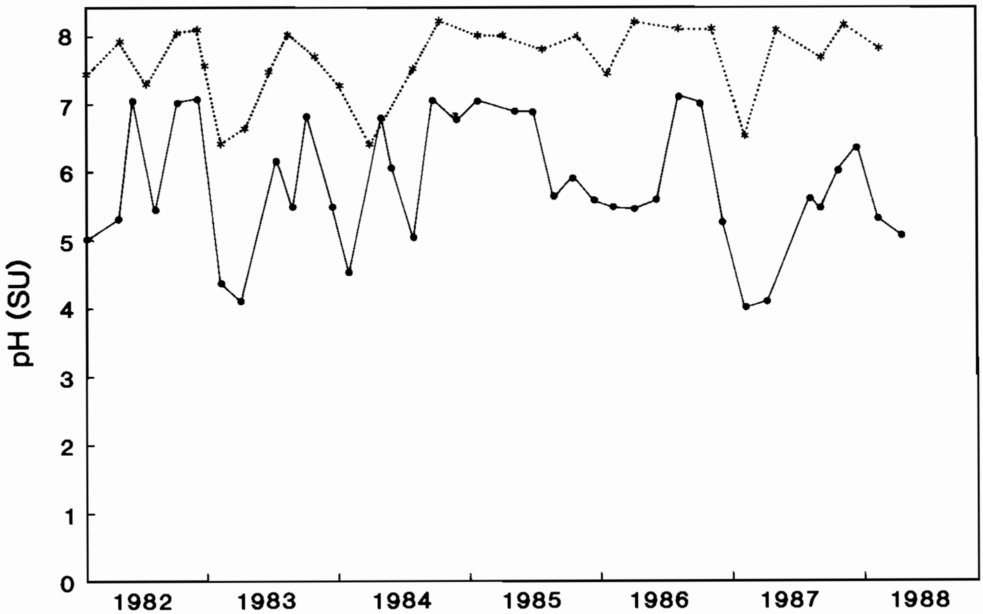


Fig. 4. Hydrogen ion activity (pH) 1982-1988, Suwannee River, Florida, sites VI (dotted line) and site IX (solid line). Data source: Florida Department of Environmental Regulation, Tallahassee.

conditions were oligotrophic-mesotrophic, i.e., total nitrogen levels were < 4 mg L^{-1} and total phosphorus (TP) levels were less < 1 mg L^{-1}. Maximum TP values at site VI were $<$ 0.6 mg L^{-1} during 1982–1988, – a level that Mackenthun (1968) reported necessary to sustain algal blooms in streams. Total organic carbon (TOC) levels for site III were highly variable with minimums of 2–3 mg L^{-1} in 1982–1983 to maximums of 30–39 mg L^{-1} in 1985 and 1987. However, most TOC values during the 5 yr were low ($<$ 20 mg L^{-1}).

During 1982–1987, annual fluctuations of ammonia nitrogen plus ammonium nitrogen (NH_3-N + NH_4-N) levels at sites IX were 0.02–0.3 mg L^{-1} (Figure 3). By comparison during the same period, these nitrogen forms were 10 fold lower at sites III and VI. Total nitrogen levels at most sites were not sufficient to create severe nuisance algal problems; however, nutrient levels in the middle reach (including site V) were sufficient to support dense algal mats on the channel bedrock. In addition, nutirents supported large stands of submerged and emergent aquatic vegetation along the banks in the lower Suwannee River.

In the fall 1987 and May 1988 at km 0.5 in the East Pass, total salinity readings near the bottom (YSI[1] Model 33 S-C-T probe) varied widely (range of 12 ppt) depending on the tidal flow. In the West Pass at km 0.2 in the fall at low ebb tide, surface salinities were below detectable limits by probe. Salinity measurements at this point in spring and early summer on incoming tides (3 ppt surface; 12–20 ppt bottom) ranged from oligosaline (0.5–5 ppt) to mesosaline (5–18 ppt). However, these salinities were moderated by strong freshwater inflow at sites I and II ($<$ 1 ppt and $<$ 0.05 ppt total salinity).

Extreme climatological factors, such as hurricanes that might dislodge or decimate benthic invertebrate communities, did not occur. In early 1988 mild drought conditions existed in the Suwannee River's upper headwater area of southern Georgia.

2.2. Survey Design and Collection Devices

2.2.1. *Survey Design*

The survey design was dependent on analysis of an exploratory set of replicate PONAR grab samples collected in early November 1987 at sites II, III and VI along the middle and lower reaches of the river (Figure 1). These trial sets provided information necessary to develop the final survey program (Table I); to determine the sampling precision of grab replicates; and to make final selection of collection devices.

Collectively, 112 samples were taken in this survey at eight sites, spaced about 25–30 km apart in the mainstem, in late November–December 1987 and in May 1988. The tributary Santa Fe River was sampled 18 km (site V) upriver from its confluence with the Suwannee River (Figure 1). The benthic invertebrate sampling sites were near known centers of Gulf sturgeon activity and were representative of benthic substrates in the area.

2.2.2. *Collection Devices*

To gather information on a wide array of benthic invertebrates, three primary devices were used; PONAR grab, multiplate and basket artificial substrate samplers, and bottom dip net. A total of 112 benthic invertebrate samples, collected in November–December 1987 at 5 sites using the PONAR grab and in May 1988 at 9 sites with grab, artificial substrates, and dip net (Table I). Bottom substrate samples were taken with a 15×15 cm square (225 cm^2) PONAR grab in replicates of six per site (3 each bank; 1 m from the bank and depth of 1–2 m). The exploratory trial series of grabs showed that six replicates in the Suwannee River would provide density estimates with a standard error of $\pm$ 40% of the mean. At each site, a single 1 m scrape with a 45×20 cm dip net (595 μm mesh) was taken perpendicular to the right bank.

Hardboard multiplate samplers (0.012 m^2 area) or limestone-filled basket samplers (0.24 m^2 area) in replicates of two per sites were anchored to the substrate on steel rods and exposed for 6 weeks at a depth of 0.5 m below the water's surface (not touching the bottom substrate). These artificial substrates mimicked one of the dominant natural benthic substrates in the reach, i.e., hardboard multiplates = snags in the lower reach and limestone-filled baskets = rock in the middle reach. On collection, the artificial substrates were raised gently to the surface in one motion and placed in a tub floating nearby. Loss of organisms on retrieval was negligible (net check) because the predominant aquatic insects stay in cases attached to surfaces and heptageniid mayflies cling to surfaces when first removed from the water.

All samples, including dip net samples, were washed in the field and laboratory with a 425 μm mesh sieve and preserved in ethanol with rose bengal stain (Mason and Yevich, 1967). Descriptions of collection devices used in this survey and information on their sampling precisions are contained in Weber (1973), APHA *et al.* (1985) and Britton and Greeson (1987).

2.2.3. *Data Interpretation*

Statistical procedures for benthic surveys (Elliott, 1977; Brower and Zarr, 1984) were used for data analysis. Calculations of descriptive statistics for the data were facilitated by using a PC-compatible tabulating package (Hintze, 1987). Samples were analyzed separately to permit a measure of sampling precision by Coefficient of Variation (CV) $= \pm 1\mathrm{SD} \times 100 / \bar{x}$.

Densities (individual counts) and diversities (taxa) of benthic invertebrates in samples are expressed in number of individuals and taxa m^{-2}. Dip net data are qualitative (single samples), and are extrapolated to m^2 for comparison with grab data.

As Gulf sturgeon were reported by Huff (1975) to eat crustaceans, worms, and aquatic insects, the predominance (densities) of these key food groups were of central importance in this survey. Therefore, densities of benthic invertebrates collected in each sampling device are expressed according to five levels based on logarithmic scale: 'Very Low' 1–9; 'Low' 10–99; 'Moderate' 100–999; 'Abundant' 1000–9999; and 'Very Abundant' ≥ 10000 $\bar{x}$ individuals m^{-2}.

To evaluate possible impacts of organic wastes on the benthic invertebrate fauna, the Empirical Biotic Index (EBI) described by Chutter (1972) was selected. EBI-type indices with weighted values for tolerance of taxa, preferably species, to organic wastes have proven highly effective (Chutter, 1972; Mason, 1975; Mason *et al.*, 1985; Hilsenhoff, 1987; Lenat *et al.*, 1987; Hilsenhoff, 1988).

EBI was calculated for the average number of individuals in replicate samples for site, date, and collection device by the formula: $\Sigma (a \times b) / N_1$; where a = number of individuals in the *i*-th species; b = quality value assigned for each species (0–10); and N = total number of individuals per sample. As described by Chutter (1972), EBIs from 0–2 indicate 'clean water'; 2–4 'slightly enriched water'; 4–7 'enriched water'; and 7–10 'polluted water'.

Quality values (QV) for each taxon – i.e., a numerical estimate of the tolerance of each taxon to organic wastes (0 least tolerant, 10 most tolerant) were assigned based on published information on the environmental requirements of each taxon and experience of the author (see Appendix). QVs were based on their saprobic value documented by experts and cross referenced to literature, e.g., Beck (1977), Surdick and Gaufin (1978), and other publications in the U.S. EPA's 'Environmental Requirements' series; and the U.S. Fish and Wildlife Service's 'Species Profiles' series. Mason (1975) and Mason et al. (1985) provide QVs for the benthic invertebrate fauna of the Lower Midwest and the interior Southeast, and Hilsenhoff (1987) gives QVs for the Upper Midwest.

3. Results and Discussion

3.1. Status of Benthic Invertebrate Communities

3.1.1. *Lower Tidal Reaches Sites I-II (km 2 East Pass; km 5 West Pass)*

In the winter 1987 at site II (West Pass, km 5) tube dwelling Corophiidae and free swimming Haustoriidae amphipods were abundant (Table II; Figure 5). In the May 1988 grabs at site I in the East Pass, benthic invertebrate densities ($\bar{x}$ 3700 individuals m^{-2}, maximum 8700 individuals m^{-2}) were double the densities at site II. However, haustoriid amphipod densities at site II (1421 m^{-2}) were equal to corophiid densities at site I.

Densities of invertebrates in the May 1988 dip net collection at site I (Figure 6) were two fold greater than densities at sites II, IV, V, and VI due to Baetidae mayflies, dipteran Ceratopogonidae and Chironomidae: Tanytarsini. The chironomid *Paratendipes* sp. 1, baetid mayfly *Centroptilum viridocularis*, and isopod *Cyathura polita* were common.

At site I, hardboard multiplate samples yielded opposite results compared to the grab and dip net samples. A total of 60 individuals / unit were collected at site I and 100 individuals / unit existed at site II (Figure 6). A two fold difference in total counts of individuals in paired artificial substrate samples is outside the expected normal sampling variability (Mason *et al.*, 1973), and therefore, greater densities on snaglike habitats at site II over site I are considered real.

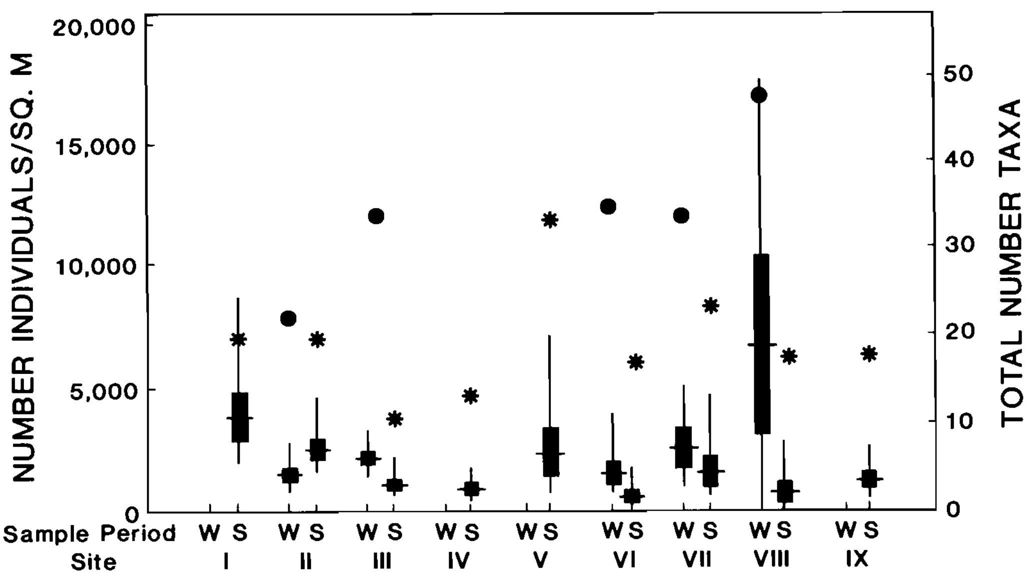


Fig. 5. Mean number of individuals ± 1 SD (black bar) and range, and total taxa (black bullets-1987; asterisks-1988) for benthic invertebrates in 6 replicate PONAR grabs/site, Suwannee River, Florida. W = November-December 1987; S = May 1988.

TABLE II

Densities of predominant benthic invertebrates in the Suwannee River, Florida: moderate (100–999) and abundant (1000–9999 $\bar{x}$ Individuals m^{-2}) in PONAR grabs[a] in winter 1987 (PW), and early summer 1988 grabs (PS) and dip net samples[b] (D)

Site	Taxa	PW	PS	D
I	Amphipoda			
km 2	Corophiidae	No	1250	
	Corophium c.f. *tuburculatum*	samples		
	Cerapus c.f. *tubularis*			
	Ischryoceridae			
	Jassa sp. 1			
	Oligochaeta			
	Tubificidae		126	
	Polychaeta			
	Ampharetidae		910	
II	Diptera			
km 5	Chironomidae		103	
	Cryptochironomus fulvus gr.			
	Paratendipes sp. 1			
	Saetheria sp. 1			
	Amphipoda			
	Corophiidae	311	541	
	Corophium c.f. *tuberculatum*			
	Cerapus c.f. *tubularis*			
	Haustoriidae			
	Parahaustorius c.f. *longimerus*	681	1421	
	Polychaeta (unid. spp.)		437	
III	Diptera			
km 48	Chironomidae	516		
	Coelotanypus sp. 1			
	Conchapelopia fasciata			
	Corynoneura sp. 1.			
	Chironomus decorus			
	Polypedilum halterale			
	Stictochironomus divinctus			
	Calopsectra sp. 1			
	Micropsectra sp. 1			
	Tanytarsus s. s. sp. 1			
	Mollusca			
	Bivalvia			
	Corbiculidae			
	Corbicula fluminea	710	592	

[a] Replicate grabs = 6 per site.
[b] Dip net samples = 1 per site.

TABLE II (cont.)

Site	Taxa	PW	PS	D
IV	Mollusca			
km 89	Bivalvia			
	Corbiculidae			
	Corbicula fluminea		303	
	Oligochaeta		267	144
	Naididae			
	Naias sp. 1			
	Tubificidae			
(cont)	*Limnodrilus hoffmeisteri*			
V	Diptera			
km 101.	Chironomidae	930[c]	825	140
018	*Ablabesmyia mallochi*			
	Cricotopus bicinctus gr.			
	C. nosticola			
	Cryptotendipes sp. 1			
	Polypedilum scalaenum			
	Stenochironomus sp. 1			
	Calopsectra sp. 1			
	Cladotanytarsus s. s. sp. 1			
	Rheotanytarsus sp. 1			
	Tanytarsus s. s. sp. 1			
	Ephemeroptera			
	Tricorythidae	799[c]		
	Tricorythodes albilineatus			
	Coleoptera			
	Elmidae	843[c]	140	
	Dubiraphia sp. 1			
	Stenelmis fuscatus			
	S. Hungerfordi			
	Amphipoda			
	Gammaridae			
	Gammarus fasciatus	710[c]	822	
	Oligochaeta			
	Tubificidae			
	Limnodrilus hoffmeisteri		207	
	Mollusca			
	Bivalvia			
	Corbiculidae			
	Corbicula fluminea		266	
	Mollusca			
	Gastropoda			
	Planorbidae			
	Helisoma sp.			
	Pleuroceridae			
	Elimia athearni	266[c]		

[c] Single PONAR grab.

TABLE II (cont.)

Site	Taxa	PW	PS	D
VI	Diptera			
km 118	Chironomidae	872	118	
	Ablabesmyia oronata			
	Coelotanypus sp. 1			
	Corynoneura sp. 1			
	Cryptochironomus blarina			
	Polypedilum halterale			
	P. scalaenum			
	Robackia sp. 1			
	Stempellina johannsoni gr.			
	Tanytarsus s. s. sp. 1			
	Mollusca			
	Bivalvia			
	Corbiculidae			
	Corbicula fluminea		259	
	Oligochaeta			
	Tubificidae			
	Limnodrilus hoffmeisteri		378	
VII	Diptera			
km 153	Chironomidae	908	828	
	Ablabesmyia oronata			
	Cryptochironomus blarina			
	Polypedilum halterale			
	P. scalaenum			
	Stempellina johannsoni gr.			
	Tanytarsus s. s. sp 1			
	Coleoptera			
	Elmidae	134		
	Stenelmis fuscatus			
	S. hungerfordi			
	Oligochaeta			
	Tubificidae			
	Limnodrilus hoffmeisteri		355	
	Mollusca			
	Bivalvia			
	Corbiculidae			
	Corbicula fluminea	1302		

TABLE II (cont.)

Site	Taxa	PW	PS	D
VIII	Diptera			
km 205	Chironomidae	5932	366	
	Thienemanniemyia sp. 1			
	Corynoneura sp. 1			
	Nanocladius sp. 1			
	Cricotopus bicinctus gr.			
	Thienemanniella sp. 1			
	Dicrotendipes modestus			
	D. nervosus			
	Cryptochironomus fulvus gr.			
	C. blarina			
	Cryptotendipes sp. 1			
	Polypedilum halterale			
	P. scalaenum			
	Cladotanytarsus sp. 1			
	Micropsectra sp. 1			
	Stempellina johannsoni gr.			
	Tanytarsus s. s. sp. 1			
	Ceratopogonidae			
	Bezzia spp.	126		
	Coleoptera			
	Elmidae	289		
	Stenelmis fuscatus			
	S. hungerfordi			
IX	*Diptera*			
km 233	*Chironomidae*		512	
	Cryptochironomus fulvus gr.			
	Cladotanytarsus sp. 1			
	Micropsectra sp. 1			
	Oligochaeta			
	Tubificidae			
	Limnodrilus hoffmeisteri		315	
	Naididae			
	Nais sp. 1		296	

The strong currents, scoured rock bottom, and highly variable salinities and oligotrophic-mesotrophic conditions restricted densities of benthic invertebrates in the lower Suwanee River during the winter and early summer. However, the greatest densities were concentrated in those major food groups of the Gulf sturgeon, i.e., amphipods, polychaetes, oligochaetes, and chironomids, reported by Huff (1975). Another reported food group of Gulf and Atlantic sturgeon, Decapoda, were abundant near the banks, but only a few were collected in dip net near the banks. Other decapods, e.g., crayfish and blue crab *Callinectes sapidus*, were likely present in May but avoided the sampling gear.

Winter grab samples at site III contained large numbers of *Dromogomphus* sp. (30 m^{-2}). Eggs of the apple snail *Pomacea paludosa* were observed on snags and vegetation at sites

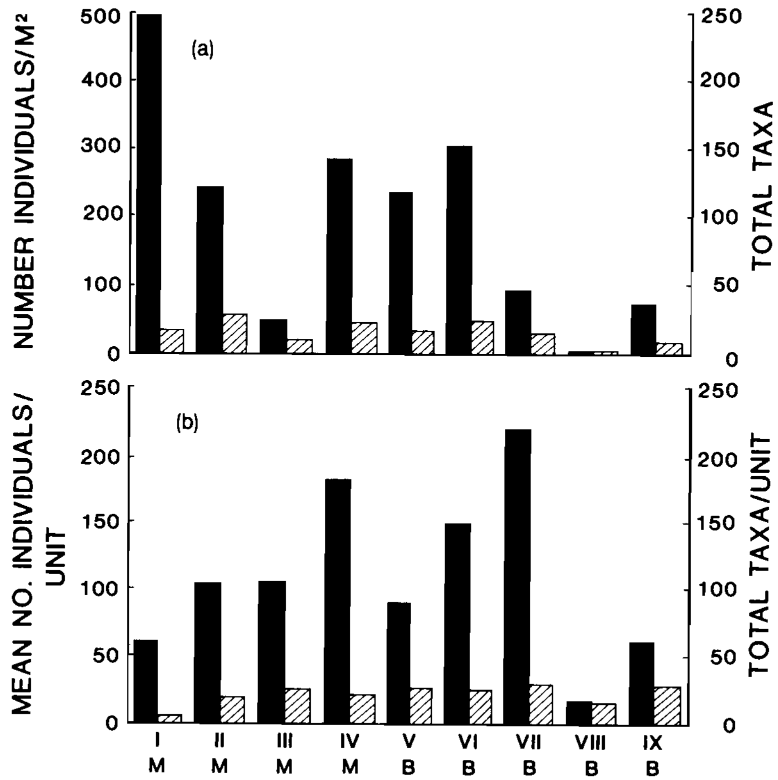


Fig. 6. (a) Number of individuals (black bar) and total taxa (cross hatched bar) per m² in dip net samples; and (b) Mean Number of individuals (black bar) and total taxa (cross hatched bar) per sampler unit in multiplate (M) and basket (B) artifical substrate samplers, Suwannee River, Florida, 1988.

I-IV in the lower Suwannee River. At sites III and IV, the Asian clam *Corbicula fluminea* was abundant (710 and 592 m^{-2}) in winter and summer grab replicates, and, along with Chironomidae, was the dominant benthic invertebrate in this reach (Table II).

3.1.2. *Middle Reach Sites V-IX (km 101 to 233)*

Densities of benthic invertebrates in winter 1987 grabs were moderate to abundant at all sites in the middle reach. The greatest invertebrate densities in bottom substrates occurred at site V in the Santa Fe River, and the diversity was double those found at the mainstem sites. At site VIII, winter grab samples contained six times the number of individuals as those replicates in summer due to chironomids that composed 86% (5932 m^{-2}) of the total density.

In winter grabs, diversities at sites VI and VII were about double the diversities in the early summer collections (Figure 5). At site VIII, diversities in winter grabs were triple those in summer grabs.

At site V, 18 benthic invertebrate taxa were predominant (Table II) and moderate densities of chironomids, caenid mayflies, beetles, gammarid amphipods were found. At site VI, Chironomidae was the only taxonomic group to rate moderate density status in winter. In the summer, although chironomids were predominant, their abundance was reduced, and moderate numbers of Asian clam and oligochaetes were collected.

Hydropsychid caddisflies (*Hypropscyhe* and *Cheumatopsyche*) and psychomyiid caddisflies (*Lype diversa, Polycentropus, Phylocentropus,* and *Cyrnellus fraternus*) were common inhabitants of basket samplers in the middle reach. The crayfish *Procambarus (Scapulicambarus) paeninsulans* was collected only in basket samplers and limited to sites IV-IX. Like Diptera, the Ephemeroptera were highly diverse in the middle reach (*Stenonema* 7 spp., *Stenacron interpunctatum, Baetis* 3, spp., *Centroptilum viridocularis,* and *Callibaetis floridense*). Other mayflies, Caenidae and Tricorythidae, were common in the sand bottom sediments. Populations of the burrowing mayfly *Hexagenia limbata,* an excellent fish food, were localized in silted eddies of river bends. Aquatic beetles of the family Elmidae (*Stenelmis* 3 spp., *Dubiraphia, Optioservus,* and *Microcylloepus pusillus lodingi*) were abundant along study banks with wood detritus at sites V and VI-IX. Densities of stonefly nymphs (*Acroneuria, Neoperla,* and *Perlesta*) in the artificial substrate samplers were ‘very low’ at site VII and ‘low’ at site VIII. Most species of these genera are listed as neutral to alkaliphilous by Surdick and Gaufin (1978), and low densities in the Suwannee River were influenced by the acidic water.

3.2. Community Similarities with Other Southeastern U.S. Coastal Streams

Benthic invertebrate communities in the Suwannee River were generally similar to those reported from other brown water, coastal rivers of the Southeastern U.S. Most aquatic insect genera collected in the Satilla River, Georgia, by Benke *et al.* (1984), where snags and coarse particulate organic matter were prevalent, also were present in the Suwannee River. They estimated greater densities for some groups of benthic invertebrates, e.g., 20000 oligochaetes m^{-2}, than I found in the Suwannee River. However, these differences in densities are attributed to the retention of fewer oligochaetes and chironomids on the 425 μm mesh sieve in this survey compared to the 100 μm and 250 μm mesh sieves used by Benke *et al.* (1984). Mason *et al.* (1975) showed that a 425 μm mesh sieve retained 60% fewer organisms in sand substrate compared to a 250 μm mesh sieve.

Roback (1953) for the Savannah River; Lenat (1987) for North Carolina streams; Smock (1988) for South Carolina streams; and Soponis (1980) and Caldwell, and Parrish (1987) for streams of northwest Florida, reported the same general composition of benthic invertebrate communities as collected in this survey, i.e., red-blooded chironomids of the subfamilies Chironominae and Tanypodinae were predominant. Chironomid genera of the subfamily Orthocladiinae were fewer than reported by the latter two authors, except at the Santa Fe River site where algae coated the bedrock.

Beck (1972) found ‘acidophilous’ chironomids; *Cryptotendipes casuarius, Polypedilum obtusum,* and *Stictochironomus divinctus,* in streams of northern Florida. Other acid tolerant, opportunistic benthic invertebrates were collected throughout the study area, and were especially common at sites VIII and IX.

3.3. Biotic Index Analysis

In the lower Suwannee River (sites I-IV), all EBI values except one (3.74; May 1988 multiplate) fall between 4–7 the 'enriched water' category (Table III). Three of the 18 EBI values (17%) for the middle reach of the river were in the 'slightly enriched water' category (EBI 2–4) and the rest of the values were in the middle range of the 'enriched water' category.

Values for EBI in the middle reach at sites VI and VIII were relatively uniform (about 4–5) and, except for a 3.64 value from dip net sampling in May 1988, indicated 'slightly enriched to 'enriched water'. Because the EBIs in Table III represent averages of replicate samples (except dip net samples), a difference of two units between sites is considered ecologically significant. At site IX, EBI values were more divergent (3.16–6.38) than for the other sites, reflecting highly variable physicochemical conditions as discussed in Section 2.1.2. Basket samples contained high numbers of Tanytarsini chironomids and heptageniid mayflies, resulting in an EBI of 3.16 'slightly enriched water'. The dip net sample contained large numbers of tubificid *Limnodrilus hoffmeisteri* (QV = 8) that contributed greatly to an EBI of 6.38, near the 'polluted water' category.

Most EBI values for this survey indicate 'slightly enriched' to enriched' water quality conditions (Table III). According to their assigned QV (Appendix), about 82% of the taxa collected fell between a value of 0 to 5 that indicate overall 'clean water' conditions existed for the study area (Figure 7). EBI values and physicochemical data for the study sites discussed in Section 2.1.2., are in mutual agreement, i.e., oligotrophic to mesotrophic waters.

Chutter (1972) found close agreement between biochemical oxygen demand (BOD-5) values and EBIs calculated for benthos in the Buffalo River, Natal, and in the Jukskei-Crocodile River system of the Transvaal, South Africa. In a mayfly-rich reach of the Jukskei-Crocodile River system, he obtained an EBI of 0.3, while in polluted a polluted reach, predominated by oligochaetes and chironomids, the EBI was 7.8. For Ekman grab, limestone-filled basket and dip net collections in late summer and fall 1971 from a small limestone stream in southwestern Ohio, U.S.A., Mason et al. (1985) found EBIs to average between 5–6.5, 3.5–5.7, and 3.7–4.7, respectively. These EBIs were indicative of 'slightly enriched' to 'enriched' waters similar to indices for the Suwannee River. Although yielding similar EBIs, there are demonstrable differences in the geophysical and chemical properties of these watersheds, and therefore, interregional, and perhaps intraregional comparisons of EBIs are likely invalid.

4. Summary and Conclusions

A survey of benthic invertebrates in the middle and lower reaches of the Suwannee River, Florida, in the winter 1987 and summer 1988 as part of a study of foods of the Gulf sturgeon, *Acipenser oxyrhynchus desotoi*, revealed moderate to abundant densities, except at the farthest upriver site (km 233) affected by erratic flow, shifting fine sand substrate, and low pH and nutrient levels. Estimates of benthic invertebrate densities in

TABLE III

Empirical Biotic Index (EBI) values for benthic invertebrates in PONAR grabs (means); hardboard multiplate and limestone-filled basket artificial substrates (means), and single dip net samples, Suwannee River, Florida, 1987–1988

Device		PONAR-W	PONAR-S	Multiplate	Basket	Dip Net
Date		Nov.-Dec. 1987	May 1988	May 1988	May 1988	May 1988
Replicates		6	6	2	2	1
Site	km					
I	2		5.33	5.77		4.87
II	5	5.14	4.95	5.76		5.07
III	48	5.25	4.59	4.33		4.13
IV	89		5.75	3.74		4.40
V	101.018		5.34		5.94	4.54
VI	118	5.27	5.27		5.38	4.65
VII	153	5.74	5.50		4.35	3.64
VIII	205	3.57	4.89		5.27	5.00
IX	233		5.30		3.16	6.38

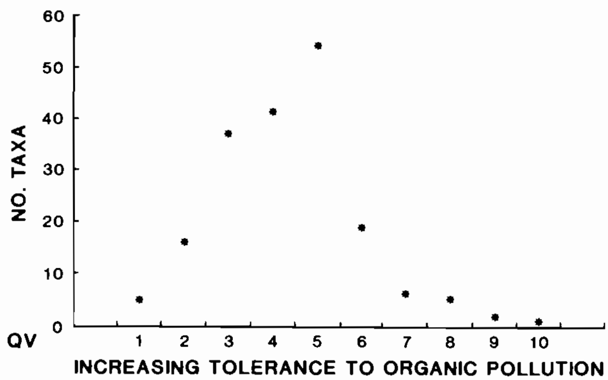


Fig. 7. Total number of taxa in all collections 1987-1988, Suwannee River, Florida (See Appendix), that were assigned to quality values (0 least tolerant to organic wastes; 10 most tolerant to organic wastes).

the Suwannee River were slightly lower than found in surveys of other Southeastern U.S. brown water coastal rivers.

In early summer, greatest densities were recorded at sites I (km 2) and II (km 5); and site V (km 101.018); and VII on the mainstem and in the Santa Fe River tributary. Due to cyclic abundance of chironomids at sites VIII (km 205) and IX in the winter, grabs in the winter contained 10 times the number of individuals than in early summer.

At the lower river sites I and II where the Gulf sturgeon activity is high during spring and winter, the greatest densities of benthic invertebrates were concentrated in many of the reported foods of Gulf sturgeon; amphipods, isopods, decapods, chironomids, oligochaetes and polychaetes. The Asian clam and olive nerite and pleurocerid gastropods were moderately abundant in the oligohaline to mesohaline lower reach of the river; however, these were not reported foods of the Gulf sturgeon. The diversity of food groups available to the Gulf sturgeon in the lower reach was considerably less than in the middle reach.

The range of Empirical Biotic Index values, 3 to 6, and physicochemical data indicated that 'slightly enriched' to 'enriched' water quality conditions existed in the middle and lower reaches. Of the 186 taxa collected in this survey, 82% are taxa that inhabit 'clean waters'.

Interregional comparisons of EBI values are not recommended due to current inconsistencies in assignment of QVs for the taxa and major physicochemical differences among ecoregions. Caution is urged for intraregional comparisons of EBIs unless QVs are assigned by expert consensus and there is consideration for current velocities, cyclic periods of abundance of species, and other major biotic and abiotic factors not reflected in the biotic index schemes. Assigned QVs for the Suwannee River (Appendix) and other regions will need adjustment as new environmental related data for species are published. QVs for thermal stress, singly and in combination with organic wastes, need to be determined for use in biotic indices.

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Appendix

Benthic invertebrate taxa and quality values ( ) used in calculating Empirical Biotic Indices (0 = least tolerant to organic pollution; 10 = most tolerant to organic pollution)

Diptera (True Flies)
  Chironomidae (Chironomids/Midges)
    Tanypodinae
      Ablabesmyia mallochi (7)
      Coelotanypus sp. 1 (6)
      Clinotanypus sp. 1 (5)
      Conchapelopia fasciata (5)
      Procladius sp. 1 (8)
      Labrundinia sp. 1 (3)
      Thienemanniemyia sp. 1 (2)
      Larsia sp. 1 (3)
    Orthocladiinae
      Orthocladiinae sp. 1 (3)
      Nanocladius sp. 1 (3)
      Corynoneura sp. 1 (2)
      C. sp. 2 (2)

Thienemanniella sp. 1 (1)
Cricotopus bicinctus gr. (5)
C. nosticola (4)
C. sp. 2 (4)
Kiefferiella sp. 1 (3)
Eukiefferiella sp. 1 (2)
Orthocladius sp. 1 (2)
Trissocladius sp. 1 (1)

Chironominae
Chironomini
Chironomus decorus (9)
Cryptochironomus fulvus (7)
C. blarina (7)
C. (Chaetolabis) ochreatus (6)
C. sp. 1 *cf. stylifer* (4)
C. pseudotener (5)
Chernovskiia sp. 1 (3)
Cryptotendipes sp. 1 (4)
Dicrotendipes modestus (6)
D. nervosus (5)
D. neomodestus (4)
Endochironomus sp. 1 (5)
Lauterborniella sp. 1 (4)
*Paratendipes sp. 1 (6)**
Paralauterborniella nigrohalteralis (4)
Pseudochironomus prasinatus (2)
Paracladopelma sp. 1 (3)
Parachironomus sp. 1 (5)
Polypedilum convictum (6)
P. halterale (4)
P. scalaenum (7)
P. pedestre (6)
P. illinoense gr. (5)
Robackia sp. 1 (2)
Saetheria sp. 1 (2)
Stenochironomus sp. 1 (4)*
Stictochironomus divinctus (3)
Stelechomyia sp. 1 (2)
Tribelos sp. 1 (5)
Xenochironomus sp. 1 (4)

Tanytarsini
Calopsectra sp. 1 (3)
C. sp. 2 cf. *guerla* Rob. (3)
Cladotanytarsus s. s. sp. 1 (4)
Micropsectra politus? (1)
Parytanytarsus dissimilis (2)
Rheotanytarsus sp. 1 (4)
R. sp. 2 (5)
Stempellina johannsoni gr. (3)
Stempellinella sp. 1 (2)
Nimbocera sp. 1 (2)
Tanytarsus s. s. sp. 1 (4)

Ceratopogonidae (No-see-ums)
Bezzia sp. 1 (5)
B. sp. 2 (5)
Palpomyia sp. 1 (6)

Simuliidae (Blackflies)
Simulium sp. 1 (6)

Tipulidae (Craneflies)
Tipula sp. 1 (6)

Trichoptera (Caddisflies)
Hydroptilidae
Hydroptila sp. 1 (3)
Neotrichia sp. 1 (2)
Ochotrichia sp. 1 (2)
Oxyethira sp. 1 (2)

Psychomyiidae
Cyrnellus fraternus (4)*
Neureclipsis sp. 1 (3)
Phylocentropus sp. 1 (4)
Polycentropus sp. 1 (4)
Lype diversa (4)

Hydropsychidae
Cheumatopsyche sp. 1 (5)
Hydropsyche sp. 1 (3)
H. sp. 2 (4)

* Different QV than reported by Mason *et al.* (1985).

Leptoceridae
Leptocera sp. 1 (3)
Oecetis sp. 1 (2)
Ephemeroptera (Mayflies)
Baetidae
Baetis pygmaeus (3)
B. propinguus (3)
Centroptilum viridocularis (3)
Callibaetis floridense (3)

Caenidae
Caenis hilaris (5)
Brachycerus maculatus (5)
Tricorythidae
Tricorythodus albilineatus (5)
T. sp. 1 (5)
Leptophlebiidae
Choropterpes hubbelli (3)
Heptageniidae
Stenonema exiguum (5)
S. integrum (6)
S. smithae (4)
S. tripunctatum (2)
S. scitulum (3)
S. femoratum (3)*
S. floridense (5)
Stenacron interpunctatum (3)

Ephemeridae
Hexagenia limbata (3)

Plecoptera (Stoneflies)
Acroneuridae
Acroneuria sp. 1 (3)

Perlidae
Neoperla sp. 1 (3)
Perlesta sp. 1 (1)

Odonata
Anisoptera (Dragonflies)
Cordulidae
Neurocordulia sp. 1 (5)
Gomphidae
Gomphus sp. 1 (5)
Dromogomphus spinosus (5)
Macromiidae
Macromia sp. 1 (5)

Zygoptera (Damselflies)
Agriidae
Agrion maculatum (5)
Heterina sp. 1 (4)

Coenagriidae
Argia moesta (6)
Chromagrion sp. 1 (5)

Lestidae
Lestes sp. 1 (5)

Coleoptera (Beetles)
Elmidae
Dubiraphia sp. 1 (5)
Microcylloepus pusillus logingi (3)
Stenelmis fuscatus (5)
S. hungerfordi (5)
Optioservus sp. 1 (5)

Neuroptera (Lacewings)
Chauliodes sp. 1 (4)

Annelida (Segmented Worms)
Oligochaeta (Oligochaetes)
Naididae sp. 1 (6)
Naididae sp. 2 (6)
Dero furcatus (4)
Nais sp. 1 (3)
Homonaias sp. 1 (3)
Homochaeta sp. 1 (3)
Stylaria lacustris (5)
S. fosilaris (6)
Stephenosoniana sp. 1 (3)

Branchiobdellidae sp. 1 (7)

Tubificidae (Sludgeworms)
Aulodrilus americana (5)
Limnodrilus hoffmeisteri (8)

Oligochaeta (Oligocahetes)
Lumbriculidae
Lumbriculus sp. 1 (5)

Polychaeta (Polychaetes)
Polychaeta sp. 1 (5)
Nereidae sp. 1 (5)
Laeoneris culveri (4)
Nereis succinea (5)
N. occidentalis (4)
Ampharetidae sp. 1 (4)
Ampharetidae sp. 2 (4)

Hirudinea (Leeches)
Erpobdellidae
Dina sp. 1 (8)
D. anoculata (9)
Placobdellidae
Placobdella multilineata (8)

Nematoda (Roundworms) (5)

Curstacea (Crustaceans)
Amphipoda (Amphipods/Scuds)
Amphipoda sp. 1 (5)
Haustoriidae
Parahaustorius c.f. *longimerus* (5)
Aoridae sp. 1 (4)

Gammaridae
Gammarus sp. 1 (5)
G. sp. 2 (5)
G. sp. 3 (5)

Talitridae
Hyalella azteca (4)

Lyanassidae sp. 1 (3)
Lyanassidae sp. 2 (3)

Corophiidae
Corophium c.f. *tuberculatum* (6)
C. c.f. *lacustre* (5)
Cerapus c.f. *tubularis* (5)
Ischryoceridae
Jassa sp. 1 (7)

Isopoda (Aquatic Sowbugs)
Asellidae
Asellus sp. 1 (6)
Anthuridae
Cyathura polita (5)

Decapoda (Shellfish)
Cambaridae (Crayfish)
Procambarus (Scapulicambarus) paeninsulanus (7)

Xanthidae (6)

Processidae sp. 1 (3)

Mysideacea (Grass Shrimp)
Mysidae
Mysis louisianae (4)

Mollusca (Molluscs)
Bivalvia (Clams/Bivalves)
Corbiculidae
Corbicula fluminea (7)
(Asian Clam)
Sphaeriidae (Fingernail Clam)
Sphaerium sp. 1 (4)
Musculium sp. 1 (3)

Dreissenidae
Mytilopsis leucophaeta (4)

Unionidae
Elliptio icterina (3)
Lampsilis claibornensis (3)

Gastropoda (Snails/Gastropods)
  Hydrobiidae
    Somatogyrus walkerianus (4)
    Spilochlamys conica (4)
    Cincinnatia parva (3)
  Lymnaeidae
    Lioplax pilsbryi choctawhatchensis (3)

  Neritidae (Olive Snails)
    Neritina reclivata (6)

  Physidae (Pond Snails)
    Physa sp. 1 (5)

  Ancylidae (Limpets)
    Ferrissia hendersoni (2)

  Pilidae
    Pomacea paludosa (4) (Apple Snail)

  Pleuroceridae (River Snails)
    Eliminia floridensis (5)
    E. athearni (5)
  Planorbidae (Orb Snails)
    Gyraulus parvus (4)
    Helisoma sp. 1 (4)
    Micromenetus dilatatus avus (3)

  Viviparidae
    Amnicola sp. 1 (3)
    Vivipartus intertexus (4)
    Campeloma floridense (4)
    C. lium (4)

Collembola (Springtails) (3)

Hydracarina (Water Mites) (5)

Coelenterata (Coelenterates/Hydras) (3)

Bryozoa (Moss Animals) (4)

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