4.5 Waterfowl

Introduction and Information Base

The impoundment of the North Anna River in 1972 created a new habitat in the Northern Virginia Piedmont for both migratory and residential waterfowl. Lake Anna is, by far, the largest enclosed body of water in Virginia's northern Piedmont and has provided a major inland "resting stop" for migratory waterfowl of the Atlantic Flyway. During extremely cold winters, Lake Anna can be the only ice-free body of water in the area. Waterfowl are, therefore, an important component of the biota of Lake Anna. Sightings and records of abundance determined the extent Lake Anna is utilized by these birds each year. Such data are also of value in determining range extensions and predicting early waterfowl abundance in other areas.

Waterfowl sighting surveys were conducted monthly January through August, 1984 in accordance with the 316(a) study plan. After the first six-month progress report to the 316(a) Technical Advisory Committee, it was decided that waterfowl surveys would be performed quarterly. Therefore, surveys were not conducted in September, October and November and a final survey for 1984 was performed in December. Waterfowl sighting surveys were deleted from the 316(a) study plan in 1985. Each survey was designed to cover at least 70% of Lake Anna's shoreline and only water-related species of birds were recorded with the exception of the hawk and osprey families, Accipitridae and

Pondionidae. The January 1984 survey was restricted to the lower half of Lake Anna due to ice cover on the upper lake. Waterfowl were identified using binoculars and several field guides.

Assessment and Discussion

A total of 41 species of birds representing 12 families was observed at Lake Anna during the 1984 surveys (Table 4.5-1). Anatidae, which contains the swans, geese and ducks, was the only family represented by more than four species. Seventeen species of ducks were recorded during the 1984 waterfowl surveys. Mallard, which has been recorded nesting at Lake Anna in previous years, was most abundant, appearing in each of the nine surveys. Other frequently encountered ducks at Lake Anna were American Black Duck (recorded in six out of nine surveys), Wood Duck (six out of nine surveys), Bufflehead (five out of nine surveys) and Greater Scaup (five out of nine surveys). Wood Duck has also been recorded nesting at Lake Anna. In general, most of the ducks were recorded during January, February and March with only four out of the seventeen duck species recorded in June, July and August. Only five species of ducks were seen during the December 1984 survey which may have been due to the mild weather experienced in the fall.

The Canada Goose was the only species of goose recorded at Lake Anna; however, it ranked second to the Mallard in relative abundance among Anatidae. Canada Geese were recorded in seven of the nine waterfowl surveys and

Table 4.5. -1 Water-related bird sightings at Lake Anna, Virginia 1984.

Family	Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Dec	Total
Accipitridae	Bald Eagle			1		2	4		1		8
	Northern Harrier							1		1	2
	Red-tailed Hawk		3	2	1	1				3	10
Alcedinidae	Belted Kingfisher	1		1	1	5	4	3	1	5	21
Anatidae	American Wigeon		10	32	1						43
	American Black Duck	150	2	18	1				4	5	180
	Blue-winged Teal				6			1			7
	Bufflehead	23	17	15	14					15	84
	Canada Goose		187	104	27	39	82	69	29		537
	Common Goldeneye	6									6
	Common Merganser		54	27							81
	Northern Pintail			30							30
	Gadwall	9	3								12
	Greater Scaup	5	14	33	1					3	56
	Hooded Merganser	15								1	16
	Mallard	273	116	304	16	17	8	12	8	80	834
	Northern Shoveler			4	5						9
	Red-breasted Merganser			17	57	1					75
	Redhead		4								4
	Ring-necked Duck			2		2					4
	Ruddy Duck			3							3
	Wood Duck			33	3	2	1	3	4		46
Ardeidae	Cattle Egret				1						1
	Great Blue Heron	10	2	2	5	7	17	28	39	17	127
	Great Egret				1			1	1		3
	Green-backed Heron					1	6	1	2		10
Chardariidae	Killdeer						2	2	12		16
	Wilson's Plover								2		2
Gaviidae	Common Loon				2						2
Laridae	Caspian Tern				6		1				7
	Herring Gull		1	9	25	2				1	38
	Ring-billed Gull	201	538	1267	911	22	2			309	3250

Table 4.5.-1 (Continued)

Family	Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Dec	Total
Pandionidae	Osprey				14		2	1	12		29
Phalacro-coracidae	Double-crested Cormorant				7		2			3	12
Podicipedidae	Horned Grebe	10	2	5							17
	Pied-billed Grebe	1									1
Rallidae	American Coot	170	401	406	91					54	1122
Scolopacidae	Least Sandpiper					1		1	4		6
	Lesser Yellowlegs								4		4
	Semipalmated Sandpiper					1					1
	Spotted Sandpiper					1					1
Totals	(No. species)	(13)	(15)	(21)	(22)	(15)	(12)	(12)	(14)	(13)	
	No. Individuals	874	1354	2315	1196	104	131	123	123	497	

several nesting flocks were observed during 1984. The absence of Canada Geese during the January and December surveys was probably due to hunting pressure.

Two families were represented by four species each: Ardeidae, herons and bitterns, and Scolopacidae, sandpipers. Great Blue Heron was the most abundant heron at Lake Anna. It, like the Mallard, was recorded during all nine surveys. Great Blue Heron counts were highest in July and August. Other ardeids observed were Green-backed Heron, Great Egret and Cattle Egret. The sandpiper species, represented by Least Sandpiper, Lesser Yellowlegs, Semipalmated Sandpiper and Spotted Sandpiper were observed during the summer months but in low abundance. Other shorebirds recorded were Killdeer and Wilson's Plover, members of family Charadriidae.

Ring-billed Gull was the most abundant seagull recorded. Gull numbers were highest during the colder months as were the numbers of duck and American Coot. Belted Kingfisher ranked as one of the more frequently occurring species at Lake Anna as it appeared in eight out of nine waterfowl surveys. Eight Bald Eagles were sighted at Lake Anna during waterfowl surveys. Four were recorded during the June survey, two were recorded in May and one each in March and August.

Historically at Lake Anna, waterfowl diversity and abundance have been lowest during the summer, increased in the fall, and peaked during the winter and early spring. Although the September, October and November surveys were

cancelled, the December survey was probably representative of a normal fall survey.

Prior to 1984, waterfowl surveys at Lake Anna were conducted by a group of area birders. Their findings were reported to both the Virginia Society of Ornithology and the National Audubon Society. In addition, Virginia Power biologists have recorded occasional sightings incidental during routine field operations since 1976. These data have been combined by Mr. John B. Bazuin, Jr. of the local birding group to produce a comprehensive list of water-related birds at Lake Anna (Table 4.5-2). In addition to the 44 species of birds identified during the 1984 waterfowl sighting surveys, 37 other species were identified when records back to 1976 were considered. The majority of these additional species are considered infrequent sightings at Lake Anna and many represent record sightings for the Virginia Piedmont.

In the past, several unusual or notable species for Virginia's Piedmont have been observed at Lake Anna, including two Cattle Egret sightings in 1979, Tundra Swan sightings in 1980 and 1981 and Bald Eagle sightings each year after 1976. Other notable sightings for Lake Anna included a Brown Pelican in the summer of 1979 and a Brant in 1980. A photograph of an Avocet taken at Lake Anna in August 1979 was the fourth sighting ever and the first documented record for Virginia's Piedmont.

In addition to rare sightings, unusually high numbers of certain species have been recorded since 1976.

Table 4.5. -2. Species list of water-related birds at Lake Anna: 1976-1983.*

Common Loon
Red-throated Loon
Red-necked Grebe
Horned Grebe
Pied-billed Grebe
Sooty Shearwater
Brown Pelican
Double-crested Cormorant
Great Blue Heron
Green-backed Heron
Cattle Egret
Great Egret
Least Bittern
Mute Swan
Tundra Swan
Canada Goose
Brant
Mallard
Black Duck
Gadwall
Northern Pintail
Green-winged Teal
Blue-winged Teal
American Wigeon
Northern Shoveler
Wood Duck
Redhead
Ring-necked Duck
Canvasback
Greater Scaup
Lesser Scaup
Common Goldeneye
Bufflehead
Oldsquaw
White-winged Scoter
Black Scoter
Ruddy Duck
Hooded Merganser
Common Merganser
Red-breasted Merganser
Bald Eagle
Osprey
American Coot
Lesser Golden Plover
Black-bellied Plover
Ruddy Turnstone
American Woodcock
Common Snipe
Spotted Sandpiper
Solitary Sandpiper
Greater Yellowlegs
Lesser Yellowlegs
Pectoral Sandpiper
Least Sandpiper
White-rumped Sandpiper
Dunlin
Short-billed Dowitcher
Semipalmated Sandpiper
Sanderling
American Avocet
Ivory Gull
Iceland Gull

Table 4.5-2 (Continued)

Great Black-backed Gull	Sooty Tern
Herring Gull	Bridled Tern
Ring-billed Gull	Caspian Tern
Laughing Gull	Black Tern
Bonaparte's Gull	Belted Kingfisher
Forster's Tern	Marsh Wren
Common Tern	

*List supplied by Mr. John B. Bazuin, Jr. - Annandale, Virginia.

During the winter, daily American Coot counts for Lake Anna have usually exceeded 1,000 birds. Large flocks of Ring-billed Gull and Mallard also have been recorded during the winter. During 1982, some of the more notable sightings included Oldsquaw, Tundra Swan, White-winged Scoter and Bald Eagle. Several rarer sightings included a Black Tern in May and a Caspian Tern in June. In addition, waterfowl surveys confirmed both the Canada Goose and Mallard nested at Lake Anna in the spring of 1982.

Four major bird surveys prior to 1984 (at least 70% coverage of lake and shoreline) involving both the local birding group and Virginia Power personnel have been performed at Lake Anna. These included three Christmas counts in the winters of 1980-1981, 1981-1982 and 1982-1983 and one Spring Breeding Bird count in May 1981. When total species and total number of birds observed in the three Christmas surveys were examined, the 1980 and 1981 counts appeared similar with 89 species numbering 8,734 birds in 1980 and 76 species numbering 8,925 birds in 1981. However, 1980 was a colder winter and waterfowl numbers or numbers of birds attracted to the lake itself were much higher in 1980 than in 1981. The sightings of large flocks of songbirds, particularly Blue Jay, American Robin and Cedar Waxwing in the 1981 survey accounted for the initial similarity in the two counts. In 1982, number of species (67) and number of birds (5,586) decreased. This decrease was probably due to the relatively mild winter experienced along the east coast of the country. It was reported by the Virginia Commission

of Game and Inland Fisheries the majority of ducks using the Atlantic Flyway in 1982 wintered in New York where waters remained ice-free. As in 1981, the majority of birds observed in the 1982 Christmas county were not classified as waterfowl.

Three species of waterfowl have been documented breeding at Lake Anna by Virginia Power biologists: Mallard, Canada Goose and Wood Duck. In 1983 and 1984 to further enhance the nesting and use of Lake Anna by waterfowl, Virginia Power, in concert with the Louisa County Chapter of Ducks Unlimited, installed 17 prefabricated wood duck nesting houses at various locations on the lake. Several of these houses were utilized during their first years of service. Continued use of these nesting boxes by Wood Duck is anticipated.

In summary, Lake Anna and its surrounding environment are utilized by a wide variety of waterfowl and other birds throughout the year. Waterfowl are usually most abundant at Lake Anna during the winter months, depending on severity of the season, when the elevated water temperatures caused by station operation may provide the only ice-free body of water in the area.

4.6 Summary of Biological Community and Ecosystem Analysis

An ecosystem is the community of interacting organisms and their nonliving environment in a specific area. The boundaries of aquatic ecosystems like Lake Anna tend to be well defined or circumscribed by the shores of the body of water. However, the allochthonous inputs of nutrients and particulate organics in Upper Lake Anna emphasize the somewhat open nature of the system. While an interrelated whole, the biological community of Lake Anna can be simplified in discussion by describing the compartments separately. These compartments will be referred to as trophic units although they are, in part, taxonomic. With the exception of the detritus element, the compartments exhibited in Figure 4.6-1 were extensively analyzed during the Lake Anna 316(a) Study. The ecosystem has varied dynamically and fundamentally since 1972. For example, the introduction of various species of fish since impoundment (e.g. threadfin shad, walleye and striped bass), the immigration of cryptomonad phytoplankton and the Asiatic clam in the early 1980's all have contributed to changes in the system. Consequently, intertrophic comparisons will generally be restricted to the 1984-85 data.

Compartment Descriptions

Primary Producers

There are three primary producer groups in Lake Anna: the aquatic macrophytes, the attached algae

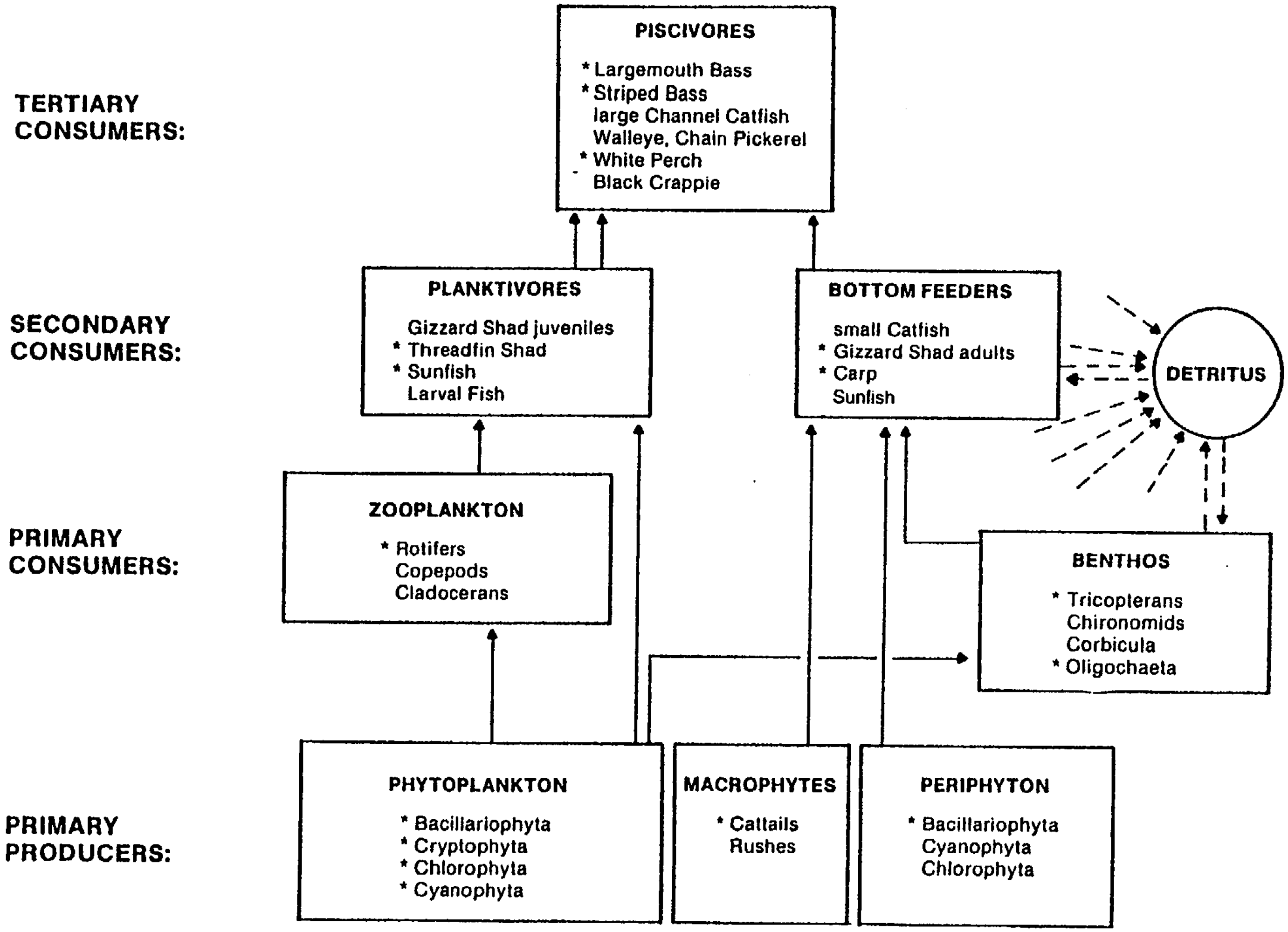

Figure 4.6-1. Tropic structure for the Lake Anna, Virginia aquatic community. The biomass-dominant or numerically-dominant elements in each compartment are starred.

(periphyton), and the free-floating algae (phytoplankton). The macrophytes and periphyton inhabit the littoral zone which includes the lake bottom from the shore out to several meters of water. The phytoplankton inhabit the limnetic zone or open water. Partly because of the instability of the littoral substrate, but more importantly because of the greater extent of the limnetic habitat, the phytoplankton are the leading primary producers in Lake Anna.

Phytoplankton Compartment

The dominant phytoplankters throughout Lake Anna in 1984-85 were the cryptomonads (Cryptophyta, Table 4.6-1) These were relatively new organisms to Lake Anna that arrived in the early 1980's. Green algae (Chlorophyta), diatoms (Bacillariophyta) and blue-greens (Cyanopyhyta) were of secondary importance in the community on a density basis. The community was seasonally variable with the cryptomonads and diatoms being more abundant during the cool months and the green algae and blue-greens dominating in the summer months. Of these divisions only the cryptomonads showed a clear preference for areas of the lake. They were more abundant in the Lower Lake.

Two measures of the condition of the phytoplankton community are algal cell density and algal biomass. Although cell density is useful for determining phytoplankton community structure, algal biomass is more informative when the phytoplankton are viewed as a food source. Phytoplankton biomass in the Lower Lake averaged

Table 4.6-1 Averaged densities of major biotic categories in Lake Anna adjusted to a $1 m^2$ area of lake bottom. Averages are based on reservoir data collected during 1984-85. The sample methods from which the estimates are derived are indicated with the trophic category.

Biotic-Trophic Category	Monthly Average (standard error)	Percent Importance of Dominant Groups			
Phytoplankton		Cryptophyta	Chlorophyta	Bacillariophyta	Cyanophyta
niskins	3,374,000,000 (332,800,000)	38.6	21.5	20.4	19.9
Zooplankton		Rotifera	Copepoda	Cladocera	
niskins	1,059,000 (108,800)	87.9	9.0	3.4	
Benthos		Trichoptera	Chironomidae	Corbicula	Oligochaeta
a. substrates	1,500 (201.3)	42.0	25.3	24.3	2.8
b. Ekmans	4,220 (404.6)	1.9	18.7	29.2	46.7
Planktivorous Fish		Sunfish	Gizzard Shad	Threadfin Shad	
rotenone	1.6	76.3	3.7	16.3	
Piscivorous Fish		White Perch	Largemouth Bass		
rotenone	.3	84.	9.7		

approximately one tenth that in the Upper Lake (150 mg/m^3 vs. 1400 mg/m^3) and the densities varied in a parallel fashion (1,827 vs. 5,703 cells/ml; Table 4.6-2). The Rt. 208 bridge site averaged only one-third as productive as the Upper Lake and so represents an intermediate biomass zone. Thus in the Lake Anna ecosystem, the Upper Lake and the Rt. 208 bridge area contain the largest primary producer food base. From below the Rt. 208 bridge down to the dam the base of the biomass pyramid is relatively small on a unit area basis. These differences in producer standing crop are germane to the distribution of consumer abundance in Lake Anna, particularly the zooplankton and benthic invertebrates which feed directly on the phytoplankton.

Periphyton and Macrophyte Compartments

The periphyton and aquatic macrophytes ecologically exploit resources similar to those of the phytoplankton. Consequently, they are similarly dependent on the dissolved nutrients and penetrating insolation. However, several characteristics of Lake Anna probably limit the occurrence of the periphyton and macrophytes much more than the nutrient or insolation regime. These aspects include a) the clear-cutting of the lake bottom and the removal of fallen trees from the shoreline, b) the lake's narrow littoral zone, c) the lake's unstable clay bottom, and d) for periphyton, the shortage of aquatic macrophytes due to the previous three factors. Consequently, attached autotrophs are relatively sparse in Lake Anna and do not contribute as

Table 4.6-2 Averaged densities of major biotic categories for three areas of Lake Anna. The sample method is indicated with the trophic category.

Trophic Category Units	Upper Lake	Mid Lake	Lower Lake
Phytoplankton niskins (no./ml)	5,703 (723.3) n=24	2,591 (274.4) n=24	1,827 (243.6) n=24
Zooplankton niskins (no./liter)	1,892 (205.3) n=23	828 (115.7) n=23	460 (62.6) n=23
Benthos a. substrates (no./.08m^2)	188 (43.2) n=10	80 (8.6) n=11	109 (11.7) n=11
b. Ekmans (no./.023m^2)	124 (21.2) n=9	111 (10.2) n=10	57 (7.1) n=10
Planktivorous Fish rotenone (no./ha)	29,471 (7,683.7) n=4	13,511 (6,987) n=2	6,100 (1,469.5) n=2
Piscivorous Fish rotenone (no./ha)	1,748 (477.9) n=4	5,909 (5143.5) n=2	504 (52.0) n=2

Note: Values from 1984-85 data, by area of lake.

much biomass and energy to the lake ecosystem as does the phytoplankton. Nonetheless, the periphyton organisms are sources of nutrition in lakes for littoral invertebrates (Jones 1984) and for the bottom feeding fishes (Fig. 4.6-1). Their biomass contribution is estimated to be 1005 mg/m^2 in the littoral zone. Macrophytes are important platforms for periphyton attachment and their beds are important refuges for small fishes and invertebrates. As Lake Anna matures the attached primary producers are expected to become more pervasive, particularly in the lower lake, and to become more important to their dependent organisms.

Zooplankton Compartment

Zooplankters occupy the second trophic level in Lake Anna. Rotifers are by far the leading group composing 88% of the 1984-85 community (Table 4.6-1). As a community zooplankton is strongly seasonal, achieving peak densities in the spring and occasionally in the autumn. Like the phytoplankton, the zooplankton exhibited a decreasing density gradient from the Upper Lake to the dam. Zooplankton compartment complexity (diversity) was also lower at the lower sampling stations.

Zooplankters' diet is largely phytoplanktonic (Conover and Mayzaud 1984) although some degree of selection occurs (Drenner et al. 1984). The down-lake decrease in zooplankton abundance is one expected consequence of this intertrophic connection. Zooplankton density should also fluctuate in response to phytoplankton community variation

between seasons (Canfield and Watkins 1984). In Lake Anna, the primary evidence of this was the positive correlation of rotifer population size with green algae density. It has been generally found that large zooplankters can reduce phytoplankton biomass (Pace 1984; Singer et al. 1984). Thus, as the zooplankters change in abundance it is expected they would in turn depress or release phytoplankton abundance. These patterns appear to some extent in Figure 4.6-2 where the plankton and benthos densities in the Lower Lake are plotted against time. The classical trend of a spring phytoplankton abundance peak succeeded by a zooplankton peak was found in only certain years (1974, 1985). In other years the spring/summer zooplankton maximum was apparently related to factors more influential than the phytoplankton density (see Section 4.2). This statistical uncoupling is possible when zooplankters shift to assimilating organic debris and bacteria during periods of low phytoplankton density.

Benthic Compartment

The benthos in Lake Anna are represented by two compositionally unique communities. Where the substrate is complex, as in the vicinity of beaver brush piles, caddisflies (Trichoptera) are expected to be dominant. The subdominants are the midges (Chironomidae) and the Asiatic clam (*Corbicula fluminea*). Where the substrate is uniform the burrowing aquatic worms (Oligochaeta) are the expected dominants instead while the subdominants are unchanged (see Section 4.3).

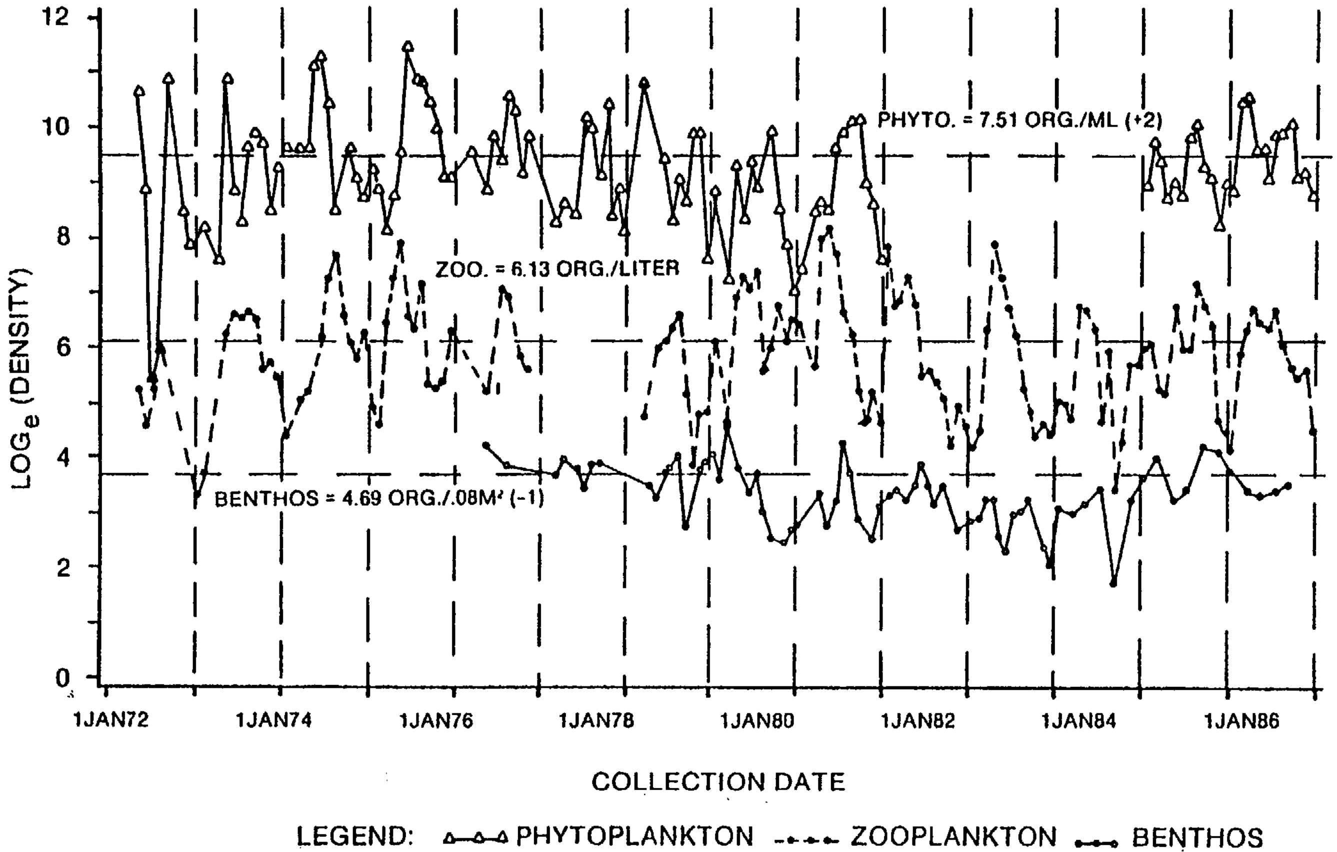

Figure 4.6-2. Monthly density of the three lowest trophic categories for 1972-1985. The points are averages over Burrus Point to Dam stations in Lower Lake Anna, Virginia. For clarity the phytoplankton density line has been elevated 2 units and the benthic line lower 1 unit. The horizontal lines are 1984-85 averages.

The benthos obtain energy from the detritus, phytoplankton, and zooplankton compartments. This variety of food choices leads to complex diets among the taxa. Subgroups like the aquatic worms and burrowing mayflys preferentially feed on the detritus. The Asiatic clams are largely herbivorous feeding on the phytoplankton, while dragonflys and the most abundant midges are predaceous. Others like the caddisflies and some midges are facultative feeders.

In 1984-85 the benthic community was generally more abundant in the Upper Lake where the plankton communities were more dense (Table 4.6-2).

Fish Compartments

The fish community in Lake Anna subdivides into at least three trophic compartments: 1) planktivore, 2) bottom feeder and 3) carnivore.

The majority of the fish standing crop is contained in the planktivore compartment which includes the shads and sunfish, the primary forage fishes in Lake Anna. Both threadfin shad, which are planktivorous throughout their lives, and gizzard shad, which are plankton feeders primarily as larvae and juveniles, function at this trophic level (Drenner et al. 1984). These herbivores are accompanied by the sunfish, the most numerous group in this category (Table 4.6-1).

The bottom feeder compartment is primarily a behavioral compartment dominated by gizzard shad adults

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which are omnivorous, as are carp and small catfish. Their energy source includes organic detritus, small crustaceans, and worms which they encounter while browsing the sediments. With increasing size, channel catfish tend to become piscivorous.

The third fish compartment is the piscivores, the highest trophic category (Fig. 4.6-1). Their food is almost exclusively fish (Eddy and Underhill 1984). Although rotenone estimates show the small-sized white perch to be dominant in this compartment (Table 4.6-1), the larger piscivores are largely underestimated by rotenone sampling. Striped bass, largemouth bass, and possibly walleye are important piscivores in terms of their biomass and based on the amount of fish they consume (see Section 4.4).

The occurrence of a fish species in a trophic compartment is based partly on its life stage. For example, most fish larvae feed on phytoplankton and zooplankton (Siefert 1972). When these larvae reach juvenile or small adult size, many will feed on larger zooplankton and benthic invertebrates. As large adults they will consume fish. This situation causes the boundaries between the fish ecosystem compartments to be less defined than for the other compartments.

Pyramid of Numbers

As mentioned above, the Lake Anna aquatic community has undergone extensive alterations over its 14 year history. However, the present community appears to have a

trophic structure typical of lentic systems. For comparative purposes, the data were put on the same unit basis using a benthic sample focal point. Benthic samples were usually collected in 2m of water. Thus a $1m^2$ segment of the lake bottom and the $2m^3$ volume of water over it were spatial units to which abundance estimates were standardized for comparison. The estimates of fish densities were obtained from the 1984-85 rotenone counts divided by the areas of the rotenoned coves. The resulting density pyramid is presented in Figure 4.6-3 and in Table 4.6-1. It exhibits the usual relationships for ecosystems (McNaughton and Wolf 1979).

On one square meter of lake bottom within the littoral zone, the benthic community numbers in the thousands. Because much of the lake bottom is structurally simple, the Ekman estimate of 4,220 benthic organisms is most applicable to the general lake bottom. This group has available to it for filter feeding just over a million zooplankters. These organisms in turn have in excess of 3.3 billion phytoplankton cells from which to select during feeding. The plankton are also food for 1.6 planktivorous fish, most of which are sunfish. The number 1.6 is probably high because it is derived from an extremely large number of small bluegill collected, primarily in the upper arms of the lake, in the August 1984-85 rotenone samples. Finally, there are approximately 0.3 piscivores over the $1m^2$ benthic community and in pursuit of the planktivorous fish.

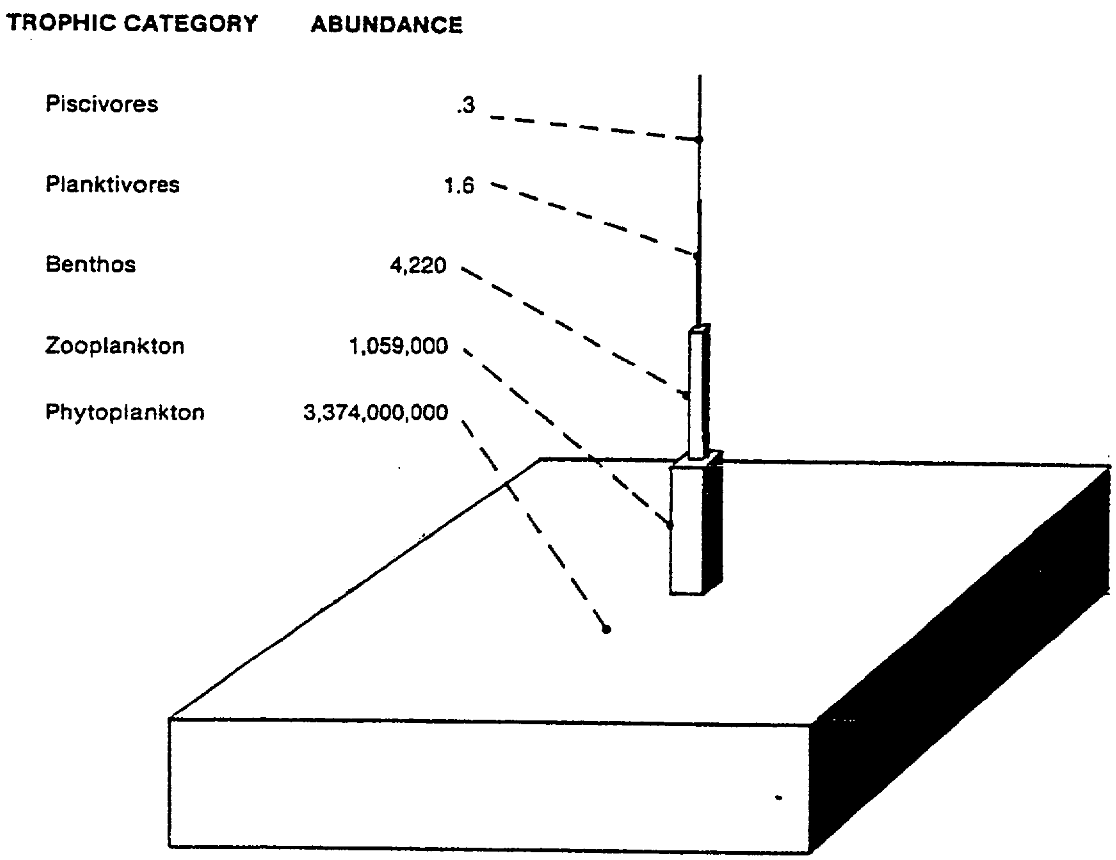

Figure 4.6-3. Pyramid of numbers for the Lake Anna trophic compartments. The values are the numbers of organisms in a two cubic meter water column over one square meter of lake bottom.

These density estimates for trophic compartments apply best to the Lake Anna shallows for which they were developed. At greater depths, the plankton densities would be greater, the benthic densities would be lower and the other compartment quantities would also vary. Nevertheless, the pyramid of numbers summarizes the tropic data collected during 1984-1985 at Lake Anna. It also forms a basis on which the biological compartments at Lake Anna can be compared.

Whereas one of the hypothesized impacts of power plant cooling on lakes have been increased eutrophication, this has not occurred at Lake Anna. If anything, the trend of high productivity typically shown by newly impounded lakes has reversed markedly so that the lower lake shows evidence of being somewhat oligotrophic. This could be in response to a power plant effect of the nutrient cycle of the lake. Nutrients, especially phosphorus, typically are regenerated in lake waters during the period of summer stratification when deepwater anoxia promotes dissolution of nutrients from the sediments. The enhanced oxygenation of the deeper lake waters in summer probably has reduced the area of bottom sediment under anoxic conditions and thus has reduced flux of sediment-bound nutrients to the water column. Although speculative at this point, the data collected in this study supports such a mechanism.

5. PHYSICAL AND CHEMICAL ASSESSMENT OF THE NORTH ANNA RIVER

This section summarizes the hydrological characteristics of the North Anna River and compares it with the South Anna River, a river of similar size with non-regulated flows. It describes the water quality data base since 1981 (which includes metals and nutrients for the study period) and hydrothermal characteristics for pre-operational and operational periods.

5.1 Hydrological Characteristics

The North Anna River (Fig. 5.1-1) originates in Albemarle and Orange Counties in the upper Piedmont Physiographic Province of Virginia and is part of the York River basin. It drains an area of 1,142 km^2 (441 sq. miles) from the headwaters to the United States Geological Survey (U.S.G.S.) gauging station near Doswell. Mean daily discharge rates during the 1972-1985 period ranged from 1.6 to 272 $m^3/5$ (40 to 15,700 cfs). Since 1972, North Anna River flows have been augmented by a minimum release of 1.1 $m^3/5$ (40 cfs) Lake Anna. Historically, the minimum and maximum daily flow rates were 0.028 $m^3/5$ (1.0 cfs) recorded from September 30 to October 2, 1932 and 702 $m^3/5$ (24,800 cfs) recorded on August 21, 1969. Approximately 16 km (10 miles) downstream from Doswell, the South Anna River joins the North Anna River to form the Pamunkey River. The Pamunkey River ultimately joins the Mattaponi River at West Point to form the York River which flows southeastward into the Chesapeake Bay.

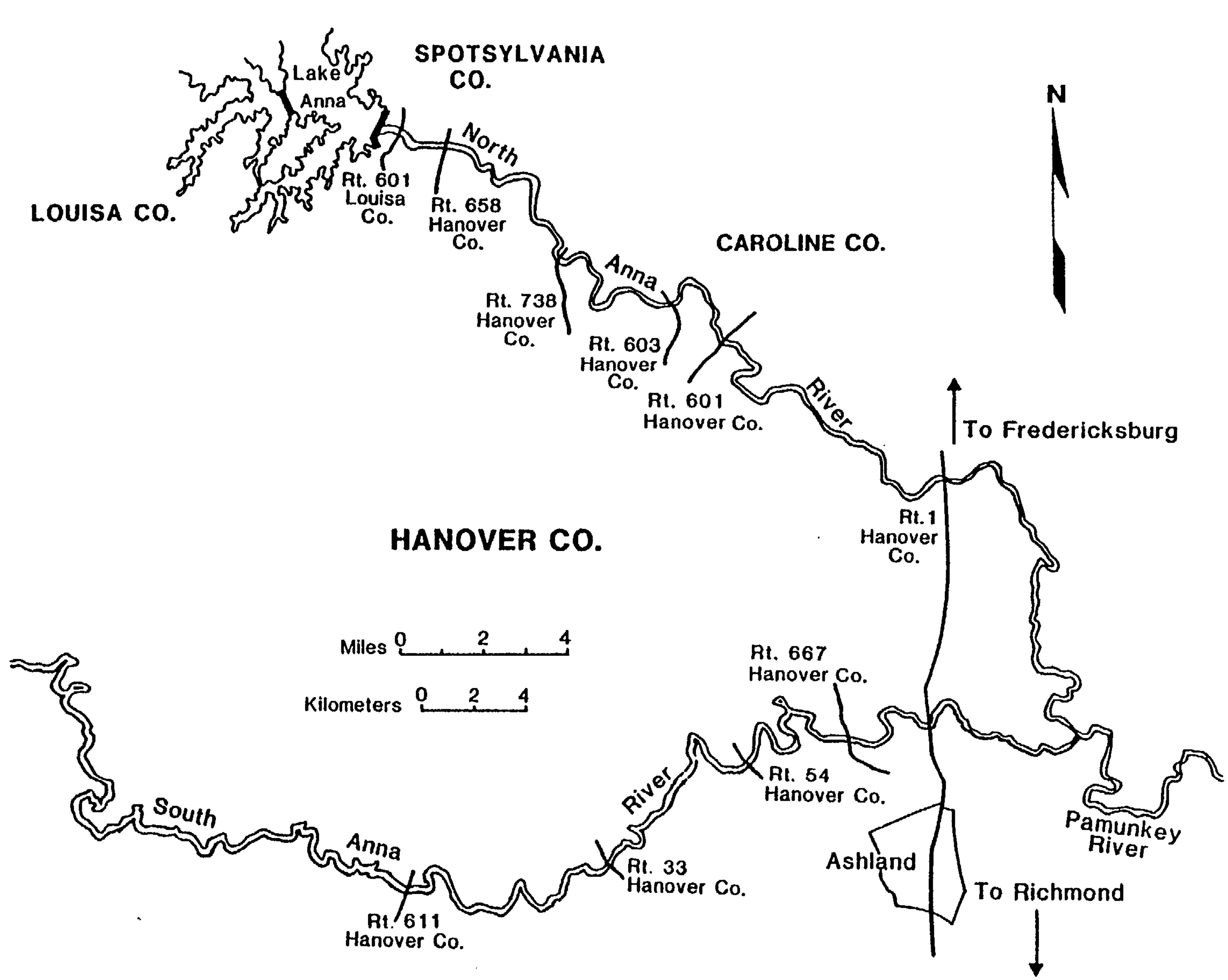

Figure 5.1-1 Location of the North Anna River and South Anna River in relation to Lake Anna, Virginia

Physical and chemical parameters at four sites on the North Anna River between the Lake Anna dam and U.S. Rt. 1 (Fig. 5.1-1) were sampled consistently from 1981-1985. Proceeding downstream from the dam, these stations are located at the bridge crossings of Rt. 601 (Louisa County), Rt. 658, Rt. 601 and Rt. 1 (all in Hanover County). It should be noted that hereafter throughout this report Rt. 601 Louisa County and Rt. 601 Hanover County will be designated Rt. 601L and Rt. 601H, respectively.

Endeco recording thermographs have been in place measuring hourly water temperatures on the North Anna River at Rt. 601L and at Rt. 603 since August 1975. This section of the river (approximately 36 river kilometers from the dam to Rt. 1) has an overall stream gradient of 1.1 m/km (Fig. 6.3). The gradient is greatest (approximately 9.0 m/km) at the geologic fall line of the river, about half-way between Rt. 601H and Rt. 1, and lowest (approximately 0.3 m/km) near the Lake Anna dam. Stream gradient as related to smallmouth bass is discussed in more detail in Section 6.3.

Samples also were collected from one site on the South Anna River for comparison purposes at the bridge crossing of Rt. 667 (Hanover County). This station is located downstream from the geologic fall line of the South Anna River which is between Rt. 33 and Rt. 54 (Fig. 6.3). A U.S.G.S. gauging station is located at Rt. 54 and measures flows from 1,020 km^2 (394 sq. miles) of the South Anna River watershed. Daily mean discharge rates for the period of 1984-1985 ranged from 0.9 to 185 $m^3/5$ (31 to 6520 cfs). The

historical minimum and maximum for the period of record were 0.033 m^3/5 (0.1 cfs) on September 12, 1966 and 484 m^3/5 (17,100 cfs) on August 23, 1969, respectively.

Hydrothermal Characteristics

The in-situ temperature recorders in the section of the North Anna River immediately downstream from the reservoir provided the most reliable long-term information about the hydrothermal characteristics (Table 5.2-1). The mean temperatures calculated from daily maximum temperatures are listed by month. For the pre-operational period (through March 1978), the maximum monthly mean was calculated for Rt. 601L for July 1977, 29.1°C; the maximum hourly pre-operation temperature recorded was 31.9°C (July 21,1977) at the same location. For the same hour (1800), the temperature at Rt. 603 was 29.9°C, a difference of 2°C. The highest monthly mean temperature for the operational period was 30.8°C at Rt. 601L which was calculated for the month of August 1983. The maximum hourly temperature occurred on August 8, 1983, 32.7°C. Simultaneously, a temperature of 29.2°C was recorded downstream at Rt. 603, or a difference of 3.5°C. Hourly temperatures at Rt. 601L greater than 32°C have occurred on five different days during the operational period (Table 5.2-2) and downstream temperatures measured at Rt. 603 ranged from 2-4°C cooler on those days. Since absolute water temperatures are determined by so many ambient variables, the warmer temperatures recorded in 1983 cannot be attributed solely to

= 89.4°F

= 90.9°F

Table 5.2-1. Monthly mean water temperatures (C) calculated from ENDECO station daily maxima in the North Anna River, Virginia

YEAR	MONTH	NARIV601	NARIV603
1975	6	25.6	23.4
	7	25.6	.
	8	28.8	26.6
	9	23.0	21.5
	10	19.3	18.1
	11	14.6	13.1
	12	8.4	7.3
1976	1	4.3	3.7
	2	5.7	6.2
	3	10.3	10.6
	4	15.1	15.3
	5	18.8	18.2
	6	24.2	23.6
	7	26.9	25.8
	8	27.1	25.1
	9	24.1	21.5
	10	.	15.7
	11	8.9	7.3
	12	5.5	4.5
1977	1	2.4	1.3
	2	4.1	4.0
	3	9.7	10.4
	4	16.6	16.6
	5	21.7	21.0
	6	24.4	23.4
	7	29.1	27.8
	8	27.9	26.8
	9	25.3	23.9
	10	17.7	15.1
	11	13.5	11.7
	12	7.3	5.2
1978	1	3.8	2.8
	2	3.2	2.7
	3	5.9	7.6
	4	13.6	14.9
	5	17.9	15.0
	6	24.9	.
	7	28.2	27.1
	8	28.7	27.7
	9	25.7	21.7
	10	20.3	16.0
	11	16.2	12.3
	12	11.2	8.5

Table 5.2-1 (continued).

YEAR	MONTH	NARIV601	NARIV603
1979	1	7.0	6.0
	2	3.8	2.9
	3	9.3	9.4
	4	14.2	14.7
	5	20.1	20.1
	6	24.7	22.8
	7	28.2	25.7
	8	28.8	26.3
	9	27.1	23.3
	10	18.8	17.8
	11	14.3	13.3
	12	8.6	7.9
1980	1	5.3	4.8
	2	5.2	4.3
	3	8.3	8.3
	4	15.0	15.2
	5	21.3	21.5
	6	25.4	23.8
	7	29.2	27.6
	8	30.1	27.3
	9	27.8	24.6
	10	21.4	16.6
	11	14.2	10.2
	12	9.5	6.1
1981	1	5.8	2.0
	2	7.3	5.6
	3	10.4	8.9
	4	16.8	17.2
	5	21.9	19.8
	6	28.1	21.7
	7	29.4	27.6
	8	29.1	26.0
	9	26.8	22.4
	10	20.4	15.8
	11	15.6	11.2
	12	10.4	5.8

Table 5.2-1 (continued).

YEAR	MONTH	NARIV601	NARIV603
1982	1	6.5	3.0
	2	8.5	7.8
	3	10.4	10.2
	4	14.1	14.4
	5	21.5	20.9
	6	23.9	23.2
	7	28.4	26.9
	8	27.1	25.3
	9	24.8	22.1
	10	19.9	16.6
	11	14.9	12.3
	12	11.6	10.1
1983	1	7.7	5.4
	2	7.0	6.4
	3	10.9	10.5
	4	13.4	12.6
	5	16.2	.
	6	27.0	24.1
	7	30.5	27.9
	8	30.8	27.6
	9	28.1	26.8
	10	21.8	15.3
	11	16.2	12.3
	12	11.8	9.8
1984	1	6.8	4.9
	2	8.2	7.5
	3	11.4	10.7
	4	14.6	14.6
	5	16.1	20.3
	6	24.6	25.5
	7	27.1	26.3
	8	28.0	25.8
	9	24.4	21.6
	10	20.5	18.0
	11	16.0	11.5
	12	13.6	11.1
1985	1	7.4	.
	2	8.1	.
	3	13.0	12.8
	4	18.6	18.0
	5	24.2	.
	6	27.4	24.7
	7	29.3	26.1
	8	28.8	25.9
	9	27.5	24.0
	10	22.8	19.2
	11	17.6	16.6
	12	10.8	8.2

Table 5.2-2. Listing of Rt. 601L ENDECO temperatures exceeding 32.0° Celsius.

Date	Time	NARIV601
800809	1800	32.1
830721	1700	32.4
	1800	32.2
	1900	32.2
	2000	32.3
830807	1800	32.4
	1900	32.3
	2000	32.4
	2100	32.1
830808	1700	32.2
	1800	32.6
	1900	32.7
	2000	32.6
	2100	32.4
	2200	32.1
830809	1600	32.3
	1700	32.4
	1800	32.2
	1900	32.4

power station influence. The reservoir has massive heat storage potential that would characteristically affect the river immediately downstream from the dam, and historically this has been observed (Fig. 5.2-1). There were considerable diurnal fluctuations and definite seasonal patterns in temperature differences between the two river locations (Fig. 5.2-2). The primary point to be noticed in Figure 5.2-2 is the pre-operational summer temperature difference of 1-2°C in which the upper station, closer to the dam, displayed warmer temperatures from the reservoir discharge.

5.3 Water Chemistry

The water quality of the North Anna River directly below Lake Anna is strongly influenced by the epilimnetic release from the reservoir. The buffering influence of the reservoir stabilizes conditions downstream resulting in reduced turbidity and pH variability and lower alkalinities. Since 1981, temperature, dissolved oxygen, pH, alkalinity and turbidity have been monitored at the four sites on the North Anna River and at the one site on the South Anna River (Appendix B-Table 1). Some obvious differences between these two rivers include the reservoir - regulated minimum flow and the more densely forested shoreline of the North Anna River compared with non-regulated flows and more intense agricultural use along the South Anna River. Since 1981, turbidity ranged from 0.6-25.0 NTUs (averaging 3.0 NTUs) on the North Anna River whereas the South Anna River

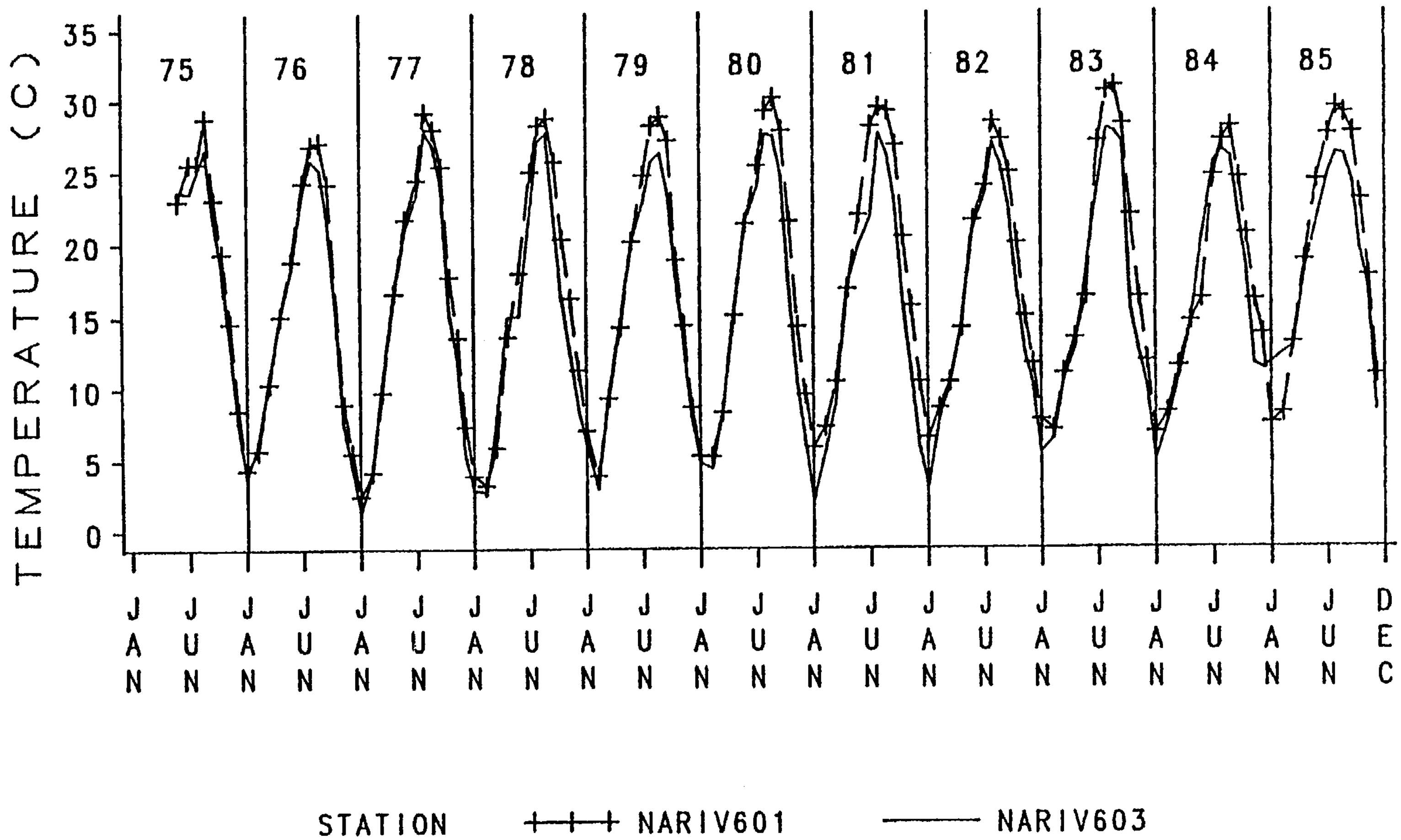

Figure 5.2-1. Monthly mean water temperatures (C) calculated from daily maximum temperatures in the North Anna River, Virginia (stations NARIV601 and NARIV603 only).

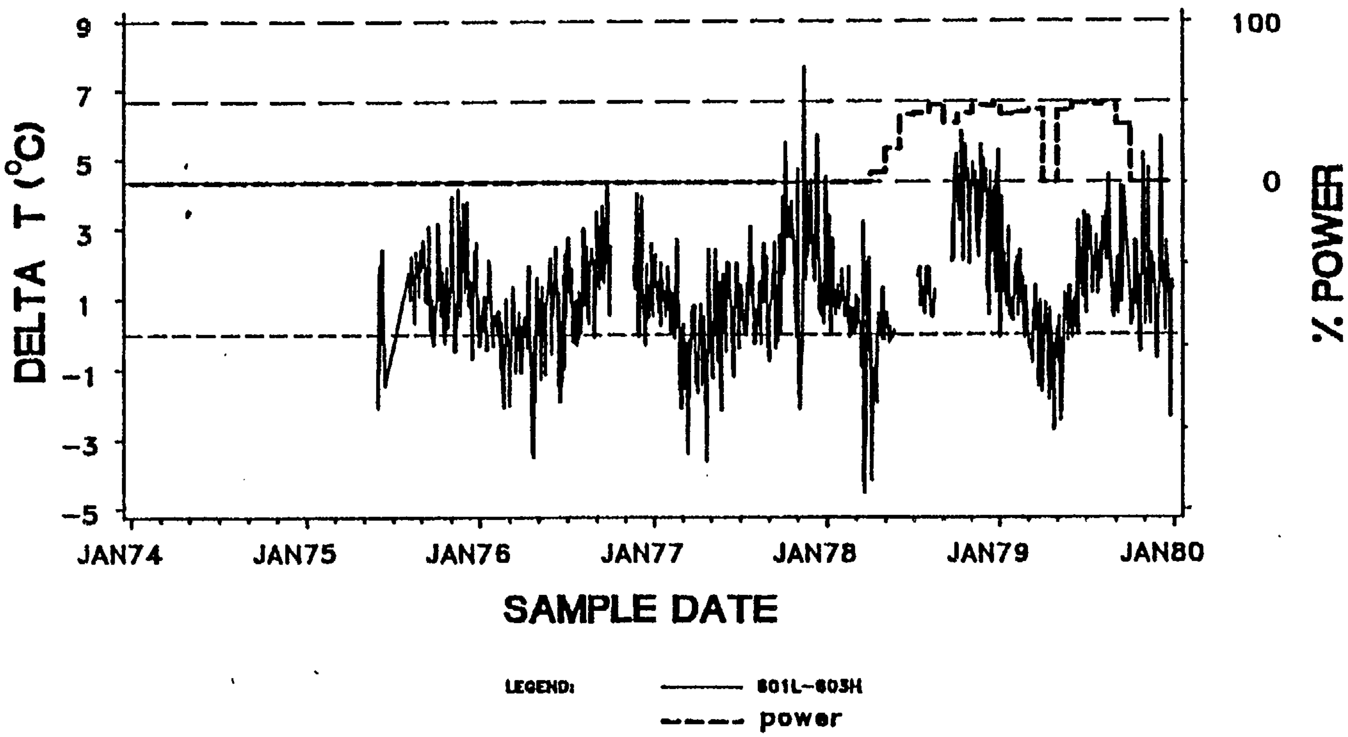

Figure 5.2-2. North Anna River temperature differences (delta) and percent power. Differences are based on the temperature at the Rt. 601L bridge minus that measured at the Rt. 603H bridge.

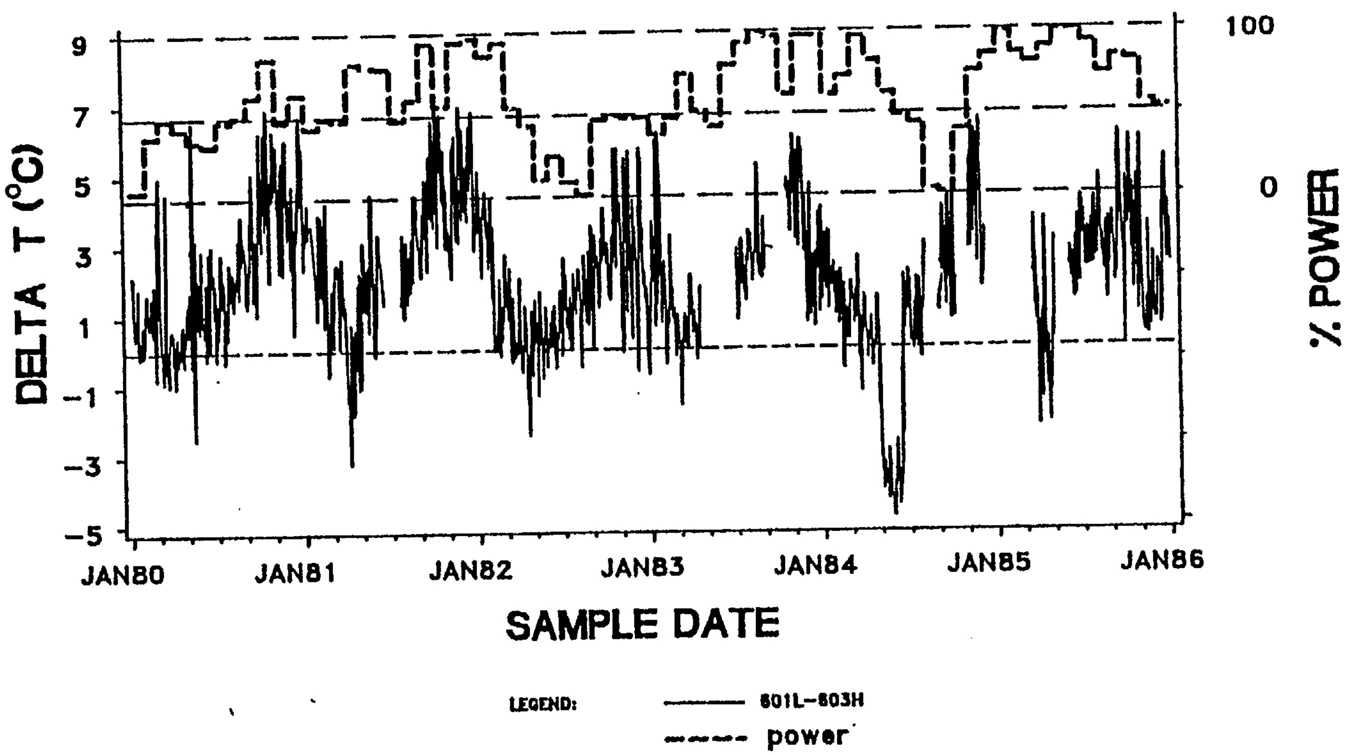

Figure 5.2-2. continued.

ranged from 1.3-100 NTUs (averaging 9.5 NTUs). The maximums occurred in summer (July), probably as a result of high intensity/short duration thunderstorms which can have a significant impact on soil erosion. Minimums occurred in the fall (October), typically the driest season in this region of the country.

The mean pH of the North Anna River of 7.0 (ranging from 6.4 to 7.5) was lower than the mean of 7.4 for the South Anna River (ranging from 6.7 to 8.8). This was also evident for alkalinity, which averaged 11.1 and ranged from 5.7 to 29.1 mg/l (as $CaCO_3$) for the North Anna River compared with a mean of 29.1 and range of 10.9 - 38.1 mg/l (as $CaCO_3$) for the South Anna. Alkalinity increased with distance downstream on the North Anna River according to the station means for the period from 1981-1985. Maximum values were measured during summer months and minimums were during the winter on both rivers.

There did not appear to be any substantial differences in dissolved oxygen concentrations between the two rivers. Since 1981, the North Anna River ranged from 6.7 to 13.8 mg/l (averaging 9.6 mg/l for the period) and increased with distance downstream. The South Anna River ranged from 7.0 to 14.1 and averaged 10.0 mg/l. The months of July and August generally reflected the minimum monthly mean oxygen concentrations in the North Anna River (7.9 and 7.8 mg/l, respectively). The months of June, July and August were similar overall on the South Anna River (averaging 8.5, 8.6 and 8.7 mg/l, respectively, for the

period from 1981-1985). Both rivers appeared to be well-saturated with dissolved oxygen during the summer months, averaging between 90-100%.

Nutrient and dissolved metals samples were collected (47 total samples) from the North Anna River water quality sites in 1984 and 1985. Nitrogen (in the form of ammonia and nitrate) was in higher concentration than phosphorous (measured as ortho and total phosphate). Both of the nitrogen forms were detected in almost every sample (96 and 100% of the samples, respectively). The maximum ammonia value recorded was 0.10 mg/l at Rt. 601 - Louisa County in March 1984. This station averaged 0.06 mg/l for the 12 sampling periods between 1984 and 1985. The two lower downstream stations (Rt. 601 and Rt. 1, Hanover) averaged 0.03 mg/l. The highest mean monthly value, averaging all the North Anna River stations, occurred in December. The maximum nitrate nitrogen value recorded was 0.29 mg/l at Rt. 601, Louisa in April 1985. Station means ranged from 0.18 to 0.11 mg/l, decreasing (as ammonia did) with distance downstream from Lake Anna.

As mentioned previously, phosphorus concentrations were much less than nitrogen. Orthophosphate was detected in about 10% of the samples collected, whereas total phosphate was found in about 30% of the samples. Total phosphate was detected in all samples collected in March, September and December 1984 with values ranging from 0.01-0.04 mg/l. In April 1985 at Rt. 601, Hanover County, a high value of 0.39 mg/l was measured. Orthophosphate was

recorded at all the stations in December 1984 (0.02-0.04 mg/l), and at Rt. 601, Hanover County in April 1985 (0.03 mg/l).

Dissolved iron was the most abundant metal measured in the North Anna River and was detected in every sample collected from 1984-1985. The values ranged from 0.01 to 0.61 mg/l (the maximum value occurred at Rt. 658 in May 1985). The river station nearest the dam averaged about 30% lower than the three other river stations farther downstream (0.10 mg/l); the highest station mean occurred at Rt. 601 in Hanover County (0.37 mg/l). A seasonal trend was not clearly evident although May, June and December averaged higher than other months.

The next most abundant metal in occurrence was zinc, detected in 72% of the samples that were collected. Measured concentrations were consistently at or below 0.03 mg/l and trends were not readily apparent. The maximum zinc value (0.08 mg/l) occurred at Rt. 601L in April 1985. The only detectable levels of copper (0.04 mg/l) and lead (0.15 mg/l) occurred in this same sample but these levels did not appear to be related to concentrations in the reservoir.

6. BIOLOGICAL ASSESSMENT OF THE NORTH ANNA RIVER

A stream is a product of its watershed-a sensitive reflection of the basin and all its activities. Most streams experience a downstream succession of organic input and production, with riparian vegetation contributing leaves and other plant parts, which, along with materials washed from the watershed, provide a main source of energy and carbon. Where streamside shade reduces light penetration and inhibits primary production, respiration of the aquatic communities generally exceeds the rate of primary production. Here organisms are adapted to shredding and collecting coarse particulate matter (e.g. leaves). Where there is less tree canopy and less shading, there is more primary production; particles of detritus become smaller and smaller and the benthic organisms collect and graze on finer particulates and periphyton. Stream communities in each reach fail to use all available nutrients and organic resources; the extra nutrients and organic resources "leak" downstream and link the successive stream communities.

Downstream succession of the stream ecosystem may be interrupted by impoundments, such as Lake Anna. Lake Anna collects suspended solids delivered by the North Anna River and Pamunkey Creek, precipitates dissolved solids, assimilates nutrients through primary production, and alters the temperature and dissolved oxygen as the waters enter the reservoir and are stored. The quality of the water entering

a reservoir, the design and use of the reservoir (e.g. cooling, flood control), design of the spillway, depth of the discharge, and the rate of water exchange (hydraulic residence time), all influence downstream water quality and the dynamics of the aquatic communities. Reservoirs with mainly surface discharges, such as Lake Anna, generally stabilize downstream flows and temperatures and lower turbidity, thus permitting better light penetration, less sedimentation, improved periphyton production, and increased winter temperatures that support longer growing seasons. The more stable downstream discharges stabilize the substrates for increased benthic production. Stable substrates in the clearer waters with better light penetration increase epilithic algae and macrophyte growth, and macrophytes can become established that trap detritus and offer shelter and food for invertebrates and fish.

Although the North Anna River carries the effects of impoundment some distance downstream, the lotic ecosystem gradually reverts to the sequence of downstream succession begun in the headwaters. Downstream of the dam, the stream still floods but flood and drought flows are moderated somewhat by the reservoir storage. Many of the nutrients that enter Lake Anna have become assimilated by lentic organisms that are then discharged as food materials for downstream river organisms. Vast amounts of zooplankton, phytoplankton, and drifting invertebrates spill over from Lake Anna and nourish the aquatic organisms downstream. The stream further benefits from the leaves and other organic

materials produced by the dense riparian vegetation of the North Anna River.

Virginia Power investigations have examined various trophic levels of the aquatic communities of the North Anna River below the impoundment. These studies related the natural stream ecosystem to Lake Anna as it is used for power production. Periphyton was studied as a measure of primary production, since growth of periphyton not only shows the utilization of nutrients coming from the lake but also is an important measure of the stream's basic productivity. Macrobenthic communities were followed through seasonal changes and through their relation to the distribution of bottom materials. Fish populations were examined along with stream habitat, with special attention given to the distribution of the smallmouth bass and factors possibly limiting its distribution. Ichthyoplankton were collected to examine the seasonal patterns of fish reproduction.

6.1 Periphyton

Introduction and Information Base

The producers that dominate the North Anna River are quite different from those of Lake Anna. In the river the habitat includes mainly shallow water with abundant rock substrate on the river margins and in riffle zones, and numerous downed trees in the water. This habitat results in a well developed community called the periphyton which is composed of single-celled or filamentous algae species that are attached to benthic or macrophytic surfaces. Because of the quality and abundance of benthic surfaces the periphyton or attached algae are the most important producers in the river. The riverine phytoplankton community is almost nil and the aquatic macrophytes occur only in the infrequent backwater shallows.

The North Anna River periphyton community was sampled monthly in the vicinity of the Rt. 601 Louisa and Rt. 1 bridges over the 1984-85 periods (Appendix B-Primary Producers - Table 2). Algae were collected on glass slides held in periphytometers that were floated in the river for approximately four weeks. After August 1984, styrofoam pads were added to the periphytometers to enable them to float at the water's surface. In most months two periphytometers were collected at each station and two slides from each periphytometer were analyzed for relative abundance of the taxa present. Thus, four replicates were planned for each station-month collection. However, reductions in the number of replicates occurred due to accidental loss or vandalism

of the periphytometers. Gaps in the monthly collection data are due primarily to high water which prevented collection. After collection and preservation the periphyton were identified to the generic level and estimates of relative abundance were made based on microscope counts. Dr. Barry H. Rosen (Virginia Commonwealth University) analyzed part of the samples.

The river periphyton showed patterns of community composition similar to the lake periphyton. In the two years of data collection, the diatoms (Bacillariophyta) dominated (exceeded 50% relative density) the community in the North Anna River at the sample sites in nearly all seasons (Fig. 6.1-1, and-2). Fluctuations in diatom relative abundance were almost exclusively due to the altered prominence of the blue-green algae (Cyanophyta) or, secondarily, of the green algae (Chlorophyta). The remaining periphyton divisions occurred with low relative density at the river sites.

From March 1984 through December 1985 the periphyton communities at the two stations were similar. Diatoms dominated in all but three months in 1984. They became less than dominant at Rt. 601 Louisa in April and June when first the green algae and next the blue-green algae became abundant (Fig. 6.1-1). At Rt. 1 the diatoms shared dominance in March with the green algae and in September with the blue-green algae (Fig. 6.1-2). Since December 1984 these secondary algal divisions have been of low relative abundance with one exception. In April 1985

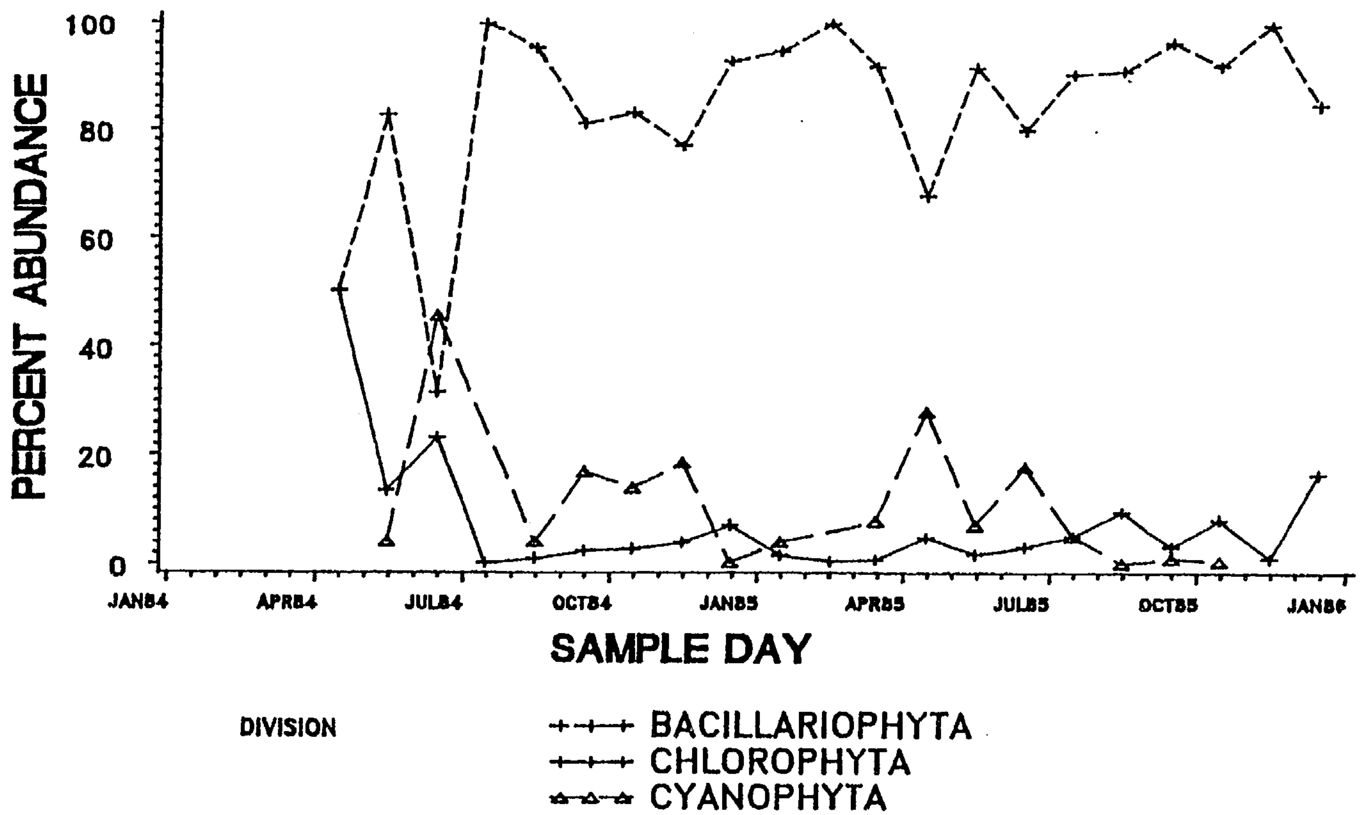

Figure 6.1—1. Relative abundance of periphyton in the North Anna River at the Route 601 Louisa bridge.

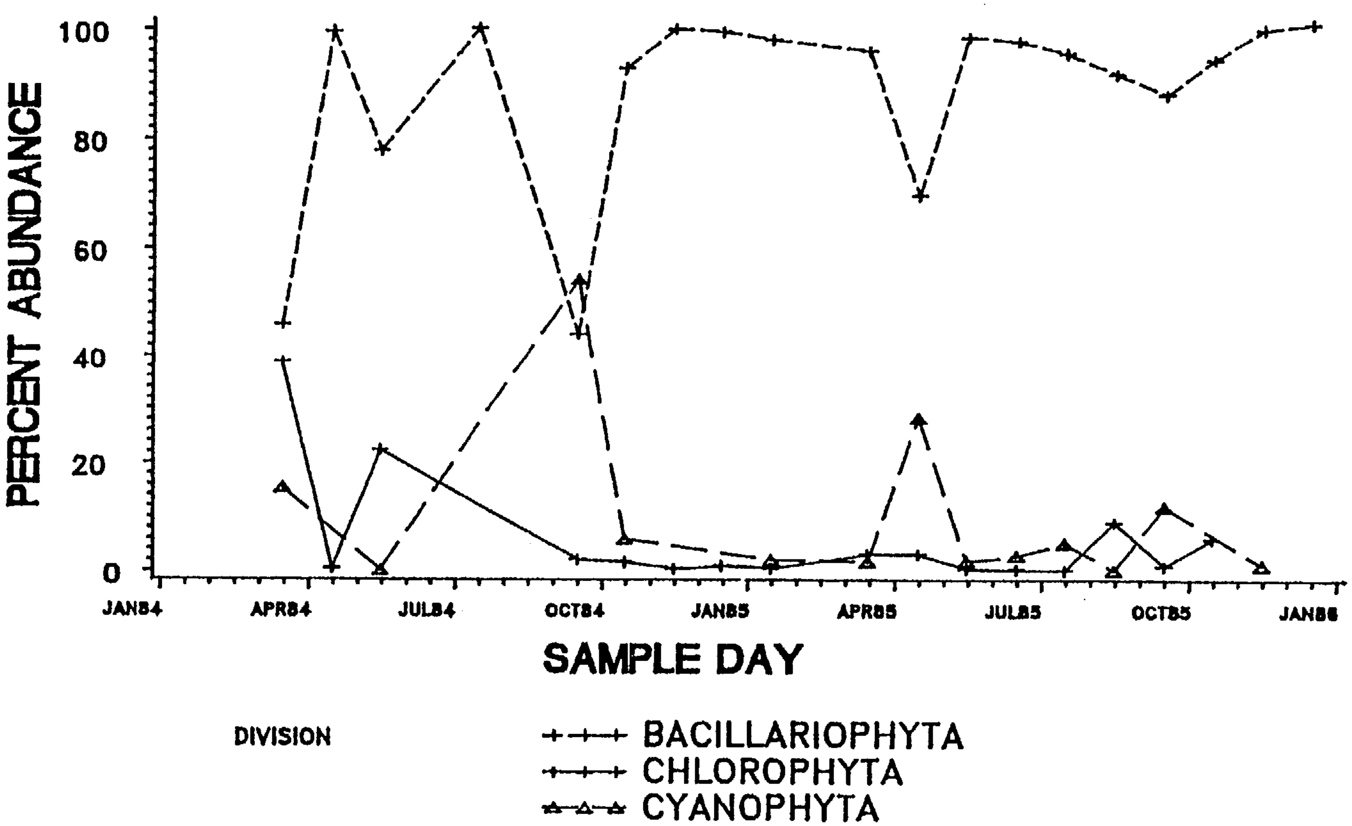

Figure 6.1—2. Relative abundance of periphyton in the North Anna River at the Route 1 bridge.

the blue-green algae reached a relative density of 28% at both stations. Their elevated relative abundance continued through a longer period at the Rt. 601 Louisa bridge crossing than at Rt. 1.

In the river, Achnanthes sp. was nearly always the most abundant diatom. Synedra sp., Navicula sp., and Cocconeis sp. (which was not found in any collections from Lake Anna) were each occasionally codominant with Achnanthes. Of lower relative density were the diatom genera Eunotia, Gomphonema, Tabellaria, Cymbella, and Fragilaria. As in the lake, green algae were occasionally abundant and included Stigeoclonium sp. in the rapids habitat of Rt. 601 Louisa only, and Ulothrix sp., a Rt. 1 spring adjunct. Green algae reached more than 20% relative density at Rt. 1 in March and May of 1984, and more than 14% at Rt. 601 Louisa in April, May and June of 1984. They did not exceed a relative density of 10% in any other month except in December 1985 at Rt. 1. Finally, blue-green algae, exhibited moderate relative abundance changes at the river sites. These changes were not strongly synchronous with station operation variables such as power level and percent operation of circulating water pumps.

Historical records on the North Anna River periphyton are available for 1976 (Simmons 1977). In that year the blue-green algae also peaked in density in the summer season. Diatoms were rich and varied in 1976 including these prominent genera: Navicula, Tabellaria, Synedra and Fragilaria. The first two were also important

in 1984. At various river sites Gomphonema, Amphora, Cymbella and Pinnularia were important. Of the green algae commonly found in 1984-85, only Hyalotheca was abundant at the 1976 sample stations.

Complete similarity between the annual periphyton communities was not expected. Periphyton composition is extremely patchy in both a spatial and temporal sense (Jones 1984). This is evident when comparing the North Anna River data for 1984 and 1985. Between the two years a total of 30 genera (43%) found in 1984 did not appear in the 1985 samples and another 17 (43%) appeared only in 1985. However, with only five exceptions these genera were uncommon; they occurred in less than three sample months. Another factor that would decrease the degree of historical:1984-85 correspondence is the historically higher concentrations of nutrients in the river water (Bothwell 1985). During the earlier sample years the periphyton should at least have been more luxuriant and possibly was composed of the more eutrophic forms.

Assessment and Summary

During the period June-October 1984 the station power level was less than 50% and was off at times during August and September of that period. In 1985 the station power level exceeded 50%. Consequently, any station effects should appear in a comparison of the June-October or August-September periods from 1984 to 1985. The similarities in river periphyton composition, particularly

in the degree of diatom dominance between 1984 and 1985, suggest the periphyton community composition had a 1984-85 pattern that was different from the pattern of station operation.

6.2 Benthic Macroinvertebrates

Introduction

Benthic macroinvertebrates (including shellfish) are those organisms living on or in the bottom substrates. They may exist beneath, within and above the sediment layers in burrows, interstitial spaces and on submerged twigs, stems and root masses, respectively. As processors and regulators of energy flow, they function to both directly and indirectly cycle nutrients and to effect their translocation or export (Resh and Rosenburg 1984). As reservoirs of stored energy themselves, they act as an intermediate "sink" for much of the energy that is continuously flowing from the primary base (periphyton and allochthonous input) to the gamefishes (see Fig. 4-1). Within this "sink", they are of differential importance to the higher secondary consumers as some (caddisflies, midges, worms) are utilized more than others (Asiatic clams, snails).

An impoundment can have varied influences on downstream biota. A dam is a physical disruption of a river, and as such interferes with the normal energy processing of allochthonous material deposited from the watershed (Vannote et al. 1980). However, the newly formed reservoir can act as a new source of energy input due to its lacustrine productivity. Both downstream thermal influences and the type of seston discharged from the reservoir are regulated by the type of release at the dam (Hilsenhoff

1971; Wallace and Merritt 1980). Reservoirs with hypolimnetic release tend to produce a thermal constancy downstream and discharge seston composed primarily of detritus and microflora (Spence and Hynes 1971; Baxter 1977). Epilimnetic releases result in lags in the normal temperature regimes downstream and discharge greater amounts of large seston, particularly zooplankton (Parker 1980; Kondratieff and Voshell 1981).

The benthos have various physical (substrate type, photoperiod, temperature), chemical (dissolved oxygen, alkalinity, turbidity, pH, absence of toxics) and nutritional (food quantity and quality) requirements, within certain ranges, that must be met in order for them to survive and reproduce. Temperature, as just one variable in temperate regions, may range from 0-40°C and provide optimum conditions for growth, maintenance and reproduction only at certain times (UWAG 1978). For this reason, aquatic insects in temperate zones characterized by seasonal and even daily fluctuations have thus had to adapt to the direct and even more complex indirect influence of temperature on various life functions such as feeding rates, timing of molting and emergence, duration of egg development (Brittain 1977; Elliot 1978; Newell and Minshall 1978;) and adult size and fecundity (Rodgers 1983; Resh and Rosenberg 1984). Limited (in the sense simulating any actual, constantly interfacing environment in a microcosm is very difficult) temperature studies have shown factors such as exposure time and ambient temperature (Ginn et al. 1974; Zimmerman and Wissing 1978),

season (Moore 1981), rate of temperature change (Salih and Grainger 1977) and thermal history or acclimation (Nelson and Hooper 1982) may be important.

Energy sources for the benthos are located within three primary reservoirs: 1) allochthonous organic matter from the surrounding watershed, 2) seston discharged from Lake Anna and 3) periphyton (see Fig. 4-1). Organisms such as most stoneflies and mayflies and some caddisflies exist largely on the energy stored within the detrital reservoir. As such, their distribution will depend, in part, on the availability of this resource as determined by the rates, amounts and subsequent physical weathering of allochthonous inputs to the North Anna River. Some types of benthos are largely primary consumers of periphyton (snails, riffle beetles), some are predaceous (some midges, beetles and stoneflies) and still others are more adapted to particularly benefit from the seston discharged from Lake Anna (some midges, blackflies, caddisflies and mayflies).

Other factors that may both directly or indirectly influence benthic community structure, abundance and/or function include water depth (Thorp and Diggins 1982), increased sedimentation due to storm runoff (Shaffer 1984), substrate composition (Williams 1978), current velocity and predation (Thorp and Bergey 1981; Gilinsky 1984), larval and adult behavior (Resh and Rosenberg 1984), invasion of exotic species such as the Asiatic clam, adult emergence, and natural succession. When considering potential effects from any of these influences, one must keep in mind the intrinsic

ecosystem "resiliency" that exists as a result of differential species tolerances and recovery response times.

Aquatic macroinvertebrates are considered by many to be excellent indicators of environmental stress due to their lack of mobility, sensitivity to various environmental perturbations and extended life cycles (Hynes 1965; Cairns and Dickson 1971; Lehmkuhl 1979). For these reasons monitoring the benthic community is considered to be an integral part of any ecological evaluation. The purpose of the macroinvertebrate sampling program in the North Anna River has been to provide data to assess changes in the benthic community abundance, structure and/or function.

Information Base For Evaluation

Benthic samples were collected in the North Anna River from 1973 through 1985 on a quarterly, bimonthly, or summer-only basis. Most of the pre-operational data, except during 1976 and 1977, was obtained by kick-net thus making it incomparable quantatively to later operational years when the Ellis-Rutter sampling device was used. For a more complete description of sample collecting and processing methodologies refer to Appendix D. Sample locations for these studies are as depicted in Fig. 5.1-1 and will be referred to as Rt. 601L (Rt. 601 Louisa Co.), Rt. 658H (Rt. 658 Hanover Co.), Rt. 601H (Rt. 601 Hanover Co.) and Rt. 1H (Rt. 1 Hanover Co.).

Much information exists regarding the benthic macroinvertebrate community in the North Anna River

extending from its early pre-regulated and regulated stage(s) to the present. These studies consisted of consultant and in-house staff assessments (Appendix E). In addition, published sources of information by independent investigators and government agencies (U. S. EPA 1977) were drawn upon to further characterize and supplement the findings in this report.

Three basic indices (abundance, structure, function) representative of community health were examined. For the operational years, 1981-85, average monthly density values were analyzed using a one-way ANOVA and Duncan's Multiple Range Test to determine if statistically significant differences existed between years at a given station. This allowed for the examination and comparison of benthic density responses to known operational levels within each time period. Since most of the historical data prior to 1981 were reported initially as averages, this specific one-way model could not be extended to include those earlier years. The Shannon-Wiener diversity index was used, along with major group compositional plots, to portray structural changes from 1981-85 and 1976-85 (where data existed), respectively. The level of taxonomic characterization prior to 1981 prohibited using the diversity index for those earlier years.

Assessment

From 1984-85, three hydropsychid caddisflies -- *Cheumatopsyche* sp., *Hydropsyche* sp. and *Macronema* sp. --

were consistently the most abundant benthic taxa in the North Anna River, particularly at Rt. 601L directly below the dam (Appendix B-Tables 1-10). At least two of these were numerically dominant in all months and all three in seven of nine months. These organisms are well adapted by way of silken capture nets to procure and subsequently utilize the seston discharged from Lake Anna (Parker and Voshell 1983), hence their abundance. Likewise, filter-feeding blackflies are also uniquely adapted to utilize this seston and occasionally were found in relatively large numbers. Other sporadic dominants included three midges (Cricotopus/Orthocladius, Cricotopus bicinctus, Eukiefferiella discoloripes), two mayflies (Stenonema sp., Psuedocloeon sp.) and one beetle (Stenelmis sp.). All of these are generally adapted to live on periphyton (scrapers) and/or detritus (collector-gatherers) as their primary food sources (Merritt and Cummins 1978).

Historical density trends for sites in both the North Anna River (Rt. 601L, Rt. 658H, Rt. 601H, Rt. 1H) and South Anna River (SAR) are presented in Figures 6.2-1 and 6.2-2. The peak at Rt. 601L in the fall of 1977 was primarily due to extremely large numbers (63,000/m^2) of caddisflies collected. Benthic communities often vary widely over short distances and "patchiness" has plagued the collecting methodology for years. Differences with respect to sample locations are likely the reason for the disparate fall peak. The present site at Rt. 601L could, in fact, be slightly downstream of an extremely productive area sampled

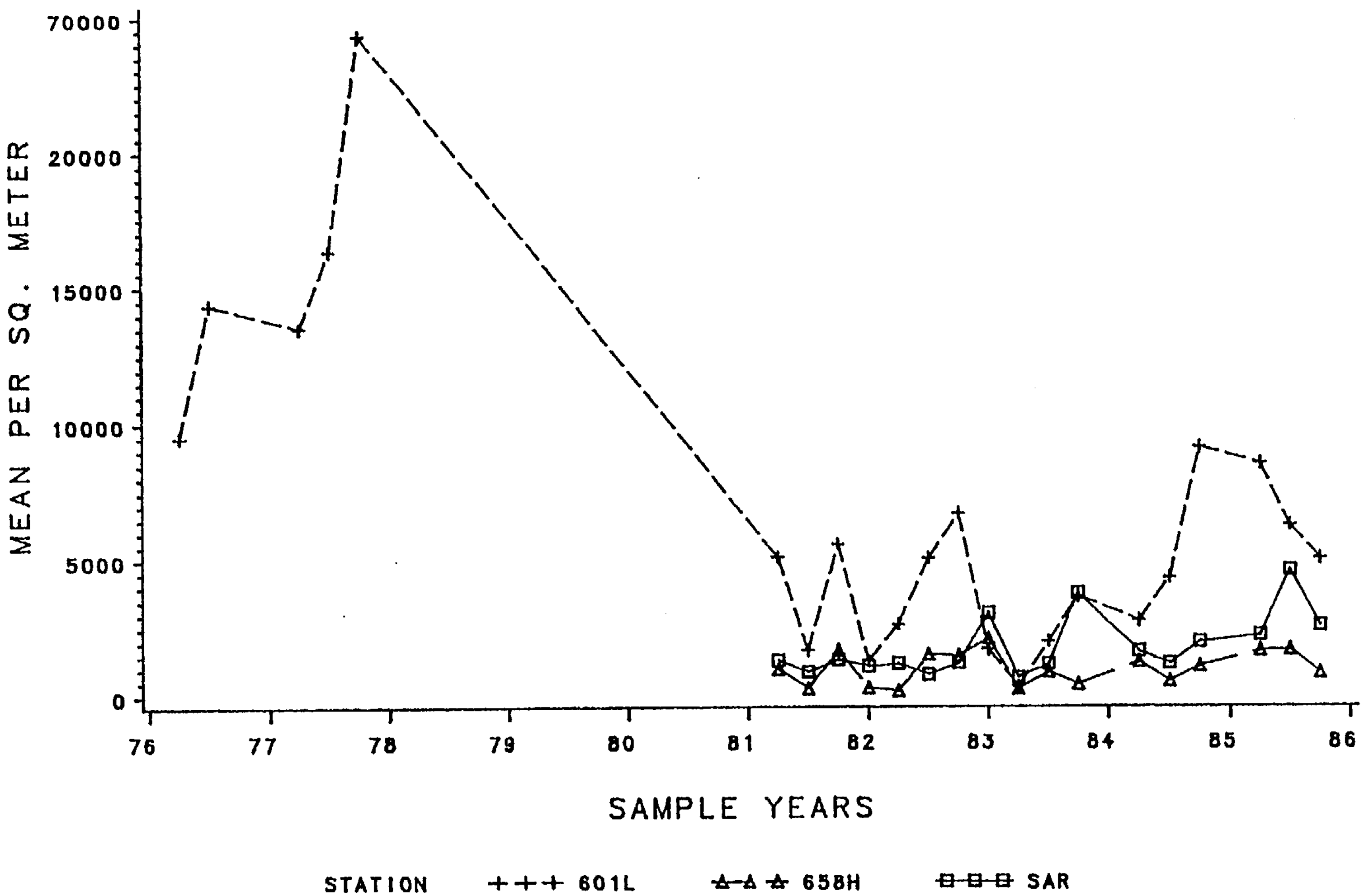

Figure 6.2-1. Average seasonal density of benthos,by station,in the North (601L,658H) and South Anna (SAR) rivers, Virginia, 1976-1985.

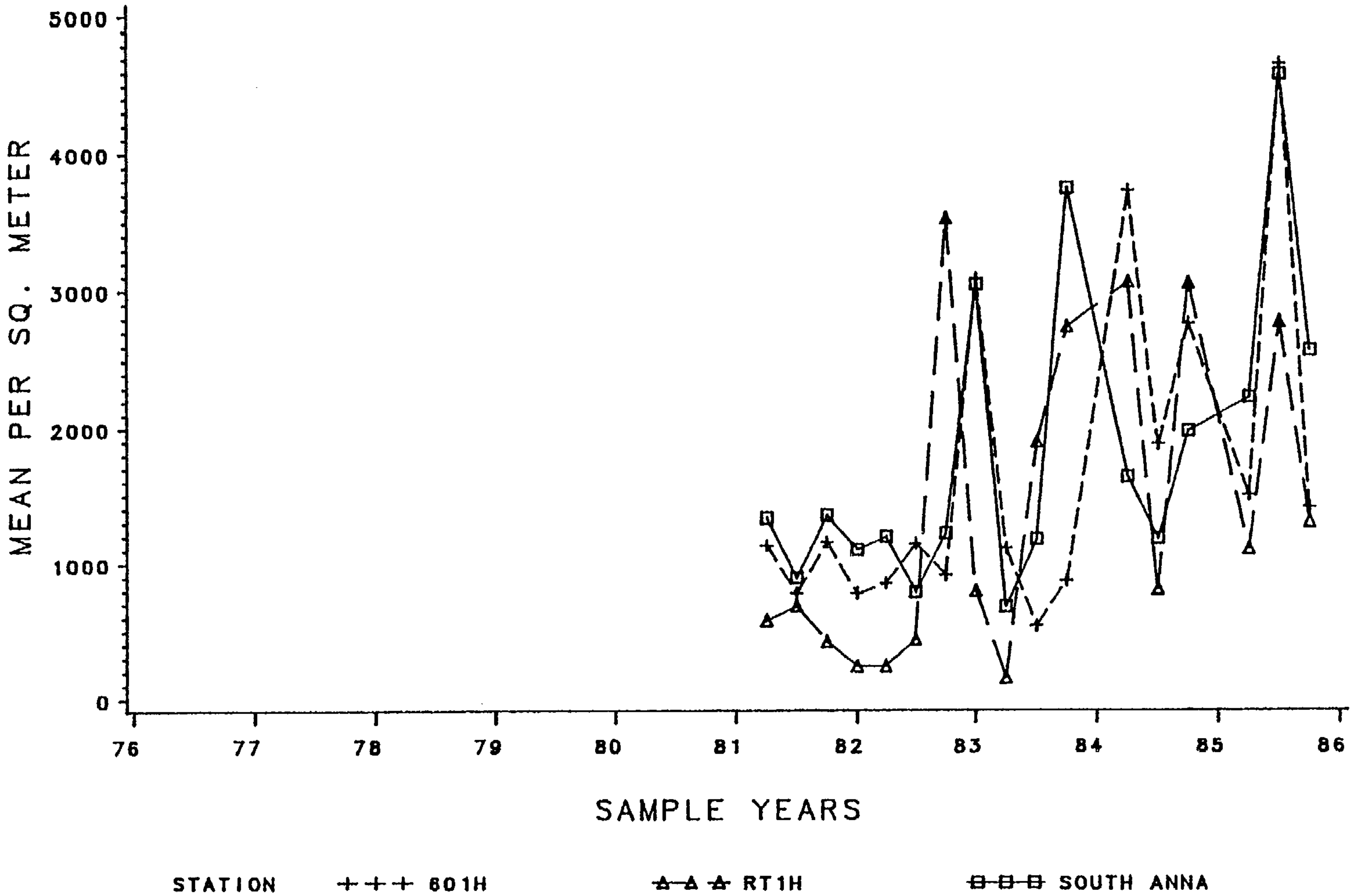

Figure 6.2-2. Average seasonal density of benthos , by station, in the North (601H,RT1H) and South Anna (SAR) rivers, Virginia, 1981-1985.

in 1977 (Dr. Reese Voshell, personal communication). Visual observations of this likely former sample area still indicate heavy localized concentrations of caddisflies. From 1981 to the present, the trend at Rt. 601L and at Rt. 1H has been one of similar fall peaks. The average seasonal numbers of benthos in the South Anna River and at all stations on the North Anna River most often fluctuated synchronously, with densities in the SAR being generally greater than each station except Rt. 601L. With the exception of the Rt. 601L sample station, no comparable surface area density estimates are available prior to 1981 due to differences in sampling techniques.

For the operational years, 1981-85, average monthly density values were analyzed using a one-way ANOVA and Duncan's Multiple Range Test to determine if statistically significant differences existed between years at a given station (Tables 6.2-1 and 6.2-2). At all stations on the North Anna River the year 1985 ranked highest, most often ranging from one-third (Rt. 601L, Rt. 658H) to one-half (Rt. 601H, Rt. 1H) of the time. At station Rt. 601L, significant differences were found between years during all months sampled except February and August. The relative ranking and frequency of statistical significance of known high-operational years (1981, 1983, 1985) did not indicate that the benthos at 601L were adversely affected during those

Table 6.2-1 Duncan's Multiple Range Test for Log transformed mena monthly benthic densities on the North Anna River, Virginia 1981-1985. Years underscored by the same line were not significantly different (.05 level). Years are listed in order of decreasing densities left to right.

STATION 601L

Feb	83	82			
Apr	85	81	84	82	
Jun	85	82	81	84	83
Aug	85	82	84	83	81
Oct	82	85	84	81	83
Dec	84	81	82		

STATION 658H

Feb	83	82			
Apr	85	81	82	84	
Jun	84	85	81	83	82
Aug	85	83	84	82	81
Oct	85	82	84	81	83
Dec	81	82	84		

STATION 601H

Feb	83	82			
Apr	81	85	84	82	
Apr	82	81			
Jun	84	85	82	83	81
Aug	85	84	82	81	83
Oct	85	84	83	81	82
Dec	84	81	82		

Table 6.2-2: Duncan's Multiple Range Test for Log transformed mean monthly benthic densities on the North and South Anna Rivers (SAR), Virginia, 1981-1985. Years underscored by the same line were not significantly different (.05 level). Years are listed in order of decreasing densities left to right.

STATION RT1H

Feb.	83	82			
	———	———			
Apr	85	84	81	82	
	———	———	———	———	
Jun	84	85	81	82	83
	———				
		———	———		
			———	———	———
Aug	85	83	84	81	82
	———	———	———	———	———
Oct.	82	84	83	85	81
	———	———	———	———	
					———
Dec	84	82	81		
	———	———			
		———	———		

STATION SAR

Feb.	83	82		
	———	———		
Apr	81	82	84	
	———	———	———	
Jun	84	82	81	83
	———	———	———	
		———	———	———
Aug	85	83	81	82
	———			
		———	———	———
Oct	83	85	82	81
	———	———	———	———
Dec	82	81		
	———	———		

periods. The same is true at each of the other three North Anna River stations.

Major benthic group compositional plots show changes in the community structure from 1976-85 at 601L and from 1981-85 at all other stations (Figs. 6.2-3 through 6.2-7). Caddisflies have consistently dominated the collections at Rt. 601L making up nearly 50% or more of the total percent composition in any given season (Fig. 6.2-2).

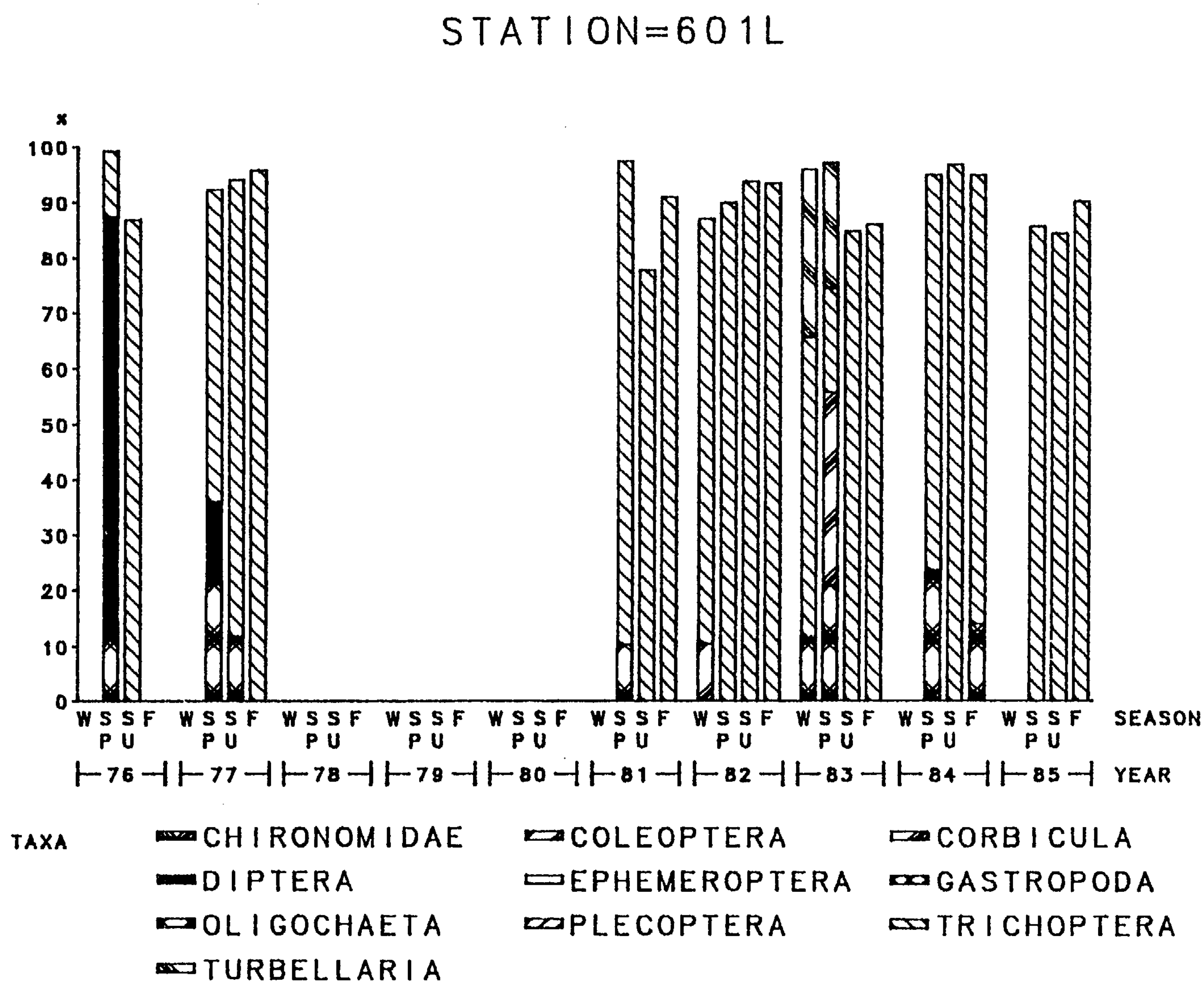

Figure 6.2-3. Average seasonal percent composition of the major(>10%) benthic groups collected at 601L in the North Anna River, Virginia, 1976-1985. No samples were taken at 601L from 1978-1980.

During the summer and fall seasons they have usually been the only group to account for better than 10% of the total benthos. As mentioned previously, their ability to filter suspended particulate organic matter discharged from Lake Anna into the river's water column undoubtedly favors their establishment and continued success at this locale. The midges were the next most frequently major group found here. Of these, Cardiocladlius sp. is known to feed on hydropsychid pupae (Parker and Voshell 1979) and their greater abundance in this area of high hydropsychid concentration reflects this feeding behavior. The midge Rheotanytarsus sp. is able, much like the caddisflies, to filter the water column for food (Simpson and Bode 1980). As a result, they too were more concentrated nearest the source of abundant seston at Rt. 601L and downstream at Rt. 658H. Blackflies, Asiatic clams and flatworms infrequently formed a large percentage of the community nearest the dam. Except for sporadic collections of these, little structural change appears to have occurred here. Late pre-impoundment and early post-impoundment studies also indicated caddisflies were the dominant organisms at Rt. 601L ranging, in three of four seasons, from 20-60% (Simmons 1972) and later from 30-80% (Reed and Simmons 1975). Although substantially present at Rt. 601L prior to impoundment, they increased even more so following impoundment. This increase was readily apparent in the first summer after Lake Anna had formed.

Station Rt. 658H just downstream was likewise consistently, but less overwhelmingly dominated by caddisflies and was more evenly mixed with midges, Asiatic clams and mayflies alternately forming a major part of the community (Fig. 6.2-4). Like the community at Rt. 601L, flatworms and blackflies were occasionally numerous. Pre-impoundment surveys here indicated caddisflies were second in abundance to the stoneflies (Acroneuria sp., Perlesta placida), the latter decreasing at both upstream stations following impoundment (Simmons 1972).

Eight alternatingly major groups were found farther downstream at Rt. 601H as compared to the five and six groups found at Rt. 601L and Rt. 658H, respectively (Fig. 6.2-5). At Rt. 601H, the caddisflies again most consistently dominated collections, rarely accounting for less than one-third of the total percent composition at any one time. The two additional groups found here in seasonally larger proportions than upstream were the winter stoneflies (Strophopteryx sp., Taeniopteryx sp.) and the riffle beetles (Microcylloepus sp., Stenelmis sp.).

Compared to the three upstream North Anna River stations, and the South Anna River sample station, there were most often larger and more equally distributed numbers of benthic groups comprising greater than 10% of the total community at Rt. 1H (Fig. 6.2-6). The benthos here were never dominated by a single group and only once by two groups. Caddisflies again were the most frequent major group with more of the philopotamids (Chimarra sp.) present

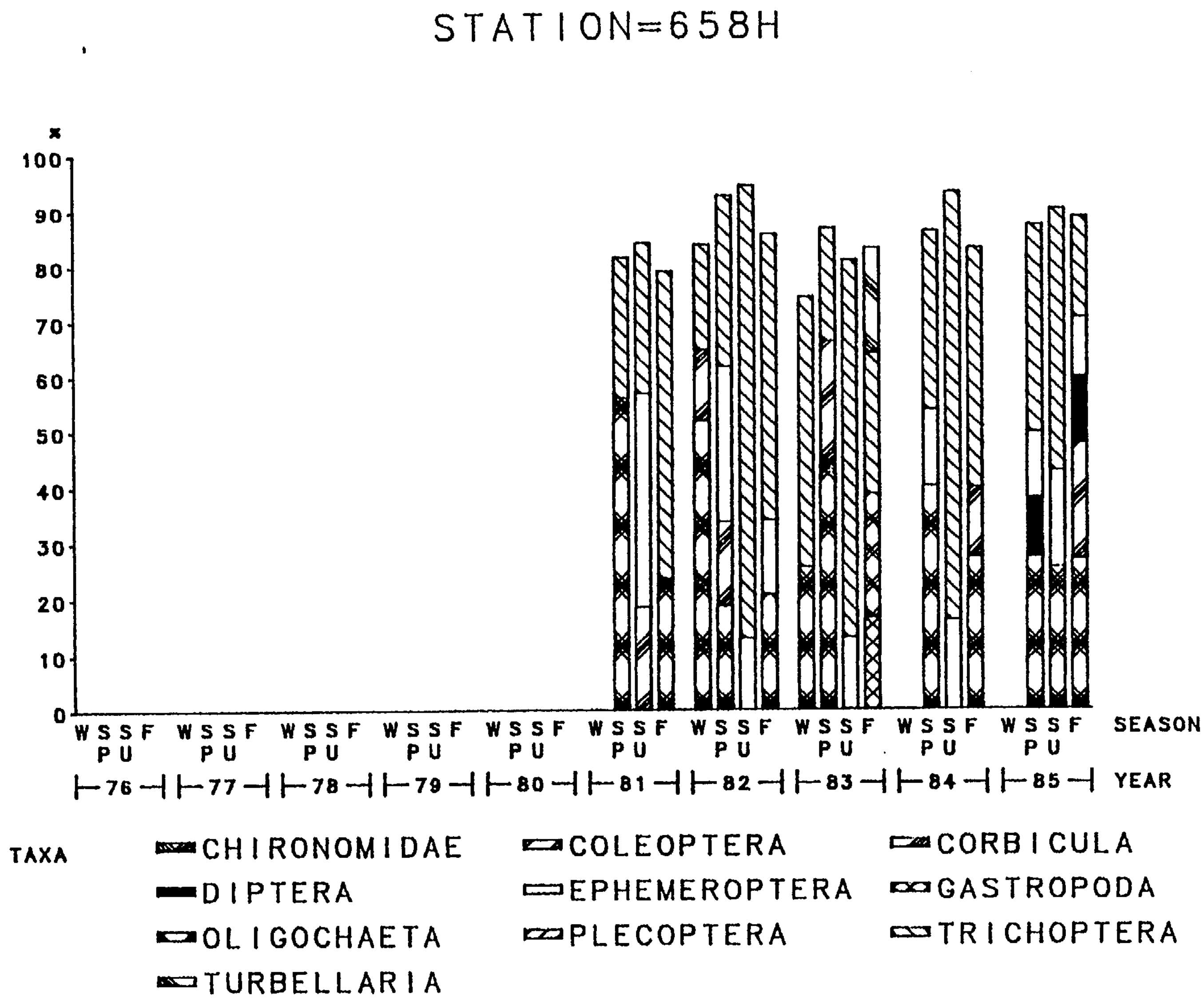

Figure 6.2-4. Average seasonal percent composition of the major(>10%) benthic groups collected at 658H in the North Anna River, Virginia, 1981-1985. No samples were taken at 658H from 1976-1980.

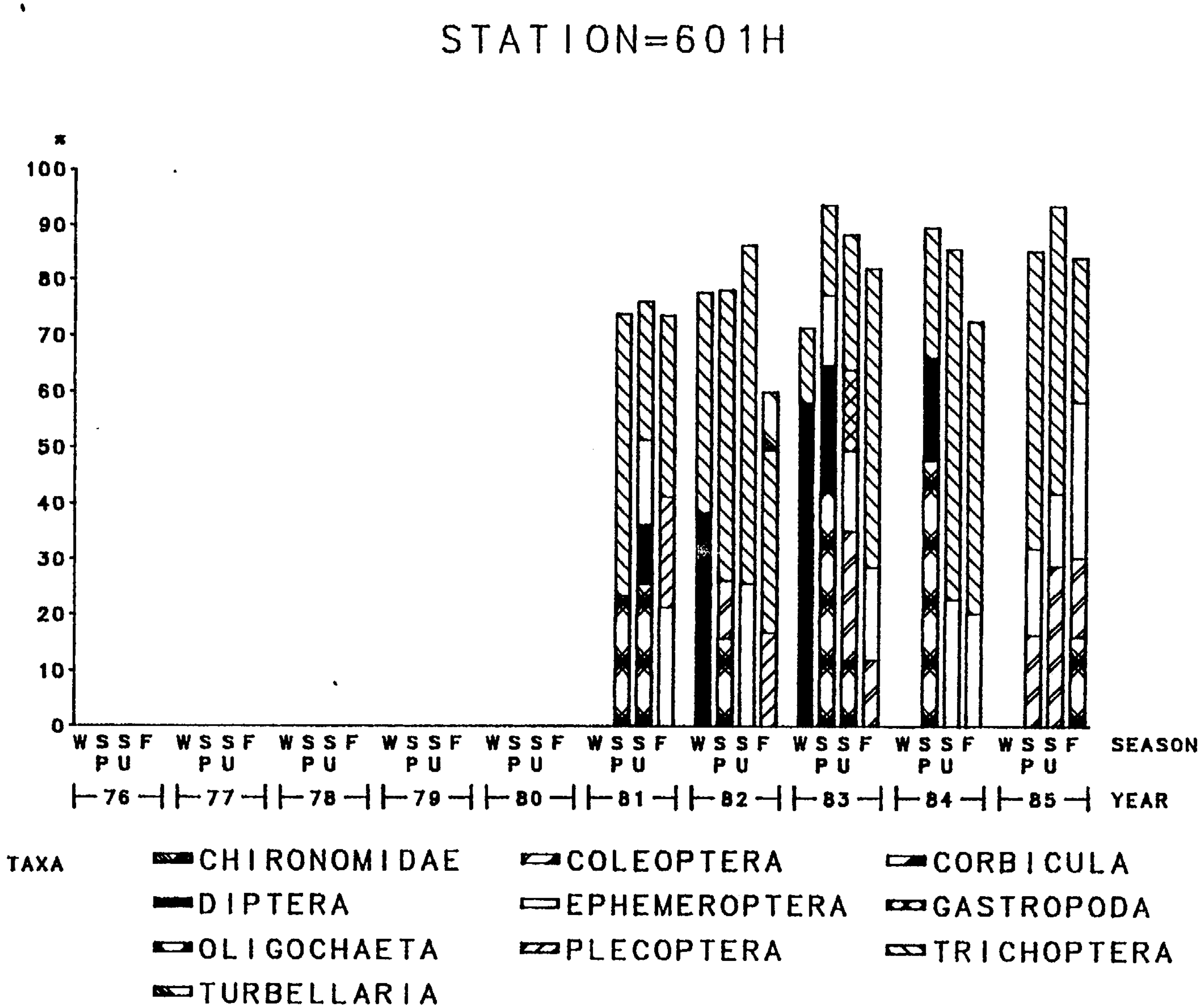

Figure 6.2-5. Average seasonal percent composition of the major(>10%) benthic groups collected at 601H in the North Anna River, Virginia, 1981-1985. No samples were taken at 601H from 1976-1980.

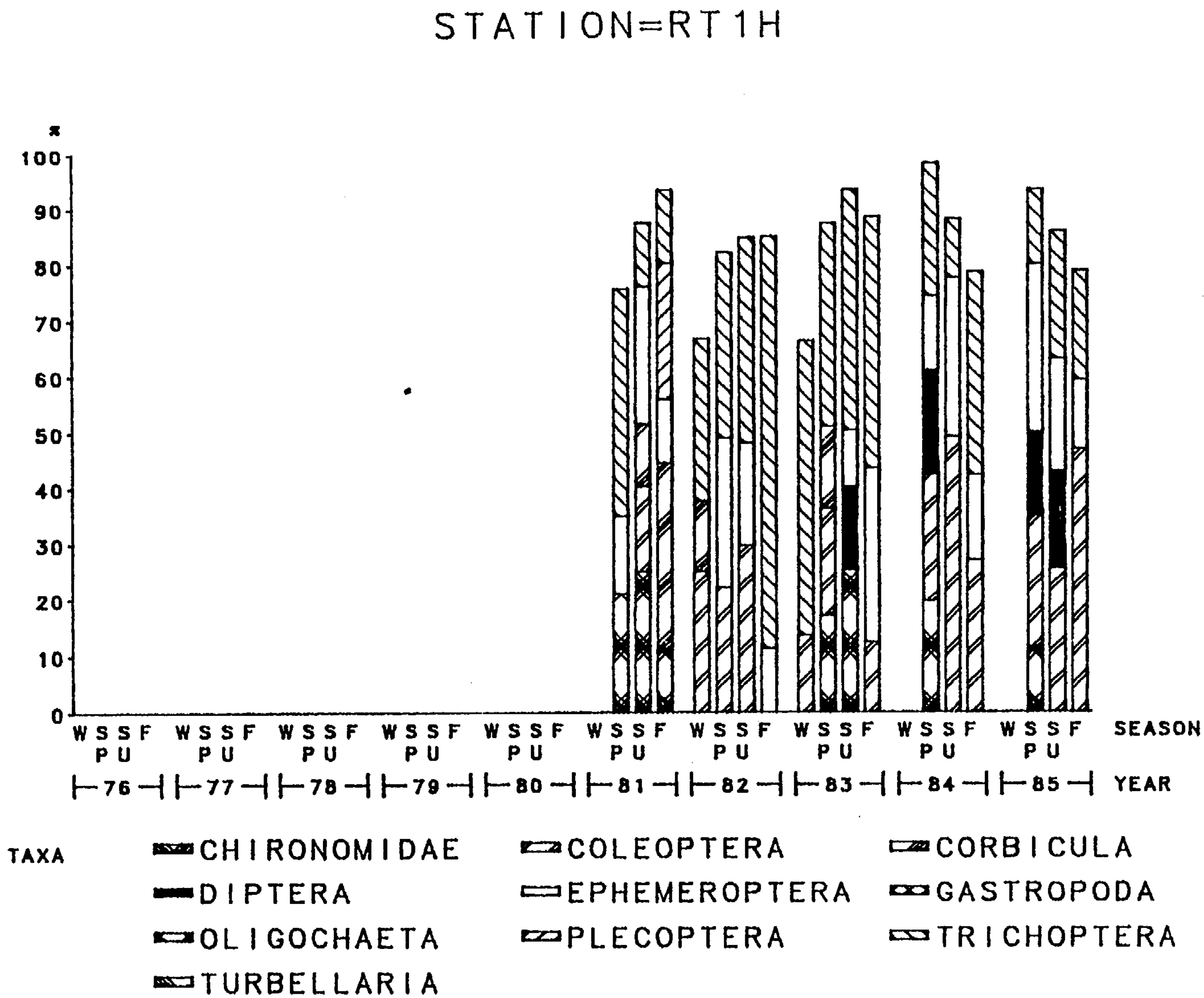

Figure 6.2-6. Average seasonal percent composition of the major(>10%) benthic groups collected at RT1H in the North Anna River, Virginia, 1981-1985. No samples were taken at RT1H from 1976-1980.

here than upstream. Additionally, mayflies (Baetidae, *Stenonema* sp.), riffle beetles (*Microcylloepus* sp., *Stenelmis* sp.), and midges contributed largely to the resident community.

Types of major groups in the South Anna River were, for the most part, similar to those in the North Anna River (Fig. 6.2-7). The primary difference between the two areas was the frequently higher percentages (and numbers) of snails (*Amnicola* sp., *Goniobasis* sp., *Pleurocera* sp.) collected in the South Anna. A brief, two month study done within the pre-impoundment basin of the North Anna River found that the mussel, *Elliptio complanatus*, and several species of snails were the dominant organisms at the Rt. 208 station upstream of Contrary Creek (Philadelphia Academy of Natural Sciences, 1955). Downstream of Contrary Creek neither was collected and community structure was generally depressed. The elimination of algae and macrophytes by acid mine drainage from Contrary Creek was cited as an important habitat loss for the benthos and was one major reason for the approximate 50% reduction in diversity downstream. Quarterly studies done from 1969-70 showed similar results (Simmons 1972). Again, community structure was depressed below Contrary Creek probably as a result of heavy metal leachates and siltation entering from the affected tributary. As in the 1954 survey, snails formed a substantial part (23-44%) of the community upstream at Rt. 208. Their failure to recolonize the North Anna River has been attributed to the loss of vegetative habitat, primarily

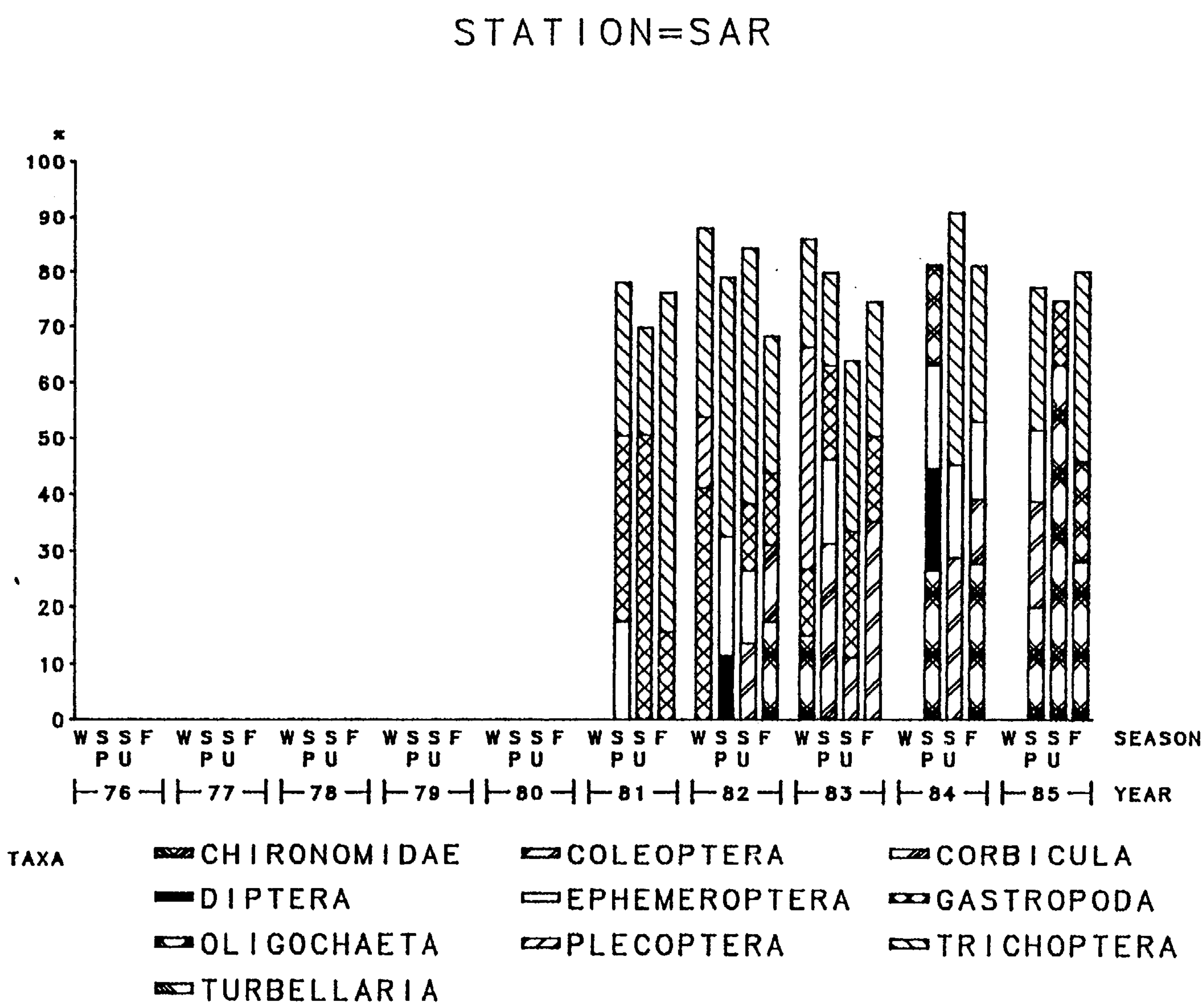

Figure 6.2-7. Average seasonal percent composition of the major(>10%) benthic groups collected in the South Anna (SAR) River, Virginia, 1981-1985. No samples were taken at SAR from 1976-1980.

Podostemum (Simmons and Reed 1973). Extensive beds of _Podostemum_ currently exist at the South Anna sample station which probably best explains the different distributions of snails between the two rivers.

Shannon-Wiener's diversity index, calculated for the more current data from 1981-85, shows that the two stations nearest the dam (Rt. 601L, Rt. 658H) usually exhibited lower diversities whereas those stations (Rt. 601H, Rt. 1H) farther downstream more closely approximated levels evident in the South Anna River (Fig. 6.2-8). Diversity at all stations on the North Anna River fluctuated in much the same pattern as the South Anna River and appears to have stabilized over the past five years. Thus, the North Anna River directly below Lake Anna is characterized by a relatively simple, less diverse community dominated by large numbers of caddisflies whereas the lower stretches become progressively more diverse with numbers of any given species more equally distributed.

Pre-impoundment studies indicated that the Mollusca, although apparently thriving above Contrary Creek, did not reestablish themselves downstream as far as Rt. 658H. This was interpreted to mean that the North Anna River had not "biologically recovered" to this point (Simmons 1972). A subsequent study defined the recovery zone of the river, based on the reestablishment of mussel genera, as the beginning of the Pamunkey River at the confluence of the North and South Anna Rivers (Simmons and Reed 1973). Lack of these species in the North Anna River

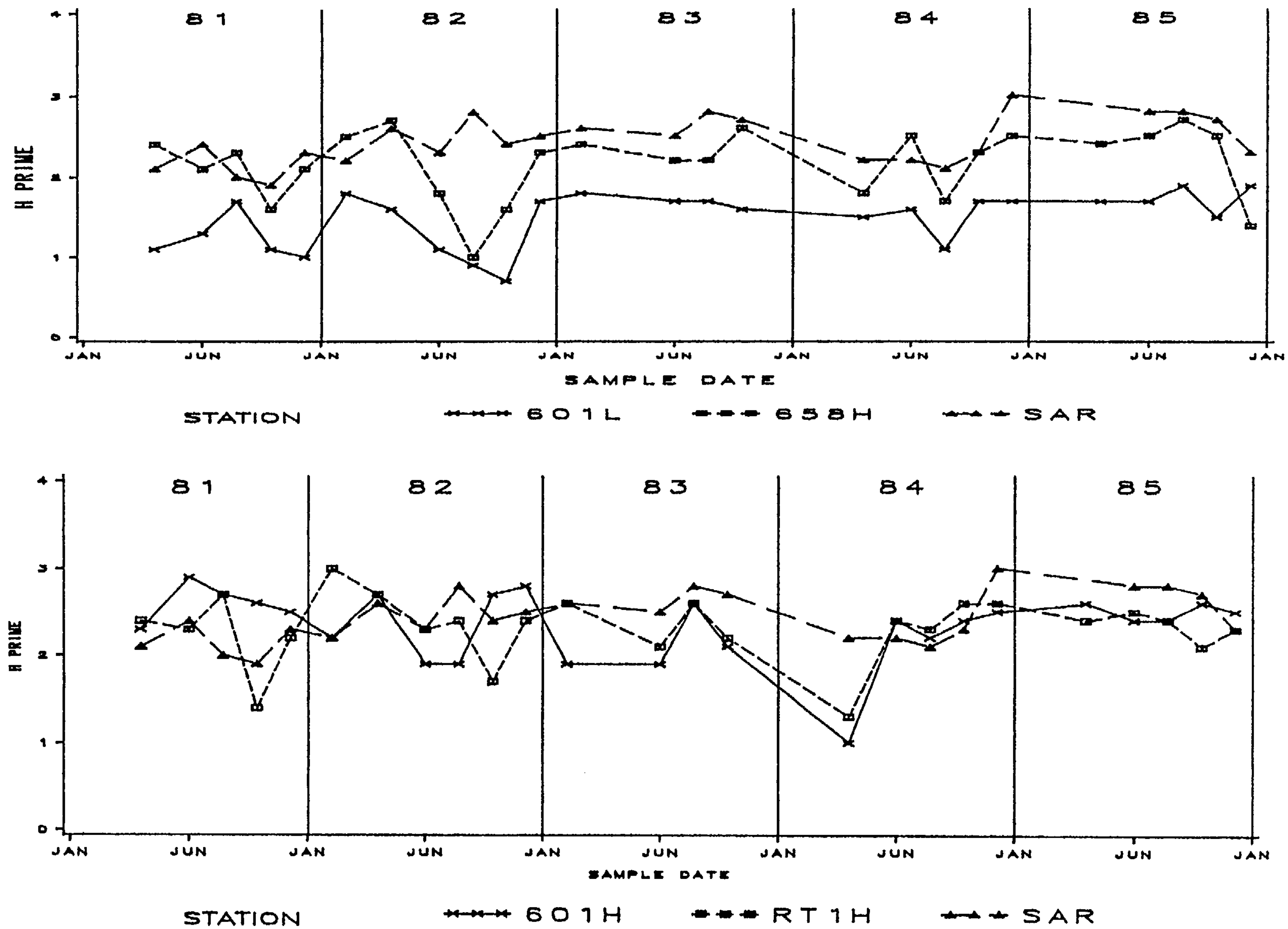

Figure 6.2-8. Benthic diversity trends at stations on the North and South Anna (SAR) rivers, Virginia, 1981-1985.

was attributed to the probable effects of siltation on the organisms themselves or associated host fishes. Ayers (1984) described two genotypes of <u>Elliptio</u> in the Pamunkey River, each apparently utilizing different fish hosts. One such primary host, the American eel, has regularly been collected throughout the North Anna which indicates that some means of <u>Elliptio</u> dispersal should exist. During 1974, SCUBA investigations above the North and South Anna confluence at Rt. 30 yielded six specimens, possibly indicative of the upstream movement of this organism (Reed and Simmons 1975). Within the present study period small groups (2-3) of this bivalve have been observed as far upstream as Rt. 601L. This seemed to occur particularly after a subsidence of the river leaving them exposed on sand bars. "Trails" evident in the sand were indicative of recent movement. Whether this further indicates recovery is unknown, as is the exact reason(s) for their apparently limited distribution.

The effects of Lake Anna on the North Anna River benthic community were reviewed by Simmons and Voshell (1978). They found Lake Anna had contributed to the improvement of water quality in the river by acting as a sink for heavy metals and sediments and by subsidizing the benthos' food source with particulate organic matter. Kondratieff and Voshell (1980) studied the life history of the mayfly, <u>Heterocloeon</u> <u>curiosum</u>, at the Fall Line of the North and South Anna. They believed subtle differences in seasonal temperature cycles between the rivers (i.e., warm,

slower in spring; cool, slower in fall) caused by the surface release at Lake Anna acted to reduce this insect's fecundity and hence abundance. Other known differences between these rivers such as discharge patterns and substrate and food type were listed as possible additional limiting factors which were then subsequently discounted for various reasons. The effects of the differences in food types remained most nebulous to the extent it was unknown whether this organism's diet in the North Anna was adequate for its normal growth rate. Sweeney et al. (1986) could not determine whether diet or temperature was generally more important to the development of a leaf-shredding mayfly. Their study suggested temperature determined the length of the nymphal growth period, while the magnitude of growth within this time period was strongly influenced by diet. Thus, the proportional importance of these two factors remains undetermined.

Discussion

In terms of community structure, the North Anna River is characterized by relatively large numbers of filter-feeding, net-spinning caddisflies within the Hydropsychidae and Philopotamidae that are particularly suited to utilize the seston contributed from Lake Anna. Other beneficiaries include the midge *Rheotanytarsus*, the blackfly *Simulium* sp. and the mayfly *Isonychia* sp. Feeding strategies in relation to food availability seemed to determine, to a large extent, the distribution and abundance

of the dominant macrobenthos in this river. Statistical estimates of community structure and major group compositional plots indicated stations nearer the dam usually exhibited a less diverse fauna, while those stations farther downstream more closely approximated the structural make-up of the South Anna benthos. Diversity at all stations on the North Anna fluctuated in very much the same pattern as the South Anna and appears to have stabilized over the last five years.

Historical seasonal and annual abundance patterns viewed in the context of station operational data, did not appear to be adversely influenced by the high average annual and summer power output evident in 1981, 1983 and 1985. The relative ranking and frequency of statistical significance for average monthly densities throughout the river from 1981-85 suggested likewise.

The insect fauna of the North Anna River is composed of most of the major groups and genera that would be expected to occur in a southeastern freshwater stream. Compared to the unregulated South Anna River, it is evident the relative proportions of the major groups and the absolute numbers of insect taxa within each group in the North Anna is similar. One notable difference between the two river communities is the relative paucity of snails in the North Anna. Based on pre-impoundment knowledge of the North Anna and current known habitat conditions in both rivers, this difference is most likely due to the lack of suitable habitat (i.e. the river weed <u>Podostemum</u>) in the North Anna.

After examining the distributional pattern of the numerically dominant species and the historical density and community developmental trends of the major groups, it would appear the benthic population in the North Anna River has been maintained over time. Both the types and amounts of benthos available for the food chain and other critical functions such as nutrient cycling have continued to persist with spatial variability due largely to the differential utilization of seston discharged from Lake Anna. The community structure has undergone distinct changes, most notably during the early years after impoundment when an obvious shift to filter-feeding organisms occurred. Midges, stoneflies, caddisflies, and mayfly nymphs are all present and apparently increasing in types (Appendix A-Table 1) to alternately provide both food and decompositional capabilities so necessary to the continued success of the system.

6.3 Fishes

Introduction

Warmwater streams are dynamic systems annually undergoing extreme, often short-term fluctuations in water temperature, flow rate, detrital input and substrate accretion and deposition (Bovee 1982). As such, fish in lotic systems are dependent on complex physical and biological interrelationships involving localized meteorological events, stream hydraulics and several trophic levels comprised of species that vary in seasonal abundance (Cummins 1979). Further, the dynamics of stream systems can be affected by human activities such as agricultural practices, flow regulation, diversion and thermal loading. The extent to which any particular stream is affected by these activities is site specific and related to the magnitude of human alterations and the stream's innate resiliency (Ney and Mauney 1981).

This section details studies conducted by Virginia Power to assess the influence of North Anna Power Station operations on the fishes of the lower North Anna River. Specifically, the health and well-being of the North Anna River's fish community was examined with regard to abundance of fishes, species composition of the fish community and community stability over time. The status of smallmouth bass (*Micropterus dolomieui*) in the North Anna River was also investigated. Studies conducted during 1984 and 1985 assessed the influence of water temperature and other factors that may have restricted this species' distribution.

Information Base for Evaluation

North Anna River fish studies have incorporated several sampling gear types and collection methods. These types and methods were chosen to provide a comprehensive picture of the North Anna River fish community and consisted of three major components: bimonthly electrofishing surveys that monitored the abundance and species composition of North Anna River fishes, ichthyoplankton sampling that documented reproductive success and spawning times of fishes and studies that addressed the relative abundance and distribution of smallmouth bass in the North Anna River.

Several investigators have sampled the fishes of the North Anna River since 1971 (Appendix E). Numbers of fish collected per sample, per year and species composition of the catch for the years 1971 - 1980 are not directly comparable as various sampling gear types, collection methods and study sites were utilized during this time period. Since 1981, bimonthly electrofishing collections have been conducted at four study sites: Rt. 601L, Rt. 658, Rt. 601H, and Rt. 1 (see Fig. 5.1-1), in a consistent, standardized manner (Appendix D). As such, only fish collections conducted between 1981 and 1985 are valid, quantitative indices of the North Anna River's fish community for comparative purposes. Additionally, various reaches of the South Anna River have been sampled by electrofishing. South Anna River collections are not quantitatively comparable to North Anna River collections due to irregular sampling periodicity; however, they do

provide for qualitative comparisons in terms of community composition.

Ichthyoplankton sampling of the North Anna River was conducted from 1981 through 1984 (Appendix E). Samples are not comparable among years due to the use of different gear types and collection methods in experimental efforts to establish sampling techniques that obtained representative samples under varying flow regimes. No one technique was found satisfactory. Therefore, for the 316(a) study, 1984 ichthyoplankton collections employed two gear types and methods (Appendix D) that were found to result in the highest catches. Collections were made at four study sites: Rt. 601L, Rt. 658, Rt. 601H, and Rt. 1 (see Fig. 5.1-1), at biweekly intervals between April and September, 1984.

Smallmouth bass studies consisted of four components: float surveys, stocking of young-of-year smallmouth bass, habitat evaluation surveys and boat electrofishing surveys. Habitat evaluation surveys and boat electrofishing surveys were conducted on the North and South Anna rivers so that the two smallmouth bass populations could be compared in relation to physical variables. Separately, each component provided data on the North Anna River's suitability as a smallmouth bass stream and, taken as a whole, allowed for evaluation of factors that may be limiting the distribution of smallmouth bass in the North Anna River.

Float surveys were conducted during 1984 to gather preliminary data on the distribution of smallmouth bass in

the North Anna River (Vepco 1984; Virginia Power 1985a). Approximately 36 km of the North Anna River from the Lake Anna dam downstream to Rt. 1 (Fig. 5.1-1) were floated, with the number of smallmouth bass and largemouth bass (M. salmoides) visually observed or caught by angling recorded by river section.

Stocking of young-of-year smallmouth bass was performed during 1984 to ascertain how well smallmouth bass introduced to areas of the North Anna River devoid of natural stocks would grow and survive (Virginia Power 1985 a and b). Stocking was done in the fall when river temperatures were well within the range preferred by smallmouth bass. Subsequent electrofishing surveys were used to evaluate stocking success.

Habitat evaluation surveys were conducted on the North and South Anna rivers during 1984 and 1985, respectively, in conjunction with Virginia Commission of Game and Inland Fisheries personnel. The North Anna River survey extended from the Lake Anna dam to Rt. 1 and the South Anna River survey from Rt. 611 to Rt. 667 (see Fig. 5.1-1). Both rivers were floated and survey transects established at major changes in habitat or after 1 hour of floating time had elapsed. Measurements of various physical parameters were made at each transect and between transects (Virginia Power 1985 a and b). Counts of riffles and pools for the North Anna River were redone in 1985 as different identification criteria had been used on North and South Anna River surveys. Final criteria for identification of

riffles were 1) the presence of turbulent water and 2) evidence of scouring as indicated by a change in substrate. Pools were defined as depositional areas with slow to nonexistent current.

Boat electrofishing surveys of the North and South Anna rivers were conducted in a quantified manner during 1985 (Virginia Power 1985 b; Appendix D). All accessible reaches of the North Anna River between the Lake Anna dam and the fall line located approximately 5 - 10 km downstream of Rt. 601H were sampled (see Fig. 5.1-1). Sampling of the South Anna River extended from Rt. 611 to Rt. 667 and was less intensive than North Anna River surveys.

Growth studies of smallmouth bass, largemouth bass and spotted bass in the North and South Anna rivers utilized fish collected by angling and electrofishing between 1983 and 1985, inclusive. All age and growth determinations were performed by Mark A. King, a graduate research assistant at Virginia Commonwealth University. Mr. King's graduate research encompasses much of the North and South Anna River fish studies presented in this report and his assistance with laboratory and field work and data interpretation is gratefully acknowledged.

Assessment

Bimonthly Electrofishing

Pre-impoundment electrofishing surveys of the North Anna River found low numbers of fish that were dominated by

species tolerant of poor water quality (see Sec. 1.2). This was due to the influx of acidic, metals-contaminated water from Contrary Creek. Following impoundment of Lake Anna, electrofishing surveys conducted from 1972 through 1980 documented a progressive increase in the occurrence and abundance of fish species typically inhabiting Piedmont streams in central Virginia (Appendix E).

By 1981, most of the species that currently inhabit the North Anna River had established viable, reproducing populations that have been sustained through 1985. A total of 43 species representing 11 families has been collected from the North Anna River during bimonthly electrofishing surveys since 1981 (Appendix A - Table 7), of which 38 species representing 10 families were collected during 1984 and 1985 (Appendix B - Tables 1 and 2). In comparison, collections from the South Anna River, Rt. 667, during 1984 and 1985 consisted of 25 species representing eight families. Only one species, the least brook lamprey (*Lampetra aepyptera*), was collected from the South Anna River and not the North Anna, whereas 14 species collected in the North Anna River were not found in South Anna River collections (Appendix B - Table 3). Ten of these species were probably introduced to the North Anna River via lake spillover, as they generally prefer lotic habitats (Hildebrand and Schroeder 1972) and occur in Lake Anna. The remaining four species are generally stream inhabitants that were rarely collected from the North Anna River.

Bimonthly electrofishing catches from the North Anna River exhibited an overall slight increase in both the numbers and biomass of fish collected per year between 1981 and 1985 (Fig. 6.3.-1). Catches by individual study site have been consistent between 1981 and 1985 in terms of the numbers and biomass of fish collected. It would be expected variability in annual and monthly catches would be greatest at those study sites nearest the Lake Anna dam if summertime station operations were stressful to the North Anna River's fish community, particularly between years of relatively high (1983 and 1985) and low (1981, 1982, and 1984) summertime operations. This effect was not observed for the period 1981 through 1985. The study sites nearest the Lake Anna dam, Rt. 601L and Rt. 658, exhibited very little variation in annual catch. Catches at the study sites farthest removed from the Lake Anna dam, Rt. 601H and Rt. 1, exhibited more year-to-year variation than those of Rt. 601L or Rt. 658 and were also more variable on a monthly basis within any year (Appendix B - Figs. 1-5). Increased variability in annual and monthly catches at Rt. 601H and Rt. 1 may have been a result of variability in the capture of schools of cyprinids consisting of many individuals, which were more frequently encountered at these study sites.

Catch in terms of number of fish collected per year was generally lowest at Rts. 601L and 658, as were Shannon-Weiner indices of species diversity (Fig. 6.3-1; Fig. 6.3-2). Reduced abundance of fishes and an associated lowered species diversity are indications of environmental

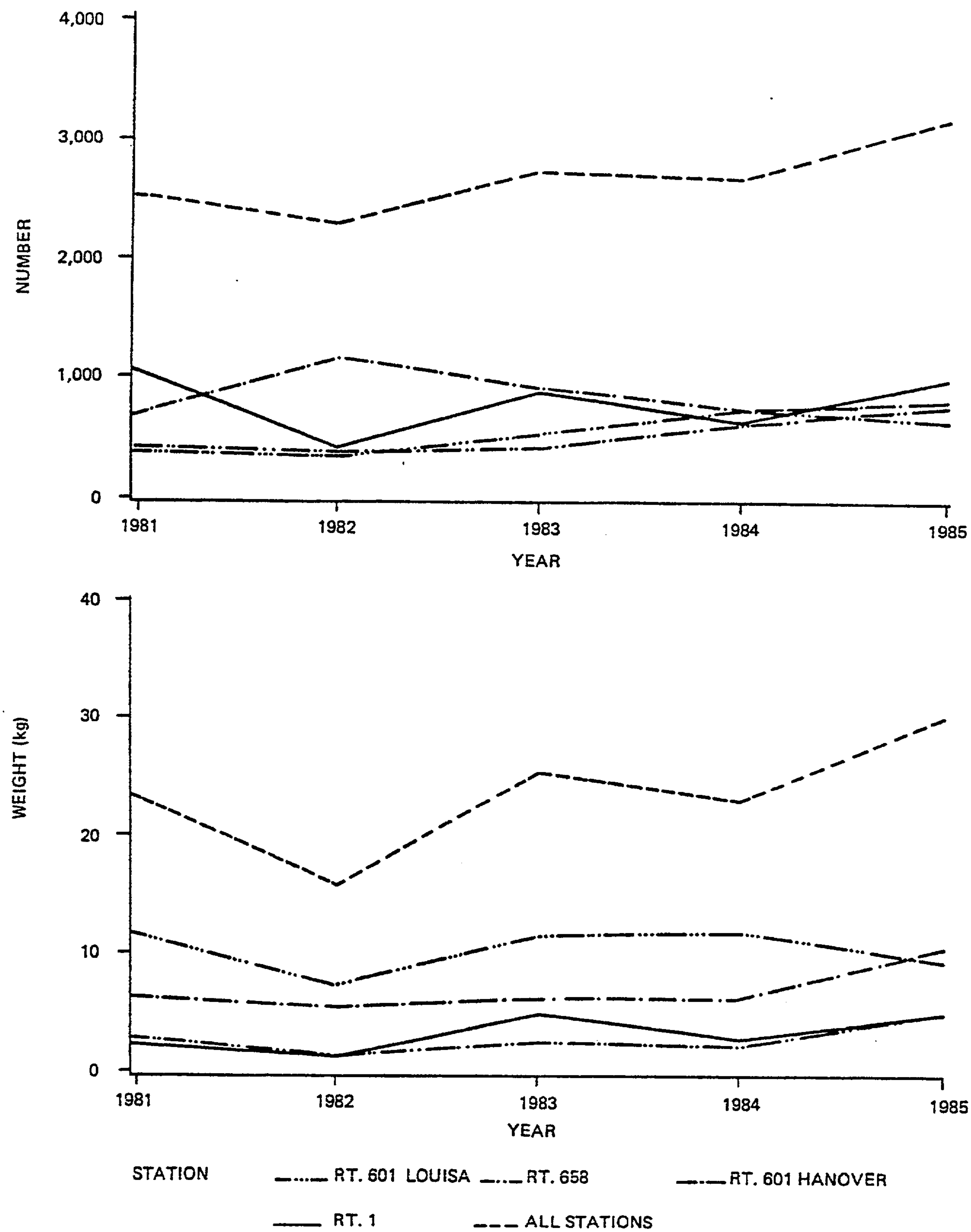

Figure 6.3-1. Bimonthly electrofishing catch from the North Anna river by station and for all stations combined.

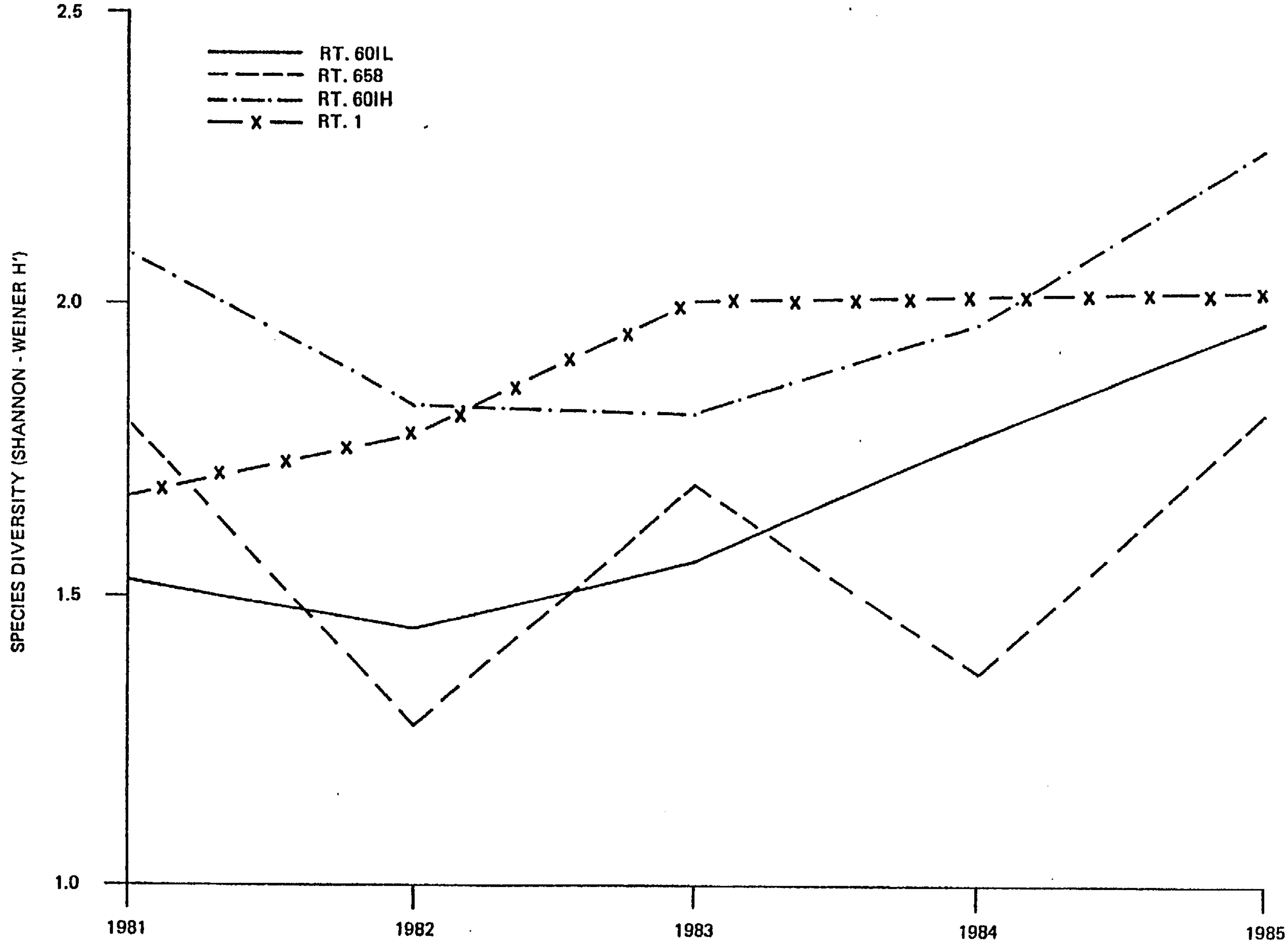

Figure 6.3-2. Mean annual species diversity for bimonthly electrofishing catch from the North Anna River, 1981-1985, by study site.

perturbations, provided reductions in these parameters occur in one area over time or between comparable areas (Hendricks et al. 1980). Although bimonthly electrofishing surveys at Rts. 601L, 658, 601H and 1 followed a standardized procedure, each study site is unique in terms of physical characteristics which relate to fish abundance and species composition. The North Anna River undergoes a progression of habitat availability changes from the Lake Anna dam to Rt. 1 (see Smallmouth Bass Studies), with availability and diversity of habitats increasing downstream. This longitudinal change in fish abundance and species diversity associated with habitat diversity is characteristic of most streams (Burton and Odum 1945; Sheldon 1968; Hocutt and Stauffer 1975). Further, aside from lake spillover those study sites nearest the Lake Anna dam are dependent on upstream colonization movements of stream fishes and subsequent reproduction, since there is no opportunity for downstream colonization movements by riverine species. As such, the lower abundance and diversity of fishes observed at Rts. 601L and 658 relative to Rts. 601H and 1 may reflect physical differences among study sites.

As mentioned previously, all study sites exhibited consistent annual catches from 1981 through 1985. Species composition of the catch by study site has also remained consistent for the period 1981-1985. Overall, annual collections have been dominated by two cyprinid species; the swallowtail shiner (Notropis procne) and the satinfin shiner (N. analostanus), the centrarchid redbreast sunfish (Lepomis

auritus), the shield darter (Percina peltata), a percid, and the American eel (Anguilla rostrata) (Table 6.3-1). Catch at Rt. 601L was influenced by lake spillover, where the lentic species black crappie (Pomoxis nigromaculatus) and bluegill (Lepomis macrochirus) were among the five most abundant species collected. Impoundments typically result in the occurrence of lentic species immediately below dams (Elser 1960; Neel 1966). American eel were present in high numbers at Rt. 601L, probably the result of upstream migrations blocked by the Lake Anna dam. Although the five most abundant species collected at each North Anna River study site have undergone some year to year variation, the period 1981-1985 has seen a stable, characteristic catch of fishes at each study site despite variation in year to year station operation.

Ichthyoplankton

Ichthyoplankton sampling of the North Anna River conducted during 1984 resulted in the collection of 23 species representing 19 genera and nine families (Appendix B - Table 4). Some larvae could not be identified to the species level and were only identified to genus or family. Of the 36 species collected during 1984 bimonthly electrofishing surveys, 21 species were represented in ichthyoplankton collections. Eleven of the 15 species not represented were minor components of the electrofishing catch and the remaining four species (Notropis ardens, N. rubellus, Nocomis leptocephalus, and N. micropogon) are

Table 6.3-1. The five most abundant species collected at each North Anna River study site during bimonthly electrofishing collections, 1981-1985.

Route 601 Louisa County

1981		1982		1983		1984		1985		1981-1985	
SPECIES	NO.	SPECIES	NO.	SPECIES	NO.	SPECIES	NO.	SPECIES	NO.	SPECIES	NO.
Pomoxis nigromaculatus	131	Lepomis auritus	88	Lepomis auritus	137	Lepomis auritus	194	Notropis procne	125	Lepomis auritus	598
Anguilla rostrata	64	Notropis procne	79	Notropis procne	101	Notropis procne	118	Lepomis aurtius	116	Notropis procne	443
Lepomis auritus	63	Anguilla rostrata	78	Anguilla rostrata	93	Percina peltata	93	Anguilla rostrata	89	Anguilla rostrata	415
Lepomis macrochirus	22	Lepomis macrochirus	25	Lepomis macrochirus	50	Anguilla rostrata	91	Percina peltata	86	Percina peltata	244
Notropis analostranus	20	Lepomis gibbosus	13	Pomoxis nigromaculatus	45	Notemigonus crysoleucas	71	Notropis analostanus	71	Pomoxis nigromaculatus	200

Route 658 Hanover County

1981		1982		1983		1984		1985		1981-1985	
SPECIES	NO.	SPECIES	NO.	SPECIES	NO.	SPECIES	NO.	SPECIES	NO.	SPECIES	NO.
Notropis procne	143	Notropis procne	170	Notropis procne	120	Notropis procne	406	Notropis procne	260	Notropis procne	1099
Notropis analostanus	64	Notropis analostanus	103	Notropis analostanus	103	Percina peltata	52	Percina peltata	86	Notropis analostanus	355
Lepomis auritus	55	Lepomis auritus	28	Lepomis auritus	62	Lepomis auritus	40	Notropis amoenus	75	Lepomis auritus	240
Anguilla rostrata	33	Percina peltata	23	Percina peltata	28	Notropis analostanus	21	Notropis analostanus	64	Percina peltata	228
Percina peltata	30	Anguilla rostrata	11	Anguilla rostrata	17	Anguilla rostrata	19	Lepomis auritus	55	Anguilla rostrata	104

Table 6.3-1. continued.

Route 601 Hanover County

1981 SPECIES	NO.	1982 SPECIES	NO.	1983 SPECIES	NO.	1984 SPECIES	NO.	1985 SPECIES	NO.	1981-1985 SPECIES	NO.
Notropis analostanus	109	Notropis procne	489	Notropis procne	317	Notropis procne	174	Notropis analostanus	119	Notropis procne	1135
Lepomis auritus	106	Notropis analostanus	237	Notropis analostanus	233	Notropis analostanus	148	Notropis procne	72	Notropis analostanus	846
Nocomis leptocephalus	83	Notropis rubellus	77	Nocomis micropogon	80	Nocomis micropogon	74	Notropis ardens	71	Nocomis micropogon	366
Notropis procne	83	Notropis amoenus	77	Notropis rubellus	66	Notropis rubellus	71	Lepomis auritus	68	Lepomis auritus	342
Nocomis micropogon	68	Nocomis leptocephalus	66	Lepomis auritus	65	Percina peltata	53	Semotilus corporalis	67	Notropis rubellus	301

Route 1 Hanover County

1981 SPECIES	NO.	1982 SPECIES	NO.	1983 SPECIES	NO.	1984 SPECIES	NO.	1985 SPECIES	NO.	1981-1985 SPECIES	NO.
Notropis procne	453	Notropis procne	132	Notropis analostanus	250	Notropis analostanus	130	Notropis analostanus	214	Notropis analostanus	1062
Notropis analostanus	346	Notropis analostanus	122	Notropis procne	174	Notropis procne	97	Notropis ardens	115	Notropis procne	964
Etheostoma olmstedi	37	Percina peltata	31	Lepomis auritus	84	Notropis ardens	85	Notropis procne	108	Lepomis auritus	263
Etheostoma vitreum	34	Lepomis auritus	31	Notropis amoenus	60	Notropis amoenus	59	Semotilus corporalis	97	Notropis ardens	243
Percina peltata	32	Etheostoma vitreum	27	Hybognathus regius	48	Lepomis auritus	44	Lepomis auritus	73	Etheostoma vitreum	173

difficult to identify to the species level during the larval stages. Three species (Dorosoma cepedianum, Ictalurus punctatus, and Moxostoma macrolepidotum) present in 1984 ichthyoplankton collections were not collected during bimonthly electrofishing surveys, but have been collected from the North Anna River during other surveys. Identification of creek chub (Semotilus atromaculatus) was probably an error, as it is morphologically very similar to fallfish (Semotilus corporalis) in its larval form and creek chub has not been collected during bimonthly electrofishing surveys conducted between 1981 and 1985 inclusive.

The time and duration of spawning by North Anna River fishes, as indicated by the occurrence of larvae in ichthyoplankton samples, followed the generalized spawning pattern of warmwater stream fishes throughout the United States (Hildebrand and Schroeder 1972; Pflieger 1975; Carlander 1977). Members of the sucker (Catostomidae) and perch (Percidae) families spawn early in the year, usually during a relatively brief period in April and May. Spawning by fishes in these families is followed by initiation of spawning by minnows and shiners (Cyprinidae) and sunfish (Centrarchidae), which often continues through July and August with more than one spawning period occurring during a given spawning season. July and August are also the months during which members of the catfish family (Ictaluridae) typically spawn. This sequence of spawning activites was evident in ichthyoplankton collections from the North Anna River during 1984 (Table 6.3-2).

Table 6.3-2. Temporal occurrence of ichthyoplankton collected from the North Anna River during 1984.

Taxon	Sample date											
	4/12	4/26	5/10	5/24	6/7	6/20	7/5	7/19-20	8/2	8/16	8/30	9/13
Aphredoderus sayanus			X	X								
Catostomidae		X	X									
Catostomus commersoni	X	X										
Centrarchidae				X	X	X	X	X	X			
Cyprinidae	X			X	X	X	X	X	X	X	X	
Dorosoma cepedianum			X	X	X	X	X	X				
Erimyzon oblongus			X	X	X		X					
Etheostoma sp.	X	X	X	X	X							
Etheostoma olmstedi						X						
Hypentelium nigricans			X	X	X							
Ictalurus natalis										X		
Ictalurus punctatus						X	X					
Lampetra appendix				X	X	X	X		X	X		X
Lepomis sp.				X		X						
Lepomis auritus					X	X	X	X	X	X	X	
Lepomis gibbosus				X								
Lepomis macrochirus						X	X		X	X		
Micropterus salmoides				X	X							
Morone americana			X	X	X							
Moxostoma macrolepidotum		X	X	X	X							
Notemigonus crysoleucas				X								
Nocomis sp.				X	X							
Notropis sp.				X	X	X	X			X		
Notropis amoenus			X	X								
Notropis analostanus						X	X		X			X
Notropis procne				X	X	X	X		X			
Noturus insignis						X	X		X	X		
Percidea	X	X										
Percina sp.	X	X	X	X								
Percina peltata											X	
Pomoxis nigromaculatus				X								
Semotilus atromaculatus							X					
Semotilus corporalis			X	X								
Unidentified	X		X	X	X	X	X	X	X	X	X	

Sampling dates on which any particular species of ichthyoplankton was first collected did not vary much between study sites near the Lake Anna dam (Rts. 601L and 658) and those farther downstream (Rts. 601H and 1; Appendix B - Table 5). Only four taxa were collected at study sites near the Lake Anna dam prior to collection at Rt. 601H or Rt. 1. In comparison, nine other taxa were collected at Rt. 601H or Rt. 1 prior to collection at Rt. 601L or Rt. 658. Differences among study sites in the times of initial collection of any particular species rarely exceeded two weeks, the interval between successive samples. Since spawning times of fishes are determined by mechanisms that promote synchrony in the gonadal development of males and females and the availability of environmental conditions conducive to survival of young (Liley 1969), it appears there was little variation in environmental conditions that influenced spawning times among study sites.

Smallmouth Bass Studies

Results of nine float surveys conducted on the North Anna River during 1984 indicated the distribution of smallmouth bass is limited to the lower reaches of the river downstream of Rt. 603 (see Fig. 5.5-1). No smallmouth bass were observed or caught by angling during repeated surveys conducted between the Lake Anna dam and Rt. 603; however, largemouth bass were commonly encountered (Vepco 1984; Virginia Power 1985a). Downstream of Rt. 603 both smallmouth bass and largemouth bass were found, with

smallmouth bass increasing in abundance and numbers of largemouth bass decreasing in a downstream direction. Observations made during 1984 float surveys first suggested the distribution of smallmouth bass in the North Anna River may be strongly influenced by physical features of the river, as the presence/absence of smallmouth bass appeared to coincide with the availability of preferred smallmouth bass habitat.

Stocking of young-of-year smallmouth bass in the upper reaches of the North Anna River at Rts. 601L and 658 was inconclusive. Approximately 2,500 young-of-year (mean total length 54.7 mm, n=40) were introduced at the two release points on 26 September 1984. Subsequent backpack and boat electrofishing surveys conducted during November and December 1984 resulted in the capture of four young-of-year smallmouth bass; two near Rt. 601L and two about 3 km downstream of Rt. 658. During July and August of 1985, four more smallmouth bass ranging in size from 125 to 200 mm total length were either caught by angling or visually observed near the release points. Although it cannot be verified that these were stocked fish, lengths of 125 to 200 mm would be expected for young-of-year stocked in September of 1984. Three other smallmouth bass, all around 200 mm total length, were observed or caught by angling 9 October 1985 between Rts. 738 and 603, and may have been stocked fish or upstream migrants. With the exception of one sub-adult smallmouth bass introduced from the James River by Virginia Power personnel (Virginia Power 1985a),

these 11 fish represent the only records of smallmouth bass occurring upstream of Rt. 603 to date.

It appears young-of-year smallmouth bass stocked at Rts. 601L and 658 have either (1) established themselves in the upper reaches of the river but have not been collected, (2) had poor survival, or (3) emigrated downstream of the stocking sites. It is unlikely stocked fish are present but not being found due to the North Anna River's exceptional water clarity (see Sec. 5.1) and the intensity of repeated electrofishing surveys (bimonthly and boat). Poor survival of young-of-year may have occurred due to predation by largemouth bass. Although Coutant and DeAngelis (1983) have indicated largemouth bass do not generally prey upon young-of-year smallmouth bass, studies of sympatric populations of largemouth bass and smallmouth bass indicate under some conditions smallmouth bass fingerlings may be utilized as a food item by adults of both species (Miner 1978). Downstream emigration may have resulted from high flows following stocking or been actively undertaken by young-of-year. Larimore (1975) demonstrated young-of-year smallmouth bass become increasingly susceptible to displacement with progressively greater water velocities, turbulence and turbidity levels associated with flooding. In late November of 1984 a major flooding event (peak flows approximately 55 m^3/s) occurred that may have displaced young-of-year or been utilized for dispersion.

It is unknown why few young-of-year were recaptured during electrofishing surveys; however, there is no evidence

water temperatures contributed to a low return. Young-of-year were stocked at temperatures slightly below optimum (Coutant 1977) that were followed by a seasonal autumn cooling trend. Results of 1984 November and December electrofishing surveys, during which only four young-of-year smallmouth bass were captured, indicate few stocked fish were present at stocking sites after a two to three month period, during which time water temperatures were conducive to growth and survival of smallmouth bass (see Sec. 5.1).

Habitat evaluation surveys conducted on the North Anna River and South Anna River revealed similar longitudinal changes in habitat that are related to increases in stream gradient, the change in streambed elevation over stream length, from the upper to the lower reaches of these rivers (Fig. 6.3-3). Both rivers are characterized by two physiographic regions; an upper region of relatively low gradient on the order of 0.4 m/km for the North Anna River and 0.6 m/km for the South Anna River and a lower region where gradient is relatively high, averaging approximately 1.6 m/km and 1.2 m/km for the North and South Anna rivers, respectively. The breakpoint between these two regions is distinct for the North Anna River and occurs near Rt. 601H (habitat evaluation survey transects 16-18). Gradient changes are more uniform on the South Anna River, with the breakpoint occurring over an approximately 5 km reach downstream of Rt. 33 (transects 8-13).

The major changes in habitat parameters observed during habitat evaluation surveys were in substrate types

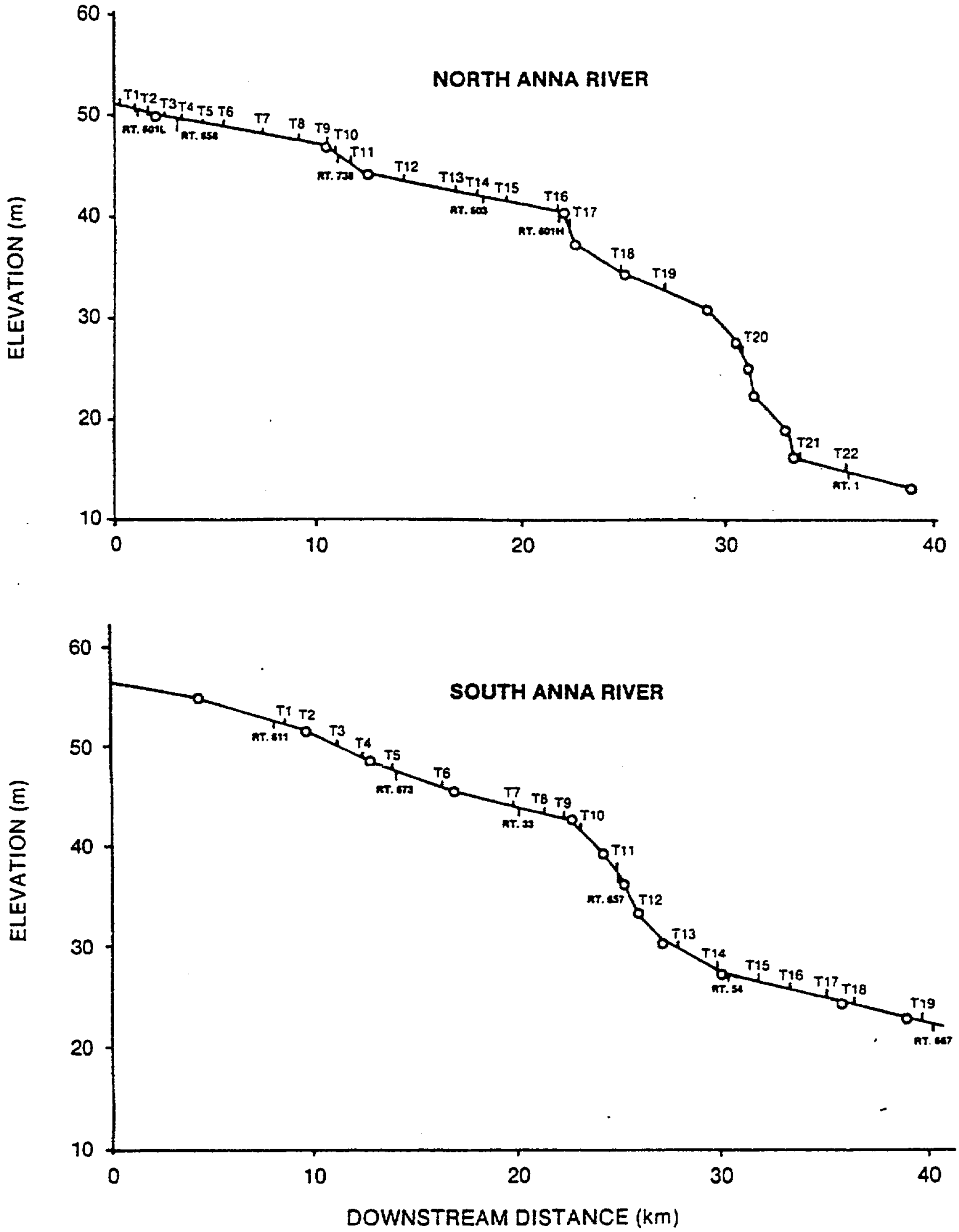

Figure 6.3-3. Longitudinal profiles of the North and South Anna rivers showing locations of habitat evaluation survey transects (T).

and the numbers of riffles and pools between transects (Table 6.3-3). Both rivers exhibited progressive increases in the amount of rocky substrate in a downstream direction, due to increases in gradient that result in faster stream flows capable of scouring sand and silt from the stream bottom. The number of riffles and pools recorded between transects also increased in a downstream direction, resulting in increased habitat diversity. These changes were especially pronounced in the North Anna River due to a sharper change in gradient between the upper and lower physiographic regions compared to the South Anna River (Fig. 6.3-3).

Results of boat electrofishing surveys designed to determine the abundance and distribution of smallmouth bass in the North Anna River were in agreement with results of 1984 float surveys. No smallmouth bass were collected from the upper reaches of the North Anna River between the Lake Anna dam and Rt. 603 (Fig. 6.3-4). Largemouth bass were collected during all surveys of the upper reaches and appeared to be especially abundant between a mill dam approximately 1 km upstream of Rt. 738 and Rt. 603 (transects 9-15; Fig. 6.3-3). These reaches encompass some of the North Anna River's lowest gradients and exhibit an upstream/downstream progression of substrate materials ranging from sand to bedrock (Table 6.3-3). Downstream of Rt. 603 both smallmouth bass and largemouth bass were collected, with smallmouth bass becoming increasingly abundant as downstream distance from Rt. 603 increased.

Table 6.3-3. Physical characteristics of the North and South Anna rivers recorded during habitat evaluation surveys.

	North Anna River				South Anna River			
Transect	Dominant Substrate	Subdominant Substrate	Riffles	Pools	Dominant Substrate	Subdominant Substrate	Riffles	Pools
Dam-1	boulder	gravel	1	2	*	*	*	*
1-2	gravel	sand	0	1	sand	gravel	4	3
2-3	sand	bedrock	3	4	gravel	sand	7	7
3-4	gravel	sand	3	3	sand	bedrock	1	2
4-5	sand	---	1	1	bedrock	boulder	9	4
5-6	sand	gravel	2	3	sand	bedrock	9	7
6-7	sand/gravel	bedrock	0	1	sand	bedrock	10	9
7-8	sand	---	0	1	sand	bedrock	1	1
8-9	sand	bedrock	1	1	bedrock	sand	4	3
9-10	sand	---	2	2	gravel	cobble	9	8
10-11	sand	gravel	2	1	bedrock	boulder	6	6
11-12	sand	cobble	5	5	boulder	bedrock	8	7
12-13	cobble/gravel	sand	5	5	bedrock	boulder	9	10
13-14	gravel	sand	3	3	bedrock	sand	6	5
14-15	bedrock	gravel	3	4	bedrock	gravel	6	6
15-16	boulder	bedrock	5	4	sand	boulder	6	6
16-17	bedrock	boulder	6	5	boulder	bedrock	11	11
17-18	bedrock	boulder	25	25	bedrock	boulder	15	15
18-19	sand/gravel	bedrock	9	10	bedrock	cobble	20	20
19-20	sand/gravel	bedrock	9	9	*	*	*	*
20-21	boulder	bedrock	25	25	*	*	*	*
21-22	sand	gravel	2	3	*	*	*	*

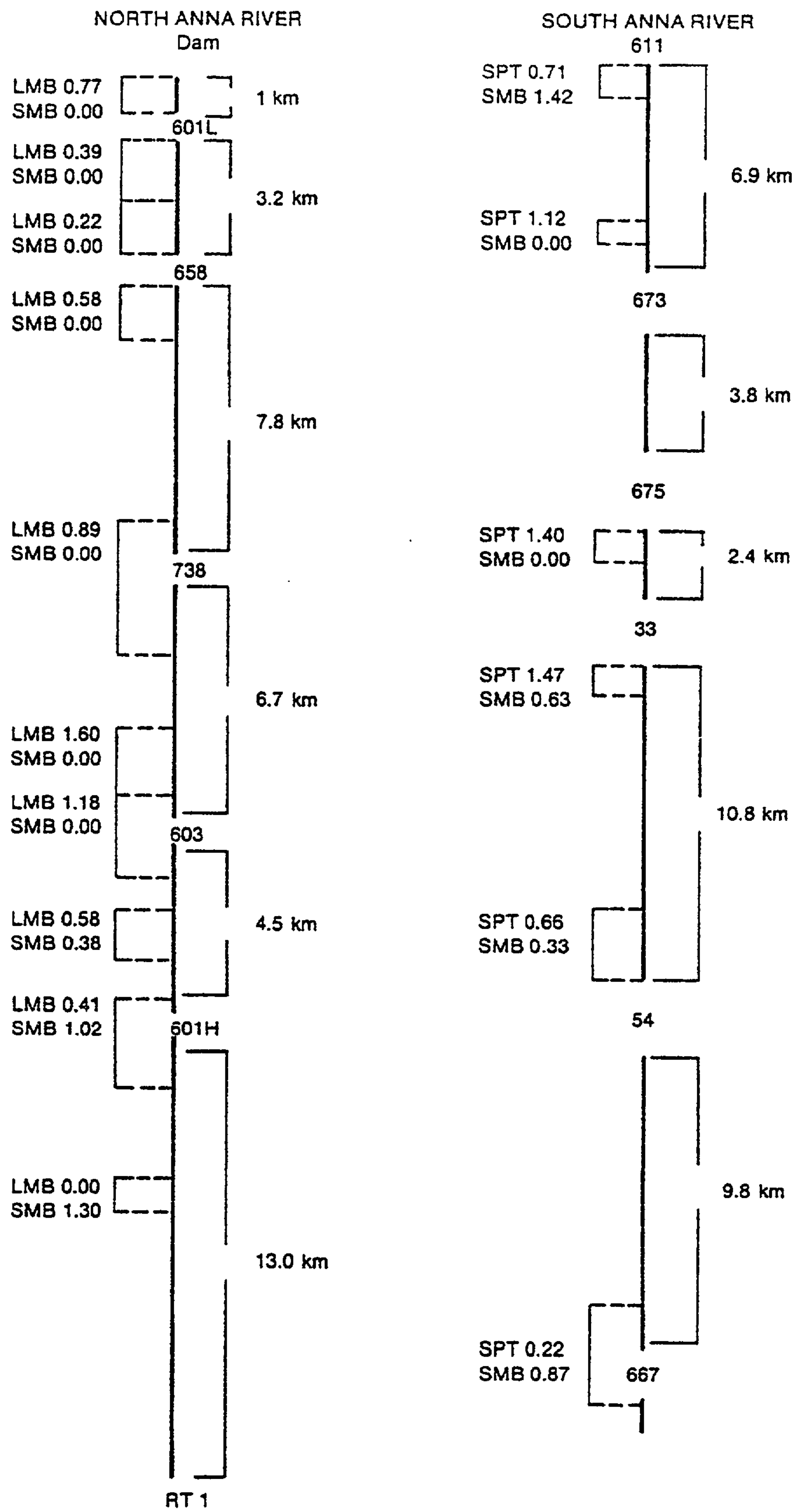

Figure 6.3-4. Catch of largemouth bass (LMB), smallmouth bass (SMB), and spotted bass (SPT) from the North and South Anna rivers per 10 minutes of electrofishing effort.

Stream gradient rapidly increases through these reaches (transects 15-19) and bedrock/boulder substrate dominates, with riffles and pools becoming more numerous and extensive.

No largemouth bass were collected during boat electrofishing surveys of the South Anna River; however, spotted bass comprised a large portion of the catch (Fig. 6.3-4). Spotted bass are morphologically more similar to largemouth bass tnan smallmouth bass and often occupy stream habitats intermediate between those preferred by largemouth bass and smallmouth bass (Vogele 1975). Smallmouth bass were common to both the North Anna River and South Anna River.

Distributions of smallmouth bass in the North Anna River and South Anna River were similar with one exception. Smallmouth bass were abundant in the uppermost reach of the South Anna River sampled near Rt. 611 (transects 1-2). Spotted bass were also abundant in this reach of the South Anna River, an area of relatively low gradient with substrate dominated by sand and gravel (Table 6.3-3). It is unknown if these smallmouth bass were immigrants from downstream or if they were part of an established stock upstream of and including Rt. 611. Regardless of their origin, the presence of smallmouth bass in the South Anna River near Rt. 611, a river reach characterized by less than optimum habitat, demonstrates a variety of factors determine habitat utilization by this species.

Excepting smallmouth bass collected near Rt. 611, the longitudinal distributions and relative abundance of

smallmouth bass in the South Anna River paralleled those of the North Anna River, as did the distribution and relative abundance of spotted bass in the South Anna River compared with largemouth bass in the North Anna River. Only spotted bass were collected from the upper reaches (transects 2-7) of the South Anna River and appeared to be most abundant between Rts. 675 and 33 (transects 6-8). These reaches of the South Anna River are of low gradient and predominately sand substrate, with exposed bedrock occurring in riffles. It is noteworthy catch per unit effort for largemouth bass in the North Anna River and spotted bass in the South Anna River was highest in the low gradient reaches of these rivers immediately upstream of the fall line. Smallmouth bass and spotted bass were collected downstream of Rt. 33 (transect 7), with smallmouth bass comprising the largest part of the catch for the lowermost reaches of the South Anna River sampled near Rt. 667 (transect 19). As with the North Anna River, rocky substrate in the form of bedrock and boulder becomes much more common through these reaches, as do extensive series of riffles and pools (Table 6.3-3). Based on boat electrofishing, habitat evaluation and angling surveys the distributions of smallmouth bass and largemouth bass in the North Anna River and smallmouth bass and spotted bass in the South Anna River conform well with published habitat preferences for these three species (see Miller 1975).

Although smallmouth bass were not found in the upper reaches of the North Anna River, other than those fish

that were probably stocked in 1984, stream habitat is available that is considered preferred smallmouth bass habitat. Following suggestions of the TAC, North Anna River habitat evaluation survey data were reviewed in conjunction with data obtained during boat electrofishing surveys to develop criteria for "good" smallmouth bass habitat. The criteria are also based on descriptions of preferred habitat found in the literature (Coble 1975; Paragamian 1981; Orth et al. 1982; Edwards et al. 1983) and fall into two categories;

1) relatively deep pools [depth $\geq$ 2.0 m at 1 m^3/s (minimum flow)] with boulder or bedrock substrate near areas of moderate to fast current; and,

2) relatively deep riffles [depth $\geq$ 1.0 m at 1 m^3/s] with boulder or gravel/cobble substrate or broken bedrock with overhanging ledges near areas of slow to moderate current.

Aerial photographs, U.S.G.S. topographic maps, and field notes were used to identify areas of the North Anna River between the Lake Anna dam and Rt. 1 that meet these criteria. Identification of these areas was subjective, due to the specific nature of the criteria and the office methodology employed that relied on recollection of habitat features by laboratory personnel. Approximately 6 km of the river downstream of Rt. 601H were omitted from evaluation as knowledge of these reaches was judged unreliable.

Overall, an estimated 24% (4.4 km) of the fish habitat in the upper reaches of the North Anna River upstream of Rt. 603 (18.1 km) contained one or both types of habitat meeting the criteria (Appendix B - Table 6). Downstream of Rt. 603 an estimated 54% (6.4 km) of the fish habitat met the criteria. Preferred habitat generally occurred in small patches upstream of Rt. 603 but frequently encompassed long, continuous reaches of the lower river.

Three explanations for why no smallmouth bass inhabit areas of good habitat upstream of Rt. 603 seem possible. One is warmer temperatures during the summer are causing smallmouth bass to avoid the upper reaches of the North Anna River. Summertime temperature differences between Rts. 601L and 603 generally range between 2 and 4°C (see Fig. 5.2-2). These differences are in part an impoundment effect, as evidenced by the greatest difference recorded occurring during 1977, a pre-operational year, and the greatest differences generally occurring between October and January of any year, due to Lake Anna's role as a heat sink. Since North Anna River temperatures rarely exceed 30° C (see Sec. 5.1), the possibility that smallmouth bass are avoiding the upper reaches due to water temperature is unlikely, based on reported temperature preferences and tolerances of smallmouth bass (Cherry et al. 1977; Coutant 1977). North Anna River temperatures are generally within or below the preferred summertime range for smallmouth bass of 29-31° C (Peek 1965; Barons and Tubb 1973; Stauffer et al. 1976) during the summer months and, except for brief periods rarely exceeding one day in length, fall within the optimum suitability range for smallmouth

bass as determined by the United States Fish and Wildlife Service (Edwards et al. 1983) during the summer. Further, North Anna River temperatures have never exceeded the recommended short-term (24-hour) maximum for smallmouth bass of 35°C (Wrenn 1980).

A second possible explanation is competition with largemouth bass. Smallmouth bass and largemouth bass are aggressive, territorial predatory fishes that consume similar food items, primarily other fishes and macroinvertebrates (Coble 1975; Heidinger 1975; Miner 1978). In the absence of largemouth bass, it may be smallmouth bass would establish themselves in the upper reaches of the North Anna River where preferred habitat is relatively limited. But as it is, the combination of continued spillover of largemouth bass from Lake Anna and the greater amount of preferred habitat for this species may give a competitive advantage to largemouth bass.

Another reason why smallmouth bass do not occur in the upper reaches of the North Anna River may be good smallmouth bass habitat upstream of Rt. 603 generally occurs in such small, isolated patches it does not favor colonization. Although there are some reports of smallmouth bass traveling long distances (Fajen 1975), most studies have found their home range is restricted (Coble 1975; Miller 1975). The long, sandy stretches that typify the upper reaches of the North Anna River offer little incentive for colonization movements. Such areas are unproductive in terms of food availability (Benke et al. 1985), provide little instream cover that is a vital component of smallmouth bass habitat (Edwards et al. 1983) and separate areas of good smallmouth bass habitat by substantial distances.

Growth of smallmouth bass in the North Anna River (Appendix B - Table 7) generally exceeded that of other smallmouth bass in rivers and streams throughout the United States (Carlander 1977) including Virginia (Smith and Kauffman 1982). Growth of largemouth bass in the North Anna River (Appendix B - Table 8) compared favorably with growth of other largemouth bass in rivers throughout the United States (Carlander 1977) but was less than that of largemouth bass in other Virginia rivers (Smith and Kauffman 1982). Neither smallmouth bass nor spotted bass in the South Anna River (Appendix B - Tables 9 and 10) seemed to grow as well as other populations in rivers (Carlander 1977; Smith and Kauffman 1982). Life requisites for smallmouth bass that determine habitat suitability in lotic systems include food, cover, water quality, reproduction, and gradient; with optimum conditions being reflected in maximal growth rates (Edwards et al. 1983). The high growth rates of smallmouth bass in the North Anna River indicate the life requisites for this species are more than adequately being met by environmental conditions, at least downstream of Rt. 603.

Summary

Overall, results of North Anna River fishery studies indicate the river is in a state of dynamic equilibrium characterized by a diverse and typical assemblage of fishes. Bimonthly electrofishing collections have remained consistent at individual study sites from 1981 through 1985 in terms of numbers of fish collected and species composition of the catch. Low fish

abundance and species diversity at the study sites nearest the Lake Anna dam, Rts. 601L and 658, may be related to longitudinal differences in physical features of the North Anna River. The temporal occurrence of ichthyoplankton in the North Anna River during 1984 followed the generalized spawning pattern of warmwater stream fishes and was similar among study sites. Segregation of smallmouth bass and largemouth bass by upper and lower reaches of the North Anna River, respectively, appears to be primarily a function of habitat availability.

7. OPERATION OF UNITS AT DESIGN CAPACITY

In March 1985 Virginia Power announced plans to increase the generating capability at North Anna by approximately 4.2% to help meet future load demands and to provide a savings to customers in fuel costs. This increase in electric power generation necessitates a change in the licensed reactor thermal power rating of 2775 MWt to 2893 MWt which approaches the design reactor power capability of 2900 MWt. Only minor modifications at the station will be required upon the Nuclear Regulatory Commission's approval of the project.

The current NPDES permit No. 0052451 for Units 1 and 2 of the North Anna Power Station includes an effluent limitation of "a maximum of 13.54×10^9 Btu/hr minus the heat removed by the waste heat treatment facilities." This Btu limit (6.6% above estimated historical maximum) is based on design power capabilities with a heat rejection margin allowance for some expected operational inefficiencies. Since a sound study framework had been established for the 316(a) demonstration and a scientific advisory committee had been overseeing the study, the opportunity existed to review the potential environmental impact as related to the increase in electric generation. Temperature (ENDECO) and biological data available from the separate and warmer WHTF (Fig. 7.1-1) were evaluated as a surrogate for hypothesizing about increased temperature impacts in the Lower Lake. A complete description of the WHTF and the discharge structure

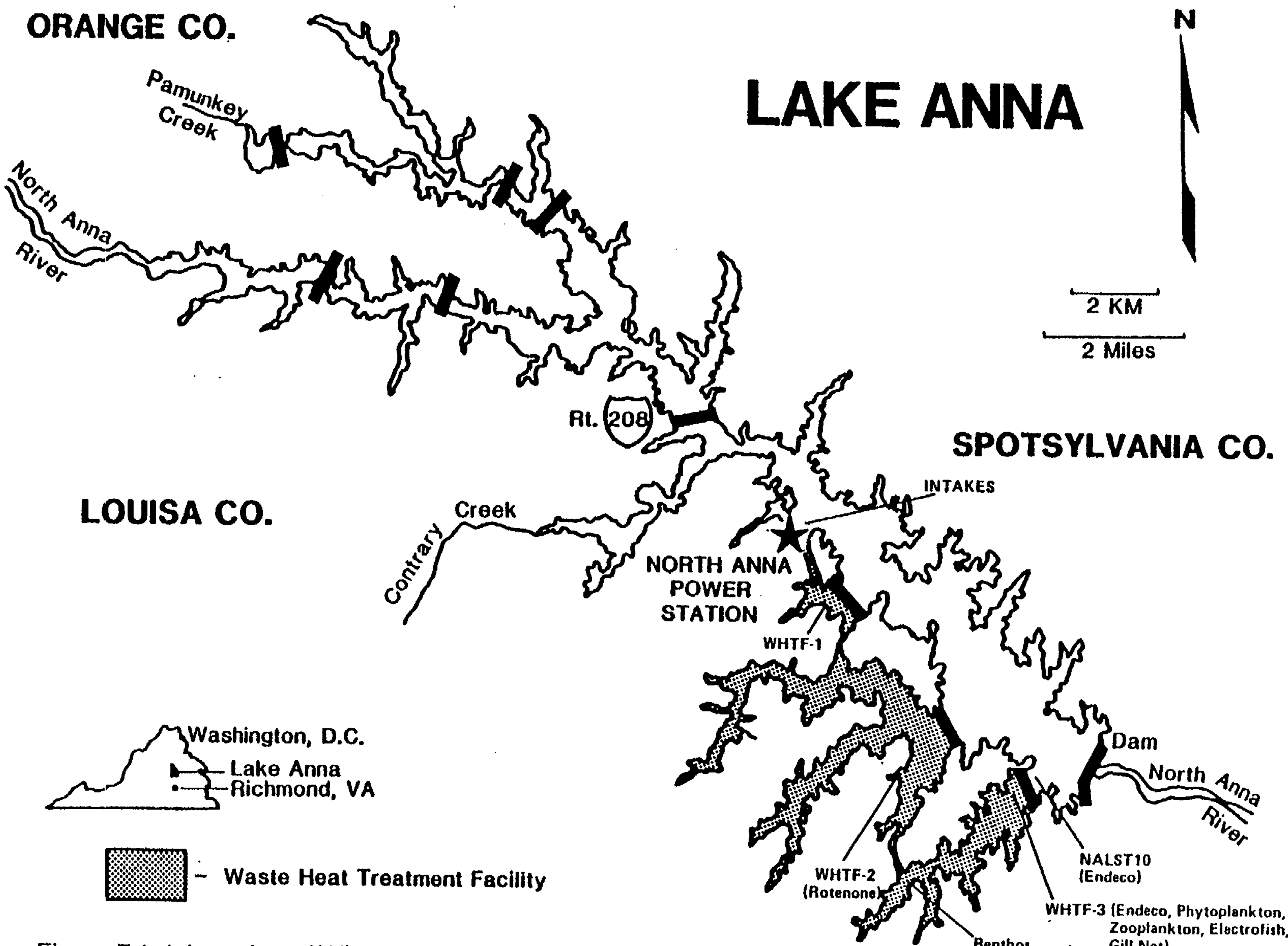

Figure 7.1-1. Location of WHTF sampling stations.

is given in Section 3.2. This comparison allows Virginia Power to address the licensed NPDES Btu level, as opposed to an operational Btu level, for North Anna Power Station for a potential ecological impact scenario.

7.1 Thermal Projections and Rationale

Increasing the power output of North Anna Power Station to the design level associated with the current NPDES permitted Btu level would result in a small increase in heat discharge to Lake Anna. Water reaching Lake Anna is projected to increase by an average of about 0.12°C in the summer (Table 7.1-1). Calculations for these values were obtained utilizing the formula:

$$\frac{T\ \text{Permit} - T_2}{T_2 - T\ \text{Natural}} = 6.6\%$$

Where T Permit $- T_2$ = Unknown temperature rise above existing two unit maximum temperatures

and T_2 $-$ T Natural = Two Unit temperature rise above natural = 1.8°C (MIT model prediction)

On examining historical summer water temperature data recorded by fixed continuous recorders in the WHTF (WHTF-3) and in the lower lake (NALST10 and NALBRPTT), water temperatures are always higher by approximately 2°C in the WHTF when the station is operating above 75% average capacity for the month (Table 7.1-2). These increases are considerably higher than those expected to occur if the station operated at the NPDES permitted Btu level. During the high station operation summer periods in 1983 and 1985,

Table 7.1-1. Comparison of the initial power level, the design power level, and the NPDES permit conditions at North Anna Power Station.

	Reactor Power Rating Per Unit MWt	Heat Rejection to Condenser For 2 Units BTU/Hr	Estimated Summer Temperature Increased Above Original License in the Lower Lake Deg C	%
Initial Power Level	2775			
Estimated Historial Max.		12.7×10^9		
Design Power Level	2900			
Estimated Design Max.		13.3×10^9	0.10	4.2
Current NPDES Permit		13.54×10^9	0.12	6.6

Table 7.1-2 Monthly means of daily average water temperatures (°C) for differences between NAWHTF3 and lake ENDECOS (NALST10 and NALBRPTT).

YEAR	MONTH	DELTA WHTF3-ST10	DELTA WHTF3-BRPTT	STATION POWER LEVEL %
81	6	.	2.8	78.6
	7	.	1.5	47.4
	8	.	1.6	59.8
	9	.	2.2	93.4
82	6	.	0.5	25.0
	7	.	1.3	9.3
	8	.	0.6	1.0
	9	.	1.9	47.2
83	6	.	2.9	79.3
	7	.	3.0	92.2
	8	.	2.8	99.4
	9	.	2.2	95.8
84	6	2.8	2.3	48.0
	7	1.6	1.7	43.1
	8	1.4	0.9	3.2
	9	0.7	0.3	0.8
85	6	3.2	3.2	99.3
	7	2.4	2.6	91.4
	8	1.4	1.8	72.2
	9	2.1	2.3	82.5

the maximum mean of the daily highs in WHTF-3 was 33.7°C (July) and 31.3°C (July), respectively. The actual maximum of hourly values in July were 34.7°C for 1983 and 33.4°C for 1985. Emphasis on temperature comparisons is placed on the summer months as temperatures are then at the higher extremes when any potential adverse biological impact is more likely to occur. In the sections which follow, information on the abundance, species composition and structure for each biotic category (See Fig. 4.-1) is compared over time within the WHTF (Fig. 7.1-1). Fish community data were analyzed from collections made in WHTF-2 and WHTF-3. Fish were collected for life history studies throughout the WHTF system (WHTF-1, WHTF-2 and WHTF-3). Collections of benthic macroinvertebrates (benthos), zooplankton and phytoplankton were assessed from WHTF-3.

7.2 Biological Data from the Waste Heat Treatment Facility

Phytoplankton

In the years since WHTF-3 was established, the phytoplankton density pattern is best described as a new-reservoir successional pattern (Fig. 7.2-1). Density was initially low, and between 1975 and 1977 monthly density was highly variable. From 1973 to 1977 annual density increased to a maximum in 1977. In 1978 monthly density abruptly declined to values lower than had been observed in the previous three years. Thereafter, the annual density has risen gradually through 1985. However, in 1984 and 1985

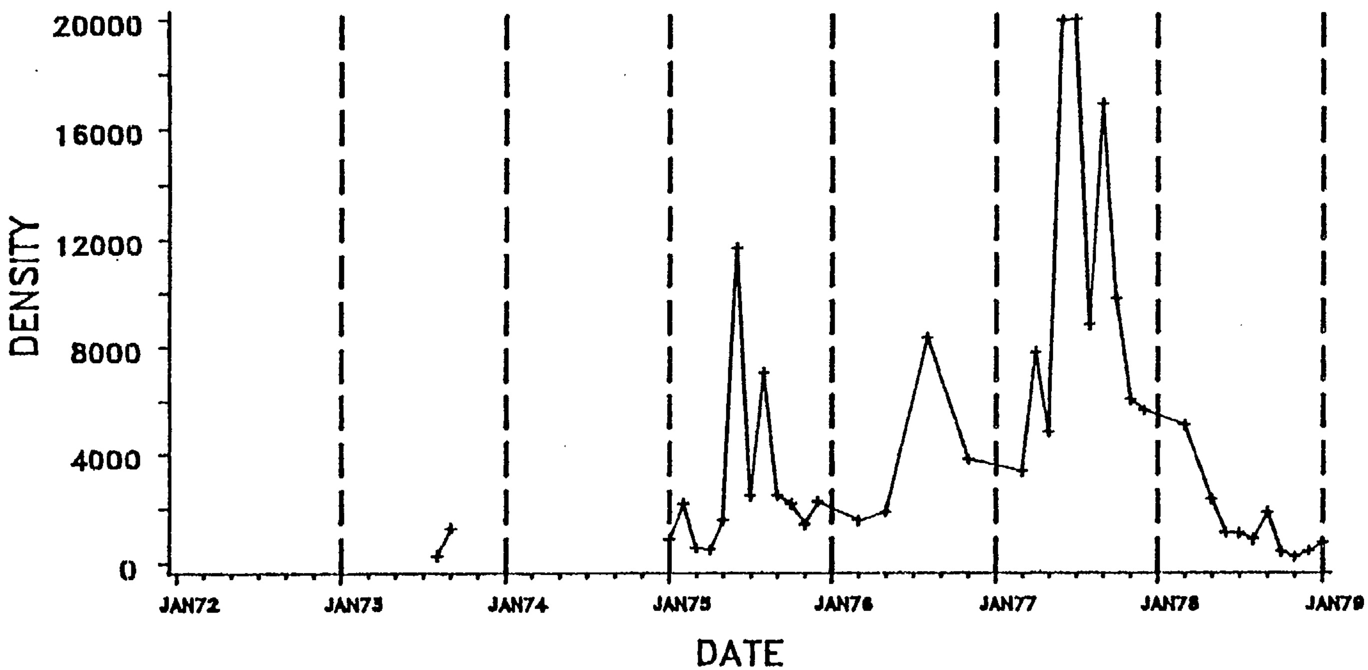

Figure 7.2–1. Mean phytoplankton monthly densities (no./ml) collected at the WHTF–3 station during 1972–1985. The means are truncated if greater than 20,000.

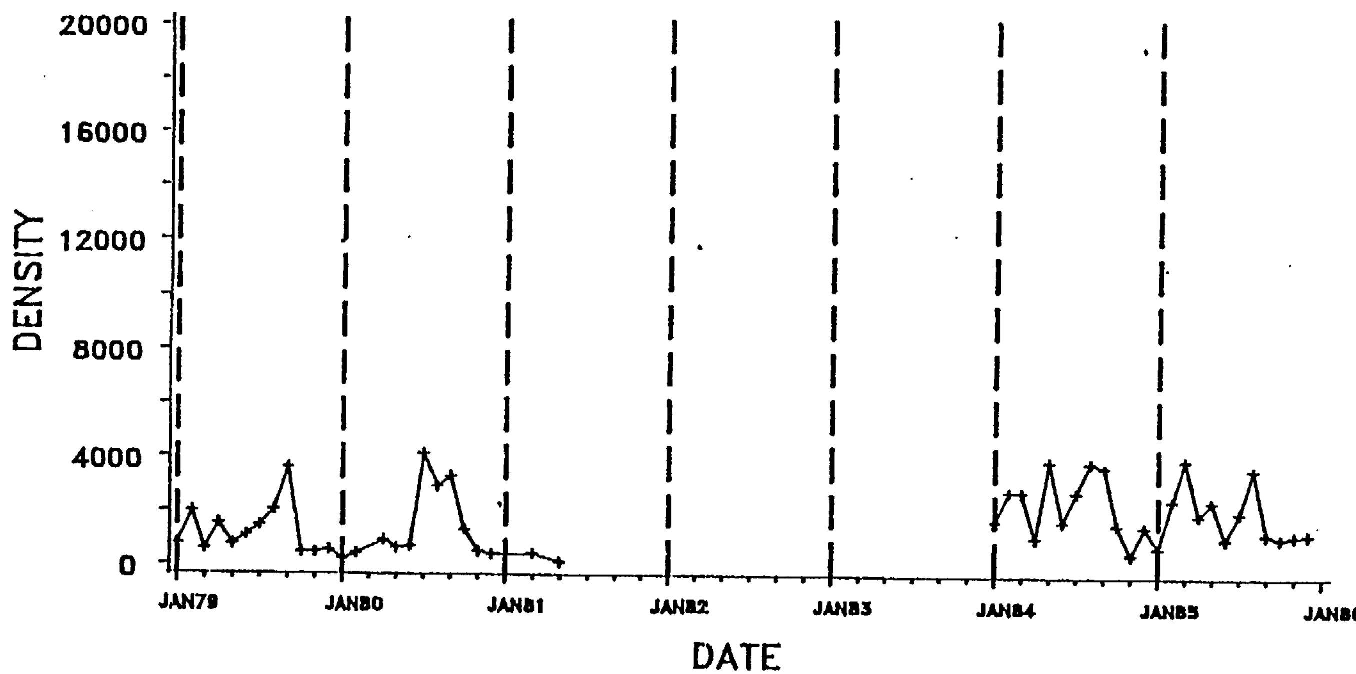

Figure 7.2–1. (Continued).

density variation was not strongly seasonal and several minor density peaks replaced the single strong summer pulse. The cause of this pattern is unknown.

In WHTF-3 the diatoms were abundant through 1979, especially in the winter and spring when they dominated the community (Fig. 7.2-2). After the 1977-78 decline, diatom density has remained relatively the same through 1985. Since 1979, however, diatoms have generally been of low relative density in the WHTF-3 phytoplankton community.

Cryptomonads appeared in WHTF-3 for the first time in the first sample collected in 1984. During 1984-85 they were the most abundant phytoplankton division in 19 of the 24 months. Meanwhile, they exhibited their typical pattern of high abundance in the winter and spring seasons. Cryptomonads tend to be abundant in oligotrophic waters. Hence, their appearance in WHTF-3 at a point in its maturation when the nitrogenous and phosphate nutrients have become relatively rare probably is not coincidental.

Green algae have maintained a relatively stable average annual density from 1978 through 1985. However, the period during which they were the most abundant division has shifted from the winter and spring seasons to the summer and autumn. The shift to warm-water periods of dominance coincides with their preferred habitat.

Unlike green algae, blue-green algae were more important community components early in WHTF history. During the 1978-80 period they had peak abundances during the summer. But from 1984 to 1985 their peak densities were

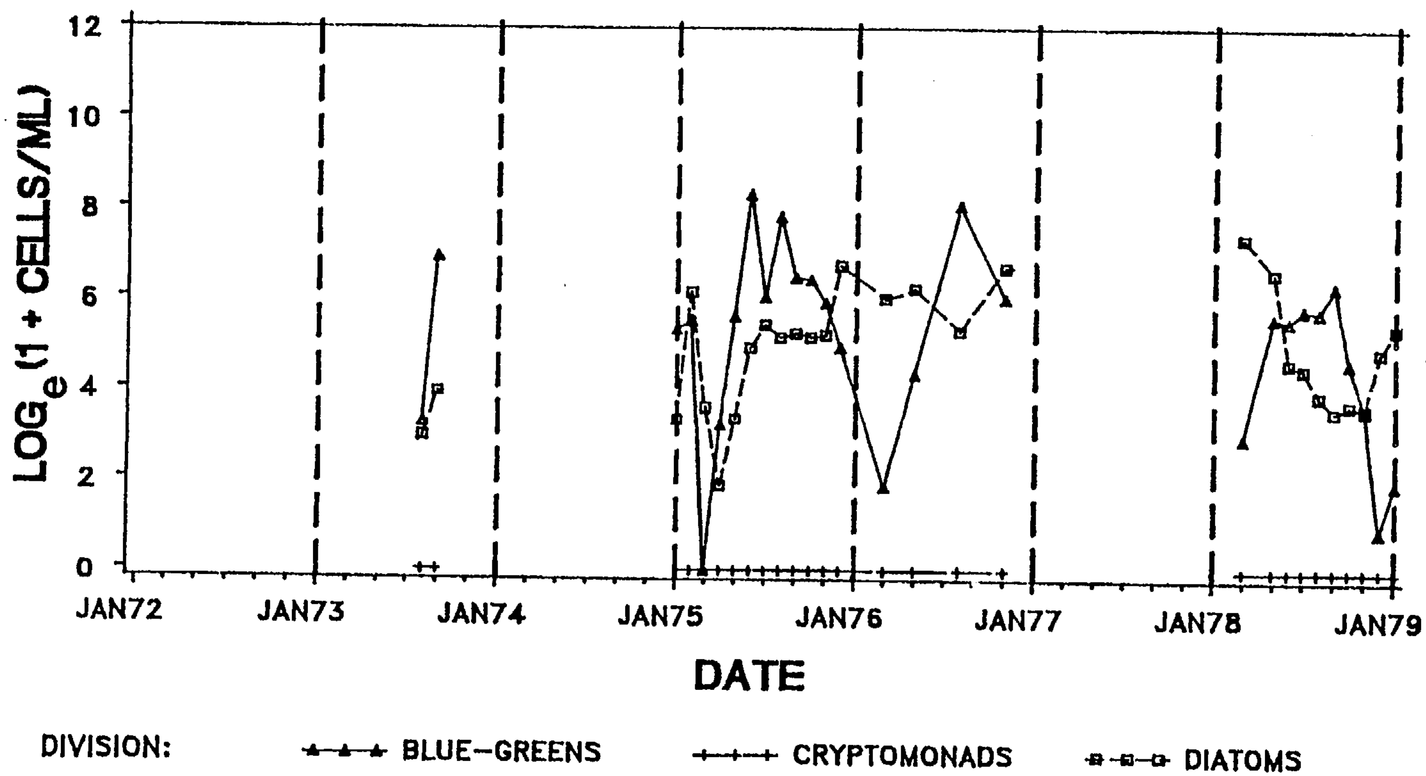

Figure 7.2–2. Density of selected phytoplankton divisions in Lake Anna, Virginia, at the WHTF–3 station during 1972–1985.

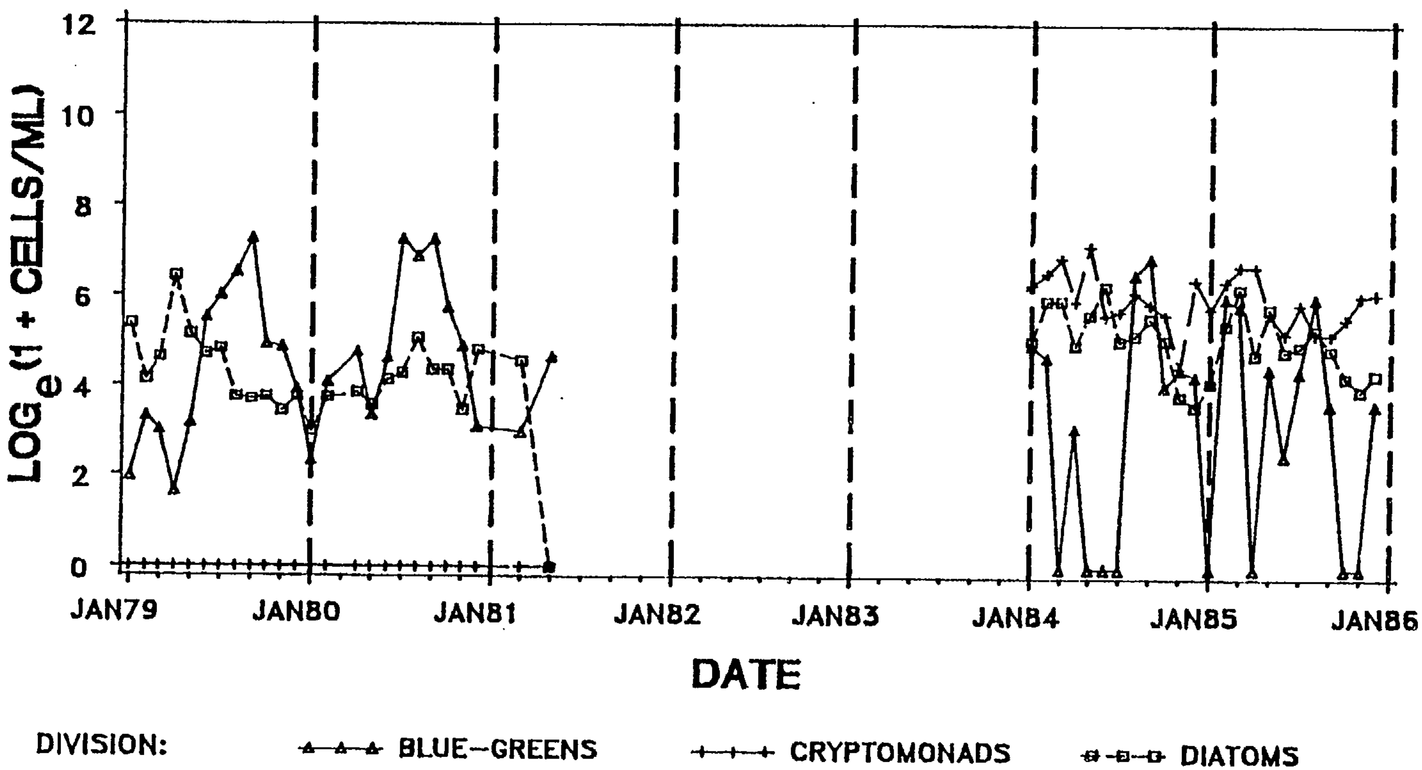

Figure 7.2-2. (Continued).

lower than in the previous period, they reached zero density in several months in each year and they were abundant for shorter periods. Although most algal groups respond to increased nutrient concentrations, blue-greens tend to be abundant when nutrients are rare. Also, because blue-greens are warm water species, their reduced abundance does not appear to be due to thermal enrichment. Consequently, their reduced degree and period of dominance since the immigration of cryptomonads may be a competitive effect.

The chlorophyll a concentrations varied in 1984-85 from 1 mg/m^3 to 7.5 units (reached in March 1985) indicating oligotrophic conditions in WHTF-3.

The only aspect of phytoplankton community structure and density pattern that suggests station operation effects is the multiple abundance peaks during 1984 and 1985 and the lack of one or, at most, two peak periods of dominance. One of the effects of operation may be the maintenance or encouragement of a relatively dense phytoplankton community in WHTF-3.

Density in WHTF-3 was similar to that at the Dam and Lower Lake in general. However, the WHTF-3 community tended to reach slightly greater densities than in the Lower Lake communities. Also, there was no single, strong period of abundance in either 1984 or 1985 in WHTF-3.

The WHTF-3 diatom record was similar in timing and in degree of importance to that at the Dam and the lower stations. In WHTF-3 the degree and timing of the Cryptophyta importance was similar to that in the Lower

Lake. In WHTF-3 the contribution of the green algae to the community was similar in pattern though of greater importance than that at the Dam station. From 1975 through 1980 the blue-green pattern of importance was similar to that at the Dam station. In 1984-85 it reached similarly low values.

Two environmental variables important for the phytoplankton are water temperature and light penetration. The environment at WHTF-3 was similar in Secchi disc depth and therefore in light penetration to the average of the Midlake and Intake stations. The light penetration was less than that at the Dam, indicating a more turbid water column. The thermal regime in WHTF-3 deviated from that in the lower lake by exhibiting warmer minimum winter temperatures and a narrower cool temperature period. Also, the warm temperature periods were broader than at the Dam station. The chlorophyll a values were comparable to those achieved in Lake Anna at Mid-lake or at the Intakes.

Zooplankton

The zooplankton assemblage in WHTF-3 is dominated by the rotifers with *Polyarthra* spp. and *Keratella* spp. the most common genera (Figs. 7.2-3 and 7.2-4). The number of rotifer taxa has remained stable (12-15) after the earlier transitional years when littoral species dropped out of the planktonic collections (Appendix B - Table 4). During the years 1973-1976 (pre-operational) and 1978-1985 (operational) the annual maximums have occurred during

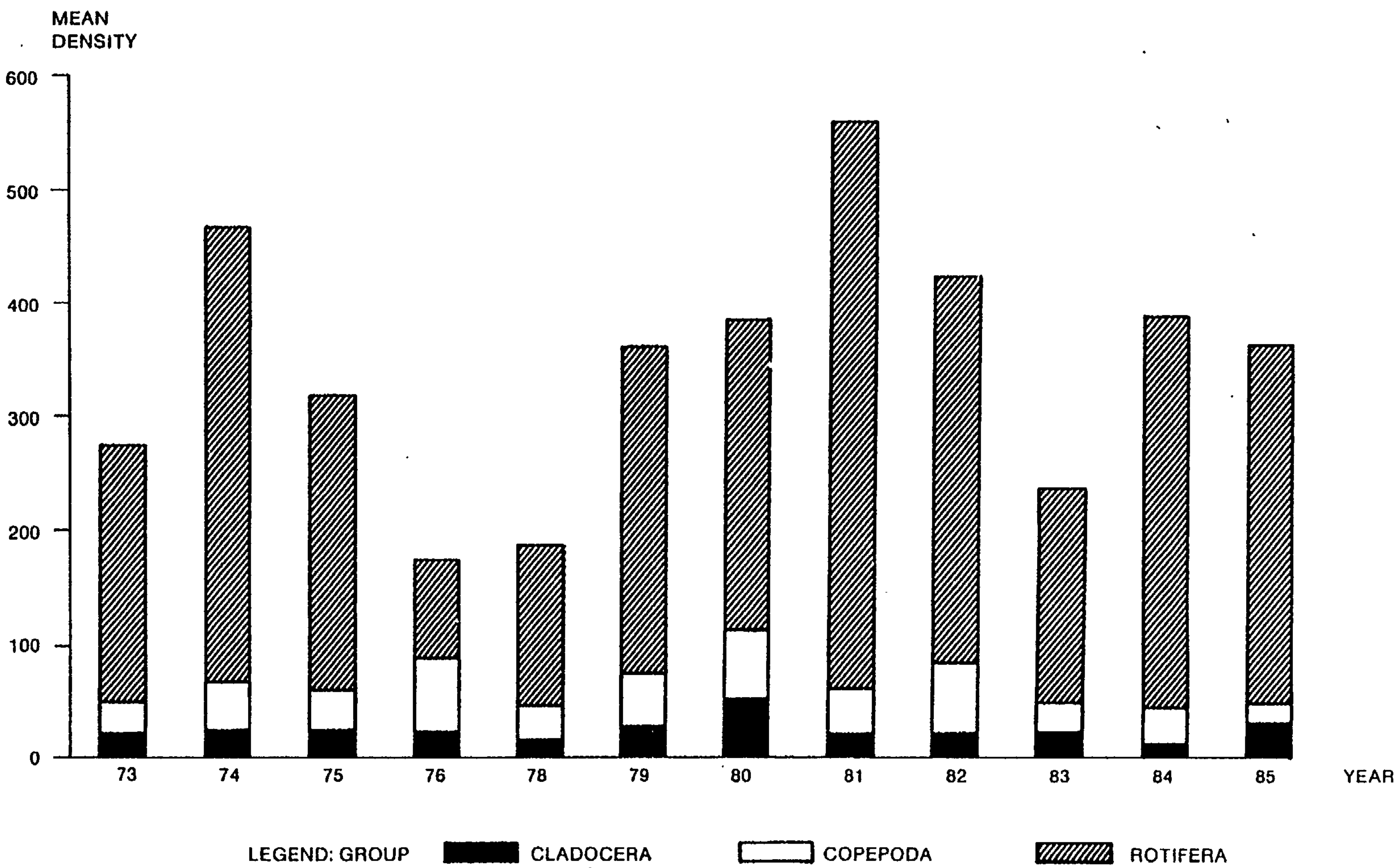

Figure 7.2-3. Comparison of mean annual densities (No./L) between years for the major zooplankton groups (Cladocera, Copepoda, and Rotifera) collected in the Waste Heat Treatment Facility-3, Lake Anna, Va., 1973-1984 (1977 data are missing).

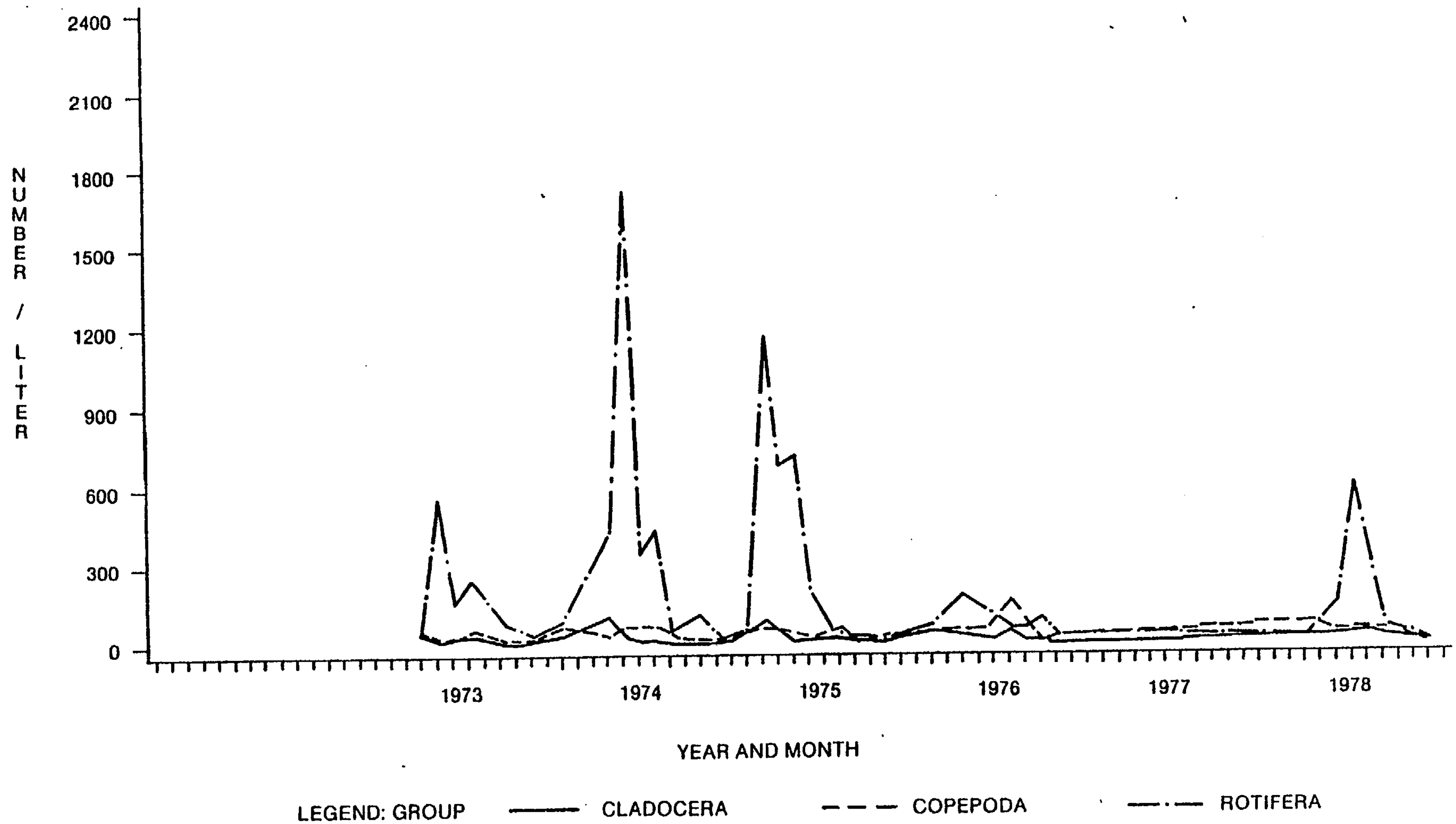

Figure 7.2-4. Comparison of mean densities (No./L) between months of the major zooplankton groups (Cladocera, Copepoda, and Rotifera) collected in the Waste Heat Treatment Facility-3, Lake Anna, Va., over 1973-1985. Means represent the average over depths.

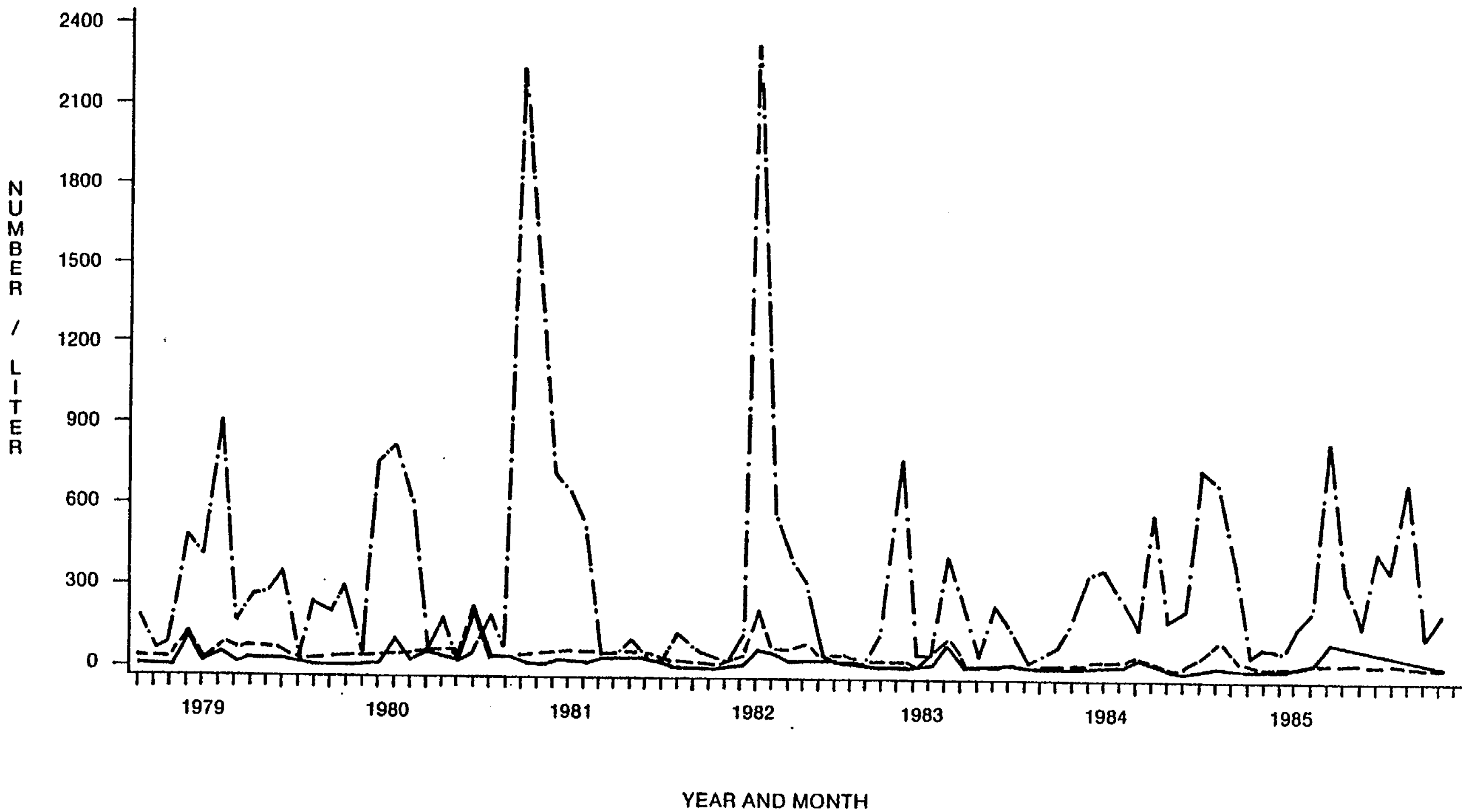

Figure 7.2-4. Continued LEGEND: GROUP —— CLADOCERA — — — COPEPODA —·— ROTIFERA

various months, influenced at times by large pulses of a single genus (Figure 7.2-3). The July annual maximum in 1973 was due to a bloom of Ptygura sp., a littoral species that later dropped out of the zooplankton assemblage. The large maxima in 1981 and 1982, although in different months, were both due primarily to a rapid increase in Polyarthra spp. With the exclusion of these years (1973, 1981, 1982), the annual densities during the operational years generally followed the density trends of the pre-operational years (Figure 7.2-4). The zooplankton community of WHTF-3 appears to be stable and balanced in terms of species richness and temporal density trends and is comparable with the communities of Lake Anna and other eastern temperature reservoirs (Appendix B-Table 1).

Benthos

The average seasonal density of benthos at the WHTF-3 station is shown over time from 1976-85 (Fig. 7.2-5). From the spring of 1976 to the spring of 1979, average densities ranged from 121-320 organisms per sampler. The spring (1976, 1979) and/or summer (1976,1978) seasons generally were characterized by greater densities during both the pre-operational and operational years. Densities increased during 1980 to a peak of 921 organisms per sampler and then steadily declined to a low of 42 in the fall of 1981. From this time to the present, densities ranged from 33-166 organisms per sampler. Average annual densities for the second and third years following initial impoundment

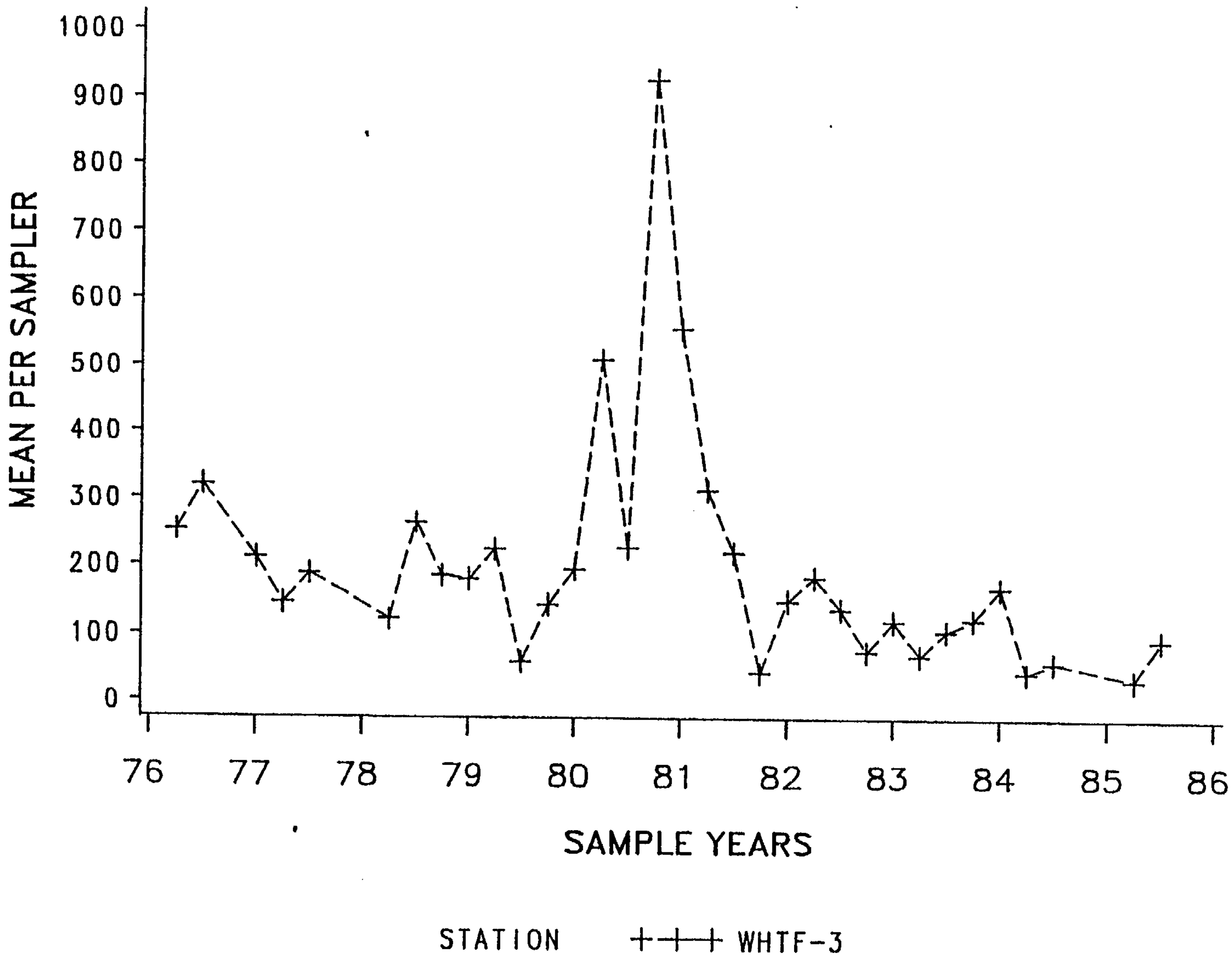

Figure 7.2-5. Average seasonal density of benthos of the WHTF-3 station on artificial substrates in Lake Anna, Virginia ,1976-1985.

were reported to be 203 and 220 per year, respectively (Reed and Simmons 1975). These densities are averages of the same 11 months (Nov., Dec., Jan.-Sept.) within each period. From Figure 7.2-5, it is evident these values are comparable to those derived for 1976-1979 (range = 150-286), less than that for 1980 (461) and greater than 1982-1985 (63-134).

For the operational years, 1981-85, average monthly density values were analyzed using a one-way ANOVA and Duncan's Multiple Range Test to determine if statistically significant differences existed between years at a given station (Table 7.2-1). The relative ranking of WHTF-3 average monthly densities from 1981-85 shows 1982 and 1984 were most often last. Monthly densities during these years, however, were rarely significantly lower than other years and neither year appeared to be influenced during any particular month. Benthic densities in this area during 1981, 1983, and 1985 did not appear to be affected by either the high average annual (1981 @ 69%, 1983 @ 72%, 1985 @ 83%) or summer (1981 @ 67%, 1983 @ 96%, 1985 @ 79%) operational levels evident at the time.

In addition to the changes in relative abundance, changes in the community structure also have occurred primarily as a result of the invasion of the Asiatic clam, *Corbicula fluminea*. Percent composition of the major benthic groups residing within WHTF-3 is shown over time from 1976-85 (Fig. 7.2-6). From the spring of 1976 to the spring of 1979, Trichoptera (caddisflies) and Chironomidae (midges) formed the largest percentage of those organisms

Table 7.2-1 Duncan's Multiple Range Test for Log transformed mean monthly benthic densities collected by artificial substrates in the WHTF3, Lake Anna, Virginia, 1981-1985. Years underscored by the same line were not significantly different (.05 level). Years are listed in order of decreasing densities left to right.

Jan	81	84	83		
Feb	81	82			
Mar	81	82	83	84	
Apr	82	81			
May	81	82	83	84	85
Jun	81	82			
Jul	83	82	85	84	
Aug	81	82			
Sep	81	82	85	83	84
Nov	83	81	82		
Dec	82	81			

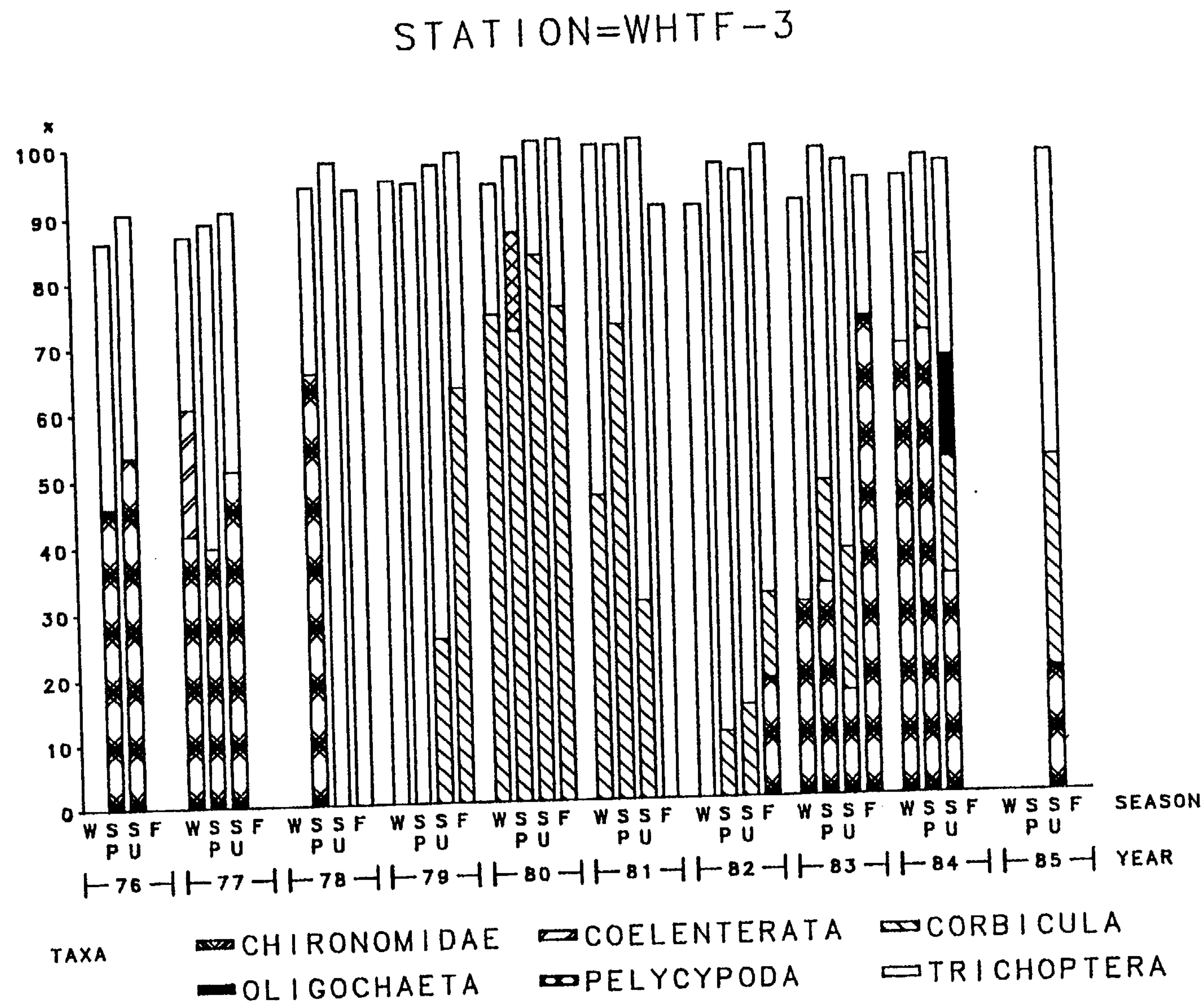

Figure 7.2-6. Average seasonal percent composition of the major(>10%) benthic groups of the WHTF-3 station on artificial substrates in Lake Anna, Virginia, 1976-1985.

found. Of these two groups, only Trichoptera appeared to be substantially present over the latter end of this period from the summer of 1978 to the spring of 1979. During the summer of 1979, the Asiatic clam was first collected and thereafter soon became the single most abundant organism through 1980 (Fig. 7.2-6).. Following its invasion in 1979 and subsequent peak in 1980, it has remained one of the dominant (greater than 10%) organisms although to a lesser degree. Beginning in the fall of 1983, all 3 groups (midges, Corbicula, caddisflies) previously dominant at one time or another became more evenly distributed and have remained so to date. As another measure of these changes in species composition over time, Shannon-Wiener's diversity index was generated and plotted from 1981-1985 (Fig. 7.2-7). This index, in support of the previously mentioned group distributional pattern, also shows an apparent improvement in the community structure taking place over the last five years.

Fish

The community structure of fishes in the WHTF has remained relatively stable since sampling began in 1976. Sunfish are the numerically dominant fishes collected in both electrofishing and rotenone samples. Bluegill is the most abundant sunfish in Lake Anna, and biomass has remained relatively high in the WHTF-2 (Table 7.2-2). Length frequency analysis of rotenone data indicate the bluegill population consists primarily of small fish (about 2.5 cm or

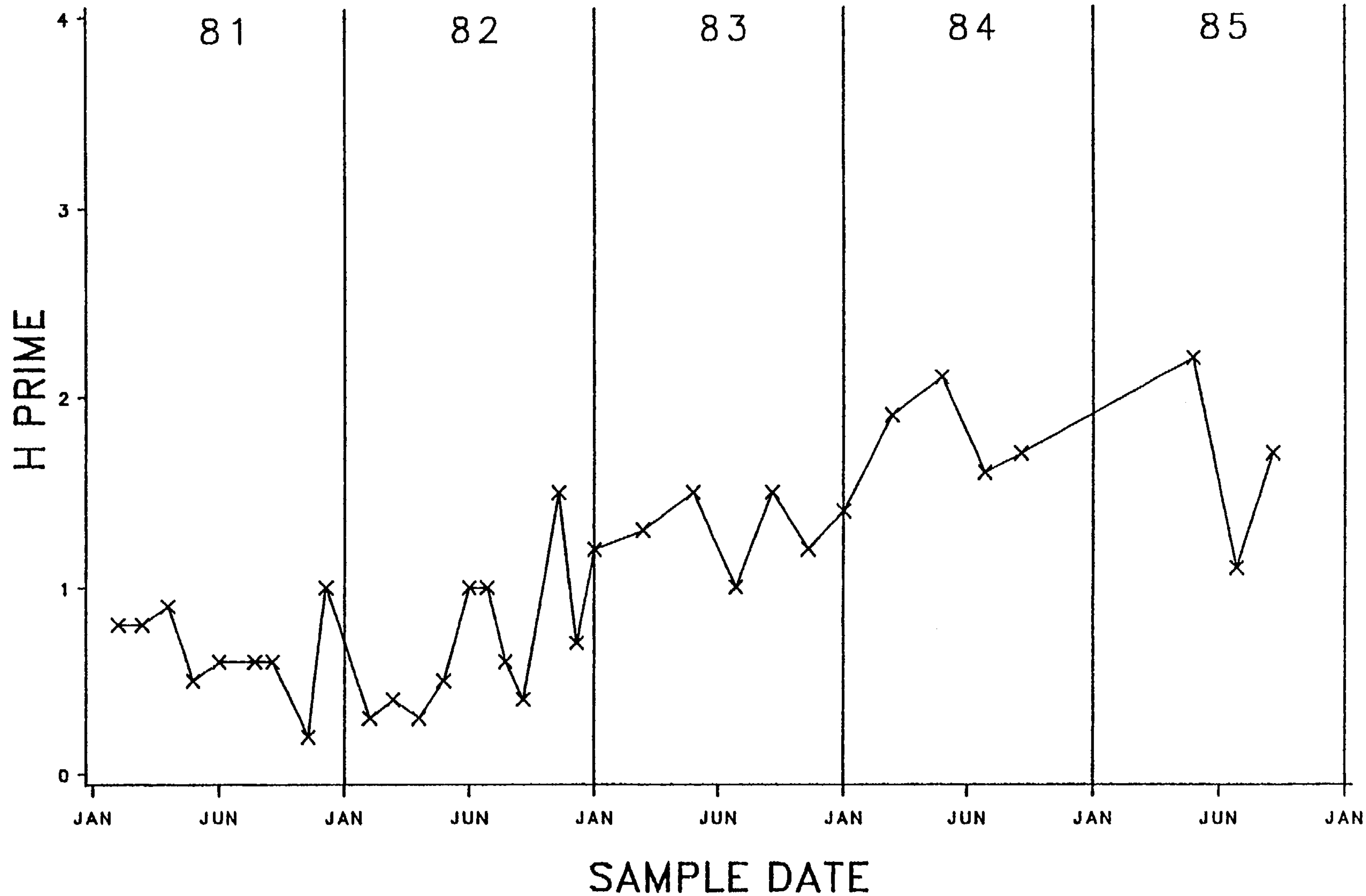

Figure 7.2-7. Benthic diversity trends at the WHTF-3 station on Lake Anna, Virginia , 1981-1985. Gear=artificial substrates.

Table 7.2-2. Second WHTF (Moody Cr.) Rotenone Data, By Biomass (kg/ha) and Number (Thousands/ha) for Major Species, 1978-1985*.

Species	kg/ha Moody	Thousands/ha Moody
Clupeidae		
Dorosoma cepedianum		
1978	39.6	-
1979	42.6	-
1980	38.0	-
1981	10.8	0.1
1982	34.6	0.3
1983	23.2	0.2
1984	87.0	0.6
1985	36.0	0.2
Dorosoma petenense		
1983	0.0	0.0
1984	0.0	0.0
1985	0.4	0.1
Esocidae		
Esox niger		
1978	0.9	-
1979	1.8	-
1980	1.0	-
1981	1.3	0.1
1982	0.0	0.0
1983	0.0	0.0
1984	0.0	0.0
1985	0.0	0.0
Cyprinidae		
Cyprinus carpio		
1978	35.4	-
1979	19.4	-
1980	0.0	-
1981	20.0	0.1
1982	47.6	0.1
1983	36.9	0.1
1984	0.0	0.0
1985	0.0	0.0

Table 7.2-2. continued

Species	kg/ha Moody	Thousands/ha Moody
Ictalaridae		
Ictalurus nebulosus		
1978	0.9	-
1979	3.9	-
1980	1.6	-
1981	2.0	0.1
1982	3.2	0.1
1983	0.5	0.1
1984	0.7	0.1
1985	0.2	0.1
Ictalurus punctatus		
1978	0.3	-
1979	3.9	-
1980	0.0	-
1981	7.6	0.1
1982	7.3	0.1
1983	2.9	0.1
1984	0.8	0.1
1985	6.0	0.1
Centrarchidae		
Lepomis microlophus		
1978	0.5	-
1979	0.4	-
1980	0.4	-
1981	5.0	0.2
1982	3.0	0.2
1983	5.0	0.1
1984	2.6	0.1
1985	6.5	0.1
Lepomis gulosus		
1978	2.8	-
1979	4.8	-
1980	0.8	-
1981	3.6	0.2
1982	2.0	0.2
1983	2.4	0.1
1984	3.3	0.2
1985	1.1	0.1

Table 7.2-2 continued

Species	kg/ha Moody	Thousands/ha Moody
Lepomis gibbosus		
1978	4.7	-
1979	4.1	-
1980	0.4	-
1981	0.7	0.1
1982	0.2	0.1
1983	0.0	0.0
1984	0.1	0.1
1985	0.1	0.1
Lepomis macrochirus		
1978	57.2	-
1979	68.8	-
1980	48.1	-
1981	42.5	6.9
1982	28.2	3.3
1983	29.0	3.5
1984	69.1	7.2
1985	68.4	12.8
Micropterus salmoides		
1978	5.5	-
1979	7.1	-
1980	2.9	-
1981	7.6	0.1
1982	2.0	0.1
1983	6.9	0.1
1984	7.0	0.1
1985	7.6	0.1
Pomoxis nigromaculatus		
1978	8.4	-
1979	50.5	-
1980	18.3	-
1981	27.4	0.8
1982	11.5	0.3
1983	8.0	0.2
1984	19.9	0.2
1985	4.4	0.1

Table 7.2-2. continued

Species	kg/ha Moody	Thousands/ha Moody
Percidae		
Perca flavescens		
1978	3.1	-
1979	6.7	-
1980	2.1	-
1981	0.5	0.1
1982	0.3	0.1
1983	0.1	0.1
1984	0.1	0.1
1985	0.1	0.1
Percichthyidae		
Morone americana		
1978	0.1	-
1979	0.8	-
1980	1.2	-
1981	3.0	0.1
1982	16.6	0.6
1983	5.1	0.1
1984	17.9	0.6
1985	18.0	0.8
Other species		
1978	5.5	-
1979	5.1	-
1980	2.6	-
1981	0.8	0.2
1982	1.2	0.2
1983	0.9	0.1
1984	1.1	0.1
1985	1.4	0.3

Table 7.2-2. continued

Species	Number of Species Moody	kg/ha	Thousanda/ha
Total species			
1978	15	164.8	-
1979	15	219.9	-
1980	12	117.4	-
1981	15	132.8	8.4
1982	16	157.7	5.1
1983	13	120.9	4.3
1984	15	209.5	8.9
1985	16	150.1	14.4

*Numerical data not readily available prior to 1981.

less) in August fluctuating between 70 and 90 percent which has been eivident since studies began. Pumpkinseed has generally been displaced by the redear sunfish (Table 7.2-2) which is the southern equivalent of the pumpkinseed (Pflieger 1975) and prefers the warmer water found in the WHTF. The redear sunfish is better adapted to feed on the hard shelled Asiatic clam, which has become more numerous in the WHTF, whereas the pumpkinseed is better adapted to feed on aquatic insects.

The standing crop of largemouth bass has remained fairly stable as indicated by examination of rotenone (WHTF-2) and electrofishing (WHTF-3) data (Table 7.2-2, Fig. 7.2-8). Gill netting (WHTF-3) results, however, show considerable fluctuations in numbers of large, largemouth bass collected (Fig. 7.2-9). This is to be expected as adults of this species are territorial and rarely range far from their own areas. Length frequencies of largemouth bass collected from the Moody Creek rotenone cove (WHTF-2) are divided into three length classes: young-of-year, less than 150mm; juveniles, less than 250mm; and adults, greater than 250mm (Fig. 7.2-10). The plot of juveniles is lagged one year behind the young-of-year plot and the adult plot is lagged two years behind the juvenile plot so as to more accurately indicate recruitment into those categories. These plots indicate numbers of young-of-year largemouth bass collected showed the greatest variability year to year with the adults the least and the juveniles intermediate. This is what one would expect in a normally developing

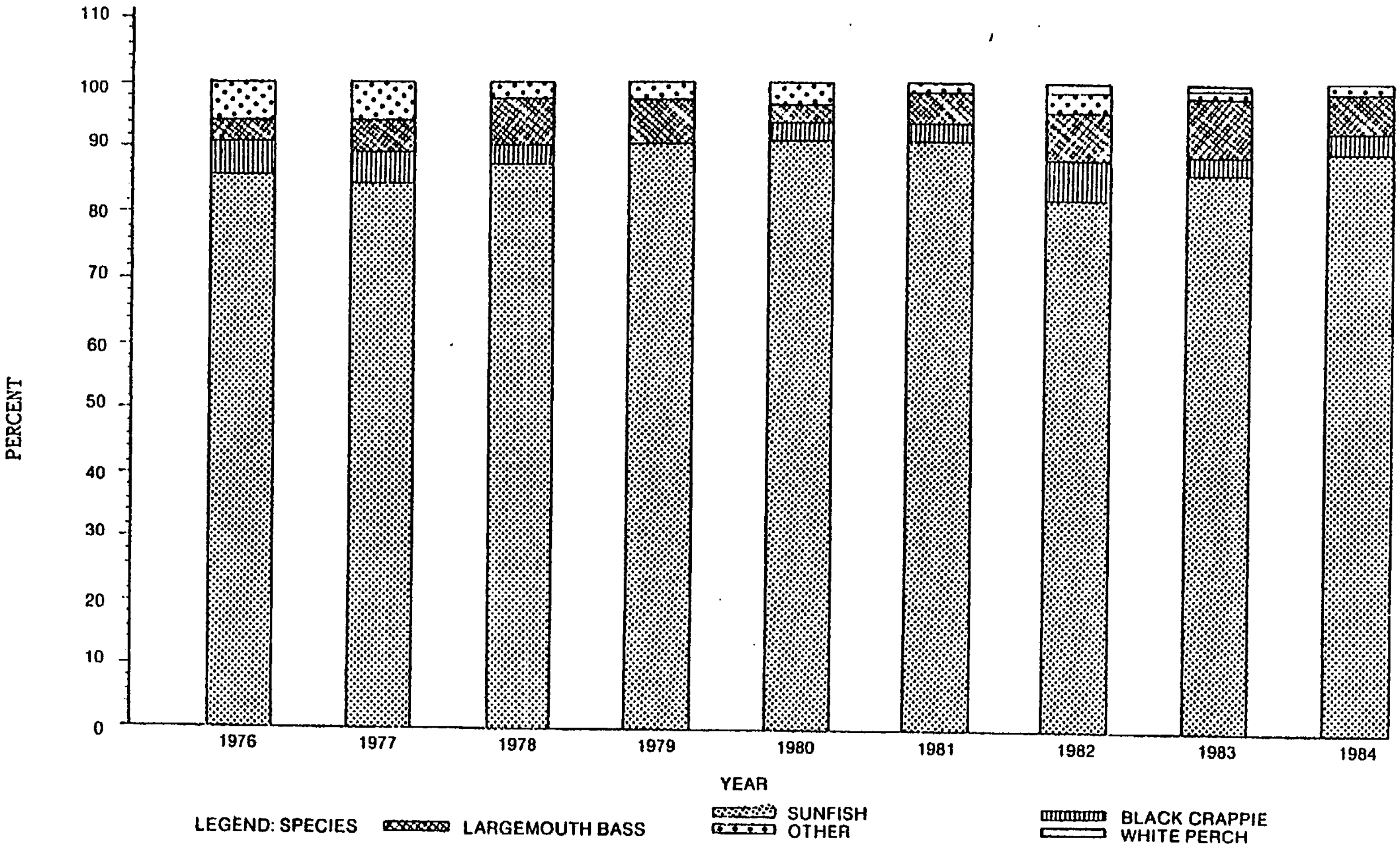

FIGURE 7.2.8. Percent Composition for WHTF-3 (Electrofish) Cove and Dike Stations Averaged.

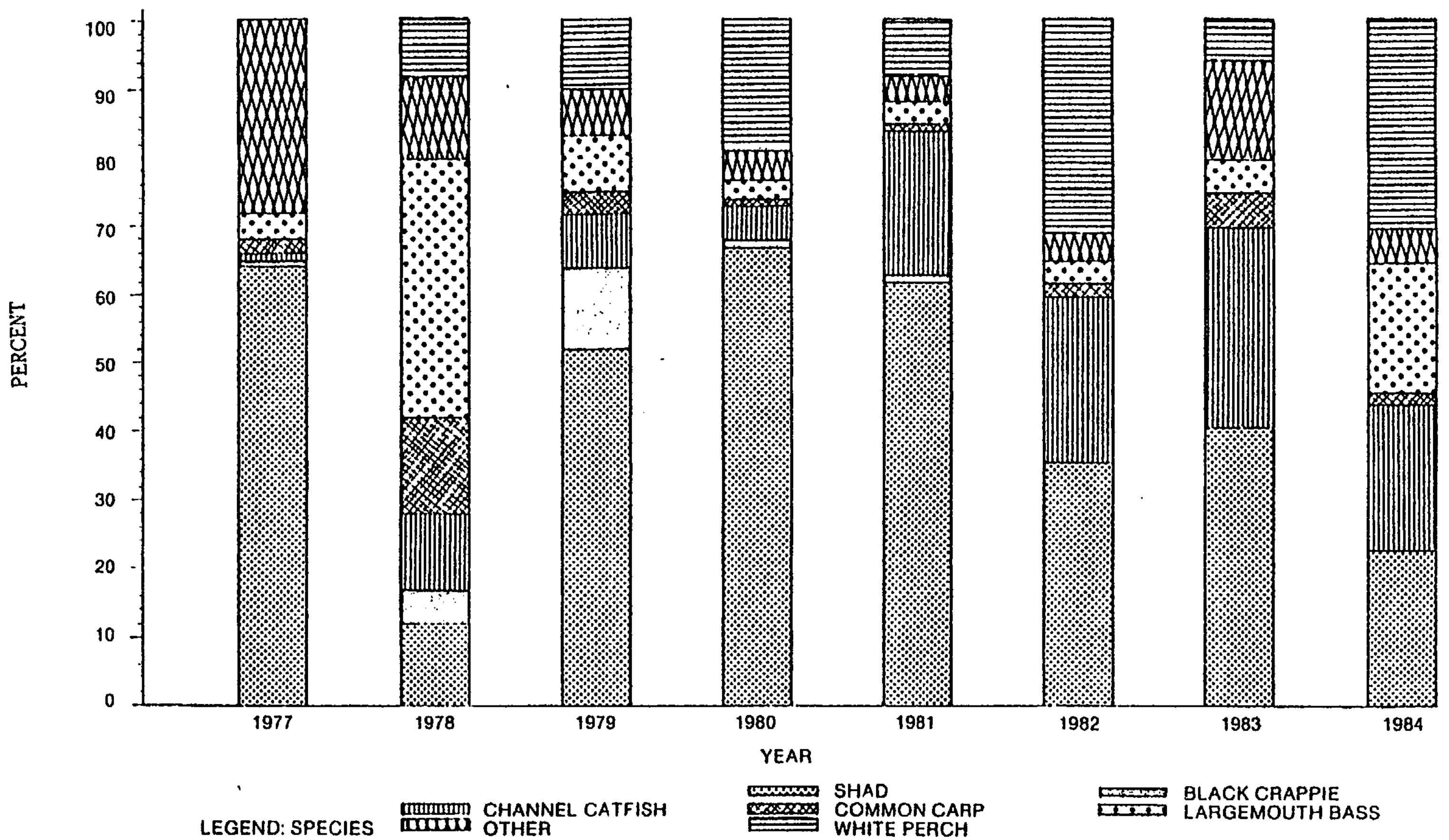

FIGURE 7.2-9. Percent Composition for WHTF-3 (Gill Net).

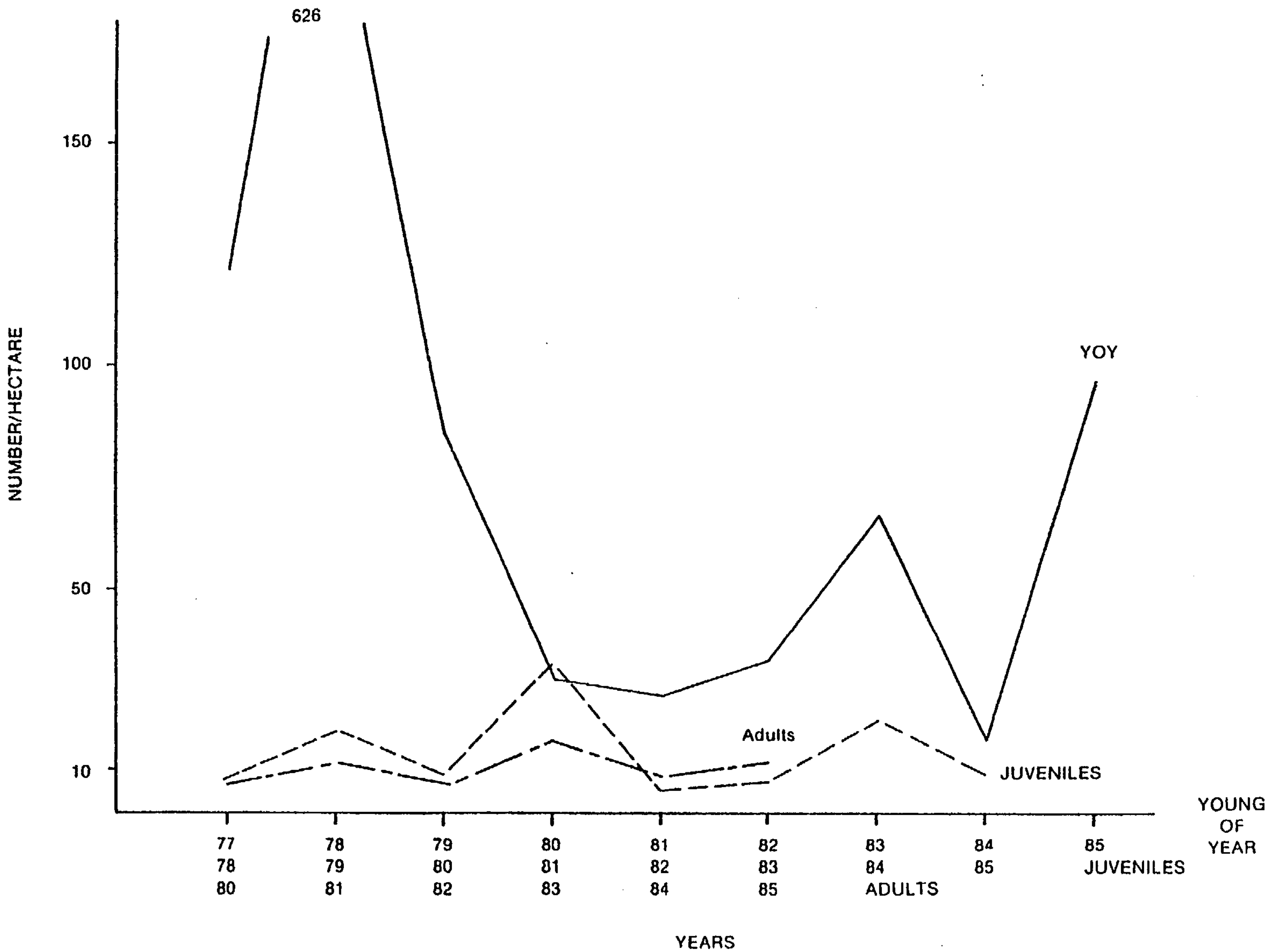

FIGURE 7.2.10. Results of Moody Creek (WHTF-2) largemouth bass rotenone data, young-of-the-year ≤150mm, 250mm>juvenile>150mm and adult ≥250mm with plots lagged to indicate recruitment.

largemouth bass population. An extremely good young-of-year class in 1978 showed up minimally in both juvenile and adult recruitment, probably due to dispersal throughout the WHTF system and not temperature related as the following operational years showed good recruitment. For example, a small young-of-year class in 1980 was followed by high recruitment for both juvenile and adult stocks, with the high adult stock extending into the next two years. This would seem to indicate a large young-of-year class in 1980 for another area of the WHTF with high migration and recruitment into the Moody Creek area. A large young-of-year class in 1983 is reflected in higher juvenile recruitment in 1984 which was evident for 1985. Overall, it would appear that a large young-of-year crop of largemouth bass is generally transposed into good recruitment for both juvenile and adult stocks. However, movement of young-of-year and juvenile largemouth bass into and out of coves tends to moderate fluctuations in young-of-year crops.

Black crappie electrofish, gill net and rotenone collection data from WHTF-2 and WHTF-3 are variable, probably due to gear selectivity, but do indicate a relatively small population of this species in the WHTF (Table 7.2-2 , Figs. 7.2-8 and 7.2-9). Although large natural fluctuations in number are common for this species (Swingle and Swingle 1967), it is hoped that the introduction of threadfin shad as an additional forage species in 1983 and the construction of underwater structures in Lake Anna will encourage a resurgence of this

species. Length frequency studies of black crappie (Moody Creek rotenone data) indicate there are more large individuals present in the population now (1985) and the number of large fish has been increasing since 1983 (Appendix B- Fig. 16). The relative uniform paucity of smaller individuals (8 cm or less) in August rotenone collections in shallow water coves may be because juvenile black crappie tend to seek out deeper water in August as their preferred temperatures may be slightly less than those of adult crappie (Edwards et al. 1982).

Collection data for white perch are also variable, probably due to gear selectivity, but gill net and rotenone data do indicate an increase in population size from 1977-78 to 1984-85 (Table 7.2-2 and Fig. 7.2-9). This species is a potential competitor with black crappie at both the larval and adult stages (Reid 1972; Keast 1978). Rotenone lake data indicate it is unlikely the white perch increase precipitated the black crappie decline. White perch may have expanded into the niche formally occupied by black crappie, however, when the latter population declined due to natural fluctuations.

Gill netting percent composition data show channel catfish have gradually increased in the WHTF-3 since 1977. This increase is indicated to a lesser degree by rotenone data (Table 7.2-2, Fig. 7.2-9). An increase would not be unusual in the WHTF as the catfish family generally is considered to be heat tolerant (Yoder and Gammon 1976) with a temperature preferendum of 30°C to 32°C. However, the

increase may not be as large as indicate by gill netting data alone as the larger individuals of this species are piscivorous and could be attracted to dead fish in gill net and become entangled, thus giving a false impression of overall density.

Number of common carp collected fluctuate greatly between years, but this probably is related to gear selectivity and the population appears to be stable in the WHTF (Table 7.2-2, Figure 7.2-9).

Gizzard shad collections have also fluctuated considerably in the WHTF-2 and WHTF-3. The percent composition of gizzard shad collected by gill netting and rotenone conflict but both results indicate an increase in size of individuals (Table 7.2-2). The lack of small forage fishes was one reason Virginia Commission of Game and Inland Fisheries personnel stocked the smaller threadfin shad in Lake Anna in 1983 (Almy 1986).

Threadfin shad, introduced to the lake in 1983, have not comprised a substantial proportion of electrofish or gill net collections in WHTF-3 nor August rotenone collections in WHTF-2. This, again, is most likely due to gear selectivity and small number of samples for this mid-water schooling species. The Lower Lake and WHTF is a winter refuge for threadfin shad and large schools have been observed there during this period.

Shannon-Wiener diversity values were calculated during the months June - August for each year (1977-1985) for electrofishing data collected from WHTF-3. Mean

diversity values were low, less than or equal to 1.0, as expected since bluegills numerically dominate the collections along the dikes. According to a one-way analysis of variance test no significant (.05 level) difference was found among yearly mean diversities, sugggesting summer diversity and structure has not changed significantly from 1977 through 1985.

Seasonal Shannon-Wiener diversity values were also examined from available combined electrofishing and gill netting data and were analyzed by a two-factor, year (1980 - 1984) and season (warming: February-April; summer: June-August; cooling: October-December), analysis of variance. The result of this analysis indicated the interaction of season and year was not significant at the 0.05 level. This suggests the seasonal patterns are similar over the time periods. Strong seasonal patterns within a year were not evident. It appears from these analyses a diverse assemblage of fishes is being maintained over time in the WHTF-3.

The food habits exhibited by adult largemouth bass in the WHTF compares favorably with the findings of studies conducted in systems containing bass populations (Lewis 1971; Zweiacker and Summerfelt 1974). The 1984 food study seemed to indicate threadfin shad throughout the WHTF became a major component of the bass diet; however, during the same year bass in the lake appeared to utilize sunfish more in their diet since threadfin shad occurred in only a small percentage of the stomach samples. It is not clear whether

this apparent dietary difference between the lake and the WHTF is due to prey selectivity or forage availability. Other systems in which threadfin shad have been stocked report their rapid incorporation into the largemouth diet (May et al. 1977; Hepworth and Pettengill 1979).

Studies of gonadal development (gonadosomatic indices, fecundity and average egg size) conducted for female largemouth bass collected throughout the WHTF system from 1979 to 1982 indicated they were developing normally prior to spawning. The values for the three methods were similar to those of bass in the lake and in other systems (Bagenal and Braum 1971; Reed 1980; Vepco 1982). Peaks in gonadal development during the four years of studies occurred two to four weeks earlier in the WHTF than in the lake possibly indicating early spawning of bass in the WHTF.

Age and growth data from largemouth bass collected throughout the WHTF system indicated growth during station operational years was greater than growth during pre-operatinal years (Fig. 7.2-11). Largemouth bass growth in the WHTF was similar to growth observed in the lake (Fig. 7.2-12).

Larval fish collections from the WHTF during 1984 and 1985 yielded the same five dominant species present in collections from the lake: shad, sunfish, yellow perch, white perch and black crappie. Overall, it appears spawning of these species was initiated about the same time in the WHTF as in the lower and mid lake despite the temperature differences between locations. During some collections four

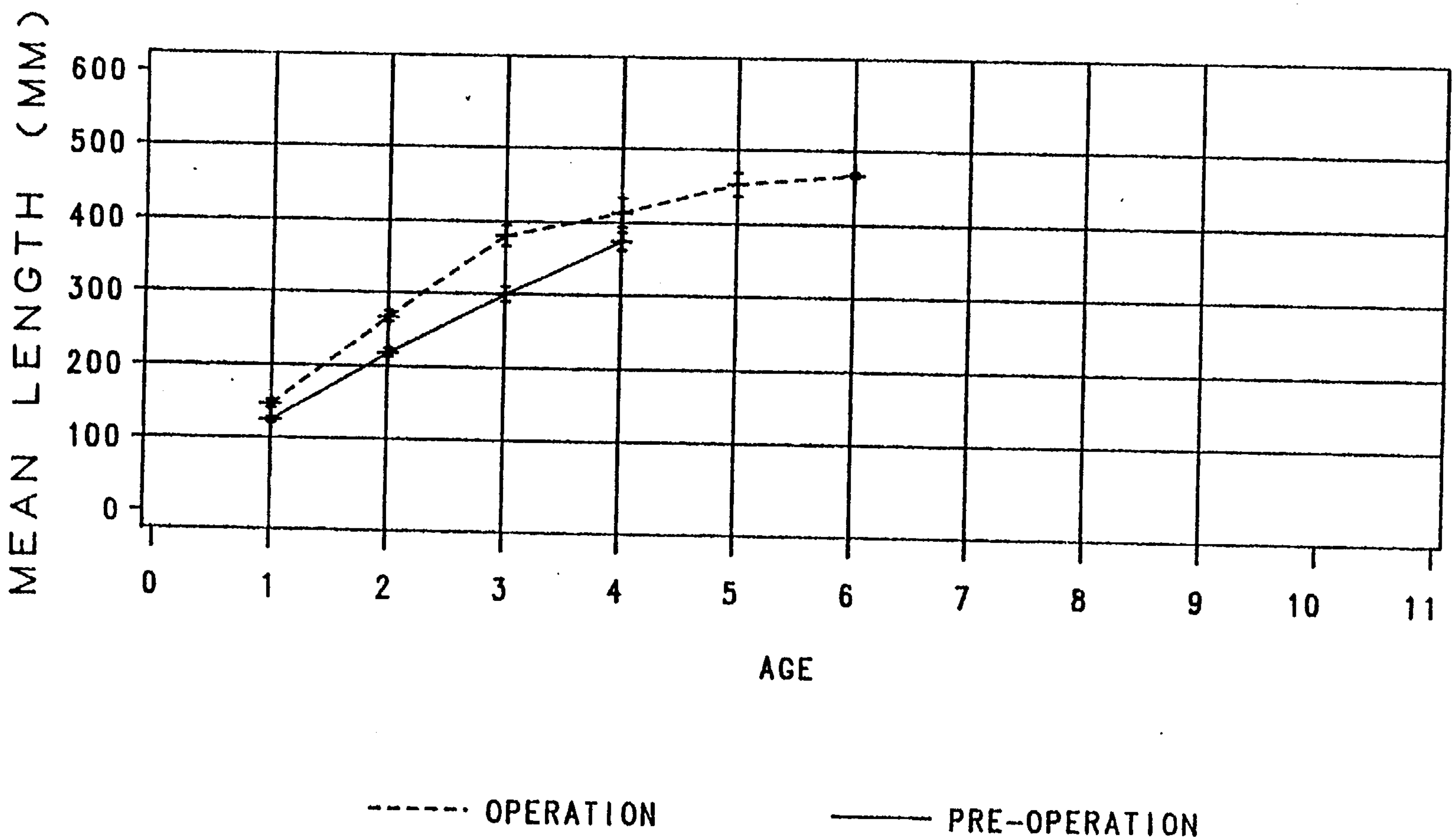

Figure 7.2-11. Comparison of growth of largemouth bass before and during station operation in the WHTF, Lake Anna, Virginia (collected from 1978 to 1985.) Two standard errors of the mean are indicated.

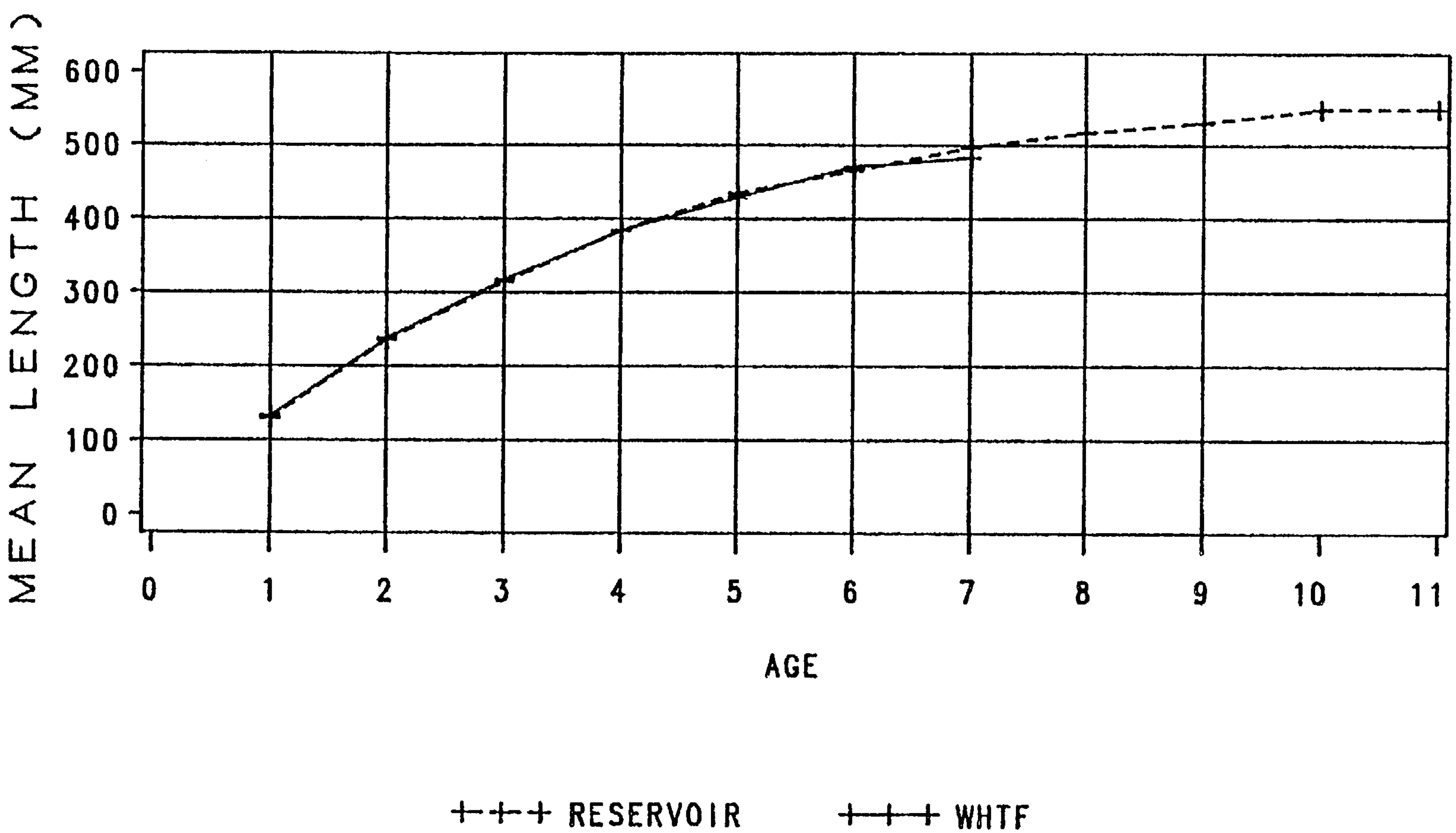

Figure 7.2-12. Comparison of growth between largemouth bass from the WHTF and Lake Anna, Virginia (collected from 1978 to 1985).

of the five species appeared to begin spawning two weeks earlier in WHTF-3 than in WHTF-2, WHTF-1, and lake locations. However, this does not appear to be related to temperature at time of spawn as temperatures both above and below WHTF-3 temperatures were present at other locations on the same dates.

7.3 Discussion

Biological data collected from the warmer WHTF were analyzed in an attempt to evaluate the potential environmental impact to Lake Anna as related to operating the two units at North Anna at design levels. A successful demonstration of a lack of impact would aid, based on the scientific data presented, in maintaining the existing NPDES permit effluent limitation of 13.54×10^9 Btu/hr which is approximately 6.6% above the estimated historical maximum. Although it is acknowledged the WHTF has some inherent differences in hydrological and morphometric characteristics compared to Lake Anna, as all bodies of water do, this surrogate approach still offers an acceptable and possibly the best approach in determining changes to the aquatic community in Lake Anna as a result of projected elevated water temperatures of 0.12°C in the summer to the lower lake.

The analyses and interpretations presented suggest that no appreciable change in the abundance or species composition of the fish, benthic and zooplankton communities in the WHTF study area has occurred over the years of study.

An exception to this is the appearance of the benthic exotic Asiatic clam in the summer of 1979 which has since remained one of the dominant organisms. Unlike the aforementioned biological groups, the phytoplankton community in WHTF-3 has changed somewhat over the years. However, the changes are consistent with those that have occurred in the Lower Lake. Largemouth bass life history studies in the WHTF indicate that feeding behavior and reproduction is adequate to maintain the population. Age and growth data suggest growth of largemouth bass has been consistent over time and compares favorably with the lake.

It appears that the biological communities are diverse and stable within the WHTF where temperatures are generally 2°C higher than in the lower lake. Because these temperatures are considerably higher than what would be expected in the lower lake under design conditions, the analyses depict potential "worst case" scenarios that may be perceived to possibly occur in the future under various station operational, meteorological and biological conditions in Lake Anna.

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