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THE STREAMS OF FLORIDA

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THE STREAMS OF FLORIDA

WILLIAM M. BECK, JR.[1]

SYNOPSIS: The various classifications of Florida streams proposed in the literature are reviewed and a revised classification offered. This is examined both statistically and with regard to factors controlling the distribution of aquatic invertebrates as outlined in Berg's Susaa study. Finally, the stream types proposed are delineated chemically, physically, and biologically.

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[1] The author is senior biologist of the Bureau of Sanitary Engineering, Florida State Board of Health. He is particularly interested in the ecology of stream invertebrates. This paper was supported in part by Research Grant No. AI-4098-04, Institute of Allergy and Infectious Diseases, National Institutes of Health. Manuscript submitted 29 April 1965.—ED.

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INTRODUCTION

Florida is abundantly supplied with varied and beautiful inland waters. Except for a few papers noted below, most limnological information on these waters is to be found in various faunal studies in which limnology is of importance mainly to help explain the ecological and geographical distributions of single groups of organisms. This has resulted in a variety of classifications which, when examined carefully, present a certain uniformity of considerable interest.

Population growth in Florida in the past 10 years has been little short of phenomenal, and industrial growth has been correspondingly great. This has placed a great demand on the natural waters of the State which, though abundant, are not always equitably distributed in time and space. Engineering alterations of the State's natural waterways have been extensive and are certain to increase in the near future. While many people consider these changes both necessary and beneficial, the fact remains that many of our most interesting waterways will soon cease to exist as natural entities.

The primary aim of this paper is to propose a uniform classification of the lotic habitats of Florida based on various published reports and my own investigations of the streams of Florida and adjacent states. Except for certain comparisons, no attempt is made to include lenitic habitats; several academic institutions in Florida are now conducting extensive lake studies. A second purpose is to record what the streams of Florida are like chemically, physically, and biologically while many virtually undisturbed examples still exist. It is hoped that this description of the streams of the area will be of use to the many biologists in North America who are helping to identify the previously unknown components of our aquatic fauna.

Throughout this discussion a stream is defined as a body of water with unidirectional flow of measurable velocity. This definition is manifestly a loose one, but such looseness—or flexibility—is necessary at present. Pollution is not a factor in any of the streams or reaches of streams on which this study is based.

The study of stream limnology in the United States has lagged far behind lake study. The basic reason for this is simple—the pioneering studies in North American limnology were made in universities located in lake regions. As these same institutions have remained dominant influences to the present time, the lag in stream studies is hardly surprising.

Most of the chemical, physical, and biological data for streams throughout the nation are to be found in the files of state and federal regulatory agencies, and they are seldom published in other than mimeographed form. This is strikingly true in Florida where the files of the Game and Fresh Water Fish Commission, the Conservation Department, the Geological Survey, and the State Board of Health contain extensive data. My own work for the past 17 years has involved water quality studies with major emphasis on streams. The biological data available consist of an estimated 180,000 distribution records for the macroscopic invertebrates.

Historical Review

The first serious study of aquatic biology in Florida was begun by Rogers in 1922 and published in 1933. He was followed shortly by Byers (1930). Subsequently the program was enlarged by their students, Carr (1940), Hobbs (1942), Pierce (1947), Berner (1950), Herring (1951), Young (1954, 1955), and Beck (1958). Other information on the streams of Florida may be found in the writings of Van Der Schalie (1940), Odum (1953a, 1953b, 1956, 1957a, 1957b), Wurtz and Roback (1955), Yount (1956a, 1956b), Sloan (1956), Whitford (1956), Yerger (1960), and Reid (1961). Of the aquatic invertebrates, major studies have been published thus far on the craneflies, dragonflies and damselflies, mayflies, aquatic bugs, chironomids, crayfishes, and plankton of selected habitats.

Currently under study in Florida are the amphipods (E. L. Bousfield, National Museum of Canada), freshwater shrimps (H. H. Hobbs, United States National Museum), stoneflies (A. R. Gaufin, University of Utah), caddisflies (H. H. Ross, Illinois Natural History Survey), ostracods (E. Ferguson, Jr., Lincoln University), blackflies (J. E. Burgess, Jr., Florida State Board of Health), and freshwater sponges (W. A. Moore, Loyola University). The mosquito fauna is one of the most intensively studied in the world.

Modest knowledge exists of the Florida faunas in the following groups: flatworms, bryozoans, mysids, isopods, water mites, dobsonflies, biting midges, and molluscs. The oligochaetes are rather poorly known, as are the leeches, alderflies, spongillaflies, and aquatic moths.

Physical aspects of Florida's streams have been covered in the publication by Smith *et alii* (1954).

It is impossible to acknowledge fully my indebtedness to the great number of people who have contributed in one way or another to the background of this paper. I wish especially to thank George A. Purcell, Statistician, Florida State Board of Health, for help with the statistical aspects of this study, and Lewis Berner and Oliver L. Austin, Jr., of the University of Florida, for reviewing the manuscript.

TERMINOLOGY AND METHODS

Table 1 summarizes and compares five previously proposed stream classifications. Their differences are largely semantic, except for Carr's and Berner's recognition of canals and Berner's emphasis on vegetation. The semantic differences are significant in such a term as "flatwoods river", which might actually be a sand-bottomed stream, a calcareous stream, or a swamp-and-bog stream. The latter more specific and descriptive terms are adopted for the present statistical examination of stream type. This study does not include estuaries, though they are mentioned briefly in the discussion of the St. Johns River.

Methods used for biological stream surveying published elsewhere (Beck, 1954, 1955, 1957) are summarized here for reference. Selected macroscopic invertebrates in Florida have been classified with regard to their observed reactions to organic pollution in streams. The approach differs from most other proposed methods in that it uses selected invertebrates to prove a stream clean on the basis of the presence of sensitive organisms, rather than the obverse approach that proves a stream polluted by the dominance of tolerant taxa. It further requires that each taxon used as an indicator organism be distributed widely both ecologically and geographically in the state. A discussion of the mayflies may help clarify these points.

Florida species of the genus *Stenonema* are almost totally confined to clean streams (Berner has recorded the genus from at least one lake). As they are distributed rather widely in the state and their reactions to organic pollution are known, they are valuable as indicator organisms. The species *Callibaetis floridanus* and *Caenis diminuta*, though much more widely distributed ecologically and geographically, are tolerant of gross pollution and are, therefore, of little value to the program. *Isonychia pictipes*, common in the flowing waters of northwestern Florida and sensitive to organic pollution, cannot be used because of its restricted range. The several species of the burrowing genus *Hexagenia* have both ecologic and geographic restrictions in their distributions that make them almost valueless in a statewide program.

Identifications are reported at several taxonomic levels, necessitated by the state of knowledge of the various groups, as many groups of aquatic organisms have been studied inadequately in Flor-

TABLE 1. TERMINOLOGIES OF AUTHORS

J. S. Rogers	A. F. Carr	H. H. Hobbs	L. Berner	J. Herring	This Paper
small streams	small streams	sand-bottomed	± vegetation	sand-bottomed	sand-bottomed
calcareous	spring runs	spring runs	calcareous	calcareous	calcareous
swamp-&-bog	with canals	small rivers	± vegetation	swamp-&-bog	swamp-&-bog
lower streams	larger streams	flatwoods rivers	slow-flowing	larger rivers	larger rivers
n. r.*	canals	n. r.*	canals	n. r.*	canals
small rills	——	springs	stagnant-rivers	——	——

* not recognized

ida. The oligochaetes are not identified beyond class, the simuliids beyond family, and only a few caddisflies beyond genus. Although this falls short of being completely satisfactory, at least the taxonomic reporting is as consistent as possible throughout.

Statistical Analysis

Thirty-five collections representing each of the live stream types listed in Table 1, plus an equal number of collections from lakes and ponds, were tabulated in order of decreasing frequency of taxa. The 10 most frequently collected taxa were tabulated for comparative purposes. Each fauna thus delineated was then compared with every other one in the manner illustrated in Table 2. This table of two colunms, A and B, is divided into four quadrants, 1, 2, 3, and 4. Quadrant 1 lists the 10 most frequently collected taxa from the sand-bottomed stream and quadrant 2 lists the numbers of records for the same taxa in the swamp-and-bog stream. Thus, the most consistent inhabitant of the sand-bottomed stream is a midge of the genus *Tanytarsus*, occurring in 33/35 collections, while the same genus occurred in only 12/35 collections from the swamp-and-bog stream. The comparison here is not of rank, but of records per 35 collections. Quadrant 3 lists the remainder of the 10 most frequently collected taxa from the swamp-and-bog stream and quadrant 4 gives the occurrence per 35 collections from the sand-bottomed stream of those taxa listed in quadrant 3. This was done for each possible pairing of water types.

The null hypothesis was used and the premise "There is no significant difference between the faunas of the several water types listed" was tested by chi-square.

$$\text{chi}^2 = \frac{N(\left| ad - bc \right| - \tfrac{1}{2}N)^2}{(a+b)\ (c+d)\ (a+c)\ (b+d)}$$

The formula includes Yates' correction (see Snedecor, 1956). Results of these tests are presented in Table 4.

Returning to Table 2, note that quadrant 1 lists five taxa represented by zeros in quadrant 2. The five taxa in question are all rheophilous taxa that would not predictably be found in waters with extremely low velocities typical of the swamp-and-bog stream. They are, therefore, typical or "character" (Berg, 1948) taxa when these two water types are compared. It was decided to retest the pairings following the removal of all taxa represented by a zero in any cell and use a revised null hypothesis as follows: "There is no significant difference between the faunas of the several water types listed when

TABLE 2.

	A Sand-bottomed		B Swamp-and-bog		
	1. *Tanytarsus* sp.	33	....	12	
	2. *Cheumatopsyche* sp.	31	....	0	
	3. Mayfly n.	31	1.	23	
	4. *Stenonema exiguum*	30	....	0	
	5. Ceratopogonidae	28	7.	15	
1.					2.
	6. Oligochaeta	27	2.	22	
	7. *Corydalis cornutus*	27	....	0	
	8. Damselfly n.	26	4.	19	
	9. Simuliidae	26	....	0	
	10. Elmidae	25	....	0	
	....	21	3. Beetle ad.	19	
	....	20	5. *Palaemonetes paludosus*	16	
	....	9	6. *Hyalella azteca*	15	
4.					3.
	....	23	8. *Cryptochironomus fulvus*	14	
	....	12	9. Beetle la.	14	
	....	9	10. *Chironomus attenuatus*	13	

TABLE 3.

	A Sand-bottomed		B Swamp-and-bog		
	1. *Tanytarsus* sp.	33	....	12	
	3. Mayfly n.	31	1.	23	
1.	5. Ceratopogonidae	28	7.	15	2.
	6. Oligochaeta	27	2.	22	
	8. Damselfly n.	26	4.	19	
	....	21	3. Beetle ad.	19	
	....	20	5. *Palaemonetes paludosus*	16	
	....	9	6. *Hyalella azteca*	15	
4.					3.
	....	23	8. *Cryptochironomus fulvus*	14	
	....	12	9. Beetle la.	14	
	....	9	10. *Chironomus attenuatus*	13	

all "typical" taxa are deleted." The data from Table 2, revised accordingly, are presented in Table 3. Results are presented in Table 5.

Table 4 shows that the original null hypothesis must be rejected unquestionably in every case. This resulted in a decision to remove all taxa represented by a zero in any cell in any pairing and to recalculate chi² and P values taking smaller degrees of freedom into consideration. Three categories (calcareous X larger rivers, larger rivers X swamp-and-bog, and swamp-and-bog X ponds) had no zeros in the original pairings and were not recalculated. Table 5 shows that even the revised null hypothesis had to be rejected in all cases. Actually, partly because of the decreased degrees of freedom, P values were even lower than in the initial chi² tests.

TABLE 4. ZERO CELLS INCLUDED.

Pairings	x^2	d.f.	P value	0.95 C.L.
Sand-bottomed X Calcareous	194.57	15	0.005	Significant
Sand-bottomed X Larger Rivers	171.93	16	0.005	"
Sand-bottomed X Swamp-&-bog	311.29	16	0.005	"
Sand-bottomed X Canals	366.92	16	0.005	"
Sand-bottomed X Ponds	305.15	15	0.005	"
Sand-bottomed X Lakes	506.13	17	0.005	"
Calcareous X Larger Rivers	99.54	17	0.010	"
Calcareous X Swamp-&-bog	153.08	17	0.005	"
Calcareous X Canal	340.87	18	0.005	"
Calcareous X Ponds	214.48	17	0.005	"
Calcareous X Lakes	370.47	19	0.005	"
Larger Rivers X Canals	194.62	16	0.005	"
Larger Rivers X Swamp-&-bog	44.58	15	0.001	"
Larger Rivers X Ponds	77.65	15	0.005	"
Larger Rivers X Lakes	245.78	18	0.005	"
Canals X Swamp-&-bog	175.24	14	0.005	"
Canals X Ponds	203.45	14	0.005	"
Canals X Lakes	581.45	19	0.005	"
Swamp-&-bog X Ponds	28.99	13	0.007	"
Swamp-&-bog X Lakes	246.22	17	0.005	"
Ponds X Lakes	237.17	16	0.005	"

Rejection of both null hypotheses points out that significant similarities are lacking. It would be possible at this point to resort to other statistical methods that would determine the significance of the existing differences. Such, however, does not appear to be necessary, as data already prepared are sufficient to point out that distinct faunal differences exist between the water types listed, and typical as well as ubiquitous taxa are listed for each stream type.

TABLE 5. ZERO CELLS EXCLUDED.

Pairings	x^2	d.f.	P value	0.95 C.L.
Sand-bottomed X Calcareous	84.13	12	0.003	Significant
Sand-bottomed X Larger Rivers	136.09	15	0.005	"
Sand-bottomed X Swamp-&-bog	79.93	11	0.002	"
Sand-bottomed X Canals	99.72	10	0.001	"
Sand-bottomed X Ponds	48.52	9	0.0005	"
Sand-bottomed X Lakes	103.05	4	0.0005	"
Calcareous X Swamp-&-bog	31.33	13	0.005	"
Calcareous X Canals	154.71	12	0.003	"
Calcareous X Ponds	58.77	12	0.003	"
Calcareous X Lakes	24.83	5	0.0005	"
Larger Rivers X Canals	138.90	14	0.005	"
Larger Rivers X Ponds	59.41	14	0.005	"
Larger Rivers X Lakes	81.10	8	0.0005	"
Canals X Swamp-&-bog	139.40	13	0.005	"
Canals X Ponds	178.18	13	0.005	"
Canals X Lakes	113.83	5	0.0005	"
Swamp-&-bog X Lakes	25.58	5	0.0005	"
Ponds X Lakes	105.85	7	0.0005	"

In Table 6 are listed the non-common faunal elements for each pairing of water types. Those marked with an asterisk are rheophilous taxa. The differences in taxa reveal differences in physical and chemical features of the stream types in question. In the pairing of sand-bottomed X calcareous streams, for example, the differences are attributable to chemical, not physical factors, due to the fact that both streams support rheophilous taxa, but the calcareous stream is populated by greater snail populations, one genus being confined to that stream type.

In comparing the sand-bottomed stream with the swamp-and-bog stream the only distinctive elements of either fauna are confined to the sand-bottomed stream (within the limits of this particular pairing) and all five distinctive taxa are rheobionts. The comparisons are discussed more thoroughly below.

The general approach used herein is hardly a new one, as the following quotation from Curtis and Greene (1949: 83) shows:

TABLE 6. NON-COMMON FAUNAL ELEMENTS.

SAND-BOTTOMED Elmidae*	X	CALCAREOUS *Goniobasis* spp.* *Campeloma* spp.
SAND-BOTTOMED Elmidae*	X	LARGER RIVERS O
SAND-BOTTOMED *Cheumatopsyche* spp.* *Stenonema exiguum** *Corydalis cornutus** Simuliidae* Elmidae*	X	SWAMP-AND-BOG O
SAND-BOTTOMED *Cheumatopsyche* spp.* *Stenonema exiguum** *Corydalis cornutus** Simuliidae* Elmidae*	X	CANALS *Chlamydotheca*
SAND-BOTTOMED *Cheumatopsyche* spp.* *Stenonema exiguum** *Corydalis cornutus** Simuliidae* Elmidae*	X	PONDS *Glyptotendipes lobiferus*
SAND-BOTTOMED *Cheumatopsyche* spp.* Mayfly nn. *Stenonema exiguum** *Corydalis cornutus** Damselfly nn. Simuliidae* Elmidae*	X	LAKES *Chaoborus* sp. *Coelotanypus* spp. *Procladius* spp. Unid. chironomids *Hexagenia* sp. *Glyptotendipes parpies*
CALCAREOUS O	X	LARGER RIVERS O
CALCAREOUS *Goniobasis* spp.* *Stenonema exiguum** *Corydalis cornutus** *Cheumatopsyche* spp.*	X	SWAMP-AND-BOG O

CALCAREOUS *Goniobasis* spp.* *Stenonema exiguum** *Corydalis cornutus** *Cheumatopsyche* spp.* *Tanytarsus* spp.	X	CANALS *Chlamydotheca*
CALCAREOUS *Goniobasis* spp.* *Stenonema exiguum** *Corydalis cornutus** *Cheumatopsyche* spp.*	X	PONDS *Glyptotendipes lobiferus*
CALCAREOUS *Goniobasis* spp.* *Stenonema exiguum** Beetle larvae Mayfly nn. *Campeloma* spp. *Corydalis cornutus** Beetle adults Hydracarina *Cheumatopsyche* spp.*	X	LAKES *Chaoborus* sp. *Coelotanypus* spp. Unid. chironomids *Hexagenia* sp. *Glyptotendipes paripes*
LARGER RIVERS *Argia* spp.*	X	CANALS *Chlamydotheca*
LARGER RIVERS O	X	SWAMP-AND-BOG O
LARGER RIVERS Sphaeriidae	X	PONDS O
LARGER RIVERS Mayfly nn. Damselfly nn. *Polypedilum illinoense* *Argia* spp.* *Pentaneura monilis* gp. Sphaeriidae Beetle ad. Hydracarina	X	LAKES Unid. chironomids *Hexagenia* sp.
CANALS O	X	PONDS *Glyptotendipes lobiferus*

CANALS	X	LAKES
Damselfly nn. *Hyalella azteca* *Palaemonetes paludosus* *Physa pumilia* Mayfly nn. Beetle ad. Dragonfly nn. *Chlamydotheca* *Ferrissia* sp.		*Coelotanypus* spp. *Procladius* sp. Unid. chironomids *Hexagenia* sp. *Glyptotendipes paripes*

SWAMP-AND-BOG	X	PONDS
O		O

SWAMP-AND-BOG	X	LAKES
Mayfly nn. Beetle la. Damselfly nn. *Palaemonetes paludosus* *Hyalella azteca* *Cryptochironomus* spp. Beetle la.		*Chaoborus* spp. *Coelotanypus* spp. *Procladius* spp. Unid. chironomids *Hexagenia* sp.

PONDS	X	LAKES
Mayfly nn. *Hyalella azteca* Damselfly nn. *Cryptochironomus* spp. *Physa pumilia* Beetle ad.		*Coelotanypus* spp. Unid. chironomids *Hexagenia* sp.

"The second method involves the study of as many stands as possible for each type of assemblage in the area. Only simple characters are examined in each stand, since the time and expense of detailed studies are prohibitive when used on this scale. Presence is the character usually recorded in the method (Braun-Blanquet, '32; Dansereau, '43). If a given species occurrs in only a few stands, it obviously is not an important member of the community, regardless of possible prominence in any one stand chosen at random. The presence method gives a valuable picture of the range of variation between the stands of each community and may indicate interrelationships between communities more readily than is possible with the single stand technique. It is easy to apply in the field and is particularly valuable in the detection of indicator species for land-use studies and other practical conservation endeavors."

The non-common faunal elements listed in Table 6 are potential indicator organisms of the several stream types. This must, however, be handled conservatively. In the pairing of sand-bottomed X larger rivers, for example, it would appear that the elmid beetles are confined to the sand-bottomed stream and are, therefore, indicative of that particular stream type. Examination of all records for elmid beetles reveals that they are occasionally found not only in the larger rivers but in calcareous streams as well. They were simply not present in the 35 collections from larger streams used in this study. In all pairings involving canals the ostracod, *Chlamydotheca unispinosa*, is the single apparently typical taxon, except in the pairing with ponds in which this ostracod is also found. In lotic environments, therefore, this organism is indicative of canals.

Table 6 also shows that the relationships between sand-bottomed streams, calcareous streams, and larger rivers are close. This is as it should be, for all three are strictly lotic habitats, as opposed to two other types which must be considered sublotic (see below). Snails of the genera *Goniobasis* and *Campeloma* appear to be typical of the calcareous stream, though only *Goniobasis* is truly typical, and the faunal distinctions between calcareous and sand-bottomed streams appear to be the result of chemical rather than physical differences. When compared with each other neither calcareous streams nor larger rivers have any distinctive taxa. This is hardly surprising as part of total flow of the larger rivers originates from calcareous streams as well as other stream types—hence the lengthier term "larger rivers of mixed origin." It is interesting to note that when compared with each other neither the swamp-and-bog streams nor the larger rivers possess any truly distinctive faunal elements despite the strong rejection of the null hypothesis in this pairing. It is also of interest that the 10 most frequently encountered taxa of the larger rivers include not one rheobiont, although rheobionts are a definite part of the normal fauna of the larger rivers.

Table 7 lists 10 taxa considered ubiquitous in order of decreasing ubiquity index. Mayfly nymphs include all mayflies other than the genera *Stenonema*, *Baetisca*, and *Hexagenia*, these being the only mayflies identified beyond order in our routine work. Oligochaetes as reported here include only those forms either belonging to or similar to the tubificids. Damselfly nymphs include all members of the suborder except species of the genus *Argia*. All beetles with the exception of the elmids are unidentified. *Tanytarsus* as here reported includes only unidentified species of the chironomid subgenus *Atanytarsus*. Only the bottom-dwelling, serpentine Ceratopogonidae are included in the family-level reporting. The short bodied genera such as *Atrichopogon* and the elongate inhabitants of algal masses are excluded.

Although this ubiquity index is an artificial device consisting simply of the average frequency of occurrence of the 10 most frequently listed taxa universally encountered in the five stream types, it does present some interesting facts. Most ubiquists so delineated are simply unidentified representatives of larger taxonomic groups, thus making the ubiquity index, within limits, a reflection of lack of identification beyond the higher categories. Of the three taxa listed that represent specific identifications, each is actually not only the most widely distributed member of its genus in Florida, but the most widely distributed member of its order. Of the normally unidentified mayflies at least two, *Callibaetis floridanus* and *Caenis diminuta*, may well be true ubiquists (See page 94). Certainly the same may be said for several oligochaetes, damselflies, and beetles.

This same approach may be used in another way by calculating such an index for the stream types (Table 7). The fact that the highest figure obtained is that for the canals, while the second highest is for the sand-bottomed stream, appears to have some value. The canals are carefully designed artificial bodies of water having quite uniform physical conditions spatially, if not temporally. This merely indicates the rather monotonous uniformity of the fauna, a fact easily deter-

TABLE 7. UBIQUITY.

	Comparative Frequencies by Stream Type					Taxon Ubiquity
Taxa	SB	Cal.	Lr	S&B	Can.	Index
Mayfly nymphs*	31	24	22	23	31	26.2
Oligochaetes	27	14	21	22	32	23.2
Damselfly nymphs	26	13	18	19	35	22.2
Beetle adults	21	19	16	19	31	19.4
Tanytarsus (*Atany.*) sp.	33	17	12	12	17	18.2
Ceratopogonidae	28	9	16	15	22	18.0
Hyalella azteca	9	15	13	15	33	17.0
Physa pumilia	12	16	13	11	31	16.6
Palaemonetes paludosus	20	11	4	16	31	16.4
Beetle larvae	12	24	12	14	13	15.0
Stream type ubiquity index	21.9	16.2	14.7	16.6	27.6	

* See page 94

mined by observation. The second highest index, that for the sand-bottomed stream, is also logical, as this stream type is the easiest to define of all the stream types found in Florida, the only great variable being the degree of development of vegetation (Berner, 1950). The three remaining types possess much greater variability and are, therefore, more difficult to delineate.

Comparison of Distributional Factors

Although the literature on stream limnology is not extensive—at least when compared with that on lake limnology—it is desirable to compare material presented in this paper with certain published observations from elsewhere. For this the excellent study of the River Susaa by Berg (1948) is used as a model, particularly his outline of factors controlling the distribution of aquatic organisms (p. 285). Each of these factors is discussed below in detail with regard to the proposed classification of the streams of Florida and to selected published material.

Velocity

A great deal has been written about the influence of velocity on the composition of stream faunas, of the causes of this influence, and of morphological adaptations to the lotic environment. That velocity exerts a major influence on the distribution of aquatic organisms is unquestioned, but no attempt is made to review the literature on this subject completely.

Shelford and Eddy (1929: 382) state: "Our hypothesis is that permanent stream communities exist, undergo successional development, reach and maintain a quasi-stable condition, and manifest seasonal and annual differences, as do terrestrial and marine communities." While I agree with this statement in general, some limitations should be imposed on it. The fact that seasonal variation is of minor consideration in Florida is not a fault. The main problem lies in the complex variations in minor habitats within short reaches of streams. Berg (1948: 285) states it thusly: "A water course changes its character more or less during its course from its rise to its discharge, and the reaches that succeed each other may differ so much that they have merely ecological features of minor importance in common.

"The consequence of this fact is that it is not possible to undertake an ecological grouping of water courses but merely of reaches of water courses. The unit of the system will not then be an entire water course, but a reach of one within which the life conditions are in the main uniform."

Thus the stream types proposed here are in a sense merely "reaches of water courses." Beck (1954: 216-7) points out that the Suwannee River in its flow across Florida is successively a swamp-and-bog stream, a sand-bottomed stream, a calcareous stream, and, according to some authors, a larger river of mixed origin. This succession is due to velocity, substrate, and chemical alteration of the "river" water by the discharge of numerous calcareous springs. In addition, no mention has been made of estuaries, a stage through which most rivers pass and which is largely ignored in the present paper. Therefore we have a choice of considering the Suwannee either as four rivers, or as a single river with four recognizable and widely duplicated reaches. Obviously the latter is the only possible choice.

Ruttner (1953: 199) makes the following statement: "Early workers were inclined to attribute these specific effects of swiftly flowing water to its higher oxygen content. It is easy to demonstrate, however, that even cascading water never has an oxygen content higher than will correspond to the momentary saturation equilibrium with respect to the air, whereas in standing water supersaturations occur commonly. The effect of strongly agitated water in promoting growth and respiration must, therefore, have some other basis. In quiet or in weakly agitated water, the organisms are surrounded by a closely adhering film of liquid, which speedily forms around the animal or plant a cloak impoverished of substances important for life. In a rapid current, however, the formation of such exchange-hindering investitures is prevented, and the absorbing surfaces are continually brought into contact with new portions of water as yet unutilized. In this manner moving water promotes respiration and the getting of food much more than quiet water of the same content; it is not absolutely but rather physiologically richer in oxygen and nutrients. *A current consequently promotes respiration as well as eutrophication.*"

These statements are firmly supported by empirical data in a paper by Whitford and Schumacher (1961: 423) who report: "An 'inherent current demand' by this lotic species was indicated (a) by ×10 increase in P^{32} uptake at current equivalents of 18 cm/sec; and (b) by a 70% increase in respired CO_2 in dark bottles at current equivalents of 15 cm/sec. In a current this demand is satisfied by the creation of a steep diffusion gradient." The reader is also referred to Nielsen's (1950) excellent review of morphological adaptations to velocity and of the specialized feeding habits of rheobionts.

In summary it may be said that faunal responses to lotic environments involve specialized feeding habits, a minor amount of morphological adaptation, and an unknown amount of physiological adaptation.

In my work I have found a descriptive terminology convenient for reporting velocities. Swift flow is that velocity in which Plecoptera are found in Florida. Moderate velocity is any velocity sufficient to maintain a population of Simuliidae (these are confined to running water in Florida). Any velocities below these two loosely defined levels are termed low. We have only recently obtained and started using velocity meters in our biological work. When the results of this work are available it will be interesting to see how well the actual measurements support the observed qualitative terminology.

From the standpoint of velocity, the lotic habitats as proposed herein must be divided into two groups: lotic and sublotic. Despite the difficulty of measuring the velocity of a swamp-and-bog stream, it is nevertheless flowing water with a transport of water from head to mouth. In the canals the seaward flow may be quite swift for definite periods, may be reversed completely, or may remain stagnant for days at a time. They must be considered lotic habitats because the long-range flow is seaward and because the visiting observer may encounter flowing water at any given time. This latter reason gains strength in light of early work with these canals, when biologists first realized that the fauna was a strange one mainly in that no stream species were present despite the obvious flow. It might be logical to change the above terminology to permanently lotic and seasonally lotic, because rainy season flows in the canals are always seaward and in dry seasons the flow may ease entirely.

Substratum

The relationship between velocity and bottom deposits (or substratum) is directly reciprocal, in that the substratum determines the velocity and the velocity determines the substratum. For instance, bottom deposits of mud do not occur under swift water, nor are bare rocks and rubble typical of sluggish water. As Hesse, Allee, and Schmidt (1937: 304) point out: "Division into lower river (with a minimum of erosion and a maximum of deposit), middle river (with a balance between erosion and deposit and a more noticeable side erosion), and upper river (with a maximum of deep erosion and a minimum of deposit) is also frequently inapplicable." The fact that such a breakdown of stream courses is frequently inapplicable does not preclude the fact that it is often applicable.

The swifter portions of a stream system are generally found in its headwaters (the head-streams and highland brooks of Carpenter (1928), the torrential streams of Nielsen (1950)). While we have no torrential streams in Florida, many of our streams, the Suwannee, Withlacoochee, and Chipola rivers for instance, have well-developed rapids. Here the substratum is frequently eroding limestone, often well supplied with growth of moss. Generally downstream from these stretches (the Chipola is an exception) are areas of a typical sand-bottomed nature and, though the Suwannee farther downstream becomes a calcareous stream with many limestone outcroppings, it eventually becomes a slower river with little erosion and greater deposition.

The substrata of the streams of Florida may be divided into two main categories—hard and soft. The hard materials may be subdivided into limestone and clay. The fauna of the limestone bottoms is largely a function of velocity, which must be high enough to prevent the deposition of finer soft materials. The faunas of clay bottoms are a function of position, a matter of whether the exposed face of the clay is horizontal or vertical. For example, two Florida chironomids, *Xenochironomus taenionotus* and *X. rogersi*, are commonly found burrowing in clay; the former species occupies vertical clay banks through which a stream has cut, the latter burrows in horizontal beds. Another occupant of the horizontal clay beds, *Glyptotendipes meridionalis*, has not been found coexisting anywhere with *X. rogersi*.

Soft bottoms divide less distinctly into two basic categories—organogenic and minerogenic—, and all degrees of intergradation exist between them. In general it may be stated that the lower the velocity, the finer (or lighter) the bottom materials. Thus a basic difference between the sand-bottomed stream and the swamp-and-bog stream lies in coarser sand bottom with a minor amount of organogenic material in the former, and finely divided organic detritus with a minor amount of fine sand in the latter. This difference in bottom deposits is demonstrated faunistically by a bottom community in the swamp-and-bog stream resembling what some have termed a "pollutional" fauna. This consists of tubificid worms, red chironomid larvae (*Chironomus, Cryptochironomus*, etc.), and serpentine ceratopogonid larvae. In contrast the sand-bottomed stream, while supporting many of these same groups, has them represented by smaller numbers and is also populated by larger burrowers such as dragonfly nymphs (*Gomphus, Progomphus, Aphylla*), mayflies (*Hexagenia, Ephemera*), caddisflies (*Molanna, Phylocentropus*), and lumbriculid oligochaetes.

Vegetation

Berner (1950) was the first worker in Florida to emphasize strongly the influence of vegetation on the distribution of aquatic insects. This and his recognition of canals as a definite stream type are the major differences between his classification and the basic one Rogers (1933) proposed. The importance of vegetation is best demonstrated by the sand-bottomed stream. In the western panhandle of Florida are many examples of this stream type, apparently quite young, and almost totally lacking in aqautic vegetation. Bottom deposits consist mainly of course, shifting sand. Invertebrate faunas are meagre. In one such, Canoe Creek in Escambia County, a rich invertebrate fauna lives in accumulations of dead leaves held against the upstream sides of small stumps by the high velocity of the water. The remaining minor habitats are virtually sterile. Similar streams in the same basin more adequately supplied with submerged vegetation support much richer faunas in a greater variety of minor habitats.

Streams such as Canoe Creek naturally lack all species that require vegetation for food or shelter. Missing groups include the pyralidids, leaf-mining or browsing chironomids, numerous mayflies, caddisflies, Odonata, and most macro-crustaceans.

Florida has a rich flora of tropical aquatic plants, some of which such as *Eichhornia crassipes*, *Pistia stratiotes*, *Alternanthera philoxeroides*, and *Salvinia rotundifolia*, have become major nuisances. It is interesting that only one of these, *Alternanthera*, has had a species of aquatic insect, *Nanocladius alternantherae*, described with that plant an apparent host. The date of the introduction of the water hyacinth (*E. crassipes*) is the only one known with certainty (Goin, 1943: 143). It appeared near New Orleans in 1835 and was established in Florida in 1840. Goin also notes that the salamander *Pseudobranchus striatus axanthus* is restricted to the water hyacinth habitat in Florida and is the only aquatic vertebrate so to be. It is surprising that no invertebrate has as yet become closely associated with this plant.

Aquatic vegetation is, therefore, a major distributional factor in all types of aquatic situations in Florida.

Temperature

Temperature extremes in Florida do not prevent the year-round occurrence of the aquatic stages of most indigenous invertebrates. Stream quality surveys may be run in January just as effectively as in June. This is not to suggest that temperature is unimportant; the minimized variation actually can be a source of difficulty.

Residents of Florida have been concerned for many years about the introduction of noisome tropical plants. Florida is subject every few years to a severe winter (by Florida standards) with freezes as far south as the northern Everglades. These occasional periods of severe weather limit the spread of most terrestrial and aquatic species of tropical origin. As an example, the midge, *Metriocnemus abdomino-flavatus,* described from the bromeliads of Costa Rica, was frequently found inhabiting the bromeliad, *Tillandsia utriculata,* as far north as Vero Beach prior to the severe winter of 1957-58. Subsequent repeated samplings did not yield a single specimen of this midge north of Ft. Lauderdale until May 1964.

The constant temperatures of the springs and, to a lesser degree, the spring runs of the State pose a definite problem with regard to introduced aquatic organisms. One such stream, located in an area of tropical fish hatcheries, is known to support some 10 species of exotic fishes, at least some of which seem to have become etablished (J. E. Burgess, personal communication). No list of introduced species of plants and animals found in the canals of Broward and Dade Counties has been compiled, and the list might well be a long one.

Recently John H. Davis of the University of Florida (personal communication) pointed out that although southern Florida has appealed to many workers as a place to study the effects of high mean annual temperatures on the distribution of organisms, actually, this area is the best place in the continental United States to study the biotic effects of cold. My own observations support this strongly.

The above paragraphs are not meant to imply that all organisms occurring in tropical latitudes require a high mean annual temperature. Mention has been made of the large ostracod, *Chlamydotheca unispinosa,* which is so prominent in the canal fauna. This ostracod, described from the cenotes of Yucatan, has been reported also from Jamaica, Maryland, Ohio, and Louisiana, hardly a tropical distribution (Tressler, 1959: 704).

The thermal effects of the springs of Florida are not inconsiderable. Near the spring heads temperatures remain nearly constant all year. Sloan (1956: 86) reports that during the period from November 1952 to February 1954, the temperature in the boil of Weekiwachee Spring varied from a minimum of 23.2°C to a maximum of 24.0°C, with a total variation of only 0.8°C. Many of the chemical components are almost as constant, making these springs and spring runs virtual outdoor laboratories. The northern Withlacoochee River, a major tributary of the Suwannee River, rises in Georgia and in its upper reaches in Florida is a typical sand-bottomed stream. During a two-year study of these streams the following temperature variations were found:

	Temp. °C Minimum	Temp. °C Maximum	Annual Range
Withlacoochee	9.5	30	20.5
Suwannee	15	28	13

The temperature differences in the two rivers are due mainly to the discharge into the Suwannee of great quantities of spring water, the thermal effects of which are obviously considerable.

Oxygen

Although dissolved oxygen is one of the most thoroughly studied factors in the aquatic environment, it is frequently a misused and misunderstood determination in stream work. At least part of this is explained by the above quotation from Ruttner.

In an area as richly supplied with anaerobic (or nearly so) springs as are many parts of Florida, the effects of spring discharge on the oxygen relationships are considerable. The Fenholloway River in one area was found to have a dissolved oxygen concentration of less than 1.0 mg/L in times of low flow. This resulted largely from the increased proportion of anaerobic spring water in the reduced quantities of "river" water. A rich fauna containing a number of pollution-sensitive species was present. Lowering the dissolved oxygen from a normal summer concentration of about 7 mg/L to the observed level would predictably destroy all but the most resistant organisms, had this been due to organic pollution such as domestic sewage. In pollution studies the effects of minor quantities of toxic decomposition products are probably often disregarded and total responsibility for faunal alteration placed on lowered oxygen concentrations.

Perhaps the most surprising oxygen relationships in any of the waters of the state are those of the canals. Summer values are almost unbelievably low. During August 1959, the North New River Canal had oxygen concentrations ranging from a minimum of 0.5 mg/L to a maximum of 3.8 mg/L, with the mean value for no station reaching 2.0 mg/L. Biochemical oxygen demand values never reached 3.0 mg/L. Pollution was not a factor, for good populations of several sensitive sunfishes were present and invertebrate communities were balanced and diverse.

Spot samples were taken from Ft. Lauderdale all the length of the canal to and including Lake Okeechobee. Oxygen values in the lake were not a great deal higher. The explanation of the low oxygen figures in the canal proved to be geological. These canals are cut through a thin overburden of soil into an extremely porous limestone. Careful observation revealed a flow of canal water into this limestone in some areas and out of it in others. Thus canal water and ground water were continuous and interchangeable.

Dissolved oxygen figures, much like isolated pH values, are seldom worth much by themselves. It matters little that the midge, *Chironomus attenuatus,* has been found in waters having oxygen concentrations ranging from 0.0 to 33.7 mg/L, but it is of interest that another midge, *Trichocladius extatus,* has never been found in a stream with less than 3.0 mg/L of oxygen. Largely because of Florida's geological history, it is necessary to know an entire stream, its geology, sociology, hydrology, and uses before its oxygen relationships may be understood.

Water Hardness

Just what Berg means by hardness is not clear, for he does not define it. This discussion is based on the assumption that he means not hardness alone, but the entire CO_2 cycle.

Determination of hardness is often neglected in limnological work. If we list the lotic water types of Florida in order of ascending hardness we have listed the order of ascending faunal importance of molluscs. This holds true within limits for other invertebrate groups, but for less obvious reasons.

In the Suwannee basin in Lafayette County two small streams flow under a highway within 100 yards of each other and join within 100 yards downstream from the bridges. The northernmost, slightly the larger of the two, is a typical sand-bottomed stream. In July 1953 the southern stream had the following characteristics: pH 7.9, alkalinity 164 mg/L, hardness 162 mg/L, $CaCO_3$, 88 mg/L, $MgCO_3$, 74 mg/L, and temperature 24°C. Color and turbidity were both low. Calcareous characteristics were unquestionable and the spring origin of this stream was subsequently confirmed. Below their confluence the effects of the sand-bottomed stream predominate for approximately a mile to the point where this stream flows into the Suwannee River. The Suwannee in this area is heavily populated with snails of the genera *Goniobasis* and *Viviparus*, the former the most typical inhabitant of calcareous streams, as was pointed out above. Neither occurred in the two small streams in question, although both could have occupied the southern stream. Apparently a chemical barrier between these streams and the Suwannee existed.

In March 1961, these streams were visited again. Though no chemical sampling apparatus was available, it was immediately apparent that the southern stream had changed completely, for it now had the appearance of a typical sand-bottomed stream. Its color was high, a condition never before seen here, and its discharge had increased an estimated 25%, although the northern stream was low. In the southern stream's narrow and well-defined bed, the increased discharge was accompanied by a major increase in velocity.

Table 8 compares the species of chironomids present in 1953 with those found in 1961. Only one species was present during both sampling periods. An examination of all records available for each chironomid listed for either period indicated that it was impossible to justify the presence or absence of a single midge species on the basis of the altered carbon dioxide cycle. What had formerly been a rich growth of many different aquatic plants now consisted of scattered patches of *Hydrocotyle* and *Ludvigia*, neither of which makes a good habitat for chironomids. Their replacement of former growths of submerged aquatic plants with ligulate leaves such as *Vallisneria* doubtless caused the disappearance of at least the first two species in the left hand column of Table 8. Former areas of quiet water with bottom deposits of fine sand and organic detritus had disappeared, and only areas of coarse sand remained. The four species in the left hand column marked with an asterisk were gone simply because their proper minor habitat no longer existed. The rest of the list reveals very little of the possible factors responsible for these changes in the fauna.

The above suggests that alteration of the carbon dioxide cycle within the limits that may take place naturally in Florida waters has little direct effect on the chironomids.

The swamp-and-bog stream is an unusual body of water when the carbon dioxide cycle is considered. With pH values ranging as low as 3.8 (this minimum has been determined both colorimetrically and potentiometrically) and figures as low as 4.0 not uncommon, one can only wonder about the physiological strain this must place on the buffering system within an organism's body. Theoretically, waters with this low a pH value should be equally low in alkalinity, hardness, and, consequently, buffering capacity.

TABLE 8. SPECIES OF CHIRONOMIDAE.

July 1953	March 1961
Cricotopus bicinctus	
Thienemanniella xena	
Tanytarsus guerla	
*Cryptochironomus fulvus**	
*Chironomus stigmaterus**	
*Chironomus attenuatus**	
Tanytarsus sp. A*	
Polypedilum sp. A	
Pentaneura carnea	
Tanytarsus politus	
Tanytarsus sp. B	*Tanytarsus* sp. B
	Polypedilum halterale
	Trichocladius extatus
	Polypedilum tritum
	Cricotopus sp. C
	Unid. Orthocladiinae

GEOGRAPHICAL DISTRIBUTION

It should, perhaps, be unnecessary to mention this as a factor in the consideration of the fauna of a stream. Frequently, however, such a factor is overlooked in studies of single streams, probably because it is so obvious.

The use of indicator organisms in my routine work keeps this factor a matter of constant consideration in that a state-wide program must be based on organisms of state-wide distribution or else consist of a series of regional programs. Although the former approach is used at present, much serious thought has been given to the possibility that the latter might well yield a more definitive program. The regional approach would definitely yield greater knowledge of the individual taxa involved. This is especially true of the western portion of Florida from the Apalachicola drainage to the Perdido River.

One aspect of distribution is the influence of man on former natural distributions. In southwestern Florida numerous canals dug for drainage purposes differ from the canals of southeastern Florida in that they have unrestricted flow to the Gulf of Mexico and, consequently, unidirectional flow. They have, in essence, become streams. Gradients have been produced that contribute velocities high enough to support rheophiles and rheobionts. These canals (or ditches) have not been considered in the stream classification because of their ephemeral nature, though they have extended the ranges of such stream-inhabiting forms as *Rheotanytarsus exiguus, Cricotopus bicinctus*, hydropsychid caddisflies, and others to a considerable degree.

Work is now underway by several state agencies to control this indiscriminate removal of surface and ground waters. If such control is not instituted, we can only expect accelerated salt water encroachment in an area of Florida already experiencing some water shortage. When proper engineering controls are instituted ranges of those species extended by the canals of unrestricted flow should again be the natural ranges of the species in the streams of Florida.

Pollution

Although it was pointed out above that pollution is not a factor in the present study, it is certainly a major factor in the distribution of aquatic organisms and, while not one of the factors listed by Berg, is nevertheless carefully considered in his work.

Discussion

The five types of lotic habitats described for Florida, while distinct entities, exhibit varying degrees of intergradation. Many sand-bottomed streams contain varying amounts of spring water and, consequently, vary in their chemical characteristics. Few, if any, calcareous streams do not have some contribution of acid waters. Only the canals of southeastern Florida fail to intergrade with the other water types. These, then, are the only truly distinctive aquatic environments in the state.

A certain amount of objection to this last statement is anticipated. It may be argued, for example, that our many springs of the first magnitude constitute a distinctive feature in Florida. Yet these springs exhibit a wide variety of chemical and physical characteristics (Ferguson, *et alii* 1947; Whitford, 1956; Sloan, 1956). In addition, Florida has several rivers that disappear underground, most reappearing not too far away (Santa Fe, Chipola, St. Marks). The reappearance of one, the Alapaha, has not positively been discovered, although several small springs along the Suwannee River, into which the Alapaha discharges during high water, have distinct color, a rare feature in Florida springs. These may well represent the reappearance of the Alapaha.

Another aquatic feature slighted in this paper is the roadside ditch. These ditches, formed when highways are constructed, are of two types. The first type contains runoff water and seepage water, has little or no true flow, and is chemically, physically, and biologically similar to a pond. The second type has constant unidirectional flow, is supplied by permanent seepage, and is basically a sand-bottomed stream.

The main point in this discussion is that it is possible, by selecting odd and virtually unique examples, to propose an almost endless list of possible lotic habitats. It is the purpose of the present paper to delineate a simple, basic classification in which major stream types are recognized and, perhaps, may be made recognizable to others.

Description of Stream Types

The following five chemically, physically, and biologically distinct stream types exist in Florida.

The Sand-bottomed Stream

This is the most widely distributed and most frequently encountered type of stream in the state. It has been the most typical lotic feature of the area and is the one disappearing most rapidly with the alteration of drainage patterns. The sand-bottomed stream is a prominent feature of the Central Highlands (see Cooke, 1939, for a discussion of the topographic regions of Florida), Coastal Lowlands, Marianna Lowlands, and Western Highlands. The fauna is dominated by rheophiles and rheobionts. Typical faunal elements are hydropsychid and philopotamid caddisflies, mayflies of the genera *Stenonema* and *Isonychia,* simuliid larvae, Plecoptera, orthocladiine chironomids, elmid beetles, and *Corydalis cornutus.* Of all lotic habitats this is the most typically so.

Chemically and physically the sand-bottomed stream is mildly acid to circum-neutral (pH 5.7-7.4), has alkalinity ranging 5 to 100 mg/L, hardness from 5 to 120 mg/L, color moderate to high, and of moderate to swift velocity. Bottom deposits consist of fine sand with varying amounts of leaf and other organic detritus in the quieter reaches. Areas of limestone outcroppings are frequent. In the western panhandle the sand-bottomed streams are usually swifter and have coarser bottom deposits. Shifting sand bottoms are common. Plant growth may be slight to quite dense and of great variety.

Typical examples are the Black Creek Complex, both Withlacoochee Rivers, the Yellow, Blackwater, and Shoal Rivers.

THE CALCAREOUS STREAM

These streams are predominantly of spring origin and many of the finest examples have been carefully protected because of their beauty. Visitors to Florida find these a major attraction; a number of the larger springs and their runs have been developed commercially, and the natural aspects of most have been carefully preserved. These are, indeed, a striking sight with their cool, very clear waters, dense and varied growths of submerged plants, and banks shaded by large, moss-hung trees. The beauty of these streams is actually a limnologic feature in that it is the result of two factors; the clarity of the water itself and the high concentrations of phosphorus.

Widely distributed in Florida, the calcareous stream is found in the Central Highlands, Coastal Lowlands, Relict Areas (Beck and Beck, 1959), Marianna Lowlands, and the southern portion of the Tallahassee Hills.

The fauna of these streams is less definitely rheophilous than that of the sand-bottomed stream. The most obvious feature is their high mollusc populations (*Goniobasis*, *Campeloma*, *Viviparus*, and *Pomacea*). Rheophiles and rheobionts are normally represented by hydropsychid caddisflies, mayflies of the genus *Stenonema*, a great variety of chironomids, *Corydalis cornutus*, and occasionally simuliids and Plecoptera.

The waters are alkaline (pH 7.0-8.2), the alkalinity ranging from 20 to 200 mg/L, hardness from 25-300 mg/L (omitting the oligohaline and mesohaline springs of Whitford (1956)). The water is normally clear (some examples have a slight turbidity from small amounts of Montmorillonite clay in suspension) and generally low in color. Velocity ranges from low to swift.

Bottom materials consist of sand, clay, limestone, and quite heavy deposits of organic detritus in the slower reaches. Submerged plant variety appears to be a function of bottom material.

Typical examples are the Suwannee, Silver Crystal, St. Marks, and Wakulla Rivers. In size they range from small rills to large rivers.

THE LARGER RIVERS

This is a category of convenience, for no two of these streams have many features in common. These are what Rogers (1933) referred to as "lower streams." Of the four examples in Florida, three (Apalachicola, Choctawhatchee, and Escambia) are interstate, rising in the hills of Georgia and Alabama. All three normally carry a significant amount of clay and silt and are always turbid. The fourth, the St. Johns River, lying entirely within the state, is quite clear but with fairly high color. As Pierce (1947: 2) describes it:

"The St. Johns River rises in the Kissimmee Prairie, west of Malabar and flows north for almost 320 kilometers (200 miles) to empty into the Atlantic Ocean 34 kilometers (21 miles) east of Jacksonville. An outstanding feature of this river is its low gradient, which is less than 6.1 meters from source to mouth. A number of interesting phenomena characterize this very small change in water level along the course of the river. One is the distance from the mouth at which daily tidal effects can be felt. Records of the Coast and Geodetic Survey show mean tidal ranges of 1.4 meters at Mayport (inside the mouth of the river) and 0.15 meters at Welaka (166 kilometers, or 103 miles, up the river). Other characters of the river which are associated with the low gradient are the slow current, the shallow depth, and the relatively broad basin for most of its length.

"These features give the St. Johns River an older appearance than its geological record (Cooke, 1939: 109) indicates. The valley of the river, which dates from the Pleistocene period, was formed in part from wave-built sand bars; its basin was formed from lagoons, streams, and solution lakes."

This states accurately many of the unusual features of this most fascinating river, which some maintain is not a river at all, but a series of connecting lakes. Anyone who has gone around the Devil's Elbow near Palatka in a small skiff would question both statements concerning low velocity and non-river characteristics. Other features of this stream are of equal interest. One of the most unusual, and perhaps also unique, factors is the behavior of its salinity. Progressing from the mouth upstream (southward) the salinity quite properly drops until a minimum is reached downstream from Palatka, the exact point varying with the season. From this point upstream the salinity rises again from the discharge of a number of mesohaline springs (see Whitford, 1956) in Marion County until the vicinity of Lake George is reached, above which it suddenly drops. This produces, in effect, a double estuary and permits the presence of a commercial crab (*Callinectes sapidus*) fishery some 125 miles above the mouth. The mesohaline springs are inhabited by several species of marine isopods, and beach-hoppers may be found around the periphery of Lake George.

Obviously this stream cannot be included in any one of the designated types, as it has reaches of swamp-and-bog characteristics, others that have sand-bottomed characteristics, and stretches not comparable to either.

The chemical characteristics for this river defy summarizing, for anything reported for one reach would be untrue of reaches a few miles upstream or downstream. Suffice it to say that perhaps no river in North America so warrants thorough study as does the St. Johns. It is hoped that a complete and careful study of this river may be made cooperatively within the next few years.

In contrast to the above probably no stream in Florida has been as carefully studied over as many years as has the Escambia River. This material has recently been summarized (Robert F. Schneider, unpub. M.S. thesis) and, it is hoped, will be published. It will suffice for the present to state that pH values for the upper Escambia River range from 6.5 to 6.9, with an increase in pH in the lower reaches from the influence of salt water penetration in the estuarine portion of the stream. The upper stream is normally well supplied with dissolved oxygen, seldom falling as low as 75% saturation. Both alkalinity and hardness are normally below 40 mg/L and chlorides below 20 mg/L. Regardless of flow this river always has a slight turbidity.

The third of the larger rivers, the Apalachicola, has also received considerable attention. It is formed by the confluence of the Flint and Chattahoochee Rivers near the junction of the states of Alabama, Georgia, and Florida. At Chattahoochee, just below the confluence, the 25-year average discharge of 22,240 cfs., is exceeded in Florida only by the St. Johns River.

The following chemical and physical data are from two surveys of this river, one during the summer and one during the winter. The area covered is from below the junction of the Flint and Chattahoochee Rivers to a point well above any possible estuarine effect, a distance of 76 miles. Ranges of the several determinations are as follows: pH 6.5 to 7.4, alkalinity 12 to 31 mg/L, hardness 22 to 56 mg/L, sulfates 6.0 to 9.0 mg/L, color 10 to 32 units (USGS), and turbidity 13 to 48 units (Jackson turbidimeter). The banks in the area covered are rather high and steep, and the stream has few shallow places and few aquatic plants. Bottom deposits consist of coarse sand and limestone and are singularly unproductive. Logs lodged against the banks constitute the most productive habitat. The invertebrate fauna is dominated by hydropsychid caddisflies, mayflies of the genus *Stenonema*, chironomids of the genera *Polypedilum* and *Xenochironomus*, the damselfly genus *Argia*, and molluscs. An outstanding feature of this river is its monotony, abetted somewhat by dredging and water level control.

THE SWAMP-AND-BOG STREAM

These highly acid, suggish streams are most typical of the Coastal Lowlands but occur occasionally in the Central Highlands. They originate in swamps, sphagnum bogs, and marshes. They show a definite relationship to the sand-bottomed streams in that all chemical differences are functions of the one significant physical difference, velocity. An increase in gradient would convert them to the sand-bottomed type by increasing turbulence, which in turn would increase reaeration, reduce carbon dioxide, and increase pH and alkalinity, and, finally, by removing the finer bottom sediments of organic silt and replacing them with sand. The swamp-and-bog stream is, then, a sand-bottomed stream with lowered velocity and the chemical and physical attributes that accompany this lowered velocity. This is suggestive of a successional relationship (see discussion of the Suwannee River above) but such is not proposed at present. While examples of succession in space are available, as in the Suwannee, streams in Florida have not been studied long enough as yet to permit any extensive discussion of temporal succession beyond the principles of base-leveling.

The swamp-and-bog stream has the following characteristics: pH 3.8 to 6.5, alkalinity and hardness both normally well below 40 mg/L, color sometimes as high as 750 units, turbidity low, and carbon dioxide at times above 100 mg/L. These streams support a surprising fish fauna, with many species normally considered sensitive to high carbon dioxide values such as sunfishes and darters.

Faunistically these streams differ little from an acid pond. Rheophilous forms are universally lacking, molluscs are represented only by *Physa pumilia,* and the general fauna gives the impression to those in pollution abatement of being composed almost totally of species highly resistant to organic pollution, though the fishes are an exception.

THE CANALS OF SOUTHEASTERN FLORIDA

In this study the term "canal," unless otherwise specified, always refers to canals of the southeastern quadrant of the State.

From a point north of the St. Lucie Canal to a point south of Homestead, a distance of some 140 miles, not a natural stream of any significance remains along the east coast of Florida. All are now canals. We have no records of the invertebrates that once inhabited the natural waters of this area, with the exception of the mayflies, beetles, and one or two other groups. That these former streams no longer exist is perhaps unfortunate, but the canals replacing them represent a very interesting and complex series of habitats whose faunas are uniform enough to permit fairly sensitive ecological differentiating. In addition the canals probably represent the only lotic aquatic habitats, insofar as streams are concerned, of the Coastal Lowlands of southeastern Florida. As a result they become extremely important to the aquatic biologist and to limnology in general.

Chemically these waters are most unusual. Their oxygen relationships have been discussed above. Other factors are: pH 7.1 to 8.1, alkalinity 135 to 250 mg/L, hardness 150 to 295 mg/L, turbidity is low, except in the vicinity of dredging, and color is about the same as found in the sand-bottomed streams with the exception of some of the southern Dade County canals, in which it is surprisingly low.

The most significant and misleading factor in the limnology of the canals is velocity. A given canal may be observed to flow eastward at quite a high rate; 24 hours later the same canal may have no water movement at all. The over-all effect is to produce a sublotic environment. These may be classified as streams for the reasons outlined above with one additional reason; they must be considered with regard to what they actually are, a present-day substitute for the former streams of the area.

The fauna is lenitic. It bears repeating that not a single rheophilous species has been found in these waters. The wide-spread presence of the large Central American ostracod, *Chlamydotheca unispinosa*, the recently introduced and rapidly spreading Colombian snail, *Marisa cornuarietis* (Hunt, 1958), and the presence of the exotic *Belonesox* not only are, at present at any rate, typical of the canals, but they suggest something of the future of these subtropical waters. The chances are excellent that the faunas of these canals in the near future will be composed to a significant degree of exotic, mainly tropical invertebrates accidentally introduced by the aquarium industry.

Another aspect of these waters worth discussing is their relative constancy with regard to chemical characteristics. This makes them excellent waters for the study of the effects of pesticides and commercial fertilizers used in the rich agricultural areas within their drainage (see Davis, 1943, 1946). Such studies have recently been instituted by the Dade County Department of Public Health, but it will be many months before results of this work will be available.

Summary

1. In Florida five basic types of streams, or reaches of streams, are chemically, physically, and biologically distinctive. These are: (1) the sand-bottomed stream, (2) the calcareous stream, (3) the larger rivers, (4) the swamp-and-bog stream, and (5) the canals of southeastern Florida.

2. Of these five types, three (1, 2, and 3) are unquestionably lotic and two (4 and 5) are sublotic.

3. One type, the larger rivers (of mixed origin), is a category of convenience covering four larger rivers, no two of which are alike, yet all differing markedly from the other proposed stream types.

4. After many years of study by a number of workers, the proposed classification does not differ materially from the classification proposed many years ago by J. Speed Rogers. This paper brings together observations based on several different groups of aquatic invertebrates, instead of past classifications reflecting the distribution of single family, order, or class.

5. Of the factors controlling the distributions of aquatic invertebrates in Florida waters, the most important appear to be physical (velocity, substratum, temperature, engineering alteration). Of secondary importance are the chemical factors (oxygen, carbon dioxide cycle). In tertiary position are the biotic factors (plant growths and parasitization). A single factor outside the limits of the above listed is the geographic distribution factor, often neglected.

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