FISH POPULATIONS AND WATER QUALITY IN NORTH FLORIDA RIVERS

RANDY S. KAUTZ, Office of Environmental Services, Florida Game and Fresh Water Fish Commission, 620 South Meridian Street, Tallahassee, FL 32301

Abstract: The status of the fish populations of 8 North Florida rivers and their relationships to major quality parameters were explored in an effort to better understand potential effects of man's activities. Of the 10 water quality parameters analyzed, only conductivity, total dissolved solids and total nitrogen were found to have significant predictive capabilities for the total fish population. Rivers in the Florida Panhandle, which are low in nutrients, pH and organic carbon and high in turbidity, support a high biomass of rough fish, a moderate biomass of sport fish, and a low biomass of commercial and forage fishes; however, numerically, these rivers are dominated by forage fishes. The rivers of northern peninsular Florida generally have equally high biomasses of rough and sport fishes and low biomasses of commerical and forage fishes; however, sport fishes dominate these rivers numerically, comprising more than 70% of all fish encountered.

Proc. Ann. Conf. S.E. Assoc. Fish & Wildl. Agencies 35:495-507

The activities of man influence the quality of surface waters in a variety of ways. For example, agricultural operations result in increased turbidity, nutrients, and pesticides in surface waters; runoff from urban areas is high in organics, nutrients, oils and greases and pesticides; and point sources discharge a wide variety of polluting substances such as heavy metals, tannins, BOD, nutrients and hydrocarbons. The cumulative effect of man's activities is to alter surface water quality, often in a very subtle manner.

Existing water quality laws have as their objective the maintenance of waters which allow the propagation of fish and other aquatic life. Because fishery managers have the professional background in the biology of fish and the management of fisheries, it is quite natural that they should assist water quality managers by inputting into the pollution permitting process. However, before this can be done effectively, it is 1st necessary to understand the basic relationships between water quality and fish populations.

In order to provide more meaningful input into the pollution permitting process in North Florida, it was 1st necessary to determine the status and structure of fish populations in major North Florida rivers. The influence of major water quality parameters on riverine fish populations was then explored and the results compiled for dissemination. It is hoped this paper will provide guidance to water quality managers to better protect the fish populations which form the basis of Florida's riverine fishery resources.

Appreciation is extended to B. Hartman, G. Bass, S. Sheinbaum and S. Hardin for their reviews of the manuscript, insightful discussions and encouragement. I also thank the Florida Game and Fresh Water Fish Commission for its support of this project and the personnel of the Commission's Word Processing Center for typing the paper.

METHODS

The fish populations of 8 North Florida rivers were sampled by Florida Game and Fresh Water Fish Commission fishery biologists from 1972 to 1980 (Bass and Hitt 1973, Anon. 1976, Bass and Hitt 1978, Bass et al. 1979, 1980). The rivers sampled were the Escambia, Yellow, Choctawhatchee, Suwannee, Santa Fe, St. Johns, Oklawaha and the southern Withlacoochee. Shoreline fish populations were electroshocked at 2 to 3 stations in each river quarterly for a period of 1 year. Similar gear was used in each instance, and all sampling was performed under the direction of the same project leader.

The species of fishes in each river were classified as sport fishes, commercial fishes, rough fishes or forage fishes according to the scheme shown in Table 1. The placement of an individual species into a group was subjective, based on the author's knowledge of the value of that species to man. The mean biomass and abundance of each group of fishes were calculated for each river, and the results were tabulated for comparison.

A characterization of the water quality of each river was obtained by calculating a mean for each of the following parameters: conductance, pH, turbidity, dissolved oxygen, total dissolved solids, total nitrogen, total phosphorus, total organic carbon and color. In addition, the mean discharge of each river was estimated. All water quality data were obtained from reports of the U.S. Geological Survey on the water resources of Florida. All data were collected by U.S.G.S. between 1975 and 1979. An effort was made to match water quality sampling location with that of the locations used for sampling fish populations; however, water quality data in the vicinity of the fish population samples in the Oklawaha and Santa Fe rivers were so scant that data from other areas of these rivers were used in addition. Although most of the parameter means were calculated from approximately 50 data points, some means were based on only 6 to 12 samples.

To determine which of the major water quality parameters had the greatest influence over fish populations, correlation coefficients were calculated to show the correlation of each water quality parameter with the biomass and abdundance of fish in each fish group. Correlations which were significant at the 5% and 1% levels were noted.

RESULTS

Yellow, Escambia and Choctawhatchee Rivers

The Yellow, Escambia and Choctawhatchee rivers drain the gently rolling to nearly level coastal plain of southern Alabama and the Florida Panhandle. Watershed soils are predominately well-drained sands, and the major land uses are silviculture and agriculture. The Escambia and Choctawhatchee rivers had moderately high mean flows averaging approximately 250 cubic meters per second (cms), whereas the Yellow River had a moderately low flow with a mean discharge of 45 cms.

From a water quality perspective, the Yellow, Escambia and Choctawhatchee rivers were quite similar (Fig. 1). With turbidities averaging 20 Jackson Turbidity Units (JTU), the Yellow, Escambia and Choctawhatchee rivers were the most

Table 1. Species of fishes encountered in North Florida rivers plus their status as sport, commercial, rough or forage fishes.

SPORT	
Chain pickerel (*Esox niger*)	Redear sunfish (*Lepomis microlophus*)
Largemouth bass (*Micropterus salmoides*)	White bass (*Roccus chrysops*)
Spotted bass (*Micropterus punctulatus*)	Ladyfish (*Elops saurus*)
Suwannee bass (*Micropterus notius*)	Crevalle jack (*Caranx hippos*)
Black crappie (*Pomoxis nigromaculatus*)	Grey snapper (*Lutjanus griseus*)
Warmouth (*Lepomis gulosus*)	Sheephead (*Archosargus probatocephalus*)
Rock bass (*Ambloplites rupestris*)	Spotted seatrout (*Cynoscion nebulosus*)
Spotted sunfish (*Lepomis punctatus*)	Spot (*Leiostomus xanthurus*)
Redbreast sunfish (*Lepomis auritus*)	Gulf flounder (*Paralichthys albigutta*)
Bluegill (*Lepomis macrochirus*)	Southern flounder (*Paralichthys lethostigma*)
COMMERCIAL	
White catfish (*Ictalurus catus*)	Channel catfish (*Ictalurus punctatus*)
Yellow bullhead (*Ictalurus natalis*)	American eel (*Anguilla rostrata*)
Brown bullhead (*Ictalurus nebulosus*)	Striped mullet (*Mugil cephalus*)
ROUGH	
Bowfin (*Amia calva*)	Lake chubsucker (*Erimyzon sucetta*)
Florida gar (*Lepisosteus platyrhincus*)	Sharpfin chubsucker (*Erimyzon tenuis*)
Longnose gar (*Lepisosteus osseus*)	Spotted sucker (*Minytrema melanops*)
Spotted gar (*Lepisosteus oculatus*)	River redhorse (*Moxostoma carinatum*)
Gizzard shad (*Dorosoma cepedianum*)	Blacktail redhorse (*Moxostoma poecilurum*)
Quillback (*Carpiodes cyprinus*)	Atlantic needlefish (*Strongylura marina*)
Highfin carpsucker (*Carpiodes velifer*)	
FORAGE	
Threadfin shad (*Dorosoma petenense*)	Bluefin killifish (*Lucania goodei*)
Gulf menhaden (*Brevoortia patronus*)	Mosquitofish (*Gambusia affinis*)
Bay anchovy (*Anchoa mitchelli*)	Sailfin molly (*Poecilia latipinna*)
Redfin pickerel (*Esox americanus*)	Brook silverside (*Labidesthes sicculus*)
Silverjaw minnow (*Ericymba buccata*)	Tidewater silverside (*Menidia beryllina*)
Pugnose minnow (*Notropis emiliae*)	Flier (*Centrarchus macropterus*)
Taillight shiner (*Notropis maculatus*)	Everglades pygmy sunfish (*Elassoma evergladei*)
Sailfin shiner (*Notropis hypselopterus*)	Banded pygmy sunfish (*Elassoma zonatum*)
Coastal shiner (*Notropis petersoni*)	Bluespotted sunfish (*Enneacanthus gloriosus*)
Longnose shiner (*Notropis longirostris*)	Dollar sunfish (*Lepomis marginatus*)
Flagfin shiner (*Notropis signipinnis*)	Longear sunfish (*Lepomis megalotis*)
Weed shiner (*Notropis texanus*)	Brown darter (*Etheostoma edwini*)
Blacktail shiner (*Notropis venustus*)	Swamp darter (*Etheostoma fusiforme*)
Ironcolor shiner (*Notropis chalybeus*)	Gulf darter (*Etheostoma swaini*)
Golden shiner (*Notemigonus crysoleucas*)	Choctawhatchee darter (*Etheostoma davisoni*)
Clear chub (*Hybopsis winchelli*)	Speckled darter (*Etheostoma stigmaeum*)
Speckled chub (*Hybopsis aestivalis*)	Florida sand darter (*Ammocrypta bifascia*)
Snail bullhead (*Ictalurus serracanthus*)	Logperch (*Percina caprodes*)
Speckled madtom (*Noturus leptacanthus*)	Blackbanded darter (*Percina nigrofasciata*)
Tadpole madtom (*Noturus gyrinus*)	Spotfin mojarra (*Eucinostomus argenteus*)
Pirate perch (*Aphredoderus sayanus*)	Spinycheek sleeper (*Eleotris pisonis*)
Seminole killifish (*Fundulus seminolis*)	Freshwater goby (*Gobionellus shufeldti*)
Blackspotted topminnow (*Fundluls olivaceus*)	Darter goby (*Gobionellus boleosoma*)
Starhead topminnow (*Fundulus notti*)	Naked goby (*Gobiosoma bosci*)
Golden topminnow (*Fundulus chrysotus*)	Hogchoker (*Trinectes maculatus*)

turbid of the 8 major North Florida rivers evaluated in this study. These 3 rivers were the lowest in fertility having the lowest specific conductance, total dissolved solids, total nitrogen, total phophorus and total organic carbon (an indicator of the amount of detrital energy available to the food chain) of the 8 rivers. The pH of the Panhandle rivers was lower than all other rivers except the Santa Fe and ranged from 6.7 to 7.0. Whereas color was low in these rivers, mean dissolved oxygen was generally higher than in the other North Florida rivers.

Rough fishes, principally catostomids, dominated the fish biomass of the Yellow, Escambia and Choctawhatchee rivers (Fig. 2) accounting for 48 of 73% of the total biomass (Table 2); however, they were generally low in abundance comprising only 5 to 15% of the total number of fish. Sport fishes also comprised a significant portion of the total biomass (20 to 36%) and total number (15 to 33%). Commercial fishes were generally low in biomass and abundance, but the Escambia had a commercial fish biomass 3 to 5 times higher than the other rivers. Forage fishes accounted for only 4 to 6% of the total biomass but were the most abundant fishes in all 3 rivers with 59 to 69% of the total number.

Suwannee and Santa Fe Rivers

The Suwannee River receives drainage from several land types that are physiographically dissimilar. The Okefenokee Swamp, with waters that are low in pH and dissolved oxygen and high in color, comprises the headwaters of the Suwannee. Major tributaries to the Suwannee contribute approximately 40% of the flow at the sampling stations and drain a portion of southern Georgia with gently rolling hills and well-drained sandy soils similar to the area drained by the Yellow, Escambia and Choctawhatchee rivers. Portions of the watershed in both Florida and Georgia drain large areas of pine flatwoods that are low in relief and have poorly drained sandy soils. In Florida, the river channel cuts through the limestone bedrock and receives large quantities of groundwater that is clear and hard but low in dissolved oxygen. The Santa Fe River, a major tributary of the Suwannee, is very similar, arising in Santa Fe Swamp, draining both rolling hills and pine flatwoods, and receiving large inputs of groundwater via springs. With a mean discharge of 217 cms, the Suwannee comprises a major North Florida river. The Santa Fe has a mean discharge of 7 cms, the lowest of the 8 rivers studied.

From a water quality perspective, the Suwannee and Santa Fe rivers were quite similar. Both rivers were low in turbidity averaging less than 5 JTU. Both rivers were characterized by moderate fertility as judged by specific conductance, total dissolved solids and total nitrogen measurements. The Suwannee and Santa Fe were the highest of the 8 rivers in total phosphorus with values 3-10 times higher than the others. This may be a function of the phosphatic soils characteristic of portions of the watersheds. Both rivers had a pH of approximately 7.0, a condition favorable to aquatic productivity. The Suwannee and Santa Fe had the highest color of the 8 rivers, most likely a reflection of swamp and flatwoods drainage. Dissolved oxygen in the 2 rivers was moderate compared to the other rivers, averaging 6.8 mg/l. Whereas the Suwannee River had a moderate concentration of total organic carbon, the Santa Fe exhibited the highest total organic carbon of all the rivers.

Sport fishes clearly dominated the Suwannee and Santa Fe rivers, accounting for 36 and 41% of the total biomass and 61 and 71% of the total number of fish,

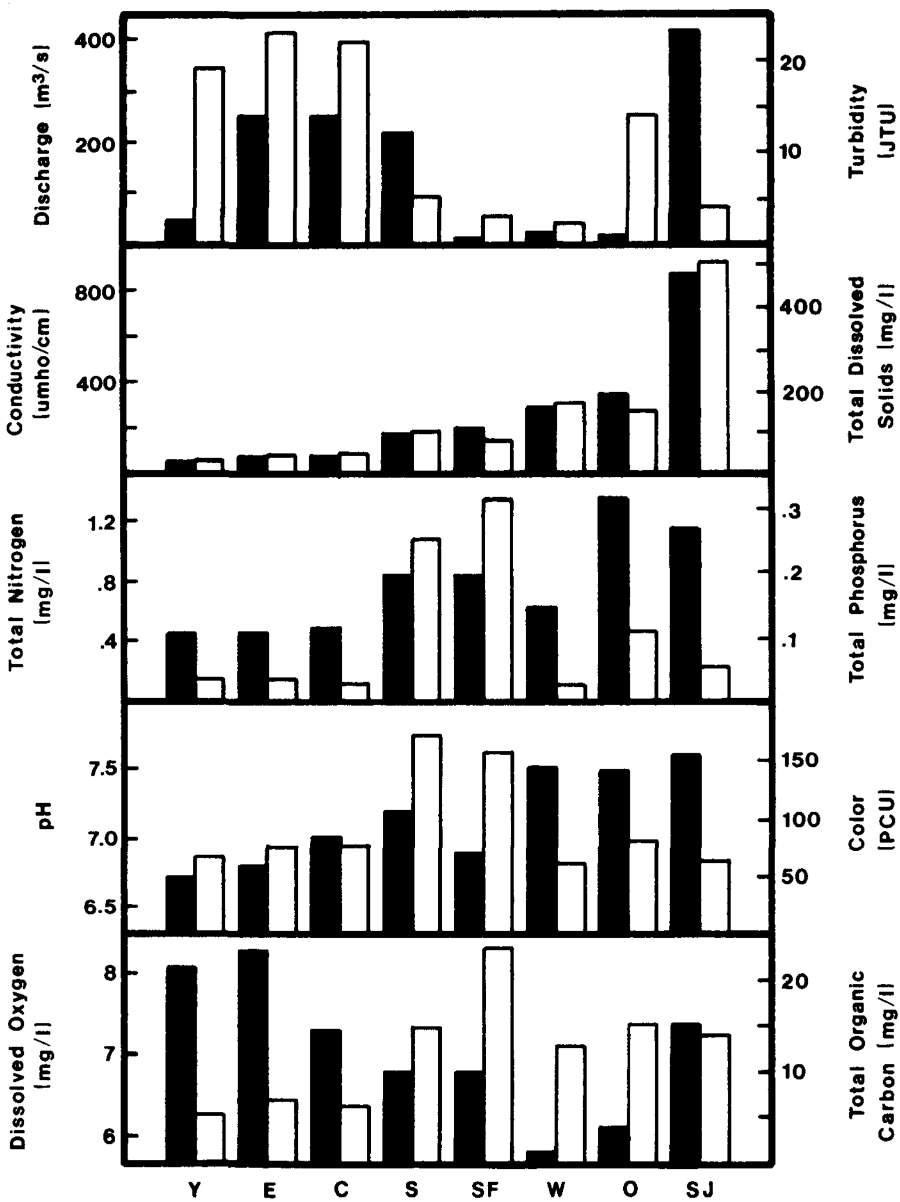


Fig. 1. Discharge and water quality characteristics of the Yellow, Escambia, Choctawhatchee, Suwannee, Santa Fe, Withlacoochee, Oklawaha and St. Johns Rivers, North Florida.

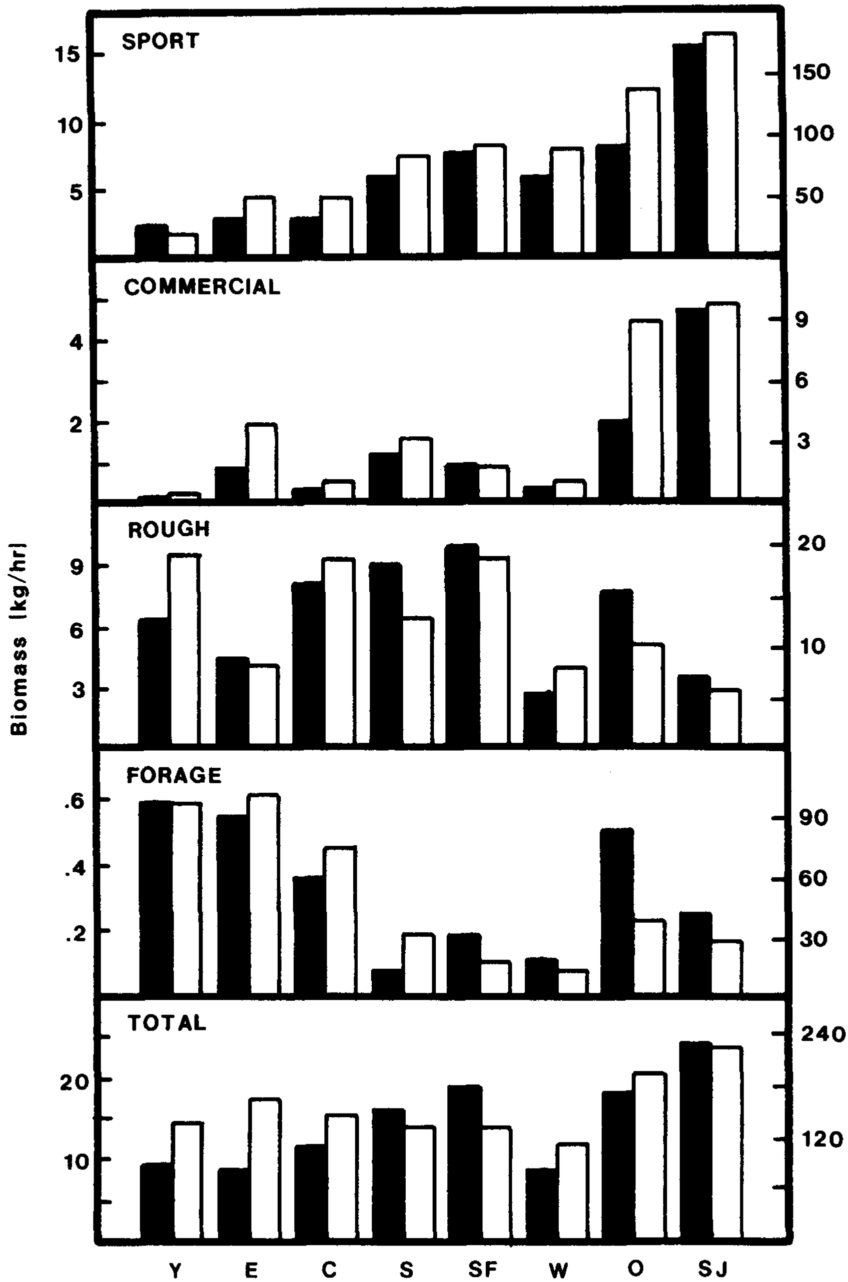


Fig. 2. Mean biomass and abundance of fish populations in the Yellow, Escambia, Choctawhatchee, Suwannee, Santa Fe, Withlacoochee, Oklawaha and St. Johns Rivers, North Florida.

Table 2. Percent composition of biomass (B) and abundance (A) of fishes in North Florida rivers by group.

River		Sport Fishes	Commercial Fishes	Rough Fishes	Forage Fishes
Yellow	B	26	2	66	5
	A	15	1	15	69
Escambia	B	36	10	48	6
	A	33	3	5	59
Choctawhatchee	B	20	3	73	4
	A	25	1	14	61
Suwannee	B	36	8	56	0.5
	A	61	2	12	25
Santa Fe	B	41	5	53	1
	A	71	1	16	12
Withlacoochee	B	63	2	34	1
	A	78	0.3	9	12
Oklawaha	B	44	11	42	3
	A	71	5	5	19
St. Johns	B	62	17	8	12
	A	81	4	3	12

respectively. Rough fishes, while having a higher biomass (53 to 56% of the total), were far less abundant, accounting for only 12 to 16% of all fish in these rivers. Commercial fishes were low in biomass (5 to 8%) and accounted for only 1 to 2% of the number of fish in the Suwannee and Santa Fe. Forage fishes were likewise low in biomass (0.5 to 1.0%) but were somewhat more significant in terms of abundance accounting for 12 to 25% of all fish encountered.

Oklawaha and Withlacoochee Rivers

The Oklawaha River drains primarily agricultural areas in the well-drained sandy soils of North-Central Florida, but contributions of runoff from pine flatwoods and of groundwater from springs are also received. The southern Withlacoochee River has its headwaters in Green Swamp, but it also drains well-drained sandy soils in agricultural use and receives large volumes of groundwater from spring runs. The Oklawaha and Withlacoochee rivers had mean discharges of 12 cms and 19 cms, respectively, the 2nd and 3rd lowest flows of the 8 rivers studied.

The Withlacoochee and Oklawaha rivers lie at approximately the same latitude, drain somewhat similar areas and have comparable flows; therefore they are considered herein together. The Withlacoochee had the lowest mean turbidity of all rivers studied, but the Oklawaha had the highest turbidity east of the Panhandle rivers. The high turbidity of the Oklawaha was probably due to high phytoplankton densities as one of the water quality sampling stations was immediately downstream of a dam. Both rivers were similar in conductance and total dissolved solids having high values compared to all other rivers except the St. Johns. This indicated that the Withlacoochee and Oklawaha rivers were quite fertile. Total nitrogen and total phosphorus in the Withlacoochee were low to moderate, whereas the maximum value for total nitrogen and a moderately high value for total phosphorus were observed in the Oklawaha River. The high values in the Oklawaha undoubtedly reflected nutrients bound in the organic matter of the plankton community downstream of the dam. Both rivers were characterized by a slightly alkaline pH, low color and low dissolved oxygen. The total organic carbon content of both rivers was moderate to high suggesting high inputs of detrital energy.

Sport fishes dominated both rivers accounting for 63% of the biomass and 78% of the number of fish in the Withlacoochee and 44% of the biomass and 71% of the number of fish in the Oklawaha. Rough fishes contributed significantly to the biomass of these rivers (34 to 42%) but were low in overall abundance (5 to 9%). Commercial fishes were poorly represented in the Withlacoochee (2% of the biomass and 0.3% of the number) but were proportionately greater in the Oklawaha (11% of the total biomass and 5% of the total number) than in any other river except the St. Johns. Forage fish biomass was low in both rivers (1 to 3%), but forage fishes were the 2nd most abundant group of fishes (12 to 19% in these rivers.

St. Johns River

The St. Johns River is the largest river in Florida with a watershed entirely within the state. The St. Johns arises from headwater marshes and drains land in urban, agricultural and silvicultural use. In the vicinity of the water quality and fish population sampling locations, the St. Johns is over 1 km wide and very shallow. Despite a very high discharge of 421 cms at this point, current velocities are very slow, and at times of high tide and low flow, reversals in the direction of flow may occur. Thus, in this area the St. Johns is reminiscent of a shallow, sluggish lake subject to a high degree of wind mixing.

The St. Johns was one of the lower rivers in terms of turbidity despite the greater potential for plankton production. Conductance and total dissolved solids were exceedingly high in the St. Johns, averaging 2 to 3 times higher than the highest of the other North Florida rivers. In addition, total nitrogen and total phosphorus were comparatively high indicating greater fertility. The St. Johns exhibited the highest pH of the 8 rivers and was among the lowest in color. The relatively high dissolved oxygen content was probably a function of wind mixing. Total organic carbon was also moderately high indicating either a substantial source of allochthonous organic matter or comparatively high plankton densities.

Sport fishes dominated the fish populations of the St. Johns River, accounting for 62% of the biomass and 81% of the number of fish. Commercial species ranked 2nd in biomass with 17% of the total, but they were low in overall abundance (4%). Rough fishes were the least significant component of the fish populations comprising only 8% of the biomass and 3% of the number fish. Forage fishes comprised a more significant portion of the total biomass in the St. Johns (12%) than in any of the other rivers and were the 2nd most abundant group of fishes (12%) after sport fishes.

Relationships Between Water Quality and Fish

The mean of each water quality parameter was tested for linear correlation with the mean biomass and mean abundance of each fish group in each river. Conductivity, total dissolved solids and total nitrogen, 3 closely related indicators of river fertility, displayed strong positive linear correlations with the biomass and abundance of sport fishes, commercial fishes and the total fish populations of North Florida rivers (Tables 3, 4). The data also seem to indicate that rough and forage fishes decreased with increasing fertility, but this conclusion lacks statistical significance. The correlation coefficients for total nitrogen and total phosphorus indicate that, of the 2 major macronutrients, nitrogen rather than phosphorus was the apparent limiting factor for sport and commerical fish production; however, it does appear that total phosphorus was a limiting factor for rough fish biomass. Fig. 3 illustrates the predictive relationships between conductivity, total nitrogen and total fish biomass and abundance.

Table 3. Correlation coefficients (r) showing relationships between water quality parameters and the biomass of each fish group in 8 North Florida rivers.

Water Quality Parameter	Sport Fish Biomass	Commercial Fish Biomass	Rough Fish Biomass	Forage Fish Biomass	Total Fish Biomass
Conductivity	.96**	.95**	–.44	–.30	.77*
Total Dissolved Solids	.94**	.93**	–.49	–.32	.71*
Total Nitrogen	.79*	.75*	.10	–.17	.85**
Total Phosphorus	.17	.02	.73**	–.50	.47
pH	.73*	.66	–.37	–.46	.53
Total Organic Carbon	.55	.32	.39	–.59	.66
Turbidity	–.63	–.39	.05	.84**	–.52
Color	.02	–.10	.76*	–.52	.30
Dissolved Oxygen	–.26	–.04	–.10	.58	–.22
Discharge	.40	.59	–.30	.10	.33

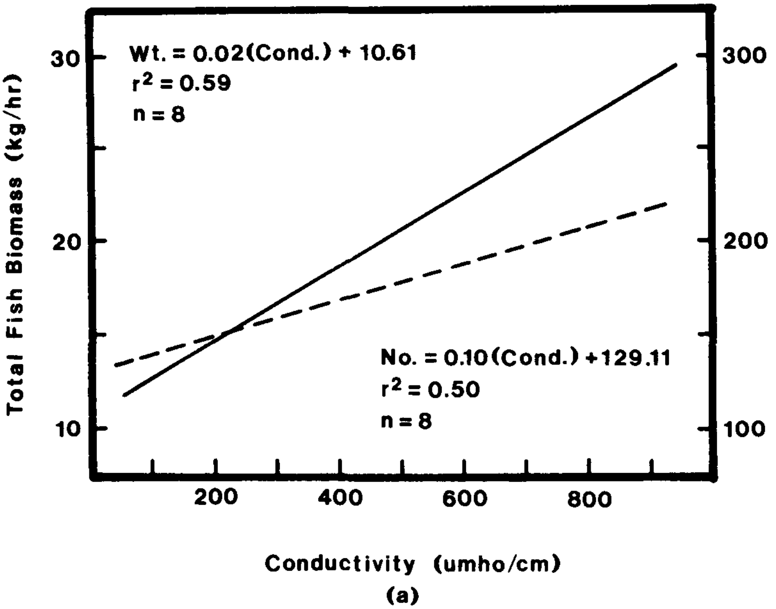
* Correlation significant at the 95% level of confidence.
** Correlation significant at the 99% level of confidence.

pH is an important water quality parameter because it controls the availabiltiy of both harmful and beneficial compounds in aquatic systems. In North Florida rivers, pH showed significant positive correlations with sport fish biomass and abundance but showed a significant negative correlation with forage fish abundance.

Total organic carbon, a possible indicator of the detrital energy available to the system, displayed a weak positive correlation with the biomass of sport and commercial fishes and with the biomass of the total population. However, total organic carbon showed a significant negative correlation with forage fish abundance and a weak negative correlation with forage fish biomass.

Turbidity exhibited a highly significant correlation with forage fish biomass and abundance, probably due to the increased difficulty of predators locating prey in more turbid rivers. Otherwise turbidity had weak negative correlations with sport fish populations and with commerical and total fish biomass.

Color showed a significant positive correlation with rough fish biomass and a weak positive correlation with rough fish abundance. For the remaining groups of fishes, color showed a weak negative correlation.



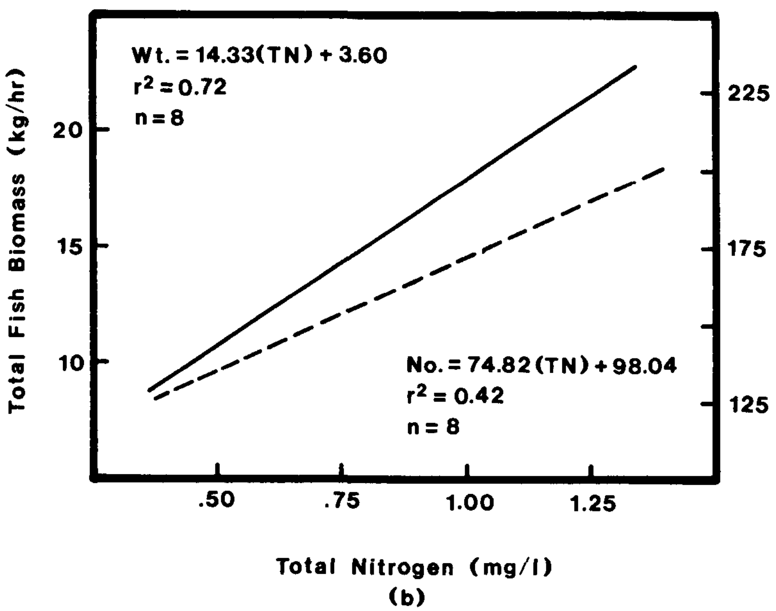


Fig. 3. Simple linear regressions of (a) total fish biomass and (b) abundance on conductivity and total nitrogen.

Table 4. Correlation coefficients (r) showing relationships between water quality parameters and the abundance of each fish group in 8 North Florida rivers.

Water Quality Parameter	Sport Fish Abundance	Commercial Fish Abundance	Rough Fish Abundance	Forage Fish Abundance	Total Fish Abundance
Conductivity	.92**	.79*	–.64	–.52	.73*
Total Dissolved Solids	.88**	.74*	–.65	–.48	.71*
Total Nitrogen	.89**	.85**	–.42	–.61	.65
Total Phosphorus	.14	.04	.32	–.52	.24
pH	.85**	.66	–.70	–.71*	.45
Total Organic Carbon	.56	.24	.01	–.83*	–.01
Turbidity	–.60	.10	.28	.87**	.10
Color	–.03	–.17	.36	–.39	–.37
Dissolved Oxygen	–.45	–.14	.22	.83*	.20
Discharge	.30	.40	–.39	.17	.57

* Correlation significant at the 95% level of confidence.

** Correlation significant at the 99% level of confidence.

For the most part, dissolved oxygen was poorly correlated with the fish populations of North Florida rivers. This result seemingly indicates that the range of oxygen concentrations found in those rivers at the sampling locations was adequate to support fish without adverse effect. However, forage fish abundance did show a significant positive correlation with dissolved oxygen, and forage fish biomass showed a weak positive correlation.

The fish populations of North Florida rivers displayed no significant correlation with discharge; however, it is interesting to note that the correlation coefficients for rough fishes were negative whereas for the remaining groups of fishes they were positive.

DISCUSSION

The Yellow, Escambia and Choctawhatchee rivers had the highest tubidity, lowest fertility, lowest pH and lowest organic carbon content of the 8 rivers. In general the Suwannee, Santa Fe, Withlacoochee and Oklawaha rivers had low to moderate turbidity, moderate to high fertility, moderate pH, low to high color, low to moderate dissolved oxygen and moderate to high total organic carbon. The St. Johns River had low turbidity, high fertility, high pH, low color, high dissolved oxygen and moderate total organic carbon.

In general, sport fishes dominated the fish populations of North Florida rivers. Although rough fishes actually outweighed sport fishes by a factor of 2 to 3, especially in less fertile rivers, sport fishes were far more abundant in all cases. Commercial fishes were generally poorly represented, usually comprising less than 5% of the total number and less than 10% of the total biomass of fish; however, G. Bass (personal communication) indicated that catfish, which comprise the bulk of commercial fishes sampled, are poorly sampled by electroshocking. Thus, while the comparative results of commercial fishes between rivers was accurate, the actual percent composition of commercial fishes was probably higher than observed. Forage fishes (i.e., fishes too small to be of economic value) were generally low in total biomass but high in number.

The fish populations of North Florida rivers may be considered in terms of water quality limiting factors. Hynes (1969) and EPA (1976) cited literature demonstrating that increasing turbidity adversely affects fish production. Hynes (1969) reported that increasing fertility, as reflected by conductance, total dissolved solids, total nitrogen and total phosphorus, increases fish production, but that overenrichment may negatively affect fish populations. EPA (1976) pointed out that a range of pH from 6.5 to 9.0 appears to provide adequate protection for aquatic life, but that the further outside of this range, the more detrimental the effects of pH. Color is viewed as a limiting factor by EPA (1976) because as color increases, the depth of light penetration decreases and limits primary production. The role of dissolved oxygen in maintaining healthy aquatic communities is well documented (EPA 1976). Cummins (1975), Kaushik (1975) and Benfield (1981) have discussed the importance of allochthonous organic matter, expressed as total organic carbon, to the maintenance of secondary production in lotic communities; however, Hynes (1969) points out that excessive inputs of organic matter reduce dissolved oxygen and limit aquatic production.

Considering the literature on water quality effects and the results of this study, river fertility, as expressed by conductivity, total dissolved solids and total nitrogen, has the strongest influence on the biomass and abundance of sport and commerical fishes and on the total fish populations of the major water quality parameters considered. Rough and forage fishes appear to decline with increasing fertility. These results are illustrated in Fig. 2 in which the fish populations of the eight rivers are ordered by increasing conductivity. Other water quality variables such as total organic carbon, turbidity and color may modify this effect upward or downward. Rough fish populations are associated with rivers of low discharge, low dissolved oxygen, low fertility and high color. Such rivers in North Florida usually receive drainage from swamps and pine flatwoods. Forage fish populations are strongly and positively correlated with turbidity and dissolved oxygen and negatively correlated with pH and total organic carbon.

LITERATURE CITED

Anonymous. 1976. Cross Florida barge canal restudy report: Fisheries study, Volume V. Fla. Game and Fresh Water Fish Comm., Tallahassee. 149pp.

Bass, D. G., Jr., and V. G. Hitt. 1973. Sport fishery ecology of the Suwannee and Santa Fe Rivers, Florida. Fla. Game and Fresh Water Fish Comm., Tallahassee, 187pp.

__________, and __________. 1978. Sport fishery ecology of the Escambia River, Florida. Fla. Game and Fresh Water Fish Comm. Tallahassee. 112pp.

__________, D. M. Yeager, and V. G. Hitt. 1979. Ecology of the Yellow River system, Florida. Fla. Game and Fresh Water Fish Comm. Tallahassee. 191pp.

__________, __________, and __________. 1980. Ecology of the Choctawhatchee River system, Florida. Fla. Game and Fresh Water Fish Comm., Tallahassee. 155pp.

Benfield, E. F. 1981. Primary production in stream ecosystems. Pages 82-90 *in* L. A. Krumholz (Ed.). Warmwater Streams Symposium. South. Div. Am. Fish. Soc. Allen Press, Inc., Lawrence, Kans.

Cummins, K. W. 1975. The importance of different energy sources in freshwater ecosystems. Pages 50-54 *in* Production of World Ecosystems. Natl. Acad. of Sci., Washington, D.C.

EPA. 1976. Quality criteria for water. U.S. Environ. Protection Agency, Washington, D.C. Rep. No. EPA-440/9-76-023. 501pp.

Hynes, H. B. N. 1969. The enrichment of streams. Pages 188-196 *in* Eutrophication: Causes, consequences, correctives. Natl. Acad. of Sci., Washington, D.C.

Kaushik, N. K. 1975. Decomposition of allochthonous organic matter and secondary production in stream ecosystems. Pages 90-95 *in* Productivity of World Ecosystems. Natl. Academy of Sciences, Washington, D.C.