The Impacts of Sand and Gravel Dredging on Trout and Trout Habitat in the Chattahoochee River, Georgia

by

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Study Objectives: To determine the impacts of sand and gravel dredging on the distribution of trout and other fish species, trout condition, and trout habitat in the Chattahoochee River.

ABSTRACT

The impact of sand and gravel dredging on trout and trout habitat in the Chattahoochee River was investigated during October-November 1984. Six 100-meter sections of the river near two sand dredges (three sections per dredge) were sampled using electrofishing and detonation cord. While one dredge created a long, deep pool with a primarily sand substrate, the other dredge created a "sediment trap" at the upstream end of its permitted area which appeared to benefit downstream trout habitat. Current velocity was significantly slower and the numbers of competitive fish and competitive fish species were greater in the dredged areas, however. Both dredge operators removed from their permitted areas large gravel and fallen trees, which had served as substrate for aquatic insects and essential cover for trout. Recommendations concerning dredge operating procedures are presented.

INTRODUCTION

The 77 km section of the Chattahoochee River below Lake Lanier has been managed as a trout fishery since 1960 by the Georgia Department of Natural Resources (DNR), Game and Fish Division. This river section is close to the metropolitan Atlanta area and receives heavy trout angling pressure. Although this section of the river represents only about 1% of Georgia's total trout stream mileage, it received 13% (129,662) of the total number of catchable trout stocked statewide during fiscal year 1983 (Martin 1985a). Anglers spent 275,775 hours of fishing effort on this river section during the 1983 trout season (Martin 1985b).

In early 1984, five sand and gravel dredges operated in the section of the Chattahoochee River designated as secondary trout waters between Lake Lanier and Atlanta. During 1984, three more applications for permits to dredge were received by the U. S. Army Corps of Engineers (COE). Two of these applications involved a 13 km section of the river where three dredges were already operating. Floating hydraulic and clamshell bucket dredges removed sand, gravel up to several centimeters in diameter, and small woody debris.

Over the past several years, river dredging has removed sand and gravel much faster than it is being replaced by tributary input, river bank erosion, and downstream bed movement. Two dredge operators reported recently that it took from three to seven days for a hole created during a day's dredging to refill. During periods of low rainfall and limited generations at Buford Dam, this refill time is much longer.

Dredging has been found to be detrimental to fish and fish habitat by increasing substrate instability, decreasing the variability of the physical habitat, and removing substrates for aquatic invertebrates (Etnier 1972; Forshage and Carter 1973). Dredging results in changes to stream channel shape, the size and amount of material in the stream bed, stream bank stability, and the amount of woody debris in the stream. These dredging effects have been found to directly influence stream habitat for salmonids (Bottom et al. 1985).

The metropolitan Atlanta area population is expected to increase 44% above present levels by 1990 (Atlanta Regional Commission). An increase in construction activities to meet the demands of that growth, which will result in more applications for permits to dredge sand and gravel in the Chattahoochee River and other nearby streams, was expected. Therefore, DNR became concerned about the cumulative impacts of dredging on this quality trout fishing stream. Prior field observations had indicated that extensive dredging activities might be having a detrimental impact on the fishery. DNR therefore requested that the COE issue only one year dredging permits until an impact assessment could be completed.

METHODS

The first step in assessing the impacts involved the observation of dredge activities and discussions with operators about techniques used in removing sand and gravel from the riverbed. Two dredge sites were visited approximately biweekly over a two month period to determine the movement patterns of the dredges in the river. This helped identify areas to be sampled in subsequent studies. Topics discussed with dredge operators included: 1) the length of stream permitted to dredge; 2) the type of materials dredged; 3) operating proximity to the river banks; 4) the procedures used when woody debris and fallen trees were encountered; 5) the daily and weekly operating frequencies; 6) the average upstream dredge movement over the period of a week, month, or year; 7) the time necessary to completely dredge the entire permitted area; 8) the average time required for sand to refill a dredged hole; 9) how the refill time was affected by periods of low rainfall or low generation activities at Buford Dam; and 10) the measures taken to reduce impacts (during dredging and material separation) on water quality.

The second step involved field sampling. Six 100-meter sample sections of the Chattahoochee River were selected adjacent to two sand dredge operations. The dredges were located just upstream of McGinnis Ferry Road and downstream of Rogers Bridge Road (Figure 1). These operations were chosen because both used floating hydraulic suction-type dredges. This is the type most often used in the river and was of more concern to DNR. At each of the two locations, three separate areas were sampled: an undredged area (U), an area which had been dredged within one week (R), and an area which had been dredged several months prior (D). The undredged areas were selected to represent the unimpacted river. The areas recently dredged (within one week) were chosen to assess the immediate or short-term effects of dredging. Areas dredged several months before were selected to assess the long-term effects of dredging. By chance, both areas selected to determine the long-term effects had been dredged approximately seven months before sampling.

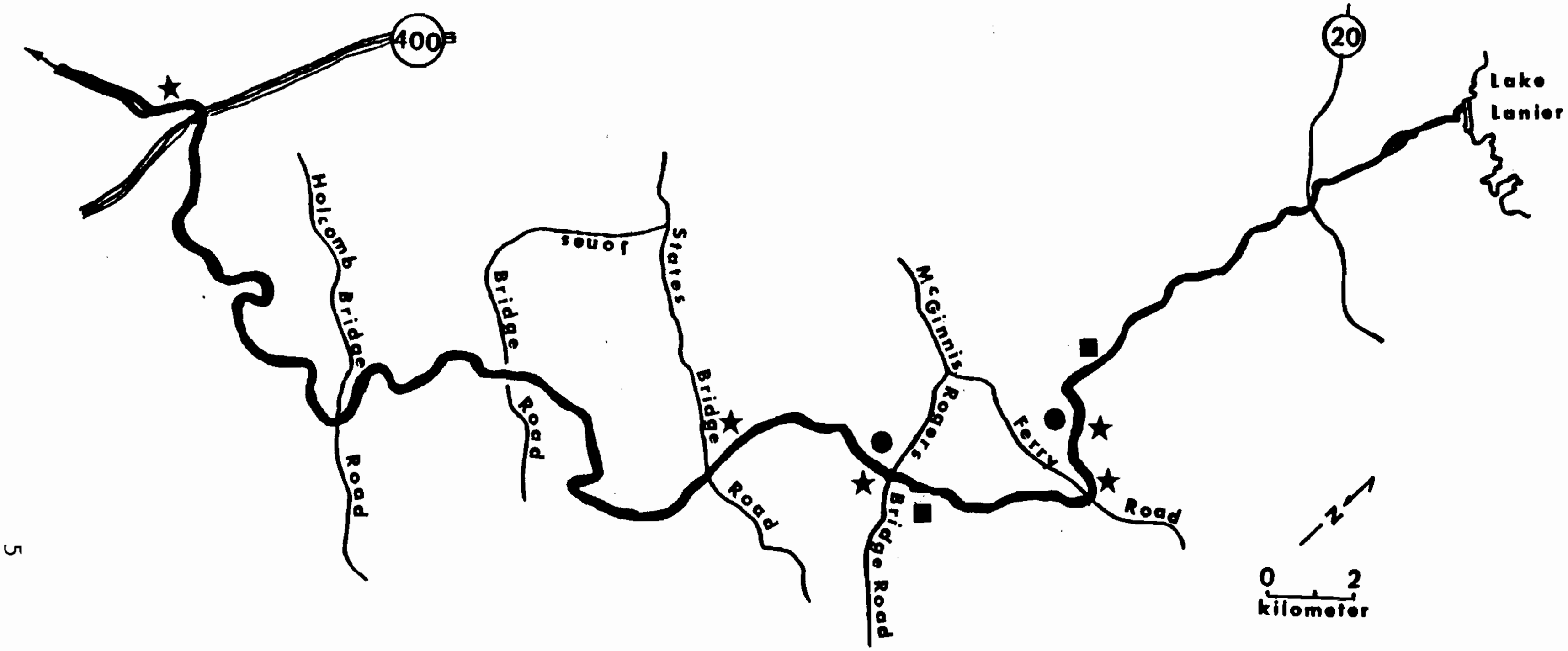

Figure 1. Locations of existing sand and gravel dredges (★), dredge operations for which permits have been applied (■), and areas sampled by electrofishing and detonation cord (●) on the Chattahoochee River, Georgia, in the fall of 1984.

The six study areas were sampled with a boat-mounted electrofisher (pulsed DC) on October 16-18, 1984. Within each area, the shorelines and shallow areas were electrofished and the study area was circuited twice. All species of fish were netted, weighed (in grams), and measured (total length in mm). Trout were anesthetized with MS 222 to reduce handling stress and were released near the site of capture.

Another sampling method was needed to supplement the electrofishing, which was believed to be biased due to its ineffectiveness in deep water areas. A more conventional sampling method, rotenone, could not be utilized because the Chattahoochee River is used as a drinking water supply for the Atlanta and surrounding counties, and because cold water temperatures (7-8°C) would reduce its effectiveness. Detonation cord (50 grains/foot), a relatively new and untested method for DNR personnel, was selected.

On 6-9 November 1984, six sites similar in location to the areas sampled by electrofishing were sampled by this method. A blockoff net was placed across the river at the downstream end of four of the sample areas (R & D at both dredge sites). A blockoff net was not used at the undredged sample areas (U) because of rising water levels caused by generations at Buford Dam, and because of personnel and time constraints. The river at the lower end of the undredged sample areas was wadable (less than three feet deep), and personnel with dip nets were stationed across the river to pick up dead fish as they floated or drifted downstream.

Just prior to detonation, 16 tagged trout were released within each sample area. Following detonation, SCUBA divers swam downstream transects (12 per area) along the bottom to recover fish and observe the river bottom characteristics. Fish collected were weighed (grams) and measured (total length in mm) by species groups. Trout condition factors were calculated through the use of the formula $K=(Wx10^5)/L^3$, where W = weight in grams, and L = total length in millimeters. No dredge was operating while sampling was being conducted. Dredge owners/operators agreed to this for safety and sampling convenience reasons.

Water quality data (dissolved oxygen, temperature, pH, and total hardness) were collected at each area just before detonation. Water velocity (m/s) was measured at the upstream end of each station. Surface to bottom flow meter readings were taken at points approximately 5m from each bank and at midstream.

Concurrently, Environmental Protection Division (EPD) personnel collected and analyzed water quality and aquatic insect samples from areas similar to those sampled for fish. Aquatic insect densities were determined from Hester-Dendy multiplate samplers retrieved after having been deployed for 60 days.

The third step in assessing the impacts of dredging involved a review of the literature referencing the effects of sand and dredging on streams and fish populations, with special emphasis on trout streams. Dr. Parley V. Winger of the Columbia National Research Laboratory, U. S. Fish and Wildlife Service, Athens, Georgia, was consulted and provided many references that could not have been otherwise obtained.

RESULTS

Dredge Operating Procedures

The two dredges operated similarly in some regards and differently in others. The dredge at McGinnis Ferry operated within a permitted area 862 meters long while the dredge at Rogers Bridge was permitted for 554 meters. No other dredging occurred upstream of the McGinnis Ferry dredge, while the Rogers Bridge dredge operator claimed that the McGinnis Ferry dredge, six kilometers upstream, affected the sand supply at his location. The McGinnis Ferry dredge moved slowly upstream and had a good upstream sand supply, while the Rogers Bridge dredge obtained most (75%) of the sand available to it from the upper 100m of its permitted area. This area took about two weeks to refill after it had been dredged. Generation activities at Buford Dam and rainfall influenced the time necessary for dredged holes to refill.

Both dredge operators were permitted to dredge within 3m of the banks and both removed sand and gravel up to several centimaters in diameter. Both dredges were floating hydraulic suction-type dredges which use an auger to loosen the sand. Both dredges pumped materials through either floating metal or PVC pipe to a separator on shore. The sand and gravel were then separated and piled. Water from the separator passed through a small settling basin(s) and returned to the river. The settling basins appeared to be relatively ineffective. At both sites, a plume of highly turbid water was evident downstream of the washwater entry point. However, this effect was localized and the plume was not evident approximately 200m downstream. Both dredge operators reported removing snags and fallen timber within their permitted areas to have access to the sand and allow free movement of the dredges and floating lines.

Electrofishing

Trout accounted for 96%, 78%, and 7% of the total fish collected from the undredged, recently dredged, and dredged seven months prior sample areas at McGinnis Ferry, respectively (Table 1). A single largemouth bass (*Micropterus salmoides*) was the only other fish collected from the undredged area. Two yellow perch (*Perca flavescens*) were the only other fish collected from the recently dredged area, while 14 fish representing six (nontrout) species were collected from the area that had been dredged seven months prior. The six additional species collected in this area were the spotted sucker (*Minytrema melanops*), redbreast sunfish (*Lepomis auritus*), bluegill (*Lepomis macrochirus*), largemouth bass, black crappie (*Pomoxis nigromaculatus*), and yellow perch.

Trout accounted for 82%, 17%, and 40% of the total fish collected in the undredged, recently dredged, and dredged seven months prior sample areas at Rogers Bridge, respectively (Table 1). While only yellow perch (two fish) were collected in addition to trout in the recently dredged area at McGinnis Ferry, several competitive species (species with food habits similar to trout) were collected in the recently dredged area at Rogers Bridge. These included the chain pickerel (*Esox niger*), warmouth (*Lepomis gulosus*), redear sunfish (*Lepomis microlophus*), largemouth bass, and yellow perch. In the area dredged seven months prior to sampling at Rogers Bridge, trout accounted

Table 1. Numbers of fish collected by electrofishing on the Chattahoochee River during October 1984 at two sand and gravel dredge sites. (U = an undredged site; R = a recently dredged site (within 7 days); D = a site dredged approximately seven months prior to sampling).

	SAMPLE SITES					
	McGinnis Ferry			Rogers Bridge		
Species	U	R	D	U	R	D
Rainbow trout	9	3	0	7	1	3
Brown trout	13	4	1	7	1	1
Chain pickerel				1	3	1
Carp						1
Spotted sucker			2			
Redbreast sunfish			1			
Warmouth					2	
Bluegill			1			
Redear sunfish					1	1
Largemouth bass	1		4		1	1
Black crappie			1			
Yellow perch		2	5	2	3	
Total Trout	22 (96%)	7 (78%)	1 (7%)	14 (82%)	2 (17%)	4 (40%)
Total Number of Competitive Fish	1 (4%)	2 (22%)	14 (93%)	3 (18%)	10 (83%)	6 (60%)

for 40% of the fish collected. Chain pickerel, carp (Carpus carpio), redear sunfish, and largemouth bass were also collected in the same area.

The sizes of trout collected in the undredged area (U) and the dredged areas (R&D) at the McGinnis Ferry site differed (Figure 2). Trout >36cm were more abundant in the undredged area. Eighty percent were brown trout. The sizes of trout collected from the three sample areas at the Rogers Bridge site were similar.

The average condition factor for trout collected from the three sample areas at the McGinnis Ferry site differed. Trout collected in the dredged areas were generally in poorer condition, although this difference was not significant ($p=0.05$) (Table 2). The average condition factors of trout collected at the Rogers Bridge dredge site were similar at all three sample areas.

Detonation Cord

The total numbers of fish collected by detonation cord at the six sample sites were adjusted to account for the incomplete recapture (25% to 63%) of tagged trout stocked just prior to sampling (Table 3). A discussion of the detonation cord sampling methodology and observations is given in the Appendix.

At McGinnis Ferry, trout accounted for 78%, 88%, and 17% of the total fish collected in the undredged, recently dredged, and dredged seven months prior sample areas, respectively (Table 3). The area dredged seven months before sampling had the greatest total number of trout competitors (76) and competitive fish species (6).

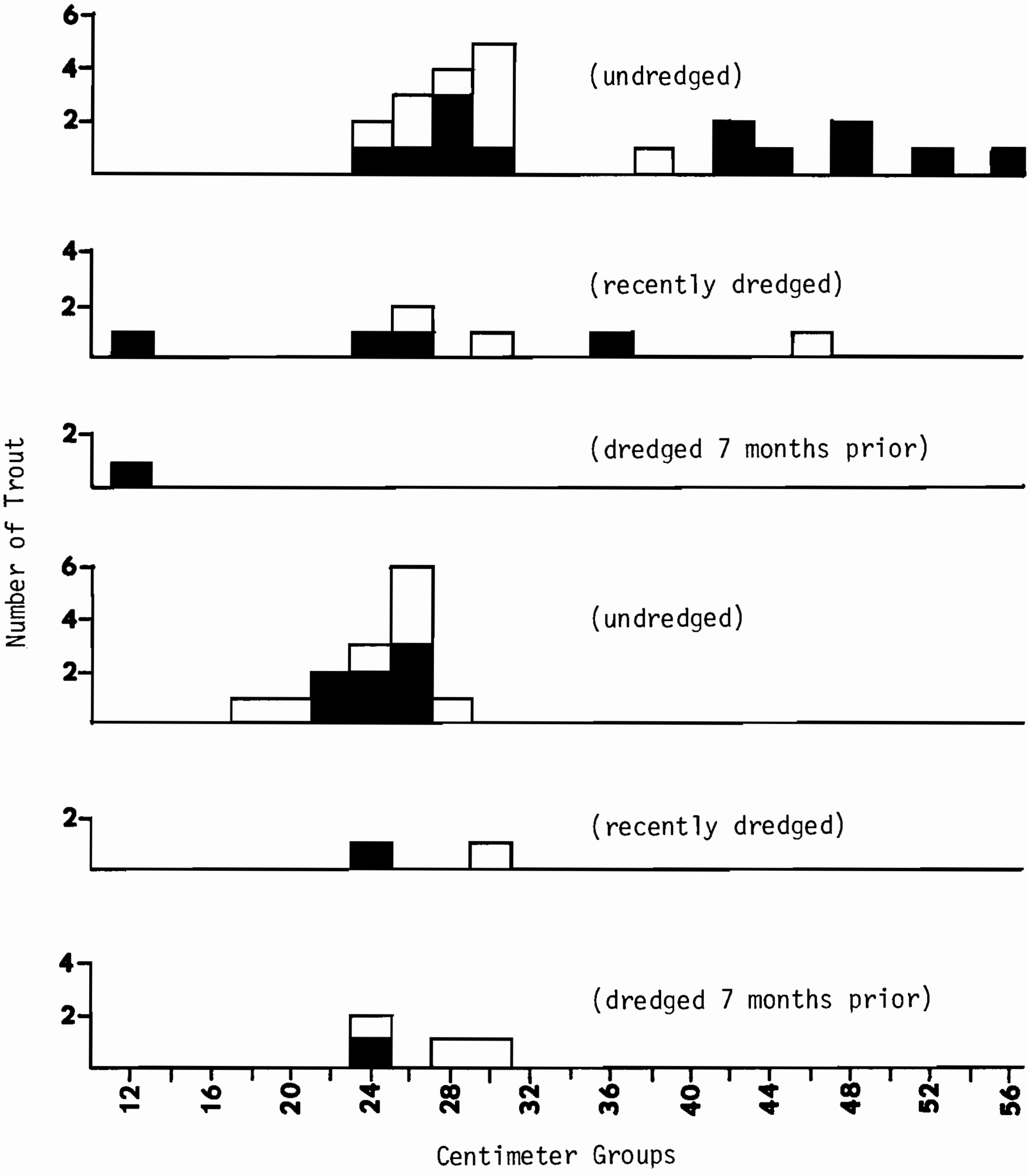

Figure 2. The length of rainbow and brown trout collected by electrofishing from the Chattahoochee River at the McGinnis Ferry site (first three) and the Rogers Bridge site (second three), 16-18 October 1984.
■ - Brown trout ▭ - Rainbow trout

Table 2. Average condition factors of trout collected by electrofishing and detonation cord in the Chattahoochee River during October-November 1984 at two sand dredge sites. (U = an undredged site; R = a recently dredged site (within 7 days); D = a site dredged approximately seven months prior to sampling). Sample size is in parentheses.

Collection Method	SAMPLE SITES McGinnis Ferry U	 R	 D	 Rogers Bridge U	 R	 D
Electrofishing	0.99 (22)	0.94 (7)	0.75 (1)	0.98 (14)	1.08 (2)	0.98 (4)
Detonation Cord	0.96 (16)	0.84 (21)	0.83 (4)	0.92 (18)	0.93 (39)	0.91 (58)

Table 3. Adjusted numbers of fish collected by detonation cord on the Chattahoochee River during November 1984 at two sand and gravel dredge sites. (U = an undredged site; R = a recently dredged site; D = a site dredged approximately seven months prior to sampling. The actual numbers of fish collected are in parentheses.

	SAMPLE SITES					
	McGinnis Ferry			Rogers Bridge		
Species	U	R	D	U	R	D
Rainbow trout	26 (8)	52(16)	12 (3)	26 (8)	37(10)	30(19)
Brown trout	26 (8)	16 (5)	4 (1)	32(10)	107(29)	62(39)
Chain pickerel					4 (1)	
Golden shiner				64(20)*		
Spotted sucker			24 (6)		4 (1)	6 (4)
White catfish			4 (1)			
Bluegill	6 (2)	3 (1)	8 (2)	16 (5)	15 (4)	3 (2)
Spotted bass	3 (1)					
Largemouth bass			4 (1)	3 (1)		
Black crappie			4 (1)			
Yellow perch	6 (2)	6 (2)	32 (8)	16 (5)	30 (8)	19(12)
Total Trout	52(16) 78%	68(21) 88%	16 (4) 17%	58(18) 62%	144(39) 73%	92(58) 77%
Total Number of Competitive Species	15 (5) 22%	9 (3) 12%	76(19) 83%	35(11) 38%	53(14) 27%	28(18) 23%
% Recapture of Tagged Trout	31	31	25	31	27	63

*noncompetitive with trout due to planktivorous food habits; these fish were probably the result of an introduction by anglers

At Rogers Bridge, trout accounted for 62%, 73%, and 77% of the total fish collected from the undredged, recently dredged, and dredged seven months prior sample areas, respectively. More trout (144) and more competitive fish (53) were collected in the recently dredged area.

At both dredge sites, the most trout were collected from the recently dredged areas. In contrast to McGinnis Ferry, the fewest number of trout (58) were collected in the undredged area at Rogers Bridge. Bluegill and yellow perch were collected at all six sampling areas, while spotted sucker, white catfish (*Ictalurus catus*), and black crappie were collected only in the areas impacted by dredges.

The lengths of trout collected from all sample areas were similar (Figure 3). The overall modal length group was 24-28 cm, which is the most common size of trout at stocking. Few trout collected from any of the sample areas were longer than 36 cm.

The average condition factors of trout collected from the three sample areas at the Rogers Bridge site were similar (Table 2). The average condition factor of trout collected in the dredge impacted areas (R and D) at the McGinnis Ferry site were significantly ($p=0.05$) lower than trout collected in the unimpacted area (U).

SCUBA divers characterized the river bottom of the recently dredged area at the Rogers Bridge dredge site (R) as composed primarily of loose, fine sand along the upper 50 meters and coarse gravel, exposed bedrock, snags, and hard packed sand along the lower 50 meters. The bottom of the area dredged seven months before sampling (D), was composed primarily of cobble with algal growth, exposed bedrock, and

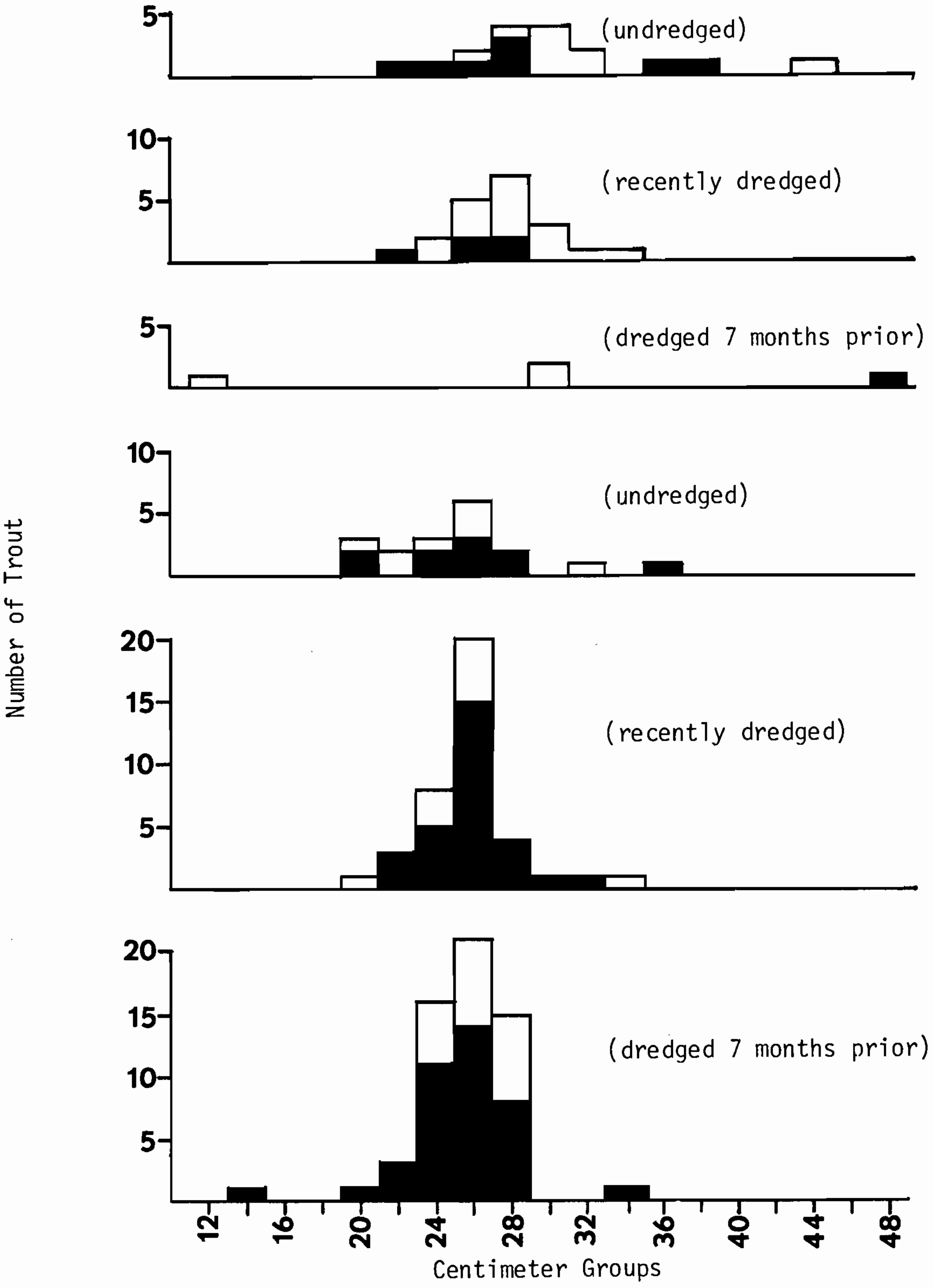

Figure 3. The length of rainbow and brown trout collected by detonation cord from the Chattahoochee River at the McGinnis Ferry site (first three) and at the Rogers Bridge site (second three), 6-9 November 1984.

■ - Brown trout ☐ - Rainbow trout

bands of cobble/gravel ridges with coarse, hard-packed sand troughs. There was some fine, loose sand evident also.

In contrast, the river bottom of the recently dredged area (R) at the McGinnis Ferry dredge site was composed mostly of fine, loose sand which ran in ridges and troughs perpendicular to the channel. Small snags were common and gravel was more prevalent at the upper end of the area where dredging had most recently occurred. The river bottom of the area dredged seven months before sampling was characterized by hard-packed sand ridges and soft sand troughs running perpendicular to the channel. Some snags were visible, but were mostly covered by sand, and some pea gravel was evident at the very upper end.

Water quality (dissolved oxygen, temperature, pH, and total hardness) was similar between the sample areas (Table 4). Dissolved oxygen concentrations tended to decrease at the lower end of the dredge sites, but were at acceptable levels for trout survival in all areas. Average water velocity decreased significantly (p=0.10) from 0.77 and 0.65 m/s in the undredged areas to 0.27 and 0.31 m/s in the areas dredged seven months prior to sampling at the McGinnis Ferry and Rogers Bridge sites, respectively.

Literature Review

It is apparent that dredging can affect trout in several ways. Pools created by dredging may serve as sediment basins to trap shifting sand which would otherwise scour or bury desirable aquatic insect substrate, destroy cover, and reduce spawning success (Alexander and Hansen 1983; Hansen et al. 1983). This trapping of sand has been found

Table 4. Water quality and velocity data collected prior to detonation cord explosion at six sampling sections in the Chattahoochee River, 6-9 November 1984. Data collected when dredges were not operating. (U = an undredged site; R = a recently dredged site; D = a site dredged approximately seven months prior to sampling)

Sample Site	Sample Area	D.O. (mg/l)	Temp. (°C)	pH	Total Hardness (mg/l)	Average Water Velocity (m/s)
McGinnis Ferry	U	8.0	11	6.5-7.0	11	0.77
	R	8.2	10	6.5-7.0	11	0.51
	D	7.8	11	6.5-7.0	11	0.27
Rogers Bridge	U	7.6	12	6.5-7.0	11	0.65
	R	7.4	12	6.5-7.0	10	0.45
	D	6.9	13	6.5-7.0	10	0.31

to be beneficial to downstream trout abundance. However, this action dictates that the upstream trout habitat must itself be altered to create the sediment basin or pool. Too much pool can be detrimental if it is created at the expense of the food producing swift water areas (Needham 1940, Borovicka 1968, Finnigan et al. 1980).

Dredging results in deeper, wider channels and slower water velocities (Etnier 1972). Deep, quiet pools often are dominated by suckers and other undesirable nongame species (Hubbs et al. 1932). Peak aquatic insect production in streams has been found to occur at water velocities of 0.62 m/s (Pearson et al. cited by Fraser 1972). Reductions in water velocities have been found to reduce invertebrate densities (Hynes 1970). Dredging also decreases invertebrate production directly through the actual removal of invertebrates from the areas dredged (Harvey et al. 1982; Thomas 1985) and indirectly through the removal of suitable substrates (woody debris, snags, fallen trees) (Benke et al. 1985; Bottom et al. 1985).

The optimum substrate size for most benthic invertebrates has been found to be about 3cm in diameter (Rabeni and Minshall 1977). Coarse gravels (those greater than approximately 1.5cm in diameter) are nearly three times more productive than sand, over ten times more productive than hardpan (clay), and over 100 times more productive than bedrock (Hubbs et al. 1932). Thus, the removal of gravel is detrimental to invertebrate populations. Substrate however, is very largely controlled by the current, and where current speeds are slow (less than approximately 0.6 m/s), the river bed is likely to be sand (Finnigan et al. 1980). Moving or shifting sand is the poorest substrate for invertebrate habitat and production (Usinger 1968; Hynes 1970).

Woody debris in a stream also provides essential cover for trout (Everest et al. 1982; Benke et al. 1985; Bottom et al. 1985). Cover is an important element of trout habitat (Chapman 1966; Lewis 1969; White 1980) and its removal has been linked directly to a reduction in trout abundance (Reiser and Bjornn 1979 cited by Bottom et al. 1985).

DISCUSSION

Growth of young trout can be negatively impacted by relatively low turbidity levels (Sigler et al. 1984), but larger trout appear to better handle this type of short-term stress (Noggle 1978 cited by Sigler et al. 1984). Though high turbidities are created by sand dredging in the Chattahoochee, the effect is very localized and only occurs while an individual dredge is operating. Some problems were observed with turbidities and/or bank erosion as a result of washing and separating operations on the shore. Despite this, water quality did not appear to be seriously impacted by sand and gravel dredging on the Chattahoochee River.

The two sand dredges on the Chattahoochee followed some similar procedures (e.g. removing fallen trees, sand, and gravel) and had some similar impacts. The dredges, however, moved at different rates within their permitted areas and appeared to impact the river bottom differently.

Dredges operating on the Chattahoochee River were found to remove sand, as well as gravel up to several centimeters in diameter. The removal of sand from a Michigan trout stream was found to be beneficial to downstream habitat (Alexander and Hansen 1983). The increased trout standing crop which resulted was attributed to either increased invertebrate production, increased trout spawning success, or more efficient feeding by trout.

Sampling by EPD personnel in the Chattahoochee River indicated that densities of aquatic insects were lower in the dredged areas due at least in part to reduced water velocities. Species that have a high current velocity requirement (such as net spinning caddisflies or midges) may not survive in the dredged pools during the low flow periods between power generations on the Chattahoochee River. Species which can survive in slow flow areas may not be able to withstand the higher current velocities present during power generation periods. Water velocity in the long, deep dredged pools was significantly ($p=0.05$) less at 0.28 m/s than the 0.71 m/s in the undredged areas.

The spotted sucker and common carp were found only in the dredged areas of the Chattahoochee (Table 5). Several warmwater game fish species such as the white catfish, redbreast sunfish, warmouth, redear sunfish, and black crappie were only collected from the dredged areas. Based on food habit studies conducted elsewhere and observations of stomach contents of some of these species in the Chattahoochee River, all would be expected to compete with trout for food to some extent (Carlander 1969; 1977).

In the detonation cord samples, trout were more numerous in the recently dredged areas than in the undredged areas. In recently dredged areas, water depth at the upper end deepened suddenly from an average

Table 5. Fish species collected by electrofishing and detonation cord from the Chattahoochee River during October - November 1984 at two sand and gravel dredge sites. (U = an undredged site; R = a recently dredged site (within 7 days); D = a site dredged approximately seven months prior to sampling).

	SAMPLE SITES					
	McGinnis Ferry			Rogers Bridge		
Species	U	R	D	U	R	D
Rainbow trout	X	X	X	X	X	X
Brown trout	X	X	X	X	X	X
Chain pickerel				X	X	X
Common carp						X
Golden shiner				X[a]		
Spotted sucker			X		X	X
White catfish			X			
Redbreast sunfish			X			
Warmouth					X	
Bluegill	X	X	X	X	X	X
Redear sunfish					X	X
Spotted bass	X					
Largemouth bass	X		X	X	X	X
Black crappie			X		X	
Yellow perch	X	X	X	X	X	X
Number of Competitive Species	4	2	7	4	8	7

[a] Golden shiners are primarily plankton feeders and are not considered competitors for food. These fish were probably introduced by fishermen that were using them for bait.

0.7m to 2.5m where dredging had ceased. Pools usually are characterized by a variety of water velocities, including minimal velocities adjacent to the stream bottom. This results in more areas for trout resting and energy conservation (Cordone and Kelley 1961). Because trout need the current close by, without actually being in it (Hynes 1970; White 1980), these "dropoffs" or "ledges" created by dredging may actually be providing a resting place for trout and an opportunistic place from which to feed on drifting insects.

More trout were found in the dredged areas at Rogers Bridge than at any of the other sites. This site serves as a regular stocking location, and it is not surprising that stocked trout would congregate in the nearest downstream pool below a stocking point (Stefanich 1951; Logan 1963). This would account for the large number of trout collected in this area, though the last stocking took place more than two months before the sampling occurred. No decline in trout condition could be detected for trout occupying the dredged areas however. Thus, the dredged pool at Rogers Bridge may actually have increased the carrying capacity of the river for trout in that immediate area. As much of the trout food undoubtedly originated upstream in undredged areas, this observation should only be extrapolated beyond this immediate site with caution.

At McGinnis Ferry, for instance, the condition of trout was poorer in the dredged areas. SCUBA divers characterized the river's bottom in the McGinnis Ferry dredged areas as primarily fine loose sand in troughs. A sand substrate is poor habitat for both trout and most invertebrates (Hubbs et al. 1932; Bottom et al. 1985). Therefore, the carrying capacity of the river for trout in this immediate area may have been negatively impacted.

Substrates in the dredged areas at McGinnis Ferry and Rogers Bridge differed. Because, 75% of the sand removed from Rogers Bridge was reportedly taken from the upper 100m of the permitted section, this small area was probably acting as a sediment trap for downstream moving sand. Therefore, a larger amount of exposed gravel, snags, and bedrock downstream in the remainder of the dredged area were rarely disturbed by the dredge. This roughness of the stream bottom plays a part in providing shelter, especially for small fish and invertebrates (Alexander and Hansen 1983). At Rogers Bridge more trout were collected in both dredged areas, which may have resulted from the exposed gravel, bedrock, and snags.

Much of the Chattahoochee River is devoid of natural cover for trout due to the smothering impacts of sand. However, trees and shrubs which have fallen into the water along the river's edge are providing relatively stable cover for trout throughout much of the river. The fallen trees and shrubs create a variety of depths, velocities, and substrates utilized by salmonids and aquatic insects (Everest et al. 1982; Benke et al. 1985; Bottom et al. 1985). Numerous studies have documented declines in salmonid abundance after the removal of cover and increases in abundance after the re-establishment of cover (Reiser and Bjornn 1979 cited by Bottom et al. 1985). Studies of 9 to 16 inch brown trout in Michigan streams found that these fish spent 80% of the time resting under cover (White 1980). The amount of cover was shown to be the most important factor in determining brown trout population levels in a Montana stream (Lewis 1969).

Most dredges in the Chattahoochee River operated from the center of the river to approximately 3m from either shore. As the dredges removed sand and gravel from the bottom of the river, snags and fallen timber were also removed. Thus, the pools created by the dredges tended to have little shelter or cover for trout beyond the protection provided by the depth of the pool itself. Besides providing cover for trout, fallen trees and woody debris in streams also provide important aquatic insect habitat. Extensive removal of snags could thus be devastating to any fish species which relies heavily upon this food source.

Besides the reduction in water velocities and the removal of trees and woody debris, dredging also impacts the abundance of aquatic insects directly. This type of impact is restricted to the immediate area being disturbed and no measurable effects (i.e. reduced invertebrate populations) are thought to occur as a result in downstream areas.

The best overall trout habitat is obtained when pools are in even number with riffles or shallow, swift areas (Borovicka 1968). Riffle-pool length ratios have been determined to range from approximately 6:4 to 4:6 in quality trout streams (Needham 1940). The middle of one pool to the middle of the next should be about six channel widths in a good trout habitat stream (Finnigan et al. 1980). If this parameter was used on the Chattahoochee River in the areas where dredges are operating (river width averages 62m), the distance from the middle of one pool to the middle of the next should be about 372m. If a minimum of 40% of this distance remained a riffle (undredged), it would mean that 149m of this area would not be altered. Conversely, a pool 223m long could be dredged without negatively impacting the river.

Interestingly enough, another technique, developed by E. A. Hansen of the U. S. Forest Service to size sediment basins for sand removal from streams, leads to the recommendation of a similar pool size (Hansen 1973). This formula utilizes the size of the material to be removed, stream discharge, average water temperature, and width of the basin (or pool) to be dug or dredged to predict how long the pool must be to effectively remove 95% of the target material (in this case sand).

If it is assumed that: 1) 95% of all sand larger than 0.090mm is to be removed; 2) the river discharge averages 650 cfs most of the time in the sections being dredged; 3) the average water temperature is 13°C; and 4) the width of the basin to be dug is 12m less than the width of the river or 50m, then the recommended basin size to effectively remove sand is approximately 200m long. This assumes that the basin would refill, and thus need to be redredged, two to three times per year. This approximation of pool length compares favorably with the 223m pool length recommended through use of the river width and the 40%:60% riffle-pool ratio mentioned previously.

SUMMARY

To be a productive trout stream, the Chattahoochee River must have a diverse habitat for both large and small fish, and for a variety of fish food organisms needed by fish. Any action that would decrease the diversity of habitat in the river would negatively impact its productivity. This may result in less growth or poorer condition of trout, and certainly a decrease in the quality of the fishery.

The removal of sand can be beneficial to insect and trout abundance while the removal of gravels and woody debris is not. Gravel and cobble substrates should be protected, especially in swift portions of the river to maintain the production of fish food organisms. Woody debris such as fallen timber should be retained in both dredged and undredged areas.

Sand dredging could potentially improve aquatic habitat diversity by creating small, short pools in a river where they did not formerly exist. Too much pool however, in the Chattahoochee River, could be detrimental if it is created at the expense of the food-producing swift water areas.

RECOMMENDATIONS

1. No dredge should operate over a continuous stretch of river for more than 223m (732 ft). This should be the maximum size of any dredged pool.

2. Immediately above and below a permitted dredge site, 149m (488 ft) of undredged river should exist. This would provide the 40% riffle to 60% pool ratio required to maintain productive trout conditions in the river.

3. A very small portion of the material removed by sand dredge operators consists of gravel 2.5cm or greater in diameter. The removal of this substrate from the river could impact the production

of aquatic invertebrates. The 2.5cm or larger material should be returned to the river bottom after separation. This would be most beneficial if the gravel were placed at the downstream end of pools or in undredged riffle or run areas.

4. The fallen trees on each shore of the river provide bank stabilization as well as macroinvertebrate substrate and trout cover. Since the trees are along the edges of the river and the center channel contains most of the sand, dredging activities should be restricted to the middle of the river. No cutting or trimming of trees or dredging should be permitted within six meters of the shore (measured during low flow conditions). This should also help to alleviate bank scour/slumping in some areas where this is now a problem. Protection of 12m of the river bottom (6m out from each shore) should not be a severe inconvenience to operators. This would still allow them access to 37 to 50m of river width.

5. River banks should be stabilized by replanting native trees (such as birch, sycamore, or willow), shrubs, and grasses in areas where the banks have been degraded by shore operations, or in areas where the dredge operator has no plan to return for more than one year.

6. Sand dredges should not destroy trees along the river bank by utilizing them as anchors. Operators should consult with the Forestry Commission to develop a means for using the trees without damaging them. Artificial anchors, such as "deadman anchors" or pilings buried in the ground at least six meters back from the river bank are a possible alternative. All efforts should be made to keep from destroying riverbank vegetation when engaged in this

activity.

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APPENDIX

Observations on the Results of Sampling with Detonation Cord

The recapture of tagged trout was greater than 31% at only one of the six sample areas. This is quite a low recovery considering the circumstances, and resulted in a relatively large (approximately 70%) adjustment of the data. There were several probable causes for this low percent return. The use of detonation cord as a quantitative sampling tool is relatively new for fisheries personnel. This method was successfully used by the Florida Game and Freshwater Fish Commission in canals prior to this study (Harry Hottel - personal communication). However, two blockoff nets were used and the recovery of fish extended over a three day period. Blockoff nets had to be removed daily during this study because of litter accumulation and the increased river flow which resulted from power generation at Buford Dam. The river current was relied upon to push dead or stunned fish downstream into the net. SCUBA divers, who recovered 32% of the fish collected, found most fish lying on the bottom or lodged against structure, however. Divers reported that very few of the dead fish were seen moving along the bottom, but most were motionless in troughs, holes, under logs and root wads where the current could not move the fish. Very few trout (14%) were picked up by personnel in boats following the explosion. Therefore, tagged trout may have been missed by the divers as they were not moved by the current to the blockoff net.

Another possible cause for the low return of tagged trout was an incomplete kill by the detonation cord explosion. To evaluate the effectiveness of detonation cord on trout, fisheries personnel placed trout on stringers (10 per stringer) at various distances from the detonation cord, behind fallen trees, and in a depression. When the trout were placed between two strands of detonation cord without any obstructions between the fish and the detonation cord, 100% were killed. When they were placed in a small depression approximately two meters from the detonation cord, only 50% were killed. When placed under a submerged log with the detonation cord several meters away, 50% were killed. But, when the detonation cord was within one meter of the submerged log, 100% were killed. At one sample area, a tagged trout was seen swimming after the explosion. If fish were under cover or in a depression some distance from the detonation cord, they may have survived the explosion, depending upon the distance from the detonation cord. If a fish was one meter or less from the detonation cord however, it would probably be killed regardless of position.

An upstream blockoff net was not used during this study. Although personnel restricted their movements within the sample area as much as possible before the explosion, fish may have been disturbed and may have left the area. The tagged trout were released approximately ten minutes before the explosion to minimize emigration. They may have left the sample areas, however, before the detonation cord explosion.

Recommendations for future detonation cord sampling studies include: 1) SCUBA divers should be utilized to recover fish from the bottom, as even a moderately swift current will not move all dead fish to the blockoff net; 2) more detonation cord should be used in streams with uneven bottoms and cover; and 3) upstream and downstream blockoff nets should be used to prevent fish migration out of the sample area.