Evaluation of Rock Relocation to Enhance Degraded Sportfish Habitat in the Apalachicola River, Florida

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Abstract: Placement of dredged rock material (90% <5 cm in diameter) on degraded sand disposal sites in the Apalachicola River, Florida, to enhance sportfish populations was evaluated between July 1988 and November 1989. Newly created rock habitats and training dikes yielded significantly greater ($P < 0.05$) sportfish catch per unit effort (CPUE) than did sand disposal sites. Water velocity, rock size, water depth, and site orientation with respect to river flow were more important in determining sportfish abundance than rock site configuration. Mean macroinvertebrate densities and number of taxa collected at rock relocation sites were greater than values previously reported for sand disposal sites.

Proc. Annu. Conf. Southeast. Assoc. Fish and Wildl. Agencies 46:421–433

The U.S. Corps of Engineers (COE) has numerous navigational projects throughout the U.S. where significant dredging and disposal has occurred. Morton (1977), Yorke (1978), Lubinski et al. (1981), and Schnick et al. (1982) have extensively reviewed the literature concerning physical and biological impacts of dredging and disposal practices to fishery habitats in large rivers and estuaries. Most of these reviews and studies were concerned with the destruction of natural habitats and subsequent negative impacts to fish and benthic communities.

In 1945, the COE was authorized by Congress to maintain a (2.7 m x 30.5 m) navigational channel in the Apalachicola River. Attempts by the COE to maintain these channel dimensions have resulted in extensive annual dredging and disposal of sand, construction of training dikes, and rock removal.

Since 1947 sand habitat has increased by more than 40 km on the Apalachicola River because of annual dredging and disposal by the COE (COE 1986). Although a few of these within-bank sand disposal sites were natural sand point bars, many were once productive, gently-sloping natural fishery habitats. Mesing and Ager (1987) reported a 75% to 50% reduction in sportfish electrofishing catch rates 1 to 5 years after sand disposal on natural habitats in the Apalachicola River.

From 1963 to 1970, the COE constructed a series of training dikes in the Apalachicola River designed to reduce meandering of the river, maintain current velocity, and minimize dredging. Ager et al. (1986) reported training dikes to be the most productive sportfish habitat in the upper Apalachicola River.

Rock was removed from the Apalachicola River channel in 1957, 1963, and 1970 without any evaluation. In 1983 and 1984, the COE dredged 84,000 m^3 of natural limestone rock from the navigation channel of the upper Apalachicola River to improve barge traffic safety. This dredged rock material was relocated to inactive sand disposal sites in an attempt to enhance sportfish and macroinvertebrate habitat. The primary objective of this 3-year cooperative study between the Florida Game and Fresh Water Fish Commission (GFC) and COE was to compare sportfish abundance at relocated rock sites to sand disposal sites. Secondary objectives were to determine optimal configuration and rock size.

This study was partially funded by the U.S. Army Corps of Engineers Mobile District Office. We wish to thank Lothian Ager for his contribution to the study design and guidance throughout the project. We acknowledge Rick Long, Roy Land, Mike Spelman and Bob Rousseau for their valuable efforts in collecting data during this study. Sharlyne Conley-Samford, Darcy Schroeder, and Judy Brown typed earlier versions of this manuscropt.

Methods

The Apalachicola River is located in northwest Florida and is formed by the confluence of the Chattahoochee and Flint rivers in Lake Seminole, a 15,176-ha reservoir. It is 171 km in length and has the greatest discharge (690 m^3/sec) of Florida rivers (Leitman et al. 1984). Below Jim Woodruff Dam the river drains approximately 4,000 km^2. Since 1929, the maximum and minimum discharges recorded were 8,292 m^3/sec (Blountstown Gage 29.97 ft) and 178 m^3/second (Blountstown Gage 0.12 m), respectively (Wooley and Crateau 1983). The Blountstown Gage station, located on the Apalachicola River at Navigational Mile (NM) 78.0, relates discharge to water level. The Apalachicola River can be divided into 3 physiographic segments. The upper section extends from the Jim Woodruff Dam 45 km downstream through steep rock bluffs to Blountstown. Rock removal and placement has occurred in this upper section. The middle and lower sections of the river meander through gently sloping lowlands and through a wide floodplain with numerous tributaries and distributaries before it enters into Apalachicola Bay.

Experimental Design

Seven rock relocation sites were established in the upper Apalachicola River from NM 106.1 to NM 92.7. Only 5 rock relocation sites (2, 3, 4, 6, 7) were inactive sand disposal sites and met the criteria for habitat comparison. Rock relocation sites ranged from 350 to 1,000 m in length and 30 to 50 m in width. During electrofishing samples, water depth at these new rock relocation sites ranged from 0.25 to 2.0 m.

Four sand disposal sites within 2 km of comparative rock relocation sites were sampled to assess the relative abundance of sportfish between habitats. Based on the habitat value of training dikes built from large rocks (90% >12.5 cm in diameter), specifications called for 50% of relocated rocks to be >12.5 cm. Observations during the pilot study indicated relocated rocks to be substantially smaller than specified. Consequently, training dikes within 2 km of sand disposal and rock relocation sites were sampled by electrofishing to assess effects of rock size on sportfish abundance. These dikes are 25–75 m in length, perpendicular to the shoreline and consist of rocks >10 cm in diameter.

The initial study design called for investigation of 3 design configurations for relocation sites: perpendicular or parallel to the shoreline, and combination perpendicular/parallel. Because 2 rock relocation sites were eliminated, the designs could not be replicated and statistical evaluation of the 3 configurations was not possible. Furthermore, preliminary inspection revealed disparate water velocities at the upstream areas of some relocation sites due either to upstream training dikes which impeded or redirected river current or placement of the site relative to the river channel. Therefore, water velocity measurements were taken in 1989 to relate the effects of water velocity on sportfish relative abundance in the Apalachicola River.

Fish Sampling

Electrofishing samples were conducted from July 1988 to November 1989 in a 4.9-m aluminum boat with 2 circular 91 cm-diameter anodes. A gas powered Smith-Root generator was used to produce pulsed DC current (7–8 amps) at 60 pulses per second. During 1988, a pilot study was conducted to determine suitable sites, gear, frequency, duration, and appropriate water levels for sampling. Electrofishing is not efficient in the Apalachicola River at high water levels (Blountstown Gage >3.0 m). Also, during low water levels many rock relocation sites were partially exposed at a Blountstown gage of 1.5 m. Therefore, electrofishing samples were conducted in spring and fall 1989 when water levels were between 1.5 m and 3.0 m on the Blountstown gage. To increase sampling efficiency, sample size, and precision, only sportfish were collected during replicated 5-minute electrofishing samples. Samples were taken at upstream and downstream portions of each rock relocation site to determine the effects of water velocity on electrofishing CPUE. These upper and lower electrofishing samples were pooled for individual rock relocation sites to determine if site configuration or location affected yield of total sportfish numbers and weight. Major sportfish species were separated into adults[1] and subadults for habitat comparisons. Data are reported as number of sportfish per minute or weight of sportfish (g) per minute (CPUE).

[1] Adults were defined as panfish (*Lepomis* spp.) >152 mm; largemouth bass (*Micropterus salmoides*), striped bass (*Morone saxatilus*), and *Morone* hybrids >254 mm; catfish (*Ictalurus* spp.) >203 mm; and black crappie (*Pomoxis nigromaculatus*) >229 mm.

Water Velocity

Water velocity was measured using a Marsh-McBirney Model 201D digital flowmeter with a wading wand. In 1989, a composite water velocity was determined from 9 measurements at upper and lower rock relocation sites, training dikes, and sand habitats at minimum and maximum water levels (Blountstown Gage 2.0 m and 2.7 m) concurrently with electrofishing samples. Each electrofishing site was subdivided into 3 transects (upper, middle, and lower) perpendicular to the river bank. Individual velocity measurements were taken at 3 equally spaced points along each transect. The configuration of these samples approximated a square. These 9 values were averaged to represent a composite velocity for each habitat. Velocity readings (m/second were measured 15 cm below the surface because of unstable readings at the standard depth (60%) resulting from irregular bottom contours for the rock relocation sites. Water velocity measurements at 60% of the water depth and 15 cm below the surface were similar for training dikes and sand habitats.

Rock Size

Size composition of the relocated rocks and training dike rocks was determined by the COE (Eubanks 1990) using a surface visual measurement technique described by Hamilton and Bergersen (1984). Rock size was determined every 66 m along 3 transects parallel to the river bank. A small 0.25 m^2 quadrat was used to sample the smaller rocks at rock relocation sites, while a 1.0 m^2 quadrat was used for training dikes with larger rocks. All surface rocks within the quadrat were enumerated and grouped into 5-cm size classes: 0–4.9 cm, 5–9.9 cm, 10–14.9 cm, 15–19.9 cm, 20–24.9 cm, 25–29.9 cm, and >30 cm.

Macroinvertebrates

Macroinvertebrates were sampled at rock relocation site 4 in May 1989 to measure effects of rock size on macroinvertebrate density. Samples were taken in May after all rock relocation sites had been completely submersed for a minimum of 30 days for maximum colonization (Hynes 1970) and with univoltine larval forms at peak abundance. Three rocks were arbitrarily collected in each of 6 size classes (based on the longest axis): 0–4.9 cm, 5–9.9 cm, 10–14.9 cm, 15–19.9 cm, 20–24.9 cm, and 25–29.9 cm. Surface area of each rock was calculated using maximum length and greatest perimeter as described by Calow (1972). Each rock and its attached organisms were preserved in a 70% isopropyl alcohol mixed with Rose Bengal stain solution. All macroinvertebrates were removed, enumerated, and identified to family or the lowest practical taxonomic level. Macroinvertebrate density was quantified, expanded, and 95% confidence limits (CL) were calculated.

Data Analysis

Because of differences in river elevation and velocity between sample periods, data were analyzed separately for spring and fall 1989. Distribution of electrofishing CPUE was skewed, as is typically the case in variable river environments. As a result, electrofishing sample data for habitat comparisons were transformed (log(CPUE + 1) for parametric analysis. The transformation resulted in a reasonable approximation to the normal distribution in all cases but adult sportfish in fall 1989. Differences among habitats were assessed using Analysis of Variance (ANOVA) for all but adult sportfish in fall 1989 where a Kruskal-Wallis (KW) distribution-free test was used. If ANOVA or KW results indicated significant differences between habitats, CPUE values were compared between pairs of habitats using Student's t-tests.

Effect of water velocity on total sportfish number and weight CPUE values was evaluated using a linear regression model. All statistical differences were declared significant at $\alpha \leq 0.05$.

Results

Habitat Comparison

A total of 215 electrofishing samples were conducted on 3 habitats: rock relocation (N = 130), training dikes (N = 45), and sand disposal (N = 40). Rock relocation sites and training dikes yielded significantly greater ($P < 0.05$) total sportfish numbers and weight per minute than sand disposal sites in each sample period (Table 1). No differences ($P > 0.05$) in adult sportfish CPUE were observed between training dikes and rock relocation sites in spring 1989. In fall 1989, training dikes had significantly greater ($P < 0.05$) numbers of total and subadult sportfish than rock relocation sites. Although there was no significant difference ($P > 0.05$) in subadult weight between rock relocation sites and sand disposal areas in spring 1989, a significant difference ($P < 0.05$) was observed in fall 1989.

Rock relocation sites and training dike samples produced 15 species of sportfish, while 6 sportfish species were collected from sand disposal sites (Table 1). Subadult sportfish dominated all habitats by number, while adults dominated by weight.

Rock Relocation Sites

Generally, rock relocation sites 3 (perpendicular dikes), 4 (parallel dikes), and 6 (combination perpendicular/parallel) yielded higher sportfish CPUE for total numbers and weights than sites 2 (perpendicular dikes) and 7 (parallel dikes) although differences were not significant at $\alpha = 0.05$ (Fig. 1). Centrarchids dominated rock relocation sites, comprising 99% of sportfish by number and weight (Fig. 2). Redbreast sunfish (*Lepomis auritus*) was the dominant sportfish species by number (58%) and weight (47%). Bluegill (*L. macrochirus*), redear sunfish (*L. microlophus*), and largemouth bass (*Micropterus salmoides*) together totaled 41% by number and 50% by weight.

Water Velocities

Water velocity at training dikes was significantly ($P < 0.05$) lower than those at rock relocation sites and sand disposal sites for upper and lower stations (Table 2). Water velocity was not significantly different ($P > 0.05$) between rock relocation sites and sand disposal areas. All rock relocation sites except 4 and 6 had lower velocities

Table 1. Mean transformed[a] number and weight per minute of sportfish collected in electrofishing samples for 3 habitat types, Apalachicola River, Florida, 1989. Values with the same letter are not significantly different ($P > 0.05$).

Habitat type	N samples	N per min	Weight (g) per min	N sportfish species
			Spring 1989	
Total sportfish				
Rock relocation	50	1.35 a	5.24 a	15
Training dikes	20	1.55 a	5.69 a	13
Sand disposal	20	0.90 b	4.00 b	6
Adult sportfish				
Rock relocation		0.56 a	4.43 a	
Training dikes		0.48 a	5.11 a	
Sand disposal		0.23 b	2.73 b	
Subadult sportfish				
Rock relocation		1.15 ab	3.63 ab	
Training dikes		1.42 a	4.12 a	
Sand disposal		0.79 b	3.41 b	
		Fall 1989		
Total sportfish				
Rock relocation	80	1.75 b	5.26 b	15
Training dikes	25	2.10 a	5.75 a	13
Sand disposal	25	0.63 c	4.11 c	6
Adult sportfish				
Rock relocation		0.63 a	4.13 b	
Training dikes		0.59 a	4.85 a	
Sand disposal		0.26 b	2.32 c	
Subadult sportfish				
Rock relocation		1.52 b	4.33 b	
Training dikes		1.99 a	4.94 a	
Sand disposal		0.93 c	3.68 c	

[a]Values have been transformed: N = LOG (N per minute + 1), Weight = LOG (Weight (g) per minute + 1).

at the lower stations, suggesting all configurations contributed to reduced water velocities. There was no difference ($P > 0.05$) between upper and lower stations for training dikes and sand habitats.

Total sportfish number per minute decreased significantly ($P = 0.03$) as water velocity increased (Fig. 3). Although no significant effect was observed for total sportfish weight per minute ($P = 0.08$), the probability for the regression suggests a similar inverse relationship between water velocity and weight CPUE. However, the low r^2 values for total number ($r^2 = 0.25$) and total weight ($r^2 = 0.20$) indicate that factors other than water velocity also influenced CPUE values.

Rock Size

Rocks at relocation sites were substantially smaller than training dike rocks (Fig. 4). Approximately 90% of the 23,837 rocks measured at rock relocation sites

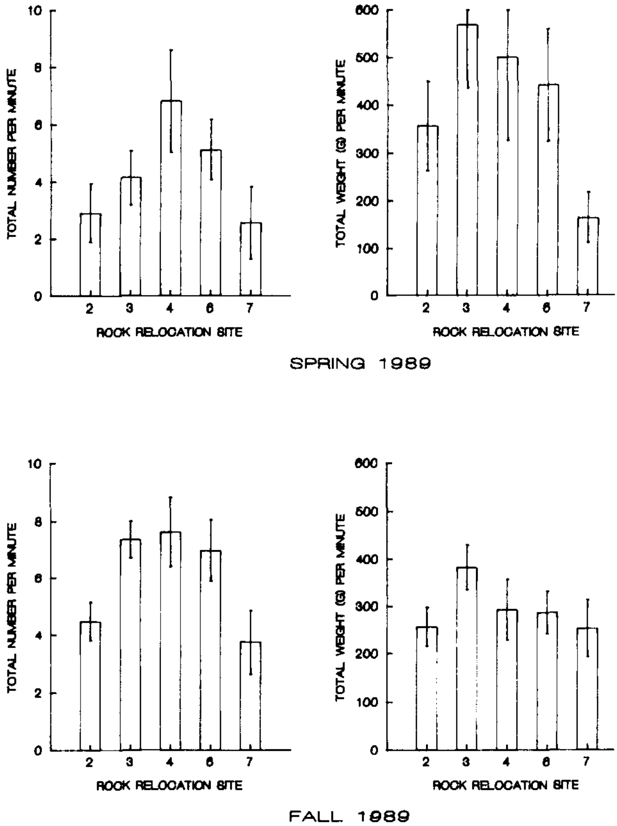

Figure 1. Mean number and weight per minute of total sportfish in spring and fall electrofishing samples from 5 rock relocation sites, Apalachicola River, Florida, 1989. Verticle bars indicate S.E.

were <5 cm in diameter while only 2% of 1,336 rocks measured at training dikes were <5 cm. Forty-two percent of rocks sampled at training dikes were >30 cm, while <1% of rocks at relocation sites were >15 cm (Fig. 4).

Macroinvertebrates

Mean macroinvertebrate densities ranged from 879 to 3,720 organism per m^2 (Table 3). The mean density for all rock samples, 1,942 ± 446 organisms per m^2 (95% CL), was greater than sand disposal sites, 745 ± 445 organisms per m^2 (95% CL), reported by Ager et al. (1986). There were no differences (95% CL) in organisms per m^2 among rock size classes except for the 20–24.9 cm class which yielded fewer macroinvertebrates per m^2 than the 5–9.9 cm size class. The number of taxa (families) increased as rock size class increased. A total of 36 taxa were identified from 18 samples. Plueroceridae (snails), Chironomidae (midges), and Tricorythidae (mayflies) were the dominant taxa collected comprising 83% of the total organisms sampled (Fig. 5).

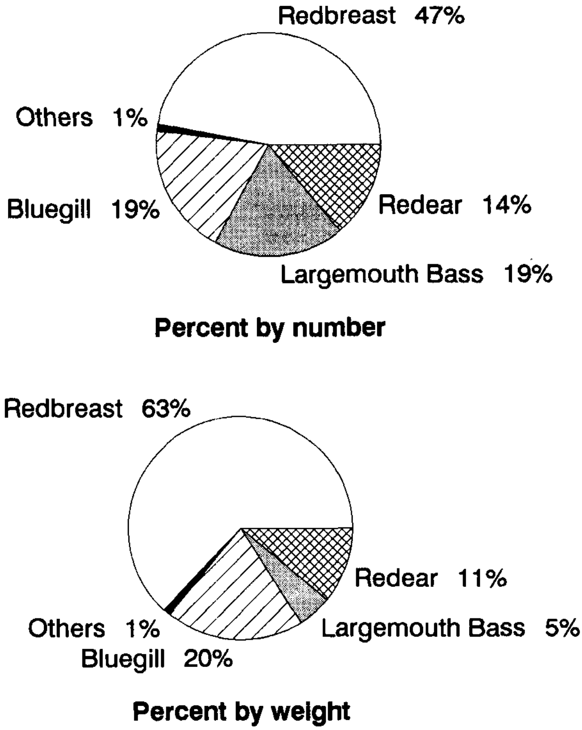

Figure 2. Percent composition by total number and weight of major sportfish collected by electrofishing at rock relocation sites, Apalachicola River, Florida, 1989.

Table 2. Average water velocities (m/sec) and standard errors within parentheses for rock relocation sites, training dikes, and sand disposal sites at 2 water levels (Blountstown Gage of 2.0m and 2.7m) for the Apalachicola River, Florida, 1989.

		Site No.					
Habitat	*N*	2	3	4	6	7	Grand mean
Upper stations							
Rock sites	2	0.58	0.32	0.18	0.17	0.63	0.37
		(0.01)	(0.01)	(0.00)	(0.04)	(0.02)	(0.09)
Training dikes	2	0.02	0.02	0.02	0.02	0.02	0.02
		(0.00)	(0.00)	(0.01)	(0.00)	(0.00)	(0.00)
Sand disposal	2	0.31	0.31	0.52	0.33	0.50	0.39
		(0.09)	(0.09)	(0.11)	(0.07)	(0.03)	(0.05)
Lower Stations							
Rock sites	2	0.28	0.25	0.48	0.20	0.29	0.30
		(0.09)	(0.00)	(0.17)	(0.02)	(0.09)	(0.05)
Training dikes	2	0.02	0.02	0.02	0.01	0.01	0.02
		(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Sand disposal	2	0.30	0.30	0.49	0.30	0.50	0.38
		(0.09)	(0.09)	(0.05)	(0.09)	(0.04)	(0.05)

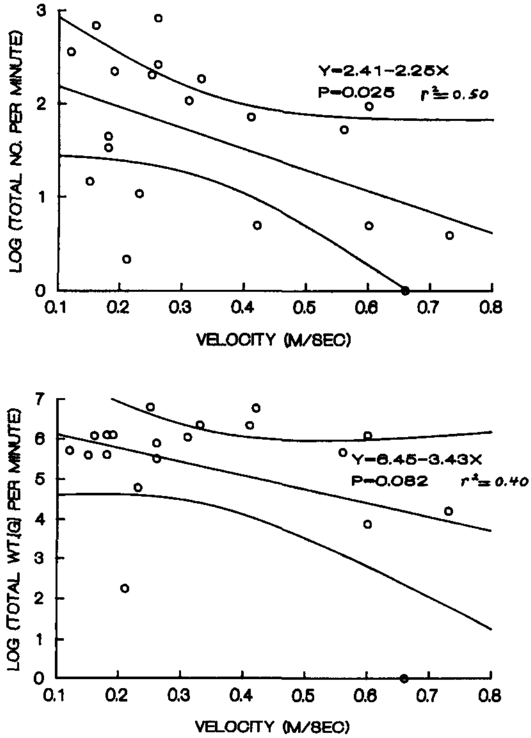

Figure 3. Spring (top) and fall (bottom) water velocity and total sportfish number and weight regression lines, and 95% confidence limits for rock relocation sites from the Apalachicola River, Florida, 1989.

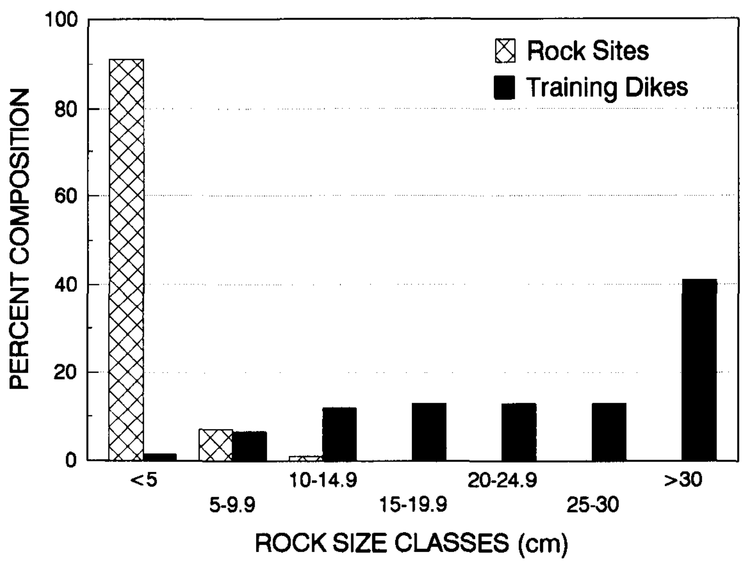

Figure 4. Percent composition by 5-cm size classes for rock relocation sites and training dikes, Apalachicola River, Florida.

Table 3. Mean macroinvertebrate densities and 95% confidence limits (CL) from 6 rock size classes collected at rock relocation site 4 in the Apalachicla River, Florida, May 1989.

Rock size classes (cm)	*N*	Mean	95% CL
<5	3	2,030	± 932
5–9.9	3	3,720	± 1898
10–14.9	3	1,731	± 537
15–19.9	3	1,939	± 751
20–24.9	3	879	± 691
>25	3	1,351	± 1636
Grand Mean	18	1,942	± 446

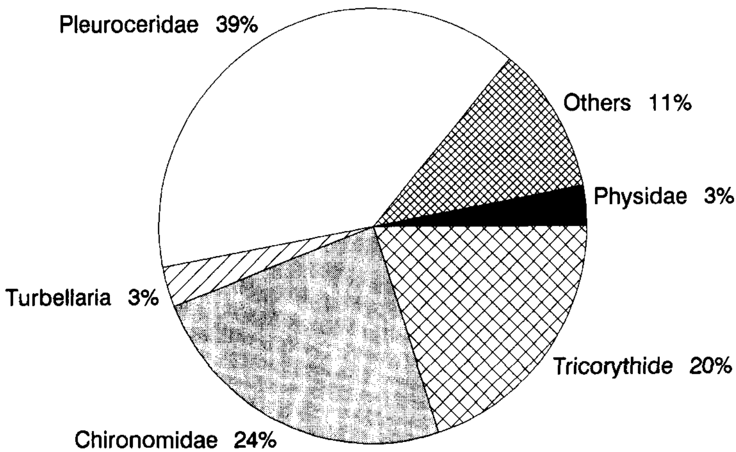

Figure 5. Percent composition of the major macroinvertebrate taxa (families) collected from rock relocation site 4, Apalachicola River, Florida, May 1989.

Discussion

The placement of dredged rock material on old sand disposal sites in the Apalachicola River altered these degraded habitats and provided a stable substrate for sportfish and macroinvertebrates. These newly created rock relocation sites consistently produced greater sportfish CPUE (number and weight) and diversity than sand habitats for both sample periods. Ager et al. (1986) reported natural rock shoal habitats and training dikes in the Apalachicola River were more productive than sand habitats for sportfish and macroinvertebrates. Macroinvertebrate density and number of taxa for individual rocks sampled were greater than macroinvertebrate density of sand disposal sites reported by Ager et al. (1986). Macroinvertebrates in our study were dominated by important sportfish food items Pleuroceridae, Chironomidae, and Tricorythidae, while Ager et al. (1986) reported sand disposal sites were dominated by the Asian clam, *Corbicula fluminea,* and midges. The most significant contribution of relocated rock material for macroinvertebrate production is the stable substrate provided for colonization (Hynes 1970) compared to unstable sand at disposal sites which is redistributed by spring floods.

Configuration of rock relocation sites was not the primary factor influencing sportfish abundance. Training dikes (perpendicular configuration) yielded greater sportfish CPUE than rock relocation sites in fall 1989. In contrast, rock relocation site 2 (perpendicular configuration) was the least productive rock relocation site, suggesting factors other than site configuration affected sportfish abundance. Differences in electrofishing CPUE in fall 1989 are more likely related to larger rocks, lower velocities, or greater water depths at training dikes.

In the Mississippi River, Farabee (1986) reported revetment sites with loosely placed 70 cm-diameter stones provided superior fishery habitat than smaller tightly packed stones. Kallemeyn and Novotny (1977) also recommended "large rocks should be used where structures are required to provide substrate for fish organisms." In our study, training dikes with large rocks had greater sportfish CPUE than rock relocation sites with small, tightly-packed rock rubble during the fall 1989 sample period. However, rock size did not affect total numbers of macroinvertebrates in our study.

Water velocity at rock relocation sites had a significant negative effect on abundance of total sportfish number and a lesser effect on total weight. Because total number was dominated by subadult fish, water velocity affected small sportfish abundance more than the larger adult sportfish which dominated total sportfish weight. Also, 2 rock relocation, sites 4 and 6 with different configurations, generally yielded the highest sportfish CPUE, but both were located just below training dikes which redirected the current toward the opposite river bank and reduced water velocity. The upstream sections of rock relocation sites 4 and 6 and the downstream section of rock site 6 had the lowest average water velocities of all rock sites. During the spring, the importance of these low flow areas was demonstrated by adult redbreast sunfish and bluegill, which congregated in these low-flow habitats and utilized these areas for spawning.

In contrast, rock relocation sites 2 (perpendicular dikes) and 7 (parallel dikes) consistently produced fewer sportfish than sites 3 (perpendicular dikes), 4 (parallel dikes), and 6 (combination perpendicular/parallel dikes) primarily due to their placement and orientation along the river bank. Upper stations at rock relocation sites 2 and 7 exhibited the highest water velocities because there were no upstream training dikes to obstruct and divert river flow. Sunfish spawning was not observed in these high flow areas during the study.

Water levels may have affected electrofishing CPUE values during the study. Water depth probably contributed to some of the variation for the regression of water velocity and CPUE at the rock relocation sites. Although depth was not measured at electrofishing stations, we observed greater water depths at training dikes than at rock relocation sites during low water levels (Blountstown Gage 2.0 m). Differences in water depths between training dikes and rock relocation sites and among rock sites was most evident during the pilot study in 1988 when an extended drought caused the lowest water level (Blountstown Gage 1.1 m) during the study. During this time, many of the rock relocation sites were in extremely shallow water or partially exposed, while training dikes had greater water depths and twice as many sportfish. However, training dike sportfish CPUE during fall 1989 was significantly greater than at rock relocation sites even though water levels and depths were adequate for fish habitat, suggesting that other factors such as rock size and velocity have more of an impact on sportfish abundance than water depth providing some minimal (1 m) depth is present.

There may be negative impacts associated with the construction of large perpendicular dikes which redirect and increase water velocities toward the main channel or opposite river bank (Anderson et al. 1983, Leitman et al. 1984). Widening of the river channel opposite training dikes has been reported by Hochstein (1981). These potential impacts to natural sportfish habitats on the opposite river bank should be investigated when selecting inactive sand disposal sites for sportfish enhancement with rock material.

Management Implications

Inactive sand disposal sites in large river systems should be primary candidates for enhancement using rock material or other stable substrates. The cost of relocating dredged rock material to degraded sand disposal sites was less expensive and more beneficial to sportfish than removing this rock material out of the system (pers. commun. COE). Selected enhancement sites should have water velocities <0.20 m/sec with water depths at least 1 m. If rock removal is necessary for channel safety, techniques (e.g., explosives) should be considered which produce large rocks >30 cm in diameter, and care should be taken during construction of sites to avoid crushing relocated rocks. For sites with water velocities >0.50 m/sec, a combination design with perpendicular-parallel dikes should be considered. Dikes should extend far enough offshore to provide areas with low water velocities for sunfish spawning.

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