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# EVALUATION OF THE EFFECTS OF CHANNELIZATION ON FISH POPULATIONS IN NORTH CAROLINA'S COASTAL PLAIN STREAMS

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## ABSTRACT

This research study was designed to determine the degree of damage, if any, to fish populations resulting from channelization, and to determine the rate of recovery, if the damage was significant.

This study points out the detrimental effects stream channelization has on fish populations and on the flora and bottom fauna of streams. The study also indicates that following channelization, and with no channel maintenance, nature can ultimately restore a coastal plain stream and its fish population to a stage reasonably near its natural condition, provided no further alterations of the stream bed, banks, forest canopy, or aquatic vegetation occur.

## INTRODUCTION

Ecologists have thought for some time that channelization projects are detrimental to fish and wildlife in project areas. Channelization, a type of stream alteration often employed under Public Law 566 and

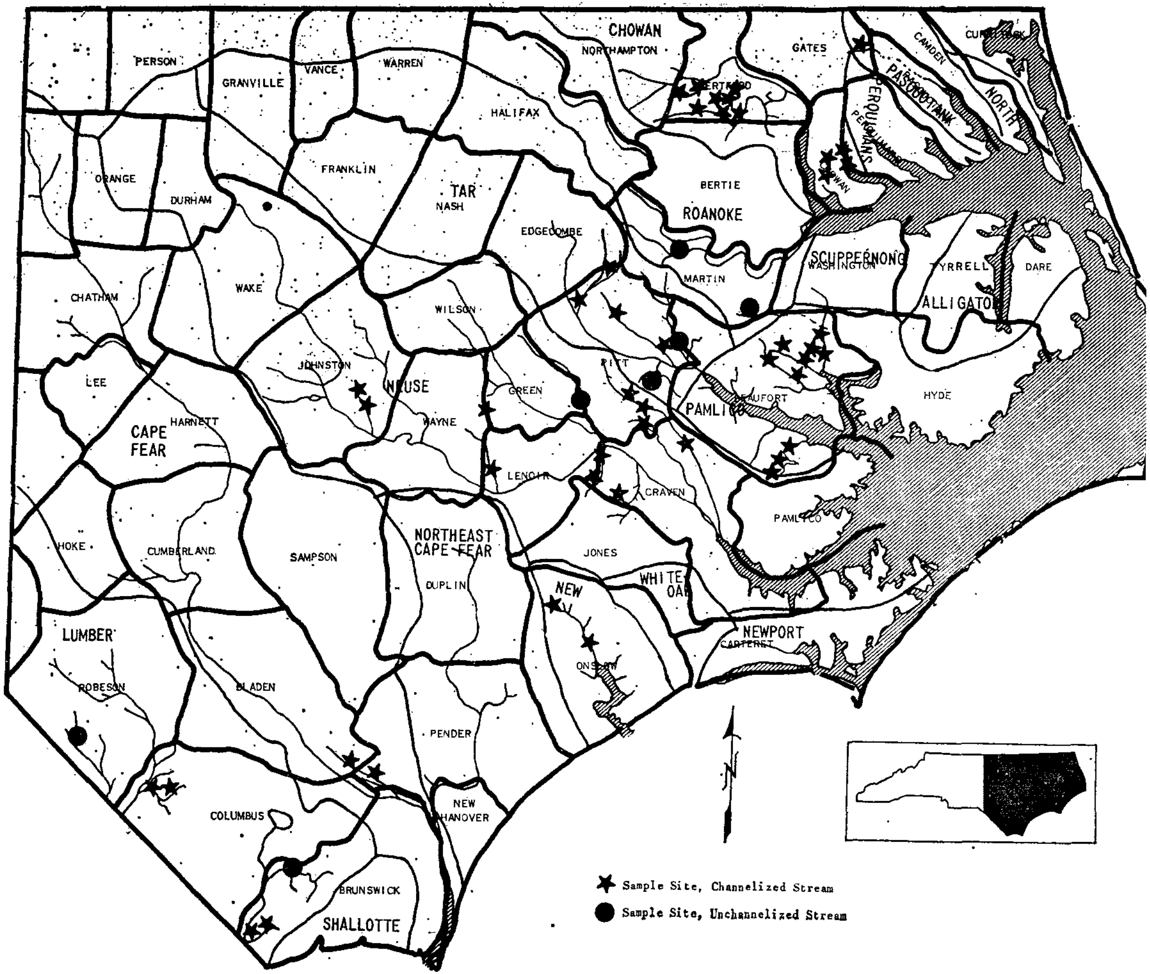


FIGURE 1. Map Showing Sample Sites on Channelized and Unchannelized Streams.

Section 205 of the 1948 Flood Control Act, probably has the most ecological significance in the Coastal Plain where it changes the whole wetland stream-swamp environment. In recent years, channelization projects have become abundant throughout the United States, although Leopold and Maddock (1954) and Hoyt and Longbein (1955) concluded that rivers are not flooding more frequently than in the past, even though it may appear so as a result of people moving onto the land which floods periodically.

The U. S. Soil Conservation Service and the U. S. Army Corps of Engineers refer to channelization as "channel improvement" and "watershed management." Others, such as Bauer and East (1970) described channelization "as an insidious cancer and stated that channelization" contradicts many of the basic principles of water management that land and wildlife experts have advocated for the past 25 years. Georgia Congressman Ben Blackburn III (1969) stated: "The intent of P. L. 566 was to save and improve, but it is being used to destroy."

In the past, there was little concrete data to support either side of the channelization argument. Both sides have formulated their arguments on their own observations and/or limited studies.

This study was designed to determine the degree of damage, if any, to fish populations and their habitat resulting from channelization, and to determine the rate of recovery, if the degree of damage was significant.

## METHODS AND PROCEDURES

At the inception of this study, listings of North Carolina streams now channelized or currently being channelized were obtained from the U. S. Army Corps of Engineers and from the U. S. Soil Conservation Service. These lists included project starting and completion dates, as well as location and extent of each project area. The streams sampled were selected from these lists with regard to the general location in the State, and the number sampled was determined by the amount of time which could be allocated for sampling (Figure 1). Streams were selected to give a representative picture of the effects of channelization in Eastern North Carolina. Seven unchannelized streams also were sampled to supplement the data on natural streams recorded previously. The date of channelization was considered to be the mid-point of the construction period.

One to three fish population samples were taken on each stream, depending on the number of different ecological types represented in the channelized portion of the stream. Upon determining the general location of the sample area, a section of stream not less than 98 feet, and not greater than 326 feet was marked off at the downstream end with ¼-inch mesh block nets. The sample areas were selected to include all factors influencing a given fish population in a particular ecological type. Large holes, such as those below highway bridges, were excluded.

Emulsifiable 5% rotenone was applied at a concentration of 1.0 ppm. to the area sampled for a period of five minutes. The rotenone was detoxified below the block net with potassium permanganate in a concentration slightly higher than 1.0 ppm. The fishes affected by the rotenone were collected with dip nets and from the block net and placed in plastic buckets for later identification and measurements.

After all fishes in the sample area were collected, physical and chemical measurements were made. Physical measurements included length and width of the stream section sampled, depth of the area sampled, rate of stream flow, water temperature, air temperature, and stream turbidity. Chemical measurements made at each sample site included dissolved oxygen, carbon dioxide, pH, and total alkalinity using methods as outlined in "Standard Methods for the Examination of Water and Wastewater," (1965).

Aquatic vegetation, forest canopy, undercut banks, bottom type, and natural stream obstructions, considered essential cover requirements for a good fish population, were evaluated at each station. Identification of aquatic vegetation was made at streamside. Any aquatic vegetation not

**Table 1.** Common and scientific names of fishes collected from natural and channelized streams in Eastern North Carolina, 1970

| | | | |
|---|---|---|---|
| Longnose gar | *Lepisosteus osseus* (Linnaeus) | Margined Madtom | *Noturus insignis* (Richardson) |
| Bowfin | *Amia calva* Linnaeus | Swampfish | *Chologaster cornuta* Agassiz |
| Ladyfish | *Elops saurus* Linnaeus | Pirate Perch | *Aphredoderus sayanus* (Gilliams) |
| American Eel | *Anguilla rostrata* Lesueur | Atlantic Needlefish | *Strongylura marina* (Walbaum) |
| Blueback Herring | *Alosa aestivalis* (Mitchill) | Marsh Killifish | *Fundulus confluentus* Goode and Bean |
| American Shad | *Alosa sapidissima* (Wilson) | Striped Killifish | *Fundulus majalis* (Walbaum) |
| Atlantic Menhaden | *Brevoortia tyrannus* (Latrobe) | Starhead Topminnow | *Fundulus notti* (Agassiz) |
| Gizzard Shad | *Dorosoma cepedianum* (Lesueur) | Mosquitofish | *Gambusia affinis* (Baird and Girard) |
| Striped Anchovie | *Anchoa hepsetus* (Linnaeus) | Tidewater Silverside | *Menidia beryllina* (Cope) |
| Bay Anchovie | *Anchoa mitchilli* (Valenciennes) | White Perch | *Morone americana* (Gmelin) |
| Eastern Mudminnow | *Umbra pygmaea* (DeKay) | Mud Sunfish | *Acantharchus pomotis* (Baird) |
| Redfin Pickerel | *Esox americanus americanus* Gmelin | Flier | *Centrarchus macropterus* (Lacepede) |
| Chain Pickerel | *Esox niger* Lesueur | Banded Pygmy Sunfish | *Elassoma zonatum* Jordan |
| Silvery minnow | *Hybognathus nuchalis* Agassiz | Bluespotted Sunfish | *Enneacanthus gloriosus* (Holbrook) |
| Golden Shiner | *Notemigonus crysoleucas* (Mitchill) | Banded Sunfish | *Enneacanthus obesus* (Girard) |
| White Shiner | *Notropis albeolus* Jordan | Redbreast Sunfish | *Lepomis auritus* (Linnaeus) |
| Highfin Shiner | *Notropis altipinnis* (Cope) | Green Sunfish | *Lepomis cyanellus* Rafinesque |
| Comely Shiner | *Notropis amoenus* (Abbott) | Pumpkinseed | *Lepomis gibbosus* (Linnaeus) |
| Satinfin Shiner | *Notropis analostanus* (Girard) | Warmouth | *Lepomis gulosus* (Cuvier) |
| Rosefin Shiner | *Notropis ardens* (Cope) | Bluegill | *Lepomis macrochirus* Rafinesque |
| Ironcolor Shiner | *Notropis chalybaeus* (Cope) | Redear Sunfish | *Lepomis microlophus* (Gunther) |
| Spottail Shiner | *Notropis hudsonius* (Clinton) | Spotted Sunfish | *Lepomis punctatus* (Valenciennes) |
| Coastal Shiner | *Notropis petersoni* Fowler | Largemouth Bass | *Micropterus salmoides* (Lacepede) |
| Swallowtail Shiner | *Notropis procne* (Cope) | Swamp Darter | *Etheostoma fusiforme* (Girard) |
| Creek Chubsucker | *Erimyzon oblongus* (Mitchill) | Johnny Darter | *Etheostoma nigrum* Rafinesque |
| Silver Redhorse | *Moxostoma anisurum* (Rafinesque) | Sawcreek Darter | *Etheostoma serriferum* |
| Redhorse Sucker | *Moxostoma* sp. | | (Hubbs and Cannon) |
| White Catfish | *Ictalurus catus* (Linnaeus) | Yellow Perch | *Perca flavescens* (Mitchill) |
| Yellow Bullhead | *Ictalurus natalis* (Lesueur) | Spot | *Leiostomus xanthurus* (Lacepede) |
| Brown Bullhead | *Ictalurus nebulosus* (Lesueur) | Striped Mullet | *Mugil cephalus* Linnaeus |
| Flat Bullhead | *Ictalurus platycephalus* (Girard) | White Mullet | *Mugil curema* Valenciennes |
| Channel Catfish | *Ictalurus punctatus* (Rafinesque) | Naked Goby | *Gobiosoma bosci* (Lacepede) |
| Tadpole Madtom | *Noturus gyrinus* (Mitchill) | Summer Flounder | *Paralichthys dentatus* (Linnaeus) |

readily identified was preserved and taken to the laboratory for positive identification. Each sample area was assigned to one of three cover classes depending on the degree of forest canopy, aquatic vegetation, and physical cover characteristics. Cover classes assigned were 0 - 4.9, 5.0 - 14.9, and 15.0 - 100 percent, on the basis of what appeared to be natural groupings for classes 1, 2, and 3, respectively.

Two stream bottom samples were taken at each sample site to determine number and kind of fish food organisms present. These samples were made with either a Surber sampler or an Ekman dredge, depending on the type of stream bottom and water depth. Bottom organisms were picked from the samples at streamside and preserved in 70% alcohol for later identification in the laboratory. The average volume per square foot was obtained by the water displacement method.

After obtaining physical, chemical and bottom fauna data from each sample site, the fishes were tentatively identified, classed according to species, grouped by inch-classes and weighed. A representative sample of each fish species was preserved in 10% formalin for later verification of identification in the laboratory (Table 1). The fishes collected were classified as game or nongame with total weights and total numbers, by species, converted to weights and numbers per surface acre.

For the purpose of this report, the following eighteen species were considered game fishes: ladyfish, American shad, redfin pickerel, chain pickerel, white perch, largemouth bass, warmouth, green sunfish, spotted sunfish, pumpkinseed, redear sunfish, redbreast sunfish, bluegill, black crappie, mud sunfish, flier, yellow perch, and spot (Table 1). Attention was given to the number of game fishes per surface acre of harvestable-size (> six inches in length).

The many factors and combination of factors affecting fish populations in both natural and channelized streams prompted a system of analysis taking these many factors into account. A diversity index was calculated for each stream sampled. The diversity index provided a method for combining or summarizing a great mass of data on community structure into one quantative expression (Wilhm and Dorris, 1968.) The Brillouin form $H=1/N \text{ Log } \left(\frac{N!}{n_1!\, n_2!\, \ldots\ldots\ldots\, n_s!}\right)$ of the diversity index as set forth by Lloyd *et al.* (1968) and Pielou (1966) was used. Sterling's approximation for factorials of $\text{Log}_{10}n!$ was used for values exceeding the table presented by Lloyd *et al.* (1968). The scale factor for conversion of logarithms to base 2 was 3.321928.

## RESULTS AND DISCUSSION

Biological samples, chemical samples and physical measurements were obtained from 7 natural and 46 channelized stream sites during 1970. In addition, 21 natural North Carolina stream surveys, made prior to 1970, were selected by size, location, and type, and were incorporated into the study for a greater comparison. The samples were taken from nine North Carolina Coastal Plain watersheds to obtain the overall view of the effects of channelization (Figure 1). While taking the 53 samples in 1970, 65 species of fishes representing 24 families were collected (Table 1).

Summertime water temperatures ranged from a cool 66° to a high of 84° Fahrenheit in the natural streams where the forest canopy had been undisturbed. In channelized streams, where the forest canopy had been removed, summertime water temperatures varied from 66° to a high of 98° Fahrenheit (Tables 2 and 3). The 66° Fahrenheit water temperature was recorded from a stream which was in the process of being channelized and the forest cover had not been completely removed.

Two streams, Caw Caw Swamp and Dunn Swamp, had summer water temperatures exceeding 90° Fahrenheit, the maximum legal water temperature permitted under the State of North Carolina's water quality standards (Dept. of Water and Air Resources, 1970). These high water temperatures resulted from the direct exposure to the sun over the

# TABLE 2.

## SUMMARY OF DATA COLLECTED FROM NATURAL STREAMS, 1970 AND OTHER LISTINGS FROM PREVIOUS SAMPLES

| STREAM NAME | WATERSHED | WATER TEMPERATURE AT TIME OF SAMPLE | COVER* CLASS | BOTTOM** COMPOSITION CLASS | AVG. DEPTH IN FEET | AVG. WIDTH IN FEET | TOTAL LBS. FISH/ACRE | LBS. GAME FISH/ACRE | HARVESTABLE GAME FISH/ACRE (≥6") | NUMBER/LB. (NONGAME FISH) | VOLUME FISH FOOD ORGANISMS /SQ. FT. | SPECIES DIVERSITY |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Aaron Swamp | Lumber | 74 | 3 | 3 | 0.9 | 13.5 | 97.42 | 42.52 | 155 | 19 | .40 | 2.7440 |
| Ahoskie Creek1/ | Chowan | 73 | 3 | 3 | 2 4 | 30.8 | 54 43 | 32.89 | 38 | 62 | .45 | 2.5364 |
| Bath Creek2/ | Pamlico | 72 | 3 | 5 | 5.5 | 21.0 | 596.19 | 239.36 | 622 | 8 | 3.20 | 3.0553 |
| Blounts Creek2/ | Pamlico | 82 | 3 | 5 | 4.5 | 19.0 | 102.10 | 39.50 | 120 | 12 | .80 | 3.2053 |
| Briery Run3/ | Neuse | 74 | 2 | 1 | 1.5 | 14.3 | 61.87 | 41.03 | 61 | 67 | .05 | 3.2924 |
| Caw Caw Swamp4/ | Lumber | 76 | 2 | 3 | 2.6 | 29.8 | 20.03 | 14.55 | 29 | 264 | .53 | 1.7786 |
| Chinkapin Creek5/ | Chowan | NR | 3 | 3 | 3.0 | 20.0 | 94.36 | 31.17 | 87 | 41 | NR | 1.8375 |
| Chinkapin Creek1/ | Chowan | 77 | 3 | 5 | 8.0 | 60.0 | 101.66 | 71.95 | 174 | 59 | ..30 | 3.1945 |
| Chocowinity Creek2/ | Pamlico | 83 | 3 | 3 | 1.2 | 17.0 | 67.60 | 55.50 | 140 | 140 | .20 | 2.8069 |
| Conoho Creek | Roanoke | 72 | 3 | 3 | 0.8 | 11.1 | 317.87 | 178.00 | 943 | 25 | .04 | 2.0287 |
| Core Creek3/ | Neuse | 77 | 3 | 3 | 1.9 | 17.9 | 525.63 | 378.70 | 1,927 | 58 | .52 | 3.3148 |
| Cow Swamp | Tar | 68 | 3 | 5 | 1.2 | 16.9 | 504.63 | 256.20 | 955 | 16 | .16 | 3.6799 |
| Dunn Swamp4/ | Lumber | 76 | 1 | 1 | 2.1 | 17.7 | 8 78 | 4.17 | 0 | 149 | .50 | 2.0693 |
| Grindle Creek6/ | Tar | 79 | 2 | 3 | 4.5 | 44.0 | 41.09 | 17.79 | 40 | 99 | 3.60 | 2.9217 |
| Juniper Branch6/ | Tar | 78 | 3 | 3 | 1.5 | 15.0 | 287.38 | 75.37 | 426 | 34 | 1.10 | 3.1659 |
| Juniper Swamp | Lumber | 80 | 2 | 5 | 2.9 | 47.4 | 70.18 | 56.76 | 78 | 88 | .12 | 2.0797 |
| Little Contentnea Creek | Neuse | 72 | 3 | 3 | 4.5 | 59.3 | 10.38 | 7.70 | 25 | 345 | .00 | 3.1745 |
| Little Contentnea Creek3/ | Neuse | 71 | 3 | 1 | 1.8 | 28.8 | 98.33 | 21.35 | 40 | 17 | .56 | 3.0895 |
| Lyon Swamp7/ | Cape Fear | 84 | 3 | 3 | 1.6 | 21.9 | 122.02 | 67.91 | NR | 147 | .25 | 3.1999 |
| Mosley Creek3/ | Neuse | 78 | 3 | 3 | 1.5 | 24.2 | 160.78 | 77.40 | 126 | 42 | .00 | 3.9172 |
| Mussle Run3/ | Neuse | 70 | 3 | 2 | 0.7 | 9.8 | 182.82 | 118.64 | 277 | 34 | 1.08 | 3.7492 |
| New River8/ | New | 66 | 3 | 1 | 3.6 | 28.0 | 91.59 | 35.45 | 62 | 19 | .10 | 3.0556 |
| New River8/ | New | 69 | 2 | 5 | 10.0 | 51.0 | 7.69 | 3.93 | 0 | NR | .40 | 2.8609 |
| Pungo Creek2/ | Pamlico | 71 | 2 | 5 | 7.9 | 75.0 | 134.76 | 67.28 | 104 | 113 | 2.20 | 1.4170 |
| Pungo Creek2/ | Pamlico | 73 | 2 | 3 | 6.5 | 57.0 | 92.48 | 36.92 | 104 | 12 | .20 | 3.3375 |
| Roberson Creek | Roanoke | 69 | 3 | 3 | 0.9 | 12.9 | 178.27 | 138.96 | 784 | 92 | .20 | 2.5414 |
| South Creek2/ | Pamlico | 83 | 2 | 3 | 7.0 | 50.0 | 310.54 | 48.40 | 60 | 135 | .60 | NR |
| Tranters Creek | Tar | 71 | 3 | 5 | 3.5 | 58.2 | 9.02 | 8.29 | 29 | 878 | .00 | 1.7874 |

1/ Smith, 1963
2/ Bayless and Shannon, 1965
3/ Bayless and Smith, 1962
4/ Louder, 1962
5/ Kearson, 1969
6/ Smith and Bayless, 1964
7/ Louder, 1963
8/ Davis and McCoy, 1965

* Class 1 - ( 0 - 4.9%)
Class 2 - ( 5 - 14.9%)
Class 3 - (15 - 100%)

** Class 1 - Sand
Class 2 - Sand-Clay
Class 3 - Sand-Silt-Mud-Detritus
Class 4 - Hard Clay
Class 5 - Silt-Mud-Detritus
Class 6 - Silt-Mud

## SUMMARY OF DATA COLLECTED FROM CHANNELIZED STREAMS, 1970

| STREAM NAME | WATERSHED | CHANNEL CONSTRUCTION DATA: DATE STARTED | CHANNEL CONSTRUCTION DATA: DATE COMPLETED | DATE OF SAMPLE | WATER TEMPERATURE AT TIME OF SAMPLE | COVER* CLASS | BOTTOM** COMPOSITION CLASS | AVG. DEPTH IN FEET | AVG. WIDTH IN FEET | TOTAL LBS. FISH/ACRE | LBS. GAME FISH/ACRE | HARVESTABLE GAME FISH (≥6") | NUMBER/LB. (NONGAME FISH) | VOLUME FISH FOOD ORGANISMS /SQ. FT. | SPECIES DIVERSITY INDEX |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ahoskie Creek | Chowan | 6/62 | 11/64 | 6/11/70 | 76 | 3 | 3 | 0.80 | 22.80 | 34.03 | 24.56 | 96 | 143 | T | 2.7476 |
| Ahoskie Creek | Chowan | 6/62 | 11/64 | 6/11/70 | 76 | 2 | 1 | 0.31 | 39.80 | 4.07 | 1.64 | 22 | 315 | .00 | 2.5440 |
| Ahoskie Creek | Chowan | 6/62 | 11/64 | 6/24/70 | 76 | 2 | 3 | 3.41 | 63.41 | 63.00 | 11.34 | 31 | 62 | NS | 2.5475 |
| Albemarle Canal | Pamlico | 1/61 | 7/61 | 7/2/70 | 78 | 1 | 1 | 0.18 | 46.44 | 20.99 | 11.03 | 56 | 174 | .05 | 3.0440 |
| Bear Creek | Neuse | 8/66 | 2/68 | 7/14/70 | 86 | 2 | 1 | 0.26 | 8.80 | 256.05 | 36.55 | 89 | 186 | .20 | 1.6406 |
| Bear Creek | Neuse | 8/66 | 2/68 | 7/14/70 | 69 | 1 | 1 | 0.69 | 38.92 | 3.03 | 0.07 | 0 | 816 | .20 | 1.5478 |
| Broad Creek | Pamlico | 9/65 | 12/66 | 7/15/70 | 86 | 2 | 3 | 4.46 | 50.70 | 63.38 | 11.74 | 37 | 216 | .00 | 0.4168 |
| Broad Creek | Pamlico | 9/65 | 12/66 | 7/15/70 | 74 | 2 | 3 | 1.41 | 16.55 | 101.50 | 18.84 | 55 | 126 | .10 | 2.1953 |
| Broomfield Creek | Pamlico | 7/68 | 6/69 | 7/7/70 | 84 | 1 | 1 | 1.50 | 23.20 | 45.88 | 11.63 | 16 | 67 | .02 | 1.8154 |
| Burnt Mill Creek | Albemarle Sound | 4/60 | 9/60 | 7/18/70 | 80 | 3 | 3 | 0.20 | 3.17 | 56.04 | 5.05 | 0 | 105 | .10 | 1.7642 |
| Burnt Mill Creek | Albemarle Sound | 4/60 | 9/60 | 7/18/70 | 80 | 3 | 5 | 0.50 | 20.50 | 154.90 | 82.60 | 383 | 28 | 1.50 | 3.5937 |
| Caw Caw Swamp | Lumber | 7/66 | 11/67 | 6/10/70 | 86 | 2 | 3 | 0.20 | 12.20 | 72.03 | 36.84 | 393 | 62 | .10 | 2.3208 |
| Caw Caw Swamp | Lumber | 7/66 | 11/67 | 6/10/70 | 98 | 2 | 1 | 0.94 | 25.70 | 0.67 | 0.45 | 0 | 232 | .15 | 0.9814 |
| Conetoe Creek | Tar | 1/65 | 11/66 | 6/22/70 | 85 | 3 | 3 | 0.61 | 14.46 | 84.23 | 36.33 | 110 | 90 | .25 | 3.1976 |
| Conetoe Creek | Tar | 1/65 | 11/66 | 6/22/70 | 80 | 2 | 1 | 0.50 | 28.50 | 16.23 | 10.42 | 23 | 183 | .00 | 2.5915 |
| Core Creek | Neuse | 10/63 | 11/64 | 7/29/70 | 88 | 2 | 1 | 0.14 | 20.40 | 33.24 | 25.11 | 41 | 927 | .40 | 1.2761 |
| Cutawhiskie Creek | Chowan | 1/62 | 1/63 | 6/12/70 | 74 | 3 | 3 | 0.81 | 26.30 | 37.95 | 12.74 | 0 | 100 | .50 | 2.8748 |
| Cutawhiskie Creek | Chowan | 1/62 | 1/63 | 6/12/70 | 86 | 3 | 3 | 0.95 | 22.10 | 10.10 | 4.37 | 39 | 709 | .10 | 1.8070 |
| Cypress Run | Pamlico | 7/68 | 6/69 | 7/9/70 | 72 | 1 | 1 | 0.31 | 16.62 | 3.13 | .53 | 0 | 1,328 | .02 | 1.1610 |
| Dunn Swamp | Lumber | 8/68 | 7/70 | 7/21/70 | 92 | 1 | 1 | 0.14 | 21.30 | 4.76 | 0.82 | 0 | 1,920 | .02 | 0.3264 |
| Dunn Swamp | Lumber | 8/68 | 7/70 | 7/21/70 | 84 | 1 | 1 | 1.69 | 36.50 | 4.70 | 4.41 | 15 | 214 | 02 | 2.0688 |
| Flat Swamp | Chowan | 6/64 | 8/64 | 6/16/70 | 72 | 3 | 1 | 0.30 | 8.35 | 11.28 | 4.95 | 52 | 82 | 05 | 0.6165 |
| Folley Ditch | Albemarle Sound | 6/59 | 1/61 | 7/17/70 | 76 | 2 | 3 | 1.28 | 21.45 | 67.97 | 11.10 | 61 | 93 | .10 | 1.9148 |
| Grindle Creek | Tar | 6/60 | 3/62 | 6/23/70 | 76 | 3 | 3 | 1.44 | 34.80 | 105.36 | 38.96 | 70 | 65 | .05 | 2.7418 |
| Grindle Creek | Tar | 6/60 | 3/62 | 6/23/70 | 72 | 3 | 1 | 0.42 | 16.78 | 156.28 | 62.36 | 214 | 67 | .10 | 2.4035 |
| Horse Swamp | Chowan | 9/60 | 4/61 | 6/16/70 | 72 | 2 | 3 | 0.47 | 20.92 | 66.52 | 12.64 | 49 | 27 | .20 | 2.8089 |
| Horse Swamp | Chowan | 9/60 | 4/61 | 6/17/70 | 70 | 2 | 3 | 2.10 | 35.40 | 76.47 | 7.07 | 21 | 34 | .25 | 2.4960 |
| Intercepting Canal | Pamlico | 1/61 | 7/61 | 7/8/70 | 80 | 1 | 1 | 2.37 | 85.50 | 0.44 | 0.05 | 0 | 851 | .00 | 2.2485 |
| Johnson's Mill Tail Creek | Neuse | 10/63 | 6/64 | 7/15/70 | 74 | 3 | 1 | 0.83 | 14.30 | 146.16 | 136.43 | 453 | 681 | .50 | 2.6782 |
| Johnson's Mill Tail Creek | Neuse | 10/63 | 6/64 | 6/24/70 | 72 | 3 | 1 | 0.38 | 14.20 | 49.57 | 44.07 | 153 | 449 | .10 | 1.8160 |
| Lyon Swamp | Lumber | 4/67 | 10/68 | 7/22/70 | 78 | 1 | 1 | 1.86 | 23.80 | 57.79 | 33.94 | 92 | 134 | .00 | 2.6992 |
| Lyon Swamp | Lumber | 4/67 | 10/68 | 7/23/70 | 74 | 1 | 1 | 2.80 | 41.80 | 0.78 | 0.69 | 10 | 811 | .00 | 0.7259 |
| Moccasin Creek | Neuse | 10/63 | 11/64 | 7/29/70 | 72 | 3 | 1 | 1.24 | 20.60 | 10.63 | 10.00 | 24 | 805 | .30 | 2.5009 |
| Moccasin Creek | Neuse | 10/63 | 11/64 | 7/29/70 | 84 | 1 | 1 | 0.53 | 16.50 | 24.41 | 8.52 | 47 | 106 | .05 | 1.7247 |
| Mosley Creek | Neuse | 5/69 | In Progress | 7/9/70 | 84 | 1 | 4 | 0.49 | 29.74 | 42.99 | 11.02 | 0 | 160 | .10 | 2.9949 |
| New River | New | 7/68 | 1/70 | 7/23/70 | 88 | 1 | 1 | 0.20 | 23.80 | 11.56 | 5.77 | 0 | 968 | .04 | 1.0002 |
| New River | New | 7/68 | 1/70 | 7/24/70 | 82 | 1 | 1 | 1.81 | 68.50 | 19.26 | 10.66 | 10 | 61 | .02 | 2.6218 |
| Pantego Creek | Pamlico | 1/61 | 7/61 | 7/1/70 | 86 | 2 | 1 | 2.04 | 43.10 | 51.63 | 1.13 | 7 | 16 | T | 0.9328 |
| Pollock Swamp | Albemarle Sound | 9/63 | 6/64 | 7/16/70 | 80 | 1 | 5 | 3.65 | 34.40 | 109.93 | 22.95 | 90 | 15 | .00 | 2.6099 |
| Pollock Swamp | Albemarle Sound | 9/63 | 6/64 | 7/16/70 | 84 | 3 | 3 | 1.50 | 14.50 | 57.42 | 36.92 | 57 | 59 | .40 | 2.4888 |
| Pungo Creek | Pamlico | 7/69 | In Progress | 7/1/70 | 78 | 1 | 6 | 6.15 | 51.17 | 2.71 | 0.00 | 0 | 404 | T | 0.6544 |
| Pungo Creek | Pamlico | 7/69 | In Progress | 6/30/70 | 66 | 1 | 6 | 0.18 | 18.72 | 28.71 | 0.93 | 9 | 316 | .00 | 1.0584 |
| South Creek | Pamlico | 7/68 | 6/69 | 7/8/70 | 80 | 1 | 1 | 5.10 | 60.05 | 12.07 | 7.53 | 40 | 313 | .04 | 2.0480 |
| Swift Creek | Neuse | 4/64 | 6/65 | 7/28/90 | 76 | 1 | 3 | 3.77 | 72.80 | 0.90 | 0.17 | 0 | 364 | .04 | 2.6568 |
| Swift Creek | Neuse | 4/64 | 6/65 | 7/28/70 | 74 | 1 | 1 | 0.73 | 54.20 | 2.06 | 0.50 | 0 | 597 | .25 | 2.2179 |
| Tracy Swamp | Neuse | 5/69 | In Progress | 7/10/70 | 76 | 1 | 3 | 0.42 | 16.30 | 90.33 | 19.12 | 75 | 73 | T | 2.5576 |

* Class 1 - ( 0 - 4.9%)
Class 2 - ( 5 -14.9%)
Class 3 - (15 - 100%)

** Class 1 - Sand
Class 2 - Sand-Clay
Class 3 - Sand-Silt-Mud-Detritus
Class 4 - Hard Clay
Class 5 - Silt-Mud-Detritus
Class 6 - Silt-Mud

stream's entire length, as a result of the complete removal of stream bank vegetation and forest canopy.

The average widths of the sampling area of the natural streams ranged from 9.8 to 75.0 feet with average depths from 0.7 to 10.0 feet. The average widths of channelized streams sampled ranged from 8.4 to 85.5 feet with average depths from 0.14 to 6.15 feet. Most channelized streams were extremely shallow and had few deep pools, whereas the undisturbed natural streams were much deeper and contained numerous deep pools (Tables 2 and 3).

One factor which repeatedly influenced a stream's fishery, directly and/or indirectly through chemical composition and physical make-up, was cover. Of the natural streams evaluated, only one was assigned cover class 1, that being Dunn Swamp, whereas 20 of the 46 channelized streams were in cover class 1. These 20 streams had one thing in common; they either were recently channelized or were intensively maintained by the removal of vegetation as it became reestablished.

In the process of channelization, all cover was stripped from the stream, the stream banks, and from an area 50 to 100 feet from the channel (cover class 1). As time passed and little-to-no maintenance work was carried out, secondary ecological succession took place in the stream bed and on the stream banks. The force of the moving water created undercut banks and potholes which provided cover for fishes, and in the shallow eddies, emergent vegetation began to grow (cover class 2). Succession continued as time passed and the forest canopy shaded part or all of a given stream. Submergent vegetation appeared, potholes became deeper, and there was greater undercutting of the banks (cover class 3). The rate of succession and channel alteration in channelized streams was related to the amount of rainfall, runoff, soil type, fertility, and other factors affecting the physical and vegetative characteristics of that given ecosystem.

To determine what adverse effects channelization had on North Carolina Coastal Plain streams, a comparison of 28 natural versus 46 channeled streams was made. Comparisons made included pounds of fish per surface acre, pounds of game fish per surface acre, pounds of nongame fish per surface acre, number of harvestable game fish per surface acre, average number of fish per pound, volume of fish food organisms, and species diversity (Figure 2).

The average weight of fish per surface acre in natural streams was found to be 155.37 pounds, whereas in channelized streams it was only 49.41 pounds, or 31.8 percent of that of natural streams. In terms of fish carrying capacity (pounds of fish per acre), none of the natural streams were as low as the channelized streams, although a high degree of variability was observed in both natural and channelized streams (Tables 2 and 3). A few channelized streams were found to have greater total weight of fish per surface acre than a few of the natural streams sampled. However, in general, the highest total weights of fish encountered per surface acre were in the natural streams and the lowest weights per surface acre were in the channelized streams.

The average poundage of game fish per surface acre was 426.7 percent greater in natural streams than in streams which had been channelized or 77.41 pounds as opposed to only 18.14 pounds. The average poundage of nongame fish per surface acre was also greater in natural streams (77.95) than in streams which had been channelized (31.27). As can be seen here, channelization appears to affect game fish more than nongame fish. There were approximately 50 percent less game fish than nongame fish by weight per surface acre in channelized streams, whereas in natural streams, there was approximately a 1:1 ratio by weight. In addition to this, the number of harvestable game fish ($> 6''$ in length) per surface acre was found to be reduced 76.7 percent, as a result of channelization (Tables 2, 3, and Figure 2). The greater reduction of game fish over nongame fish following channelization reduced the value of the stream to the sport fisherman even more than was indicated by the reduction in total weights of fish.

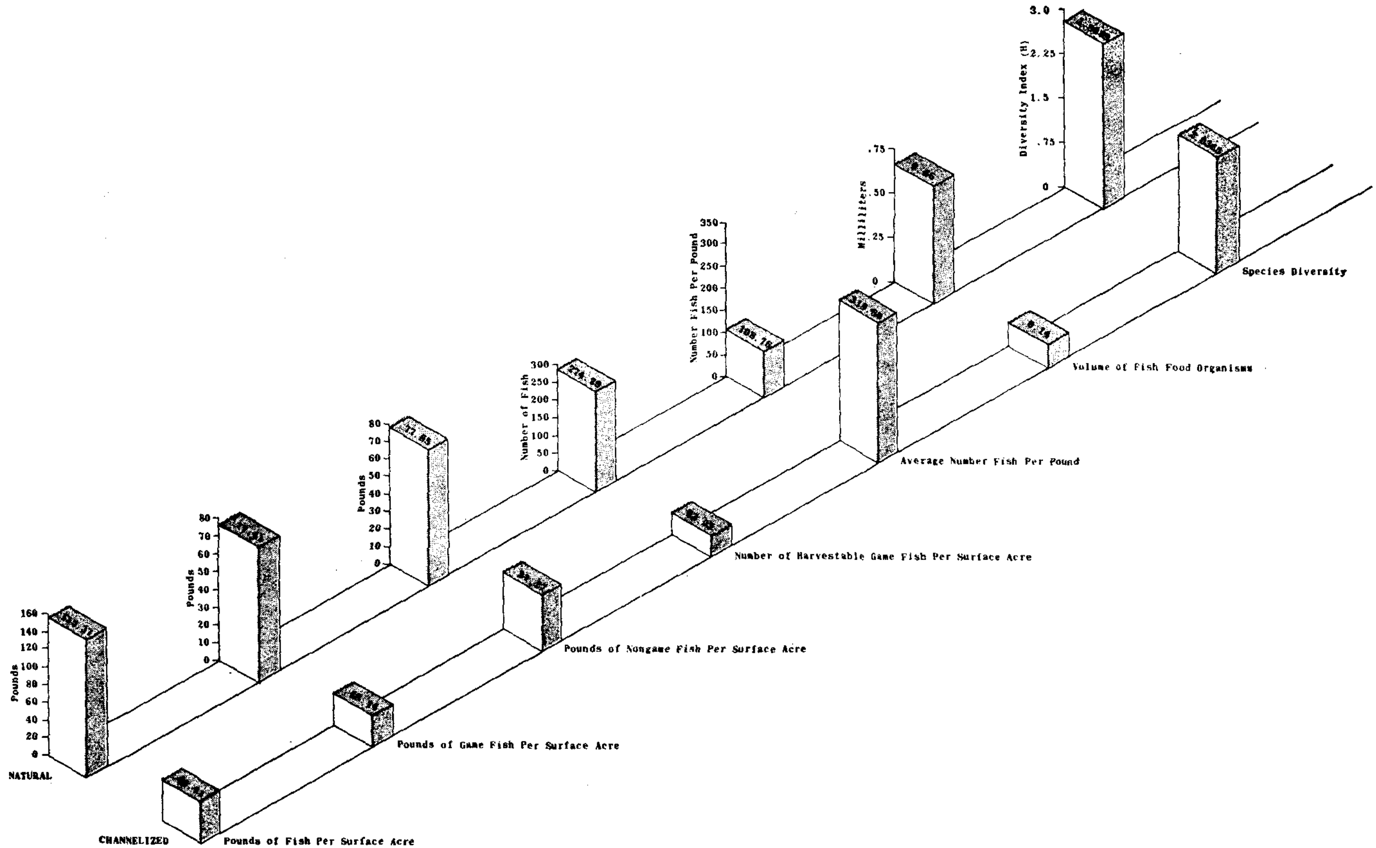


FIGURE 2. Comparison of Natural and Channelized Streams.

The average size of fish in channelized streams was found to be smaller than was the average size of fish in natural streams (Figure 2). Channelized streams on the average yielded 319.80 fish per pound as compared to 108.76 fish per pound in natural streams. One probable factor influencing this was the 78.8 percent reduction of macrobenthic invertebrates which occurred as a result of the alteration of bottom type and stream flow regimen associated with channelization (Figure 2). In an ecosystem where the components of lower trophic levels are reduced, it follows that the biomass of consumers in higher trophic levels, will be reduced.

The difference between the mean species diversity in natural and channelized streams indicated that the overall quality of streams was reduced 27.5 percent following channelization. The mean species diversity for natural streams was 2.8089 and the mean species diversity for channelized streams was 2.0365 with standard deviations of 0.6621 and 0.8304, respectively. The diversity index calculated for South Creek in 1965 was considered to be biologically unsound because a school of juvenile Atlantic menhaden entered the sample area during the period of sampling. For this reason, this figure was omitted from calculations involving diversity index.

When dealing with fish populations in streams, either natural or channelized, there are certain factors that cause natural variations in fish populations. In view of this, the data were partitioned to compare natural and channelized streams taking these natural variations into account. Streams were compared as to the percentage of streams sampled with total weight of fish per surface acre in 25- and 50-pound classes. Considerably more channelized streams exhibited low fish-carrying capacities than did natural streams.

Forty-four percent of the 46 channelized streams sampled had carrying capacities of less than 25 pounds of fish per surface acre, whereas, only 18 percent of the 28 natural streams sampled yielded less than 25 pounds (Figures 3 and 4). Forty-six percent of all natural streams

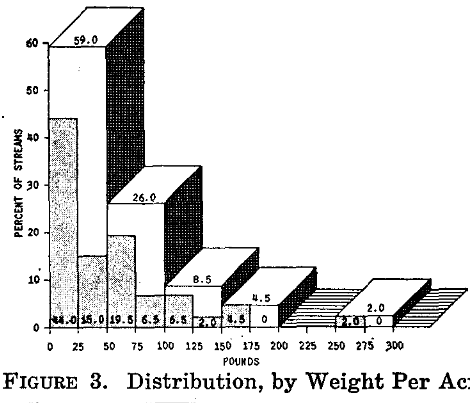


FIGURE 3. Distribution, by Weight Per Acre, of Fish in Natural Streams

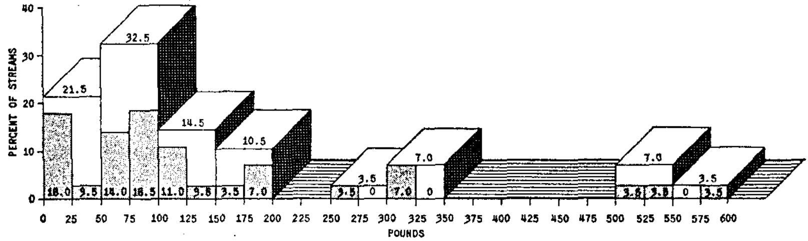


FIGURE 4. Distribution, by Weight Per Acre, of Fish in Channelized Streams

sampled yielded greater than 100 pounds of fish per surface acre; however, only 15 percent of the channelized streams had more than 100 pounds of fish per surface acre. No channelized streams had more than 300 pounds of fish per surface acre, yet 10.5 percent of the natural streams had greater than 500 pounds of fish per surface acre.

Comparisons of total weight per surface acre of game fish demonstrated a striking difference between natural and channelized streams. For instance, 76 percent of the channelized streams, compared to only 25 percent of the natural streams studied, had less than 25 pounds of game fish per surface acre (Figures 5 and 6). Furthermore, 46 percent

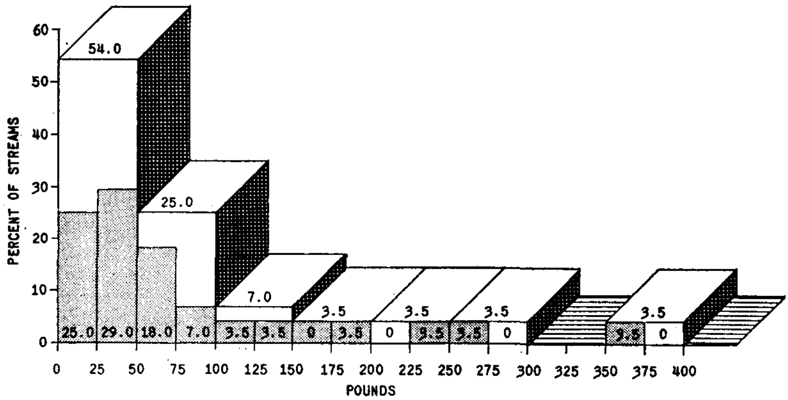


FIGURE 5. Distribution, by Weight Per Acre, of Game Fish in Natural Streams

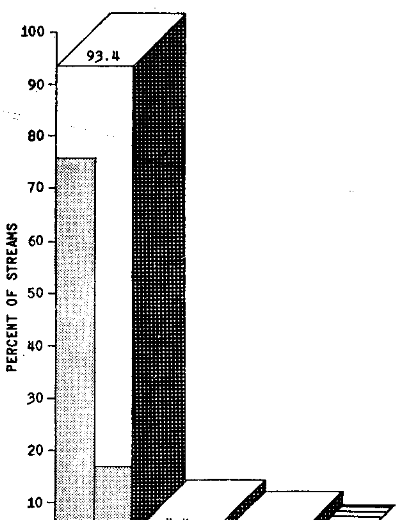


FIGURE 6. Distribution, by Weight Per Acre, of Game Fish in Channelized Streams

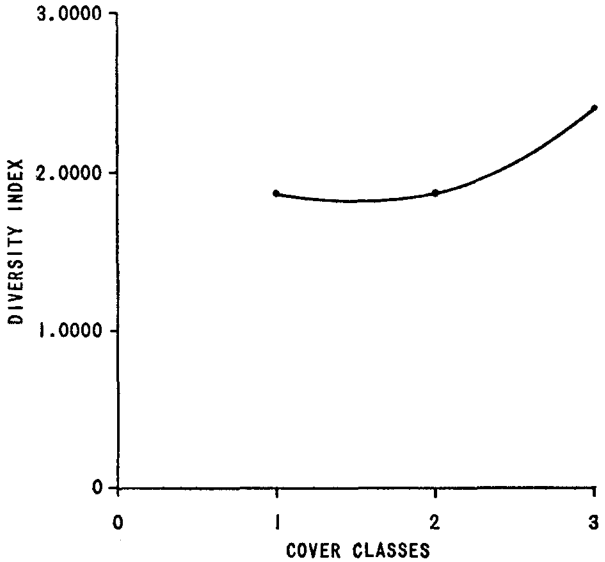


FIGURE 7. The Relationship Between Diversity Index and Cover in Channelized Streams

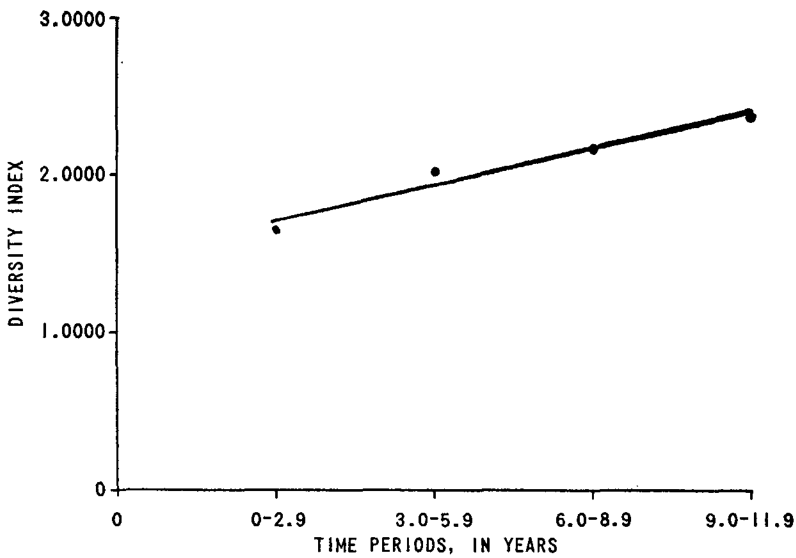


FIGURE 8. The Relationship Between Diversity Index and Time, Since Channelization

of the natural streams, compared to only 6.6 percent of the channelized streams, had game-fish populations greater than 50 pounds per surface acre. The greatest carrying capacity of game fish found in a channelized stream was 150 pounds, whereas, 14 percent of the natural streams had game-fish populations varying from 150 to 375 pounds per surface acre.

There are some distinct differences in fish populations within channelized streams which appear to be related to cover and time. Species diversity was plotted against cover and a line fitted to the points by eye (Figure 7). As can be seen from the figure there was only a slight increase in the diversity index between cover class 1 and cover class 2, whereas, a considerable increase occurred between cover class 2 and cover class 3. From these data, it appeared that an increase in cover from 0 - 14.9 percent did little to increase the quality of a stream. However, the data indicated that increases in cover above 15 percent resulted in marked improvements in habitat quality and total pounds of fish per acre.

Diversity also was plotted against time since channelization to determine the rate of recovery following stream channelization (Figure 8). Using the criteria outlined above, fish populations in channelized streams appeared to recover in approximately 15 years, provided no further alteration of the stream bed, banks, forest canopy, or aquatic vegetation occur.

This study clearly pointed out the detrimental effects that stream channelization had on fish populations and the stream's flora and bottom fauna. The study also indicated that, following channelization and with no channel maintenance, nature can restore a stream and its fish population to a stage reasonably near its natural condition in a period of about 15 years. It would appear from this study that the implementation of channelization activities that preclude the destruction of stream bank cover would greatly ameliorate the destructive effects of present channelization practices (Figure 9).

## CONCLUSIONS

The conclusions reached from this study of the effects of channelization on fish populations in North Carolina Coastal Plain streams were:

1. The removal of forest canopy and stream cover by channelization can warm Coastal Plain streams having white, shifting sand bottoms to a temperature higher than that permitted by North Carolina State law.
2. Most channelized streams are extremely shallow, have a flat bottom and contain few deep pools, whereas, undisturbed natural streams are deeper and contain numerous deep pools.
3. The greatest single factor affecting a fish population appears to be the amount of stream cover.
4. Data indicate that natural streams have an average carrying capacity per surface acre in excess of three times that found in streams which have been channelized.
5. The average poundage of game fish per surface acre was over 400 percent greater in the natural streams than in the channelized streams.
6. Channelization appears to adversely affect game fish more than nongame fish.
7. The number of harvestable game fish ($>$ 6″ in length) was reduced by more than 75 percent by channelization.
8. Natural streams produce larger fish than do channelized streams.
9. Invertebrate macrobenthos were reduced by 78.8 percent in volume following channelization.
10. The overall quality of streams, as based on species diversity, was reduced by 27.5 percent following channelization.
11. Species diversity increased with corresponding increases in cover, and time since channelization.

*Top:* Stream prior to channelization

*Right:* Stream immediately following channelization

*Below:* Channelized stream showing stream recovery without channel maintenance


FIGURE 9. Photographs Depicting Channelization

12. Forty-six percent of the natural streams yielded fish populations greater than 100 pounds per surface acre, whereas only 15 percent of the channelized streams had more than 100 pounds per surface acre.
13. Forty-six percent of the natural streams revealed game-fish carrying capacities greater than 50 pounds per surface acre, whereas, only 6.6 percent of the channelized streams had a game-fish carrying capacity in excess of 50 pounds per surface acre.
14. There was a considerable increase in the diversity index between cover classes 2 and 3 indicating that stream quality increases proportionately to the amount of cover.
15. Fish populations, as represented by species diversity, in a channelized stream may recover to natural levels in approximately 15 years provided no further alterations of the stream bed, bank, forest canopy, or aquatic vegetation occur.

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# THE GROWTH OF CAGED Tilapia aurea (Steindachner) IN FERTILE FARM PONDS

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Caged *Tilapia aurea* were cultured for a 10-week period in four experimental ponds (between 10 and 26 acres) to determine how efficiently these fish are able to use plankton as a source of food and to determine the value of Purina Trout Chow and Auburn No. 2 as supplemental rations for caged *T. aurea* in two common types of fertile farm ponds.

Fingerling *T. aurea* were stocked at the rate of 150 fish per 0.25-cubic meter cage (0.956 pounds per cage). There were four cages per pond.

Blooms of plankton were produced by inorganic fertilizer in two ponds which contained established bluegill-bass populations, and blooms of plankton were produced by a combination of supplemental feeding of catfish and inorganic fertilizer in the other two ponds which contained catfish under intensive culture.

One cage of *T. aurea* per pond received no supplemental ration. Three cages of *T. aurea* received supplemental rations six days per week. The three rations consisted of Purina Trout Chow at 3.0 per cent of the weight of fish per day, Auburn No. 2 at 3.0 per cent, and Auburn No. 2 at 1.5 per cent.

*T. aurea* consumed plankton efficiently enough for considerable growth. The mean production of *T. aurea* which received no supplemental feed was 8.90 pounds of fish per cage in the bluegill-bass ponds and 24.39 pounds of fish per cage in catfish ponds.

C feed conversion values (Swingle, 1958) indicated that Auburn No. 2 as a supplemental ration in all cases was unsatisfactory. C values for *T. aurea* which received the Purina Trout Chow ration in the bluegill-bass ponds were 1.0 and 1.5. C values for *T. aurea* which received the Purina Trout Chow ration in the catfish ponds were 3.3 and 6.3.

There was less variation in weight among harvested *T. aurea* than among the fingerlings which were stocked. There was less variation in weight among *T. aurea* in catfish ponds than among *T. aurea* in bluegill-bass ponds.

## INTRODUCTION

The blue tilapia, *Tilapia aurea* (Steindachner), has been evaluated as a pondfish (Swingle, 1960; McBay, 1961; Shell, 1966; Kilgen, 1969; Pagan, 1970) and as a new exotic in several lakes of South Central Florida (Buntz and Manooch, 1969). Buntz and Manooch (1969) demonstrated that *T. aurea* did not provide an additional sport fishery in Florida but that these fish did provide a source of additional food when the public harvested them by special methods, such as snagging or cast netting. Swingle (1960) demonstrated that *T. aurea* (then identified as *Tilapia nilotica*), when fed, was an efficient pondfish, yielding a maximum of 4,003.7 pounds per acre in 208 days from 100 brood. However, there was a high percentage of fish of unharvestable size. Swingle (1960) noted that ponds stocked with *T. aurea* withstood high feeding rates, up to 100 pounds of feed per acre per day, without any depletion of dissolved oxygen or heavy phytoplankton scums. McBay (1961) demonstrated that temperatures below 55°F for extended periods were lethal to *T. aurea* (then identified as *T. nilotica*) at sizes of 11 inches and below. McBay also demonstrated that *T. aurea* (then identified as *T.*