AN ECOLOGICAL INVESTIGATION OF CUTOFF BENDWAYS IN THE TENNESSEE-TOMBIGBEE WATERWAY (TOMBIGBEE RIVER): AN OVERVIEW[1]

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Abstract: A field investigation of 3 cutoff bendways and 1 natural bendway in the Tennessee-Tombigbee Waterway (Tombigbee River) was conducted from December 1979 to September 1980. Conductivity, pH, and current were significantly different ($P < 0.05$) among transects regarding corresponding bendway locations. Conductivity, dissolved oxygen, current, carbon dioxide, alkalinity, secchi visibility, turbidity, ammonia, total phosphorus, and orthophosphorus were significantly different among bendways. Dissolved oxygen stratification occurred from late July through August with little or no dissolved oxygen in the bottom stratum at most transects. Six divisions of phytoplankton including 150 taxa were observed. Lowest total numbers of plankton occurred in December (121/ml) and increased to a maximum of 20,632 organisms/ml in late August. Chlorophyll and carotenoids varied significantly with seasons and with changes in phytoplankton abundance, secchi readings, conductivity, pH, turbidity, dissolved oxygen, ammonia, and orthophosphorus. Sediment sample analysis indicated that while there were substantial amounts of gravel in 2 bendways, fine sand clearly predominated the total sediment from each transect over all bendways. The greatest number of benthic taxa was represented at the natural bendway. Transect samples from within bendways had more taxa represented and a greater density of organisms than river transect samples. Sixteen unionid mollusks were collected with representatives taken from 3 of the 4 bendways. Two species taken, *Pleurobema taitianum* and *P. marshalli*, are under status review by the Fish and Wildlife Service to determine if they are endangered. Significantly ($P < 0.05$) higher diversities of fish were associated with stations located in bendways which had been cut off for longer time periods.

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The controversial Tennessee Tombigbee Waterway (TTW) has been kept in the public eye through numerous legal suits brought against the U. S. Army Corps of Engineers by environmental groups, coalitions of various interest groups, and most recently through stiff appropriation battles in the United States Congress. As the largest public works project ever undertaken by this country, it's not surprising that such a massive alteration of the natural environment is controversial. The completed TTW will connect the Tennessee River with Mobile Bay on the Gulf of Mexico. This project will be accomplished in 3 sections: the 64-km divide cut from Bay Springs, Mississippi to Pickwick Lake, the 71-km canal section from Amory,

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Mississippi, to Bay Springs, Mississippi, and the 238-km river section from Demopolis, Alabama to Amory, Mississippi.

The river section contains numerous bendways (meander loops) which will be cut off to eliminate these sharp curves and to reduce the length of the waterway. Cutoff bendways superficially resemble oxbow lakes resulting from natural processes of cutting off meandering river loops. Certain oxbow lakes provide tremendous recreational resources, while others are thought to be of limited value. To our knowledge, little or no data are available to adequately predict the fate of man-made cutoff bendways.

A better understanding of natural and man-made processes and their associated influences on the biotia may point to various management strategies for developing and utilizing the potential of cutoff bendways. The management of cutoff bendways offers the Corps of Engineers a tremendous potential for mitigation measures.

The U. S. Army Corps of Engineers Waterways Experiment Station (WES) funded a study to investigate 4 bendways (Hairston Bend, Big Creek Bend, Cook's Bend and Rattlesnake Bend) within the TTW. The overall objective of the study was to evaluate ecological impacts associated with the severing of the bend from the main stem of the river, to compare the relative ecological value of each bendway and to evaluate the relative value of each bendway as aquatic habitat for different flora and fauna. The implications of such a study are much greater than a restricted view of the TTW. Cutoff bendways are not unique to the TTW construction, but are common wherever river navigational projects occur.

The purposes of this paper are to present an overview of the study, to summarize major conclusions from the study, and to reference the final report (Robinette 1981) of the study for in-depth analyses.

This project was contracted by the WES to the Mississippi Cooperative Fisheries and Wildlife Research Unit and subcontracted to the Department of Wildlife and Fisheries, Mississippi State University. C. H. Pennington was WES contract officer. Contributors to the final project report other than the authors of this paper were: Robert Muncy, Opal Dakin, Terry Heaton, Edward Harrison, Chris LaGarde, Scott Knight, Marion Gray, Andrew Miller and Doug Darr.

METHODS

Study Area

The Tombigbee River drainage arises in northeastern Mississippi in Tishomingo and Prentiss Counties and generally drains from northwest to southeast. The east and west forks unite in northern Monroe County to form the Tombigbee River. The river also transverses Itawamba, Clay, Lowndes and Noxubee Counties in Mississippi and Sumter, Greene and Pickens Counties in west central Alabama. The TTW project is confined to the upper Tombigbee River which is defined as the reach of the river north of its confluence with the Black Warrior River near Demopolis, Alabama. The Black Warrior Watershed is contiguous with the eastern border of the upper Tombigbee Watershed.

Fig. 1 illustrates the section of the Tombigbee River involved in this project with specific study sites (bendways) indicated. Hairston Bend is located in Lowndes County at approximate river kilometer (RK) 558 about midway between Columbus, Mississippi and Pickensville, Alabama in the Aliceville Pool section of the waterway.

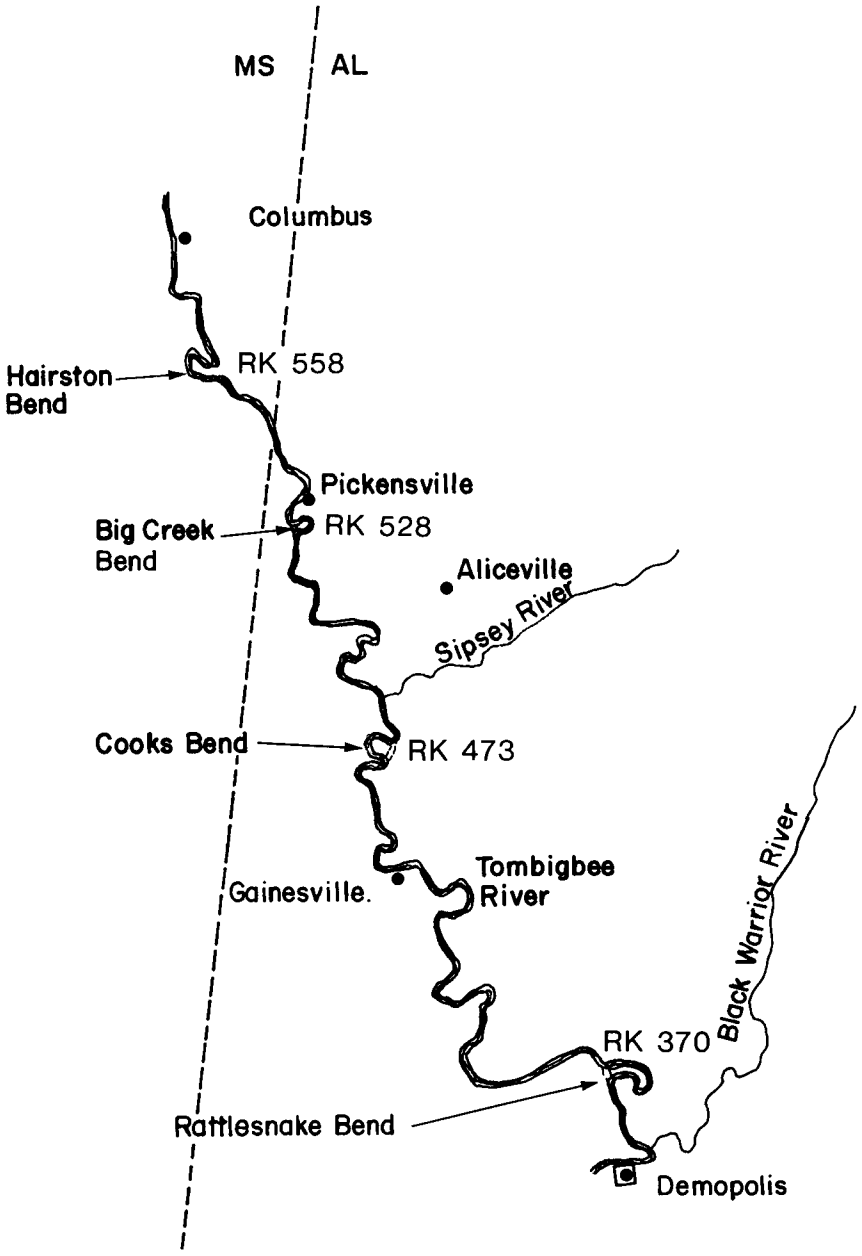

Fig. 1. Tombigbee River between Columbus, Mississippi, and Demopolis, Alabama, illustrating the relative location of the 4 study bendways (RK = river kilometer).

The bendway was not cut off during the period of this study. The bendway is approximately 8 river kilometers in length. Big Creek Bend is located in Pickens County, Alabama at RK 528 within the upper Gainesville Pool section of the waterway. The cutoff was completed in 1978 and the resulting cutoff bendway is approximately 5 river kilometers in length. Cook's Bend is located in Sumter County, Alabama within the Gainesville Pool of the waterway at RK 473. The cutoff of the bendway was completed during the early phase of this study (Jan 1980). This bendway is approximately 6 river kilometers in length. Rattlesnake Bend is part of the boundary between Greene and Sumter Counties, Alabama and is located at RK 370 within the Demopolis Pool section of the waterway. The cutoff was completed in 1975 and the resulting bendway is approximately 13 km in length.

Initial construction of locks and dams started at the lower end of the proposed waterway. The navigation structures closer to the Gulf of Mexico were completed before those farther upstream. During the period of this study, Rattlesnake Bend had been flooded for 5 years, Cook's Bend and Big Creek Bend for 3 years and Hairston Bend flooded at pool level during January, 1980 between our December, 1979 and May, 1980 sampling periods.

Bendway and river sampling transect locations were designated by WES personnel. Individual sampling transects on each bendway followed the pattern depicted for Big Creek Bend in Fig. 2. These transects corresponded to established sedimentation transects monitored by Army Corp Engineers personnel. Transects were numbered and designated as follows: 100's - above the bendway, 200's - within the cutoff, 300's - below the bendway, and 600's -within the bendway (Fig. 2). Transect number designations were marked on a permanent shore object (usually a tree). Transects were imaginary lines perpendicular to the river channel. Sampling stations were located on a transect and referred to as: left bank, right bank, and mid-channel stations.

Sampling Procedure

Water quality, plankton, chlorophyll, sediments and benthos were sampled on the following transects: uppermost above bendway, upper bendway, lower middle bendway, lowermost below bendway. Fish were collected by electrofishing and by fishing hoopnets at all transects.

All subject areas of this study were investigated in December 1979 and May, June, and early August 1980. In addition, water quaility, plankton and chlorophyll were monitored in early and late July, late August, and early September 1980, during low-flow, high-water temperature conditions.

Water Quality

A Hydrolab 8000 series was used to measure water pH, conductivity, dissolved oxygen, and temperature on each transect at left and right banks and at mid-channel. Water column profiles were obtained for each variable at the mid-channel station. Benthic and phytoplankton collections were taken from these stations also. Stream current (m/sec) was measured with a Teledyne-Gurley current meter at each station.

Water samples were collected from the surface for analysis of carbon dioxide,

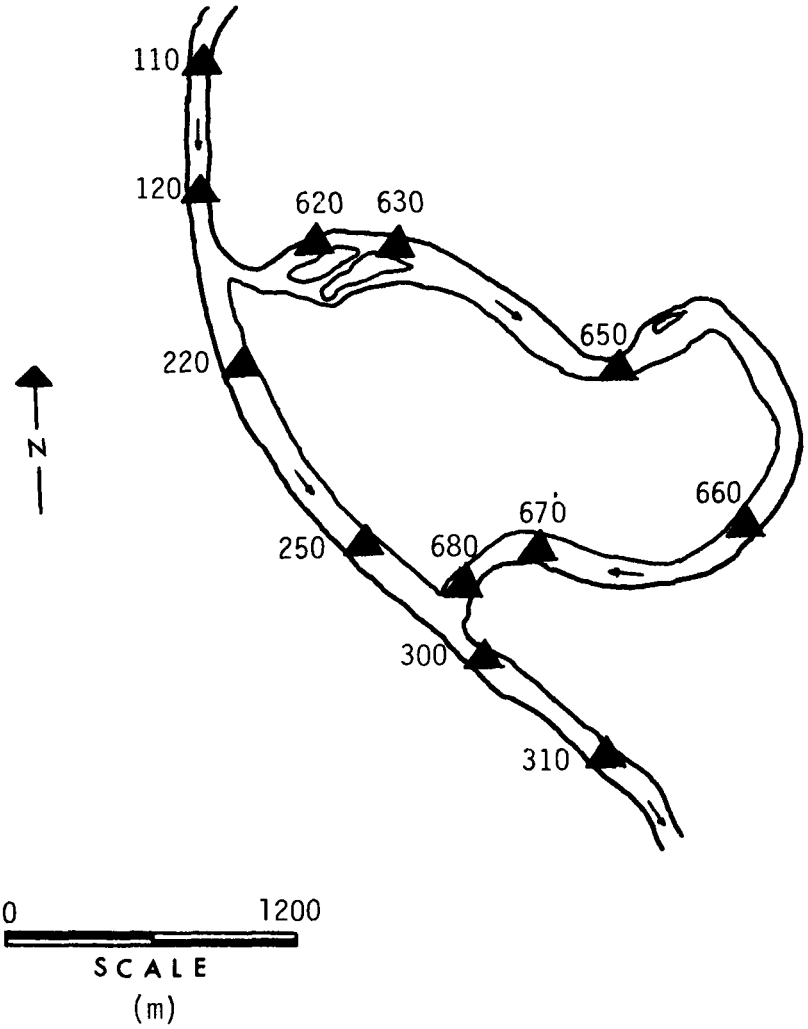

Fig. 2. Transect locations (sampling sites) on Big Creek Bend and the Tombigbee River. All transects were used to establish electrofishing stations. Water quality, plankton, chlorophyll, sediments and benthos were sampled on transects 110, 310, 620, 650, 660 and 670.

total alkalinity, turbidity, ammonia-N, nitrite-N, nitrate-N, orthophosphorus, and total phosphorus at each mid-channel station on each transect. Carbon dioxide and total alkalinity concentrations were determined using titration methods as outlined in Standard Methods (APHA 1975). Turbidity was determined with a HACH 2100A Turbidimeter. Turbidity was also monitored by using a Secchi disc in the field. Water samples were preserved on ice and taken to the Mississippi State Chemical Laboratory for determinations of nitrogen and phosphorus concentrations.

Plankton and Chlorophyll

Sample collections were 500-ml "grab" samples, preserved with 5 ml of Lugol's solution. Phytoplankton was enumerated by the Utermohl procedure described by Lund et al. (1958) and was made using a Leitz Diavert II inverted microscope equipped with 32× and 100× objectives and 10× eyepieces fitted with an ocular scale. Identification was to genera in most cases. Five hundred-millimeter water samples were filtered with a vacuum pump for chlorophyll analysis. During the last stages of filtration, a fixative (magnesium carbonate) was added and glass fiber filter pads were frozen to preclude pigment degradation. Laboratory analysis was primarily accomplished using techniques defined by Strickland and Parsons (1972).

Sediments

One sediment sample was obtained with a petite ponar sampler at each benthic sampling station during each sampling period. Sediment samples were returned to the laboratory and dried in a Poweromatic 60 oven at 110 ± 5 C for 45 min to 2 hours. Dried samples were weighed on a top loading Sartorius balance to the nearest 0.1 g. The samples were then placed in a series or nest of U.S. standard sieves with openings ranging from 76.2 to 0.074 mm. The samples were shaken by a Tyler "Ro-Tap" Shaker for 10 min. Contents of individual sieves were weighed to the nearest 0.1g. Procedures conformed to those outlined in Laboratory Soils Testing (U.S. ACE 1970).

Benthos

Benthic samples were taken with a petite ponar grab sampler, emptied into a Wildco wash buket #190 standard mesh (#30 - 0.59 mm) and washed. Contents were preserved with 10% buffered formalin solution. Organisms were picked under a Baush and Lomb stereoscopic microscope and identified to the lowest practical taxonomic level.

Mollusk Survey

Brailling was conducted at each bendway using a 1.83-m crowfoot bar which was dragged down river from the bow of a 4.88-m jonboat. A total of 57 10-min drags was conducted. Shells were also handpicked along the river bank at exposed sand bars. All specimens were saved and identified.

Fisheries

One 0.92-m diameter hoop net was fished at both left and right bank stations of each transect. The transect marker was used as the center of a 457-m electrofishing station established parallel to each bank of the river at each transect. Station distance was measured using a Del Norte radio micro-wave postition system. Fish samples were also taken with a 7.66-m long, 1.83-m deep minnow seine pulled 8 m along the bank at transect stations with suitable depths and free of obstructions.

All fish were identified to species and total length and weight were recorded for all fishes in good condition. Stomachs were removed and preserved from largemouth bass (*Micropterus salmoides*), spotted bass (*M. punctulatus*), white crappie (*Pomoxis annularis*), black crappie (*P. nigromaculatus*), bluegill (*Lepomis macrochirus*), and flathead catfish (*Pylodictus olivaris*). Scales were removed from the centrarchids and spines from the flathead catfish for age and growth studies.

Aquatic Macrophyte Survey

The bendway study sites were examined for aquatic macrophytes along both banks and adjacent shallow water areas. Plants were identified and the significance of a bed of vegetation was determined as to its spatial coverage or abundance.

Statistical Procedures

The statistical packages for the social sciences (SPSS) (Nie et al. 1975) were used for 1-way analysis of variance (ANOVA) procedures and for correlation of parameters. Cochran's C was used to test for homogeneity of variances and the Student-Newman-Keuls (SKN) multiple comparisons test was used to separate significant differences detected by the ANOVA tests. Differences were considered significant when $P \leq 0.05$.

RESULTS

Water Quality

Analysis of combined water quality data from the 3 cutoff bendways indicated that only conductivity, pH, and current differed significantly with location (transect) within the bendway and river. Analyses of data from individual bendways showed that only the natural bendway (Hairston Bend) had no significant differences among transects. Differences in current, with respect to transect location, were common to the other 3 bendways, but other parameters varied on an individual bendway basis. When bendways were compared using data from all transects, the following parameters werre significantly different among bendways: conductivity, dissolved oxygen, current, carbon dixoide, total alkalinity, secchi visibility, turbidity, ammonia-N, total phosphorus, and orthophosphorus. Significant differences were observed for the following parameters among sampling periods: temperature, turbidity, conductivity, total phosphorus, orthophosphorus, and current. Dissolved oxygen stratification frequently occurred in the 3 cutoff bendways during the summer sampling periods. The late August and September dissolved oxygen concentrations were too low (typically < 3.0 mg/l) to sustain fish populations in the lower water column.

Phytoplankton and Chlorophyll

The lowest total phytoplankton population (121/ml) occurred in December; the maximum population (20,632/ml) occurred in late August. Chlorophyll "a" and carotenoid concentrations also peaked during the July and August sampling periods.

Six different algal divisions were represented, but the dominant organism was the diatom, *Melosira* sp. Phytoplankton was less dense in samples from above and below the bendway as compared to within bendway samples in Big Creek Bend and Cook's Bend.

Sediments, Benthos, and Mollusk Survey

While there were substantial amounts of gravel in 2 bendways, fine sand predominated in average percentage of the total sediment from each transect over all bendways.

The greatest number of benthic taxa was identified from Hairston Bend, but the greatest number of organisms per sample was taken from Big Creek Bend. Dipterans, oligochaetes and ephemeropterans were the most abundant invertebrates. Generally, bendway transect samples had more taxa and a greater abundance of organisms than river transect samples. August benthic samples were more diverse and had greater densities of organisms than December, May or June samples.

No mollusks were collected at Hairston Bend, but 18 species of Unionidae were taken at the other bendway study sites. Most specimens were hand collected on exposed samd bars at Big Creek Bend. Two species collected (*Pleurobema marshalli* and *P. taitianum*) are under status review by the Fish and Wildlife Service to determine if they are endangered.

Fisheries

Sixty-three of 112 fish species reported as occurring in the Tombigbee River drainage (Lee et al. 1980) were collected. Age composition and growth analyses for largemouth bass, spotted bass, white crappie, black crappie, and bluegill were similar to those reported in studies from Alabama and the lower Mississippi River drainage. Compared to stations in the river proper, there was greater species composition at within bendway stations at Big Creek Bend and Battlesnake Bend, the 2 study areas with the oldest bendway cutoffs. Shads (*Dorosoma* sp.) were the most abundant species collected from these within bendway stations.

Food habit analyses showed that largemouth bass fed mostly on small fish while white and black crappie fed on small fish and benthic invertebrates. Bluegill consumed numerous fish eggs, but benthic and terrestrial invertebrates were major diet components. Flathead catfish fed mostly on centarchid fishes.

Macrophyte Survey

Aquatic macrophytes were generally scattered and seldom formed large mats or beds in any of the study areas. The most common aquatic plant was waterwillow (*Justicia americana*) which had formed numerous small beds in Rattlesnake Bend, located in the oldest pool on the river.

DISCUSSION

Bendway cutoff channels and impoundments of the river behind lock and dam complexes were the two overriding ecological factors that influenced the results of

this study. Undoubtedly, the concurrent impoundment of the river and the dredging of the cutoff channels masked effects which might have been attributed to one or the other factor had they occurred independently. However, it is clear that current was affected by both cutoff channels and impoundment.

A series of pools will be created along the length of the TTW. Thus, the Tombigbee River will be changed from a lotic environment of pools and riffles to a lentic environment of slow-moving lake-like water. The alteration of current or flow patterns is a dominant factor in the changing Tombigbee riverine ecosystem. Current in the river above and below the 3 cutoff bendways averaged more than twice the current within the bendway. There was no significant current differences between river and within bendway transects in Hairston Bend, an uncut bendway.

Some of the more important influences of current are as follows: on stratification, on sediment load and deposition, and on composition of plankton, benthos, and fish communities. Tubulence created by current would be expected to mix the water column sufficiently to prevent stratification. Current was often undetectable within the bendways and also in the river transects late in the summer. Consequently, within bendway transects and some river transects showed strong dissolved oxygen stratification from early July to September. Lower water column strata often had less than 2.0 mg/l total dissolved oxygen. Low levels of dissolved oxygen must have influenced the distribution of most organisms. Hairston Bend stratified less frequently than the other bendways.

Sediment load capacity is directly related to current velocity. Suspended sediments are deposited when current decreases. Thus, it should be expected that the bendways will undergo increased sediment deposition as compared to the river proper. Although no baseline data were available for comparison, tremendous sedimentation had occurred at Big Creek Bend to the extent that the upper end of the bendway was completely closed off from the river by a large sand bar. Thus, the upper end of Big Creek Bend was static water with exchange with the river occurring only at the lower end of the bendway. Changes in substrate resulting from sedimentation and siltation can be expected to influence species composition and population distribution of mollusks and other benthic organisms as well as affecting fish spawning sites.

Sediment deposition in the bendways will probably encourage plankton growth by increasing light penetration into the water. In fact, plankton populations within the bendway at Big Creek Bend and Cook's Bend were greater than plankton populations in the river proper. Chlorophyll concentrations showed the same trends as the plankton populations. Current also inversely influences plankton communities because plankton can develop more readily in a static (or nearly so) situation than where the algal cells are being continually carried downstream. Enhancement of plankton communities throughout the TTW by the series of pools, particularly within cutoff bendways, will be reflected by density increases at each trophic level.

Current directly affects benthic and fish communities simply because certain organisms are better adapted to a lotic rather than a lentic environment. Therefore, shifts in species dominance has probably already occurred on the lower end of the TTW and will continue as the ecosystem matures. Changes in community composition will occur as the upper TTW is impounded.

Compared to the river proper, fish species composition and diversity were significantly greater within the bendways at Big Creek Bend and Rattlesnake Bend (bendways with older cutoff channels). Length of time since the creation of the cutoff channel and the impoundment of the pool may be important from the standpoint of allowing the new ecosystem to mature, i.e. time for new communities and associations to develop and flourish.

Water quality differences between bendways and between locations (transects) at each bendway study site were probably not great enough to account for the differences in fish catch success. Substrate and or current may have been most important in distribution of bottom dwelling species, but submerged structure appeared to be the overriding factor in sport fish distribution. Electrofishing success often increased near submerged objects, irrespective of within bendway or river stations. As a result of river morphology and channeling efforts on the river proper and in the cutoff channels, within bendway stations typically had more structure in the water than did other stations.

Aquatic macrophyte communities were more developed at Rattlesnake Bend (as compared to other bendways) in the oldest impoundment on the TTW. As time since impoundemt of the study site increases, macrophyte populations can be expected to increase. Development of macrophyte communities will be directly related to sediment deposition creating shallow water habitat.

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