EFFECTS OF GRAVEL DREDGING ON THE BRAZOS RIVER[1]

Allen Forshage
Texas Parks and Wildlife Department
Fort Worth, Texas 76107
and
Neil E. Carter
Texas Parks and Wildlife Department
Austin, Texas 78701

ABSTRACT

A study of the physicochemical and biological conditions of the Brazos River in Hood and Somervell Counties, Texas to determine the effects of a gravel dredging operation on river fauna was made in 1971-73. Physical damages resulting from dredging caused a change in the river course, depth, and substrate. Turbidity and settleable solids were increased. Alkalinity varied significantly (0.05 level) at the dredting site when gravel was taken from the river and processed. Dredging was responsible for major changes in benthic macroinvertebrate populations and fish populations in the immediate area of activity as well as in areas further downstream.

INTRODUCTION

The taking of gravel from stream sources is common practice in Texas because of the low operational costs involved and a liberal stream dredging permit system. However, dredging in streams is being seriously questioned since it may vitally affect bottom communities upon which the productivity of these waters depends. To evaluate the effects of gravel dredging, the Texas Parks and Wilklife Department undertook a study from January, 1971 to June, 1973 of the physicochemical and biological conditions of the Brazos River.

The study was centered around one gravel plant located in Somervell County. The plant had not begun operation at the beginning of this study. Dredging was underway by June, 1971 and continued until 6 months before the study was terminated. Therefore, it was possible to study the physicochemical and biological conditions of the river before, during and after dredging.

A dragline was used to remove gravel from the Brazos. The first step in this removal process involved construction of a temporary island. From this island the material was loaded into pit trucks and hauled to a nearby processing plant where it was washed with river water. This water was returned to the river via a settling pit.

The writers wish to express sincere thanks to Dr. Kenneth Stewart (North Texas State University) and Dr. Sidney Edwards (Southwest Texas State University) for their assistance with the taxonomy of the macroinvertebrates; to chemists Joe Mayhew and Tom Chandler, Texas Parks and Wildlife Department, who assisted in water quality analyses; to fisheries technicians Gerald Boyd, Harry Mack and Ken Moore who assisted in field and laboratory work; and to the Brazos River Authority for river flow and area rainfall data.

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METHODS AND MATERIALS

Locations of the gravel plant, island, settling pit and sampling stations are shown at river miles (R.M.) in Figure 1. In 1971, four of these sampling stations were used to evaluate river conditions before dredging (R.M. 527, 522, 519 and 511.5). These stations were located at the head of riffle areas with an average depth of 1.3 feet. The substrate at these points was primarily gravel that ranged in diameter from 0.2 to 2.0 inches. During the study, velocity of flow at these stations varied from 1 to 5 feet per second. The stations were situated in a region where the Brazos was around 170 feet wide.

After the gravel plant started its dredging operation, nine additional stations were established to gaim more information about the longitudinal effects of dredging on water quality and biological conditions. In general, these stations were comparable with respect to habitat characteristics found at the already existing stations.

All stations remained fixed throughout the study except for one located immediately below the dredging activity (R.M. 518.1-518.7). Since the dragline position changed from one sampling date to the next, a corresponding move of this station was made so that its positon would always remain the same in relation to the dredging activity.

Field samples were scheduled to be taken on a monthly basis. Physicochemical and benthic population statistics were taken from the start of the study. Fish sampling started with the outset of dredging. Frequent floods during the postdredging study period allowed only 3 months of physicochemical-benthic data to be collected. Fish sampling was attempted during this period, but it met only limited success.

Dissolved oxygen, total alkalinity, free carbon dioxide, chlorides, total hardness and settleable solids were determined for water taken just below the water surface with a Kemmerer sampler. Analyses were made according to standard methods (A.P.H.A., 1971). Turbidity and silica were determined by Hach Chemical Company's DR colorimetric methods. Specific conductance was measured with a Beckman conductivity meter, and pH was measured with a Beckman pH meter. Light penetration was determined with a Secchi disk. Air and water temperatures were measured with a standard centigrade thermometer. Average depth of each station was determined by a line transect method and a meter ruler. Volume of flow and rainfall records were obtained from the Brazos River Authority, Waco, Texas. Noted changes in substrate of each station were recorded as the study progressed.

Two methods were used to collect macroinvertebrates. One method utilized a Surber's bottom sampler. Seven samples were taken with this device by the line transect method at R.M. 527, 522, 519 and 511.5. The second method employed a modification of the Multiple-plate sampler described by Hester and Dendy (1962). A long support rod anchored with a concrete block held the plates in position. Five of these devices were exposed 31 days at R.M. 520, 518.7, 518, 517 and 516 during the dredging period of the study.

The micro- and macroinvertebrates collected were separated by a Number 30 standard seive in the field. The macroinvertebrates were the organisms used for this study, and they were stored in an 80 percent ethanol preservative for laboratory analysis. Organisms were identified to genus by using Pennak (1953) and Hilsenhoff (1970) keys. In addition, specimens were sent to Dr. Kenneth Stewart (North Texas State University) and Dr. Sidney Edwards (Southwest Texas State University) for verification. Occurrence of genera and their numbers was recorded for each station sampled.

Fish samples were taken by electrofishing, gill netting and seining. A backpack shocker was used 30 minutes at each sample site. Five 150-foot experimental gill nets were used per station sampled. An experimental gill net is a net containing webbing of different mesh sizes. The mesh sizes employed were: 1-, 1½-, 2-, 2½-, 3-, 3½-inch square measure. A 20-foot common seine (3/16-inch square mesh measure) was used to make two 50-foot hauls at each sample location.

RESULTS

A visible change in the river was seen at the dredging site. An island that was approximately 1.6 miles long by 150 feet wide was constructed in the middle of the stream (R.M. 519.8 to 518.2). During construction of the island the river flow was forced to change course from one bank to the other. A portion of this island was never moved to the gravel plant for processing. The sand from this portion shifted downstream to form a sheet 150 feet long by 100 feet wide with a 3-foot depth. The area of dredging and the area immediately below dredging were changed from a sand-gravel-organic material complex to a shifting sand and inorganic silt condition. Logs and brush were removed from the dredged area. The stream at the dredging site was also increased in average depth from 1 to 3 feet (depth measurements taken at water flow under 1,000 cfs). The maximum depth at this station reached 7 feet during the dredging period while maximum depths at other stations never exceeded 2.5 feet.

Figure 2 (top) gives average turbidity readings before, during and after dredging. The values represent both high flow (over 1,000 cfs) and low flow (under 1,000 cfs) data. High flow was a result of water releases from Lake Granbury. No corresponding increase in turbidity was observed with these releases. Increased flow and turbidity caused from rainfalls on the watershed was omitted from this analysis so that the effects of dredging under normal operating conditions could be evaluated. The dredging operation caused an increase in turbidity at the dredging site (R.M. 519). Transparencies comparable to those found above the dredging area (R.M. 527 and 522) had returned by the time the water reached a station 7.5 miles downstream (R.M. 511.5). After the dredging operation ceased, turbidity conditions returned to predredging levels.

To establish a better picture of how turbidity caused by dredging activities affected the water quality of the river, several stations were sampled on a plant operating day (Figure 2, bottom). On this day turbidities remained high for 2 miles below the operation. A considerable decrease in turbidities was observed 3 miles downstream. Further decreases were evident 7.5 miles downstream, but turbidity measurements were still not as low as those taken above the gravel plant. The cause for higher turbidity at R.M. 517 and 514 was probably a product of the time samples were taken at the stations and degree of activity at the dredging site.

Before dredging started all measurements for settleable solids were less than 0.05 ml/l. Water used to wash sand and gravel at the plant increased the solids to 2.35 ml/l where it entered the river (R.M. 518.9). This increase occurred even though the washwater had passed through a settling pit. An average of less than 0.25 ml/l was found just below the dredging area (R.M. 518.1 to 518.7). All settleable solids were deposited on the river bottom within 1 river mile of the dredging operation.

Measurements of other physicochemical variates taken from R. M. 522 were compared to corresponding ones taken from R.M. 518.9, 518.7 to 518.1 and 511.5. No significant changes were observed during the study in the variability of measurements taken for water temperature, pH, specific conductance, dissolved oxygen, free carbon dioxide, silica, chlorides and hardness (F-tests; 0.05 level). Significant variability in measurements of total alkalinity was found at the dredging site during the dredging period of the study. But, it should be pointed out that, because of the turbid conditions at the dredged site, the end points used for determining alkalinity were difficult to see, and this could account for the significant finding. In general, the observed minimum and maximum values for all of these water quality constituents taken during the various phases of the study remained similar from station to station. Other studies have shown similar results (Ellis, 1936; Ziebell and Knox, 1957; and Casey, 1959).

Changes in occurrence and density of benthic macroinvertebrates among sample stations at R.M. 527, 522 and 511.5 were observed (Figures 3, 4 and 5). These changes are partly due to differences in substrate found at each station. Usinger and Needham (1954) have found similar conditions in populations of bottom organisms from area to area because of substrate differences. The macroinvertebrate populations for each of these three sampling sites also fluctuated from month to month. These fluctuations are expected because of the variation associated with sampling, emergence, reproduction, foraging of predator species, periodic stream scouring by large volumes of water, etc. Dynamics of benthic populations at these stations appeared normal.

Dredging had an adverse effect on the benthic community (Figure 6). River Mile 519 had an abundant and diverse population of benthic macroinvertebrates before dredging. After dredging began, a large reduction in number of organisms and number of genera occurred. This reduction was due to physical damage of the stream bottom caused by dredging activity. Signs of recovery had started in January, 1972 after the draglines moved upstream, but periodic dredging in the area never allowed populations to reach before dredging conditions. Even after dredging had stopped, populations did not recover before this study ended.

Figures 3, 4, 5 and 6 also show diversity indices (d). These values were calculated by using equations derived from Patten (1962). It was interesting to these writers that d was not a sensitive measure of the dredging effects on macroinvertebrates at R.M. 519 unless all of the organisms were eliminated (Figure 6). No statistical difference between mean d values for before, during and after dredging time periods occurred (F-test; 0.05 level). Apparently the probability of collecting a specific genus of macroinvertebrates remained fairly constant throughout the study. In other words, all kinds of organisms and their numbers appeared to be affected in a proportional manner at the dredged site.

Multiple-plate samplers indicated benthic macroinvertebrates were affected by silt accumulation caused by dredging (Figure 7). Number of organisms was reduced 97 percent at the dredging site (R.M. 518.7) as compared to an upstream site (R.M. 520). At R.M. 517 the bottom fauna had 50 percent of the numbers observed at the above site. The stream recovered rapidly from this point on, and samples from R.M. 516 indicated normal conditions. Number of genera decreased only slightly at dredging (R.M. 518.7); thus, there was no obvious evidence that any one type of aquatic macroinvertebrate was more intolerant of siltation than any other type.

Sport fishes, rough fishes and minnow populations at the dredging site (R.M. 519) were compared to those of an upstream station at R.M. 524 (Figure 8). See Figure 9 for separation of fishes to sport, rough and minnow groups. Rough fishes increased in the dredged area in number, but no change was seen in species composition. No obvious change was seen for sport fish populations. Minnows appeared to be affected more than other fishes since a decrease in both number of individuals and species occurred.

Number and species of rough fishes, sport fishes and minnows collected are shown in Figure 9. The most apparent increase for rough fishes in the dredged area was made by river carpsucker. Threadfin shad was the only species that decreased. Drum and gray redhorse statistics did not change. For sport fishes, a substantial decrease in number of spotted bass was observed in the dredged area.

Also decreases were noted for largemouth bass, green sunfish and bluegill. Redear disappeared from the samples. Increases were observed for white crappie, warmouth, channel catfish and flathead catfish. However, crappie had the only pronounced increase. No change in population numbers of longear sunfish were seen. In the case of minnows, a large decrease in blacktail shiner and red shiner populations was noted in the area of dredging. Several species (silver chub, redfin shiner, stoneroller, blackstriped topminnow and orangethroat darter) were missing altogether. Bullhead minnow, mosquitofish, brook silverside, Mississippi silverside and logperch did not appear to be affected adversely.

DISCUSSION

There would appear to be sufficient evidence that the gravel operation on the Brazos River had a limiting effect on benthic organisms. Physical damage to the habitat that caused a change in substrate from a gravel to a sand-silt bottom was mainly responsible. The gravel condition was the most productive substrate since it was more stable and provided more shelter and food for bottom organisms than sand and inorganic silt. The fact that insect populations are less abundant on sand bottoms and more abundant on gravel had been well established (Pennak and Van Gerpen, 1947; Smith and Moyle, 1944; Sprules, 1947; and Tarzwell, 1937).

Increased turbidity caused by the dredging operation may also account in part for the observed decrease in benthic organisms. Drift rate of bottom organisms has been shown to increase with increase in turbidity levels (Gammon, 1970). The effects of turbidity directly on fishes probably were not significant since critical levels reported by Wallen (1951) were never reached.

Observed changes in minnow and game fish populations were surely due to a combination of factors among which disappearance of sheltered areas and reduction of food organisms were most apparent. Logs, brush and gravel served as shelter to these fishes as well as sources of food organisms. Shifting sand and siltation in the dredged area and the immediate areas below dredging decreased or destroyed shelters. The result was that fishes had no place to hide and food chains leading to them had been deleteriously affected. Because of this many fishes were either reduced in number or driven out of a considerable stretch of the river. A corresponding increase of less desirable fishes was seen. Such changes in fish populations associated with siltation have been observed many times before (Aitken, 1936; Casey, 1959; and Trautman, 1957).

From the aesthetic point of view, dredging was displeasing. Several miles of the Brazos River were turbid because of the dredging operation, and there was always a dragline in the middle of the river. Trees on the bank were either partly or completely covered by huge gravel piles. Trees were cleared to make room for buildings and a settling pit. Much of the operational waste (old vehicles, barrels, sand and gravel piles, buildings, etc.) was left on the bank after the gravel operation had closed down.

There is no doubt from this study that gravel operations can influence stream substrate type, reduce the abundance of bottom-dwelling invertebrates and change fish populations to favor less desirable species. The standing crop of food organisms and important game fishes such as the spotted bass may be permanently lowered unless gravel and some type of vegetative shelter are returned to areas affected by dredging. This is not likely to happen because of the numerous dams that have been constructed on the Brazos River. Flows below these structures are not sufficient to move gravel to dredged areas and flush inorganic sediment from pools. Continued dredging will eat away at various sections of the river until significant harm to its productive capacity has occurred.

In the case of the Brazos, this primarily means a change from a gravel to a sand bottom. Our observations in this study and our review of literature bring us to the conclusion that dredging should be halted in the streams of Texas in order to prevent their gradual but definite biological deterioration.

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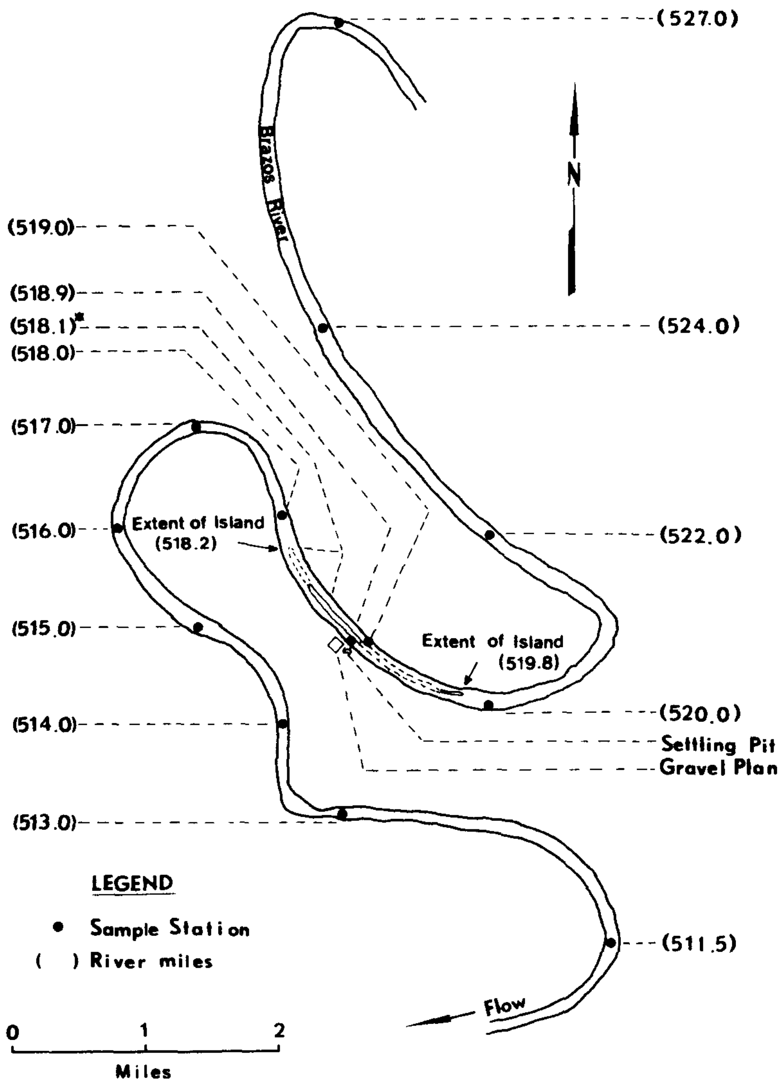

Figure 1. Brazos River in Hood and Somervell Counties, Texas showing gravel plant and sample station sites, 1971-73 (* = R.M. 518.1 to 518.7).

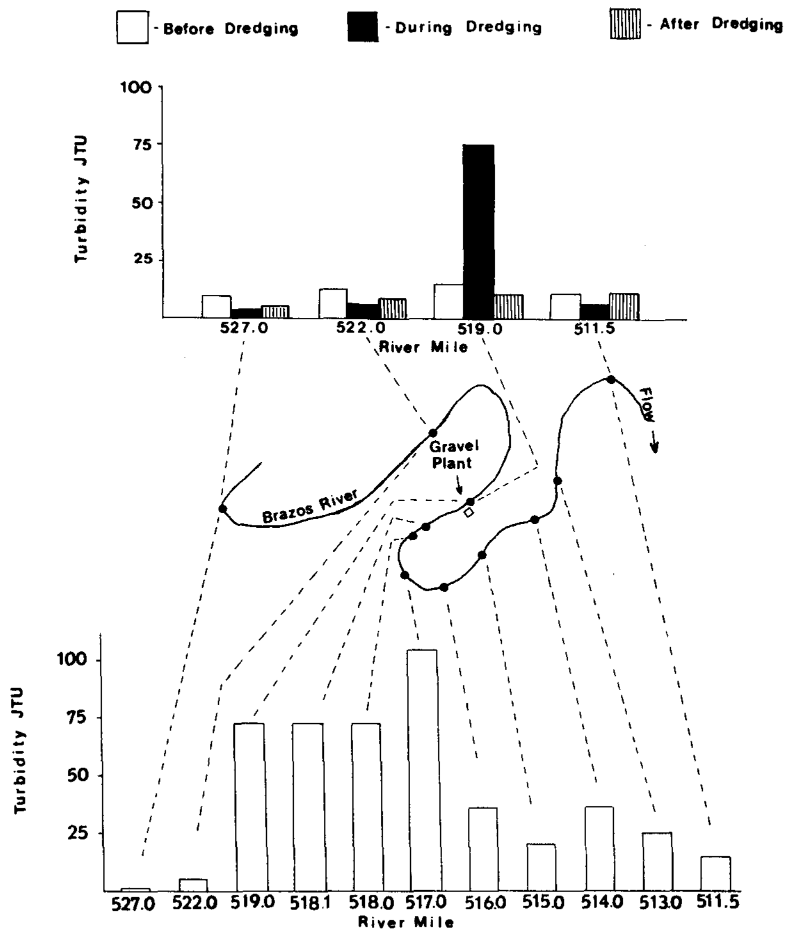

Figure 2. Average turbidity in Jackson Turbidity Units (JTU) of the Brazos River before, during and after dredging for 1971-73 (top). Low flow (under 1,000 cfs) and high flow (over 1,000 cfs) data have been combined. Turbidity at low flow on July 20, 1972 (bottom).

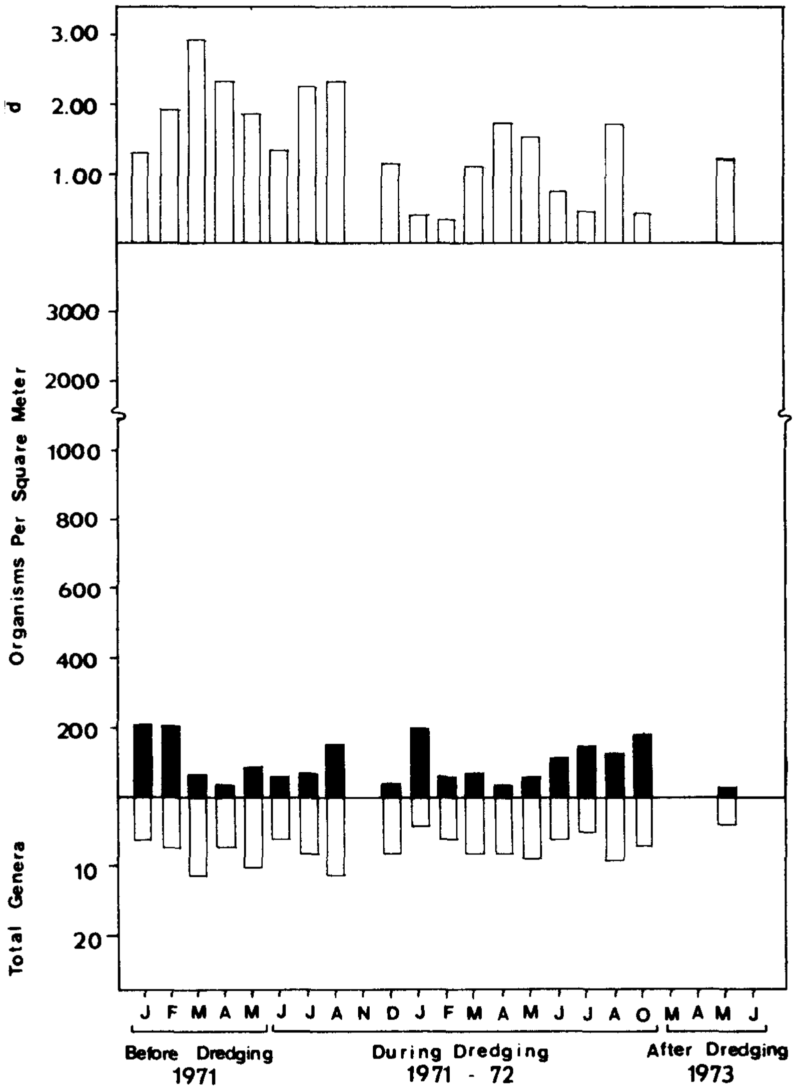

Figure 3. Species indices and populations of benthic macroinvertebrates collected by Surber bottom sampler at River Mile 527 before, during and after dredging, Brazos River, 1971-73.

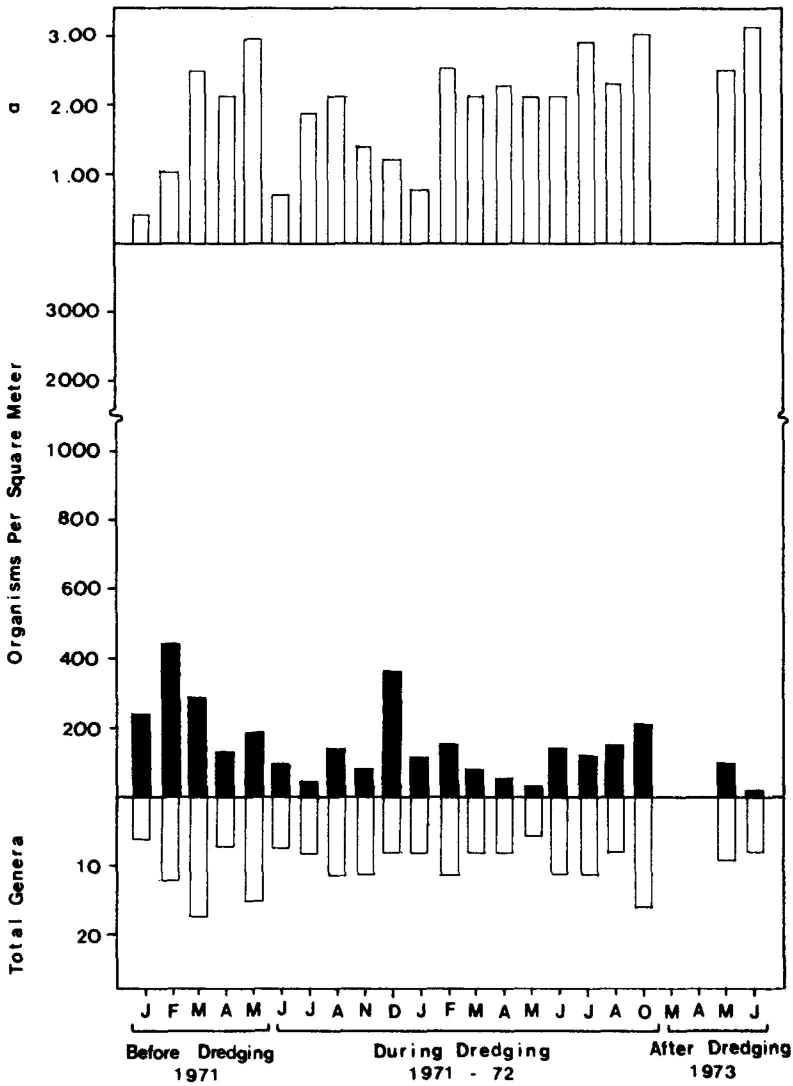

Figure 4. Species indices and populations of benthic macroinvertebrates collected by Surber bottom sampler at River Mile 522 before, during and after dredging, Brazos River, 1971-73.

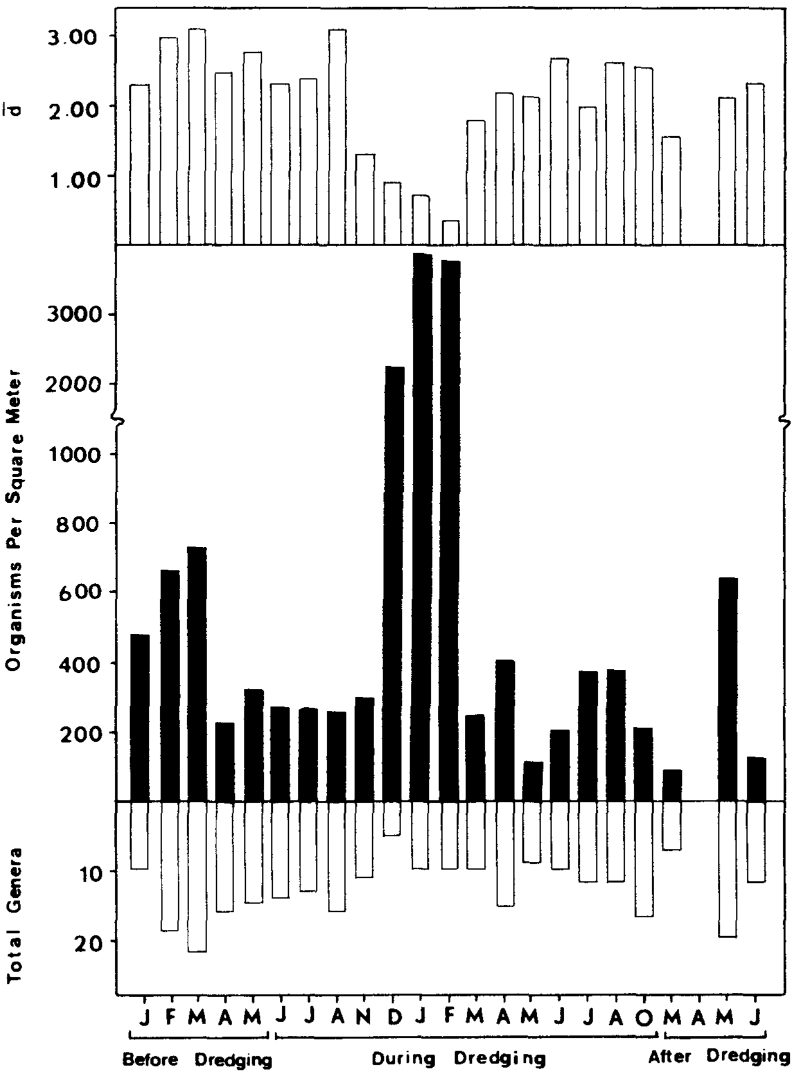

Figure 5. Species indices and populations of benthic macroinvertebrates collected by Surber bottom sampler at River Mile 511.5 before, during and after dredging, Brazos River, 1971-73.

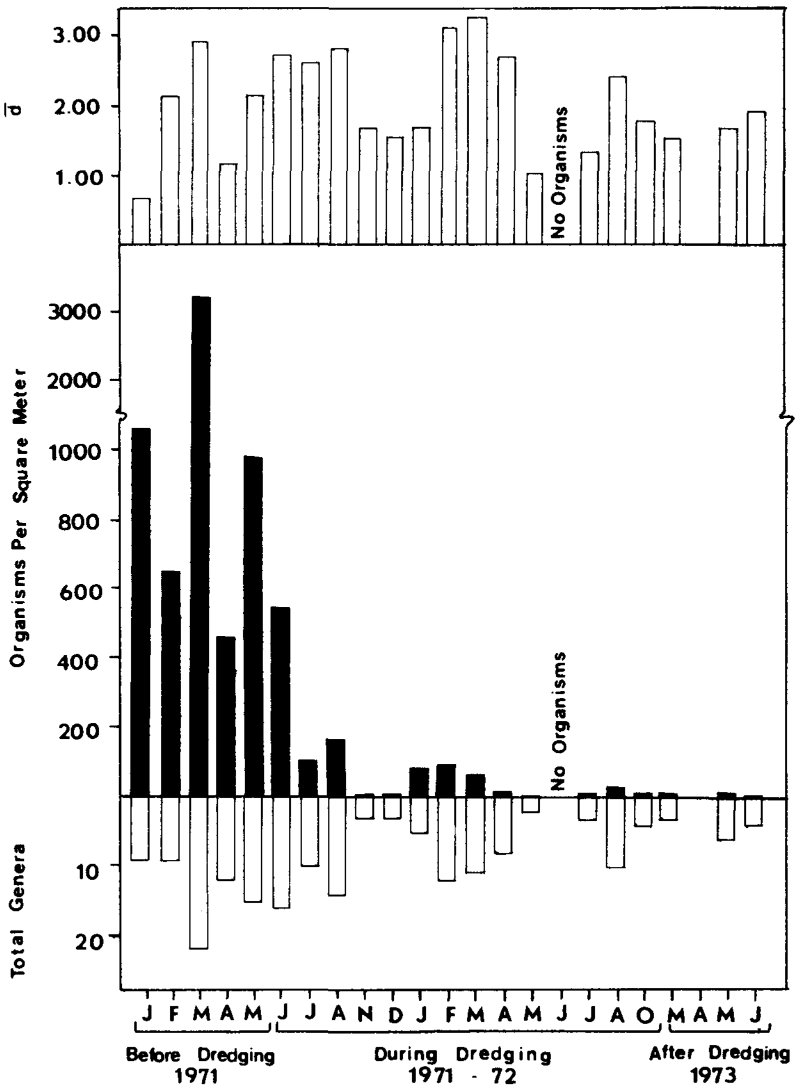

Figure 6. Species indices and populations of benthic macroinvertebrates collected by Surber bottom sampler at River Mile 519 before, during and after dredging, Brazos River, 1971-73.

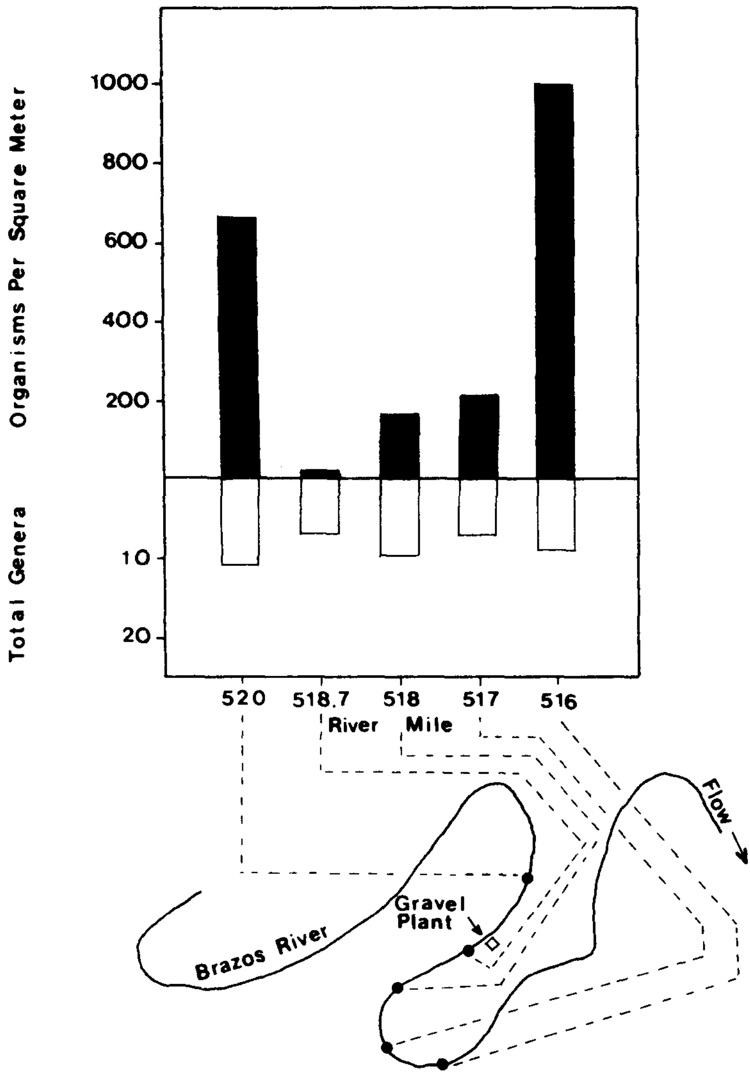

Figure 7. Populations of macroinvertebrates collected by Multiple-plate samplers during dredging, Brazos River, 1972.

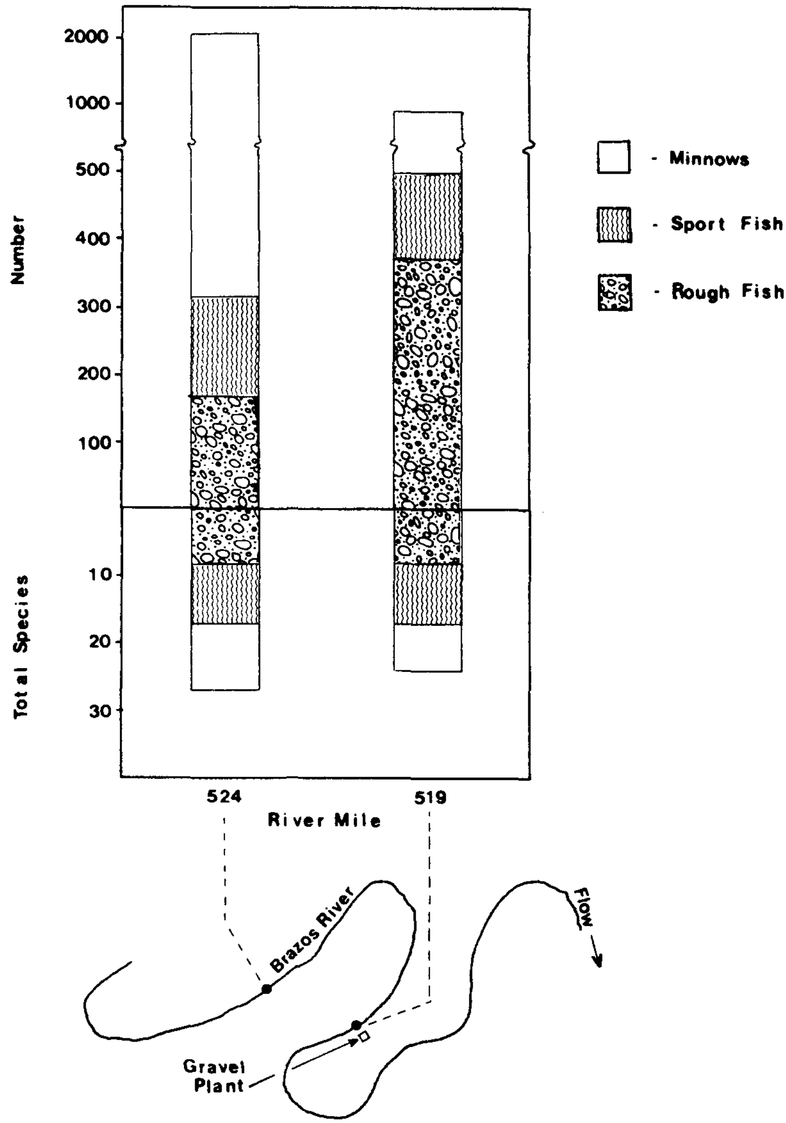

Figure 8. Fish data, Brazos River, 1971-72 (combined electrofishing, seining, and gill net samples).

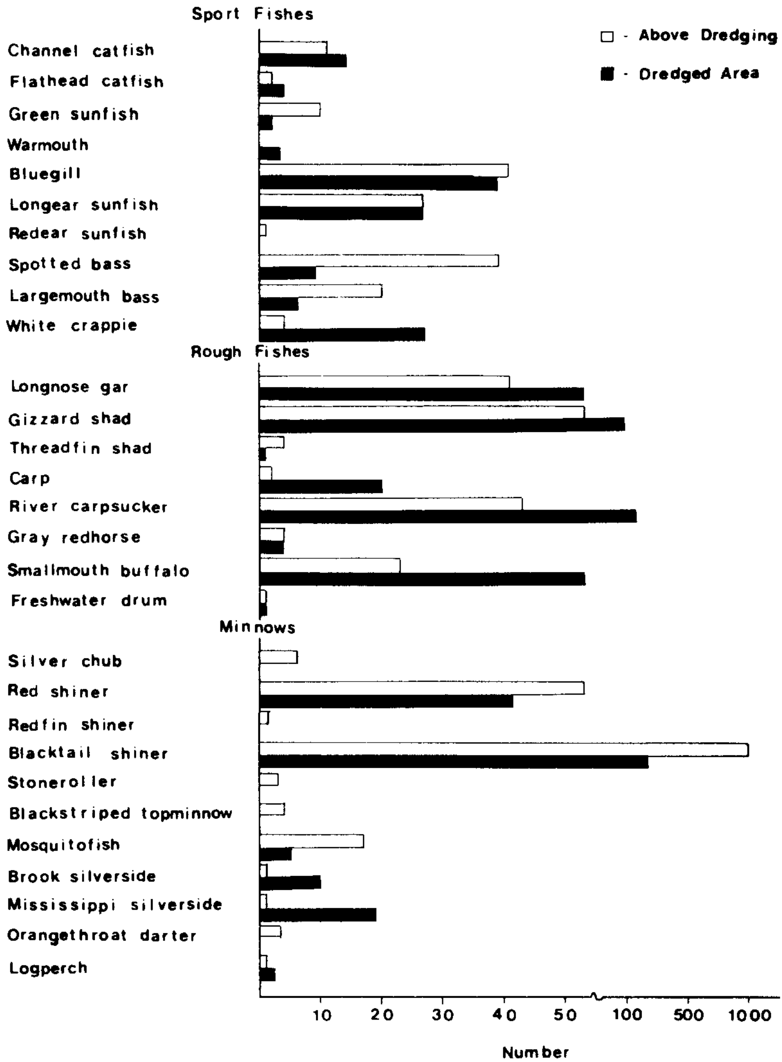

Figure 9. Number of sport fishes, rough fishes and minnows (combined electro-fishing, seining and gill net samples), Brazos River, 1971-72 (Common names obtained from Bailey, *et al.*).