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**STUDY OF IMPORTANCE OF BACKWATER
CHUTES TO A RIVERINE FISHERY**

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Prepared for:

Army Engineer Waterways Experiment Station

August 1974

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)

20. ABSTRACT (Continued)

amount of data has been published. The direct effects of the physicochemical factors (current, turbidity, substrate, and dissolved oxygen) were examined. Based on the literature, it was concluded that extra-channel areas provided the most favorable conditions of existence for the fishes recorded as present in the study area. (Extra-channel areas include the complex of habitats classified as side channels, river lakes and ponds, and sloughs.) Identification is made of those specific fish that would and those that would not be affected by the hypothetical physicochemical conditions that would prevail following the loss or alteration of the extra-channel areas.

Unclassified

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PREFACE

The work described in this report was performed under Contract DACW 39-73-C-0015, titled "Study of Importance of Backwater Chutes to a Riverine Fishery," dated Sept 1972, between the U. S. Army Engineer Waterways Experiment Station (WES), Vicksburg, Mississippi, and the Fisheries Research Laboratory, Southern Illinois University, Carbondale, Illinois.

The report is a review of the literature basic to the preparation of an environmental impact statement in connection with proposed changes in the channel of the Mississippi River between St. Louis, Missouri, and Cairo, Illinois. The report was prepared by Mr. H. L. Schramm, Jr., Research Assistant, and Dr. W. M. Lewis, Director of the Fisheries Research Laboratory, Southern Illinois University.

The contract was monitored by William P. Emge under the general supervision of Dr. John Harrison, Chief, Environmental Effects Laboratory, WES. The Directors of WES during the study and preparation of the report were BG E. D. Peixotto, CE, and COL G. H. Hilt, CE. Technical Director was Mr. F. R. Brown.

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U.S. ARMY ENGINEER
WATERWAYS EXPERIMENT STATION
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VICKSBURG, MISSISSIPPI 39180

FINAL PROJECT REPORT

STATE Illinois

CONTRACT NO. DACW39-73-C-0015

PROJECT TITLE Study of Importance of Backwater Chutes
to a Riverine Fishery

PERIOD COVERED September 1, 1972 - May 31, 1973

PREPARED BY Harold L. Schramm, Jr., Research Assistant
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INTRODUCTION

This is a review of the literature basic to the preparation of an environmental impact statement in connection with proposed changes in the channel of the Mississippi River between St. Louis, Missouri, and Cairo, Illinois.

Emphasis is on the possible effects on the side channels of altering the river channel. An attempt has been made to condense and organize the available literature in such a way that the importance of the side channels is apparent. Basically, the approach is to describe the habitats which occur in the above mentioned section of the Mississippi River, to discuss the conditions of existence most favorable and least favorable to the biota, and, on this basis, to conclude the effects that these changes might have on the biota, especially the fishes.

To determine the environmental impact of the loss of backwater areas, a comprehensive review of the literature was conducted by the author from 1 September 1972 to 31 May 1973. Approximately 600 hours were spent retrieving and reviewing literature in two general areas: literature pertaining to the physical, chemical, and biotic factors of larger rivers, and literature pertaining to the biology of the fishes recorded as present in the section of the Mississippi River of concern. One hundred and eighty hours were spent preparing the report.

The limited data that were available has been tabulated. The conclusions of this report are based on these tables, and on the conclusions and information supplied by the authors whose works were employed.

Initial access to the pertinent literature relied on

several specific bibliographies: Mechanic (1971); Sport Fisheries Abstracts; Fishery Publication Index, 1920 - 1954; U.S. Government Publications (1972); MacDonald (1921); Biological Abstracts; and UMRCC (1967). Additionally, the bibliographies of each article used were consulted for references.

The literature reviewed is organized into three parts: classification of the habitats; comparison of habitats, including physical and chemical conditions, and the biota of rivers, excluding fish; and the ecology of the fishes. Two discussions of factor interactions are presented. The first describes the interactions among the biota, excluding the fish, and the interactions between the biotic elements, excluding the fish, and the physicochemical factors. The second discussion of factor interactions pertains to the fish and other biotic elements. These discussions are designed to serve as statements of the impact of the proposed engineering works on the river environment and the river fishery.

CLASSIFICATION OF HABITATS

The Fish Technical Section of the Upper Mississippi River Conservation Committee made a recent study of river habitats to standardize nomenclature and description. The habitat types are: Main Channel, Main Channel Border, Tail Waters, River Lakes and ponds, Side Channels, and Sloughs (UMRCC, 1967).

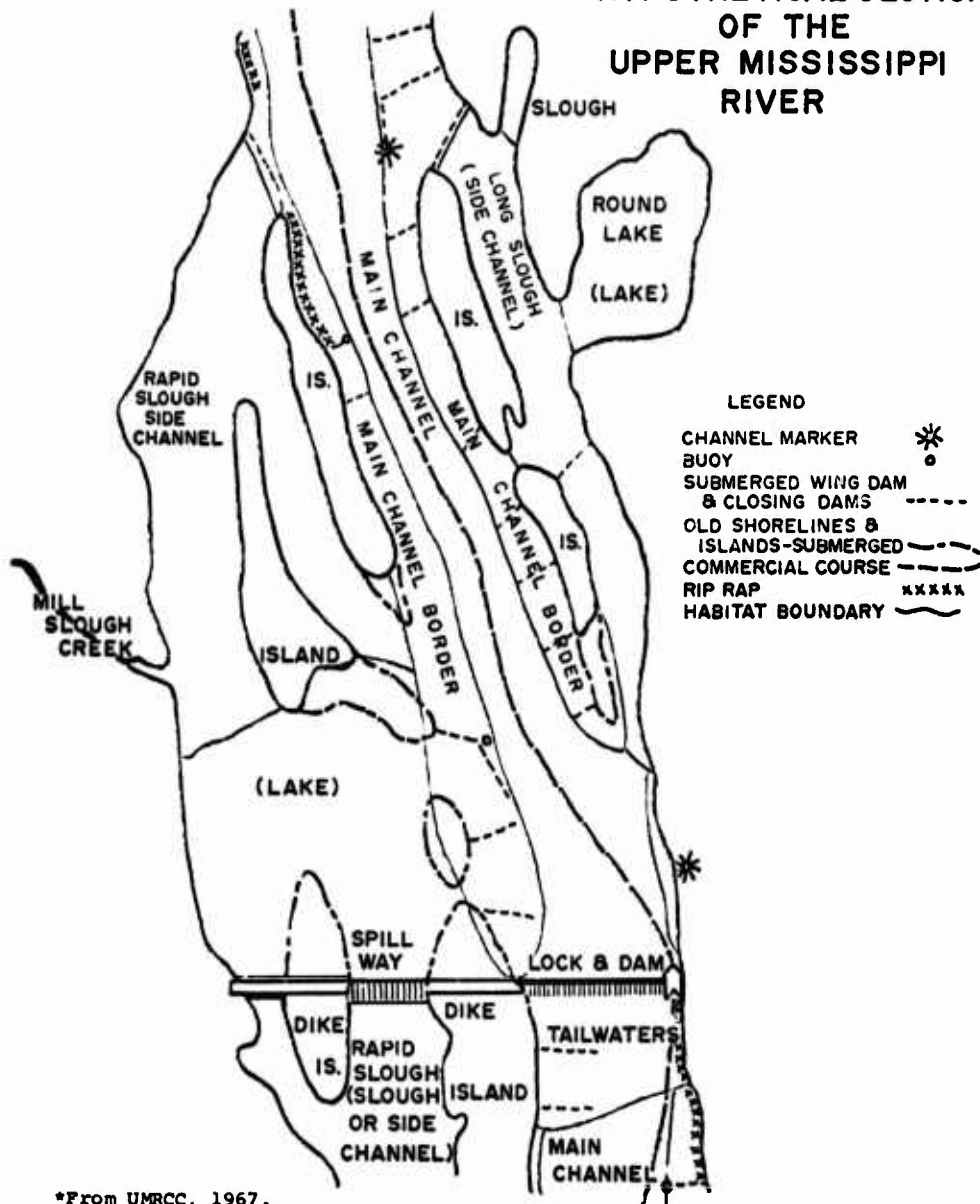
These habitats are pictured in Figure 1, and will be briefly described.

Main channel includes only the portion of the river in which large commercial craft can operate. It is defined by combinations of contraction works (wing dams and riprap), river banks, islands, and buoys and other markers. It has a minimum depth of nine feet and a minimum width of 400 feet. A current always exists, varying in velocity with water stages. The bottom type is mainly a function of current: sand, silt over sand, and occasional patches of gravel are the main types. Most of the main channel is subject to scouring action during periods of rapid water flow and by passage of tow boats in shallower stretches. No rooted aquatic vegetation is present.

The main channel border is the zone between the nine-foot channel and the main river bank, islands, or submerged definitions of the old main river channel. It includes all areas in which wing dams occur along the main channel. Buoys often mark the channel edge of this zone. Where the main channel is defined only by the bank, a narrow border still occurs, and often the banks have riprap and fair to good fish habitat. Dredge spoil has been placed in some sections of this zone, sometimes covering the wing dams. The bottom is sand or silt. Little or no rooted aquatic vegetation is present. This zone provides some of the better fishing along the river at certain times of the year.

Figure 1*

HYPOTHETICAL SECTION OF THE UPPER MISSISSIPPI RIVER



*From UMRCC, 1967.

Tail waters include the main channel, main channel border, and other areas immediately below dams which are affected by water passing through dams and locks.

Side channels include all departures from the main channel in which there is current during normal river stages. The gradations in this category are wide, ranging from fast flowing watercourses with high banks to sluggish streams winding through marshy areas. The banks are usually unprotected; undercut or eroded banks are common along side channels near their departure from the main channel. Bottom type varies from sand to silt. There is no rooted vegetation in areas of swifter current, but vegetation is common in the shallower areas which have silt bottoms and moderate to slight current. Other terms that have been used for this habitat are sloughs, running sloughs, chutes, cuts, cut-offs, and canals.

River lakes and ponds is a general category for the following lake types described by Hutchinson (1957):

- Type 49 - lakes formed by fluviatile dams,
- Type 55 - oxbows or isolated loops of meanders,
- Type 56 - lakes formed in depressions on floodplains,
- Type 57 - lakes formed between natural levee and scarp, and
- Type 73 - lakes formed by man-made dams.

Only those lakes having some connection with the river during normal water stage are usually considered. River lakes and ponds may or may not have a current, depending on location.

Bottoms are mostly mud and silt, often two, or more, feet thick. Many of these waters have an abundance of rooted vegetation, both submerged and emergent. They are often surrounded by marsh land. The term backwater has often been used to name this habitat. Using this present classification system, backwaters and bayous are considered either river lakes and ponds or sloughs (see following habitat type description) depending on specific characteristics.

Sloughs include all the remaining aquatic habitat in the river. Certain sloughs border on the "lake or pond" category; other sloughs approach the characteristics of "side channels". Sloughs may be former side channels that have been cut off or have only intermittent flow. They may be relatively narrow branches or off-shoots of other bodies of water. They are characterized by no current at normal water stage, muck bottoms, and an abundance of submerged and emergent aquatic vegetation. Another term for slough is "dead slough".

The present study concerns the environmental impact of dikes (wing dams) on backwater chutes between St. Louis, Missouri, and Cairo, Illinois. These backwater chutes can, in general, be called side channels, following the UMRCC habitat classification scheme.

A full treatment of the environmental impact of changes in side channels necessitates the study of additional habitat

types. The conditions of existence in sloughs and river lakes and ponds can be dependent on the hydrologic conditions of the side channels. Also, the side channel itself can exhibit a diversity of environmental conditions, e.g. bottom type, depth, channel morphometry, and velocity of flow. Because of the potential interdependence and similarity, the complex of habitats classified as side channels, river lakes and ponds, and sloughs will be designated "extra-channel" areas.

Although specific predictions about the effect of wing dams on the hydrologic conditions of the side channels cannot be made without looking at the individual side channel, three general changes are possible: increased volume of flow and decreased volume of flow in the side channel, and closing the side channels from the main channel. The literature review has been directed towards gaining information about side channels and associated habitats, and information about systems which would be similar to the systems resulting from the possible changes of the side channels. The importance of side channels has been determined by comparing the physical, chemical, and biotic conditions of main channels and main channel borders with those conditions of side channels, river lakes and ponds, and sloughs. From knowledge of the effects of changes in the extra-channel habitats, and the importance of side channels and associated habitats, the environmental impact of wing dams

which would close the side channels was determined.

COMPARISON OF HABITATS

It is necessary to compare habitats to determine the benefit of extra-channel habitats to the Mississippi River fishery. A full understanding of the fishery entails a knowledge of physical and chemical limnological factors, phytoplankton, zooplankton, benthos, macrophytic vegetation, and fish. We must investigate the food chains and the environmental factors which affect the constituents and levels of the food chain.

Tables 1 through 9 have been prepared from the available literature on river systems. Emphasis has been placed on slow flowing North American rivers with habitat diversity similar to that found in the Mississippi River from St. Louis to Cairo. Several conclusions can be drawn from these tables.

Physical and chemical factors

Among the physical factors such as current, bottom type, turbidity, water level fluctuation, alkalinity, nutrients, and oxygen concentration, several correlations are apparent. Current has been considered a predominating factor in lotic systems. Although bottom type and turbidity are affected by local geological differences in different areas, Table 1 indicates that faster current areas have a bottom of coarse, hard materials (rock, gravel, bedrock) and higher turbidity (e.g. the Missouri River, Berner, 1951). Slower current areas

have a bottom of soft, fine materials (mud, silt, and fine sand) and lower turbidity. These relationships become more apparent when the extra-channel habitats are compared with the main channel. It can be seen that current varies from reduced to slack in these areas, bottom types are primarily soft mud, silt, sand, often with a top layer of organic matter. Butcher (1927) has shown a gradation of bottom types with current velocity and fall per mile, and stated that current determined bottom type (Butcher, 1933).

Current has been considered the primary factor affecting flowing water systems by its effect on turbidity and sediment load (Lakshminaryana, 1965; Jackson and Starrett, 1959; Dill, 1944; Reinhard, 1931; and Briggs, 1948). Turbidity is greatly reduced with reduced velocity. Morris, et al. (1968) found silt turbidity of the channel to be twice the value of a slack water chute in a study of the Missouri River. Stuart (1960) has shown a correlation between increased current, lack of substrate diversity, and increased turbidity as a result of dredging works. Ellis (1936) considered silt and turbidity to be the major factor that influences the biota in lotic systems due to its reduction of low wavelength light, the retention of organic matter and inorganic nutrients, which can disrupt the chemical cycles, and the covering of organic matter on the substrate, which will retard oxidation and

change the water chemistry. He stated that anything that affects the current will affect silt turbidity. Edwards (1969) adds that siltation can change or eliminate habitats.

Although no direct data are available to demonstrate the water fluctuations associated with different habitat types, Stuart (1960) has reported increased fluctuations in water level following channelization. Stuart supported several reasons for the increased fluctuations of level. The straightened watercourse and smoothed, homogeneous bed result in a loss of bed friction and an increase in effective slope. This increases the velocity of flow, and, thus, allows a given amount of water to pass downstream faster. The longitudinal and lateral asymmetry and roughness of a diverse substratum would hinder the flow and slow the rate of fluctuations. A second reason is the loss of areas of water storage which would act as reservoirs. These areas would augment the volume of discharge of the river during periods of low water, and, therefore, tend to stabilize the flow.

A study of correlations between habitat types and chemical factors (Tables 2 and 3) indicates that most differences in chemical factors are due, not to the influence of habitat types within the river itself, but rather are due to the geographic and geologic area through which the river flows (Griffiths, 1923). Alkalinity will be higher in calcareous

regions. The quantity of inorganic and organic nutrients can be greatly increased by domestic and industrial pollution (e.g. the upper Mississippi River, Reinhard, 1931).

Oxygen values have been reported as the range of values reported by various authors. This takes into consideration the seasonal differences in dissolved oxygen due to temperature and photosynthesis and respiration. The dissolved oxygen values are, in general, lower in the main channel than the extra-channel areas. Since, in running water systems, dissolved gases are usually more or less in equilibrium with the atmosphere (Hynes, 1970), this observation appears aberrant, but aeration by current is not the only factor which affects dissolved oxygen. Washed in organic matter and the decrease of photosynthesis caused by turbidity can lower oxygen concentrations (Dorris, et al., 1963; Gessner, 1961). This is further discussed in the section on phytoplankton. Also organic matter will tend to remain in circulation in the water column instead of settling to the bottom, and, therefore, increase the oxygen demand. Under conditions of complete stagnation, high organic content can lower oxygen concentrations (Kajak, 1968). Wave action plays a role in aeration of lake-like habitats (Boruff, 1930).

The importance of physical and chemical factors, and the interaction of the factors, are discussed more fully in the

sections dealing with the various groups of the biota.

Phytoplankton:

The phytoplankton forms the base of aquatic food chains. Although not the exclusive source of nutrition for the consumers in the food web, their role in primary production is essential to the system (Hynes, 1970). Forbes (1928) outlines the flow of energy from algae and protozoa to zooplankton, to macro-invertebrates, and to small fish. Table 4 shows the taxa, and their abundance, in the different habitat types found in the Mississippi River, St. Louis, Missouri, to Cairo, Illinois. Interpretation of Table 4 is made difficult by the available data which was used to compile the table. Most studies on river phytoplankton have been concerned with the taxa present, with the effect of pollution on the biota, the seasonal periodicity of the biota, or the ecology of the organisms. Only several studies dealt with the biotic differences between habitat types, and of those that did, accurate habitat descriptions are often wanting. For the purpose of this paper, the results of various authors have been categorized into the main habitat classifications used in this paper as accurately as possible. An additional problem involved in using this data to draw valid conclusions is that few rivers have the habitat [^]diversity of the Mississippi River, and, therefore, equal amounts of information are not available for all habitat

types. Table 4 shows that the amount of research done on main channel habitats exceeds that of the extra-channel habitats. This prevents the application of diversity indices to the various habitat types. The first conclusion that can be drawn from Table 4 is the need for research pertaining to biotic differences between the different habitat types within the same river system.

Study of Tables 4 and 5 indicates that Chrysophyta dominate in the habitats under the influence of the current. Cyanophyta and Euglenophyta show reduced abundance and diversity. Comparison of the channel border habitat with the main channel shows that the flora is reduced in diversity. The Chlorophyta are slightly reduced in abundance and the Chrysophyta show an increase in abundance. Cyanophyta show little change, except a filamentous form (Lyngbya) shows a great increase in abundance. The increase in Lyngbya may be due to the decreased current, and possibly the difference in substratum type. The data for Lakes Pepin and Keokuk (Galtsoff, 1924) are useful in indicating the increase in abundance as the current slows. This is especially apparent when the results from upper Lake Keokuk are compared with lower Lake Keokuk. The increased abundance pertains to the Chrysophyta, Chlorophyta, and Cyanophyta. In reduced current and slack current habitats, the chlorophytans are dominant and the cyanophytans

increase in abundance. Fritsch (1903) found green algae decreased in diversity but increased in abundance in backwaters. Fritsch (1902) found that diatoms were the dominant plankters in the backwater areas.

Typical communities have been derived from Table 4. (See Table 5.) It can be seen that the community of dominant organisms in the main channel is made up of the same organisms found in the extra-channel habitats except for the filamentous green algae typical to the river lakes and ponds (Zygnema, Ulothrix, Spirogyra, Chaetophora, and Cladophora) and several cyanophytans (Cathrocystis, Aphanizomenon, and Oscillatoria) typical of standing water. The information in Table 5 indicates that floristic differences in different habitats are primarily due to differences in abundance and not due to changes in species composition.

The limited data on phytoplankton production (Galtsoff, 1924) indicated that production is highest in standing water, lowest in the channel border, and intermediate in the main channel. Data were not available for side channels and river lakes and ponds, but Fritsch (1903) found a richer phytoplankton in the backwaters of the River Thames than in the channel itself.

The source of phytoplankton varies in different river systems. Fritsch (1902, 1903), Zacharias (1898), Kofoid (1908),

Berner (1951), Purdy (1930), and Schmidle (1898) stated that algae are derived from tributary areas (small streams, backwaters, ponds, bays, etc.) above sampling areas. Hartman and Himes (1961) found that impoundments affect phytoplankton for a considerable distance downstream. In larger, deeper rivers phytoplankton are derived from pools, backwaters, and the littoral zone, but the riverbed is the most important source (Butcher, 1932). Blum (1956) found benthic plankton to greatly exceed euplankton. Macrophytic vegetation has been shown to be an additional source of plankton (Fritsch, 1905; Blum, 1960; and Rice, 1938). Galtsoff (1924) used the term "polymixic" to describe the origin of river plankton; i.e. plankton is supplied from the littoral and benthic areas of the river, and from adjacent lakes and ponds of the river basin.

Several physicochemical factors affect the abundance and diversity of phytoplankton. Current is a factor of major importance. Schroeder (1899) stated that plankton is inversely proportional to the slope of the bed. Although some benthic algae are benefited by increased current, in general phytoplankton showed an increase in production in the following order: rapid streams, slow streams, quiet portions of streams (Blum, 1956). Eddy (1934) stated that velocity determined the point in the stream at which plankton development begins.

This is in agreement with Allen (1920): current velocity above a certain level is inimical to plankton algae. High current velocity can cause mechanical destruction of the algae (Hartman and Himes, 1961; Hynes, 1970; Reinhard, 1931; and Galtsoff, 1924). Because of the effect of current on phytoplankton, productivity is different in different areas of the river (Galtsoff, 1924). The following authors are supportive of the reductive effect of current on phytoplankton abundance: Hutchinson (1939), Starrett and Patrick (1952), Coker (1929), Berner (1951), Lakshminaryana (1965), Brook (1954), Brook and Rzoska (1954), and Swale (1969). It has been shown that some current is beneficial to phytoplankton due to a physiological enrichment; i.e. the "diffusion shell" of nutrient poor water surrounding an organism is reduced by current (Whitford, 1960). This can result in increased production (Ruttner, 1963).

The composition of the phytoplankton changes with current. Butcher (1932) found green and blue-green algae to increase in larger rivers. This is in agreement with the increase of these two groups in backwater areas (Fritsch, 1903). Swale (1969) attributed the scarcity of blue-green algae to the absence of areas with slow flow.

Mechanical destruction is one of the direct ways current can affect phytoplankton. All forms are reduced (Hartman and Himes, 1961), but because diatoms are the most tolerant of

current, the composition of the phytoplankton is changed (Hynes, 1970).

Water level fluctuations can cause changes in the phytoplankton. Changes in water level fluctuations are often associated with current, the effects of which have been discussed, but are also associated with nutrient replacement. For this reason, plankton increased following flood conditions (Blum, 1956). Coker (1929) found plankton to increase in inundated areas during floods; this could be due to nutrient enrichment. Plankton has been shown to decrease during flood stages and/or increase under stable conditions by the following authors: Lakshminaryana (1965), Hutchinson (1939), Galtsoff (1924), Kofoid (1903), and Rice (1938).

Turbidity can be a controlling factor of phytoplankton occurrence. The effect of turbidity on nutrients and light penetration, and the relationship with current has been mentioned in the section on physical factors. High turbidity can so effectively reduce light penetration that phytoplankton growth is prevented (Blum, 1956). The inhibitory effect of turbidity on phytoplankton by light reduction has been shown by Lakshminaryana (1965), Berner (1951), and Edwards (1969). Turbidity becomes especially important when the algae of the river bed are considered. Turbidity also causes a settling-out of the plankton (Starrett and Patrick, 1952; and Dill,

1944), or mechanical destruction of the cells (Hynes, 1970).

Reduced current, turbidity, and water level fluctuations are the most favorable conditions of existence for phytoplankton and periphyton production. These physical conditions are associated with the extra-channel habitats.

Zooplankton

The zooplankton is essential to the aquatic food web. Although some larger consumers are herbivorous, phytoplanktophagic, or detritophagic, the zooplankton serve as a link between the primary producers and the higher level consumers -- macroinvertebrates and small fishes.

Table 6 is a list of the zooplankton recorded from various river habitat types and their abundance. The problems associated with interpretation of Table 6 are the same as discussed for Table 3 (see section on phytoplankton), but several conclusions can be drawn.

Rotifera dominate in the main channel, both in number and diversity. (See Tables 6 and 7). Rotifers decline in occurrence in the channel borders, where the fauna is quite limited, although Rotifer remains abundant. Rotifers also decline in sloughs. The rotifer fauna of river lakes and ponds exceeds that of the main channel in diversity, but the results indicate that abundance is lower.

Cladocera are also quite diverse in the main channel and

river lakes and ponds, relative to the other habitat types. The greatest abundance occurs in river lakes and ponds.

Copepods are restricted in diversity in the main channel and channel border, and show increased diversity in river lakes and pond habitats. The abundance is lowest in sloughs. The maximum abundance was noted in a bank area of Lake Pepin ($125,000/m^3$). A maximum abundance of $44,000/m^3$ was recorded for the channel border habitat (Galtsoff, 1924).

The protozoans were found to show greatest diversity in river lakes and ponds and the main channel. References are insufficient for the other habitats to allow adequate comparison.

A more precise indication of the effect of reduced current habitats on zooplankton can be seen by focusing on several studies. The dominant genera of rotifers increased in abundance in the slack current section of the Hocking River (Hutchinson, 1939) and the Ohio River (Purdy, 1923). Cladocera and Copepoda showed no change with decreasing current. The reduction of current in Lakes Pepin and Keokuk had little effect on the zooplankters.

A study of typical communities (Table 8) indicates differences between the zooplankton in different habitat types. The rotifers, cladocerans, and copepods of the main channel are also found in the river lakes and ponds and sloughs, but several genera are dominant in the latter two habitats which are only

of occasional occurrence in the main channel (Asplanchna, Lecane, Euchlanis, Triarthra, Noteus, Rattulus, Leptodora, Sida, Moina, and Simocephalus).

Generalizations available in the literature indicate that the abundance and diversity of zooplankton are affected by environmental factors very similar to those factors affecting the phytoplankton.

Current exerts a marked effect on zooplankton. Low zooplankton concentrations were associated with a high stream gradient (Starrett and Patrick, 1952; and Schroeder, 1899). Zooplankton have been found to increase in abundance (Cushing, 1964; Ellis, 1931; Galtsoff, 1924; Kofoid, 1903; Swale, 1969; Hutchinson, 1939; Eddy, 1934; and Brook and Rzoska, 1954) and in diversity in slack current areas. Jones (1941) and Eddy (1934) found the increased abundance and diversity in slack current areas was due to the addition of lenitic species. The entomostraca showed the greatest increases (Coker, 1929; Brook and Rzoska, 1954), although Galtsoff (1924) found rotifers also increased. Galtsoff (1924) found zooplankton to increase near bank areas but found a decreased abundance behind pile dikes. This indicates that current is not the only limiting factor.

Rapid water level fluctuations, in general, tend to reduce the populations, and greatest abundance is associated with

stable conditions (Galtsoff, 1924; and Hutchinson, 1939). Water level fluctuations, excluding the inimical association with current, can be beneficial. An increase in shallow-water areas increased total plankton production (Forbes and Richardson, 1913). It can be seen that inundated areas increase during floods.

Turbidity is deleterious to zooplankton. Silt can interfere with feeding and respiration (Chutter, 1969). A general decrease in zooplankton caused by silt turbidity was found by Eddy (1934) and Berner (1951).

The source of supply of river zooplankton is primarily quiet water areas (Berner, 1951; Ellis, 1931a; Coker, 1929; Reinhard, 1931; Forbes and Richardson, 1913; Chandler, 1937; Schmidle, 1898; Kofoed, 1908; and Galtsoff, 1924). Macrophytic vegetation contributes some zooplankton to the main channel (Monakov, 1969). This enrichment lasts up to five miles below the source area (Hartman and Himes, 1961). Zooplankton are also affected by mechanical destruction in the current (Reinhard, 1931; and Hynes, 1970).

Benthos:

The benthos is an integral component of the river food web. Many of the larger consumers in the river are, at least in part, benthophagic. Table 8 is a compilation of benthos found by various researchers categorized into major habitat

types. Problems of interpretation of this data are as discussed for Table 3 in the section which discussed phytoplankton, except the available literature on benthos shows as even greater preponderance of data about main channel fauna.

To simplify the interpretation of Table 8, only those organisms frequently utilized for food by fish have been compared. The data indicates no striking differences between the different habitats for the following groups: Diptera, Ephemeroptera, Trichoptera, Oligochaeta, Gastropoda, and Pelyceoda.

A more precise understanding of faunistic differences between habitat types can be seen by a detailed study of the work of several authors. Morris, et al. (1968), studying the effect of channelization on the Missouri River (see Table 8), found that channelization resulted in the elimination of gradually sloping bank areas and chutes (side channels). Current velocity, fluctuations in water level, and mud bank area increased. The oligochaetes increased in abundance with channelization. This increase was due to the increase in mud bank area. Ephemeroptera and Trichoptera decreased in abundance. The standing crops were highest in the chutes and mud bank areas of both the channelized and unchannelized sections. Mikulski (1961) found the greatest benthic density to occur in stagnant areas and found decreased density in the channel borders, and a further decrease in the main channel. Berner

(1951) found a higher standing crop in the mud banks of the channel border compared to the main channel. The production of slack current areas (sloughs, lakes, bays, cut-off bends) exceeded the poor production of the main channel (Dill, 1944).

The above studies and the interpretation of Table 8 indicate the importance of current in benthic production. Benthos showed increased abundance with reduced current velocity. The general reductive effect on benthic diversity with increased current has been found by Briggs (1948), Richardson (1921), Berner (1951), Mikulski (1961), and Berg (1948).

Substrate, turbidity, water fluctuations, depth, and dissolved oxygen are also major factors which affect benthic abundance. Richardson (1921) found the richest benthos in sluggish sections of the Illinois River with heavy sedimentation. Lake production in open water was less than in the river, but the benthos of the shoreline vegetation approached the abundance in the river. Mikulski (1961) observed greater density on "transit silts" (silt deposited in narrow bands on the channel floor) than adjacent sand habitats. Lyman (1943) and Forbes (1928) found mud bottoms were the most productive areas. Barnickol and Starrett (1951) point out the lack of favorable substrates and substrate diversity in sections of the Mississippi River where extra-channel areas are minimized. This results in reduced quantity and diversity of benthos.

Macrophytic vegetation acts as a substrate for benthos, and, indirectly, affects benthos by modifying the bottom. The increased abundance associated with macrophytic vegetation has been shown by Monakov (1968), Moore (1920), Berg (1948), Dill (1944), and Richardson (1921). All of the above works indicate that the substrate affects benthic production.

Fluctuating water levels are generally detrimental to benthic fauna. The occurrence of benthos is affected by uneven flow (Spence and Hynes, 1971). Production decreased under unstable conditions (Berner, 1951; Mikulski, 1961; and Briggs, 1948). Flooding caused organisms to be washed away or carried downstream (Richardson, 1928; Sprules, 1947).

Silt turbidity can exert a severe effect on benthic organisms. Siltation is indirectly deleterious to the bottom dwellers by filling in interstices (Chutter, 1969; Ellis, 1936) and changing and eliminating habitats (Harrison, et al., 1963; Edwards, 1969; Ellis, 1931b). Silt directly affects the benthos by covering the organisms themselves (Ellis, 1931a), and by affecting feeding (Chutter, 1969), and respiration (Paloumpis and Starrett, 1960). Siltation was shown to cause a change in fauna to types less desirable as forage for fish (Eustis and Hillen, 1954). Decreased benthic productivity due to silt turbidity was observed by Berner (1951), Dill (1944), Morris, et al. (1968), Sumner and Smith (1939), and

Taft and Shapavalov (1938). Certain degrees of siltation can be beneficial, as has already been cited in Richardson's (1921) and Mikulski's (1961) work. (See discussion of the effect of the substrate.) In quiet water areas, nutrients and organic debris settle, yielding an increased richness of the substrate for the benthos (Dill, 1944; Lambou, 1959).

Depth has been found to affect the occurrence and abundance of benthos. Greatest production was observed in shallower waters (Ludwig, 1932; Richardson, 1921; Needham, 1934).

Very low oxygen levels, or oxygen depletion, are inimical to almost all aerobic heterotrophs. Various concentrations of oxygen can determine the composition of the benthic organisms. Wiebe (1927) found that low dissolved oxygen concentrations severely affected clean water benthos.

We can now see that the conditions found in extra-channel areas, i.e., reduced current, reduced turbidity, reduced water fluctuations, shallower water, soft substrate, increased concentrations of dissolved oxygen, are the most favorable conditions for the development of benthic communities. The conditions found in the main channel have a reductive effect on the benthos. Therefore, habitats with the general characteristics of extra-channel areas are needed.

Macrophytic vegetation

The macrophytic vegetation of rivers must be considered

when concerned with the fishery. Macrophytes are larger types of flora, visible to the observer without special equipment; macroscopic filamentous algae are considered macrophytes. Macrophytes are used as a food supply by some fish (Moore, 1920). Although macrophytes play a minor role in the food web directly, they are important modifiers of the habitat, producing oxygen, substrate for algae (Butcher, 1933) and various micro- and macroinvertebrates (Berg, 1948; Jones, 1949), and facilitating nutrient circulation. Table 9 illustrates the increase in vegetation in slow flowing areas and in silted areas, compared to fast flowing, hard substrate streams. This is supported by Butcher (1933). Macrophytic vegetation can also be inhibited by silt turbidity (Butcher, 1927; Edwards, 1969), which will reduce light penetration, and, subsequently, photosynthesis (Cordone and Kelley, 1961). Fluctuating water levels can subject the plants to dessication or submerge them to such a depth that insufficient light is available for photosynthesis. It has been shown that fast currents, hard bottoms, high turbidities, and widely fluctuating water levels are characteristics of the main channel areas. Therefore, main channel areas are inimical to macrophytic vegetation. These inimical conditions are, although they may still be present, reduced in extra-channel areas. Westlake (1966) reported that some current caused increased productivity of Ranunculus fluitans, compared

to static water. Therefore, chutes, sloughs, and river lakes and ponds provide more favorable conditions of existence for macrophytic vegetation.

Interaction of biotic elements and physicochemical factors

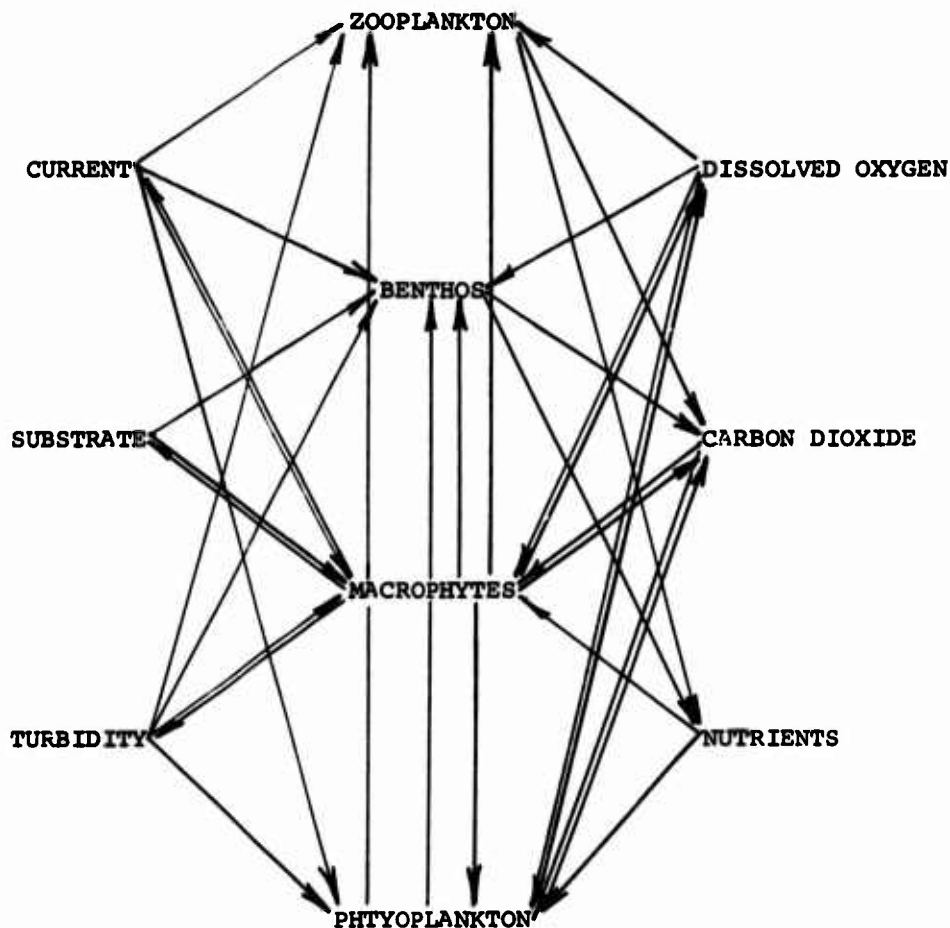
Before proceeding to the presentation of information about the fishes found in the section of the Mississippi River, St. Louis to Cairo, and a discussion of the importance of various habitat types, physical and chemical conditions, and food supplies, it may be beneficial to recapitulate the variables that have been indicated as important to the fishery, and to more fully discuss the factor interactions of these important parameters.

It has been shown that increased current and turbidity are detrimental to the algae, zooplankton, benthos, and rooted aquatic vegetation. Hard, homogeneous substrates are also inimical to the production of benthos and macrophytic vegetation. Dissolved oxygen can limit the fauna, micrometazoan and macro-metazoan. Dissolved oxygen, carbon dioxide, and various nutrients can limit the growth of the microscopic and macroscopic flora. High current velocities, high silt turbidities, and a hard substrate are typical characteristics of the main channel areas of large rivers. Dissolved oxygen is frequently lower in main channel habitats, due to reduced photosynthesis (primarily a function of increased current, turbidity, and depth) and

recirculation of decomposable matter. Nutrients can be limiting in the main channel, due to physical association with silt particles and dilution effects during flooding. From the direct effect of these physical and chemical factors on the flora and fauna, it can be seen that main-channel habitats are inimical to the development of the biota. The extra-channel habitats provide more favorable conditions of existence for the biota, and will hence increase the biota.

To approach a full understanding of the conditions of existence for the flora and fauna which are directly, or indirectly, important to the fishery, we must also consider the interactions among the biota and the interaction of the biotic factors and the physicochemical factors. (See Figure 2.) The zooplankton and benthos utilize algae. Therefore, the algae affect the zooplankton and benthic productivity. The zooplankton and benthos facilitate nutrient cycling by consumption of the algae and excretion of readily decomposed waste products. The oxygen-carbon dioxide cycle is maintained by the algae and macrophytes, suppliers of much oxygen, and the zooplankton and benthos, the suppliers of much of the carbon dioxide. In addition to the production of oxygen, their role in nutrient cycling, the provision of substrates, and as a food supply (Pond, 1905; Hotchkiss, 1941) aquatic macrophytes can be significant modifiers of the environment by their effect on reducing the current

Figure 2
The interaction of physical, chemical, and biotic factors



Legend:

- CURRENT ———> MACROPHYTES indicates current is affected by macrophytes
 MACROPHYTES ———> CURRENT indicates macrophytes are affected by current
 PHYTOPLANKTON ———> ZOOPLANKTON indicates zooplankton are supported by phytoplankton

and turbidity (Butcher, 1933). An additional ramification of rooted aquatic plants is to facilitate the buildup of a soft, often highly organic, due to the death and decomposition of plant parts, stable substrate in areas of heavy stands of phanerogams (Butcher, 1933; Edwards, 1969). Therefore establishment of rooted aquatic vegetation in areas with high currents and turbidities and firm substrate can result in a reduction of these inimical factors. As conditions of existence for macrophytes improve, the abundance of the macrophytes will increase, and thereby, the benefits imparted by these plants to other members of the food web will subsequently increase. Of course the beneficial effect will be maximized in extra-channel areas where conditions are more favorable for the development of rooted vegetation; i.e., the habitat which favors increased macrophytic vegetation will receive the greatest degree of benefit provided by the vegetation.

It should now be obvious that the conditions of existence associated with extra-channel habitat types are more favorable for the production of organisms related, directly or indirectly, to the food of fishes. This is supported by the work of Dill (1944), Eggleton (1939), Richardson (1921), and Stuart (1960). The favorability of these conditions of existence is determined primarily by physicochemical conditions, and when the conditions of existence become increasingly suitable for the biota,

biotic factors and factor interaction can additionally increase the favorability of the habitat.

An indirect benefit of the favorable conditions of existence for development of the biota in extra-channel areas is self-purification of organically polluted water.

The high biological oxygen demand necessitated by the decomposition of organic compounds is best met by the oxygen production of the primary producers (Boruff, 1930; Marsson, 1911; Richardson, 1928; Purdy, 1930). The presence of adequate oxygen provides suitable conditions for aerobic decomposition (Marsson, 1911) and prevents oxygen depletion that would be detrimental to all heterotrophs.

Organic pollutants are directly consumed by some organisms. Diatoms, fungi, protozoans, rotifers, crustaceans and a diversity of benthic invertebrates (Marsson, 1911; Purdy, 1923, 1930) are able to directly reduce the quantity of dissolved and particulate organic matter in the water.

The overall effect of self-purification is the change from a polluted habitat to a habitat with conditions favorable for clean water organisms (Wiebe, 1927; Purdy, 1923; Richardson, 1928), as a source of clean dilution water for the river system (Bardach, 1964; Boruff, 1930), and as a source of usable nutrients for the primary producers (Marsson, 1911; Purdy, 1923).

The most favorable conditions of existence for the organisms involved in self-purification have been shown to occur in extra-channel areas. This is supported by Richardson (1928) and Wiebe (1927).

Therefore, because the extra-channel habitats provide the most favorable area for the production of organisms intricately involved in the food webs in which fish are the final consumers, and in improving the quality of water in which all organisms live, destruction of these habitats, or any manipulation which hinders access to these habitats, may result in some degree of reduction of fish production to the river fishery. Stuart (1960) supports the creation of slack current habitats to improve the physical conditions and benefit the biota.

ECOLOGY OF THE FISHES

The following pages and Table 10 are included to describe, in detail, the biology of the fishes recorded as present in the ongoing study. Lists of the fishes known to be present in the Mississippi River, St. Louis, Missouri, to Cairo, Illinois, were supplied by S. Lewis and D. Ragland. From the information gathered about these fish, better estimates of the importance of the physical, chemical, and biotic factors can be determined, and the impact of the loss of the extra-channel areas concluded.

The following descriptions of the biology of fishes are

based on information in the following references: Calhoun (1966), Carlander (1969), Barnickol and Starrett (1951), Gerking (1945), Swingle (1956), UMRCC (1967), Forbes (1888), Forbes and Richardson (1920), Coker (1930), Fish (1932), Luce (1933), Hankinson (1919), and Trautman (1933). Specific references are cited where appropriate.

The fishes present

Amia calva

The bowfin, dogfish, grindle, spot-tail or mudfish is of general occurrence in rivers and lakes but is most abundant in sloughs adjacent to the Mississippi River. The adult bowfin is exclusively carnivorous; its diet is comprised of varying percentages of fish, frogs, crayfish, molluscs and occasionally leeches. Although the bowfin is prepared for food in certain areas, it is generally not sought commercially. The bowfin is extremely gamy, but few fishermen actively seek this fish. Due to minimal fishing pressure, reduced vulnerability due to large size, and tenacity this fish often becomes abundant. The bowfin's abundance and predatory nature have led fishermen and some biologists to regard it as a nuisance species.

Spawning occurs in May to June in southern Illinois and is preceded by movement into shallow, densely vegetated areas where the smaller male clears vegetation away from plant roots or builds a form of nest of the vegetation. Nests are

frequently colonial. The large female deposits 2000 to 5000 eggs in the nest. The eggs are adhesive and adhere to the roots and rubble in the nest. Eddy and Surber (1943) have reported 64,000 eggs/ovary in a 21-inch fish. Maturity is reached in 4 years. The eggs hatch in 8 to 14 days and leave the nest at 9 days depending on the temperature. The young remain in a dense school guarded by the male until 4 inches long.

The bowfin has a vascularized swim bladder. This allows the fish to breathe air at the surface, and thereby serves as an adaptation to life in stagnant, low oxygenated water often found in swamps and shallow lakes.

Lepisosteus osseus

The northern longnose gar, billy gar, or billfish is widely distributed in lakes and large rivers and is most abundant in stagnant waters. The longnose gar is not recognized as a fish of commercial or sport importance, but when hooked this fish puts up a good fight.

Reproduction occurs May to June. Spawning occurs in shallow water over weed, where a single female, usually accompanied by several males, will deposit up to 77,000 adhesive eggs. These eggs are poisonous and hatch in 3 to 9 days depending on temperature. The young remain in shallow, vegetated water and grow rapidly, reaching a mean total length of

15 to 20 cm in the first year. Young have been reported to become piscivorous at 5 cm (Carlander, 1969). Maturity is reached at 4 years in males and 6 years in females.

The longnose gar is almost exclusively piscivorous, frequently feeding on valuable game fish. Coker (1930) states that the longnose gar is commonly known as a nuisance, but this fish's harmful effect on game fish is by competition with game fish for food. The ability to breathe air, due to a vascularized swim bladder, the tough, armor-like skin, the rapid growth to a large size, high fecundity, and lack of fishing pressure frequently result in great abundance and can make this fish a severe nuisance.

Lepisosteus platostomus

The shortnose gar, short bill, stub-nose gar, or billy gar is usually the most abundant gar in rivers and lakes and prefers open waters. Like the longnose gar, this fish has little or no commercial and sport fishing importance.

The life history and ecology of L. platostomus is very similar to that of L. osseus. Reproduction differs from the longnose gar in that spawning often occurs over inundated land and the eggs are able to withstand dessication (Forbes and Richardson, 1920), and spawning period extends into the summer.

Due to the lack of fishery importance and the life history and ecology similar to the longnose gar, the shortnose gar is

a serious nuisance to sport and commercial fisheries.

Hiodon alosoides

The goldeye is widely distributed in some lakes and larger rivers but is common in only some Mississippi River oxbow lakes. Little specific information is available for this fish and the next fish discussed, H. tergisus.

Reproduction occurs in early spring or immediately following the time ice leaves the lakes in Canada (Battle and Sprules, 1960). Spawning takes place in shallow water where an average of 14,000 semibuoyant eggs are shed. The young of the year grow quickly to total lengths up to 15 cm. Maturity is variable with latitude, from 2 to 10 years.

The food of the adult goldeye is primarily benthos. Occasionally small minnows are consumed. Forbes and Richardson (1920) indicate that H. alosoides prefers current areas, but Harlan and Speaker (1951) indicate this fish to reach greatest abundance in slack current areas. The goldeye is quite tolerant of silt turbidity but sensitive to industrial pollution.

The goldeye is not recognized as a food fish but can be eaten, hence, this fish has no commercial importance. It is a gamy fighter and will take artificial bait, although it is not actively sought by anglers south of Canadian waters.

Hiodon tergisus

The mooneye (toothed herring, big-eyed shad) is most common

in larger rivers and is more abundant than the goldeye in the Mississippi River. As discussed for the goldeye, this fish has no commercial value and receives only minimal angling attention, although it is a gamy fighter on light tackle and will take artificial and live baits.

Knowledge of the reproduction of H. tergisus is limited. This fish spawns in early spring in shallow water. The young fish grow to total lengths of up to 15 cm in their first year.

The food of the mooneye is primarily micro- and macro-invertebrates. No information is available about specific ecological tolerances or preferences.

Dorosoma cepedianum

The gizzard shad (shad, skipjack, flatfish) is abundant and of ubiquitous occurrence in warmer waters and waters without prolonged ice cover of rivers and lakes and other standing waters associated with rivers.

Reproduction begins in the spring at temperatures over 10°C and may continue into the summer months. The fish may or may not migrate upstream to spawn but do move from their pelagic habitat to shallow water to spawn. During spawning up to 400,000 demersal, nonadhesive eggs are released which develop in 36 to 100 hours depending on the temperature. The young are zooplanktophagic, occasionally ingesting small benthos and grow rapidly to one-half their adult size in their first

year. The fish mature in 1 to 3 years, depending on latitude; the males mature first.

The adults are primarily phytoplanktophagic, although some zooplankton are utilized for food. Forbes and Richardson (1920) describe the mud-eating habits of the gizzard shad, but this information is not provided by other authors. These fish are tolerant of salinity changes and silt turbidity but are adversely affected by low temperatures.

The gizzard shad has no commercial nor sport fishery value directly but has been considered a valuable forage fish. The utility of gizzard shad as a forage organism for game fish has been questioned due to their rapid growth, and hence the length of time they remain vulnerable to predators, and direct competition with the planktophagic larvae of many game fish (Miller, 1960). Walsh (1953) indicates that frequent winter die-offs of the gizzard shad can cause severe health problems.

Dorosoma petenense

The threadfin shad is abundant in the open-water zone of large lakes and in large rivers, usually in areas of current and eddies, such as behind dams.

Reproduction of threadfin shad occurs in open-water areas in deep water, or occasionally near shore over aquatic vegetation, in the spring when ambient temperature is 21°C. The eggs are adhesive and semibuoyant and sink to the bottom or

to a depth at which the water density equals egg density. The eggs hatch in 3 days at 27°C. The young shad grow approximately 2.5 cm/month until 7 cm long. Early spring hatched fish may spawn the succeeding fall. The fish travel in schools as adults. Lengths greater than 10 cm are rarely attained.

The threadfin shad is planktophagic as an adult. Phytoplankton and zooplankton are consumed in variable quantities in different waters. Detritus has been found to be a major constituent of the diet in some collections (e.g., Ewers and Boesel, 1935).

Current and turbidity are well tolerated by the threadfin. Temperature is a factor controlling the distribution of threadfin shad. Prolonged temperatures below 7°C are usually fatal.

The threadfin has no commercial or sport fishery importance but has proven to be a species with great value as a forage fish.

Alosa chrysochloris

The skipjack (shad, river shad, river herring) is found in low numbers in the channels of large silty rivers but has been found in standing water (Gerking, 1945).

The skipjack spawns in the spring, usually in small aggregations. The exact location of spawning is not known and few details about the life history have been explored.

The skipjack feeds on insects and fish. Larger adults

are almost exclusively piscivorous.

The fish is tolerant of current and silt turbidity. The skipjack has little value as food and is not commercially fished. It is rarely caught by anglers.

Anguilla rostrata

The American eel (common eel, Boston eel, Atlantic eel, freshwater eel) occurs in lakes and streams and is especially common in larger, deep, mud-bottomed rivers in the Mississippi Valley. The American eel is recognized as an excellent food fish but does not seem to have the popularity merited by its table qualities. The commercial eel fishery is minimal and eels caught by sport fishermen are usually taken while fishing for other species.

The eel is noted for its long unknown methods of reproduction. A. rostrata migrates from its freshwater home in lakes and rivers to the Sargasso Sea where a female will spawn 5 to 20 million eggs. The adults die after spawning. The young eels (elvers) remain in the ocean for 2 to 3 years, after which time they return to freshwater to grow and mature.

The American eel has been indicated to be omnivorous in its food habits (Table 10). Eals have been reported to be carnivorous, eating many fish (Harlan and Speaker, 1951), and scavengers, eating dead fish and animal matter (Forbes and Richardson, 1920). No information on current or turbidity

requirements are available. Skin respiration may facilitate respiration in poorly oxygenated waters.

When abundant, eels can be a minor nuisance because of their carnivorous tendency.

Ictiobus cyprinellus

The bigmouth buffalo (common buffalo, lake buffalo, blue buffalo) is widely distributed in lakes and larger streams but prefers slower current areas in deep water over mud bottoms. This fish attains large size (up to 50 pounds) and is commercially important. The combined buffalofish catch in the Mississippi River ranked third in commercial value in 1958 and 1963 (UMRCC, 1967). This fish is of no sport value; specimens are only rarely taken by anglers while fishing for other species.

The bigmouth buffalo moves into sloughs and shallow water extra-channel areas to spawn in mid-April to May in the area of concern. Frequently the onset of reproduction is triggered by rising water levels which permit the bigmouth buffalofish to spawn on the vegetation of inundated areas. Spawning also takes place over mud bottoms. An average of 400,000 eggs are deposited which adhere to vegetation when available. The eggs hatch in 8 to 14 days depending on water temperature. The young grow rapidly and reach lengths of 17 cm after the first growing season. The fish mature in 3 years generally. Adult growth is quite rapid (up to 0.7 kg/year) due to a long growing season.

The adults are benthophagic and eat a wide variety of foods including entomostracans, rotifers, insects, algae, plant seeds, and distillery slops (Forbes and Richardson, 1920). The bigmouth buffalo prefers slow current but is tolerant of current and turbidity.

The bigmouth buffalo is beneficial to the fishery, although in direct competition with other benthophagic fishes, especially the carp.

Ictiobus bubalus

The smallmouth buffalo (roach-back, razor-back buffalo fish, thick lipped buffalo) is similar to the bigmouth buffalo in many characteristics, although the following differences have been noted from the data available. Spawning of the smallmouth buffalo requires rising water levels. This fish does not, in general, attain the size of the bigmouth buffalo but is usually the more abundant of the two species.

Carpoides carpio carpio

The northern river carpsucker (carpsucker, white carp, quillback, silver carp) is quite generally distributed but is most abundant in medium size to large rivers, usually turbid and frequently associated with brush piles. The poor quality flesh and small size are reasons for this fish's poor commercial and sport value.

The northern river carpsucker spawns from April to June, although Bucholz (1957) found ripe females in August and indicated that the river carpsuckers are intermittent spawners. Fecundity is high: an average of 100,000 eggs/female. The eggs are laid randomly and develop in 8 to 12 days. The young grow to 3 to 5 inches at the end of the first growing season. Maturity is reached in 3 years; some males mature in 2 years.

The river carpsucker is benthophagic and consumes great quantities of bottom ooze. The very numerous gill rakers are well adapted to filtering diatoms, green algae, blue-green algae, desmids, protozoa, rotifers, and copepods (in order of decreasing occurrence) from the bottom ooze (Harlan and Speaker, 1951). Insect larvae, primarily dipterans, and molluscs are also consumed. This fish tolerates current and turbid waters.

The river carpsucker has little effect on the fishery, although, due to the feeding habits, this fish may compete to some degree with certain minnows and small channel catfish.

Cyprinus carpio

The carp was introduced from Europe in the late nineteenth century and has become well established in lakes, ponds, and rivers of all sizes. Gerking (1945) indicates that areas with weak currents and mud bottoms are the preferred habitat.

Reproduction occurs in shallow areas of lakes and rivers,

sloughs, and inundated lands in late spring, although spawning frequently continues into the summer. Rehder (1959) indicated the occurrence of multiple spawning. Carp have a very high fecundity; up to 7,000,000 eggs/female have been recorded (Leach, 1919). The eggs are adhesive and attach to masses of vegetation in small bunches. The eggs develop in 3 to 20 days depending on temperature. The young of the year frequently seek shelter in vegetation and may reach 1 pound by the end of the first growing season. Maturity is generally reached in 2 to 4 years. Growth is rapid and attained weights in excess of 20 pounds are not uncommon.

Carp are omnivorous in their feeding habits and rely most heavily on benthos, although plankton are consumed. Insects and plant material are the primary foods.

The carp is tolerant of a wide range of current, turbidity, and pollutional conditions.

Carp migrate into shallow waters to spawn and frequently migrate into the shallows daily to feed. Concerning general migratory tendencies, the carp has been recorded to migrate upstream (Rehder, 1959), and downstream (Thompson, 1933). Luce (1933) described the carp as nomadic.

The wide tolerances, and often extreme abundance make the carp a commercially important species. Carp receive a considerable amount of angling pressure, especially near urban areas.

Carp exert a negative effect on a sport fishery. Luce (1933) indicates that carp serve as forage for game fish, but the advantage is necessarily limited by this fish's rapid growth to nonvulnerable sizes. The carp create an unfavorable habitat by increasing the turbidity and uprooting aquatic vegetation. The carp also compete with other benthophagic fishes for food.

Notemigonus crysoleucas

The golden shiner is widely distributed in lakes, ponds, streams, and backwater areas. The preferred habitat is weedy areas with a mud or mud and debris bottom.

The information available on the reproduction of the golden shiner indicates that this fish broadcasts adhesive eggs over beds of vegetation and algal mats. Spawning begins in the spring and extends through the summer. After hatching the young seek shelter in dense vegetation. Most individuals reach maturity and spawn after 1 year of growth.

Golden shiners are omnivorous and feed on zooplankton, phytoplankton, insects, and filamentous algae. Various authors disagree as to whether the preferred food is zooplankton or phytoplankton. (See Carlander, 1969.)

The golden shiner is quite tolerant of wide ranges of current and turbidity conditions. Gerking's (1945) collections indicated this fish's tolerance of polluted conditions.

The golden shiner is important as a bait minnow and a forage fish for larger game fish. Although valuable as a bait fish, this fish has little importance to the commercial fishery of the river; most production of golden shiners occurs under controlled conditions in ponds.

Pimephales notatus

The bluntnose minnow is widely distributed and abundant in all sizes of lakes and streams; greatest abundance is reached in smaller streams and rivers.

Reproduction begins in May and continues into August. P. notatus is considered an intermittent spawner (Starrett, 1951). A mature female produces an average of 2,000 eggs/year, which are spawned at different separate times. The adhesive eggs are deposited on the under surface of logs, stones, large rubble, etc. The eggs hatch in 7 to 14 days, depending on temperature.

Most studies indicate that the bluntnose minnow feeds on small organisms and debris about equally from the plankton and from the bottom. Hankinson (1908) reported consumption of fish eggs.

The small size, trophic level, and abundance makes the bluntnose minnow important to the fishery as a source of forage for larger piscivorous fishes. The extent to which this fish eats the eggs of other fish may indicate this fish to be somewhat detrimental to the fishery.

Pimephales vigilax

The bullhead minnow is widely distributed in streams, and occurs in some lakes. Greatest abundance has been observed in large rivers.

Spawning occurs May to August. No other information on reproduction is available.

P. vigilax is an omnivorous feeder, and like P. notatus, frequently ingests large quantities of mud. In addition, the bullhead minnow feeds on aquatic and terrestrial insects.

As P. notatus, P. vigilax is important to the fishery as a forage organism for piscivorous species.

Hybognathus nuchalis

The silvery minnow is found in many lakes and ponds but prefers the slower, turbid waters of large rivers and back-water areas such as oxbows, overflow ponds, and slack water behind dams.

Reproduction begins in May and extends into the summer. Carlander (1969) indicates that H. nuchalis is an intermittent spawner. Other authors indicate a brief spawning period. Breder and Rosen (1966) state that this fish spawns in the same areas as carp, and therefore must spawn before the growth of dense vegetation begins. The fish migrate into coves and quiet areas near shore prior to spawning. An average of 3,000 eggs/female are spawned directly on the bottom ooze. No

information is available about hatching time. Growth is rapid and sexual maturity is reached in 1 year.

The food of the silvery minnow is plant material. Forbes and Richardson (1908) found that the gut contents of this fish was fine mud and diatoms, filamentous algae, and other vegetable forms.

H. nuchalis appears to tolerate running water conditions but prefers slack current areas. This fish is quite tolerant of turbidity.

This fish is valuable to the fishery as forage for piscivorous fish. This fish has no commercial value. Its use as a bait fish is restricted by its softness, and therefore is difficult to hold on a hook.

Notropis lutrensis

The plains red shiner is of general occurrence in lakes and streams and attains greatest abundance in large turbid rivers.

Various authors indicate different spawning times, but all records indicate spawning to occur from late spring through summer. Spawning occurs in inundated weedy areas. N. lutrensis matures and spawns after 1 year. No other specific information is available for this species.

The food of N. lutrensis consists of algae, small crustaceans, and insects.

Based on collection records, the plains red shiner shows wide tolerances to current velocity and turbidities.

This fish is important to the fishery as a forage fish. Because of the small size, this forage fish remains vulnerable to larger predatory fish.

Notropis atherinoides

The emerald shiner is a common inhabitant of rivers and lakes. It prefers open waters, with a moderate current and usually high turbidities. When found, this fish frequently occurs in large schools.

This fish spawns from late spring through summer. The eggs are released near the surface in open water and develop within 24 hours.

The emerald shiner eats a wide range of food, primarily entomostraca, and terrestrial insects. Specimens have been found with amphipods, benthic invertebrates, and filamentous algae in their guts.

The wide current and turbidity tolerances, nonspecific spawning requirements, and small size make this fish a valuable source of forage. The emerald shiner also has some economic value as a bait fish.

Hybopsis storeriana

The silver chub (Storer's chub) occurs in most waters

but seems to prefer the open, turbid, flowing waters of the channels of large river channels. Gravel, often sand is the most favored substrate.

Spawning takes place June to July. River-dwelling fish migrate into creeks to spawn. Lake inhabitants spawn in open water. A large female will produce 11,000 eggs/spawn.

The food of this larger chub consists primarily of mayflies, chironomids, and amphipods. Mayflies are the preferred food when available.

The silver chub demonstrates wide tolerances to current velocities and turbidity conditions.

This fish may be of some value to the sport fishery as forage for large game fish, but the large size may reduce the benefit of this fish. The feeding habits may indicate severe competition with more valuable fish. This fish has no commercial value.

Fundulus nctatus

The black stripe top minnow (top minnow) occurs in many lakes and streams of all sizes. The preferred habitat is shallow, weedy water with a moderate or sluggish current, over mud or debris bottom. This fish is usually found swimming at the water surface.

Reproduction occurs from late May to June in southern Illinois latitudes. Spawning takes place on weed-filled shore-

lines. Breder and Rosen (1966) report that the eggs are flipped, by the anal fin, individually into the leaves of the aquatic weeds. Hatching takes place in upto 24 days. After hatching the young and subadults seek shelter in the vegetation. Growth is rapid; near adult size is reached by the end of the first growing season. Presumably, because of growth rate, maturity is reached in 1 year.

The primary food of F. notatus is insects. This fish has also been found to consume entomostraca, amphipods, and filamentous algae.

Although preferring sluggish currents, this fish is found under a wide range of current conditions. The top minnow is tolerant of silt turbidity.

This fish is of no commercial value. The small size and habitat and behavior indicate that this fish has some value as a forage species.

Gambusia affinis

The mosquito fish is common in quiet water areas of lakes and rivers and is most abundant in backwater areas.

The reproduction of this fish is peculiar in that G. affinis is viviparous: the young are born alive. Because of viviparity, no specific spawning habitats are necessary. Spawning occurs during the warmer months, May to September, in our latitude, and more than one brood/season is frequently produced.

By multiple reproduction, up to 315 new individuals may be produced per year. Maturity and a size of 3 cm are reached in one growing season.

This fish is adapted to feed on organisms associated with the surface film, and the mosquito fish's food overlaps to a large extent with that of Fundulus notatus. This species is rarely found in current areas. No information is available pertaining to turbidity tolerances, but by surface breathing, G. affinis can withstand low dissolved oxygen conditions.

This fish has no commercial importance. Although a small fish, and therefore very vulnerable to predation, this fish often seeks shelter in water too shallow for large predators, and is, therefore, only of limited value as a forage fish.

Labidesthes sicculus

The brook silversides (ghost minnow, transparent fish) is a small fish of lakes and streams. This fish is most frequently found at, or near, the water surface, often in large schools.

The breeding season is in mid-June. Spawning takes place in open water. According to Hubbs (1921), the greatest abundance of spawning fish was found over a gravel shoal in moderate current. This is consistent with the observation that the eggs have a sticky, thread-like process that serves as both a flotation organ and subsequently as a holdfast when the egg

comes in contact with an object. After hatching the young form large schools, develop rapidly, and reach adult size and maturity in one growing season.

These fish are tolerant of current conditions but prefer quiet water after the spawning season. Turbidity is not a limiting factor.

The food of the brook silversides is primarily aquatic insects. Some entomostraca are eaten.

This small, open-water fish is a valuable forage item for predacious fish, and is utilized by many game fish. This fish is tender and not hearty, and is not recognized as a good bait minnow. Therefore, this fish has no commercial value.

Aplodinotus grunniens

The freshwater drum (sheepshead, white perch, croaker, grunter, grinder, silver bass) is common to abundant in large, shallow lakes and channel and extra-channel areas of large rivers. This fish is usually found over mud bottoms.

Reproduction occurs in May and June in our latitude. The eggs are pelagic, and no special spawning sites are favored. Most spawning occurs in open water. The eggs develop in 25 to 35 hours depending on temperature. The newly hatched larvae remain at the surface for several days and then form large schools. Despite the vulnerability of the eggs and larvae, they receive little predation from other fish (UMRCC, 1967). The

young attain lengths of 12 cm in their first year of growth. Maturity is reached in 3 to 7 years in males, 5 to 6 years in females.

The drum is primarily benthophagic, feeding on insects. Fish, crustaceans, and mollusks are also consumed. The percentages of each food item vary with season and with bodies of water.

This fish occurs in many current and turbidity situations and appears quite tolerant to both factors. The fish is not tolerant of low dissolved oxygen concentrations.

The drum is quite valuable commercially. The smaller fish (1 to 4 kg) are quite palatable and very abundant in some areas. Although considered a rough fish by some anglers and agencies, this fish will take bait and lures, and is pursued as a game fish by anglers.

One limitation to the value of A. grunniens is its frequent predation on some more desirable fish and food competition with yellow perch, white bass, and the smallmouth bass. (Many Ictalurids can also be added to this list.)

Ictalurus natalis

The yellow bullhead (brown bullhead, white whiskered bullhead, Mississippi bullhead) is widely distributed but reaches greatest abundance in large streams and rivers.

Breeding begins in May and may extend to July in Illinois

waters. The fish move into shallow water and deposit 2000 to 7000 eggs. Undercut bank, logs, and other forms of shelter are the preferred spawning sites. The eggs hatch in 5 to 10 days. The young fish school and are guarded by the male. The young reach 8 cm during their first year. Maturity is reached in 3 years for most males and females.

Yellow bullheads are omnivorous feeders. Their primary foods are benthic insects. Some fish, and occasionally algae and small vascular plants are consumed. The yellow bullhead also feeds as a scavenger.

I. natalis is a very hardy fish. It tolerates low dissolved oxygen and high turbidities very well. Although it prefers sluggish water, it is found in wide ranges of current conditions.

The flesh of the yellow bullhead is superior in taste to that of the other bullheads, and is quite palatable, but the small size (rarely 1 kg) makes this fish not commercially important. Although not considered a game fish, the yellow bullhead ranks high on the sport fish catch record.

Ictalurus punctatus

The channel catfish (spotted cat, fiddler, channel cat, and catfish) is widely distributed and reaches greatest abundance in moderate to large sized streams.

Reproduction occurs in May and June in Illinois. The

mature fish move into shallow water and spawn 3000 to 8000 eggs. Hollow logs, undercut banks, muskrat dens, and other hollow structures are the preferred spawning sites. The male guards the nest for 6 to 10 days until the young hatch. The young school for several days and then separate but remain in the shallows to feed. Lengths of 15 to 25 cm are attained in the first year. Nearly all fish are mature by age five.

Channel catfish have omnivorous feeding habits. Benthos, primarily insects, are the major food item, but fish become more important with increased age and size.

Channel catfish prefer clear, flowing water but are found in widely different habitats with respect to current and turbidity. This fish is not as tolerant of low dissolved oxygen as other ictalurids.

The wide variety of foods and wide tolerances to current and turbidity impart good survival advantage to this fish, and usually large populations occur.

The size, abundance, and excellent table quality make this fish commercially valuable and popular with anglers.

Ictalurus furcatus

The blue catfish (chucklehead cat, forktail cat, great blue cat) is common in larger rivers and streams and rarely found in lakes.

No information is available pertinent to the reproduction

of the blue cat, but presumably it does not differ greatly from the channel catfish.

The presence of this fish in the Mississippi and Missouri Rivers, and the disappearance of this species from South Dakota reservoirs indicates that this species tolerates current and turbidity, and possibly requires current during at least part of the life cycle.

The food of this fish varies according to different authors and different localities. Brown and Dendy (1961) found the blue catfish to be primarily piscivorous and primarily benthophagic in the Tombigbee and Tensaw Rivers, respectively.

The large size and excellent quality flesh make this fish highly sought after by the commercial and sport fisherman alike.

Pylodictus olivaris

The flathead catfish (shovelhead cat, mud cat, yellow cat, Mississippi cat, goujan, nigger-belly) is common in larger rivers and their associated tributaries and backwaters. This fish is frequently found below dams and in deeper water.

Reproduction begins in May or later at water temperatures of 24°C. This fish moves toward quiet shore water but does not seek water shallower than 3 m. The nest is a hollow in the mud bottom into which 6900 to 11,300 eggs/female are

deposited. These eggs hatch in 6 to 7 days. Growth is rapid; lengths of up to 0.2 m are attained in the first year. Maturity is reached in 3 to 5 years. This is a long lived fish and attains weights of 20 kg; 5- to 10-kg fish are not uncommon.

The flathead catfish is considered entirely piscivorous.

This fish occurs in backwater and main channel areas of silty rivers. Apparently P. olivaris is quite tolerant of a range of current conditions and silt turbidity.

This fish is sought to some extent by commercial fishermen and anglers. Possibly attention toward this fish is prejudice against the table quality of the flesh (Jordan and Evermann, 1934). Actually this is an excellent food fish, and its large size and piscivorous habits should make this fish a favorable commercial and sport species.

Morone chrysops

The white bass is found primarily in large, deep lakes, and secondarily in larger rivers. Schools of this fish are abundant in the Mississippi River. The white bass occurs over hard and soft bottom, and in weedy and weedless areas.

Reproduction occurs from April to June, usually in May in Illinois waters. The mature fish seek sand or gravel, shallow shoals with a moderate to strong current for spawning. Frequently migration upstream is necessary to find such conditions. A large, mature female will produce 650,000 to 970,000 eggs

which hatch in 46 hours at 15°C. The young develop rapidly, attaining 10 to 12 cm in the first growing season. Maturity is reached in 2 years.

The food of the white bass is primarily fish, insects, and crustaceans; the frequency of each food varies with season and habitat.

This fish prefers standing water during nonspawning season but occurs in a wide variety of habitats with respect to current velocity. This fish is extremely mobile and will frequent a wide variety of habitat types.

This fish is of little commercial value, but the fair to good quality as food, abundance, mobility, feeding habits, size, and fighting ability rank the white bass high as a sport fish.

Micropterus salmoides

The largemouth bass (largemouth black bass) is found in all habitat types but prefers small ponds, lakes, and backwater areas of rivers. Shallow water, mud bottom and weedy areas are also associated with the greatest abundance.

Reproduction occurs during April to June at water temperatures of 15 to 17°C. Males select spawning sites in shallow water (0.25 to 1 m) without current, and circular nests are made in the mud bottom. Vegetation or rubble is a common characteristic of spawning sites. The mature females produce

2000 to 25,000 eggs, which are guarded by the male and hatch in 9 to 10 days. The young school for several weeks, and then seek shelter in weed beds. Lengths of 10 to 15 cm are reached in the first year of growth. Maturity is reached in 2 to 3 years in Illinois waters. Sizes up to 4 kg are reached by Mississippi River fish, although larger fish are taken from lakes.

Largemouth bass are primarily piscivorous as adults, although large crustaceans and other invertebrates are utilized as food.

Although the largemouth bass prefers standing water, the widespread collections of this fish indicate that wide ranges of current conditions are not inimical. This fish is also tolerant to mild silt turbidity, although highly turbid water can exert a negative effect on spawning success. Rapid decreases in temperature are also inimical to reproductive success.

This fish does not receive the attention of river anglers that it receives in inland lakes (UMRCC, 1967), but the large size, feeding habits, and gaminess make this fish attractive to the angler.

Micropterus punctulatus

The spotted bass (Kentucky bass) is found in large and small streams of slow to moderate current. Unlike the largemouth bass (M. salmoides) hard substrates and nonvegetated areas are preferred. Spawning occurs over nests built in

gravel areas. In other characteristics, M. punctulatus is very similar to M. salmoides.

Lepomis cyanellus

The green sunfish (rubber tail, green perch, sunfish, sand bass) attains abundance in all habitats. The most abundant occurrence is in small and moderate sized streams and weedy areas with mud bottoms.

Reproduction begins in May at temperatures greater than 15°C and extends to August. Nests are constructed on gravel substrate, usually in direct sunlight areas. The young remain in weed areas for shelter and to feed. Maturity is reached by almost all fish in 2 years.

Green sunfish are carnivorous and prefer larger animal foods which include fish, insect larvae, freshwater shrimp and snails.

Although L. cyanellus prefers weak current areas, this fish is tolerant of a variety of current conditions and standing water. This fish is also tolerant of turbidity and low oxygen concentrations.

The green sunfish is of no commercial value and only fair sport value. The piscivorous nature, early maturity, and hardiness and tolerance, together with low fishing pressure make this fish a nuisance species in some waters.

Lepomis humilis

The orange-spotted sunfish (redspotted sunfish, pumpkinseed, dwarf sunfish, pigmy sunfish) occurs in all habitats. This fish usually occurs in greatest abundance in flowing water habitats with hard substrates and reduced vegetation.

Reproduction takes place in May and June in Illinois waters. A circular nest is built in gravel substrates in shallow water. Nesting will occur on mud substrate. Mature females have been found with 18,000 to 23,000 eggs. The young fish reach maturity in 3 years.

The feeding habits and ecological tolerances are similar to the green sunfish.

Like the green sunfish this fish has no commercial and still lower sport value due to its small size. The high fecundity and lack of fishing pressure can result in a buildup of a population of orange-spotted sunfish. The resulting stunt population and the feeding habits of this fish (resulting in competition with more valuable fish) make this fish deleterious in some waters.

Lepomis macrochirus

The bluegill (sunfish, sun perch, bream, pumpkinseed, blue sunfish) is found in practically all waters. Bluegill are most abundant in protected areas with clear, quiet water, beds of vegetation and a sand, gravel or muck bottom.

Bluegill reproduction occurs in May and June in Illinois water at temperatures above 20°C. The males build saucer-shaped nests on sand, gravel, mud, and debris bottoms in 0.6- to 2-m depths. A mature female will deposit up to 49,400 eggs. The eggs hatch quickly and the new fry are protected by the male for several days. The young fish reach lengths up to 6 cm in their first growing season. Maturity is attained in 2 to 3 years. These fish rarely exceed 0.5 kg.

Bluegills feed primarily on aquatic insects and zooplankton. Small fish, fish eggs, snails, molluscs, crayfish, and amphipods are also eaten when available. Some authors have found aquatic plants to comprise the bulk of the diet at certain times of the year. (See Calhoun, 1966.)

Bluegills prefer quiet water but are found in running water habitats. Turbidity has been shown to be detrimental to growth and reproduction (Buck, 1956). Bluegills tolerate dissolved oxygen concentrations greater than 1.0 ppm at temperatures in excess of 28°C.

The size of this panfish, good quality flesh, and catchability on natural and artificial lures makes the bluegill much sought after by anglers.

Lepomis microlophus

The red-ear sunfish (shellcracker) is most common in clear, quiet water with aquatic vegetation but also occurs in large

rivers and associated backwater areas. The red-ear inhabits deeper water than the bluegill.

Reproduction begins in late spring and continues through summer. Multiple spawnings are not uncommon. Nests are built on sand, gravel, or mud bottom in water depths of several centimeters to 3 m. Up to 2400 eggs/female have been recorded. Otherwise reproduction is similar to the bluegill.

As mentioned for the bluegill, turbidity is detrimental to growth and reproduction. The red-ear has a stronger preference for standing water than the bluegill. The red-ear is very susceptible to sudden temperature fluctuations (Rounsefell and Everhart, 1953).

The food of the red-ear consists primarily of benthic invertebrates: insect larvae and molluscs. Filamentous algae and aquatic plants are also consumed.

The red-ear is an important sport fish. The flesh is good quality and it is an acceptable sized panfish. Because this fish occupies deeper water and because of the difference in feeding habits, this fish is not as catchable as the bluegill.

Lepomis megalotis

The longear sunfish is not usually abundant in local habitats. Its greatest occurrence is in shallow, weedy areas with mud, detritus bottom. It is more common in large streams than lakes.

Reproduction occurs from May to August. Nests are built on hard substrate in shallow water with slow to moderate current. The eggs that are deposited adhere to the stones in the nest, or roots of vegetation, if present. The fish mature in 3 years.

The food of L. megalotis is primarily aquatic insect larvae, crustaceans, and fish.

The scanty information available pertinent to ecological requirements indicates that the longear sunfish is tolerant of wide ranges of current conditions.

This fish is of no commercial value and only limited sport value due to lack of abundance and small size.

Lepomis gulosus

The warmouth (warmouth bass, wood bass, mud bass, weed bass) occur in all waters. They usually occur in greatest numbers in waters with a low gradient, soft bottom, and abundant vegetation or other cover. In the Mississippi River, the warmouth is most abundant in backwater areas.

Reproduction occurs in June or July when the water temperature reaches 21^o C, although females may spawn an indefinite number of times (Larimore, 1957). Nests are built in shallow areas (less than 1.6 m) with vegetation and a lightly silt-covered bottom. The nest is usually near a stationary object (e.g., rocks, stumps, clumps of vegetation) (Larimore, 1957).

The eggs hatch in 35 hours at 25° to 27°C. The young grow rapidly, reaching 5 cm by the end of the growing season, and often reaching 8 to 10 cm and maturity by the following summer.

The food of the adult warmouth consists of insects, small crustaceans, snails, zooplankton, and fish. Warmouth are more piscivorous than the other sunfishes; fish comprise a large component of the food of warmouth over 13 cm (Lewis and English, 1949).

The warmouth tolerates current, high turbidity, and low dissolved oxygen conditions (Larimore, 1957).

The warmouth is of no commercial importance but is of some importance to the sport fishery. This fish has fair to good quality as a food fish and attains a size large enough to interest panfish anglers. From a fishery management standpoint, the warmouth has several disadvantages. Dense populations can result from low exploitation rates and a high population fecundity due to early maturity. At dense population levels, stunting is not uncommon. The warmouth is also a food competitor with the more valuable largemouth bass. Conversely, in controlled populations, the piscivorous habits of the warmouth qualify this fish as a secondary predator to control populations of small fish (Lewis and English, 1949).

Pomoxis nigromaculatus and P. annularis

The black crappie (P. nigromaculatus) and the white crappie

(P. annularis) are common to abundant in all types of water. Both species prefer standing or weak current waters with vegetation and mud or detritus bottoms. The white crappie has a more southern range and would be expected to be more abundant in the Mississippi River between St. Louis and Cairo.

Reproduction occurs in the spring when water temperature is 15 to 18°C and 18 to 20°C (black and white crappie, respectively). Nests are built near stationary structures, and 1000 to 213,000 eggs are spawned. When possible, the eggs are attached to vegetation or roots. Maturity is reached in 2 to 3 years. Growth to 30 cm or more is common. The crappies are the largest members of the group of fish considered panfish.

The food of both fish consists of aquatic insects, fish, and crustaceans. Fish become increasingly important with increase in size.

The black and white crappie are tolerant of mild current conditions. The white crappie is quite tolerant of silt turbidity, but the black crappie is found in clean waters. In California, vegetation is necessary to maintain a good crappie fishery (Calhoun, 1966).

The crappies are highly rated as a sport fish. They are frequently abundant, reach a large size, and have good table quality. The crappies can be a nuisance to the fishery unless numbers can be controlled.

Stizostedion vitreum

The walleye (pike-perch, walleyed pike, pike, jack fish, jack salmon) is found in larger lakes and rivers. This fish prefers lakes but is found in the channels and side channels of clearer rivers with rock, gravel, or hard clay bottom.

Reproduction occurs in early spring when the water temperature approaches 10°C. Spawning takes place in shallow water over rock or gravel shoals in areas with a moderate current. The fecundity ranges from 23,000 to 50,000 eggs/pound of fish weight. The eggs are broadcast, and hatch in 12 to 18 days, depending on temperature. Growth is rapid; the young of the year attain lengths of 15 cm in the first growing season. The males mature in 2 years and females in 3 years in most waters. Although fish as large as 1 m and 11 kg occur, a 6-kg fish is considered large.

Walleye are voracious predators. The adults are primarily piscivorous, but larger aquatic invertebrates are frequently consumed.

Walleye are tolerant of current and are frequently caught in fast water. The fish avoids turbid waters.

The excellent quality flesh, large size, schooling behavior, and gaminess makes this fish very popular with anglers.

Stizostedion canadense

The sauger (sand pike, river pike, spotfin pike, jackfish,

jack salmon) is known from rivers and ponds and lakes associated with rivers. The sauger is most abundant in the main channel and side channel areas of large rivers with a hard substrate.

Reproduction is like the walleye. The sauger does not grow as fast as the walleye. A maximum length of 10 cm is reached in the first growing season, and the fish mature later in 3 to 4 years.

The food is similar to that of the walleye. Fish are the largest component of the diet.

This fish prefers running water areas and is more tolerant of silt turbidity than the walleye.

The sauger is an important sport species. This is an excellent food fish and reaches sizes large enough to make it a desirable game fish.

Environmental factors:

Current

To consider the effect of various physical and chemical factors on fish, one must consider all species individually, and their life cycles. The species considered are those that have been recorded as present in the current ongoing study of the Mississippi River, St. Louis, Missouri, to Cairo, Illinois.

If the direct effect of current on fish is considered, current is rarely a limiting factor. (See Table 10.) All fish that have been recorded as present are tolerant of at

least mild current conditions.

Current is an important factor in reproduction. From Table 11, it can be seen that 22 species that have been recorded as present require standing water for reproduction. Slack current will occur in the channel border areas, but 15 of the 22 species requiring slack current also require vegetation or some form of rubble or shelter for spawning. These conditions are met most frequently in the extra-channel habitats. Martin and Campbell (1953) stated that a high incidence of young fish were found in Missouri River backwaters, and this indicates the use of these habitats as nursery areas. Barnickol and Starrett (1951) indicated the importance of backwaters and sloughs for fish spawning and noted a reduction in game fish in the section of the Mississippi River with reduced backwater areas. The game fish population increased following impoundment of the Clinch River to form Melton Hill Reservoir (Fitz, 1968). Coker (1930) found game fish and "desirable" commercial fish (e.g., paddlefish, catfish, sturgeon) increased following the formation of Lakes Pepin and Keokuk by the impoundment of the Mississippi River. Richardson (1921) noted that as percent lake acreage (adjacent to the river) decreased, the fish yield decreased more severely.

In addition to the specific advantages of reduced current, the general favorability of reduced current areas to the

production of fishes has been supported by Eggleton (1939) and Fritsch (1903).

Turbidity

Turbidity can affect fish directly and indirectly (Crass, 1969). Silt turbidity can be harmful to fishes by interference with gill functions. This interference with gill functions is due to clogging of the respiratory surface of the gills (Ellis, 1937; Kemp, 1949; Trautman, 1933) and/or actual mechanical damage of the gills (Ellis, 1944; Kemp, 1949).

Silt turbidity can interfere with reproduction. Stuart (1953) found that silt adheres to the chorion of brown trout ova. Hobbs (1937), Shapovalov and Berrian (1940), and Shaw and Maga (1943) have shown the deleterious "smothering" effect of siltation from silt turbidity on redds of various species. Alderdice and Wickett (1958) indicate that siltation prevents the flush of wastes away from the eggs. Langlois (1941) described one of the deleterious effects of turbidity as causing destruction of the spawning beds by siltation.

Silt turbidity can inhibit growth of fish. Buck (1956) found bluegill and red-ear sunfish and largemouth bass to grow faster in clear water. He also found production in clear water (177 pounds/acre) to exceed that in turbid water (117 pounds/acre) in an Oklahoma reservoir.

Turbidity can cause a change in species composition.

Thompson (1941) reported that increased turbidity caused a decrease in sight feeders. This can cause a decrease in game fish, which are sight feeders, and an increase in rough fish. Barnickol and Starrett (1951) describe the Mississippi River below the Missouri River as more turbid and a poorer game fish habitat than the upper reach.

Turbidity indirectly affects the fish via the food chain. Turbidity has been shown to be inimical, in various ways, to phytoplankton, zooplankton, macrophytic vegetation, and benthos. As the food supply of an organism is reduced, it is logical to expect the consumer to decline in number, or to decrease its growth rate. The converse is shown by the increased yield of Lakes Pepin and Keokuk following impoundment. After impoundment, the current and turbidity decreased, and the conditions of existence for the fish, the quantity of fish food, and the conditions necessary for reproduction improved. The result was more fish with a better food supply, and thereby, increased production (Galtsoff, 1924).

Substrate

The importance of substrate type has been discussed for benthos and macrophytic vegetation. Many authors have made comments about the bottom preferences of various fishes, and these references have been used in Table 10 and the description of the biology of each species for convenience. At this point

it is beneficial to point out that the fishes may not prefer a particular type of substratum, but rather they seek suitable current, depth (Cleary and Greenbank, 1954) and turbidity conditions, and suitable food organisms. It is these conditions that may determine over what substratum type a fish is found, rather than active selection of substratum type by the fish. For these reasons, the precise nature of the bottom is not of great importance. The substrate is important to the fish as a source of shelter (Saunders and Smith, 1962; Hartman, 1965), and we may speak of the shelter preferences of fish. In larger rivers where the bed is relatively smooth, the preference for shelter becomes increasingly clear, and "fish of many species tend to congregate near obstructions, in bays, and along the banks, or anywhere else that offers some shelter" (Hynes, 1970).

If the various types of shelter are considered (e.g., vegetation, fallen logs and tree stumps, rubble, rocks, substrate diversity, any structure that would interfere with current, etc.), it can be seen that extra-channel areas have more and a greater diversity of shelter. The main channel, over short distances, is, conversely, comparatively homogeneous and deleterious to fish which seek shelter (Stuart, 1960).

Again the importance of extra-channel areas to the river fishery has been shown.

Dissolved oxygen

A last factor of the physicochemical environment that can affect fish is dissolved oxygen. Although different species of fish have different oxygen tolerances and requirements, oxygen concentrations below 2.0 ppm, at low temperatures, are considered lethal (Thompson, 1925; Moore, 1942). At warmer temperatures, the minimum oxygen concentrations required increases.

Although oxygen is rarely a limiting factor in lentic environments, due to aeration at the air-water interface, and subsequent mixing, the addition of large amounts of organic matter can cause low oxygen concentrations. Thompson (1925) reported fish moving into backwaters and floodplain lakes during periods of stagnation and low dissolved oxygen. This interaction of dissolved oxygen, primary producers, fish and extra-channel areas will be discussed in the following section.

THE WHOLE SYSTEM AND CONCLUSIONS

The direct effects of the physicochemical factors (current, turbidity, substrate and shelter, and dissolved oxygen) have been discussed, and it has been concluded that the extra-channel areas provide the most favorable conditions of existence for the river fishes recorded as present from St. Louis, Missouri, to Cairo, Illinois. Table 13 lists those fish that are adversely affected, or not affected, based on the

hypothetical physicochemical conditions that would prevail following the loss of the extra-channel areas and a knowledge of the ecological requirements (Table 10) of the fish.

Application of the information presented earlier in this report about the groups which comprise the food web of the fishes should complete our understanding of what is known about the impact of the loss of the extra-channel habitat on the fishes.

Many of the fishes of commercial or sport importance that occur in the river are benthophagic and/or piscivorous. The fish that rely on benthos as a food source are indirectly dependent on zooplankton, phytoplankton, and/or macrophytic vegetation. The fish that serve as prey for the predatory fish may be benthophagic, phytoplanktophagic, or zooplanktophagic. Although most adult commercial and sport fish are benthophagic and/or piscivorous, all of the fish recorded as present are planktophagic for at least a brief period during the early developmental stages. The necessity of plankton in the diet was realized by Forbes and Richardson (1913) who stated that the plankton supply is a good index of the food supply of young fishes. In all cases the food chain start with the primary producers, phytoplankton, periphyton, and macrophytic vegetation, and allochthonous materials. (See Figure 3.) Without the primary producers, the food chain is built on the

Figure 3
Biotic interaction and feeding relationships
of fish (1 of 2 sheets)

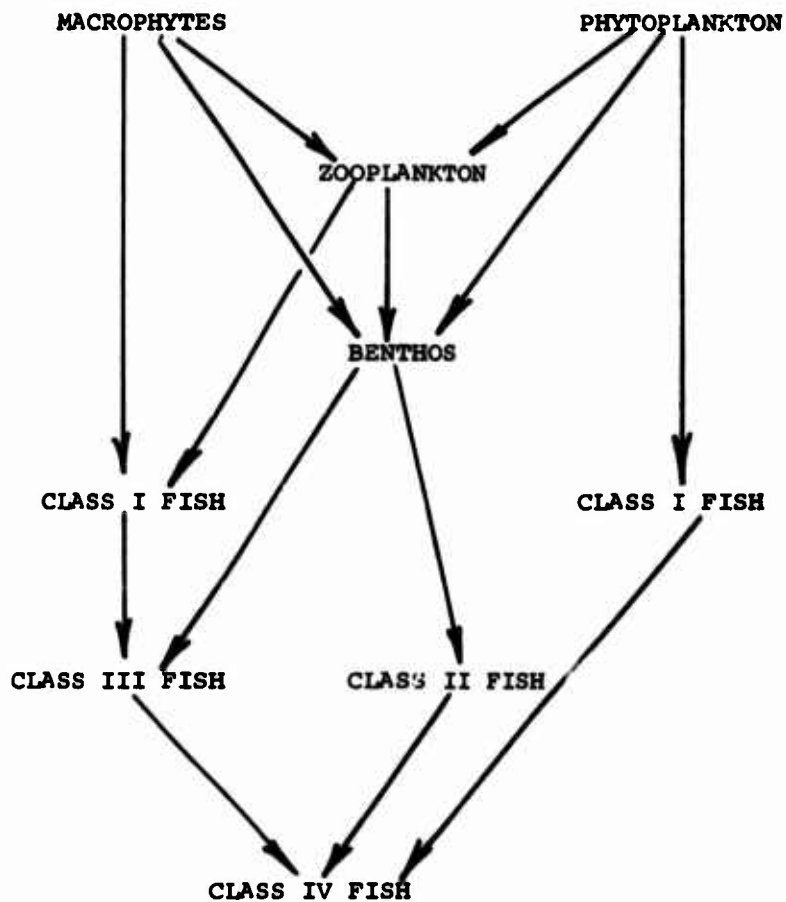


Figure 3 (2 of 2 sheets)

Class I Fish

(Diet primarily plankton)

Dorosoma cepedianum
D. petenense
Notemigonus crysoleucas
Pimephales vigilax
P. notatus
Hybognathus nuchalis
Notropis lutrensis
Gambusia affinis

Class II Fish

(Diet primarily benthos)

Hiodon tergisus
Ictiobus cyprinellus
I. bubalus
Carpionoxenus carpio
Hybopsis storeriana
Fundulus notatus
Labidesthes sicculus
Aplodinotus grunniens
Ictalurus natalis
Lepomis humilis
L. macrochirus
L. microlophus
L. megalotis

Class III Fish

(Diet primarily benthos and fish)

Anguilla rostrata
Hiodon alosoides
Ictalurus punctatus
Morone chrysops
Lepomis cyanellus
L. gulosus
Pomoxis nigromaculatus
P. annularis

Class IV Fish

(Diet primarily fish)

Amia calva
Lepisosteus osseus
L. platostomus
Ictalurus furcatus
Pylodictus olivaris
Micropterus salmoides
M. punctulatus
Alosa chrysochloris
Stizostedion vitreum
S. canadense

limited amount of allochthonous matter; the quantity of which will vary seasonally with the waters which wash material into the river. When conditions are favorable for primary producers, the amount of utilizable organic matter will increase, and the food supply will be more constant seasonally. An increase in biomass at a lower level will affect an increase in biomass at the next higher level of a food chain. This statement is applicable to fish, whether planktophagic or piscivorous; i.e., the biomass of fish is related to the biomass of food organisms upon which the fish feeds. The abundance of phytoplankton, zooplankton, and benthos has already been shown to be greater in the slack current, extra-channel areas. The following authors offer general support of the increased abundance of food organisms in extra-channel areas: Nikolski (1933), Berg (1948), Forbes (1928), Eddy (1934), Kofoid (1903), Hutchinson (1939), Eggleton (1939), and Fritsch (1903). Because an abundance of plankton is necessary for reproduction of the fishes, plankton becomes more important than as only a supplement to allochthonous organic matter and as a link in the food chain to benthos and planktophagic fish. In addition to the above, and previously cited, information about the abundance of plankton in extra-channel areas, Forbes (1880) supported the need for extra-channel areas: "Running water is relatively destitute of entomostraca, and hence fishes denied access, while breeding,

to slow, or stagnant, water in which entomostraca abound have no chance to multiply." This view is also held by Nikolski (1933). It can be seen that the loss of extra-channel areas will be detrimental to the survival of adult and young fishes.

The rooted aquatic plants and macroscopic algae have been found to be beneficial to fishes as shelter for young fish, spawning sites, aeration of the water, and as a food supply (Pond, 1905; Hotchkiss, 1941; Dill, 1944). Evidence has been provided to support the inimical effect of current on macrophytes, and the benefit of maintaining the extra-channel habitats. It is also appropriate to remind the reader of the previously described improvement in conditions of existence affected by macrophytes.

Lastly, purification of the water will benefit the fish. The benefit can be direct, by removal of toxic organic compounds, or indirect, by maintaining adequate dissolved oxygen levels and providing an environment conducive to the development of food organisms (Wiebe, 1927). The sport fishery will benefit because game fish, rather than rough fish, will be favored by the cleaner water (Medford and Simco, 1971), commercial species will increase, the value of the fish will increase due to improvement in the taste and odor (UMRCBS, 1970; Richardson, 1928), and the incidence of disease will decrease (UMRCBS, 1970). The occurrence of slack water areas is greatly

beneficial to the purification of waters, and, therefore, maintenance of extra-channel areas will aid the provision of cleaner water which is beneficial to the fish.

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Table 1. Physical Factors
A. Main Channel

Reference	Size	Current	Seasonal change	Turbidity	Bottom type
R. Vistula (Mikulski, 1961)			Flooding, frequent oscillations		90% sand, very solid silt deposited during low stages (transit silts)
R. Ganges (Lakshminarayana, 1965)	Large	Fast	Fluctuations of level	High during high water	
R. Dovey (Jones, 1941)	20' wide	Gradient: 330'/mi.			Small stones
R. Dovey (Jones, 1941)	40' wide	Gradient: 50'/mi.			Bedrock, stones, some silt and sand
R. Dovey (Jones, 1941)	90' wide	Gradient: 20'/mi.			Boulders, gravel, silt behind rock
R. Dovey (Jones, 1941)	200' wide	Gradient: 7-10'/mi.			Primarily mud, some sand
R. Tees (Butcher, 1932)		Gradient: .2m/sec.			Gravel
R. Lark (Butcher, et al., 1931)		Slow-flowing	Little fluctuation		Fine gravel and mud
Des Moines R. (Starrett and Patrick, 1952)		Gradient: 1.5'/mi.			
A. 2 mi. above dam		Sluggish			Sand-silt, sand-gravel, sand, gravel, boulders, rubble, silt
B. Below dam		Swift			
C. 2 mi. below dam		Moderate			
Mississippi R. (Reinhard, 1931)		1.5'/sec.		5-70 ppm	Firm sand
St. Croix R. (Reinhard, 1931)	Varies in width	Fast		4 ppm avg.	
Mississippi R. at Quincy (Dorris, et al., 1963)		Fast		1.9-75 ppm	
R. Wharfe (Percival and Whitehead, 1930)					
A. At Grassington		Variable	Great fluctuations: flooding to partial dryness	"Clear"	Stone, gravel
B. At Pool Bridge	0.7-2 m wide				Sand to gravel: hard Sand, silt
C. At Ulleskelf	1-4 m	Uniform, moderate	Flooding		
R. Itchen (Butcher, 1927)	Small, many channels	1/2-5'/sec.			Large stones to mud
Upper Mississippi R. (Galtsoff, 1924)		0.8-3.14'/sec.	Considerable fluctuations	32-995 ppm 8-84 cm	
Ohio R. (Purdy, 1923)					
A. Young		Fast	Fluctuations	23.8 ppm	
B. Stable		Slow	Reduced fluctuations	11.2 ppm	
C. Stable		Slack	Reduced fluctuations	5.8 ppm	
Coosa R. (Scott, 1951)					
A.	500-900' wide	3+'/sec.			Sand, gravel, few mud areas Mud and debris
B.	400' wide 10-15' deep	1-2'/sec.			
Missouri R. (Morris, et al., 1968)					
A. Unchannelized	4-20' deep	Swift		16-275 ppm	Coarse or fine sand with organic matter
B. Channelized	4-20' deep	Swift		53-3000+ ppm	Sand, silt
Black R. (Campbell and Funk, 1953)	Shallow	1.2-3.6'/sec.	Seasonal flooding	16-24 ppm	Gravel: some sand and silt
Missouri R. (Bernier, 1951)		3-10'/sec.		<8000 ppm	Gravel and coarse sand

(Continued)

(1 of 3 Sheets)

Table 1. (Continued)
B. Channel Border

Reference	Size	Current	Seasonal change	Turbidity	Bottom type
R. Vistula - Behind regulating dams (Mikulski, 1961)		Moderate to stagnant	Seasonal flooding; changes in water level		Silt-sand; stable
Missouri R. (Morris, et al., 1968)					
A. Mud banks	1-12' deep	Slack			Soft mud
B. Behind pile dikes	10-28' deep	Slack to circular			Packed sand with thin organic matter layer
Missouri R. - Behind pile dikes (Berner, 1951)		Slack			Silty ooze
Mississippi R. (Galtsoff, 1924)		0-0.91'/sec.	Considerable fluctuations		
		Main Channels			
R. Vistula - Old river channel (Mikulski, 1961)		Stagnant			Silt; stable
Missouri R. (Morris, et al., 1968)	Length: 200'-1+ mi.				
A. Unchannelized			Wide fluctuations; flood to dryness	24-260 ppm	Sand and silt with organic matter
B. Channelized			Rapid fluctuations	34-2000 ppm	Sand and silt with organic matter
Mississippi R. Cottonwood Chute (Dorris, et al., 1963)					
A. Upper chute		Reduced cf. river; 0.6 ft ³ /sec. ice cover	High water in spring; 2 mos. ice cover	2.7-75+ cm	
B. Lower chute		57% reduction cf. upper chute; 0.26 ft ³ /sec. ice cover	High water in spring; 2 mos. ice cover	4.7-75 cm	
Upper Mississippi R. (Galtsoff, 1924)		0.32-1.0 ft/sec.	Considerable fluctuations		

(Continued)

(2 of 3 Sheets)

Table 1. (Concluded)
D. River Lakes and Ponds

Reference	Size	Current	Seasonal change	Turbidity	Bottom type
Mississippi R. L. Pepin (Reinhard, 1931)	2 mi. wide 22 mi. long avg. depth= 25-35'	Slack		0-10 ppm at outlet	Mud
Mississippi R. L. Keokuk (Ellis, 1931) (Coker, 1929)		Slack		Varies with wind; de- creased cf. river	Silt, up to 6" thick; high or- ganic content
Mississippi R. Valley (Dorris, 1958)					
A. Goose L.	63 acres depth = 2- 6 1/2'	None	Rare flooding by tributary streams	8-70 JTU	Sand, mud, drab clay
B. Big L.	56 acres depth = 1-4'	None	Fluctuating water level; drought prevented by pump- ing well water	0-80 JTU	Drab clay, drab clay loam
C. Sand L.	42 acres depth = 1-5'			10-80 JTU	Mud, drab clay loam
D. Mud L.	38 acres depth = 1-5'			10-80 JTU	Drab clay loam
Mississippi R. (Galtsoff, 1924)					
A. L. Keokuk		0-1.0 ft/sec	Wide, rapid fluc- tuations due to drawdown		Soft mud
B. L. Pepin		None		Greatly re- duced	Silt and sand
E. Sloughs					
Mississippi R. (Christenson and Smith, 1965)					
A. Miller L.	11.9 acres	Slack		320 ppm	
B. Area A.	1.35 acres avg. depth= 2.4'; max. depth=4.5'	None			
C. Area B.	3.36 acres avg. depth= 5.5'; max. depth=9'	None			

(3 of 3 Sheets)

Table 2. Chemical Factors
A. Main Channel

Reference	Dissolved oxygen (ppm)	Alkalinity (mg/liter CaCO ₃)	Inorganic nutrients	Organic nutrients
R. Ganges (Lakshminaryana, 1965)	2.1-6.8 (highest during rainy season)	44-130 ppm		
Illinois R. (Forbes and Richardson, 1913)	0.48-14.0 (low value from pol- luted section)			
Black R. - Middle and upper stations (Campbell and Funk, 1953)	6.7-11.1	64-134		
Missouri R. (Morris, et al., 1968)				
A. Unchannelized	7.2-10.9	152-190		
B. Channelized	5.1-10.0	155-232		
Upper Mississippi R. (Reinhard, 1931)	1.5-12.7	99-243		High
Various pollutional levels				
Mississippi R. - Adjacent to Cottonwood Chute (Dorris, et al., 1963)	4.4-14.2 x=8.8 (seasonal ranges)	101-183 ppm x=132 (seasonal ranges)	TDS=185-682 mg/liter x=335	Total organic solids 67-182 mg/liter x=103
Upper Mississippi R. (Galtsoff, 1924)			200 ppm	
Danube R. (Claus, 1961)	7.5-8.7	8.1-9.9	Conductivity 264-361 x 10 ⁻⁶ mhos	BOD=3.0 mg/liter
Vaal R. (Chutter, 1963)				
A. High flow	3.8-5.6	37-61	TDS=72-239 mg/ liter; conductivity 112-165 mhos	
B. Low flow	2.5-5.3	44.6-69	TDS=95-309 conductivity 137-452	
B. Channel Border				
Illinois R. (Forbes and Richardson, 1913)	1.8-11 (low value in polluted section)			
Vaal R. (Chutter, 1963)				
A. High water	5.6-7.8	39-44.5	TDS=91.6-197.3 Conductivity; 147-312 micromhos	
B. Low water	2.5-3.9	45.6-53.2	TDS=91-206 Conductivity; 150-292 micromhos	

(Continued)

Table 2. (Concluded)
C. Side Channel

Reference	Dissolved oxygen (ppm)	Alkalinity (mg/liter CaCO ₃)	Inorganic nutrients	Organic nutrients
Missouri R. (Morris, et al., 1968)				
A. Unchannelized	7.3-11.1	151-263		
P. Channelized	5.2-12.4	143-237		
Mississippi R. - Cottonwood Chute (Dorris, et al., 1968)				
A. Upper chute	3.6-20.4 $\bar{x}=9.1$ (seasonal range)	110-188 $\bar{x}=134$	TDS=1-1,112 $\bar{x}=492$	Total organic solids 70-198 mg/liter $\bar{x}=113$
B. Lower chute	3.5-24.3 $\bar{x}=9.4$	100-189 $\bar{x}=133$	TDS=285-1062 $\bar{x}=433$	Total organic solids 75-193 mg/liter $\bar{x}=117$
Danube R. (Claus, 1961)	8.9-13.6	8.3 mg/liter carbonate hard- ness	264-362 x 10 ⁻⁶ mhos	BOD=1.2-3.2 mg/liter per 48 hrs.

D. River Lakes and Ponds

Illinois R. - Depue L. (Forbes and Richardson, 1913)	12.92			
Mississippi R. - Outlet of L. Pepin (Reinhard, 1931)	3.7-11.9 $\bar{x}=7.3$	105-193 $\bar{x}=135$		Less than in pol- luted conditions upstream
Mississippi R. (Ellis, 1931)				
A. L. Keokuk	57% saturation (bottom) 60% saturation (surface)			
B. 2 mi. above L. Keokuk	80% saturation (bottom) 83% saturation (surface)			
Mississippi R. - Near Quincy, Illinois (Dorris, 1958)				
A. Sand L.	4-14 (seasonal)	55-240 (seasonal)		
B. Goose L.	2-16 (seasonal)	40-150 (seasonal)		
C. Big L.	4-14 (seasonal)	90-240 (seasonal)		
D. Mud L.	2.5-16 (seasonal)	70-255 (seasonal)		

E. Sloughs

R. Susaa (Berg, 1943)	Vertical change with slow flow
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Table 3. Chemical conditions of various habitat types in the Mississippi River.*
 A. Mile 280 to 275.



— Cross-sectional stations of the Mississippi River and adjacent waters between Clarksville, Missouri and Louisiana, Missouri. September and December, 1944.

* From Plather, 1946.

Table 3A (cont'd)

Chemical analysis of water samples from the Mississippi River, including sloughs and
and lakes flooded in periods of high water (September 1944)

NILE 275

Stations	Sp. Cond. mho x 10 ⁻⁶ @ 25°C	pH	O ₂ in p.p.m. R.S./	Parts per million												
				HCO ₃	CO ₃	CO ₂	Total NH ₃ (N)	Mn	Zn	F	Cu	Fe	PO ₄	Cl	Ca	
A I SNY	662	7.82	5.62	115.0	0.00	3.50	1.34	1.30	1.30	0.00	0.00	0.00	1.80	0.72	103.20	55.
B II BARROW PIT	337	7.35	0.32	96.0	0.00	15.00	3.25	2.08	1.70	0.00	0.00	0.00	3.80	3.90	0.00	39.
III CRUTE	354	7.90	5.52	80.5	0.00	1.70	1.09	0.75	0.00	0.00	0.00	0.00	1.20	0.53	1.54	37.
IV ISLAND	290	8.00	5.05	83.0	0.00	1.70	1.25	0.77	0.00	0.00	0.00	0.00	1.15	0.53	1.44	37.
V ISLAND	289	8.11	5.54	84.5	0.00	1.70	1.23	0.82	0.00	0.00	0.00	0.00	1.16	0.58	0.38	36.
VI CHANNEL	341	8.25	5.63	83.0	0.00	1.70	1.13	0.95	0.05	0.00	0.00	0.00	0.95	0.51	2.60	39.
VII CHANNEL	326	8.25	5.61	84.0	0.00	1.70	1.08	0.25	0.03	0.00	0.00	0.00	1.21	0.48	2.12	38.
A VIII WOODS	362	8.30	7.23	93.0	2.40	0.03	1.42	0.37	0.15	0.00	0.00	0.00	0.70	0.34	2.22	43.
C IX ISLAND	363	8.24	5.68	93.0	0.60	0.00	1.22	0.42	0.25	0.00	0.00	0.00	0.61	0.34	0.66	40.
C X ISLAND	363	8.36	7.12	92.0	2.00	0.00	1.37	0.37	0.26	0.00	0.00	0.00	0.75	0.41	3.46	44.
C XI ISLAND	364	8.51	6.43	92.0	0.60	0.00	1.18	0.35	0.15	0.00	0.00	0.00	0.75	0.34	1.16	44.

R.S.- oxygen method of Rideal and Stewart.

iron, manganese, zinc, fluoride and copper were determined on acidified samples.

A Slough habitat

B River lake and pond habitat

C Channel border habitat

Table 3A (cont'd)

Chemical analysis of samples of water from the Mississippi River and adjacent waters
(September, 1944)

MILE 278

Stations	Sp. condl rho $\times 10^{-6}$ @ 25°C.	pH	O ₂ in p.p.m. R.S.	HCO ₃	CO ₃	Total (M)	NH ₃	Ca	Zn	F ///	Cu	Fe	PO ₄	Cl	Ca
XII CHUTE	336	8.40	6.00	86.5	0.00	1.70	0.63	0.07	0.00	0.00	0.00	1.63	0.53	0.28	39.2
CXIII ISLAND	335	8.34	6.25	86.0	0.00	1.70	0.67	0.15	0.00	0.00	0.00	1.68	0.57	0.38	41.8
CXIV ISLAND	336	8.20	4.15	84.0	0.00	2.60	0.69	0.15	0.00	0.00	0.00	1.58	0.54	0.46	40.5
XV CHANNEL	340	8.10	5.10	84.5	0.00	1.70	0.55	0.15	*	0.00	*	1.31	0.52	2.12	39.5
XVI CHANNEL	344	8.21	6.25	83.0	0.00	2.60	0.65	0.20	0.00	0.00	0.00	1.42	0.50	0.76	38.5

Iron and manganese determined on acidified samples. Total nitrogen, *zinc=0.0125 p.p.m., and *
Copper=0.027 p.p.m., determined by acidified samples concentrated from four liters of water.
R.S.-Method of Rideal and Stewart.

C Channel border habitat

Table 3A (cont'd)

Chemical analysis of samples of water from the Mississippi River and adjacent waters
(September 1944)

MILE 280

Stations	Sp. Cond; mho x 10 ⁻⁶ @ 25°C	pH	Parts per Million													
			O ₂ R.S.	HCO ₃	CO ₃	CO ₂	Total NH ₃	Mn	Zn	F	Cu	Fe	PO ₄	Cl	Ca	
B XVII SPRING LAKE	212	8.21	4.72	55.5	0.00	1.70	1.66	0.63	0.75	0.00	0.00	2.10	0.59	0.00	24.4	
D XVIII THE SLY	582	8.10	6.54	95.5	0.00	5.50	1.14	0.96	0.70	0.00	0.00	1.55	0.55	55.60	47.2	
B XIX SWAN LAKE	297	7.77	5.28	63.5	0.00	1.70	1.84	0.84	0.80	*	0.00	1.50	0.52	5.86	30.4	
B XX 1903 BRANK	409	7.65	6.80	114.0	0.00	8.80	1.01	0.95	1.95	0.00	0.00	1.95	0.53	0.70	46.8	
B XXI BARROT. PIT	345	7.50	2.45	93.0	0.00	10.50	0.67	0.50	1.10	0.00	0.00	1.20	1.25	0.96	41.9	
C XXII CHUTE	336	7.90	3.65	83.0	0.00	1.70	1.17	0.46	1.52	0.00	0.00	1.52	0.52	0.08	36.8	
C XXIII ISLAND	339	8.05	5.40	86.0	0.00	1.70	1.35	0.52	2.00	0.00	0.00	2.00	0.62	2.12	38.0	
C XXIV ISLAND	336	8.20	5.05	85.0	0.00	1.70	1.08	0.50	1.40	0.00	0.00	1.40	0.53	1.14	38.5	
C XXV CHANNEL	348	6.14	5.35	83.0	0.00	1.70	1.16	0.60	1.35	0.00	0.00	1.35	0.46	1.92	38.1	
C XXVI TREES	351	8.20	7.55	83.0	0.00	1.70	1.56	0.73	1.70	0.00	0.00	1.70	0.53	2.50	39.9	

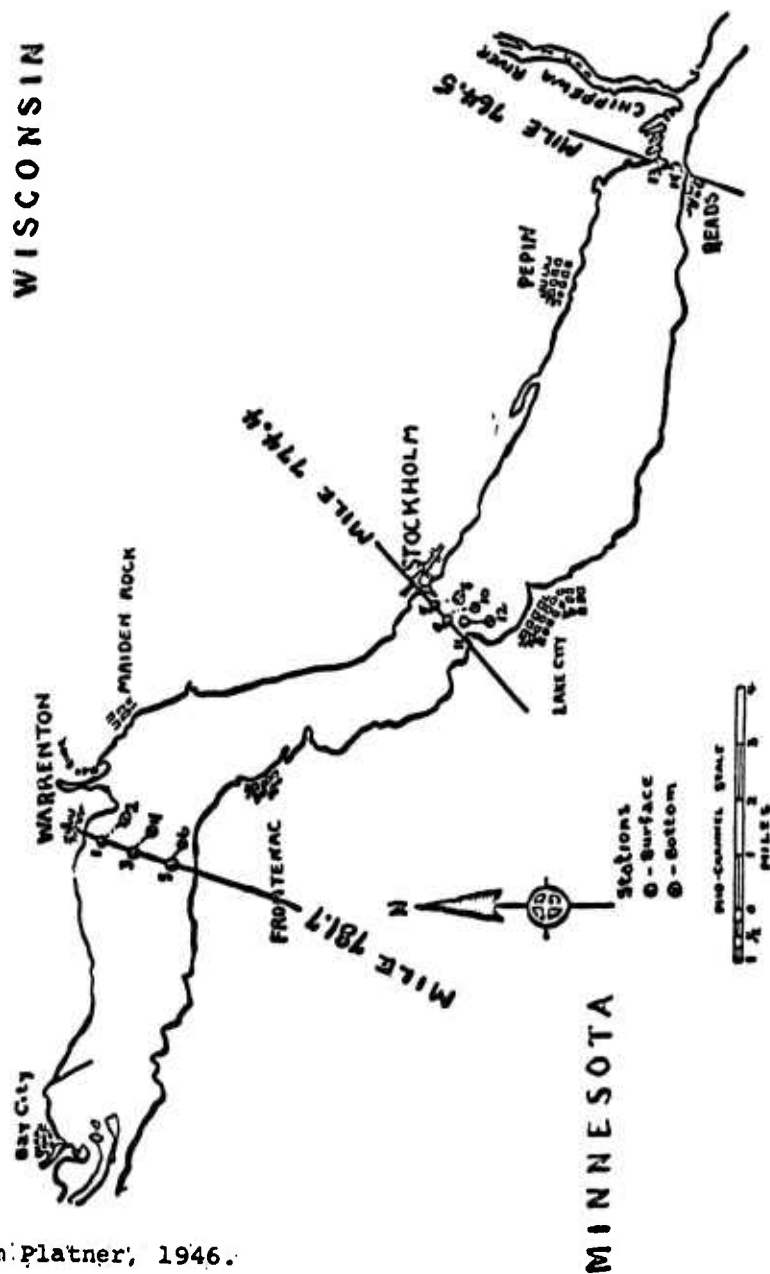
Iron and manganese determined from acidified samples.

Total nitrogen, *zinc-0.165 p.p.m., *copper-0.027 p.p.m., determined from acidified samples concentrated from four liters of water.

R.S.--Method of Ideal and Stewart.

- B River lake and pond habitat
- C Channel border habitat
- D Side channel habitat

Table 3. Chemical conditions of various habitat types in the Mississippi River.*
 B. Mile 78.1 to 764, Lake Pepin



Cross-section sampling of Lake Pepin.
 (Surface and bottom sample, were collected a few minutes apart)

* From Platner, 1946.

Table 3B (cont'd) --Physical Characteristics of Lake Pepin (August 20, 1944)

Mile 721.7

Station See fig. 8	Turbidity p.p.m.	Percentage sedimen- tation (30 min.)	Water temp. °C	Air temp. °C	Time	Depth in feet	Sample Depth in feet	Bottom
Upper Lake								
1. surface	132	Trace	23.0	20.5	8:45 a.m.	18	3.0	Mud containing bloodworms
2. bottom	213	0.03	25.0	20.5	8:55 a.m.	18	18.0	
3. surface	113	Trace	23.2	20.5	9:10 a.m.	21	3.0	Mud
4. bottom	113	Trace	25.2	20.5	9:15 a.m.	21	21.0	
5. surface	81	0.00	23.2	20.5	9:30 a.m.	24	3.0	Mud containing bloodworms
6. bottom	103	0.00	23.2	20.5	9:35 a.m.	24	24.0	

Mile 774.4

Upper Lake								
7. surface	74	0.00	24.0	22.7	10:30 a.m.	27	3.0	Mud containing bloodworms
8. bottom	100	0.01	24.0	22.7	10:35 a.m.	27	27.0	
9. surface	70	0.00	24.2	22.7	10:40 a.m.	30	3.0	"
10. bottom	100	0.03	23.0	22.7	10:45 a.m.	30	30.0	
11. surface	70	0.00	23.7	22.7	10:50 a.m.	39	3.0	"
12. bottom	70	Trace	23.5	22.7	10:50 a.m.	39	35.0	

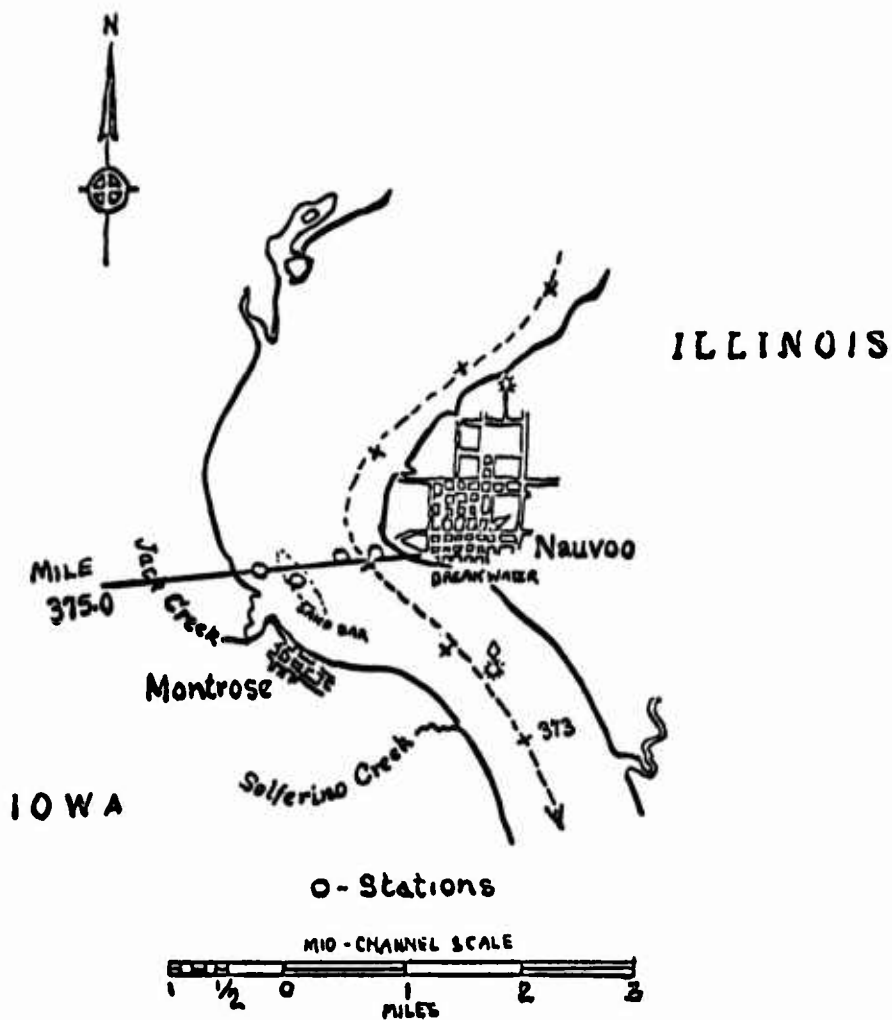
Mile 784.5

Lower Lake								
13.	56	Trace	24.7	24.5	12:10 p.m.	9	4.5	coarse gravel small shells, 1st 1/2"
14.	43	Trace	25.6	24.5	12:40 p.m.	15	7.5	

Table 3B (cont'd)
Chemical analysis of water samples collected in Lake Pepin
(August 20, 1944)

Mile 781.7											
Stations (see Figure 8)	Sp. cond. mho x 10 ⁻³ at 25°C.	pH	Parts per million								
			Dis- solved oxygen	O.C.	HCO ₃	CO ₃	NH ₃	PO ₄	Cl	SO ₄	Ca
1 Surface	277.0	8.00	5.03	--	74.2	2.76	--	--	--	--	--
2 Bottom	280.0	8.02	4.18	--	73.7	2.76	--	--	--	--	--
3 Surface	276.0	8.10	3.14	25.5	77.8	2.77	0.28	0.36	1.00	0.00	38.0
4 Bottom	268.0	8.06	3.64	--	70.5	2.76	--	--	--	--	--
5 Surface	264.0	8.20	5.20	--	70.9	3.60	--	--	--	--	--
6 Bottom	276.0	8.14	4.77	--	72.5	2.04	--	--	--	--	--
Mile 774.4											
7 surface	302.0	8.20	3.47	--	80.6	4.20	--	--	--	--	--
8 Bottom	312.0	8.15	3.25	--	81.3	3.60	--	--	--	--	--
9 Surface	270.0	8.18	5.20	25.5	77.8	2.77	0.31	0.33	1.25	0.00	39.5
10 Bottom	277.0	8.18	4.12	--	73.8	2.76	--	--	--	--	--
11 Surface	270.0	8.18	5.20	--	75.0	2.76	--	--	--	--	--
12 Bottom	271.0	8.18	4.61	--	73.3	2.76	--	--	--	--	--
Mile 764.4											
13 Surface	319.0	8.22	5.26	27.0	89.2	3.60	0.31	0.32	2.50	0.00	48.2
14 Surface	323.0	8.12	3.47	--	84.9	2.76	--	--	--	--	--

Table 3. Chemical conditions of various habitat types in the Mississippi River.*
C. Mile 375



- Cross-section sampling of the Mississippi River between Montrose, Iowa, and Nauvoo, Illinois.

* From Platner, 1946

Table 3C (cont'd)

Chemical analysis of samples of water collected across the Mississippi River
between Montrose, Iowa, and Nauvoo, Ill. (June 26, 1944)

MILE 375.0

Stations see fig. 7	Sp. cond. x 10 ⁻⁶ 25°C	pH	O ₂ R. S.	O. C.	HCO ₃	CO ₃	Parts per million							Ca
							Total (14)	NO ₃	PO ₄	Cl	SO ₄			
A East bank	301	7.80	5.17	36.0	96.0	0.00	Trace	2.16	0.19	0.28	1.70	0.00	34.5	
B Mid channel	291	7.89	5.38	25.0	29.0	0.00	do	3.14	0.28	0.27	1.70	0.00	34.5	
A Sand bar	299	7.83	2.82	27.5	51.5	0.00	do	0.62	0.17	0.28	1.40	0.00	34.6	
A West bank	330	7.89	3.17	34.2	100.0	0.00	do	4.12	0.18	0.28	2.00	5.80	34.5	

Note:—Sandbar noted for good fishing for carp and catfish.

Iron, zinc, fluoride, manganese and copper were not detected by methods used.

A trace of CO indicated 1.0 p.p.m. or less.

A Channel border habitat
B Main channel habitat

Table 4. Phytoplankton
A. Main Channel

	Mississippi R. - St. Louis Eddy, 1934 ($\times 10^3/m^3$)	Mississippi R. - Keokuk to St. Louis ($\times 10^3/m^3$) Eddy, 1934	Mississippi R. - Fairport, Iowa. Galtsoff, 1924	Upper Mississippi R. Reinhard, 1931	Upper Mississippi R. Station 5 Wiebe, 1927	Upper Mississippi R. Station 6 Wiebe, 1927	Upper Mississippi R. Station 7 Wiebe, 1927	Upper Mississippi R. Station 9 Wiebe, 1927	Upper Mississippi R. Station 11 Wiebe, 1927	Upper Mississippi R. Station 14 Wiebe, 1927	Rock R. - Sterling, Ill. ($\times 10^3/m^3$) Eddy, 1934	Ohio R. - Pittsburgh, Ohio Full current Purdy, 1923	Ohio R. - Pittsburgh, Ohio Moderate current Purdy, 1923	Ohio R. - Pittsburgh, Ohio Slack current Purdy, 1923	Hocking R. - Ohio Hutchinson, 1939	R. Thames Rice, 1938
Total Phytoplankton																
Cyanophyta																
Microcystis					480/L		860/L	210/L	120/L	60/L	262					
M. aeruginosa				+				90			2598					
M. flos-aquae				-		60		90		8						
Aphanocapsa																
Anabaena																
A. spiroides																
A. planktonica																
A. affinis				0												
A. flos-aquae				++												
A. circinalis				++												
Clathrocystis								30			1042					
C. aeruginosa																
Aphanizomenon																
A. americanum				++	420											
A. flos-aquae				+												
Coelosphaerium				+	960		60	480								
Gloeocapsa				-												
Merismopedia																
Dictyosphaerium																
Gomphosphaeria																
Lynbya					60		840	70								
Oscillatoria																
O. chlorina				+												
O. limnosa				+												
O. princeps				0												
O. tenuis				0												
Chlorophyta																
Pediastrum	35	424			1720		860	30			187					
P. simplex				+												
P. duplex				+												
P. boryanum				+												
P. integrum				+				30								
Closterium				+												
C. moniliferum				+												
C. ehrenbergii				+												
C. gracile				0												
C. keitzingii																
C. striolatum																
C. acerosum																
Eudorina																
E. elegans				+												
Scenedesmus																
S. minutus				+												
S. quadracauda																
Pleodorina illinoisensis																
Platydorina caudata																
Peridinium																
Actinastrum hantzschii																
Pandorina																
P. morum				+				60	80							
Coelastrum microporum																

[illegible]

Chrysophyta

- rare
o common
+ abundant
++ very abundant
+++ prevalent

- rare

Table 4. Phytoplankton
B. Channel Border

	Mississippi R. Behind dike Caltsoff, 1924	Upper Mississippi R. Station 5 Wiebe, 1927	Upper Mississippi R. Station 6 Wiebe, 1927	Upper Mississippi R. Station 7 Wiebe, 1927	Upper Mississippi R. Station 9 Wiebe, 1927	Upper Mississippi R. Station 11 Wiebe, 1927	Upper Mississippi R. Station 14 Wiebe, 1927	Upper Mississippi R. Reinhard, 1931
Total Phytoplankton								
Cyanophyta								
<i>Clathrocystis aeruginosa</i>	0							
<i>Anabaena</i>		135 / 1	3600 / 1					
<i>Microcystis</i>		360	00	120 / 1	90 / 1			
<i>Aphanocapsa</i>		90		60				
<i>Coelosphaerium</i>		810		60	180	45 / 1		
<i>Sphaerocystis</i>		90						
<i>Dictyosphaerium</i>					30			
<i>Lyngbya</i>			25200		30			
Chlorophyta								
<i>Pediastrum</i>				800		60		
<i>P. duplex</i>								
<i>P. simplex</i>								
<i>Scenedesmus</i>		2405		1600	2230	1600	45 / 1	
<i>S. quadricauda</i>								
<i>Aetinastrum</i>				135				
<i>A. hantzschii</i>								
<i>Staurastrum</i>				800		270	45	
<i>A. gracile</i>								
<i>Platydorina caudata</i>	0							
<i>Chlorella</i>		2400		2400	8000	28000	12000	
<i>Oocystis</i>				1800				
<i>Crucigenia</i>				800				
<i>pandorina</i>				2400				
<i>Eudorina</i>					25			
<i>Closterium</i>						25		
<i>Ulothrix</i>								+
<i>Mougeetia</i>								+
<i>Zygnema</i>								+
<i>Chaetophora</i>								+
<i>Cladophora</i>								+
Euglenophyta								
<i>Phacus longicaudus</i>								
Chrysophyta								
<i>Melosira</i>		10930	11100	11000	70220	4100	1300	
<i>M. crenulata</i>	+							
<i>Synedra</i>		10105	46300	11400	1100	1600	1600	
<i>S. delicatissima</i>	+							
<i>Fragillaria</i>								
<i>F. crotonensis</i>								
<i>Stephanodiscus</i>		9000		11060	4040	270	890	
<i>S. niagarae</i>								
<i>Cyclotella meneghiniana</i>								
<i>Pleurosigma</i>		22760		13720	3260		1600	
<i>Navicula</i>		800		12300	1710		1600	
<i>Amphora</i>		800				2400		
<i>Synura</i>		45			1600	800		
<i>Nitzschia</i>			600					
<i>Epithemia</i>			3000					
<i>Asterionella</i>				60	310	1510	270	
<i>Actinastrum</i>				240				
Misc. diatoms		1600	1200		3100			

- rare
o common
+ abundant
++ very abundant
+++ prevalent

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A

Table 4. Phytoplankton
C. River Lakes and Ponds

	Mississippi R. Floodplain lakes Dorris, 1958	Mississippi R. Horseshoe L. ($\times 10^3/m^3$) Eddy, 1934	Upper Mississippi R. Reinhard, 1931	Lake Pepin Galtsoff, 1924	Upper Lake Keokuk Galtsoff, 1924	Lower Lake Keokuk Galtsoff, 1924	Rock R. Slough ($\times 10^3/m^3$) Eddy, 1934
Total Phytoplankton							
Cyanophyta							
Aphanizomenon flos-aquae							
A. americanum	++		++	+	0	+	
Anacystis inerta	+						
A. montana							
Anabaena flos-aquae	+		+	++	+	++	
A. affinis			0				
A. spiroides				++	0	++	
A. circinalis				++		++	
Pleurocapsa minor	+						
Microcystis							
M. aeruginosa	+		0	+	+	-	
Merismopedia							
M. tenuissima	+		-				
Coelosphaerium kuetzingianum	+						
Ciathrocystis aeruginosa				++	+	++	
Oscillatoria sp.				-		-	
O. aghardii							
Cylindrospermum	+						
Lynghya					0		
Chlorophyta							
Carteria	+						
Gonium			++				
Pandorina morum	+						
Volvoxina	+						
Eudorina elegans		540	-	0	0	+	
Platydictyon caudata	+						
Volvox aureus	+						
V. spermatosphaera					0	0	
Uronema	+						
Ulothrix	+		0				

[illegible]

Table 4. Phytoplankton
D. Side Channel

R. Thames
Rice, 1938

	++
	++
	++
	++
	++
	++
	++
	++
	+
	+
	o
	o
	+
	o
	o
	o

o common
+ abundant
++ very abundant

Chrysophyta
Melosira varians
Fragilaria capucina
Synedra ulna
S. acus
Navicula cryptocephala
Gyrosigma attenuatum
Fragilaria pinnata
Synura uvella
Asterionella gracillima
Amphora ovalis
Nitschia linearis
N. recta
N. sigmoides
N. acicularis

Table 4. Phytoplankton
E. Sloughs

	Rock R. Slough Erie, Ill. (x 10 ³ /m ³) Eddy, 1934	Hatwood Slough Erie, Ill. (x 10 ³ /m ³) Eddy, 1934	Slough near Byron, Ill. (x 10 ³ /m ³) Eddy, 1934	Mississippi R. Andalusia Slough Galtsoff, 1924	Mississippi R. Sturgen Bay Galtsoff, 1924
Total Phytoplankton				66 cm ³ /m ³	50 cm ³ /m ³
Cyanophyta					
Clathrocystis aeruginosa				0	
Microcystis sp.				0	
Oscillatoria				0	
Anabaena spiroides				+	-
Chlorophyta					
Pediastrum duplex	81	1022	30	+	
P. simplex				0	
Closterium acerosum		533	320		
Eudorina elegans	10			0	+
Scenedesmus caudatus	66	462		0	-
Actinastrum hantzschii				+	
Staurostrum gracile				-	
Peridinium				-	
Platydorina caudata				0	++
Pleodorina illinoisensis				-	
Euglenophyta					
Euglena viridis	66	360	960		
E. oxyurus	78	46			
E. acus		733	8000		++
E. spirogyra					++
Phacus longicauda	78	750		-	
Trachelomonas schaninslandii					++
Chrysophyta					
Melosira crenulata				+	-
Synedra delicatissima				+	-
Fragilaria crotonensis				0	
Stephanodiscus niagarae				0	-
Cyclotella meneghiniana				0	-
Pleurosigma spenceri				0	-

- rare
o common
+ abundant
++ very abundant

Table 5. Typical Communities: Phytoplankton.

	Main channel	Channel border	Side channel	River lakes and ponds	Sloughs
Cyanophyta					
Microcystis	+	+		+	+
Aphanocapsa	+	+			
Anabaena	+	+		+	+
Coelosphaerium	+	+			
Merismopedia	+				
Lyngbya	+	+			
Clathrocystis				+	
Aphanizomenon				+	+
Oscillatoria					+
Chlorophyta					
Pediastrum	+	+		+	+
Closterium	+				+
Eudorina	+			+	+
Scenedesmus	+	+		+	+
Pleodorina	+			+	
Platydorina	+				
Pandorina	+			+	
Dictyosphaerium	+				
Tetraspora	+				
Chlorella	+	+			
Volvox				+	
Ulothrix				+	
Spirogyra				+	
Zygnema				+	
Chaetophora				+	
Cladophora				+	
Euglenophyta					
Euglena	+			+	
Phacus	+			+	
Chrysophyta					
Asterionella	+	+			
Meiosira	+	+	+	+	+
Synedra	+	+	+	+	+
Fragillaria	+		+	+	+
Stephanodiscus	+	+		+	+
Cyclotella	+			+	+
Diatoma	+				
Nitzschia	+		+		
Siurella	+				
Navicula	+	+	+		
Synura	+	+			
Pleurosigma	+	+			
Actinastrum	+			+	
Gyrosigma			+		

+ abundant in all collections

VAGI N.
 (no./100 liters)
 Chutter, 1963

	Mississippi R. - St. Louis Eddy, 1934 (x 10 ³ /m ³)	Mississippi R. - Keokuk to St. Louis (x 10 ³ /m ³) Eddy, 1934	Mississippi R. - Hastings, Minn. to Alexandria, Mo. Galtsoff, 1924	Mississippi R. Rock Island Rapids Galtsoff, 1924	Upper Mississippi R. Reinhard, 1931	Upper Mississippi R. Galtsoff, 1924	Ohio R. - Pittsburgh, O. Full current Purdy, 1923	Ohio R. - Pittsburgh, O. Moderate current Purdy, 1923	Ohio R. - Pittsburgh, O. Slack current Purdy, 1923	Illinois R. Kotold, 1903	Illinois R. Havana, Ill. Forbes and Richardson, 1913	Rock R. - Sterling, Ill. Eddy, 1934 (x 10 ³ /m ³)	Hocking R. "Young" stream Hutchinson, 1939	Hocking R. "Mature" stream Hutchinson, 1939	Spoon R. Kotold, 1903	Missouri R. Bernier, 1951	Vaal R. (no./100 liters) Chutter, 1963
Total plankton	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22
Total zooplankton	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22
Protozoa																	
Mastigophora																	
Trachelomonas volvocina																	
Synura uvella																	
Ceratomyxa hirundinella																	
Peridinium sp.																	
Glenodinium sp.																	
Sarcodina																	
Diffugia																	
D. lobostoma																	
D. pyriformis																	
D. corona																	
D. lebes																	
Arcella																	
A. vulgaris																	
Centropyxis aculeaton																	
Euglypha																	
Rhizopoda																	
Ciliata																	
Codonella cratera																	
C. lacustris																	
Colpidium																	
Paramecium																	
Stentor																	
Euplotes																	
Vorticella																	
Colpoda																	
Halteria grandinella																	
Tintinnidium fluviatile																	
Rotifera																	
Keratella																	
K. quadrata																	
K. cochlearis																	
Brachionus																	
B. angularis																	
B. capsiiflorus																	
B. calyciflorus																	
B. budapestinensis																	
B. havanaensis																	
B. pala																	
B. bakeri																	
B. patulus																	
Polyarthra																	
P. tripla																	
P. palyptera																	
Synchaeta																	
S. stylata																	
S. pectinata																	
Asplanchna																	
A. brightwellii																	
A. amphora																	
Filinia																	
F. longiseta																	
Rotifer																	
Pedalia																	
P. mira																	
Conchiloides natans																	
Cathypna																	
Triarthra																	
T. longiseta																	
Notops																	
N. brachionus																	
Durella stylata																	
Euchlanis dilatata																	

Table 6. Zooplankton
B. Channel Border

	Upper Mississippi R. Galtsoff, 1924	Upper Mississippi R. (no./liter) Wiebe, 1927	Upper Mississippi R. Behind dike Galtsoff, 1924	Vaal R. Marginal vegetation Chutter, 1963	Hocking R. Hutchinson, 1939
Total plankton					
Total zooplankton	30 - 330 cm ³ /m ³				
Protozoa					
Rotifera					+
Brachionus					
B. angularis			-		
Keratella		0.8 - 15.0			
K. cochlearis			-		
Noseus		1.2 - 18.0			
Rotifer		0.6 - 78.0			
Polyarthra		1.6 - 4.0			
Triarthra		0.4 - 2.2			
Distyla		0.6 - 1.2			
Asplanchna		0.4 - 0.6			
Crustacea					
Copepoda	400 - 125,000 /m ³				
Cyclops		0.8 - 2.4		++	
Parachlops				+	
Harpacticidae				+	
Diaptomus		0.6 - 3.0			
Simocephalus		2.4			
Nauplii		9 - 34.4			
Cladocera	2 - 70 /m ³				
Bosmina		0.4 - 4.4			
Daphnia		0.6			
Chydorus		0.6 - 2.0		+	
Ceriodaphnia		1.2		+	
Simocephalus				+	
Moina					
M. rectirostris					
Macrothrix spinosa				+	
Alona sp.				+	
Ostracoda					
Stenocypris				+	
Cypridopsis				+	
Pinocypris				++	
Ilyocythere				+	
Cyprilla				+	

- rare
o common
+ abundant
++ very abundant

Table 6. Zooplankton
C. River Lakes and Ponds

Upper Mississippi R.	Reinhard, 1931	Mississippi R. - Flood-plain lakes near Quincy, Ill.	Dorris, 1958	Mississippi R.	Horseshoe L. ($\times 10^3/m^3$)	Upper L. Keokuk	Galtsoff, 1924	Lower L. Keokuk	Galtsoff, 1924	L. Pepin	Galtsoff, 1924	Illinois R. Thompson L.	Forbes and Richardson, 1913	Illinois R. Outer L.	Forbes and Richardson, 1913	Kotold, 1903	Hocking R. Behind dam	Hutchinson, 1939	Scottish Hill Lochs	Replacement quotient=91 days	Brook and Woodward, 1956	Scottish Hill Lochs	Replacement quotient=26 days	Brook and Woodward, 1956	Scottish Hill Lochs	Replacement quotient=5 days	Brook and Woodward, 1956
----------------------	----------------	--	--------------	----------------	------------------------------------	-----------------	----------------	-----------------	----------------	----------	----------------	-------------------------	-----------------------------	----------------------	-----------------------------	--------------	-----------------------	------------------	---------------------	------------------------------	--------------------------	---------------------	------------------------------	--------------------------	---------------------	-----------------------------	--------------------------

Total plankton																											
Total zooplankton																											
Protozoa																											
Sarcodina																											
Arcella																											
A. vulgaris																											
Diffugia																											
D. pyriformis																											
D. corona																											
D. lebes																											
D. lobostoma																											
Centropixis aculeata																											
Mastigophora																											
Trachelomonas volvocina																											
Synura uveilla																											
Peridinium																											
Ceratium hirundinella																											
Ciliata																											
Frontonia																											
Lacrymaria																											
Paramecium																											
Stentor																											
S. coerules																											
Codonella																											
C. cratera																											
C. lacustris																											
Colpidium																											
Vorticella																											
Colpoda																											
Tintinnidium fluviatile																											
Rotifera																											
Asplanchna																											
A. brightwellii																											
A. amphora																											
A. priodonta																											
Brachionus																											
B. angularis																											
B. bidentata																											
B. budapestinensis																											
B. calyciflorus																											
B. caudatus																											
B. havanaensis																											
B. quadridentatus																											
B. urceolaris																											
B. caudatus																											

B

[illegible]

[illegible]

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Mississippi R.
Prairie du Chien
Miss. 1931.

110 cm³/m³

Page - 210, 111.

Graph - Ex 10, Ill.

roughness
($\approx 10^3/\lambda$)

Misses Appl R.
Sturgeon Bay
Tatloff, 1924

**Mississippi R.
Ardeolus Slough
Salteoff, 1924**

ILLINOIS
MAY 1967

[illegible]

- rare
- common
- + abundant
- ++ very abundant

Table 7. Typical Communities: Zooplankton

	Main channel	Channel border	Side b	River lakes and ponds	Sloughs
Total zooplankton	0.3-22.7 cm ³ /m ³	3-22.0 cm ³ /m ³	11.0 cm ³ /m ³	0.465-11.46 cm ³ /m ³	
Protozoa					
Ceratium	+			+	+
Peridinium	+				
Diffugia	+				+
Arcella	+			+	
Codonella	+			+	+
Paramecium	+				
Stentor	+			+	
Vorticella	+				
Trachelomonas					+
Rotifera					
Keratella	+	+		+	+
Brachionus	+				
Polyarthra	+	+		+	+
Synchaeta	+	+			
Filinia	+			+	
Rotifer	+			+	
Pedalia	+			+	
Notus		+		+	+
Triarthra		+		+	
Asplanchna				+	+
Lecane				+	+
Euchlanis				+	
Rattulus				+	
Cladocera	0.00-0.000 /m ³	2-7.0 /m ³		0.00-0.100 /m ³	0.00-0.000 /m ³
Bosmina	+	+		+	
Chydorus	+	+		+	+
Diaphanosoma	+			+	
Daphnia	+			+	+
Leptodora kindtii				+	+
Sida				+	+
Moina				+	+
Copepoda	0.000-2.000 /m ³	0.40-44.00 /m ³		0.000-12.000 /m ³	0.00-10.00 /m ³
Cyclops	+	+		+	+
Nauplii	+	+		+	
Simcephalus		+			
Diaptomus				+	+

+ abundant in all collections

A

Table 8. Benthos
A. Main Channel

	Upper Mississippi R. (no./liter)	Illinois R. Richardson, 1921	Illinois R. Havana, Ill. Richardson, 1928	Missouri R. channelized (mg/m ²) Mortz, et al., 1968	Missouri R. - partially channelized (mg/m ²) Mortz, et al., 1968	Missouri R. channelized (mg/m ²) Mortz, et al., 1968	Missouri R. Bernier, 1951	Ohio R. - Pittsburgh, O. Full current Purdy, 1923	Ohio R. - Pittsburgh, O. Moderate current Purdy, 1923	Ohio R. - Pittsburgh, O. Black current Purdy, 1923	Black R. O'Connell and Campbell, 1953	R. Wata Sand bottom Mikulski, 1961	R. Wata Transit silt Mikulski, 1961	R. Wata "Reefs" Mikulski, 1961	R. Dovey - West Wales (no./collection) Jones, 1941	Marginal vegetation Chutler, 1963
Total Benthos	720	24	1,720	2,800	240	2,800						48/m ²				
Tubellaria																
Planariidae																
Polycelis nigra																
Nematoda																
Annelida																
Hirudinea																
Haemaphys sanguisuga																
Herpobdella atomaria																
Helobdella stagnalis																
Glossiphonia complanata																
Oligochaeta																
Tubificidae																
Limnodrilus																
Protoparus volki																
Mollusca																
Gastropoda																
Ancylidae																
Ancylastrum fluviatile																
Physidae																
Limnaeidae																
Lymnaea natalensis																
Bulinus tropicus																
Lurnupia																
Corbicula																
Planorbidae																
Polycepe																
Pisidium pusillum																
Unionidae																
Sphaeriidae																
Sphaerium rivicola																
Amphipoda																
Hyalella																
Gammarus zaddachi																
Isopoda																
Asellidae																
Asellus aquaticus																
Trichoptera																
Rhyacophilidae																
Rhyacophila																
R. dorsalis																
Glossosoma boltoni																
Hydroptilidae																
Ithytrichia lamellaris																
Leptoceridae																
Philopotamidae																
Helicopsychidae																
Hydropsychidae																
Hydropsyche																
H. instabilis																
H. pellucida																
Chironomopsycha																
Psychomyiidae																
Polycentropis																
Nereidopsis																
Phitopolamus montanus																

Gammarus zaddachi
 Isopoda
 Asellidae
 Asellus aquaticus
 Trichoptera
 Rhyacophilidae
 Rhyacophila
 R. dorsalis
 Glossosoma boltoni
 Hydroptilidae
 Hydroptilia lomellaris
 Leptoceridae
 Philopotaridae
 Helicopsychidae
 Hydropsychidae
 Hydropsyche
 H. instabilis
 H. pellucidula
 Chenopopsychae
 Psychomyidae
 Polycentropis
 Neureclipsis
 Philopotamus montanus
 Odontoceridae
 Molannidae
 Phryganidae
 Platostomus
 Lepidostomatidae
 Lepidostoma hirtum
 Diptera
 Tipulidae
 Dixidae
 Ceratopogonidae
 Culicidae
 Anopheles
 Cixiæ
 Tabanidae
 Simuliidae
 Syrphidae
 Psychodidae
 Chironomidae
 Chironomus
 C. plumosus
 C. thummi
 Cryptochironomus
 C. parastroatus
 C. detritus
 Paratendipes connectens
 Stempellina hauseri
 Stictochironomus
 Tanytarsus
 Ephemeroptera
 Baetidae
 Amotrupus eatoni
 Brachyterys
 Caenis
 Ephemerella
 Stiphodonas
 Cloeon
 Baetis
 Heptageniidae
 Rithrogena
 Ephemerellidae
 Ephoron
 Peragenia
 Hexagenia
 Coileoptera
 Hydrophilidae
 Psephenidae
 Gyniidae
 Dystacidae
 Belontiidae
 Corixidae
 Corixa striata
 C. schubertaei
 C. fahneni
 Sagaria mitchelliana
 Hydrometra stagnorum
 Gerridae
 Gerris palaeus

C. defectus	
Pirandipus connectens	
Stomellia baurei	
Stictochironomus	
Tagipus	
Ephemeroptera	
Baetidae	
Ametropus caloni	
Brachymerus	
Caenis	
Ephemerella	
Stiphodon	
Cleon	
Baetis	
Heptageniidae	
Rithrogena	
Ephemeridae	
Ephoron	
Pentagenia	
Hexagenia	
Coleoptera	
Hydrophilidae	
Psephenidae	
Gyrinidae	
Dytiscidae	
Helodidae	
Hemiptera	
Corixidae	
Corixa striata	
C. shillerbergi	
C. tuberosa	
Sagara munda	
Hydroptilidae	
Hydroptera stagnans	
Gerridae	
Gerris nalis	
G. lacustris	
Veliidae	
Velia curvipes	
Odonata	
Libellulidae	
Aeschnidae	
Coenagrionidae	
Ischnura elegans	
Agrionidae	
Eallipterix	
Gomphidae	
Gomphus	
Oedonophus	
Plecoptera	
Chloroperlidae	
Chloroperla	
Perlidae	
Perla	
Nemoura	
Leuctra	
Nemura	
Neuroptera	
Sialidae	
Sialis	
Lepidoptera	
Pieridae	

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- rare
o common
+ abundant
++ very abundant
+++ prevalent

C

Table 8. Benthos
B. Channel Border

	Upper Mississippi R. (no./m ²) Wiebe, 1927	Illinois R. (lbs./acre) Richardson, 1921	Missouri R. Steep bank Berner, 1951	Missouri R. Behind pile dike Berner, 1951	R. Wista - Sand and silt in mild current Mikulski, 1961	R. Wista - Sand and silt bottom with no current Mikulski, 1961	Vaal R. Marginal vegetation Chutter, 1963
Total Benthos							
Turbellaria							
Planariidae							+
Rhabdocoela							+
Prostoma							+
Nematoda							
Oligochaeta		0.5					
Tubificidae							
Limnodrilus	3,000-50,000					700/m ²	+
Nais							+
Naididae							+
Pristina							+
Hirudinea		4.7					+
Mollusca		0.3					
Amphipoda							
Hysalella azteca	3,200-3,600						
Tardigrada							+
Trichoptera							
Cheumatopsyche thomasetti							+
Amphipsyche scottae							+
Tranodes falculata							+
Orthotrichia							+
Diptera							
Ceratopogonidae							+
Tipulidae							+
Syphridae							+
Empididae							+
Ephydriidae							+
Pleidae							0
Chironomidae	36-54	1.0					
Chironomus							
C. thummi					+		
C. plumosus					+		
Allochironomus					+		
Limnochironomus nervosus						+	
Tanytarsus lobatifrons						+	
Trichocladus alagarom						+	
Procladius						+	
Ablabesmyia lentiginosa						+	
Cryptochironomus demeieri						+	
Simuliidae							
Simulium							+
S. memahoni							+
S. nigratarsis							-
S. damnosum							+
Ephemeroptera							
Baetis							+
B. harrisoni							+
B. bullus							+
Centroptilium excisum							+
Pseudocloeon maculosum							+
P. vinosum							+
Austrocloeon							+
A. africanum							0
Caenidae							+
Coleoptera		0.5					
Dytiscidae							0
Hydraenidae							0
Elmidae							0
Moneta							0

0 common
+ abundant

Table 8. Benthos
C. River Lakes and Ponds

Black R.
Clearwater L.
O'Connell and Campbell, 1953

Illinois R.
Peoria L.
Richardson, 1928

Illinois R. - Thompson L.
No vegetation (lbs./acre)
Richardson, 1921

Illinois R. - Thompson L.
With vegetation (lbs./acre)
Richardson, 1921

Mississippi R.
Floodplain lakes
Dorris, 1958

Porifera	+				
Meyenia crateriformis					
Nematoda					
Limnomermis	0				
Pseudomermis	0				
Oligochaeta		0.1			+++
Tubificidae				3.2-1292 #/A	
Sparganophilus	+				
Pelosclex multisetosus	+				
Hirudinea		1.4	3.9	3.2-106 #/A	+
Glossiphonia fusca	+				
Placobdella montifera	+				
Helobdella stagnalis	+				
Erpobdella punctata	+				
Amphipoda					
Talitridae					+
Mollusca					
Gastropoda		316.5	206.3	14.7 #/A	+
Physidae					+
Limnaeidae					+
Ancylidae					
Ferrissia	+				
Pelyceopoda		1.4	10.2		
Unionidae					
Anodonta grandisi	+				+
A. corbulenta	+				

	T					
Erpobdella punctata	+					
Amphipoda						
Talitridae						
Mollusca						+
Gastropoda						
Physidae						
Limnaeidae		316.5	206.3	14.7	W/A	+
Ancyclidae						+
Ferrissia						+
Pelyceopoda	+					
Unionidae		1.4	10.2			
Anodonta grandisi	+					+
A. corpulenta	+					
Cyrenidae						
Sphaeriidae					0.7-5.4 11.2	W/A
Decapoda						
Cambarus immunis						+
Palaemonetes						+
Diptera						
Chironomidae						
Chironomus dorsalis	+	170.5	88.9	132.5	W/A	+++
C. nervosus	+					
C. crassicaudata	+					
Harnischia tenuicaudata	0					
Cryptochironomus digitatus	0					
C. pararostris	+					
Glyptotendipes lobiferus	+					
Tanytus stellata	+					
Clinotanytus	+					
Coelotanytus concinnus	0					
Procladius adumbratus	+					
P. culiciformis	+					
Culicidae						+++
Chaoborus punctipennis	++					
Psorophora ciliata	+					
Tabanidae						
Ceratopogonidae						+
Tipulidae						+
Ephemeroptera						+
Baetidae						+
Ephemoridae						+
Caenis	+					
Odonata						
Coenagrionidae						
Ischnura verticulis	0					
I. posita	0					
Enallagma signatum						
Agriumidae						
Agriaviola	0					+
Aeschnidae						

P. culiciformis
 Culicidae
Chaoborus punctipennis
Psorophora ciliata
 Tabanidae
 Ceratopogonidae
 Tipulidae
 Ephemeroptera
 Baetidae
 Ephemeridae
 Caenis
 Odonata
 Coenagrionidae
Ischnura verticulis
I. posita
 Enallagma signatum
 Agriumidae
 Agriaviolacea
 Aeschnidae
 Nasiaeschna
 Gomphidae
 Gomphus submedianus
 Libellulidae
 Heleidae
 Atrichopogon
 Palpomyia
 Ephydriidae
 Parydra
 Coleoptera
 Hydrophilidae
 Parnidae
 Gyrinidae
 Hemiptera
Trichocoria verticalis
Sigara alternata
 Trichoptera
 Leptoceridae
 Heliopsychidae
 Hydropsychidae

+						+++
++						
+						
						+
						+
						+
						+
						+
+						+
o						
o						
o						+
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o						+
+						
+						
+						
						+
						+
						+
+						
+						
+						
+						
				17	11	
						+
						+
						+
o common						

+ abundant
 ++ very abundant
 +++ prevalent

Table 8. Benthos
D. Side Channel

R. Wista
Old channel
Mikulski, 1961

11,000/m ²
1,550/m ²
1,631/m ²
+++

Oligochaeta
Tubifex tubifex
T. barbatus
Mollusca
Gastropoda
Diptera
Chironomidae
C. plumosus

A

Table 10. Ecology of the fishes recorded as pres

Fish	Habitat	Food	Migration/Mobility	Abundance	Size	Commercial importance	Sport importance	Relationship with other fish
<u>Amia calva</u>	General distribution; prefer sluggish waters and weedy areas	Primarily piscivorous; some molluscs and crayfish	Migrate into shallow backwaters to spawn	Frequently abundant	1 1/2'-2' (3')	None; can be eaten with correct preparation	Good fighting	Detrimental; voracious predator
<u>Lepisosteus osseus</u>	Large rivers, lakes, ponds, sloughs; prefer areas with logs, weeds, brush, mud and sand bottom	Piscivorous; small fish	Move into shallows to spawn	Abundant	2.2 m	None	Good fighting	Predator
<u>Lepisosteus platostomus</u>	Large rivers, lakes; prefer channels of large, silty rivers, with hard bottoms and no vegetation	Piscivorous	Often move into shallows or flooded areas, or upstream from lakes	Abundant	2.5 m	None	Good fighting	Predator
<u>Anguilla rostrata</u>	Lakes and rivers; prefer larger streams, deep water with mud bottom	Carnivores; scavengers of dead fish and animal matter; omnivorous	Catadramous	Rare	1-2 m	Valuable food	None	
<u>Niodon alosoides</u>	Lakes and rivers; prefer large, silty streams and oxbow lakes	Insects, molluscs, small minnows		Rare	0.4 m	None; poor food fish	Some game value where abundant; will take artificial lure	
<u>Niodon tergisus</u>	Lakes and large rivers	Primarily invertebrates including plankton		More common than <u>N. alosoides</u>		None	Game fish, will take artificial lure	
<u>Dorosoma cepedianum</u>	Lakes, large rivers, backwater areas; prefer open waters over mud bottoms	Debris, phytoplankton, zooplankton, some benthic and nektonic fauna	Some movement, associated with spawning; upstream or in to shallows	Very abundant	.25 m	None	Forage	Forage
<u>Ictiobus cypri-nellus</u>	Lakes and rivers; prefer slower current over mud bottom, deep water	Benthophagic; macro and microinvertebrates, algae, detritus	Upstream migration into sloughs to spawn	Up to 600 lbs. per acre	1 m 50 lbs.	Limited	None	Compete with benthophagic fish
<u>Ictiobus bubalus</u>	Larger streams and lakes	80% macro and microinvertebrates, 20% algae and vascular plants	Movement into shallows	More abundant	40 lbs.	Limited	None	Compete with benthophagic fish
<u>Carpiodes carpio carpio</u>	Large, turbid rivers; lakes, ponds	Insects, molluscs, entomostracans, algae, protozoa, bottom ooze		Abundant in some areas	2 lbs.	Little, poor quality food		Compete with benthophagic fish
<u>Cyprinus carpio</u>	All habitats; prefer weak currents and mud bottom	Omnivorous; insects, plants, other invertebrates, organic debris; prefer animal food	Variable migrations; nomadic; migrate to shallows to spawn	Very abundant	Up to 20 lbs. common	Low price, but large quantity makes fish valuable	Some sport fishing	Increase turbidity, compete with benthophagic fish
<u>Notemigonus crysoleucas</u>	Lakes, ponds, streams; prefer weak currents, vegetated areas, mud and debris bottom	Omnivorous		Very abundant	15-25 cm	Bait fish	Bait fish	Forage
<u>Pimephales notatus</u>	Lakes and streams of all sizes; most abundant in small and medium sized streams with firm bottom	Omnivorous		Abundant	9 cm	Bait fish	Forage fish	Forage
<u>Pimephales vigilax</u>	All streams	Omnivorous		Very abundant; more abundant in larger rivers than <u>P. notatus</u>	8 cm	Bait fish	Forage fish	Forage
<u>Hybognathus nuchalis</u>	Large and small rivers, silty rivers and backwater areas over mud bottom	Mud feeder; only eats algae	Migrate to quiet water to spawn	Abundant	10 cm	None	Forage fish	Forage
<u>Notropis lutrensis</u>	Large streams	Algae, insects, crustaceans		Abundant	6 cm	None	Forage	Forage
<u>Notropis atherinoides</u>	Open water of larger lakes and rivers with clean bottom	Entomostraca, some algae, terrestrial insects		Abundant	10 cm	Bait fish	Forage	Forage
<u>Hybopsis storeriana</u>	Larger lakes and rivers; prefer gravel bottom	Mayflies, chironomids, amphipods	Moves into creeks to spawn	Common	20 cm	None	None	Forage
<u>Fundulus notatus</u>	Lakes and streams; prefer weedy areas, mud, detritus bottom; usually at surface	Insects, some filamentous algae, amphipods and entomostraca		Common	8 cm	None	Forage	Forage
<u>Gambusia affinis</u>	Quiet waters of lakes and streams			Common	5 cm	None	Limited value as forage	Forage
<u>Libidesthes sicculus</u>	Open water, lakes and streams; at surface	Aquatic insects, entomostraca		Common	8 cm	None	Limited value as forage	Forage
<u>Ambloplites rupestris</u>	Shallow, eutrophic	Insects, fish, crusta-	Move into shallow	Abundant	1.25 m	Valuable	Rough fish;	Compete with

B

Table 10. Ecology of the fishes recorded as present, St. Louis, Missouri, to Cairo, Illinois.

Species	Abundance	Size	Commercial importance	Sport importance	Relationship with other fish	Current requirements	Turbidity requirements	Dissolved oxygen requirements	Special requirements	Spawning time	Spawning site
<i>M. l.</i>	Frequently abundant	1 1/2'-2' (3')	None; can be eaten with correct preparation	Good fighting	Detrimental; voracious predator	Tolerate current	Prefer clear water	Can breathe air		Late spring	Quiet water with vegetation and debris; 2-3' deep; vegetation "nest" nest in colonies
<i>M. s.</i>	Abundant	2.2 m	None	Good fighting	Predator	Prefer stagnant water		Can breathe air		Late spring	Shallow water among grass and weeds
<i>M. d.</i>	Abundant	2.5 m	None	Good fighting	Predator	Prefer sluggish water		Can breathe air		Late spring to summer	Shallow water (1-3') with weeds; often in flooded areas
<i>M. r.</i>	Rare	1-2 m	Valuable food	None		Tolerant		Skin respiration		Summer; begin migration in early spring	Atlantic Ocean
<i>M. r.</i>	Rare	0.4 m	None; poor food fish	Some game value where abundant; will take artificial lure		Prefer swift water	Tolerant		Not tolerant to pollution	Early spring	Shallow areas
<i>M. r.</i>	More common than <i>M. al-</i> <i>oides</i>		None	Game fish, will take artificial lure			Less tolerant		Not tolerant to pollution	Early spring	Shallow areas
<i>M. s.</i>	Very abundant	.25 m	None	Forage	Forage	Tolerant	Tolerant		Tolerant of salinity, not with prolonged temperature	Mid spring to summer	Shallow areas of lakes, rivers, sloughs
<i>M. l.</i>	Up to 600 lbs. per acre	1 m 50 lbs.	Limited	None	Compete with benthophagic fish	Prefer quiet water	Tolerant			Mid April to May	Sloughs and flooded land over grass and vegetation or mud
<i>M. l.</i>	More abundant	40 lbs.	Limited	None	Compete with benthophagic fish	Prefer sluggish or standing water	Tolerant			Mid April to May; requires rising water	Sloughs and flooded land over grass and vegetation or mud
<i>M. l.</i>	Abundant in some areas	2 lbs.	Little, poor quality food		Compete with benthophagic fish	Prefer sluggish water	Tolerant			April to June	Randomly distribute eggs
<i>M. l.</i>	Very abundant	Up to 20 lbs. common	Low price, but large quantity makes fish valuable	Some sport fishing	Increase turbidity, compete with benthophagic fish	Tolerant	Tolerant	Tolerant		Spring through summer	Marshes, flooded land, shallow areas; eggs scattered at random over vegetation rubble and debris
<i>M. l.</i>	Very abundant	15-25 cm	Bait fish	Bait fish	Forage	Tolerant	Tolerant	Tolerant		May to August	Quiet areas; beds of vegetation and mats of filamentous algae
<i>M. l.</i>	Abundant	9 cm	Bait fish	Forage fish	Forage	Wide tolerance, prefer quiet water	Wide tolerance			May to August	Under surface of various objects in shallow water or over gravel or sand bottom
<i>M. l.</i>	Very abundant; more abundant in larger rivers than <i>p. notatus</i>	8 cm	Bait fish	Forage fish	Forage	Prefer rapid current				Late May to August	
<i>M. l.</i>	Abundant	10 cm	None	Forage fish	Forage	Tolerant	Tolerant			May to August, intermittent spawner	Calm water near shore; lays eggs on bottom ooze
<i>M. l.</i>	Abundant	6 cm	None	Forage	Forage	Wide tolerance	Wide tolerance			May to October	Newly flooded weedy areas in lakes and rivers
<i>M. l.</i>	Abundant	10 cm	Bait fish	Forage	Forage	Prefer current	Tolerant			Mid May to August	Near surface in open water
<i>M. l.</i>	Common	20 cm	None	None	Forage	Tolerant	Tolerant			June to July	In creeks or open water
<i>M. l.</i>	Common	8 cm	None	Forage	Forage	Prefer weak current	Tolerant			Late May to June	Weed-filled shorelines
<i>M. l.</i>	Common	5 cm	None	Limited value as forage	Forage	Tolerant; prefer quiet water	Tolerant			May to September, more than 1 brood/season	Viviparous
<i>M. l.</i>	Common	8 cm	None	Limited value as forage	Forage	Tolerant				June	Shoal areas, frequently with current
<i>M. l.</i>		1.25 m	Unusable	Game fish	Compete with	Tolerant	Tolerant, pre-	Fairly high		May to June	No specific require-

B

as present, St. Louis, Missouri, to Cairo, Illinois.

C

Ship or sal;	Current requirements	Turbidity requirements	Dissolved oxygen re- quirements	Special requireme nts	Spawning time	Spawning site	Reproduction		Young	Maturity
							Eggs	Hatching time		
sal; pre-	Tolerate current	Prefer clear water	Can breathe air		Late spring	Quiet water with vegetation and debris; 2-3' deep; vegetation "nest". nest in colonies	Adhesive; adhere to plant roots; 2000-5000/nest	8-10 days; leave nest in 9 days	School	4 years
	Prefer stagnant water		Can breathe air		Late spring	Shallow water among grass and weeds	Up to 77,000 deposited on vegetation; adhesive; poisonous	3-9 days	Rapid growth, 6-8" in first year	4-6 years
	Prefer sluggish water		Can breathe air		Late spring to summer	Shallow water (1-3') with weeds; often in flooded areas	Adhesive; withstand dessication	8-9 days	5-6" after first year	
	Tolerant		Skin respiration		Summer; begin migration in early spring	Atlantic Ocean	10 million			2 years
	Prefer swift water	Tolerant		Not tolerant to pollution	Early spring	Shallow areas	14,000; semi-buoyant		15 cm after first year	2-4 years
		Less tolerant		Not tolerant to pollution	Early spring	Shallow areas			15 cm after first year	
	Tolerant	Tolerant		Tolerant of salinity, cannot withstand prolonged low temperature	Mid spring to summer	Shallow areas of lakes, rivers, sloughs	400,000; demersal and adhesive	36-100 hours	15 cm after first year; school	1-3 years
with bagic	Prefer quiet water	Tolerant			Mid April to May	Sloughs and flooded land over grass and vegetation or mud	Adhere to vegetation 400,000 from 10-lb. female	8-14 days	17 cm after first year	3 years
with bagic	Prefer sluggish or standing water	Tolerant			Mid April to May; requires rising water	Sloughs and flooded land over grass and vegetation or mud	Adhere to vegetation 400,000 from 10-lb. female	8-14 days	17 cm after first year	3 years
with bagic	Prefer sluggish water	Tolerant			April to June	Randomly distribute eggs	100,000	8-12 days	3-5" in first year	2-3 years
with tur- compete with fish	Tolerant	Tolerant	Tolerant		Spring through summer	Marshes, flooded land, shallow areas; eggs scattered at random over vegetation rubble and debris	39,000-2,000,000	3-20 days	5" by end of first summer, 1 lb. after first year	2-4 years
	Tolerant	Tolerant	Tolerant		May to August	Quiet areas; beds of vegetation and mats of filamentous algae	Adhesive			1 year
	Wide tolerance, prefer quiet water	Wide tolerance			May to August	Under surface of various objects in shallow water or over gravel or sand bottom	2,000/year	7-14 days		
	Prefer rapid current				Late May to August					
	Tolerant	Tolerant			May to August, intermittent spawner	Calm water near shore; lays eggs on bottom once	Average of 3,000; non-adhesive			1 year
	Wide tolerance	Wide tolerance			May to October	Newly flooded weedy areas in lakes and rivers			4 cm after first year	1 year
	Prefer current	Tolerant			Mid May to August	Near surface in open water		24 hours		
	Tolerant	Tolerant			June to July	In creeks or open water	11,000		4 cm after one year	
	Prefer weak current	Tolerant			Late May to June	Weed-filled shorelines	"Thrown" into vegetation	24 days	5 cm after one year	
	Tolerant; prefer quiet water	Tolerant			May to September, more than 1 brood/season	Viviparous	1-315/season			1 year
	Tolerant				June	Shoal areas, frequently with current	Float until contact with object, then adhere		School; adult size in 1 year	1 year
with	Tolerant	Tolerant, pre-	Fairly high		May to June	No specific require-	Pelagic	25-30 hours	School;	3-7 years

<u>Notropis lutrensis</u>	Large streams	Algae, insects, crustaceans		Abundant	6 cm	None	Forage	Forage
<u>Notropis atherinoides</u>	Open water of larger lakes and rivers with clean bottom	Entomostraca, some algae, terrestrial insects		Abundant	10 cm	Bait fish	Forage	Forage
<u>Hybopsis storeniana</u>	Larger lakes and rivers; prefer gravel bottom	Mayflies, chironomids, amphipods	Moves into creeks to spawn	Common	20 cm	None	None	Forage
<u>Fundulus notatus</u>	Lakes and streams; prefer weedy areas, mud, detritus bottom; usually at surface	Insects, some filamentous algae, amphipods and entomostraca		Common	8 cm	None	Forage	Forage
<u>Gambusia affinis</u>	Quiet waters of lakes and streams			Common	5 cm	None	Limited value as forage	Forage
<u>Labidesthes sicculus</u>	Open water, lakes and streams; at surface	Aquatic insects, entomostraca		Common	8 cm	None	Limited value as forage	Forage
<u>Aplodinotus grunniens</u>	Shallow, eutrophic lakes, large rivers and tributaries	Insects, fish, crustacea; primarily benthophagic	Move into shallow water in spring, return to deeper water in fall	Abundant	1.25 m 20-25 kg avg. 1-2 kg	Valuable	Rough fish; will take bait or lure	Compete with benthophagic fish
<u>Ictalurus natalis</u>	Ubiquitous; most abundant in larger streams	Omnivorous; insects, fish, also scavenger		Abundant	1 kg	Little	Fair, good quality meat	Compete with benthophagic fish
<u>Ictalurus punctatus</u>	Lakes, rivers, streams	Benthic insects, fish, filamentous algae	Nomadic	Abundant	10 kg usually 2.2 kg	High	High	
<u>Ictalurus furcatus</u>	Large streams; rarely in lakes and small streams	Primarily piscivorous; some large crustaceans	Move into flooded area during water, downstream in winter	Common	60 kg 10-12 kg common	High	High	
<u>Pylodictus olivaris</u>	Large rivers, tributaries, and backwaters	Piscivorous	Homing and nest-seeking, migrate into tributaries	Rare to common	20 kg	Limited	Limited	Predator
<u>Morone chrysops</u>	Deep, standing water, lower portions of rivers	Fish, insects, crustaceans	Move freely in schools; upstream in spring to spawn	Abundant	1.5 kg 45 cm		Good	Predator
<u>Micropterus salmoides</u>	All waters, most abundant in lakes	Primarily piscivorous	Restricted movement	Abundant	6 kg		Good	Predator
<u>Micropterus punctulatus</u>	Prefer streams and rivers (deeper water than <i>M. salmoides</i>)			Common	1 kg		Good	Predator
<u>Lepomis cyanellus</u>	Widely distributed, all habitats, weedy areas with mud bottom	Insects, crustaceans, fish		Very abundant	15-20 cm in tributaries and extra-channel areas		Fair	
<u>Lepomis humilis</u>	Streams	Insects, crustaceans, occasionally small fish		Abundant in some areas	10 cm	None	Poor	
<u>Lepomis macrochirus</u>	All warm water areas	Aquatic insects and zooplankton		Abundant	0.5 kg	None	Good	
<u>Lepomis microlophus</u>	Primarily lakes	Aquatic insects, molluscs, filamentous algae, macrophytic vegetation			0.3 kg 15-20 cm	None	Good	
<u>Lepomis megalotis</u>	Large streams, ponds, weedy areas with mud, detritus bottom	Aquatic insects, crustaceans, fish	None	Common	20 cm	None	Good	
<u>Lepomis gulosus</u>	Lakes, streams; all bottom types with or without vegetation	Fish, crayfish, aquatic insects		Rare	25 cm	None	Good	Predator as adult
<u>Pomoxis nigromaculatus</u>	Lakes and streams, weedy areas with mud, debris bottom	Aquatic insects, fish, crustaceans	Random	Abundant	35 cm	None	Good	Predator as adult
<u>Pomoxis annularis</u>	Lakes and streams; mud, debris bottom	Crustaceans, insects, fish	Random	Abundant (more abundant in warmer waters than <i>P. nigromaculatus</i>)	30 cm	None	Good	Predator as adult
<u>Dorosoma petenense</u>	Lakes (pelagic zone), streams in current areas	Plankton	Travel in schools	Abundant	10-15 cm	None	Important as forage	Forage
<u>Alosa chrysochloris</u>	Large rivers	Primarily fish	Anadromous in some streams	Rare	1 kg	None	None	Predator
<u>Stizostedion vitreum</u>	Lakes, rivers with hard bottoms	Fish, larger invertebrates	Usually confined to home pool, but may move up or down stream in schools	Common in certain areas	6 kg .6 m		Good	Predator
<u>Stizostedion canadense</u>	Large rivers, lakes, ponds with firm bottom	Fish, insects, crustaceans	Move randomly from home pool	Abundant in certain areas, more abundant than walleye in southern waters	.5 m maximum		Good	Predator

	Abundant	6 cm	None	Forage	Forage	Wide tolerance	Wide tolerance		May to October	Newly flooded weedy areas in lakes and rivers	
	Abundant	10 cm	Bait fish	Forage	Forage	Prefer current	Tolerant		Mid May to August	Near surface in open water	
aka	Common	20 cm	None	None	Forage	Tolerant	Tolerant		June to July	In creeks or open water	11
	Common	8 cm	None	Forage	Forage	Prefer weak current	Tolerant		Late May to June	Weed-filled shorelines	7
	Common	5 cm	None	Limited value as forage	Forage	Tolerant; prefer quiet water	Tolerant		May to September, more than 1 brood/season	Viviparous	1-
	Common	8 cm	None	Limited value as forage	Forage	Tolerant			June	Shoal areas, frequently with current	Fl wi ad
low y, er	Abundant	1.25 m 20-25 kg avg. 1-2 kg	Valuable	Rough fish; will take bait or lure	Compete with benthophagic fish	Tolerant	Tolerant, prefer clean water	Fairly high requirement	May to June	No specific requirement; usually shallow open water	60
	Abundant	1 kg	Little	Fair, good quality meat	Compete with benthophagic fish	Tolerant, prefer sluggish	Tolerant	Tolerate low dissolved O ₂	May to July	.2-1.2 m deep water	20
	Abundant	10 kg usually 2.2 kg	High	High		Tolerant	Tolerant, prefer clear water	Fairly high requirement	May to June	Shallow water in shelter	30
ded ter,	Common	60 kg 10-12 kg common	High	High					April to June		
te as	Rare to common	20 kg	Limited	Limited	Predator	Tolerant	Tolerant		May to August	3.5-5 m deep; build nest in secluded water	60 ad
am awn	Abundant	1.5 kg 45 cm		Good	Predator	Prefer standing water			April to June	Sandy or rocky shoals with running water	60
ne-	Abundant	6 kg		Good	Predator	Prefer sluggish or standing water	Deleterious to nests	Constant temperature important for spawning success	April to June	Shallow water with vegetation or debris	20
	Common	1 kg		Good	Predator	Prefer running water				Shallow water; gravel bottom	
	Very abundant in tributaries and extra-channel areas	15-20 cm		Fair		Prefer weak current	Tolerant	Tolerant	May to August	Nest in shallow, slow water; gravel bottom	
	Abundant in some areas	10 cm	None	Poor		Prefer running water	Tolerant		May to June	Shallow water (18 cm to 1 m)	15
	Abundant	0.5 kg	None	Good		Prefer quiet water	Require clear water	Semi-tolerant of low O ₂	May to June	Shallow water; sand, gravel, mud, debris bottom	23
		0.3 kg 15-20 cm	None	Good		Prefer quiet water	Require clear water	Sudden temperature fluctuations deleterious	May to September (may spawn more than once a year)	Shallow water; build nest on sand, gravel, or mud	24
	Common	20 cm	None	Good		Tolerant			May to August	Shallow water, slow to moderate current, hard substrate	Ad or
	Rare	25 cm	None	Good	Predator as adult	Tolerant, prefer weak current	Tolerant	Tolerant	June to July	0.15-1.6 m deep; nest built near rubble; tolerate light silt bottom	
	Abundant	35 cm	None	Good	Predator as adult	Prefer weak current	Prefer clean water		May to June	.1-6 m deep	Att veg rod 137
	Abundant (more abundant in warmer waters than <i>P. nigromaculatus</i>)	30 cm	None	Good	Predator as adult	Prefer weak current	More tolerant than <i>P. nigromaculatus</i>		May to June	1-6 m deep	Att veg rod 213
ols	Abundant	16-15 cm	None	Important as forage	Forage	Tolerant	Tolerant	Temperature above 7°C	Spring	Surface	670
some	Rare	1 kg	None	None	Predator	Tolerant	Tolerant		Early spring		
ed to may ols	Common in certain areas	6 kg .6 m		Good	Predator	Tolerant	Tolerant		Early spring	.7-1.3 m. deep water over rock or gravel shoals	23, egg of
from	Abundant in certain areas, more abundant than walleye in southern waters	.5 m maximum		Good	Predator	Prefer running water	Tolerant; more tolerant than walleye		Early spring	.5-1.3 m. sand shoals	23, egg of

E

Tolerant			August	water				
Tolerant	Tolerant		June to July	In creeks or open water	11,000		4 cm after one year	
Prefer weak current	Tolerant		Late May to June	Weed-filled shorelines	"Thrown" into vegetation	24 days	5 cm after one year	
Tolerant; prefer quiet water	Tolerant		May to September, more than 1 brood/season	Viviparous	1-315/season			1 year
Tolerant			June	Shoal areas, frequently with current	Float until contact with object, then adhere		School; adult size in 1 year	1 year
Tolerant	Tolerant, prefer clean water	Fairly high requirement	May to June	No specific requirement; usually shallow open water	Pelagic	25-30 hours	School; 5" after one year	3-7 years
Tolerant, prefer sluggish	Tolerant	Tolerate low dissolved O ₂	May to July	.2-1.2 m deep water	2000-7000	5-10 days	School; 3" in first year	3 years
Tolerant	Tolerant, prefer clear water	Fairly high requirement	May to June	Shallow water in shelter	3000-8000	6-10 days	School; remain in shallows	5 years
			April to June					
Tolerant	Tolerant		May to August	3.5-5 m deep; build nest in secluded water	6900-11,300; adhesive	6-7 days	0.2 m in first year	3-5 years
Prefer standing water			April to June	Sandy or rocky shoals with running water	650,000-970,000	46 hours	10-12 cm in first year	2 years
Prefer sluggish or standing water	Deleterious to nests	Constant temperature important for spawning success	April to June	Shallow water with vegetation or debris	2000-25,000	9-10 days, guarded by male	School when hatch; remain in weedy areas, 10-15 cm	1-3 years
Prefer running water				Shallow water; gravel bottom			15 cm in first year	2 years
Prefer weak current	Tolerant	Tolerant	May to August	Nest in shallow, slow water; gravel bottom			Remain in weeds; 2-7 cm in first year	1 year
Prefer running water	Tolerant		May to June	Shallow water (18 cm to 1 m)	15,000-58,000			3 years
Prefer quiet water	Require clear water	Semi-tolerant of low O ₂	May to June	Shallow water; sand, gravel, mud, debris bottom	2360-49,400	32 hours at 22°C		2-3 years
Prefer quiet water	Require clear water	Sudden temperature fluctuations deleterious	May to September (may spawn more than once a year)	Shallow water; build nest on sand, gravel, or mud	2400			
Tolerant			May to August	Shallow water, slow to moderate current, hard substrate	Adhere to stones or roots			3 years
Tolerant, prefer weak current	Tolerant	Tolerant	June to July	0.15-1.6 m deep; nest built near rubble; tolerate light silt bottom			5 cm in first year	1-2 years
Prefer weak current	Prefer clean water		May to June	.1-6 m deep	Attach eggs to vegetation or roots; 30,000-137,000			2-3 years
Prefer weak current	More tolerant than <i>P. nigromaculatus</i>		May to June	1-6 m deep	Attach eggs to vegetation or roots; 970-213,213			2-3 years
Tolerant	Tolerant	Temperature above 7°C	Spring	Surface	6700-12,400	3 days	Grow 2.5 cm per month	6 months
Tolerant	Tolerant		Early spring				8-10 cm in one year	
Tolerant	Tolerant		Early spring	.7-1.3 m, deep water over rock or gravel shoals	23,000-50,000 eggs per pound of fish weight	12-18 days	15 cm in first year	2-3 years
Prefer running water	Tolerant; more tolerant than walleye		Early spring	.5-1.3 m, sand shoals	23,000-50,000 eggs per pound of fish weight	12-18 days	Up to 10 cm in first year	3-4 years

E

F

Table 11. Current requirements of adult fish.¹

Fast current	Tolerant	Slack current
	<u>Amia calva</u>	→
	<u>Lepisosteus osseus</u>	→
	<u>Lepisosteus platostomus</u>	→
	<u>Anquilla rostrata</u>	→
←	<u>Hiodon alosoides</u>	
	<u>Hiodon tergisus</u>	
	<u>Dorosoma cepedianum</u>	
	<u>Ictiobus cyprinellus</u>	→
	<u>Ictiobus bubalus</u>	→
	<u>Carpiodes carpio</u>	→
	<u>Cyprinus carpio</u>	
	<u>Notemigonus crysoleucas</u>	
	<u>Pimephales notatus</u>	
←	<u>Pimephales vigilax</u>	
	<u>Hybognathus nuchalis</u>	
	<u>Notropis lutrensis</u>	
	<u>Notropis atherinoides</u>	
	<u>Hybopsis storeriana</u>	
←	<u>Fundulus notatus</u>	
	<u>Gambusia affinis</u>	→
	<u>Labidesthes sicculus</u>	→
	<u>Aplodinotus grunniens</u>	
	<u>Ictalurus natalis</u>	
←	<u>Ictalurus furcatus</u>	
←	<u>Ictalurus punctatus</u>	
	<u>Pylodictus olivaris</u>	
	<u>Morone chrysops</u>	→
	<u>Micropterus salmoides</u>	→
←	<u>Micropterus punctulatus</u>	
	<u>Lepomis cyanellus</u>	→
←	<u>Lepomis humilis</u>	
	<u>Lepomis macrochirus</u>	→
	<u>Lepomis microlophus</u>	→
	<u>Lepomis megalotis</u>	
	<u>Lepomis gulosus</u>	→
	<u>Pomoxis nigramaculatus</u>	→
	<u>Pomoxis annularis</u>	→
	<u>Dorosoma petenense</u>	
	<u>Aloso chrysochloris</u>	
	<u>Stizostedion vitreum</u>	→
←	<u>Stizostedion canadense</u>	

¹ Arrows indicate the preferred habitat.

Table 12. Current requirements for spawning.¹

Flowing water	Tolerant	Slack water
		<u>Amia calva</u> *
		<u>Lepisosteus osseus</u> *
		<u>Lepisosteus platostomus</u> *
	<u>Hiodon alosoides</u> →	
	<u>Hiodon tergisus</u> →	
	<u>Dorosoma cepedianum</u> →	
		<u>Ictiobus cyprinellus</u> *
		<u>Ictiobus bubalus</u> *
	<u>Carpoides carpio</u> →	
		<u>Cyprinus carpio</u> *
		<u>Notemigonus crysoleucas</u> *
		<u>Pimephales vigilax</u>
		<u>Pimephales notatus</u>
		<u>Hybognathus nuchalis</u>
		<u>Notropis lutrensis</u> *
	<u>Notropis atherinoides</u>	
	<u>Hybopsis storeriana</u> ←	
		<u>Fundulus notatus</u> *
		<u>Gambusia affinis</u>
<u>Labidesthes sicculus</u> →		
	<u>Aplodinotus grunniens</u>	
		<u>Ictalurus natalis</u>
		<u>Ictalurus punctatus</u> *
		<u>Pylodictus olivaris</u> *
		<u>Micropterus salmoides</u> *
		<u>Micropterus punctulatus</u>
		<u>Lepomis cyanellus</u>
		<u>Lepomis humilis</u>
		<u>Lepomis macrochirus</u>
		<u>Lepomis gulosus</u> *
		<u>Pomoxis nigromaculatus</u> *
		<u>Pomoxis annularis</u> *
<u>Morone chrysops</u>		
	<u>Dorosoma petenense</u>	
←	<u>Stizostedion vitreum</u>	
←	<u>Stizostedion canadense</u>	

¹ Arrows indicate the preferred spawning habitats.

*Also requires vegetation.

Table 13. Effects of loss of backwater chutes.
A. Fish adversely affected by loss of backwater.

<u>Amia calva</u> P	<u>Ictalurus natalis</u> S
<u>Lepisosteus osseus</u> P	<u>Ictalurus punctatus</u> (?) C,S
<u>Lepisosteus platostomus</u> P	<u>Pylodictus olivaris</u> C,S
<u>Dorosoma cepedianum</u> F	<u>Morone chrysops</u> S
<u>Ictiobus cyprinellus</u>	<u>Micropterus salmoides</u> S
<u>Ictiobus bubalus</u>	<u>Micropterus punctulatus</u> S
<u>Carpiodes c. carpio</u> C,S	<u>Lepomis humilus</u> S
<u>Notemigonus crysoleucas</u> F	<u>Lepomis cyanellus</u> S
<u>Pimephales notatus</u> F	<u>Lepomis macrochirus</u> S
<u>Hybognathus nuchalis</u> F	<u>Lepomis microlophus</u> S
<u>Notropis lutrensis</u> F	<u>Pomoxis nigramaculatus</u> S
<u>Fundulus notatus</u> F	<u>Pomoxis annularis</u> S
<u>Gambusia affinis</u> F	<u>Stizostedion vitreum</u> S
<u>Aplodinotus grunniens</u> (?) C,S	<u>Stizostedion canadense</u> S

C = Commercial importance
F = Important for forage
P = Predatory species
S = Sport importance

Table 13. Effects of loss of backwater chutes.
B. Fish not affected by loss of backwater areas.

<u>Notropis atherinoides</u> F	<u>Pylodictus olivaris</u> C,S
<u>Hybopsis storeriana</u> F	<u>Micropterus punctulatus</u> S
<u>Labidesthes sicculus</u> F	<u>Lepomis humilus</u> S
<u>Aplodinotes grunniens</u> C,S	<u>Lepomis megalotis</u> S
<u>Ictalurus punctatus</u> C,S	<u>Lepomis gulosus</u> S
<u>Ictalurus furcatus</u> C,S	<u>Pomoxis annularis</u> S
<u>Hiodon alosoides</u> S(?)	<u>Dorosoma petenense</u> F
<u>Hiodon tergisus</u> S(?)	<u>Alosa chrysochloris</u>
<u>Carpiodes c. carpio</u> C(?)	<u>Stizostedion canadense</u> S
<u>Pimephales notatus</u> F	<u>Stizostedion vitreum</u> S
<u>Pimephales vigilax</u> F	

C = Commercial importance

F = Important for forage

S = Sport importance

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Study of importance of backwater chutes to a riverine fishery; final report, by H. L. Schramm, Jr. and W. M. Lewis. Vicksburg, U. S. Army Engineer Waterways Experiment Station, 1974.

144 p. illus. 27 cm. (U. S. Waterways Experiment Station. Contract report Y-74-4)

Prepared for U. S. Army Engineer District, St. Louis, St. Louis, Missouri, under contract No. DACW39-73-C-0015.

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TA7.W34c no.Y-74-4