CHANGES IN THE FISH POPULATION OF LEWIS AND CLARK LAKE, 1956-74, AND THEIR RELATION TO WATER MANAGEMENT AND THE ENVIRONMENT

UNITED STATES DEPARTMENT OF THE INTERIOR

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CHANGES IN THE FISH POPULATION OF LEWIS AND CLARK LAKE, 1956-74, AND THEIR RELATION TO WATER MANAGEMENT AND THE ENVIRONMENT

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ABSTRACT

Lewis and Clark Lake, an 11,300-ha main stem Missouri River reservoir at the boundary of Nebraska and South Dakota, is managed by the U.S. Army Corps of Engineers for flood control, hydroelectric power, navigation, and other purposes. Annual sampling of the reservoir fish population in 1956–74 indicated that fish abundance decreased about 66% and the number of species about 20% between 1956, the first year of impoundment, and the early 1970's. Poor fish reproduction and decreasing recruitment to adult stocks were caused by the regimen of water management and related shoreline modification. Low and fluctuating water levels during May and June were detrimental to fish spawning and survival of young. The water exchange time decreased from 10 days during the early years of impoundment to 4 or 5 days in 1969–72. The river-like downstream water currents associated with short water exchange times were harmful to the fish population, partly because large numbers of young of the year were lost from the reservoir in the discharge. This loss of young not only decreased the potential abundance of adults of these species, but also had a detrimental effect on the growth and survival of predator species for which they served as prey. Erosion of shorelines and deposition of silt in the upstream end of the reservoir eliminated many areas formerly used for spawning.

With the present water management regimen, fish abundance in Lewis and Clark Lake will probably remain similar to that in the early 1970's. The fish population is expected to be dominated by freshwater drum, *Aplodinotus grunniens*; channel catfish, *Ictalurus punctatus*; sauger, *Stizostedion canadense*; river carpsucker, *Carpiodes carpio*; white bass, *Morone chrysops*; and emerald shiner, *Notropis atherinoides*. Suggested management measures that might improve sport fish abundance, such as construction of spawning and nursery ponds adjacent to the reservoir or the maintenance of high reservoir water levels during May and June to enhance reproduction of desirable species, are either too costly to be currently undertaken or are inconsistent with the primary flood-control function of the reservoir.

CHANGES IN THE FISH POPULATION OF LEWIS AND CLARK LAKE, 1956-74, AND THEIR RELATION TO WATER MANAGEMENT AND THE ENVIRONMENT

INTRODUCTION

Lewis and Clark Lake is the smallest and lowermost of six reservoirs on the main stem Missouri River, constructed and managed by the U.S. Army Corps of Engineers for flood control, hydroelectric power, downstream navigation, irrigation, and recreation. The reservoir was formed by the closure of Gavins Point Dam in July 1955 and water reached operational level in 1956.

The fish population was studied by the South Dakota Department of Game, Fish and Parks in 1956-61 and by the U.S. Fish and Wildlife Service in 1962-74. Investigations were divided into three phases: (1) the development of the fish population was documented in 1956-61; (2) various types of fish sampling gear were tested and the most effective means for measuring the population was determined in 1962-64; and (3) fish population abundance was monitored each year in 1965-74.

The lake areas studied during the three phases were not identical, but the sampling results gave reasonable estimates of abundance trends of major fish species. Considerable effort in 1962-74 was also directed toward studying the life histories of the major species. The overall objectives of these investigations were to document and explain the causes of changes in the population over time and to suggest management measures that might increase the abundance of desirable species.

Walburg (1964) summarized the data collected on the fish population in 1956-62 which documented changes during the first 7 yr of impoundment, and Walburg (1969) reported on the development of sampling techniques to measure population changes. The present paper describes the changes in the fish population through 1974 in relation to the management of the reservoir. The future fish population is forecast on the basis of the water management regimen that prevailed near the end of the study and is expected to be followed in the future.

LEWIS AND CLARK LAKE AND THE MISSOURI RIVER TO FORT RANDALL DAM

The Reservoir

Gavins Point Dam is 8 km west of Yankton, South Dakota, on the boundary between South Dakota and Nebraska. Significant morphometric features of the reservoir are as follows: maximum length, 34 km; average width, 3.4 km; maximum depth, 17.7 m; average depth, 4.9 m; surface

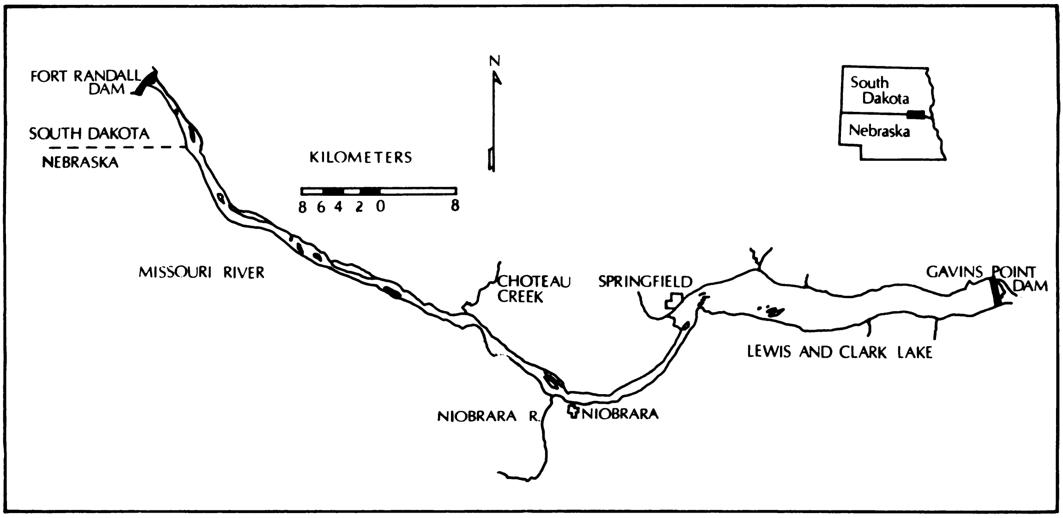

Figure 1.—Map of Lewis and Clark Lake and the Missouri River upstream to Fort Randall Dam. Over most of this course, the waterway is the boundary between Nebraska and South Dakota.

area, 11,330 ha; and volume, $555 \times 10^6 m^3$ at surface elevation 368.2 m above mean sea level (Fig. 1). Lake level is maintained between 367.0 and 368.2 m above mean sea level under normal operating conditions.

The reservoir does not stratify thermally, and oxygen depletion occurs only in isolated, deep areas after extended periods of calm weather. Wind speeds of 50 to 80 km/h occur frequently in the spring and fall, and the resulting wave action on the shore and over shallow bottom produces high turbidity, especially in the western end of the reservoir. Other hydrographic and physical-chemical features were reported by Cowell (1967).

Much of the reservoir is bounded by steep bluffs composed of Niobrara chalk overlain with alluvium. Brush and trees were cleared from the lower two-thirds of the lake bottom before it was flooded. The upstream or western portion has clusters of partly inundated dead trees, but many have been eliminated over the years by wind, ice, and waves. The shoreline is essentially straight except for narrow bays at the mouths of six small intermittent tributary streams. The lake bottom is largely mud and silt, with a few areas of sand and gravel. Aquatic vegetation is scarce except for scattered beds of smartweed, *Polygonum*, in the upper reservoir and common cattail, *Typha latifolia*, and pondweed, *Potamogeton*, in the backwaters.

The River

The section of the Missouri River between Fort Randall Dam and the head of Lewis and Clark Lake is 71 km long (Fig. 1). Its width varies from 0.4 to 1.6 km, but the width of the main channel ranges only from 45 to 90 m. Maximum channel depth is 6 m. The flood plain has numerous sand bars and the water depth is generally less than 2 m. The bottom is primarily sand, with a few gravel and rubble areas. In backwaters and oxbows, which are most common in the lower third of the river, mud and silt predominate.

The Niobrara River, which has a mean annual flow of 49.5 m^3/s, enters the Missouri River about 15 km above the reservoir. This stream carries a considerable load of sand, silt, and organic debris, which is deposited in the upper end of the reservoir. Choteau Creek, an intermittent stream, enters the Missouri River 12 km above the Niobrara River.

Water Management

A major function of Lewis and Clark Lake is the reregulation of water releases from Fort Randall Dam (Fig. 1). This dam has a peaking power plant; water releases are usually greatest at about 1200 and 1900 h, and least at 0600. Water releases during the April-November navigation season usually range from 85 to 1,200 m^3/s.

Under usual regulation the elevation of Lewis and Clark Lake is maintained near the base of flood control, 367.0 m, through the March-July flood season, except when additional storage is accumulated from floods in the Niobrara River or from higher than normal upstream releases. During the rest of the year the lake level is maintained near the base of exclusive flood control, 368.2 m, insofar as practical. Water level changes normally do not exceed 15 cm daily or 30 cm weekly.

Water releases from Lewis and Clark Lake in April-November are uniform and usually approach power plant capacity of 934.5 m^3/s; in December-March the average is about 500 m^3/s. At maximum turbine discharge, a volume of water equal to the storage capacity of the reservoir is discharged every 5.5 to 7.2 days, depending on lake water level. This outflow, termed "exchange time," is defined as the number of days required to empty the reservoir at a given water elevation and discharge. Water exchange times exceed 7.2 days when reservoir discharge is less than maximum or lake levels are above 368.2 m, and are less than 7.2 days when the discharge exceeds turbine capacity or lake levels are less than 368.2 m. Discharge from the reservoir in some years exceeds turbine capacity because of upstream flooding or greater than average precipitation over the upper Missouri River basin; excess water is released through spillway gates.

There is an obvious downstream current throughout the reservoir in April-November, because of the relatively small volume of the basin in relation to the amount of water discharged. The current is especially evident in the shallow upstream end. Little information is available on reservoir current velocity in relation to discharge. Measurements with a Price current meter on a transect about 1.6 km above the dam in August 1969, when the water exchange time was 5.3 days, indicated velocities of 6 cm/s (1 m above the bottom) to 10 cm/s (1 m below the surface). Current velocities in July 1970, when the water exchange time was also 5.3 days, were similar.

THE FISH POPULATION

Forty-two fish species were collected in Lewis and Clark Lake in 1956–74 (Table 1). All were present in this section of the Missouri River before reservoir construction except rainbow trout, white bass, and spottail shiners. Rainbow trout were stocked in the tailwaters below Fort Randall Dam in 1956 and 1957, but none survived. White bass were stocked in the reservoir in 1959, 1960, and 1961 and became firmly established (Walburg 1964). Spottail shiners were stocked in the reservoir in 1973.

Studies in Lewis and Clark Lake and in the Missouri River from Fort Randall Dam downstream to the lake during the summers of 1962 and 1963 indicated that the species composition of fish in the two areas was similar. Some fish movement occurs between the river and

Table 1.—*Species of fish collected in Lewis and Clark Lake, 1956-74*

Common name	Scientific name
Pallid sturgeon	*Scaphirhynchus albus*
Shovelnose sturgeon	*Scaphirhynchus platorynchus*
Paddlefish	*Polyodon spathula*
Longnose gar	*Lepisosteus osseus*
Shortnose gar	*Lepisosteus platostomus*
Gizzard shad	*Dorosoma cepedianum*
Rainbow trout	*Salmo gairdneri*
Goldeye	*Hiodon alosoides*
Northern pike	*Escx lucius*
Carp	*Cyprinus carpio*
Silvery minnow	*Hybognathus nuchalis*
Flathead chub	*Hybopsis gracilis*
Silver chub	*Hybopsis storeriana*
Emerald shiner	*Notropis atherinoides*
Spottail shiner	*Notropis hudsonius*
Red shiner	*Notropis lutrensis*
Sand shiner	*Notropis stramineus*
Fathead minnow	*Pimephales promelas*
River carpsucker	*Carpiodes carpio*
White sucker	*Catostomus commersoni*
Blue sucker	*Cycleptus elongatus*
Smallmouth buffalo	*Ictiobus bubalus*
Bigmouth buffalo	*Ictiobus cyprinellus*
Shorthead redhorse	*Moxostoma macrolepidotum*
Blue catfish	*Ictalurus furcatus*
Black bullhead	*Ictalurus melas*
Channel catfish	*Ictalurus punctatus*
Stonecat	*Noturus flavus*
Flathead catfish	*Pylodictus olivaris*
Burbot	*Lota lota*
White bass	*Morone chrysops*
Green sunfish	*Lepomis cyanellus*
Orangespotted sunfish	*Lepomis humilis*
Bluegill	*Lepomis macrochirus*
Largemouth bass	*Micropterus salmoides*
White crappie	*Pomoxis annularis*
Black crappie	*Pomoxis nigromaculatus*
Johnny darter	*Etheostoma nigrum*
Yellow perch	*Perca flavescens*
Sauger	*Stizostedion canadense*
Walleye	*Stizostedion vitreum vitreum*
Freshwater drum	*Aplodinotus grunniens*

the reservoir. For example, the major spawning grounds of saugers and walleyes are in the Missouri River downstream from Fort Randall Dam, and tagging studies have shown that some channel catfish move from the reservoir up the Niobrara River, apparently for spawning. Inasmuch as paddlefish move out of Lake of the Ozarks, Missouri, to spawn over gravel bars in the Osage River (Purkett 1961), paddlefish of Lewis and Clark Lake probably also move into the Missouri River to spawn.

The following species were more common in the reservoir than in the river: gizzard shad, carp, white crappies, black crappies, and freshwater drum. Those more common in the river were shovelnose sturgeons, shortnose gar, and river carpsuckers. Other species were about equally distributed between the river and reservoir.

Fish were most numerous in Lewis and Clark Lake during the first 3 yr after impoundment; thereafter abundance declined (Walburg 1964). By 1962 only 12 species were common. Most of the present report concerns collections made in the reservoir in 1965–74. Fishes commonly collected during that period were carp, river carpsuckers, smallmouth buffalo, bigmouth buffalo, channel catfish, white crappies, white bass, saugers, freshwater drum, gizzard shad, and emerald shiners. (Shovelnose sturgeons were common in 1962 but not in 1965–74.)

Methods of Sampling

In 1956–61 fish were sampled from the reservoir in June, July, and August with frame nets (modified fyke nets), experimental gill nets, and seines. These gears plus a 220-volt electroshocker and otter trawls were used in 1962, 1963, and 1964; trap nets were added in 1964. Sampling gears and methods used in these years were described by Walburg (1964, 1969).

Annual monitoring of stocks of small fish was begun in the summer (June-September) of 1965 with bag seines and otter trawls. Seines were 30.5 m long and 2.4 m high, and mesh size was 0.6 cm. (All mesh sizes refer to stretch measure.) Trawls had a headrope length of 8.2 m, a mesh size of 3.8 cm, and a 0.6-cm mesh liner in the cod end. Seines were fished from shore, and trawls on the bottom of the old river flood plain at depths from 2.0 to 4.5 m and in the old river channel at depths from 8 to 12 m. Samples were taken at flood plain and channel stations near the central part of the lake. Sampling was conducted weekly in 1965 and 1969–74, and at 2-wk intervals in 1966–68. Details on this program were reported by Nelson et al. (1968).

Annual monitoring of age-I and older fish in the fall (September and October), with experimental gill nets and trap nets, was begun in 1966 and extended through 1972. Gill nets, 106.8 m long and 1.8 m high, consisted of seven 15.2-m panels, each with a different mesh size: 3.8, 5.1, 6.4, 7.6, 10.2, 12.7, and 17.8 cm. Nets were fished on the bottom at depths from 3 to 11 m. Trap nets, which were similar to those commonly used by commercial fishermen in the Great Lakes, had a single pot and double hearts (Crowe 1950). The nets were 2.7 m high, leads were 152.5 m long, wings were 7.6 m long, and cribs or pots were 2.4 m wide and 3.0 m long. Mesh sizes were: leads, 10.2 cm; hearts, 7.6 cm; and cribs and tunnels, 3.8 cm. Trap nets were fished perpendicular to shore in depths ranging from 3.0 to 9.2 m. Because shallow water, strong currents, winds, and obstructions interfered with netting in the upper third of the reservoir, all nets were fished in the lower two-thirds. Trap nets were fished continuously and were usually lifted 6 days each week; gill nets were fished 4 days each week. Fishing crews moved trap nets weekly and gill nets daily, to randomize sampling effort. Other details on collecting procedures were given by Walburg (1969).

Total length (mm) was recorded for all fish collected. For fish of age I or older of selected major species, scale or spine samples were collected and weight (g), sex, and maturity were recorded. Scale or spine samples were taken from subsamples of the catch that included the entire length range of each species caught. A plastic impression of three or more scales from each fish was made for age determination. Ages of channel catfish were determined from cross sections of a pectoral spine. All fish were aged by two biologists working independently. When their age determinations differed, the materials were reexamined and usually the differences were reconciled. From the sample aged, the age distribution of each species was assigned on the basis of length-frequency of the total catch. Empirical length and weight at each age were determined for each species. Annual growth was essentially complete by mid-September. Therefore, fish collected in the fall had completed one more growing season than indicated by the number of annuli counted—e.g., a fish with three annuli had completed four growing seasons.

Estimates of apparent abundance and relative year-class size were based on catch per standard unit of effort (CPE) with a given gear: one gill net fished on the bottom overnight, one frame net fished overnight, one trap net fished for 24 h, one seine haul, and one 10-min trawl tow at 2 knots. Seines and trawls were fished during daylight.

Spawning and nursery areas throughout the reservoir and in the lower section of the Missouri River were sampled for fish eggs and larvae with 0.5-m-diameter plankton nets (0.76- and 1.05-mm mesh). Larger fish were sampled with an otter trawl with a 4.9-m headrope, a mesh size of 3.8 cm, and a 0.6-cm mesh liner in the cod end.

Records of water temperature and elevation at the Gavins Point powerhouse and water inflow and outflow for Lewis and Clark Lake were obtained from the U.S. Army Corps of Engineers. Water levels and water temperatures in reservoir headwater areas were measured with recording instruments. Current speeds in these areas were estimated by timing the movement of sea-bed drifters (Harvey and Gould 1966) over a measured distance. Zooplankton was sampled every 6 h, 1964–73, with an automatic plankton sampler installed in the Gavins Point powerhouse (Swanson 1965); standing crop estimates were based on weekly composite samples.

Spawning and Nursery Areas

Four general spawning and nursery zones of the reservoir and the important fish species that use them are as follows: (1) river and reservoir—saugers; (2) near-shore areas of the reservoir—emerald shiners, white bass, and channel catfish; (3) open water areas of the reservoir—freshwater drum; and (4) protected areas such as embayments or coves, backwaters, and boat basins—carp, river carpsuckers, smallmouth and bigmouth buffaloes, white crappies, and gizzard shad.

Spawning of only saugers and carp was observed; information on other species was inferred from capture of eggs and larvae or is based on accounts in the literature.

Saugers spawn in the river over a 6.5-km long gravel, rubble, and boulder beach, 11.3 km below Fort Randall Dam (Nelson 1968). Spawning occurs in late April or early May, and the incubation period is 21 days at an average water temperature of 8.7 C. Newly hatched larvae are carried by the current down the river into Lewis and Clark Lake. Larvae are planktonic until they reach a length of about 15 mm, when they move into shallow inshore areas. When fish are 40 to 50 mm long in July and August they disperse throughout the reservoir.

Emerald shiners spawn in near-shore surface waters where depth is about 3 m and bottom type is hard sand or mud swept clean of detritus (Flittner 1964). Fertilized eggs sink to the bottom, where they hatch in 24 to 36 h. Prolarvae remain near the bottom for 72 to 96 h; during this period their swimming movements are directionless. At about 96 h they become free-swimming postlarvae. Most are planktonic in the upper 2 m of water, and therefore subject to drifting with downstream water movement or wind-induced currents. Spawning locations in Lewis and Clark Lake are not known, but emeral shiners of all ages, postlarvae to adult, are commonly observed near shore; spawning occurs from June through August (Fuchs 1967).

White bass apparently prefer the running water of tributary streams for spawning, but when such waters are lacking they spawn along wind-swept lake shores in water 0.6 to 2.1 m deep; firm bottom such as sand, gravel, rubble, or rock is required for successful spawning (Riggs 1955). Spawning occurs near the water surface, and fertilized eggs sink to the bottom where they adhere to sand, gravel, sticks, and vegetation. Eggs hatch in about 2 days; newly hatched larvae are about 2 mm long (Yellayi and Kilambi 1970). Larvae 4 to 10 mm long are planktonic, and most are 1 to 2 m below the surface. In Lewis and Clark Lake white bass spawn in late May and early June. Most larvae (4 to 10 mm long) were collected near shore in the lower one-third of the lake. Fish longer than 10 mm were found near the bottom in water 2 to 4 m deep.

Channel catfish spawn in sheltered areas in rivers and lakes, such as overhanging banks, in crevices, or near sunken logs and other debris. Although spawning sites in Lewis and Clark Lake have not been delineated, egg-sac larvae (shorter than 15 mm) were collected from the old river channel at depths from 10 to 12 m in early July. Young-of-the-year fish were common in channel areas throughout the summer. The young remain in schools for the first several weeks after hatching but apparently disperse when about 25 mm long.

Freshwater drum spawn in the open waters of the central section of the reservoir (Swedberg and Walburg 1970), mostly in June and early July. The eggs are planktonic and remain near the water surface. They hatch in 1 or 2 days into planktonic larvae about 3 mm long, which become scattered over much of the reservoir, presumably by currents induced by water exchange and wind. When the larvae are about 10 mm long, they begin moving to the deeper water of the old river channel. Some fish apparently move out of the channel to shallower water by the end of summer.

Carp, river carpsuckers, and smallmouth and bigmouth buffaloes are all typical river fishes. Spawning is most successful in years when water levels rise in the spring to flood marshes or low-lying meadows. Eggs released into the water adhere to any object they contact. These species usually spawn in June in Lewis and Clark Lake. However, in some years, more than half of the fish collected in July, August, and September had not spawned or were only partly spent—suggesting that suitable spawning habitats were not available. Few young were collected in summer sampling, which further suggests that spawning was largely unsuccessful.

White crappie reproduction occurs in most protected areas and particularly in isolated localities in the western part of the reservoir. Siefert (1969) collected larvae in or near coves and boat basins with plankton nets, but none were found in the open reservoir. Spawning occurs during June and most young of the year move out of protected areas and into the reservoir during the summer; few longer than 45 mm remain near the spawning areas. Fish 80 to 100 mm long were common in most years in trap nets fished in the fall.

Gizzard shad usually spawn in shallow water coves and backwaters (Miller 1960). Spawning occurs near the

Table 2.—*Average number of young-of-the-year fish of different species seined per hectare, Lewis and Clark Lake, 1956-74*[a]

Species	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
Shortnose gar	5	—	—	—	—	—	—	t	—	—	—	—	—	—	—	—	—	—	t
Gizzard shad	72	352	119	766	664	412	588	597	6,138	872	620	557	147	272	44	27	129	101	193
Carp	1,060	—	—	1	3	67	15	2	1	2	1	—	—	—	—	—	6	1	—
Silvery minnow[b]	1,002	82	—	—	20	3	1	—	—	—	—	—	—	—	—	—	—	—	—
Flathead chub[b]	—	3	—	—	13	—	3	—	—	—	—	—	—	—	—	—	—	—	—
Silver chub[b]	—	3	—	—	—	—	—	—	—	2	t	3	—	—	—	—	—	2	1
Emerald shiner[b]	18	32	—	508	613	185	470	393	988	2,081	1,133	672	630	438	576	357	329	276	504
Spottail shiner[b]	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	3	1
Red shiner[b]	26	35	—	7	16	81	20	—	—	54	1	—	—	—	—	—	6	1	2
Sand shiner[b]	2	8	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Fathead minnow[b]	13	—	—	—	4	—	7	—	—	—	—	—	—	—	—	—	t	—	—
Unidentified minnows[b]	—	64	171	—	—	—	—	70	—	—	—	—	—	—	—	—	—	—	—
River carpsucker	312	15	3	23	106	140	27	t	5	21	7	4	3	3	7	5	1	9	8
Smallmouth buffalo	89	3	—	—	—	—	—	4	4	1	t	t	—	1	1	t	1	t	—
Bigmouth buffalo	49	—	—	—	2	1	3	4	5	t	t	1	—	6	2	—	1	t	—
Shorthead redhorse	18	—	—	—	—	—	—	t	—	—	t	—	—	—	—	—	—	1	4
Black bullhead	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Channel catfish	1	1	—	1	—	1	3	1	—	t	t	—	t	—	—	t	—	—	—
White bass	—	—	—	—	1	2	40	54	45	528	30	156	25	253	50	26	42	195	162
Green sunfish	1	—	—	—	—	—	—	1	1	—	—	—	—	—	—	—	—	—	—
Bluegill	8	3	—	6	1	—	1	16	12	5	1	4	1	—	—	—	—	1	—
Orangespotted sunfish	1	—	—	—	—	—	1	27	24	10	4	—	—	—	—	t	—	—	—
Largemouth bass	34	—	6	1	3	—	5	9	—	—	1	—	t	1	t	1	4	t	t
White crappie	106	5	4	2	—	—	30	217	100	19	t	7	t	9	1	1	5	14	t
Black crappie	104	1	6	1	1	—	3	34	—	—	1	—	t	—	—	1	t	—	—
Johnny darter	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	t
Yellow perch	50	25	41	—	6	—	3	12	18	35	3	1	12	11	3	2	6	6	13
Sauger	6	3	4	4	6	5	4	1	3	30	9	12	5	3	5	2	2	2	4
Walleye	—	—	—	—	—	—	1	—	—	2	6	4	1	3	6	1	2	3	3
Freshwater drum	—	—	1	—	1	—	7	1	2	4	16	4	1	4	3	4	4	15	15
Total catch per hectare	2,979	635	355	1,320	1,460	897	1,232	1,433	7,346	3,666	1,833	1,425	825	1,004	698	427	538	630	910
Total area seined (ha)	1.84	1.20	0.94	1.60	1.82	1.10	3.77	7.39	2.53	5.98	2.26	3.06	2.19	3.72	4.23	4.38	4.08	3.50	2.40
Number of species	22	16	9	11	16	10	20	20	14	17	20	13	13	12	12	14	16	18	16

[a] t = Less than 0.5 fish per hectare.
[b] Includes all ages.

surface in water 0.3 to 1.6 m deep, and the adhesive eggs either sink to the bottom or drift with the current and adhere to any object they contact. Eggs hatch in 1.5 to 7 days into larvae 3.5 mm long (Bodola 1966). The larvae are weak swimmers for at least several weeks after hatching. All larvae collected with plankton nets in Lewis and Clark Lake were taken in backwater areas, coves, and boat basins.

Young of the Year

Trends in Abundance

The abundance of small fish has been estimated for 19 consecutive yr, 1956–74, on the basis of seine collections (Table 2). Most species were most abundant in 1956, the first year of full impoundment. Of the 29 species captured, gizzard shad and emerald shiners were the most numerous; white bass have been common since 1962.

Changes in seine catch over the 19 yr were difficult to interpret because of differences in the size of net fished, the location of sampling, and physical changes in the reservoir. From 1956 to 1964 a 12.2-m seine was used, but sampling areas were not the same—particularly in 1963 and 1964, when much effort was confined to backwaters. In 1965–74, 30.5-m seines were used, and the same localities were sampled each year. Numbers of small fish taken per unit of area by seine tended to decrease irregularly from 1965 to 1974 (Table 2).

Abundance of small fish in Lewis and Clark Lake was best estimated on the basis of catches in several kinds of gear. Studies conducted in 1962–64 indicated that the seine was most effective for sampling emerald shiners and gizzard shad, and the otter trawl for the capture of other major species (Walburg 1969). The effectiveness of trawls was highest in the old river channel for collecting channel catfish and freshwater drum, and on the old river flood plain for collecting white bass, white crappies, yellow perch, saugers, and walleyes (Table 3).

The CPE of small fish captured by trawl and seine declined almost steadily from 1965 to 1972 (Table 4). The downward trend was interrupted in 1973, when an exceptionally strong year class of freshwater drum was produced. Abundance of the young generally declined for channel catfish, white crappies, emerald shiners, and gizzard shad, but varied irregularly for white bass, yellow perch, saugers, walleyes, and freshwater drum.

Year-class Strength

Seasonal CPE (Table 4) does not always provide a sound estimate of species year-class strength because mortality differs during the first summer of life. For some species, samples taken in late summer or fall offer a more reliable estimate of recruitment to the adult stock. Year-class strengths of channel catfish, white bass, white crappies, saugers, and freshwater drum, 1965–74, were estimated (Table 5), but methods used differed by species because of changes in catchability with time. The estimates were based on CPE for young of the year in trawls in August for channel catfish, in trawls in June for saugers, and in trap nets in September and October for white crappies. For white bass and freshwater drum, year-class strength was estimated from linear regressions of the abundance of fish when 85 mm long, on the basis of capture of fish 25 to 84 mm long in trawls in July, August, and September. As discussed in a later section, these estimates of year-class strength based on catches of young of the year were not always directly correlated with estimates based on age distribution of larger fish in later years.

Table 3.—*Number of young-of-the-year fish collected by 8.2-m otter trawl in June-September from the flood plain (FP) and in July-September from the channel (C), and number of species collected each year, Lewis and Clark Lake, 1965-74*

Species	1965		1966		1967		1968		1969		1970		1971		1972		1973		1974	
	FP	C	FP	C	FP	C	FP	C	FP	C	FP	C	FP	C	FP	C	FP	C	FP	C
Paddlefish	—	27	—	27	—	28	—	30	—	15	—	39	—	36	—	162	—	168	—	43
Gizzard shad	78	2	41	1	50	1	75	1	23	2	91	3	154	—	261	3	38	—	107	—
Carp	3	1	—	1	1	2	1	—	78	9	—	4	18	2	50	52	12	32	4	9
Silver chub[a]	42	1	7	2	—	—	—	—	80	—	—	—	—	—	155	16	372	21	245	11
Emerald shiner[a]	42	20	862	24	2	—	—	—	43	—	97	7	574	13	79	2	140	5	34	5
River carpsucker	9	26	9	30	12	18	14	32	40	4	7	67	19	80	16	33	35	61	10	22
Smallmouth buffalo	—	—	—	3	—	1	—	—	12	—	—	11	—	—	11	5	8	2	—	—
Bigmouth buffalo	1	2	1	7	4	1	—	—	24	—	—	—	—	—	4	1	6	5	2	—
Shorthead redhorse	—	—	1	—	—	—	3	—	—	—	—	—	—	—	—	—	1	—	—	—
Channel catfish	6	1,733	16	1,204	1	339	2	399	—	81	1	1,047	10	356	6	513	5	834	6	757
Flathead catfish	—	24	—	10	—	28	—	3	—	—	—	1	—	2	—	—	—	37	—	14
White bass	1,751	24	640	2	1,762	10	1,023	6	3,164	8	477	13	933	9	1,582	1	2,154	1	1,204	2
Bluegill	—	—	—	—	7	3	5	—	—	—	—	—	2	—	12	—	19	—	—	—
Largemouth bass	—	—	2	—	—	—	2	—	1	—	—	—	1	—	—	—	1	—	1	—
White crappie	1,046	8	529	1	231	—	228	1	369	—	5	6	45	—	410	5	200	1	129	—
Black crappie	4	—	6	—	3	—	—	—	4	—	1	—	16	—	9	—	1	—	—	—
Johnny darter[a]	—	—	—	—	—	—	—	—	—	—	5	8	—	3	—	6	2	1	3	3
Yellow perch	84	—	29	—	1	—	525	2	896	—	204	—	54	—	242	—	574	11	867	2
Sauger	490	15	393	3	95	—	260	23	343	4	403	69	382	21	239	16	277	23	855	42
Walleye	15	—	20	—	14	—	37	1	203	—	452	20	216	4	124	1	101	8	144	—
Freshwater drum	1,466	9,700	582	3,304	458	1,680	242	3,196	1,532	970	33	4,116	101	2,998	217	2,416	3,689	27,481	1,348	7,886
Other species[b]	—	20	—	—	—	—	—	—	—	—	11	—	3	—	3	3	14	1	11	1
Total catch	5,037	11,603	3,138	4,619	2,641	2,111	2,417	3,694	6,812	1,093	1,787	5,411	2,528	3,524	3,420	3,235	7,649	28,682	4,970	8,797
Effort (number of tows)	55	40	32	24	32	24	32	24	56	34	60	40	60	40	56	40	48	36	46	32
Number of species	14	14	15	14	14	11	13	11	15	8	15	14	15	11	19	17	20	17	17	13

[a] Includes all ages.
[b] Northern pike, black bullhead, spottail shiner, burbot, fathead minnow, green sunfish, and orangespotted sunfish.

Table 4.—*Average number of young-of-the-year fish caught per standard haul of a trawl or seine, Lewis and Clark Lake, 1965-74. Sampling gear, location, and time were: trawl, flood plain, June-Sept. (TF); trawl, channel, July-Sept. (TC); and seine, shoreline, June-Sept. (S)*[a]

Species	Sampling method	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
Channel catfish	TC	43	50	14	17	2	26	9	13	23	24
White bass	TF	32	20	55	32	56	8	16	28	45	26
White crappie	TF	19	16	7	7	7	t	1	7	4	3
Yellow perch	TF	2	1	t	16	16	3	1	4	12	19
Sauger	TF	9	12	3	8	6	7	6	4	6	19
Walleye	TF	t	1	t	1	4	7	4	2	2	3
Freshwater drum	TC	242	138	70	133	28	103	75	60	763	246
Emerald shiner[b]	S	152	83	49	44	32	42	26	24	20	38
Gizzard shad	S	64	45	40	11	20	3	2	9	7	14
	S	52	6	14	4	20	6	3	6	18	16
Other species[c]	TC	4	5	4	4	1	6	4	9	10	5
	TF	30	49	17	11	33	4	15	16	90	38
	S	268	134	103	59	72	51	31	39	45	68
Total CPE	TC	289	193	88	154	31	135	88	82	796	275
	TF	92	99	82	75	122	29	43	61	159	108
	S	82	31	42	30	51	58	60	56	48	33
Fishing effort	TC	40	24	24	24	34	40	40	40	36	32
	TF	55	32	32	32	56	60	60	56	48	46

[a] t = Less than 0.5.
[b] Includes all ages.
[c] CPE for all species not listed individually.

Table 5.—*Numbers of young of the year of major fish species caught per unit of effort, Lewis and Clark Lake, 1965-74. (Units of effort differed for different species; see text for methods of estimation)*

Year class	Channel catfish	White bass	White crappie[a]	Sauger	Freshwater drum
1965	34.2	5.7	—	45.6	9.6
1966	28.4	3.4	10.8	36.1	4.6
1967	23.0	2.5	0.6	6.6	1.7
1968	34.9	3.9	3.4	26.4	2.3
1969	0.9	10.7	14.6	24.4	0.5
1970	2.3	1.6	9.4	41.3	1.4
1971	3.9	5.2	6.5	27.6	2.2
1972	22.9	4.6	18.1	14.8	1.8
1973	38.8	3.2	—	7.7	5.5
1974	5.4	1.8	—	53.6	3.1

[a] Trap nets, which were used to determine CPE for white crappies, were not fished in 1965 or 1973-74.

On the basis of CPE's for young of the year, channel catfish year classes were far stronger in 1965-68 and 1972-73 than in 1969-71 and 1974 (Table 5). The strongest white bass year class was produced in 1969 and the two weakest in 1970 and 1974. Year classes of white crappie were strong in 1966, 1969, and 1972 and weakest in 1967, whereas those of saugers were strong in 1965, 1970, and 1974 and weak in 1967 and 1973. Year classes of freshwater drum were strong in 1965 and 1973, and weakest in 1969.

Growth

Average seasonal growth was determined for young-of-the-year channel catfish, white bass, saugers, and freshwater drum in 1965-74 (Fig. 2). Too few fish of other species were consistently collected in some years to support a meaningful comparison. The ranges and variances in mean length by week were greatest for saugers, intermediate for white bass and channel catfish, and least for freshwater drum. The average growth rate (mm/wk) for each species over the capture period was as follows: saugers, 7.4; white bass, 6.2; freshwater drum, 4.1; and channel catfish, 4.1.

Annual seasonal growth of each species differed considerably among years in 1965-74 (Fig. 3). Mean length in the 1st wk of September was estimated by linear regression for channel catfish, white bass, and freshwater drum. Mean length in the 1st wk of August was estimated for saugers; too few saugers were collected after this time to permit meaningful comparison. Channel catfish growth was fastest in 1971 and slowest in 1967 and 1969. Among the other species growth was fastest in 1973 and slowest in 1967 for both white bass and saugers, and fastest in 1965 and slowest in 1967 for freshwater drum. Growth for all or most of these four species was above average in 1965, 1970, and 1971 and below average in 1967 and 1972.

Growth of young-of-the-year fish and summer water temperatures were directly related (Fig. 3). Below-average growth was usually associated with low summer temperatures, and above average growth with high summer temperatures. To test this relation, I coded the annual growth of each species to obtain an annual growth index. Above-average growth was assigned a value of 3, average growth (within ± 5 mm of the mean) a value of 2, and below

Table 6.—*Water temperatures in day-degrees (above 17 C) during June, July, and August, and growth index for young of the year of four species, Lewis and Clark Lake, 1965-74*

Year	June	July	August	Total	Growth index[a]
1965	73	199	197	469	11
1966	46	195	126	367	9
1967	32	142	162	336	4
1968	111	178	152	441	8
1969	13	144	199	356	8
1970	64	155	160	379	9
1971	69	154	159	382	10
1972	21	130	147	298	6
1973	68	167	188	423	10
1974	44	155	110	299	6

[a] See text for explanation.

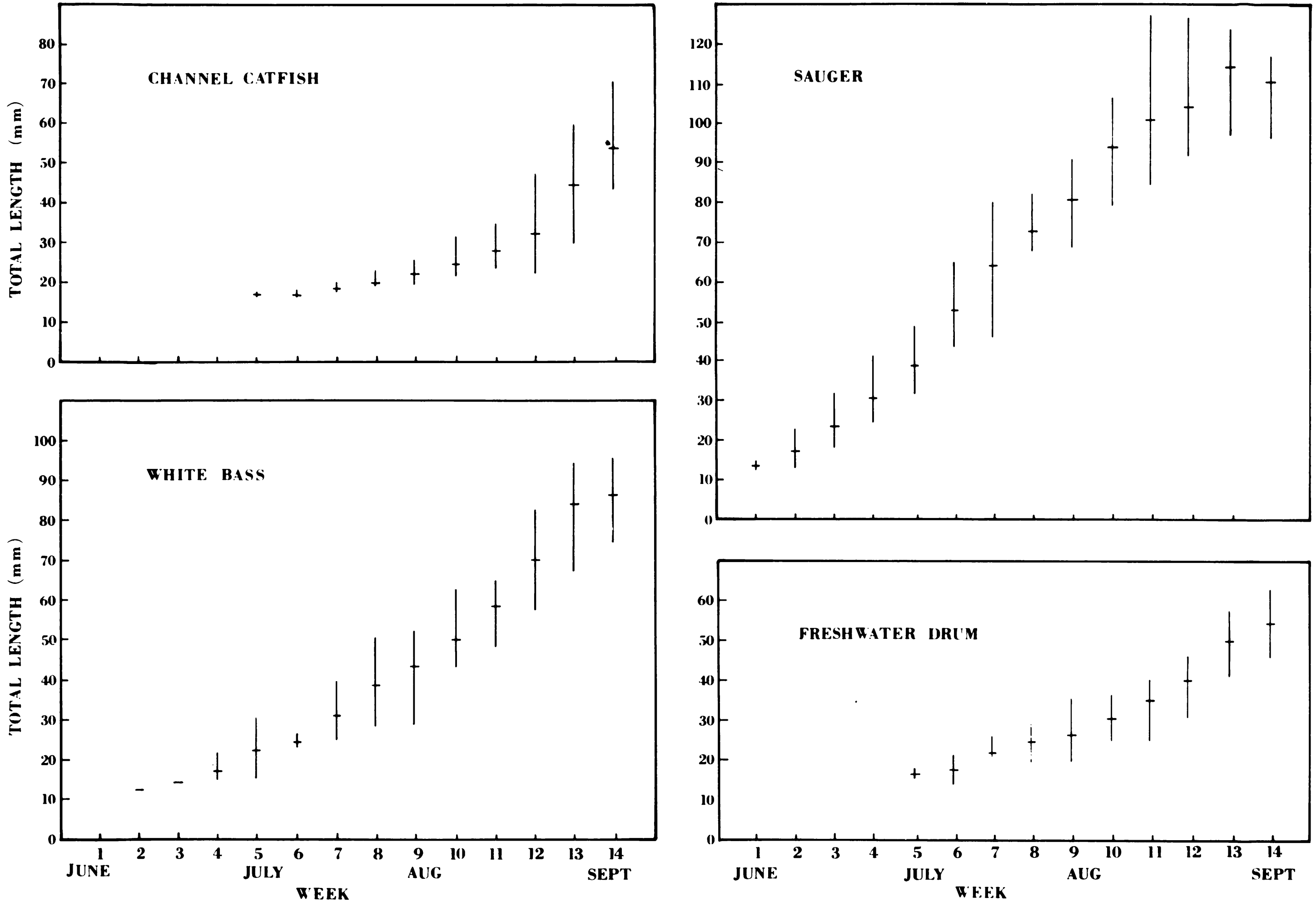

Figure 2.—Grand weekly mean length (horizontal bar) and range in mean length (vertical bar) for young-of-the-year fish collected by trawl, Lewis and Clark Lake, 1965–74. Collections were taken from the 1st wk in June (wk 1) through the 1st wk in September (wk 14) during each year.

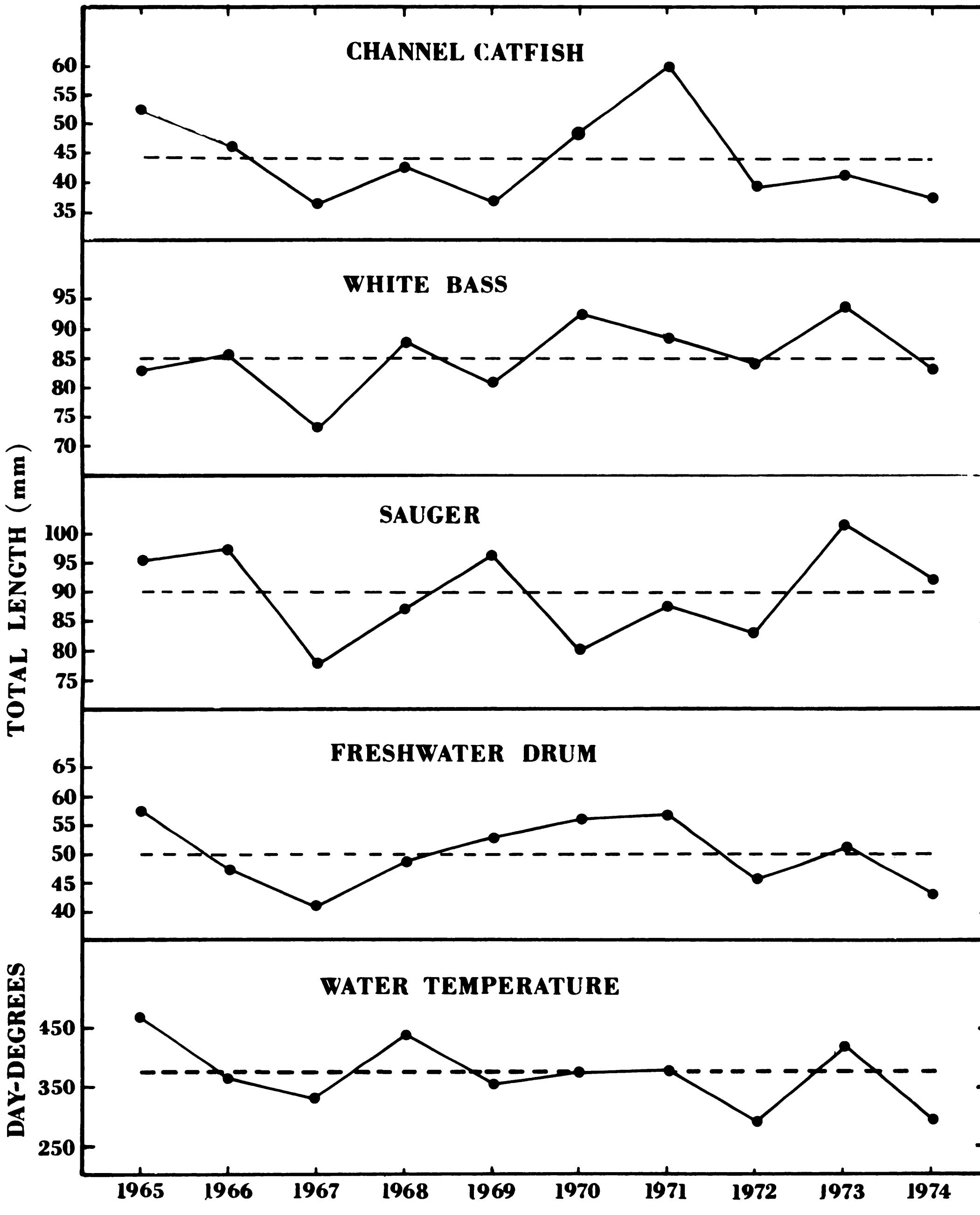

Figure 3.—Estimated mean length of young-of-the-year channel catfish, white bass, and freshwater drum in the 1st wk of September and young-of-the-year saugers in the 1st wk of August, and the accumulated day-degrees water temperature (above 17 C—see Table 6) for June, July, and August, Lewis and Clark Lake, 1965–74. The broken lines show the mean lengths and day-degrees water temperature for the 10-yr period.

Table 7.—*Mean monthly standing crops (no./1) of* Daphnia *and* Diaptomus *in June, July, and August, Lewis and Clark Lake, 1965-73*

Year	June	July	August	Total
1965	7.7	1.6	1.2	10.5
1966	7.5	3.2	0.9	11.6
1967	5.8	2.6	2.1	10.5
1968	13.8	2.6	0.7	17.1
1969	13.1	5.7	1.1	19.9
1970	3.6	3.2	1.8	8.6
1971	3.0	3.3	3.6	9.9
1972	3.6	3.8	1.7	9.1
1973	14.2	6.7	2.7	23.6

average growth a value of 1. For example, in 1965 the annual index for the four species was 11 (3 + 2 + 3 + 3, for channel catfish, white bass, saugers, and freshwater drum, respectively). There was a highly significant positive correlation (r = 0.759; $P \approx$ 0.01; 8 d.f.) between these annual indices and reservoir water temperatures during June, July, and August (Table 6).

Although *Daphnia* and *Diaptomus* are of major importance in the diet of young-of-the-year channel catfish, white bass, freshwater drum, and saugers (Walburg 1975; Ruelle 1971; Nelson 1968; and Swedberg and Walburg 1970), no apparent relation was found between standing crops of zooplankton (Table 7) and growth of any of these fish except saugers (Fig. 3). There was a moderately strong positive correlation between June-July abundance of *Daphnia* and *Diaptomus* and length of saugers by the 1st wk of August, 1965-73 (r = 0.666; P = 0.05; 7 d.f.).

Yearling and Older Fish

Age-I and older fish were sampled in Lewis and Clark Lake each year in 1956-72, except 1965. The fish population in 1956-64 was described by Walburg (1964, 1969); except for some general comments on trends in abundance since impoundment, most of the present discussion concerns collections made in 1966-72.

Trends in Abundance

The CPE of fish in gill nets (Table 8) suggested that fish were less than half as abundant in the early 1970's as in the mid-1950's; catches in frame nets and trap nets for other periods of years (Tables 9 and 10) tended to confirm the downward trend in abundance with increasing age of the reservoir. The decreases over the years among species still present in 1972 were greatest for shovelnose sturgeons, carp, smallmouth buffalo, bigmouth buffalo, white crappies, and black crappies. Black bullheads, largemouth bass, green sunfish, and bluegills were no longer found in the main reservoir by 1972, although some remained in backwaters of the western upstream end. Some decrease in abundance was suggested for shortnose gar, river carpsuckers, and gizzard shad. Species that apparently increased over the years were yellow perch, saugers, walleyes, and freshwater drum. The number of species taken by gill net was as high as 28 in 1957 and as low as 17 in 1972 (Table 8). This suggested decrease in species numbers was less evident from frame and trap net catches

Table 8.—*Catch of fish per unit of effort in gill nets, and number of species collected, Lewis and Clark Lake, 1956-64 and 1966-72. (Nets were fished in June, July, and August, 1956-63; in April and May, 1964; and in September and October, 1966-72)*[a]

Species	1956	1957	1958	1959	1960	1961	1962	1963	1964	1966	1967	1968	1969	1970	1971	1972
Shovelnose sturgeon	10.4	10.1	1.1	2.3	0.5	1.6	3.1	0.8	0.3	t	t	t	t	t	t	—
Shortnose gar	0.9	1.2	0.8	0.7	1.2	1.2	0.9	0.9	1.1	0.2	0.1	0.2	0.2	0.3	0.2	0.1
Gizzard shad[b]	0.5	5.9	0.5	2.7	0.6	0.3	0.4	1.2	0.2	3.4	0.7	1.4	1.5	3.1	2.4	1.3
Goldeye	2.9	1.6	0.7	0.1	0.7	0.5	0.4	0.3	0.5	1.9	0.5	0.6	0.6	0.4	0.4	1.0
Carp	21.1	29.1	20.8	20.9	18.4	17.4	16.7	9.1	3.8	3.3	2.1	2.4	2.1	2.1	2.0	1.4
River carpsucker	1.8	5.7	8.3	7.1	10.2	10.4	5.1	4.4	7.3	3.5	3.6	5.0	2.9	2.7	2.9	2.9
Smallmouth buffalo	0.2	0.7	1.9	1.8	2.5	1.2	1.0	1.3	0.9	0.2	0.3	0.5	0.3	0.2	0.2	0.1
Bigmouth buffalo	1.3	1.4	1.5	1.3	0.5	0.9	0.7	0.1	0.3	0.1	0.5	0.6	0.4	0.5	0.2	0.4
Shorthead redhorse	0.5	1.2	1.2	0.4	0.6	1.4	0.8	0.2	0.3	1.0	0.7	0.6	0.7	0.8	0.8	0.4
Black bullhead	0.2	0.3	0.2	—	—	—	—	—	—	—	—	—	—	—	—	—
Channel catfish	8.6	6.8	4.0	3.9	4.5	5.4	7.6	3.9	4.6	4.0	2.9	3.0	2.5	3.1	3.1	5.4
Flathead catfish	—	0.1	0.1	—	—	0.1	t	0.2	0.1	0.1	t	0.1	t	t	t	—
White bass	—	—	—	—	—	—	0.1	0.2	1.0	1.7	0.7	0.3	0.4	0.6	0.4	0.6
White crappie	0.5	2.0	9.9	2.6	2.5	1.7	1.6	0.9	0.9	2.0	0.8	0.5	0.1	0.7	0.3	0.2
Black crappie	t	1.8	0.2	0.1	t	0.1	0.1	0.1	0.1	0.1	t	t	—	—	t	—
Yellow perch	0.2	0.1	0.1	0.1	0.1	0.1	0.1	—	—	0.2	0.1	—	0.2	0.5	0.5	0.3
Sauger	0.6	1.3	1.0	2.1	3.0	1.8	1.9	2.9	4.6	6.1	3.9	4.4	4.0	4.0	4.1	4.1
Walleye	—	0.2	0.3	—	0.1	0.1	0.4	0.5	0.4	1.2	0.8	1.8	1.2	1.6	1.6	1.5
Freshwater drum	0.4	0.6	0.6	0.5	0.8	1.1	6.0	4.2	1.7	5.5	5.6	5.3	4.4	4.6	5.1	5.1
Other species[c]	0.5	0.7	0.3	0.3	0.2	0.3	0.2	0.2	0.2	0.1	0.2	0.1	t	t	0.1	t
Total CPE	50.6	70.8	53.5	45.9	46.4	45.6	47.1	31.8	28.3	34.8	23.6	26.5	21.4	25.4	24.3	24.8
Gill net sets	32	39	51	54	33	36	27	17	65	68	102	68	96	96	96	96
Number of species	19	28	22	20	18	20	20	22	20	21	23	19	20	20	21	17

[a] t = Less than 0.05

[b] Most were young of the year, particulary in 1966-72.

[c] Pallid sturgeon, paddlefish, longnose gar, rainbow trout, northern pike, blue sucker, white sucker, blue catfish, stonecat, burbot, green sunfish, and orangespotted sunfish.

(Tables 9 and 10), although relatively few fish of some species were collected in trap nets in 1972. Some of the changes in abundance and species numbers were undoubtedly caused by the transition from a river to a reservoir environment.

Year-to-year differences in abundance of fish older than 1 yr were determined on the basis of sampling in September and October, 1966–72. Only species most common in the catches were included: river carpsuckers, smallmouth buffalo, bigmouth buffalo, white bass, white crappies, and freshwater drum taken in trap nets; channel catfish and saugers in gill nets; and carp in both gears. Daily catches of each species by gear type and year were compared by analysis of variance. Although CPE varied considerably among years, it was significantly lower (1% level) in 1972 than in 1966 for all species except channel catfish (Table 11). Channel catfish abundance decreased from 1966 to 1969 and then increased through 1972 to a level similar to that in 1966. Annual abundance of each species reflected the contribution of new year classes to the population. Since carp, smallmouth buffalo, and bigmouth buffalo had little or no reproduction, however, their abundance decreased each year. Between-year changes for the other species were more variable.

The annual catch of each major species was converted from numbers to weight on the basis of the length-frequency of the catch and a length-

Table 9.—*Catch of fish per unit of effort in frame nets and number of species collected, Lewis and Clark Lake, 1956-64. (Nets were fished in June, July, and August, 1956-63, and in April and May, 1964)*[a]

Species	1956	1957	1958	1959	1960	1961	1962	1963	1964
Shortnose gar	2.1	2.8	2.7	2.4	3.3	3.8	0.6	1.0	1.5
Gizzard shad	0.1	0.1	—	t	t	—	t	—	0.1
Smallmouth buffalo	0.1	2.4	1.3	0.6	0.4	0.5	1.1	1.1	3.3
Bigmouth buffalo	0.5	0.6	0.3	0.5	0.1	0.1	0.2	0.5	0.4
River carpsucker	16.3	15.0	8.7	5.2	3.5	5.0	9.8	7.4	7.2
Shorthead redhorse	0.2	0.5	1.3	1.0	0.2	0.2	0.3	0.4	0.5
Carp	125.7	79.0	14.1	6.9	3.7	7.3	9.0	4.0	3.8
Channel catfish	3.6	0.4	0.3	0.1	0.1	t	0.1	0.2	t
Flathead catfish	0.1	0.3	t	0.3	0.1	0.2	0.1	—	t
Black bullhead	0.9	1.3	0.1	0.1	t	—	—	—	—
Largemouth bass	0.2	0.3	0.4	0.3	0.6	0.3	0.1	—	0.1
Green sunfish	0.1	0.5	0.1	t	0.1	t	—	—	—
Bluegill	0.2	1.2	3.0	1.8	2.2	2.1	0.2	0.1	t
White crappie	4.4	10.0	46.6	33.0	4.9	17.6	6.3	5.8	9.4
Black crappie	2.8	105.1	50.9	18.6	2.9	1.8	0.8	0.2	1.9
Yellow perch	1.2	0.2	0.2	—	—	t	t	—	t
Sauger	0.1	0.4	1.0	0.8	0.4	0.8	0.7	0.3	0.8
Walleye	—	0.1	—	—	—	—	0.1	0.1	0.3
Freshwater drum	0.9	0.3	0.5	0.2	0.2	0.3	1.2	0.5	0.8
Other species[b]	0.2	t	0.2	0.1	t	0.1	0.1	0.4	0.6
Total CPE	159.7	220.5	131.7	71.9	22.7	40.1	30.7	21.9	30.8
Frame net sets	51	44	50	48	30	33	56	22	69
Number of species	22	23	22	20	18	18	21	17	22

[a] t = Less than 0.05.

[b] Goldeye, blue sucker, white sucker, orangespotted sunfish, shovelnose sturgeon, northern pike, burbot, and white bass.

Table 10.—*Catch of fish per unit of effort in trap nets and number of species collected, Lewis and Clark Lake, 1966-72 (Nets were fished in September and October)*[a]

Species	1966	1967	1968	1969	1970	1971	1972
Paddlefish	0.2	0.4	0.2	0.1	0.2	0.1	t
Shortnose gar	0.4	0.2	0.4	0.3	0.3	0.2	t
Gizzard shad[b]	0.9	4.6	1.5	1.0	1.1	0.9	0.1
Goldeye	0.1	0.3	0.2	0.1	0.2	0.1	0.4
Smallmouth buffalo	4.5	5.0	5.0	2.3	2.9	1.1	0.7
Bigmouth buffalo	19.0	11.7	10.1	8.5	6.0	4.7	4.2
River carpsucker	9.4	18.0	20.2	19.1	10.8	12.1	7.3
Shorthead redhorse	0.1	0.2	0.2	0.2	0.1	t	0.1
Carp	2.2	1.8	1.4	1.5	0.8	1.0	0.4
Channel catfish	0.7	0.6	0.5	0.4	0.3	0.3	0.3
Flathead catfish	0.2	0.2	0.2	0.3	0.1	t	0.1
White bass	9.1	12.3	5.0	5.7	9.5	3.8	3.3
White crappie	10.9	15.0	5.4	4.4	7.8	4.7	3.2
Black crappie	1.2	1.3	0.4	0.1	0.2	0.2	0.1
Sauger	1.3	1.9	1.3	0.9	1.0	0.8	0.6
Walleye	0.4	0.8	0.8	0.8	1.1	0.8	0.5
Freshwater drum	10.1	19.2	14.1	11.0	7.8	9.9	7.5
Other species[c]	t	0.1	t	t	0.1	t	t
Total CPE	70.7	93.8	66.9	56.8	50.3	41.0	28.9
Trap net days	140	112	112	112	112	112	112
Number of species	22	22	19	19	21	20	18

[a] t = Less than 0.05.
[b] Young of the year
[c] Shovelnose sturgeon, blue sucker, blue catfish, northern pike, bluegill, and yellow perch.

Table 11.—*Average catch of different species per unit of effort in trap and gill nets, Lewis and Clark Lake, September and October, 1966-72. Difference between catches in successive years are indicated as significant at the 5% level (*), or the 1% level (**); all unmarked year-to-year differences were nonsignificant*

Gear and species	1966	1967	1968	1969	1970	1971	1972	Abundance change 1966 vs. 1972
Trap nets								
Carp	2.2	1.8	1.4	1.5**	0.8	1.0**	0.4	Decrease**
River carpsucker	9.4**	18.0	20.2	19.1**	10.8*	12.1**	7.3	Decrease**
Smallmouth buffalo	4.5	5.0	5.0**	2.3	2.9**	1.1*	0.7	Decrease**
Bigmouth buffalo	19.0**	11.7	10.1	8.5*	6.0	4.7	4.2	Decrease**
White bass	9.1**	12.3**	5.0	5.7**	9.5**	3.8	3.3	Decrease**
White crappie	10.9	15.0**	5.4	4.4*	7.8**	4.7*	3.2	Decrease**
Freshwater drum	10.1**	19.2**	14.1	11.0**	7.8**	9.9	7.5	Decrease**
Gill nets								
Carp	3.3*	2.1	2.4	2.1	2.1	2.0	1.4	Decrease**
Channel catfish	4.0**	2.9	3.0	2.5	3.1	3.1**	5.4	No change
Sauger	6.1**	3.9	4.4	4.0	4.0	4.1	4.1	Decrease**

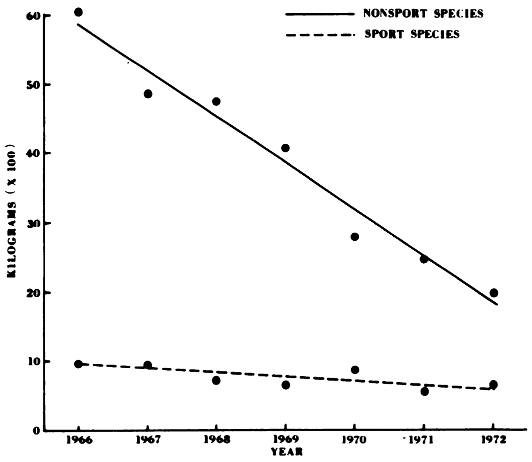

Figure 4.—Estimated total annual biomass indices for age-I and older nonsport species (carp, river carpsuckers, smallmouth buffalo, bigmouth buffalo, and freshwater drum) and sport species (channel catfish, white bass, white crappies, saugers, and walleyes) collected from Lewis and Clark Lake in successive years, 1966-72.

weight regression formula (discussed in a later section) calculated for each species and year. The combined data provided the basis for an estimate of relative change in population biomass, 1966-72. Percentage change in biomass index (Fig. 4) was -64 for all major species, -38 for sport species (channel catfish, white bass, white crappies, saugers, and walleyes), and -69 for nonsport species (carp, river carpsuckers, smallmouth buffalo, bigmouth buffalo, and freshwater drum). Sport species made up 14% of the biomass in 1966 but 24% in 1972. Most of the decrease in estimated biomass of nonsport species was caused by the decrease in abundance of smallmouth and bigmouth buffaloes.

Year-class Strength

Age distribution of channel catfish and saugers captured by gill net, and white bass, white crappies, and freshwater drum captured by trap net was determined for all fish collected in 1966-72. Carp, river carpsuckers, and smallmouth and bigmouth buffaloes were not aged because most were older than age VI, and I was not sure that year marks could be reliably identified.

Dominant year classes were not evident from the age distribution of channel catfish (Table 12). Because estimates of year-class strength based on the capture of young-of-the-year fish in 1965-71 (Table 5) differed from those based on the later adult catch, I concluded that CPE for young-of-the-year channel catfish was not a sound basis for prediction of adult year-class strength. Limited tagging studies (unpublished) suggest considerable movement of channel catfish within the reservoir and between the reservoir and the Missouri and Niobrara Rivers above the reservoir; this movement may explain the difference between the catches of young of the year and the later catches of older fish.

Catches of white bass in trap nets suggested that year classes were strong in 1965-66, weak in 1967-68, and moderate in 1969-71 (Table 12). Year-class strength estimated from capture of young-of-the-year white bass in 1965-71 (Table 5) showed little relation to that based on the adult catch. The difference in estimates may be directly related to fish behavior and the location at which adults were sampled. White bass were generally distributed throughout the reservoir, but tended to school by size. Trap nets fished in the lower two-thirds of the reservoir may not have taken random samples of the population, and thus may have failed to provide the

Table 12.—*Number of fish of five species, arranged by year class, captured in September and October, Lewis and Clark Lake, 1966-72. Channel catfish and saugers were taken with gill nets and the catches adjusted to 96 net-days. White crappies, white bass, and freshwater drum were taken with trap nets and the catches adjusted to 112 net-days*

Species and year class	Year of capture						
	1966	1967	1968	1969	1970	1971	1972
Channel catfish							
1971	—	—	—	—	—	—	12
1970	—	—	—	—	—	6	76
1969	—	—	—	—	6	56	188
1968	—	—	—	0	33	60	72
1967	—	—	0	6	71	66	54
1966	—	7	16	45	58	20	22
1965	3	13	79	64	41	26	29
1964	28	78	44	35	22	—	—
1963	140	44	27	19	19	—	—
1962	58	25	27	13	—	—	—
1961	38	20	23	—	—	—	—
1960	34	17	—	—	—	—	—
White bass							
1971	—	—	—	—	—	—	151
1970	—	—	—	—	—	151	100
1969	—	—	—	—	272	74	25
1968	—	—	—	73	47	16	21
1967	—	—	77	38	76	47	58
1966	—	359	80	127	293	87	13
1965	314	350	207	318	342	5	—
1964	197	543	206	31	37	—	—
1963	472	83	—	—	—	—	—
1962	26	2	—	—	—	—	—
White crappie							
1971	—	—	—	—	—	—	299
1970	—	—	—	—	—	439	51
1969	—	—	—	—	719	84	11
1968	—	—	—	311	145	8	3
1967	—	—	263	117	9	1	—
1966	—	897	269	35	2	—	—
1965	828	525	46	4	1	—	—
1964	359	76	7	1	—	—	—
1963	152	80	8	2	—	—	—
1962	37	34	3	—	—	—	—
1961	32	8	3	—	—	—	—
Sauger							
1971	—	—	—	—	—	—	118
1970	—	—	—	—	—	132	128
1969	—	—	—	—	95	109	52
1968	—	—	—	148	137	71	41
1967	—	—	65	78	44	44	23
1966	—	85	167	68	49	21	16
1965	223	120	92	43	39	16	4
1964	158	99	58	8	15	2	—
1963	89	51	35	12	3	—	—
1962	88	16	10	8	—	—	—
1961	13	4	1	—	—	—	—

Continued

Table 12.—*Number of fish of five species, arranged by year class, captured in September and October, Lewis and Clark Lake, 1966-72. Channel catfish and saugers were taken with gill nets and the catches adjusted to 96 net-days. White crappies, white bass, and freshwater drum were taken with trap nets and the catches adjusted to 112 net-days*—Continued

Species and year class	Year of capture						
	1966	1967	1968	1969	1970	1971	1972
Freshwater drum							
1971	—	—	—	—	—	—	16
1970	—	—	—	—	—	113	156
1969	—	—	—	—	123	259	155
1968	—	—	—	58	247	200	124
1967	—	—	31	45	50	65	97
1966	—	147	303	167	125	259	162
1965	74	452	231	117	151	120	91
1964	154	420	322	260	132	63	24
1963	431	642	485	368	22	25	8
1962	227	270	106	60	12	7	—
1961	112	135	113	27	10	—	—
1960	98	45	28	2	—	—	—

basis for a sound estimate of age distribution.

Catches of white crappies in trap nets suggested that year classes were strong in 1965, 1966, and 1969 and weak in 1967, 1968, and 1971 (Table 12). The abundance of young-of-the-year white crappies in 1966–71 (Table 5) was positively correlated with the abundance of age-I fish captured in trap nets in the following year ($r = 0.805$; $P \approx 0.05$; 4 d.f.).

Catches of saugers in gill nets suggested that strong year classes were produced in 1965, 1968, and 1970 and weak year classes in 1967 and 1969 (Table 12). Year-class strength estimated from the capture of young-of-the-year saugers in 1965–71 (Table 5) was directly correlated with that estimated from the capture of fish of the same year class in gill nets at ages I and II, combined ($r = 0.869$; $P < 0.05$; 4 d.f.).

Catches of freshwater drum in trap nets suggested that fish were not fully vulnerable to capture until age II, and that year classes were strong in 1963–66 and weak in 1967 (Table 12). There was a positive correlation between the annual abundance of young-of-the-year freshwater drum in 1965–70 (Table 5) and the abundance of the same year class at age II captured in trap nets ($r = 0.793$; $P \approx 0.05$; 4 d.f.).

Age and Growth

Although (as mentioned earlier) carp, river carpsuckers, smallmouth buffalo, and bigmouth buffalo captured in 1966–72 were not aged, length-frequency plots of the annual catch of these species revealed a gradual increase in mean length in most succeeding years (Fig. 5). These data further indicated that annual growth was slow, which may account for my inability to satisfactorily assign ages to scales taken from these species. None of these species has had significant reproduction since the early years of impoundment (Table 2, and Walburg and Nelson 1966).

The average empirical length of channel catfish, white bass, and white crappies that had completed two or more growing seasons when collected in 1966–72 (Table 13) varied relatively little

Table 13.—*Average empirical total length (mm) by growing season for five fish species collected in September and October, Lewis and Clark Lake, 1966-72 (number of fish in parentheses)*

Species and year of capture	Growing seasons completed							
	2	3	4	5	6	7	8	9
Channel catfish								
1966	150(2)	252(20)	315(99)	370(41)	404(27)	433(24)	479(8)	—
1967	141(7)	219(14)	301(84)	367(47)	406(27)	445(22)	486(19)	—
1968	178(3)	255(8)	303(56)	350(31)	424(19)	446(19)	496(16)	504(16)
1969	—	255(6)	309(45)	355(64)	409(35)	448(19)	486(13)	524(14)
1970	163(6)	247(33)	298(71)	347(58)	394(41)	445(22)	489(15)	515(14)
1971	172(6)	256(56)	300(60)	340(66)	390(20)	449(26)	488(14)	518(6)
1972	168(12)	257(76)	312(188)	360(72)	395(54)	441(22)	478(29)	512(16)
White bass								
1966	229(392)	285(246)	316(590)	351(32)	—	—	—	—
1967	212(359)	289(350)	320(543)	332(83)	365(2)	—	—	—
1968	224(77)	279(80)	321(207)	336(206)	369(5)	—	—	—
1969	227(73)	293(38)	320(127)	331(318)	352(31)	—	—	—
1970	230(272)	290(47)	312(76)	330(293)	341(342)	346(37)	—	—
1971	236(151)	287(74)	309(16)	329(47)	347(87)	349(5)	—	—
1972	230(151)	288(100)	309(25)	336(21)	352(58)	351(13)	—	—
White crappie								
1966	183(901)	235(385)	265(161)	289(38)	314(35)	331(8)	355(2)	—
1967	178(897)	224(525)	268(76)	284(80)	307(34)	328(8)	338(4)	—
1968	178(274)	228(288)	252(48)	296(8)	308(10)	328(3)	328(3)	—
1969	188(311)	229(117)	250(35)	280(4)	—	—	—	—
1970	199(719)	221(145)	247(9)	280(2)	—	—	—	—
1971	200(439)	237(84)	258(8)	285(1)	—	—	—	—
1972	196(299)	235(51)	254(11)	292(3)	—	—	—	—
Sauger								
1966	296(158)	357(112)	417(63)	463(62)	536(9)	—	—	—
1967	250(89)	331(127)	396(105)	479(54)	538(17)	595(4)	—	—
1968	258(46)	329(118)	390(65)	470(41)	521(25)	561(7)	—	—
1969	256(148)	320(78)	374(68)	423(43)	510(8)	542(12)	586(8)	—
1970	258(95)	328(137)	385(44)	422(49)	480(39)	541(15)	558(3)	—
1971	229(132)	332(109)	387(71)	437(44)	478(21)	536(16)	590(2)	—
1972	250(118)	310(128)	364(52)	424(41)	491(23)	536(16)	562(4)	—
Freshwater drum								
1966	174(92)	232(193)	276(539)	303(284)	320(140)	342(122)	367(46)	389(5)
1967	166(147)	222(452)	265(420)	296(642)	324(270)	345(135)	348(45)	388(3)
1968	169(31)	220(303)	260(231)	294(322)	318(485)	341(106)	355(113)	368(28)
1969	172(58)	219(45)	255(167)	287(117)	313(260)	330(368)	357(60)	368(27)
1970	179(123)	224(247)	251(50)	277(125)	313(151)	325(132)	346(22)	363(12)
1971	182(113)	227(259)	256(200)	279(65)	311(259)	330(120)	351(63)	363(25)
1972	189(16)	227(156)	255(155)	273(124)	298(97)	323(162)	342(91)	366(24)

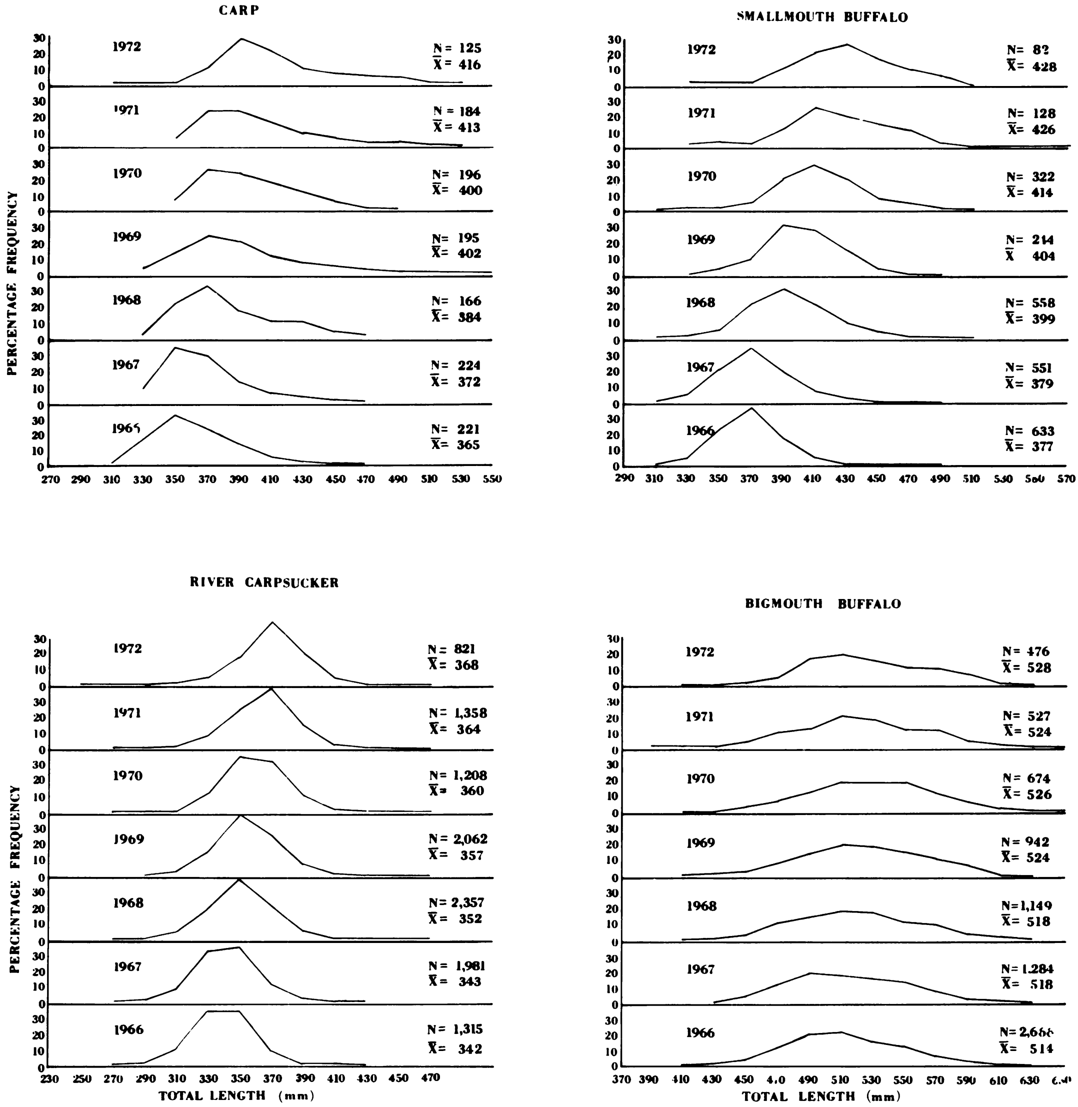

Figure 5.—Length frequency (%) by 20-mm length classes for carp captured by graded-mesh gill nets and river carpsuckers, smallmouth buffalo, and bigmouth buffalo captured by trap nets, Lewis and Clark Lake, September and October, 1966–72. (N = number of fish in sample; $\overline{X}$ = mean length in millimeters).

among fish of the same species and age, although growth of saugers and freshwater drum tended to decrease somewhat over the years. Decrease in abundance of white bass and white crappies between 1966 and 1972 (Table 11) had little apparent influence on their growth.

Mean lengths, by growing season, for channel catfish, white bass, white crappies, saugers, and freshwater drum for year classes produced after impoundment of Lewis and Clark Lake varied widely between 1966–72 and certain earlier 2- to 8-yr periods (Table 14). The average length by growing season was

Table 14.—*Mean lengths (mm), by growing season, for five species captured in 1958-65 and (data from Table 13) in 1966-72, Lewis and Clark Lake. Annual growth increments are in parentheses*

Species and years of capture	Number of growing seasons completed						
	2	3	4	5	6	7	8
Channel catfish							
1962-63	138	213(75)	253(40)	285(32)	338(53)	374(36)	—
1966-72	162	249(87)	305(56)	356(51)	403(47)	444(41)	—
White bass							
1962-64	285	340(55)	362(22)	—	—	—	—
1966-72	227	287(60)	315(28)	335(20)	351(16)	—	—
White crappie							
1958-63	112	155(43)	196(41)	222(26)	250(28)	274(24)	—
1966-72	189	230(41)	256(26)	286(30)	310(24)	329(19)	—
Sauger							
1958-63	306	384(78)	452(68)	508(56)	549(41)	—	—
1966-72	257	330(73)	388(58)	445(57)	508(63)	—	—
Freshwater drum							
1958-65	161	207(46)	240(33)	269(29)	304(35)	341(37)	354(13)
1966-72	176	224(48)	260(36)	287(27)	314(27)	334(20)	352(18)

about 20% greater for channel catfish collected in 1966-72 than in 1962-63. (Fish collected before 1962 were not aged.)

White bass, which were introduced into the reservoir in 1959-61, grew exceptionally fast in 1962-64. The average length of fish through four growing seasons was about 16% less for those collected in 1966-72 than for those collected in 1962-64. In the third and fourth growing seasons, growth rate of fish collected in 1966-72 averaged 14% greater than for those collected in 1962-64.

The average length attained by white crappies by growing season was about 33% greater for fish collected in 1966-72 than in 1958-63. Siefert (1969) also studied growth of white crappies in Lewis and Clark Lake and noted an improvement in growth for fish collected from 1962-66 over those collected in earlier years. Although white crappie growth improved in the more recent periods, abundance was much reduced (Tables 9 and 10), and fewer age groups occurred in net catches.

Growth of saugers decreased an average of about 12% between 1958-63 and 1966-72, and that of freshwater drum increased slightly between 1958-65 and 1966-72. Much of the observed difference in growth rate of all species occurred during the first 2 yr of life and is probably related to changes in food supply.

Length-Weight Relation

The length-weight relation was determined for each of the nine major species; fish were grouped by 10-mm length classes and the mean length and empirical weight determined for each interval. I then determined calculated weights for each mean length each year, using the length-weight regression formula: $\log W = a + b \log L$, where W = weight in grams, L = total length in millimeters, and a and b are constants. Annual calculated weights at 50-mm length intervals for each species for

Table 15.—*Average calculated weight (g) at various total lengths (mm) for nine species collected in Lewis and Clark Lake, September and October, 1966 and 1968-72*

Species and length (mm)	1966	1968	1969	1970	1971	1972	Mean
Carp							
350	510	459	468	470	491	479	480
400	768	704	704	762	750	741	738
450	1,103	1,023	1,008	1,167	1,090	1,089	1,080
River carpsucker							
250	188	171	176	181	174	184	179
300	322	297	300	309	304	312	307
350	508	473	470	485	487	488	485
400	753	706	693	718	732	718	720
450	1,066	1,009	977	1,015	1,048	1,008	1,020
Smallmouth buffalo							
350	569	530	522	538	584	596	556
400	862	815	827	830	876	917	854
450	1,244	1,192	1,240	1,218	1,252	1,341	1,248
500	1,725	1,671	1,783	1,717	1,725	1,884	1,751
Bigmouth buffalo							
450	1,377	1,374	1,450	1,304	1,339	1,341	1,364
500	1,953	1,914	2,033	1,873	1,891	1,941	1,934
550	2,679	2,581	2,760	2,599	2,587	2,711	2,653
600	3,575	3,392	3,648	3,505	3,443	3,676	3,540
Channel catfish							
250	105	120	107	117	107	113	112
350	330	352	334	345	326	338	338
450	777	789	782	775	749	764	773
550	1,537	1,503	1,543	1,478	—	1,466	1,505
White bass							
150	44	42	44	44	46	44	44
200	100	95	102	102	104	101	101
250	189	178	195	194	196	193	191
300	317	298	333	328	330	327	322
350	492	—	524	512	513	510	510
White crappie							
150	36	42	41	52	42	40	42
200	91	89	101	115	103	99	100
250	187	161	201	185	210	201	191
Sauger							
250	120	109	109	109	103	108	110
300	208	190	193	193	187	194	194
350	331	304	314	314	309	317	315
400	495	457	478	478	478	486	479
450	707	655	693	693	702	709	693
500	972	905	966	966	990	994	966
550	1,296	1,210	1,305	1,304	1,351	1,348	1,302
Freshwater drum							
200	77	72	83	83	84	85	81
250	160	151	170	168	170	167	164
300	291	275	306	300	302	300	296
350	481	456	501	488	490	487	484

1966 and 1968–72 were generally similar to the 6-yr mean (Table 15). Most fish were heaviest in 1966 and lightest in 1968, but no trend in weight by length over time was evident.

EFFECTS OF WATER MANAGEMENT ON THE FISH POPULATION

Water Exchange Time

Many of the fish population changes observed in Lewis and Clark Lake have been caused by management practices which affect water exchange times and water levels. Average water exchange time, April through November, decreased from 10 days during the early years of impoundment to 4 or 5 days in 1969–72. Inasmuch as downstream speed of water currents throughout the reservoir is directly related to the rate of water exchange, the exchange time during the summer (Table 16) is especially important because of the presence of young-of-the-year fish in the reservoir. Since the reservoir is relatively shallow, with few protected areas, many young fish are transported out of the reservoir. Studies in 1969 and 1970 (Walburg 1971) showed that the young of 16 species, of which 7 were common, were lost in the discharge; most fish were less than 25 mm long. Species commonly lost were those with planktonic larvae. Estimated peak 24-h losses were 10 million freshwater drum, 800,000 emerald shiners, 700,000 saugers and walleyes, and 170,000 channel catfish.

Water exchange time during the summer and abundance of young-of-the-year fish (Table 4) were directly related. This relation for data collected by seine in 1965–74 was statistically significant (r = 0.729; $P < 0.02$; 8 d.f.). Although this relation for data collected by trawl in all years, 1965–74, was not statistically significant (r = 0.407), it was significant when the 1973 data were excluded (r = 0.649; $P \approx 0.05$; 7 d.f.). The nonconformity of the 1973 data was caused by an extremely large catch of young-of-the-year freshwater drum (Table 3). The correlation between water exchange time and catch of young of the year by trawl (freshwater drum excepted) in 1965–74 was significant (r = 0.676; $P < 0.05$; 8 d.f.). Furthermore, year-class strength of freshwater drum in 1965–74 (Table 5) was correlated with the mean July-August water exchange time (r = 0.736; $P < 0.02$; 8 d.f.), as was the year-class strength of channel catfish (r = 0.720; $P < 0.02$; 8 d.f.). The negative influence of short water exchange times during June on the strength of sauger year classes was shown by Walburg (1972). Short water exchange times during the summer, especially when less than 6 days, reduced the reservoir fish population directly by decreasing the numbers of small fish.

Table 16.—*Mean monthly water exchange time (days) in June, July, and August, Lewis and Clark Lake, 1956–74*

Year	June	July	August
1956	—	5.9	5.6
1957	9.4	7.8	7.8
1958	7.2	8.1	8.8
1959	9.2	8.3	7.7
1960	10.2	8.3	7.7
1961	9.5	7.7	7.8
1962	13.2	10.1	10.2
1963	8.7	7.1	7.6
1964	8.5	7.9	7.2
1965	8.7	8.5	7.5
1966	7.6	7.2	7.6
1967	9.3	7.7	6.8
1968	6.6	6.6	6.9
1969	6.1	6.5	4.4
1970	5.8	5.8	5.5
1971	4.2	4.8	5.0
1972	4.9	5.0	4.9
1973	6.8	7.1	7.4
1974	6.5	6.2	6.8

Loss of small forage fish had a detrimental effect on the growth and survival of the adults of some species and decreased the potential abundance of the stocks. Ruelle (1971) found that growth of adult white bass in Lewis and Clark Lake was directly related to the quantity of fish in their diet; growth was best in years when small fish were most abundant in the reservoir. I found a similar relation between seasonal growth of young-of-the-year saugers and abundance of young-of-the-year fish of other species in trawl catches (Table 4) in 1965–74 ($r = 0.670$; $P < 0.05$; 8 d.f.). Decrease in growth of adult saugers in recent years (Tables 13 and 14) also paralleled the decrease in abundance of small fish in the reservoir.

In addition to the loss of small fish from Lewis and Clark Lake, some adult fish pass Gavins Point Dam. The tailwaters below the dam have supported a good sport fishery, and at least some of the fish caught have come directly from the reservoir (Walburg et al. 1971). Movement of tagged adult saugers, white crappies, and white bass from the reservoir to the tailwater was reported by Nelson (1969), Siefert (1969), and Walburg (1971). Such downstream movement is facilitated by the discharge of water from almost the entire water column. In contrast, relatively few fish are carried into Lewis and Clark Lake because water from Lake Francis Case, the reservoir immediately upstream, is drawn from a depth of more than 30 m.

Water Level

The daily water elevations of Lewis and Clark Lake for the calendar year 1973 (Fig. 6) show the pattern of seasonal water levels (low but variable elevations from about 1 March through 15 July) that was typical during at least the later years of the 1956–74 period.

Low water levels in spring and early summer have had a detrimental effect on the spawning success of near-shore or shallow-water spawners such as gizzard shad, emerald shiners, white bass, white crappies, and yellow perch. Especially affected are white crappies and other nest-builders. Nests of white crappies are usually at water depths of less than 1.5 m, and decreasing water levels may expose eggs to the air or subject them to destruction by wave action. White crappie reproduction, as indicated by collections of young of the year (Table 5), was good in years when water levels changed little (< 15 cm) or rose somewhat (0.3 to 0.6 m) during the spawning period.

Fishes that require flooded vegetation in the spring for successful reproduction had strong year classes in the first several years after impoundment of Lewis and Clark Lake. During later years of normal reservoir operation, when water levels were irregular during spring and early summer (Fig. 6), the year classes of these species were poor. Walburg and Nelson (1966) documented these changes for carp, river carpsuckers, smallmouth buffalo, and bigmouth buffalo. Studies in other main stem Missouri River reservoirs have also shown the relation of high spring water levels and flooded vegetation to strong year classes for these species (Gasaway 1970; Elrod and Hassler 1971), and studies in Russian reservoirs have shown similar results for related species (Il'ina and Gordeyev 1972).

Spawning success of some common species in the reservoir was not influenced by changes in water level: freshwater drum, which are pelagic spawners; channel catfish, which spawn in water too deep to be affected by the water level regimen; and walleyes and saugers, which spawn in the Missouri River below Fort Randall Dam. Newly hatched larvae of walleyes and

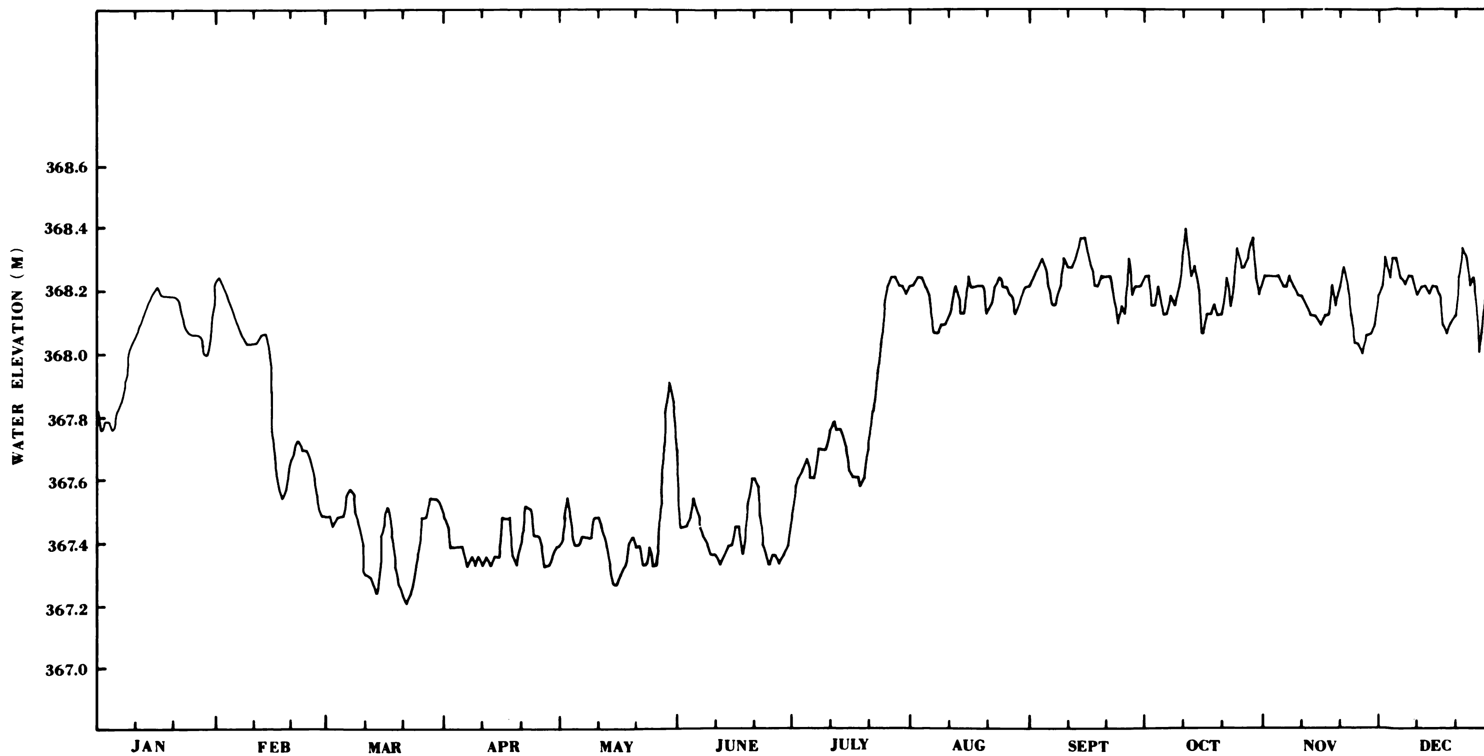

Figure 6.—Daily water elevations above mean sea level, Lewis and Clark Lake, 1973.

saugers are carried by river currents into Lewis and Clark Lake. Although changes in reservoir water levels do not influence the reproductive success of walleyes and saugers, a paucity of young forage fish could influence their later survival and growth. Walburg (1972) demonstrated the benefit to sauger reproduction of maintaining a release flow of at least 566 m^3/s from Fort Randall Dam during May.

Upper Reservoir Spawning and Nursery Areas

During the summers of 1971 and 1972, studies were conducted in protected areas in the upper reservoir and in the lower portion of the Missouri River from Springfield, South Dakota, to Choteau Creek (Fig. 1) to identify fish spawning and nursery areas, particularly for white crappies, and to determine the environmental conditions most suitable for reproduction. This information could be useful in the design and operation of artificial fish spawning and rearing areas, if such areas were to be constructed adjacent to the reservoir. Twenty-four locations were sampled to determine the relation of abundance of young-of-the-year fish to water temperature, water level fluctuation, water current, and abundance of plankton and bottom fauna. Six of the 24 species collected in both years accounted for 96% of the 54,000 fish captured: white crappies, 38%; black crappies, 15%; carp, 13%; gizzard shad, 11%; bluegill, 11%; and orangespotted sunfish, 8%. Three environmental conditions were common to the areas with the greatest abundance of young fish: little or no water current (< 2.5 cm/s), water depth exceeding 1 m, and little or no fluctuation in water level. Water temperatures and food were similar in the different areas.

EFFECTS OF OTHER ENVIRONMENTAL CHANGES

Sedimentation

The reservoir has accumulated sediment at a rate of about $3.45 \times 10^6 m^3/yr$ (U.S. Army Corps of Engineers, Omaha District, 1974, unpublished records). Origin of these sediments is from upland drainage of tributary watersheds, erosion from reservoir banks or bluffs, and erosion from the banks and bed of the Missouri River between Fort Randall Dam and Lewis and Clark Lake. The Niobrara River is the primary source of sediment.

Because of this high rate of sedimentation, many areas of the upper reservoir are covered with 0.5 to 1 m of sand and silt. Water in these areas is shallow and of limited value for fish spawning because water levels are usually low in spring and early summer (Fig. 6). Small embayments adjacent to Lewis and Clark Lake have accumulated silt, and most are isolated from the reservoir by barrier beaches. Many of these embayments were formerly used by fish—especially the white crappie—for spawning and nursery areas. In addition, silt deposited in protected or quiet waters forms a flocculent layer on the reservoir bottom. These areas are unsuitable for spawning because eggs of most species are demersal and sink into the loose bottom and suffocate.

Formation of barrier beaches and continued siltation have caused a straightening of shorelines. Except for boat basins, protected areas along the reservoir shore have been essentially eliminated. Attempts by the U.S. Army Corps of Engineers to remove barrier beaches and silt from embayments by dredging have been unsuccessful because wind and wave action soon restores the barrier beaches, and erosion of reservoir banks and the watershed is continuous.

Turbidity

Lewis and Clark Lake is the most turbid of the six main stem Missouri River reservoirs. Because the reservoir is shallow (mean depth 4.9 m), wave action erodes the reservoir bottom and the unstabilized banks and keeps materials in suspension. Runoff from watersheds adjacent to the reservoir, and especially the Niobrara River, also contributes to the turbid conditions. Turbidities are extremely variable and localized; values are highest in the western end of the reservoir and near shore. In the lower two-thirds of the reservoir, turbidities usually range between 10 and 170 mg/l (mode 21-50). Cowell (1967) reported that turbidity ranged from 10 to 675 mg/l and was highest in the upper reservoir.

Turbidity and silt deposition are known to limit survival (or at least are associated with poor survival) of fish eggs and larvae of many warmwater fishes (Buck 1956, Hassler 1970, Muncy 1962). Buck (1956) reported that spawning of largemouth bass, redear sunfish (*Lepomis microlophus*), and bluegills was severely restricted or nonexistent when turbidities exceeded 100 mg/l. The European Inland Fisheries Advisory Commission (1964) reported that waters normally containing 80 to 400 mg/l of suspended solids were unlikely to support good freshwater fisheries. Although the turbidities in Lewis and Clark Lake probably have little adverse direct effect on adult fish, they may limit survival of eggs and larvae of species which spawn in the western end of the reservoir where turbidities are often high.

Zooplankton and Bottom Fauna

Zooplankton standing crops decreased 75% between 1964 and 1971 but recovered somewhat in 1973 (Table 17). Most of the decrease occurred in the *Cyclops* group. Abundance of bottom fauna has also decreased. The standing crop of *Hexagenia* nymphs, measured by dredge samples (Hudson and Swanson 1972) taken in May 1963-71, decreased irregularly but rather sharply between 1965 and 1971 (Table 17). Abundance of chironomid larvae sampled by bottom dredge in May and October increased 40% between 1964 and 1970 (unpublished data, North Central Reservoir Investigations).

Table 17.—*Annual mean standing crops (no./l) of the most abundant zooplankton groups 1964-73, and the May abundance of Hexagenia nymphs (no./m²), 1963-71, Lewis and Clark Lake*

	Zooplankton				
Year	*Daphnia*	*Cyclops*	*Diaptomus*	Total	*Hexagenia*
1963	—	—	—	—	41
1964	0.8	13.8	1.0	15.6	92
1965	0.9	11.0	0.6	12.5	152
1966	0.7	7.5	0.7	8.9	139
1967	1.0	10.2	0.9	12.1	160
1968	1.2	7.5	2.8	11.5	82
1969	1.1	7.0	1.6	9.7	93
1970	0.5	3.2	1.3	5.0	114
1971	0.3	1.8	1.7	3.8	64
1972	0.6	2.6	2.1	5.3	—
1973	1.2	5.3	2.2	8.7	—

Because of the large size of *Hexagenia* nymphs in relation to chironomid larvae, I estimate that the overall decrease in bottom fauna biomass must have been at least 50% from 1965 to 1971. It is not known if changes in zooplankton and bottom fauna abundance have limited fish survival and abundance in Lewis and Clark Lake. However, there was a parallel decrease in abundance of fish, zooplankton, and bottom fauna between the mid-1960's and the early 1970's.

SUMMARY AND CONCLUSIONS

Fish were most abundant in Lewis and Clark Lake during the first several years after impoundment; thereafter, abundance and the number of species declined. Net catches suggest that numbers of adults were only about one-third as abundant in 1972 as in 1956. The biomass index for adults of major species decreased 64% between 1966 and 1972. Thirty-six species were taken in net catches in 1956–57, but only 28 of these species were taken in 1972–74. Fishes taken in the early but not in the later period were shovelnose sturgeons, sand shiners, silvery minnows, white suckers, blue catfish, black bullheads, stonecats, and burbot. The decreases in number of fish species and in biomass resulted from the change from a river to a reservoir environment, and water management in the reservoir. Spawning conditions for most species have deteriorated over the years because shoreline siltation and water level fluctuations during the May-June spawning period have been unfavorable for survival of young fish. In addition, many young are lost from the reservoir in the discharge because of the rapid rate of water exchange.

Species most common in net collections over the years were gizzard shad, emerald shiners, carp, river carpsuckers, smallmouth buffalo, bigmouth buffalo, channel catfish, white bass, white crappies, saugers, and freshwater drum. Forage fish experienced the greatest decrease in numbers. Seine catches suggested that abundance of emerald shiners and young-of-the-year gizzard shad decreased more than 75% between the mid-1960's and the early 1970's (Table 4). Because of the decrease in forage, predators must increasingly depend on young-of-the-year white crappies, white bass, and freshwater drum for food. Abundance of carp, smallmouth buffalo, and bigmouth buffalo decreased an average of about 80% between 1965 and 1972 (Table 11). Because there has been little successful spawning in recent years, the abundance of these species is expected to remain low.

If the schedule of water management of the early 1970's is continued, the fish population of Lewis and Clark Lake will be dominated by species that do not depend on reservoir shore areas for reproduction—e.g., saugers, channel catfish, and freshwater drum. River carpsuckers will also remain common because they apparently move into the reservoir from the river upstream. White bass, emerald shiners, and especially white crappies will be only moderately abundant because spawning habitat is limited and survival of young is low.

In 1974 sport fishing in Lewis and Clark Lake was limited almost exclusively to saugers, walleyes, and channel catfish. Some white bass were taken in early summer, and a few white crappies were taken in May and June in boat basins. For the foreseeable future, sport fishing success in Lewis and Clark Lake is expected to remain similar to that in 1974.

The major benefit of Lewis and Clark Lake to sport fishing is provided in the tailwater below Gavins Point Dam. This tailwater supports one of the most intense fisheries in the Missouri River reservoir system. Species most sought by anglers are saugers, walleyes, paddlefish, white bass, and channel catfish. Fishing success was excellent for about 6 yr after closure of Gavins Point Dam in 1955, but thereafter declined, following a pattern similar to the decrease in the reservoir fish stocks. Fishing success in the tailwater improved in 1970–74, after particularly high water releases from the reservoir during the summers of 1969, 1970, 1971, and 1972. Recruitment to tailwater fish stocks is partly supplied from the reservoir. Fish concentrate in the tailwater mainly because food is abundant (Walburg et al. 1971).

Because flexibility in the water management program of Lewis and Clark Lake is limited, little can be done to improve the sport fish population. I have shown that siltation of near-shore spawning areas and low water levels during the May-June spawning period have reduced the spawning potential of most fish species. In addition many young fish are lost from the reservoir because of the short water exchange time. Abundance of forage fish and growth of predator species have decreased over the years. Stocking the reservoir with additional predator species would not be prudent because they would compete with established predator populations—saugers, walleyes, and white bass—for available forage. Spottail shiners were introduced into the reservoir in 1973 in an attempt to increase forage abundance, but fish collections in 1974 suggested that few survived. Another possibility for increasing forage is the construction of spawning and nursery ponds adjacent to the reservoir. Fish produced in these ponds could be released into the reservoir at a size when few would be expected to be lost in the downstream discharge. However, funds for pond construction are unavailable. The most promising method of increasing fish reproduction and thereby sport fish abundance would be that of maintaining a relatively high water level in Lewis and Clark Lake during May and June—a method that apparently cannot be applied if the reservoir is to serve its primary flood control function.

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