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87. Changes in Young-of-the-year Fish Stocks During and After Filling of Lake Oahe, an Upper Missouri River Storage Reservoir, 1966–74

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CHANGES IN YOUNG-OF-THE-YEAR FISH STOCKS DURING AND AFTER FILLING OF LAKE OAHE, AN UPPER MISSOURI RIVER STORAGE RESERVOIR, 1966-74

by

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Abstract

The young-of-the-year fish stocks of Lake Oahe were sampled with a 30.5-m by 2.4-m haul seine at semimonthly intervals, from July to September, in 1966-74. The catch comprised 41 species, of which 6 accounted for about 93% of the total number of fish caught. Species numbers declined after the reservoir filled.

Abundance increased and was highest in the lower third of the reservoir while it was filling, whereas it decreased and was generally highest in the upper two-thirds of the reservoir after it was filled. Forage fishes, mostly those produced in littoral areas, determined the trends and levels of total fish abundance. Abundance of species produced in littoral areas was greater while the reservoir was filling—particularly in years when spring water levels covered vegetation, fluctuated little, and were maintained through May or longer—than after the reservoir was filled.

The yellow perch *(Perca flavescens)* was the most abundant species in every year; its abundance increased during filling, but declined thereafter. Growth rate of yellow perch increased after the reservoir had filled; it was inversely related to the abundance of young-of-the-year yellow perch and emerald shiners *(Notropis atherinoides)* and to the mean summer water temperature.

Emerald shiners—all ages combined—ranked second in abundance; their abundance also increased during filling and decreased thereafter. The post-filling decline reflected an increased mortality of yearling and older fish and reduced recruitment of young of the year. Growth of yearling emerald shiners was variable, but generally slowest during filling. Growth was faster in upstream than in downstream areas during filling, but faster in downstream areas after the reservoir had filled.

Reduction and generalized degradation of the littoral spawning and nursery habitats were probably responsible for the general decline in species numbers and abundance after filling of the reservoir.

As of the end of 1974, prospects for most commercial species (which are mainly littoral spawners) were poor, whereas those for certain sport species were good.

Introduction

Beckman and Elrod (1971) described the distribution and some trends in the abundance of young-of-the-year (YOY) fishes during the last 5 years of filling of Lake Oahe (1965-69). In this paper, I (1) reexamine their general findings, (2) analyze trends in species numbers and abundance of the YOY stocks during the last 4 years of filling (1966-69) and the first 5 years after filling (1970-74), (3) examine some apparent interactions between the young fish and their environment, and (4) draw some inferences concerning future adult stocks in Lake Oahe. I conclude that, although the YOY stocks had still not reached equilibrium in 1974, the potential yield of certain sport fishes appeared to be good, but that of most commercial species appeared to be poor.

Background and Statement of the Problem

Lake Oahe is the lowermost of three large storage reservoirs on the upper Missouri River. It was formed by the closure of Oahe Dam, at Pierre, South Dakota, in August 1958; filling required nearly 10 years. At maximum operating pool (493.8 m above mean sea level), the reservoir is about 370 km long and has a maximum width of 10 km, a surface area of 1,520 km^2 (152,160 ha), and a maximum depth of 56 m (Fig. 1).

About 50 intermittent tributaries enter the reservoir along the west bank and roughly half that number along the east bank. About a dozen of these streams form the major embayments; however, most of the embayments have a surface area exceeding several square kilometers. The Cheyenne, Moreau, Grand, and Cannonball Rivers, all along the west bank, are the largest tributaries; all may be classified as intermittent, since there is no flow during some periods in most years (Larimer and Decker 1974). The Cheyenne River is the largest of these; its lower end consists of an embayment that is about 40 km long and 2 to 4 km wide and has a maximum depth of 36 m (Fig. 2). This embayment has a number of tributaries, ranging up to 10 km long, that form the largest single network of fish spawning and nursery habitats in the reservoir.

During 1966-74, the reservoir water level rose each spring and reached the base of annual flood control, 489.8 m above msl, in December 1967; an initial peak of 492.7 m was reached in May 1969 and a crest level of 492.8 m in June 1971 (Fig. 3). Annual water level fluctuations during the 9 years ranged from 2.2 to 5.9 m and followed no consistent pattern. Major changes in the flow regimen included (1) a higher inflow in relation to outflow before 1968, and (2) an increased discharge volume during the summer in 1969-74 (June 1974).

Because of the large size of Lake Oahe, there has been much interest in its fish production potential. Although early estimates of the commercial fishery potential were highly optimistic (Carbine 1966), annual landings by the commercial fishery during 1964-70 ranged from 156,000 kg (1964) to 451,000 kg (1969) and averaged only 309,000 kg (Higham 1974), or about 0.5 kg/ha. Annual landings decreased progressively in 1969-74. The recreational fishery was light and well below its potential because of the remoteness of the reservoir, limited resort facilities, the incidence of relatively high mercury levels in

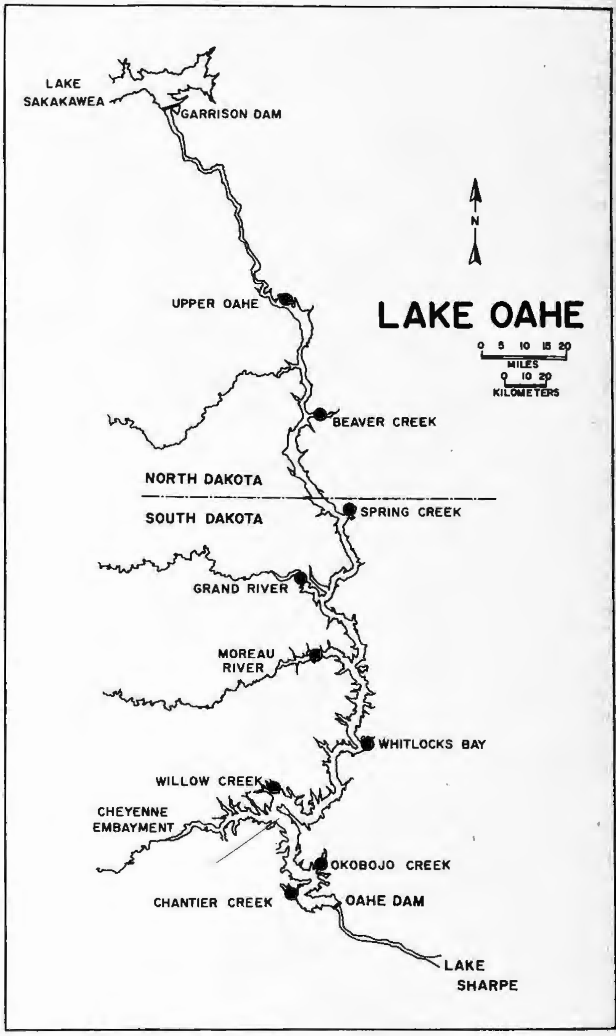

Fig. 1. Lake Oahe, showing fish-sampling locations other than those in the Cheyenne River embayment, 1966-74.

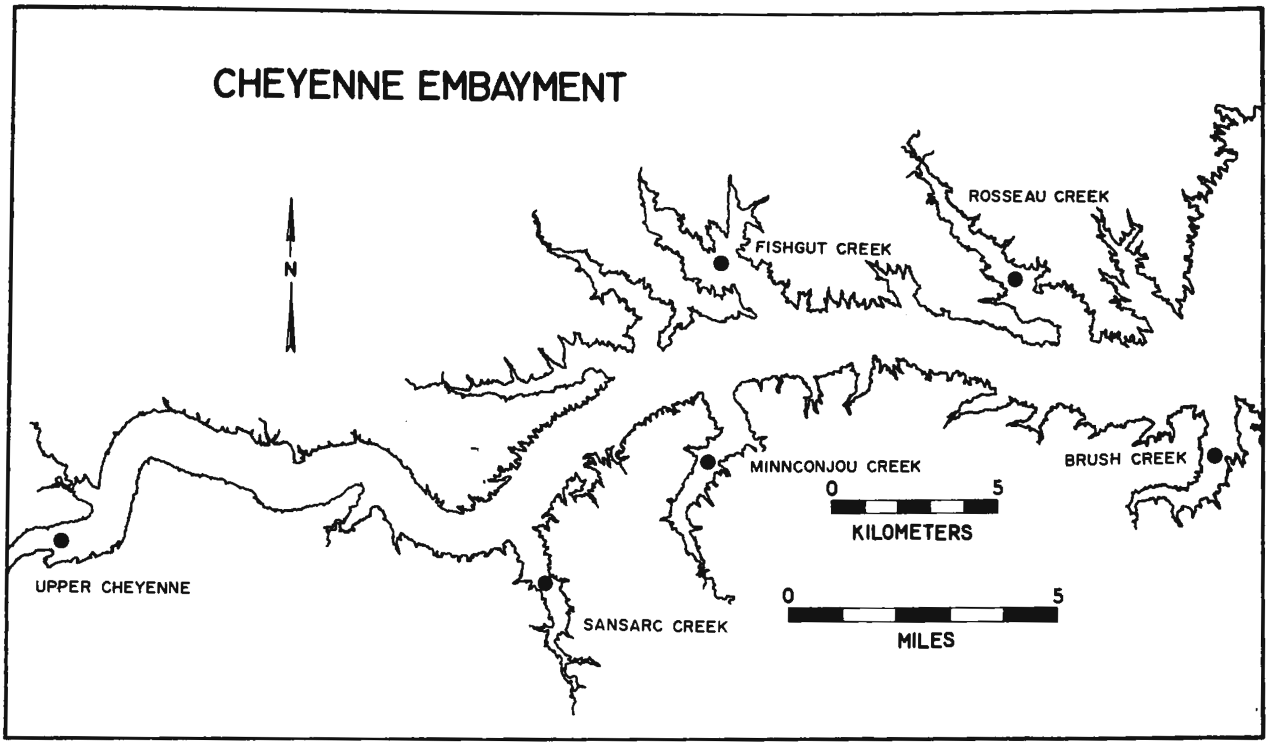

Fig. 2. The Cheyenne River embayment, showing fish-sampling locations, 1966–74.

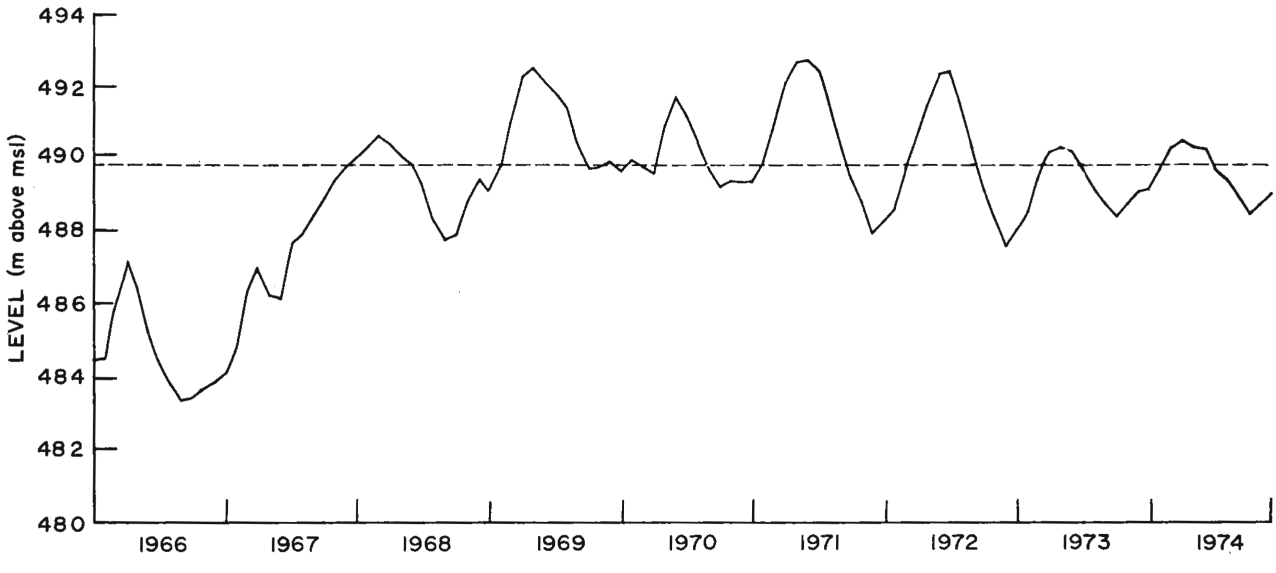

Fig. 3. Monthly mean water levels, Lake Oahe, 1966–74. The broken line shows the base of annual flood control (operational level), 489.8 m above msl.

some game fishes (Walter et al. 1973), and other factors. Thus the commercial fish catch was relatively low, whereas the game fish stocks were largely unutilized.

Establishment of a sound basis for estimating the fish potential of this reservoir required that an assessment be made of the identity and dynamics of the stocks and the effects of impoundment and the water regimen upon them. Primary interest lay in the young of the year, because their welfare ultimately signals the fate of the adult stocks; the early life stages of fish are first affected by environmental changes—and often most dramatically. Initial assessment of the recruit stock and elucidation of the effects of environmental changes on individual species can be made most efficiently and inexpensively during the first few months of life. Accordingly, a study of the YOY fish stocks was begun in 1964 with the general purpose of establishing a method for assessing changes in relative abundance during the first summer of life. Secondary objectives were to (1) determine the species structure and number and the summer distribution of the young fish, (2) estimate growth and mortality rates of major species, and (3) determine the effects of impoundment and the water regimen on the well-being and survival of individual species or groups of similar fishes.

The work in 1964 and 1965 is not included in the present paper; much of it was exploratory and chiefly concerned with determining the distribution of the young fish and developing methods of capture. Work was limited to the Cheyenne River embayment in 1964 and extended to the main reservoir in 1965. Because of its large size and the number and arrangement of its tributaries, the Cheyenne embayment functions much like the main reservoir. Moreover, because of its downstream location, effects of impoundment had a longer period to run their course and become apparent there than in upstream portions of the reservoir. I therefore compared the YOY stocks in this embayment with those in the rest of the reservoir.

Six sampling localities were established in the Cheyenne embayment (Fig. 2) and eight in the main reservoir in 1966 (Fig. 1). A ninth locality was added in the upper main reservoir in 1969 when a near-record water level inundated new upstream areas. A standardized seine haul with a 30.5-m × 2.4-m bag seine of 6.4-mm mesh was made at three stations in the lower, middle, and upper portion of each sampling locality. Seining was conducted annually during five 2-week periods from about 1 July to 1 September, 1966-74. Further details of the sampling methods were given by Beckman and Elrod (1971).

Areal and Seasonal Occurrences of Young-of-the-Year Fishes

Young-of-the-year fishes were found in most tributary embayments and in the upper reach of the main reservoir. Eggs and larvae were primarily concentrated in the shallow, upstream waters of the embayments in spring, and few were collected outside the embayments. For example, only 28 fish larvae and 6 eggs were taken in 190 surface tows made in the main reservoir with a ½-m conical net of 0.50-mm mesh during 1966–70; 20 of these larvae were caught near shore in the upper portion of the reservoir (North Central Reservoir Investigations, unpublished data).

By the time that YOY fishes became vulnerable to the seine—usually during the last week in June or the first week in July—they were rather uniformly distributed throughout the littoral areas of tributary embayments. Of 114 possible comparisons within the tributary embayments sampled (five in the Cheyenne embayment and eight in the rest of Lake Oahe), seasonal mean catches were highest in the lower reach in 48 comparisons, the middle reach in 40, and the upper reach in 26. Chi-square analyses, however, indicated only a few statistically significant differences ($P < 0.05$) among the seasonal numbers of fish from the three locations within a tributary. This finding differs somewhat from that of Beckman and Elrod (1971), who stated that the abundance of most species was greatest upstream and lowest downstream; however, their conclusion was based on collections in only four downstream localities of Lake Oahe.

As YOY fish got larger during the progress of the season, some moved into deeper water. Indeed, Beckman and Elrod (1971) found that mid and late season deepwater trawl catches of some species, such as yellow perch *(Perca flavescens)*, walleye *(Stizostedion vitreum vitreum)*, black crappie *(Pomoxis nigromaculatus)*, and white crappie *(Pomoxis annularis)*, at times exceeded seine catches in littoral areas. In every year, seine catches decreased noticeably by early September and decreased earlier in the upper reaches of tributaries than in the middle or lower reaches. In most localities, catches were lowest during the last 2-week sampling period, and few fish were caught during this period in 1973 or 1974 (supplemental seining in some years yielded few or no fish in the littoral zone after mid September, indicating that they had probably moved out of the shallower waters). Within this reservoir, YOY fishes were thus primarily associated with the littoral zone of tributary embayments only through most of their first summer.

Species Structure and Number

The fish fauna of Lake Oahe consisted mostly of warmwater species and differed considerably from that of the Missouri River before impoundment. Forty-one species of 28 genera and 13 families were represented as YOY in the seine catches (Table 1). About 73% of the total number of species taken were in four families (Cyprinidae, Catostomidae, Centrarchidae, and Percidae), and six species accounted for 86 to 98% of the annual catches (Table 2). Beckman and Elrod (1971) reported the collection of YOY of 32 species. With the exception of the black bullhead (not collected in 1971, 1973, or 1974), all of the species collected by them continued to be represented in seine catches in most years during 1970–74.

Table 1. *Apparent abundance and population trend of young-of-the-year fishes seined in Lake Oahe, 1966–74.*

Family and species		Apparent abundance[a]	Apparent population trend[b]
Lepisosteidae			
Shortnose gar	*Lepisosteus platostomus*	R	N
Hiodontidae			
Goldeye	*Hiodon alosoides*	I	I
Salmonidae			
Rainbow trout	*Salmo gairdneri*	R	N
Esocidae			
Northern pike	*Esox lucius*	I	D
Cyprinidae			
Carp	*Cyprinus carpio*	C	N
Brassy minnow	*Hybognathus hankinsoni*	R	N
Silvery minnow	*H. nuchalis*[c]	C	D
Plains minnow	*H. placitus*[c]	R	N
Flathead chub	*Hybopsis gracilis*	I	N
Golden shiner	*Notemigonus crysoleucas*	S	D
Emerald shiner	*Notropis atherinoides*	A	D
Pugnose minnow	*N. emiliae*	R	N
Spottail shiner	*N. hudsonius*	R	I
Topeka shiner	*N. topeka*	R	N
Bluntnose minnow	*Pimephales notatus*[c]	S	D
Fathead minnow	*P. promelas*[c]	S	D
Blacknose dace	*Rhinichthys atratulus*	R	N
Creek chub	*Semotilus atromaculatus*	R	N
Catostomidae			
River carpsucker	*Carpiodes carpio*	S-I	N
White sucker	*Catostomus commersoni*	S-I	N
Blue sucker	*Cycleptus elongatus*	R	N
Smallmouth buffalo	*Ictiobus bubalus*	S-I	D
Bigmouth buffalo	*I. cyprinellus*	S-I	I
Shorthead redhorse	*Moxostoma macrolepidotum*	I-R	N
Ictaluridae			
Black bullhead	*Ictalurus melas*	C	D
Channel catfish	*I. punctatus*	I-R	N
Gadidae			
Burbot	*Lota lota*	R	N
Gasterosteidae			
Brook stickleback	*Culaea inconstans*	R	N
Percichthyidae			
White bass	*Morone chrysops*	C	I

(Continued)

Table 1. *Apparent abundance and population trend of young-of-the-year fishes seined in Lake Oahe, 1966–74.*

Family and species		Apparent abundance[a]	Apparent population trend[b]
Centrarchidae			
Green sunfish	*Lepomis cyanellus*	R	N
Orangespotted sunfish	*L. humilis*	R	N
Bluegill	*L. macrochirus*	S-I	N
Largemouth bass	*Micropterus salmoides*	I-R	N
White crappie	*Pomoxis annularis*	C	D
Black crappie	*P. nigromaculatus*	C	D
Percidae			
Iowa darter	*Etheostoma exile*	S-I	N
Johnny darter	*E. nigrum*	I-R	N
Yellow perch	*Perca flavescens*	A	D
Sauger	*Stizostedion canadense*	S	D
Walleye	*S. vitreum vitreum*	S	I
Sciaenidae			
Freshwater drum	*Aplodinotus grunniens*	C	I

[a] A = abundant (> 20 per seine haul); C = common (1–5 per haul); I = intermittent (0.1–5 per haul in some years and absent or < 0.1 in others); R = rare (< 0.1 per haul, including single captures); S = scarce (0.1–0.9 per haul).

[b] D = decreasing; I = increasing; N = no trend.

[c] In most collections *Hybognathus nuchalis* and *H. placitus* were combined, as were *Pimephales notatus* and *P. melas*.

Table 2. *Percentage contributions by major species to seine catches of young-of-the-year fishes, Lake Oahe, 1966–74.*

Species	1966	1967	1968	1969	1970	1971	1972	1973	1974	Percent of 9-yr total
Yellow perch	64.8	78.4	83.2	76.0	65.8	42.1	53.8	31.4	36.5	71.4
Emerald shiner[a]	18.0	6.1	8.4	5.1	11.4	25.0	20.3	23.1	5.4	10.5
White bass	2.0	4.6	0.6	8.7	18.5	19.6	18.2	27.6	33.1	7.7
White crappie	0.8	4.5	3.1	0.4	0.1	0.3	1.1	1.0	1.4	2.1
Black crappie	0.4	3.8	2.1	0.9	0.1	0.8	0.2	0.3	0.1	1.7
Bigmouth buffalo	0.3	0.1	0.1	0.6	0.5	0.6	0.4	8.2	15.8	0.8
Percent of total	86.3	97.5	97.5	91.7	96.4	88.4	94.0	91.6	92.3	94.2
Total number (thousands)	47.8	137.7	150.6	91.8	55.5	29.2	22.5	17.8	12.9	565.8

[a] All ages combined.

Bailey and Allum (1962) listed 38 native and 7 introduced species of 14 families in the portion of the Missouri River lying within South Dakota, but they considered only 33 species as "characteristic inhabitants." Of the total of 45 species, 12 were not found in the present seine collections. Five of these 12 have persisted as adult stocks (pallid sturgeon, *Scaphirhynchus albus*; shovelnose sturgeon, *S. platorynchus*; paddlefish, *Polyodon spathula*; blue catfish, *Ictalurus furcatus*; and flathead catfish, *Pylodictis olivaris*), and four probably did not occur in this portion of the river before impoundment (silver lamprey, *Ichthyomyzon unicuspis*; longnose gar, *Lepisosteus osseus*; skipjack herring, *Alosa chrysochloris*; and silver chub, *Hybopsis storeriana*). Ignoring the doubtful forms, there thus are no known recent young of two families of present adult inhabitants (Polyodontidae and Acipenseridae). On the other hand, two families (Salmonidae and Percichthyidae) and the following 14 species for which Bailey and Allum (1962) had no Missouri River records were represented in the 1966-74 YOY seine catches: northern pike; rainbow trout; golden, spottail, and Topeka shiners (spottail shiners were stocked in 1973); creek chub; pugnose and brassy minnows; shorthead redhorse; black nose dace; brook stickleback; Iowa and johnny darters; and white bass.

The burbot is the only native cold-water fish in the reservoir. Adult rainbow trout have occasionally been caught in gill nets, and YOY were taken by seine a few days after a known stocking of fingerlings, but there is no evidence that this species has successfully reproduced within the reservoir. Additionally, the South Dakota Department of Game, Fish and Parks has stocked the reservoir with four other cold-water species—kokanee *(Oncorhynchus nerka)*, Bonneville cisco *(Prosopium gemmiferum)*, brown trout *(Salmo trutta)*, and lake trout *(Salvelinus namaycush)*—(Table 3); however, test netting has failed to recover any specimens in Lake Oahe. Other than rainbow trout, the only known survivors from these stockings were seven kokanee and three Bonneville cisco, all of which were caught in Lake Sharpe, the adjacent downstream reservoir. These specimens, along with numerous rainbow trout fingerlings, verify the

Table 3. *Cold-water fishes stocked in South Dakota waters of Lake Oahe, 1970-74.*[a]

Species and stocking date	Location[b]	Number	Size
Kokanee			
Jan. 1970	Cow Creek	262,000	Fry
May 1970	Cow Creek	82,000	Fingerlings
Jan. 1971	Cow Creek	385,000	Fry
Jan. 1972	Cow Creek	290,000	Fry
Feb. 1974	Cow Creek	370,000	Fry
Bonneville cisco			
Jan. 1973	Above Oahe Dam	5,000	Adults (16.5-18.5 cm)
Jan. 1973	Above Oahe Dam	75,000	Eggs
Jan. 1974	Above Oahe Dam	3,500	Adults (16.5-18.5 cm)
Rainbow trout			
Aug. 1972	Above Oahe Dam	33,000	Fingerlings
Mar. 1973	Cow Creek	20,000	Fingerlings
Aug. 1973	Above Oahe Dam	300,000	Fingerlings
Sept. 1973	Above Oahe Dam	207,000	Fingerlings
June 1974	Above Oahe Dam	57,100	Fingerlings
June 1974	Above Oahe Dam	500	Adults (16.5-18.5 cm)
Aug. 1974	Above Oahe Dam	98,000	Fingerlings
Brown trout			
Aug. 1972	Above Oahe Dam	16,000	Adults ($\overline{X}$ = 22.5 cm)
Lake trout			
Oct. 1972	Cow Creek	40,000	Yearlings (10-15 cm)
Oct. 1973	Whitlocks Bay	26,000	Fingerlings

[a] Source: South Dakota Department of Game, Fish and Parks.

[b] Cow Creek is about 1 km downstream from Okobojo Creek (Fig. 1).

successful passage of some individuals through the powerhouse turbines and indicate a possible source of further additions to the Lake Oahe fish fauna from upstream stockings in Lake Sakakawea, North Dakota, and Fort Peck Lake, Montana.

Thus, the most obvious change in the structure of the fish fauna after impoundment of Lake Oahe was one of kind, rather than of number. Although about 30% of the species reported from the river were lacking in the impoundment, they were replaced by other species.

Two simple indices—total number of species caught per year and number of species caught per seine haul—were used for the examination of annual changes in the species structure from 1966 to 1974. The number of species caught per haul was used for the analysis of trends within localities.

Total species number varied only slightly between years, but a slight downward trend was suggested during 1969-74 (Table 4). The peak number in 1969 reflected an increase within the main reservoir sampling localities in the first year of peak water level. Numbers were highest in the Cheyenne embayment in 1966 and 1968. In most years, fewer species were caught in the Cheyenne embayment than in the rest of the reservoir, and the downward trend in total number after 1969 was mostly due to reductions in the Cheyenne embayment in 1973 and 1974.

Total species number varied annually within localities (Table 4), but upward or downward trends in relative numbers were suggested in most localities (Fig. 4). As reported by Beckman and Elrod (1971), most species were usually taken in the upper reaches of tributary embayments and fewest in the lower reaches. Excluding the Cheyenne embayment, average numbers were lowest in downstream localities and highest in the middle third of the reservoir (Moreau and Grand Rivers). Greatest variation in species numbers was in the downstream locality (Chantier Creek), but variations were generally greater in localities in the upper third of the reservoir. The 9-year trend lines suggest a decrese in relative diversity of species in all localities except Beaver Creek and upper Oahe, although none of the trend lines differ significantly from zero. On the other hand, declining trends from peak numbers in 1969 are significant at the 5% level for five localities in the

Table 4. *Total number of species of young-of-the-year fishes in seine catches in various localities of Lake Oahe, 1966-74.*

Locality[a]	1966	1967	1968	1969	1970	1971	1972	1973	1974	Mean
Lake Oahe (excluding Cheyenne embayment)										
Chantier Creek	7	14	11	16	11	8	10	5	6	9.8
Okobojo Creek	7	9	10	12	12	13	7	8	7	9.4
Willow Creek	8	13	13	13	14	13	11	8	8	11.2
Whitlocks Bay	9	10	13	14	12	15	11	9	10	11.4
Moreau River	19	14	18	22	22	17	16	16	14	17.6
Grand River	18	14	20	22	22	16	15	15	15	17.4
Spring Creek	20	12	15	15	13	17	10	12	14	14.2
Beaver Creek	15	9	15	17	22	14	14	16	17	15.4
Upper Oahe	b	b	b	16	19	15	17	14	14	15.8
Total	26	21	24	30	27	26	26	23	25	25.3
Cheyenne embayment										
Brush Creek	11	9	8	10	9	11	10	10	8	9.6
Rosseau Creek	13	9	13	11	10	11	15	6	7	10.6
Fishgut Creek	15	11	14	14	10	10	10	7	10	11.2
Minnconjou Creek	18	16	19	14	9	15	11	7	9	13.1
Sansarc Creek	21	15	16	16	13	14	13	12	13	14.8
Upper Cheyenne	24	16	21	19	19	17	18	11	14	17.7
Total	24	21	24	23	21	23	21	15	18	21.1
Grand Total	26	24	27	30	27	27	27	24	25	26.3

[a] See Figs. 1 and 2 for locations.

[b] No data.

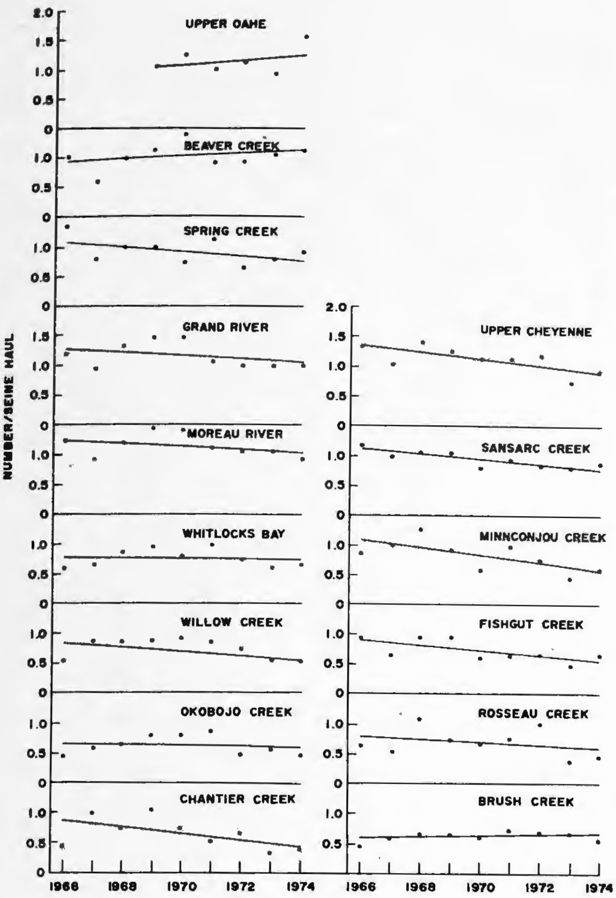

Fig. 4. Nine-year trends in the mean number of species of young-of-the-year fishes caught per seine haul in various localities of Lake Oahe (left panel) and in the Cheyenne embayment (right panel), 1966–74. See Figs. 1 and 2 for locations.

lower two-thirds of the reservoir (Chantier, Okobojo, and Willow Creeks and Moreau and Grand Rivers) and of borderline significance for one (Whitlocks Bay).

Within the Cheyenne embayment, species numbers averaged highest upstream and lowest downstream (Table 4). Total numbers in Brush Creek averaged about the same as in the downstream localities of the main reservoir (Chantier and Okobojo Creeks). Numbers also remained nearly constant and least variable in Brush Creek, but in all other localities the trend was downward (Fig. 4). The 9-year trend lines for Fishgut and Minnconjou Creeks and the upper Cheyenne are significant at the 5% level and that for Sansarc Creek at the 1% level.

Although spatial and temporal differences in species numbers indicate the semi-independence of the Cheyenne embayment as a nursery area, the patterns of variations in the range, mean, and trends within its major tributaries were similar to those in the rest of the reservoir and suggest no great divergences in the composition of their fish faunas. Only four rare species (blue sucker, blacknose dace, creek chub, and brook stickleback) were not represented in the catches from the Cheyenne embayment.

The seine catches indicate that the species composition of the fish fauna changed after the reservoir filled. It remains to be determined whether this variation was random or foreshadows a further loss of species. A continuing loss might indicate a reduction in the food supply and perhaps reflect a further general degradation of the spawning and nursery habitats.

Abundance

Preliminary analysis of the seine catches generally indicated statistically significant geographical and temporal variations in abundance. The data were therefore summarized according to the three major sources of variation—years, localities, and 2-week time periods—for estimates of abundance. Since primary interest is in the nature and source of observed variation in the relative survival of the YOY stocks, the annual abundance estimates are emphasized. The relative abundance of YOY fishes is expressed as the catch per standardized seine haul, or C/f (Beckman and Elrod 1971).

Estimated abundance of YOY fishes reached a maximum in 1968 and declined thereafter (Table 5). The low in 1974 was less than one-twelfth that in 1968. General trends in the Cheyenne embayment and in the rest of the reservoir were the same, except that the peak occurred a year earlier in the Cheyenne embayment. The average rate of decrease from 1968 to 1974 was about 16% per year in the Cheyenne embayment and about 15% in the rest of the reservoir.

Abundance within localities varied annually, but trends were downward everywhere except in the upper Oahe sampling locality (Fig. 5). Trend lines are significant at the 1% level for seven of the localities (Whitlocks Bay and Chantier, Willow, Brush, Rosseau, Minnconjou, and Sansarc Creeks) and at the 5% level for three (Willow and Fishgut Creeks and Upper Cheyenne). Declines were thus greatest in downstream localities, including all tributaries of the Cheyenne embayment. The peak in most downstream localities of the Cheyenne embayment and the main reservoir was in 1967; exceptions were Okobojo, Brush, and Willow Creeks, where the peak was in 1968. In most upstream localities the peak was in 1968 or in 1969. Annual variations in abundance were least in the uppermost sampling localities and

Table 5. *Mean catch of young-of-the-year fishes per seine haul in various localities of Lake Oahe, 1966-74.*[a]

Locality	1966	1967	1968	1969	1970	1971	1972	1973	1974	Mean
Lake Oahe (excluding Cheyenne embayment)										
Chantier Creek	256	829	416	92	74	20	37	21	41	198
Okobojo Creek	74	728	1235	122	138	47	26	32	51	272
Willow Creek	285	379	559	527	200	292	66	113	29	272
Whitlocks Bay	897	2303	1765	397	345	179	76	124	82	685
Moreau River	184	494	1198	654	169	333	56	99	96	365
Grand River	67	1608	389	282	345	127	202	106	62	354
Spring Creek	147	138	830	1880	881	252	536	322	109	566
Beaver Creek	43	120	855	610	592	254	70	121	162	314
Upper Oahe	—	—	—	123	38	72	40	85	163	87
Mean	244	825	906	521	309	175	123	114	85	367
Cheyenne embayment										
Brush Creek	246	339	352	91	211	59	70	42	25	159
Rosseau Creek	362	1182	853	113	65	77	75	25	9	307
Fishgut Creek	60	794	465	306	62	65	34	16	14	202
Minnconjou Creek	102	699	356	163	90	54	28	10	35	171
Sansarc Creek	258	205	286	256	272	56	79	30	22	163
Upper Cheyenne	207	175	724	508	218	63	105	39	24	229
Mean	206	550	499	240	153	62	65	27	21	202
Grand mean	228	721	738	408	247	130	100	79	59	301

[a] Annual mean catch in each locality was based on 15 seine hauls, with the following exceptions (number of hauls in parentheses): Chantier Creek, 1967(14); Upper Oahe, 1966-68(0) and 1974(9); Brush and Rosseau Creeks, 1967 and 1968(12 each); and Fishgut, Minnconjou, and Sansarc Creeks, 1967(11 each).

greatest in the lowermost tributaries of both the Cheyenne embayment and the main reservoir. The 9-year mean was generally higher for tributaries in the upper two-thirds of the main reservoir, but was lowest in the uppermost locality. The 9-year mean for the Cheyenne embayment was about the same as for the lowermost tributary of the main reservoir (Chantier Creek).

As suggested above, localities of maximum abundance shifted upstream while the reservoir was filling (Table 5 and Fig. 5). Whitlocks Bay ranked first in mean fish abundance from 1966 to 1968 and thereafter continued to rank among the first five. In four of the following years, maximum abundance was in Spring Creek, and in 1971 the maximum was in the Moreau River. The Cheyenne embayment did not rank first in any year, and during the last several years of the study, mean abundance within this embayment ranked near or at the bottom. Moreover, there was no upstream shift in abundance within the Cheyenne embayment like that in the main reservoir. Although Rosseau Creek ranked first from 1966 to 1968, all other tributaries of this embayment (Fishgut Creek excepted) ranked first or last, without sequence, at one time or another during the 9 years.

These observations lead to a conclusion different from that of Beckman and Elrod (1971), who stated that levels of fish abundance were higher in embayments associated with permanent streams than in those associated with intermittent ones. However, they classified the Cheyenne, Grand, and Moreau Rivers as permanent streams, whereas I have classified them as intermittent. The pertinent conclusions to be drawn are that (1) during filling, abundance of YOY fishes increased through 1968 and was generally highest in the lower or middle third of the reservoir, (2) after the reservoir had filled, abundance declined markedly, and levels were highest in the middle or upper third of the reservoir, and (3) with the noted exceptions, variations and trends in abundance in the Cheyenne embayment were similar to those in the rest of the reservoir.

In most years the abundance of YOY fishes in tributaries along the east bank of the reservoir averaged nearly twice that in tributaries along the west bank (Table 6). Abundance in the Cheyenne embayment generally averaged lower than that in either the west or east group of tributaries and most

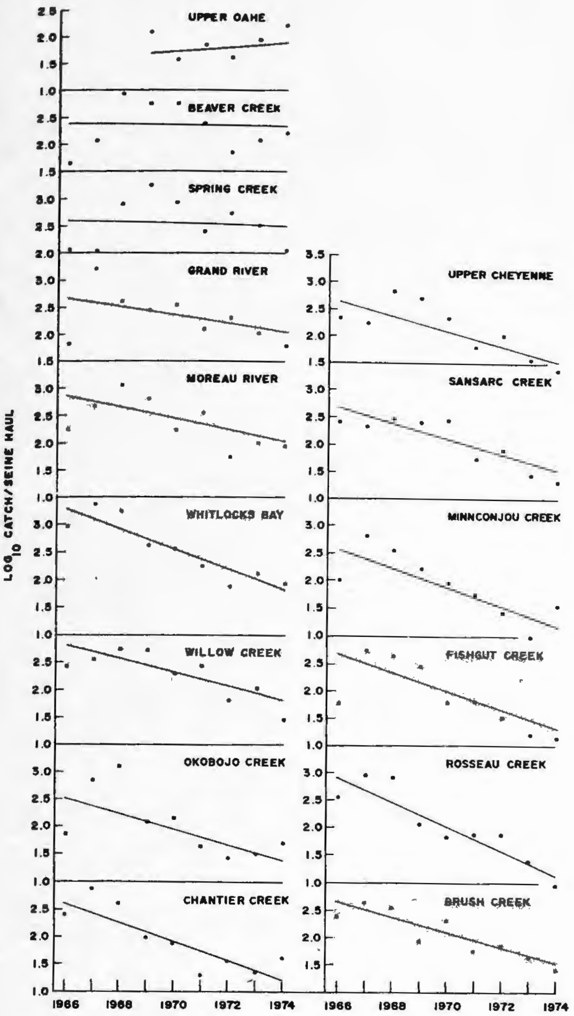

Fig 5. Nine-year trends in the mean catch of young-of-the-year fishes per seine haul in various localities of Lake Oahe (left panel) and in the Cheyenne embayment (right panel), 1966–74. See Figs. 1 and 2 for locations.

closely approximated that in Chantier Creek, the adjacent downstream tributary on the west bank (Table 5). Comparisons of the 9-year means with the post-filling 5-year means lead to the same general conclusions. The east bank tributaries, which are characterized by a glacial till bottom and greater water clarity, apparently provide more favorable spawning and nursery habitats than do the shallow, heavily silt-laden tributaries that lie within the Pierre Shale formation along the west bank. This difference may have management implications; because of the unstable shorelines of tributaries along the west bank, habitat improvement programs are likely to be more successful in east bank than in west bank tributaries.

Abundance of Some Associated Groups of Fishes

The nature and impact of changes in relative abundance within the YOY stocks can perhaps best be realized by considering some trends within and between some arbitrary groups of fishes. Seven groups whose ecological or economic roles in Lake Oahe are generally known were examined: forage, predatory, sport, commercial, riverine, and littoral fishes and minnows. Some species were included in more than one group. The groupings admittedly are over-simplified, for there are numerous interactions which are either assumed or not understood.

Forage and Predatory Fishes

Catches of forage species combined (goldeye, minnows, suckers, black bullhead, white crappie, black crappie, yellow perch, and freshwater drum) determined the trends and levels of overall abundance estimates (Fig. 6). The 9-year trend in *C/f* of the four principal predatory species combined (northern

Table 6. *Mean catch of young-of-the-year fishes per seine haul in east and west bank tributaries (excluding the Cheyenne embayment) of Lake Oahe, 1966–74.*

										Mean	
Locality	1966	1967	1968	1969	1970	1971	1972	1973	1974	1966–74	1970–74
East bank tributaries[a]	290	822	1171	752	489	183	177	150	101	460	220
West bank tributaries[b]	198	828	640	389	197	193	90	85	57	297	124

[a] Okobojo, Spring, and Beaver Creeks and Whitlocks Bay.

[b] Chantier and Willow Creeks and Moreau and Grand Rivers.

pike, white bass, sauger, and walleye) was inversely related to that of overall abundance. Abundance estimates of the predatory species were similar to those of the forage species in 1966-67, but the *C/f* of predatory species dropped sharply in 1968; it rose again in each of the following 2 years and fluctuated only slightly thereafter. Thus, after the reservoir filled, the predatory stock remained relatively stable, whereas the prey stock decreased steadily.

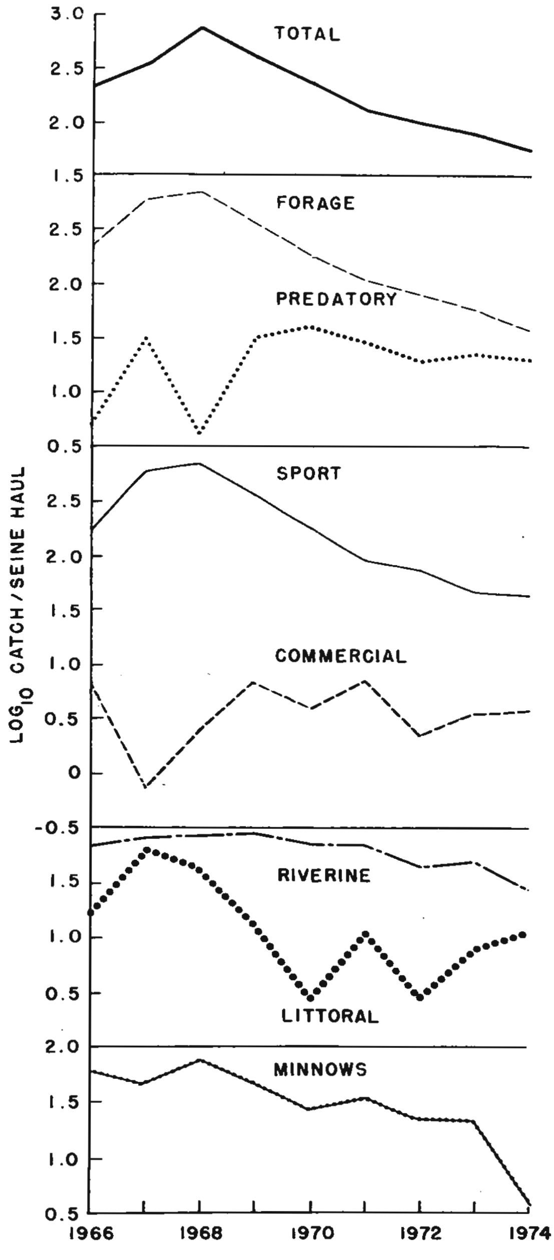

Fig. 6. Mean catches of some selected groups of young-of-the-year fishes, compared with the total mean catch per seine haul, Lake Oahe, 1966-74. See text for identity of species in the different groups.

Sport and Commercial Fishes

The relative abundance of major sport fishes combined (northern pike, channel catfish, black bullhead, white bass, walleye, sauger, black crappie, and white crappie) was highest in 1968 and followed a generally downward trend in 1969-74 (Fig. 6). The white bass ranked first within this group; its contributions were relatively high through most of the 9 years (Table 2). Abundance of both species of crappies decreased noticeably after a peak in 1967, although the white crappie persisted in greater numbers than the black crappie in 1972-74 (Table 2). Walleye abundance was least variable, with some indication of higher levels in 1968-73. Sauger abundance also remained relatively stable throughout the period. Northern pike were scarcest of all; none were caught in 1968 or 1973, and catches in other of the later years of the study were made in only one upstream locality (Beaver Creek), which had been stocked. Thus, within this group, the white bass, walleye, and perhaps sauger showed the greatest reproductive success through the early 1970's.

The abundance of commercial fishes (goldeye, carp, river carpsucker, smallmouth buffalo, bigmouth buffalo, channel catfish, and freshwater drum), collectively and individually, was low, and the 9-year trend tended to be inversely related to overall abundance (Fig. 6). The spawning success of all of these species has varied. Abundance of goldeye was high in 1971 and 1973. Carp abundance was highest in 1969 and 1971 and low in all other years. The river carpsucker was most abundant in 1966, but none were taken in 1967, and catches in later years were small. The tendency of larvae and postlarvae of this species to remain in the river portion of the major tributaries through much of the summer, however, undoubtedly resulted in underestimation of the YOY stock, especially in years of high river flows. Smallmouth buffalo abundance peaked in 1969. Bigmouth buffalo abundance reached an initial peak in the same year, followed by even higher levels in 1973 and 1974 (Table 2). The higher *C/f* for bigmouth buffalo in 1973 resulted almost entirely from catches in upstream localities of Lake Oahe (only nine individuals were taken elsewhere), but in 1974 this species was taken in most sampling localities. Of this group, fewer channel catfish than other species were caught; none were taken in 3 of the 9 years. Beckman and Elrod (1971) suggested that the shelter-seeking habits of the young resulted in their low availability to a seine. Abundance of freshwater drum was moderately low, least variable, and showed signs of increase during 1971-74. Although their contributions have remained small, slight increases in goldeye, bigmouth buffalo, and freshwater drum were largely responsible for maintaining a fairly stable level of abundance of YOY commercial fishes after 1969 (Fig. 6).

Fishes of Riverine or Littoral Areas

Annual variations in the abundance of 27 combined species that were either produced in, or whose life cycle is principally associated with, riverine habitats (shortnose gar, goldeye, 13 species of minnows, 4 species of suckers, channel catfish, white bass, 2 species of darters, sauger, walleye, brook stickleback, and freshwater drum) were slight, but a downward trend was suggested in 1970-74 (Fig. 6). Beckman and Elrod (1971) noted a downward trend in 10 riverine species studied during the years of filling (brassy minnow, silvery minnow, plains minnow, flathead chub, Topeka shiner, river carpsucker, white sucker, shorthead redhorse, stonecat *(Noturus flaxus)*, and sauger).

The combined abundance of YOY produced by 11 species of littoral spawners (northern pike, carp, smallmouth buffalo, bigmouth buffalo, black bullhead, green sunfish, orangespotted sunfish, bluegill, largemouth bass, white crappie, and black crappie) fluctuated widely, and the 9-year trend was directly related to overall abundance (Fig. 6). Abundance of fish constituting this group was highest in 1967 and lowest in 1970 and 1972.

During filling of the reservoir, maximum abundance of YOY produced by the four principal sport or commercial species that spawn in littoral areas (northern pike, smallmouth buffalo, bigmouth buffalo, and carp) coincided with the initial peak water level in 1969 (Fig. 3). On the other hand, northern pike abundance was low in 1967, the year of peak abundance for most other species in this group. The water level in that year rose from a low of 484.0 above msl on 1 January to an initial peak of 487.1 m on 16 April; however, the level fell continually thereafter to 485.4 on 8 June, after which it again rose. The early spring rise had inundated extensive grassy areas, and what may have otherwise provided ideal conditions for pike reproduction and survival of young was lost by the rapid drawdown during peak spawning and the critical period in May and early June when eggs were incubating and larvae were beginning to feed.

After the reservoir filled, abundance of YOY produced by species that spawn in littoral areas was moderately good in the 3 years (1971, 1973, and 1974) when spring water levels (1) inundated terrestrial vegetation, (2) fluctuated little during the period of spawning, embryonic development, and early larval feeding, and (3) were maintained through May or longer (Fig. 3). Conversely, abundance was below average in years when water levels (1) dropped and exposed extensive littoral areas, or (2) were erratic during the spawning season.

Minnows

Minnows (shiners, chubs, and dace) constituted 7 to 27% of the total annual seine catches and 13% of the 9-year total. Because they formed an important component of the forage base in Lake Oahe, and age groups were difficult to identify at sight, fish of all ages were combined in the abundance estimates. Trends in abundance generally followed those of overall abundance (Fig. 6). Except for a slight rise in 1971, when stream flows and water levels were near maximal, the abundance of minnows as a group declined steadily after 1968. The *C/f* in 1974 was one-fifth that in 1973 and only about 5% that in 1968.

Although 13 species of minnows were identified in the catches, the emerald shiner dominated in every year. This species accounted for 43 to 93% of the combined annual catches of minnows and 78% of the 9-year total. *Hybognathus* sp. (chiefly *H. nuchalis*) ranked second in importance in this group. Its abundance was highest in 1966, but steadily declined thereafter. This genus accounted for 16% of the total seine catch (44,124 fish) in the Cheyenne embayment during exploratory work in 1965, but only some 100 to 200 specimens were taken in the entire reservoir in 1973-74 combined. Beckman and Elrod (1971) noted that the catch of *Pimephales* sp. *(P. notatus* and *P. promelas)* was never high, except in 1968 and 1969 when these fish may have been washed into Lake Oahe by the flooding of a subimpoundment on upper Spring Creek. Neither species showed a noteworthy increase in 1970-74. Other minnow species were either scarce or not collected in every year.

Spottail shiners were stocked in Whitlocks Bay in May 1973, and by August they were distributed throughout the bay. In 1974, YOY and older age groups were also taken in the Cheyenne embayment.

Abundance, Growth, or Mortality of Four Selected Species

Although various characteristics of the YOY stocks of every species have changed over the years, biostatistical data were either too scanty or variable to establish clear-cut trends for most. Three species—the yellow perch, emerald shiner, and white bass—were collected in adequate numbers to permit closer examination of changes in abundance, growth, or mortality and the possible influence of various factors on these characteristics. An example of the apparent demise of a species is provided by the black bullhead.

Yellow Perch

Beckman and Elrod (1971) reported the yellow perch to be the most abundant species in 1965–69, and it continued to dominate the seine catches in all localities in 1970–74. The YOY reached maximum abundance in 1968, when they accounted for 83% of the total catch (Fig. 7 and Table 7). In 1974, however, the abundance of perch was only about 3 or 4% that in 1968; nevertheless, it was still the most abundant species and made up 36% of the total catch (Table 2). Trends in abundance were similar in the Cheyenne embayment and the rest of the reservoir, except that abundance peaked a year earlier (1967) in the Cheyenne embayment, and the average annual rate of decrease during 1969–74 was greater (50%) than in the rest of the reservoir (38%).

The 9-year abundance trend was downward in every locality except Spring Creek. Peak abundance was in 1967, 1968, or 1969, and tended to occur later in upstream than in downstream localities of both the Cheyenne embayment and the remainder of the reservoir (Table 7). Abundance averaged higher in east bank than in west bank tributaries, including the Cheyenne embayment, in every year. The mean *C/f* in east bank tributaries for the 5-year period after the reservoir filled (152 per seine haul) was more than double that in west bank tributaries (61 per seine haul). Abundance averaged highest and was most variable in Whitlocks Bay, whereas average abundance was usually lowest in the upper Cheyenne. The average annual rate of decline in abundance slackened in 1972-74, and the *C/f* in several scattered localities in 1974 was at its highest level during this period.

Young-of-the-year yellow perch in seine samples ranged from 12 to 82 mm in total length. Length-frequency distributions of fish within each of the three subsamples (upper, middle, and lower reaches) taken within a locality on a given date were usually unimodal and symmetrical, and the ranges, modes, and means of the subsamples usually agreed closely; however, some subsamples contained fish of different length ranges, and their means differed. The lengths vary because the spawning season is protracted, especially in some years, in this reservoir (North Central Reservoir Investigations, unpublished data), and YOY yellow perch tend to school according to

Table 7. *Mean catch of young-of-the-year yellow perch per seine haul in various localities of Lake Oahe, 1966–74.*

Locality	1966	1967	1968	1969	1970	1971	1972	1973	1974	Mean
Lake Oahe (excluding Cheyenne embayment)										
Chantier Creek	136	668	337	70	61	7	28	17	35	151
Okobojo Creek	46	684	1213	102	126	27	12	16	46	252
Willow Creek	234	288	445	496	178	209	51	50	2	217
Whitlocks Bay	653	2058	1730	388	297	135	39	99	19	602
Moreau River	12	216	1062	554	74	15	6	4	48	221
Grand River	14	1251	311	249	270	49	92	11	11	251
Spring Creek	56	78	756	1495	742	162	474	122	67	439
Beaver Creek	14	104	807	505	399	152	24	18	60	232
Upper Oahe	a	a	a	80	18	11	8	9	1	21
Mean	145	674	832	438	241	85	82	38	34	285
Cheyenne embayment										
Brush Creek	182	370	309	71	176	25	42	12	9	133
Rosseau Creek	336	913	820	92	38	10	21	5	2	249
Fishgut Creek	32	474	350	285	22	12	3	2	8	132
Minnconjou Creek	33	471	203	137	52	4	4	3	3	101
Sansarc Creek	86	27	149	108	22	2	1	2	2	44
Upper Cheyenne	35	4	90	24	1	1	2	1	1	18
Mean	120	410	303	119	52	9	12	4	4	115
Grand mean	134	574	614	310	165	55	54	25	21	217

[a] No data.

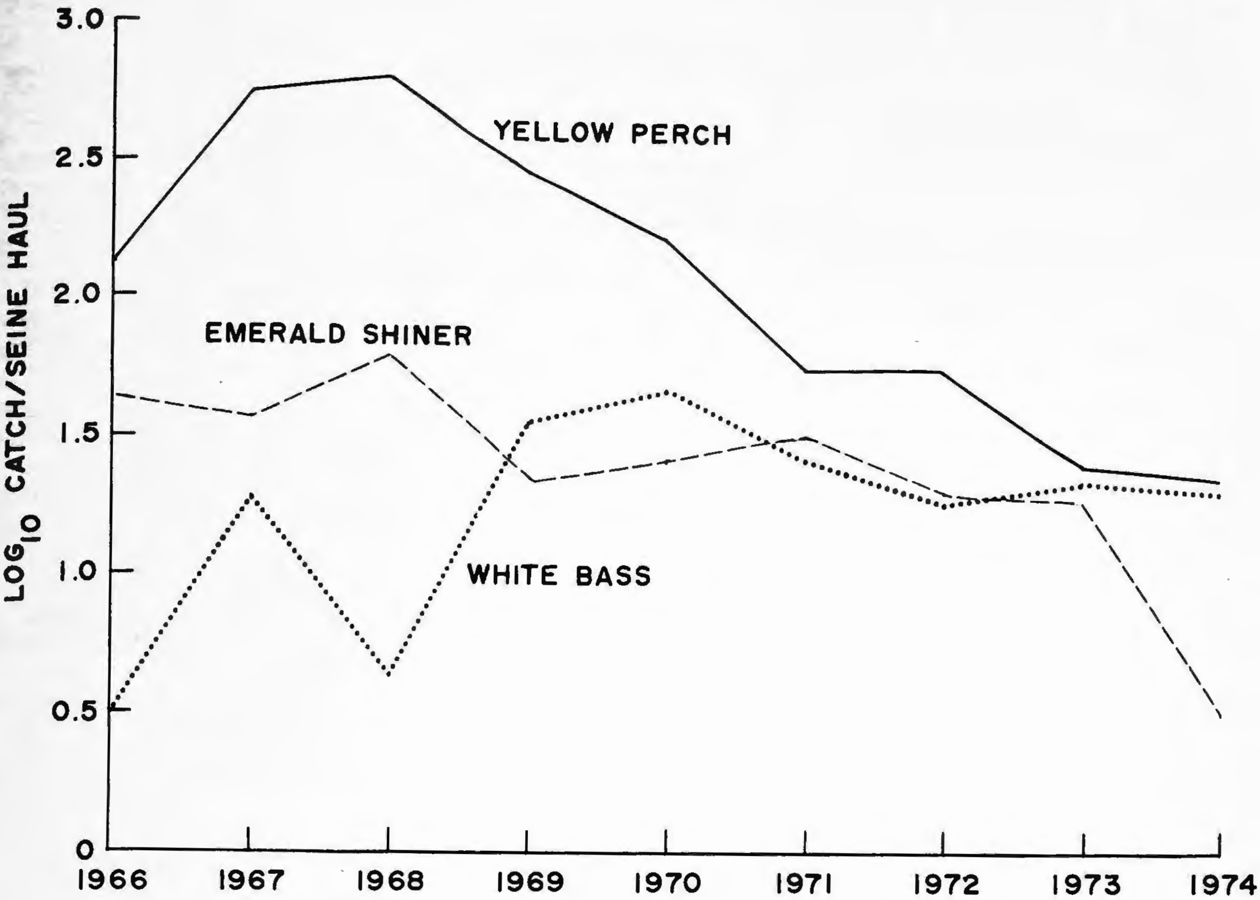

Fig. 7. Mean catches of young-of-the-year yellow perch, emerald shiner (all ages), and white bass per seine haul, Lake Oahe, 1966–74.

length. Because there was no rational basis for differentially weighting the samples, all length measurements were given equal weight in estimating growth within localities. Although the resulting estimates may not precisely represent the growth pattern of a synchronously spawned cohort within a locality, differences involved were not sufficiently great to invalidate conclusions drawn from the data.

Plots of mean total length by date for each locality demonstrated that a linear relation was a satisfactory growth model for yellow perch during their first summer. Due to variability caused by small sample size late in the season, I estimated growth only through the third week in August. Regressions of mean length on coded date (28 June = 1, 29 June = 2, . . .) were calculated. The instantaneous growth rate and the mean length on 23 August were estimated from the regression for each locality.

Growth rate of yellow perch varied annually and geographically. A two-way analysis of variance of summary data in Table 8 indicated significant heterogeneity among means—both annual ($F = 25.42$; $P < 0.01$) and locality ($F = 3.41$; $P < 0.01$). Differences between the calculated annual grand mean lengths on 23 August (Table 9) ranged from 0.2 (1966 and 1968) to 12.5 mm (1966 and 1974). In most localities the fish were smallest during the first 3 years of the study period and largest during the last 4 years; however, this pattern of variations in length was not the same in every locality. Annual variations were greater in downstream than in upstream localities; variation was least in Spring Creek and greatest in Okobojo Creek. On the other hand, mean attained lengths and the pattern of annual variations were strikingly similar in certain adjacent localities, such as Willow Creek and Whitlocks Bay, and Rosseau and Fishgut Creeks. Moreover, growth noticeably increased in most localities in 1969; exceptions were in the Grand River and Spring Creek. Length-frequency distributions in

Table 8. *Estimated mean instantaneous growth rates in length of young-of-the-year yellow perch in various localities of Lake Oahe, 1966-74.*

Locality	1966	1967	1968	1969	1970	1971	1972	1973	1974	Mean
Lake Oahe (excluding Cheyenne embayment)										
Chantier Creek	0.31	0.38	0.51	0.61	0.71	0.67	0.65	0.56	0.75	0.57
Okobojo Creek	0.30	0.23	0.49	0.63	0.54	0.56	0.63	0.78	0.66	0.54
Willow Creek	0.34	0.54	0.45	0.62	0.63	0.65	0.68	0.68	0.77	0.60
Whitlocks Bay	0.41	0.48	0.44	0.60	0.52	0.61	0.61	0.58	0.72	0.55
Moreau River	0.43	0.60	0.41	0.47	0.47	0.45	0.59	0.55	0.56	0.50
Grand River	0.43	0.42	0.47	0.39	0.48	0.41	0.44	0.76	0.65	0.49
Spring Creek	0.46	0.48	0.50	0.45	0.45	0.54	0.51	0.54	0.62	0.50
Beaver Creek	0.21	0.27	0.35	0.52	0.43	0.54	0.40	0.55	0.53	0.42
Upper Oahe	a	a	a	0.42	0.42	0.62	0.51	0.36	0.37	0.45
Mean	0.36	0.42	0.45	0.52	0.52	0.56	0.56	0.60	0.62	0.51
Cheyenne embayment										
Brush Creek	0.31	0.51	0.52	0.55	0.63	0.67	0.63	0.77	0.66	0.58
Rosseau Creek	0.32	0.54	0.53	0.77	0.68	0.60	0.64	0.60	0.75	0.60
Fishgut Creek	0.24	0.52	0.55	0.58	0.51	0.54	0.81	0.75	0.73	0.58
Minnconjou Creek	0.22	0.50	0.56	0.58	0.64	0.54	0.49	0.88	0.60	0.56
Sansarc Creek	0.34	0.52	0.42	0.53	0.53	0.61	0.58	0.77	0.73	0.56
Upper Cheyenne	0.36	0.46	0.37	0.47	0.50	0.46	0.59	0.74	0.70	0.52
Mean	0.30	0.51	0.49	0.58	0.58	0.57	0.62	0.75	0.70	0.57
Grand mean	0.33	0.46	0.47	0.55	0.54	0.56	0.58	0.66	0.65	0.53

[a] No data.

Fig. 8 furnish an example of the faster growth in 1969 compared with 1968 in Whitlocks Bay, the locality with the highest overall mean apparent perch abundance. Average lengths of fish in downstream localities of both the Cheyenne embayment and the main reservoir generally were shorter than those of fish in upstream localities (Table 9); notable exceptions were in Beaver Creek in 1966 and 1967 and upper Oahe in 1969 and 1970. Although mean calculated lengths were generally shorter, and the year of slow growth occurred earlier in the Cheyenne embayment, overall trends were otherwise the same as those elsewhere in the reservoir.

Annual differences in growth of YOY yellow perch were most likely due to variations in the food supply, competition with other species for food, or water temperature. For example, during the 5 years, 1966-70, when data on zooplankton density were available (June 1974), seasonal mean yellow perch growth was negatively correlated with mean zooplankton abundance, mean perch abundance, and mean summer water temperature. Data for the 9 years, 1966-74, corroborate the last two of these correlations. There was an inverse relation between the mean attained length of yellow perch on 23 August and mean perch abundance (r = -0.74; $P < 0.05$), mean emerald shiner abundance (r = -0.80; $P < 0.01$), and the mean June-August water temperature (r = -0.71; $P < 0.05$). A multiple regression analysis indicated that 77% of the observed variability in the grand mean seasonal growth of YOY yellow perch might be explained with these three variables. Thus, growth was fastest in years when yellow perch and emerald shiners were less abundant and water temperatures lower than the average for the years of observation. The faster growth when emerald shiners were less abundant suggests competition between yellow perch and associated species for a limited food supply.

Apparent mortality rates were estimated from regressions of the natural logarithm of the mean catch per seine haul on coded dates during the period when C/f was assumed to be reasonably proportional to the true population. Differences between the annual means (Table 10) were highly significant (F = 4.14; $P < 0.01$), but differences between locality means were not. Overall annual mean mortality was highest in 1967 and lowest in 1972. In the Cheyenne embayment, mortality was highest in the lower four tributaries in 1967; lowest annual mortality in most

Table 9. *Calculated mean total lengths (mm) on 23 August of young-of-the-year yellow perch in various localities of Lake Oahe, 1966–74.*

Locality	1966	1967	1968	1969	1970	1971	1972	1973	1974	Mean
Lake Oahe (excluding Cheyenne embayment)										
Chantier Creek	45.6	48.6	50.0	51.6	56.2	62.3	58.8	54.9	62.4	54.5
Okobojo Creek	45.0	39.0	48.3	55.2	55.0	60.2	57.6	62.5	59.5	53.6
Willow Creek	52.1	53.4	46.7	54.5	55.1	62.8	60.8	59.0	62.9	56.4
Whitlocks Bay	55.7	52.6	47.0	55.0	52.1	59.8	57.2	56.3	61.2	55.2
Moreau River	59.1	59.9	50.0	55.4	57.3	60.6	65.9	59.3	62.5	58.9
Grand River	58.4	56.7	55.2	54.4	56.0	59.3	62.5	69.7	68.4	60.1
Spring Creek	61.9	57.2	55.8	55.5	55.6	60.1	58.5	61.5	62.4	58.7
Beaver Creek	48.0	49.7	53.6	59.0	55.2	62.8	59.5	67.7	63.1	57.6
Upper Oahe	a	a	a	47.9	49.4	61.9	59.2	65.2	58.7	57.0
Mean	53.2	52.1	50.8	54.3	54.6	61.1	60.0	61.8	62.3	56.7
Cheyenne embayment										
Brush Creek	46.9	53.2	49.6	53.4	56.4	64.8	60.6	62.2	61.6	56.5
Rosseau Creek	45.6	56.6	50.3	58.4	58.6	62.4	62.1	57.0	64.9	57.3
Fishgut Creek	45.9	56.2	53.3	57.8	55.0	61.3	67.4	62.9	65.8	58.4
Minnconjou Creek	45.6	56.7	55.3	58.9	61.7	63.6	61.6	64.3	63.2	59.0
Sansarc Creek	53.5	58.7	54.2	61.1	60.3	67.6	64.8	66.8	72.8	62.2
Upper Cheyenne	56.3	57.0	53.6	63.8	59.5	67.4	69.3	63.0	69.1	62.1
Mean	49.0	56.4	52.7	58.9	58.6	64.5	64.3	62.7	66.2	59.2
Grand mean	51.4	54.0	51.6	56.1	56.2	62.5	61.7	62.2	63.9	57.7

[a]No data.

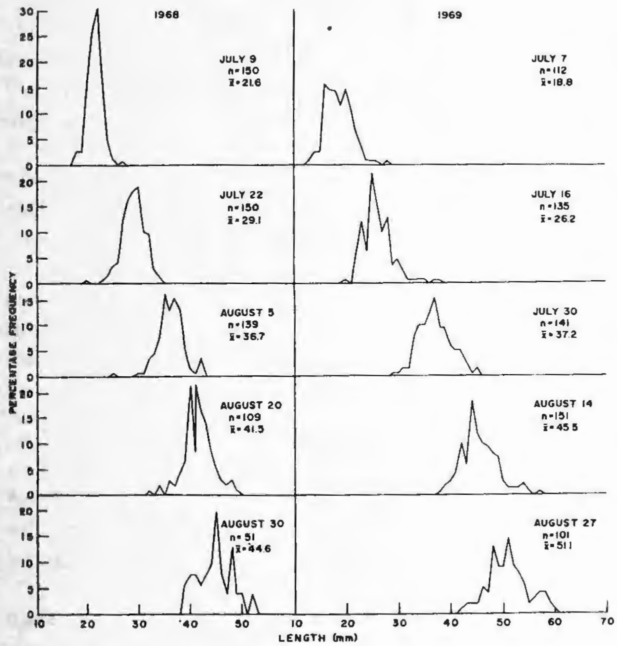

Fig. 8. Length-frequency distributions of young-of-the-year yellow perch, Whitlocks Bay, Lake Oahe, 1968 and 1969.

localities within this embayment was in 1972. Elsewhere in the reservoir the annual mean estimate was highest in 1974 and lowest in 1972. The variability of the estimates among localities within years may have arisen from variable availability of the fish, differential interaction between the fish and the prevailing physical environmental conditions within localities, variable numbers of predators, or a combination of factors.

I found no functional relation between the abundance of YOY yellow perch, or their apparent mortality, and any single biological or environmental variable that had predictive value. Some 30 comparisons were made, involving the following variables: trawl catches of older-age yellow perch, walleyes, saugers, and white bass; seine catches of emerald shiners (YOY and all ages combined) and YOY predatory fishes combined; zooplankton abundance; and water temperature, level, and discharge rate. Only the positive correlation between YOY yellow perch abundance and YOY emerald shiner abundance was significant ($r = 0.74$; $P < 0.05$), suggesting that nursery habitat requirements of these two species may be similar. Yellow perch and the emerald shiner were also the two species most commonly caught together in all localities throughout the study.

Table 10. *Estimated mean instantaneous rates of change in the natural logarithms of biweekly catches of young-of-the-year yellow perch per seine haul in various localities of Lake Oahe, 1966–74.*

Locality	1966	1967	1968	1969	1970	1971	1972	1973	1974	Mean
Lake Oahe (excluding Cheyenne embayment										
Chantier Creek	-0.0484	-0.0801	-0.0622	-0.0776	-0.1989	—	-0.0145	-0.1075	-0.0925	-0.0852
Okobojo Creek	-0.0218	-0.0784	-0.0797	-0.0454	-0.0615	-0.0444	-0.0813	-0.0552	-0.1036	-0.0635
Willow Creek	-0.0974	-0.0589	-0.0742	-0.1190	-0.0530	-0.0419	-0.0653	-0.0841	-0.1549	-0.0832
Whitlocks Bay	-0.0741	-0.0801	-0.0798	-0.0506	-0.0969	-0.0484	-0.0340	-0.1123	-0.0698	-0.0718
Moreau River	-0.0548	-0.1126	-0.1001	-0.0622	-0.0405	-0.0531	-0.0311	-0.0667	-0.0669	-0.0653
Grand River	-0.0318	-0.0942	-0.0778	-0.0585	-0.0886	—	-0.0305	-0.0725	-0.0552	-0.0636
Spring Creek	-0.0824	-0.0542	-0.1009	-0.1184	-0.1032	-0.0727	-0.1518	-0.0947	-0.0725	-0.0945
Beaver Creek	-0.0838	-0.0865	-0.0653	-0.0887	-0.0668	-0.0877	-0.0272	-0.0689	-0.1139	-0.0765
Upper Oahe	a	a	a	-0.0538	-0.0732	-0.0494	-0.0247	-0.0513	—	-0.0505
Mean	-0.0618	-0.0806	-0.0800	-0.0749	-0.0870	-0.0568	-0.0512	-0.0792	-0.0912	-0.0736
Cheyenne embayment										
Brush Creek	-0.0462	-0.1305	-0.0869	-0.0368	-0.0676	-0.0448	-0.0194	-0.0602	-0.0254	-0.0575
Rosseau Creek	-0.0832	-0.1624	-0.0857	-0.0738	-0.0962	-0.0930	-0.0278	-0.0586	-0.0296	-0.0789
Fishgut Creek	-0.1120	-0.1195	-0.0740	-0.0575	-0.0616	-0.0545	-0.0360	-0.0807	-0.0666	-0.0736
Minnconjou Creek	-0.0642	-0.1162	-0.0982	-0.0571	-0.1070	-0.0453	-0.0269	—	-0.0253	-0.0675
Sansarc Creek	-0.0873	-0.0517	-0.1041	-0.0399	-0.1213	-0.0540	-0.0308	-0.0337	-0.0925	-0.0684
Upper Cheyenne	-0.0508	-0.0511	-0.1219	-0.0589	-0.0501	—	-0.0418	-0.0598	-0.0589	-0.0617
Mean	-0.0740	-0.1052	-0.0951	-0.0540	-0.0840	-0.0583	-0.0304	-0.0586	-0.0497	-0.0677
Grand mean	-0.0670	-0.0912	-0.0865	-0.0665	-0.0858	-0.0574	-0.0429	-0.0719	-0.0734	-0.0714

[a] No data.

The foregoing findings indicate that either the abundance or mortality estimates are unrealistic, or that most of the factors examined play a minor role, or more likely act in concert, in determining the abundance and mortality of YOY yellow perch. Indeed, one of the key factors contributing to the phenomenal reproductive success of yellow perch during filling of the reservoir was one for which no quantitative measure is at hand—namely, the amount of inundated brush or similar substrate available for egg deposition during spawning. As filling progressed upstream, newly inundated brush-covered bottoms and draws provided extensive spawning habitat. Eventually, however, much of this vegetation was destroyed, either by scouring of the bottom or by sedimentation. If the above hypothesis is true, the abundance of YOY yellow perch can be expected to increase in years when remaining brush again becomes flooded during the spawning season.

Emerald Shiner

Abundance of the emerald shiner (YOY and older ages combined) peaked in 1968, dropped markedly in the following year, and fluctuated near the reduced level until 1974, when it again dropped sharply (Fig. 7 and Table 11). Abundance varied in the different localities and showed no particular pattern; except for Rosseau Creek, the peak in all localities within the Cheyenne embayment was in 1967 or in 1968. In contrast to yellow perch, the mean *C/f* of the emerald shiner for the 5-year period after the reservoir filled was higher in west bank tributaries (26 per seine haul) than in east bank tributaries (15 per haul).

Emerald shiners ranged from age 0 to perhaps age III, but most were age I; however, the age composition of the catch changed notably during the 9 years (Table 12). Separation of YOY from older age groups was based on length-frequency distribution of fish in individual samples. Mean catch of age-0 fish decreased in nearly every year. Mean catch of age-I and age-II and older fish fluctuated throughout the period and reached their lowest levels in 1974. Both the mean *C/f* of YOY and their rate of increase during the season, for example, were highest in 1966 (Table 13). The later reduction in YOY was due to either a change in the recruitment pattern after 1969 or increased mortality, or both. The instantaneous rate of decline of age-I fish was variable and showed no trend, whereas that for age-II and older fish increased

Table 11. *Mean catch of emerald shiners (ages combined) per seine haul in various localities of Lake Oahe, 1966–74.*

Locality	1966	1967	1968	1969	1970	1971	1972	1973	1974	Mean
Lake Oahe (excluding Cheyenne embayment)										
Chantier Creek	114	49	74	6	6	8	5	4	2	30
Okobojo Creek	19	25	14	4	2	12	13	13	2	11
Willow Creek	44	61	104	24	9	39	10	60	5	39
Whitlocks Bay	38	133	26	2	18	11	12	8	2	28
Moreau River	63	50	73	37	52	84	5	22	2	43
Grand River	11	49	29	11	18	56	66	66	8	35
Spring Creek	34	26	15	32	67	43	12	7	1	26
Beaver Creek	19	9	34	91	40	8	19	12	2	26
Upper Oahe	a	a	a	16	8	45	5	2	1	13
Mean	43	49	46	25	24	34	16	21	3	29
Cheyenne embayment										
Brush Creek	32	42	42	15	16	28	22	18	3	24
Rosseau Creek	18	35	29	5	14	46	34	16	7	23
Fishgut Creek	8	25	92	6	13	33	15	8	1	22
Minnconjou Creek	64	17	147	13	21	25	14	4	2	34
Sansarc Creek	79	18	83	20	24	15	8	12	4	29
Upper Cheyenne	58	28	98	30	72	35	65	23	4	46
Mean	43	28	85	15	27	30	26	14	4	30
Grand mean	43	41	62	21	26	33	20	18	3	30

[a] No data.

during 1971–74. The change in the recruitment pattern of YOY and the reduction in the age-II and older fish are shown, for example, by the monthly length-frequency distributions for 1968 and 1973 (Fig. 9). Thus, the decrease in abundance of emerald shiners after 1968 was due to reduced recruitment of age-0 fish and increased mortality of fish older than age I.

Recruitment of age-0 fish was variable and continuous during late summer, reflecting the protracted spawning period. During 1966–68, YOY appeared in the catches before mid July and accounted for about one-fourth of the seasonal catches (Fig. 9 and Table 12). By 1969, recruitment was not evident until early August, and the contribution to the catch was

Table 12. *Percentage age composition and mean catch of emerald shiners per seine haul, by age group, Lake Oahe, 1966–74.*

Year	Age 0 %	Age 0 C/f	Age I %	Age I C/f	Age II and older %	Age II and older C/f	Total C/f
1966	29.4	12.6	58.1	24.9	12.6	5.4	42.9
1967	23.5	8.9	60.6	23.0	15.9	6.0	37.9
1968	14.2	8.8	69.6	43.2	16.2	10.0	62.0
1969	5.4	1.1	70.8	14.7	23.8	4.9	20.7
1970	5.8	1.5	79.8	20.4	14.3	3.6	25.5
1971	4.8	1.6	70.2	22.8	25.0	8.1	32.5
1972	5.5	1.1	80.6	16.4	13.9	2.8	20.3
1973	2.7	0.5	92.2	16.8	5.0	0.9	18.2
1974	17.9	0.6	62.8	2.0	19.2	0.6	3.2

Table 13. *Estimated mean instantaneous rates of change in the natural logarithms of biweekly catches of emerald shiners per seine haul, by age group, Lake Oahe, 1966-74.*

	Age		
	0	I	II and older
1966	1.7675	-0.0990	-0.3199
1967	1.3563	-0.1901	-0.4973
1968	1.0829	-0.0269	-0.4409
1969	0.9914	0.4104	-0.2765
1970	1.0336	-0.2718	-0.3554
1971	0.3018	0.0468	-0.0978
1972	1.2020	-0.1573	-0.4658
1973	1.1131	-0.0773	-0.6836
1974	0.9669	0.2225	—

negligible. The cause of the change in the recruitment pattern is unknown. However, an inverse relation between the *C/f* of YOY emerald shiners and white bass (r = -0.69; $P < 0.05$) suggests that the white bass may have increased the rate of predation. The relative similarity of the *C/f* values for age-0 fish in the fall and age-I fish at the beginning of the season in 1970-74 suggests good overwinter survival.

Emerald shiners ranged from 7 to 114 mm in total length; YOY fish reached a maximum length of 60 mm by the end of the summer. The length of age-I fish ranged from 31 to 87 mm. I used mean lengths of age-I fish to examine growth rates and factors associated with annual variations in growth. Instantaneous growth rate and mean fish length on 23 August were estimated following the methods previously described for yellow perch.

Comparisons of the mean lengths of fish on 23 August indicated no statistically significant difference in fish size among localities within any year (Table 14). Slower growing fish in the lower main reservoir and the Cheyenne embayment reached about the same length by 23 August as did the faster growing fish in the upstream localities. A comparison of the mean lengths of age-I fish on 23 August in the Cheyenne embayment and elsewhere in the reservoir, for example, shows that annual variations were

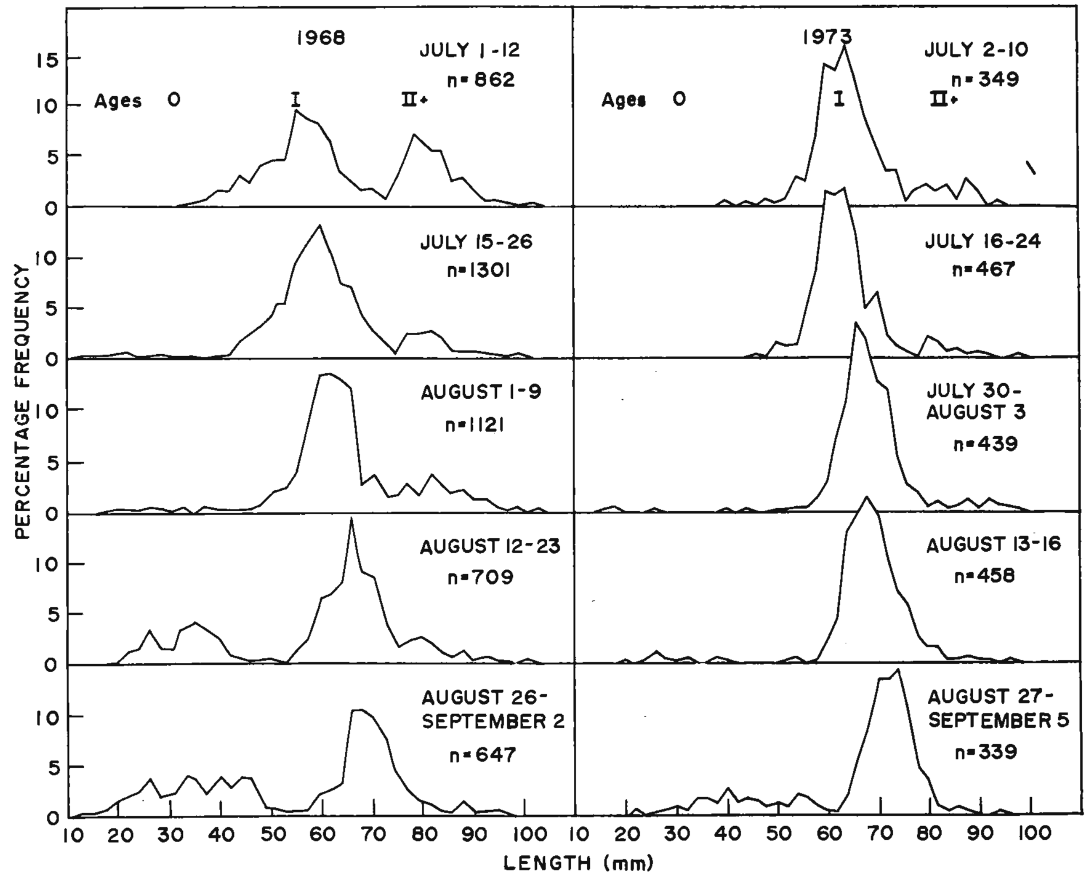

Fig. 9. Length-frequency distributions of emerald shiners, Lake Oahe, 1968 and 1973.

Table 14. *Calculated mean total lengths (mm) on 23 August of age-I, emerald shiners in various localities of Lake Oahe, 1966-74.*

Locality	1966	1967	1968	1969	1970	1971	1972	1973	1974	Mean
Lake Oahe (excluding Cheyenne embayment)										
Chantier Creek	70.7	71.0	63.8	67.2	74.5	67.3	74.6	69.0	77.7	70.6
Okobojo Creek	73.9	69.7	66.8	68.1	73.8	70.2	74.0	72.4	75.9	71.6
Willow Creek	70.4	66.5	67.7	67.1	69.6	72.3	75.1	71.9	75.8	70.7
Whitlocks Bay	69.3	69.6	68.3	68.4	70.8	70.9	74.3	68.5	74.8	70.5
Moreau River	69.2	68.6	64.9	71.0	70.7	70.9	73.1	69.8	69.4	69.7
Grand River	71.0	71.7	68.8	68.3	69.0	71.4	72.2	68.8	74.6	70.6
Spring Creek	68.8	70.9	67.7	69.8	70.6	74.1	74.1	73.4	69.4	71.0
Beaver Creek	70.2	71.4	70.5	74.5	72.1	74.5	73.1	75.4	75.3	73.0
Upper Oahe	a	a	a	71.3	75.6	74.0	73.2	79.0	73.9	74.5
Mean	70.4	69.9	67.3	69.5	71.8	71.7	73.7	72.0	74.1	71.2
Cheyenne embayment										
Brush Creek	70.6	70.0	67.4	65.6	70.0	72.0	73.3	69.0	75.4	70.4
Rosseau Creek	71.6	69.7	67.2	70.6	68.1	71.8	74.3	67.3	74.2	70.5
Fishgut Creek	74.5	70.5	67.6	67.6	70.7	74.7	74.0	69.1	79.2	72.0
Minnconjou Creek	71.6	71.4	67.7	69.4	69.3	70.5	74.8	67.9	78.3	71.2
Sansarc Creek	74.0	71.6	69.8	66.5	70.9	73.5	74.8	70.7	74.5	71.8
Upper Cheyenne	71.8	71.2	69.4	67.6	74.2	73.8	76.0	71.8	70.9	71.9
Mean	72.4	70.7	68.2	67.9	70.5	72.7	74.5	69.3	75.4	71.3
Grand mean	71.2	70.3	67.7	68.9	71.3	72.1	74.1	70.9	74.6	71.2

[a] No data.

small and followed similar trends. Consequently overall mean lengths were used to examine variations in length and the effects of environmental influences.

Growth rate of age-I fish was variable within and between localities in the different years (Table 15). Average growth was good in 1966, 1968, 1969, and 1974, and poor in 1971 and 1972. The faster rate in 1968 and 1969 was associated with highest initial water levels and upstream flooding and that in 1974 with low abundance. The faster growth in 1968 was shown most clearly by the increases in Okobojo and Beaver Creeks in the main reservoir and in Rosseau Creek and the upstream locality in the Cheyenne embayment. Also, the initial peak in the mean growth rate occurred a year earlier in the Cheyenne embayment (1968) than in the rest of the reservoir.

Although the emerald shiner was the most abundant minnow in Lake Oahe, I found no functional relation between its abundance or mortality and any environmental variable examined. Nevertheless, because of the close association of emerald shiners with YOY yellow perch, I believe that the reduction in the older age group reflected increased predation on emerald shiners as the abundance of YOY yellow perch decreased. This interpretation may also account for the change in the recruitment pattern of YOY emerald shiners.

White Bass

The white bass provides the best example of the few species whose abundance and distribution expanded during the study period. This species accounted for less than 1% of the total catch in 1968 but contributed 33% in 1974, and made up about 8% of the 9-year total (Table 2). From a low in 1966, abundance increased to a peak in 1970 (Fig. 7 and Table 16), declined to about one-half that level in 1971, declined further in 1972, and remained at about that level in 1973-74.

The distribution pattern of white bass was variable. Before 1972, abundance was much higher in the Cheyenne embayment than elsewhere in the reservoir, but in 1973-74 the catch rates were reversed (Table 16). This species was never abundant in the two downstream localities of the main reservoir. It was generally most abundant in tributaries entering the mid or upper portions of both the Cheyenne embayment and the main reservoir, although it was never abundant in upper Oahe. Catches of white bass

Table 15. *Estimated mean instantaneous growth rates in length of age-I emerald shiners in various localities of Lake Oahe, 1966-74.*

Locality	1966	1967	1968	1969	1970	1971	1972	1973	1974	Mean
Lake Oahe (excluding Cheyenne embayment)										
Chantier Creek	0.26	0.32	0.20	0.31	0.30	0.06	0.22	0.14	0.50	0.26
Okobojo Creek	0.24	0.17	0.30	0.30	0.19	0.08	0.18	0.28	0.26	0.22
Willow Creek	0.30	0.03	0.28	0.24	0.18	0.14	0.24	0.27	0.29	0.22
Whitlocks Bay	0.28	0.20	0.32	0.30	0.19	0.10	0.15	0.13	0.34	0.22
Moreau River	0.22	0.35	0.16	0.32	0.16	0.10	0.15	0.16	0.12	0.19
Grand River	0.21	0.20	0.14	0.15	0.18	0.08	0.10	0.10	0.28	0.16
Spring Creek	0.20	0.26	0.26	0.31	0.22	0.16	0.17	0.28	0.08	0.22
Beaver Creek	0.20	0.18	0.23	0.24	0.19	0.18	0.10	0.21	0.29	0.20
Upper Oahe	[a]	[a]	[a]	0.26	0.27	0.13	0.14	0.50	0.24	0.23
Mean	0.24	0.21	0.24	0.27	0.21	0.11	0.16	0.23	0.26	0.21
Cheyenne embayment										
Brush Creek	0.15	0.16	0.20	0.16	0.17	0.09	0.14	0.15	0.16	0.15
Rosseau Creek	0.22	0.14	0.25	0.33	0.15	0.17	0.14	0.15	0.35	0.21
Fishgut Creek	0.40	0.15	0.21	0.26	0.20	0.18	0.17	0.15	0.36	0.23
Minnconjou Creek	0.22	0.15	0.21	0.23	0.17	0.08	0.22	0.05	0.17	0.17
Sansarc Creek	0.24	0.24	0.31	0.13	0.20	0.19	0.23	0.17	0.21	0.22
Upper Cheyenne	0.17	0.21	0.29	0.16	0.25	0.28	0.20	0.20	0.14	0.21
Mean	0.23	0.17	0.25	0.21	0.19	0.16	0.18	0.15	0.23	0.20
Grand mean	0.24	0.20	0.24	0.25	0.20	0.13	0.17	0.20	0.25	0.21

[a] No data.

averaged higher in east bank tributaries (37 per seine haul) than in west bank tributaries (26 per haul) during the post-filling period (in 1971, unusually high catches were made during the first sampling period in the Moreau River). Although catches in the Cheyenne embayment averaged about the same as in other west bank tributaries in 1970-74, catches were declining in the Cheyenne embayment and increasing in most other upstream west bank tributaries. I found no relation between abundance and any environmental variable.

Time-series data for individual localities were too variable to permit meaningful seasonal mortality and growth rate estimates for white bass, and differences among localities were sufficiently great to preclude pooling of the data. Schooling behavior and emigration of larger fish appeared to be the two chief factors responsible for the variability among samples within localities.

The continuing successful reproduction of white bass after the reservoir was filled suggested that the population had reached a relatively stable condition.

Black Bullhead

The dramatic demise of a species, presumably as a result of gross changes in the reservoir environment, is perhaps best demonstrated by the black bullhead. In exploratory seining in 1965 (results not included in the present study), this species accounted for 40% of the YOY catch in the Cheyenne embayment and 23% of that in the rest of the reservoir. The mean catch in 1965 was 104 fish per seine haul in a total of 227 hauls. Two years later, only two black bullheads were taken in the Cheyenne embayment, and none were taken there in 1968-74. Although the species simultaneously disappeared or was taken in only small numbers in most downstream tributaries of the main reservoir, YOY fish continued to be caught in upstream tributaries as filling advanced. None were taken in 1970; although a few specimens were caught in the upper tributaries in 1971 and 1972, none were taken anywhere in 1973 or 1974.

Inasmuch as the nests of this species were usually located near shore in protected embayments,

Table 16. *Mean catch of young-of-the-year white bass per seine haul in various localities of Lake Oahe, 1966-74.*

Locality	1966	1967	1968	1969	1970	1971	1972	1973	1974	Mean
Lake Oahe (excluding Cheyenne embayment)										
Chantier Creek	<1	<1	0	1	3	4	1	<1	4	2
Okobojo Creek	0	2	0	<1	2	1	<1	2	1	1
Willow Creek	<1	2	<1	1	8	19	2	3	21	6
Whitlocks Bay	<1	<1	<1	<1	25	23	22	7	36	13
Moreau River	2	38	<1	11	15	198	29	34	35	40
Grand River	3	6	<1	6	41	14	34	19	30	17
Spring Creek	12	<1	2	1	59	25	46	139	24	34
Beaver Creek	<1	0	6	3	141	10	24	80	79	38
Upper Oahe	a	a	a	0	3	4	4	2	1	2
Mean	2	6	1	2	33	33	18	32	27	17
Cheyenne embayment										
Brush Creek	1	11	<1	2	17	5	4	10	7	6
Rosseau Creek	<1	37	<1	2	12	17	7	4	2	9
Fishgut Creek	13	62	2	8	25	14	12	4	3	16
Minnconjou Creek	1	142	<1	7	14	16	5	3	22	23
Sansarc Creek	6	32	4	119	219	25	58	10	12	54
Upper Cheyenne	6	10	42	371	114	9	25	12	5	66
Mean	5	46	8	85	67	14	19	7	9	28
Grand mean	3	21	4	35	46	26	18	22	19	22

[a] No data.

degradation of the littoral area and lowering of the water during the spawning season (June), and perhaps increased predation, were probably the main factors responsible for the apparent disappearance of this species.

Discussion

Measures of the structure, abundance, and other characteristics of the YOY fish stocks presented here indicate that population instability continued after Lake Oahe reached operational water levels. During 1970-74, for example, 17 species decreased in abundance; 20 (mostly incidental species) showed no trend; and only 4 of the major species increased. During this same period, the number of species also declined; seven species disappeared from the seine catches, and only one (spottail shiner) of the six species introduced in 1970-74 appeared to be reproducing successfully.

Certain species did not reproduce successfully under the reservoir conditions present in 1970-74 and will probably be lost to the fauna. Since continuing low levels of recruitment are especially critical among short-lived species, many of the forage fishes—particularly the minnows—are especially vulnerable. The black bullhead is an example of a short-lived species that nearly or completely disappeared within about 5 years. During 1972-74, the northern pike, once the most sought after and relatively common sport fish in Lake Oahe, became reduced to the point of scarcity. The last successful year class was produced in 1969, and by 1974 these fish were approaching the end of their moderately long life span (about 8 years) in Lake Oahe (June 1971). A total of only 46 YOY northern pike were taken in the samples in 1971-74. Reductions in recruitment, combined with cumulative mortality of advancing age groups, suggest that this species may disappear in this reservoir.

The YOY catch data also indicate that the development of the fish fauna was governed by the two main phases in the history of the reservoir—filling and post filling. During the filling phase the fish stock was dominated by species that required or used areas with inundated littoral vegetation for spawning and nurseries—northern pike, yellow perch, carp, black crappie, white crappie, black bullhead, and certain minnows. During the post-filling phase, most of these species decreased in abundance, and other species with less restrictive reproductive and nursery requirements—goldeye, walleye, sauger, white bass, and freshwater drum—persisted or became more plentiful. The large populations associated with filling are not likely to recur under the fluctuating water regimen of full impoundment, although fortuitous favorable spawning and nursery conditions in the future may result in an occasional strong year class of some species in this group.

These considerations have important implications concerning the fishery potential of Lake Oahe. From its inception in 1964, the commercial fishery was largely supported by accumulated large year classes of several relatively long-lived species produced during the early years of filling (Gabel 1974; Miller and Nelson 1974; Moen 1974). These year classes are now disappearing as a result of cumulative mortality, and the fluctuating and continuing low abundance of YOY commercial fishes as a group after the reservoir had filled cannot be expected to lead to increases in adult stocks. Therefore the commercial fish catch is expected to decline and continue to be low in the foreseeable future.

Although the general abundance of YOY sport fishes as a group also declined after the reservoir filled, annual abundance of three prime species—the walleye, sauger, and white bass—remained relatively stable or increased. Moreover, the sauger and walleye are fairly long-lived species (up to 12 years) in this reservoir, thus further enhancing population stability. Consequently prospects for the sport fishery for these species should continue to be good.

Spawning and early development of most fishes in Lake Oahe are largely confined to the littoral areas of tributary embayments and shallow, upstream portions of the main reservoir. During filling, each new rise in water level augmented the nutrient supply and inundated terrestrial vegetation, which, in turn, created a myriad of suitable spawning habitats and afforded protection, living space, and an abundance of food for the young fish. Because of the slope and structure of the reservoir basin, the extent of this new, artificially created littoral area was many times greater in embayments than in the main reservoir. As a result of these favorable conditions, abundance of the species normally associated with the littoral zone increased sharply.

After the reservoir was filled, prolonged inundation led to the decomposition and eventual disappearance of most of the terrestrial vegetation below about 493 m above msl (maximum water level), and this vegetation has not been replaced. Land and water interactions have led to continuing erosion and restructuring of the shoreline, massive slumping of unconsolidated shoreline formations, and sediment accumulations in the upper reaches of the embayments. Lowered water levels in spring have interrupted spawning (June 1970) and, at other times, left large numbers of eggs stranded on shore above the water line (North Central Reservoir Investigations, unpublished data). Although the total impact of these factors has not been quantitatively assessed, it seems certain that the reduction and generalized degradation of the littoral spawning and nursery habitats were the major causes of the decline in species numbers and abundance after the reservoir filled.

Although it has not been possible to establish a functional relation between production of YOY fish and the two key characterictics of the water regimen—level and discharge—the management implication seems clear and is neither novel nor sophisticated. Provision of natural littoral areas during spawning and throughout the early development of the fish may be all that is required to maintain a healthy, diverse stock within this reservoir. If suitable spawning and nursery habitats are not provided, populations will continue to diminish, and some species may be eliminated.

In view of irrigation developments, the increased demand for hydroelectrical power production, and projected water needs for exploitation of coal deposits in the northern Great Plains, it is unlikely that the water regimen in Lake Oahe will be primarily managed for the maximum production of fish. Nevertheless, whatever allocation scheme or other course of water management may eventually be adopted, it is certain that the fish stocks in this reservoir can be effectively managed only by a water regimen that is in harmony with their biological requirements.

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