STATEMENT ON LAKE ERIE

by

U. S. Bureau of Commercial Fisheries
Department of the Interior
Ann Arbor, Michigan

Presented at
The Lake Erie Enforcement Conference
Cobo Hall
Detroit, Michigan
June 3, 1970

Delivered by Dr. Wilbur L. Hartman, Investigation Chief,
Lower Great Lakes Program.

PREFACE

Although there are many facets to Lake Erie's environmental and pollution problems, it is the aquatic life organisms from the smallest algal cells to the largest fish that have borne the brunt of the changes and are the principal vectors for transmitting the effects of change to man. The Bureau of Commercial Fisheries has been engaged in research on all of these organisms and their environment for almost 50 years. Today it is virtually the only U.S. Federal agency conducting basic research directly related to fish and aquatic life resources of the Great Lakes. Our statement for the June 3, 1970 Lake Erie Enforcement Conference was prepared from this perspective.

INTRODUCTION

Despite the tremendous value of the Great Lakes, America's greatest freshwater resource, a malaise is seriously destroying their worth. Accelerated enrichment, unabated pollution, over-exploitation, and introductions of exotic species, have all been guided--more often misguided--by man. Of all five Great Lakes, Lake Erie stands out as the one most seriously damaged and in the greatest jeopardy at the present time.

For over 100 years Lake Erie has supported a viable commercial fishery. Even today, more than 50 million pounds of fishes are landed annually by U. S. and Canadian fishermen which is comparable to levels dating back to 1915. The U. S. sport fishery has tremendously increased in the last decade. The current value of these combined U. S. fisheries in Lake Erie is nearly $5,000,000. This represents nearly 70 million pounds of fish. The capital investment in gear for these fisheries is hundreds of millions of dollars when the thousands of pleasure boats are considered.

Unfortunately there has been a drastic shift in the commercial and sport harvest from high-value fishes to medium- and low-value fishes. The famous commercial and sport fisheries for lake trout, northern pike, blue pike, and sauger are now a thing of the past. Sturgeon, whitefish, and ciscoes have also nearly reached extinction. Emphasis now is on catching such medium-value fishes as yellow perch and white bass.

Many other changes in the aquatic living resources and environment of Lake Erie have been more directly caused by industrial, municipal, and

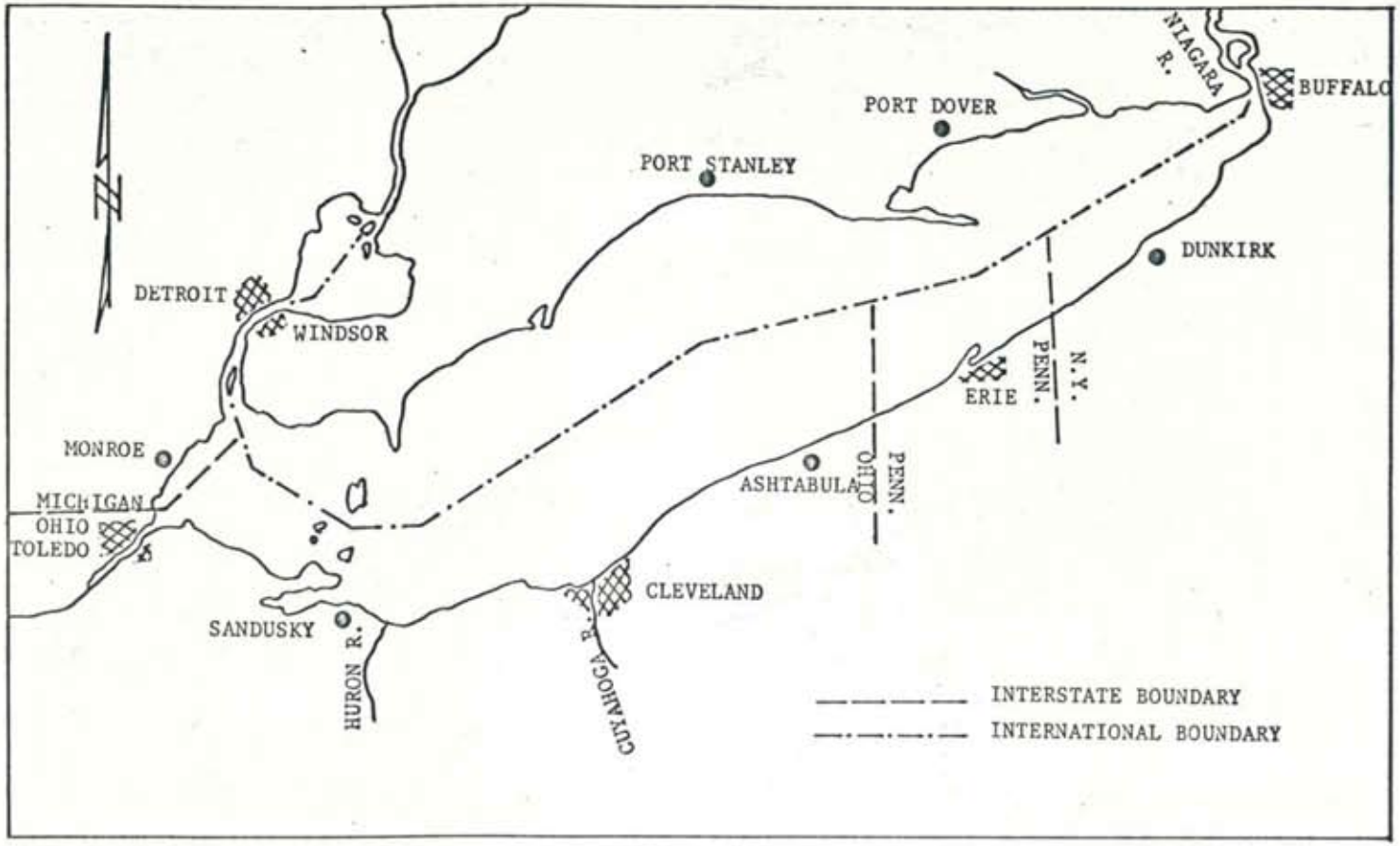
agricultural pollution and enrichment: specifically, massive nuisance and toxic algal blooms of Microcystis and Aphanizomenon, destruction of the valuable mayfly benthos in the western and central basins, a 20-fold increase in plankton which is the diet staple for several nuisance and low-value fishes that have undergone population explosions in the last 15 years, increased levels of such pesticides as DDT and Dieldrin in fish flesh, dangerously high levels of mercury in many fishes, the destruction of spawning areas of some of our most valuable fishes, and disappearance of oxygen from the bottom waters of the central basin during the summer.

Unless major action is taken immediately to remedy these deleterious activities of man--Lake Erie tomorrow will have very few walleyes, an unhealthy perch population, increasingly larger populations of low-value fishes such as carp, goldfish, suckers, freshwater drum (sheepshead), and alewives. Without effective action, Lake Erie tomorrow will have increased fish kills, smothering algal blooms, greater bacterial contamination, and more extensive oxygen depletion.

CHARACTERISTICS OF LAKE ERIE

Morphometry

Lake Erie is fourth in size among the Great Lakes. It is 241 miles long, 57 miles wide at its widest point, and has a surface area of 9,900 square miles (Figure 1). Its drainage area is 32,490 square miles. It is the shallowest of the Great Lakes; over 90 percent of its total area is less than 80 feet in depth.



Lake Erie is about 241 miles long, has a maximum width of 57 miles, and is morphometrically divided into a shallow western basin (average depth 24 feet), a deeper and flat-bottomed large central basin (average depth 78 feet), and a very deep eastern basin (maximum depth 210 feet). About 13 million people live around Lake Erie and depend in many ways on its fishery and aquatic resources.

FIGURE 1

The lake is about evenly divided between the United States and Canada; four states (Michigan, Ohio, Pennsylvania, and New York) share jurisdiction with the province of Ontario. The 13 million people that live around Lake Erie depend in many ways on its fishery and aquatic resources. This population is expected to double by the year 2020.

Lake Erie is geologically divided into three basins--western, central, and eastern. The western basin extends east to a line connecting the tip of Point Pelee and the tip of Cedar Point. It contains numerous shoals and islands and has an average depth of less than 25 feet. This basin, representing 12 percent of the lake area, is often considered the fish spawning and nursery grounds for the entire lake, and it is the site of very extensive boating, fishing, and other recreational activities. Because of its shallow depth, however, it has been more vulnerable to change caused by man's activities. The large central basin, making up 64 percent of the lake area, extends east to a line connecting the base of Long Point and the base of Presque Isle. It is somewhat deeper than the western basin and has a huge flat plain between 60 and 78 feet deep. The eastern basin, the deepest of the three, has a maximum depth of 210 feet, and represents 24 percent of the lake area.

Lake Erie receives the waters of the Detroit River at an average flow of 177,600 cfs. It discharges through the Niagara River, which can vary in flow from 162,000 to 330,000 cfs in a week but averages 195,800 cfs. Aside from the Detroit River, the lake drainage contributes an average of only 18,200 cfs.

Thermal Conditions

The waters of Lake Erie undergo considerable thermal change each season. During severe winters 95 percent of the surface may be ice covered. Gradual warming begins in March or April and continues through the spring. Warming progresses somewhat faster along the shore and around islands, and may be 4 to 6°F higher in these areas than in the open lake. Summer surface temperatures exceed 75°F every year.

The western basin is usually homothermous but prolonged periods of hot, calm weather can cause temporary thermal stratification during the summer period. Thermal stratification in the central basin is more stable. Waters deeper than 40 feet are usually well stratified by mid-July every year although transitory stratification may occur a month earlier. This stratification usually breaks down in early September. Stratification in the deeper areas of the eastern basin starts in July and may continue into October.

At the present time Lake Erie averages about 2°F warmer than during the early 1920's. The greatest increase in mean annual temperatures (air and water) occurred between 1925 and 1930.

Currents

The surface currents are greatly influenced by wind action. Their general west to east direction is caused by the predominantly westerly winds along the axis of the lake. The Detroit River flow usually does not spread out over the entire western basin. Entering the lake, it flows toward the north shore and enters the central basin between Pelee Point and Pelee Island.

Polluted waters from the Maumee and Raisin Rivers and the west side of the Detroit River usually flow through the southern part of the western basin and between Pelee and Kelleys Islands and Kelleys Island and Marblehead Peninsula into the central basin. The usual flow pattern in the central basin is dominated by a west to east current along the Ohio shore. Little information is available on currents in the eastern basin, but these currents are probably dominated by the influence of the Niagara River.

Water Chemistry

Lake Erie waters are bicarbonate (average total alkalinity, as $CaCO_3$, 95 ppm). The average pH is 8.3 and the specific conductance is 242 umhos at 18°C. Sulfate concentrations (24.0 ppm) are virtually the same as chlorides (23.4 ppm). Calcium, magnesium, sodium, and potassium concentrations are 38.3, 8.9, 9.6, and 1.4 ppm respectively. In general, the concentrations of the major cations and anions increase from west to east. Silica concentrations average 1.5 ppm although at times only traces may be found due to the high demand of diatom algae.

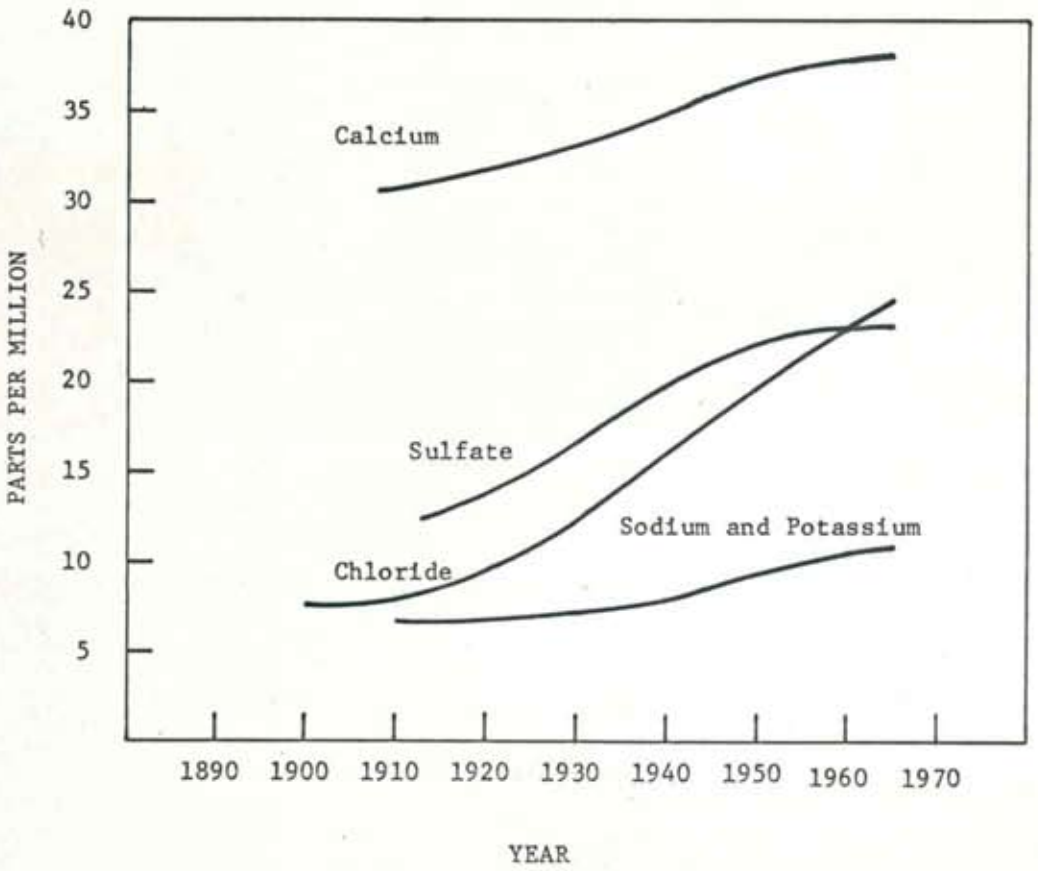
Man is presently responsible for dumping about 40 billion gallons of untreated municipal sewage and many billion gallons more of partially treated sewage into the lake each year. An estimated 137,000 pounds of phosphorous enter Lake Erie each day, the majority (72%) from municipal waters. The consequence of long-term additions to Lake Erie of such a magnitude has been substantial increases in nutrient levels.

Total dissolved solids all increased significantly (50 ppm) in Lake Erie during the past 50 years. The rate of change of the major ions during recent

years has been: sodium-plus-potassium 0.16 ppm/yr, chloride 0.35 ppm/yr, sulfate 0.19 ppm/yr, and calcium 0.13 ppm/yr (Figure 2). Some of the individual dramatic changes during that time have been: sodium and potassium increased from 6 ppm in 1920 to 13 ppm in 1967, calcium from 30 to 39 ppm, sulfate from 12 to 23 ppm, chloride from 8 to 23 ppm, nitrates from 0.1 to 0.8 ppm, and phosphorous from 14 to 36 ppm. These increases are not such as to in-themselves directly cause fish mortalities. Yet they reflect the changes man has wrought, and have serious indirect effects as seen below.

The most recent data on water chemistry of Lake Erie indicates that there has been no slowdown in the increase rates.

Besides such enriching and fertilizing agents as phosphates and nitrates, other chemicals that are clearly toxic and harmful to aquatic life are discharged into Lake Erie in industrial wastes. The levels of DDT and the other pesticides have been found at moderate levels in Lake Erie fishes. Oil spillages from commercial shipping are frequent. Phenols, cyanides, acids, and exotic organic compounds are among the many outright pollutants. Increased siltation is another physical factor with potentially great impact on the fishery resources, especially for those fishes such as whitefish and walleye that broadcast their eggs along the lake bottom. About 33,000,000 tons of sediment reach Lake Erie each year, with about half coming from lakeshore erosion. Use of the open lake as a dumping grounds for dredgings from channel excavations still remains a critical problem. The smothering effect of sedimentation on fish eggs and other bottom associated organisms has



Over the past 50 years a considerable increase in the chemical content of Lake Erie water has taken place. Total dissolved solids have risen from 140 to 185 parts per million. Increases in certain specific ions are shown here.

FIGURE 2

unquestionably been detrimental and may be a major factor in the decline of some of our valuable fish stocks.

Plankton (floating plants and animals)

The combination of generally warm water temperatures, slightly increasing over the years, and tremendous increases in nutrient levels has resulted in dramatic increases in organic production, particularly at the algal level. There has been a 20-fold increase in the abundance of plankton algae over the past 50 years. The growths of filamentous algae such as Cladophora have dramatically increased. This combination has created a real nuisance problem along the shores of Lake Erie costing the economy millions of tax dollars via devalued properties.

During the past 26 years a consistent increase had been noted in the quantity of phytoplankton at the Cleveland water intake. Periods of peak abundance now last longer than in the past. Asterionella, the dominant diatom in the spring in earlier years has been replaced by Melosira. Synedra dominated the fall pulse in the 1920's, but it has been replaced by Melosira. More recently, Fragilaria and the blue-green alga, Anabaena, have become important in the composition of the summer phytoplankton.

Adverse changes have occurred in the composition of other plankton algae. The noxious blue-green algaes, Microcystis and Aphanizomenon, have recently become dominant summer species. In 1969, the late summer blooms of these noxious forms in the western basin were unusually and unbelievably dense and widespread.

Oxygen Levels

Organic production has a direct impact on the oxygen regime in Lake Erie. The fallout of dead algae sinking through the water column to the lake bottom creates a tremendous biological-oxygen-demand (BOD) during decomposition. The greater the organic production, the higher will be this BOD. This phenomenon plus the introduction of reduced, oxygen-demanding organic and inorganic materials into Lake Erie have seriously degraded the oxygen levels.

In general, during thermal stratification the sediments and bottom waters become isolated from the overlying surface waters. Oxygen lost in the bottom waters cannot be adequately replenished until stratification breaks down and a mixing with the oxygen-charged surface waters takes place.

Dissolved-oxygen content in the surface waters may vary considerably. Diurnal changes can be significant. During temporary stratification of the western basin, dissolved oxygen in bottom waters is seriously depleted, sometimes to levels far below those which can support fish life. Synoptic surveys conducted in 1959 and 1960 in the central basin revealed that less than 1 ppm dissolved oxygen was found to be in bottom water over between 641 and 1,390 square miles of Lake Erie. Much more extensive oxygen depletion has been observed in the bottom waters of the central basin every year since 1959.

Critically low dissolved oxygen has not been reported to date in the eastern basin, although in the "deep hole", concentrations as low as 5.5 ppm (47 percent saturation) have been reported, indicating that the depletion

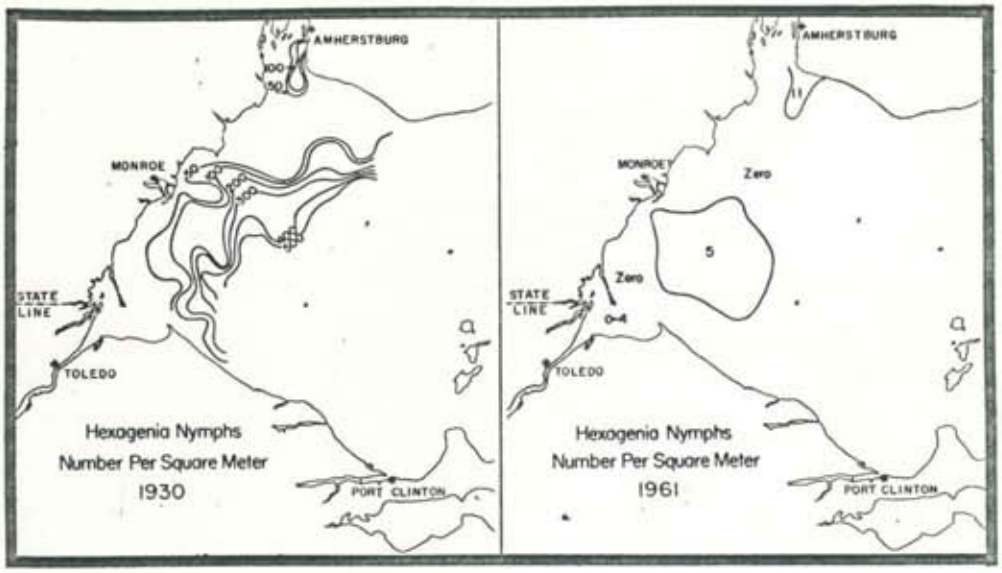
process has already started. The latest data available confirm these earlier findings. Oxygen deficits are at least as serious as they were 10 years ago.

The problem of low oxygen levels in Lake Erie is doubly complex. Although organic production has greatly increased, the biological-oxygen-demand even in the lower waters does not appear to be sufficient to fully deplete the dissolved oxygen to the enormous extent we have seen. However, the sediments have a high oxygen demand which is both biological and chemical. Recent laboratory tests showed that a small amount of western basin sediment (5 gm) can remove almost all the dissolved oxygen in a 250 ml water sample in less than 5 minutes.

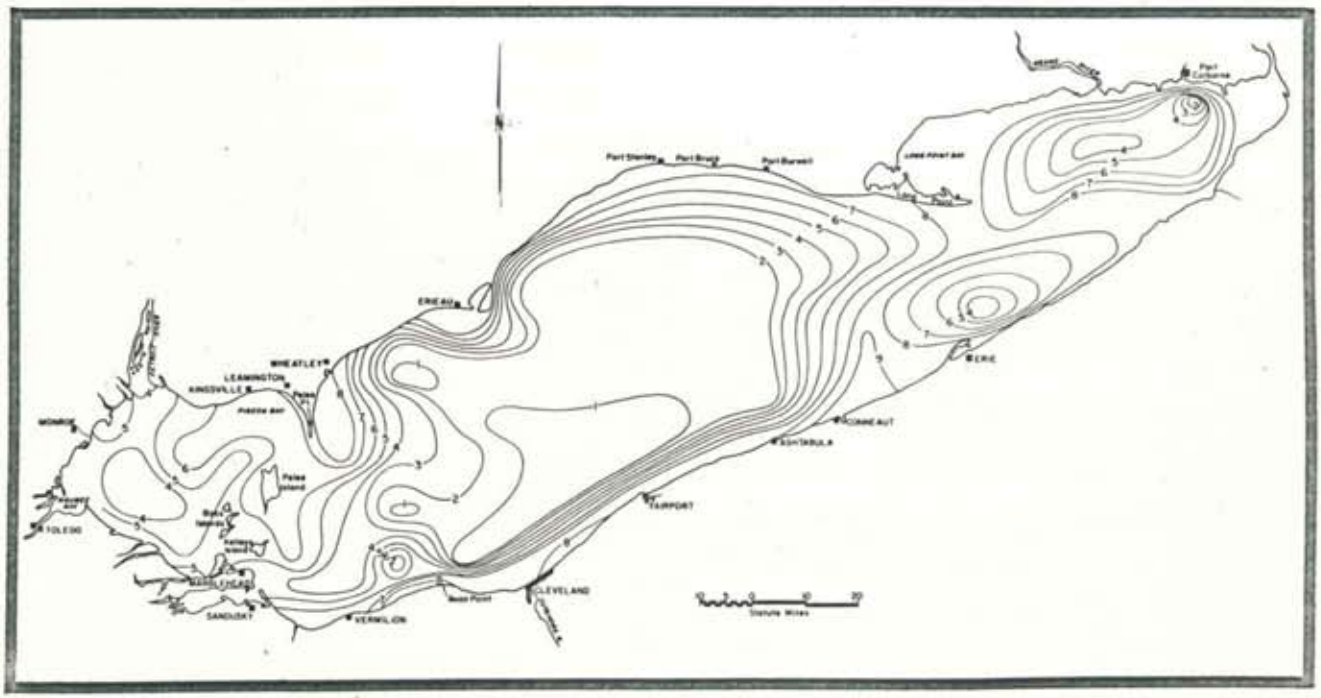
The fallout of plankton cells is one of the two primary sources of oxygen demand. Solution of this problem merely requires that the input of nutrients be reduced. From the fishery resources standpoint, every encouragement should be given to achieving this removal which is technically possible. But, oxygen-demanding materials have accumulated in the sediments for many years, and the problem is obviously more complex. It will be correspondingly more difficult to correct.

Bottom Organisms

Degradation of the oxygen regime has dramatically altered the populations of bottom organisms so essential in the diet of certain valuable fish. Since 1953, this phenomenon has reduced the abundance of mayfly larvae (Hexagenia) from 400 to 10 individuals per square meter (Figure 3), and in places, entirely eliminated them; increased the numbers and distribution of sludge worms (oligochaetes) many-fold, reduced caddisfly larvae almost to the vanishing



In 1930, the general abundance of mayfly nymphs in the western basin of Lake Erie was between 50 and 500 per square meter of bottom. Low oxygen caused by polluted sediments virtually destroyed this valuable fish food resource by 1961.



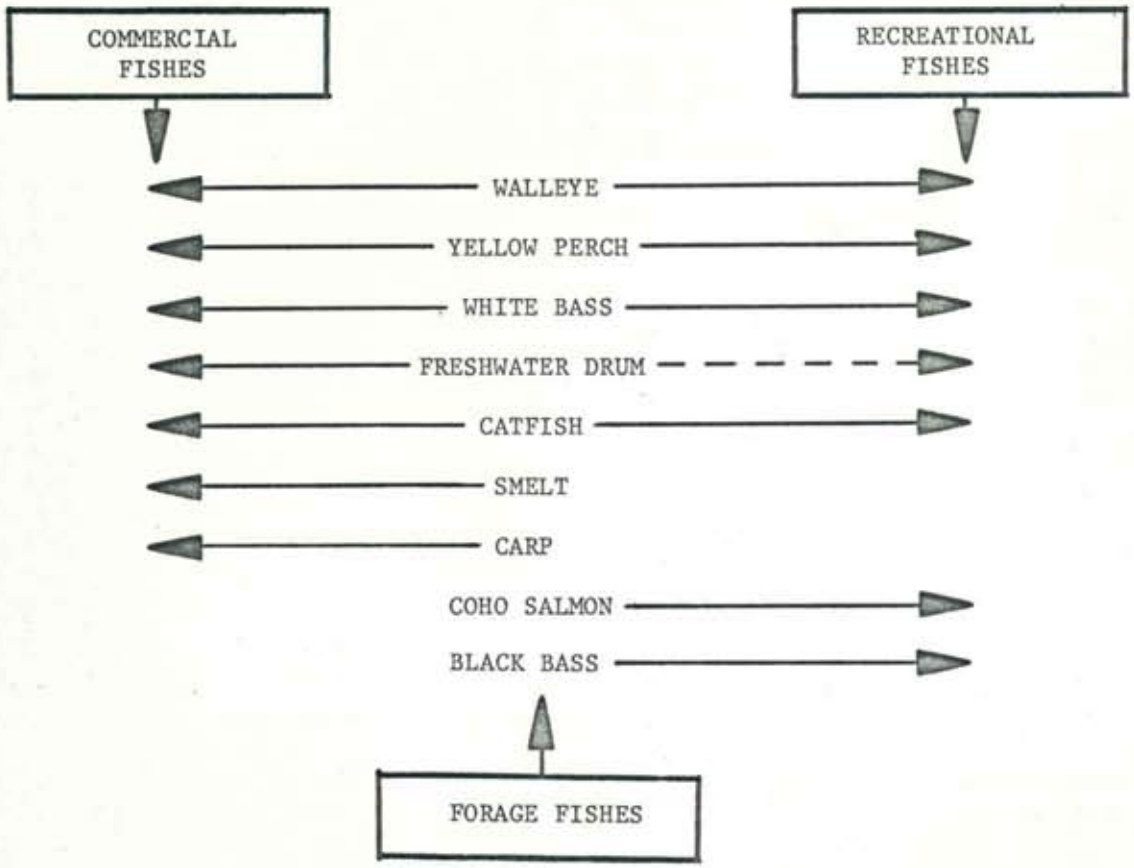
Up until 20 years ago there was enough dissolved oxygen in the bottom waters of the central basin of Lake Erie all summer long to sustain insect and fish life. A synoptic survey in the summer of 1960 showed oxygen levels lower than 2 parts per million over vast areas of the bottom.

FIGURE 3

point, favored large increases in the populations of low oxygen-tolerant forms of midges; reduced the nontolerant midge forms; caused an increase in some species of fingernail clams; and generally reduced the numbers of all pollution-sensitive bottom organisms. The original community of organisms was an essential part of the food chain which contributed vital components to the survival and normal growth of the various species of fish that were desirable in the fishery. Changes in this community of food organisms have adversely affected the more desirable fish populations and, in turn, the economics of the fishing industry. To the Bureau of Commercial Fisheries, this rather narrow stratum in the bottom of Lake Erie, with its associated low dissolved oxygen content, is so polluted that the status of the entire lake as a useful producer of fishery products is uncertain.

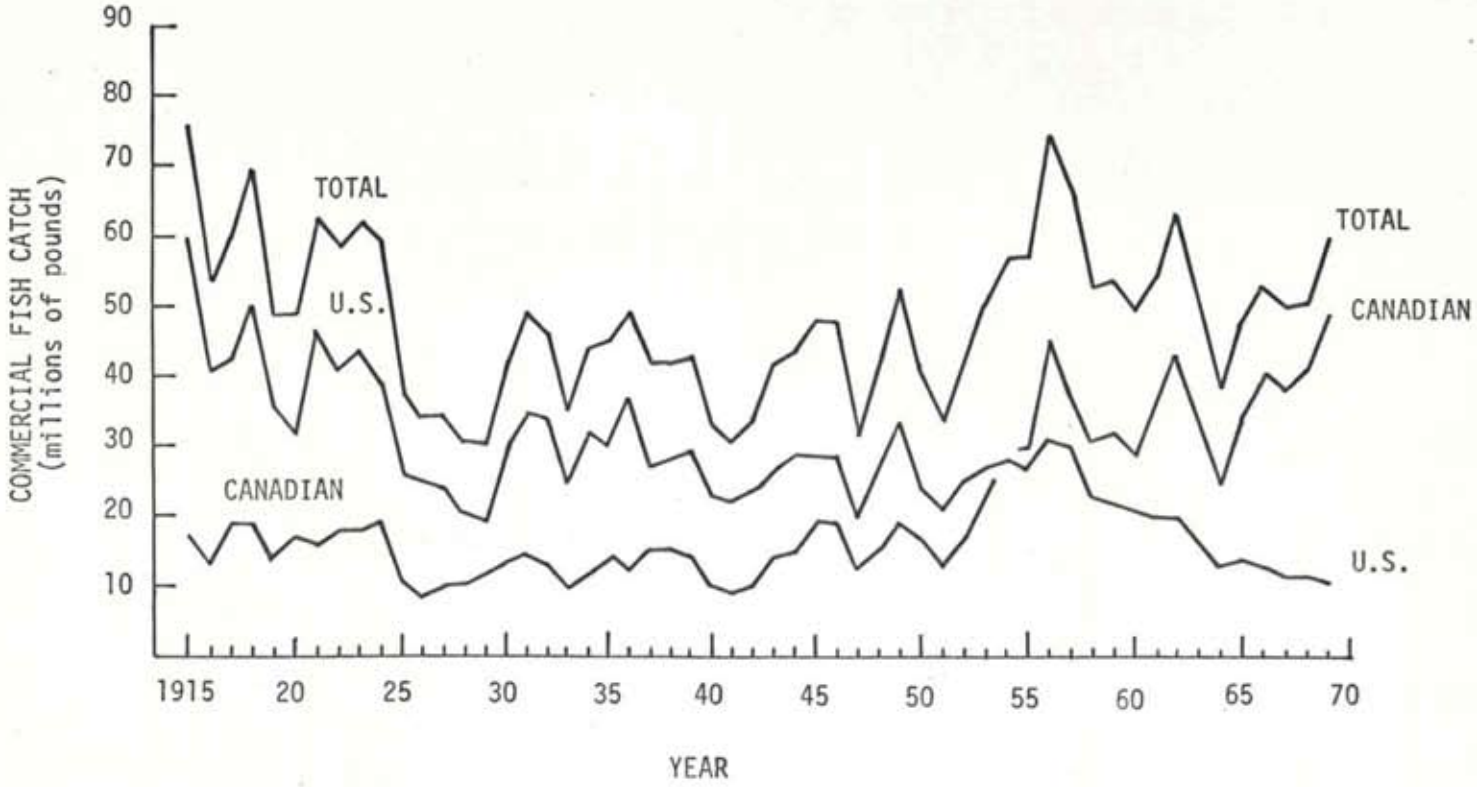
LAKE ERIE FISHERY RESOURCES

Lake Erie has consistently produced the greatest variety of commercial species of fishes of any of the Great Lakes (Figure 4). No less than nineteen species have been significant in the landings at one time or another in the more than 150 years since fishing began. Records of fish production from Lake Erie were collected as early as 1867 in Ontario and 1885 in the United States. The combined United States and Canadian catch has averaged 50 million pounds per year over the past 55 years (Figure 5). It has often equaled the combined production of the remaining four Great Lakes, and has always accounted for at least a third of the total Great Lakes production. Presumably the shallowness of Lake Erie, its warmer water temperatures, and the much higher level of fertility has been responsible for its greater productivity.



The fish resource of Lake Erie is a complex biological system involving predator fish--walleye--, forage fish--emerald shiners--, competitor fish--yellow perch and freshwater drum--, parasitic fish--sea lamprey--, and fish that seriously disturb the environment--carp--.

FIGURE 4



The commercial catch of Lake Erie fish has averaged 50 million pounds since 1915. Before 1954, U.S. fishermen landed most of the catch. Now Canadian fishermen reap the harvest and U.S. landings are at an all time low.

FIGURE 5

Despite continued high productivity, a number of valuable species have virtually disappeared from the commercial landings. Early records suggest a fairly stable production until 1913. This early fishery was based on sturgeon, cisco, whitefish, and northern pike. By the 1920's the populations of sturgeon and northern pike were virtually depleted and the cisco and whitefish bore the brunt of the fishery. Production was fairly stable between 1930 and 1950, although by 1950 the cisco were in a rapid and unexplained decline. By 1955 they were commercially extinct.

Beginning in the early 1950's a period of great instability in the Lake Erie fish population began. Walleyes and yellow perch began explosive increases. This change from the cold-water forms to the warm-water species reflected environmental changes in the lake. Canadian fish production rose in the decade 1950-60 because of increased landings of walleyes and yellow perch due to increased effort and such technological advances as nylon gill nets and ship-to-ship radio transceivers. During this time, however, United States catches were substantially reduced as three "high-value" species--the whitefish, blue pike, and sauger--declined drastically in abundance. Whitefish landings abruptly decreased in 1955 and have become virtually nil since then. By 1963, for example, less than 1,000 pounds per year were being landed. Blue pike production dropped from over 10 million pounds in 1957 to less than 2 million in 1958. The population then completely collapsed, and the blue pike is now on the national endangered species list. Saugers began to decline in 1945 and are now almost extinct in Lake Erie.

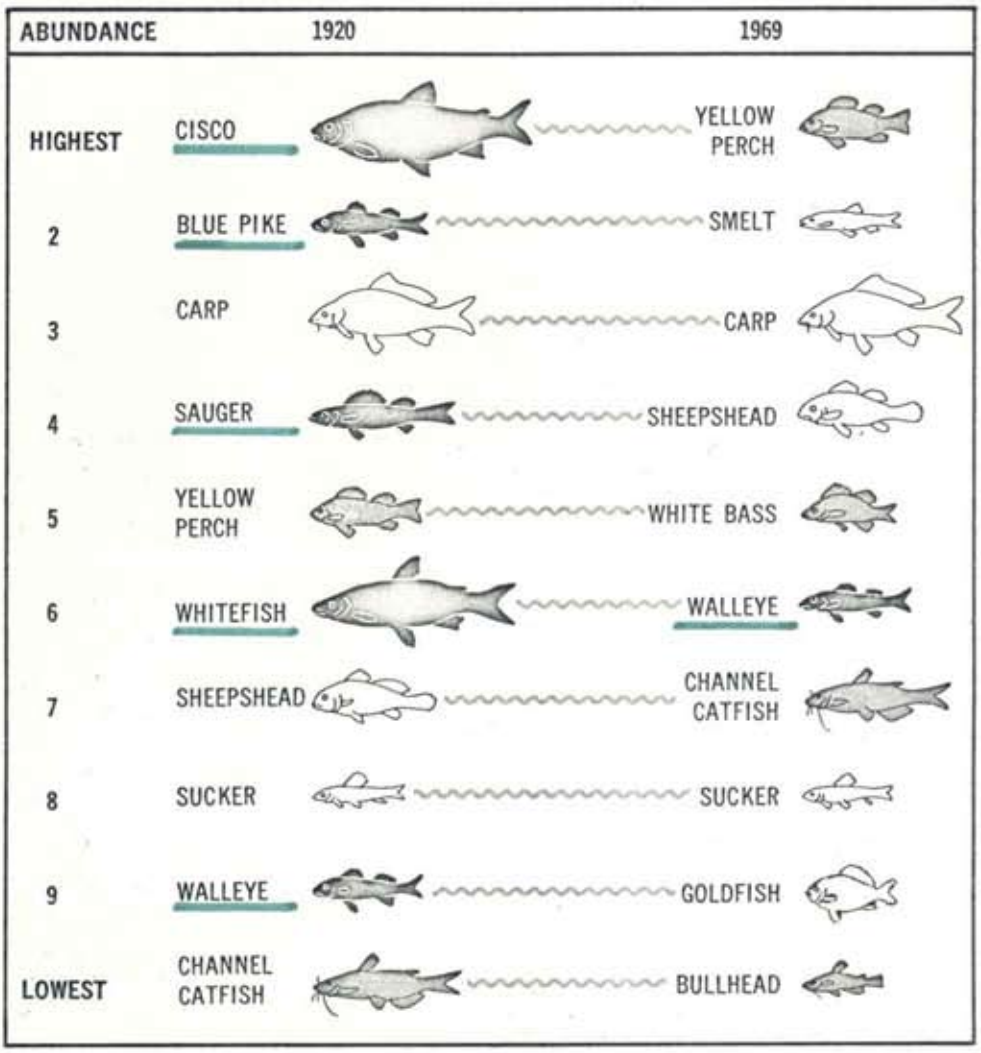
In summary, we have seen the commercial extinction of six species of fish that were historically of great importance to the Lake Erie fishery: sturgeon, northern pike, cisco, whitefish, blue pike, and sauger.

Over the last 55 years the composition of the commercial catch has dramatically shifted to medium-value and low-value fishes (Figure 6). Between 1920 and 1940, five of these high-value fishes dominated the catch. By 1960 the only high-value fish represented in the commercial catch was the walleye. In 1920, only three low-value fishes, carp, freshwater drum, and suckers, were minor components of the catch. Today these three low-value fishes together with smelt and goldfish dominate the catch. Table 1 summarizes the Lake Erie commercial fish landings for 1969.

Dramatic changes in the aquatic environment in Lake Erie over the past 30 years have paralleled the disappearance of some high-value fishes, the explosive appearance of low-value fishes, and wide fluctuations in year class strength of such fishes as walleye, yellow perch, and white bass.

Although the pounds of fish landed have not decreased in the last 50 years, the U. S. share has declined steadily. The Canadian fishery accounted for less than 25 percent of the catch in the 1920's, and barely 40 percent in the 1930's. Now they produce more than 80 percent of the commercial catch.

Another area of man's influence on the fishery resources of Lake Erie is in the introduction of exotic fishes. Some introductions have been inadvertent, such as that of the sea lamprey which entered via the Welland Canal. The impact of the sea lamprey on the fishery resources of Lake Erie can never be



In 1920, the commercial catch from Lake Erie was dominated by five high-value fishes--cisco, blue pike, sauger, whitefish, and walleye. Now only the walleye is left and it is in serious decline. The pressures of rapid environmental degradation and heavy exploitation have left us with a fishery resource composed only of medium and low-value fishes.

FIGURE 6

COMMERCIAL LANDINGS IN LAKE ERIE, 1969* (IN POUNDS)

Species **	Mich.	Ohio	Pa.	N. Y.	U. S.	Canada	Total
High value							
Walleye	47,161	139,302	4,793	91,304	282,560	192,591	475,151
Whitefish/Cisco	3	746	147	8	904	1,417	2,321
Others	2		9	29	40	1,549	1,589
Medium value							
Yellow perch	111,815	2,660,536	479,446	112,709	3,364,506	29,801,833	33,166,339
White bass	57,213	1,155,867	2,563	3,043	1,218,686	874,840	2,093,526
Channel catfish	21,144	713,465	744	673	736,026	101,513	837,539
Others				1,003	1,003	98,840	99,843
Low value							
Freshwater drum	39,885	1,992,877	2,992	24,532	2,060,286	339,377	2,399,663
Bullhead	472	35,030	32	2	35,536	19,448	54,984
Smelt		464	1,399	310	2,173	15,075,522	15,077,695
Buffalo/Quillback	9,151	46,544			55,695		55,695
Carp	431,785	2,586,849	788	351	3,019,773	189,531	3,209,304
Goldfish/Hybrids		98,912			98,912		98,912
Suckers (redhorse & white)	25,374	110,200	3,876	33,272	172,722	16,317	189,039
Mixed scrap						1,291,769	1,291,769
Others		77		625	702	21,449	22,151
Total all species	744,005	9,540,869	496,789	267,861	11,049,524	48,025,996	59,075,520

*Preliminary figures only; not for publication.
**Others: High value - Blue pike, northern pike, sturgeon, saugers, etc.
Med. value - Rock bass, crappies, sunfishes, etc.
Low value - Mooneye, burbot, eels, bowfin, etc.

TABLE 1

measured, but undoubtedly was less severe than in the upper Great Lakes. Other species either intentionally or indiscriminately planted in Lake Erie waters over the years include carp, buffalofish, goldfish, eel, smelt, alewife, and salmon. Just what effect these releases have had on existing aquatic resources are unknown, but they did supply some species capable of proliferating in a degraded environment.

Current Status

The last "high-value" species, the walleye, is in sharp decline. The Lake Erie fishery now depends on such "medium-value" species as yellow perch, white bass, and channel catfish, and such "low-value" species as carp, goldfish, smelt, and freshwater drum. A few brief statements follow for the major commercial and sport fishes in Lake Erie today.

Walleye.--The walleyes have long provided one of the primary commercial and sport fisheries in Lake Erie. In the mid-1930's, commercial landings began to increase and the trend of production was upward, slowly at first, then rising rapidly in the 1950's to an unprecedented catch of 15.5 million pounds in 1956. Since that date the production has dropped abruptly to pre-1935 levels.

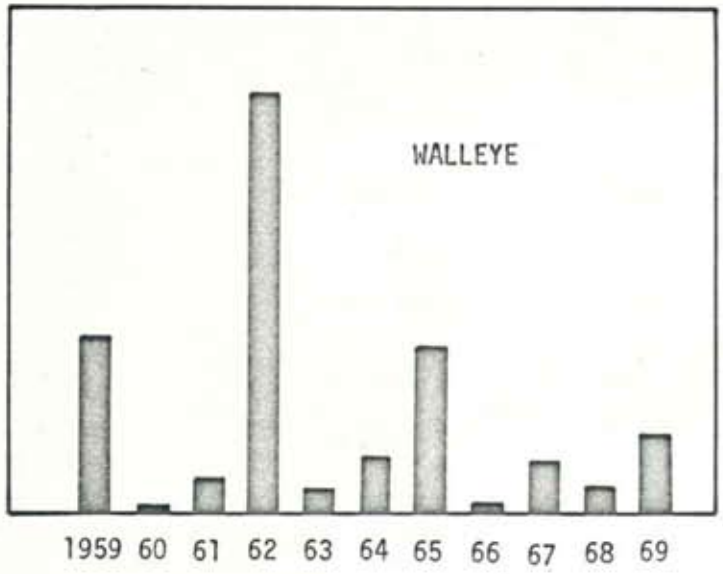
In the 1940's and early 1950's the commercial harvest was composed of significant numbers of six or more year classes. Since 1955, fishing for the few relatively successful year classes of walleye has become intensive. It has been determined that strong year classes of walleye were produced in nearly all years from 1943 to 1954. Comparatively weak year classes were

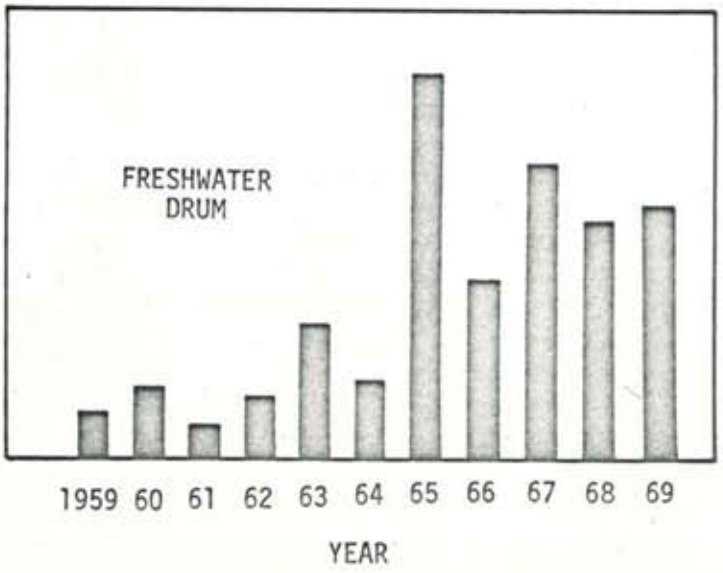
produced in 1955-58. Within the past decade, good fry hatches have been produced in only 3 years--1959, 1962, and 1965 (Figure 7). Exploitation has been concentrated on only a few year classes and catches have sharply declined. For example, 1969 landings were the lowest recorded for Lake Erie dating back to the 1913 era (the period when complete statistics were first available).

The recent downward trend in walleye production has taken place entirely in the western and central basins of the lake. Catches at eastern basin ports have increased. The eastern basin fish are an independent self-sustaining sub-population. It is not fully clear what has brought on this long period of generally unsuccessful walleye hatches in the western basin. It seems reasonable, however, to assume that environmental degradation is a causative factor, perhaps intensified by heavy utilization.

Yellow perch.--Long a significant element in the fish population of Lake Erie, the yellow perch has contributed consistently to the commercial landings. Until the 1950's, the yellow perch was considered of secondary importance. However, in recent years producers have come to depend increasingly upon the yellow perch.

Relatively strong year classes of perch are known to have been produced in the mid-1950's, culminating in an exceptionally good hatch in 1959. Unfortunately, the spawning success and survival of young perch has undergone considerable fluctuation during the past decade. Good hatches did occur in 1962 and 1965. On the other hand, all other year classes since 1960 have been





Here are shown the relative numbers of young-of-the-year walleye and freshwater drum (sheepshead) sampled with bottom trawls in Western Lake Erie at permanent index stations, 1959-69. The walleye, the last high value fish in Lake Erie, is in drastic decline with good hatches only every third or fourth year. Freshwater drum on the other hand are rapidly increasing in numbers and constitute a huge underutilized resource.

FIGURE 7

comparatively weak. The lack of a relatively good year class being produced within the past 3 years is discouraging. These poor hatches and low survivals from a stock more than adequate to replenish the population points toward "deteriorating environmental conditions" as a contributing factor.

The unusually high production of yellow perch during the past several years tends to mask the pessimistic outlook for this species. The commercial production has been extremely high in comparison to that of former years. In fact, the 1969 production of 33 million pounds is the highest in the history of the yellow perch fishery. However, a marked decline in production is forecast for 1970 and will continue a downward trend thereafter until other successful year classes are produced.

The anticipated decline of yellow perch will have a tremendous economic impact on both the commercial and sport fisheries of Lake Erie. Biologists associated with the sport fishery have estimated the annual harvest of yellow perch in Ohio waters in recent years to be equal to or greater than that of the commercial fishery. Although statistics are not available for the other state sectors, the sport fishery is steadily increasing in all areas and its significance is becoming fully recognized.

Smelt.--The smelt in Lake Erie apparently owe their origin to fish that escaped from an inland lake into Lake Michigan. First reported in Lake Erie in 1932, the smelt was not commercially important until the early 1950's. Since 1959, Canadian fishermen have harvested over 10 million pounds annually mostly with trawls. During the past year, over 15 million pounds of smelt were landed, second only to yellow perch in production.

Smelt frequent the deeper waters of the central and eastern basins and migrate into Canadian waters of the western basin only in winter and early spring. A variable but generally good hatch and survival of the species has occurred in all recent years.

Freshwater drum.--The freshwater drum (sheepshead) has always been plentiful in Lake Erie, but in the last 10 years the strength of year classes has substantially increased. Commercial landings have averaged over 3 million pounds annually since the early 1900's. However, the catches fail to reflect abundance since freshwater drum have been harvested only in quantities that would meet a restricted demand. Recently, some increase in landings have been made to meet a demand for animal food. Some progress is also being made to market this species for human consumption.

The importance of this species cannot be over-stressed due to their increasing abundance and potential as a commercial fish. The freshwater drum probably constitutes the largest underexploited fish population in Lake Erie today. Greater catches might benefit the stocks of other fishes in the lake that are considered more desirable.

White bass.--Since 1952 (when complete production figures were first available for this species) total landings have ranged from 2 to 9 million pounds annually. In the earlier years of the Lake Erie fishery, the white bass was considered an "incidental" species and was not actively sought by the fisherman. Today the white bass, along with yellow perch, are the most "sought after" species by the commercial and sport fishery alike.

Channel catfish.--The channel catfish has supported a relatively stable fishery for the past 15 years with annual landings ranging from 1.2 to 2.0 million pounds. A good market for live catfish is always available and the demand far exceeds the supply. There is evidence that the population may now be slightly overexploited. The landings in 1969, for example, were less than 838,000 pounds. Channel catfish are rather slow growing, requiring between 6 and 7 years to attain the legal minimum commercial size of 14 inches (Ohio and Michigan). This species is also highly sought by sportsmen, particularly during the late spring period when the catfish congregate in shoal areas.

Carp, goldfish, suckers, and bullheads.--These species are frequently classified as "coarse" or "noxious" fishes. It is unlikely that commercial production in recent years has ever fully exploited the available stocks of any of these rather abundant species. Collectively, they have significant value as a potential industrial resource because of their high abundance and flourishing recruitment.

Forage species.--There are two species, while not presently of commercial significance in Lake Erie, that should be mentioned. These are the alewife and gizzard shad. Although both fluctuate greatly in abundance, it is believed that these among other low-value fishes have considerable potential in the industrial market.

The alewife, first recorded in Lake Erie in 1931, became established at a modest level of density. Gizzard shad are indigenous to Lake Erie and have exhibited drastic population fluctuations from year to year. These presently non-commercial species represent a huge biomass currently tied up in non-productive uses.

Coho salmon.--The recent stocking of coho salmon in Lake Erie has been purposeful and interest in this sport fish is rapidly expanding. There are no indications yet just what effect this introduction will have on the various fishery resources. If it is deleterious, at least this experiment can be terminated by discontinuing the stocking program. This introduction, however, can prove beneficial not only as an attraction to the sportsman's eye, but also as a terminal predator that is needed.

Collectively, all the aforementioned species provide a valuable resource that cannot be overlooked nor neglected. The current value of the U. S. landings alone of commercial, bait, and sport fish in Lake Erie is estimated at nearly $5,000,000. This represents nearly 70 million pounds of fish. The capital investment for gear for these fisheries is hundreds of millions of dollars when the thousands of pleasure boats are considered. Shore property values are worth billions of dollars. All these values are, however, declining because of the changing environment.

FISHERY RESOURCES - SPECIAL ENVIRONMENTAL PROBLEMS

Thermal Effluents

The number of nuclear power plants on Lake Erie is proliferating. Considerable concern on our Bureau's part deals with potential deleterious effects of heated discharges on the fishery and associated aquatic resources for the following reasons:

First, a uniform increase of temperature in Lake Erie by any mechanism will increase the metabolic activities of organisms and result in ever-increasing

levels of organic production. This, in turn, would increase the rates of BOD and the degradation of the oxygen regime. We have already mentioned the wholesale destruction of bottom organisms over hundreds of square miles of Lake Erie.

Second, the highly valuable walleye in western Lake Erie have discrete spawning sites on shallow reefs. The spawning areas are shallow, 2 to 10 feet in depth, and the spawning and incubation physiologies of this species are such that heated discharges would severely disrupt spawning activities and could destroy incubating eggs.

Third, unpublished data from the Bureau of Commercial Fisheries Sandusky Fishery Laboratory show that an increase in incubation temperatures, for example from 10 to 15°C, will decrease the incubation period of walleyes from 20 days down to 10 days. It is quite possible that unnatural heating in areas where eggs are incubating would result in unnaturally earlier hatching when the environment could be unsuitable to their survival. German scientists have demonstrated this phenomenon for the reduction of whitefish in Lake Constance.

Thus, for these and other reasons we are most apprehensive about the discharge of any heated effluents into Lake Erie, and especially the western basin. From the fisheries standpoint, there should therefore be no significant additional thermal inputs into Lake Erie, and especially the western basin, until the consequences have been assessed by adequate research. In the meantime, the Bureau of Commercial Fisheries will continue to conduct basic research related to this problem.

Walleye Spawning Reefs

Of great concern now is the instability of year class success and sharp decline for western basin populations of both walleye and yellow perch, the two most important species for commercial and sport fishermen. Not since 1965 have either species had a real successful spawning, despite a large spawning population available in 1968 and 1969 from the 1965 year class.

For years many people have felt that the decline and disappearance of so many valuable species of fishes from Lake Erie were due to over-exploitation. Actually, the combination of over-exploitation, environmental degradation, and the introduction (accidental or otherwise) of exotic fishes such as sea lamprey, carp, and goldfish have all contributed together in some measure over the years to changes in the abundance of our valuable species. Yet the decline of the walleye and yellow perch today must be attributed in larger part to deterioration of the environment. In this sense, the populations are in double jeopardy.

Research on the walleye spawning season in 1969 tend to support our contentions that the degraded environment is a primary factor influencing the levels of abundance of certain fish populations in Lake Erie.

Underwater observations for 2 weeks during the first half of the spawning season showed a rapid buildup of algae growth (Cladophora) all over the rubble on the spawning reef. Although eggs were abundant in the rubble and laying on the algae mat, they were vulnerable to the effects of sedimentation in the rubble, and predation while exposed on the algae mat. This luxurious algae mat of Cladophora is another consequence of eutrophication. Then, following

a severe "Northeaster" storm, the spawning reef was dramatically changed. This occurred half-way through the spawning season. The rubble, including boulders 2 feet in diameter, had been overturned and disarranged. The rubble was scoured bare of algae. The reef was cleared of sediment. A seemingly ideal spawning environment remained for the second half of the spawning season. Water temperatures were rapidly rising, shortening the length of the incubation period and lessening exposure to further sedimentation. The resultant year class was unexpectedly good, though not nearly the magnitude of the one in 1965, despite a relatively small spawning population.

Normally, the rate of sedimentation on the walleye reefs is quite high. About 15,000,000 tons of sediment are carried into Lake Erie each year and as much more is eroded off the shoreline. It builds up over time and degrades the environment in the rubble where the eggs lie on the bottom. Suffocation through oxygen depletion in the interstitial waters on the bottom can be a real problem. Although our observations in 1969 cannot be supported with a great deal of data, they have suggested to us that sedimentation on the walleye reefs may be already reducing population levels of walleye, and may have been doing so for years. The reduction of sediment discharge into Lake Erie is undoubtedly necessary for the preservation of such bottom egg-laying fishes as walleye, white bass, smelt, and yellow perch to some extent.

Introduction of Coho Salmon

Although several species of salmon fry have been repeatedly stocked in Lake Erie since 1870 without triumph, the experimental introductions of

yearling coho salmon in recent times appear to be gaining steady momentum with resounding success. The newly coordinated coho program officially began in the spring of 1968 with the release of 121,000 salmon in the tributary waters of Ohio, Pennsylvania, and New York. Plantings were continued in 1969 with the spring release of 230,000 yearlings and again this spring with another 545,000 fish. The technological advances over the past 15 years in raising coho salmon to yearling size (4-7 inches) have assured a better chance of success for these current plantings over those in the past.

Most of these coho salmon were fin clipped for identification of state origin. These fish mature to adult size in the fall of the following year and return to their origin of release to spawn. Based on the returns from the 1968 stockings, the adults may range in weight from 4 to 10 pounds. Sufficient numbers are being captured in the fall to initiate and continue a hatchery and propagation program on an indefinite basis.

Important research information on these stockings, however, is meager. Estimates of harvest of coho from the original 1968 stocking were about 10 percent. These catches represent sportsmen's landings and returns to weirs on the spawning streams. The commercial fishery is prohibited from taking this species. Additional data suggests that the cohos move slowly about the lake in a clockwise direction during the season. Actually, their midsummer distribution is restricted to the colder and still oxygenated waters on the north side of the eastern basin. Further degradation of the oxygen regime in the eastern basin may eventually place limits on Lake Erie's capacity to support this coldwater form.

Little, however, is known about their rate of growth, feeding habits, and association with other fishes. We have no idea what the impact of coho salmon will be on the other valuable commercial and sport fishery resources such as yellow perch, smelt, and the forage fishes. The most important questions currently are unanswered and will remain so until such time that more emphasis can be given to the coho.

Insecticides

The Bureau of Commercial Fisheries began monitoring insecticide residues in Great Lakes fishes about 5 years ago. However, it was not until early 1969 with the discovery of dangerously high levels of insecticides in Lake Michigan coho salmon exceeding the action level of 5.0 ppm that the subject received national headlines. This announcement prompted a monitoring program for all of the Great Lakes and was focused on the more important sport and commercial fishes. In only a few months the Bureau of Commercial Fisheries was able to obtain considerable data to add to its already existing information.

Excepting Lake Superior, the levels of DDT and its derivatives and Dieldrin for Lake Erie fish are comparatively lower than in the other Great Lakes, and fall well under the action level of 5.0 ppm. Nevertheless, its presence is still a serious problem. In the past few years growing concern about the buildup of DDT in the environment has culminated in banning the sale of these pesticides in several states. We can only hope that such restrictions on the widespread use of pesticides reflect the beginning of an awareness of the

harmful effects of pesticide pollution. The only sure control will be the replacement of these insecticides with less persistent materials.

The Mercury Crisis

The most recent environmental crisis in Lake Erie is mercury contamination of fish. Canadian officials announced on March 25 this year that levels of mercury in walleye, northern pike, and other species taken from Lake St. Clair were considerably in excess of the 0.5 ppm action level set by the Canadian Food and Drug Directorate. They subsequently placed a total ban on taking fish for any purpose from Lake St. Clair and its tributaries. Immediately U. S. public health and resource agencies were concerned about Lake Erie and sampling programs were initiated. Since then, several hundred fish samples from the Lake Erie - St. Clair areas have been examined by the several federal and state agencies. As more data became available on fish taken from U. S. waters of Lake Erie, the states of Ohio, Michigan, and New York instituted varying degrees of fishing bans.

Preliminary data from the Bureau of Commercial Fisheries sampling program in Lake Erie give the following ranges in mercury levels for certain fish from the western basin. Keep in mind now the 0.5 ppm tolerance level established by FDA: yellow perch (0.2 to 0.5 ppm), coho salmon (0.2 to 1.0 ppm), carp (0.1 to 0.8 ppm), white bass (0.3 to 1.5 ppm), channel catfish (0.3 to 0.6 ppm), freshwater drum (0.1 to 1.0 ppm), and walleye (1.0 to 3.0 ppm). An inspection of fish analyses by FDA shows most of their values

falling within these ranges. Also, predator fish show higher values than forage fish. We have very little data from the eastern basin but the mercury levels there are somewhat lower.

The consequences of mercury contamination have been tremendous and sport and commercial fisheries have suffered considerable economic losses. A more detailed report on the entire mercury crisis with recommendations for corrective actions on future research is addended to the lengthy background statement that we are submitting here today.

FISHERIES RESEARCH AND DEVELOPMENT PROGRAM

A major National objective of the Fish and Wildlife Service, and both its Bureaus, is the protection and enhancement of fishery and related aquatic resources. BCF translates its mission in Lake Erie into two broad goals:

1. To understand the population dynamics, the life history, and the ecology of such valuable food and recreational fishes as the walleye, yellow perch, freshwater drum, white bass, coho salmon, channel catfish, and associated species.

2. To determine the relationship between the changing physical, chemical, and biological environments and the survival, growth, and reproduction of valuable Lake Erie fishes.

Over the past years, a great deal of experience and expertise in handling resource problems in Lake Erie has been gained by BCF. For example, research by the Bureau on the oxygen regime in the central basin first alerted appropriate agencies and the public 10 years ago to the rate and consequences of eutrophication (lake enrichment by pollution) in Lake Erie. On the fishery side, our findings on survival, growth, abundance, and movements of such valuable fishes

as walleye and yellow perch have been continually used by State fishery managers as a basis for rational management of the fish stocks. Valuable information has constantly been transmitted to such Federal agencies as the Army Corps of Engineers and the Federal Water Quality Administration and to the four States involved with Lake Erie, and to the Industry. The research foundation, in terms of past performance and experience and expertise, exists in the BCF for a continued and expanded program on the fishery and associated aquatic resources of Lake Erie.

Research and Development Program

The BCF research and development program in Lake Erie is deeply involved in three related critical problem areas: (1) instability and decline in the valuable commercial and sport fish populations, (2) the explosion and under-utilization of low-value fishes, and (3) the effect of a deteriorating environment on the fishery resources. The main framework of our program is described below in brief form.

1. Statistical compilations.--Catch and effort statistics for the U. S. commercial fishery are gathered from all four States. In addition, biological samples of the commercial catch are taken during both the spring and fall fisheries. Statistics on the valuable sport fishery not now being gathered should be obtained in the near future.

2. Monitoring fish stocks.--Systematic analyses of the year class strength of valuable Lake Erie fishes is done each year by trawling at indicator stations during July, August, and September. The results are used to forecast

the strength of the populations when they will become vulnerable to the commercial and sport fisheries.

Other collections of fishes are made throughout the year to provide material for specific studies. Studies on the diet of freshwater drum and walleyes, the fecundity of walleyes, the occurrence of fishes in Lake Erie, and embryonic development of walleye eggs have recently been completed. Underway are studies on the fecundity of yellow perch, age and growth of walleyes, yellow perch and white bass, and fish predation on walleye eggs.

3. Delineation and assessment of populations.--The existence of sub-populations of certain fishes in Lake Erie must be determined for management purposes. Not only differences in distribution may exist, but differences in age composition, growth, survival, and fecundity may also occur. Tagging studies on western and eastern basin walleye populations are nearly complete. These populations prove to be isolated from each other with no intermixing at any time of the year. Similar studies should be carried out on yellow perch and other valuable fishes.

4. Biology, physiology, and behavior.--Basic to any fishery resource management program on Lake Erie fishes is information on their fecundity, diet, age and growth, survival rates, mortality factors, physiology, behavior, spawning requirements, and interrelations with other fishes. Many of our current and scheduled studies attack these questions. Yet more emphasis and greater funding should be directed towards the effects of domestic wastes,

industrial wastes, and resultant environmental changes on fish and fish-food organisms in all life-history stages.

5. Diseases, parasites, pesticides, heavy metals.--Little is known of the influence of diseases, parasites, pesticides such as DDT and Dieldrin, and heavy metals such as mercury and chromium on growth, longevity, fecundity, and egg viability of Lake Erie's fishes. Several studies in this area have been designed and submitted for funding. However, at present, we do have a continuing monitoring program on all valuable Lake Erie fishes for levels of pesticides and mercury.

6. Genetic improvement and new species.--Accidental and intentional introduction of species such as the alewife, sea lamprey, and carp plus environmental modifications due to climatic change or water use have markedly altered the ecology of Lake Erie. The greatest challenge in resource management is to initiate beneficial changes or set up measures to counteract accidental or natural adverse changes. Genetic modifications of established species or introductions of new species should be carefully screened by extensive physiological and behavioral tests. The chosen species must exhibit a reasonable chance of being more beneficial than species already present. The current introductions of coho salmon are being accompanied by only a modicum of research and population assessment. We have virtually no information on their lake movements, diet, and impact on other valuable fishery resources such as smelt and yellow perch.

7. Fishery limnology.--Deterioration of the lake environment has reached a point where it is now the dominant factor controlling the distribution and abundance of fishes. Several studies have been completed on oxygen depletion and changes in bottom organisms. We are continuing other studies that directly relate to environmental factors with the well-being of certain fish populations.

Yet we need to increase our evaluations of the changes in the fish, plankton, benthic, and water resources, to determine what and how certain factors are causing these environmental changes, and to predict what the future changes in all resources will be under different levels of pollution abatement.

Bottom organisms are consumed by almost all fish at some stage of their lives, and the scarcity of certain forms may significantly affect the growth and survival of fish. Bottom organisms are also useful indicators of subtle physiochemical changes in water quality. A sound plan for research on the bottom organisms would also involve measurement of: the rate of sedimentation, oxygen required to oxidize the newly deposited sediment, the components of the collected sediment, and the BOD of the hypolimnetic waters.

The role of bacteria as the causative agent in producing significant chemical changes in both the overlying water and the sediment should be investigated. We must learn the rate of synthesis, the rate of decomposition, the mechanisms of decomposition, the micro-organisms concerned, and the nature of the resulting products. Concurrently, a biological investigation should be made of bacteria as key organisms in the cycling of oxygen, nitrogen, phosphorus, iron, and carbon through the ecosystem.

The amounts and rates of nutrient fixation by plankton are considered by many to be the most influencial factors in controlling the levels of abundance and potential yield of fish stocks. Thus, the mechanics and role of this system must be measured to predict fluctuations and levels of fish abundance, and to discover means of achieving higher levels of sustained yield.

It is also imperative for us to continue and expand our overall research on the fish and associated aquatic resources as expensive and expansive pollution abatement programs are implemented by Government and Industry. We need a firm baseline of present fishery and environmental conditions in Lake Erie so that we can measure the effects of the pollution abatement programs. It would be an oversight of the highest degree to spend billions of dollars on abating pollution around Lake Erie without substantially increasing environmental research on the fish and the associated resources of Lake Erie.

Conclusion

The environmental problems of Lake Erie identified here are complex and discouraging. And we certainly are in for further crises. Yet, we in the Bureau of Commercial Fisheries are hopeful that the mounting National concern over the fate of our environment will generate greater urgency and support for all of the programs that are aimed at reducing the degradation of Lake Erie's environment and its aquatic living resources. Lake Erie is not dead. It can be saved if we all work together.

SUMMARY

Based on analysis of all available data, the following conclusions are drawn concerning the past, present and future status of the commercial and sport fishery and related aquatic resources of Lake Erie.

1. Lake Erie has been the most fertile and productive of all the Great Lakes. A total of 19 species have been significant in the commercial landings at one time or another. Annual combined U. S. and Canadian production has fluctuated little in the past 50 years, averaging approximately 50 million pounds.

2. The value of the catch is declining, however, which reflects the changing conditions of the fish stocks from high-value to low-value species. High-value species like the sturgeon, northern pike, whitefish, cisco, blue pike, and sauger have virtually disappeared from the catch. Walleye, yellow perch, white bass, and channel catfish constitute the major remaining species of higher and medium value. These species are declining and show signs of difficulty in perpetuating themselves. Stocks of such less valuable species as freshwater drum, carp, suckers, and goldfish are, with few exceptions, greatly underexploited.

3. Prior to 1954, U. S. fishermen landed more pounds of fish than Canadian fishermen. Now, however, the U. S. catch is less than 20 percent of the total catch from Lake Erie.

4. Three States bordering Lake Erie have been introducing yearling coho salmon since 1968. Growth and survival have been relatively good. However, very little open-lake research has been conducted and little is known about the impact of coho salmon on other valuable fishery resources such as yellow perch and smelt.

5. By most criteria accepted by limnologists, Lake Erie is classified as a eutrophic lake with changing water quality in both inshore and open waters. Industrial, municipal, and agricultural pollution and enrichment of Lake Erie has caused: (a) massive nuisance and toxic algal blooms of Microcystis and Aphanizomenon, (b) destruction of the valuable mayfly benthos in the western and central basins, (c) a 20-fold increase in plankton, the diet staple for several nuisance and low-value fishes that have undergone population explosions in the last 15 years, (d) increased levels of such pesticides as DDT and Dieldrin in fish flesh, (e) dangerously high levels of mercury in many fishes, (f) the destruction of spawning areas of some of our most valuable fishes, and (g) disappearance of oxygen from the bottom waters of the central basin during the summer.

6. The concentration of dissolved solids is still well below levels directly lethal to fish and food organisms even though solids have increased by 50 ppm since 1920. However, the continued accelerated rate of increase is cause for future concern.

7. Warm water temperatures and high nutrient levels have led to tremendous algae blooms. This organic production has created in turn a large BOD during decomposition. Furthermore, reduced materials have accumulated in the sediments over the years. The combined BOD and chemical oxygen demand from these two phenomena have caused widespread oxygen depletion in the bottom waters of the western and central basins during periods of summer thermal stratification. The consequence of this has been widespread destruction of bottom organisms so important in the diet of many Lake Erie fishes. Any increase in nutrient levels or average water temperatures will undoubtedly worsen this situation.

8. Pesticides, heavy metals such as mercury, phenols, cyanides, acids and exotic inorganic and organic chemicals are among the many outright pollutants discharged into Lake Erie. Pesticide levels (DDT and Dieldrin) are moderately low in Lake Erie fishes and all fall safely under the 5.0 ppm level set by the FDA. Mercury levels are, on the other hand, dangerously high. Values in some walleyes and white bass especially have exceeded the action level of 0.5 ppm set by the FDA.

9. Observations on walleye reefs during the 1969 spawning season suggest that the smothering effect of sedimentation on fish eggs and other bottom associated organisms may be detrimental and a major factor in the decline of some of our valuable fish stocks. Obviously, increasing siltation is a serious problem that needs full attention by the appropriate agencies now.

10. The historical record and current status of all the valuable sport and commercial fishes in Lake Erie are presented. The Bureau's program of fishery-limnology research on the fishery and aquatic resources of Lake Erie is described with special emphasis on the continuing effects of environmental degradation on the fishery and related aquatic resources.

11. Practically and legally speaking, halting degradation of the water quality of Lake Erie will require the establishment of sound and workable water quality standards, including standards and criteria for fish and aquatic life. This is an area where acceleration of research is needed. Interim standards will probably have to be set before the results of such research become available.

12. Because of their inherent sensitivity to subtle, long-range environmental changes, fish and aquatic organisms make excellent indicators of such changes. This has not been recognized sufficiently in the past. As more expensive and expansive pollution abatement programs are initiated, more aquatic research on Lake Erie will be needed to measure the effects of such abatement programs.

13. The comprehensive fishery-limnology research program of the Bureau of Commercial Fisheries is outlined in detail.

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