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OVERVIEW OF THE GREAT LAKES COMMERCIAL FISHERY, WITH SPECIAL EMPHASIS ON THE USE OF GILL NETS AND IMPOUNDMENT GEAR

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SUMMARY

A review of the history and mechanics of commercial fishing in the Great Lakes demonstrated the overall effects the fisheries had on the fish resources. In retrospect it appears that until recently most fishery scientists and fishermen take the view that most changes in fish abundance were cyclical and a function of environmental problems rather than the effects of exploitation. However, during the last decade fishery scientists and managers have taken a closer look at the effects of the commercial and sport fisheries upon the fish stocks. It is apparent that the commercial fisheries, especially the gill net fishery, has had a detrimental effect on fish abundance. The use of gill nets must be drastically reduced if a multi-species fish resource is to provide future good returns to both sport and commercial interest and maintain a safe reproductive level.

One of the major goals of the Michigan Department of Natural Resources is to build and maintain a population of large, valuable predator fishes in the Great Lakes which, according to Christie (1974), provides the best economic returns to both commercial and sport fisheries. He reports that little, if anything, can be gained economically by managing the Great Lakes for commercial production of the small, very numerous species such as smelt and alewife. Obviously, an unrestricted commercial fishery is not consistent with such a goal. This is precisely why Michigan and most other Great Lakes management agencies have had so much difficulty over the last 15 or 20 years. Michigan has had the legal authority to establish necessary regulations for the commercial fishery only since passage of Act 336 in 1968. One of the major thrusts since then has been an attempt to strictly limit and, in some cases, eliminate the gill net fisheries because of their nonselectivity. Other methods of commercial fishing, such as impoundment gear, offer a nearly equal opportunity for commercial harvest with more potential for control of the catch and the incidental kill of protected fishes. This type of selective harvest is absolutely essential for restoration and maintenance of the predator-prey balance.

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INTRODUCTION

The early explorers and adventurers who traveled around the Great Lakes wrote about the bountiful fish resources that they observed everywhere. Apparently fish were taken easily at almost any shore location which provided these travelers a staple food source. This period, before 1830, was appropriately characterized by a great abundance of what we now consider to be the high-value species such as lake trout, lake whitefish and lake sturgeon. The Indians also relied on fish at certain times and places for their subsistence.

Today the best use of the total species complex would seem to depend upon a mechanism that would allow certain species to be harvested commercially, others by the sport fishery, and still others by a combination of the two fisheries or not at all. We know that the abundance of adult spawners for any species must be above a certain level or its reproductive success will fall to a point where the population cannot recover (Abrosov, 1969). This reproductive failure, coupled with other possible negative influences such as continued gill net exploitation via incidental catch and/or environmental degradation probably accounts for most disappearances of species that have occurred in the Great Lakes since the commercial fishery first began operating. At least 11 of the original species either are no longer present or are found only in very isolated situations where they do not have any further commercial significance. A number of other species including yellow perch, walleye, lake whitefish, and lake trout are reduced in distribution and abundance to the point that only very limited commercial fisheries exist. This report reviews the commercial fisheries and the gear that was developed over the years. Scientific names for all fish species mentioned are taken from Special Publication No. 2 (1960), American Fisheries Society, and appear in Table 1.

HISTORY OF EXPLOITATION

The first major commercial fisheries on the Great Lakes were seine operations in Lake Erie which probably started about 1815 (Van Oosten, 1936). Major seining operations in the Detroit River were started about five years later. By 1830, the fur trade had essentially ended and immigration was rapidly accelerating. This combination of events provided the impetus for extensive commercial fishing in the Great Lakes. Gill nets were first used as a major commercial fishing gear in Lake Huron in 1835 (Milner, 1874). After that, gill net fishing expanded throughout the rest of the Upper Great Lakes area at a rate closely proportional to the expansion of human settlement.

Commercial fishing exploitation was very strong and selective for a few fish species around the turn of the century. The historical sequence of events in the fisheries was very much alike in all of the Upper Great Lakes. The

Table 1. List Of Common And Scientific Names Of Fishes Used In This Paper

Lake trout	Salvelinus namaycush
Lake whitefish	Coregonus clupeaformis
Lake sturgeon	Acipenser fulvescens
Yellow perch	Perca flavescens
Walleye	Stizostedion vitreum
Lake herring	Coregonus artedii
Rainbow smelt	Osmerus mordax
Sea lamprey	Petromyzon marinus
Atlantic salmon	Salmo salar
Brown trout	Salmo trutta
Alewife	Alosa pseudoharengus
Longnose sucker	Catostomus catostomus
Coho salmon	Oncorhynchus kisutch
Chinook salmon	Oncorhynchus tschawytscha
Sockeye salmon	Oncorhynchus nerka

first indications that the commercial fishery was observably overharvesting fish were reported by the Michigan State Fish Commission (1875). Substantial decreases in local lake whitefish and lake trout fisheries were apparently the gravest complaints. These changes probably involved the inshore stocks, often during spawning activity, which were highly susceptible to capture. The declines prompted the fishermen to look for more lucrative fishing areas. The Michigan Fish Commission (1885) reported that the size of fish in the catch had greatly decreased and yield had failed in many localities. In addition, the fishing area had been greatly expanded to keep up production; and the mesh size in gill nets and trap nets had been substantially reduced to capture smaller fish. Commercial effort continued to grow and expand to new areas and total fish production peaked at about 30 million pounds during the early 1890's when about 40,000 nets were fished in Michigan (Michigan State Board of Fish Commissioners, 1895). In 1919 there were 100,000 gill nets and 4,500 pound nets being fished in Michigan's waters of the Great Lakes; by 1930 this had dropped to 62,000 gill nets and 1,500 pound nets (Scott, 1974). Gill net effort then stabilized until about 1943 when effort again rose to around 100,000 nets. High levels of production for the principal species were maintained through the period 1943-1960 by improvements in netting materials which effectively raised the catch efficiency of the gill nets.

One can easily look back now and see how the commercial fishery exerted a pronounced effect upon the fish stocks. As explained by Christie (1974), the fishery could overharvest first the local stocks of a species near shore and then, motivated by lower catch rates, progressively switch to those stocks farther and farther from the fishing ports. Thus the amount of fishing activity and even the poundage of fish landed remained fairly stable until there eventually were no more stocks of fish to exploit. Then, and only then, was the great extent of fish depletion readily observable. Regier and Loftus (1972) described this "fishing up" process further, explaining that as each local stock was reduced the fishing emphasis would switch to lesser valued species as well as to the more distant stocks of valuable species. In addition, more efficient and easily transportable fishing gear was developed and fishermen gained more knowledge on fish movements and their distributions. All this helped to maintain relatively high commercial production while the fish stocks declined. This fishing up process has been observed in a number of places throughout the world (Regier and Loftus, 1972).

In the Great Lakes, the lake whitefish was the most valuable species, followed in order by lake trout, lake herring, lake sturgeon and chubs (Coregonus spp.). Changes in abundance of these species since 1900 have not necessarily followed the fisheries interest because of variation in their apparent sensitivity to the fishing pressure (Smith, 1972). The approximate order of declines in these species from the most to the least seriously affected was lake sturgeon, lake herring, chubs, lake trout, and lake whitefish.

Most of the sturgeon catch probably came from seines and pound nets. However, it is important to note that in the early years these sturgeon were selectively killed by the fishermen because of their interference with, and damge to, the various fishery operations (Harkness and Dymond, 1961). They had little or no market value.

The early decline in herring abundance in Lake Erie was caused by very extensive pound net and gill net fisheries. A sudden drop in abundance occurred shortly after the intensive gill net effort moved inshore from its normal, deep-water fishing areas (Rathbun and Wakeham, 1898). By 1920, this heavy fishing had apparently reduced the population in western and central Lake Erie and good catches were being made only in the eastern basin (Hartman, 1972). By 1925, this eastern basin population had also virtually collapsed. Most authors (Van Oosten, 1930; Smith, 1968) have agreed that the essentially unregulated commercial fishery was largely responsible. Lack of recovery since 1925 has been attributed to other factors in addition to excessive fishing pressure.

In Lake Superior, the herring fishery did not develop fully until the early 1940's. The stocks declined severely between 1961 and 1969. The specific reasons for collapse are apparently not clear but, according to Lawrie and Rahrer (1972), it is perhaps significant that depletion was greatest where heavy fishing pressure either had existed longer or started earlier.

The early decline of lake herring in Lake Michigan was largely the result of heavy gill net exploitation and further declines in the 1920's and 1930's were probably related to exploitation and the introduction of rainbow smelt (Wells and McLain, 1972).

Koelz (1926) reported that when inshore lake trout stocks were reduced in Lake Superior, gill nets were shifted to deeper water to utilize the deep-water lake trout. He also reported that by 1880 gill netting for chubs in Lake Michigan had started to develop into a major industry at most ports. There were seven species of chubs present, some considerably larger in size than others. Gill nets with mesh sizes of 3 and 2 7/8 inches were used. By 1910, the gill net industry had grown tremendously and the populations of the larger chubs were severely reduced. In response to this decline in chub stocks, the fishery reduced the mesh size to 2 3/4 and 2 1/2 inches to take advantage of three smaller species of chubs. The chub fishery again flourished but by 1920 these three species also had declined considerably. The two larger chubs of the original group were already considered to be commercially extinct by 1920 (Koelz, 1926). Smith (1972), in a discussion on chubs in the Great Lakes, showed that the large species were reduced sequentially according to their size, as the gill net mesh was reduced periodically to take the largest chubs available in the lake.

The gill net fishery had unmistakably depleted the stocks of several species of chubs during a period when gill nets were in a state of developmental infancy. Christie (1968) pointed out that if a fishery shifts attention to a smaller fish species after collapse of a larger one, and if this fishery uses a smaller mesh, the capture of the few remaining young of the larger species may permanently suppress that species.

The sea lamprey probably played a prominent role in the depletion of the lake trout. However, again there are some rather obvious signs of excessive exploitation by the gill net fishery. Lawrie and Rahrer (1972) cite Hile, Eschmeyer and Lunger's (1950) data that documented a substantial increase in the effective fishing effort over a large part of Lake Superior during the 1930's and 1940's prior to severe lamprey problems. This provided convincing evidence that lake trout abundance was declining despite a constant level of harvest by the fishery. Dryer and King (1968) also contended that lamprey abundance was not the only factor affecting spawning lake trout abundance in Lake Superior during the early 1950's. The commercial fishery also was an important factor in the decline of spawning stocks. Wells and McLain (1972) described the decline in abundance of Lake Michigan lake trout between 1890 and 1940 concurrent with an increase in fishing intensity. Christie (1974) proposed that this heavy gill net fishing pressure stressed the population sufficiently that it was not able to survive lamprey predation.

GILL NETS

Gill nets are constructed of fine thread, have a low visibility, and hang in the water to intercept passing fish. They resemble tennis nets when in place on the bottom of the lake. Individual commercial gill nets vary from 250 to 800 feet long, and usually are set in strings from 2,000 feet to 8 miles in length on the lake bottom in depths from six feet to 600 feet, depending on the species sought (Van Oosten, 1936). The time interval between setting and lifting of the nets has varied from one to nine days depending upon water temperature, weather and other factors.

Fish are caught when they swim into the nets and are snared in the mesh by gilling, wedging, or tangling. If the mesh size is properly matched to the size of fish caught, they will penetrate through a mesh until the twine slips behind the gill covers thus "gilling" the fish. If the fish is a little smaller, it will penetrate further through the mesh until it is wedged in an area of greater body circumference. The other type of capture is when a fish becomes "tangled" in the fine fibers of net material by its bony projections, teeth or rough body contours without ever actually penetrating one of the meshes. The distinction between these types of gill net capture is important since various nets and net materials tend to catch different sizes and/or kinds of fish. This can significantly influence the eventual effect upon the fish populations.

Gill net materials have changed considerably since the earliest fishing activity and these changes were usually accompanied by a substantial increase in efficiency. The American Indians made nets from natural vegetable fibers and used pieces of cedar for floats and notched stones for weights. The first commercial fishermen on the Great Lakes reportedly used linen imported from Europe to make their gill nets. This material was heavy, highly visible, and inelastic and therefore had to be tied very taut to make the gilling process work. The incidence of capture by tangling was probably minimal since the material was coarse and tightly tied.

Cotton was introduced to the Great Lakes gill net industry during the 1930's (Pycha, 1962). Cotton proved to be significantly better than linen at catching fish but required a great deal of maintenance.

Nylon was first used during the early 1950's and revolutionized the gill net industry. It was the "perfect" material, being far superior to linen or cotton in its ability to catch fish and required only a small fraction of the maintenance cost. According to Pycha (1962), the change from linen to cotton gill nets significantly raised their fishing efficiency. However, that increase was small compared to the increase resulting from the change to nylon.

Several innovations in associated equipment also had a major impact on the effectiveness of the fishery. Prior to 1870, all gill net fishing was done from boats powered by humans or sails (Van Oosten, 1936). From 1870 to 1875 the steam-powered boat was introduced with petroleum-burning tugs following shortly thereafter. These motorized boats substantially increased the area that could be fished, the amount of netting used, and allowed operations under almost all weather conditions. The power gill net lifter was developed as an adjunct to the power boat around 1900. Until then, gill nets had to be lifted by hand. The power lifter allowed more nets to be handled by fewer people and, according to Van Oosten (1936), played an important part in maintaining the annual yield of the dwindling fisheries by increasing the amount of gill net effort as the catch per unit of effort decreased because of reduced stocks of fish.

Several physical characteristics of gill nets affect their efficiency. The mesh size, or perimeter of the mesh opening, is very important because most gilling occurs when a fish's girth is about 1 1/4 times the mesh perimter (Pope, Margetts, Hamley, and Akyuz, 1975). This is especially true for smooth-bodied fishes. Other important characters of gill nets are invisibility, elasticity and tautness.

Visibility probably depends mainly upon the transparency of net materials with fish being more susceptible to capture by the less visible twines. The recent monofilament nylon nets constructed of single-thread line are designed to be invisible in water; as expected, they are extremely efficient in capturing fish.

Elasticity is the capability of the net material to stretch beyond its normal size which allows larger fish to wedge than non-stretching nets of comparable size. It also permits more tangling and a wider size range in the catch than in the non-elastic nets (Ishida, 1969). Another factor affecting the catch is the tautness of the material while the net is being made. The less tightly it is held, the looser the material will hang when set. Slack nylon gill nets tend to capture fish of larger average size and greater size ranges than taut nets.

Thus, gill net materials started with the highly visible and inelastic linen fibers, changed to a thinner, more flexible cotton, and finally went to the almost invisible, highly elastic nylon. Tautness accounted for the capture of fish of a relatively small average size plus a narrow range in size which caused the fishery to be somewhat selective. In other words, a relatively specific size and type of fish was harvested without too many illegal or unwanted fishes being incidentally caught. However, as net materials became less visible, more elastic and were tied looser, a much less selective gear was developed. Many more sizes and types of fish were caught regardless of a fisherman's intentions. Decreases in fish populations were obviously related to all of these changes in gill net efficiency.

A number of scientific studies have been done to determine the selectively characteristics of gill nets (Hamley, 1975). Basically, selectivity in this sense refers to any feature of a net that accounts for capture of only a portion of the fish encountering the net. As the net becomes more selective, a smaller segment of the fish are caught irregardless of size or species or both. Control of selectivity is one of the most important tools in management of a commercial fishery. An analagous situation is the harvest of timber. A forester might "select" certain mature trees for cutting while leaving some others for seed production or until maximum growth has been obtained. Likewise, the fisheries biologist attempts to manage the commercial fishery for fish that are mature and surplus to the population's reproductive needs. This approach tends to stabilize abundance and growth of the fish population and maximize the total weight of fish commercially harvested. Wise commercial or sport utilization also requires that the commercial catch be restricted to certain suitable species.

GILL NET MORTALITY

Gill nets kill almost all of the fish they capture because they tangle and suppress opercular movement, and fish are prevented from passing sufficient water across the gills for breathing. The victim also exhausts itself in the struggle to get free from the twine. In addition, gill net filaments are very fine, and strong, and easily cut into the fish or cause severe skin, muscle and visceral injury.

The capacity of gill nets to kill and destroy great numbers of fish was recognized and reported early in the historical literature. Milner (1874) reported that fish caught in impoundment gear were superior in quality to gill net fish because the former were always fresh when put in the ice boxes while those from gill nets may have been dead from one to several days. He also pointed out that gill nets were quite wasteful since a portion of the fish would spoil before the nets were pulled and the fish were iced and taken to market. During periods of severe weather, gill nets sometimes could not be retrieved, which allowed great quantities of fish to be caught and lost through spoilage. Gill nets were also lost in the lake but could continue to catch fish for months afterward until they loaded up with fish and debris and sank to the bottom. Rathbun and Wakeham (1898) also reported that, while many fish caught in gill nets were in good condition at the markets, a considerable portion was decidedly inferior in quality to the fish taken from pound nets. Koelz (1926) surveyed the Great Lakes commercial fisheries during the 1920's and reported that most fish were dead by the time gill nets were lifted from the lake.

Some Michigan commercial fishermen voluntarily recorded whether or not lake trout incidentally caught in gill nets were, in their estimation, alive or dead when the nets were lifted. It is important to remember that this is a very subjective observation on the part of the fisherman since he has no way of determining the nature and extent of internal injuries or physiological stress from fighting the net plus being brought to the surface from considerable depth. His main criteria was whether or not the fish was moving and swam away when put back into the water. These observations might be considered a measure of the absolute minimum level of mortality that would be caused by the nets. Patriarche (1977, personal communication) examined the catch records of one Lake Superior gill net fisherman who had kept such a record for the small lake trout caught incidentally while fishing for chubs. The fisherman reported the following numbers of live and dead lake trout at the time of lifting during 1972-1974:

	1972	1973	1974
Alive	694	668	425
Dead	1,642	2,215	2,026
Percent Reported As Dead	70.3	76.8	82.7

Accepting the fact that 70-80 percent of these trout were dead at the time of lifting, it is not difficult to imagine that nearly all of these incidentally caught trout were killed because most of the remainder probably died from exhaustion and physical injury.

The gill net fisheries for other species in Lake Michigan were also detrimental to lake trout stocks. During 1929-1954 the incidental catch and kill of very small lake trout in the chub fishery was estimated to be about 15 million fish (data from Eschmeyer, 1957). This is only 500,000 lake trout less than were caught during the same time period in the lake trout fishery.

Some research has been done to determine the effect of gill net capture upon fish, including damage to tissues and delayed rates of death after escapement or release. Murray, White and Whitaker (1969) examined 10 Atlantic salmon that had been captured in gill nets and sold to consumers through normal marketing channels. The salmon appeared to be a normal, high-quality product. However, when these consumers prepared the salmon for cooking they discovered severe internal muscle damage which prompted them to present the fish for scientific examination. Autopsies revealed deep muscle lesions which must have come from mechanical injury. This induced an examination of additional salmon that were taken directly from gill nets which showed that very extensive muscle lesions were caused by pressure of the gill net twine around the body of the fish.

French and Dunn (1973) examined the incidence of loss of large fish from gill nets either due to dropping out, escaping while the net was set, falling out as the net was being lifted into the boat, or by being physically removed from the net by predators and scavengers. Positions of the fish in the nets at night were marked by tying colored threads to the float line. The number lost was then obtained by counting the threads that did not correspond to the fish observed when the nets were lifted. It was found that 41 percent of the fish initially caught were lost from the nets before lifting due to dropping out within an 11-hour period. Loss rates from large and small mesh gill nets were very similar. Furthermore, many of these fish, even though they escape, will die within several days because of injuries received in the net. Thompson, Hunter and Patten (1971) studied escapement from gill nets in a controlled situation and found that 46 percent of the sockeye salmon eventually freed themselves from the net. The most conclusive evidence of mortality showed a 73 percent mortality for dropouts within six days (Thompson and Hunter, 1972).

These studies substantiate the feeling shared among fisheries managers that nylon gill nets kill almost all fish caught and are quite wasteful due to loss of fish prior to the time of lifting. This has rather serious management implications in that the total number of fish killed in the fishery is not controllable. It also shows that gill nets are relatively wasteful of fish compared to impoundment nets since the gill netted fish have been dead longer and consequently are of lower quality at the market, not to mention the greater tissue damage.

Rybicki (unpublished) reported on the Michigan Department of Natural Resources monitoring activities in 1968 of the Lake Michigan gill net permit fisheries for lake whitefish and chubs. He found that these nets killed about 71,000 lake trout in 1968 even though lake trout were illegal to catch. He estimated that 6 percent of the 1965 planting of lake trout had been caught by the permit fishery in 1967 and 1968 alone. These immature fish would not have spawned at least until 1970. It is doubtful that a significant number of any particular planting could survive long enough to successfully reproduce at this level of exploitation.

As mentioned earlier, some 15 million sublegal lake trout were caught incidental to chubs in the Lake Michigan chub fishery from 1929 through 1954. In 1935, 1936, and 1938 greater numbers of small lake trout were estimated to have been killed then were caught in the authorized lake trout fishery (Eschmeyer, 1957). Such extensive mortality of valuable predator fish prior to maturity cannot be considered insignificant.

Planting of hatchery lake trout in Lake Superior was started in 1958 and extended to Lake Michigan in 1965 in an effort to restore the populations. The average number planted per year in Lake Michigan between 1965 and 1974 was 2.1 million fish. If an unrestricted chub gill net fishery had been operating similar to that during the 1930's and 1940's, it would have removed more than one-quarter of the juvenile trout being stocked each year through incidental catches long before their growth and reproductive potential had been realized.

SELECTIVITY TOWARDS LAKE TROUT

Length distributions of lake trout caught in gill nets show that these nets are not very selective as to size of trout captured. Length distributions of lake trout from various Great Lakes waters caught in large and small mesh nets are given in Table 2. All length distributions were collected from commercial gill net operations and represent over 44,000 fish. The small mesh was set to catch chubs and not lake trout so the latter were incidentally caught. The large mesh was set with the intention of catching whitefish or trout. These data, even though representing different times and areas, are quite consistent in showing the wide size ranges of trout that are vulnerable to each mesh size. The small mesh tends to catch a smaller average size; the two length modes do not overlap.

The minimum legal size for lake trout is 1.5 pounds or 17.0 inches so most of the trout caught in the chub nets and even a significant number in the large mesh were sublegal. The catch in the large mesh is probably representative of the sizes of lake trout that would be caught in a gill net fishery for whitefish. It is easy to see why the present planting program for lake trout and a commercial gill net fishery for whitefish are incompatible. The non-selective aspect of nylon gill nets for fish is further reflected by their tendency to catch whatever fish are present rather than to select for certain sizes or species. A good example is the catch of lake trout shown in Table 3. These Lake Michigan fish were caught in experimental gill nets of six different mesh sizes ranging from 2.5 to 6.0 inches. The average length of fish captured increases with each mesh size. However, there is a very wide spread in length for each one and there is even a significant overlap between the smallest (2.5 inches) and the largest (6.0 inches) mesh sizes. This is because lake trout are notorious for being caught by the teeth, irrespective of size of the fish.

Similar data taken in 1973 and 1975 from the United States Fish and Wildlife Service vessel Cisco, show that the average lengths of lake trout captured in experimental nylon gill nets of the same mesh as above vary only a small amount. A statistical analysis showed that there was no significant difference, at the 95% level, between the average lengths of the trout caught in meshes of 4.0 through 6.0 inches. A total of 1,945 lake trout were measured.

ENFORCEMENT PROBLEMS

Gill nets pose an enforcement problem in that they tend to be quite non-selective in the sizes and types of fish caught and killed. The problem, mentioned earlier, concerns the incidental catch of protected species or sublegal sizes of commercial species. The incidental catch takes two forms, one of which is to catch non-target species of fish that are protected. These species inhabit the same water areas as the commercial species and are likely to be caught and killed in the gill nets. For example, it is impossible to develop and maintain a desirable level of predator fish in an area that is heavily laced with gill nets since so many are lost through this incidental mortality. The second type of non-selective capture is related

Table 2. Percentage Length-Frequency Distribution Of Lake Trout Caught In Gill Nets Used in Lakes Michigan And Superior

	Small Mesh[1]				Large Mesh[2]			
Inch Group	Dryer[3]	Van Oosten[4]	Eshmeyer[5]	MDNR[6]	MDNR[6]	Dryer[3]	Eshmeyer[4]	MDNR[7]
5								
6	<1			1				<1
7	1			1		<1		<1
8	1	<1		1				1
9	7		1	2	<1	<1		1
10	14	1	1	11		<1		3
11	15	10	18	28		1		2
12	14	32	51	18	<1	1		3
13	13	29	22	10	<1	1		7
14	12	15	14	9	1	1		13
15	9	8	10	7	<1	1		21
16	5	3	7	6	<1	1	5	21
17	3	2	2	5	1	7	3	15
18	2	1	1	2	3	13	3	8
19	1	1	4	1	8	19	3	4
20	1	<1	<1	1	12	18	6	1
21	1			<1	14	15	12	<1
22	1				12	10	16	<1
23	<1				11	6	14	
24	<1				9	3	15	
25	<1				8	2	10	
26					7	1	8	
27	<1				5	<1	3	
28					4	<1	2	
29					3	<1	3	
30					2			
31					1	<1		
32					<1			
33					<1			
34					<1			
Number Of Fish	2,495	2,833	506	2,817	13,975	3,830	1,522	16,225

[1]Stretched mesh 2.0 to 3.0 inches

[2]Stetched mesh 4.0 to 5.0 inches

[3]Dryer and King, 1968

[4]Van Oosten and Eshmeyer, 1956

[5]Eshmeyer, 1957

[6]Michigan Department of Natural Resources: Lake Trout Assessment Fishery on Lake Superior During the Spring of 1976.

[7]Michigan Department of Natural Resources report to the Lake Michigan Committee of the Great Lakes Fishery Commission for 1969.

Table 3. Percentage Length-Frequency Of Lake Trout Caught In Experimental Gill Nets Of Variable Mesh Size In Lake Michigan, 1968-1970[1]

Inch Group	Mesh Size In Inches (Stretched Measure) 2.5	3	3.5	4	4.5	5	5.5	6
10	0.9		0.4	0.3	0.4			
11	6.3		0.2	0.3	0.4			
12	13.4	1.0	0.2	0.4	0.6	1.0		
13	19.8	14.1	0.9	0.7	1.6	0.8		1.7
14	7.2	21.2	3.2	0.6	2.1	1.4	1.1	
15	3.6	20.2	7.5	3.4	1.8	3.7	1.1	1.7
16	2.7	3.0	14.7	11.3	2.9	4.7	6.5	
17		9.1	18.3	19.6	5.5	8.1	4.3	
18	1.8	2.0	17.0	19.8	11.3	10.3	8.6	1.7
19			10.5	11.1	15.9	14.4	8.6	
20	2.7	4.0	4.6	5.4	13.8	13.3	4.3	
21	22.5	2.0	6.0	6.6	10.3	8.5	1.1	3.4
22	2.7	2.0	5.1	5.5	9.1	11.8	4.3	1.7
23		1.0	4.9	5.2	7.2	8.8	6.5	6.9
24	2.7	5.1	1.4	3.6	6.5	4.7	11.7	10.3
25	3.6	6.1	1.4	2.2	4.2	3.3	17.1	22.5
26	6.3	5.1	2.1	1.6	3.4	3.0	12.9	13.9
27	1.8	4.0	0.7	1.6	1.6	1.0	6.5	17.3
28	0.9		1.1	0.7	0.7	0.4	4.3	8.6
29	0.9			0.1	0.2	0.8	1.1	10.3
Number of Fish	111	99	570	726	5,718	509	93	58

[1]Unpublished data collected by Michigan Department of Natural Resources

to size. Modern gill nets made of multifilament and monofilament nylon capture a wide range of fish sizes due to very efficient gilling and tangling. Gilling is most important in the capture of smooth, tapered fish such as whitefish, chubs, herring, and longnose suckers; while tangling is relatively more important for rough bodied or toothy fishes such as walleye, lake trout, brown trout, coho and chinook salmon, yellow perch, and catfish (*Ictalurus sp.*).

The incidental catch makes meaningful regulatory control of a gill net fishery impossible. The fishermen know they can change the catch characteristics of their nets. Since gill nets are easily moved and are only fished for periods of several hours to several days, the enforcement activity required to adequately police the Great Lakes waters is monumental. In addition, the level of regulation necessary to ensure that gill nets would not jeopardize the fishery restoration and maintenance goals would make them so inefficient that it would hardly pay the commercial operator to fish. These kinds of commercial fishery problems were reported on by Ishida (1969) who found that when the legal mesh size is larger than the optimum for fishing, fishermen use a less elastic thread in order to produce the same effect as a smaller mesh size. On the other hand, they sometimes use a more elastic thread in order to catch a wider range in length. Both of these changes occur regularly in Great Lakes fisheries in response to a decline of the larger individuals of a particular fish species if the mesh size is restricted by law. Of course, intensive gill net fisheries tend to reduce the larger individuals first. Several agencies have collected information on the incidental catch of salmonids in gill nets set for other species. In most cases the catch was quite substantial indicating that gill nets are a real threat to the management objectives of restoring a balanced level of predators.

IMPOUNDMENT GEAR

Impoundment gear is generally stationary and catches fish by leading them into a pot or crib which has very small openings to prevent escape. The pot portion of the net is lifted onto the boat after several days in the water and the fish, which are usually alive and unharmed, can be sorted and transferred to shore. These nets are constructed of heavy, highly visible materials to facilitate leading the fish into the pot.

Pound nets consist of four main parts; lead, heart, tunnel, and pot. The first three are arranged so as to intercept fish and lead them into the pot. Their leads range between 800 and 1,500 feet in length and can be fished surface to bottom in water depths of 10 to 90 feet. They are anchored in place by driving long stakes into the lake bottom to which the nets are tied. Almost all sizes and kinds of fish can be caught in these nets, with the smallest size being determined by the mesh size of the material in the pot. Fish that are small enough can escape by passing through these meshes.

Trap and fyke nets are very similar to pound nets except that they are usually smaller, are held in place by anchors instead of stakes, and often are not fished from bottom all the way to the surface. Trap nets are more easily moved and cared for than pound nets and therefore are much more prevalent in the modern industry.

Impoundment gear may be set individually but are often set in strings starting from shore and going out quite a distance into the lake. Maximum water depth for efficient use of this type of net seems to be around 100 feet.

Pound nets were introduced into the Upper Great Lakes about the mid-1850's (Van Oosten, 1936). Fish harvest then rose at a rapid rate. Some people consider this period to be the beginning of the decline in Great Lakes fish stocks. Pound nets proved to be an extremely effective gear. If small mesh netting material was used in the crib or pot, large numbers of small fish were captured. For this reason these nets were sometimes criticized as being very destructive of young fish. If, on the other hand, the size of the mesh was increased in the pot, undersized fish would escape through the larger mesh openings (Van Oosten, Hile and Jobes, 1946).

Shallow-water trap nets were developed about 1875 but did not find substantial use in Michigan waters until the late 1890's. Deep-water trap nets, made to catch lake whitefish, were introduced into the Michigan waters of Lake Huron in 1928 (Van Oosten, 1936). These deep-water nets were highly efficient but were also criticized for damage to juvenile fish. However, according to Van Oosten, et al (1946), observations on the lifting of trap and pound nets did not indicate the destruction of excessive numbers of small whitefish, even though large numbers of them were caught and released. As a further substantiation of this observation, Smith and Van Oosten (1939) reported a high recovery of sublegal whitefish that had been caught in trap nets, tagged and released. This high recovery rate (22.1 percent) suggested a very high survival rate.

Numerous references in this report have been made to the desirability of using impounding gear as the best management option. These gear require more effort and materials to construct and are harder to fish than gill nets, but they produce a better product and are potentially more efficient and easier to regulate since they allow a much more selective catch.

When the State of Michigan began its Great Lakes rehabilitation program in about 1964, the Department of Natural Resources made a major policy change in that the Great Lakes should be managed for maximum public benefit by emphasizing the sport fishery as well as the commercial fishery. Prior to that, these lakes were considered to be primarily commercial fishing grounds. To facilitate this change in policy, a vigorous planting program was adopted involving various predator species such as lake trout and salmon that could utilize the vast quantities of alewives and rainbow smelt available for food. The catch of these newly planted predators in the commercial gill net fisheries of the late 1960's was extremely high, as was pointed out earlier in this report. It soon became clear that the essentially unrestricted gill net fishery was not compatible with restoration of large predator fishes and wise management of the Great Lakes fishery resource. At this point the emphasis of management of the commercial fishery switched from gill nets to impoundment gear because it could be selectively fished for all commercial species (with the possible exception of chubs) without threatening the rehabilitation of salmon, trout, and other valuable fish stocks.

The commercial fishing industry was requested to make every effort to convert from gill nets to impoundment fishing gear but it was extremely reluctant to do so. Significant progress has only been made towards conversion within the last several years after many bitter court battles and rule changes. Even today the gill net fishery is fiercely resisting the switch to impoundment gear. The arguments raised by the fishery against conversion were based either on the rather high cost of conversion or the contention that impoundment gear could not be used successfully to catch the target fish. The cost argument was not very appropriate since other options such as being compensated for leaving the fishery were available.

In answer to the second argument, impoundment gear has been used in virtually every area of Michigan's Great Lakes waters to commercially harvest fish. A summary of past catch records submitted by Michigan's commercial fishery for the period 1929 through 1949 showed that pound and trap nets were effectively used in all districts of both Lake Michigan and Superior with the exception of waters around Isle Royale.

For further support, it should be pointed out that considerable portions of the annual Great Lakes fish production have come from impoundment gear in recent years. According to the minutes of the Great Lakes Fishery Advisory Committee for 1972, there were 130 Michigan commercial fishermen licensed to fish 2.7 million feet of gill net in 1972 but note, also, the following percentages of fish that were harvested from impoundment gear in 1970 to show that it can also be a very successful method:

Species	Percent Taken In Impoundment Gear
Smelt	96%
Suckers	81%
Alewife	68%
Perch	55%
Whitefish	51%

Impoundment gear was used to catch 34.5 million pounds of mixed commercial species during 1971-1975 from Michigan's waters of the upper three lakes. During the same period, gill nets produced only 28.6 million pounds from the same wtaers. Both types of gear caught the same species of fish except chubs which came mainly from gill nets. This evidence shows that practically any species of commercial value can be efficiently harvested with selective impoundment gear throughout Michigan's Great Lakes waters.

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