MINIMUM SIZE LIMITS FOR YELLOW PERCH *(PERCA FLAVESCENS)* IN WESTERN LAKE ERIE

by

WILBUR L. HARTMAN
Great Lakes Fishery Laboratory
U.S. Fish and Wildlife Service
1451 Green Road
Ann Arbor, Michigan 48105

STEPHEN J. NEPSZY
Ontario Fisheries Research Station
Ministry of Natural Resources
R.R. #2
Wheatley, Ontario, Canada NOP 2P0

and

RUSSELL L. SCHOLL
Ohio Department of Natural Resources
Fountain Square, Building C
Columbus. Ohio 432 15

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Wilbur L. Hartman, Stephen J. Nepszy, and Russell L. Scholl

ABSTRACT

During the 1960's yellow perch *(Perca flavescens)* of Lake Erie supported a commercial fishery that produced an average annual catch of 23 million pounds, as well as a modest sport fishery. Since 1969, the resource has seriously deteriorated. Commercial landings amounted to only 6 million pounds in 1976, and included proportionally more immature perch than in the 1960's. Moreover, no strong year classes were produced between 1965 and 1975. An interagency technical committee was appointed in 1975 by the Lake Erie Committee of the Great Lakes Fishery Commission to develop an interim management strategy that would provide for greater protection of perch in western Lake Erie, where declines have been the most severe. The committee first determined the age structure, growth and mortality rates, maturation schedule, and length-fecundity relationship for the population, and then applied Ricker-type equilibrium yield models to determine the effects of various minimum length limits on yield, production, average stock weight, potential egg deposition, and the Abrosov spawning frequency indicator (average number of spawning opportunities per female). The committee recommended increasing the minimum length limit of 5.0 inches to at least 8.5 inches. Theoretically, this change would increase the average stock weight by 36% and potential egg deposition by 44%, without significantly decreasing yield. Abrosov's spawning frequency indicator would rise from the existing 0.6 to about 1.2.

BACKGROUND

The yellow perch (Perca flavescens) was relatively unimportant in the fisheries of Lake Erie during the first 40 years of this century. Lake whitefish *(Coregonus clupeaformis),* lake herring *(Coregonus artedii),* and blue pike *(Stizostedion vitreum glaucum)* dominated commercial harvests during that era (Baldwin and Saalfeld 1962). But by the mid-1950's, these species had virtually disappeared as a result of intensive fishing, environmental degradation, and possibly stress from the invasion and extensive proliferation of rainbow smelt *(Osmerus mordax)* (Hartman 1973). The commercial fishing industry then focused its efforts on the abundant walleye *(Stizostedion vitreum vitreum)* and yellow perch. Sport fisheries for yellow perch did not become existent until after World War II.

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1 Contribution 552, Great Lakes Fishery Laboratory, U.S. Fish and Wildlife Service, Ann Arbor, Michigan 48105.

Annual commercial harvests of perch in Lake Erie averaged 4 million pounds in the 1940's but increased rapidly in the 1950's. They averaged about 22 million pounds by the mid-1960's (Fig. 1) and reached a record high of 34 million pounds in 1969 (primarily the product of a very strong year class produced in western Lake Erie in 1965).

Although these values represent lakewide harvests, at least 80% of the perch are landed from western Lake Erie and the western end of the central basin. These stocks have shown clear, classic signs of stress and deterioration since at least 1969. Commercial harvests steadily declined to less than 7 million pounds in 1976. Proportionally many more immature perch and far fewer older perch were present in commercial catches in the mid- 1970's than in the 1960's. For example, in the 1960's the average total length of perch in the catches usually exceeded 8 inches, in the 1970's it seldom reached 8 inches. Recruitment, as represented by a yearly index of the relative abundance of young-of-the-year perch based on number caught per hour of trawling with standard bottom trawls, became unstable

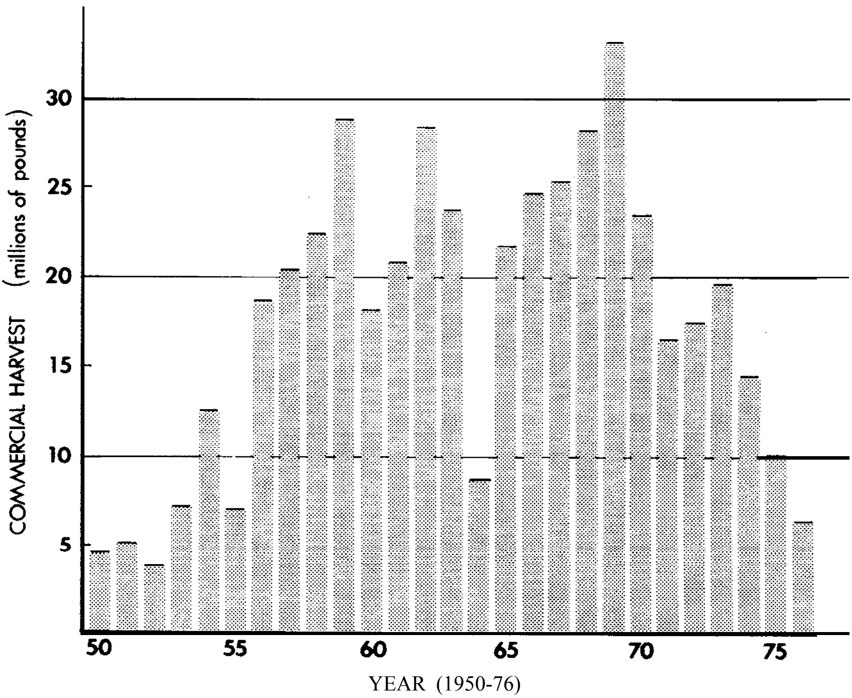

Figure 1. Commercial production of yellow perch from Lake Erie, Canadian and United States landings combined, 1950-76.

and greatly reduced; no strong year classes were produced in 1966-75 (Fig. 2).

The sport fishery for yellow perch has expanded during the past 15 years, but little was known about its magnitude until the mid-1970's. An intensive creel census, conducted in western Lake Erie by the Ohio Department of Natural Resources and the Ontario Ministry of Natural Resources in 1975-77, revealed that the current sport fishery accounts for nearly 40% in Ohio's waters and 10% in Canadian waters of the total harvest by both commercial and sport fisheries. Such an impact behooves fishery managers to at least consider measures to reduce total effort and catch by both fisheries. In this study, however we focus mainly on the effectiveness of the existing minimum size limit of 8.0 inches for the commercial fisheries.

Concern over the status of the yellow perch resource and the demonstrated signs of stress and deterioration developed rapidly during the early 1970's. By 1975, the agencies sharing management jurisdiction of western Lake Erie yellow perch-namely Michigan, Ohio, and Ontario-established a Yellow Perch Technical Committee under the auspices of the international Great Lakes Fishery Commission. This committee was directed to (1) develop the technical information required for considering alternative minimum size limits (MSL) as a management measure to help protect and enhance the perch stocks; (2) submit recommendations for an

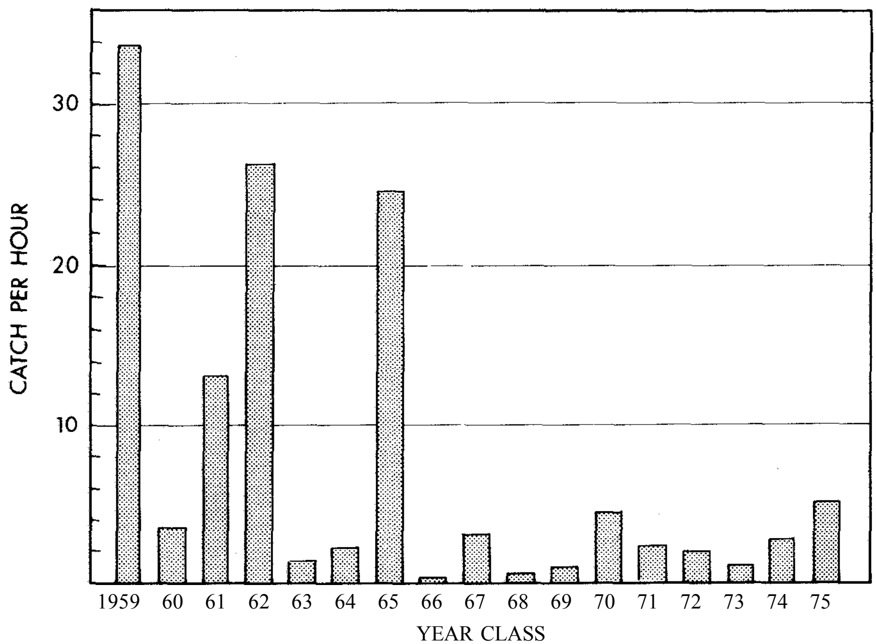

Figure 2. Average number of young-of-the-year yellow perch caught per hour of trawling in western Lake Erie, summer and fall, in different years. 1959-75.

alternative MSL: and (3) recommend an assessment protocol for evaluating the response of perch to such experimental management.

The choice of examining an indirect management strategy such as an increase in MSL to reduce catch, rather than a direct strategy such as a limited quota system, was predicated on the urgency for an immediate management option. But all agencies agreed that, as soon as possible, attention should be given to developing the scientific basis for implementing and evaluating a direct management strategy (i.e., a limited quota system), in the event such a system is required to stabilize the declining resource and to begin rebuilding it.

ANALYTICAL APPROACH

Delineation of the resource

The technical committee decided that the major portion of the resource showing signs of severe stress and the need for rehabilitation was encompassed by the most westerly fishery statistical districts ME-1, OE-1, O-1, and 0-4 (Sandusky Bay) as described by Smith et al. (1961). The technical committee believed, however, that the methodology employed in this study and indeed the results, with some modifications based on different population characteristics, would also be applicable to more easterly stocks of yellow perch in Lake Erie.

Source of data

Comparable data from State, Provincial, and Federal research and management tiles, when available, were usually pooled. Otherwise, a data set or display from a single agency was used as documentation when it was accepted by all three agencies as being the most complete and reasonable representation of the particular parameters concerned.

General approach

After establishing growth and mortality rates, based on the analysis of pooled data, the committee used Ricker-type (Ricker 1975) equilibrium yield models to determine the effects of alternative MSL's on yield, production, and average stock weight. Then, after establishing the fecundity relation and the maturity schedule for females, we modified the equilibrium yield models to examine the effects of alternative MSL's on potential egg deposition. We also developed and evaluated Abrosov-type spawning frequency indicators (Abrosov 1967) for yellow perch from western Lake Erie. Finally, on the basis of all these data and analyses, we recommended the most reasonable MSL for experimental management.

PROCEDURES AND RESULTS

Growth

Growth rates, as reflected by the average length of age groups 0^+ to III+ in the fall, have remained stable in western Lake Erie with little variation from year to year since the late 1950's (Fig. 3). They did not increase even after the sharp declines in abundance of yellow perch in the years after 1969. We conclude, therefore, that yellow perch in the highly productive waters of western Lake Erie may be close to their full growth potential under present environmental and community conditions. Such stability in growth rate greatly enhances the reliability and predictability of our equilibrium yield projections. Mean lengths of each age group (sexes combined) at the start of the year were determined from samples taken from spring commercial trap-net landings over the past several years. Mean weights of each age group were computed from a length-weight relation determined for 381 yellow perch sampled in the western basin in 1971-74 (Fig. 4). Instantaneous growth rates were computed as the difference between the natural logarithms of average weights for adjacent age groups.

Mortality

An average total mortality rate of A = 70% was estimated from Ontario commercial catch curve analyses for the years 1965-73. We gave

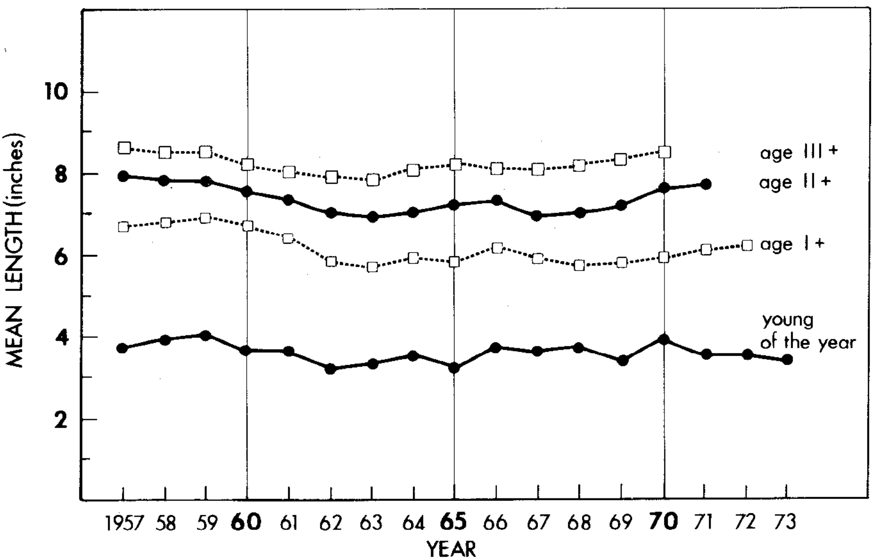

Figure 3. Trend in growth for age groups of yellow perch in western Lake Erie, 1957-73, as determined from average lengths of fish sampled in the fall each year.

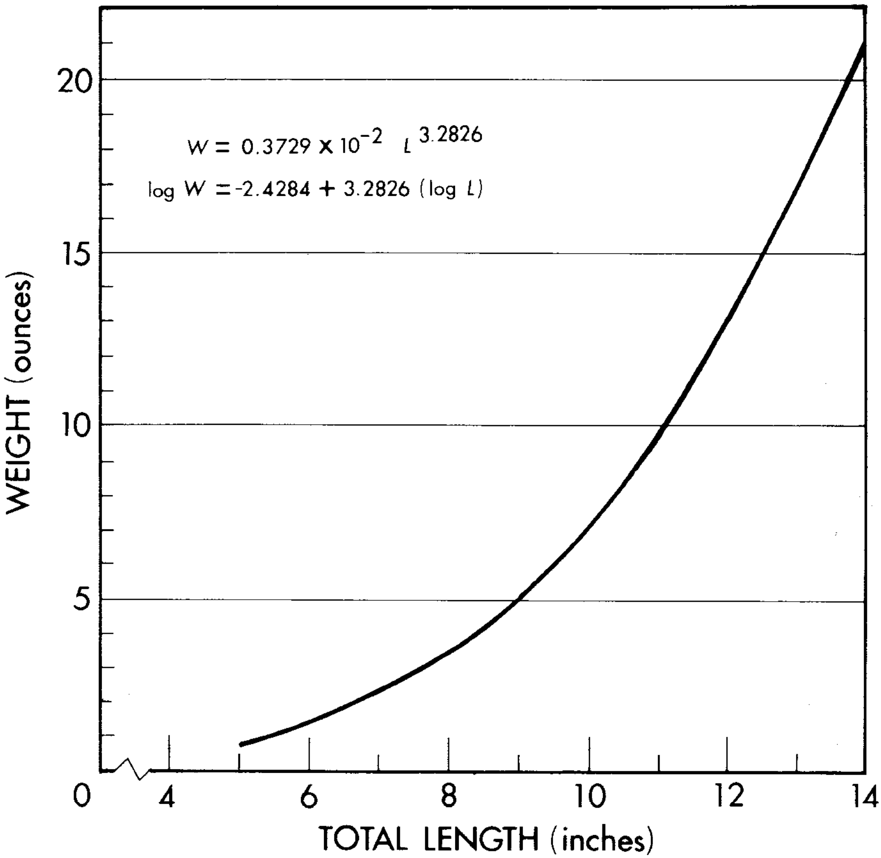

Figure 4. Length-weight relationship for western Lake Erie yellow perch, 1971-74, based on 381 specimens.

the estimates for 1971, 1972, and 1973 double weight to more closely reflect the most current conditions. Since perch are heavily exploited immediately after recruitment each year and since fishing is by far the larger component of total mortality, we considered the relative annual rates of total and fishing mortality to be essentially constant from year to year.

An annual natural mortality rate of n = 22.5% was arbitrarily selected on the basis of limited data published for other systems (e.g., for yellow perch in Red Lakes, Minnesota, *n* was 20 to 25% under heavy fishing pressure, see Heyerdahl and Smith 1971). As a first approximation, the value of n = 22.5% was considered uniform over all age groups recruited to the fishery. In a second and biologically more realistic approximation we employed a staggered natural mortality rate schedule that averaged

22% over all age groups but reflected an increasing mortality rate at successive ages (15% for III-IV; 18% for IV-V; 21% for V-VI; 24% for VI-VII; 27% for VII-VIII).

An annual fishing mortality rate of 6 1.3% was derived by determining the instantaneous rates for total mortality (Z) where A = l-e-z, and natural mortality (M) where n = $1-e^{-M}$, then determining the instantaneous rate for fishing mortality (F) where Z = F+M, and finally transforming back to the annual fishing mortality rate (m) where *m = 1-e-F.*

On the basis of historical data on longevity of yellow perch from western Lake Erie, we concluded that age-group VIII should be the upper limit of the model population age structure. Fish in age-group IX were rarely observed in commercial or survey catches.

Yield

Using the growth and mortality parameters described above, we constructed Ricker-type equilibrium yield models to determine the effects of the successive protection of age groups III, IV, and V by alternative MSL's on the yield from a recruitment unit of 1,000 pounds of fish. We used three different fishing mortality rates-55, 61.3, and 70% to ensure that the range of empirical expectation for the yellow perch of western Lake Erie would be fully covered. The results of the equilibrium yield computations are given in Tables l-6.

In the basic model employing empirical growth characteristics and mortality rates of 22.5% (natural) and 61.3% (fishing), the yield changes little whether yellow perch are first exploited as III year old fish, or not until they are IV, V, or VI years old. The lowest expected yield is 1,048 pounds and highest 1,167 pounds, the differences being less than 10% of the maximum. Virtually the same conclusions can be drawn from Model II where a lower rate of fishing was applied, and Model III where a higher rate of fishing was used. Ricker (1975), who found this same condition for bluegills in Muskellunge Lake, Indiana, arrived at the following conclusions:

First, there is considerable leeway allowed for errors in the data from which the computation of minimum size is made. Secondly, it is evidently not important to determine the exact optimum minimum size for maximum yield. *Third,* if it were known that a certain minimum size is best from the point of view of regulating the size of the stock so as to obtain optimum recruitment, then a considerable adjustment of the minimum could be made to meet this requirement without sacrificing any significant part of the yield from whatever recruits actually appear. *Fourth,* if either the individual size of the fish caught, or the catch per unit of effort, are important considerations in respect to the fishery, either of these can be favored by the regulations to a considerable degree without significant loss of yield. *Fifth,* if the minimum size has to be specified as to what a given mesh of net will catch rather than as a fixed limit based on measure-

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Table 1. Instantaneous rates of growth (G), natural mortality (M), and fishing mortality (F) for yellow perch of western Lake Erie. Model I. Mortality rates n = 22.5% and m = 61.3% are assumed to be constant within years and between years when operative. Submodels demonstrate effect on yield of successively protecting age group II, age group III, etc.

Age Group	Mean Total Length (in)	Mean Weight (lbs)	G	M	F	G-M-F	Weight Change Factor	Stock Weight (lbs)	Average Stock Weight (lbs)	Production (lbs)	Yield (lbs)
Submodel 1. - Age Group III and Older Vulnerable.											
III	7.3	0.159						1,000			
			0.343	0.255	0.949	-0.866	0.423		712	244	676
IV	8.1	0.224						423			
			0.272	0.255	0.949	-0.932	0.394		295	80	280
V	8.8	0.294						167			
			0.285	0.255	0.949	-0.919	0.399		117	33	III
VI	9.6	0.391						66			
			0.262	0.255	0.949	-0.942	0.390		46	12	44
VII	10.4	0.508						26			
			0.243	0.255	0.949	-0.961	0.382		18	4	17
VIII	11.2	0.648						10			
									1,188	373	1,128
Submodel 2. - Age Group IV and Older Vulnerable.											
III	7.3	0.159						1,000			
			0.343	0.255	0	+0.088	1.092		1,046	359	0
IV	8.1	0.224						I.092			
			0.272	0.255	0.949	-0.932	0.394		761	207	722
V	8.8	0.294						430			
			0.285	0.255	0.949	-0.919	0.399		301	86	286
VI	9.6	0.391						172			
			0.262	0.255	0.949	-0.942	0.390		120	31	114

VII	10.4	0.508						67			
			0.243	0.255	0.949	−0.961	0.382		47	11	45
VIII	11.2	0.648						26			
									2,275	694	1,167

Submodel 3. - Age Group V and Older Vulnerable.

III	7.3	0.159						1,000			
			0.343	0.255	0	+0.088	1.092		1,046	359	0
IV	8.1	0.224						1,092			
			0.272	0.255	0	+0.017	1.017		1,102	300	0
V	8.8	0.294						1,111			
			0.285	0.255	0.949	-0.919	0.399		777	221	737
VI	9.6	0.391						443			
			0.262	0.255	0.949	-0.942	0.390		308	81	292
VII	10.4	0.508						173			
			0.243	0.255	0.949	-0.961	0.382		120	29	114
VIII	11.2	0.648						66			
									3,353	990	1,143

Submodel 4. - Age Group VI and Older Vulnerable.

III	7.3	0.159						1,000			
			0.343	0.255	0	+0.088	1.092		1,046	359	0
IV	8.1	0.224						1,092			
			0.272	0.255	0	+0.017	1.017		1,102	300	0
V	8.8	0.294						1,111			
			0.285	0.255	0	+0.030	1.031		1,128	321	0
VI	9.6	0.391						1,145			
			0.262	0.255	0.949	-0.942	0.390		796	209	755
VII	10.4	0.508						447			
			0.243	0.255	0.949	-0.961	0.382		309	75	293
VIII	11.2	0.648						171			
									4,381	1,264	1,048

Table 2. Instantaneous rates of growth (G), natural mortality (M), and fishing mortality(F) for yellow perch of western Lake Erie. Model II. Mortality rates n = 22.5% and *m* = 55% are assumed to be constant within years and between years when operative. Submodels demonstrate effect on yield of succesively protecting age group II, age group III, etc.

Age Group	Mean Total Length (in)	Mean Weight (lbs)	G	M	F	G-M-F	Weight Change Factor	Stock Weight (lbs)	Average Stock Weight (lbs)	Production (lbs)	Yield (lbs)
Submodel I. - Age Group III and Older Vulnerable.											
III	7.3	0.159						1,000			
			0.343	0.255	0.799	-0.711	0.49 I		746	256	596
IV	8.1	0.224						491			
			0.272	0.255	0.799	-0.782	0.457		358	97	286
V	8.8	0.294						224			
			0.285	0.255	0.799	-0.769	0.464		164	47	131
VI	9.6	0.391						104			
			0.262	0.255	0.799	-0.792	0.453		76	20	61
VII	10.4	0.508						47			
			0.243	0.255	0.799	-0.81 I	0.444		34	8	27
VIII	11.2	0.648						21			
									1,378	428	I.101
Submodel 2. - Age Group N and Older Vulnerable.											
III	7.3	0.159						1,000			
			0.343	0.255	0	+0.088	I.092		1,046	359	0
IV	8.1	0.224						I.092			
			0.272	0.255	0.799	-0.782	0.457		796	217	636
V	8.8	0.294						499			
			0.285	0.255	0.799	-0.769	0.464		366	104	292
VI	9.6	0.391						232			
			0.262	0.255	0.799	-0.792	0.453		169	44	135
VII	10.4	0.508						105			
			0.243	0.255	0.799	-0.811	0.444		76	18	61

VIII	*11.2*	*0.648*						47			
									2,453	742	1,124

Submodel 3. - Age Group V and Older Vulnerable.

III	7.3	0.159						1,000			
			0.343	0.255	0	+0.088	1.092		1,046	359	0
IV	8.1	0.224						I.092			
			0.272	0.255	0	+0.017	1.017		1,102	300	0
V	8.8	0.294						1,111			
			0.285	0.255	0.799	-0.769	0.464		813	232	650
VI	9.6	0.391						515			
			0.262	0.255	0.799	-0.192	0.453		374	98	299
VII	10.4	0.508						233			
			0.243	0.255	0.799	-0.811	0.444		169	41	135
VIII	11.2	0.648						104			
									3,504	1,030	1,084

Submodel 4. - Age Group VI and Older Vulnerable.

III	1.3	0.159						1,000			
			0.343	0.255	0	+0.088	1.092		1,046	359	0
IV	8.1	0.224						1,092			
			0.212	0.255	0	+0.017	1.017		1,102	300	0
V	8.8	0.294						1,111			
			0.285	0.255	0	+0.030	1.031		1,128	321	0
VI	9.6	0.391						1,145			
			0.262	0.255	0.799	-0.792	0.453		832	218	665
VII	10.4	0.508						519			
			0.243	0.255	0.799	-0.81 I	0.444		375	91	300
VIII	11.2	0.648						230			
									4,483	1,289	965

Table 3. Instantaneous rates of growth (G), natural mortality (M), and fishing mortality (F) for yellow perch of western Lake Erie. Model III. Mortality rates *n* = 22.5% and m = 70% are assumed to be constant within years and between years when operative. Submodels demonstrate effect on yield of successively protecting age group II, age group III, etc.

Submodel I. - Age Group III and Older Vulnerable.

Age Group	Mean Total Length (in)	Mean Weight (lbs)	G	M	F	G-M-F	Weight Change Factor	Stock Weight (lbs)	Average Stock Weight (lbs)	Production (lbs)	Yield (lbs)
III	7.3	0.159						1,000			
			0.343	0.255	1.204	-1.116	0.328		664	228	799
IV	8.1	0.224						328			
			0.272	0.255	1.204	- 1.187	0.305		214	58	258
V	8.8	0.294						100			
			0.285	0.255	1.204	-1.174	0.309		66	19	79
VI	9.6	0.391						31			
			0.262	0.255	1.204	-1.197	0.302		20	5	24
VII	10.4	0.508						9			
			0.243	0.255	1.204	- 1.216	0.296		6	1	5
VIII	11.2	0.648						3			
									970	311	1,165

*Submodel 2. - Age Group **IV** and Older Vulnerable.*

Age Group	Mean Total Length (in)	Mean Weight (lbs)	G	M	F	G-M-F	Weight Change Factor	Stock Weight (lbs)	Average Stock Weight (lbs)	Production (lbs)	Yield (lbs)
III	7.3	0.159						1,000			
			0.343	0.255	0	+0.088	1.092		1,046	359	0
IV	8.1	0.224						1,092			
			0.272	0.255	1.204	-1.187	0.305		713	194	858
V	8.8	0.294						333			
			0.285	0.255	1.204	-1.174	0.309		218	62	262
VI	9.6	0.391						103			
			0.262	0.255	1.204	-1.197	0.302		67	18	81
VII	10.4	0.508						31			
			0.243	0.255	1.204	-1.216	0.2%		20	5	24

VIII	11.2	0.648						9			
									2,064	638	***1.225***

Submodel 3. - Age Group V and Older Vulnerable.

III	7.3	0.159						**1,000**			
			0.343	0.255	0	+0.088	1.092		1,046	359	**0**
IV	8.1	0.224						1,092			
			0.272	0.255	0	+0.017	1.017		1,102	300	**0**
V	8.8	0.294						1,111			
			0.285	0.255	1.204	-1.174	0.309		727	207	875
VI	9.6	0.391						343			
			0.262	0.255	1.204	-1.197	0.302		224	59	270
VII	10.4	0.508						104			
			0.243	0.255	1.204	-1.216	0.2%		68	17	82
VIII	11.2	0.648						31			
									3,167	942	1.227

Submodel 4. - Age Group VI and Older Vulnerable.

III	7.3	0.159						**1,000**			
			0.343	0.255	0	+0.088	1.092		1,046	359	**0**
IV	8.1	0.224						1,092			
			0.272	0.255	0	+0.017	1.017		1,102	300	**0**
V	8.8	0.294						1,111			
			0.285	0.255	0	+0.030	1.031		1,128	321	**0**
VI	9.6	0.391						1,145			
			‘0.262	0.255	1.204	-1.197	0.302		746	195	898
VII	10.4	0.508						346			
			0.243	0.255	1.204	-1.216	0.296		224	54	270
VIII	11.2	0.648						102			
									4,246	1,229	1,168

Table 4. Instantaneous rates of growth (G), natural mortality (M), and fishing mortality (F) for yellow perch of western Lake Erie. Model IV. Mortality rate m = 61.3% is assumed to be constant within years and between years when operative. Natural mortality rate is assumed to increase from 15% for age group III for 30% for age group VIII at equal yearly increments of 3%. Submodels demonstrate effect on yield of successively protecting age group II, age group III, etc.

Age Group	Mean Total Length (in)	Mean Weight (lbs)	G	M	F	G-M-F	Weight Change Factor	Stock Weight (lbs)	Average Stock Weight (lbs)	Production (lbs)	Yield (lbs)
Submodel I. - Age Group III and Older Vulnerable.											
III	7.3	0.159						1,000			
			0.343	0.163	0.949	-0.769	0.464		732	251	695
IV	8.1	0.224						464			
			0.272	0.198	0.949	-0.875	0.417		329	89	312
V	8.8	0.294						193			
			0.285	0.236	0.949	-0.900	0.407		136	39	129
VI	9.6	0.391						79			
			0.262	0.274	0.949	-0.961	0.382		55	14	52
VII	10.4	0.508						30			
			0.243	0.315	0.949	-1.021	0.360		21	5	20
VIII	11.2	0.648						II			
									1,273	398	1,172
Submodel 2. - Age Group N und Older Vulnerable.											
III	7.3	0.159						1,000			
			0.343	0.163	0	+0.180	I.197		1,099	377	*0*
IV	8.1	0.224						1,197			
			0.272	0.198	0.949	-0.875	0.417		848	231	805
V	8.8	0.294						499			
			0.285	0.236	0.949	-0.900	0.407		351	100	333
VI	9.6	0.391						203			
			0.262	0.274	0.949	-0.961	0.382		141	37	134
VII	10.4	0.508						78			

			0.243	0.315	0.949	-1.021	0.360		53	13	50
VIII	11.2	0.648						28			
									2,492	758	1,322

Submodel 3. - Age Group V and Older Vulnerable.

III	7.3	0.159						1,000			
			0.343	0.163	0	+0.180	1.197		1,099	377	0
IV	8.1	0.224						1,197			
			0.272	0.198	0	+0.074	1.076		1,243	339	0
V	8.8	0.294						1,288			
			0.285	0.236	0.949	-0.900	0.407		906	258	860
VI	9.6	0.391						524			
			0.262	0.274	0.949	−0.961	0.382		362	9.5	344
VII	10.4	0.508						200			
			0.243	0.3 15	0.949	-1.021	0.360		136	33	129
VIII	*11.2*	*0.648*						72			
									3,746	1,102	1,333

Submodel 4. - Age Group VI and Older Vulnerable

III	7.3	0.159						1,000			
			0.343	0.163	0	+0.180	1.197		*1,099*	377	0
IV	8.1	0.224						1,197			
			0.272	0.198	0	+0.074	1.076		1,243	339	0
V	8.8	0.294						1,288			
			0.285	0.236	0	+0.049	1.050		1,320	376	0
VI	9.6	0.391						1,352			
			0.262	0.274	0.949	-0.96 I	0.382		935	245	887
VII	10.4	0.508						517			
			0.243	0.315	0.949	- 1.021	0.360		352	86	334
VIII	11.2	0.648						186			
									4,949	1,423	1.221

Table 5. Instantaneous rates of growth (G), natural mortality (M), and fishing mortality (F) for yellow perch of western Lake Erie. Model V. Mortality *m* = 55% is assumed to be constant within years and between years when operative. Natural mortality rate is assumed to increase from 15% for age group III to 30% for age group VIII at equal yearly increments of 3%. Submodels demonstrate effect on yield of successively protecting age group II, age group III, etc.

Age Group	Mean Total Length (in)	Mean Weight (lbs)	G	M	F	G-M-F	Weight Change Factor	Stock Weight (lbs)	Average Stock Weight (lbs)	Production (lbs)	Yield (lbs)
Submodel I. - Age Group III and Older Vulnerable.											
III	7.3	0.159						*I.000*			
			0.343	0.163	0.799	-0.699	0.497		749	257	598
IV	8.1	0.224						497			
			0.272	0.198	0.799	-0.725	0.484		369	100	295
V	8.8	0.294						241			
			0.285	0.236	0.799	-0.750	0.472		178	51	142
VI	9.6	0.391						114			
			0.262	0.274	0.799	-0.8 I I	0.444		82	21	66
VII	10.4	0.508						50			
			0.243	0.315	0.799	-0.871	0.419		36	9	29
VIII	11.2	0.648									
									1,414	438	I.130
Submodel 2. - Age Group N and Older Vulnerable.											
III	7.3	0.159						1,000			
			0.343	0.163	0	+0.180	1.197		I ,099	377	0
IV	8.1	0.224						1,197			
			0.272	0.198	0.799	-0.725	0.484		888	242	710
V	8.8	0.294						579			
			0.285	0.236	0.799	-0.750	0.472		426	121	340
VI	9.6	0.391						273			
			0.262	0.274	0.799	-0.811	0.444		197	52	157
VII	10.4	0.508						121			

			0.243	0.315	0.799	-0.87 I	0.419		86	21	69
VIII	11.2	0.648									
									2.696	813	1,276

Submodel 3. - Age Group V and Older Vulnerable.

III	7.3	0.159						1,000			
			0.343	0.163	0	+0.180	1.197		1,099	377	0
IV	8.1	0.224						1,197			
			0.272	0.198	0	+0.074	1.076		1,243	338	0
V	8.8	0.294						1,288			
			0.285	0.236	0.799	-0.750	0.472		948	270	757
VI	9.6	0.391						608			
			0.262	0.274	0.799	-0.811	0.444		439	115	3.51
VII	10.4	0.508						270			
			0.243	0.315	0.799	-0.871	0.419		192	47	153
VIII	11.2	0.648						113			
									3,921	1,147	1,261

Submodel 4. - Age Group VI and Older Vulnerable

III	7.3	0.159						1,000			
			0.343	0.163	0	+0.180	1.197		1,099	377	0
IV	8.1	0.224						1,197			
			0.272	0.198	0	+0.074	1.076		1,243	338	0
V	8.8	0.294						1,288			
			0.285	0.236	0	+0.049	1.050		1,320	376	0
VI	9.6	0.391						1,352			
			0.262	0.274	0.799	-0.81 I	0.444		976	256	780
VII	10.4	0.508						600			
			0.243	0.3 15	0.799	-0.871	0.419		426	104	340
VIII	11.2	0.648						252			
									5,064	1,451	1,120

Table 6. Instantaneous rates of growth (G), natural mortality (M) and fishing mortality (F) for yellow perch of western Lake Erie. Model VI. Mortality *m* = 70% is assumed to be constant within years and between years when operative. Natural mortality rate is assumed to increase from 15% for age group III to 30% for age group VIII at equal yearly increments of 3%. Submodels demonstrate effect on yield of successively protecting age group II, age group III, etc.

Age Group	Mean Total Length (in)	Mean Weight (lbs)	G	M	F	G-M-F	Weight Change Factor	Stock Weight (lbs)	Average Stock Weight (lbs)	Production (lbs)	Yield (lbs)
Submodel I. - Age Group III and Older Vulnerable.											
III	7.3	0.159						**1,000**			
			0.343	0.163	1.204	-1.204	0.359		680	233	819
IV	8.1	0.224						359			
			0.272	0.198	1.204	-1.130	0.323		238	65	287
V	8.8	0.294						116			
			0.285	0.236	I.204	-1.155	0.315		77	22	93
VI	9.6	0.391						37			
			0.262	0.274	1.204	- 1.216	0.296		24	6	29
VII	10.4	0.508						II			
			0.243	0.315	1.204	- 1.276	0.279		7	2	8
VIII	11.2	0.648						3			
									I.026	328	1.236
Submodel 2. - Age Group IV and Older Vulnerable.											
III	7.3	0.159						**1,000**			
			0.343	0.163	0	+0.180	1.197		1,099	377	0
IV	8.1	0.224						1,197			
			0.272	0.198	1.204	-1.130	0.323		792	215	954
V	8.8	0.294						387			
			0.285	0.236	1.204	- 1.155	0.315		255	73	307
VI	9.6	0.391						122			
			0.262	0.274	1.204	- 1.216	0.2%		79	21	95
VII	10.4	0.508						36			

			0.243	0.315	1.204	- 1.276	0.279		23	6	28
VIII	11.2	0.648						10			
									2,248	692	1,384

Submodel 3. - Age Group V and Older Vulnerable.

III	7.3	0.159						1,000			
			0.343	0.163	0	+0.180	1.197		1,099	377	0
IV	8.1	0.224						1,197			
			0.272	0.198	0	+0.074	1.076		1,243	338	0
V	8.8	0.294						1,288			
			0.285	0.236	1.204	-1.155	0.315		847	241	1,020
VI	9.6	0.391						406			
			0.262	0.274	1.204	-1.216	0.2%		263	69	317
VII	10.4	0.508						120			
			0.243	0.315	1.204	- 1.276	0.279		77	19	93
VIII	11.2	0.648						34			
									3,529	1,044	1,430

Submodel 4. - Age Group VI and Older Vulnerable.

III	7.3	0.159						1,000			
			0.343	0.163	0	+0.180	1.197		1,099	377	0
IV	8.1	0.224						1,197			
			0.272	0.198	0	+0.074	1.076		1,243	338	0
V	8.8	0.294						1,288			
			0.285	0.236	0	+0.049	1.050		1,320	376	0
VI	9.6	0.391						1,352			
			0.262	0.274	1.204	-1.216	0.296		876	230	1,055
VII	10.4	0.508						400			
			0.243	0.315	1.204	-1.276	0.279		256	62	308
VIII	11.2	0.648						112			
									4,794	1,383	1,363

ment of individual fish, this will usually be almost as effective as a sharp cut-off size (though the fate of the rejected fish needs to be considered whether they survive or die). *Finally,* if it is desirable to have a uniform minimum standard apply to a number of bodies of water, or even to different kinds of fish, for which the optimum minima are different, this will be possible without any great sacrifice of yield, provided the optima are not too diverse.

The same three rates of fishing are used in Models IV, V, and VI, but with a graduated schedule of natural mortality increasing with age from n = 15% for age group III to n = 27% for age group VII. Yield maxima occur in the MSL range of protecting age groups III and IV in Models IV and V, respectively, and at age group V in Model VI. However, as in the first three models, estimated yields across this range of MSL are very similar (Fig. 5) and the conclusions of Ricker presented above apply here as well.

Average stock weight

Inasmuch as we have found that yield in weight per recruitment of 1,000 pounds was not seriously reduced by any reasonable increase in the MSL, we examined the effects of alternate MSL's on the critical problem of inadequate recruitment. Average stock weight reflects population size during the year, and can also be considered average biomass or average

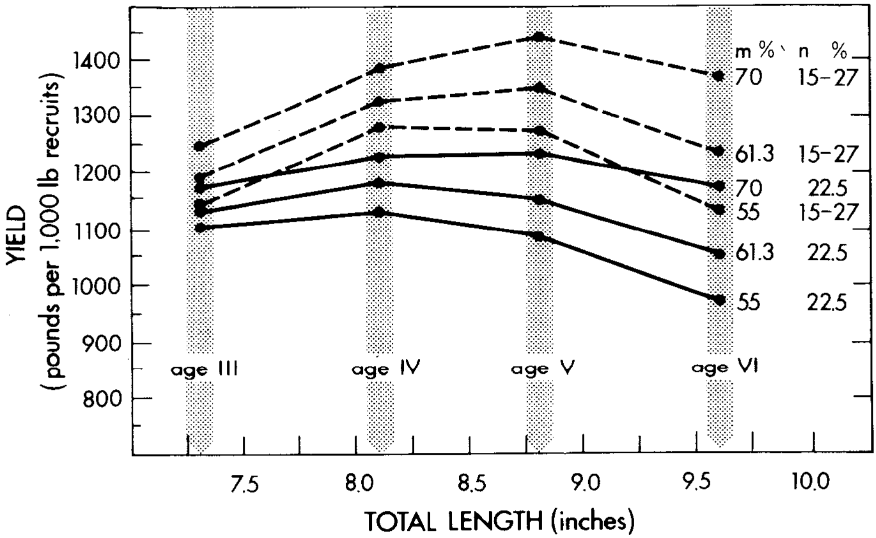

Figure 5. Yield of yellow perch in pounds per 1,000 pounds of recruits at age III from computation of equilibrium yield for six models employing different rates of natural (n) and fishing *(m)* mortality and successively protecting age group II, age group III, etc.

standing stock. Average stock weights were totaled over all the years between age III and age VIII for all six models. Substantial increases in total average stock weight occurred in each model as each successive age group was protected by an elevated MSL (Table 7). In Model I, for example, with age group III protected, the total average stock weight was nearly doubled to 2,275 pounds. With age group IV protected, the total average stock weight increased another 1,000 pounds to 3,353 pounds. Finally, with age group V protected the total average stock weight increased to 4,381 pounds. The mean lengths of age groups III, IV, and V are roughly 0.7 inch apart. Therefore, raising the present MSL of 8.0 inches to 8.5 could increase biomass by about 50%, and raising it to 9.0 inches could nearly double it, once the system stabilized. Yet, in all these submodels there was virtually no change in yield per recruitment of 1,000 pounds. Consequently, as more units of 1,000 pounds become available total commercial production would increase correspondingly.

Production of yellow perch in weight was estimated in these models by multiplying average stock weight by the instantaneous growth rate (G). As stock weight increases through each model as age groups are sequentially protected by elevating the MSL, axiomatically natural production also increases. Theoretically, when production and yield are equal, the standing biomass fluctuates around a value that remains fairly stable through the years.

Fecundity, maturity, and potential egg deposition

The relation between number of eggs and total length has been determined for 66 yellow perch from the western basin of Lake Erie (Harry Van Meter, FWS unpublished data). The relation is expressed as $\log F = -4.119 + 3.629L$. where F is the number of eggs and L is total length in mm (Fig. 6). Fish 8 inches (203 mm) long produced about 17,000 eggs, and those 10 inches (254 mm) long produced about 38,300 eggs. Jumbo perch reaching 12 inches (305 mm) produced about 74,200 eggs.

The maturity schedule for male and female yellow perch from the western basin of Lake Erie was derived from a sample of 252 males and 143 females sampled during the spring, 1960-66 (Harry Van Meter, FWS unpublished data). Males mature at a much smaller length than females, as expected (Fig. 7). In terms of total length, virtually all males mature before any females reach maturity.

The equilibrium yield Model I presented above was modified to demonstrate the effects of alternative MSL’s on potential egg deposition (PED). The unit of recruitment into age group III is set at 1,000 pounds. Mean weights were used to convert the stock weight into numbers of females, and this number was adjusted into the numbers of mature females on the basis of the maturity schedule. The average egg content per age group was then multiplied by the adjusted number of females to estimate PED. The PED was then summed over the life span of that cohort to age group VIII.

Table 7. Yield, production, and average stock weight from computations of equilibrium yields (Ricker 1975) in relation to minimum size limit and different rates of fishing and natural mortality for yellow perch from western Lake Erie.

First Age Group Vulnerable	Average Stock Weight (lbs)	Yield (lbs)	Production (lbs)
Model I: m = 61.3%; F = 0.949; n = 22.5%: M = 0.255			
III	1.188	1,128	373
IV	2,275	1,167	694
V	3,353	1,143	990
VI	4,381	1.048	1,264
Model II: m = 55%; F = 0.799; n = 22.5%: M = 0.255			
III	1,378	1,101	428
IV	2,453	1,124	742
V	3,504	1,084	1,030
VI	4,483	965	1,289
Model III: m = 70%; F = 1.204; n = 22.5%; M = 0.255			
III	970	1,165	311
IV	2,064	1,225	638
V	3,167	1,227	942
VI	4,246	1,168	1,229
Model IV: m = 61.3%; F = 0.949[a]			
III	1,273	1.172	398
IV	2,492	1,322	758
V	3,746	1,333	1,102
VI	4,949	1,221	1,423
Model V: m = 55%: F = 0.799[a]			
III	1,414	1,130	438
IV	2,696	1,276	813
V	3,921	1,261	1,147
VI	5,064	1,120	1,451
Model VI: m = 70%; F = 1.204[a]			
III	1,026	1,236	328
IV	2,248	1,384	692
V	3,529	1,430	1,044
VI	4,794	1,363	1.383

[a]For models IV-VI, values n and Mare as follows:

	Age Groups					
	III	*IV*	*V*	*VI*	*VII*	*VIII*
n	15	21	24	27		
M	**0.163**	**0.198**	**0.236**	**0.274**	**0.315**	

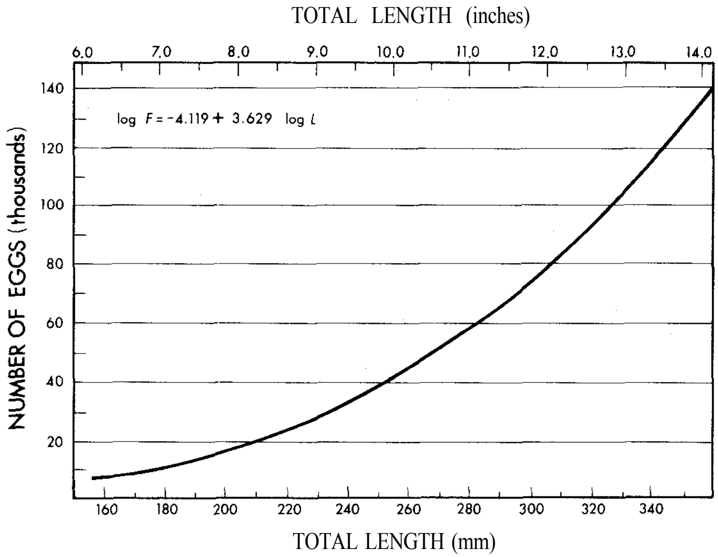

Figure 6. Relation between the number of eggs and total length in 66 yellow perch taken from western Lake Erie (curve fitted by regression).

Most fishery scientists agree that mortality is essentially compensatory during the early life history of most fishes (Ricker 1954), although no clear cut and direct relation between yellow perch brood stock (i.e., PED) and subsequent year-class strength has been documented in the literature. For our models on equilibrium yield, we assumed a general direct relation between numbers of spawners and numbers of young produced, although we are of course aware of the variability introduced by environmental factors.

Potential egg deposition increases substantially as each successive age group is protected in the model (Table 8). With age group III vulnerable to fishing, the PED is roughly 117 million. Protection of age group III essentially elevated the MSL by 0.8 inch, increased PED to 205 million. Protection of age group IV increased PED to nearly 294 million, and so on. Thus as the MSL in this model is raised, PED is considerably increased as a result of both greater stock weight and greater numbers of large fish with high fecundity.

Abrosov indicator of spawning frequency

The increase in the relative numbers of larger and older fish in the population not only increases potential egg deposition, but also the average number of times that a fish spawns during its life span. In the general indicator of spawning frequency developed by Abrosov (1967), t = 0-z where (0) the "commercial turnover indicator" is the time in years between hatching of fish and their average age when removed from the population

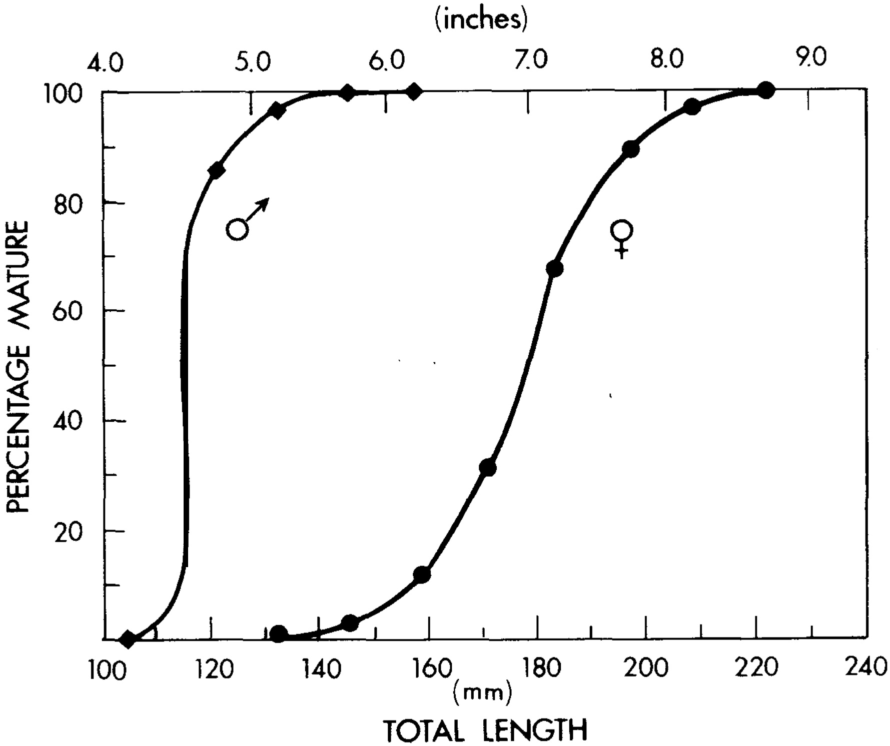

Figure 7. Relation between sexual maturity and total length for male and female yellow perch taken from western Lake Erie in spring, 1960-66 (unpublished data, Great Lakes Fishery Laboratory).

by the fishery, (z) is the time from hatching to the age of onset of sexual maturity, and (t) is the time from the age of sexual maturity to the average age at commercial removal. The symbol *t* represents the extent to which the average age at commercial capture exceeds the age at onset of sexual maturity in a specific population, and can be considered an indicator of spawning frequency.

Abrosov suggested r-values of 1.0 to 1.5 years in calculations based on numbers for pike-perch (*Lucioperca lucioperca*). Of the six species examined by Abrosov, the pike-perch is most closely related to yellow perch. Nevertheless, differences in longevity, maturity schedule, and age at capture must be considered. Our preliminary analyses for yellow perch from western Lake Erie suggested a present (1977) *t* value of 0.7 which is biologically too low. Theoretically, where yield equals production at approximately 9.1 inches (age group V) for yellow perch in western Lake Erie, *t* should equal 2. We did not expect this upper limit to be reached, but would expect t to increase somewhat as an older age structure is rebuilt by elevating the MSL. The increase in t would give some measure of the degree and rate at which management reaches its objectives. The protection afforded yellow perch that would result in a t value of between 1.1 and 1.5 years may be adequate to halt the present decline and permit the resource to rebuild. This in essence would result theoretically from protection of age group V fish.

CONCLUSIONS AND RECOMMENDATIONS

A synoptic picture of the effects on yield, average stock weight, biomass production, and potential egg deposition of protecting successive age groups, based on Model I in our equilibrium yield analyses, is given in Figure 8. The slopes of the four plotted relations are most important because they reflect incremental differences between different total lengths. Values for these characteristics of the model at total lengths of 7.50, 7.75, 8.00, 8.25 (etc.) inches were estimated from Figure 8 and itemized in Table 9, along with other biological information.

On the basis of the data in Table 9 and Figure 8, and elsewhere in this report, we offer the following conclusions.

1) The current MSL of 8.0 inches for the U.S. and Canadian commercial fisheries on yellow perch in western Lake Erie is inadequate to protect the declining resource under the current intensity of fishing: the potential for increased average stock weight and recruitment must be substantially improved. We believe that environmental conditions in western Lake Erie are still suitable for the production of sizable year classes if brood stock is adequate and weather conditions are favorable during spawning and egg incubation periods.
2) The theoretical MSL at which production would equal yield is about 9. I inches. An increase in MSL from 8.0 to 9.1 inches would increase average stock weight by 76% and PED by 92%, with no major decrease in yield. However, natural mortalities in the older age groups may be higher than we assumed in preparing our model, and the length where production equals yield may be somewhat less than 9.1 inches. Consequently, an MSL of 9.1 was treated as the upper limit during our considerations.
3) An MSL of 8.5 inches was considered the absolute minimum increase that would be likely to have a sustained positive effect on the declining resource. One member of the Technical Committee favored this value. Increasing the limit from 8.0 to 8.5 inches would increase average stock weight 36% and PED 44%, with essentially no decrease in yield. Abrosov's spawning frequency indicator (t) could rise from about 0.7 to 1.2. These potential benefits may be larger if the MSL of 8.5 inches is rigidly enforced, because in the past several years until 1976, especially in Canadian waters, the effective MSL has been slightly less than the statutory 8.0 inches.

Table 8. Effects of potential egg deposition of western Lake Erie yellow perch following the results of protecting age group II, age group III, etc. in Ricker's yield Model I with mortality rates n = 22.5% and m 61.3%.

Age Group	Mean Total Length (in)	Mean Weight (lbs)	Stock Weight (lbs)	Number Females	Mature Females (Percent)	Adjusted Number Females	Mean Egg Content		Potential Egg Deposition (Thousands)
Submodel I. - Age Group III and Older Vulnerable.									
III	7.3	0.159	1,000	6,289	75	4,717	12,950		61,085
IV	8.1	0.224	423	1,888	96	1,813	18,880		34,228
V	8.8	0.294	167	568	99	562	23,460		13,193
VI	9.6	0.391	66	169	100	169	29,970		5,059
VII	10.4	0.508	26	51	100	51	45,160		2,311
VIII	11.2	0.648	IO	15	100	15	71,710		1,107
								TOTAL	116,983
Submodel 2. - Age Group IV and Older Vulnerable.									
III	7.3	0.159	1,000	6,289	75	4,717	12,950		6 I,085
IV	8.1	0.224	I ,092	4,875	96	4,680	18,880		88,358
	8.8	0.294	430	1,463	99	1.448	23,460		33,969
VI	9.6	0.39 I	172	440	100	440	29,970		13,184
VII	10.4	0.508	67	132	100	132	45,160		5,956
VIII	11.2	0.648	26	40	100	40	71,710		2,877
								TOTAL	205,429

Submodel 3. - Age Group V and Older Vulnerable.

III	7.3	0.159	1,000	6,289	75	4,717	12,950		61,085
IV	8.1	0.224	1,092	4,875	%	4,680	18,880		88,358
				3,779	99	3,741	23,460		87,767
VI	8.8 9.6	0.294 0.391	1,111 443	1,133	100	1,133	29.970		33.956
VII	10.4	0.508	173	341	100	341	45,160		15,379
VIII	11.2	0.648	66	102	100	102	71,710		7,304
								TOTAL	293.849

Submodel 4. - Age Group VI and Older Vulnerable.

III	7.3	0.159	1,000	6,289	75	4,717	12,950		61,085
IV	8.1	0.224	1,092	4,875	%	4,680	18,880		88,358
V	8.8	0.294	1.111	3,779	99	3,741	23,460		87.764
VI	9.6	0.391	1,145	2,928	100	2,928	29,970		87,764
VII	10.4	0.508	447	880	100	880	45,160		39,737
VIII	11.3	0.648	171	264	100	264	71.710		18.923
								TOTAL	383.634

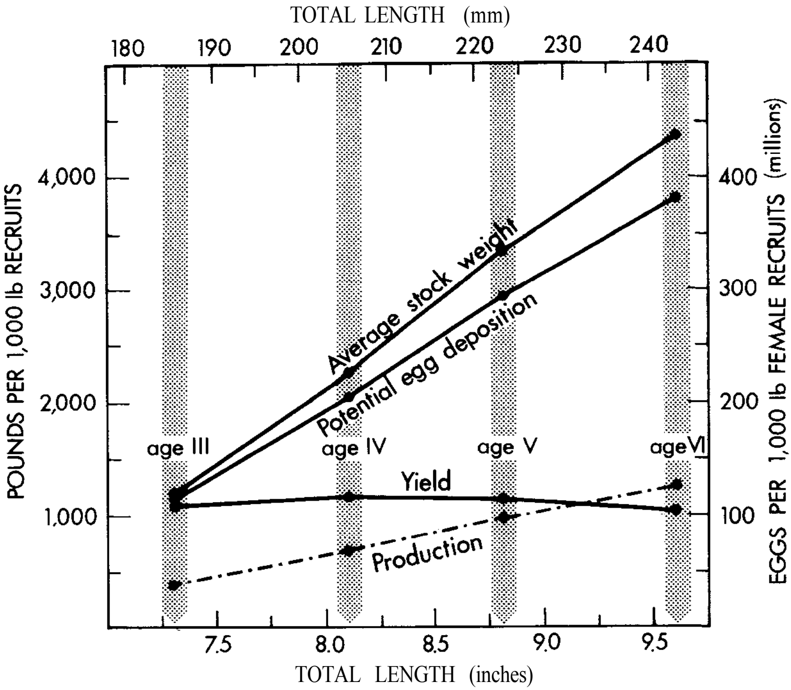

Figure 8. Yield, average stock weight, and biomass production derived in Model I using n = 22.5, m = 61.3%, and successively protecting age group II, age group III, etc. Potential egg deposition derived from Model I assuming a recruit of 1,000 pounds of females at age III.

4) The two other members of the Technical Committee favored recommendations of a new MSL of 8.75 inches. The theoretical benefits from elevating the MSL from 8.0 to 8.75 inches would be an increase in average stock weight of 54%, and an increase in PED of 66%, with essentially no decrease in yield. Abrosov's spawning frequency indicator could rise to 1.6. These members felt that the increase had to be substantial enough to have some positive impact, despite the possibility of continued poor spawning success over the next several years. In fact, evaluation of the spawning success for yellow perch in western Lake Erie for 1975 was only slightly better than the average since 1965. It was much poorer in 1976, much better than average in 1977, but again much poorer than average in 1978.
5) The final result was a recommendation by the Technical Committee of a new MSL between 8.5 and 8.75 inches, indicating that two of the three members favored the higher value. We acknowledged that the ultimate selection by the management agencies involved would depend not only on the technical evidence and evaluation presented in this report, but also on social, economic,

Table 9. Biological and population characteristics for yellow perch of western Lake Erie at different minimum size limits from 7.5, to 9.25 inches. Yield is based on a recruitment of 1,000 pounds (sexes combined). Potential egg deposition is based on a recruitment of 1,000 pounds of females.

Size Limit (Total Length in inches)	Mean Weight (lbs)	Mature Females[a] (Percent)	Yield (lbs)	Average Stock Weight (lbs)	Number Females	Adjusted Number Females		Mean Egg Content (no.)		Potential Egg Deposition (Thousands)
7.50	.172	82	1,120	1,450	8,430	6,913	×	14,280	-	98,718
7.75	.191	91	1,135	1,790	9,372	8,528	×	16,080	-	137,130
8.00	.213	95	1,150	2,125	9,977	9,478	×	18,050	-	171,078
8.25	.237	98	1,150	2,500	10,549	10,338	×	20,180	-	208,621
8.50	.262	99	1,145	2,890	11,031	10,920	×	22,490	-	245,591
8.75	.289	100	1,140	3,270	11,315	11,315	×	24,980	-	282,649
9.00	.320	100	1,110	3,610	11,281	11,281	×	27,680	-	3 12,258
9.25	.346	100	1,075	3,930	I 1,358	I 1,358	×	30,570	-	347,214

[a]All males would be expected to be mature at all minimum size limits shown.

and political constraints within each agency. However because of the continued deterioration of the resource through 1976, we strongly emphasized the urgency of more protective regulations.

Special considerations

If the MSL is substantially elevated, temporary decreases in harvest must not be mistaken for indications of long-term prospects. Change from old to new conditions, based on predictions from the equilibrium yield models and other evidence, will take at least 2 (if not 3) years for western Lake Erie yellow perch. This is the number of age groups vulnerable and available in significant numbers to the contemplated fishery. In other words, the age groups gaining protection by an increased MSL will take 2 or 3 years to grow into the fishable stock. The process of increasing the biomass and restoration of the more acceptable age structure will then require 2 or 3 more years. Favorable or adverse environmental conditions during spawning may accelerate or delay the rehabilitation process each year.

The Technical Committee also recognized that the manner in which a standard MSL would be regulated would differ between fisheries and would be the prerogative of the individual management agencies. For example, in a trapnet fishery, the regulation may be the actual MSL; but for a gillnet fishery the regulation may stipulate the use of a minimum mesh size that will effectively produce the same MSL.

The Technical Committee also suggested that the agencies consider further restrictions on exploitation *by* all user groups (including sport fisheries) until the resource has recovered to former levels of abundance and exhibits a greater degree of stability than presently exists.

The Technical Committee also noted that statistical limits of variability associated with the relation presented for length/weight, length/fecundity, and length/maturity were not displayed in the report. In all of these standards relationships, the raw empirical data points formed a tight and consistent pattern along each of the regression lines.

Protocol for evaluating response of the resource to experimental management

The Committee became aware of the inadequacies of some of the historical biological data used to develop the basis for evaluating the effects of different minimum size limits. The representatives of all three agencies were convinced of the need for continuous collection of more nearly complete, more accurate, and more closely comparable data on the biological and population characteristics of yellow perch and on the effort and catch characteristics of the fisheries. Consequently the Technical Committee recommended the following guidelines to the management agencies:

1) Maintain resource-wide catch statistics in pounds for sport and commercial fisheries to determine yield levels and trends, and examine sport and commercial catches for increases in average fish size and the strengthening of older age groups in the population structure.
2) Maintain abundance indices for young-of-the-year and other young fish to detect any relative increases in recruitment.
3) Monitor growth and mortality rates for changes. The results of this analysis of MSL were predicated on the instantaneous rate of fishing mortality (F) remaining relatively stable over the years. Any substantial increases in F, caused possibly by a substantial increase in fishing effort, could, to some extent, reduce the benefits of an increased MSL.
4) Annually reassess Abrosov's spawning frequency indicator (t) for trends.
5) Provide for periodic interagency evaluation of the effectiveness of , any new MSL, and readjustment if required.

EPILOGUE

Although the technical report and recommendation were accepted in 1976 by all fishery agencies sharing jurisdiction over yellow perch in western Lake Erie-namely Ontario, Michigan, and Ohio-an elevated MSL had not yet been imposed by early 1980. Although stricter enforcement of the existing MSL of 8.0 inches for commercial catches since 1976 has resulted in a smaller percentage of sublegal fish in the catch and a higher average size, overall the condition of the resource has not improved and new management initiatives may ultimately be necessary. The analyses and recommendations of this Technical Committee should then **be** useful.

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