Collection and Analysis of Commercial Fishery Statistics in the Great Lakes

Great Lakes Fishery Commission

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COLLECTION AND ANALYSIS OF COMMERCIAL FISHERY STATISTICS IN THE GREAT LAKES

by

RALPH HILE

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

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GREAT LAKES FISHERY COMMISSION
1451 Green Road
P.O. Box 640
Ann Arbor, Michigan

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ABSTRACT

Catch-effort statistics are submitted on closely similar monthly report forms by licensed commercial fishermen throughout U.S. and Canadian waters of the Great Lakes. This form was tested experimentally in State of Michigan waters in 1926; monthly submittal was required of Michigan fishermen beginning September 1927. Use of the form spread gradually to other states and Ontario; full coverage was achieved in 1950. The procedure for tabulation and analysis of the statistics also is the same in all states and Ontario.

Much of the present report is concerned with the development of the analytical procedure and the illustration, through example, of its operation. An early discovery was the need for completely independent tabulations of effort for each of the principal species. To meet this need, effort was charged to a species only on those days when some poundage was produced. At about the same time it was learned that the catch per lift of stationary gear, without any consideration of fishing time (nights out) before lifting, gives satisfactory estimates of fluctuations in abundance.

Later developments were concerned mostly with the use of catch-effort statistics for dissimilar gears to obtain single index figures for abundance and fishing intensity. The procedure now employed is described and illustrated.

Special circumstances have made necessary certain exceptions to the standard procedure. Exceptions made to date are listed and the reasons for them explained. Explanations are given also of certain special computational problems, and the disruptive effects of changes of regulation are reviewed.

INTRODUCTION

The extensive and diverse fisheries of the Great Lakes offer many unique situations. Despite their considerable area of 95,000 square miles, the lakes contain no international waters; the boundary between the United States and Canada is precisely defined. The 61,000 square miles that lie within the United States are subdivided-again by clearly defined boundaries-among the 8 bordering states. The states thus own the U.S. waters of the Great Lakes and they have absolute jurisdiction over the fisheries within their several borders. All Canadian waters of the Great Lakes (34,000 square miles) lie in the Province of Ontario, but the fisheries are the property of the Canadian federal government. Under arrangements between the federal and provincial governments, however, Ontario has, in effect, power over its fisheries almost equal to that of any state.

The division of Great Lakes waters among 9 political jurisdictions has led to 9 largely independent approaches to management of the fisheries-regulations on licensing, boats, gear, size limits, closed season, ... The lack of uniformity is irritating to the industry and sometimes is economically burdensome. Many and sincere attempts have been made to ease the situation but improvements at best have been meager.

The collection and analysis of commercial fishery statistics stand in refreshing contrast to the confusing differences in regulation. All 8 states and Ontario collect these statistics by the same method and all statistical data are treated by the same analytical procedure. It is the purpose of this paper to review the origin and development of this statistical system, to explain the logic that underlies the analytical procedure, and to comment on various sources of weakness and strength.

The accounts of procedure given here are based almost entirely on work with the statistics for the State of Michigan waters of the Great Lakes. Usable records for other waters do not yet cover a sufficient span of years for the establishment of the base or reference period that is fundamental to the system of analysis.

Although this paper is concerned only with the collection and analysis of catch-effort data for major species, the tabulations include the recording of the take of all species. They supply then a full record of commercial production.

References to fishes throughout the paper are by common names. Most of these names conform with the approved list of the American Fisheries Society (1960) but a few are according to local or trade usage. To facilitate exact identification the following list of common and scientific names is offered; if the name used in this paper differs from the Society's approved common name, the latter is given in parentheses.

Common name	*Scientific name*
Blue pike	*Stizostedion vitreum glaucum*
Carp	*Cyprinus carpio*
Catfish (channel catfish)	*Ictalurus punctatus*

Chubs (deepwater ciscoes)	*Coregonus spp.*
Lake herring	*Coregonus artedii*
Lake trout	*Salvelinus namaycush*
Round whitefish	*Prosopium cylindraceum*
Sauger	*Stizostedion canadense*
Sheepshead (freshwater drum)	*Aplodinotus grunniens*
Smelt (American smelt)	*Osmerus mordax*
Sturgeon (lake sturgeon)	*Acipenser fulvescens*
Suckers	
Longnose	*Catostomus catostomus*
Redhorse	*Moxostoma spp.*
White	*Catostomus commersoni*
Walleye	*Stizostedion vitreum vitreum*
White bass	*Roccus chrysops*
Whitefish (lake whitefish)	*Coregonus clupeaformis*
Yellow perch	*Perca flavescens*

DEVELOPMENT OF THE REPORTING SYSTEM

The first move toward the development of the present statistical system in the Great Lakes was initiated by Dr. John Van Oosten in 1926. He was motivated by the knowledge that effective research and management of the Great Lakes fisheries required sound statistics on both the catch and the fishing effort expended to produce that catch; and further by the realization that the fisheries were so constituted that statistical data could not be collected effectively by agents at ports of landing.

The Great Lakes fisheries, unlike many marine fisheries, do not have a few major ports at which the greater part of the total production is landed. Instead, Great Lakes fish are landed at scores-indeed hundreds-of ports scattered along the 9,600 miles of shoreline. If records of catch and effort are to be had, they must be maintained and supplied by the individual operators. To test the feasibility of this type of reporting, Van Oosten designed a monthly report form that carried space for daily records of gear and catch and, with the assistance of the Michigan Department of Conservation, placed supplies with a group of cooperating fishermen.

The test of the new report was so successful that in September 1927 the State of Michigan made its regular submittal a requirement for all holders of commercial fishing licenses. The data on the early reports were incomplete and inaccurate in many respects, but the quality of the returns improved rapidly. By 1929 the statistics were sufficiently sound that analyses could be started. These analyses of State of Michigan statistics have always been carried out in the Biological Laboratory of the Bureau of Commercial Fisheries in Ann Arbor, Michigan.

The inability of the Ann Arbor Biological Laboratory to handle additional reports and of states to undertake the work themselves hampered the extension of the reporting system to other Great Lakes waters. Of the few states that installed the system in the 1930's some later abandoned it because tabulation and treatment of the data could not be made. The use of monthly commercial fishing reports did, however, spread gradually. The years in which continuing submittals were started in the 8 states and Ontario were: Michigan 1927; Ohio 1931; Wisconsin 1936; Ontario 1946; Minnesota 1947; Illinois, Indiana, New York, and Pennsylvania 1950. The completion of coverage in 1950 followed an expansion of the Bureau program which made it possible to assure the newly cooperating states of adequate treatment of records.

The monthly report forms of the states and Ontario are closely similar and much the same as the one originally designed by Van Oosten. Principal differences among current forms are occasioned by differences in species produced and kinds of gear authorized. The major deletion from the original report has been a column calling for the nights out-that is, the number of days stationary gear was fished before it was lifted.

The head of each report form carries space for general information needed to identify and classify the report, including lake (if the state or province borders on more than one); name or number of boat; port of landing; commercial fishing license number; and name and address of licensee. The body of the report provides a line for day of the month for a record of: exact locality of fishing; kind and amount of gear; pounds of each species taken. A bottom line has space for the monthly total catch of each species, but the fisherman is not asked to make the addition. Reports of Ontario, Pennsylvania, Michigan, Illinois, and Minnesota carry a second bottom line for a record of the average monthly price received for each species, but submittal of price information is mandatory only in Ontario and Pennsylvania.

DEVELOPMENT OF ANALYTICAL PROCEDURES

The basic procedures for the treatment of the catch and effort statistics on the commercial fisheries of the Great Lakes were developed during the 1930's and were not in their final form until the latter part of the decade. The rate of progress can be attributed to the peculiarly complex conditions in the Great Lakes fisheries that made caution and deliberation necessary. It was desirable further to see how the procedures performed over a period of several years. Caution was learned also from the publication of the premature paper on statistical methods by Hile and Duden (1933). One of the two major theses laid down-that concerning the overriding importance of fishing time in the estimation of fishing intensity and abundance from records for stationary gear-was shortly thereafter found to be erroneous.

The subsections that follow are rather closely in the order in which points had to be considered as the statistical program was developed. A general treatment of procedural problems, including exceptions to procedure and the basis for them, is reserved for later sections.

STATISTICAL DISTRICTS

The establishment of the boundaries of statistical districts was based principally on three criteria: a district must be large enough that the catch-effort data for the major species can be based on a substantial annual production; a district should not include a wide diversity of ecological situations; boundaries should be so placed as to minimize the number of reports that carry records of fishing in more than one district. Rarely could all of the three criteria be met satisfactorily by *a* proposed boundary and sometimes they conflicted sharply. The placement of almost every boundary, therefore, represented a compromise that was judged to be the best possible (Figs. 1-5).

The State of Michigan waters of the Great Lakes originally were divided into the following numbers of districts: Lake Erie 1; Lake Huron 6; Lake Michigan 11; Lake Superior 7. No occasion has since arisen to sub-divide the Lake Erie district or to change the boundaries of the Lake Huron districts. The number in Lake Superior soon was reduced from 7 to 6 by the combination of two districts, neither of which alone had sufficient production to provide sound records. The combined districts form the present district MS-2. Greatest difficulty arose in Lake Michigan where several district boundaries proved to be highly unsatisfactory. A broad reorganization of the northern area reduced the number of districts from 11 to 8. Five, however, of the 11 original districts (the present districts MM-1, 4, 6, 7, and 8) still have their original boundaries.

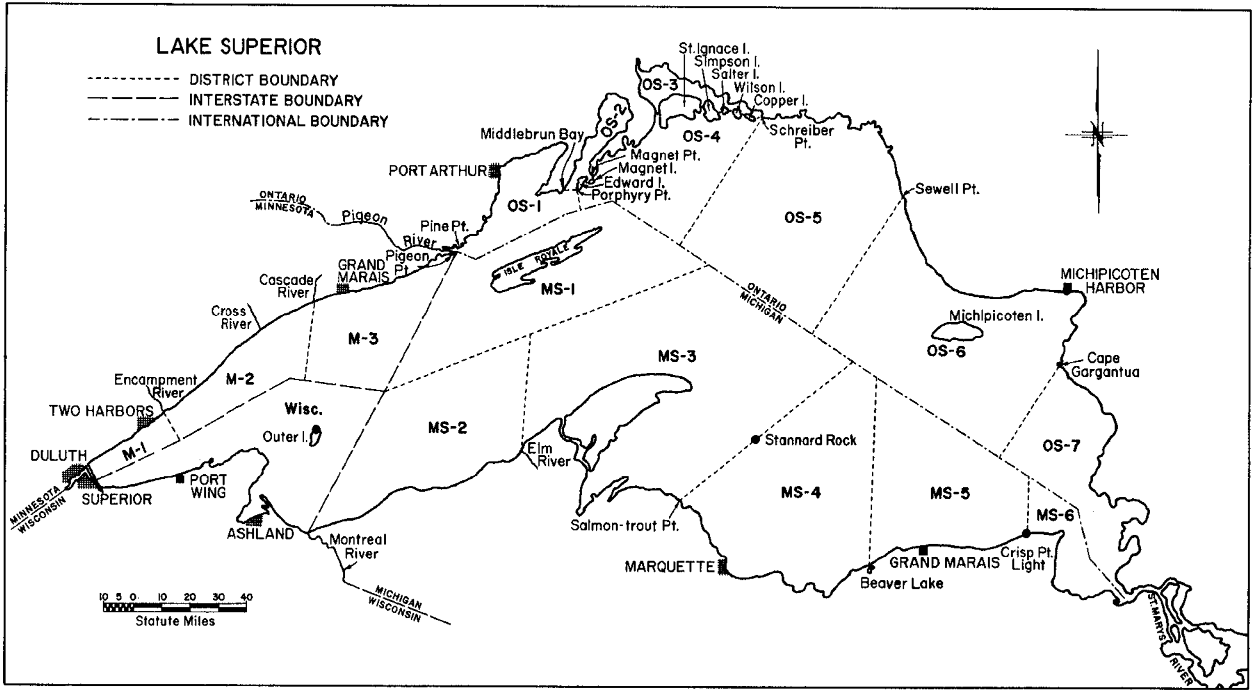

Figure 1.—Statistical districts of Lake Superior.

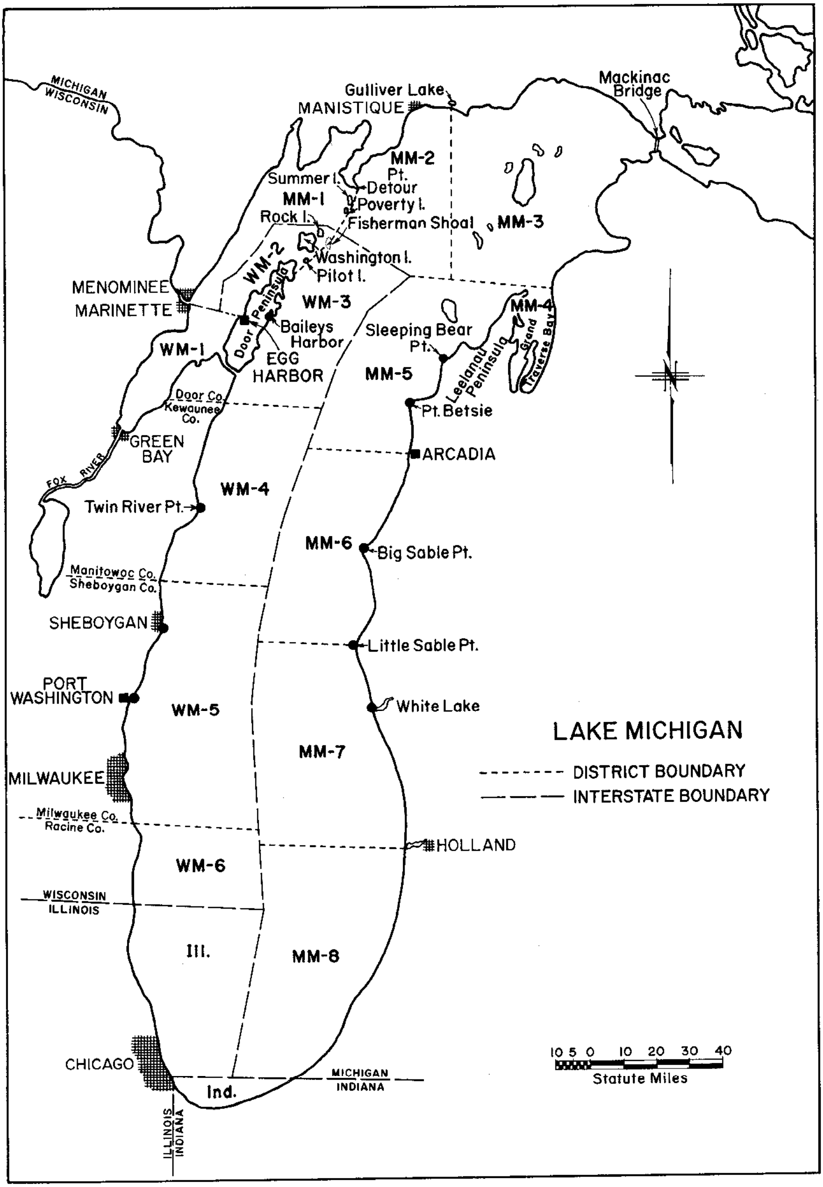

Figure 2.—Statistical districts of Lake Michigan.

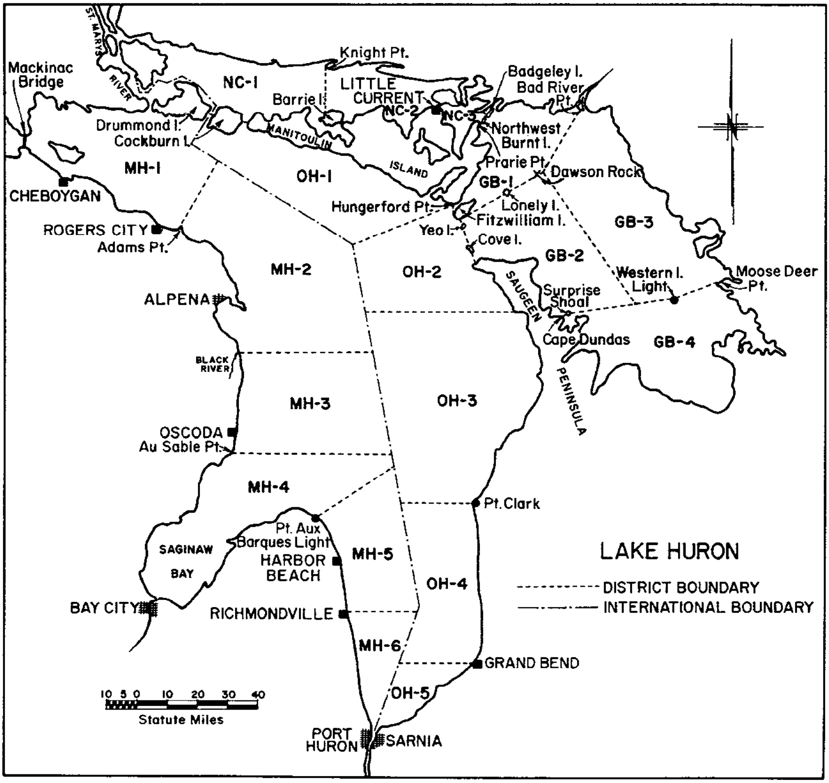

Figure 3.—Statistical districts of Lake Huron.

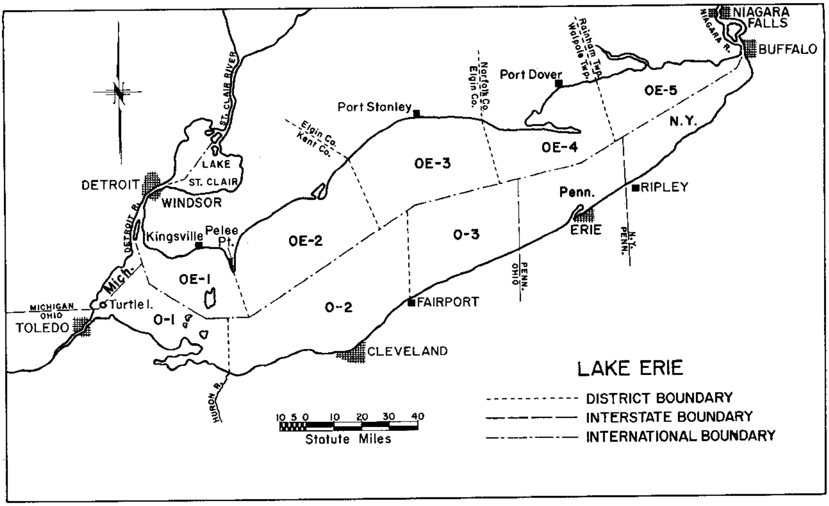

Figure 4.—Statistical districts of Lake Erie.

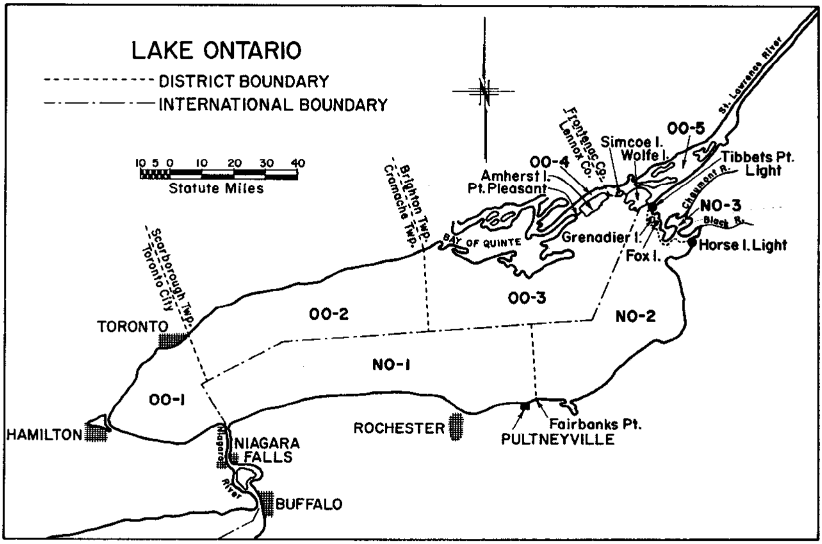

Figure 5.—Statistical districts of Lake Ontario.

The necessary reorganization of the original districts of northern Lake Michigan drove home an important principle. If a danger of "over-districting" exists, care should be taken to place boundaries so that consolidation can be achieved by the combination of pre-existing districts. The work involved in combination is limited and simple. The shifting of a district boundary to a new position, on the contrary, necessitates the retabulation of records for the districts affected.

A detailed review and criticism of the present districting of Great Lakes waters (described and charted by Smith, Buettner, and Hile, 1961[1]) could serve little purpose here. In the main, the present district boundaries appear to be satisfactory. Conceivably a combination of districts in Minnesota may be needed to give greater bulk of data and the open-lake districts of the New York waters of Lake Ontario still contribute scanty production even though they represent consolidations of former districts.

In a few situations, the conditions that dictated the original placement of boundaries no longer exist. The adjacent open-lake waters were included in the Saginaw Bay district of Lake Huron (MH-4), for example, to separate the whitefish grounds off the mouth of the Bay from the more northerly grounds of the Oscoda area and the southerly grounds of the Harbor Beach region. Now that whitefish production has fallen to a low level, the inclusion of the open-lake waters in district MH-4 is almost a handicap. If we were districting the lake now for the first time, MH-4 most likely would be restricted to Saginaw Bay proper and the offshore waters (which now produce principally chubs) divided between MH-3 and MH-5 or retained (with some small difference of boundaries) as a separate district. Should whitefish production again reach high levels, however, the present definition of MH-4 once more would become useful. It seems to be impossible to establish districts that will meet all needs in perpetuity. Neither is it practical to undertake a series of boundary shifts as conditions change. The recompilation of records that may cover more than 30 years entails far too much

[1] Figures 1-5 of the present paper are (with some slight modifications) from this publication. One of the changes has been a correction of a district boundary on the map for Lake Michigan. The boundary between MM-2 and MM-3 is not as stated and charted in the Smith, Buettner, and Hile report. It is instead a north-south line from the mouth of the Gulliver Lake outlet to the northern boundary of MM-5. The error arose partly from the lack of a precise definition of the Michigan-Wisconsin boundary when the districts were originally set up.

work and cost. It appears best to retain established districts except for combinations where they seem to be desirable. If an urgent need arises for information on an area that constitutes only part of a district, it is best to make special compilations from original records.

FISHING EFFORT

Units of effort

At the start of the tabulations, units of effort were set up for each of the major types of gear: gill nets; impounding nets; set hooks; and haul seines. A definition for trawls has been added recently. Definitions and comments are offered in the following paragraphs.

Gill nets: The lift of 1,000 linear feet of gill netting. Records are maintained separately for five ranges of mesh size, extension measure: bait (small chubs as bait for set hooks) or smelt nets, usually 1 1/2-1 5/8 inches; small-mesh nets, 2 1/8-3 inches but mostly near 2 1/2 and fished for such species as blue pike, chubs, lake herring, round whitefish, and yellow perch; large-mesh gill nets, mostly near 4 1/2 inches but as much as 6 1/2 inches, and fished mainly for lake trout, suckers, walleye, and whitefish; carp gill nets, usually 7-8 inches; sturgeon gill nets, usually 10-12 inches.

Impounding nets (pound nets, deep trap nets, shallow trap nets, and fyke nets): The lift of one net. The broad term "fyke net" includes such gear as hoop nets, the drop net of Green Bay, and the gobbler net. The gobbler has about the same fishing power as a fyke net, but the pot is supported by rectangular frames instead of hoops. The impounding nets are not classified by mesh size but the separation of trap nets into deep and shallow gives a large measure of separation for that gear. Deep trap nets, now fished only in the Michigan waters of Lake Huron, have meshes not less than 4 1/2 inches in the pot; the depth of the pot normally is from 25 to 40 feet but may be greater. The mesh size in the pot of shallow trap nets usually is under 3 inches, but may be 4 1/2 inches in Lake Superior where numbers are fished for whitefish; the depth of the pot ranges from 15 feet down to as little as 3 or 4 feet according to the principal species sought.

Set hooks: The lift of 1,000 hooks. The original tabulations are rounded to the nearest 0.1 unit (to the nearest 100 hooks). Set hooks include the floated hooks as well as bottom hooks fished for lake trout in Lake Superior and the bottom lines formerly set for the same species in Lakes Huron and Michigan. They are fished also for catfish and rarely for other species.

Haul seines: One haul of a 100-rod seine. (Most, though not all seiners use the rod-16 1/2 feet-as a unit of length). The original tabulations are rounded to the nearest 0.1 unit (to the nearest 10 "rod-hauls").

Trawls: One hour of actual dragging.

In addition to the listing of "fishing effort" in terms of the units just defined the early tabulations (through 1934) carried a record of "fishing intensity" for the stationary gears-gill nets, impounding nets, and set hooks. The effort for a day was defined as the amount of gear lifted on that day. The intensity was the amount of gear lifted, multiplied by the number of days (nights out) the nets or hooks had fished before lifting. It was held that the fishing pressure of stationary gear is directly proportional to the length of time the net is in the water. The logic of this assumption was laid down by Hile and Duden (1933). Experience caused the validity of the assumption to be suspected early but the tabulation of fishing intensity was continued through a 6-year period. This tabulation provided material most useful in a study of the actual relation between fishing time and catch per lift-a point that is discussed later.

Effective 'fishing effort

The original or "test-run" tabulations of the statistics contained the following entries for each monthly report: total fishing effort; total fishing intensity; total catch in pounds of each species. When the annual totals of these entries were made and the catch per unit effort (or intensity) computed for each gear, it became obvious immediately that the system was falling short of its purpose of providing a measurement of the quality of fishing. The take of yellow perch, for example, might be less than 5 pounds per 1,000 feet of small-mesh gill net, though one with even casual acquaintance with the fishery knew that the true figure rarely fell under 20 pounds (else the fisherman suspended operations) and commonly was much greater. Again, the average take of whitefish per pound-net lift might be 1O-20 pounds when the lifts actually ran from 50 to 100 pounds or more.

Examination of a series of reports made the cause of the difficulty clear. The total lift of small-mesh gill nets, for example, included not only nets that were set on yellow perch grounds and took perch but also those set in deep water for chubs or on spawning grounds for lake herring. These nets fished for chubs and herring rarely take any perch at all. Inclusion of them in the computation of the catch per unit effort for yellow perch yielded a meaningless statistic. Similarly with pound nets-the large-mesh nets set for whitefish rarely take lake herring and whitefish seldom enter the small-mesh pound nets fished inshore for herring.

The examples of the preceding paragraphs illustrate a point but are oversimplified. In much of the Great Lakes fishing, especially in shallow water, several species are taken in good quantities in the same net. The problem, then, is not one of deciding for which single species the fisherman fished his gear. Rather it is one of obtaining a useful statistic on fishing effort for each species in a lift that produces several.

The distribution of a day's fishing effort among the species according to their contribution to the total catch was abandoned with little consideration. To illustrate the procedure, if 10 trap nets are lifted and yellow perch make up 38 percent of the catch, the species is charged with 3.8 trap-net lifts. If, on the next lifting day perch make up 27 percent of the total, they are charged with 2.7 lifts. Yet, the catch of perch may be identical on the 2 days; the change of percentage can result from change in the catch of other species. The assignment of effort thus has limited value.

It was decided next that either all or none of the day's fishing effort should be charged to each species for which records of effort are kept. and a basis was sought for the decision. The requirement that the species contribute at least a minimal percentage of the take could not be used since that percentage must vary according to the catch of other species. The basis for decision had to be founded wholly on the records for the species under consideration. It needed to include also the requirement for some minimal catch of the species in order to exclude fishing conducted where the species does not occur. The establishment of some small but significant minimum level of catch per unit effort was considered but abandoned because of the difficulty of setting truly realistic values for each species and gear in each district; furthermore, fishing effort chargeable in years of high abundance might be rejected in years of low abundance. The only practical requirement for a minimum take proved to be any catch at all. Thus all the gear lifted by a fisherman on a particular day is charged to a species taken, even if the amount is as little as a pound.

It is not held that effective fishing effort as defined and used provides a wholly unbiased measure of fishing pressure. It has been employed because a better one could not be devised for a fishery in which most nets are set with the intent and expectation Of taking several species simultaneously. Effective fishing effort does not provide for "water hauls" but in the Great Lakes this provision would serve small purpose; the distribution of fish varies little, other than seasonally, from year to year and is such that nets fished on grounds occupied by a species almost invariably take some quantity of that species. Indeed, the lack of provision for water hauls is probably overcompensated by the charging of the entire amount of gear lifted against a species on days when the actual catch is extremely small.

Other possible sources of bias exist but discussion of them here would be little to the point since no measure of their importance can be given and no remedy can be offered.

It has been comforting to learn from the many years of record (now exceeding 30 in State of Michigan waters) that the catch per unit of gear computed from effective fishing effort does reflect clearly known changes in the quality of fishing. How finely these changes are measured is not known. The degree of accuracy no doubt varies with species, area, and local conditions of the fishery. If production is high and the fishery not disrupted by changes of regulation, gear, or fishing method, the sensitivity of catch per unit of effort may be high.

The effective fishing effort is not a distributive statistic. It provides a separate and independent accounting of fishing effort for each species. To illustrate the point, let it be assumed that a fisherman lifts 10 shallow trap nets on each of 15 days within a month and that he lands yellow perch every day, walleyes on 10 days, suckers on 7 days, . . . The assignments of fishing effort then become: yellow perch 150 net-lifts (identical with the total fishing effort); walleyes 100 net-lifts; suckers 70 net-lifts; . . . .

The adoption of effective fishing effort as a measure of fishing pressure calls immediately for a selection of species for which the record will be maintained. It would be unduly costly to tabulate effort for the numerous minor species that are caught in relatively small quantities. The species that are classed as "major" or "principal" vary according to species composition in different waters but decisions for the State of Michigan provide an example. The principal species for which records are kept in every district except the Erie district are: lake trout, whitefish, lake herring, chubs (all species collectively), walleye, yellow perch, and suckers (white suckers and redhorse suckers combined; longnose suckers excluded). The original list included also sauger and carp for the Saginaw Bay district (MH-4); the catfish was added in this district later and data from reports for early years tabulated to give a full record. When smelt became plentiful, the species was classed as principal in the Green Bay district (MM-1) and northeastern Lake Michigan (MM-3). The Lake Erie district was assigned no "principal" species because of the belief that conditions in the area were so nearly uniform as to justify a mere tabulation of the total fishing effort and the catch of each species (the method of tabulation in the “test-run”). Experience proved the belief to be erroneous. For a number of years effective fishing effort has been tabulated for the following species in the Michigan waters of Lake Erie: carp, catfish, sheepshead, suckers (no longnose suckers in the district), walleye, white bass, and yellow perch. The Lake Erie statistics for a good span of the earlier years remain, however, to be retabulated.

The establishment of principal species (or groups of species) for which effective fishing effort is tabulated in all State of Michigan districts of the three upper lakes does not mean that each species or group is taken in sufficient quantity in each district to yield reliable data. Rather, it was held that the uniform tabulation procedure was more economical and more likely to be accurate than one with numerous exceptions. This view was especially justified in the earlier years when much of the tabulation had to be done by hand (data are now handled by IBM equipment) by staff of limited experience. Actually, adherence to the procedure entails relatively little additional work.

Elimination of the time factor

The tabulation of catch-effort statistics on the commercial fisheries of the Great Lakes had not been underway long before examinations of the fishing reports gave rise to strong skepticism as to the validity of the assumption that the fishing intensity represented by the lift of stationary gear is proportional to the length of time (nights out) the gear fished before it was lifted. True, nets that had been out the greater length of time usually had the larger catches but the improvements of catch with increase of time were small. Because sound knowledge of the true relation of fishing time to catch was fundamental to the development of proper analytical procedure, a detailed inquiry into the matter was undertaken. This study covered every important stationary gear fished in the Great Lakes, including the two principal mesh sizes of gill nets. The relation between nights out and catch was examined not only for the total catch but also for individual species in the same gear.

The detailed results of the study of the relation between fishing time and catch were not published but rather placed in a manuscript report (written by Hile) for the statistical files. Certain of the data were published, however, by Hile (1935), Van Oosten (1935), and Van Oosten, Hile, and Jobes (1946).[2] Principal findings and conclusions in the time-catch investigation were:

1. The catch improved with increase of fishing time but the increase was far less than proportional. The catch of gear out 2 nights, for example, averaged less than 20 percent above the take in gear out 1 night. The trends were similar for all stationary gears and for the individual species.
2. The most precise catch per unit effort for judging the availability (abundance) of fish is neither the catch per lift nor the catch per night, but rather the catch per lift adjusted for fishing time from an empirically determined curve of the regression of catch on time.
3. The mean annual fishing time for a particular gear in a single district varied within narrow limits.
4. Because of the limited mean annual variation in fishing time, estimates of annual fluctuations in abundance based on catch per lift and on catch per lift, adjusted for fishing time, differed insignificantly. The cross multiplication of amount of gear lifted and number of nights out is therefore, not necessary.

The discovery that the amount of gear lifted without regard to time was a satisfactory measure of fishing effort eliminated the most costly, tedious, and time-consuming step in the tabulation of catch-effort statistics. The "fishing intensity" was eliminated from the original tabulations. The same term is now employed in an entirely different sense as is explained in the next subsection.

INDICES OF ABUNDANCE AND FISHING INTENSITY

The major problem was the development of single descriptive index figures for abundance and fishing intensity from records of catch per unit effort (CPE) and effort (E) for such dissimilar gears as gill nets, pound nets, set hooks, ... If almost the entire catch of a species is produced by a single gear (nearly all chubs for example, were caught by small-mesh gill nets before the recent start of trawling) the fluctuations of abundance can be described readily by expressing the CPE for each year as a percentage of the unweighted mean of the annual

[2] Those interested in this subject should consult also the article by Kennedy (1951) on the relation of nights out and catch per net in the gill-net fishery of Great Slave Lake.

values for a base period of reference. The records of the annual amount of gear lifted provide the basis for a similar series of intensity indices (a small adjustment of the figures may be needed, as is explained later in this subsection, to account for the portion of the catch not taken by the principal gear). A one-gear fishery, however, is exceptional in the Great Lakes; consequently, a more general method of analysis had to be devised.

The procedure that was developed requires first a record of the unweighted base-period mean of the annual CPE for each gear that was important in the production of a species in a district. (This “base” or “reference” period in State of Michigan waters is 1929-43.) Once these averages are in hand the abundance and fishing intensity for a particular year are computed as follows:

1. The production that would have *been* made had the CPE been exactly at the 15-year mean is determined from the current-year values of E for each gear included in the estimation of abundance. These figures are expected catches (Ex).
2. The expected catches, determined separately for each gear, are added to obtain the total expected catch.
3. The true catches of the same gears are totaled to obtain the actual catch (Act).
4. The ratio of the actual to the expected catch, expressed as a percentage, is the abundance index (Ab).
5. The fishing intensity (Int) is determined by adjusting the total expected catch upward to include the intensity represented by the take in gears not employed in the estimation of the abundance index. Fishing intensity is, therefore, computed originally in terms of pounds of fish. For publication, the intensity is expressed in one or both of two forms:

    a. A percentage index in which a value of 100 corresponds to the base-period average intensity in pounds for the species and district.
    b. A unit index (U) in which 100 units represent the base-period average intensity in pounds for the species in the combined districts of the lake and state. The sum of the units for the individual districts thus provides an index for the combined districts that is parallel to the percentage index which holds only within a single district.

The preceding brief outline of procedure can be understood best from an actual illustration, based on materials from the statistical files-the “cover sheet” and the 1954 data on the fishery for white and redhorse suckers in the Green Bay district of the State of Michigan waters of Lake Michigan (MM-1-designated merely as M-l in the State of Michigan files). Both the cover sheet (table 1) and the 1954 sheet (table 2) are exact copies of the original handwritten records in the sense that all original abbreviations and symbols have been retained. Several of the abbreviations have already been explained. Those referring to fishing gears are:

2+ and 4+, small-mesh and large-mesh gill nets of mesh sizes as stipulated in the section on units of effort.

Pd, pound net

ST, shallow trap net

Fy or F&H, fyke or hoop nets

Table 1. - Copy of averages and factors employed in the estimation of abundance and fishing intensity for white and redhorse suckers in district MM-1

[See text for explanation of abbreviations]

M-l Suckers
Averages, factors 1929-1943

CPE

4+	24.16
Pd	63.19
ST	83.46
Fy	67.92

Int (U) = Int (#) x 811787 (U ca. 12,300#)
Int (%) = Int (#) x 134069 (100 ca. 746,000#)

The cover sheet carries all information required for the estimation of abundance and fishing intensity for white and redhorse suckers in this district (a similar sheet appears at the start of the folder for each “principal” species in each district). The first set of figures is the unweighted base-period (1929-43)

Table 2. - Copy of statistical data sheet for white and redhorse suckers, district MM-l, 1954

[See text for explanation of abbreviations and computational procedures]

STATE OF MICHIGAN LAKE MICHIGAN DISTRICT 1 1954	White and redhorse suckers	STATE OF MICHIGAN LAKE MICHIGAN DISTRICT 1 1954

	2+	4+	Pd	ST	F & H	Σ
Jan.	1	4,494	23	5,086	530	10,134
Feb.	19	6.733	5	1,935	79	8,771
Mar.	4	10,640	4	3,766	1,751	16,165
Apr.	. .	. . .	. . .	1,206	. . .	1,206
May	. 27	12	740	4,455	. . .	5,234
June	120	. . .	4,581	21,964	1,155	27,820
July	83	. . .	4,225	20,137	275	24,720
Aug.	102	. . .	33	26,516	197	26,848
Sept.	498	170	1.345	60,525	397	62,935
Oct.	398	706	1,683	28,331	428	31,546
Nov.	112	1,029	45	13,506	366	15,058
Dec.	44	11	. . .	970	. . .	1,025
Total	1,408	23,795	12,684	188,397	5,178	231,462
E	2+	4+	Pd	ST	F & H	
Jan.	1	367	14	81	8	
Feb.	16	5.27	4	198	8	
Mar.	6	656	2	249	18	
Apr.	. .		. . .	40	. . .	
May	. 19	. ii	30	131	. . .	
June	59	. . .	136	676	10	
July	55	. . .	40	394	7	
Aug.	33	. . .	‘2	355	4	
Sept.	89	30	33	910	42	
Oct.	226	79	134	886	7	
Nov.	81	114	5	514	25	
Dec.	14	2	. . .	64	. . .	
Total	599	1,788	400	4,498	129	
CPE	. . .	13.31	31.71	41.88	40.14	
Ex	. . .	43,198	25,276	375,403	8,762	

Σ	Ex	452,639
Σ	Act	230,054
Ab		50.8
Int	#	455,634
	U	37.0
	%	61

mean CPE (pounds of fish)[3] for each gear employed in the estimation of abundance. The next item, Int (U), is a factor for converting fishing intensity in pounds into units that may, as has been stated, be added to give an index figure for the combined districts. This factor is the same for suckers in all State of Michigan districts of Lake Michigan. The second factor converts intensity in pounds to the percentage index that applies only to the district under immediate consideration. Both of these factors are reciprocals but without any indication of their true decimal value. To aid in the placement of the decimal, approximate values of the unit (fishing intensity of about 12,300 pounds) and of the loo-percent level (fishing intensity of roughly 746,000 pounds) are added at the right.

The first step in the treatment of the 1954 data (table 2) is the determination of the CPE in 1954 for each of the four major producing gears. The catch per unit of 1,000 linear feet of large-mesh gill nets lifted was, for example, 23,795/1,788 = 13.31 pounds. Figures for pound nets, shallow trap nets, and fyke and hoop nets are similarly computed. The CPE figures for 1954 are for the record; they do not enter directly into the estimation of the abundance index.

The second step is the determination of the poundage of white and redhorse suckers that would have been produced in 1954 had the fishing success for each gear been exactly at the average for the 15-year base period of 1929-43. Had large-mesh gill nets, for example, taken 24.16 pounds per 1,000 feet instead of the actual 13.31 they would have produced 1,788 x 24.16 = 43,198 pounds rather than the actual 23,795 pounds.

The sum of the expected catches in four gears in 1954 was 452,639 pounds. They actually took 230,054 pounds. The actual take expressed as a percentage of the expected gives the abundance index of 50.8.[4] Abundance indices computed by this procedure do not add to 100n within a base period of n years (Hile, 1937), and hence must be adjusted. If, for example, the mean abundance index for the reference period proves to be 103.7, each index in the series is multiplied by 1/1.037 = 0.96432 to adjust the values to a mean of 100. No adjustments are made for the years following the base period.

[3] For computational reasons, values of CPE are carried in file records to the second decimal. Published figures are rounded to the nearest pound.

[4] The abundance index is rounded to the nearest whole figure for publication.

The best estimate of fishing intensity in pounds is slightly greater than the total expected catch since an adjustment should be made to cover the 1,408 pounds taken in small-mesh gill nets, a gear that did not enter into the estimation of abundance. The adjustment is accomplished by dividing the ratio of the actual to the expected catch into the grand total catch for all gears: 231,462/0.508 = 455,634. The adjustment here is almost trifling, but often it is substantial. In other words, the fishing intensity for white and redhorse suckers in northern Green Bay in 1954 was at a level that would have yielded 455,634 pounds had fishing quality been exactly at the base-period "normal" for all gears.

The estimated fishing intensity in pounds represented 37.0 units. One unit is 1/1,500 of the total fishing intensity in pounds for all State of Michigan districts of Lake Michigan in 1929-43. Examples of the distribution of intensity units among districts and of their summation to provide lake-wide indices have been given for lake trout in Lake Huron by Hile (1949), Lake Michigan by Hile, Eschmeyer, and Lunger (1951a), and Lake Superior by Hile, Eschmeyer, and Lunger (1951b).

The 1954 fishing intensity in pounds for suckers in northern Green Bay amounted also to 61 percent of the 1929-43 mean for this district.

A peculiar feature of the system of computing fishing intensity in terms of the expected catch in pounds is the flexibility it gives to the basic units of effort. For example, three of the gears used in the estimation of abundance and fishing intensity for white and redhorse suckers in northern Green Bay (MM-1)- large-mesh gill nets, pound nets, and shallow trap nets-are employed also in northeastern Lake Michigan (MM-3). The 1929-43 mean CPE (pounds) in the latter. district ran: gill nets 11.09; pound nets 23.64; shallow trap nets 145.36. Comparison of these figures with those of table 1 shows that the expected catches per unit effort (15-year mean CPE) for large-mesh gill nets and pound nets in MM-3 were less than half those in MM-l; the average CPE for shallow trap nets in MM-3, on the other hand, was almost 1 3/4 times that for MM-l. It is possible, therefore, for identical quantities of gear fished in different districts to contribute different numbers of intensity units to the total for a lake. Within a single district, fishing intensity varies directly with the effort (amount of gear fished). For combined districts, the variation is not according to the sum of the effort units for the different gears in the several districts, but rather reflects the total fishing intensity in pounds computed independently for each district.

In the combination of abundance indices to obtain estimates for groups of districts or all districts within a lake and state, the index for each district has been weighted by the percentage the district contributed to the total production in all districts over the base period.

EXCEPTIONS TO STANDARD PROCEDURE

In the development of analytical methods an attempt was made to arrive at a procedure that would have wide applicability. The attitude was held, nevertheless, that exceptions to procedure should be made when they contributed to the attainment of the true goal of obtaining the best possible information on the fluctuations of the fisheries for the principal species. Experience proved that certain exceptions were in fact needed. They were not numerous but a listing of those made or contemplated and justification for the decisions are desirable. Others may be made later; as a matter of procedure the statistics for a particular species are placed under closest scrutiny when the files are entered to obtain materials for a report on the fishery or for statistics in support of biological studies.

WEIGHTING OF ABUNDANCE INDICES

It has been necessary to make only one exception to the procedure of weighting the abundance index of each district by the percentage the district contributed to the base-period production of all districts to obtain estimates of abundance for combinations of districts. The development and expansion of the fishery with deep trap nets in Lake Huron so disrupted the typical distribution of the catch of whitefish among the districts that Van Oosten, Hile, and Jobes (1946) held it preferable to weight abundance indices according to the percentage of whitefish taken in each district in a single year, 1929. It is unlikely that a similar extreme situation will appear soon again.

MODIFIED DEFINITIONS OF DISTRICTS

These modifications have included: the pooling of data for different districts for particular species to gain greater bulk of statistical data; assignment of fishing to districts according to nature of catch rather than on the basis of the precisely defined boundaries; ignoring of boundaries in favor of the arbitrary assignment by ports.

The pooling of districts has been limited to date to the southerly State of Michigan districts of Lake Michigan. Here the districts MM 6, 7, and 8 have been combined for studies of walleye (Hile, 1937) and lake herring (Hile and Buettner, 1955) and the records for yellow perch have been pooled for two pairs of districts (MM-5 and 6; MM-7 and 8). All of these combinations were justified by similarities of trends in the districts for which data were combined. Combinations are made after the data are tabulated and annual totals of catch and effort determined for the districts separately.

Smith, Buettner, and Hile (1961) defined the boundary between MM-1 and MM-2 precisely but the actual assignment of fishing has been on the basis of species caught rather than the defined boundary. The effective difference between the two methods would be small. The boundary of MM-l was set originally to the east of the islands that separate northern Green Bay from Lake Michigan proper to include in the district the fishing for whitefish immediately outside the islands. Accordingly, any large-mesh gill nets that took whitefish and all deep trap nets (basically whitefish gear) fished along the east side of the islands have been assigned to MM-l. Large-mesh gill nets fished deep enough to take only lake trout have been assigned to MM-2, as have been also small-mesh gill nets fished for chubs.

The boundary between MM-2 and MM-3 has been ignored in the assignment of chubs caught along southeasterly courses out of Manistique. All have been placed in MM-2 even though the nets actually were set across the border in the western part of MM-3. This procedure separates the statistics for the chub fishery of the northern part of the open lake from the somewhat dissimilar fishery for chubs in the eastern part of MM-3, between the islands and the mainland. The boundary between the two districts holds, of course, for other fishing.

A similar procedure has been established at Rogers City, Lake Huron, which lies almost exactly on the boundary of MH-1 and MH-2. All chubs landed at Rogers City are assigned to MH-1, regardless of the actual location of the nets, to keep the records separate from those for the chub fishery out of Alpena in the southern part of MH-2. The boundary between MH-2 and MH-3, however, is observed strictly.

EXCEPTIONS TO EFFECTIVE EFFORT

A situation was found in Lake Superior that required exception to the principle that fishing effort shall be charged to a species provided any quantity of the species is taken. In several districts of the lake, small poundages of lake herring are produced in small-mesh gill nets set in deep water for chubs. Gangs of chub gill nets typically are long-often 20,000 to 25,000 feet-and the catch per unit of effort of lake herring in them rarely exceeds a small fraction of a pound. The gangs fished inshore for lake herring are short-a few thousand feet-and take herring at a high rate that normally averages several hundred pounds per 1,000 feet. The charging of chub gill nets that take lake herring to the fishing effort for lake herring would cause misleading distortion of the lake herring statistics. The effort of the chub nets is accordingly excluded from the lake herring statistics and the small catches of herring are entered in the records as produced by small-mesh gill nets without data on effort.

As was seen in the example of table 2, determinations of CPE and estimates of abundance have been based typically on annual totals of catch and effort. The first statistical review of a fishery (Hile, 1937) disclosed, however, a situation in the Saginaw Bay district (MH-4) that required deviation from this procedure. The production of walleyes in large-mesh gill nets fell into two entirely distinct phases: an intensive April fishery on the spawning run fairly deep in the bay that yielded the bulk of walleye production by the gear; small-scale production of walleyes in whitefish gill nets in other months in the outer bay or off the mouth. Quantities of gear per lift were small and the CPE ran high in April; the gangs of whitefish gill nets were long and the catches and CPE of walleye both were extremely small. Because the effort expended in the whitefish fishery varied widely from year to year the CPE for walleyes, computed from annual totals, also could fluctuate greatly even when the CPE in the main April fishery was stable. Calculations of CPE for walleyes in large-mesh gill nets accordingly were based exclusively on the April records. The exclusion of data for the other months corresponds in a sense with the exclusion of the fishing effort of Lake Superior chub gill nets that take small quantities of lake herring.

The experience with gill-net fishing for walleyes in Saginaw Bay inspired alertness for other situations in which the determination of CPE and abundance should not be based on annual totals of effort and catch. Indeed the next statistical review of a major fishery (Van Oosten, Hile, and Jobes, 1946) was preceded by detailed comparisons of estimates of fluctuations as determined from annual totals of catch and effort for whitefish and from the statistics for the months in which the bulk of the catch was taken. The restriction of the statistics to the "major season" gave much higher annual figures for CPE but the annual fluctuations of the abundance index were nearly the same from the two sets of data. Annual catch and effort totals have been satisfactory for other published statistical reviews except smelt (Van Oosten, 1947; Hile, Lunger, and Buettner, 1953), where month-by-month records were needed to describe the fishery in northern Green Bay.

A statistical study, soon to be undertaken, of the lake herring in Lake Superior almost surely will require a separation of records for the November-December spawning-run fishery (which accounts usually for 85 percent or more of the total annual production) from those for the remainder of the year. Similar situations may be uncovered in still other fisheries as the file records are employed for statistical reviews.

SPECIAL COMPUTATIONAL PROBLEMS

ESTIMATES OF BASE-PERIOD CATCH PER UNIT EFFORT FROM INCOMPLETE DATA; ADJUSTMENT FOR CHANGED EFFICIENCY OF GEAR

The appearance of a new gear in a fishery, the disappearance (or decline of fishing effort to inconsequential levels) of an established gear before the end of the base or reference period, and the fluctuations in the fishing effort for an important gear so wide that reliable determinations of CPE can be made for only part of the years within the base period all offer the same problem-the estimation of a base-period CPE (such as those listed in table 1) when data on the gear are not available for all years within the period. The problem is similar when the fishing capacity of a gear suddenly is changed as occurred with shallow trap nets fished for walleyes in northern Green Bay (Hile, Lunger, and Buettner, 1953; Pycha, 1961). An increase of efficiency similar to the one that led Pycha to adjust the “normal” CPE for walleyes taken by shallow trap nets in MM-l, required a change in the “normal” CPE for lake herring in shallow trap nets in MH-4, but Hile and Buettner (1959), omitted reference to the adjustment as inappropriate in the brief discussion in their article.

The estimation of a base-period CPE from incomplete data requires first the determination of the mean of the annual CPE for the gear with incomplete records and subsequently the adjustment of that mean according to the CPE (expressed as percentage indices) of other gears that produced the same species in the same district in the same years. The procedure can be understood best, perhaps, from an example (table 3). Let it be assumed that gear A has made its appearance in a district where gears B and C have been fished continuously and that it is wished to determine a "normal" CPE for gear A on the basis of 5 years of record (years 7-11 within the base period).

Table 3. - Illustration of procedure for estimation of a mean base-period CPE for gear fished through only part of the base period

[See text for explanation]

Year in base period	CPE (pounds)	CPE (percentage of base-period mean)	
	Gear A	Gear B	Gear C
7	37.91	105	110
8	49.32	129	141
9	44.24	120	110
10	38.17	98	95
11	41.79	108	102
Average	42.29	[1] 111.8	

[1] Unweighted mean for 10 entries.

The mean CPE for gear A was 42.29 pounds. The unweighted mean for the CPE of gears B and C, each expressed in terms of percentages of the average CPE for the base period was 111.8. The CPE for gear A for the base period is estimated, therefore, as 42.29/1.118 = 37.83 pounds. The procedure is similar for estimating the adjusted base-period CPE for a gear in which the efficiency has changed. Once the new level of efficiency has been established the gear is merely treated as new.

If a newly introduced gear interferes with the fishing of existing gears and/or leads to a sharp drop or discontinuation of their use, estimates of the type just illustrated become undependable. Van Oosten, Hile, and Jobes (1946), for example, considered their estimates of the "normal" CPE for deep trap nets in MH-5 and MH-6 to be highly untrustworthy. They held that abundance indices for whitefish in these districts could be compared within the period before the deep trap net became dominant and within the period after it had become the principal gear, but warned against comparisons between these two periods.

Adjustments of the base-period CPE of an existing gear to accommodate changes of efficiency also are subject to some error since the changeover normally comes about over a period of years, not suddenly (Pycha, 1961).

The disappearance of a gear used in the estimation of abundance offers no computational problems if it comes about later than the last year of the base period. The introduction of new gear calls for the estimation of a base-period CPE regardless of the time of occurrence.

The greatest recent change in the efficiency of gear-that resulting from the change from cotton to nylon twine in gill-nets-found the Laboratory staff in poor position to gain sound quantitative data on the actual increase of efficiency. Normally, staff members would obtain the data directly from fishermen during the period of changeover. Regrettably, however, pressures arose for legal restrictions on nylon and persisted through and beyond the period of change for most gill-net fisheries and it was not discreet to ask fishermen to give records, privately or on their official monthly reports, on such a highly controversial matter. Nor has the Bureau been in position to conduct the extensive experimental fishing to resolve the question for a variety of species in a number of areas. Our one study has been limited to experimental fishing with nylon and cotton gill nets for lake trout in a single area (Pycha, in press).[5]

Even if discriminating estimates of the relative efficiency of cotton and nylon gill nets could be obtained today, the application of our findings for the "correction" of earlier records would be of questionable dependability in fisheries in which the characteristics of the present stocks differ greatly from those of earlier years. The size distribution of lake trout stocks of Lake Superior and of whitefish of Lakes Huron and Michigan have been altered greatly. In the latter two lakes both the size and species composition of chub populations have changed. Furthermore, the change from cotton to nylon gill nets proceeded at different rates in different areas and fisheries. In fact, both kinds of gill nets still are fished in the lake herring fishery in parts of Lake Superior, and possibly in other fisheries in various lakes. Still another complicating factor lies in the changes that

[5] "The relative efficiency of nylon and cotton gill nets for taking lake trout in Lake Superior," by Richard L. Pycha. Accepted for publication in the Journal of the Fisheries Research Board of Canada.

have taken place in nylon twine since it first was introduced. Finally, changes of fishing habits-the tendency for the reduced numbers of fishermen to concentrate their operations on the best grounds during the best seasons-have reduced the dependability of data, particularly on the lake trout fishery of Lake Superior.

The fact must be accepted, therefore, that gill-net statistics are now to a considerable degree undependable for comparisons with earlier fishing and have been for a number of years. It is known that estimates of abundance based on them have been too high. The opinion can be offered that the overestimates are between twofold and threefold in a number of situations, but precise adjustments are not feasible. At such time as the major gill-net fisheries become better stabilized, new base periods can be established to follow changes but the exact relation of the new base level to the earlier one will be unknown and the interpretation of the statistics over considerable stretches of time will continue to be uncertain.

CATCH WITHOUT RECORDS OF EFFORT

The earlier statistical reports included numbers that indicated the kind of gear fished but lacked usable records of the amount. As fishermen became better acquainted with the reporting system and inspection of reports in the original offices of receipt grew more effective, the numbers of defective reports declined to unimportance. Even today, however, a few escape detection up to the point of final tabulation. The system of treatment of these “no-gear-data” catches is accordingly explained briefly by means of the example in table 4.

Table 4. - Illustration of procedure for adjustment of fishing effort to compensate for catches of fishermen whose reports lacked usable data on the amount of gear

[See text for explanation]

Total annual catch	
With gear data	97,310
No gear data	8,432
Grand total	105,742
Recorded effort (E)	3,110
Catch per unit effort (CPE)	31.29
Corrected effort (CE)	3,379

A gear took 97,310 pounds of fish for which usable records of effort were carried on the reports. The CPE for this part of the catch was 97,310/3,110 = 31.29 pounds. The same gear, however, took 8,432 pounds for which gear records were lacking, to bring the total catch to 105,742 pounds. It is estimated then that if all operators who fished the gear had submitted complete reports the true or "corrected" effort (CE) would have been 105,742/31.29 = 3,379. The correction is made on the assumption that fishermen who submitted defective reports caught fish at the same rate (same CPE) as those who turned in usable records.

EFFECTS OF CHANGES IN REGULATIONS

Almost any change of regulation bearing on grounds open to fishing, gear, size limits, or seasons produces an interruption in continuity that hampers comparisons of statistics for years preceding and following the change. If the change becomes effective during the fishing season, the year of change falls into still another category. A lowering of the size limit, for example, suddenly makes available a segment of the stock that previously could not be landed. The catch per unit effort is increased, but the higher abundance index does not reflect a corresponding increase of abundance over that of previous years. Fishing intensity is underestimated under the new lower size limit since the base-period values for CPE were derived in part or wholly on the data for years in which the limit was higher. Similar effects of other changes of regulation are so obvious as not to require illustration or explanation.

A full listing of the changes that have taken place in Great Lakes fishery regulations over the years since the present statistical system was established, could serve no purpose here. Among those that have affected State of Michigan statistics most severely have been: restriction of deep trap nets in Lake Huron to depths of 80 feet or less; a series of changes in the minimum mesh size for small-mesh gill nets (Hile and Buettner, 1955, reviewed the problem of these changes for chub gill nets in Lake Michigan); decrease in size limit for yellow perch from 9 to 8 1/2 inches; two changes of size limit for walleye; change of size limit of whitefish from 2 pounds (equivalent generally to a total length of 18 to 18 1/2 inches) to 17 inches; various changes of closed seasons and particularly the elimination of any closed season on yellow perch in Saginaw Bay (MH-4).

Recent modifications of fishery regulations have been sweeping in Lake Erie-especially in New York, Pennsylvania, and Ontario-where many size limits have been lowered or eliminated and restrictions on mesh size eased or dropped altogether.

The immediate effects of a change of closed season can, of course, be determined readily by a time-stratification of records. If the change of season involves fractions of months, special tabulations of data are required. It is not feasible usually to obtain the information to measure the effects on the statistics of other changes of regulations. No agency engaged in research on the Great Lakes is in position to carry out the intensive, detailed studies to obtain a sound solution to the problem. For any change, knowledge of the immediate effects can have only limited value since the stocks themselves are modified in response to the new method of exploitation. Comparisons between years, before the change and after the change thus become uncertain. Changes of regulations must be accepted, therefore, as disruptive of the continuity of statistical records and appropriate discretion must be exercised in interpretations.

LITERATURE CITED

AMERICAN FISHERIES SOCIETY.

1960. A list of common and scientific names of fishes from the United States and Canada. (Second Edition) Am. Fish. Soc., Spec. Pub. No. 2, 102 p.

HILE, RALPH.

1935. Daily reports reveal new facts and figures. The Fisherman, vol. 4, no. 12, p. 1-2, Grand Haven, Mich.

1937. The increase in the abundance of the yellow pike-perch, Stizostedion vitreum (Mitchill), in Lakes Huron and Michigan, in relation to the artificial propagation of the species. Trans. Am. Fish. Soc., vol. 66 (1936), p. 143-159.

1949. Trends in the lake trout fishery of Lake Huron through 1946. Trans. Am. Fish. Soc., vol. 76 (1946), p. 121-147.

HILE, RALPH, AND HOWARD J. BUETTNER.

1955. Commercial fishery for chubs (ciscoes) in Lake Michigan through 1953. Fish and Wildlife Serv., Spec. Sci. Rep. - Fish. no. 163, 49 p.

1959. Fluctuations in the commercial fisheries of Saginaw Bay, 1885-1956. Fish and Wildlife Serv., Res. Rep. 51, 38 p.

HILE, RALPH, AND WILLIAM R. DUDEN.

1933. Methods for the investigation of the statistics of the commercial fisheries of the Great Lakes. Trans. Am. Fish. Soc., vol. 63, p. 292-305.

HILE, RALPH, PAUL H. ESCHMEYER, AND GEORGE F. LUNGER.
1951a. Decline of the lake trout fishery in Lake Michigan. Fish. Bull., Fish and Wildlife Serv., vol. 52 (Bull. 60), p. 77-95.

1951b. Status of the lake trout fishery in Lake Superior. Trans. Am. Fish. Soc., vol. 80 (1950), p. 278-312.

HILE, RALPH, GEORGE F. LUNGER, AND HOWARD J. BUETTNER.
1953. Fluctuations in the fisheries of State of Michigan waters of Green Bay. Fish. Bull., Fish and Wildlife Serv., vol. 54 (Bull. 75), p. l-34.

KENNEDY, W. A.
1951. The relationship of fishing effort by gill nets to the interval between lifts. Jour. Fish. Res. Bd. Canada, vol. 8, no. 4, p. 264-274.

PYCHA, Richard L.
1961. Recent changes in the walleye fishery of northern Green Bay and history of the 1943 year class. Trans. Am. Fish. Soc., vol. 90, no. 4, p. 475-488.

SMITH, STANFORD H., HOWARD J. BUETTNER, AND RALPH HILE.
1961. Fishery statistical districts of the Great Lakes. Great Lakes Fish. Comm., Tech. Rep. no. 2, 24 p.

VAN OOSTEN, JOHN.
1935. Logically justified deductions concerning the Great Lakes fisheries exploded by scientific research. Trans. Am. Fish. Soc., vol. 65, p. 71-75.

1947. Mortality of smelt, Osmerus *mordax* (Mitchill), in Lakes Huron and Michigan during the fall and winter of 1942-1943. Trans. Am. Fish. Soc., vol. 74 (1944), p. 310-337.

VAN OOSTEN, JOHN, RALPH HILE, AND FRANK W. JOBES.
1946. The whitefish fishery of Lakes Huron and Michigan with special reference to the deep-trap-net fishery. Fish. Bull., Fish and Wildlife Serv., vol. 50 (Bull. 40), p. 297-394.

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