DRAFT

Report of the
Lake Erie
Forage Task Group

March 1994

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Presented to:

Standing Technical Committee
Lake Erie Committee
Great Lakes Fishery Commission

1.0 Charges to the Forage Task Group in 1993-94

The Forage Task Group (FTG) in addressed five major charges from the Lake Erie Committee (LEC) during the 1993-94 work year. These charges were:

1) Prepare a brief report describing the status of forage species in 1993 for each basin of Lake Erie (section **2.0**),

2) Conduct analyses with the interagency trawling program that includes
   a) a procedure for calibration of trawls, incorporating SCANMAR results (section **3.1**),

   b) a continuation of analyses with trawl data sets to determine the most appropriate statistic for describing central tendency (section **3.2**),

   c) a summary of species CPE statistics and biomass estimates from calibrated trawls (section **3.3**),

   d) establishment of a standard trawling protocol in eastern Lake Erie (section **3.4**);

3) Information regarding the qualitative and quantitative aspect of planktonic and benthic organisms and their roles in the Lake Erie ecosystem is limited. This is an area in which the USFWS is interested in expanding their partnership with Lake Erie management agencies, the FTG would welcome dialogue and a planning meeting to determine informational needs and develop an efficient program (section **4.0**);

4) Evaluate hydroacoustic techniques as a method for producing a basinwide assessment of the distribution and abundance of rainbow smelt in the Eastern Basin (section **5.0**);

5) Examine the implications of increased demand on the forage base, particularly on rainbow smelt and alewife, at a time when productivity appears to be declining in the Eastern Basin. The task group should incorporate independent assessments and analyses conducted by the participating agencies. The product may take the form of a risk assessment (section **6.0**).

The bracketed numbers printed above in bold face, indicate the subsection where progress is reported for a particular charge in this document.

2.0 Status of Forage Species

2.1 Eastern Basin (by L. Witzel)

Forage fishes known to comprise important components of piscivore diets in eastern Lake Erie include rainbow smelt, alewife, gizzard shad, white perch, and spottail and emerald shiners. Relative contributions of these species to the diets of fish predators varies with annual fluctuations in abundance.

The status of forage fish in the eastern basin of Lake Erie has been determined annually by independent bottom trawl assessments conducted in the fall by the Ontario Ministry of Natural Resources (OMNR), New York Department of Environmental Conservation (NYDEC), and Pennsylvania Fish Commission (PFC). Recently (since 1991) an Ontario partnership trawl survey comprised of members from the Ontario Fish Producers Association, the Ontario Federation of Anglers and Hunters, and OMNR has provided additional information on the abundance of smelt and other forage species. Indices of relative abundance of forage fish are summarized in agency annual reports to the Lake Erie Committee. Other forage indicators monitored annually in eastern Lake Erie include predator growth rates, piscivore diet composition and zooplankton size structure.

The summary of forage status reported below is based largely on annual trawl assessments conducted by OMNR in offshore (using a 10-m trawl) and nearshore (using a 6.1-m trawl) waters of Long Point Bay (LPB), Lake Erie. All indices of abundance from OMNR trawl surveys are reported as geometric mean catch per trawl hour (GMCPTH).

Smelt are the most abundant forage species available to predators in the offshore waters of eastern Lake Erie. Smelt typically comprise 90 percent or more of index trawl catches (by number) in Long Point Bay and are generally the dominant food item found in the diets of salmonines and walleye.

Recruitment of young-of-the-year (YOY) smelt was poor in 1993 (GMCPTH=146), much worse than the moderately good year class produced in 1992 (GMCPTH=872). YOY comprised 14% by number and 5% by weight of the smelt catch in 10-m index trawls in Long Point Bay. Yearling smelt (1992 year class) was the dominant cohort in the 1993 trawl catch; the 1993 index of yearling abundance (GMCPTH=522) was the highest observed in Long Point Bay since index trawling began in 1984. Age 1 smelt comprised 96% (in number) of the yearling-and-older (YAO) smelt caught, and represented the first significant increase in abundance of YAO smelt since 1986 and the elimination of the strong 1984 year class. The Ontario partnership and NYDEC trawl surveys also indicated a poor '93 year class and increased abundance of YAO smelt dominated by the 1992 year class. Yearlings made up 86% (by number) of the smelt harvested by Ontario commercial trawlers during October to December, 1993.

Average weight of YOY smelt in 1993 was the highest (1.6 g) ever observed in the OMNR index trawl survey. YOY smelt were comparatively large (average weight = 1.4 g) in 1992 as well, but growth of this cohort slowed considerably in 1993; age-1 smelt in 1993 were the smallest on record.

Clupeids typically make up less than three percent (by number) of index trawl catches in the offshore waters of Long Point Bay, and indices of their abundance may not accurately reflect recruitment. Offshore LPB trawl catches of YOY alewife in 1993 continued in a downward trend that began in 1988; 1993 YOY alewife recruitment (GMCPTH=1.1) was below the historical average (1984-92 GMCPTH=4.7). Offshore LPB index trawl catches of YOY gizzard shad in 1993 (GMCPTH=0.5) were below the long term average (1984-92 GMCPTH=2.1). A decrease in relative abundance of YOY alewife from 1992 to 1993 was also evident in the Ontario partnership trawl survey, but not the NYDEC trawl survey. All three surveys however, reported zero catches of YOY gizzard shad in 1992 and a moderate increase in 1993.

Catches of alewife and gizzard shad are typically low in the nearshore waters of Long Point Bay. YOY alewife abundance decreased in 1993 (GMCPTH=0.3) after consecutive increases in 1991 (GMCPTH=1.9) and 1992 (GMCPTH=5.0). Recruitment of YOY gizzard shad was poor in 1993 (GMCPTH=0.8), but slightly higher than in 1992 (GMCPTH=0.1). The historical (1980-92) average abundance indices (GMCPTH) for YOY alewife and gizzard shad in the nearshore LPB trawl survey were 1.8 and 2.3, respectively.

The offshore LPB trawl survey characterizes the 1993 year class of emerald shiner as being moderate (GMCPTH=2.2), somewhat better than the long term average (1984-92 GMCPTH=1.8), and the first increase in recruitment since 1987. Recruitment of YOY emerald shiners was poor from 1984 to 1986, increased to its highest level in 1987 (GMCPTH=6.5), declined sharply in 1988 and 1989, and has remained relatively low there after (GMCPTH=1.4 - 2.2). The relative abundance of adult (YAO) emerald shiners (since 1984) peaked in 1986 (GMCPTH=45.1), then exhibited mostly successive annual decreases through to 1992. The 1993 YAO index of abundance (GMCPTH=6.9) was the highest observed since 1987. An increase in relative abundance of YOY and YAO emerald shiners was also apparent in the NYDEC trawl survey.

OMNR trawl surveys in Inner Bay and outer Long Point Bay indicate that recruitment of YOY spottail shiners increased in 1993. The abundance index of YOY spottail shiners in 1993 (GMCPTH=261) was the highest ever observed in the outer Long Point Bay survey (1980-92 average GMCPTH=24.4). The Inner Bay trawl survey however, rated recruitment in 1993 (GMCPTH=7.4) as slightly less than the long term average (1980-92 GMCPTH=8.7). Relative abundance of YAO spottail shiner from 1992 to 1993, increased slightly in Inner Bay (GMCPTH=0.1 to 0.3) and was largely unchanged in outer Long Point Bay (GMCPTH=3.0 to 2.9). Indices of adult spottail shiner abundance in 1993 were below the long term average for both surveys (1980-92 YAO GMCPTH=0.9 and 3.1 for Inner Bay and outer Long Point Bay, respectively). The Ontario partnership and NYDEC trawl surveys showed a large increase in abundance of YOY spottail shiners in 1993 (compared to 1992) as well.

Widely conflicting trends in abundance indices of clupeids and shiners between surveys (nearshore vs offshore) and among agencies may be attributable to large variations in catches associated with widely clumped distributions of these species. Furthermore, temporal and spatial variations may be confounded by differential effects exerted on fish distributions by zebra mussels. For instance, increased water clarity may render bottom trawls increasingly less effective in the nearshore , relative to offshore areas of the lake.

Recruitment of YOY white perch was stronger in 1993 compared to 1992. Increased catches of YOY white perch during 1993 were observed in trawl surveys by the OMNR, NYDEC and the Ontario partnership program..

In summary, the relative abundance of forage fish appeared to improve in 1993, due largely to the strong recruitment of age-1 smelt (1992 year class). Availability of yearling smelt to predators however, may have been suppressed due to the unusually small size of this cohort. Continued growth of age-2 smelt in 1994 should increase their vulnerability to offshore predators. Forage pressure may be increased on the slow-growing '92 year class if poor recruitment continues for YOY clupeids, shiners, and white perch in 1994.

2.2 Central Basin (by R. Knight)

Forage fish status in the central basin during 1993 was assessed from fall bottom trawl surveys by ODNR and PFC, from growth rates of prey species and key predators (walleye and yellow perch), and walleye prey-size selectivity.

Index values (geometric mean catch per hour trawling) of relative abundance were below historical averages for nearly all of the six targeted forage fish species. Emerald shiners, spottail shiners, trout-perch, alewife, and age-0 smelt were of low abundance. Age-0 gizzard shad were near average abundance. Relative abundance was generally above average for age-1 and older smelt.

Growth rate of walleye in the central basin was at or above that of the last 10 years for most age groups, which suggests prey fish availability was at least moderate in 1993. Age-1 and older walleye ate clupeids from a relatively narrow length range (57-145 mm) in fall 1993 as compared to other years, again reflecting moderate availability of these prey. In prior years, walleye growth rates have been inversely-related to the size of clupeids they eat in fall.

Mean lengths from age-0 fish of several forage and predator species were near long-term averages in ODNR trawl surveys. Trends in growth were not discernible for any of these species in the past 5 years, suggesting that food (zooplankton) availability has not changed substantially. However, this could be masked by declines in abundance for many species over this same time frame.

2.3 Western Basin (by K. Muth)

Data on the relative abundance and growth of young-of-year (YOY) and forage fishes in the western basin of Lake Erie are collected annually by bottom trawl surveys conducted by the Ohio Department of Natural Resources (ODNR), the National Biological Survey (NBS), the Ontario Ministry of Natural Resources (OMNR), and the Michigan Department of Natural Resources (MDNR). Data from these sources are not directly comparable because of the sampling procedures used and the methods of reporting results. However, the comparison of independently derived data serves as a method to confirm the reliability of relative abundance changes.

Summer surveys conducted by ODNR and NBS in August suggested year class strength for many species would be good when compared to summer abundance indices from 1992. Likewise, the interagency trawling by OMNR and ODNR in August indicated higher summer abundance indices for most species in 1993 as compared to 1992 indices. Alewife, emerald shiner, and freshwater drum were the only species with index values in 1993 that were lower than in 1992 (NBS data). Abundance of both YOY walleye and yellow perch increased from last year (data from all agencies) and this was encouraging because both species produced weak year classes in 1992.

Trawling surveys conducted by ODNR included both inshore (shallow) stations and offshore (deep) stations. Catches for all species except gizzard shad were nearly always lower inshore than at the deeper offshore sites. Causes for this difference in catches are unknown but there may be a change in distribution caused by the increased water clarity that has been evident since zebra mussels have become prevalent in the western basin. Alternately, catchability with the trawl may be changing with increased water clarity.

While summer abundance of YOY and forage fishes was higher in 1993 than in 1992, a better perspective of changes in abundance can be gained by comparing current indices with long term averages. A 15-year period from 1979 to 1993 was selected to calculate long term average index values (ODNR and NBS data) for comparisons. Indices for some species span a 25-year period but a shorter time interval may be more appropriate for comparison with current abundance levels because the fish community changed greatly after the mid-1970's when walleye stocks recovered. Based on the 15-year average indices produced by both agencies the summer abundance of most species in 1993 was lower than the long term average. While YOY yellow perch and walleye were the exception with 1993 indices being higher than the long term averages, both species failed to produce a strong year class that would begin to compare with those produced in 1982 and 1986.

Fall abundance indices are generally considered more reliable indicators of year class strength because the effects of early mortality have occurred. Based on fall survey data provided by NBS and ODNR, the abundance indices for all species are lower than they were in the summer surveys and most indices are lower than in the fall of 1992.

The 1993 fall abundance index for YOY freshwater drum was the lowest ever recorded by NBS since 1960. Likewise, the fall index for spottail shiners was among the lowest recorded by both agencies during the past 25 years. Alewife abundance decreased sharply from the very high level indicated in the fall of 1992, while the white perch index was the lowest since 1983 (NBS data) when this species was first becoming abundant in the western basin. Emerald shiner and gizzard shad fall indices were both slightly higher in 1993 than in 1992 and these species probably provided the best forage availability for piscivores. Finally, the abundance of trout-perch was uncertain because the indices provided by NBS and ODNR were in conflict. The NBS index for this species was among the lowest ever recorded while the ODNR index was among the highest they have recorded. Reasons for this difference in relative abundance indices are unclear. However, the uncertainty in trout-perch abundance may not be of much concern because trout-perch are not typically an important forage species in the diets of Lake Erie piscivores.

The abundance of YOY predator species, as indicated by NBS fall index data, may be of some concern. While the 1993 yellow perch index was higher than in 1992, it remained below the high indices produced in 1990 and 1991 when good year classes were produced. Walleye and white bass fall indices were lower than those produced in 1990 and 1991 so recruitment provided by the 1993 year classes may be limited.

Fall length measurements for YOY forage and predator fishes in 1993 suggest growth for most species was comparable to the growth in 1992. This might indicate that zooplankton food resources were sufficient in 1993 to sustain growth of the planktivores. No discernible long-term trend in YOY growth for the primary forage species is evident based on ODNR data from 1982 to the present.

One significant exception to the sustained growth pattern of YOY fishes was for walleye. Mean YOY walleye total length in the fall of 1993 (NBS data) was 162.5 mm as compared to 212.6 mm in 1992. Walleye growth in 1993 was the lowest recorded in more than 20 years (NBS data) and nearly 33% lower than the long-term average. Fall growth data were not available from the OMNR survey but average YOY walleye length in August was about 10% lower than in 1992 and the lowest recorded since 1987. Reasons for this decreased growth are unclear.

Comparing 1993 fall abundance indices with 15-year averages produced by data from both agencies indicates that abundance of most species in 1993 is below average levels. Based on these data, we concluded that the 1993 overall availability of forage fishes in the western basin was relatively low.

3.0 Interagency Trawling

0 An ad-hoc task group, called the Interagency Index Trawl Group (ITG) was formed in 1992 to 1) review the interagency index trawl program in western Lake Erie and recommend standardized trawling methods for measuring fish community indices, and 2) lead in the calibration of agency index trawling gear using SCANMAR acoustical instrumentation. Upon their termination in March 1993, the ITG recommended that work on interagency trawling issues be continued by the FTG on four matters. Progress on these charges are reported below.

3.1 Calibration of Bottom Trawls (by R. Knight)

In 1992, each of the Lake Erie agencies that use the "standard" 10-m index bottom trawl tested their gear with SCANMAR sensory equipment on loan from either the USFWS or University of Rhode Island. Agency reports previously distributed summarize these results. In this section I address two basic questions. What did we learn from SCANMAR testing? And secondly, what needs to be done to fulfil our overall objective toward the calibration of trawls among agencies such that relative abundance data can be pooled or compared across geographic areas?

We learned several things from the SCANMAR experience, most notably that trawl openings (vertical, wing and door spread) at index configurations (speed and scope used during standard surveys), differed substantially within and among agencies (Table 3.1.1). Certainly, true characterization of trawl opening during index surveys would require much more effort than was expended in these pilot experiments, encompassing a variety of environmental conditions (temperatures, wind speeds and directions, depths, sizes of catch, etc.), but at least we have an idea now. More disturbing was that the actual use of SCANMAR equipment was not identical among agencies because an experienced technician participated only with some agencies. Perhaps this is why several agencies found it difficult to obtain reasonable readings on some measurements, particularly vertical opening and clearance. It also became apparent that the so-called "standard" index trawl was not identical among agencies in terms of construction or deployment.

Compounding these problems is the high variability inherent in trawl catches. This variability can be separated into two general components: that due to patchy distributions of fish, and that due to sampling error. Although we need to understand both to best design trawl surveys, it is the latter that we need to focus upon relevant to the calibration of trawls. Sampling error in this case becomes synonymous with trawl efficiency, which is affected by a multitude of factors such as fish behaviour (avoidance to vessel noise and approaching gear, escapement, "herding" inclination, swimming speed), fish density, light intensity, temperature, and gear design. Further complicating matters is that fish behaviour varies both within and among species. Thus, it is critical that "target" species and sizes are established prior to the calibration process. In Lake Erie, all agencies probably would agree that age-0 walleye and age-0 and age-1 yellow perch are the principal target species. That leaves us with the task of coming to grips with trawl efficiency.

If all agencies were without trawling capability, we would probably best serve our cause by investing in several research projects to address trawl efficiency on the targeted species, ultimately using results to purchase identical vessels and gear. Obviously, this is not an option available to us. Alternatively, I propose we adopt a three-step process (listed below) to address this issue.

1) Standardization of trawl opening at index configuration within agencies:

Ideally, each agency would have a SCANMAR unit to measure trawl opening of each tow to verify that opening is relatively constant across all sampling stations. Lacking this, we need to have some sense that openings are at least similar over a range of stations representative of those we sample at the usual towing speed and scope. Do SCANMAR results from 1993 suffice or do we need to test this hypothesis with SCANMAR again but under a more specific, rigid experimental design?

2) *Develop correction factors to standardize trawl catches among agencies:*
Once we feel trawl opening is reasonably constant across stations within each agency, the next step is to conduct joint trawling exercises to calculate correction factors to apply to relative abundance estimates for all species. This will probably entail a much more robust, intensive cooperative effort than any undertaken in the past to get sufficient precision on estimates. Even then, we should probably expect to find fairly wide confidence intervals about the correction factor estimates.

3) *Design and implement gear research projects to examine factors that affect trawl efficiency:*
Gunderson (1993) concludes this is ultimately more successful than developing correction factors in the estimation of fish abundance. His review of literature indicates fish behavior is extremely important, particularly how it is influenced by research vessels and differences in gear (i.e. sweep lines), how it varies in response to environmental cues (temperature and light), and how it varies among sizes and species of fish.

3.2 Central Tendency Statistics

Resource management agencies on Lake Erie typically report the relative abundance of selected fish species from index trawls as an arithmetic mean or geometric mean catch per unit effort (catch per trawl-hour). B. Haas has been leading a charge to determine the most appropriate statistic for describing the relative abundance. He has written a computer program that simulates trawl catches of fish from populations of known size and distribution characteristics. The arithmetic mean, geometric mean, and median are generated from multiple trawl-catch simulations. These statistics are then evaluated on the basis of how close they compare to the known (true) population size. Development and application of the trawl-catch simulation program is continuing and no results were available for this report.

3.3 Summary of Species CPE Statistics

Previous analyses of the western basin interagency trawl data by R. Knight revealed a number of data entry errors and discrepancies between agencies in the classification of small fish to age categories (i.e., age-0 versus yearling and older). These problems have been rectified, but reanalysis of the corrected data sets has not been completed and results were not available for this report. Proposed analyses will include the following:

1) calibration of basin-wide abundance indices for age-0 walleye, yellow perch, white perch, gizzard shad, alewife, trout perch and spottail shiners;
2) analysis of variance of CPE for the major species to identify appropriate stratification for grouping data;
3) comparison of growth data among areas within the western basin;

4) examine the effects of water transparency, temperature, and dissolved oxygen on catch rates of the major species.

3.4 Standard Index Trawling Protocol in the Eastern Basin
(by D. Einhouse, L. Witzel, S. Scholten, and R. Kenyon)

The NYDEC, PFC and OMNR conduct independent trawl assessments annually in the eastern basin. However, these surveys differ in terms of their design and trawl gear, and all of them exclude the deepest areas of the basin.. An OMNR trawl assessment in partnership with the Ontario commercial fishing industry was initiated in 1991 and has provided the broadest coverage of any trawl assessment in eastern Lake Erie to date.

The FTG has developed a draft outline describing the essential elements of a proposed interagency trawl survey for the eastern basin. The principal objective was to assess the relative abundance of YOY and YAO rainbow smelt. Proposed procedures closely follow methods developed for interagency index gill net and trawl surveys in western Lake Erie (Table 3.4.1). We estimated the amount of trawling effort (No. tows) required to achieve a 95% confidence limit, within 20% of the log-transformed mean catch rate of YOY and YAO based on the distribution of catches (mean and variance) in the 1993 NYDEC trawl survey.

This proposal was developed without knowledge of the constraints and with no prior commitment by individual agencies in implementing an interagency survey. Our approach was to develop a trawling protocol that might begin to address basin-wide assessment of smelt stocks, while remaining somewhat compatible with ongoing surveys. Further elaboration of these procedures can build upon this framework when such a survey is effected.

4.0 Role of Invertebrate Communities (by T. Czapla)

This charge attempts to examine the roles and trophic relationships of planktonic and benthic communities within the Lake Erie ecosystem. As a first step toward addressing this charge we initiated a mail survey to determine the extent and nature of past and ongoing assessments of invertebrate populations. A survey letter/questionnaire was sent to 45 contacts at various government, academic and private institutions throughout the Lake Erie drainage area in 1993. Contacts were asked to describe the experimental design, sampling methodology, data analyses and level of reporting of their respective surveys.

Returns from our data inventory survey are still being received. Additional contacts are expected to arise from the initial solicitation and final results are expected in 1994. A list of reports and publications is being compiled as well.

5.0 Hydroacoustic Survey of the Eastern Basin (by D. Einhouse and L. Witzel)

Beginning in 1993, a mid-summer fisheries acoustic survey was implemented to provide a more comprehensive evaluation of the distribution and abundance of rainbow smelt in eastern Lake Erie. This new initiative was led by NYDEC under the auspices of the FTG.

5.1 Methods

A hydroacoustic survey of the eastern basin was conducted during July 1993 using a Simrad EY-M single-beam echosounder. Signal processing was accomplished through Hydro Acoustic Data Acquisition System (HADAS) software, Version 3.9. Three nighttime acoustic transects were completed at depths beyond the 25-m (82-ft) contour and roughly perpendicular to the axis of Lake Erie in eastern basin waters (Figure 5.1.1). Accompanying nighttime mid-water trawling was done concurrently with acoustic data collection by the NBS (Sandusky, Ohio). Additional nighttime mid-water trawling was conducted two weeks after the acoustic survey.

5.2 Results

Acoustic data sets were analyzed, in conjunction with the OMNR Port Dover office. The summer, 1993 acoustic survey collected data along three transects for a total linear distance of 117 km (73 miles). Nighttime mid-water trawl catches during the acoustic survey were very small due to apparent difficulty of the trawl gear to open properly. Subsequent efforts (two weeks later) with a much larger trawl produced larger catches. In all, six mid-water trawl tows produced the fish samples to assist characterizing species composition of acoustic targets. Daytime, bottom trawling during the NYDEC annual forage fish and lake trout assessments also produced a large sample of fish for characterizing species composition in offshore areas. These mid-water and bottom trawl collections suggest that smelt were the dominant species in offshore waters (Table 5.2.1).

Acoustic fish density estimates were pooled into "small" and "large" fish categories, based on measured target strengths (TS) of individual fish. Fish with TS $\leq$ -44 dB were classified as "small", and those greater than -44 dB were pooled as "large" fish. The empirical formula derived by Love (1977), which relates target strength to fish length, predicts a length of 120 mm (4.7 in) at TS=-44 dB. We assumed that small fish represented mostly YAO smelt, approximately 120 mm and smaller.

Figure 5.2.1 shows small fish densities in coldwater habitat at regular intervals along acoustic transects. Mid-water trawl catches suggest nearly all of these small, coldwater fish were yearling-and-older smelt. Highest densities of these fish were encountered in the easternmost transect. Fish densities also tended to be greatest at the ends of the transects. Expansion of mean density estimates to the total surface area encompassed by the 25-m contour of the eastern basin, yielded a numerical abundance estimate of 515 million small pelagic fishes in offshore coldwater habitat. Total small, pelagic fish abundance was estimated as 777 million fish for the entire water column. These are provisional estimates based on a preliminary analyses made for this report.

5.3 Discussion

The 1993 acoustic survey provided a useful evaluation of this technique for assessment of the distribution and abundance of pelagic fishes in eastern Lake Erie. However, the initial numerical abundance estimates reported above seem too low to accurately reflect the eastern basin smelt resource. Annual commercial harvests have ranged between 0.5 and 1.0 billion smelt in eastern Lake Erie, although the 1993 harvest was apparently much smaller due to a shift in commercial fishing effort to the central basin during summer and fall (L. Witzel, personal communication). Our survey did not encompass the full extent of smelt habitat in Lake Erie as highest densities occurred at the edge of our sampling area. Therefore, our estimate is likely an approximation of minimum abundance. This pilot year suggests a much more comprehensive survey is necessary to characterize absolute abundance.

In other respects, acoustics appear to have considerable potential as an assessment tool. Species discrimination does not seem to be an issue, as available trawl data suggest smelt are the dominant member of the coldwater community. The nighttime pelagic behaviour of this species also lends itself well to acoustic studies. Finally, a basinwide assessment of smelt distribution and abundance can be achieved at a lower operational cost using acoustical gear than with an extensive trawl survey.

Ideally, biannual acoustic surveys that bracket the season of highest smelt consumption and YOY smelt recruitment would provide opportunities to assess smelt production and mortality. However, significant expansion of the present NYDEC survey could only occur by displacement of other valuable, ongoing assessments or by receiving additional assistance from another agency.

6.0 Impact of Increased Forage Demand in the Eastern Basin

In 1991 the LEC assigned the FTG the charge of evaluating the predatory impact of walleye and salmonine fishes upon Lake Erie's rainbow smelt stocks. During the two years that followed, the FTG produced two reports answering this charge. The first, examined consumption of rainbow smelt by lake trout at two equilibrium stocking densities (Einhouse et al. 1992). The second, reported on the estimated consumption of rainbow smelt by walleye and salmonine species in the central and eastern basins from 1984 to 1991 (Einhouse et al. 1993).

The current charge attempts to relate the FTG estimates of predator demands on smelt with an independent investigation lead by Phil Ryan (Ryan and Paine 1994) that described the productivity of the eastern basin rainbow smelt stock from 1985 to 1991. Zebra mussels did not become widely distributed in the eastern basin until after 1989, therefore the smelt consumption estimates reported by Einhouse et al. (1993) and productivity analyses by Ryan and Paine (1994) were for a period before significant zebra mussel impacts. Recent changes in the water clarity and trophic structure of eastern Lake Erie may have profound effects on the productivity of smelt stocks.

Amalgamation of the consumption and productivity studies was extended beyond the 1985-91 reference period to provide a longer time series (of consumption and smelt biomass) that included zebra mussel colonization. The following report is a summary of work largely done by Phil Ryan (OMNR, Port Dover, Ontario).

6.1 Surplus Production Models for the 1985-91 Fishery (by Phil Ryan)

Surplus production models were applied to commercial harvest and biological data of rainbow smelt for the period 1985 to 1991 (Ryan and Paine 1994). A major parameter influencing the results of the surplus production models was the estimated value of natural mortality (M). The FTG estimates of smelt consumption (Einhouse et al. 1993) provided a way of estimating M as a portion of total mortality (Z) according to the ratio of predation to harvest from 1985 to 1991. Surplus production models were fitted to 1) the relationship of harvest to Z, through an intercept of M=0.72, and to 2) the relationship of total use (harvest plus predation) to Z, through the origin (Figure 6.1.1). The data series for predation was extended back to 1982 by assuming that walleye predation was proportional to abundance (commercial gillnet CPUE), and that salmonine predation remained the same as 1985-1991.

6.2 History of Use of the Smelt Stock

Estimates of smelt predation were extended back to 1982 and ahead to 1993 by using the following approximations. Diet composition was the same as the average for 1985 to 1991. Salmonine abundance, hence predation was assumed to be relatively constant due to similar stocking levels between years. Large mesh CPUE (kg/km) could be used to represent walleye abundance in the eastern basin. A regression of consumption on walleye CPUE (forced through the origin) for the years 1985 to 1991 was used to estimate predation on smelt by walleye in years previous to 1985 and years after 1991.

Total use of the smelt resource increased from 1978 to 1983, due to increased commercial harvest (Figure 6.2.1). The level of use varied from 1984 to 1990. The portion used by the fishery decreased as the walleye population increased from 1985-1989. Total use of the resource declined from the peak in 1988 (circa 17000 t) to a lower level in 1993 (circa 11000 t).

The walleye component of consumption declined from 1987 to 1992, but increased strongly in 1993. Predators accounted for 52% of use in 1992 and 83% in 1993. The current (1993) predator abundance is at a level corresponding to the highest estimates in the 1980s.

6.3 Estimation of Smelt Stock Size

The logistic population modelling provided an estimate of stock catchability (q=0.000045), from which smelt stock size was estimated as

Biomass = CPUE/q

A series of biomass estimates were made for 6 month intervals in Table 6.3.1. These estimates were corrected for potential bias associated with commercial fishing practices by comparing the CPUE from a systematic trawl survey with that from the fishery (S. Scholten, personal communications). The "corrected" CPUE's for stock size estimation are also reported in Table 6.3.1.

The 1993 fall fishery data (Oct.-Dec.) were used to estimate the biomass as 15,322 t. This estimate was used in subsequent analyses because there was little difference between it and the adjusted biomass.

6.4 Significance of Alewife

FTG analysis of forage demands by fish predators in Lake Erie showed that smelt comprised the bulk of the diet (average 7551 t out of an average total 12562 t consumption, Einhouse et al. 1993). The composition of the remaining 40% was not identified. If we assume that alewife were an important component of the remainder, then we should be concerned about the recent dynamics of alewife. Catches in index gillnets and trawls in the eastern basin and Pennsylvania Ridge dropped very low in 1993. Long Point Bay trawl catches show a second year of low recruitment.

Numbers of alewife caught with standard survey effort in Ontario waters:

Year	East Basin Trawl	East Basin Gillnet	Pennsylvania Ridge Gillnet	Long Pt. Bay Trawl
1989		1881		973
1990		86		879
1991	217	1357	740	2091
1992	185	1040	1530	203
1993	4	161	0	292

We have estimated the predator demand for smelt for 1993 as 9000 t. A reduction in alewife availability must inevitably lead to increased predation on smelt. If half of the "other" category was shifted to smelt, it would mean that predation increased by 2500 t (50% of 5011 t), for a total of 11,500 t.

6.5 Has Productivity of the Smelt Stock Changed?

The smelt stock has been modelled for the period 1982-1991 using a logistic population model that was fitted using conventional surplus production models (Ryan and Paine 1994). Figure 6.5.1 shows the relationship between commercial harvest and stock mortality rate and between total use of the stock (=production) and stock mortality rate.

The recent behaviour of the smelt stock suggests that the productivity of eastern Lake Erie for smelt has been reduced by approximately 30%. The effects of this can be shown using the relationship between stock production and biomass, and reducing the carrying capacity (B_{∞}) of the stock from the 1985-91 value of 34,000 t by 30% to 24,000 t (Figure 6.5.1). The peak production occurs at 1/2 of the carrying capacity biomass, when the mortality rate is approximately 62%. Peak production was estimated as 17,000 t/yr for 1985-91 and 12,000 t/yr for recent years.

6.6 Level of Use of the Stock Relative to Production and Biomass

The total use of smelt (predation+harvest) averaged 14308 t from 1985 to 1991. This represented 84% of the potential maximum production of the smelt stock. The level of resource use by predators may be as high as 11500 t in 1994. This would represent 96% of the potential maximum production of the smelt stock. Total use has to fit within production, and should be substantially less. Predation by burbot and other sources of mortality have not been evaluated.

The production models (Figure 6.5.1) smooth out the fluctuations of smelt biomass from year to year (Figure 6.1.1). The current biomass is estimated to have averaged 15300 tonnes between October and December 1993. Subtraction of 1/2 of the fall commercial harvest (660 t) would leave a biomass of 14640 t. A predator consumption of 11,500 t would leave a stock of 3140 t in the fall of 1994. This is similar to previous low values of the smelt stock in 1993 (Oct 1992-March 1993; biomass 2780 t) and 1989 (Oct 1988-March 1989; biomass 3542 t).

There is a fairly strong 2 year pattern of recruitment and production in the smelt stock. Recruitment of a cohort as age 1 and subsequent growth of age 1 fish takes the biomass of the population from a very low spring level to a peak of biomass in the fall as age 1. The biomass of the smelt stock (primarily of this cohort) is then depleted over the following 12 to 18 months as age 2 or 3 fish. We must assume that we are the depletion phase of the 2 year cycle now because of the dominance of age 2 fish. Using the stock size data (Table 6.3.1), the stock will run down from the 14640 t level (Jan 1, 1994) through 1994 and reach the lowest level in April 1995, before resurging with age 1 recruits during the summer of 1995. In the absence of commercial fishing, the current stock of 14640 t would be reduced by 11,500 t to 3,140 t by fall 1994.

The forage demands in the eastern basin by predator fish species are projected to have actually increased since 1991, because of the increase in walleye and the steady background level of salmonines. The low alewife abundance in 1993 may be a symptom of the high predator demand on forage. Harvest of smelt by the commercial fishery has declined, although quotas have permitted higher levels of harvest. The harvest in 1993 was 1841 tonnes, representing 17% of the estimated total use of smelt (11034 t) in 1993.

The logistic production models have provided a reference value of maximum production, against which to compare estimated use of the stock. From 1985-1991 the maximum production was 17,000 t and use was 84% on average. We project that the current maximum production is 12,000 t and that an 85% level of use would be 10,200 tonnes.

The projected level of consumption of smelt by predator species assumes an increase in pressure on smelt due to low alewife abundance. It also assumes that predators species will remain in the eastern basin, and not move into the central basin.

Since this analysis was conducted, additional information has become available concerning walleye abundance. The walleye abundance and demand for forage in 1993 (and 1994) was projected from the fishing success in the commercial and sport fisheries in northern (Ontario) waters of the eastern basin. Sport fishing success was also found to have increased in the southern (New York) waters, but did not reach the CPUEs observed in 1988. This suggests that walleye abundance was higher in the northern half of the lake, in 1993 than in the southern half.

8.0 References

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Love, R. H. 1977. Target strength of an individual fish at any aspect. J. Acoust. Soc. Am. 62: 1397-1403.

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Table 3.1.1. Mean opening of standard 10-m bottom trawl at index configuration for each agency, as determined from SCANMAR equipment in 1992.

Agency	Bridle Length (m)	Speed (Knots)	Scope[a]	Measured Opening (m)		
				Doors	Wings	Gape[b]
MDNR	45.7	2.1	9:1	12.1	6.6	2.3[c]
NYDEC	—[d]	2.5	3:1	14.3	5.0	1.4
ODNR						
Sandusky	16.2	1.3	3:1	7.6	4.7	1.1
Fairport	—[d]	1.3	3:1	9.5	6.5	<1.5[e]
OMNR						
Wheatley	—[d]	2.5	6:1	9.9	5.6	2.3
Pt. Dover	21.0	2.5	5:1	9.6	5.8	2.0
PFC	—[d]	3.0	3:1	12.5	4.3	2.4

[a] Warp length to depth ratio
[b] Vertical opening at mouth of trawl
[c] Estimated value, actual measurement of 4.2 is inaccurate
[d] Double-warp systems
[e] Detection level = 1.5 m for Rhode Island University SCANMAR

Table 3.4.4 Draft proposal of a standardized protocol for an Interagency index trawling survey in eastern Lake Erie.

Objective:	Produce an annual index of abundance of smelt and five other forage fish species identified by the Forage Task Group.
Sampling Strategy:	Proportional allocation among 3 strata; stratified random sampling of 2.5 minute grids.
Temporal Stratification:	September
Spatial Stratification:	10-20 m Epilimnion 20-30 m Thermocline >30 m Hypolimnion
Tow Time:	10 minutes
Tow Speed:	2.5 knots
Gear:	2-seam biloxi otter trawl with 10-m headrope and 11.4-m footrope. Fishing configuration consists of a single warp line to a 21-m bridle, deployed at a 5:1 scope. Cod-end mesh = 0.375 inches.

Total Effort by Stratum and Jurisdiction:

	Ont	*PFC*	*DEC*	*Total*
10-20 m	9	4	4	17
20-30 m	9	4	5	18
> 30 m	21	10	9	40
TOTAL	39	18	18	75

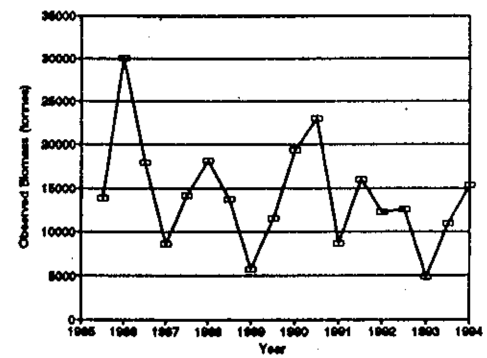
Table 5.2.1 Summary of mid-water and bottom trawl catches to characterize species composition in offshore areas (>25 m contour) of the eastern basin of Lake Erie, 1993.

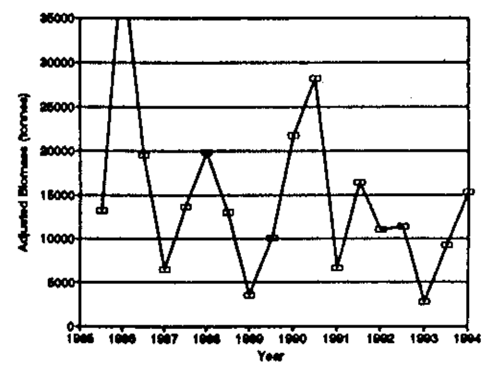
Trawl Gear	Time	Tows	Stratum	Number of YAO Smelt	Number of Other Fish	Percent YAO Smelt
Midwater	Night	1	Epilimnion	75	11	87.2
Midwater	Night	2	Thermocline	108	5	95.6
Midwater	Night	3	Hypolimnion	369	4	98.9
Bottom	Day	37	Hypolimnion	95,556	108	99.9

Table 6.3.1. Observed and adjusted commercial catch-per-unit-effort of rainbow smelt and estimates of stock biomass based on catchability coefficient (q).

q: 4.5E-05

Year	Observed CUE (kg/hr)	Adjusted CUE (kg/hr)	Observed Biomass (tonnes)	Adjusted Biomass (tonnes)
1985				
1985.5	624.47	595.84	13,877	13,241
1986	1,352.80	1,892.14	30,062	42,048
1986.5	810.77	880.26	18,017	19,561
1987	387.37	291.83	8,608	6,485
1987.5	638.68	616.22	14,193	13,694
1988	819.46	894.40	18,210	19,876
1988.5	618.62	587.51	13,747	13,056
1989	258.46	159.39	5,744	3,542
1989.5	520.97	454.45	11,577	10,099
1990	871.88	981.26	19,375	21,806
1990.5	1,036.39	1,270.55	23,031	28,235
1991	393.10	298.31	8,736	6,629
1991.5	721.04	738.71	16,023	16,416
1992	553.06	496.93	12,290	11,043
1992.5	565.63	513.91	12,570	11,420
1993	219.78	125.09	4,884	2,780
1993.5	492.54	417.89	10,945	9,286
1994	689.50	690.93	15,322	15,354





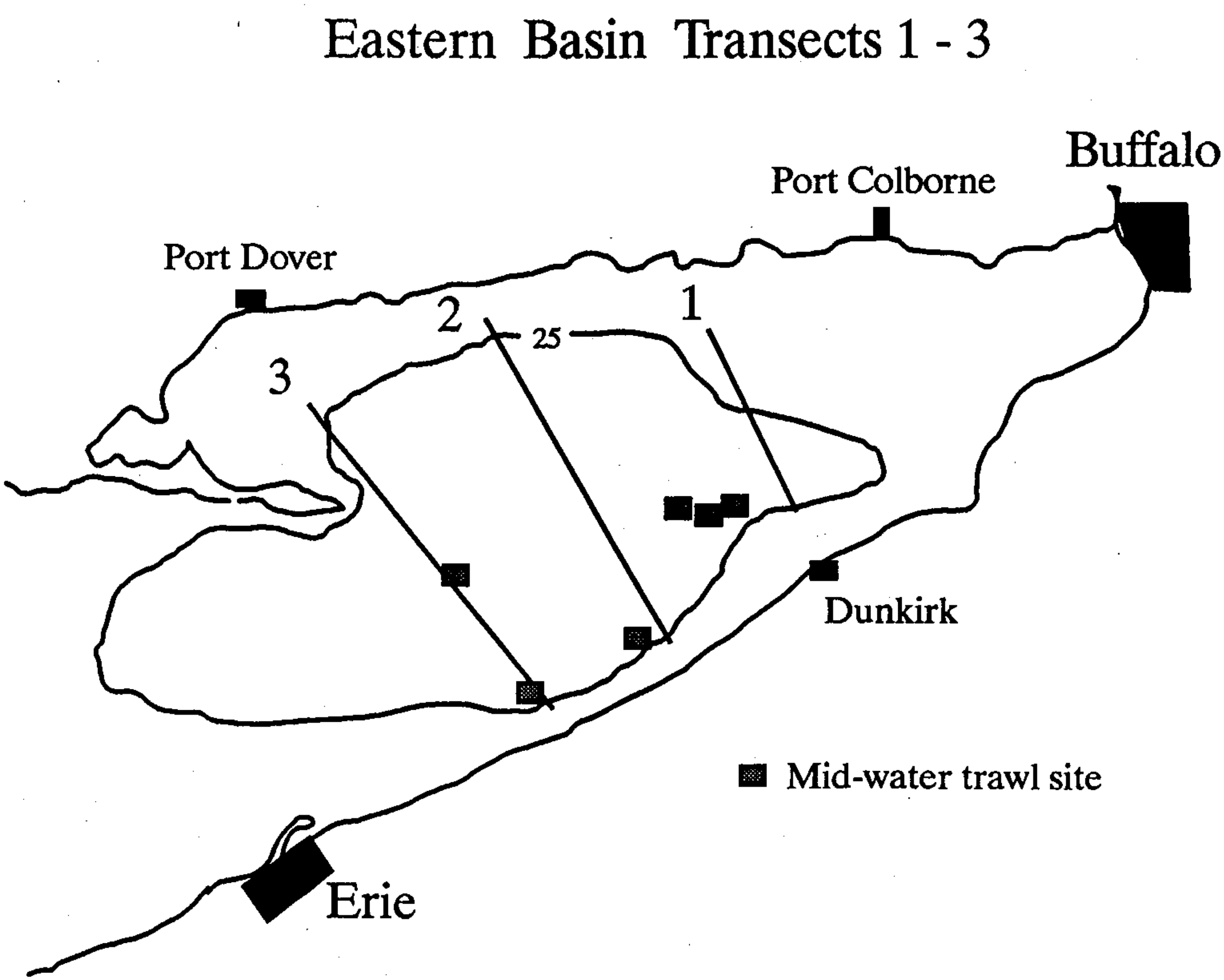
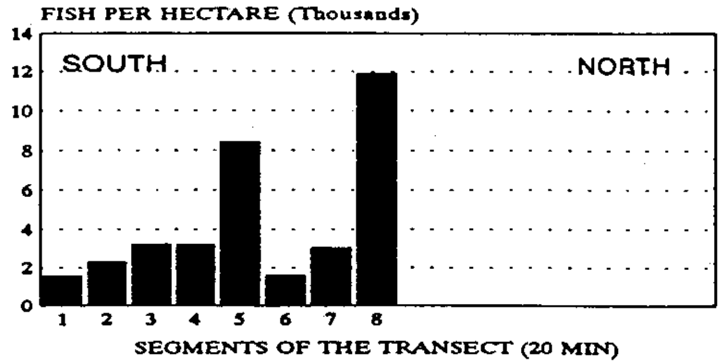


Figure 5.1.1 Approximate location of transects cruised by NYDEC/NBS during a hydroacoustic survey of fish stocks in eastern Lake Erie, July 1993. Transect 4 was not completed.

TRANSECT 1



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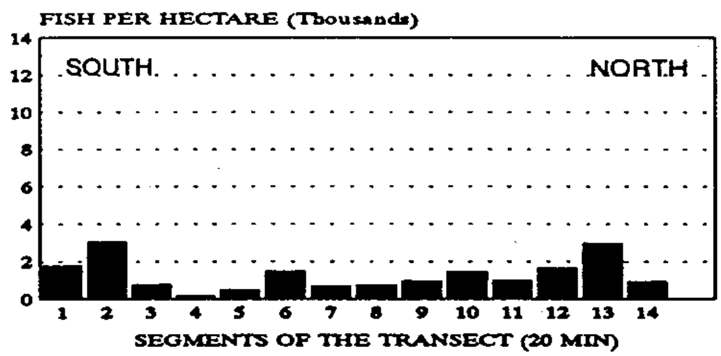

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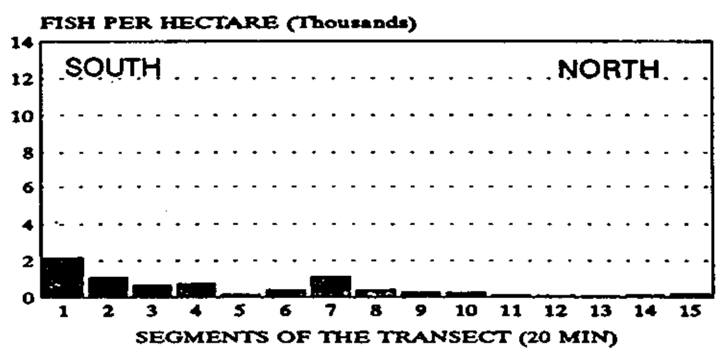

Figure 5.2.1 Densities of small fish (YAO smelt) in coldwater habitat along three transects of a NYDEC/NBS hydroacoustic survey in eastern Lake Erie during July 1993.

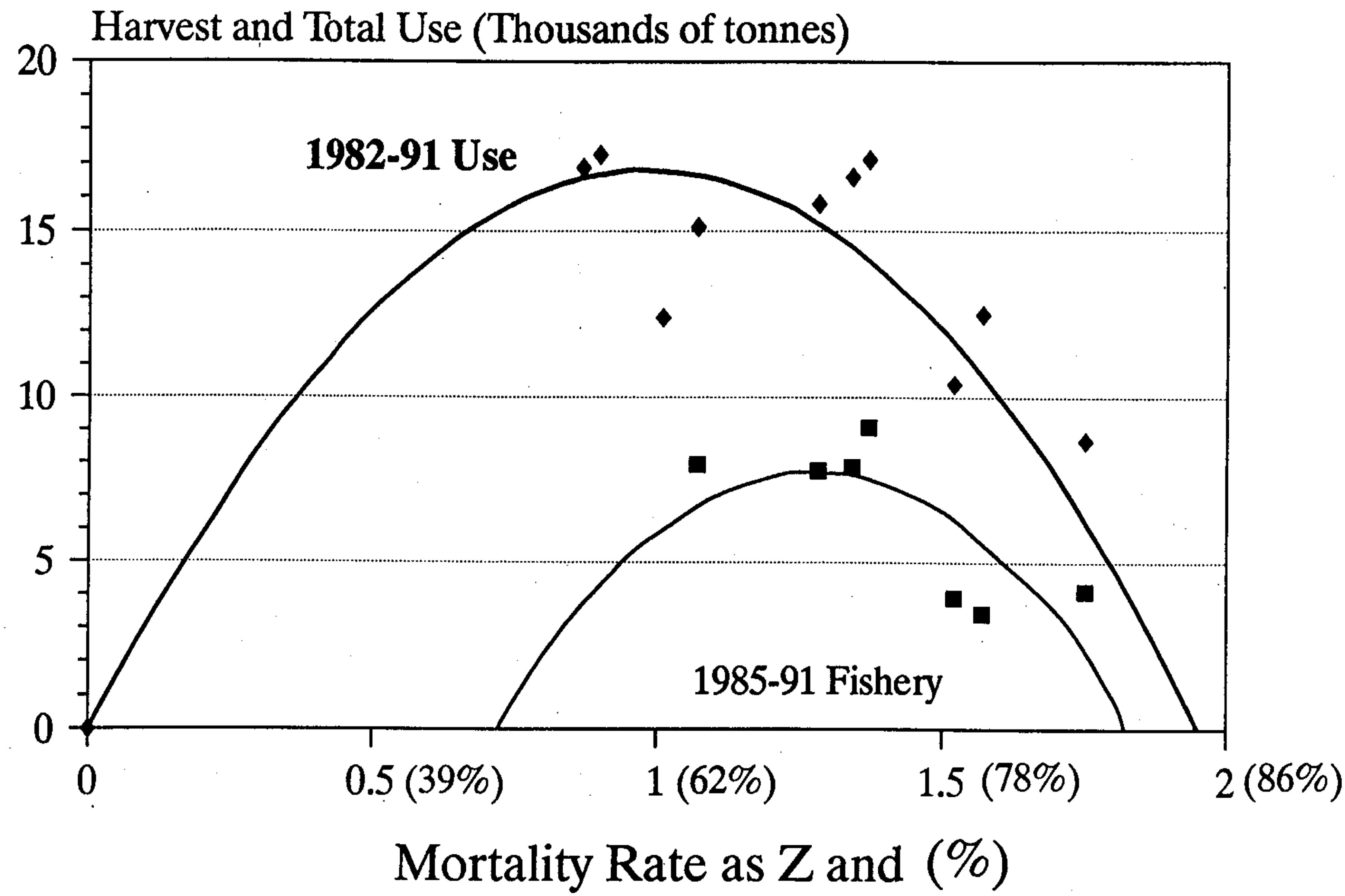

Figure 6.1.1. **Csirke and Caddy models of the commercial rainbow smelt harvest (1985-91) and total use of the smelt resource (1982-91).**

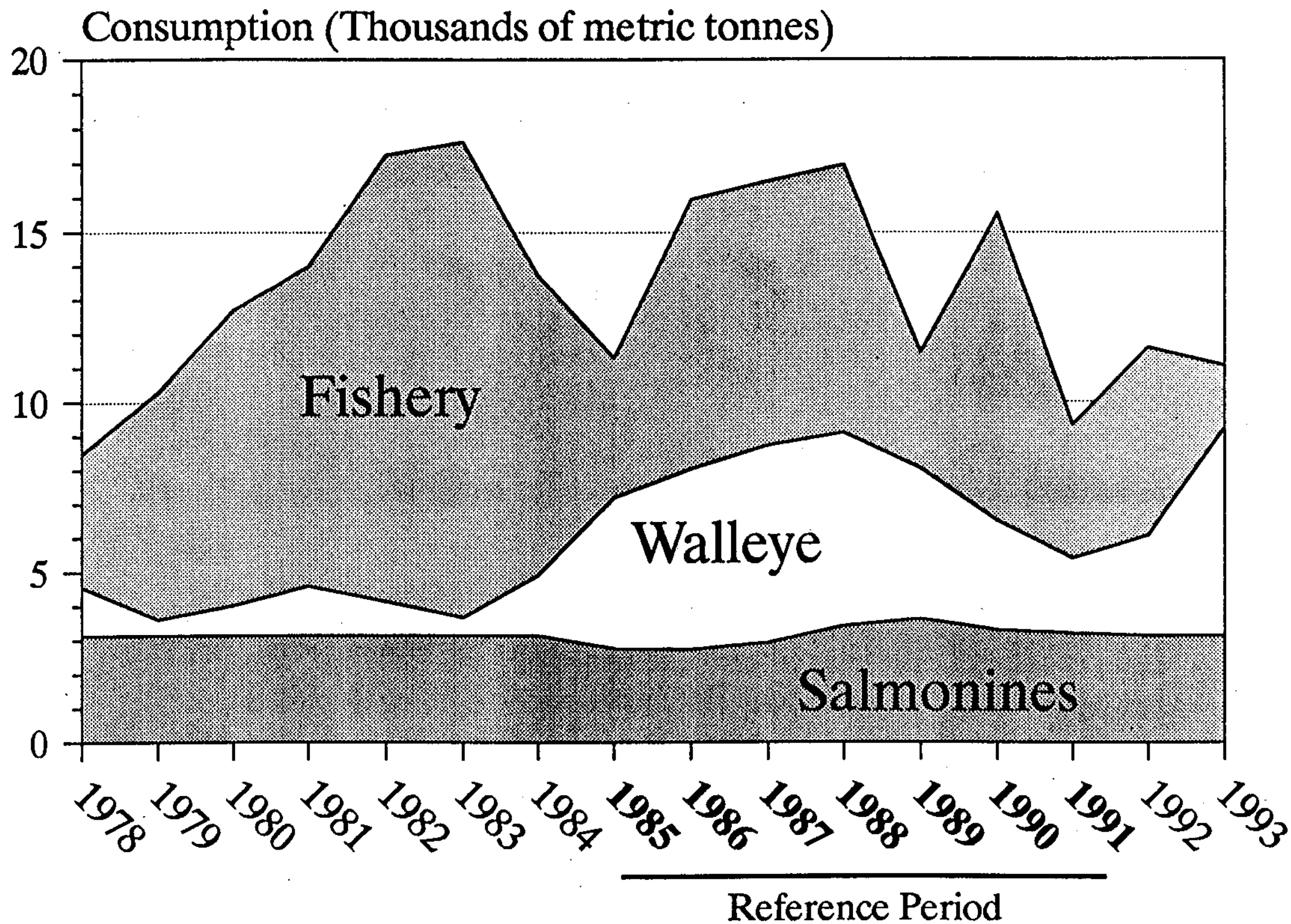

Figure 6.2.1. A graphic summary of use of the eastern basin rainbow smelt stock from 1978 to 1993, partitioned between consumption by salmonines and walleye, and harvest by the commercial fishery.

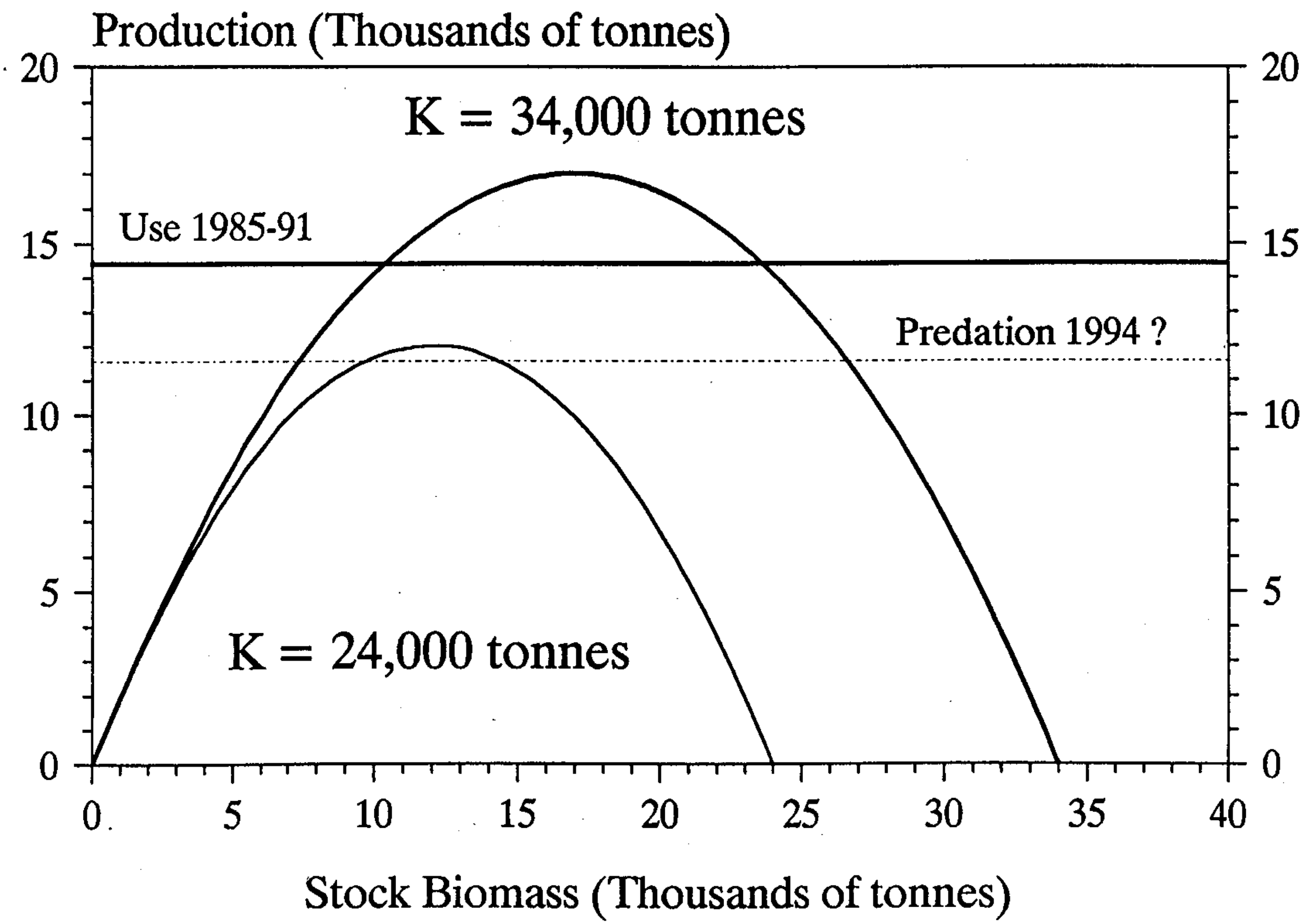

Figure 6.5.1 Estimates of production as a function of biomass (B) that are predicted to occur by the eastern basin rainbow smelt stock at a carrying capacity (K) of 24,000 tonnes and comparison to productivity and total use of the stock during a reference period (1985-1991) when K = 35,000 tonnes.