Report of the
Lake Erie
Forage Task Group

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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 1997-1998

The Forage Task Group (FTG) addressed four major charges from the Lake Erie Committee (LEC) during the 1997-1998 work year:

1) Continue to describe the status and trends of forage fish species and invertebrates in 1997 for each basin of Lake Erie;

    a) Forage Task Group Bullet Statements (section **2.0**);

    b) Detailed Basin summaries (section **3.0**);

        - Eastern Basin summary (section **3.1**)
        - Central Basin summary (section **3.2**)
        - Western Basin summary (section **3.3**)
        - Predator Diet summary (section **3.4**)

2) Continue the investigation and analyses regarding the utility of the interagency trawl assessment program (section **4.0**):

    a) Support the use of SCANMAR equipment for interagency calibration of assessment trawl gear. Continue the development of an experimental design to facilitate forage assessment (section **4.1**),

    b) Continue trawl catch simulations to select appropriate measures of central tendency expressing species' abundance (section **4.2**),

    c) Complete statistical evaluation of species CPE indices and effects upon sampling from physical and environmental features (section **4.3**),

3) Conduct bioenergetics simulation to estimate consumption of smelt and other prey fish by predators in the central and eastern basins (section **5.0**);

4) Develop a hydroacoustics program to assess important forage fish stocks in the central and eastern basin. Plan should include sampling schedule, protocol, implementation costs, objectives, as well as agency staff and vessel requirements (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 Forage Task Group Bullet Statements

Eastern basin

- *Dreissenid*s (mostly quagga mussels) now comprise more than 90% of the benthic invertebrate biomass. Conversely, biomass of the amphipod *Diporeia* has decreased in deeper regions of the Eastern Basin. Also, cladoceran and copepod biomass have dramatically decreased since 1984.

- Forage fish species diversity remains poor, with rainbow smelt ranking as the dominant species available to open water piscivores. Rainbow smelt continue to experience high mortality; age-2 smelt are poorly represented and age-3 and older cohorts remain virtually absent from the population. Mean size of age-1 smelt during fall, 1997 was the lowest observed in a time series spanning from 1984, and annual trends in age-1 smelt size have shown a progressive decline since 1995. The first confirmed observation of the round goby (*Neogobius melanostomus*) in Long Point Bay occurred in February, 1998, and raises many questions concerning the potential impacts of another new exotic species on an already much altered Eastern Basin fish community.

- Rainbow smelt continue to dominate the diet of open water piscivores. The Forage Task Group is using a bioenergetics approach to quantify forage fish demand by walleye, rainbow trout, lake trout, and burbot. Results of these simulations will be described in a second report later this year.

- Age-1 walleye, age-1 yellow perch and sub-adult smallmouth bass were small in 1997. However, no consistent pattern of change in growth has been apparent for adults of these species or lake trout.

Central basin

- Zooplankton biomass has not changed significantly in the central basin, but composition has changed since zebra mussel introduction. *Daphnia* biomass decreased and calanoid copepod biomass increased in the central basin.

- Smelt continue to be the most abundant age-0 forage species, with goby being the most abundant yearling-and-older forage species. Age-0 abundance indices decreased from 1996, while most yearling-and-older indices increased over 1996.

- Smelt and *Notropis* spp. were the principle prey in walleye diets through the summer and fall. There was a dramatic increase in the occurrence of emerald shiners in the diets of walleye from the west-central basin.

- Endemic benthic fauna decreased from 16.3 g/m^3 to 12.2 g/m^3 in 1993. *Dreissena* accounted for the rest of the benthic biomass for a total of 296.9 g/m^3.

Western Basin

- Abundance of zebra mussel larvae peaked in the western basin in 1993 and has gradually declined since. Zooplankton abundance has been relatively stable since the precipitous decline in the late 1980's. On the other hand, large benthic macroinvertebrates such as amphipods, caddisflies, and mayflies have increased dramatically during the past 4 years.

- A diverse forage fish base is present in the western basin, with balanced representation of 3 functional groups: clupeids (age-0 alewife and gizzard shad), soft-rayed fish (smelt, spottail shiners, emerald shiners, and silver chub), and spiny-rayed fish (age-0 white perch, yellow perch, white bass, walleye and freshwater drum). Clupeids dominated the catches in 1997. The large decrease in total forage abundance and biomass over the past 10 years is attributable to decreases in spiny-rayed forage fishes, particularly age-0 white perch. Increases in abundance and biomass of soft-rayed forage fishes are due primarily to increased abundance of age-1 and older emerald and spottail shiners.

- Increases in shiner abundance in recent years are reflected in fall walleye diet composition. Yellow perch diets in the western basin reflect the increased abundance of *Hexagenia*, trichopterans, and amphipods.

- Size of age-0 walleye and yellow perch have been below average during the past two years. No consistent pattern of change in growth is apparent for age-1 and older walleye and yellow perch in Ohio surveys of the western basin, but growth of age-1 and older walleye and yellow perch is down in Ontario surveys.

3.0 Detail Status of Forage

3.1 Eastern Basin (by L. Witzel, D. Einhouse, E Trometer, C. Murray)

The status of prey 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 State Department of Environmental Conservation (NYSDEC), and Pennsylvania Fish and Boat Commission (PFBC). NYSDEC has also conducted a summer (July) trawl survey of deep water stations (< 36 m) since 1987. All indices of abundance from agency trawl surveys are reported below as geometric mean catch per trawl hour (GMCPTH). Long-term average species abundance is reported as the arithmetic mean of the annual GMCPTH estimates for the time series associated with each agency's trawl survey.

Fall trawl assessments indicate that recruitment of young-of-the-year (YOY) smelt was poor throughout eastern Lake Erie in 1997 (Table 3.1-1). OMNR and NYSDEC trawl survey data show that YOY smelt recruitment was well below long-term average abundance in 1997 (Figure 3.1-1). Relative abundance of yearling-and-older (YAO) smelt increased in 1997, but remained below long-term average abundance (Table 3.1-1). All agencies reported near record low catches of YAO smelt in 1996 (Figure 3.1-2). The 1996 year class was the dominant cohort among YAO smelt in eastern basin index trawl catches in 1997. Cohorts older than age-2 remain scarce in the population.

Growth of YOY smelt (OMNR data) improved in 1997 following near record low size in 1996 (Figure 3.1-3). The smallest YOY smelt were observed in 1988 (54.0-mm FL). Yearling smelt in 1997 were the smallest ever observed in OMNR index trawl catches (Figure 3.1-3). The pattern of alternate year increases in size of age-1 smelt that characterized the population from 1984 to 1994 has changed in recent years to progressively smaller yearlings.

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. All agencies reported poor recruitment of YOY alewife and gizzard shad in 1997; YOY catch rates of these species were below long-term average abundance (Table 3.1-1). Agency trawl surveys indicate that emerald shiners experienced very poor YOY recruitment in 1997 (Table 3.1-1). The strong 1996 year class did not successfully recruit to yearlings in 1997, suggesting that this cohort experienced high mortality during 1997. Depressed smelt populations may have contributed to increases in predation pressure on emerald shiners. Agency trawl surveys indicate that YOY spottail shiner recruitment declined below long-term average abundance in 1997 (Table 3.1-1). Recruitment of YOY white perch continued to be poor throughout the eastern basin in 1997 (Table 3.1-1). All agency trawl surveys reported a decline in availability of YOY white perch.

Widely conflicting trends in abundance indices of clupeids and shiners between surveys (nearshore versus 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 *Dreissena* spp. For instance, increased water clarity may render bottom trawls increasingly less effective in the nearshore, relative to offshore areas of the lake.

Smelt are the most abundant prey fish 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) and are generally the dominant food item found in the diets of salmonines and walleye. Other prey fishes known to comprise important components of piscivore diets in eastern Lake Erie include alewife, gizzard shad, white perch, and spottail and emerald shiners. Relative contribution of these species to the diets of fish predators varies with annual fluctuations in abundance.

With the introduction of zebra mussels into Lake Erie, eastern basin benthic invertebrate communities have undergone substantial changes. Currently, in deep-water areas of the eastern basin, over 91% of the total benthic invertebrate biomass is *Dreissena* (mostly quagga mussels) (Dermott and Kerec 1997). Density of non-dreissenid invertebrates increased significantly, but biomass decreased significantly from 1979-1993. The greatest reduction in benthic invertebrate biomass occurred in *Diporeia*, chironomid, and *Pisidium* species.

Additional reductions in invertebrates have also occurred in zooplankton in the eastern basin. Dahl et al. (1993) found that zooplankton biomass and composition has changed dramatically from 1984-1993. Large *Daphnia*, which accounted for 22.3% of zooplankton biomass in the mid-80's, were virtually absent in 1993. Additionally, the NYS Department of Environmental Conservation (NYSDEC) has conducted a zooplankton survey in the eastern basin since 1984. From 1984-1988, several sites in New York waters of the eastern basin have been sampled, with some changes in methodology over this period. From 1989-1996, the methods and sample sites have remained the same. NYSDEC data show that mean annual cladoceran biomass has declined dramatically since 1984 (Figure 3.1-4). The decrease at the Van Buren and Dunkirk shallow stations from 1984-1995 were only marginally significant ($p=0.075$) due to the high variability inherent in the data. Annual cladoceran biomass decreases are driven primarily by decreases in biomass in June. In 1996, cladoceran biomass increased in at the Dunkirk nearshore station, but remained extremely low at the Dunkirk deep site (Figure 3.1-4). NYSDEC data also indicate that mean annual copepod biomass has declined slightly from 1984-1996 (Figure 3.1-5). Monthly abundance of copepods varied inter-annually, but generally decreased within years. While quite variable, there were no observable changes in average copepod or cladoceran lengths.

In summary, the relative abundance of prey fish in the eastern Lake Erie appeared to be well below average levels during 1997, due largely to low abundance of YAO smelt. Poor recruitment by clupeids and shiners in the eastern basin may shift greater forage pressure to smelt in the offshore waters in 1998. The moderately poor 1996 year class of smelt will likely continue to provide the largest single supply of forage for offshore piscivores in 1998.

3.2 Central Basin (by J. Deller and E. Trometer)

Fall assessment bottom trawls are conducted by the Pennsylvania Fish and Boat Commission (PFBC) and the Ohio Department of Natural Resources (ODNR) in the central basin of Lake Erie during late September and early October of each year. In 1997 the PFBC was unable to complete the fall survey in the central basin due to adverse weather conditions. The data for the central basin forage fish assessment is from the ODNR fall trawl survey only.

Basin wide, except alewife and goby, age-0 abundance indices decreased from 1996, and are well below an eight year mean (Table 3.2-1). The 1997 year class will be one of the smallest since 1990. Smelt continue to be the most abundant age-0 forage species, while goby are the most abundant YAO forage species (by number) in the central basin (Table 3.2-2). Some species from the 1996 year class are apparent in the YAO abundance indices. Smelt, yellow perch, white perch and goby have increased over 1996, with smelt being at the second highest levels since 1990. Relatively large 1996 age-0 abundance indices for trout perch and *Notropis* spp. did not carry through to the YAO indices, suggesting poor survival of these forage species. Overall prey abundance (in numbers) in 1997 was similar to the early 1990's, but the composition has changed from being predominantly spiny-rayed in 1990 and 1991 to soft-rayed species in 1997 (Figure 3.2-1). This change is due to a decrease in white perch abundance and an increase in round goby. Depending on the size of the1998 year class, the 1998 forage base will probably decrease in the central basin due to the poor 1997 year class and consist mainly of goby, smelt and shiners.

Large scale changes in the lower tropic levels of the central basin have occurred over the past several decades, in concert with phosphorous reduction and zebra mussel introduction. Zebra mussels accounted for over 99% of the benthic biomass nearshore and 27% of the benthic biomass offshore at a deeper station in 1993 (Dahl et al. 1995). As in the western basin, there has been little change in biomass of endemic benthic fauna (16.3 g-m^{-2} in 1979 and 12.2 g/m^{2} in 1993), but *Dreissena* added to the biomass for a total of 396.9 g-m^{-2} in 1993 (Dahl et al. 1995). Mean veliger density in the west-central basin was 28,000 m-^{3} in 1996, down 71% from 1995 (OMNR 1997). In 1993, there was no reduction in mean zooplankton biomass in the west-central basin from the pre-zebra mussel period to the post-mussel period but there were changes in species composition (Dahl et al. 1995). *Daphnia* biomass decreased and calanoid copepod biomass increased.

3.3 Western Basin (by J. Tyson, T. Johnson, M. Thomas, and E. Trometer)

Forage fish abundance in the western basin in 1997 was assessed using the August interagency bottom trawl survey conducted by ODNR and OMNR at 72 sites in the western basin (Figure 3.3-1). Both agencies have used SCANMAR to calibrate their nets enabling us to pool the data and generate a basin-wide estimate of absolute abundance and biomass for functional prey groups. These groups include clupeids (age-0 alewife and gizzard shad), soft-rayed fish (smelt, spottail shiners, emerald shiners, and silver chubs), and spiny-rayed fish (age-0 white perch, yellow perch, walleye, white bass, and freshwater drum). Round goby continued to expand through the western basin in 1997 and may be added to the soft-rayed prey group in future years. It should be noted that OMNR trawls in 1997 were conducted by a vessel not yet calibrated by SCANMAR. For purposes of simplicity, the trawl opening values for the standard Ontario survey vessel and net were used to generate this year's pooled values. These values will be corrected after the RV Loftus trawl has been calibrated by SCANMAR this summer.

Clupeids were the most abundant functional prey group in 1997, by both numbers and biomass (Figure 3.3-2). Clupeid abundance was the highest observed since 1993. Combined biomass of clupeids and soft-rayed forage fish in 1997 was similar to values reported in 1996, with both years considerably higher than reported in 1994 and 1995. Spiny-rayed fish abundance and biomass declined in 1997 relative to the levels seen in 1996, and was much lower than the levels present during the late 1980's and early 1990's, when white perch abundance was much higher. This decrease in abundance of age-0 spiny rayed forage may translate into a reduced buffer from walleye predation for gizzard shad and shiners.

Since 1988, the abundance and biomass of clupeids has generally been higher in the southern portion of the western basin (Ohio trawl sites). In 1997, this pattern returned following unusually high clupeid abundance and biomass in Ontario waters in 1996 (Figure 3.3-3). In 1997 the highest biomass estimates for clupeids were found near Catawaba Island and Sandusky Bay (Figure 3.3-4). Abundance and biomass of soft-rayed forage fish was also higher in 1997, especially in Ontario waters as a result of increased abundance of yearling and older spottail shiners (Figure 3.3-5). Waters between Kingsville and Leamington produced the highest biomass estimates for soft-rayed fish in 1997 (Figure 3.3-4). The highest density of spiny-rayed forage biomass in 1997 was centered around the Lake Erie islands, with an area of moderate biomass density extending northward toward Leamington (Figure 3.3-4).

Numerous changes in the lower trophic levels of the western basin food web have been observed in recent years. Abundance of zebra mussel larvae peaked in the west basin in 1993 and has gradually declined since (OMNR 1997). Zooplankton abundance has remained relatively constant in recent years, after a precipitous decline in the late-1980's (OMNR 1997). However, most of the decline in zooplankton from 1988-1996 is associated primarily with declines in the abundance of small rotifers and nauplii (declines of 72% and 56% for rotifers and nauplii, respectively); cladoceran abundance has not changed appreciably during the time series. On the other hand, an explosive increase in the burrowing mayfly, *Hexagenia*, has been documented across the western basin since 1994 (Table 3.3-1) (Krieger 1997). There has also been a dramatic increase in *Gammarus* biomass in the western basin. Biomass of *Gammarus* increased from an average of 1.6 g/m^2 in 1979 to 487.4 g/m^2 in 1993 (Dahl et al. 1993, Krieger, pers. comm.).

Fish diet studies in the western basin reflect some of the observed changes in both invertebrate production and in forage fish species composition. Yellow perch stomachs examined by ODNR and the USGS-BRD showed substantial increases in the occurrence of large benthic macroinvertebrates such as *Hexagenia*, tricopterans, and amphipods (Figure 3.3-6) in recent years. ODNR walleye diet data indicate an increasing occurrence of emerald shiners in recent years (Figure 3.3-7).

While no consistent trends in mean lengths for the major forage species in the western basin are evident from the interagency trawl data, age-0 walleye and yellow perch both exhibited lower than average growth in 1996 and 1997 (Figures 3.3-8, 3.3-9). This may be a function of cooler growth conditions and density-dependent growth resulting from the large 1996 year classes of each species. No consistent pattern of change in growth has been apparent for age-1 and older walleye or yellow perch in Ohio surveys (ODNR 1998), while Ontario surveys indicate that growth is down for ages 0-4 (Cook 1998).

In summary, the forage outlook for the western basin in 1998 appears to be good. Clupeids, the primary forage of walleye, continued to contribute substantially to the total forage biomass in 1997 and should experience lower than normal over-winter mortality due to the unseasonably warm conditions during winter 1997-98. If trends of increasing soft-rayed forage fish biomass and macroinvertebrate production continue through 1998, predators in the western basin should experience better than average conditions for growth and production.

3.4 Predator Diet (by L. Sztramko, M. Bur, D. Einhouse, and A. Cook)

Walleye

Walleye stomachs were examined for food contents by ODNR and OMNR in the western and central basins, and by NYSDEC and OMNR in the eastern basin. ODNR samples were obtained from index gill nets (kegged and bottom sets) fished at random and fixed (historic) sites across a range of depths during October. In 1996 and 1997, OMNR samples were obtained through a partnership arrangement that is described in the *Lake Erie Food Web Study* section below. Budgetary constraints prevented OMNR samples, which were collected from anglers during June-August of 1996 from being analyzed. Samples were not collected in 1997. NYSDEC samples were from the summer angling fishery. Mean percent volume was calculated by NYSDEC as the mean percent displacement volume of stomach contents. Mean percent by weight was calculated by ODNR as the ingested volumes derived by calculating a mean total length from backbone, standard, or total lengths and then applying a year and species-specific length-weight regression to each prey item found in the stomach to obtain weight estimates.

Walleye in the western basin of Lake Erie were found to have a diverse intake of prey fish that included clupeids (mostly gizzard shad), emerald shiners, rainbow smelt, yellow perch, and *Morone* spp. (mostly white perch) (Figure 3.4-1). Gizzard shad have been the primary prey species for age-1 and older walleye within the western basin (ODNR) during the late summer and fall, when age-0 clupeids become available to walleye as prey. In 1997, the proportion of emerald shiners consumed by walleye increased, the proportion of gizzard shad remained stable, and alewife declined. In the west-central basin in 1997, the proportion of emerald shiners in walleye stomachs increased dramatically, comprising about 50% of stomach contents; the proportion of alewife remained the same; the proportion of gizzard shad declined (Figure 3.4-2).

Central basin diet data indicated that rainbow smelt and *Notropis* spp. were the principle prey in walleye diets throughout the summer and fall (Figure 3.4-3). The discrepancy in stomach contents of walleye between the west-central and central basins may be attributed to differences in sampling gear (size selectivity), methods, season, time of day (day vs night), and where walleye were captured in relation to distributions of prey fish. Additionally, water current patterns, and presumably water temperatures, are unique on both sides of the Pointe Aux Pins Peninsula. Walleye diet information from the west-central basin includes fish collected from Huron to Avon Point, OH while data from the central basin include fish collected from Cleveland to Ashtabula, OH. Occasionally, yellow perch have been a minor component of walleye diet in the central basin during the last 10 years.

In the eastern basin walleye consumed smelt almost exclusively (NYSDEC data) (Figure 3.4-4). A small percentage of the summer diet of walleye was comprised of benthic macroinvertebrates, particularly Ephemeroptera. Emerging Ephemeroptera densities are typically at their highest during that period. *Morone* spp., *Notropis* spp., and clupeids were also present in eastern basin walleye diets.

Yellow Perch and White Perch

Yellow and white perch were examined for food contents by USGS-BRD in the western basin. Western basin samples were from bottom trawls fished at index stations during May and August-October, since 1989. Mean percent volume was calculated as the mean percent displacement volume of stomach contents.

The diet of yellow perch in the western basin from 1991 to 1997 has consisted mostly of benthic macroinvertebrates (Figure 3.4-5). Mollusks, zebra mussels, amphipods, chironomids, and *Hexagenia* spp. have traditionally comprised a major component of the stomach contents. Zooplankton, on the other hand has pulsed as a major food component with high proportions in 1993 and 1995. The relative contribution of prey fish in the diet of yellow perch has remained relatively constant over time with pulses in 1992, 1994, and 1996 when fish comprised about 20, 30, and 60%, respectively, of the total stomach volume.

The main food of white perch has been zooplankton (*Daphnia* spp. and *Bythotrephes cederstroemi*) and macrozoobenthos (chironomids and amphipods) (Figure 3.4-6). As in yellow perch above, fish (clupeids, *Morone* spp., *Notropis* spp.), as a food item, pulsed in 1992, 1994, and 1996. Mollusks were not as important a food item in white perch as they were to yellow perch. Zebra mussels usually comprised less than 3% of the food volume in white perch stomachs.

Lake Erie Food Web Study, 1995-97

A partnership study involving Environment Canada, The Lake Erie Fish Packers and Processors Association and the Ontario Ministry of Natural Resources was conducted between June and October , 1995, and May and June , 1996. Approximately 3,277 fish stomachs were examined from walleye, smallmouth bass, yellow perch, white perch, channel catfish, salmonids, coregonids, white bass, burbot, and freshwater drum. Although originally intended to cover the entire lake, the majority of samples were from the western and central basins. Samples that were taken in 1997 have not been analyzed yet.

Walleye stomach contents revealed that generally, clupeids and smelt are the major components of walleye diet with smelt assuming a greater role moving from west to east. In addition, there is a general temporal shift in the western basin with smelt and *Notropis* spp. comprising the majority of the diet in May and June, and clupeids, the majority, in August and September. In 1996, OMNR data indicated that yellow perch were consumed by yearling walleye (<381-mm total length) in July and August in the western basin and in May by walleye >533-mm total length (10% mean volume).

4.0 Interagency Trawling Program

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 three matters. Progress on these charges are reported below

4.1 Calibration of Bottom Trawls (by M. Bur)

The SCANMAR hydroacousitics equipment has been reserved for the first two weeks of July, 1998. This year we hope to aquire more precise estimates of bottom trawl net openings. Sample size analyses indicated that 10 replicate tows would give us an 80% precision level on net opening parameters. In addition, Ontario and Ohio will each have new boats conducting interagency trawling, and SCANMAR will be used to calibrate the trawls. In 1997, ODNR used the equipment on the RV Explorer to reparameterize their bottom trawl based upon the aforementioned sample sizes. The results of this exercise, as well as those conducted in 1992 and 1995, are included in (Table 4.1-1).

Demand for this type of gear on the Great Lakes has risen over the past few years. The SCANMAR gear, which is owned by the Great Lakes Science Center, Ann Arbor, is being used in several research projects. Available time slots for the gear may be limited in the future. Information on the cost of purchasing additional equipment is currently being gathered. Potentially, the purchase of additional gear would allow for increased use of the gear during assessment cruises.

4.2 Central Tendency Statistics (by B. Haas)

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 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 approximate the known (true) population size.

4.3 Summary of Species CPUE Statistics (by J. Tyson)

Interagency trawling in August has been conducted in Ohio, Michigan, and Ontario waters of the western basin of Lake Erie from 1987-1997. This interagency trawling series was developed to more precisely measure basin-wide fish community indices including growth and abundance of forage species. Information collected during interagency trawling surveys include species-specific length and abundance data. A total of 75-80 standardized tows per year are conducted in Ohio, Michigan, and Ontario waters of Lake Erie's western basin (see western basin summary, Figure 3.3-1). Tows are stratified into four depth strata (0-3 m, 3-6 m 6-9 m, and >9 m).

Historically, indices as computed from standard bottom trawling have been reported as relative indices which cannot be combined across agencies and could only be compared on a qualitative basis. In 1992, the Interagency Trawling Group charged the Forage Task Group with development of standardized trawling procedures and calibration of agency trawls such that the indices could be combined and quantitatively analyzed. Preliminary calibration work was done in 1992 by several Lake Erie agencies using SCANMAR acoustic equipment to assess the dimensions of the bottom trawls being used. Subsequent work with SCANMAR has been conducted in 1995 for both OMNR and ODNR boats, and in 1997 for the ODNR boat.

Currently, the Forage Task Group reports basin-wide estimates of forage abundance in the western basin, using information from SCANMAR trials, total trawling distance, and catches from August interagency trawling. The estimate of volume sampled by each tow in conjunction with the species-specific abundance estimates of each tow allows for computation of a species-specific quantitative abundance estimate (in # /m^3 or hectare) for each tow (see western basin forage summary). Additionally, using the volumetric estimate of abundance in conjunction with the length/weight data from the interagency trawls, a species-specific biomass estimate (in g/m^3) for each tow can be generated. These estimates are then extrapolated by depth strata to the entire western basin of Lake Erie to obtain an absolute estimate of abundance by species.

With the parameterization of trawl opening, combined density estimates are now being used to estimate absolute abundance. Because we have moved beyond treating the trawling survey as a "relative abundance index", we need to understand other sources of bias and variability that influence the abundance estimates. There are several factors that have not been quantified and could introduce sizeable bias and variability into the abundance estimates (Gunderson 1993). These factors include:

1) The effects of extrapolating abundances based upon depth strata rather than some other method of stratification,
2) "Haul effects", due to differences in vessel avoidance, deployment, and gear configuration,
3) The effects/magnitude of visually cued avoidance.

Two of the aforementioned factors can be addressed in the near future. The effects of extrapolation of abundances based upon depth strata could potentially be addressed using acoustics techniques. Data from acoustics surveys could be used to validate extrapolation of nearshore (shallow) abundances to offshore pelagic areas that are not effectively sampled by the bottom trawls. ODNR is planning a slightly more extensive acoustic survey of the western basin in 1998, to examine pelagic fish distribution and abundance.

The other potential bias that could be addressed in the near future is the effect of visual avoidance on abundance estimates. This could be an extremely important issue. The interagency trawling series has been conducted from 1987-1997, which spans the period when zebra mussels colonized Lake Erie, and subsequently, the increases in water transparency (Figure 4.3-1). These large increases in water transparency could potentially increase the incidence of visually cued avoidance. There is a substantial amount of evidence in the literature that suggests that visually cued avoidance, particularly for clupeids, could seriously bias abundance estimates (Gunderson 1993, Michaletz 1997). In conjunction with the acoustics pilot project, ODNR did a series of day/night tows, and found significant differences in both abundance and length distributions of gizzard shad between the day and night samples (Figures 4.3-2, 4.3-3). These differences could translate into large biases in absolute abundance estimates of clupeids. Additionally, the USGS-BRD has a data series of day/night tows that is currently being key-entered. With information on forage fish distribution and the magnitude of visually cued avoidance, forage abundance indices should be refined substantially.

5.0 Bioenergetics Modeling of Predator Consumption

(by L. Witzel, D. Einhouse, T. Johnson, and A. Cook)

Notice to readers:

Modeling the abundance of walleye spatially and temporally has been a major challenge in this exercise and we were unable to complete bioenergetic simulations on time for inclusion in this report. Since walleye are the single largest consumer of prey among Lake Erie's fish predators, it is inappropriate to present consumption estimates for the other modeled predators in the absence of comparative walleye estimates. We expect to have a final summary of this charge available as a separate report some time during this year. Persons interested in receiving a copy of the report can make a request to the current FTG chairmen (J. Tyson and D. Einhouse) or to L. Witzel at their respective agency address. The Introduction (section 5.1) and Methods (sections 5.1 and 5.2 below) summarize our progress.

5.1 Introduction

The Lake Erie Forage Task Group was assigned a charge to evaluate the consumption demands of smelt and other prey fish by predators in the central and eastern basins. Our task group had addressed a similar charge beginning in 1991 with lake trout and continuing in 1992-93 with coverage of walleye and other salmonines. The results of these earlier bioenergetic simulations were reported in the 1992 and 1993 issues of the FTG Annual Reports to the LEC (Einhouse et al. 1992 and 1993, respectively). This material was also presented at the 1996

IAGLR Conference and a final manuscript of the same has been accepted for publication in a book entitled "State of Lake Erie Ecosystem (SOLE): Past, present and future" (Einhouse et al. 1998, in press). These earlier simulations are now dated due to recent dramatic changes in the Lake Erie ecosystem, to salmonine stocking levels and to abundance of Erie's keystone predator, the walleye. It is typically the predator abundance estimates that most influence consumption estimates from the model simulations.

The present bioenergetic model simulations will focus on only the major predator species of Lake Erie: walleye, lake trout , rainbow trout (including steelhead), and burbot in the eastern basin; walleye and rainbow trout in the central basin. Other salmonines, modeled in our earlier simulations, will not be directly considered because these predators are not major components of the fish community and information specific to these species is lacking. We included burbot in our streamlined approach because it now appears to be a significant predator, particularly of smelt in the eastern basin. Unfortunately reliable data concerning population size, mortality rates, age structure and diet were lacking for Lake Erie burbot, requiring us to make a number of assumptions and approximations.

For walleye and rainbow trout, we believe the current simulations will be an improvement upon our earlier analyses because of an increased availability of species-specific or Lake Erie-specific data such as, caloric density data for smelt, walleye diet data, and abundance estimates of lake trout and walleye.

5.2 Methods

5.2.1 The model

A generalized bioenergetics model of fish growth was used to model consumption of walleye, lake trout, rainbow trout and burbot (Hewett and Johnson 1987). Bioenergetics (or physiological energetics) involves partitioning energy acquired through ingestion into the major physiological components of the basic energy budget equation as described by Warren and Davis (1967) where:

$$C = \underbrace{(M_r + M_a + SDA)}_{\text{(metabolism)}} + \underbrace{(F + U)}_{\text{(waste)}} + \underbrace{(G_s + G_r)}_{\text{(growth)}};$$

C = rate of energy consumption,
M_r = standard metabolic rate,
M_a = metabolic rate increase due to activity,
SDA = metabolic rate increase due to specific dynamic action,
F+U = waste losses due to egestion (feces) and excretion (urine) rates,
G_s = somatic growth rate due to protein synthesis and lipid deposition, and
G_r = growth rate due to gonad (reproductive) synthesis.

One of the more common and robust applications of bioenergetic budgets is in estimations of predator fish consumption from observed growth (Kitchell et al. 1977, Rice et al. 1983, Stewart et al. 1983,). We used the most recent version of the fish bioenergetics software **[Fish Bioenergetics 3.0 for Windows** developed by Hanson et al. 1997**].**

We modeled predator consumption for the period from 1984 to 1996. The bioenergetics model required the following species specific information: 1) *metabolic parameters* for consumption, respiration, egestion and excretion; 2) *temperature data* representing the predators life history; 3) *caloric density of predator and prey*; 4) *diet*; 5) *predator weight-at-age and reproductive losses*; and, *7) population abundance*. Details of these model inputs are provided below.

5.2.2 Metabolic parameters

We used the standard physiological parameters values of respiration, egestion and excretion for walleye, lake trout and rainbow trout that are provided as defaults in the *Fish Bioenergetics 3.0 for Windows* software (Hanson et al. 1997). A companion set of metabolic parameters did not exist for burbot, but did for an alternate, ecologically similar gadoid, the Atlantic cod (*Gadus morhua*). We used the cod bioenergetics model as a surrogate for burbot following the work of Rudstam et al. (1995), who used a cod-based model to estimate prey consumption by burbot in the Wisconsin waters of Green Bay, Lake Michigan.

5.2.3 Thermal distribution

Walleye.

The seasonal thermal history of walleye was modeled using daily lake temperatures recorded at municipal water intakes and information on species temperature preference. Water intake facilities included Port Dover (eastern basin), Port Stanley (east-central basin), Wheatley (west-central basin), and Ruthven (western basin). We assumed walleye would reside in the warmest temperatures available, up to their physiological optimum (22°C for adults, 26°C for juveniles; Kitchell et al. 1977). During the winter months we assumed walleye would find thermal refuges, enabling them to avoid temperatures below 2.5°C.

We assumed that western basin temperatures would best represent the thermal distribution of all yearling walleye throughout the year, based on their preference for littoral habitats and warmer temperatures (Hokanson and Koenst 1986).

Rainbow Trout.

Eastern basin, Lake Erie water temperatures were used to describe the thermal habitat of rainbow trout. The thermal cycle of eastern Lake Erie was described from water temperature data collected over approximately a 30-year period (1956-1985) at the municipal water intake of Port Dover. In our model simulations we assumed rainbow trout occupied the warmest water available up to their physiological optimum, 16°C for age-1, and 13°C for age-2 rainbow trout, as reported by Negus (1995).

Lake Trout.

Water temperatures recorded at the Dunkirk, NY municipal water intake were used to describe the thermal history of lake trout in eastern Lake Erie. Fish stock assessments in the New York waters of Lake Erie indicate lake trout are most abundant in thermal strata of 8 to 10°C during late summer. This 10°C maximum summer temperature corresponds with Lake Ontario collections of stocked lake trout by Elrod and Schneider (1987) that were comprised of the same genetic strains used in the Lake Erie stocking program. As such, we assumed the maximum water temperature that lake trout occupied was 10°C.

Burbot.

We used the same source of temperature data to describe the thermal history of burbot as was used for lake trout. We assumed that burbot would occupy the warmest water available up to a physiological optimum, which we set as 12°C for ages 1 to 3 and 10°C for age 4 and older burbot according to Rudstam et al. (1995).

5.2.4 Caloric density of predator and prey

Walleye.

Energy density of walleye was assumed to be constant at 4814 J·g^{-1} wet mass (1150 cal·g^{-1}) for all ages of walleye in all seasons (Kelso 1972). Prey caloric densities were also assumed to be constant for all prey sizes and in all seasons (Mark Kershner, Ohio State University, personal communication).

	Rainbow Smelt	**Yellow perch**	**Shiners**	**Clupeids**	**Other fish**	**Invertebrates**
Energy density (cal/g)	1150	1000	1200	1250	1000	750

Rainbow Trout.

Energy density of smelt and "other fish" were assigned a constant value of 1100 cal·g^{-1} throughout all seasons and across all years of the time series. This value is similar to the measured energy content of another population of smelt dominated by younger cohorts in Lake Ontario (Lantry and Stewart 1993). Invertebrates were assigned a constant energy density value of 750 cal·g^{-1}.

Lake Trout.

Energy density of lake trout was assumed to be constant at 1362 cal·g^{-1} for all ages across seasons. Caloric density of prey items "other" and "invertebrates" also were held constant for all ages across seasons at 1100 cal·g^{-1} and 750 cal·g^{-1}, respectively. We modeled two different prey caloric densities of smelt. In one set of simulations we assumed smelt caloric density remained constant at 1100 cal·g^{-1} throughout the year for all ages and years. In a second independent set of simulations, we assumed smelt caloric density remained constant at 1400 cal·g^{-1} for most of the year, decreasing from 1400 to 1100 cal·g^{-1} between model days 108 and 197 to simulate an over-winter energy loss, followed by a gradual return to 1400 cal·g^{-1} between days 197 and 280 to simulate a post-spawning recovery in condition.

Burbot.

Energy density of burbot was assumed to be constant at 1000 cal·g^{-1} for all ages across seasons. Caloric density of prey items "smelt", "other fish", and "invertebrates" were set at 1100, 1100, and 750 cal·g^{-1}, respectively.

5.2.5 Diet Composition

Walleye.

Upon evaluation of all available diet data we considered only 6 diet categories: rainbow smelt, yellow perch, shiners, clupeids, other fish and invertebrates. We used information presented in the comprehensive spatial and temporal survey of Cook et al. (1996) to describe walleye diets in each season in each basin. We then compared the observations of Cook et al. with the agency surveys which spanned many years, but lacked the comprehensive spatial and seasonal information of Cook et al. These agency reports have been summarized in section **3.4** of this report. In general, few long term changes in diet composition were seen across years. As a result we used a standard diet to characterize the diet of the walleye in all years. We also had good agreement between the agency estimate and those reported in Cook et al, reinforcing our assumption to use a single source for diets. The only exception was for the eastern basin of Lake Erie, where few samples were obtained by Cook et al. In this basin only, we opted to use the NYSDEC data exclusively.

We used diet information summarized for number 2 walleye (<383 mm) to represent age-1 fish. Size-at-age information collected with the diet information suggests this size group is almost exclusively age-1 fish. For older age groups of walleye, there was little evidence to suggest significant diet shifts associated with walleye size. As a consequence we pooled all information for all other size classes (383 mm and larger) to report a single diet per basin per season. Any unidentified fish remains were allocated to the known fish types in proportion to their reported abundance.

Rainbow Trout.

Data describing rainbow trout diet in Lake Erie remain scarce and incomplete. There are no diet data representing juvenile cohorts in Lake Erie and we assigned diet proportions described by Jude et al. (1987) in Lake Michigan. The only Lake Erie data available for this analysis came from a small OMNR sample of angler caught rainbow trout (n=24 central basin, n=7 east basin) in 1987. These data, representing only adult cohorts, suggest a diverse array of prey fishes comprise the diet of rainbow trout, with smelt contributing less than half of the volume attributable to forage fish. This view of a diverse rainbow trout diet is supported by other Great Lakes observations (Rand et al. 1993), but remains inconsistent with observed species composition of forage fishes determined from Lake Erie trawl surveys (see section **3.0**), and also is dissimilar to diet descriptions for other eastern and central basin piscivores (see section **3.4**) that portray smelt as the principal forage fish species available to open water predators.

In the rainbow trout bioenergetics model, we partitioned rainbow trout diet into three categories: "smelt", "other fish" and "invertebrates". We addressed the information gaps and apparent inconsistencies by using the smelt segment of the diet described from the small Lake Erie sample, pooled with the Rand et al. (1993) diet depiction as a characterization of a low bound for smelt consumption (approx. 30 % of total), and alternatively pooled "smelt" and "other fish" to represent a high bound of smelt consumption. The remaining non-fish contribution to the rainbow trout diet was apportioned to invertebrates as fixed contributions for various life stages and seasons. As such, we provide a range for potential smelt consumption ranging from minimum values assuming ~ 30 % smelt by volume in the diet, to a ceiling of the total estimated fish consumption over the time series.

Lake Trout.

We examined available diet information for lake trout from stomach content analyses conducted by NYSDEC and PFBC, mostly during summer gill net assessments from 1984 to 1996. For all age groups of lake trout examined, smelt was the dominant prey species, accounting for 80% or more of the stomach volume. Diet data were described for three life stages: age-1, age-2 and age-3+. For each lake trout life stage we categorized the diet into three components: "smelt", "invertebrates" and "other", and ascribed proportions of these components that varied seasonally to reflect observed shifts in food habits.

Burbot.

Information describing the diet of eastern Lake Erie burbot were provided from stomach samples collected in New York (1992-96 sampling of 189 burbot stomachs) and Pennsylvania waters (1987-93 sampling of 90 burbot stomachs). Prey items from these samples were quantified as percent frequency of occurrence instead of the preferred measure - percent volume (or percent mass). These data indicate that burbot ate predominately smelt; other prey included white perch, dreissenid mussels, and much smaller amounts of several other fish species and a variety of invertebrates. Cook et al. (1996) examined the stomachs of 7 burbot and found that smelt represented 52 to 86% of the stomach volume in samples collected from two areas of eastern Lake Erie during September 1995. Cook et al. also reported stomach contents for a sample of 37 burbot caught by a commercial trawler in Ontario waters of eastern Lake Erie on June 9, 1996. Smelt comprised 90% of the stomach volume from this sample. However their freshness (undigested condition) lead the author to suspect that the smelt consumption may have occurred while the burbot were in the trawl. We relied on a Green Bay study (Rudstam et al. 1995) for diet information of young burbot. From these data sources we pieced together a generalized description of burbot diet. For age-1 and age-2 burbot we assumed a diet of 55% fish and 45% invertebrates. For age-3 and older burbot we assumed the diet was 80% smelt, 15% other fish and 5% invertebrates.

5.2.6 Predator weight-at-age and reproductive losses

Walleye.

We used annual observed weight-at-age for fish collected as part of the interagency gillnet assessment conducted annually in October between 1978 and 1992. Subsequent to 1992 we used weight-at-age data collected in September as part of the LEFPPA / OMNR Partnership gillnet assessment. Sexes were pooled and we assume a 1:1 sex ratio. The simulated model year began Jan 1, so weight-at-age was adjusted to account for growth between January 1 and the actual fall sampling period (September / October). We ran the bioenergetics model for a one year period (Oct 1 to Oct 1) for all ages of walleye in all basins for 1 year. From the output, we estimated the growth increment attained by a walleye between Oct 1 and Jan 1 (30% of annual growth increment). Therefore, we concluded the remaining 70% of the growth occurred between Jan 1 and the Oct 1 sampling. These numbers were verified using monthly average weight-at-age data for commercially caught walleye collected in the central basin. We estimated this fall / winter growth increment to be 18.2% above the October observed weight (Don MacLennan, OMNR, personal communication).

We assumed a 10% weight loss associated with spawning for adult (age-5^+) walleye (Henderson and Nepszy 1994). Spawning occurred on model day 90 (April 1) in all years.

Rainbow Trout.

We used observed weight-at-age data for rainbow trout collected between 1984 and 1987 from an autumn electrofishing survey in the New York waters of Lake Erie. Mean weight-at-age for each sex was pooled equally to represent an assumed 1:1 sex ratio for the population. These observed autumn weights were adjusted to align with the population estimates for the simulated model year, which began May 1 by initially running the bioenergetics model for a one year period (Oct 1 to Oct 1) and using the predicted May 1 weights for each cohort. We also assumed a 10 % spawning loss to occur on March 1, beginning with age-3 rainbow trout.

Lake Trout.

We fit a vonBertalanffy growth model to observed weights-at-age of lake trout collected from index gill nets fished annually during August in eastern Lake Erie waters. The predicted weights from the growth model were preferred over observed weights because the former eliminated some intra-cohort variation in weight-at-age.

We assigned a 6.8% spawning losses to age-5 and older lake trout. Spawning occurred on model day 77 (Nov. 1st) in all years.

Burbot.

We fit a vonBertalanffy growth model to observed weights-at-age of burbot caught incidentally in lake trout assessment gill nets. The growth model predicted a negative weight for age 1 burbot, so we used 70g as a value for this cohort based on comparative data from Green Bay, Lake Michigan (Rudstam et al. 1995). We assigned a 11% spawning loss to age-3 and older burbot. We assumed spawning occurred on model day 213 (March 15th).

5.2.7 Population abundance

Walleye.

We used CAGEAN (catch-at-age analysis) output produced by the Walleye Task Group to estimate walleye standing stock for Lake Erie. This technique combines all catch and effort data from the commercial and angler fisheries with estimates of natural mortality (M=0.32) and terminal fishing mortality (0.174) to estimate population size at the start of any given year. Annual output from the model includes the total number of walleye by age from age-2 to age-7^+.

We applied an estimated survival of 71% to hindcast the number of yearling walleye from the CAGEAN estimated number of 2 year-olds for each year. Using lakewide index data collected in September of each year since 1989 as part of the Partnership gillnet assessment, we estimated 81.6% of the yearling walleye are resident in the western basin, 17.3% in the central basin, and 1.1% in the eastern basin.

For the older age groups of walleye (ages-2 through 7+) we allocated the population seasonally and spatially (between basins) using the distribution of commercial catch in Lake Erie. The fishery targets ages 3-5 walleye (the model age of the population), and is selective in targeting effort when and where walleye are distributed. This assumed migratory nature of the walleye is supported by independent tagging and index assessment (Henderson and Wong 1993; Bob Haas, MDNR, personal communication). Population size-at-age from CAGEAN were then combined with the allocation algorithm to estimate the number of walleye by age in each basin in each season.

Rainbow Trout.

Rainbow trout abundance in Lake Erie's central and eastern basins was estimated for the stocked population only using the reported rainbow/steelhead stocking densities of yearlings (or yearling equivalents) from each agency bordering central and eastern basin waters, and reducing these stocked yearling totals by an assumed initial stocking survival rate of $S = 0.6$, as recommended by Lake Erie's Coldwater Task Group (pers. comm. F. Cornelius). Annual abundance of rainbow trout cohorts beyond this inital "stocking mortality" stage were then simulated by applying a constant, annual survival decrease function in four succeeding years. This survival decrease function for rainbow trout was developed from an OMNR tagging study from 1984 to 1991. Rainbow trout tag return data from the OMNR study were used in the program "ESTIMATE" as described by Brownie et al. (1985) to calculate a mean annual survival rate of 32.9%. These initial stocking and annual survival estimates were applied uniformly over both basins and the entire 1984 to 1996 time series.