Michigan Fish Contaminant Trend Monitoring Strategy:
Peer Review Workshop

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Best Western Gateway International Hotel
Romulus, Michigan

Workshop Proceedings

Prepared by

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Introduction

A. Purpose of the workshop

In 1990, the Michigan Department of Environmental Quality (MDEQ) began implementing a fish contaminant trend monitoring strategy to measure temporal and spatial contaminant trends in whole fish from the waters of the state. In 2001, MDEQ hired Exponent to assist with a review of the design of the whole-fish trend monitoring strategy and recommend changes (if any) to improve the design. The purpose of this workshop was to conduct a peer review of the design of MDEQ's fish contaminant trend monitoring strategy and Exponent's recommendations regarding the strategy. The workshop, coordinated and facilitated by the Great Lakes Commission in conjunction with MDEQ, was held April 29-30, 2003 at the Best Western Gateway International Hotel in Romulus, Michigan.

The workshop included an invited array of experts in the fields of contaminant trend monitoring, statistics, laboratory analyses, and fish collection techniques. Experts included one representative from Exponent, one representative from Conestoga-Rovers & Associates (a subcontractor to Exponent), and two from MDEQ. There were 18 total participants, including three staff members from the Great Lakes Commission. The list of workshop participants is included as Appendix A.

To produce the monitoring strategy review report, MDEQ and Exponent reviewed the design of Michigan's fixed station fish contaminant trend monitoring strategy. MDEQ and Exponent identified several key issues related to fish contaminant trend monitoring and gathered information from a variety of sources to address these key issues and develop recommendations for changes (if any) to the existing design of the fish contaminant trend monitoring strategy. The information sources include the results of a MDEQ survey of fish contaminant monitoring program coordinators in federal, state, provincial and tribal organizations; a review of fish contaminant data collected by other agencies; and a literature review of publications dealing with trend monitoring designs and factors that influence contaminant concentrations in fish.

Exponent developed a written report addressing the key issues related to fish contaminant trend monitoring and describing a list of monitoring recommendations. The contents of the report were discussed at the peer review workshop. The report can be obtained from the MDEQ's web site (Michigan.gov/-/media/Project/Websites/egle/Documents/Programs/WRD/GLWARM/Monitoring-Lake/fcmp-review-recommendations.pdf). This workshop proceedings document summarizes Exponent's commentary and recommendations from the report and provides a summary of the discussion at the workshop.

B. Background: How and why MDEQ is reviewing the design of the whole fish trend monitoring program

Note: Background text includes excerpts from Fish Contaminant Monitoring Program: Review and Recommendations (Exponent 2003).

The presence of persistent toxic substances (PTS) in aquatic ecosystems is one of the most important environmental policy issues currently facing the Great Lakes states. PTS, such as polychlorinated biphenyls (PCBs), DDT, chlordane, and mercury, bioaccumulate to high levels in fish. Contaminated fish are the primary source of these chemicals to most humans and semi-

aquatic wildlife, and thus are the cause of widespread fish consumption advisories. Consequently, interpretation of spatial and temporal trends of these chemicals is critical to the planning and assessment of regulatory policies in the Great Lakes region. To that end, several federal, state, and provincial agencies in the United States and Canada have set up fish contaminant monitoring programs (FCMP) to track trends of PTS in the environment.

The Michigan Department of Environmental Quality (MDEQ) retained Exponent to review the elements of its FCMP devoted to tracking trends of PTS. Two factors suggested that such a review would be worthwhile. First, a considerable amount of experience and expertise has been accumulated over the 20 to 30 years that these FCMPs have been in operation. Michigan wanted its FCMP to make use of that experience. In addition, fundamental changes have occurred in our understanding of the processes underlying bioaccumulation of chemicals in fish. Together, these factors have led to ongoing evolution in our understanding of how trends in PTS bioaccumulated by fish and other biota should be assessed, and ultimately, what those trends really mean.

In short, trend analyses with biomonitoring data are evolving to consider factors at greater spatial scales – from the organism itself to its food chain to the entire ecosystem. These analyses are also evolving to consider factors over greater temporal scales, because of the increasing response times of whole ecosystems versus food chains versus individual fish. Because these changes are ongoing, there is currently no consensus concerning how trends in biomonitored data should be deduced and what they imply. Recent trends analyses of PTS in biota have focused on very short-term (e.g., IJC 2002) or very long-term trends (Offenberg and Baker 2000; Simcik et al. 2000), and they have assumed everything from tight coupling (IJC 2002) to no coupling (Smith 2000) with external loading, over the time period considered. The lack of well-defined methods has produced a panoply of predictions about future declines of PTS in Great Lakes biota.

Thus, interpreting trends of chemicals in biota has become something akin to a Rorschach test, where the final trend that is observed depends as much, or more, on the viewer as on the data. Because temporal plots of these data typically have repetitive waves of concentration, analysts can find evidence for any hypothesis, or policy decision, depending upon which data, assumptions, and statistical methods are used. Consequently, some trends analyses based on PTS concentrations in biota currently lack scientific rigor.

Recognizing that the underlying science of biomonitoring is evolving and unsettled, MDEQ retained Exponent to review the trends monitoring elements of its FCMP. Specifically, Exponent reviewed literature pertaining to the mechanisms affecting bioaccumulation and detection of trends of chemicals in fish. Along with a survey of methods employed by MDEQ and other FCMPs, Exponent reviewed options for biomonitoring with fish, and recommended changes, if warranted, to MDEQ's program. The recommendations were intended to integrate recent science and accumulated experience, in order to make resulting trends analyses as robust as possible.

Given this background, the overall objectives of this project were to:

1. Quantify the temporal or spatial change in contaminant concentrations that could be detected with the existing trend monitoring design;

2. Determine the geographic scale of temporal changes in contaminant concentrations that could be detected with the existing design (e.g., could a change in contaminant

concentrations measured in fish from individual water bodies be extrapolated to all water bodies in a region or statewide); and,

3. Recommend changes to the trend monitoring elements of the FCMP (if any) which would improve or enhance the program.

C. Brief Description of the Contents of the Exponent Report

Review of Confounding Factors Affecting Observed Levels of Bioaccumulation and Detection of Trends

Successfully detecting trends in concentrations of PTS in fish depends on identifying primary sources of variability and controlling for those factors with the sampling design or post-hoc statistical analyses (Bjerkeng et al. 1998; Uthe et al. 1991; Lamon and Stow 1999). To that end, this section of the report presents a review of factors important to bioaccumulation of PTS by fish. It is divided into two major categories: 1) Endogenous Factors Affecting Bioaccumulation and Detection of Trends; and 2) Exogenous Factors Affecting Bioaccumulation and Detection of Trends.

Endogenous Factors Affecting Bioaccumulation and Detection of Trends

This section of the report considers aspects of the fish that control or affect bioaccumulation of PTS and the final concentrations in tissue. To provide the reader with a basic understanding of how bioaccumulation works, mechanisms thought to be important to bioaccumulation are discussed first. Subsequently, physical factors that potentially reflect these underlying mechanisms are discussed. Topics discussed include:

- Growth Rates/Growth Efficiency
- Lipid Concentrations
- General Metabolism – Degradation and Absorption of Chemicals
- Age and Size (Length and Weight)
- Gender
- Species
- Tissue Type
- Recent Migratory Behavior

Exogenous Factors Affecting Bioaccumulation and Detection of Trends

This section of the report reviews factors external to the fish itself that affect the final concentrations of PTS in tissue. These include a number of factors that are critically important to bioaccumulation, notably food chain effects and, with respect to mercury, limnological factors affecting mercury bioaccumulation. The exogenous factors also include methodological decisions, such as time of sampling, location of sampling, and variability due to analytical methods. Topics discussed include:

- Food Chain Effects – Trophic Level and Prey Concentrations
- Limnological Factors Affecting Mercury Bioaccumulation
- Limnological Factors Affecting Bioaccumulation of Hydrophobic Substances
- Degree of Steady-State with External Loading
- Season of Sampling

- Analytical Precision, Quantization and Extraction Method, Analysts, and Lab Effects
- Sampling Location

The Michigan Department of Environmental Quality FCMP

MDEQ samples a variety of chemicals in fish across Michigan. There are three elements to the MDEQ program:

- ***Caged Fish Monitoring*:** The primary goal of this program element is to evaluate whether existing pollution prevention, regulatory and remedial programs are effectively reducing chemical contamination in the aquatic environment. Caged fish are used to identify sources of contaminants and spatial trends in contaminant concentrations.

- ***Edible Portion Monitoring*:** The primary goal of this program element is to provide data necessary to develop sport fish consumption advisories and commercial fishing restrictions. However, data are also used to evaluate environmental quality and track temporal trends at a few sites.

- ***Whole Fish Monitoring:*** The near-term goal of this program is to identify spatial differences and temporal trends in the quality of Michigan's surface waters. The ultimate goal is to evaluate whether existing pollution prevention, regulatory and remedial programs are effectively reducing chemical contamination in the aquatic environment.

The Exponent report touches on each of these program elements. However, the primary focus of the Exponent review was the design of the whole-fish trend monitoring program.

Also, this section of the report also includes a subsection titled *Estimation of Power of Current Sampling (Whole Fish Sampling)*. The power of MDEQ's current whole fish sampling program was estimated using data from ten combinations of location and species. It includes approaches and methods, and results.

Options and Recommendations

Options

This section of the Exponent report considers various options for revising the MDEQ's whole fish trend monitoring program. The section is subdivided into a series of questions where each question pertains to a specific aspect of the FCMP and was developed in conjunction with a review of the literature, surveys of other FCMPs and consultation with MDEQ. The responses are based on literature review and data analyses presented in previous sections of the report. In some cases, additional analysis and examples are provided. Each response concludes with Exponent's recommendation for the MDEQ FCMP. The questions include:

- Should MDEQ adopt randomized site selection for some monitoring?
- In general, should variability be controlled with stratified sampling or *post hoc* with statistical methods?
- Should MDEQ stratify sampling by fish size or consider size in post-sampling statistical analyses?
- Should MDEQ consider gender in its sampling or statistical analyses?
- Should MDEQ monitor YOY fish?

- Should hydrophobic PTS concentrations be lipid-normalized?
- Should analyses be controlling for age rather than, or in addition to, length/weight?
- Should limnological factors such as pH, temperature, oxygen concentration, and productivity be considered as part of the trend monitoring program design and/or *post hoc* statistics?
- Should sampling be stratified by season?
- Should abiotic concentrations or external loading be monitored along with fish data?
- Should food chain exposure be monitored directly or indirectly?
- Can edible-portion samples be used to supplement whole fish trend monitoring data?
- Should fish samples be archived?
- What model for PTS decline should be assumed in temporal trend analyses?
- Should MDEQ assess or control for fish movement/migration?
- Should MDEQ continue to freely release its data?
- Should MDEQ continue to maintain rigorous quality control for its analytical methods?

Recommendations

Exponent, in consultation with MDEQ, developed fish contaminant trend monitoring recommendations from its research of trend monitoring options. These recommendations were the highlight of the Exponent report. The report includes both Exponent's recommended trend monitoring options and an assessment of each option.

The above questions and their associated responses are followed by a subsection titled *Feasibility of Recommendations*. It examines Exponent's recommendations in terms of their logistical feasibility and potential effects on statistical power.

This section of the report concludes with a subsection titled *Impacts of Exponent's Recommendations on Historical Data*. In choosing recommendations, Exponent tried to balance cost and feasibility along with potential gains in information compared to previous sampling methods. This subsection details these considerations.

Appendices

The report includes the following appendices:

- Literature Review of Endogenous Factors That Affect Bioaccumulation of Persistent Toxic Substances and Statistical Methods for Trends Analyses
- Survey of Fish Contaminant Monitoring Programs
- Detailed Description of How to Calculate Power and Minimum Detectable Trend
- Power Calculations for Trend Ranges for Selected Locations
- Detailed Trend Analysis of Mercury and PCB Concentrations in Walleye from South Manistique Lake and Upper Peninsula Inland Lakes

Literature Review of Endogenous Factors That Affect Bioaccumulation of Persistent Toxic Substances and Statistical Methods for Trends Analyses

Exponent reviewed and summarized peer-reviewed literature regarding fish contaminant trend analyses. The literature review includes articles describing trend monitoring programs, statistical study design, fish growth rates and bio-energetics as they relate to contaminant

uptake. It also includes reviews of the impact of variables such as fish length, age, sex, weight, condition, lipid content, species, sample type and collection dates (season) on the contaminants of interest.

Survey of Fish Contaminant Monitoring Programs

Prior to reviewing the trend monitoring components of MDEQ's fish contaminant monitoring programs, Exponent conducted a survey of FCMPs to determine the state of the art for trend monitoring programs. It was felt that other FCMPs might have considered many of the same issues that concern MDEQ, and their insights and experiences would be valuable in evaluating Michigan's FCMP. To that end, managers of several FCMPs, from the Great Lakes and elsewhere, were contacted and asked to fill out a questionnaire. The questionnaire considered the goals, methods, and uses of their FCMPs. Information concerning these FCMPs was also obtained from published reports and scientific literature.

Exponent prepared a summary of all surveyed FCMPs. The surveyed FCMPs span a range of program size, longevity, and goals. The summary includes the goals of each trend monitoring program, a description of the study design, the period of record, and the major conclusions of each of the programs.

Exponent also prepared a detailed evaluation of the fish contaminant trend monitoring elements of MDEQ's FCMP. The detailed evaluation of MDEQ's trend monitoring elements includes:

- An assessment of the magnitude of temporal or spatial change in contaminant concentrations that could be detected with the existing trend monitoring design;
- A assessment of the geographical scale of temporal changes in contaminant concentrations that could be detected with the existing design (e.g., could a change in contaminant concentrations measured in fish from individual water bodies be extrapolated to all water bodies in a region or statewide); and
- A summary of the strengths and weaknesses of the existing trend monitoring design.

Detailed Description of How to Calculate Power and Minimum Detectable Trend

This appendix describes in detail the process for calculating the power of a simple linear regression model to detect a trend over time. It also describes in detail the process for calculating the minimum detectable trend level. This method is used to calculate how large the trend would have to be in order to be detected.

Power Calculations for Trend Ranges for Selected Locations

This appendix includes a list of figures of power curves from various sampling locations throughout the State of Michigan.

Detailed Trend Analysis of Mercury and PCB Concentrations in Walleye from South Manistique Lake and Upper Peninsula Inland Lakes

MDEQ requested that Exponent demonstrate how to estimate trends in chemical concentrations in fish tissue over time, including the possible impact of age, lipid content, length, sample type, pH, and conductivity. A data set was furnished by MDEQ, which contained walleye data from two sites – South Manistee Lake and Upper Peninsula inland lakes, represented by many lakes. Specifically, MDEQ requested to see the process of evaluating the trends over time in mercury and PCB concentrations in walleye samples from both locations with consideration of age, lipid content, sample type, and length; and consideration of pH and conductivity for the Upper Peninsula inland lakes. This appendix provides a detailed analysis, showing all intermediate steps, to illustrate how this kind of analysis would be done. It includes a list of figures and tables.

A. Welcome and Introductions

Matt Doss gave a brief background on the Great Lakes Commission, contracted to facilitate the workshop. Ric Lawson of the Commission served as workshop facilitator. Bob Day followed with background on MDEQ's fish contaminant trend monitoring program and a description of the workshop objectives. Michigan's FCMP includes three major elements: edible portion monitoring, whole-fish trend monitoring, and caged fish monitoring. The Exponent review focused primarily on the whole fish trend monitoring program which accounts for about 20% of the FCMP's analytical budget. However, the MDEQ also asked Exponent to consider the potential to use edible portion or caged fish data to support trends analyses. Day noted that the Exponent review was funded by The Clean Michigan Initiative (CMI) and that the MDEQ anticipates that CMI funding will provide a stable source of funds for fish contaminant trend monitoring through the next decade. Day introduced the Exponent report, *Fish Contaminant Monitoring Program: Review and Recommendations*, and stated that workshop input will be used to help the MDEQ select recommendations to implement. Day added that he hoped that the report, recommendations and workshop discussion will benefit not just the State of Michigan, but other states and agencies working with similar programs and issues.

B. Review Content of Strategy/Exponent's Six Tasks

Dan Smith outlined six tasks that Exponent was charged with in its contract with MDEQ:

- Task 1: Literature Review
- Task 2: Fish Contaminant Data Retrieval
- Task 3: Review Existing Fish Contaminant Trend Monitoring Programs
- Task 4: Develop Fish Contaminant Trend Monitoring Options and Recommendations
- Task 5: Review Factors Affecting Bioaccumulation (endogenous, exogenous, and limnological factors)
- Task 6: Participate in a Peer Review Workshop

Task 1: Literature Review

Exponent reviewed papers on trend monitoring programs; statistical design and power analyses; and, the effects of age, size, gender, lipid content, species, sample type, food chain impacts, collections dates and limnological factors on bioaccumulation of PTS in fish . The review is presented in the Exponent report in three sections. The first section presents a review of papers that address endogenous factors affecting bioaccumulation of persistent toxic substances in large fish. The second section contains a review of fish contaminant monitoring programs (FCMPs) that use young-of-the-year (YOY) fish. The final section is a review of papers that address statistics and sampling design of fish monitoring studies. Each citation in the literature review includes a summary and its relevance to FCMP.

Task 2: Fish Contaminant Data Retrieval

Exponent collected fish contaminant trend data from several agencies in addition to MDEQ. These included:

- Canada Department of Fisheries and Oceans (DFO)

- Ontario Ministry of the Environment
- State of Ohio
- State of New York (YOY only)
- State of Minnesota

Task 3: Review Existing Fish Contaminant Trend Monitoring Programs (FCMP)
Exponent summarized survey results from the following FCMPs:

- Canada DFO
- EPA National Tissue Monitoring
- Great Lakes Indian Fish & Wildlife Commission
- Inter-tribal Fisheries and Assessment Program
- Massachusetts Water Resources Authority
- Ontario Ministry of the Environment
- State of Illinois
- State of Indiana
- State of Minnesota
- State of New York (YOY only)
- State of Ohio
- State of Pennsylvania
- State of Wisconsin

The following conclusions resulted from the survey of FCMPs:

- Most FCMPs used fixed sampling sites for trends analyses.
- Many FCMPs were double duty (trends and advisories).
- Most had significant changes in methodology over time.
- Most generally used simple statistical methods to analyze trends.
- Analyses were generally not published in peer-reviewed literature.
- The design of FCMPs devoted to trends differed.
- Few FCMPs employed more complex statistical analyses before and after sampling and publish their work.

Task 4: Develop Fish Contaminant Trend Monitoring Options and Recommendations
This was the basis of the Exponent report. This section of the report considers various options for revising the MDEQ's FCMP. It is organized through a series of questions where each question pertains to a specific aspect of the FCMP and was developed in conjunction with a review of the literature, surveys of other FCMPs, and consultation with MDEQ. The responses to the questions were based on the literature review and data analysis presented in previous sections of the report. Each response concludes with Exponent's recommendation for the MDEQ's FCMP.

Task 5: Review Factors Affecting Bioaccumulation (endogenous, exogenous, and limnological factors)

Exponent reviewed the following factors affecting bioaccumulation:

Endogenous Factors:

- Growth Rate/Growth Efficiency
- Lipid Concentrations
- General Metabolism
- Age and Size

- Gender
- Species
- Tissue Type

Exogenous Factors:
- Food Chain Effects – Trophic Level and Prey Concentrations
- Limnological Factors – Mercury; Hydrophobes
- Degree of Steady-State with External Loading
- Season of Sampling
- Analytical Precision and Lab Analyst Effects
- Sampling Location

Task 6: Participate in a Peer Review Workshop
As part of its contract with MDEQ, Exponent was asked to participate in a workshop (for agenda, see Appendix B) convened to conduct a peer review of the proposed monitoring strategy and participate as a technical expert.

C. Group Discussion of Strategy Recommendations

Recommendations Chosen for Discussion at Workshop
Workshop participants discussed the following recommendations:

Recommendation dealing with appropriate goals and hypotheses:
- Goals and Hypotheses

Recommendations dealing primarily with exogenous factors:
- Random vs. fixed station
- Fish movement
- Seasonal effects
- Food chain effects
- Water chemistry
- Surficial sediments/multi-media
- YOY monitoring

Recommendations dealing primarily with endogenous factors:
- Lipids
- Fish age
- Tissue types
- Gender
- Size

Other recommendations:
- Archive
- Quality assurance

Each of the above recommendations was discussed to some degree at the peer review workshop. They are listed below sequentially as covered in the workshop. Each recommendation is followed by the key question being answered, background information on

the recommendation from the Exponent report and a summary of the workshop discussion for that recommendation.

D. Recommendations

Recommendation 4.14 – Goals and Hypothesis

Key Question: *What model for PTS decline should be assumed in temporal trend analyses?*

Recommendation:
Exponent recommends that MDEQ determine an appropriate model for contaminant declines. Exponent recommends a bumpy exponential decline for organic PTS and a bumpy exponential decline to some asymptote for mercury.

Background:
Determination of an appropriate model for contaminant decline within an ecosystem is a critical but often overlooked requirement for defensible analyses of temporal trends of PTS in biota, especially when results of these analyses are used, explicitly or implicitly, to track effectiveness of pollution prevention and remediation actions. Before deciding whether rates of decline are too slow or too fast, or whether those rates of decline are significantly increasing or decreasing over time, it is necessary to have an expectation for how concentrations should decline over time. Statistically significant deviations from this expected decline produce results that can then be appropriately interpreted as significant in a policy sense.

Summary of Workshop Discussion:
One objective of this recommendation was to warn against determining trends from a review of relatively short periods of record. Contaminant concentrations (particularly in Great Lake fish) fluctuate based on a number of conditions including changes in the food chain, fish growth rates and a complex array of other factors. Workshop participants noted that MDEQ analysts need to be aware that short term increases or decreases in contaminant concentrations may not reflect long term trends. Others suggested that the MDEQ acknowledge the expectation that short term changes in concentrations may not reflect long term trends as an explicit hypothesis prior to sample collection.

Some participants felt that the “bumpy first order decay” was a useful hypothesis because it can be used to acknowledge short term changes that are not consistent with the long term trends. Other participants recommended that MDEQ let the data determine the appropriate model – and design sampling and statistical analyses programs to test and improve the models. They noted that other models or multiple models may better describe observations than any single descriptive model. Also, having alternate models will not impose a structure on data and allows for flexibility in interpreting data and establishing trends. This flexibility would allow for a better inclusion of the variability in the data.

Workshop participants discussed the use of fish contaminant trends to estimate changes in loading rates of contaminants to water bodies. Participants commented that the MDEQ would need to link the fish contaminant trend models to mass balance models before conclusions could be developed since fish contaminant trends may not correspond to actual loading changes. It was noted that using trends in fish as a surrogate for trends in loads is a high risk exercise since there are many other factors confounding trends in fish. Some participants noted

that, due to lags in biotic response, fish contaminant trends were a reflection of past activities and not indicative of ongoing load reductions.

Most agreed that the impact of remediation or load reduction activities could be demonstrated most effectively on a relatively small geographic scale (e.g., assessing changes in fish contaminant concentrations in resident populations following site remediation).

Recommendations Dealing Primarily With Exogenous Factors

Recommendation 4.1 – Random vs. Fixed Station

Key Question: *Should MDEQ adopt randomized site selection for some monitoring?*

Recommendation:
Exponent recommends that inland fixed stations that are primarily tracking dispersed sources of mercury be reallocated to randomized sites. Those fixed stations primarily tracking localized sources of organochlorine or mercury, or both, should be retained as fixed stations.

Background:
Many factors should be considered when deciding whether to sample at fixed vs. randomly selected locations. However, the primary determinant appears to be one of geographic scale. Fixed sampling sites appear to be better for answering questions about trends over small spatial scales. This sampling is best for determining spatial and temporal trends that will be applicable to small areas and for chemical trends arising from localized sources. Randomized site selection appears more suited to trends analyses concerned with large spatial scales. This sampling would be better for questions concerning trends across many lakes or large parts of the state and for widely dispersed pollution sources.

A review of the Michigan FCMP suggests that it intends to address both local and widespread contamination, arising from both local and dispersed sources. Much of the sampling of edible tissue for fish consumption advisories and before-after assessments of remediation is focused on local sources. Trends analyses focused on this type of analysis are best addressed with sampling at fixed sites. Advisories based on mercury, on the other hand, are primarily based on dispersed sources and limnological factors such as lake alkalinity that vary across geographic regions. Thus, questions addressing the efficacy of ongoing regulation of mercury and long-term trends of mercury contamination in fish are better addressed by randomized site selection.

Summary of Workshop Discussion:
Participants noted that the decision regarding fixed stations versus randomly selected sites should be dependent on the questions to be answered as well as factors such as sources of contaminants, characteristics of the target water bodies, and behavior of the preferred species.

Participants discussed a range of potential site selection options. Most agreed that fixed station designs were best for trends analyses at sites with barriers to fish movement and known sources of contaminants at which investigators are primarily interested in site specific conclusions. Either fixed or random site selection may be appropriate for large water bodies like the Great Lakes. However, if fixed stations are established in the Great Lakes, it may be necessary to examine site variability within a lake. If variability is observed between sites in a Great Lake, investigators should consider treating site as a co-variable in trends analyses where lakewide conclusions are preferred (as opposed to site specific conclusions). Randomly selected sites or randomly selected panel designs should be considered for trends analyses of a

sample of water bodies (such as inland lakes) with diffuse sources of contaminants at which investigators are interested in statewide or regional conclusions.

Participants discussed the pros and cons of a fixed station sampling design (such as the design currently implemented by the MDEQ) versus a design based on random site selection.

Some participants expressed concern about the randomized approach given the potential for between-lake variability to overwhelm analysts' ability to detect trends. A number of participants noted that fixed stations provide some certainty of finding targeted species of fish and sizes. Others indicated that having good information (i.e. food web, water quality) for fixed stations may be more useful than a randomized design with relatively poor information about the lakes selected for monitoring. However, participants agreed that statewide or regional trend conclusions require some type of randomized design. While trends may be easier to measure at fixed stations, the conclusions cannot be transferred to other water bodies with any defined confidence. Also, it was noted that randomly selected sites can also help identify new "hot spots" or emerging issues; however one loses the ability to identify trends at a given location without repetitive sampling.

Participants noted that the mercury concentrations measured in Michigan walleye were highly variable and that it was not possible to detect mercury trends in Upper Peninsula walleye (Exponent Report Appendix E). However, mercury trends could be detected at all three of the MDEQ's inland lake fixed stations located in the Upper Peninsula. Participants discussed stratified random sampling designs with strata defined by lake type, pH, conductivity, percentage of wetlands in the watershed, land use or other factors. While stratified random sampling strategies may be used to control between-lake variability, some participants expressed concern about the cost of collecting enough information to place lakes in appropriate sampling strata prior to randomly selecting monitoring locations. Further, given that the MDEQ will likely never have enough data to adequately pre-stratify water bodies, the MDEQ should consider randomly selecting sites and then post-stratifying samples from each water body. Others suggested ranking exogenous factors to determine which are most meaningful, and then performing a more limited stratification.

Participants also discussed the importance of an adequate sampling design to determine temporal trends. A fundamental problem with randomly selected sites is that sample sizes are usually too small. Also, rotating panel designs are useful if an appropriate number of stations can be selected.

Finally, participants expressed concern about completely abandoning the fixed station design in favor of a randomized approach given the time necessary to detect trends. Some participants suggested that the MDEQ should consider continuing the fixed station trend monitoring while simultaneously beginning some type of randomized design (limited to mercury only) with edible portion samples.

Recommendation 4.15 – Fish Movement

Key Question: *Should MDEQ assess or control for fish movement/migration?*

Recommendation:
Exponent cannot recommend any changes to MDEQ's current sampling to either control or assess fish movement/migration.

Background:
Fish migration can significantly impact fish concentrations. MDEQ has historically been concerned about the potential impacts of fish movement on detection of spatial and temporal trends in PTS concentrations. For example, many of its fixed sampling sites were specifically chosen to minimize migration.

Summary of Workshop Discussion:
Workshop participants discussed the general implications of fish movement particularly in the Great Lakes and Connecting Channels. Some actions have been taken in other areas of the country to mitigate or control variability due to the impacts of fish movement. However, the participants did not feel that any of these options were applicable to the Great Lakes and did not offer any recommendations.

The participants discussed MDEQ's existing fixed stations in the St. Clair River, Lake St. Clair, Detroit River and Lake Erie. Some workshop participants observed that while tagging studies indicate that individual walleye move between these water bodies, the populations are probably discrete and tagging studies are insufficient to fully understand migration patterns. Others noted that tagging data shows some site fidelity, but brings into question the reasonableness of fixed-site design. It was suggested that patterns of residence from one water body to another be examined, but the requirement of fish origin adds a new layer of data collection. Others note that a principle component analysis based on chemical residues may offer a solution.

Some participants noted that if the MDEQ was interested in obtaining statewide trend information then four stations located so closely together may not be necessary. If interest is in a specific site, then fish should be sampled that have not migrated. Others noted that specific trends in Areas of Concern might be better handled with site-specific projects rather than a statewide program.

Recommendation 4.9 – Seasonal Effects

Key Question: *Should sampling be stratified by season?*

Recommendation:
Exponent recommends that the MDEQ continue to collect samples throughout the year as opposed to sampling in any particular season.

Background:
Seasonal effects have been noted for bioaccumulation of some contaminants in some fish, notably mercury (Ward and Newman 1999). Given the potential influence of seasonal factors on bioaccumulation, it may also be important to consider the impact of season on observed concentrations. Except in the case of sampling fall run Coho and Chinook salmon, MDEQ does not now focus sampling on any particular season. The timing of sample collection conducted for the MDEQ by other agencies has been dependent of the project specific goals or resource constraints of the other agency.

Summary of Workshop Discussion:
Workshop participants discussed the impact of sampling season on fish contaminant concentrations. Participants discussed changes in mercury concentrations that have been linked to seasonal changes in fish condition or water chemistry. In addition, some participants were aware of species and locations in which concentrations of organic contaminants varied with spawning condition noting that pre- and post-spawning fish may have dramatically different

concentrations of organic contaminants. The Exponent recommendation reflected a lack of peer-reviewed literature dealing with changes in organic concentrations between seasons and sampling constraints faced by MDEQ.

Some participants indicated that concentrations may not vary by season. However, most participants thought that seasonal variability could be significant and that MDEQ should make an effort to control this variability by collecting samples during the same time of the year at each site and avoiding post-spawning collections.

Some suggested that post-hoc stratification of the data could help determine the level of effect. Analysis of Covariance (ANCOVA) was used to account for seasonal effects in mercury concentrations. However, other participants indicated that neither lipids nor fish condition could be used effectively to correct for seasonal effects due to spawning condition or fish condition.

Recommendation 4.11 – Food Chain Effects

Key Question: *Should food chain exposure be monitored directly or indirectly?*

Recommendation:
Exponent recommends that MDEQ continue to employ multifish comparisons. Also, Exponent recommends that MDEQ begin to monitor delta nitrogen and delta carbon.

Background:
Changes in a food chain can have very significant effects on PTS concentrations in fish. Consequently, identification of changes in the underlying food chain is a critical factor in understanding trends of PTS in fish across time and space. Several methods have been used in the past to monitor food chain effects, including direct measures such as assessing gut contents and measuring concentrations in prey fish (Madenjian et al. 1999). Indirect methods for identifying food web changes include correlation between changes in PTS concentrations and prey stocks dynamics (Borgmann and Whittle 1991a,b; Smith 1995b) or food chain length (Rasmussen et al. 1990, Rowan and Rasmussen 1992), and changes in delta nitrogen and delta carbon signature (Whittle et al. 2000). Analysts have also considered multichemical, multifish, multimedia, and multimethod approaches. The first compares the behavior of different chemicals in the same organisms over time or space (Smith 1995a,b,c). The multifish method—comparisons of trends across different fish species (e.g., Stow et al. 1995; Lamon et al. 1999) – also represents a way to deduce potential food chain effects that affect different species. The benefits of multifish comparisons are persuasively described in Lamon et al. (1999). Comparisons of trends across media are described above. Lastly, some analysts compare empirically derived trends versus those derived from theory or modeling (e.g., Endicott et al. 1992a; Gobas et al. 1995; Smith 2000). Each of these methods offers certain advantages, which are detailed in the Exponent report.

Summary of Workshop Discussion:
Most workshop participants agreed that changes in the food chain over time and space are potentially the most important confounding effects not controlled by current sampling or considered in post hoc trends analyses of biomagnifying substances in Great Lakes fish. From a Great Lakes perspective, it is important to study food chain effects because the composition of the food web and diets are continuously changing. Several noted that MDEQ should continue to conduct multi-fish analyses and the MDEQ was encouraged to make more use of multi-chemical analyses to identify short term “bumps” in the long term trends.

Participants discussed the use of delta nitrogen and delta carbon to identify changes in the food chain. The Department of Fisheries and Oceans (DFO) collects delta nitrogen and delta carbon data. The DFO uses these data qualitatively in post hoc analyses to help explain "bumps" in the data that may be caused by food chain effects. However, the DFO believes that these data could be used qualitatively in regression equations as well.

Other participants expressed concern regarding the use of delta nitrogen as a measure of food chain changes in fish from inland lakes. Changes in delta nitrogen over time at inland lakes can be influenced by human activities and human sources of nitrogen. Therefore, one would also need a measure of nitrogen ratios and trends in the watershed before conclusions could be made about changes to the food chain based on changes in delta nitrogen concentrations in fish tissue. This would require a baseline isotopic composition of the water body first.

Also, some participants noted that delta nitrogen might not explain the bumps if corresponding diet and forage contaminant data are not available. This analysis would largely be based on having good diet data. For example, if predator species switch from a relatively uncontaminated prey species to a relatively contaminated prey species at the same position in the food chain, then delta nitrogen will not explain the changes in predator contaminant levels associated with changes in diet.

Participants discussed forage fish contaminant monitoring but noted that forage base contaminant information without corresponding diet information will not explain "bumps" related to changes in the food web. Large scale gut studies could be cost prohibitive but a few gut samples could be collected for comparison with other techniques.

Participants also discussed the influence of growth efficiency on PTS concentrations in top predators. However, estimating growth efficiency and including this measure in trends analyses could be problematic.

Many participants felt that delta nitrogen and delta carbon analyses were relatively inexpensive and worthwhile. Some noted that these analyses could be done on hard features, such as spines or scales, and that these structures could easily be collected, saved and analyzed after reviewing contaminant concentrations

Recommendation 4.8 – Water Chemistry

Key Question: *Should limnological factors such as pH, temperature, oxygen concentration, and productivity be considered as part of the trend monitoring program design and/or post hoc statistics?*

Recommendation:
Exponent recommends that MDEQ collect data on basic water chemistry, notably pH and conductivity in inland lakes from which fish are collected for mercury trends analyses.

Background:
Limnological factors including lake chemical characteristics such as pH and dissolved organic carbon (DOC) and lake physical characteristics such as surface area and watershed size are often correlated with fish mercury concentration. Data on these characteristics are generally easy to acquire and have the potential to assist in post-sampling analysis of fish mercury concentration data. For example, trends analysts can stratify the data based on chemical or

physical characteristics in order to identify trends in subsets of lakes, or these factors could be covariates in multiple regressions.

The primary lake chemical characteristics that influence fish mercury concentration are pH and DOC. Several studies also evaluated and found significant relationships with alkalinity, conductivity, hardness, total nitrogen, total phosphorus, and various ions, some of which are measures of productivity.

Several lake physical characteristics are generally found to correlate with fish mercury concentration and are recommended for consideration in subsequent trend analyses concerning mercury. These data should be readily available from state or federal databases. These characteristics are surface area of lake, type of lake (i.e., seepage, drainage, or impoundment), presence/absence of annual anoxic hypolimnion, watershed area, and land use in watershed (i.e., percent wetlands, forest, and farmland).

Summary of Workshop Discussion:
Exponent noted that limnological factors are often correlated with mercury concentration and can be collected easily without collecting, preserving and shipping a water sample to a laboratory. Most participants agreed that MDEQ should measure pH and conductivity at inland lakes. It was noted that pH and conductivity expresses seasonal variation. However, several participants noted that DOC should also be collected. They noted that the Exponent report indicated that DOC was also correlated with mercury concentrations in fish tissue and felt that the extra costs associated with collecting water samples were warranted.

James Breck from the Michigan Department of Natural Resources (MDNR) indicated that Fisheries Division staff would be collecting water samples at sites that are monitored as part of their fish population status and trends monitoring program. Gary Kohlhepp from MDEQ indicated the statewide water quality monitoring program can add DOC for mercury into their regular sampling protocol.

Some participants warned against collecting water chemistry data without rigid protocols and procedures. This quality control issue may be particularly relevant for field personnel collecting samples that are not targets for their programs. Without standardized approaches the water chemistry data will not be helpful and could make mercury trends analyses more difficult.

Recommendation 4.10 – Surficial Sediments/Multi-Media

Key Question: *Should abiotic concentrations or external loading be monitored along with fish data?*

Recommendation:
Exponent recommends that MDEQ begin to collect a surficial sediment sample at each fish collection station if this can easily be done.

Background:
Given all the confounding factors affecting bioaccumulation, several analysts have conducted multimedia comparisons to lend credence to trends observed in biota. Thus, for example, analysts have compared PTS trends in fish with PTS trends in water (DeVault et al. 1996), trends in sediments (Rasmussen et al. 1990; Rowan and Rasmussen 1992), trends in overlying atmosphere (Simcik et al. 2000), and trends in gull eggs, fish, water, sediments, suspended sediments, and overlying air (Smith 2000; Offenberg and Baker 2000). When trends across

media are concurrent, multi-media comparisons support the legitimacy of trends found in all media. When trends across media are divergent (DeVault et al. 1996), however, it suggests the importance of confounding factors. Consequently, multimedia comparisons are a robust method to determine if trends observed in biota are real.

Summary of Workshop Discussion:
Exponent recommended surficial sediment sampling in part because of ease of sampling. Most participants agreed that sediment sampling along with fish contaminant monitoring would be a useful activity for the MDEQ. However, several participants recommended collecting sediment core samples and analyzing sectioned cores instead of surficial sediment samples. Many participants felt that paired fish and sediment contaminant trend monitoring was appropriate and would provide more information than independently run sediment core and fish trend monitoring programs. Some participants suggested that it was relatively cheap to collect sediment core samples while on site collecting fish contaminant samples. They noted that the MDEQ could decide later whether or not to analyze the sediments.

Some participants were hesitant to recommend collection of sediments at a site given the potential difficulties relating the data to fish contaminants. They note that fish sampling reflects relatively current conditions while sediment sampling is retrospective. Also, while some parameters from a core sample could provide useful information to supplement fish contaminant trends analyses, mercury analyses from core samples did not always provide reliable estimates of trends. Many agreed that a measure of trends in multiple media would be useful but they warned the MDEQ to be careful to assess the costs and benefits of adding a sediment monitoring component to the fish contaminant trend monitoring program. Collecting sediments properly requires rigid sampling protocols and careful identification of depositional areas.

Recommendation 4.5 – YOY Monitoring

Key Question: *Should MDEQ monitor YOY fish?*

Recommendation:
Exponent recommends against sampling of YOY fish for use in trends analyses.

Background:
Compared to FCMPs using older fish, YOY FCMPs are thought to monitor PTS concentrations over smaller temporal and spatial scales. YOY fish are generally less mobile than adult fish, so they are thought to better reflect local PTS concentrations. Similarly, concentrations of PTS in very young fish are also assumed to reflect current conditions, whereas older, larger fish are assumed to integrate the effects of ecosystem concentrations over many years. YOY sampling would, therefore, have advantages for trend analyses concerning localized contamination, or following recent changes resulting from a new source, or remediation. YOY fish offer FCMPs other advantages and disadvantages. For example, YOY fish are generally numerous and small, making compositing many small fish easier than compositing large fish. YOY fish also provide information on trends of chemicals at low trophic levels, which may be important in assessing food chain effects. On the other hand, concentrations of PTS in small fish are often too low to be detected with conventional detection limits. At most sites on the Great Lakes, for example, only PCBs and DDT are currently detectable in YOY spottail shiners. Even these chemicals are becoming progressively harder to detect as concentrations continue to decline over time. (The problem with undetected data applies to the use of these data for trends analyses. This is likely not a problem if the intent of monitoring is assessment of risk or status,

as detection limits for most chemicals are generally below concentrations that represent a problem.) MDEQ periodically collects data on YOY perch from a number of sites. As with YOY collections for other species, these samples suggest that most chemicals cannot be detected in YOY perch at most sites. Although mercury and PCBs were detected in 100 percent and 71 percent of samples, respectively, most other chemicals (DDT, DDE, octachlorostyrene, dieldrin, and hexachlorobenzene) were rarely or never detected in YOY perch. Also, Exponent's recommendation is based on the relatively high variability in YOY sample concentrations that is associated with exogenous factors that are hard to control with sampling design or statistical techniques.

Summary of Workshop Discussion:
Some workshop participants agreed that the YOY inter-year variability is high due to factors such as weather, food chain effects, time of collection, size and others. Some said YOY may not represent true contaminant dynamics and questioned investing effort and resources in this particular activity. Some felt that yearling fish may be less variable but have less site fidelity and others noted that while yearling inter-year variability might be less it will not likely be less than inter-year variability associated with adult fish.

Several participants acknowledged that YOY fish can be an effective spatial monitoring tool but other media (such as lipid bags or caged fish) may be better. In areas like the lower connecting channels, YOY monitoring could help where issues are complex and variable (e.g., Lake St. Clair vs. Detroit River). Others suggested that given the statewide character of Michigan's fish contaminant trend monitoring program, site-specific changes might be better handled with site-specific projects as opposed to program changes.

A participant suggested that the MDEQ consider monitoring round gobies. Round gobies do not move much and inter-year variability will be low.

Recommendations Dealing Primarily with Endogenous Factors

Recommendation 4.6 – Lipids

Key Question: *Should hydrophobic PTS concentrations be lipid-normalized?*

Recommendation:
In cases in which lipid levels change over time, Exponent recommends that trends analyses be conducted with and without lipids as a covariate. Also, Exponent recommends that ANCOVA or multiple regression be used instead of the ratio method.

Background:
Lipid normalization appears to be justified when bioconcentration is the primary mechanism of bioaccumulation. This would pertain to those chemicals that do not biomagnify or those situations, such as with the caged fish, where uptake across the gills is the primary exposure. Thus, MDEQ's current method of evaluating lipid normalized caged fish data is appropriate, assuming that the caged fish are not consuming significant amounts of food during the 28 day study.

However, lipid normalization, using the ratio method, does not appear warranted under most situations for biomagnifying chemicals in wild fish. While concentrations of lipids may affect excretion and absorption of biomagnifying hydrophobic chemicals, the available theoretical and empirical evidence indicates that lipids play only a minor to moderate role in total

bioaccumulation of hydrophobic PTS. The Exponent report suggests that in cases in which lipid levels change over time, trends analyses should be conducted with and without lipids as a covariate. Exponent warns that analysts should be wary of data sets and resulting trends analyses in which lipids vary dramatically over time and space. Differences in lipid concentration indicate that food chain, growth efficiency, or other exogenous factors may influence changes in contaminant concentrations over time.

Summary of Workshop Discussion:
Workshop participants discussed the often poor relationships between lipids and contaminant concentrations. Some noted that these poor relationships could be caused by analytical procedures. Lipid analyses often include nonpolar fats (which are strongly associated with nonpolar contaminants) as well as polar lipids that are not strongly associated with nonpolar contaminants. While total lipids could be fractionated into polar and nonpolar components these analyses are rarely done.

Most workshop participants agreed that lipids should not be considered in trends analyses unless lipids change over time. In these cases, lipids could be used as a covariate in multiple regression or ANCOVA models.

Recommendation 4.7 – Fish Age

Key Question: Should analyses be controlling for age rather than, or in addition to, length/weight?

Recommendation:
Exponent recommends that fish age be assessed in the lab and be considered as a covariate in subsequent trends analyses.

Background:
While many analysts believe that fish age, rather than fish size, is critical to bioaccumulation, only a few, notably from Canada's Department of Fisheries and Oceans (DFO), actually assess fish age on a regular basis. Also, some FCMPs, such as YOY and fall Chinook and Coho Salmon sampling, rely on fish behavior and size as a way to focus on a limited age range. Because aging fish in the field is generally impractical, most FCMPs and trends analyses rely on fish size as the primary covariate. Similarly, while there are some mathematical models and empirical evidence that suggest that age effects are important above and beyond size effects (e.g., Borgmann and Whittle 1991b; Stow and Carpenter 1994a; Eby et al. 1997), other mathematical models adequately predict concentrations in fish based on size alone (e.g., Campfens and Mackay 1997).

In summary, it is uncertain whether fish age has significant effects on bioaccumulation beyond those associated with fish size. On the other hand, there is evidence, mostly based on modeling, that age may significantly affect bioaccumulation beyond those effects associated with fish size.

Summary of Workshop Discussion:
Participants agreed that the MDEQ should collect age information as part of its trend monitoring program. Some noted that age versus contaminant relationships could be relatively strong in young fish and relatively weak in older fish of some species. However, participants felt that age information was important information and relatively cheap and easy to collect. It was further

suggested that a range of sizes be collected and age be assessed to provide enough variability to establish an effect.

Recommendation 4.12 – Tissue Types

Key Question: *Can edible-portion samples be used to supplement whole fish trend-monitoring data?*

Recommendation:
Exponent recommends that MDEQ combine data from fish tissue types for trends analyses.

Background:
MDEQ collects data on PTS concentrations in fillets for use in fish consumption advisories but does not routinely use these data in trends analyses. However, the fillet data represent a significant source of information that could potentially be used in conjunction with the whole fish monitoring program to better deduce trends. With respect to its potential utility, it is notable that other analysts have used MDEQ fillet data for trend analyses (e.g., see Stow et al. 1995).

There are several ways that fillet data could be used to augment the whole fish monitoring program. First, separate analyses on fillets and whole fish could be run in parallel, and trends compared between the two tissue types. Second, data from one tissue type could be converted to the other type by some sort of conversion factor, and analyses run on the combined data set. Third, trend analyses could be run with the two types of data in a mixed linear model, with tissue type used as a covariate. A fourth method, lipid normalization, is not recommended with data that will be used in trend analyses for reasons discussed in the section on lipid normalization.

In addition to the obvious differences in tissue type, PTS concentration data obtained from MDEQ fillet samples differ in two other ways from data generated with the whole fish program. First, fillet data are generally based on a wide range of fish sizes, whereas the whole fish monitoring program targets a limited size range. In addition, some fillets samples are sometimes composites of several fish, while individual whole fish are analyzed. Analyses that tried to combine these data in a single analysis would also have to deal with these issues.

Adding fillet data can enhance the validity of observed trends by increasing the spatial and temporal spread of the data set and the total number of observations. On the other hand, combining data from different tissue types data adds variability and potential biases that may also affect trends. Multiple regression may produce coefficients that are counter-intuitive.

Summary of Workshop Discussion:
Workshop participants discussed the variability associated with correction factors intended to predict whole fish concentrations from edible portion samples. Several of the workshop participants warned that correction factors could be highly variable based on species, size, location, condition and other factors that might not be easy to predict or control.

Most workshop participants felt that the MDEQ should not combine tissue types in trends analyses. They felt that it would be better to keep edible portion and whole fish data separate, conduct trends analyses on two different data sets, and compare the results.

Recommendation 4.4 – Gender

Key Question: *Should MDEQ consider gender in its sampling or statistical analyses?*

Recommendation:
Exponent recommends that gender be assayed in the future and considered using post-sampling statistical analyses.

Background:
Gender has significant effects on PTS concentrations in some species under some circumstances. Thus, stratified sampling by gender of walleye has been recommended (Madenjian et al. 1998b) to improve statistical power of trend analyses, and at least one FCMP currently targets specific genders for different analyses (HELCOM 2002). MDEQ does not control for fish gender in its trends analyses. This is unlikely to be problematic for some of the species monitored by MDEQ, because gender does not appear to have significant effects on PTS concentrations in Coho salmon (Williams et al. 1989) or lake trout (Figure 4-1).

However, based on MDEQ and MOE data from multiple locations, male walleye tend to have 50 percent or more PCBs than similarly-sized female walleye (Figure 4-2). Walleye gender may also affect mercury concentrations (Figure 4-2). Similarly, inspection of MDEQ data suggests that male carp tend to have higher concentrations of PCBs and mercury than do female carp. However, MDEQ does not now control for fish gender and does not routinely assess gender.

Summary of Workshop Discussion:
Several workshop participants agreed that gender was an important consideration in populations where differential growth rates exist between sexes. Others felt that the effect of differential growth rates between sexes might be eliminated by including age in some situations such as inland lakes. Some participants noted that age would not account for the influence of differential growth rates between sexes in cases where differences between male and female behavior was contributing to differing contaminant concentrations between genders. For example, Saginaw Watershed male walleye tend to spend more time at the relatively contaminated Saginaw River mouth than female walleyes.

Most agreed that gender should be measured for use in trends analyses where appropriate. However, in cases where gender cannot be assessed in the field the MDEQ should consider increasing the number of walleye collected and analyzing a subset of the total number collected to improve the odds that sufficient numbers of male and female walleye will be analyzed.

Recommendation 4.3 – Size

Key Question: *Should MDEQ stratify sampling by fish size or consider size in post-sampling statistical analyses?*

Recommendation:
Exponent recommends that MDEQ switch to selecting a wider range of fish sizes each year and accounting for size with statistical techniques. To retain the benefits of stratified sampling, Exponent recommends stratified sampling at sites where fish in targeted size range are available.

Background:
Most FCMPs devoted to trend analyses stratify sampling on the basis of fish size. The primary problem with stratifying by size is the difficulty of finding fish of the appropriate size. As with any stratified sampling, there is also some loss of information because the results pertain only to the size sampled. The advantages of unstratified sampling are ease of sampling and more complete information about trends across fish sizes.

As demonstrated by MDEQ's sampling of lake trout in Grand Traverse Bay, Lake Michigan, finding the targeted fish size is sometimes difficult at some sites. In this case, samplers took the closest size range available. The resulting size differences that occur from sample to sample sometimes compromise resulting trends analyses. For example, the data from whole lake trout from Traverse Bay between 1990 and 1998 showed highly significant increasing trends, in PCBs (8.5 percent per year), mercury (12 percent per year), and sum of DDT and its breakdown products (5 percent per year). However, the length and age of the fish also increased during this period, so these trends in contaminants are potentially attributable to changes in fish length and age.

This problem can potentially be addressed by adding length into a multiple regression, but the results of these analyses are difficult to interpret because length and year are themselves correlated. In addition, there is generally not a sufficient range of sizes in any one year to determine if the statistically-derived coefficient is reasonable.

Summary of Workshop Discussion:
Participants agreed that stratifying sampling based on a limited size range results in trend conclusions that are limited to fish in the sampled size strata. Some workshop participants recommended that the MDEQ collect a range of sizes at all sites and use statistical methods to account for the influence of length on contaminant concentrations. They believe that moving away from a sampling strategy stratified by size will protect MDEQ's ability to determine contaminant trends in the future if fish of a targeted size range are not available at sites of interest.

Other Recommendations

Recommendation 4.13 – Archive

Key Question: *Should fish samples be archived?*

Recommendation:
Exponent made no recommendation regarding archived samples.

Background:
Some FCMPs archive their fish samples. Archived material can be useful when new analytical methods are adopted (e.g., Glassmeyer et al. 1997) and when other information is sought. Examples of the utility of archived samples are found in several papers based on tissue archived by DFO. For example, Huestis et al. (1996) reanalyzed archived extracts with new analytical methods and with the original analytical methods to determine precision across time and analytical method. Archived material was subjected to delta nitrogen analyses in several studies to determine if trends were affected by changes in trophic level (Whittle et al. 2000).

In addition, other agencies in the area are archiving tissue, and these tissues will be available to identify any emerging issues that affect the entire area. Thus, the benefits of an MDEQ tissue archive are difficult to estimate.

Summary of Workshop Discussion:
Workshop participants discussed the costs and benefits associated with archiving fish tissue or sample extracts. Many participants agreed that tissue archives could be important components of long term trend monitoring programs because they provide a source of tissue that can be used to confirm results when laboratory methods change and can be used to evaluate trends of emerging pollutants that were not historically monitored.

Some participants noted that the MDEQ should carefully consider the questions that archived materials might help answer before determining the types of samples to be archived, the amounts of material, sites of interest and methods for preserving samples.

Some participants felt that if the decision was made to keep fish tissue archives, then freezing fish tissue in sealed jars at -80 degrees Centigrade was the best approach. However, other systems or approaches may be adequate depending on the needs of the agency. Several participants suggested adopting a protocol that accounted for the loss of moisture over time in freezers. Others proposed using alternative types of archival capabilities – outside the realm of freezers with jars full of samples. Participants noted that both the DFO and the U.S. Geological Survey (USGS) laboratory in Ann Arbor maintain tissue archives and have written protocols. DFO collects multiples of every sample and eliminates replication through time as necessary.

Several participants suggested that state and federal agencies use and maintain a central archive.

Recommendation 4.17 – Quality Assurance

Key Question: *Should MDEQ continue to maintain rigorous quality control for its analytical methods?*

Recommendation:
Exponent recommends that MDEQ's quality control system be continued.

Background:
Analytical precision is essential for successfully determining trends of PTS. Several respondents to the FCMP survey stressed the importance of analytical precision and quality control. MDEQ currently has a quality control system.

Summary of Workshop Discussion:
Most of the workshop participants agreed that analytical variability associated with the use of multiple laboratories should be avoided in programs designed to monitor contaminant trends in the environment. However, in cases where the use of multiple laboratories over time cannot be avoided, measures should be taken to minimize the impact of analytical variability on trends analyses.

Participants discussed the use of check samples to detect variation due to the development of new methods and account for variability due to changes in laboratories. Check samples along with quality control criteria can be used as performance criteria for contract laboratories. Two types of quality assurance/quality control (QA/QC) approaches were discussed: methods-

based and performance-based. Method-based contracts prescribe exact methodologies. Performance-based contracts require the contract laboratory to analyze reference materials or check samples and obtain results within specified levels of accuracy and precision.

Participants discussed the importance of requiring contract laboratories to analyze appropriate certified reference materials. Also, contract laboratories should be asked to provide laboratory certification, identify QA/QC procedures and describe their participation in any laboratory comparison studies.
Participants also discussed the development of analytical standards using radioactive carbon isotopes. The USGS developed a fish tissue standard by allowing 4,4'-DDE marked with Carbon-14 to bioaccumulate in laboratory fish. The known concentration of marked 4,4'-DDE in the fish tissue standard was determined by counting Carbon14 isotopes. The known concentration could be compared to concentrations estimated using standard analytical techniques. Workshop participants agreed that having a regional source of this type of check sample would be beneficial to agencies conducting fish contaminant monitoring programs.

E. Review and Discussion/Wrap-up

Due to time constraints, there was minimal discussion following the recommendations. Day asked participants to send him additional protocols/recommendations for the Michigan FCMP. Lawson thanked everyone for attending and welcomed additional comments on the proceedings document resulting from the workshop. Smith thanked participants for comments on the Exponent report.

References

References cited in introduction

Bjerkeng, B., N. Green, and K. Hylland. 1998. Sorfjorden, western Norway: A case for testing alternative monitoring strategies using accumulation in and effects on Atlantic cod (*Gadus morhua*). International Council for the Exploration of the Sea, ASC 1998 CM 1998/P2. Copenhagen, Denmark.

Exponent. 2003. Fish Contaminant Monitoring Program: Review and Recommendations. 1:1-5.

IJC. 2002. The eleventh biennial report. Great Lakes Water Quality. The Challenge to Restore and Protect the Largest Body of Fresh Water in the World. The International Joint Commission, Windsor, Ont. September 2002.

Lamon, E.C., S.R. Carpenter, and C.A. Stow. 1999. Rates of decrease of PCB concentrations in five species of Lake Michigan fish. Can. J. Fish. Aquat. Sci. 56:53-59.

Offenberg, J.H., and J.E. Baker. 2000. PCBs and PAHs in southern Lake Michigan in 1994 and 1995. Urban atmospheric influence and long term declines. J. Great Lakes Res. 26: 196–207.

Simcik, M., R.M. Hoff, W.M.J. Strachan, C.W. Sweet, F. Basu, and R.A. Hites. 2000. Temporal trends of semivolatile organic contaminants in Great Lakes precipitation. Environ. Sci. Technol. 34: 361–367.

Smith, D.W. 2000. Analysis of rates of decline of PCBs in different Lake Superior media. J. Great Lakes Res. 26:152-163.

Uthe, J.F., C.L. Chou, R.K. Misra, P.A. Yeats, D.H. Loring, C.J. Musial, and W. Cofino. 1991. Temporal trend monitoring: Introduction to the study of contaminant levels in marine biota. Report No. 14. ICES Techniques in Marine Environmental Sciences Series. International Council for the Exploration of the Sea, Copenhagen, Denmark.

References cited in recommendations

Borgmann, U., and M. Whittle. 1991a. Bioenergetics and PCB, DDE, and mercury dynamics in Lake Ontario lake trout (*Salvelinus namaycush*): A model based on surveillance data. Can. J. Fish. Aquat. Sci. 49:1086-1096.

Borgmann, U., and M. Whittle. 1991b. Contaminant concentration trends in Lake Ontario lake trout (*Salvelinus namaycush*); 1977 to 1988. J. Great Lakes Res. 17:368-381.

Campfens, J., and D. Mackay. 1997. Fugacity-based model of PCB bioaccumulation in complex aquatic food webs. Environ. Sci. Technol. 31:577-583.

DeVault, D.E., W.A. Willford, R. Hesselberg, D.A. Nortrup, E.G.S. Rundberg, A.K. Alwan, and C. Bautista. 1986. Contaminant trends in lake trout from the upper Great Lakes. Arch. Environ. Contam. Toxicol. 15:349-356.

Eby, L.A., C.A. Stow, R.J. Hesselberg, and J.F. Kitchell. 1997. Modeling changes in growth and diet on polychlorinated biphenyl bioaccumulation in *Coregonus hoyi*. Ecol. Appl. 7:981-990.

Endicott, D.D., W.L. Richardson, and D.J. Kandt. 1992a. MICHTOX: A mass balance and bioaccumulation model for toxic chemicals in Lake Michigan. U.S. EPA Large Lakes Research Station, Grosse Ile, MI.

Glassmeyer, S.T., T.R. Myers, D.S. DeVault, and R.A. Hites. 1997. Toxaphene in Great Lakes fish: A temporal, spatial, and trophic study. Environ. Sci. Technol. 31:84-88.

Gobas, F.P.C., M.N. Z'graggen, and X. Zhang. 1995. Time response of Lake Ontario ecosystem to virtual elimination of PCBs. Environ. Sci. Technol. 29:2038-2048.

HELCOM. 2002. Manual for marine monitoring in the COMBINE programme of HELCOM. PART D. Programme for monitoring of contaminants and the effects of contaminants. Sampling manual for the Helsinki Commission sampling of the Baltic Sea.
(The link provided was broken and has been removed.)

Huestis, S.Y., M.R. Servos, D.M. Whittle, and D.G. Dixon. 1996. Temporal and age-related concentration trends for polychlorinated biphenyl congeners and organochlorine contaminants in Lake Ontario lake trout (*Salvelinus namaycush*). J. Great Lakes Res. 22:310-330.

Madenjian, C.P., G.E. Noguchi, R.C. Hass, and K.S. Schrouder. 1998b. Sexual differences in polychlorinated biphenyl accumulation rates of walleye (*Stizostedion vitreum*). Can. J. Fish. Aquat. Sci. 55:1085-1092.

Madenjian, C.P., T.J. Desorcie, R.M. Stedman, E.H. Brown, Jr., G.W. Eck, L.J. Schmidt, R.J. Hesselberg, S.M. Chernyak, and D.R. Passino-Reader. 1999. Spatial patterns in PCB concentrations of Lake Michigan lake trout. J. Great Lakes Res. 25:149-159.

Offenberg, J.H., and J.E. Baker. 2000. PCBs and PAHs in southern Lake Michigan in 1994 and 1995. Urban atmospheric influence and long term declines. J. Great Lakes Res. 26: 196–207.

Rasmussen, J.B., D.J. Rowan, D.R.S. Lean, and J.H. Carey. 1990. Food chain structure in Ontario lakes determine PCB levels in lake trout and other pelagic fish. Can. J. Fish Aquat. Sci. 47:2030-2038.

Rowan, D.J., and J.B. Rasmussen. 1992. Why don't Great Lakes fish reflect environmental concentrations of organic contaminants? An analysis of between-lake variability in the ecological partitioning of PCBs and DDT. J. Great Lakes Res. 18:724-741.

Simcik, M., R.M. Hoff, W.M.J. Strachan, C.W. Sweet, F. Basu, and R.A. Hites. 2000. Temporal trends of semivolatile organic contaminants in Great Lakes precipitation. Environ. Sci. Technol. 34: 361–367.

Smith, D.W. 1995a. Current and near future trends of PCBs in the Great Lakes. Report prepared for the PCB panel of the Chemical Manufacturers Association, Washington, D.C.

Smith, D.W. 1995b. Are PCBs in the Great Lakes reaching a new equilibrium? Environ. Sci. Technol. 29:42A-46A.

Smith, D.W. 1995c. Synchronous response of hydrophobic chemicals in Great Lakes herring gull eggs. Environ. Sci. Technol. 29:740-750.

Smith, D.W. 2000. Analysis of rates of decline of PCBs in different Lake Superior media. J. Great Lakes Res. 26:152-163.

Stow, C.A., and S.R. Carpenter. 1994a. PCB accumulation in Lake Michigan coho and chinook salmon: Individual based models using allometric relationships. Environ. Sci. Technol. 28:1534-1539.

Stow, C.A., S.R. Carpenter, L.A. Eby, J.F. Amrhein, and R.J. Hesselberg. 1995. Evidence that PCBs are approaching stable concentrations in Lake Michigan fishes. Ecol. Appl. 5:248-260.

Ward, S.M., and R.M. Neumann. 1999. Seasonal variation in concentrations of mercury in axial muscle tissue of largemouth bass. N. Am. J. Fish. Manage. 19:89-96.

Whittle, D.M., R.M. Kiriluk, A.A. Carswell, M.J. Keir, and D.C. MacEachen. 2000. Toxaphene congeners in the Canadian Great Lakes basin: Temporal and spatial food web dynamics. Chemosphere 40:1221-1226.

Williams, L.L., J.P. Giesy, N. DeGalan, D. Verbrugge, D.E. Tillitt, and G.T. Ankley. 1989. Size and seasonal variations of PCBs in Chinook salmon fillets from Lake Michigan near Ludington, Michigan. Michigan Sea Grant College Program MICHU-SG-89-202.

Appendix A

Workshop Participants and Affiliations

Michigan Fish Contaminant Trend Monitoring Strategy
Peer Review Workshop

List of Participants and Affiliations

Jim Breck, Michigan Department of Natural Resources – Fisheries Division
Bob Day, Michigan Department of Environmental Quality
Dave DeVault, U.S. Fish and Wildlife Service
Matt Doss, Great Lakes Commission
Melanie Edwards, Exponent
Cory Groetsch, Great Lakes Indian and Wildlife Commission
Dan Hayes, Michigan State University, Department of Fisheries and Wildlife
Sandy Hellman, U.S. EPA – Great Lakes National Program Office
John Hummer, Great Lakes Commission
Gary Kohlhepp, Michigan Department of Environmental Quality
Ric Lawson, Great Lakes Commission
Chuck Madenjian, U.S. Geological Survey
Pat McCann, Minnesota Department of Health
Pete Redmon, U.S. EPA Region 5 – Water Division
Chris Schmitt, U.S. Geological Survey
Candy Schrank, Wisconsin Department of Natural Resources
Dan Smith, Conestoga-Rovers & Associates
Mike Whittle, Canada Department of Fisheries and Oceans

Appendix B

Workshop Agenda

Michigan Fish Contaminant Trend Monitoring Strategy
Peer Review Workshop

April 29-30, 2003
Best Western Gateway International Hotel
Romulus, MI
734-728-2800

AGENDA

Tuesday, April 29

11:45 a.m.	**Lunch** • Pre-workshop luncheon provided at hotel	
1:00 p.m.	**Welcome and Introductions** • Purpose of workshop and individual introductions	Bob Day, Michigan Department of Environmental Quality
1:15 p.m.	**Review content of Strategy** • Presentation on findings and recommendations in strategy	Dan Smith, Exponent
1:45 p.m.	**Group discussion of Strategy Recommendations** • Discussion of ground rules	Discussion facilitated by Ric Lawson, Great Lakes Commission
1:50 p.m.	**Recommendation** • *4.14 Goals and Hypotheses*	
2:30 p.m.	**Break**	
2:45 p.m.	**Recommendations dealing primarily with exogenous factors:** • *4.1 Random vs. fixed station* • *4.15 Fish movement* • *4.9 Seasonal effects* • *4.11 Food Chain Effects* • *4.8 Water chemistry* • *4.10 Surficial sediments/Multi-media* • *4.5 YOY monitoring*	
5:00 p.m.	**Adjourn**	
6:00 p.m.	**Reconvene for dinner provided at local restaurant**	

Wednesday, April 30

8:00 a.m.	**Continental breakfast**	
8:30 a.m.	**Review results of Day 1 and renew charge**	Ric Lawson, Bob Day
8:45 a.m.	**Recommendations dealing primarily with endogenous factors:** • *4.6 Lipids* • *4.7 Fish age* • *4.12 Tissue types* • *4.4 Gender* • *4.3 Size*	
10:15 a.m.	**Break**	
10:30 a.m.	**Other Recommendations:** • 4.13 Archive • 4.17 Quality Assurance	
11:00 a.m.	**Review and Discussion**	
11:30 a.m.	**Wrap-up**	Matt Doss, GLC; Bob Day
12:00 Noon	**Adjourn**	