Great Lakes Fish Eaters Project:

Analysis of Data on Individuals Eating at Least Twenty-six Great Lakes Fish Meals per Year

By

Christopher S. Sigouin

A Project
Submitted to the School of Graduate Studies
in Partial Fulfillment of the Requirements
for the Degree
Master of Science

McMaster University

MASTER OF SCIENCE (1999) McMaster University
(Statistics) Hamilton, Ontario

TITLE: Great Lakes Fish Eaters Project: Analysis of Data on Individuals Eating at Least Twenty-six Great Lakes Fish Meals per Year

AUTHOR: Christopher S. Sigouin

SUPERVISOR: Dr. P. D. M. Macdonald

NUMBER OF PAGES: v, 56

Abstract

The Great Lakes Fish Eaters Project (Eaters Project) was funded by Health Canada to identify individuals consuming large amounts of Great Lakes fish ($\geq$ 26 meals over the past 1 year period) and to document relevant contaminant information to describe the potential health risks and benefits associated with the consumption of fish from the Great Lakes. Data were analyzed on 91 participants in the Eaters Project.

The Great Lakes are home to a wide variety of fish. In this study alone, the participants have collectively eaten over 35 different species of Great Lakes fish.

The participants of this study were asked for their opinions on the environment and their health. In addition, blood work was completed on 89 participants. The laboratory results were collected on different contaminants. Seven contaminants were considered for modeling purposes since the laboratory value was above a pre-defined detection limit in greater than 75% of the participants in this study.

These seven contaminants included six Organochlorine Pesticides: p,p'-DDE (100% of the participants above the detection limit), hexachlorobenzene (HCB) (100%), β-hexachlorocyclohexane (β-HCH) (92.1%), mirex (78.7%), oxychlordane (92.1%), transnonachlor (98.9%) and one Polychlorinated Biphenyl Congener, Aroclor 1260 (100%). Organic mercury was also modeled since it contributed on average 77.2% to a maximum of 97.5% of the total mercury value.

A 2-stage modeling approach on linear and categorical variables was done as a hypothesis building exercise. Each contaminant was age-adjusted at the start of this modeling exercise. The age-adjusted contaminant was then used as the response variable in the second stage of the modeling of each specific contaminant.

The gender (male and female) and country of birth (Canada/Europe/US and Asian) variables were confounded with each other. The model was be stratified on country of birth or on gender if one of the variables were found to be the only significant variable left in the full model.

Not all the contaminants that were modeled had significant results. That is, there were levels of certain contaminants that the modeling approach could not explain.

The country of birth (Canada/Europe/US and Asian) variable was important in the modeling of some of the contaminants. This suggested stratifying by the two country-of-birth groups.

Acknowledgements

I would like to thank Peter Macdonald, D.Phil. (Co-ordinator, Graduate Program in Statistics), my supervisor, for his support, time and valuable comments on this project. He was pivotal in the admissions process that allowed the opportunity to further my education at McMaster University.

I am also grateful to Donald Cole, M.D., M.Sc., who I worked closely along side with on this project. Our many informal meetings, the ceaseless e-mail exchanges of thoughts and ideas and his helpful consulting advice provided an excellent opportunity to groom my skills as a consultant. In addition, Fran Scott, M.D., M.Sc., continuously explained this project from the participant point of view and gave me countless reasons why this was an important study.

I would also like to thank Charles Goldsmith, Ph.D., and Andrew Willan, Ph.D., for their friendly and candid statistical advice.

Most importantly, I would like to thank Teri, my fiancée, for her patience, understanding and unconditional love. Her comforting support and reassuring nature helped me achieve a balanced mix of education and fun. She continuously cheered me on.

Last but not least, I would like to thank my parents, for the continuous support and their relentless inquires about my M.Sc. program date of completion.

Chapter 1

Introduction

1.1 Background

The Fish and Wildlife Nutrition Project (FWNP) team along with Jill Kearney of Health Canada developed the Great Lakes Fish Eaters Project (Eaters Project). The Eaters Project was funded by Health Canada to identify individuals consuming large amounts of Great Lakes fish ($\geq$ 26 meals over the past 1 year period) and to document relevant contaminant information to describe the potential health risks and benefits associated with the consumption of fish from the Great Lakes. Data were analyzed on 91 participants in the Eaters Project.

The FWNP team is a multi-disciplinary group of researchers and staff affiliated with McMaster University and the University of Guelph that worked alongside Health Canada staff in surveys of anglers in Ontario.

My active participation in the Eaters Project started on August 25, 1998. Dr. Cole (FWNP), Dr. Scott (FWNP) and Dr. Macdonald supervised this Master's Project. A draft of the final report, which included the results of the analyses described here, was delivered at the end of December 1998 to Health Canada. The final report on this study was delivered in March 1999.

1.2 Study Design/Population

The Eaters Project used a combined qualitative/quantitative design. The design was essentially retrospective for fish and wildlife consumption, and cross-sectional for contaminant levels and biological measures of nutritional status measured once during the period. Multiple methods were used to explore the context for health risk and benefits. These included interviews with household members, informal observations and formal dialogue based on pre-conceived questions.

A minimum of twenty-six meals per year of Great Lakes fish and an age of 14 years or older were inclusion criteria for participation in the Eaters Project. Individuals that could not provide data in English, Cantonese, Mandarin or Vietnamese language were excluded from the study. This was done to save time and money involved with hiring and training research assistants and with the translation and interpretation of the data collected for the Eaters Project. Individuals that had a current bleeding disorder (e.g. hemophilia), or were currently taking anti-coagulants (e.g. coumadin), or had previously fainted or had seizures when having blood taken were excluded from the study.

The Eaters Project participants were recruited from Chinese and Vietnamese focus groups, community contacts and community recruitment drives. In addition, the participants and their spouses from the previous Shore Survey (1995-1997) [FWNP, 1996] were recruited. The Shore Surveys recruited 51 (44.0%) participants and the community recruitment drive recruited 40 (56.0%) participants in the Eaters Project.

The participants of the Eaters Project was based on a establish priority criteria with females enrolled in preference to males, non-anglophone participants in preference to anglophone participants.

1.3 Tasks/Objectives:

The Eaters Project required me to become part of the FWNP team and I was tasked to complete the following:

- Assist in preparing the database for analyses
- Conduct descriptive analyses of demographic, contaminant and health outcome information
- Conduct comparative analyses on team questions with respect to demographic, contaminant and health outcome information
- Act as a statistical consultant to the FWNP team members with respect to statistical modeling and programming
- Provide a critical analysis of the limitations of the data set in considering additional analyses

Preparing the database for analyses required data integrity checks for data inconsistencies and data entry errors. Once the data sets were deemed sufficiently clean, the data analyses were started. As the descriptive and comparative analyses were performed, the results were written up and added to the final report by the FWNP team.

Chapter 2

Data Issues

2.1 Data Storage/Management

The data were collected on case report forms by research assistants and subsequently entered into SPSS for Windows for data storage and manipulation by the data manager. The data for the Eaters Project were stored in SPSS for Windows, Release 6.1.4, data sets created at the University of Guelph.

MDS Laboratories performed the laboratory work and the results were sent to the data manager on case report forms and later entered into a separate SPSS for Windows database.

2.2 Data Quality Control

Before the data integrity checks could be written to ensure data correctness, I had to get acquainted with the data sets. Each variable in each data set had to be mapped back to the appropriate case report form or questionnaire to ensure that each response to a question was in fact being stored in the database. Some variables in the data sets were unnecessary since there was not a question in the case report forms associated with it. Some other variable names were spelled incorrectly and subsequently used in calculations. The calculations that used the correctly spelled variable names instead of the incorrectly spelled variable names produced false results.

There were many data sets but the ones that were of interest held the lab results, the demographic questionnaire, the fish and wildlife information, the health and reproductive history and the risk perception information.

The SPSS data sets were formatted to SAS for Windows, Release 6.12, data sets. In SAS, the data checking was performed on the Demographic Questionnaire and parts of the Health & Reproductive History Questionnaire. For both categorical and continuous variables, a frequency table was generated to look for general data entry errors. In the case of a multiple question, if the first response was "no" the following parts of the question were checked to ensure that no response was given. If the first response was "yes", the following parts of the question were checked for completion. For example, a participant indicated that he/she was born in Canada, the question pertaining to year of immigration must be blank. The participant's gender was checked across the questionnaires for homogeneity.

In SPSS, the lab values that were deemed important by the FWNP were examined by box plots and scatter plots for visible outliers. In addition, the minimum, maximum, range and mean of each of the lab values were checked for possible errors in data entry.

All problems that were found required the data manager to inspect the original case report forms before the necessary corrections were made.

Due to a flaw in the database creation, the names of species of the Great Lakes fish and the location of where the Great Lakes fish were caught were re-entered for the 91 participants of the

Eaters Project at the beginning of September 1998 by the data manager. This task took seven days to complete.

Chapter 3

Demographic Questionnaire

3.1 Results

Because of the recruitment methods used, only 36 of the 91 (39.6%) Eaters Project participants were born in Canada. Thirty-eight (41.7%) of the participants were born in Vietnam. The country of births for all of the participants listed in Table 3.1. Based on the country of birth, the 91 participants were grouped into 4 ethnicities (Table 3.2).

Table 3.1

Country of Birth	Frequency	Percent
Vietnam	38	41.7
Canada	36	39.6
China	2	2.2
Hong Kong	2	2.2
Portugal	2	2.2
England	1	1.1
Germany	1	1.1
Hungary	1	1.1
Italy	1	1.1
Malta	1	1.1
Philippines	1	1.1
Poland	1	1.1
Romania	1	1.1
Taiwan	1	1.1
Yugoslavia	1	1.1
United States	1	1.1
Total Participants	91	100.0

Table 3.2

Ethnicity	Frequency	Percent
North American: (Canada, United States)	37	40.7
Asian: (Vietnam, China, Hong Kong, Philippines, Taiwan)	44	48.3
Eastern European: (Hungary, Poland, Romania, Yugoslavia)	4	4.4
Western European: (Portugal, England, Germany, Italy, Malta)	6	6.6
Total Participants	91	100.0

The 55 non-Canadian-born participants had immigrated to Canada from 1952 to 1996. Of the 55 non-Canadian-born participants, 33 (60.0%) had immigrated to Canada since 1990.

Forty-seven (51.6%) of the participants were male and 44 (48.4%) were female. The mean age (and range) of the 91 participants was 37 years (17 – 74 years). The mean body mass index (and range) of the 90 participants was 25.6 kg/m^2 (17.1 – 38.5 kg/m^2).

The highest level of education completed ranged from some primary school to graduate studies (Table 3.3). Fifty-five (60.4%) of the participants had at least completed high school.

Table 3.3

Highest level of education completed	Frequency	Percent
Some primary	6	6.6
Completed primary	3	3.3
Some high school	26	28.5
Completed high school	29	31.9
Some college	12	13.2
Completed college	7	7.7
Some university	2	2.2
Bachelors degree	3	3.3
Professional degree	1	1.1
Graduate degree	1	1.1
Not reported	1	1.1
Total Participants	91	100.0

The main activity for 44 (48.3%) of the participants was working, followed by keeping house for 21 (23.1%) of the participants (Table 3.4).

Table 3.4

Main activity during the last 12 months	Frequency	Percent
Working	44	48.3
Looking for work	5	5.5
Going to school	11	12.1
Keeping house	21	23.1
Retired	5	5.5
Compensation/Disability	4	4.4
Not reported	1	1.1
Total Participants	91	100.0

The only data collected on marital status was a yes/no answer to the question, 'Are you currently living with a spouse, partner or in a common-law relationship? If yes, when did you start living together?'. A specific relationship question to determine the number of participants that were married, single, widowed, divorced/separated or in a common-law relationship would have given a better description of marital status. This extra information would have given a better description of the people that lived in the same dwelling as the participant.

Fifty-seven (64.8%) of the participants were living with a spouse or partner and the household size ranged from 2 to 7 people (Table 3.5, 'yes' section). The total household income ranged from $5,000 to $80,000 with a median of $24,000; 4 participants did not respond to the question. The monthly household food expense ranged from $150 to $1,200 with a median of $500; 1 participant did not respond to the question.

The household size ranged from 1 to 9 people for the 32 (35.2%) participants that were not living with a spouse or partner (Table 3.5, 'no' section). The total household income ranged from $9,999 to $100,000 with a median of $23,500; 10 participants did not respond to the question. The monthly household food expense ranged from $50 to $1,000 with a median of $270; 6 participants did not respond to the question.

Table 3.5

Living with spouse, partner or in common-law	Number of people in household	Frequency	Percent
Yes	2	9	9.9
	3	13	14.2
	4	21	23.1
	5	9	9.9
	6	4	4.4
	7	1	1.1
No	1	10	11.0
	2	4	4.4
	3	6	6.6
	4	9	9.9
	5	1	1.1
	8	1	1.1
	9	1	1.1
Not reported		2	2.2
Total Participants		91	100.0

If the participants were living with a spouse or partner, the interviewer asked for a response from them for most of the same demographic questions. This study could have saved time and money by not asking these additional questions of the spouse or partner and instead concentrating more on the actual participant.

Chapter 4

Risk Perception Questionnaire

4.1 Results

The participants were asked for their opinion on the environment and their health. The participants were required to rate 8 statements (Statements 1-8, Tables 4.1-4.8) on an ordinal scale from 1 to 5, where 1 is 'strongly agree', 2 is 'agree', 3 is 'neither agree nor disagree', 4 is 'disagree' and 5 is 'strongly disagree'. This questionnaire did allow a 'don't know' response.

The participants were divided into two groups based on their country of birth. One group consisted of the countries, Canada, Europe and the United States; the other group consisted of only the Asian countries. One participant, in the Asian group, did not respond to any of the risk perception questions. Therefore, there were 47 and 43 participants in the Canada/Europe/US and Asian groups, respectively.

The 'don't know' response was assumed equivalent to the 'neither agree nor disagree' response and therefore combined (Tables 4.1-4.8). The 2-tailed Fisher's Exact test was used to calculate p-values on the 5x2 tables. The null hypothesis tests the assumption that there are no differences in the participant's response to the statements between the two groups (Canada/Europe/US and Asian). P-values less than 0.05 were considered significant.

The distribution of the five responses to statements 1-2 and 4-7 were statistically different between the two groups at the 0.05 level. In addition, the Asian group had more 'don't know' responses for every question than the Canada/Europe/US group.

The combined percentage of the participants checking the 'agree', 'neither agree nor disagree' and 'disagree' responses, excluding the 'don't know' response, revealed a difference in the way the two groups answered the statements 1-8. For the eight statements, the Canada/Europe/US group had a combined response average of 80.1%, and the Asian group had a combined response average of 69.5%. A non-parametric Wilcoxon rank-sum test was used to determine if the ranking of the combined response percentages for the eight statements differed significantly by group. An exact 2-tailed p-value for this test was 0.0460. This significant difference by group can be attributed to the tendency for the Asian group to respond more often to 'don't know' which left a lower combined response percentage to the eight statements.

For the eight statements, the percentages of 'don't know' responses were statistically different for the two groups. The Canada/Europe/US group had an average 'don't know' response of 1.9% and the Asian group had an average 'don't know' response of 17.4%. A non-parametric Wilcoxon rank-sum test revealed an exact 2-tailed p-value <0.005 by group.

For the eight statements, there was no significant difference by group found when the 'don't know' response was included in the combined percentage of the participants checking the 'agree', 'neither agree nor disagree' and 'disagree' responses.

Figures (4.1.-4.10) were developed using SPLUS 4.0, Release 2 for Windows.

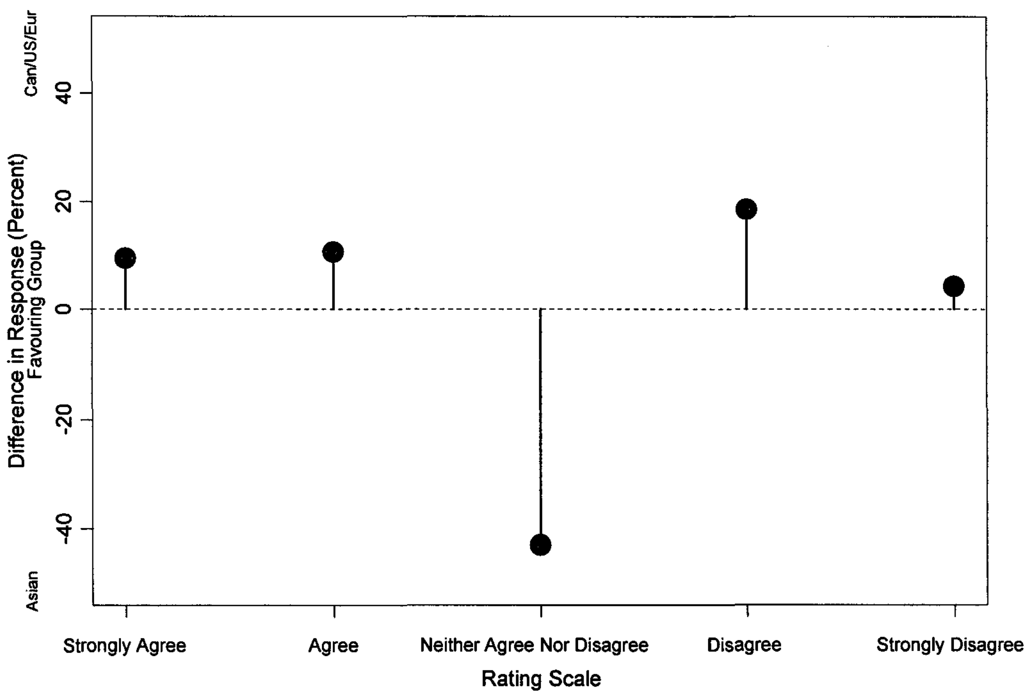
The first three statements concentrated on the Great Lakes region in general (Statements 1-3, Tables 4.1-4.3).

1. The Great Lakes are more contaminated than lakes and rivers "up North".

Table 4.1
P-value: <0.005

	Country of birth			
	Canada/Europe/ United States (n=47)		Asian (n=43)	
Rating	Frequency	Percent	Frequency	Percent
Strongly agree	11	23.4	6	13.9
Agree	17	36.2	11	25.6
Neither agree nor disagree + don't know	3 + 2	10.6	13 + 10	53.5
Disagree	12	25.5	3	7.0
Strongly disagree	2	4.3	0	0

Figure 4.1
Country of birth difference in response (percent) to the ratings:

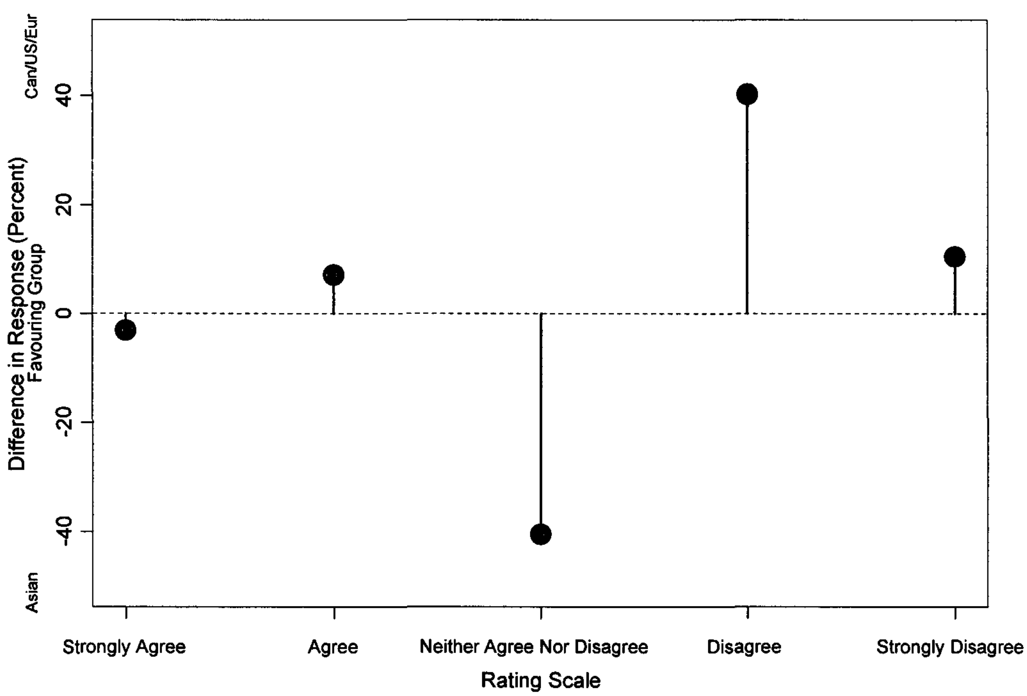


2. The water in the Great Lakes is more contaminated now than 10 years ago.

Table 4.2
P-value: <0.005

	Country of birth			
	Canada/Europe/ United States (n=47)		Asian (n=43)	
Rating	Frequency	Percent	Frequency	Percent
Strongly agree	4	8.5	5	11.6
Agree	12	25.5	14	32.6
Neither agree nor disagree + don't know	3 + 2	10.6	7 + 15	51.2
Disagree	20	42.6	1	2.3
Strongly disagree	6	12.8	1	2.3

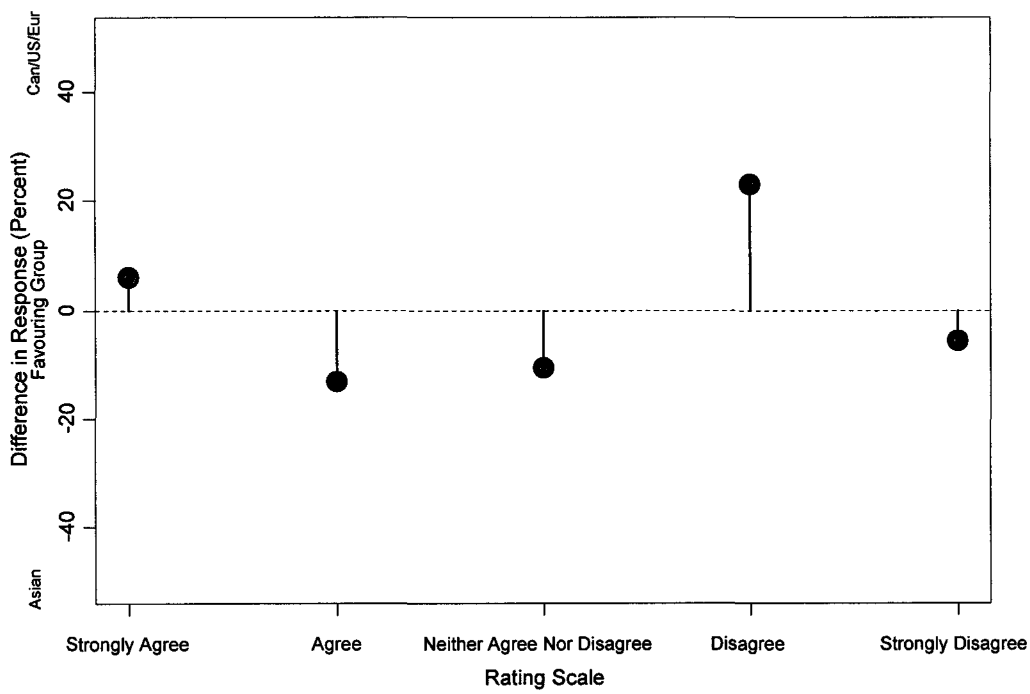
Figure 4.2
Country of birth difference in response (percent) to the ratings:



3. People living beside the Great Lakes have greater risks of health problems.

Table 4.3 P-value: 0.109	Country of birth			
	Canada/Europe/ United States (n=47)		Asian (n=43)	
Rating	Frequency	Percent	Frequency	Percent
Strongly agree	5	10.6	2	4.7
Agree	7	14.9	12	27.9
Neither agree nor disagree + don't know	6 + 0	12.8	5 + 5	23.3
Disagree	25	53.2	13	30.2
Strongly disagree	4	8.5	6	13.9

Figure 4.3
Country of birth difference in response (percent) to the ratings:



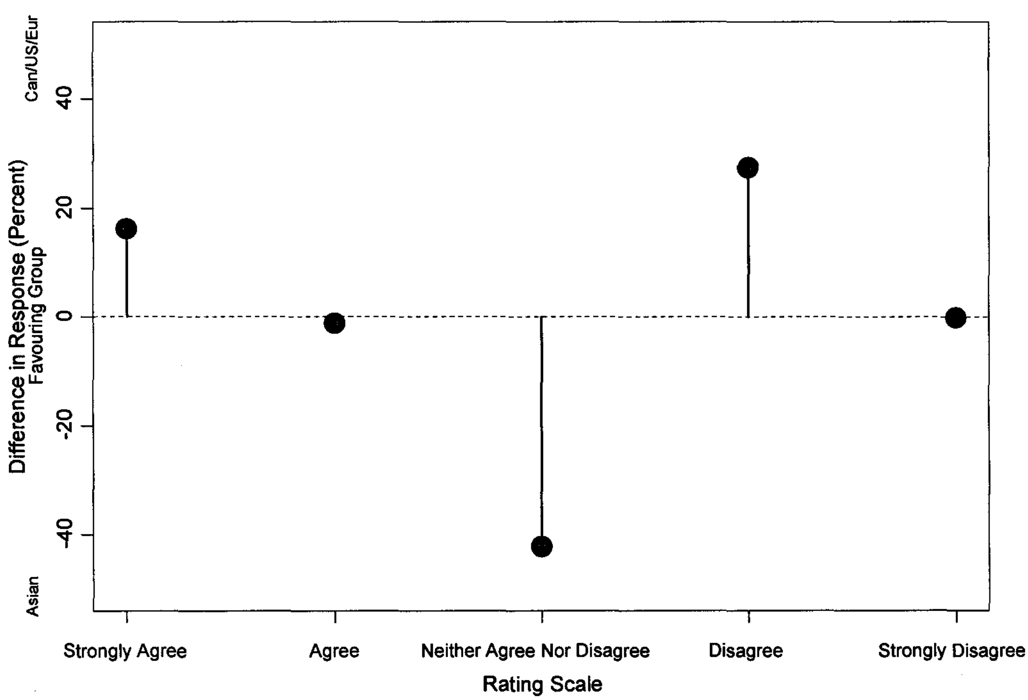
The next five statements asked the participants to think about the people who were fishing the Great Lakes and the fish they had caught and had eaten (Statements 4-8, Tables 4.4-4.8).

4. Fish caught 'up North' are safer to eat than fish caught from the Great Lakes.

Table 4.4
P-value: <0.005

	Country of birth			
	Canada/Europe/ United States (n=47)		Asian (n=43)	
Rating	Frequency	Percent	Frequency	Percent
Strongly agree	12	25.5	4	9.3
Agree	18	38.3	17	39.5
Neither agree nor disagree + don't know	2 + 0	4.3	10 + 10	46.5
Disagree	14	29.8	1	2.3
Strongly disagree	1	2.1	1	2.3

Figure 4.4
Country of birth difference in response (percent) to the ratings:

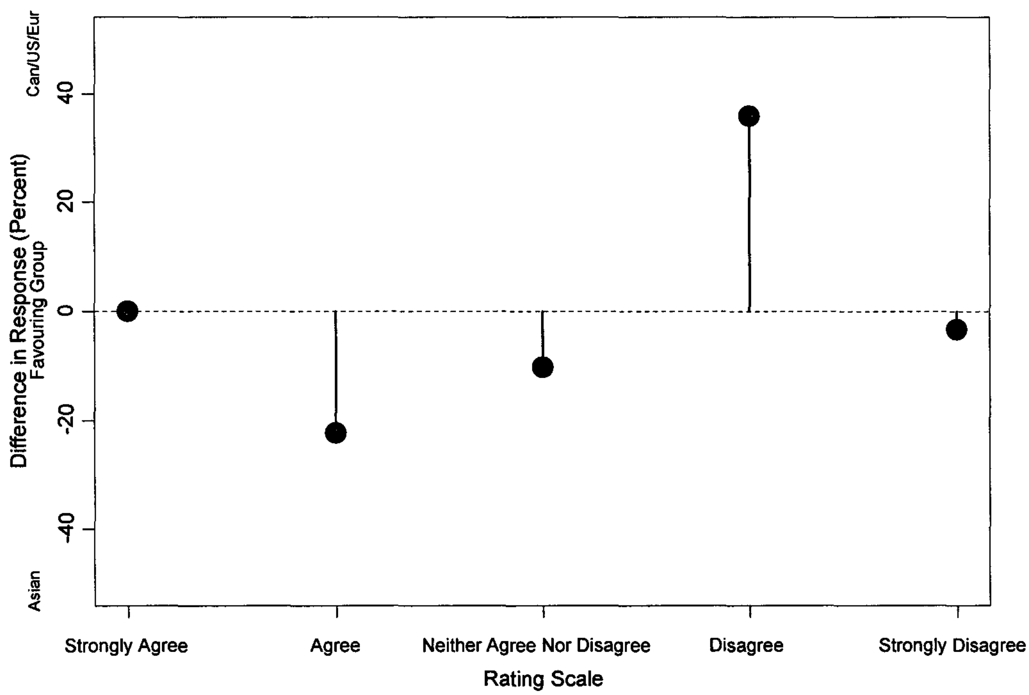


5. Fish bought at the store are safer to eat than fish from the Great Lakes.

Table 4.5
P-value: 0.0056

Rating	Country of birth: Canada/Europe/ United States (n=47) Frequency	Percent	Asian (n=43) Frequency	Percent
Strongly agree	0	0	0	0
Agree	7	14.9	16	37.2
Neither agree nor disagree + don't know	5 + 0	10.6	7 + 2	20.9
Disagree	30	63.8	12	27.9
Strongly disagree	5	10.6	6	13.9

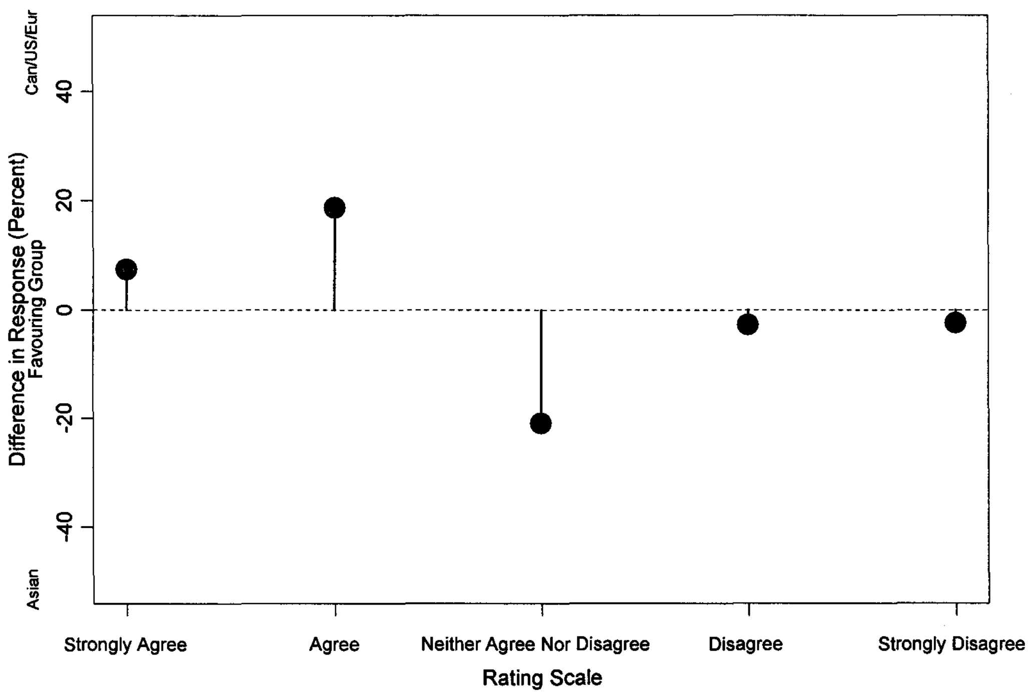
Figure 4.5
Country of birth difference in response (percent) to the ratings:



6. Some fish bought at a market may be from the Great Lakes.

Table 4.6 P-value: <0.005	Country of birth			
	Canada/Europe/ United States (n=47)		Asian (n=43)	
Rating	Frequency	Percent	Frequency	Percent
Strongly agree	10	21.3	6	13.9
Agree	35	74.5	24	55.8
Neither agree nor disagree + don't know	0 + 0	0	6 + 3	20.9
Disagree	2	4.3	3	7.0
Strongly disagree	0	0	1	2.3

Figure 4.6
Country of birth difference in response (percent) to the ratings:

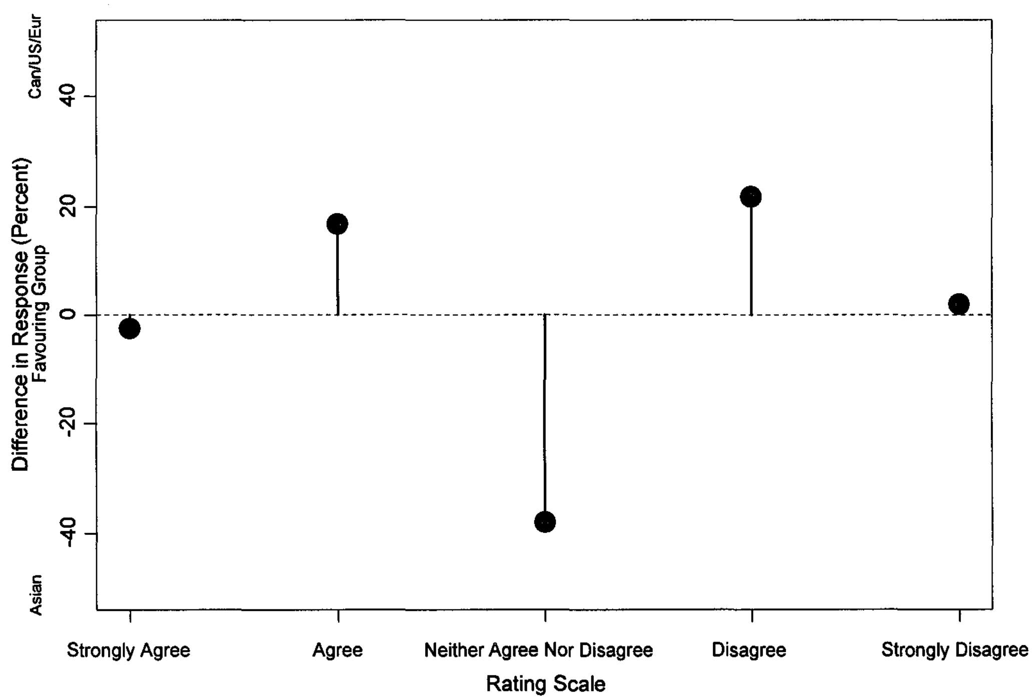


7. People who eat contaminated Great Lakes fish might develop short-term health problems.

Table 4.7
P-value: <0.005

Rating	Country of birth			
	Canada/Europe/ United States (n=47)		Asian (n=43)	
	Frequency	Percent	Frequency	Percent
Strongly agree	1	2.1	2	4.7
Agree	21	44.7	12	27.9
Neither agree nor disagree + don't know	2 + 2	8.5	11 + 9	46.5
Disagree	19	40.4	8	18.6
Strongly disagree	2	4.3	1	2.3

Figure 4.7
Country of birth difference in response (percent) to the ratings:

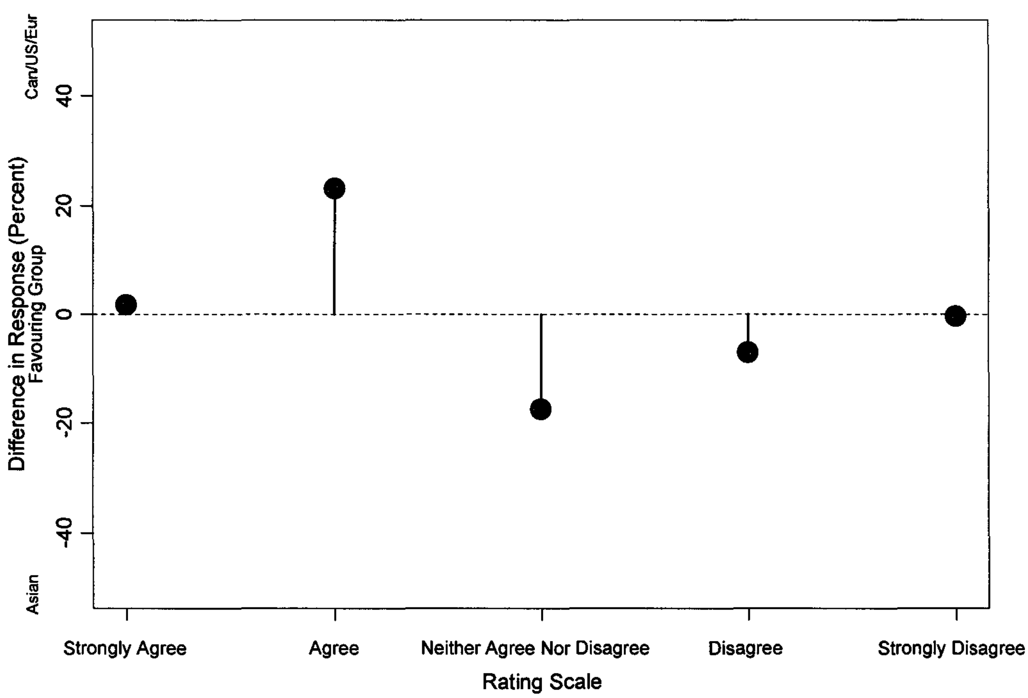


8. People can offset health problems they might get from eating Great Lakes fish by improving their lifestyle, such as exercising and eating properly.

Table 4.8
P-value: 0.129

	Country of birth			
	Canada/Europe/ United States (n=47)		Asian (n=43)	
Rating	Frequency	Percent	Frequency	Percent
Strongly agree	3	6.4	2	4.7
Agree	24	51.1	12	27.9
Neither agree nor disagree + don't know	5 + 1	12.8	7 + 6	30.2
Disagree	12	25.5	14	32.6
Strongly disagree	2	4.3	2	4.7

Figure 4.8
Country of birth difference in response (percent) to the ratings:



The next two statements (Statements 9-10, Tables 4.9-4.10) were rated by the participants on a different ordinal scale from 1 to 5, where 1 is 'very concerned', 2 is 'somewhat concerned', 3 is 'slightly concerned', 4 is 'not at all concerned' and 5 is 'don't know'.

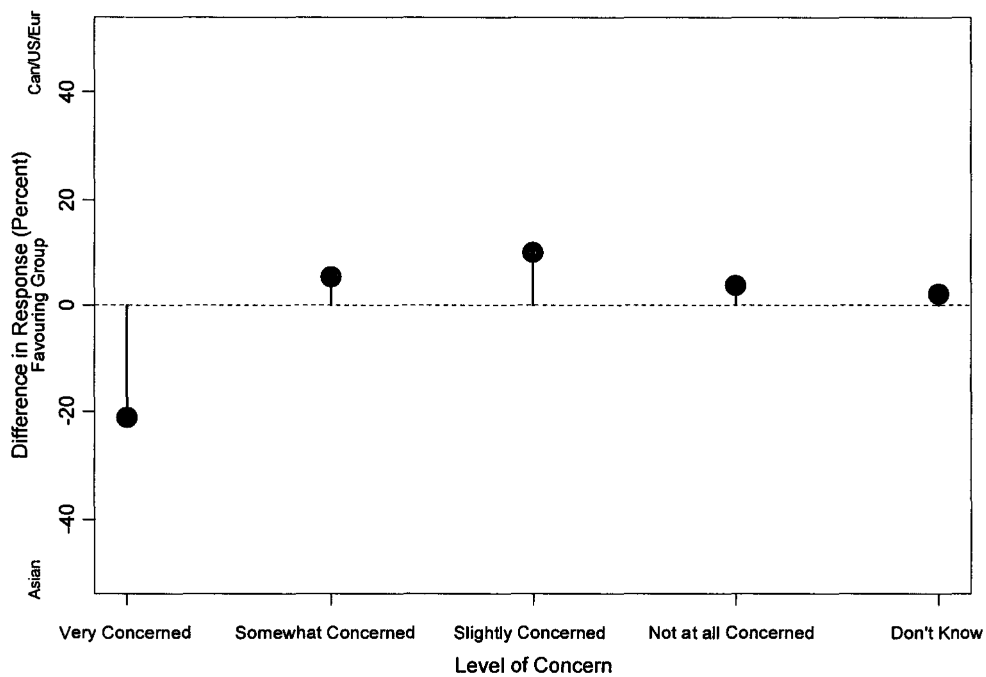
The participants were asked to consider all negative and positive aspects of eating Great Lakes fish when answering the next two statements (Tables 4.9-4.10). The Asian group did not have a 'don't know' response to the last two statements.

The two groups had proportionally inverted views regarding statement 10.

9. How concerned should the general public be about the potential health risks from Great Lakes fish?

Table 4.9 P-value: 0.190	Country of birth			
	Canada/Europe/ United States (n=47)		Asian (n=43)	
Rating	Frequency	Percent	Frequency	Percent
Very concerned	13	27.7	21	48.8
Somewhat concerned	20	42.6	16	37.2
Slightly concerned	8	17.0	3	7.0
Not at all concerned	5	10.6	3	7.0
Don't know	1	2.1	0	0

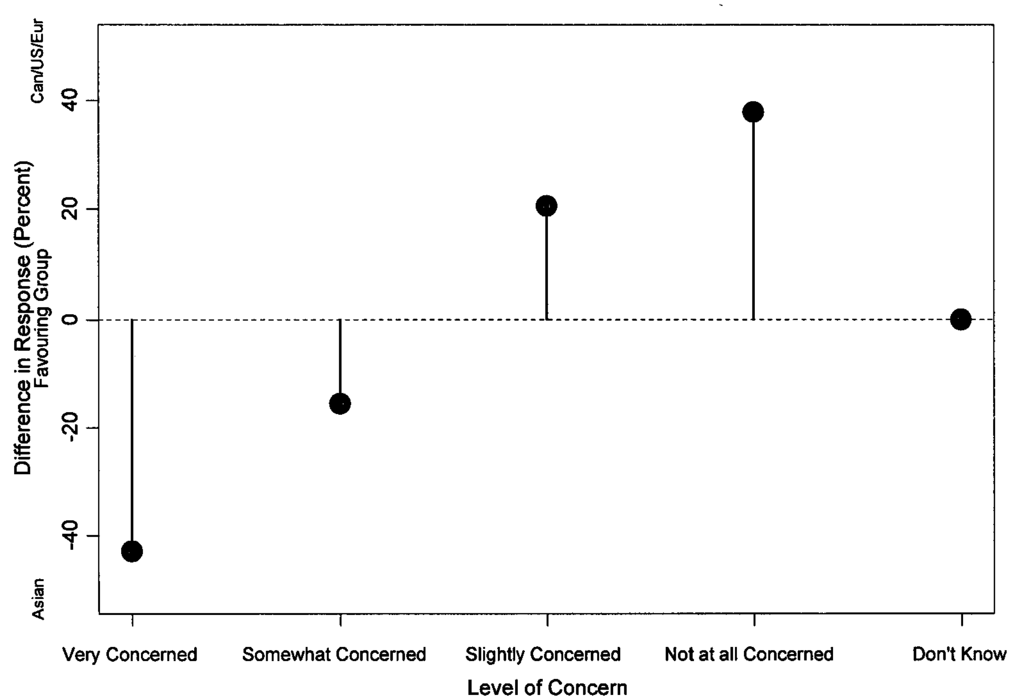
Figure 4.9
Country of birth difference in response (percent) to the levels of concern:



10. How concerned are you personally that eating Great Lakes fish is a potential health risk to you or members of your immediate family?

Table 4.10 P-value: <0.005	Country of birth			
	Canada/Europe/ United States (n=47)		Asian (n=43)	
Rating	Frequency	Percent	Frequency	Percent
Very concerned	5	10.6	23	53.5
Somewhat concerned	8	17.0	14	32.6
Slightly concerned	14	29.8	4	9.3
Not at all concerned	20	42.6	2	4.7
Don't know	0	0	0	0

Figure 4.10
Country of birth difference in response (percent) to the levels of concern:



For most of the 10 statements the Asian and Canada/Europe/US groups had different overall responses. This might reflect the knowledge of the Asian born participants about the Great Lakes and surrounding areas since they have not been living in Canada long enough to form an opinion.

4.2 Alternative Graphical Interpretation

The simplex method offers a different graphical interpretation of Figures 4.1-4.8. The simplex is labeled as "Agree", "Disagree" and "Neither". The "Strongly Agree" and "Agree" responses and the "Strongly Disagree" and "Disagree" responses to the first 8 statements (1-8) have been consolidated to the Agree and Disagree labeled responses, respectively. The simplex figure

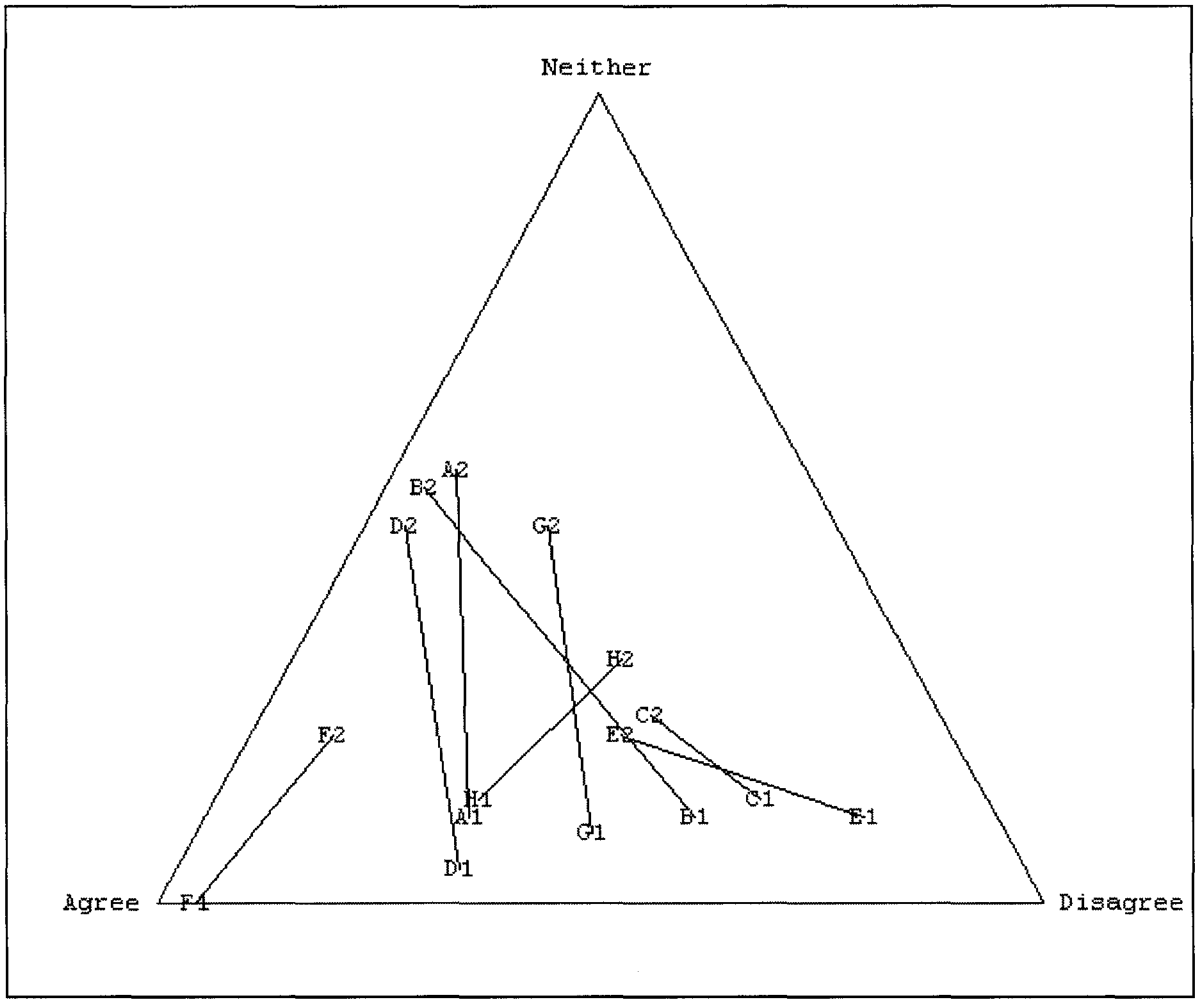
(Figure 4.11) shows how the response to the individual statements differs between the two different country of birth groups. Each statement (1-8) by country of birth (Canada/Europe/US vs Asian) has been mapped into the simplex figure.

The points labeled with "A" represent the responses to statement 1, while points labeled with "B" represent the responses to statement 2, and so forth. The point labels ending in a "1" represent the Canada/Europe/US responses and the point labels ending in a "2" represent the Asian responses for each statement. The lines between the two points for each statement show how much the two groups differ on opinion about that particular statement.

From the simplex figure, statement 2 has the longest distance between the 2 points (B1, B2), implying the lowest amount of agreement between the two groups. Statement 3 has the shortest distance between the two points (C1, C2), implying the highest amount of agreement between the two groups. The simplex figure shows that all the points for the Asians (ending with 2) tend to lie towards the "Neither" end of the triangle explicitly displaying the greater number of neither agree nor disagree responses to statements 1-8.

The three responses to each statement are summarized as the counts of Agree (P_1), Disagree (P_2), and Neither (P_3), where $P_1 + P_2 + P_3 = 1$. Therefore the point lies on a simplex.

Figure 4.11
Simplex



Chapter 5

Contaminants

5.1 Great Lakes Fish

The Great Lakes are home to many different species of fish. In this study alone, the participants have collectively eaten over 35 different species of Great Lakes fish. The fish have been caught throughout the year. The number of Great Lakes fish meals per year eaten by individual participants varies from 26 to 501, with a median of 88. Table 5.1 shows the quantity of the top five fish meals eaten by the participants.

Table 5.1

Species	Quantity
Walleye	1014.4
Yellow Perch	986.4
Rock Bass	779.5
Smallmouth Bass	726
Crappie	660

This study did not collect any information on the actual length of the fish or size of the fish portion eaten. This lack of information creates a problem when modeling the contaminants, since the actual amount of fish available to be eaten varies drastically from species to species.

5.2 Selection for Modeling

Seven of the eight contaminants were considered for modeling purposes since the laboratory value was above a pre-defined detection limit in greater than 75% of the participants in this study.

The levels of the contaminants were first measured in the laboratory on a "wet weight" basis (μg/L). That is, the levels were not adjusted for the percentage of body fat found in the participant at the laboratory. The "lipid weight" contaminant conversion (μg/kg) was completed once the percentage of body fat was known for each participant (Tables 5.2-5.8).

These seven contaminants included six Organochlorine Pesticides; p,p'-DDE (100% of the participants above the detection limit of 0.08 μg/L), hexachlorobenzene (HCB) (100% above 0.02 μg/L), β-hexachlorocyclohexane (β-HCH) (92.1% above 0.02 μg/L), mirex (78.7% above 0.02 μg/L), oxychlordane (92.1% above 0.02 μg/L), transnonachlor (98.9% above 0.02 μg/L) and one Polychlorinated Biphenyl Congener; Aroclor 1260 (100% above 0.02 μg/L). Organic mercury was also modeled since it contributed on average 77.2% to a maximum of 97.5% of the total mercury value.

5.2.1 Organochlorine Pesticides

5.2.1.1 p,p'-DDE

In 1874, DDT was first synthesized and its insecticide properties were discovered in 1939 [U.S. Public Health Service, 1989]. DDT and DDE are stored and slowly released from fatty tissues. It is difficult to determine a correlation between the concentrations of DDT and DDE in fatty tissues and the time of exposure [Van Ert and Sullivan Jr., 1992].

Recent studies have found no direct causal relationship found between DDT and DDE concentrations in blood, fat or other tissues in relation to specific health effects [Van Ert and Sullivan Jr., 1992]. A literature review conducted by the International Agency for Research on Cancer (IARC) on the carcinogenicity risk of DDT and DDE found no convincing evidence for humans [Van Ert and Sullivan Jr., 1992].

5.2.1.2 β-hexachlorocyclohexane (β-HCH) and Hexachlorobenzene (HCB)

According to [Van Ert and Sullivan Jr., 1992], no immunotoxic effects of HCH isomers have been detected in humans, but the neurotoxic effects of HCH include seizures, headaches, dizziness and tremors. HCB is a metabolite of HCH. That is, HCB is one of the products found after the chemical breakdown of HCH.

5.2.1.3 Mirex

Mirex was first used in 1955, to control fire ants in the southern United States [WHO, 1984]. In the environment, Mirex is a stable compound and bioaccumulates up the food chain; therefore, human exposure can occur from food ingestion and contaminated soil [Van Ert and Sullivan Jr., 1992]. There have been no reported cases of human poisoning [Van Ert and Sullivan Jr., 1992].

5.2.1.4 Oxychlordane and Transnonachlor

There was no evidence of related acute and/or subacute hepatic effects found in persons exposed to oxychlordane regardless of their serum concentrations of pesticide residue [Stehr-Green et al., 1988].

Transnonachlor is a major constituent of chlordane. Chlordane was used to control termites and used for homes and gardens as an insecticide. In addition, as a control for soil insects during the growth of crops of corn [Sittig, 1985].

There have been very few renal health effects reported and very little information regarding hepatotoxicity secondary to chlordane exposure [Van Ert and Sullivan Jr., 1992]. In addition, there are currently no studies that suggest immunological effects in humans, no studies that indicate reproductive toxicity in humans, and no evidence that chlordane is a human carcinogen [Van Ert and Sullivan Jr., 1992].

5.2.2 Polychlorinated Biphenyl (PCB) Congener

5.2.2.1 Aroclor 1260

PCBs were first manufactured in 1929 and found use in a variety of applications. The electrical utility industry used PCBs as coolants for capacitors and transformers. They were also used in fluorescent light ballasts, television sets, air conditioners and carbonless copy paper [Durfee, 1975].

The Aroclor group of PCBs were labeled by the percentage of the chlorine weight content. That is, the last two digits of Aroclor 1260 denotes 60% chlorine by weight. The United States Congress, under the Toxic Substances Control Act, banned further manufacturing and limited the distribution of PCBs beyond 1979 [Shields et al., 1992].

PCBs degrade relatively slowly. Once released into the environment, PCBs undergo cycling and transport within the ecosystem, which causes them to bioaccumulate as they move up the food chain [Hoivik and Safe, 1998].

PCBs can account for health effects in humans, although, dermatological effects are the only consistent findings which have clinical relevance [Shields et al., 1992]. A few studies have found an association between PCB exposure and various symptoms but have not been corroborated by other studies.

5.2.3 Organic Mercury

The lungs, gastrointestinal tract and the skin rapidly and completely absorb organic mercury compounds. The absorption of organic mercury even when mixed with food is about 95% in adults [Siegers and Sullivan Jr., 1992].

The toxic effects of organic mercury are on the central nervous system, including the brain [Siegers and Sullivan Jr., 1992]. Fine tremors of the hands and in some cases of the face and arms are apparent in the early stages of chronic poisoning [Sittig, 1985].

Regardless of the chemical form of exposure, mercury readily crosses the placenta into fetal tissue. Fetal intoxication by way of the mother has been documented in cases of methylmercury poisoning [Amin-Zaki et al., 1974]. There have been severe cerebral effects seen in infants born to mothers that had eaten large amounts of methylmercury-contaminated fish [Sittig, 1985].

5.3 Laboratory Measurements of Contaminants Found in the Participants (Lipid Weight)

The following Tables (5.2-5.9) show the descriptive statistics for the eight contaminants that were modeled. "Lipid weight" refers to the level of each contaminant adjusted for the percentage of body fat found in each participant. For the purposes of calculating the mean, geometric mean and standard deviation in Tables 5.2-5.8, the non-detectable values were replaced with a value of half (½) the corresponding laboratory contaminant detection limit.

There are some differences in the contaminants by country of birth and gender. Some of these contaminants have a varied effect on the different genders. Most of these contaminants are excreted through the breast of the female while nursing a newborn baby.

Table 5.2
p,p'-DDE (μg/kg)

Country of Birth	Gender	Descriptive Statistics						
		n	min	max	median	geometric mean	mean	std. dev.
Canada/Europe/ United States	Male	30	55.0	681.7	187.9	192.0	233.8	152.5
	Female	15	102.6	4910.9	220.4	271.5	609.5	1227.4
Asian	Male	13	1123.5	6526.0	1788.3	2079.3	2427.0	1569.1
	Female	27	216.8	11628.6	1593.6	2180.9	3160.9	2771.9

Table 5.3
Hexachlorobenzene (HCB) (μg/kg)

Country of Birth	Gender	Descriptive Statistics						
		n	min	max	median	geometric mean	mean	std. dev.
Canada/Europe/ United States	Male	30	7.9	29.7	17.4	16.4	17.5	6.3
	Female	15	8.9	59.4	16.6	19.4	22.8	14.8
Asian	Male	13	4.9	48.4	17.1	16.9	20.1	12.1
	Female	27	4.2	50.9	10.1	10.2	11.9	9.0

Table 5.4
β-hexachlorocyclohexane (β-HCH) (μg/kg)

Country of Birth	Gender	Descriptive Statistics						
		n	min	max	median	geometric mean	mean	std. dev.
Canada/Europe/ United States	Male	30	2.0	32.7	10.7	9.5	12.0	8.0
	Female	15	1.8	832.9	14.5	14.8	74.6	211.3
Asian	Male	13	9.3	3167.2	90.7	136.1	692.9	1101.0
	Female	27	9.3	700.3	50.6	57.8	94.9	134.5

Table 5.5
Mirex (μg/kg)

Country of Birth	Gender	Descriptive Statistics n	min	max	median	geometric mean	mean	std. dev.
Canada/Europe/ United States	Male	30	1.0	176.2	4.1	6.1	19.7	39.1
	Female	15	1.2	51.6	2.5	3.9	8.5	13.6
Asian	Male	13	1.8	75.4	35.9	22.5	36.3	28.0
	Female	27	1.6	192.4	14.6	13.5	24.0	36.6

Table 5.6
Oxychlordane (μg/kg)

Country of Birth	Gender	Descriptive Statistics n	min	max	median	geometric mean	mean	std. dev.
Canada/Europe/ United States	Male	30	5.4	27.4	12.7	13.1	14.6	6.6
	Female	15	1.8	19.5	10.2	8.2	9.8	5.1
Asian	Male	13	1.8	23.1	8.6	9.0	11.1	6.9
	Female	27	1.8	16.1	6.7	5.3	6.5	4.0

Table 5.7
Transnonachlor (μg/kg)

Country of Birth	Gender	Descriptive Statistics n	min	max	median	geometric mean	mean	std. dev.
Canada/Europe/ United States	Male	30	5.4	68.5	18.5	21.1	25.7	16.7
	Female	15	5.4	28.9	15.7	14.1	15.8	7.2
Asian	Male	13	4.0	98.2	29.3	29.4	38.0	25.9
	Female	27	5.2	84.8	15.1	17.5	21.5	16.3

Table 5.8
Aroclor 1260 (μg/kg)

Country of Birth	Gender	Descriptive Statistics n	min	max	median	geometric mean	mean	std. dev.
Canada/Europe/ United States	Male	30	90.7	2252.2	482.9	470.8	629.5	540.2
	Female	15	170.5	1424.5	390.6	451.8	548.0	370.6
Asian	Male	13	203.5	2303.4	1215.3	922.9	1174.8	734.9
	Female	27	269.4	3208.6	664.0	644.9	780.2	599.9

Table 5.9
Organic Mercury (μg/L)

Country of Birth	Gender	Descriptive Statistics n	min	max	median	geometric mean	mean	std. dev.
Canada/Europe/ United States	Male	30	0.38	4.82	1.41	1.30	1.69	1.31
	Female	15	0.0	6.02	1.81	1.75	1.99	1.51
Asian	Male	14	0.80	23.77	8.53	8.19	10.58	6.49
	Female	27	0.60	19.45	5.62	6.04	7.20	4.21

Chapter 6

Modeling of Contaminants

6.1 Explanatory/Predictor Variables

There were five explanatory variables that targeted the different types of fish meals consumption over the past 1 year period (Table 6.1): the sum of Great Lakes fish meals eaten (sum_gl), the sum of inland sportfish meals eaten other than Great Lakes fish (sum_inl), the sum of the other fish meals (sum_othe), the total number of Great Lakes fish caught (fishnum) and the sum of the top three Great Lakes fish meals eaten in kgs (top3kg).

The top3kg variable was calculated by allocating an average weight to each specific species of fish. The sum_inl variable consists of fish (other than Great Lakes fish) purchased at the farmer's market, supermarket, street vendor or the fish market . The sum_oth variable consists of fresh, frozen, canned, salted, pickled, smoked, or dried fish eaten (not Great Lakes fish) and caviar/fish eggs, fish noodles and fish cakes.

Table 6.1
Spearman Correlation Coefficients:

Variables	top3kg	fishnum	sum_gl	sum_inl	sum_othe
top3kg	1.00000				
fishnum	0.44862	1.00000			
sum_gl	0.46113	0.98885	1.00000		
sum_inl	-0.27854	-0.00018	-0.02536	1.00000	
sum_othe	-0.32636	-0.04911	-0.09511	0.91430	1.00000

The fish consumption variables appeared to be highly correlated in some instances. For example, the variables sum_gl and fishnum and the variables sum_inl and sum_othe. Based on Table 6.1 of the Spearman correlation coefficients, the following explanatory variables were used in modeling the response (contaminants) to avoid confounding; top3kg, sum_gl and sum_inl.

Tetrachoric correlations were calculated on the 2x2 table of gender (male/female) against country of birth (Asian/Canada,US, East and Western Europe). This analysis assumes that the underlying distribution is bivariate normal [Kendall and Stuart, 1979]. Mainly psychologists whose material is often of the 2x2 type have used this type of correlation [Kendall and Stuart, 1979].

The SAS manuals that were available did not make any reference to tetrachoric correlations. A SAS macro program, called POLYCHOR, which I downloaded from the Internet site of the SAS Institute was used. Using this program, the tetrachoric correlation result on the 2x2 table of gender against country of birth was –0.5091.

Table 6.2 indicates the final explanatory variables that were used in the modeling.

Table 6.2

Explanatory Variable	Description
sum_gl	Sum of Great Lakes fish meals eaten
sum_inl	Sum of inland sportfish meals eaten other than Great Lakes fish
top3kg	Sum of the top 3 Great Lakes fish meals eaten in kgs
edcn	Years of education
gend	Gender (males/females)
cob	Country of birth (Asian/Canada,US, East and Western Europe)
age	Age of participants
sumwild	Sum of wildlife meals eaten (only in Canada,US, East and Western Europe)
yrsincan	Years in Canada (only in Asian)

The following Tables (6.3-6.8) show the descriptive statistics for explanatory variables that were used in the modeling.

Table 6.3
Sum of Great Lakes fish meals eaten (sum_gl)

		Descriptive Statistics						
Country of Birth	Gender	n	min	max	median	geometric mean	mean	std. dev.
Canada/Europe/ United States	Male	32	26	254	95.0	90.5	101.0	49.0
	Female	15	43	280	74.0	80.9	91.5	58.1
Asian	Male	15	30	515	95.0	107.9	137.4	118.3
	Female	28	31	277	90.5	87.5	98.5	51.4

Table 6.4
Sum of inland sportfish meals eaten other than Great Lakes fish (sum_inl)

		Descriptive Statistics						
Country of Birth	Gender	n	min	max	median	geometric mean	mean	std. dev.
Canada/Europe/ United States	Male	32	2	212	38	32.0	47.9	44.0
	Female	15	6	157	29	34.4	54.5	50.3
Asian	Male	15	26	189	76	78.2	93.7	54.1
	Female	28	5	312	121	82.1	122.4	87.6

Table 6.5
Sum of the top 3 Great Lakes fish meals eaten in kgs (top3kg)

Country of Birth	Gender	Descriptive Statistics n	min	max	median	geometric mean	mean	std. dev.
Canada/Europe/ United States	Male	32	5.6	437.6	26.7	37.6	75.1	106.9
	Female	15	6.7	201.3	22.4	27.9	47.0	55.3
Asian	Male	15	3.7	298.4	14.1	15.7	37.8	75.7
	Female	28	2.8	99.4	11.9	13.5	20.3	21.1

Table 6.6
Years of education (edcn)

Country of Birth	Gender	Descriptive Statistics n	min	max	median	geometric mean	mean	std. dev.
Canada/Europe/ United States	Male	32	6	17	13	12.6	12.8	2.4
	Female	15	6	18	12	11.9	12.3	2.7
Asian	Male	15	2	20	12	9.2	10.5	4.6
	Female	28	4	16	10	10.2	10.7	3.0

Table 6.7
Sum of wildlife meals eaten (sumwild)

Country of Birth	Gender	Descriptive Statistics n	min	max	median	geometric mean (n)	mean	std. dev.
Canada/Europe/ United States	Male	32	0	29	0	3.5 (15)	3.3	6.7
	Female	15	0	8	0	2.9 (3)	0.8	2.1
Asian	Male	15	0	0	0		0	0
	Female	29	0	0	0		0	0

For the participants that were born in Canada the years in Canada variable was calculated using the age of the participant.

Table 6.9
Years in Canada (yrsincan)

Country of Birth	Gender	Descriptive Statistics						
		n	min	max	median	geometric mean	mean	std. dev.
Canada/Europe/ United States	Male	32	17	63	35	32.8	34.5	10.9
	Female	15	3	55	25	17.3	24.9	17.7
Asian	Male	15	1	20	7	5.9	7.5	4.8
	Female	28	1	16	6	5.4	6.5	3.6

6.2 Approach

After exploring the correlation amongst the explanatory variables and looking over the values of the response variables (contaminants), a modeling plan was established.

The PROC GLM (General Linear Models) procedure in SAS for Windows, Release 6.12 was used to model each contaminant. The natural logarithm of each contaminant was used in the modeling, not the original values, to aid in controlling for the large range and variation of the values.

The 2-stage modeling approach was considered a hypothesis building exercise and a p-value of 0.10 was considered significant. Each contaminant was age-adjusted (Stage 1) at the start of this modeling exercise. The age-adjusted contaminant was then used as the response variable in the second stage of the modeling of each specific contaminant. The age-adjustment takes into account most of the contaminants that were modeled bioaccumulate up the food chain and the longer a participant lives the more likely the contaminant value will be larger.

Each age-adjusted contaminant was modeled with the following explanatory variables using a backward elimination approach: sum_gl, sum_inl, top3kg, edcn, gend and cob.

If gender (gend) was the only variable left in the final model that was significant after initially modeling with all the predictors in the model, a subsequent modeling approach was applied. This new modeling approach was now stratified on gender (male and female), keeping the same set of initial predictors (sum_gl, sum_inl, top3kg, edcn and cob).

If country of birth (cob) was the only variable left in the final model that was significant after initially modeling with all the predictors in the model, a subsequent modeling approach was applied. This new modeling approach now stratified on the country of birth. For the Asian group, the new variable, years in Canada (yrsincan), was added to the initial set of predictors (sum_gl, sum_inl, top3kg, edcn and gend). For the Canada/Europe/United States group, the new variable, wildlife (sumwild), was added to the initial set of predictors (sum_gl, sum_inl, top3kg, edcn and gend).

If country of birth (cob) and gender (gend) were the only two variables left in the final model that were significant after initially modeling with all the predictors in the model, a test for interaction was completed. No subsequent models were considered after this final model.

Different modeling approaches were needed in this project since the contaminants are known to have different effects in males and females and since the country of birth seemed to have a significant effect in modeling some of the contaminants.

The following scatter plot matrices of the responses (age-adjusted natural logarithm), Aroclor 1260 (Figure 6.1) and p,p'-DDE (Figure 6.2) will show the appropriateness of the linear regression modeling, in particular the linearity assumption. The variable residage in the Figures 6.1 and 6.2 is the age-adjusted natural logarithm of the responses Aroclor 1260 and p,p'-DDE respectively.

Figure 6.1
Scatter plot matrix for Aroclor 1260:

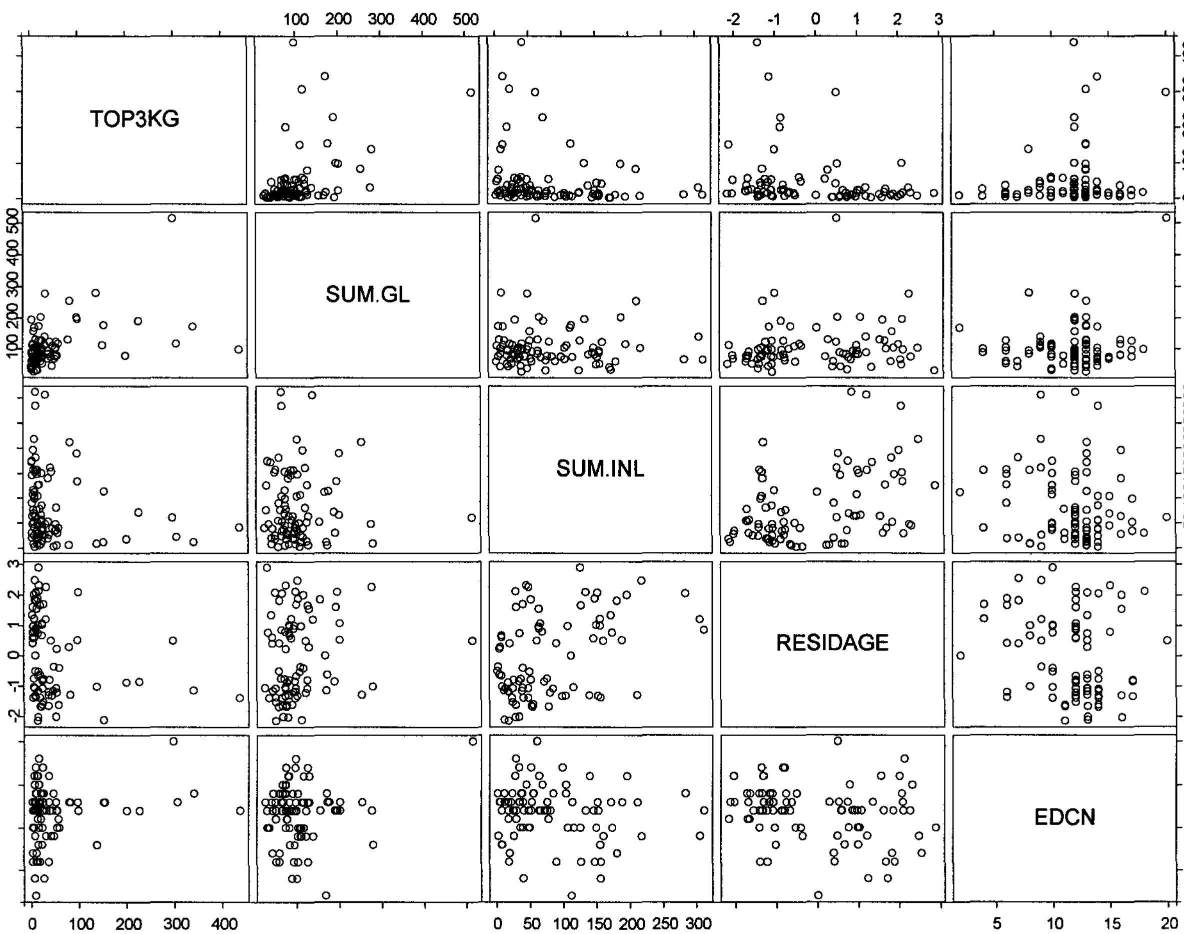
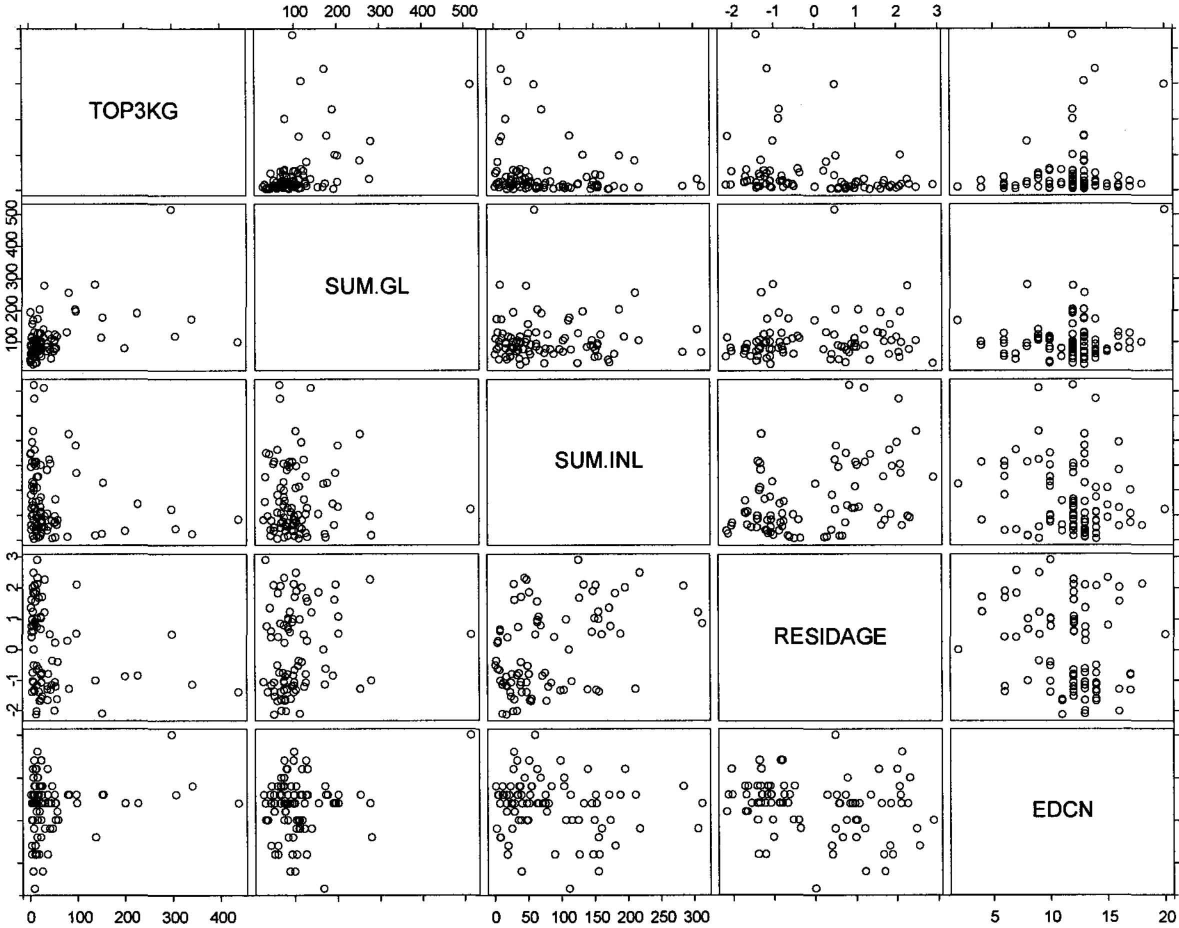


Figure 6.2
Scatter plot matrix for p,p'-DDE:



6.3 Results

Not all the contaminants that were modeled had significant results. That is, there were levels of certain contaminants that our modeling approach could not explain. Only the best models are indicated.

6.3.1 p,p'-DDE

Table 6.10 presents the stratified country of birth model for the Asian born participants and Table 6.11 presents the parameter estimates. The model had 39 observations with an adjusted R-Square = 0.060 and a Root Mean Square for Error = 0.832 after adjusting for the parameters in the model.

Adjusted R-square = $1 - [((n - i)(1 - R^2)) / (n - p)]$, where i is equal to 1 if there is an intercept, 0 otherwise; n is the number of observations; p is the number of parameters in the model; and R^2 is the R-square outputted from PROC GLM [SAS, 1990].

Table 6.10

Source	Degrees of Freedom	Sum of Squares†	Mean Square	F Value	Pr > F
Model	1	2.36	2.36	3.41	0.073
Residual	37	25.64	0.69		

†Corrected for the mean

Table 6.11

Parameter	Estimate	Standard Error
Intercept	1.629	0.258
Yrs in Canada	-0.061	0.033

The parameter estimate for years in Canada suggests that the levels of p,p'-DDE decrease with every year the Asian born participants are living in Canada.

6.3.2 β-hexachlorocyclohexane (β-HCH)

Table 6.12 presents the stratified country of birth model for the Asian born participants and Table 6.13 presents the parameter estimates. The model had 39 observations with an adjusted R-Square = 0.106 and a Root Mean Square for Error = 1.203 after adjusting for the parameters in the model.

Table 6.12

Source	Degrees of Freedom	Sum of Squares†	Mean Square	F Value	Pr > F
Model	2	9.41	4.70	3.25	0.050
Residual	36	52.1	1.45		

†Corrected for the mean

Table 6.13

Parameter	Estimate	Standard Error
Intercept	2.057	0.471
Gender (female)	-0.743	0.409
Yrs in Canada	-0.090	0.048

The parameter estimate for years in Canada suggests that the levels of β-HCH decrease with every year the Asian born participants are living in Canada. The Asian female participants have lower levels of β-HCH than the Asian males.

6.3.3 Hexachlorobenzene (HCB)

Table 6.14 presents the stratified country of birth model for the Asian born participants and Table 6.15 presents the parameter estimates. The model had 40 observations with an adjusted R-Square = 0.125 and a Root Mean Square for Error = 0.523 after adjusting for the parameters in the model.

Table 6.14

Source	Degrees of Freedom	Sum of Squares†	Mean Square	F Value	Pr > F
Model	1	1.79	1.79	6.56	0.015
Residual	38	10.38	0.27		

†Corrected for the mean

Table 6.15

Parameter	Estimate	Standard Error
Intercept	0.095	0.145
Gender (female)	-0.452	0.176

The parameter estimate for gender suggests that the Asian female participants have lower levels of HCB than the Asian males.

6.3.4 Mirex

Table 6.16 presents the full model for both the Asian and Canada/Europe/US born participants and Table 6.17 presents the parameter estimates. The model had 84 observations with an adjusted R-Square = 0.201 and a Root Mean Square for Error = 1.127 after adjusting for the parameters in the model.

Table 6.16

Source	Degrees of Freedom	Sum of Squares†	Mean Square	F Value	Pr > F
Model	3	30.38	10.13	7.97	< 0.005
Residual	80	101.61	1.27		

†Corrected for the mean

Table 6.17

Parameter	Estimate	Standard Error
Intercept	0.630	0.540
Education	-0.077	0.040
Gender (female)	-0.452	0.261
Country of birth (Asian)	1.016	0.274

The parameter estimate suggests the higher educated (number of years in school) participant has lower levels of mirex in their body. The female participants have lower levels of mirex than the male participants do and the Asian born participants have higher levels of mirex than the Canada/Europe/US born participants.

6.3.5 Oxychlordane

Table 6.18 presents the full model for both the Asian and Canada/Europe/US born participants and Table 6.19 presents the parameter estimates. The model had 84 observations with an adjusted R-Square = 0.311 and a Root Mean Square for Error = 0.549 after adjusting for the parameters in the model.

Table 6.18

Source	Degrees of Freedom	Sum of Squares†	Mean Square	F Value	Pr > F
Model	2	11.95	5.98	19.99	< 0.005
Residual	82	24.52	0.30		

†Corrected for the mean

Table 6.19

Parameter	Estimate	Standard Error
Intercept	0.442	0.092
Gender (female)	-0.464	0.126
Country of birth (Asian)	-0.453	0.126

The parameter estimate suggests the female participants have lower levels of oxychlordane than the male participants do. In this model the Asian born participants have lower levels of oxychlordane than the Canada/Europe/US born participants. This information can be confirmed by a visual scan of Table 5.6 in Chapter 5.

6.3.6 Transnonachlor

There were no significant predictors found for the transnonachlor contaminant. This suggests that the important predictors that might help to explain the levels of transnonachlor were not modeled or the information was not collected.

6.3.7 Aroclor 1260

6.3.7.1 Canada/Europe/US born

Table 6.20 presents the stratified country of birth model for the Canada/Europe/US born participants and Table 6.21 presents the parameter estimates. The model had 45 observations with an adjusted R-Square = 0.129 and a Root Mean Square for Error = 0.534 after adjusting for the parameters in the model.

Table 6.20

Source	Degrees of Freedom	Sum of Squares†	Mean Square	F Value	Pr > F
Model	2	2.42	1.21	4.25	0.021
Residual	42	11.97	0.28		

†Corrected for the mean

Table 6.21

Parameter	Estimate	Standard Error
Intercept	-0.482	0.171
Number of Great Lakes fish meals	0.004	0.002
Number of wildlife meals	-0.048	0.020

The parameter estimate suggests the higher quantity of Great Lakes fish consumed by the Canada/Europe/US born participants the higher the levels of Aroclor 1260. This implies that the Aroclor 1260 contaminant is found locally in the Great Lakes fish. The negative parameter estimate for the number of wildlife meals is questionable. This could be either cause by α, a Type I error or by confounding with an unknown variable.

6.3.7.2 Asian born

Table 6.22 presents the stratified country of birth model for the Asian born participants and Table 6.23 presents the parameter estimates. The model had 39 observations with an adjusted R-Square = 0.180 and a Root Mean Square for Error = 0.599 after adjusting for the parameters in the model.

Table 6.22

Source	Degrees of Freedom	Sum of Squares†	Mean Square	F Value	Pr > F
Model	2	3.71	1.85	5.17	0.011
Residual	36	12.90	0.36		

†Corrected for the mean

Table 6.23

Parameter	Estimate	Standard Error
Intercept	0.330	0.308
Education	-0.056	0.027
Yrs in Canada	0.070	0.024

The parameter estimate for years in Canada suggests that the levels of Aroclor 1260 increase with every year the Asian born participants are living in Canada. This implies that the Aroclor 1260 contaminant is found locally. The higher educated (number of years in school) Asian participants have lower levels of Aroclor 1260.

6.3.8 Organic Mercury

Table 6.24 presents the full model for both the Asian and Canada/Europe/US born participants and Table 6.25 presents the parameter estimates. The model had 84 observations with an adjusted R-Square = 0.552 and a Root Mean Square for Error = 0.707 after adjusting for the parameters in the model.

Table 6.24

Source	Degrees of Freedom	Type III Sum of Squares†	Mean Square	F Value	Pr > F
Model	2	52.12	26.06	52.12	< 0.005
Residual	81	40.49	0.50		

†Corrected for the mean

Table 6.25

Parameter	Estimate	Standard Error
Intercept	-0.866	0.122
Number of inland sportfish meals	0.003	0.001
Country of birth (Asian)	1.359	0.176

The parameter estimate suggests the level of organic mercury increases with the increased consumption of inland lake fish meals. The Asian born participants have higher levels of organic mercury than the Canada/Europe/US born participants.

Chapter 7

Conclusions

7.1 Discussion

There are noticeably elevated levels of contaminants in the participants of the Great Lakes Eaters Project. Where did these contaminants really come from? Are the contaminants in the Great Lakes fish or in other food items that are bought at the markets or the processed fish items purchased in supermarkets? One hypothesis for the possible increase in contaminants was the fish sauce imported into Canada from Asia and sold in the Oriental shops. Another hypothesis is the consumption of waterfowl and game by hunters.

There was no information collected on the overall quantity of Great Lakes fish (in kilograms) that was consumed by the participants. The amount of fish consumed by the participants will vary by species, length and the amount left after cleaning the fish. The lack of an accurate Great Lakes fish meals consumption explanatory variable is the key problem in this study. This is one of the variables that are definitely needed to aid in modeling the contaminants legitimately.

Thirty-three (36%) of the participants had immigrated into Canada since 1990. There was no blood work completed when these participants entered the country to help find out if the values of these contaminants were already elevated. Baseline values on some of the contaminants when the participants entered the country would also aid in explaining the contaminant levels but are not available.

Recall bias is a potential problem in this study. Most of the questions the participants were asked required them to recall the last 12 months of consumption. The varying levels of contaminants could also be associated with the different types of fish available to be consumed or caught during the different seasons of the year. The numbers recorded relating to the number of fish eaten must be viewed with skepticism due to recall bias.

An observational study of this type cannot establish whether or not there is a causal relationship between the number of Great Lakes fish consumed and contaminant levels.

7.2 A Different Study Approach

If more funds were available, a prospective design could be applied. This different approach could yield an accurate quantity of Great Lakes fish meals (in kilograms) consumed and baseline contaminant values.

Before the participants were enrolled into the study, consent would have to be given to collect baseline laboratory measurements as well as laboratory measurements one year later on the important contaminants. I realize that this could stunt the already low participation rate but it would provide some necessary baseline information. With this information gathered, I would also try to recruit the spouse or partner into the study, since it is implied in the current literature that there is a different effect on males and females.

The participants would be given a study-specific diary, to be collected and a new one issued each month, to record the quantity of Great Lakes fish meals (in kilograms) consumed. This diary could also be used to record the length (cm) of the fish caught that were consumed. To ensure a reliable record of the kilograms of fish meals consumed, an appropriate scale that the participants could use and keep at the end of the study would have to be issued. In addition, this diary could be used to record the other items consumed that may have been purchased at the market or given to them by others. I think this could add the necessary details required in this type of study.

The participants would also be given a book that has pictures of the different species of Great Lakes fish that might be caught. This would ensure proper recording of the different species of Great Lakes fish. In addition, it would be beneficial if we had more detailed information on the location where these fish were caught.

I would also want lab work done on the different types of fish sauce purchased in the Oriental markets/stores and the recipes recorded or a sample given if the participants in the study make their own fish sauce. I feel that the effect (if any) of the fish sauce is still one outstanding issue in the Eaters Project.

I think this would be a good start to another study of this type and hopefully give accurate information that could later be modeled on. The study would be still being observational but a greater range of fish consumption habits could lead to a more comprehensive study.

7.3 Final Note

This study offered an excellent chance to be an integral part of a team. The statistical consulting experience gained while working on this project was priceless. There was lots of opportunity to learn new statistical problem-solving skills in a comfortable/educating environment.

Not only did I learn and apply new statistical methods, I learned how to deal with people that have different research backgrounds and education. Patience, understanding and listening are very important skills to have in any consulting situation. This project provided the chance to work on these skills as well as others.

During this project, the ongoing contact with the different researchers and people provided an excellent opening to network, which could lead to the possibility of future projects/contract work after graduation.

I have learned the most important ingredient to being successful in the applied field of statistics is that of teamwork. No project is ever really completed by oneself. The statistical element is only one small part of the much larger research regime.

References:

Amin-Zaki L, Elhassani S, Majeed MA, Clarkson TW, Doherty RA, Greenwood MR. Studies of infants postnatally exposed to methylmercury. *Journal of Pediatrics* 1974;85:81-84

Durfee RL. Production and usage of PCB's in the United States. Proc Natl Conf PCB 1975;103-107

FWNP (Fish and Wildlife Nutrition Project). Sport fish and wildlife consumption in areas of concern. Interim report to Great Lakes Health Effects Program, Health Canada 1996.

Hoivik DJ, Safe SH. Chapter 87 Environmental and occupational medicine, Third edition, Lippincott-Raven Publishers, Philadelphia 1998.

Kendal MG, Stuart A. The advanced theory of statistics, Volume 2, Fourth edition, Charles Griffin & Company Limited, London, 1979:324-326

Porterfield SP. Vulnerability of the developing brain to thyroid abnormalities: Environmental insults to the thyroid system. Environmental Health Perspective 1994;102(Suppl 2):125-130.

SAS/STAT user's guide, Version 6, Volume 2, Fourth edition, SAS Institute Inc., Cary, 1990.

Shields PG, Whysner JA, Chase KH. Chapter 65 Hazardous materials toxicology: Clinical principles of environmental health, Williams & Wilkin, Baltimore 1992.

Siegers CP, Sullivan Jr. JB. Chapter 91 Hazardous materials toxicology: Clinical principles of environmental health, Williams & Wilkin, Baltimore 1992.

Sittig M. Handbook of toxic and hazardous chemical and carcinogens, Second edition, Noyes Publications, Park Ridge 1985.

Stehr-Green PA, Wohlleb JC, Royce W, Head SL. An evaluation of serum pesticide residue levels and liver function in persons exposed to dairy products contaminated with heptachlor. JAMA 1988 Jan 15;259(3):374-377

USPHS. Toxicological profile for p,p'-DDT, p,p'-DDE, p,p'-DDD. Agency for Toxic Substances and Disease Registry, US Public Health Service, Government Printing Office, December 1989:75.

Van Ert M, Sullivan Jr. JB. Chapter 102 Hazardous materials toxicology: Clinical principles of environmental health, Williams & Wilkin, Baltimore 1992.

WHO. Environmental Health Criteria 44, Mirex, World Health Organization, Geneva, 1984.