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SPORT CAUGHT GREAT LAKES FISH CONSUMPTION AND HUMAN SERUM POLYCHLORINATED BIPHENYL LEVELS: CROSS-SECTIONAL AND LONGITUDINAL RELATIONS IN MICHIGAN ANGLERS

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ABSTRACT

SPORT-CAUGHT GREAT LAKES FISH CONSUMPTION AND HUMAN SERUM POLYCHLORINATED BIPHENYL LEVELS: CROSS-SECTIONAL AND LONGITUDINAL RELATIONS IN MICHIGAN ANGLERS

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The present study combined 3 cross-sectional surveys conducted by Michigan Department of Community Health in 1973-74, 1979-82, and 1989-91. The association between fish consumption and serum contaminant levels and their joint change pattern are examined longitudinally. Over the period of the 3 surveys, there was a decline in the total annual pounds of fish consumed (median 40, 38, and 31, respectively). Men reported consuming more fish than women at each survey. In addition to eating less fish, fisheaters reported modifying their fish preparation methods, and changing in the favorite fish species eaten. Median PCB levels (ppb) were 2 to 3 times higher in fisheaters than nonfisheaters in each survey (14.0 versus 6.0; 19.4 versus 7.0; and 17.3 versus 5.8, respectively). In repeated measure models analyses, fish consumption decreased significantly over 20-year study period (b=-21.16 pound/decade, $p<.001$). After adjusting for potential confounders, log PCB were associated with concurrent fish consumption; log PCB levels significantly increased from survey I to II (b=.31, p=.002) and remained high in survey III (b=.13, p=.19). It is concluded that sport caught Great Lakes fish consumption has declined among Michigan anglers. Levels of PCB have not declined in parallel with declining fish consumption probably reflecting the long PCB half-life.

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LIST OF ABBREVIATIONS

PCB	Polychlorinated biphenyl
DDT	Dichlorodiphenyl trichloroethane
DDE	The ethylene metabolite of DDT
PBB	Polybrominated biphenyl
survey I	Michigan angler PCB survey conducted in 1973-74
survey II	Michigan angler PCB survey conducted in 1979-82
survey III	Michigan angler PCB survey conducted in 1989-91

1 Introduction

1.1 *The Great Lakes*

The Great Lakes are the largest single collection of fresh water on the surface of the earth, excluding the polar ice caps. About 25 percent of the Canadian population and 10 percent of the United States population live within the Great Lakes watershed(1). The Great Lakes has been used a valuable resource for both the United States and Canada in industry, agriculture, shipping, and recreation for more than 200 years.

Although the Great Lakes are open to the ocean through the St. Lawrence River, the ecosystem of the Great Lakes is actually much like a closed system. The water exchange rate is very low--it takes three years for Lake Erie to exchange its waters, and 173 years for Lake Superior. The long retention times make the Great Lakes act as the reservoir for any introduction of change. By the early 1960's, the environmental quality of the Great Lakes had deteriorated significantly as a result of eutrophication, overfishing, and the widespread presence of toxic substances. Due to reports on detrimental effects on fish and wildlife, and the potentially adverse effects on human health, an increasing widespread concern has been shown since the 1970s.

More than 1,000 chemicals have been detected in the waters, sediment, or biota of the Great Lakes. Many of these toxic substances tend to absorb onto particles and eventually settle to the bottom of the Great Lakes and become permanent or make their impact until they have very slowly eliminated from the system (2-4). The International Joint Commission has identified various persistent toxic substances in the Great Lakes, including organo-chlorines (e.g. polychlorinated biphenyls), heavy metals (e.g. methylmercury), and benzo[a]pyrene(a member of a class of substances known as PAHs). Eleven of the most persistent substances were identified as 'critical Great Lakes pollutants'(2, 3). The critical Great Lakes pollutants identified by the International Joint Commission are: Polychlorinated biphenyls (PCBs), dichlorodiphenyl trichloroethane (DDT) and metabolites, benzo[a]pyrene, hexachlorobenzene, alkylated lead, methylmercury, toxaphene, mirex, furans, dieldrin, and dioxins. Because of their lipophilic nature and long half-lives, all 11 such toxic substances, including polychlorinated biphenyls, tend to bioaccumulate in organisms and biomagnify in food chain. PCBs were detected in significant concentrations in fish and wildlife in the late 1960s. Statistical sampling surveys of contaminants in the Great Lakes fish began in 1972. The Great Lakes have been monitored for contaminants in the water, the flora, and the fauna since the 1970s. Several categories of pollutants have been investigated extensively, including PCBs, DDT, and DDE(5).

1.2 *The nature of PCBs*

PCBs are chemical compounds having the empirical formula $C_{12}H_{10-n}Cl_n$, with n equals 1 to 10. The generalized molecular structure of chlorinated biphenyls and the numbering of the carbon atoms in the rings are shown in Figure 1.

There are 209 theoretically possible discrete synthetic chemical compounds called PCB congeners which can be divided into nine isometric groups and decachlorobiphenyls, each of which has a systematic number(6). PCBs were first synthesized in 1881, but did not see industrial application in the United States until 1929.

Commercially, PCBs are manufactured by the batch chlorination of biphenyl, which results in technical mixtures containing a given chlorine content, depending on the duration of the chlorination process. PCB products had the trade name 'Aroclor' and were manufactured by Monsanto in the United States until 1977(7). These Aroclor compounds were characterized and named by their different degrees of chlorination. The particular kind of Aroclor is identified by a four-digit number. The first two digits refer to the 12 carbon atoms, and the second two refer to the percent, by weight, of chlorine in the mixture. Thus, Aroclor 1254 contains about 54% chlorine, and Aroclor 1260, about 60% chlorine.

Most PCBs are oily liquids or solids, clear to light brown in color, and have no smell or taste. The physical-chemical properties of PCBs, which vary on a congener-by-congener basis, are influenced by the different degrees of chlorination around the phenyl rings. Because of their high dielectric constant, their chemical and thermal stability, their non-flammability, and their low cost, PCBs were once widely used(8). They mostly used as insulating fluids in electrical transformers and capacitors, heat transfer substances, cutting oils, hydraulic fluids, lubricating oils, and as plasticizers for making brittle plastic pliable. Application was also found for these compounds in paints, in inks and dyes, as ingredients in pesticides, in adhesives, in protective wood coatings, in carbonless-copy paper. There are several properties of PCBs affecting their biodegradability, i.e., thermal stability (low volatility), difficult to oxidize and reduce, very low water solubility (i.e. high lipophilicity, high dielectric constant), resistant to acid-base, hydrolysis, chemical oxidation, photodegradation reactions, and existence of a large numbers of PCB congeners, each of which have differing susceptibilities to biodegradation (9, 10). These characteristics make PCBs persistent and accumulative in the environment. Some components of the mixture are more easily degraded in the environment than others. PCBs with fewer chlorine atoms, or with fewer chlorine atoms attached to the biphenyl molecule, or with at least one paraposition on the molecule not occupied by a chlorine, are more soluble, and thus more amenable to chemical and biological degradation. They can be more easily metabolized and are therefore less persistent in the environment than those PCBs with more chlorine atoms. The most toxic congeners however, are those that hold a coplanar conformation with chlorine substitutes on the meta and para positions of the phenyl rings (11). Since PCBs are poorly soluble in water and extremely soluble in oils and fats, they tend to partition out of the aquatic ecosystem into biologic tissue. Because of their persistence and the fact that they are poorly metabolized PCBs can bioaccumulate in the food chain leading to an increase in concentration at each succeeding trophic level (biomagnification)(12).

PCBs do not occur naturally and were never intended to be released into the environment. PCBs have entered the environment partly because of accidental leaks and fires in electrical equipment, past disposal in dumps, accidents in transport, and leakage from hazardous waste sites (6). They exist everywhere in the environment as a result of their widespread usage and their long half lives(13). Although the production was ceased in 1977, PCB residuals have been detected in animal and human tissue ever since.

1.3 *The toxicity of PCBs*

PCBs rarely cause acute toxicity. The dose required to kill 50% of a treated sample of animals is quite high, which ranges anywhere from 0.5 g/Kg to 11.3g/Kg body weight(14). Most of the effects observed are the result of repetitive or chronic exposure. People and most animals absorb PCBs through the skin, the lungs, and the gastrointestinal tract. Once these chemicals are inside an individual they are transported through the blood stream to various tissues. However, because they are highly lipophilic, the PCBs largely tend to settle in adipose tissue(15).

The body of data reported to date indicates that the toxicity and half-lives of PCB varies with the extent of chlorination of the biphenyl molecule. Our knowledge of their effects is based on some studies of people exposed in the workplace or who ate contaminated food, especially two tragic episodes in Japan and Taiwan, and on experimental studies with animals. The toxic effects of PCBs on humans and animals may vary according to the route of exposure, age, sex and the area of the body where the PCBs are concentrated(16).

Identification of highly toxic polychlorinated dibenzofurans (PCDFs) in commercial PCBs has contributed to the belief that they play a major role in the PCBs toxicity(17). Some of the PCBs are stereochemically similar to the planar 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD). The toxicity of such PCBs can be expressed in terms of TCDD-equivalency factors (TEFs), that is, expressed as a fraction of the toxicity of TCDD, including body weight loss, thymic atrophy, reproductive toxicity, liver enzyme induction, teratogenicity, immunotoxicity, alterations in lipid metabolism and formation of reactive intermediate metabolites which may be responsible for cytotoxicity and carcinogenicity(18).

Planar PCBs and some of their mono-ortho substituted congeners exist in very low concentrations in commercial PCB mixtures. Hence, their environmental occurrence is relatively low compared to that of many other PCB congeners. Their mono-ortho, non-coplanar derivatives were detected at much higher levels in commercial Aroclor mixtures and this may be even more important in terms of toxic activity. In human adipose tissues, the concentrations of non-coplanar PCBs may impose a greater threat than the PCDFs to humans and probably to wild life also.

1.4 ***Findings from animal studies***

Most laboratory-based animal studies conducted in the past 20 years used mixtures of PCBs. In general, PCBs have been found to affect reproduction and the immune response and to cause liver tumors in rodents(19). In animal studies, more recently some of the isomers of the PCBs mixture have been found to be much more toxic than others. The more toxic isomers constitute only a very small portion of the mixture, particularly those with less chlorine by weight. Scientists were able to produce hepatocellular carcinomas in rats with a German PCB mixture(20) or Aroclor 1260 (21, 22). When Aroclor 1254 was fed to rats, fewer liver tumors developed in exposed rats; however, the incidence of gastric intestinal metaplasia and adenocardinoma of the stomach increased (23). Aside from tumor formation, PCBs cause a variety of other biological effects, such as the induction of enzyme(24). In some species they may cause atrophy of the thymus, intrahepatic bile duct hyperplasia, hyperplasia of the epithelial lining of the urinary bladder, atrophy of the sebaceous glands and hyperkeratosis of the ducts (25).

Information on the effects on wild life of exposure to these compounds has come from mice, mink, birds, rhesus monkeys, and seals(26-28). The Great Lakes bird populations and mink and otter populations have demonstrated inverse relationship between reproductive success and organo-chlorine levels(29). In laboratory-based studies, reduced reproductive success has been observed in mink fed Great Lakes coho salmon, carp, sucker, perch(30, 31) (32). The chemicals may interfere with fertility and reproduction in bald eagles and river otters (26). Arnold (33) researched the prevalence of endometriosis in rhesus monkeys ingesting Aroclor 1254 and the results suggested a possible link between the PCB treatment and the occurrence of endometriosis but there was no dose-response relationship. A study conducted by de Swart and co-workers (34) demonstrated immunosuppression in seals, one of the top marine predators. The seals in the experimental group were fed high levels of persistent lipophilic environmental contaminants. Two and half years later, impaired natural killer and specific T cell responses were found in the experimental group.

In general, PCB intoxication produces a wide range of symptoms including: neurological dysfunction, altered neuromuscular reflexes, increased susceptibility to infections, reproductive dysfunction, and lowered birth rates. Rhesus monkeys were unique in having symptoms such as facial swelling, loss of hair, increased skin pigmentation, and a skin condition known as chloracne(28). The difficulties in using animal data to predict human health effects for PCBs and related compounds is that animal species very greatly in their responses. Subhuman primates, mink, and guinea pigs are particularly sensitive to the toxic effects of PCBs; other species, such as the rat, the mouse, and the dog, can tolerate much higher doses. Further, many of the animal studies use relatively high doses. Therefore, determining how such animal studies relate to the human situation is difficult.

1.5 *Routes of human exposure to PCBs*

In industry, absorption by the skin (dermal route) is the major route of exposure to these contaminants(35). The primary route of general population exposure to PCBs is ingestion of contaminated food(36, 37). Ingestion of untreated drinking water is a third route of human exposure to organo-chlorines (38, 39). A fourth, less prominent, exposure pathway is inhalation of polluted air. PCBs are also known to be passed from the mother to the fetus through placental blood, and to the baby via breast milk(40-42).

In the Great Lakes region, consumption of contaminated fish has been identified as an important exposure route (43) (44). PCBs enter the bodies of fish from water, sediment and from eating prey that have PCBs in their bodies. PCBs build up in the Great Lakes fish and can reach levels hundreds of thousands of times higher than the levels in water(43). The state and federal inspection systems control exposure to PCBs from commercial sources by seizure of contaminated fish before it reaches the market. However, Michigan is the only state that is surrounded by four of the five Great Lakes and it has the longest shoreline of any state. Many Michigan residents engage in sport fishing. Since many Great Lakes fish species are contaminated with a variety of organo-chlorine compounds, particularly PCBs, sport fishing represents an uncontrolled source of PCB contaminated fish for distribution and human consumption. Due to the persistent nature of these contaminants and their biomagnification and accumulation, Michigan anglers who consume larger amount sport caught Great Lakes fish and wildlife than the general population are likely to constitute a population at-risk of exposure to PCBs compounds. It is estimated that perhaps four million of the 40 million people living in the Great Lakes basin eat the fish and are therefore exposed to these chemicals (44).

Although we are not able to exactly quantify the amount of fish consumed by Michigan anglers annually, it is estimated that sports fishermen as a group consume in excess of the national average of fish consumption(45). Sport fish anglers and their families thus represent a population with potential elevated risk for exposure to PCB compounds.

1.6 *Effects of PCBs on human health*

The effects of acute human exposure to PCB mixtures containing other contaminants are reasonably well documented, mainly as a result of two widely known tragic episodes--1968 Japanese mass poisoning and the 1979 outbreak in Taiwan. Both of these incidents were caused by the accidental introduction of PCBs and heat-degraded by-products into rice oil used for domestic cooking. These by-products included polychlorinated dibenzofurans, terphenyls, and quarterphenyls. Since the disease was caused by ingesting contaminated rice oil, it was called 'Yusho' in Japan and 'Yu-cheng' in Taiwan, which both meaning 'rice-oil disease'(46, 47). Approximately 1,600 individuals in Japan suffered a classic set of disease symptoms. Chloracne was one of the leading signs in those who became ill. A broad spectrum of effects was observed and these are typified by the toxic symptoms observed by Kuratsune and coworkers (17). These symptoms or signs included hyperpigmentation of the skin, distinctive hair follicles, increased sweating at palms, acne-like skin eruptions and so on. Many of these same symptoms were also observed in Yu-Cheng patients(48, 49). And it is clear from numerous studies that both poisonings share a common etiology.

The effect of the acute poisoning of Yusho / Yu-Cheng victims has been monitored over the succeeding decades. Offspring of exposed mothers have exhibited dermatological, neurological, dental and immunological effects(50, 51) (52). Some Japanese offspring, termed the 'Yusho' cohort, exhibited developmental abnormalities including small birth weight, growth deficits, hypotonicity, apathy and IQ impairments (53). The Taiwanese children, victims of the 'Yu-Cheng' accident, have been the most extensively investigated(54). These Children had higher than expected rates of low birth weight, growth retardation, increased incidence of hyperpigmented skin, abnormal dentition, otitis media (middle-ear infections) and lower scores on various tests of cognitive development(55). However, interpretation of these findings is complicated by the fact that there did not appear to be any relationship between available indices of exposure and severity of effects, and by the fact that the PCBs to which the Taiwanese were exposed contained unusually high concentrations of dibenzofurans, which are many times more toxic than PCBs, and may have been responsible for some or all of the observed effects (56, 57).

Occupational exposures have been reported since 1930, with the beginning of jobs such as capacitor and transformer manufacture workers and machinists. Workplace exposure to commercial PCBs can result in significant uptake of these compounds and this is reflected in the high serum or adipose tissue levels detected in the groups of exposed workers(58). The effects of occupational exposure to PCBs are comparable to some of the effects observed in laboratory animals. Chloracne and related skin problems have been observed in several groups of workers(59). It was suggested that the air concentrations of commercial PCBs > 0.2 mg/m3 were associated with this effect(60). The effects of occupational exposure to PCB on the levels of several serum chemical and hematological parameters have been reported by several studies. Mildly elevated SGOT and glutamyl transpeptidase (GGTP) suggest some liver damage and induction of hepatic monooxygenase enzyme (61). Warshaw and colleagues(60) reported a relatively high incidence of pulmonary dysfunction in capacitor workers and the symptoms included coughing, wheezing, tightness in the chest, and upper respiratory problems or eye irritation. It has been speculated that prolonged exposure to potential carcinogens with a long half-life could produce continuous target organ exposure to which should result in tumor production. However, there is no strong evidence of elevated mortality rates in human population (62-64). The epidemiological evidence is not of sufficient strength to link exposure to these compounds with the elevated cancer incidences(65, 66).

Serum levels of PCBs in the general population are usually less than 10-15 parts per billion (ppb) and these concentrations are significantly lower than observed in occupationally exposed workers in whom serum PCB concentrations as high as 3,000 ppb have been reported(67). Individuals who consume relatively large amounts of fish represent a small sub-population exposed to higher levels of PCBs and this is reflected in elevated serum PCB concentration (68). Researchers have suggested that PCBs carried by lake trout and salmon can impair the children of mothers who eat a steady diet of the fish(69-71). The developing fetus and neonate are considered to be at particular risk as there is great potential for exposure to environmental contaminants in utero and through breast milk(72). The developmental consequences of exposure to high concentrations of organo-chlorinated contaminants include intrauterine growth retardation (IUGR), shortened or prolonged gestational lengths, low birthweight, congenital malformations, and spontaneous abortion (73-77).

Studies on male reproductive endpoints have shown reduced fertility in men working in pesticide manufacturing plants (78). Carlsen and co-workers (79) reported a decline in semen quality, compared with published information on semen quality appearing in the literature over the preceding 50 years. Recent female reproductive studies (80, 81) have shown consumption of contaminated sport fish was associated with shorter menstrual cycles but there was no evidence of having a large detrimental effect on time to pregnancy. Now new concerns are being raised that chemicals in the fish may spread the onset of nervous system problems in the elderly. The body of research data has demonstrated an age-related decline in cognitive and motor function in humans(82, 83). Because of this decline, the aged may be at increase risk for neurological dysfunction following prolonged exposure to neurotoxicants, such as PCBs.

1.7 *The hypotheses and objectives of the present study*

Due to advantageous physical and chemical properties, PCBs were once used extensively in a variety of applications. As a consequence of this use, accumulation and storage of PCBs would theoretically make them available, under appropriate conditions, for re-circulation within the body allowing continuous or repeated exposure of target organs long after the original dose has ceased or when multiple low doses are received and accumulated to a critical level. Therefore, human consumption of chemically contaminated fish poses a potential health risk, the magnitude of which depends on the amount of fish consumed and the degree of contamination. Evaluation of the potential risks to populations that may be exposed to chemically contaminated fish requires knowledge of the patterns and frequencies of fish consumption by these populations.

The objectives of the present study are: 1) to examine fish consumption behaviors measured by quantity of fish consumed, fish preparation, fish cooking methods, favorite fish eaten, and changes in fish consumption behaviors among Michigan anglers over time; 2) to describe variation in PCB levels in human serum and patterns of change in study population; and 3) to integrate questionnaire information and laboratory findings on human serum to evaluate the relationship between fish consumption and contaminant levels in human serum and their joint change pattern over about 20 years. We hypothesize that there has been a decrease in consumption of sport caught Great Lakes fish among fisheaters. Because the health advisory of fish consumption tends to target women, we further hypothesize women reduced their total sport fish consumption more than men. We hypothesize that elevation of PCB levels is largely due to consume of sport caught Great Lakes fish. We expect to see PCB levels are higher among fisheaters than nonfisheaters and change in PCB levels is associated with concurrent sport caught Great Lakes fish.

The present study will provide the opportunity to study human exposure to a synthetic chemical removed from once common use and provide a significantly historic foundation for research testing health outcome hypotheses.

2 Methodology

2.1 *Population and setting*

2.1.1 *Study population*

The Michigan Department of Community Health (MDCH) has investigated human exposure to waterborne contaminants, especially PCBs, for more than 25 years. The data presented here were collected by MDCH from three cross-sectional surveys between 1973 and 1991. The subjects of these surveys were not a random sample of the general population residing along the whole shoreline of Lake Michigan. Instead, the target population was licensed sport fish anglers. They were selected for study if their recreational sport-caught Great Lakes fish consumption was significantly high (24 pounds or more sport fish consumed yearly) or if their sport caught Great Lakes fish consumption was less than six pounds per year. The former comprised the fisheater group; the latter, the nonfisheater group. This strategy was deliberately designed to evaluate significant exposures which then would amplify the association between fish consumption and human serum PCBs burden if the association was to exist. Study participation was voluntary and without compensation. All participants signed an informed consent statement approved by the MDCH.

2.1.2 *Time windows*

2.1.2.1 1973-74 (survey I)

The first pilot survey in a series of MDCH sponsored studies, initiated in 1971, focused on mercury exposure.

This was followed in 1973-74 by a study funded by the Food and Drug Administration (FDA) to investigate human exposure to PCBs from consumption of sport caught fish from Lake Michigan in 1973-74, which was the first cross-sectional PCB survey in Michigan anglers. The 1973-74 survey recruited 156 individuals with a median age of 46 years, with a range of 37 (25 percentile) to 56 (75 percentile). Four major communities along the western Michigan shoreline of Lake Michigan were involved in the first survey, South Haven, Ludington, Manistee, and Traverse City. These communities represented the principal areas of Lake Michigan where PCB contaminated fish had been identified. Algonac, a shoreline community on Lake St. Clair where PCB levels in fish were not excessive, was also included, with a primary intention to make a geographic comparison.

2.1.2.2 1979-82 (survey II)

Additional funding from the Environmental Protection Agency (EPA) in 1979-81 was used to implement a large multi-site PCB survey in Michigan anglers residing in Western Michigan along the shoreline of Lake Michigan. Eleven major communities representing points of access to the lake were selected as regional study sites. These communities spanned the entire shoreline of Lake Michigan. The sample size was enlarged to 1255 individuals. Participants in survey I were re-contacted and encouraged to enroll in survey II. 115 participants identified in survey I continued to participate in survey II. The remaining 1140 were new participants in the series of Michigan PCB surveys.

2.1.2.3 1989-91 (survey III)

Seven hundred and twenty eight persons participated in survey III. Each subject from survey II was re-contacted and invited to participation. Nearly 57 percent (717/1255) agreed to participate in the third survey, which accounted for 98 percent of (717/728) participants in the third survey. Included among survey III participants were 64 persons who had participated in both surveys I and survey II. Figure 2 illustrates the sample sizes from these three cross-sectional surveys.

2.1.3 ***Recruitment***

Participants were persons who have resided in selected communities for at least 1 year and were between the ages of 18 and 72. People who did not fit the age range or criteria of fish consumption, they did not want to be included, or did not wish to donate a blood specimen for testing, were excluded from surveys.

All subjects (fisheater or nonfisheater) in survey I and all fisheaters in survey II were directly selected by Michigan Department of Public Health field workers. Field workers went to boat launch sites, piers, bait shops, sporting goods shops, fishing clubs to find participants. In order to speak to avid sport anglers, a 'snowball approach' was used in recruiting potential participants. Interviewees were asked to give leads to other persons who might also be interested in participation in the study, including his/her family members. All potential participants were personally interviewed to determine their eligibility (either as fisheaters or as nonfisheaters). Those judged eligible, as determined by the response to the brief fish consumption questions, were invited to participate in the study.

Eleven Western Michigan communities involving in survey II were grouped into 3 regions by MDCH: the northern region went from Petoskey to Pentwater, the middle region went from Montague to Grand Haven, and the southern region included communities from Holland to Benton Harbor. A Michigan map displays the 11 communities in Figure 3. A random digit dialing method was performed in each of the regions to recruit nonfisheaters for survey II. Over 1,000 households were contacted and screened for eligible anglers. Four hundred and nineteen agreed to participate, creating a regional comparison group for the fisheater group in survey II.

2.2 *Data collection instruments*

The questionnaires used in three surveys were mainly composed of two modules, a fish consumption module and a general information module.

2.2.1 *Fish consumption assessment*

The fish consumption module contained detailed questions about sport caught Great Lakes fish consumption behaviors. The main questions included that the number of years eating sport caught Great Lakes fish, annual number of fish meals, usual portion serving size, species of fish most frequently consumed (e. g. trout, salmon, perch, catfish, whitefish, etc.), the most frequent cooking methods (e.g. pan-frying, deep-frying, broiling, baking, etc.), fish preparation methods (trimming off dorsal or belly fat areas and removing skin prior to cook), and preservation (freezer or canned). MDCH field interviewers used a plastic fish model in a dinner plate in order to help individuals determine more accurately the usual portion size of fish consumed during a meal. At each time point of surveys, the interviewer began by asking the respondents about participants' fish consumption habits, specifically if they had eaten any sport caught Great Lakes fish in the preceding year. Only if the respondents had consumed significant amounts of fish, i.e. greater than 24 pounds of Great Lakes sport fish, in the preceding 12 months were they asked to complete the fish consumption module. Participants in survey II who consumed little fish (less than 6 pounds), or did not eat fish at all in the last year, completed the demographic module and skipped all the questions relevant to fish consumption habits in fish consumption module.

The fish consumption module in the questionnaire of survey I did not include comprehensive information on the usual portion serving size, fish preparation and cooking methods. However, 66 percent (103/156) of participants of survey I provided detailed fish consumption diaries, which contained type and quantity of fish consumed, and how they were prepared and cooked, for every specific fish meal over a fishing season. An average portion serving size was calculated based on all fish meals for each participant doing a fish diary. Preparation and cooking methods were not provided in the fish consumption module of the questionnaire of survey II. Four hundred and thirty one fisheaters in survey II who reported more than six fish meals per year voluntarily provided fish preparation charts to keep track of the type of fish consumed, preparation methods, and the cooking methods. All fish consumption questions were built into the questionnaire of survey III. Therefore, in the present study there existed differences with regard to the sources of detailed fish consumption information.

Separate questionnaires were developed for fisheaters and nonfisheaters in survey II. The questionnaire for nonfisheaters removed the fish consumption module and made it much shorter than that for fisheaters.

2.2.2 *General information module*

The questionnaires included several important demographic and other control variables that may influence the outcome of interest. Questions in the demographic module included date of birth, gender, race, educational attainment, and region where participants lived. Information on height and weight was reported in survey I and survey II. Body mass index (BMI) was calculated as weight in kilograms divided by square of height in centimeters. However, BMI was not available in survey III, because survey III only provided the magnitude of yearly weight change. Participants were asked to report if they were potentially exposed to PCB related industrial/agricultural chemicals, such as hydraulic oils, capacitors, transformers, pesticides and so on. Information on self-assessed health conditions was obtained in surveys I and II. In both surveys, participants were asked if they were taking any medications for a health condition/illness, if they were hospitalized in the past year, and if they were currently under the care of a physician for a particular condition. Lifestyle information, for example, tobacco use and alcohol consumption, included. Detailed information on smoking and drinking, including the age of starting smoking and drinking included the age started smoking, the quantity of cigarette smoked daily, the frequency and amount of drinking, etc., was obtained during the interview of survey III.

Specific parameters of interest with regard to fish consumption behaviors and other relevant variables in the questionnaire stated above have basically remained unchanged across different surveys, which enhance the comparability of the data generated across surveys and provide the basis to examine if the patterns of fish consumption habits changed over about 20-year follow-up.

2.2.3 *Measurement of serum PCB and other contaminants*

Serum samples were drawn from the majority of participants, both fisheaters and non-fisheaters, at all survey points to assess PCBs and nine other contaminants, detected in the Great Lakes. Levels of serum contaminant were analyzed at the MDCH Environmental Laboratories in Lansing. Serum PCB levels were evaluated by using the modifications of the Webb-McCall packed-column gas chromatography methodology (94). Quantitation of PCB from electron capture chromatograms was complicated during 1970s because the electron capture detector responds differently to each Aroclor. The Webb-McCall packed-column method Utilizes several Aroclor standards against which the quantitative composition of each electron capture chromatograms peaks can be calculated. Aroclor 1260 is a standardized mixture that permits quantitation of certain defined sets of Webb-McCall peaks. The same was true for Aroclor 1254 and Aroclor 1016, but they refer to different sets of the Webb-McCall peaks. Most PCB contaminated samples of fish, water, sediment, and human serum contain residues characteristic of several Aroclors. The overlap of Aroclor 1016, Aroclor 1254, and Aroclor 1260 in these three surveys is clarified by a protocol that prescribed which peak and going to be quantified by each of the PCB standards. In order to have comparable data on PCB using a consistent laboratory technique, the Webb-McCall packed-column method was used in all three surveys.

The detection limit for PCB was 3 parts per billion (ppb). Specimens with serum PCB levels below the detection limit were assigned a value of 1.5 ppb in the present data analysis. Only Aroclor 1254 and Aroclor 1260 were utilized as standards in 1973-74. In laboratory data from surveys II and III, the samples were analyzed for Aroclor 1260 and nine other contaminants, including DDT, DDE, PBBs, hexachlorobenzene (HCB), oxychlordane, dieldrin, mirex, mercury, and lead. Levels of total serum lipids were also tested in surveys II and III.

2.3 *Data management and preparation*

2.3.1 *Definition of fish eating status*

One of the objectives of this study is to compare the fish consumption and contaminant levels longitudinally, and we therefore needed to develop a criterion to define if a participant was a fisheater or non-fisheater in the study analysis. And this criterion had to be consistent across the three surveys. The new definition used in present study was that in survey I a fisheater was a person who reported eating an average of 24 pounds or more sport caught Great Lakes fish in the preceding 12 months. Forty-four persons who annually ate moderate amount of sport caught Great Lakes fish (less than 24 pounds but greater than 6 pounds) represented as a mild range group in Humphrey's 1976 report of survey I to the FDA. Applying the definition, these participants will be defined as a non-fisheaters. They will be treated in the same way as those annually ate less than 6 pounds, and would therefore remain in the analysis as nonfisheaters.

For participants in survey II, fisheaters were defined by their fish eating status, which based upon whether or not their annual weight of fish consumed exceeded 24 pounds. Generally, fish consumption behaviors among nonfisheaters in survey II were not available, since the questionnaires were administered separately based on the fish eating status. However, information on fish consumption habits for a very small proportion of new participants (1.6%) in survey II, who claimed they annually ate more than 24 pounds but actually ate less than that amount of sport caught Great Lakes fish, were also available. Fish eating status was determined at the beginning of the interview based on participant's self-reported amount of fish consumed (24 pound/year or more: fisheater; 6 pound/year or less: nonfisheater). Once participant was classified as a nonfisheater in survey II, a nonfisheater questionnaire, which did not include fish consumption module, would be used. We were not able to know the detailed fish consumption behaviors in nonfisheaters, including total weight of fish consumed. Probably some participants, who classified as nonfisheaters, actually ate quite large amount of fish. However, we believe that number should be very small, because in the process of recruitment of the regional control group, based on the response to the screening fish consumption, those self-reported consuming 24 pounds or more were recruited into the fisheater group instead of the nonfisheater group.

Participants in survey III were basically a subset of survey II, as 98 percent (717/728) of participant's fish eating status had been decided at the time of either survey I or II and kept unchanged. The fish eating status of 11 (728 - 717) new participants in survey III were also determined by total weight of fish consumed the year prior to survey III was conducted.

In general, the fish eating status was based on the participant's total weight of sport caught Great Lakes fish consumption at the first time they were enrolled in survey. Once the participant's fish eating status was decided, it would remain the same no matter whether or not his/her annual total pounds of fish consumed changed during follow-up time.

2.3.2 *Computation of fish consumption*

Consumption of sport caught Great Lakes fish was considered as the primary exposure variable in the present study. In each time point of surveys, the categorical designation as a fisheater or non-fisheater was used to represent cumulative exposure status. The current exposure was expressed as two continuous variables: 1) number of annual sport caught Great Lakes fish meals-calculated by summing the reported number of fish meals consumed in the preceding 12 months; 2) the total weight (pounds) of fish consumed--measured by multiplying annual meals of sport caught Great Lakes fish by usual portion serving size, assuming the portion serving size was consistent across the preceding 12 months. The portion serving size itself was ascertained across three-time point of surveys and provided the basis of looking into the change pattern too. For the majority of nonfisheaters, with no information on fish consumption, their annual fish meals and total weight of fish consumed were set to zero in the multiple linear regression analyses to estimate the prediction equations of contaminant levels.

2.3.3 *Choice of Aroclor*

Aroclor 1254 was used as a standard in survey I but not in survey II or survey III. Aroclor 1016 was used as a standard in survey II but not in survey I or survey III. Since only Aroclor 1260 used as a quantitative standard in the Webb-McCall packed gas-columns laboratory technique consistently over the three surveys, it was used to examine the pattern of changing PCB levels across the surveys.

Actually, data from serum PCB concentration analysis do not reflect the analysis of a specific Aroclor mixture, for example, Aroclor 1260. Rather, the serum contains a mixture of PCB congeners that is different from that in chemist to produce a standard mixture of PCBs that could reflects the ever changing components of the serum mixture of PCBs. The laboratory selects a particular Aroclor mixture (or a set of Aroclors) to serve as a standard so that the chromatographic peaks can be translated into micrograms of total PCBs. The numbers that are generated from this procedure are rather arbitrary but since the same procedure was used for all samples (i.e., Aroclor 1260 was used as a standard) the numbers are comparable. So it can be used with some confidence to estimate the variation of total PCBs in serum.

2.3.4 *Integration of data within each survey*

Within each survey, information from the questionnaire was merged with laboratory data by matching on each participant's unique identification number. Questionnaire information in survey I was obtained from its pilot study, and from the main study phases of survey I during 1973 to 1974. Questionnaires used in the pilot study and the main study were basically the same. There were 241 records in survey I with 156 unique identification numbers. Seventy-one participants had one record, which provided questionnaire information through either the pilot or the main study at survey time. All these 71 records were included in this analysis. The other eighty-five participants had two records collected in both pilot and main study. There were at least three choices of which data to use from the participants who have both main and pilot data --1) simply choose main study records; 2) simply choose pilot study records; 3) combine information from two studies, and average all the key variables. For instance, calculate the mean of annual total fish meals consumed based on pilot and main questionnaire responses. Using the average value could increase the precision of measurements for an individual by reducing the variance. From an individual point of view, it may better represent the 'true' value. However, these 85 records would be not comparable to 71 records from participants who only provided one record because of the effect of regression toward the mean. Therefore, the third choice was ruled out.

In order to make a rational choice, a reproducibility analysis was performed for the key variables. These variables were general characteristics such as sex, height, weight, education attainment, as well as main fish consumption variables including portion serving size, and most common species of fish consumed within this short period of time. Information was grouped into categorical variables and continuous variables. Kappa values were calculated for categorical variables to assess the agreement between pilot and main studies. Pearson correlation analyses were performed for continuous variables. The results of the reproducibility analysis are displayed in Appendix 1. Excellent agreement was observed in general characteristics such as gender, height and weight. Kappa values for categorical key fish consumption variables (e.g. the 3 most common species of fish consumed) showed good agreement. All Kappa values were greater than 0.4. The differentiation was observed within one-degree category in a cross-tabulation. In sum, we considered there was good agreement between two measurements collected from pilot and main studies. In the present data analysis, information from main study of these 85 participants was selected. In combination with the rest of the 71 records, a total of 156 records were used in further analysis as questionnaire data of survey I.

Many of participants in survey I provided multiple samples of blood. Some of them gave as many as 9 blood specimens during 1973 and 1974. The original objective in study design was to test a seasonal variation of the PCB levels. Humphrey (1976) examined the survey data and concluded that there are no statistically significant changes in PCB blood levels during the survey period. Because there were no apparent short-term change was observed, the first measure value of each participant was used in the present data analysis to represent the participant's PCB body burden at the time survey I conducted.

After merging within surveys, the number of participants with questionnaire and laboratory data in surveys I, II, and III year were 153, 1093, and 413, respectively.

2.3.5 *Integration of data between surveys*

Due to losses to follow-up and changes in sampling strategy over time, varying numbers of individuals had data for multiple time points. Data between surveys were merged by matching the unique identification number of the participant. One hundred fourteen participants had questionnaire and laboratory data for both surveys I and II; 43

participants had complete data were available for surveys I and III; 391 participants had complete data for survey II and III. A total of 462 participants had complete data from at least two surveys; forty-three participants had full information across all the three survey points.

2.4 *Statistical methods*

2.4.1 *Univariate analysis*

Univariate analyses stratified by gender were performed to provide a summary of descriptive statistics for the study population. With 73 percent (115/156) of participants of survey I re-enrolled in survey II, the overwhelming proportion of participants in survey III having participated in survey II, and survey II having the largest sample size, survey II data could be treated as a representative of the study population. In the present study, the demographic description of the study population was therefore only performed for survey II data. Age was calculated from the participant's birth date given during survey II interview. Only survey III data provide information on tobacco use and alcohol consumption, therefore the information on these variables was based on survey III data only.

Within each survey, univariate analysis of fish consumption variables was restricted to the exposure group (fisheaters) as no information on fish consumption was available in the majority of non-fisheaters. Mean, standard deviation, median, and range (25, 75 percentiles) were calculated for continuous fish consumption variables, such as annual fish meals, usual portion size in ounces, total pounds of fish consumed in the past year. Frequencies were used to describe the categorical fish consumption variables, such as, the most common species of fish consumed, common fish preparation and cooking methods. Mean, Standard deviation, median and range (25, 75 percentiles) were calculated for laboratory measurements stratified by gender and by fish eating status at each survey point. Laboratory values of all contaminant levels reported as less than the detectable limit would be coded as the middle value between zero and the detect limit. For instance, where the detect limit for PCB was 3 parts per billion (ppb), all the values reported under the detectable limit were set to 1.5 ppb.

All tests for statistical significance were set at the two-sided 0.05 level. Differences in means were examined by using Student T test for two group comparisons, one-way ANOVA was used to compare for 3 or more groups. The linear associations were also examined. Distribution frequencies of occurrences were tested using the Chi-square test. Estimates of the mean and median values for contaminant levels were both available from the analysis; when the data appeared log-normally distributed, the median provided a better sense of the center of the contaminant concentrations. In addition, median estimates are more resistant to the effect of outlying observations than are means. Tests on contaminant levels were performed both on natural log scale and on an arithmetic scale to evaluate the sensitivity of the test when different scales were used.

For the cross-sectional analysis at each survey point, the data were analyzed as follows: 1) fish consumption and contaminant levels were categorized as none, low, medium and high. The Chi-square test was employed to evaluate relationship between fish consumption factors and general characteristics such as age, education, region, body mass index (if applicable), and self-reported chemical exposure; 2) Pearson or Spearman correlation coefficients were generated to assess the direction and strength of possible associations between contaminant levels and continuous fish consumption variables. Subsequently, simple linear regression was use to examine the relationship between laboratory measurements and continuous fish consumption variables.

2.4.2 *Multivariate analysis*

Multiple linear regression analyses were performed to identify significant predictors of serum contaminant levels after controlling for potential confounders by including these factors in models. The primary exposure variable in models was sport caught Great Lakes fish consumption. As described above, cumulative exposure was expressed as a categorical variable, i.e. fish eating status (fisheater vs. nonfisheater). Current exposure was described as two variables, i.e. annual number of fish meals and the total weight of fish consumed in the preceding year. The collinearity of these variables needed to be considered

Model construction was initiated with a basic regression equation that included age, gender, education, and region as predictor variables. After selection of the most appropriate fish consumption variable between annual fish meals and total weight of fish consumed, additional secondary exposure variables, such as body mass index and self-reported chemical exposure, were examined. The selection of variables to be evaluated in the regression models was based upon biological relevance to the outcome of interest-contaminant levels and demonstrated association with the outcome of interest in preliminary bivariate analyses. Instead of using annual fish meals as a continuous variable, quartiles of annual fish meals were used in prediction equations of contaminant levels within each survey. The reason for this choice is that annual fish meals is not a constant continuous variable; the same number of annual fish meals could represent different quantities of fish among different fisheaters. The same was true for total weight of fish consumed. Once the model was determined, standard diagnostic techniques were used to examine the goodness of fit of the final models and the validity of the underlying assumptions of linear regression.

Pairwise comparisons (survey I versus II; survey II versus III; survey I versus III) were performed for participants with two-time point survey data. Paired student t-tests were used for continuous variables to assess whether a statistically significant difference between two surveys had occurred with regard to quantity of fish consumption, fish consumption behaviors, and contaminant levels. The McNemar test or Wilcoxon rank sum test was generated for categorical variables, such as the commonly eaten fish species, fish preparation practices, and common cooking methods. The difference of fish consumption and contaminant levels between two time point measurements was calculated to express the magnitude of change. Furthermore, regression analyses were used to assess the change in fish consumption over time adjusted for age, gender, education, region, baseline body mass index, and baseline contaminant levels. The same approach would be used to assess the change in the population contaminant levels over time adjusted for fish consumption as well as potential confounders stated above.

For participants with data from at least two-time points, time trends in fish consumption, in Aroclor 1260 levels, and their joint change pattern were examined. This analysis is complicated by the dependence among repeated observations made on the same participant, data were analyzed by Proc Mixed with the statement 'repeated' in SAS.

3 Findings

3.1 *Descriptive results and bivariate analysis*

3.1.1 ***Background characteristics of study population*** (Tables 1- 3)

Nearly 49 percent (610/1255) of participants were fisheaters, of whom male fisheaters were twice more than female fisheaters (66.3 percent versus 33.7 percent, $p<.001$) (Table 1). This difference may reflect that annually more fishing licenses issued to male than to females. The mean age of fisheaters was three years older than that of nonfisheaters (46 versus 43, $p<.001$), reflecting more nonfisheaters aged 15-24 and more fisheaters above age 45. Fisheaters education levels were lower than those of nonfisheaters. Overall, 17 percent of fisheaters reported having less than a high school level education, compared with less than 15 percent of nonfisheaters. Fisheaters were taller and heavier than nonfisheaters and they were more likely to report having been exposed to chemicals at the work place or at home. About the same proportion of fisheaters and nonfisheaters lived in the three regions of Michigan, i.e. Northern, Middle, and Southern established by the sampling scheme.

Once stratified by gender background characteristics of the study population, some difference between fisheaters and nonfisheaters became non-statistically significant. There were no significant differences observed with regard to educational attainment, region, height, and self-reported exposure to any chemicals between male fisheaters and nonfisheaters (Table 2). Male fisheaters were a little older and somewhat heavier than nonfisheaters. Nonfisheaters tended to be more highly educated but it was not significant (p=0.07). In females, fisheaters' age is older than that of nonfisheaters (p=0.04). Overall, 52 percent of fisheaters were 45 or more years of age, compared with 44 percent of nonfisheaters (Table 3). The association between fish eating status and education in fisheaters was significant (p=0.04), reflecting more nonfisheaters having a high school education or above. No differences were observed between fisheaters and nonfisheaters in terms of region, height, weight, and self-reported chemicals exposure.

3.1.2 *Characteristics of tobacco use and alcohol consumption in study population* (Tables 4, 5)

The proportion of never smoking was significantly higher in male nonfisheaters than that in fisheaters, 36 percent and 22 percent, respectively (Table 4). Among male participants who reported current or prior smoking, the average age of starting smoking was 18 years. Prior smokers in both the fisheater group and nonfisheater group reported that the mean age of they last smoked regularly was about 38 years of age. Current smokers, whether fisheaters or nonfisheaters, reported smoking about 25 cigarettes a day. Seventy seven percent of participants were current alcohol consumers, similar in both fisheaters and nonfisheaters. However, abstainers were more frequent among male nonfisheaters than among fisheaters. Fisheaters were more likely to be beer drinkers, and they usually drank more bottles/cans beer at a sitting than did their nonfisheater counterparts. Reported drinking of wine was more likely in nonfisheaters, regardless of whether judged by drinking frequency or by the quantity consumed at a sitting. No difference was observed in terms of liquor drinking habits. Fish consumption status did not appear to be a significant determinant of tobacco use or overall alcohol consumption among women, but was associated with beer drinking (Table 5). Nearly 37 percent of female fisheaters reported they drank beer more than once a week, compared with 22 percent of female nonfisheaters.

3.1.3 ***Fish consumption behaviors***

3.1.3.1 The first survey (Tables 6, 7):

One hundred and fifty six persons participated in 1973-74 survey, of whom 74 (47.4%) reported they annually ate 24 or more pounds of sport caught Great Lakes fish. These 74 constituted the fisheater group. The median number of annual fish meals reported consumed by male fisheaters is 56, which less than that for female fisheaters, 72 (Table 6). However, male fisheaters tended to eat a larger quantity of fish at each meal than did female fisheaters. The median usual portion serving size was 12.5 ounces for male and 9.0 ounces for female fisheaters. As a consequence, the total annual weight of fish consumed by female fisheaters was very similar to that consumed by male fisheaters, with the median total weight of fish consumed in the previous year being about 40 pounds for both males and females.

Fish consumption behaviors regarding the most common fish species eaten, as well as cooking and preparation methods are displayed in Table 7. Almost all fisheaters cited trout as one of their three favorite species of fish consumed. Nearly 65 percent referred to salmon and over 30 percent to perch. Less than a quarter of participants mentioned whitefish or catfish. Similar patterns were observed in both male and female fisheaters. Since every participant could report up to three most favorite fish species, the total proportion does not sum to 100. 50.8 percent of fisheaters preferred pan-frying to other cooking methods. Less than one-third of fisheaters cited broiling, or baking as one of their three favorite cooking methods. Nearly eight percent of male fisheaters, but no female fisheaters referred to deep-frying. The proportions of fisheaters reporting always trimming off fatty areas and removing skin in fish preparation prior to cooking were uniformly small for both males and females. No fisheaters reported they always removed fish skin prior to cooking. 9.5 percent of female fisheaters mentioned that they trimmed dorsal or belly fat areas prior to fish preparation, but 5.3 male fisheaters reported trimming off belly fat area and none reported trimming of dorsal fat area.

3.1.3.2 The second survey (Tables 8, 9):

Six hundred and ten out of 1255 participants (48.6 %) were fisheaters. As shown in Table 8, the proportion of fisheaters was higher in men than in women, 66 % versus 34%. Differences between men and women were observed with respect to total fish meals in a year and usual portion serving size. Female fisheaters reported a higher median number of annual fish meals consumed than did male fisheaters (58 versus 53), but the median usual portion serving size among women was one-third smaller than among their male counterparts (8 ounces versus 12 ounces). Based on the total weight of fish consumed in the preceding year, annual fish consumption for female fisheaters was lower than that of male fisheaters, 33 pounds compare to 40 pounds.

Trout and salmon were most frequently cited by fisheaters as one of the 3 most common species of fish consumed in survey II (Table 9). Forty two percent of fisheaters named perch, only 2 percent mentioned catfish, and none referred to whitefish. 65 percent of male fisheaters reported that pan-frying was one of their three favorite cooking methods, followed by broiling and deep-frying. None mentioned baking. Over half of female fisheaters cited broiling and pan-frying as one of their 3 most frequent cooking methods. About one-third percent mentioned deep-frying, only 3.3 percent named baking. With regard to fish preparation, 86.1 percent of fisheaters reported they always trimmed away the dorsal and belly fat area, and nearly half of fisheaters reported they always removed fish skin prior to cooking.

3.1.3.3 The third survey (Tables 10, 11):

Seven hundred and twenty eight persons participated in survey III (1989-91), of whom two-thirds were men; 49.3 percent (359/728) of the sample were classified as fisheaters. The median number of male fisheaters' annual fish meals, 34, was substantially higher than for females, 27. And the median usual serving size for males was larger than for females, 8 ounces versus 6 ounces. The total weight of annual fish consumption in male fisheaters was higher than in female fisheaters, 18 pounds compare to 11 pounds (Table10).

Fish consumption behaviors in fisheaters on survey III displays in Table 11. Around 50 percent of fisheaters picked trout, salmon, or perch as one of the three most frequently eaten fish, but everyone mentioned whitefish. Concerning cooking methods, pan-frying was most commonly mentioned as one of top 3 frequently used cooking methods. Approximately 30 percent of fisheaters picked baking, broiling, and deep-frying. With reference to fish preparation prior to cooking, about 90 percent of fisheaters reported they always trimmed away dorsal and belly fatty area, while 82 percent mentioned removing fish skin prior to cooking.

Figure 4 illustrates quantity of fish consumption among fisheaters over the three surveys. Figure 5 displays proportions mentioning as one of the top three species of fish consumed over the three surveys. Figure 6 shows fish preparation methods by survey.

3.1.4 *Laboratory measurements*

3.1.4.1 Laboratory data at survey I (Table 12):

One hundred sixty three persons donated blood samples in survey I, of whom male participants accounted for 47.9 (78/163) percent. 47.2 (77/163) percent were fisheaters. One participant's gender was unknown. Male participants had higher median levels of Aroclor 1254 in serum than did females, 35 ppb and 23 ppb, respectively (Table 12). The same pattern appeared for Aroclor 1260. The median levels of Aroclor 1260 were 12.5 ppb for men, 6.5 ppb for women. When PCB levels were stratified by fish eating status, Aroclors 1254 and 1260 serum levels in fisheaters were considerably higher than in nonfisheaters of both genders.

3.1.4.2 Laboratory data at survey II (Table 13):

In survey II, serum samples were tested for the presence of levels of Aroclor 1260, DDT, DDE, PBB, Aroclor 1016, hexachlorobenzene (HCB), beta-isomer of hexachloro-cyclohexane (Beta BHC), oxycholrdane, trans-nonachlor, and dieldrin. The contaminant levels in men were consistently higher than females with regard to Aroclor 1260, DDT, DDE, and PBB. The median levels of Aroclor 1260 in men and women were 16.3 ppb and 8.3 ppb, respectively. Median levels of PCB total were higher in men 17.6 ppb than in women 9.0 ppb . Levels of 22.5 ppb of DDT, 18.9 ppb of DDE, 1.9 ppb of PBB were found in men, compared with 14.2 ppb of DDT, 12.2 ppb of DDE, and 1.2 ppb of PBB in women. Aroclor 1260, PCB total, DDE, and DDT values were all significantly higher in fisheaters than in nonfisheaters for both sexes. After stratifying by fish eating status, male fisheaters had the highest contaminant levels of Aroclor 1260, DDT and DDE; female nonfisheaters had the lowest levels of these contaminants, while contaminant levels in female fisheaters were higher than male nonfisheaters but lower than those in male fisheaters. However, PBB levels did not show this pattern. Since very few serum samples had detectable levels of other contaminants, such as Aroclor 1016, HCB, beta BHC, oxychlordane, trans-nonachlor, and dieldrin, the results on these contaminants were not presented here and would not be used in any further analysis.

3.1.4.3 Laboratory data at survey III (Table 14):

The median levels of contaminant concentrations and ranges of contaminants detected in human serum samples at survey III are displayed in Table 14. The contaminant levels in men were consistently higher than in women in terms of all the contaminant levels tested in the survey, namely Aroclor 1260, DDT, DDE, and PBB. The median levels of contaminants in men were 13.1 ppb of Aroclor 1260, 12.6 ppb of DDT, 11.4 ppb of DDE, and 2.8 ppb of PBB, compared with 6.8 ppb Aroclor 1260, 7.8 ppb DDT, 7.0 ppb DDE, and 1.8 ppb PBB in women, respectively. Values of total PCB in survey III, as measured by Aroclors 1260 and 1016 as standards, were almost the same as Aroclor 1260, because Aroclor 1016 was hardly found in participants' serum specimens at that time. Again, all contaminant levels were higher in fisheaters than in nonfisheaters, the highest levels were always found in male fisheaters.

Figure 7 illustrates serum levels of Aroclor 1260 stratified by gender and fish eating status over the three surveys.

3.1.5 *Effect of general characteristics on the main fish consumption behaviors* (Tables 15 - 19)

A borderline significant linear trend between increasing age and increasing mean number of annual fish meals was demonstrated in male fisheaters (linear trend F=4.03, p=.05), but not in females. There was no linear trend between increasing age and increasing fish consumption with respect to the total weight of fish consumed in males or females (Table 15).

Education was significantly associated with fish consumption as measured by number of annual fish meals or total amount (pounds) of fish consumed. Fisheaters who reported having high school education or above ate less fish than those did not attain high school education level. This was especially true for female fisheaters (Tables 16).

Male fisheaters in the southern region reported eating less annual fish meals than those in the other two regions, whereas for women there was more of a north to south consumption in fish meals yearly (Linear trend F=3.44, p=.06 for men; Linear trend F=5.32, P=.02 for women). Male fisheaters living in the middle shoreline of Lake Michigan reported eating larger amount (pounds) of fish than those in either the south or north. Female fisheaters, however, consumed more pounds of fish among in the northern region (Table 17).

Body mass index in male fisheaters was significantly associated with fish consumption in terms of annual fish meals (chi-square=44.14, p<.001) as well as total weight of fish consumed (chi-square=42.90, $p<.001$). In male fisheaters, but not in females, a significant linear trend was also shown between body mass index and the total weight of fish consumed although the upward trend was irregular (Linear trend $F=5.50$, $p=.02$) (Tables 18-a, 18-b).

Self-reported chemical exposure status was not associated with the quantity of fish consumption (Table 19).

3.1.6 ***Effect of general characteristics on contaminant levels*** (Tables 20-24)

After stratifying by gender and fish eating status, the means of Aroclor 1260, DDT, and DDE levels in fisheaters were two to four times higher than in nonfisheaters at each age group. The magnitude of differences in these contaminant levels across different age groups was greater in males than in females. Linear trends were established between age and these contaminant levels both in fisheaters and nonfisheaters. No linear association between fisheater status and PCB levels or between age and PBB levels was found ($F=2.38$, $p=.12$) (Table 20).

A weak inverse association between education levels and mean Aroclor 1260 levels was demonstrated in fisheaters ($F=5.0$, $p=.03$ for male fisheaters; $F=13.0$, $p<.001$ for female fisheaters) as well as male nonfisheaters ($F=4.66$, $p=.03$). This effect pronounced most when comparing college education and non-college educated men. Education level appeared to be a significant determinant of mean DDT and DDE levels both in female fisheaters (DDT: linear trend $F=18.91$, $p<.001$; DDE: linear trend $F=21.38$, $p<.001$) and female nonfisheaters (DDT: linear trend $F=13.61$, $p<.001$; DDE: linear trend $F=14.82$, $p<.001$), but not in male participants. Female nonfisheaters with higher levels of education were more likely to have slightly lower PBB levels than less educated female nonfisheaters (linear trend $F=5.33$, $p=.02$). Such a linear trend between education and levels of PBB was found neither in fisheaters of both sexes nor in male nonfisheaters (Table 21).

Region was significantly associated with DDT levels both in male fisheaters (linear trend $F=20.27$, $p<.001$) and male nonfisheaters (linear trend $F=4.68$, $p=.03$) with the highest levels in northern Michigan. Mean DDT levels were twice as high in Northern than southern residents. The linear trends with respect to DDE and Aroclor 1260 levels were pronounced only in male fisheaters. Trends were similar, but not statistically significant in females. Mean PBB levels were strongly associated with region, regardless of gender and fish eating status. Participants who lived in middle part shoreline of Lake Michigan had the highest levels of PBB, compared with those lived in northern and southern region (Table 22). The results were consistent with greatest amount of affected PBB farms in the middle region.

Body mass index was significantly linearly related to DDT and DDE levels in both sexes, regardless of fish eating status. The same pattern was observed in 1260 levels for men but not for women. An inverse linear trend between body mass index and levels of PBB was shown in female fisheaters ($F=7.32$, $p=.01$) (Tables 23-a, 23-b).

No association between self-reported chemical exposure status and these four contaminant levels were found (Table 24).

3.1.7 ***Relationship between fish consumption and contaminant levels*** (Tables 25, 26)

Significant linear trends were demonstrated between fish consumption both in terms of annual fish meals (Tables 25-a, 25-b) and total weight of fish consumed (Table 26-a, 26-b) and Aroclor 1260, DDT, DDE levels. Similar patterns were observed in men and women. There was no such trend in PBB levels.

3.1.8 ***Pairwise comparisons of individuals surveyed more than once***

3.1.8.1 Survey I versus survey II (Tables 27-29)

Fifty-two men and 63 women participated in survey I and survey II. Paired comparisons stratified by gender are displayed in Table 27. Information on quantity of fish consumption was available in 55 fisheaters-34 males and 21 females. In male fisheaters, a small non-significant decrease in fish consumption was observed with regard to total fish meals and also a small decreasing in usual portion size. Total weight of fish consumed in a year did decline significantly (paired t=2.0, p=0.05). In female fisheaters, time change was strongly associated with fish consumption behaviors. The means annual fish meals were 94 in survey I and 61 in survey II (paired t=3.88, p=0.01). A considerable decrease was presented in mean portion serving size, which changed from 10.3 ounces in survey I to 7.9 ounces in survey II (paired t=7.9, p=0.01). The mean total weight of fish consumed in the preceding year decreased nearly 50 percent-from 60.8 pounds to 33.1 pounds in females (paired t=3.43, p=0.01).

Data on surveys I and II indicated an overall similar profile in male and female fisheaters with respect to fish preparation and cooking methods, and favorite fish species consumed. The proportions of fisheaters reporting trimming away dorsal and belly fatty area were low in survey I (under 10 percent), but substantially higher in survey II (over 50 percent) (Table 28). None of fisheaters reported removing fish skin in survey I, but over 20 percent reported doing so in survey II. With regard to cooking methods, pan-frying was the commonest procedure cited by males in both surveys and by females in survey I. Women also picked baking as one of the three most common cooking methods, but no significant difference was observed between surveys I and II data. A trend towards less baking and more pan-frying was seen in both genders. Trout and salmon were consistently picked by fisheaters as their preferred fish species in both surveys. A slight shift from trout to salmon was seen in both men and women--the proportion citing trout being one of top 3 went down (McNemar test $p=0.03$ for men, $p=0.06$ for women), and the proportion citing salmon went up but there is no statistical significance. Although approximately 20 percent of subjects listed whitefish as preferred in survey I, none of fisheaters named whitefish as one of top 3 fish species in survey II, a reduction was significant for men ($P=.004$).

An upward shift of serum Aroclor 1260 was observed between the two surveys in the 58 men and 65 women for whom serum data were available. Results presented in Table 29. Over this period, levels of Aroclor 1260 significantly increased from 21.3 to 34.0 ppb for men, 8.3 to 15.2 ppb for women (Paired t test: $t=4.26$, $p<0.001$ for men; $t=6.61$, $p<0.001$ for women). These significantly increased changes in Aroclor 1260 were pronounced in both sexes, regardless of fish eating status. The magnitude of increase in Aroclor 1260 was higher in fisheaters than in nonfisheaters, and was higher in men than in women.

3.1.8.2 Survey II versus survey III (Tables 30-32)

Substantial reductions in the overall mean number of annual fish meals and in portion serving size were apparent in both male and female fisheaters, and as a result, a considerable decrease in total weight of fish consumed in a year was demonstrated (Table 30). Fisheaters reported annually consuming 52 pounds for men, 40 pounds for women in survey II, but their consumption was reduced to 25 and 16 pounds in survey III, respectively.

Data pertaining to trimming away dorsal and belly fat and removing fish skin prior to cooking showed that these practices had substantially increased in men and women. Approximately 72 percent in men and 62 percent in women fisheaters reported trimming away fat areas in survey II, whereas these proportions went up to over 90 percent in men and 88 percent in women in survey III (Table 31). As many as 80 percent of fisheaters reported removing fish skin before cooking in survey III, compared with only one-third of fisheaters who did so in survey II. The proportions of fisheaters that named pan-frying and deep-frying as one of the three commonest cooking methods remained basically unchanged. About a 30 percent increase was observed in the proportion of fisheaters who mentioned baking as one of the top three cooking methods in survey III, compared with very few fisheaters who did so in the previous two surveys. Fewer fisheaters referred to broiling as one of the top three cooking methods in survey III, but a statistically significant reduction in this cooking method was observed in men only. A noteworthy change appeared in the common species of fish consumed. With respect to one of three most common species of fish consumed, less than 47 percent of fisheaters cited trout and less than 60 percent cited salmon in survey III, as compared with over 90 percent for both species in survey II. The magnitude of differences was larger in terms of trout than of salmon. The change in referring to whitefish as one of 3 top favorite fish species was very striking-from none in survey II to all in survey III.

A considerable downward shift was found both in fisheaters and nonfisheaters with respect to DDT, and DDE levels in serum (Table 32). The mean serum Aroclor 1260 levels decreased significantly from 26.3 to 21.7 ppb in men ($t=6.86$, $p<.001$). A reduction of marginal statistical significance also appeared in females (11.1 ppb in survey II to 10.0 ppb in survey III; $t=1.92$, $p=.06$). After stratifying by fish eating status, decreasing changes of Aroclor 1260 levels in all subgroups were statistically significant with exception of female nonfisheaters. Over the same time period, there was slight increase seen in the levels of serum PBB distributions in females (2.5 ppb in survey II and 2.6 ppb in survey III, respectively) but not in males.

3.1.8.3 Survey I versus survey III (Tables 33-35)

Twenty eight fisheaters, 15 of whom were male, 13 female, provided information on fish consumption in both surveys I and III. Forty three participants had Aroclor 1260 values during these two-time points. Although decreasing tends in annual fish meals and serving size in male fisheaters were not statistically significant over this time period, the total weight of fish consumed in a year decreased considerably (44 pounds and 25.8 pounds between survey I and III, respectively) ($t=2.25$, $p=.04$) (Table 33). A substantial decrease in number of annual fish meals ($t=3.30$, $p=0.01$) and total weight of fish consumed was also seen in female fisheaters ($t=3.02$, $p=.02$).

The proportions of fisheaters reported trimming away fat areas and removing fish skin increased in a great deal from survey I to survey III . An increasing proportion of fisheaters cited baking and pan-frying as one of the top three cooking methods these change were not statistically significant (Table 34). More fisheaters referred to whitefish as one of the three favorite species of fish consumed in survey III. Significant reductions in the proportions of fisheaters choosing trout and salmon occurred, especially in males.

Changes in Aroclor 1260 levels based on 15 male and 28 female paired blood samples from survey I to III are presented in Table 35. Aroclor 1260 levels in males tended to be higher in survey III than in survey I, but no statistical significance was found for either fisheaters or nonfisheaters. Levels of Aroclor 1260 in females were significantly higher in survey III.

3.2 *Multivariate analysis*

The bivariate analyses reported above document substantial variability in fish consumption behavior and serum contaminant levels. This section presents the results of multivariate statistical analyses of the survey data undertaken in order to address the following question--when the various factors considered are taken into account simultaneously (i.e., controlled statistically), which factors emerged as the key dimensions underlying the observed variations in fish consumption behaviors and/or serum contaminant levels? The answer to this question is important to decision-makers, both for the purpose of targeting research efforts at particular population subgroups, as well as for use in refining health education strategies so as to more effectively 'reach' different population sub-groups.

3.2.1 ***The structure of multivariate analysis***

3.2.1.1 Multiple linear regression analysis within each survey

Within each survey, quantity of fish consumed and log transformed contaminant levels were selected and analyzed as dependent variables. Participants' age, education level, region, and body mass index were used as potential predictors in regression models of fish consumption. In models for predicting contaminant levels, current sport fish exposure (annual fish meals) and cumulative sport fish exposure (fish eating status) were treated as main exposure variables and included in the models. The models were controlled for potential confounding factors by including these factors into the models. Analyses were performed for males and females separately.

3.2.1.2 Multiple linear regression analysis between surveys

For participants with data from two time points, differences for two primary fish consumption variables (annual fish meals and total weight of fish consumed) and changes in contaminant levels (Aroclor 1260, and DDT, DDE, PBB, if applicable) were calculated. The absolute changes in these two measures of fish consumption and in contaminant levels between two-survey time were chosen and analyzed as outcomes or dependent variables in multiple linear regression. Changes in annual fish meals and changes in total weight of fish consumed were included in multiple linear regression models separately. Apart from general characteristics considered in bivariate analyses-age, education, region, baseline body mass index, baseline annual fish meals were also included in models, where baseline mean data obtained in the earlier survey of the two compared surveys. Change in annual fish meals served as the main predictor variable of

interest, and was included in regression models of predicting differences in contaminant levels, after adjustment for age, education, region, baseline body mass index, fish eating status, and baseline contaminant levels.

3.2.1.3 Repeated measures model analysis over the three surveys

Over the three cross-sectional surveys, participants were involved in either one, or two, or all three surveys. Two to three repeated measures were obtained from 462 participants over the three survey times. Since the analysis is complicated by the dependence among repeated observations made on the same participant, and data on some participants may be unbalanced or partially incomplete, such scenarios can be handled by Procedure Mixed with statement 'repeated' available through Statistical Analysis Software (SAS). The repeated measure models were used to examine time trends in quantity of fish consumption and joint changes in levels of serum Aroclor 1260 over about 20 years period of the three surveys.

3.2.2 ***The coding of multivariate analysis***

Linear regression results are presented in the form of regression coefficients and respective standard errors. Regression coefficients are interpretable as the association of the average change in outcome for a unit change in a given predictor variable, adjusted for potential confounders. The regression coefficients provide a measure of adjusted, or net, quantitative association. Levels of statistical significance are indicated next to each regression coefficient. The operational definitions of the outcome variables and the predictor variables considered in the analysis are indicated in the box below.

Variable	Regression coding
Gender	Female (reference) Male
Age	Entered as continuous variable (year)
Education	4 dummy variables: Elementary school (reference) Some high school High school graduation Some college College graduation and above
Region	2 dummy variables: North (reference) Middle South
Body mass index	Entered as continuous variable
Fish eating status	Nonfisheaters (reference) Fisheaters
Annual fish meals	Entered as continuous variable
Total weight of fish consumed	Entered as continuous variable (lbs)
Quartile of total weight of fish consumed	3 dummy variables: 1 (reference) 2 3 4
Change in annual fish meals	Entered as continuous variable (meal)
Change in total weight of fish consumed	Entered as continuous variable (lbs)
Aroclor 1260, DDT, DDE, PBB levels	Entered as continuous variable in scale either arithmetic (ppb) or log transformed
Change in Aroclor 1260, DDT, DDE, PBB levels	Entered as continuous variable (ppb)
Survey time	2 dummy variables. survey I (1973-74) (reference) survey II (1979-81) survey III (1989-91)

3.2.3 *Results of multivariate analysis*

3.2.3.1 Fish consumption within surveys I, II, and III (Tables 36, 37)

The two outcomes chosen for further analysis for fish consumption at each survey time were 1) annual fish meals, and 2) total weight of fish consumed. Except for region, general characteristics of male fisheaters, namely age, education, and body mass index were not significantly linear associated with either annual fish meals or total weight of fish consumed within each survey time point. Survey II data shows that males who lived in the south reported a considerably larger amount of fish consumed as measured by total pounds of fish consumed yearly, compared with those living in north of Michigan (B=10.60, p=.01) (Table 37). Females living in the middle area of Michigan reported a considerably higher quantity of fish consumption than those living in north Michigan as measured either by annual fish meals (B=36.17, p=.002) (Table 36) or total weight of fish consumed (B=28.25, p=.001) (Table 37) in survey II. The first and second surveys showed that women having some high school, had graduated from high school, or had some college, had fewer annual fish meals. However, this relationship was reversed in survey III data, making it difficult to be interpreted. It is noteworthy to point out that factors considered in models to predict the quantity of fish consumption were not strong predictors, especially in surveys II and III. In combination, these four predictors only explained 3 to 19 percent of the variances of models, as indicated by R square values.

3.2.3.2 Log levels of Aroclor 1254 in survey I (Table 38)

After controlling for demographic characteristics and body mass index, quartiles of total weight of fish consumed (pounds) appeared to be predictors of Aroclor 1254 levels (log transformed) in both sexes. The significant linear association between age and log levels of Aroclor 1254 was demonstrated in female fisheaters (b=0.02, p<.001). This association was identified in male fisheaters, but it was not statistically significant (b=0.01, p=.07). The older the participant's age, the higher the levels of Aroclor 1254.

In the models, adjusting for general characteristics, either eating status or quartile of annual fish meals is significantly associated with log levels of Aroclor 1254 while these two variables included in the models separately. The association between eating status and Aroclor 1254 levels became non-statistically significant once including quartile of annual fish meals into the models. The regression coefficients of quartile of total weight of fish consumed did not change much (less than 5 percent) with or without eating status in the models (Data not presented here).

3.2.3.3 Log levels of Aroclor 1260 within surveys I, II, and III (Table 39)

Within each survey in both sexes, the results showed that the larger the amount of fish consumed, the higher the Aroclor 1260 levels. Participants' fish eating status were also significantly associated with log levels of Aroclor 1260 in both surveys II and III in men and survey III in women. An association was seen between increasing age and elevated log Aroclor 1260 levels in both surveys II and III in men and all three surveys in women. Participants, who were male, older, a fisheater, or reported having large quantity of fish consumed annually, were more likely to have a high level of Aroclor 1260. The same patterns were demonstrated in women. In addition, female's education level was significantly related to her log levels of Aroclor 1260 in surveys II and III. Women having high school education or above presented considerably lower log levels of Aroclor 1260, compared with those educated at only elementary level. After adjusting for general characteristics, regression coefficients for the separate model with eating status or with quartile of total weight of fish consumed were statistically significant. In models with both sport fish exposure variables, eating status contributed to the models is getting more significant in survey III, while quartile of total weight of fish consumed contributed more in the earlier surveys. Figures 8 and 9 display multiple linear regression of log Aroclor 1260 levels against quartile of total weight of fish consumed over the three surveys for males and females, respectively.

3.2.3.4 Log levels of DDT and DDE within surveys II and III (Tables 40, 41)

Log DDT and DDE levels were highly associated (Pearson $r=0.98$, $p<.001$). After adjusting for potential confounding factors, quartile of total weight of fish consumed was significant associated with log levels of these two contaminants in survey II in both sexes and in survey III in women, whereas survey III data in men shows a significant association between quartile of annual fish meals and log levels of DDT or DDE which was diminished once fish eating status was included in the models. A significant linear association between age and log levels of DDT or DDE was consistently shown in men and women. Education level is inversely related to log DDT or DDE levels in both surveys for females but not for males. Women who living in middle or south Michigan had higher DDT and DDE levels than those in north Michigan.

3.2.3.5 Log levels of PBB within surveys II and III (Table 42)

Region appears to be a strong predictor of log PBB levels in both sexes at surveys II and III. Participants living in middle or south Michigan had higher PBB levels than those in north Michigan. No statistically significant association between log PBB levels and fish consumption as measured by fish eating status or by quartile of total weight of fish consumed was observed in either sex. But in survey III, women with the third or forth quartiles of total weight of fish consumed had higher log PBB levels compared with those with lowest quartile.

3.2.3.6 Changes in fish consumption between surveys--- from survey I to II and from survey II to III (Table 43)

Results of regression analyses showed the same pattern based on the two dependent variables of fish consumption with respect to quartile of absolute change in annual fish meals and absolute change in total weight of fish consumed. Therefore, Table 43 only presented results of regression analysis on change in total weight of fish consumed based on two time point data from survey I to II or survey II to III. There were 114 participants with data on demographic characteristics and Aroclor 1260 levels during survey I and II. Age, education, region, and baseline body mass index were included as independent variables in regression models to explain the variability of change in total weight of fish consumed. All results are stratified by sex. Baseline total weight of fish consumed, in addition to age, gender, region, and baseline body mass index, was a covariate in the final model, with p values less than 0.001 in both sexes. The regression coefficients (standard error) for baseline total weight of fish consumed were 0.73 (0.14) for male fisheaters and 0.59 (0.07) for female fisheaters, respectively. The R square was 0.47 and 0.68 for the model in male fisheaters and female fisheaters, respectively. The decline in fish consumption was greater in fisheaters who reported having higher baseline fish consumption than that in fisheaters having lower baseline fish consumption.

There were 391 participants with information on fish consumption from surveys II and III. Two hundred and three of 391 (51.9 percent) participants were regular fisheaters, of whom 139 were male. Separate data for both sexes showing the linear relation of general characteristics to change in total weight of fish consumed from survey II to III are presented in Table 43. Only baseline fish consumption entered the model at the significance level of p less than 0.05; other factors considered in models were not strong predictors of changes in total weight of fish consumed.

3.2.3.7 Changes in levels of Aroclor 1260 between surveys----from survey I to II and survey II to III (Table 44)

In women, the largest quartile of change in total weight of fish consumed from survey II to III is strong predictor of changes in Aroclor 1260, as compared to the lowest quartile of change in total weight of fish consumed (b=3.61, p=.03); cumulative sport fish exposure status and baseline Aroclor 1260 levels also significantly contributed to the model of change in levels of Aroclor 1260 from survey II to III (b=-3.56, p=.02 for fish eating status; b=0.26, p<.001 for baseline Aroclor 1260 levels, respectively), this associations was not found in data from survey I to II. Change in Aroclor 1260 levels in men has different pattern from women. Quartile of change in total weight of fish consumed did not appear to be a strong predictor of changes in Aroclor 1260 levels in men based on data of survey II to III, while male participants with larger baseline body mass index had smaller changes in Aroclor 1260 levels (b=-61.71 p=.02); no significant association between change in PCB levels and other covariates was found in both survey intervals. Figures 10 shows multiple linear regression of change in Aroclor 1260 levels against quartile of change in total weight of fish consumed in males and females over the three surveys.

3.2.3.8 Changes in levels of DDT from survey II to III (Tables 45-a, 45-b)

Based on the two-time points data of survey II and III, regression of change in DDT against quartile of changes in total weight of fish consumed after controlling for age, education, region, baseline BMI, and baseline DDT levels are presented, stratified by gender, in Tables 45-a and 45-b. Fish consumption was a significant predictor of changes in DDT levels; the change in contaminant levels were strong predicted by changes in annual fish meals in men (b=0.09, p=.03), and by cumulative sport fish exposure status in women (b=-3.43, p=.03). Baseline DDT levels were positively associated with changes in DDT levels in both sexes. Men with larger body mass indexes had slower reductions of serum DDT levels (b=-123.00, p=.003). Older women experienced considerably slower reductions in DDT levels (b=-0.15, p=.004) (Table 45-a). However, when quartile of change in total weight of fish consumed was included in the model instead of absolute change in annual fish meals, no association between change in DDT levels and quartile of change in total weight of fish consumed was found in both sexes (Table 45-b).

3.2.3.9 Changes in levels of DDE from survey II to survey III (Table 46-a, 46-b)

Change in annual fish meals significantly contributed to change in DDE levels. After stratified by gender, this association was only found in men (b=0.08, p=.02) (Table 46-a). when quartile of change in total weight of fish consumed was included in the model instead of absolute change in annual fish meals, the highest quartile of change in fish consumption was marginal associated with change in DDE levels, as compared with the lowest quartile of fish consumption in men (b=8.24, p=.05) (Table 46-b). No significant association between change in DDT levels and fish consumption was found in women. Consistently, baseline DDE levels were also significantly associated with DDE change from survey II to III in both sexes. Baseline body mass index in men was inversely related to change in DDE levels (b=-117.55, p=.003) (Table 46-b).

3.2.3.10 Changes in Levels of PBB from survey II to III (Table 47)

After adjusting for potential confounders, change in PBB levels in both sexes only depended on the baseline PBB levels and was not associated with either fish eating status or change in fish consumption.

3.2.3.11 Trends of changes in fish consumption, in log Aroclor 1260 levels, and joint changes in fish consumption and log Aroclor 1260 over the three surveys (Tables 48-51)

Repeated measures analyses were performed based on 462 participants with two- or three-time point data in order to evaluate the changes in fish consumption, in log Aroclor 1260 levels, and joint changes in fish consumption and log Aroclor 1260 levels over three surveys. Significantly decreasing trends were observed in fish consumption among fisheaters as measured by the annual fish meals (b=-21.93 meal/decade, p<.001) or total weight of fish consumed (b=-21.16 pound/decade, p<.001) after controlled for potential confounding factors-gender, age, education, and region. Table 48 displays total weight of fish consumed against 3 times of survey after controlling for gender, age, education, and region. Figure 11 illustrate time trends in total weight of fish consumed in the period of the three surveys. Log levels of Aroclor 1260 elevated from survey I to II (b=0.10 ppb/decade, p=0.37) and significantly decreased in survey III compared with survey I (b=-0.42 ppb/decade, p<.001), after controlling for sex, age, education, region, but not for fish consumption (Table 49). However, when including variable-total weight of fish consumed in the model stated above, log levels increased significantly from survey I to II (b=.31, p=.002) and remained high in survey III (b=.13, p=.19) (Table 50). Significant linear relationship between log Aroclor 1260 levels and group of total weight of fish consumed was seen in both sexes after adjusting for age, gender, education, and region (Table 51 and Figure 12).

4 Discussion

4.1 Strength of the present study

Most previous studies investigating the relation between sport caught Great Lakes fish consumption and human serum levels of contaminants were cross-sectional (43, 84). But Hovinga's work(85, 86) examined change in PCB and DDT levels from two Michigan anglers survey conducted in 1982 and 1989. In the present study, the unique strength is that this secondary data analyses combined three cross-sectional surveys conducted in 1973-74, 1979-82, and 1989-91. The association of contaminant levels and fish consumption behaviors could not only be examined within each survey separately, but between surveys. Pairwise comparisons could be made among participants with two-time survey data; furthermore, nearly one-third of participants had two- or three- time points data which provided an basis for evaluation of patterns of changes in fish consumption and in contaminant levels through long term, low dose environmental exposure to contaminated fish over about a 20-year time window.

4.2 *Time trends in fish consumption behaviors among fisheaters*

It is clear from three- survey data that considerable decline has been observed in annual fish meals and total weight of fish consumed over 20 years among fisheaters. The combination of eating less sport caught Great Lakes fish, of modifying fish-cleaning or preparation methods, and changing the choice of favorite fish species sought and eaten, are the three most common changes. This may come as no great surprise, as awareness of the potential toxicity of sport caught Great Lakes fish motivated health departments in several states around the Great Lakes to issue fish consumption advisories. Survey III data shows that the majority of fisheaters now trim away fatty areas and remove fish skin prior to cooking. The shift of favorite fish species began during the period of survey I and II, but a larger shift occurred between survey II to III- with every fisheater in the study citing whitefish, a less contaminated fish species, as one of the most frequent fish consumed and the proportion of fisheaters citing trout and salmon dropping significantly. Our results are comparable to the survey conducted by Connelly and Knuth (87). They studied 8,000 licensed sport anglers from all the US Great Lakes States and found that 36 percent of the respondents had made changes in their fish consumption behaviors with respect to consuming less fish and modifying their fish preparation methods. In response to increasing study findings from fish, wild life, and animal studies, fisheaters become more aware of their general health and reduced their sport fish consumption accordingly. It is also possible that the number of fishermen who depend on fish as a food supplement has decreased because of economic improvement. The purpose of fishing is probably more for recreation now than for seeking food searching. Changes in fish-cleaning and preparation ways and favorite fish species shift may be attributable to state health fish advisories. It may be possible that the shift in the most common fish species consumed to whitefish may happen to be more whitefish are available than salmon and trout because of ecosystem changes. This needs to be confirmed. No clear pattern of cooking method or change in cooking methods could be identified in fisheaters. Fish advisories encourage fisheaters to broil or bake fish and to avoid frying. Yet fisheaters have their personal preferences about produces the best taste, despite acknowledgment of other advice.

4.3 Determinants of contaminant levels

4.3.1 Fish consumption

Although each of the general factors considered was observed to be associated with serum contaminant levels and their changes at one point or another in the analysis, two factors emerge from the surveys as being especially strong determinants of levels of Aroclor 1260, DDT, DDE. The first of these is fish consumption. Serum contaminant levels of fisheaters are strikingly higher than those of participants from the same area who report eating less sport Great Lakes fish in a year, even after adjusting for potential confounding factors. A dose-response relationship was observed-the higher the fish consumption, the higher the levels of contaminants. Statistical coherence in the form of a linear dose-response relationship strongly supports the causal relationship, but any other statistical relationship needs to be explored further.

In the multiple linear models, adjusting for general characteristics, either eating status or quartile of annual fish meals is significantly associated with log levels of contaminants. Once both fish eating status and annual fish meals were included in the models, one or the other is statistically significant. In the earlier survey data, total weight of fish consumed contributed more to the models than did eating status, while fish eating status contributed more to the models in the later survey data. Almost every participants' fish eating status was defined at survey I or survey II, based on quantity of fish consumed and remained unchanged over the survey time. Hence, quantity of fish consumption, such as total weight of fish consumed or number of annual fish meals, may carry more information than does the binary variable-fish eating status. In survey III, fish eating status became more important than quantity of fish consumption to the models, which reflects cumulative sport fish exposure being more important than current exposure in the late survey time. The overall environment has been improved for more than 20 years. The levels of contaminants in fish have decreased greatly. Among fisheaters, the drop in quantity of fish consumed and the shift in fish consumption behaviors to recommended fish preparation practices have been demonstrated. As a result, effect of current sport fish exposure on levels of contaminants has been diminished, but cumulative sport exposure indicating historical exposure still remains a strong predictor of current contaminant levels.

4.3.2 Gender

The second factor is gender. The results indicate that contaminants found in human serum especially DDT, DDE and Aroclor 1260 were consistently and significantly higher in males than females. This could be explained by men having more contaminated fish exposure than women. Since the lipophilic nature of these contaminants, levels of total lipids in human blood need to be taken into account when examining the relationship between gender and levels of contaminants. Storage and excretion of these contaminants in human tissue may be influenced by the lipid levels. The descriptive statistics of total lipids levels stratified by gender and fish eating status based on survey II data is presented in Appendix II, and results of Pearson correlation analyses are displayed in Appendix III. Lipid levels are significantly higher than in males than females. Lipid levels are positively associated with levels of contaminants (Pearson $r=0.36$ for Aroclor 1260; $r=0.34$ for DDT; $r=0.34$ for DDE; all p values $<.001$; Pearson $r=0.09$ for PBB, $p=.002$). Lipid levels alone contributed to 13% of the variance of log Aroclor 1260 levels, 12% of the variance of log DDT levels, and 11% of the variance of log DDE levels; all p values are less than .001. Therefore, regression analyses have been rerun after controlling for lipid levels by including lipid levels in the models. The results show an association between the quantity of fish consumption and levels of Aroclor 1260, or DDT, or DDE, after adjusted potential confounding factors included in previous models as well as lipid levels. The lipid levels did not explain gender differences in log PCB body burden based on our data.

Hovinga(85) found that between 1982 and 1989, mean serum DDT levels decreased substantially in both 115 fisheaters and 95 comparisons, while no correlation was found between changes in DDT body burden and fish consumption. Hovinga's work failed to detect the effect of fish consumption on changes in DDT, which is probably attributable to the relatively small sample size. In the present study, reduction in levels of DDT, and DDE contaminants from survey II to survey III has been demonstrated and confirms that finding in Hovinga's work. Data from the present study further demonstrate that changes in DDT and DDE levels are determined by not only the baseline DDT or DDE levels, but by the number of annual fish meals as well. While stratified by sex, the effect of eating less fish on reduction in DDT or DDE is pronounced for men only. Since the use of DDT was banned in the United States in 1972, DDT and DDE levels in western populations have declined since the 1970s(88, 89). The measurable reduction in DDT or DDE body burdens found in this study may be due in part to the overall reduction in environmental DDT or DDE contamination in the environment and in fish tissue. But also it appears that high-risk populations are heeding fish consumption advisories and therefore reducing their quantity of fish consumption, which also leads to reduce in DDT/DDE body burden.

4.4 Joint change in fish consumption and contaminant levels

Although studies of Great Lakes fish and wildlife confirm that the levels of PCB have declined since the mid-1970's(90-93), and the results from this study documented downward trends in fish consumption, over the time period of the surveys, the levels of Aroclor 1260 have not yet decreased. The lack of concurrent decline in PCB concentrations in human serum probably reflects the persistent nature of PCBs. An apparently declining trend has been demonstrated in DDT concentrations in at-risk sub-population (fisheaters) from 1980s to 1990s, but considering PCB was banned later than DDT. A decrease in body burdens of PCBs in human population may be expected to follow declining DDT levels. And because of the long half-live of PCBs, this decline may be expected to lag considerably behind the PCB decline in the environment. There may have other reasons for the static PCB levels in the target population studied. Although PCB production was ceased in the United States in 1977, very large quantities of PCB remain in industrial use. Thus, waste site leakage or other sources of PCB contamination such as atmospheric deposition may be major sources of exposure rather than fish consumption. Restrictions on PCB production alone may reflect not ensure apparently decreasing levels of PCBs exposure in human populations.

PBB is a unique contaminant for Michigan residents. It is not a fish-born contaminant and its levels were not associated with the quantity of fish consumption. This has been confirmed in this study, which indirectly illustrates that our study data are reliable.

5 Limitations

5.1 *It was not a population-based sample.*

Because the recruitment in the three surveys was based on volunteers, selection bias may exist. Participants who remained in the study from the earlier studies may be more aware of the safety of fish consumption. This may affect their fish consumption behaviors.

5.2 *Information on fish consumption in the majority of nonfisheaters was not available.*

Fish consumption information on the majority of nonfisheater was not available. Probably some of nonfisheaters ate a small amount of fish, but it is impossible to quantify their fish consumption in this study. The values of these participants' quantity of fish consumption were set to zero in the analysis. This may slightly dilute the association between fish consumption and levels of contaminants, but would not alter our overall conclusions.

5.3 *Information on PCB levels in the Great Lakes fish was not integrated into the analysis.*

We are not able to integrate PCB levels of fish tissue in the analysis due to lack of detailed information on PCB levels in the Great Lakes fish. Therefore, it is impossible to ascertain exposure more precisely. Since PCB levels in fish are associated with fish's characteristics, for example, fish species, size, age, etc.

5.4 ***Few participants had three data points.***

Participants remained in the surveys were more likely to be fisheaters. However, in terms of gender, age, and body mass index, there is no difference between participants with one survey data and with 2- or 3- survey data (data not present here).

6 Future study needs

Although earlier studies showed higher body burdens of PCBs in populations who consumed a lot of fish from contaminated waters, the health effects in humans are controversial. PCB body burdens have been measured in the majority of the epidemiological studies. However, PCB may simply reflect exposure to other fish-borne contaminants.

No information is available in the United States on the levels of polychlorinated dibenzodioxins PCDDs and PCDFs in anglers who consume a great deal of fish presumed to be contaminated by these chemicals. In light of the above statement, future epidemiological studies should focus on highly exposed, susceptible populations such as occupational exposed workers, reproductive aged women, children, and the aged. Results from these studies would provide important information on the risk of perinatal or adult exposure to PCBs, although generalization of results obtained in these populations to the general population may be fraught with difficulties.

A downward trend of human serum PCB, DDT and DDE has been shown since 1980s. And a continuous decline of PCB, DDT and DDE human body burden could be expected due to documented decreases in the overall environment. Fish advisories need to be modified based on updated information on contaminant levels.

TABLES

Table 1. Background characteristics of all study population, 1979-82

	Fisheaters	Non-Fisheaters	χ^2/ t	P-value
Number of participants	610	645		
(%) Gender:			64.62	<.001
Male	66.3	42.9		
Female	33.7	57.1		
(Mean) Age in years	46.0	43.1	3.54	<.001
(%) Age:			28.68	<.001
15 - 24	3.6	10.2		
25 - 34	20.0	24.7		
35 - 44	26.3	21.4		
45 - 54	21.2	18.3		
55 - 64	17.9	15.0		
65+	11.0	10.4		
(%) Education:			12.08	.02
Elementary school	4.6	5.2		
Some high school	12.4	9.2		
High school graduate	42.0	35.8		
Some college	23.3	26.6		
College graduate	17.7	23.2		
(%) Area of residence			1.71	.43
North	28.9	27.7		
Middle	31.6	35.2		
South	39.5	37.1		
(Mean) Height in inches	68.5	67.1	6.17	<.001
(Mean) Weight in pounds	175.6	158.2	9.08	<.001
(%) Exposed to any kind of			7.55	.01
chemicals: Yes	32.5	25.4		
No	67.5	74.6		

Table 2. Background characteristics of male participants, 1979-82

	Fisheaters	Non-Fisheaters	χ^2/ t	P-value
Number of participants	403	241		
(%) Age:			12.74	.03
15 - 24	4.0	7.5		
25 - 34	18.4	24.9		
35 - 44	28.5	21.2		
45 - 54	19.9	18.7		
55 - 64	18.1	13.7		
65+	11.2	14.1		
(%) Education:			8.83	.07
Elementary school	4.7	7.2		
Some high school	12.7	9.7		
High school graduate	39.2	32.5		
Some college	24.7	24.1		
College graduate	18.7	26.6		
(%) Area of residence			1.46	.48
North	29.3	25.3		
Middle	31.3	34.9		
South	39.5	39.8		
(Mean) Height in inches	70.6	70.4	0.74	.45
(Mean) Weight in pounds	191.5	178.3	5.88	<.001
(%) Exposed to any kind of			0.00	0.99
chemicals: Yes	41.4	41.5		
No	58.6	58.5		

Table 3. Background characteristics of female participants, 1979-82

	Fisheaters	Non-Fisheaters	χ^2/ t	P-value
Number of participants	205	321		
(%) Age:			11.69	.04
15 - 24	2.5	9.0		
25 - 34	23.5	24.6		
35 - 44	21.6	22.1		
45 - 54	24.0	19.9		
55 - 64	17.6	17.4		
65+	10.8	6.9		
(%) Education:			9.93	.04
Elementary school	4.5	2.6		
Some high school	11.9	8.7		
High school graduate	47.5	38.8		
Some college	20.8	27.5		
College graduate	15.3	22.3		
(%) Area of residence			1.08	.58
North	28.3	29.3		
Middle	32.2	35.5		
South	39.5	35.2		
(Mean) Height in inches	64.5	64.6	0.42	.67
(Mean) Weight in pounds	144.4	142.8	0.72	.47
(%) Exposed to any kind of			0.01	.92
chemicals: Yes	14.6	14.3		
No	85.4	85.7		

Table 4. The characteristics of tobacco use and alcohol consumption of male participants, 1989-91

	Fisheaters	Non-Fisheaters	χ^2/ t	P-value
Number of participants	238	152		
(%) Smoking			9.89	.01
Never	22.3	36.2		
Ex-smoker	48.9	44.3		
Current smoker	28.8	19.5		
Among ex_smoker and cur_smoker				
(Mean) Age started smoking	18.0	18.0	0.11	.91
Among ex_smoker				
(Mean) Age last smoked regularly	38.9	38.3	0.27	.79
Among cur_smoker				
(Mean) number of cigarettes a day	25.5	25.2	0.11	.91
(%) Drinking			10.64	.004
Abstainer	7.6	15.9		
Ex_user	15.1	7.3		
Current user	77.3	76.8		
Among current drinkers:				
(Mean) bottles/cans beer at a sitting	1.1	0.8	2.10	.04
(%) Beer drinking			7.86	.05
None	7.1	13.8		
< 1 /wk	32.1	40.5		
1-3 /wk	30.4	24.1		
4+ /wk	30.4	21.6		
(Mean) Glasses wine at a sitting	0.3	0.5	3.10	.002
(%) Wine drinking			8.02	.02
None	64.7	50.9		
< 1 /wk	30.4	37.1		
1+ /wk	4.9	12.1		
(Mean) Drinks of liquor at a sitting	0.7	0.6	1.67	.10
(%) Liquor drinking			1.56	.67
None	45.1	49.1		
< 1 /wk	33.7	30.2		
1-3 /wk	8.7	11.2		
4+ /wk	12.5	9.5		

Table 5. The characteristics of tobacco use and alcohol consumption of female participants, 1989-91

	Fisheaters	Non-Fisheaters	χ^2/ t	P-value
Number of participants	120	214		
(%) Smoking			0.23	.89
Never	52.6	54.4		
Ex-smoker	27.2	24.8		
Current smoker	20.2	20.9		
Among ex_smoker and cur_smoker				
(Mean) Age started smoking	18.7	20.5	1.81	.07
Among ex_smoker				
(Mean) Age last smoked regularly	39.3	41.5	0.68	.50
Among cur_smoker				
(Mean) number of cigarettes a day	20.7	19.3	0.58	.56
(%) Drinking			0.12	.94
Abstainer	21.0	19.8		
Ex_user	10.1	9.4		
Current user	68.9	70.8		
Among current drinkers:				
(Mean) bottles/cans beer at a sitting	0.4	0.4	0.14	.89
(%) Beer drinking			8.18	.04
None	28.0	39.3		
< 1 /wk	35.4	38.7		
1-3 /wk	18.3	14.7		
4+ /wk	18.3	7.3		
(Mean) Glasses wine at a sitting	0.5	0.5	0.01	.99
(%) Wine drinking			0.44	.80
None	47.6	45.3		
< 1 /wk	41.5	40.7		
1+ /wk	11.0	14.0		
(Mean) Drinks of liquor at a sitting	0.7	0.6	1.50	.14
(%) Liquor drinking			3.61	.31
None	48.8	50.7		
< 1 /wk	28.0	34.7		
1-3 /wk	9.8	8.0		
4+ /wk	13.4	6.7		

Table 6. The quantity of fish consumption among fisheaters stratified by gender, 1973-74

	Male	Female	Total
Number of fisheaters	44	29	74*
Annual fish meals			
Mean±SD	66.2±43.3	90.9±48.1	76.4±46.3
Median	56.0	72.0	66.0
Range(Q25-Q75)	40.0-69.0	61.0-104.0	49.0-90.5
Portion serving size (oz)			
Mean±SD	13.0±4.4	9.4±3.4	11.5±4.3
Median	12.5	9.0	10.0
Range(Q25-Q75)	9.3-16.0	6.5-11.0	8.0-16.0
Total weight of fish consumed (lb)			
Mean±SD	50.9±31.6	52.2±35.9	51.7±33.0
Median	39.8	40.0	40.0
Range(Q25-Q75)	28.0-58.5	29.3-54.9	28.4-56.3

*: One participant's gender was unknown.

Table 7. Fish consumption behaviors among fisheaters stratified by gender, 1973-74

	Male	Female	Total
Number of fisheaters	44	29	74**
One of top 3 fish species consumed (%)			
Trout	100.0	93.1	97.3
Salmon	65.9	62.1	64.9
Perch	31.8	41.4	36.5
Catfish	4.5	3.4	4.1
Whitefish	25.0	17.2	21.6
Number of fisheaters*	38	21	61***
One of top 3 cooking methods (%)			
Broiled	31.6	28.6	29.5
Baked	18.4	52.4	29.5
Pan fried	55.3	47.6	50.8
Deep fried	7.9	0.0	4.9
Fish preparation prior to cooking (%)			
Always trim away dorsal fat area	0.0	9.5	3.3
Always trim away belly fat area	5.3	9.5	6.6
Always remove skin	0.0	0.0	0.0

Note: Total proportion in every sub-category would not sum to 100, because every participants could report up to three most favorite fish species or cooking methods.

* Information was based on fish diaries.

** One participant's gender was unknown.

***Two participants' genders were unknown.

Table 8. The quantity of fish consumption among fisheaters stratified by gender, 1979-82

	Male	Female	Total
Number of fisheaters	403	205	610*
Annual fish meals			
Mean±SD	61.0±28.8	71.0±49.5	64.4±37.3
Median	53.0	58.0	54.0
Range(Q25-Q75)	44.0-71.5	51.0-82.3	47.0-76.0
Portion serving size (oz)			
Mean±SD	13.9±6.5	10.1±4.6	12.6±6.2
Median	12.0	8.0	12.0
Range(Q25-Q75)	9.0-16.0	8.0-12.0	8.0-16.0
Total weight of fish consumed (lb)			
Mean±SD	51.7±38.0	43.4±38.6	48.9±38.3
Median	40.0	33.0	38.0
Range(Q25-Q75)	28.0-60.0	26.0-46.8	27.0-57.0

* Two participants' genders were unknown.

Table 9. Fish consumption behaviors among fisheaters stratified by gender, 1979-82

	Male	Female	Total
Number of fisheaters	403	205	610**
One of top 3 fish species consumed (%)			
Trout	94.3	91.2	93.3
Salmon	89.6	93.2	90.8
Perch	43.9	39.0	42.3
Catfish	1.5	2.0	1.6
Whitefish	0.0	0.0	0.0
Number of fisheaters*	280	121	402**
One of top 3 cooking methods (%)			
Broiled	51.8	55.4	52.7
Baked	0.0	3.3	1.0
Pan fried	65.0	54.5	61.9
Deep fried	33.6	32.2	33.3
Fish preparation prior to cooking (%)			
Always trim away dorsal fat area	84.6	89.3	86.1
Always trim away belly fat area	84.6	89.3	86.1
Always remove skin	48.6	52.1	49.5

Note: Total proportion in every sub-category would not sum to 100, because every participants could report up to three most favorite fish species or cooking methods.

* Information was based on fish chart.

**Two participants' genders were unknown.

Table 10. The quantity of fish consumption among fisheaters stratified by gender, 1989-91

	Male	Female	Total
Number of fisheaters	238	120	359*
Annual fish meals			
Mean±SD	41.6±32.6	35.2±31.7	39.6±32.4
Median	34.0	27.0	31.0
Range(Q25-Q75)	18.0-52.0	12.0-52.0	15.0-52.0
Portion serving size (oz)			
Mean±SD	9.4±3.7	7.2±3.5	8.7±3.8
Median	8.0	6.0	8.0
Range(Q25-Q75)	8.0-12.0	4.0-8.0	2.0, 16.0
Total weight of fish consumed (lb)			
Mean±SD	24.7±22.9	15.9±16.7	21.9±21.4
Median	18.0	10.8	15.5
Range(Q25-Q75)	9.4-31.4	4.5-19.5	6.4-30.0

* One participants' gender was unknown.

Table 11. Fish consumption behaviors among fisheaters stratified by gender, 1989-91

	Male	Female	Total
Number of fisheaters	238	120	359*
One of top 3 fish species consumed (%)			
Trout	47.1	45.8	46.5
Salmon	58.4	60.8	59.3
Perch	52.1	45.0	49.9
Catfish	0.4	0.0	0.3
Whitefish	100.0	100.0	100.0
One of top 3 cooking methods (%)			
Broiled	29.0	33.3	30.4
Baked	27.7	39.2	31.8
Pan fried	46.6	40.0	44.3
Deep fried	29.8	26.7	29.0
Fish preparation prior to cooking (%)			
Always trim away dorsal fat area	92.0	88.3	90.8
Always trim away belly fat area	92.4	88.3	91.1
Always remove skin	83.2	78.3	81.6

Note: Total proportion in every sub-category would not sum to 100, because every participants could report up to three most favorite fish species or cooking methods.
* One participants' gender was unknown.

Table 12. Levels (ppb) of serum Aroclor 1254 and Aroclor1260 stratified by gender and eating status, 1973-74

	N	Mean±SD	Median	Q25-Q75
Aroclor 1254				
Male	78	52.1±47.7	35.0	25.0-66.5
Fisheater	47	65.5±55.4	40.0	27.0-91.0
Nonfisheater	31	31.6±20.3	29.0	15.0-42.0
Female	84	27.9±17.1	23.0	15.3-35.0
Fisheater	29	39.2±20.5	35.0	23.0-50.5
Nonfisheater	55	21.9±11.4	20.0	15.0-27.0
Aroclor 1260				
Male	78	21.5±21.4	12.5	90.-23.25
Fisheater	47	26.0±25.3	17.0	10.0-32.0
Nonfisheater	31	12.1±8.6	10.0	6.0-15.0
Female	84	8.2±6.2	6.5	4.0-10.0
Fisheater	29	12.4±7.5	11.0	7.5-15.5
Nonfisheater	55	5.9-3.9	5.0	4.0-8.0

Table 13. Levels (ppb) of serum contaminants (Aroclor 1260, PCB total, DDT, DDE, and PBB) stratified by gender and eating status, 1979-82

	N	Mean±SD	Median	Q25-Q75
Aroclor 1260				
Male	615	23.5±23.5	16.3	8.5-29.5
Fisheater	401	30.7±25.8	22.9	14.5-38.6
Nonfisheater	214	10.1±7.9	8.1	5.6-11.5
Female	502	12.9±14.6	8.3	4.9-15.5
Fisheater	205	19.6±19.0	14.5	8.2-22.8
Nonfisheater	297	8.3-7.7	6.0	3.9-10.1
PCB total				
Male	615	25.2±25.4	17.6	9.0-32.3
Fisheater	401	32.9±27.8	24.7	15.5-41.5
Nonfisheater	214	10.7±8.9	8.2	5.6-12.1
Female	502	14.1±16.2	9.0	5.0-17.0
Fisheater	205	21.4±21.2	15.1	8.9-25.4
Nonfisheater	297	9.0±8.5	6.3	4.0-10.7
DDT				
Male	615	42.5±63.4	22.5	11.6-43.8
Fisheater	401	56.4±74.1	30.8	17.0-53.8
Nonfisheater	214	16.3±15.2	12.4	6.3-21.2
Female	502	22.7±33.2	14.2	8.0-25.6
Fisheater	205	32.5±45.5	19.9	11.0-34.3
Nonfisheater	297	15.9±18.2	11.1	6.6-19.5
DDE				
Male	615	36.6±55.4	18.9	10.1-37.2
Fisheater	401	48.6±64.9	26.7	14.9-44.7
Nonfisheater	214	14.2±13.1	11.0	5.5-18.4
Female	502	19.1±28.1	12.2	6.9-21.4
Fisheater	205	27.6±39.8	16.8	9.7-28.8
Nonfisheater	297	13.2±12.6	9.5	5.9-16.8
PBB				
Male	615	3.4±4.4	1.9	0.5-4.2
Fisheater	401	3.6±4.9	1.9	0.5-4.2
Nonfisheater	214	3.2±3.4	2.0	0.5-4.3
Female	502	2.1±2.5	1.2	0.5-2.5
Fisheater	205	1.9±2.1	1.1	0.5-2.5
Nonfisheater	297	2.2±2.7	1.3	0.5-2.6

Table 14. Levels (ppb) of serum contaminants (Aroclor 1260, PCB total, DDT, DDE, and PBB) stratified by gender and eating status, 1989-91

	N	Mean±SD	Median	Q25-Q75
Aroclor 1260				
Male	226	20.9±27.0	13.1	6.3-25.3
Fisheater	140	29.0±31.4	21.0	12.0-33.6
Nonfisheater	86	7.8±6.2	6.0	3.7-9.6
Female	189	9.9±9.0	6.8	4.3-13.1
Fisheater	65	14.8±10.4	12.8	7.3-18.2
Nonfisheater	124	7.3±6.6	5.6	4.0-9.1
PCB total				
Male	226	20.9±27.0	13.1	6.25-25.3
Fisheater	140	29.0±31.4	21.0	12.0-33.6
Nonfisheater	86	7.8±6.2	6.0	3.7-9.6
Female	189	10.0±9.02	6.9	4.4-13.4
Fisheater	65	14.8±10.4	12.8	7.3-18.2
Nonfisheater	124	7.5±7.0	5.7	4.0-9.1
DDT				
Male	226	19.1±25.5	12.6	5.8-20.9
Fisheater	140	22.6±26.7	14.8	9.0-26.4
Nonfisheater	86	8.3±7.1	6.2	3.7-12.4
Female	189	11.7±12.5	7.8	4.5-14.7
Fisheater	65	14.1±15.3	10.2	5.3-16.2
Nonfisheater	124	8.6±7.5	5.9	3.4-10.8
DDE				
Male	226	17.1±22.6	11.4	5.6-18.8
Fisheater	140	22.6±26.7	14.8	9.0-26.4
Nonfisheater	86	8.3±7.1	6.2	3.7-12.4
Female	189	10.5±11.1	7.0	4.0-13.2
Fisheater	65	14.1±15.3	10.2	5.3-16.2
Nonfisheater	124	8.6±7.5	5.9	3.4-10.8
PBB				
Male	226	4.5±4. 4	2.8	1.6-6.0
Fisheater	140	4.7±4.8	2.7	1.6-6.0
Nonfisheater	86	4.2±3.8	2.8	3.7-9.6
Female	189	2.7±2.8	1.8	0.5-3.5
Fisheater	65	2.5±2.4	1.8	0.5-3.6
Nonfisheater	124	2.8±2.9	1.8	0.5-3.5

Table 15. Effect of the age on quantity of fish consumption stratified by gender, 1979-82

	Age (year)					
	<35	35-44	45-54	55+	χ^2/F value**	p value
Male						
No. of Cases	90	115	80	118		
Mean. No. of fish meals*	54.81	60.73	62.05	63.25	4.03	.05
Pct. No. of fish meals					16.65	.05
None	47.6	30.7	38.4	36.8		
Low	22.6	22.9	16.8	18.9		
Middle	16.1	25.9	22.4	25.9		
High	13.7	20.5	22.4	18.4		
Mean. pounds of fish consumed*	53.09	52.25	49.68	49.18	0.72	.40
Pct. pounds of fish consumed					16.48	.06
None	47.6	30.7	38.4	36.8		
Low	17.9	24.7	20.8	27.6		
Middle	17.9	18.7	19.2	20.0		
High	16.7	25.9	21.6	15.7		
Female						
No. of Cases	53	44	49	58		
Mean. No. of fish meals*	68.13	58.13	73.45	77.51	2.28	.13
Pct. No. of fish meals					9.40	.40
None	67.1	61.7	60.2	58.1		
Low	10.6	20.0	15.9	15.4		
Middle	9.3	11.3	9.7	11.8		
High	13.0	7.0	14.2	14.7		
Mean. pounds of fish consumed*	46.49	35.38	40.53	43.98	0.01	.94
Pct. pounds of fish consumed					10.23	.33
None	67.1	61.7	60.2	58.1		
Low	11.2	14.8	8.0	16.9		
Middle	10.6	12.2	18.6	11.0		
High	11.2	11.3	13.3	14.0		

*: Analyses were restricted to fisheaters.

**: F values were testing for linearity

Table 16. Effect of education levels on quantity of fish consumption stratified by gender, 1979-82

	Education			
	< High school	>= High school	χ^2/t value	p value
Male				
No. of Cases	70	331		
Mean. No. of fish meals*	68.71	58.73	2.64	.01
Pct. No. of fish meals			5.73	.13
None	37.3	37.9		
Low	14.5	22.0		
Middle	22.7	22.9		
High	25.5	17.2		
Mean. pounds of fish consumed*	56.88	49.82	1.41	.16
Pct. pounds of fish consumed			4.30	.23
None	37.3	37.9		
Low	18.2	24.2		
Middle	18.2	19.3		
High	26.4	18.6		
Female				
No. of Cases	33	169		
Mean. No. of fish meals*	94.15	65.05	1.75	.09
Pct. No. of fish meals			16.88	<.001
None	51.5	62.3		
Low	10.3	16.5		
Middle	10.3	10.8		
High	27.9	10.4		
Mean. pounds of fish consumed*	60.61	38.32	2.45	.02
Pct. pounds of fish consumed			20.65	<.001
None	51.5	62.3		
Low	4.4	14.7		
Middle	16.2	12.6		
High	27.9	10.4		

*: Analyses were restricted to fisheaters.

Table 17. Effect of region on quantity of fish consumption stratified by gender, 1979-82

	Region				
	North	Middle	South	χ^2 / F value**	p value
Male					
No. of Cases	118	126	159		
Mean. No. of fish meals*	63.11	62.38	56.96	3.44	.06
Pct. No. of fish meals				2.78	.84
None	34.6	41.9	38.0		
Low	21.2	20.0	20.4		
Middle	22.9	21.4	23.5		
High	21.2	16.7	18.0		
Mean. pounds of fish consumed*	49.15	58.55	46.79	0.54	.46
Pct. pounds of fish consumed				17.47	.01
None	34.6	41.9	38.0		
Low	29.6	14.8	25.1		
Middle	15.6	19.0	21.2		
High	20.1	24.3	15.7		
Female					
No. of Cases	58	66	81		
Mean. No. of fish meals*	80.29	67.92	62.00	5.32	.02
Pct. No. of fish meals				11.16	.08
None	63.2	64.4	58.8		
Low	9.2	15.0	20.1		
Middle	10.5	10.0	10.8		
High	17.1	10.6	10.3		
Mean. pounds of fish consumed*	48.00	39.77	38.12	2.52	.11
Pct. pounds of fish consumed				3.99	.68
None	63.2	64.4	58.8		
Low	13.8	11.7	13.4		
Middle	9.2	12.8	15.5		
High	13.8	11.1	12.4		

*: Analyses were restricted to fisheaters.

**: F values were testing for linearity

Table 18-a. Effect of body mass index on quantity of fish consumption in males, 1979-82

	Body Mass Index					
	.10-.23	.24-.25	.26-.28	.29-.45	χ^2 / Fvalue**	p value
No. of Cases	102	101	99	101		
Mean. No. of fish meals*	56.74	59.08	61.88	62.46	2.17	.14
Pct. No. of fish meals					44.14	<.001
None	55.6	41.2	31.6	24.4		
Low	16.9	17.6	19.6	28.1		
Middle	16.3	24.8	27.8	21.9		
High	11.3	16.4	20.9	25.6		
Mean. pounds of fish consumed*	44.91	44.40	57.95	53.93	5.50	.02
Pct. pounds of fish consumed					42.90	<.001
None	55.6	41.2	31.6	24.4		
Low	16.9	23.0	22.8	29.4		
Middle	14.4	20.0	23.4	18.1		
High	13.1	15.8	22.2	28.1		

Table 18-b. Effect of body mass index on quantity of fish consumption in females, 1979-82

	Body Mass Index					
	.18-.20	.21-.22	.23-.26	.27-.39	χ^2 / F value**	p value
No. of Cases	51	51	51	51		
Mean. No. of fish meals*	60.49	72.75	72.61	70.08	0.81	.36
Pct. No. of fish meals					13.07	.16
None	68.5	62.1	52.3	64.8		
Low	14.6	18.2	17.4	10.9		
Middle	9.2	8.3	12.1	11.7		
High	7.7	11.4	18.2	12.5		
Mean. pounds of fish consumed*	42.89	38.45	41.61	44.57	0.13	.72
Pct. pounds of fish consumed					15.19	.09
None	68.5	62.1	52.3	64.8		
Low	10.8	15.9	13.6	10.9		
Middle	13.8	12.1	15.9	9.4		
High	6.9	9.8	18.2	14.8		

*: Analyses were restricted to fisheaters.

**: F values were testing for linearity

Table 19. Effect of the chemicals exposure status on quantity of fish consumption stratified by gender, 1979-82

	Chemical exposure			
	Yes	No	χ^2 / t value	p value
Male				
No. of Cases	167	236		
Mean. No. of fish meals*	58.57	61.70	1.12	.26
Pct. No. of fish meals			1.25	.74
None	39.0	37.9		
Low	21.0	20.2		
Middle	23.6	22.0		
High	16.5	19.9		
Mean. pounds of fish consumed*	52.02	50.33	0.44	.66
Pct. pounds of fish consumed			3.50	.32
None	39.0	37.9		
Low	20.2	24.9		
Middle	21.7	17.0		
High	19.1	20.2		
Female				
No. of Cases	30	175		
Mean. No. of fish meals*	72.81	68.86	0.42	.67
Pct. No. of fish meals			2.03	.57
None	60.5	62.2		
Low	13.2	15.6		
Middle	9.2	10.7		
High	17.1	11.6		
Mean. pounds of fish consumed*	41.53	41.7	0.02	.98
Pct. pounds of fish consumed			1.78	.62
None	60.5	62.2		
Low	15.8	12.4		
Middle	9.2	13.3		
High	14.5	12.0		

*: Analyses were restricted to fisheaters.

Table 20. Effect of the age on contaminants levels stratified by eating status and gender, 1979-82

	Age (year)					
	<35	35-44	45-54	55+	F value*	p value
Male						
Mean. Aroclor 1260 (ppb)						
Non-fisheater	6.45	8.75	11.68	12.60	34.16	<.001
Fisheater	18.35	26.79	35.56	40.46	78.84	<.001
Mean DDT (ppb)						
Non-fisheater	7.97	13.17	22.17	22.50	39.91	<.001
Fisheater	24.75	41.79	69.66	85.64	86.21	<.001
Mean DDE (ppb)						
Non-fisheater	6.93	11.50	19.27	19.46	43.00	<.001
Fisheater	21.13	35.80	60.68	73.77	84.18	<.001
Mean PBB (ppb)						
Non-fisheater	3.10	3.10	4.26	2.65	<0.01	.98
Fisheater	3.91	3.51	3.84	3.28	<0.01	1.00
Female						
Mean. Aroclor 1260 (ppb)						
Non-fisheater	4.50	8.58	9.97	9.91	50.44	<.001
Fisheater	10.87	12.78	22.16	30.68	69.72	<.001
Mean DDT (ppb)						
Non-fisheater	8.07	18.47	15.33	21.63	44.97	<.001
Fisheater	16.24	18.86	35.71	55.13	65.73	<.001
Mean DDE (ppb)						
Non-fisheater	6.95	13.26	13.98	18.43	52.11	<.001
Fisheater	13.60	15.87	30.70	46.97	62.51	<.001
Mean PBB (ppb)						
Non-fisheater	1.96	1.89	1.84	2.95	3.41	.07
Fisheater	2.06	1.72	1.97	1.93	0.05	.82

*: F values were testing for linearity and were calculated after contaminant levels had been log transformed.

Table 21. Effect of education on contaminants levels stratified by eating status and gender, 1979-82

	Education						
	Elemen. school	Some high school	High school grad.	Some college	college grad.	F value*	p value
Male							
Mean. Aroclor 1260 (ppb)							
Non-fisheater	12.47	9.28	11.59	7.79	8.28	4.66	.03
Fisheater	33.76	32.00	33.51	29.13	24.28	5.00	.03
Mean DDT (ppb)							
Non-fisheater	24.25	14.13	16.66	13.17	15.84	1.24	.27
Fisheater	49.34	57.51	68.07	48.16	41.95	3.29	.07
Mean DDE (ppb)							
Non-fisheater	20.90	13.11	14.45	11.45	13.52	2.92	.09
Fisheater	42.08	50.09	58.76	41.32	36.02	3.49	.06
Mean PBB (ppb)							
Non-fisheater	3.22	5.17	3.42	2.46	2.84	1.65	.20
Fisheater	2.58	4.43	3.44	3.42	3.83	0.09	.77
Female							
Mean. Aroclor 1260 (ppb)							
Non-fisheater	10.14	8.19	8.19	7.04	7.54	2.60	.11
Fisheater	49.10	27.05	17.64	15.69	15.93	13.00	<.001
Mean DDT (ppb)							
Non-fisheater	26.83	17.41	15.44	15.80	11.22	13.61	<.001
Fisheater	95.77	51.16	28.66	24.66	20.66	18.91	<.001
Mean DDE (ppb)							
Non-fisheater	23.13	14.94	13.59	11.54	9.60	14.82	<.001
Fisheater	82.17	44.35	24.39	20.77	17.45	21.38	<.001
Mean PBB (ppb)							
Non-fisheater	3.38	2.40	2.28	2.13	1.97	5.33	.02
Fisheater	1.82	1.95	2.05	1.55	1.83	2.05	.15

*: F values were testing for linearity and were calculated after contaminant levels had been log transformed.

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Table 22. Effect of region on contaminant levels stratified by eating status and gender, 1979-82

	Living area				
	North	Middle	South	F value*	p value
Male					
Mean. Aroclor 1260 (ppb)					
Non-fisheater	11.96	9.03	9.09	0.80	.37
Fisheater	36.17	31.40	26.01	12.43	<.001
Mean DDT (ppb)					
Non-fisheater	20.79	15.19	14.27	4.68	.03
Fisheater	74.33	62.22	38.56	20.27	<.001
Mean DDE (ppb)					
Non-fisheater	17.91	13.17	12.49	3.18	.08
Fisheater	64.40	53.91	32.78	20.71	<.001
Mean PBB (ppb)					
Non-fisheater	2.88	4.83	2.20	8.90	.003
Fisheater	4.33	5.60	1.49	62.60	<.001
Female					
Mean. Aroclor 1260 (ppb)					
Non-fisheater	9.29	7.06	7.63	0.49	.48
Fisheater	22.05	19.03	18.39	0.07	.79
Mean DDT (ppb)					
Non-fisheater	17.23	15.94	13.20	1.25	.26
Fisheater	35.18	33.92	29.42	0.60	.44
Mean DDE (ppb)					
Non-fisheater	14.45	12.40	11.75	0.33	.56
Fisheater	29.99	29.10	24.77	0.94	.33
Mean PBB (ppb)					
Non-fisheater	1.83	3.54	1.10	10.47	.001
Fisheater	1.76	2.86	1.27	4.25	.04

*: F values were testing for linearity and were calculated after contaminant levels had been log transformed.

Table 23-a. Effect of body mass index on contaminant levels stratified by eating status in males, 1979-82

	Body Mass Index					
	.10-.23	.24-.25	.26-.28	.29-.45	F value*	p value
Mean. Aroclor 1260 (ppb)						
Non-fisheater	7.52	9.22	10.01	12.43	11.00	.001
Fisheater	28.20	29.25	34.19	31.12	3.83	.05
Mean DDT (ppb)						
Non-fisheater	8.59	15.85	20.58	20.10	20.75	<.001
Fisheater	50.33	50.50	59.24	65.62	13.47	<.001
Mean DDE (ppb)						
Non-fisheater	7.53	13.67	17.72	17.59	24.91	<.001
Fisheater	43.02	43.65	51.11	56.75	13.57	<.001
Mean PBB (ppb)						
Non-fisheater	3.08	3.10	3.51	3.17	0.03	.86
Fisheater	4.51	3.18	3.56	3.14	1.50	.22

Table 23-b. Effect of body mass index on contaminant levels stratified by eating status in females, 1979-82

	Body Mass Index					
	.18-.20	.21-.22	.23-.26	.27-.39	F value*	p value
Mean. Aroclor 1260 (ppb)						
Non-fisheater	6.51	9.09	7.82	8.38	1.51	.22
Fisheater	15.94	22.28	18.26	22.31	0.33	.57
Mean DDT (ppb)						
Non-fisheater	11.54	16.56	13.79	19.71	3.88	.05
Fisheater	19.48	36.49	32.10	42.28	5.86	.02
Mean DDE (ppb)						
Non-fisheater	10.12	14.22	12.36	14.62	3.78	.05
Fisheater	16.74	30.99	27.70	35.70	5.83	.02
Mean PBB (ppb)						
Non-fisheater	2.21	2.37	1.72	2.53	0.08	.78
Fisheater	2.41	1.95	1.83	1.53	7.32	.01

*: F values were testing for linearity and were calculated after contaminant levels had been log transformed.

Table 24. Effect of chemicals exposure status on contaminant levels stratified by eating status and gender, 1979-82

	Chemical exposure			
	Yes	No	t value*	p value
Male				
Mean. Aroclor 1260 (ppb)				
Non-fisheater	9.78	9.85	0.88	.38
Fisheater	28.55	32.15	1.09	.28
Mean DDT (ppb)				
Non-fisheater	15.82	16.58	0.71	.48
Fisheater	53.10	58.71	1.24	.22
Mean DDE (ppb)				
Non-fisheater	13.81	14.34	0.68	.50
Fisheater	45.75	50.62	1.21	.23
Mean PBB (ppb)				
Non-fisheater	3.26	3.18	0.37	.71
Fisheater	3.65	3.56	0.10	.92
Female				
Mean. Aroclor 1260 (ppb)				
Non-fisheater	6.75	8.15	1.05	.30
Fisheater	17.42	20.01	0.80	.43
Mean DDT (ppb)				
Non-fisheater	13.83	15.69	0.45	.65
Fisheater	26.51	33.53	0.40	.69
Mean DDE (ppb)				
Non-fisheater	12.11	12.94	0.24	.81
Fisheater	22.65	28.50	0.31	.76
Mean PBB (ppb)				
Non-fisheater	2.31	2.16	1.38	.17
Fisheater	1.74	1.95	0.54	.59

*: t values were calculated after contaminant levels had been log transformed.

Table 25-a. Effect of annual fish meals on contaminants levels in males, 1979-82

	group of annual fish meals					
	None	12-48	49-63	64-180	χ^2/F value*	p value
Mean. Aroclor 1260 (ppb)	10.37	26.21	30.36	35.73	261.14	<.001
Pct. Aroclor 1260					212.91	<.001
Low	70.4	17.4	14.4	10.1		
Middle	22.8	42.4	39.7	33.6		
High	6.8	40.2	45.9	56.3		
Mean DDT (ppb)	17.52	43.71	58.45	67.17	140.48	<.001
Pct. DDT					124.30	<.001
Low	60.2	23.5	19.2	15.1		
Middle	29.1	37.9	37.0	31.1		
High	10.7	38.6	43.8	53.8		
Mean DDE (ppb)	16.65	48.33	69.66	73.25	140.10	<.001
Pct. DDE					120.90	<.001
Low	59.2	22.7	20.5	16.0		
Middle	30.1	40.2	34.9	29.4		
High	107	37.1	44.5	54.6		
Mean PBB (ppb)	15.19	37.26	50.49	58.24	0.56	.45
Pct. PBB					2.26	.89
Low	31.6	32.6	34.9	36.1		
Middle	32.5	31.8	34.2	34.5		
High	35.9	35.6	30.8	29.4		

Aroclor 1260 (ppb): Low=(1.5, 10.5); Middle=(10.6, 23.9); High=(24.0, 202.7)
DDT (ppb): Low=(0.5, 15.1); Middle=(15.2, 34.6); High=(34.7, 512.6)
DDE (ppb): Low=(0.5, 12.8); Middle=(12.9, 28.8); High=(28.9, 425.3)
PBB (ppb): Low=(0.5, 1.0); Middle=(1.1, 3.2); High=(3.3, 33.1)
*: F values were testing for linearity and were calculated after contaminant levels had been log transformed.

Table 25-b. Effect of annual fish meals on contaminants levels in females, 1979-82

	group of annual fish meals					
	None	14-52	53-72	73-600	χ^2/F value*	p value
Mean. Aroclor 1260 (ppb)	8.17	17.14	15.75	25.87	124.77	<.001
Pct. Aroclor 1260					118.63	<.001
Low	47.9	11.3	16.4	9.2		
Middle	36.5	35.0	27.3	23.1		
High	15.6	53.8	56.4	67.7		
Mean DDT (ppb)	15.73	24.27	36.69	38.96	57.55	<.001
Pct. DDT					45.27	<.001
Low	42.7	20.0	23.6	15.4		
Middle	34.7	32.5	29.1	32.3		
High	22.6	47.5	47.3	52.3		
Mean DDE (ppb)	13.08	20.67	31.18	33.20	52.78	<.001
Pct. DDE					44.17	<.001
Low	42.7	23.8	23.6	13.8		
Middle	34.7	27.5	32.7	33.8		
High	22.6	48.8	43.6	52.3		
Mean PBB (ppb)	2.21	1.93	1.58	2.09	0.35	.55
Pct. PBB					6.76	.34
Low	39.6	48.8	50.9	36.9		
Middle	27.4	18.8	27.3	27.7		
High	33.0	32.5	21.8	35.4		

Aroclor 1260 (ppb): Low=(1.5, 5.7); Middle=(5.8, 12.5); High=(12.6, 146.9)
DDT (ppb): Low=(0.5, 9.2); Middle=(9.3, 20.3); High=(20.4, 403.9)
DDE (ppb): Low=(0.5, 8.3); Middle=(8.4, 17.1); High=(17.2, 38.8)
PBB (ppb): Low=(0.5, 0.5); Middle=(0.6, 2.0); High=(2.1, 16.2)
*: F values were testing for linearity and were calculated after contaminant levels had been log transformed.

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Table 26-a. Effect of the total weight of fish consumed on contaminants levels in males, 1979-82

	group of total weight of fish consumed					
	None	7-32	33-53	54-413	χ^2/F value*	p value
Mean. Aroclor 1260 (ppb)	10.37	29.57	30.06	32.29	211.83	<.001
Pct. Aroclor 1260					206.27	<.001
Low	70.4	15.5	12.3	14.2		
Middle	22.8	39.9	37.7	38.6		
High	6.8	44.6	50.0	47.2		
Mean DDT (ppb)	17.52	51.80	59.31	58.22	110.89	<.001
Pct. DDT					119.23	<.001
Low	60.2	19.6	18.9	19.7		
Middle	29.1	37.8	32.0	36.2		
High	10.7	42.6	49.2	44.1		
Mean DDE (ppb)	15.19	44.43	51.02	50.55	106.97	<.001
Pct. DDE					113.62	<.001
Low	59.2	20.3	18.9	20.5		
Middle	30.1	37.2	32.0	35.4		
High	10.7	42.6	49.2	44.1		
Mean PBB (ppb)	3.32	3.41	3.30	3.93	0.20	.65
Pct. PBB					4.28	.64
Low	31.6	38.5	32.0	32.3		
Middle	32.5	30.4	38.5	32.3		
High	35.9	31.1	29.5	35.4		

Aroclor 1260 (ppb): Low=(1.5, 10.5); Middle=(10.6, 23.9); High=(24.0, 202.7)
DDT (ppb): Low=(0.5, 15.1); Middle=(15.2, 34.6); High=(34.7, 512.6)
DDE (ppb): Low=(0.5, 12.8); Middle=(12.9, 28.8); High=(28.9, 425.3)
PBB (ppb): Low=(0.5, 1.0); Middle=(1.1, 3.2); High=(3.3, 33.1)
*: F values were testing for linearity and were calculated after contaminant levels had been log transformed.

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Table 26-b. Effect of total weight of fish consumed on contaminants levels in females, 1979-82

	group of total weight of fish consumed					
	None	7-27	28-41	42-413	χ^2/F value*	p value
Mean. Aroclor 1260 (ppb)	8.17	17.54	16.41	25.02	122.08	<.001
Pct. Aroclor 1260					117.75	<.001
Low	47.9	8.8	14.9	12.3		
Middle	36.5	36.8	26.9	23.1		
High	15.6	54.4	58.2	64.6		
Mean DDT (ppb)	15.73	31.92	27.27	38.39	51.64	<.001
Pct. DDT					49.05	<.001
Low	42.7	16.2	26.9	15.4		
Middle	34.7	33.8	32.8	27.7		
High	22.6	50.0	40.3	56.9		
Mean DDE (ppb)	13.08	27.06	23.34	32.66	47.98	<.001
Pct. DDE					45.25	<.001
Low	42.7	19.1	25.4	16.9		
Middle	34.7	30.9	34.3	27.7		
High	22.6	50.0	40.3	55.4		
Mean PBB (ppb)	2.21	1.95	1.55	2.16	0.26	.61
Pct. PBB					5.34	.50
Low	39.6	51.5	46.3	38.5		
Middle	27.4	22.1	26.9	23.1		
High	33.0	26.5	26.9	38.5		

Aroclor 1260 (ppb): Low=(1.5, 5.7); Middle=(5.8, 12.5); High=(12.6, 146.9)
DDT (ppb): Low=(0.5, 9.2); Middle=(9.3, 20.3); High=(20.4, 403.9)
DDE (ppb): Low=(0.5, 8.3); Middle=(8.4, 17.1); High=(17.2, 38.8)
PBB (ppb): Low=(0.5, 0.5); Middle=(0.6, 2.0); High=(2.1, 16.2)
*: F values were testing for linearity and were calculated after contaminant levels had been log transformed.

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Table 27. Changes in quantity of fish consumption among fisheaters stratified by gender from survey I to survey II

	# pairs	Mean I	Mean II	t-value*	p-value
Annual fish meals					
male	34	68.0	57.4	1.21	.24
female	21	93.6	61.3	3.88	.001
Serving size (oz)					
male	34	13.2	12.0	1.45	.16
female	21	10.3	7.9	3.18	.005
Total weight of fish consumed (lb)					
male	34	54.8	41.2	2.00	.05
female	21	60.8	33.1	3.43	.003

* paired t-test

Table 28. Changes in fish consumption behaviors among fisheaters stratified by gender from survey I to II

	Male				Female			
	#pairs	I	II	p-value*	#pairs	I	II	p-value*
Always trim away prior to cooking								
Dorsal fat area	34	0.0	50.0	<.001	21	9.5	52.4	.004
Belly fat area	34	5.9	50.0	<.001	21	9.5	52.4	.004
Remove skin	34	0.0	20.6	.02	21	0.0	23.8	.06
One of top 3 cooking methods								
Broiled	34	23.5	32.4	.58	21	28.6	23.8	1.00
Baked	34	11.8	0.0	.13	21	38.1	14.3	.06
Pan Fried	34	47.1	44.1	1.00	21	38.1	19.0	.29
Deep Fried	34	8.8	23.5	.18	21	0.0	14.3	.25
One of top 3 fish species consumed								
Trout	34	100	82.4	.03	21	95.2	71.4	.06
Salmon	34	61.8	64.7	1.00	21	61.9	76.2	.51
Perch	34	32.4	50.0	.15	21	38.1	28.6	.75
Catfish	34	5.9	0.0	.50	21	4.8	0.0	1.00
White fish	34	26.5	0.0	.004	21	14.3	0.0	.25

* McNemar test

Table 29. Changes in levels serum Aroclor 1260 stratified by gender and eating status from survey I to II

Aroclor 1260 (ppb)	# pairs	Mean I	Mean II	t-value*	p-value
Male	58	21.3	34.0	-6.70	<.001
Fisheater		26.3	43.2	-5.19	<.001
Nonfisheater		12.4	17.7	-4.37	<.001
Female	65	8.3	15.2	-6.66	<.001
Fisheater		12.7	22.9	-5.13	<.001
Nonfisheater		6.2	11.6	-4.84	<.001

* paired t-test was performed after log transformation.

Table 30. Changes in quantity of fish consumption among fisheaters stratified by gender from survey II to survey III

	# pairs	Mean II	Mean III	t-value*	p-value
Annual fish meals					
male	238	61.3	41.9	7.87	<.001
female	120	66.0	35.9	7.54	<.001
Serving size (oz.)					
male	238	13.7	9.29	11.08	<.001
female	120	10.1	7.1	8.02	<.001
Total weight of fish consumed (lb.)					
male	238	51.7	24.7	9.77	<.001
female	120	40.2	15.8	9.91	<.001

* paired t-test

Table 31. Changes in fish consumption behaviors among fisheaters stratified by gender from survey II to survey III

	Male				Female			
	#pairs	II	III	p-value*	#pairs	II	III	p-value*
Always trim away prior to cooking								
Dorsal fat area	238	71.8	91.2	<.001	120	61.7	88.3	<.001
Belly fat area	238	71.8	92.4	<.001	120	61.7	88.3	<.001
Remove skin	238	39.9	83.2	<.001	120	37.5	78.3	<.001
One of top 3 cooking methods								
Broiled	238	44.5	29.0	<.001	120	42.5	33.3	.15
Baked	238	0.0	27.7	<.001	120	2.5	39.2	<.001
Pan Fried	238	55.9	46.6	.05	120	37.5	40.0	.78
Deep Fried	238	27.7	29.8	.65	120	25.0	26.7	.86
One of top 3 fish species consumed								
Trout	238	95.0	47.1	<.001	120	90.8	45.8	<.001
Salmon	238	89.9	58.4	<.001	120	93.3	60.8	<.001
Perch	238	41.2	52.1	.007	120	31.2	45.0	.04
Catfish	238	1.7	0.4	.38	120	3.3	0.0	.13
White fish	238	0.0	100	<.001	120	0.0	100	<.001

* McNemar test

Table 32. Changes in levels of serum Aroclor 1260, DDT, DDE, and PBB stratified by gender and fish eating status from survey II to survey III

	# pairs	Mean		t-value*	p-value
		II	III		
Aroclor 1260 (ppb)					
Male	212	26.3	21.7	8.68	<.001
Fisheater	139	34.9	29.2	7.53	<.001
Nonfisheater	73	10.5	8.0	2.88	.01
Female	179	11.1	10.0	1.92	.06
Fisheater	64	17.0	14.8	2.16	.04
Nonfisheater	115	7.8	7.2	0.95	.35
DDT (ppb)					
Male	212	48.6	19.9	15.54	<.001
Fisheater	139	65.4	25.4	13.12	<.001
Nonfisheater	73	17.8	9.8	8.62	<.001
Female	179	20.8	11.8	11.10	<.001
Fisheater	64	28.2	15.8	8.36	<.001
Nonfisheater	115	16.5	9.6	7.82	<.001
DDE (ppb)					
Male	212	42.0	17.8	15.1	<.001
Fisheater	139	56.4	22.7	12.79	<.001
Nonfisheater	73	15.5	8.7	8.34	<.001
Female	179	16.9	10.5	10.22	<.001
Fisheater	64	24.0	14.1	7.63	<.001
Nonfisheater	115	12.9	8.5	7.22	<.001
PBB (ppb)					
Male	212	4.8	4.3	0.71	.48
Fisheater	139	5.2	4.6	0.68	.50
Nonfisheater	73	4.0	3.7	0.28	.78
Female	179	2.6	2.6	-2.81	.01
Fisheater	64	2.3	2.5	-2.54	.01
Nonfisheater	115	2.7	2.7	-1.64	.10

* paired t-test was performed after contaminant levels had been log transformation.

Table 33. Changes in quantity of fish consumption among fisheaters stratified by gender from survey I to survey III.

	# pairs	Mean I	Mean III	t-value*	p-value
Annual fish meals					
male	15	67.4	43.5	1.44	.12
female	13	123.0	31.0	3.30	.01
Serving size (oz.)					
male	15	12.5	9.6	1.74	.10
female	13	9.1	7.4	1.60	.15
Total weight of fish consumed (lb.)					
male	15	44.0	25.8	2.25	.04
female	13	68.1	13.4	3.02	.02

* paired t-test

Table 34. Changes in fish consumption behaviors among fisheaters stratified by gender from survey I to III

	Male				Female			
	#pairs	I	III	p-value*	#pairs	I	III	p-value*
Always trim away prior to cooking								
Dorsal fat area	15	0.0	80.0	.001	13	15.4	69.2	.04
Belly fat area	15	6.7	80.0	.001	13	15.4	69.2	.04
Remove skin	15	0.0	53.3	.008	13	0.0	46.2	.03
One of top 3 cooking methods								
Broiled	15	13.3	6.7	1.00	13	30.8	30.8	1.00
Baked	15	13.3	40.0	.22	13	30.8	61.5	.29
Pan Fried	15	46.7	60.0	.73	13	30.8	46.2	.69
Deep Fried	15	13.3	13.3	1.00	13	0.0	7.7	1.00
One of top 3 fish species consumed								
Trout	15	100	33.3	.002	13	92.3	61.5	.13
Salmon	15	46.7	46.7	1.00	13	61.5	30.8	.13
Perch	15	40.0	60.0	.38	13	38.5	23.1	.69
Catfish	15	33.3	100	.002	13	-	-	-
White fish	15	0.0	80.0	<.001	13	23.8	100	.002

* McNemar test

Table 35. Changes in levels (ppb) of serum Aroclor 1260 stratified by gender and eating status from survey I to survey III

Aroclor 1260 (ppb)	# pairs	Mean		t-value*	p-value
		I	III		
Male	15	20.1	32.8	-0.98	.35
Fisheater	6	38.8	70.5	-0.52	.63
Nonfisheater	9	10.8	14.0	-0.78	.45
Female	28	7.5	12.7	-3.76	.001
Fisheater	9	13.6	19.2	-2.59	.03
Nonfisheater	19	4.7	9.6	-2.95	.01

* paired t-test was performed after contaminant levels had been log transformation.

Table 36. Adjusted linear regression of annual fish meals on demographic characteristics among fisheaters stratified by gender and survey

	Men		Women	
	B±SE	p	B±SE	p
Survey I				
R square	.13		.38	
Age	.40±.80	.62	-.71±.96	.47
Education				
Elementary	-	-	-	-
Some high school	-26.26±35.89	.47	-41.87±57.09	.48
High school graduate	-5.85±29.86	.85	-93.75±-43.96	.05
Some college	-31.38±36.93	.40	-70.81±41.92	.12
College and above	-30.99±32.90	.35	-42.35±44.90	.36
Region				
North	-	-		
Middle	-10.41±22.00	.64	-80.78±43.46	.09
South	*	*	*	*
Body mass index	120.37±233.01	.61	546.20±429.32	.23
Survey II				
R square	.04		.09	
Age	.18±.11	.11	.39±.27	.14
Education				
Elementary	-	-	-	-
Some high school	5.20±7.66	.50	-25.10±17.73	.16
High school graduate	-1.98±6.92	.77	-30.72±15.78	.05
Some college	.26±7.35	.97	-32.78±16.74	.05
College and above	-8.31±7.46	.27	-28.61±17.32	.10
Region				
North	-	-	-	-
Middle	6.96±4.04	.09	36.17±11.24	.002
South	3.52±3.33	.29	4.40±7.76	.57
Body mass index	53.51±41.98	.20	12.00±87.93	.89
Survey III				
R square	.04		.19	
Age	.33±.24	.19	-.02±.24	.94
Education				
Elementary	-	-	-	-
Some high school	6.90±19.55	.72	16.76±21.81	.45
High school graduate	16.99±17.66	.34	33.73±17.68	.06
Some college	16.81±17.77	.35	41.08±18.24	.03
College and above	10.57±18.45	.58	32.07±18.43	.09
Region				
North	-	-	-	-
Middle	6.25±9.48	.51	25.69±10.77	.02
South	-5.88±7.78	.45	-4.54±-6.87	.51
Body mass index	*	*	*	*

B ± SE: Regression coefficient ± Standard error

- : Reference group

*: No data

Table 37. Adjusted linear regression of total weight of fish consumed on demographic characteristics among fisheaters stratified by gender and survey

	Men		Women	
	B±SE	p	B±SE	p
Survey I				
R square	.35		.32	
Age	.61±.50	.24	-.43±.76	.58
Education				
Elementary	-	-	-	-
Some high school	11.31±22.58	.62	9.91±45.17	.83
High school graduate	23.03±18.79	.23	-10.79±34.78	.76
Some college	.76±23.23	.97	-4.63±33.17	.89
College and above	1.89±20.70	.93	50.68±35.53	.18
Region				
North	-	-	-	-
Middle	-23.92±13.84	.10	-24.21±34.39	.49
South	*	*	*	*
Body mass index	239.63±146.59	.11	327.18±339.74	.35
Survey II				
R square	.05		.09	
Age	-.18±.15	.22	-.002±.21	.99
Education				
Elementary	-	-	-	-
Some high school	1.04±9.94	.92	-10.81±13.71	.43
High school graduate	-3.19±8.99	.72	-16.55±12.20	.18
Some college	-4.21±9.54	.66	-27.43±12.94	.04
College and above	-17.60±9.68	.07	-23.04±13.38	.09
Region				
North	-	-	-	-
Middle	5.27±5.25	.32	28.25±8.69	.001
South	10.60±4.32	.01	.17±6.00	.98
Body mass index	87.53±54.48	.11	12.25±67.95	.86
Survey III				
R square	.03		.07	
Age	.08±.18	.66	-.09±.13	.52
Education				
Elementary	-	-	-	-
Some high school	4.25±14.16	.76	4.61±12.32	.71
High school graduate	7.23±12.80	.57	12.33±9.99	.22
Some college	8.52±12.87	.50	12.82±10.31	.22
College and above	.47±13.37	.97	8.11±10.42	.44
Region				
North	-	-	-	-
Middle	.77±6.87	.91	5.83±6.09	.34
South	-6.14±5.63	.28	.71±3.88	.86
Body mass index	*	*	*	*

B ± SE: Regression coefficient ± Standard error
- : reference group
*: no data

Table 38. Adjusted linear regression of levels of Aroclor 1254 (log transformed) on demographic characteristics and quartiles of total weight of fish consumed stratified by gender, 1973-74

	Men		Women	
	B±SE	p	B±SE	p
R square	.53		.52	
Age	.01±.01	.07	.02±.01	<.001
Education				
Elementary	-	-	-	-
Some high school	-.27±.35	.45	.22±.32	.49
High school graduate	-.05±.26	.84	-.11±.18	.54
Some college	.10±.32	.75	-.12±.20	.57
College and above	-.40±.26	.12	.09±.20	.67
Region				
North	-	-	-	-
Middle	.20±.18	.28	.19±.14	.18
South	*	*	.40±.48	.41
Body mass index	.02±2.32	.99	-3.21±1.56	.04
Eating status				
Non-Fisheater	-	-	-	-
Fisheater	.12±.30	.69	-.02±.26	.93
Quartile of total weight of fish consumed				
1 (male: 24-28; female: 24-28)	-	-	-	-
2 (male: 29-39; female: 29-39)	.71±.26	.01	.47±.19	.02
3 (male: 40-53; female: 40-54)	.71±.39	.07	.79±.22	.001
4 (male: 54-413; female: 55-163)	1.19±.38	.003	.87±.33	.01

Note: Aroclor 1254 was tested in 1973-74 survey only.
B ± SE: Regression coefficient ± Standard error
- : Reference group
*: No data

Table 39. Adjusted linear regression of levels of Aroclor (log transformed) on demographic characteristics and quartile of total weight of fish consumed stratified by gender and survey

	Men		Women	
	B±SE	p	B±SE	p
Survey I				
R square	.53		.63	
Age	.01±.01	.09	.02±.01	.002
Education				
Elementary	-	-	-	-
Some high school	-.29±.37	.45	.17±.36	.63
High school graduate	-.06±.28	.82	.12±.21	.55
Some college	-.01±.34	.98	-.13±.23	.56
College and above	-.51±.27	.07	.17±.22	.45
Region				
North	-	-	-	-
Middle	.11±.19	.58	.41±.16	.01
South	*	*	.31±.54	.57
Body mass index	-2.90±2.46	.25	-6.22±1.75	.001
Eating status				
Non-Fisheater	-	-	-	-
Fisheater	.17±.32	.59	-.12±.30	.68
Quartile of total weight of fish consumed				
1 (male: 24-28; female: 24-28)	-	-	-	-
2 (male: 29-39; female: 29-39)	.74±.28	.01	.63±.22	.01
3 (male: 40-53; female: 40-54)	.73±.41	.08	1.02±.24	<.001
4 (male: 54-413; female: 55-163)	1.23±.40	.004	1.39±.37	<.001
Survey II				
R square	.48		.42	
Age	.02±.00	<.001	.02±.00	<.001
Education				
Elementary	-	-	-	-
Some high school	-.10±.13	.43	-.26±.16	.11
High school graduate	-.00±.12	.99	-.28±.14	.05
Some college	-.08±.12	.54	-.36±.15	.02
College and above	-.10±.12	.40	-.37±.15	.02
Region				
North	-	-	-	-
Middle	.36±.08	<.001	.18±.10	.04
South	.12±.06	.06	.03±.07	.63
Body mass index	1.07±.78	.17	-1.04±.80	.19
Eating status				
Non-Fisheater	-	-	-	-
Fisheater	.38±.18	.04	.06±.15	.71
Quartile of annual fish meals				
1 (male: 7-28; female: 7-28)	-	-	-	-
2 (male: 29-40; female: 29-33)	.57±.18	.002	-	-
3 (male: 41-60; female: 34-46)	.76±.19	<.001	.76±.15	<.001
4 (male: 61-413; female: 47-413)	.74±.19	<.001	.87±.16	<.001

(To be Continued)

Table 39. Adjusted linear regression of levels of Aroclor 1260 (log transformed) on demographic characteristics and quartile of total weight of fish consumed stratified by gender and survey (continued)

	Men		Women	
	B±SE	p	B±SE	p
Survey III				
R square	.48		.49	
Age	.02±.00	<.001	.03±.00	<.001
Education				
Elementary	-	-	-	-
Some high school	-.13±.28	.63	-1.01±.25	<.001
High school graduate	-.07±.23	.78	-.61±.19	.002
Some college	-.09±.24	.70	-.58±.20	.005
College and above	-.34±.24	.16	-.64±.21	.002
Region				
North	-	-	-	-
Middle	.46±.16	.005	.31±.14	.04
South	.30±.13	.02	.23±.11	.03
Body mass index	*	*	*	*
Eating status				
Non-Fisheater	-	-	-	-
Fisheater	1.04±.13	<.001	.53±.10	<.001
Quartile of total weight of fish consumed				
1 (male: 0.4-9; female: 0.3-4)	-	-	-	
2 (male: 10-18; female: 5-10)	.10±.15	.49	.47±.14	.001
3 (male: 19-31; female: 11-19)	.07±.17	.69	.35±.12	.004
4 (male: 32-159; female: 20-93)	.27±.18	.14	.49±.13	<.001

B ± SE: Regression coefficient ± Standard error
- : Reference group
*: No data

Table 40. Adjusted linear regression of levels of DDT (log transformed) on demographic characteristics and quartile of total weight of fish consumed stratified by gender and survey

	Men		Women	
	B±SE	p	B±SE	p
Survey II				
R square	.40		.32	
Age	.03±.00	<.001	.03±.00	<.001
Education				
Elementary	-	-	-	-
Some high school	.01±.18	.98	-.17±.18	.35
High school graduate	.17±.16	.28	-.21±.16	.18
Some college	.10±.17	.54	-.29±.17	.08
College and above	.12±.17	.46	-.52±.17	.003
Region				
North	-	-	-	-
Middle	.59±.10	<.001	.09±.11	.43
South	.16±.08	.05	.05±.08	.53
Body mass index	4.04±1.05	<.001	1.11±.90	.22
Eating status				
Non-Fisheater	-	-	-	-
Fisheater	.39±.24	.11	.08±.17	.63
Quartile of total weight of fish consumed				
1 (male: 7-28; female: 7-28)	-	-	-	-
2 (male: 29-40; female: 29-33)	.45±.24	.07	-	-
3 (male: 41-60; female: 34-46)	.69±.26	.01	.53±.17	.002
4 (male: 61-413; female: 47-413)	.66±.25	.01	.53±.18	<.005
Survey III				
R square	.36		.27	
Age	.03±.00	<.001	.03±.005	<.001
Education				
Elementary	-	-	-	-
Some high school	-.18±.33	.58	-.87±.35	.01
High school graduate	-.10±.28	.71	.36±.27	.19
Some college	-.15±.29	.60	-.30±.29	.29
College and above	-.43±.13	.15	-.56±.29	.06
Region				
North	-	-	-	-
Middle	.63±.19	.001	.39±.20	.06
South	.42±.15	.001	.33±.15	.03
Body mass index	*	*	*	*
Eating status				
Non-Fisheater	-	-	-	-
Fisheater	.78±.16	<.001	.26±.15	.08
Quartile of total weight of fish consumed				
1 (male: 0.4-9; female: 0.3-4)	-	-	-	-
2 (male: 10-18; female: 5-10)	-.06±.18	.76	.34±.20	.08
3 (male: 19-31; female: 11-19)	-.08±.20	.70	.36±.17	.04
4 (male: 32-159; female: 20-93)	.05±.22	.83	.28±.18	.13

Note: DDT was tested in 1979-82 and 1989-91 survey only.

B ± SE: Regression coefficient ± Standard error; - : Reference group; *: No data

Table 41. Adjusted linear regression of levels of DDE (log transformed) on demographic characteristics and quartile of total weight of fish consumed stratified by gender and survey

	Men		Women	
	B±SE	p	B±SE	p
Survey II				
R square	.39		.32	
Age	.03±.00	<.001	.03±.00	<.001
Education				
Elementary	-	-	-	-
Some high school	.10±.17	.55	-.14±.18	.45
High school graduate	.21±.15	.17	-.18±.15	.23
Some college	.12±.16	.46	-.28±.16	.09
College and above	.14±.16	.39	-.51±.17	.002
Region				
North	-	-	-	-
Middle	.57±.10	<.001	.07±.11	.48
South	.14±.08	.07	.05±.08	.48
Body mass index	4.19±1.03	<.001	.72±.87	.41
Eating status				
Non-Fisheater	-	-	-	-
Fisheater	.37±.24	.11	.08±.17	.65
Quartile of total weight of fish consumed				
1 (male: 7-28; female: 7-28)	-	-	-	-
2 (male: 29-40; female: 29-33)	.40±.24	.10	-	-
3 (male: 41-60; female: 34-46)	.63±.24	.01	.49±.17	.003
4 (male: 61-413; female: 47-413)	.63±.25	.01	.48±.18	.001
Survey III				
R square	.38		.27	
Age	.03±.00	<.001	.03±.01	<.001
Education				
Elementary	-	-	-	-
Some high school	-.18±.32	.58	-.83±.35	.02
High school graduate	-11±.27	.69	-.35±.27	.21
Some college	-.10±.28	.73	.28±.29	.33
College and above	-.41±.28	.14	-.53±.29	.07
Region				
North	-	-	-	-
Middle	.60±.18	.001	.39±.20	.06
South	.43±.15	.003	.33±.15	.03
Body mass index	*	*	*	*
Eating status				
Non-Fisheater	-	-	-	-
Fisheater	.77±.16	<.001	.26±.14	.08
Quartile of total weight of fish consumed				
1 (male: 0.4-9; female: 0.3-4)	-	-	-	-
2 (male: 10-18; female: 5-10)	-.04±.17	.80	.35±.19	.07
3 (male: 19-31; female: 11-19)	-.08±.19	.68	.36±.17	.03
4 (male: 32-159; female: 20-93)	.11±.21	.62	.29±.18	.11

Note: DDE was tested in 1979-82 and 1989-91 survey only.

B ± SE: Regression coefficient ± Standard error

- : Reference group

*: No data

Table 42. Adjusted linear regression of levels of PBB (log transformed) on demographic characteristics and quartile of total weight of fish consumed stratified by gender and survey

	Men		Women	
	B±SE	p	B±SE	p
Survey II				
R square	.28		.22	
Age	-.003±.00	.25	.003±.00	.28
Education				
Elementary	-	-	-	-
Some high school	.24±.19	.21	-.14±.20	.48
High school graduate	.04±.17	.83	-.22±.17	.20
Some college	-.10±.18	.55	-.29±.18	.10
College and above	-.08±.18	.65	-.41±.18	.02
Region				
North	-	-	-	-
Middle	1.07±.11	<.001	.64±.12	<.001
South	1.19±.09	<.001	.91±.09	<.001
Body mass index	-3.06±1.14	.01	-2.23±.97	.02
Eating status				
Non-Fisheater	-	-	-	-
Fisheater	.34±.26	.19	-.06±.19	.76
Quartile of total weight of fish consumed				
1 (male: 7-28; female: 7-28)	-	-	-	-
2 (male: 29-40; female: 29-33)	-.35±.26	.18	-	-
3 (male: 41-60; female: 34-46)	-.32±.28	.22	-.01±.19	.94
4 (male: 61-413; female: 47-413)	-.41±.28	.14	.04±.20	.84
Survey III				
R square	.17		.17	
Age	.00±.01	.50	.01±.01	.16
Education				
Elementary	-	-	-	-
Some high school	.39±.33	.24	.07±.38	.86
High school graduate	-.07±.28	.80	-.02±.29	.95
Some college	-.25±.29	.38	-.16±.31	.61
College and above	-.24±.29	.40	-.30±.31	.34
Region				
North	-	-	-	-
Middle	.63±.19	.001	.44±.22	.04
South	.90±.15	<.001	.70±.16	<.001
Body mass index	*	*	*	*
Eating status				
Non-Fisheater	-	-	-	-
Fisheater	.03±.16	.85	-.28±.16	.07
Quartile of total weight of fish consumed				
1 (male: 0.4-9; female: 0.3-4)	-	-	-	-
2 (male: 10-18; female: 5-10)	-.04±.18	.82	.10±.21	.65
3 (male: 19-31; female: 11-19)	-.04±.20	.86	.37±.18	.04
4 (male: 32-159; female: 20-93)	.15±.22	.49	.59±.19	.002

Note: PBB was tested in 1979-82 and 1989-91 survey only.

B ± SE: Regression coefficient ± Standard error

- : Reference group

*: No data

Table 43. Adjusted linear regression of change in total weight of fish consumed of predicted against demographic characteristics and baseline fish consumption stratified by gender, from survey I to II and from survey II to III

	Men		Women	
	B±SE	p	B±SE	p
Survey I to II				
R square	.47		.68	
Age	.17±.38	.65	-.14±.17	.42
Education				
Elementary	-	-	-	-
Some high school	-28.99±17.21	.10	-39.89±10.30	<.001
High school graduate	-26.72±13.06	.05	-7.98±5.84	.18
Some college	-26.30±15.91	.11	-14.88±6.25	.02
College and above	-8.97±12.58	.48	-15.07±6.74	.03
Region				
North	-	-	-	-
Middle	.03±9.45	.99	-7.10±4.66	.13
South	*	*	-6.68±16.54	.69
Baseline body mass index	-139.34±123.88	.27	43.78±50.49	.39
Baseline total weight of fish consumed	.73±.14	<.001	.59±.07	<.001
Survey II to III				
R square	.72		.78	
Age	-.11±.13	.38	.02±.06	.77
Education				
Elementary	-	-	-	-
Some high school	-3.85±8.78	.66	-1.10±3.97	.78
High school graduate	-8.02±7.70	.30	-2.62±3.09	.40
Some college	-7.74±7.97	.33	-1.30±3.27	.69
College and above	-2.06±8.03	.80	-.30±3.29	.93
Region				
North	-	-	-	-
Middle	-3.38±4.71	.47	-2.72±2.26	.23
South	2.43±3.79	.52	-.05±1.67	.78
Baseline body mass index	-10.61±49.00	.83	12.08±18.03	.50
Baseline total weight of fish consumed	.82±.04	<.001	.84±.04	<.001

B ± SE: Regression coefficient ± Standard error

- : Reference group

*: No data

Table 44. Adjusted linear regression of change in Aroclor 1260 levels of predicted against demographic characteristics, baseline Aroclor 1260 levels, and change in fish consumption stratified by gender, from survey I to II and from survey II to III

	Men		Women	
	B±SE	p	B±SE	p
Survey I to II				
R square	.26		.27	
Age	.26±.32	.42	-.12±.10	.24
Education				
Elementary	-	-	-	-
Some high school	-13.32±14.75	.37	-4.36±5.94	.47
High school graduate	-11.27±10.37	.28	.91±3.35	.79
Some college	-20.29±13.82	.15	2.18±3.32	.51
College and above	-5.90±10.35	.57	.84±3.60	.82
Region				
North	-	-	-	-
Middle	-7.92±7.80	.32	-2.18±2.58	.40
South	*	*	-6.85±8.86	.44
Baseline body mass index	-36.02±97.49	.71	-7.16±28.00	.80
Eating status				
Non-Fisheater	-	-	-	-
Fisheater	-.1.03±8.84	.91	-7.22±3.62	.05
Baseline Aroclor 1260	-.23±.19	.23	-.27±.24	.24
Quartile of change in total weight of fish consumed				
1 (male:-95 to -7; female:-51 to 0)	-	-	-	-
2 (male: -6 to 5; female: 1 to 6)	-1.16±11.53	.92	-3.92±3.69	.29
3 (male: 6 to 26; female: 7 to 17)	4.81±9.46	.61	-.44±3.04	.89
4 (male: 27 to 105;female: 18 to 95)	-9.50±10.54	.37	6.45±4.41	.15

(To be continued)

Table 44. Adjusted linear regression of change in Aroclor 1260 levels of predicted against demographic characteristics, baseline Aroclor 1260 levels, and change in fish consumption stratified by gender, from survey I to II and from survey II to III (continued)

	Men		Women	
	B±SE	p	B±SE	p
Survey II to III				
R square	.09		.26	
Age	.02±.07	.82	-.03±.03	.27
Education				
Elementary	-	-	-	-
Some high school	-2.23±4.92	.65	1.26±2.13	.55
High school graduate	2.78±4.33	.52	-.54±1.64	.74
Some college	-.20±4.44	.96	1.14±1.71	.50
College and above	.87±4.45	.85	-.72±1.73	.68
Region				
North	-	-	-	-
Middle	-3.06±2.63	.25	-.67±1.18	.57
South	-3.69±2.08	.08	1.44±.88	.10
Baseline body mass index	-61.71±27.30	.02	-10.13±9.28	.28
Eating status				
Non-Fisheater	-	-	-	-
Fisheater	1.40±2.93	.63	-3.56±1.54	.02
Baseline Aroclor 1260 levels	.04±.04	.21	.26±.05	<.001
Quartile of change in total weight of fish consumed				
1 (male:-113 to -5; female:-46 to -2)	-	-	-	-
2 (male: -4 to 6; female: -1 to 0)	.53±2.52	.83	-.11±.94	.91
3 (male: 7 to 23;female: 1 to 14)	3.94±2.85	.17	2.52±1.75	.15
4 (male: 34 to 395;female: 15 to 89)	3.29±2.98	.27	3.61±1.60	.03

B ± SE: Regression coefficient ± Standard error

- : Reference group

*: No data

Table 45-a. Adjusted linear regression of change in DDT levels of predicted against demographic characteristics and baseline DDT levels, and change in annual fish meals stratified by gender, from survey II to survey III

	Men		Women	
	B±SE	p	B±SE	p
Survey II to III				
R square	.88		.86	
Age	-.15±.12	.23	-.15±.05	.004
Education				
Elementary	-	-		
Some high school	-10.27±7.79	.19	4.74±3.42	.17
High school graduate	2.93±6.96	.67	3.01±2.64	.25
Some college	-1.93±7.13	.79	5.58±2.81	.05
College and above	-.41±7.15	.95	2.62±2.82	.35
Region				
North	-	-	-	-
Middle	1.24±4.24	.77	-1.22±1.98	.54
South	-2.66±-3.36	.43	-1.12±1.44	.44
Baseline body mass index	-132.00±43.10	.003	14.23±15.84	.37
Eating status				
Non-Fisheater	-	-	-	-
Fisheater	-5.10±3.28	.12	-3.43±1.65	.04
Baseline DDT levels	.77±.02	<.001	.68±.02	<.001
Change in annual fish meals	.09±.04	.03	.02±.02	.36

B ± SE: Regression coefficient ± Standard error

- : Reference group

*: No data

Table 45-b. Adjusted linear regression of change in DDT levels of predicted against demographic characteristics and baseline DDT levels, and quartile of change in total weight of fish consumed stratified by gender, from survey II to III

	Men		Women	
	B±SE	p	B±SE	p
Survey II to survey III				
R square	.88		.86	
Age	-.15±.12	.22	-.15±.05	.003
Education				
Elementary	-	-		
Some high school	-9.97±7.96	.21	4.69±3.48	.18
High school graduate	3.47±7.11	.63	2.86±2.70	.29
Some college	-1.40±7.23	.85	5.29±2.85	.06
College and above	-.21±7.26	.98	2.47±2.87	.39
Region				
North	-	-	-	-
Middle	1.65±4.33	.70	-1.13±1.98	.57
South	-3.17±-3.39	.35	-1.11±1.46	.45
Baseline body mass index	-136.00±44.21	.002	14.09±15.87	.38
Eating status				
Non-Fisheater	-	-	-	-
Fisheater	-6.30±4.47	.16	-3.51±2.54	.17
Baseline DDT levels	.77±.02	<.001	.68±.02	<.001
Quartile of Change in total weight of fish consumed				
1 (male:-113 to -5; female:-46 to -2)	-	-	-	-
2 (male: -4 to 6; female: -1 to 0)	3.62±4.09	.38	2.27±1.54	.14
3 (male: 7 to 23;female: 1 to 14)	5.93±4.55	.19	2.53±2.95	.39
4 (male: 34 to 395;female: 15 to 89)	8.68±4.77	.07	3.04±2.69	.26

B ± SE: Regression coefficient ± Standard error

- : Reference group

*: No data

Table 46-a. Adjusted linear regression of changes in DDE levels of predicted against demographic characteristics and baseline DDE levels, and change in annual fish meals stratified by gender, from survey II to III

	Men		Women	
	B±SE	p	B±SE	p
Survey II to III				
R square	.87		.81	
Age	-.16±.11	.13	-.06±.04	.10
Education				
Elementary	-	-	-	-
Some high school	-9.32±6.89	.18	2.89±2.64	.28
High school graduate	2.14±6.16	.73	2.68±2.04	.19
Some college	-2.70±6.32	.67	3.07±2.17	.16
College and above	-.88±6.33	.89	1.61±2.18	.46
Region				
North	-	-	-	-
Middle	1.09±3.76	.77	-.33±1.54	.83
South	-2.52±2.98	.40	-.99±1.11	.38
Baseline body mass index	-113.25±38.17	.003	-19.97±12.04	.10
Eating status				
Non-Fisheater	-	-	-	-
Fisheater	-5.09±2.90	.08	-1.24±1.29	.34
Baseline DDE levels	.77±.02	<.001	.58±.02	<.001
Change in annual fish meals	.08±.04	.02	.01±.02	.65

B ± SE: Regression coefficient ± Standard error

- : Reference group

*: No data

Table 46-b. Adjusted linear regression of change in DDE levels of predicted against demographic characteristics and baseline DDE levels, and quartile of change in total weight of fish consumed stratified by gender, from survey II to III

	Men		Women	
	B±SE	p	B±SE	p
Survey II to III				
R square	.87		.81	
Age	-.17±.11	.13	-.07±.04	.09
Education				
Elementary	-	-	-	-
Some high school	-9.03±7.05	.20	2.53±2.69	.35
High school graduate	2.74±6.29	.66	2.29±2.09	.27
Some college	-2.14±6.40	.74	2.64±2.20	.23
College and above	-.59±6.42	.93	1.24±2.22	.58
Region				
North	-	-	-	-
Middle	1.55±3.83	.69	-.20±1.53	.89
South	-2.97±3.00	.32	-.85±1.13	.45
Baseline body mass index	-117.55±39.14	.003	-19.99±12.04	.10
Eating status				
Non-Fisheater	-	-	-	-
Fisheater	-6.09±3.95	.12	-2.21±1.96	.26
Baseline DDE levels	.77±.02	<.001	.58±.02	<.001
Quartile of Change in total weight of fish consumed				
1 (male:-113 to -5; female:-46 to -2)	-	-	-	-
2 (male: -4 to 6; female: -1 to 0)	3.44±3.62	.34	1.18±1.20	.32
3 (male: 7 to 23;female: 1 to 14)	5.18±4.03	.20	3.08±2.28	.18
4 (male: 34 to 395;female: 15 to 89)	8.24±4.24	.05	2.45±2.08	.24

B ± SE: Regression coefficient ± Standard error
- : Reference group
*: No data

Table 47. Adjusted linear regression of change in PBB levels of predicted against demographic characteristics and baseline PBB levels, and quartile of change in total weight of fish consumed stratified by gender, from survey II to survey III

	Men		Women	
	B±SE	p	B±SE	p
Survey II to III				
R square	.40		.23	
Age	-.02±.01	.10	-.01±.01	.26
Education				
Elementary	-	-	-	
Some high school	-.20±.71	.79	-.23±.66	.73
High school graduate	-.27±.62	.67	-.51±.51	.32
Some college	-.43±.63	.50	-.18±.54	.74
College and above	-.08±.64	.90	-.20±.55	.72
Region				
North		-	-	-
Middle	-.04±.38	.92	-.24±.38	.53
South	-.32±-.31	.31	-.01±.29	.97
Baseline body mass index	1.43±3.95	.72	-3.02±2.98	.31
Eating status				
Non-Fisheater	-	-		-
Fisheater	.20±.39	.61	-.38±.48	.43
Baseline PBB levels	.25±.02	<.001	.25±.04	<.001
Quartile of change in total weight of fish consumed				
1 (male:-113 to -5; female:-46 to -2)	-	-	-	-
2 (male: -4 to 6; female: -1 to 0)	-.08±.36	.83	.44±.30	.14
3 (male: 7 to 23;female: 1 to 14)	-.48±.41	.23	.61±.56	.28
4 (male: 34 to 395;female: 15 to 89)	.03±.42	.94	.75±.51	.15

B ± SE: Regression coefficient ± Standard error

- : Reference group

*: No data

Table 48. Adjusted linear regression of total weight of fish consumed against general characteristics based on repeated measure model

	B±SE	p
Gender		
Female	-	-
Male	13.38±3.03	<.001
Age	-.06±.11	.59
Education		
Elementary	-	-
Some high school	14.26±9.30	.13
High school graduate	9.86±8.43	.24
Some college	11.43±8.63	.19
College and above	3.37±8.82	.70
Region		
North	-	-
Middle	-4.53±3.01	.13
South	-9.59±5.13	.06
Survey time		
survey I (1973-74)	-	-
survey II (1979-82)	10.12±5.02	.04
survey III (1989-91)	-35.85±5.13	<.001

B ± SE: Regression coefficient ± Standard error

- : Reference group

Table 49. Adjusted linear regression of Aroclor 1260 levels against general characteristics based on repeated measure model

	B±SE	p
Gender		
Female	-	-
Male	.69±.06	<.001
Age	.02±.002	<.001
Education		
Elementary	-	-
Some high school	.22±.21	.27
High school graduate	.33±.19	.08
Some college	.35±.19	.07
College and above	.04±.19	.85
Region		
North	-	-
Middle	.24±.06	<.001
South	-.20±.12	.10
Survey time		
survey I (1973-74)	-	-
survey II (1979-82)	.10±.11	.37
survey III (1989-91)	-.42±.11	<.001

B ± SE: Regression coefficient ± Standard error

- : Reference group

Table 50. Adjusted linear regression of Aroclor 1260 levels against total weight of fish consumed and general characteristics based on repeated measure model

	B±SE	p
Gender		
Female	-	-
Male	.51±.06	<.001
Age	.02±.002	<.001
Education		
Elementary	-	-
Some high school	.08±.19	.67
High school graduate	.21±.17	.22
Some college	.23±.17	.19
College and above	.06±.18	.75
Region		
North	-	-
Middle	.11±.06	.05
South	-.14±.11	.20
Total weight of fish consumed	.01±.00	<.001
Survey time		
survey I (1973-74)	-	-
survey II (1979-82)	.31±.10	<.002
survey III (1989-91)	-.13±.10	.19

B ± SE: Regression coefficient ± Standard error

- : Reference group

Table 51. Adjusted linear regression of Aroclor 1260 levels of predicted against fish consumption and general characteristics stratified by gender based on repeated measure model

	Men		Women	
	B±SE	p	B±SE	p
Age	.02±.00	<.001	.02±.00	<.001
Education				
Elementary	-	-	-	-
Some high school	.28±.22	.20	-.64±.36	.08
High school graduate	.26±.19	.17	-.43±.34	.21
Some college	.40±.20	.05	-.50±.35	.15
College and above	.10±.20	.60	-.45±.35	.20
Region				
North	-	-	-	-
Middle	.13±.08	.10	.14±.07	.06
South	-.26±.14	.06	-.21±.15	.17
Survey time				
survey I (1973-74)	-	-	-	-
survey II (1979-82)	.24±.14	.08	.55±.12	<.001
survey III (1989-91)	-.05±.15	.73	.23±.13	.07
Group of total weight of fish consumed				
1(None)	-	-	-	-
2 (male: 1-24; female: 1-6)	.74±.11	<.001	.57±.11	<.001
3 (male: 25-48: female: 7-24)	1.10±.10	<.001	.73±.10	<.001
4 (male: 48+: female: 25+)	1.34±.10	<.001	.89±.09	<.001

FIGURES

Figure 1. The structure of biphenyl

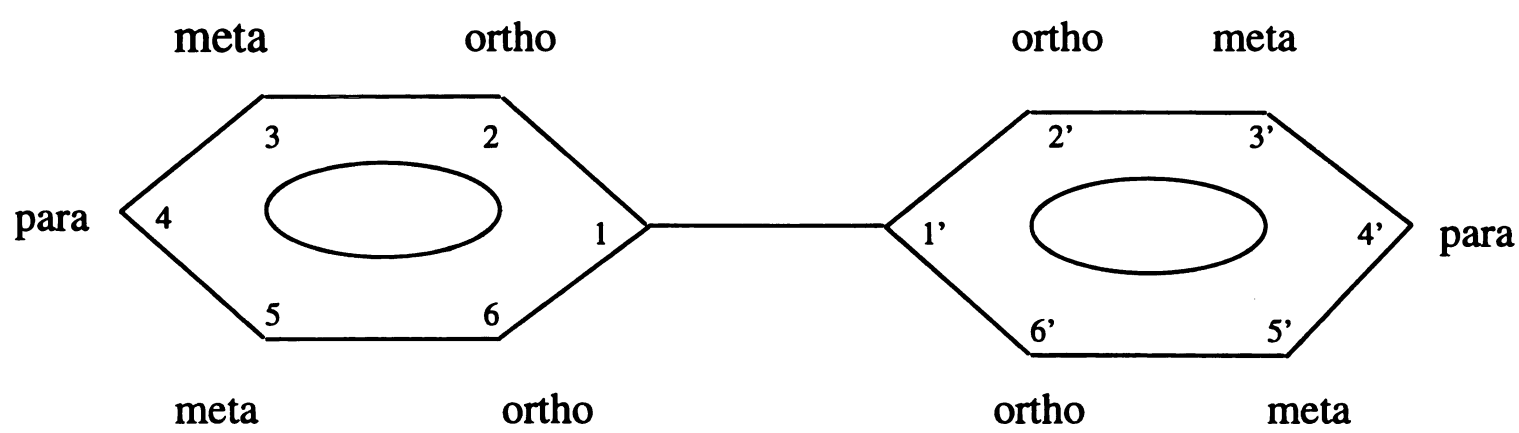


Figure 2. Sample sizes from the 3 cross-sectional surveys

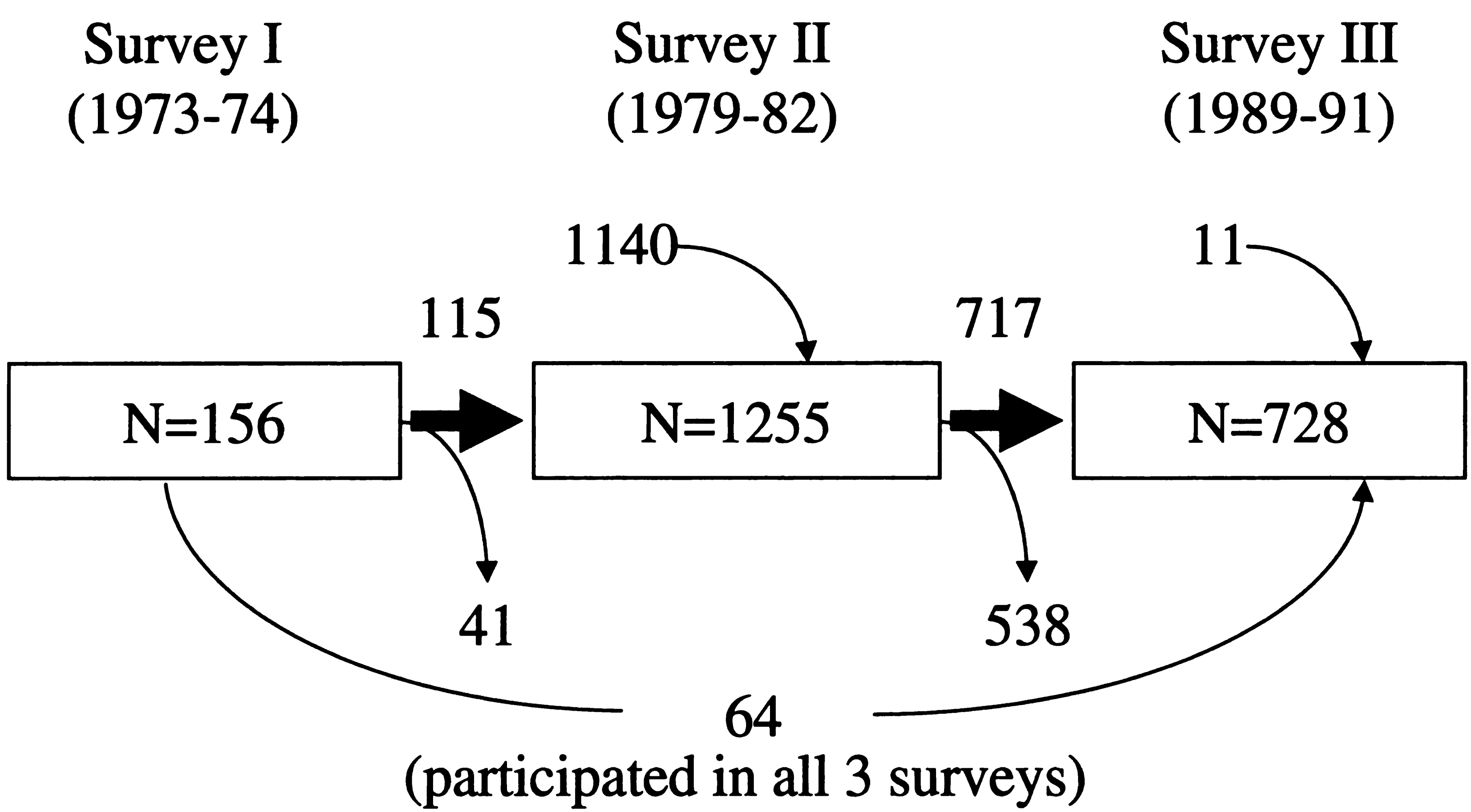


Figure 3. Eleven Western Michigan Counties Covered in the Study

Figure 4. Fish consumption, by survey

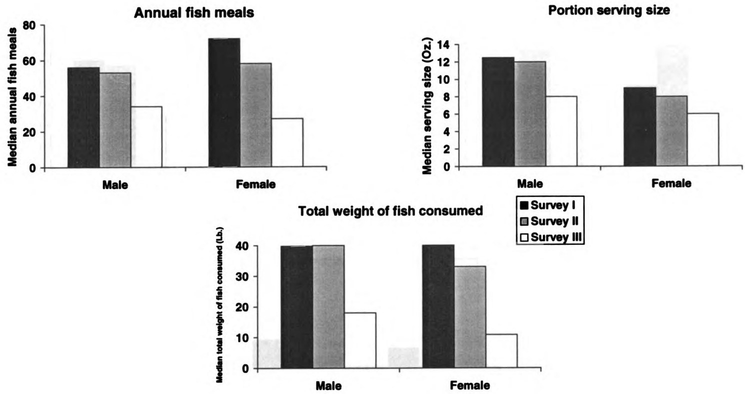


Figure 5. Mentioned as one of top three species of fish consumed, by survey

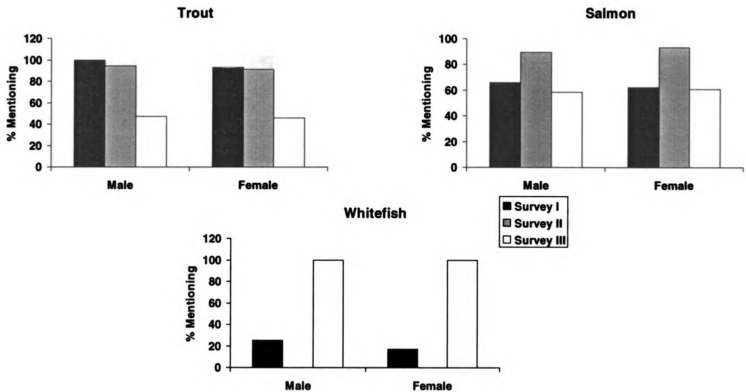


Figure 6. Fish preparation methods, by survey

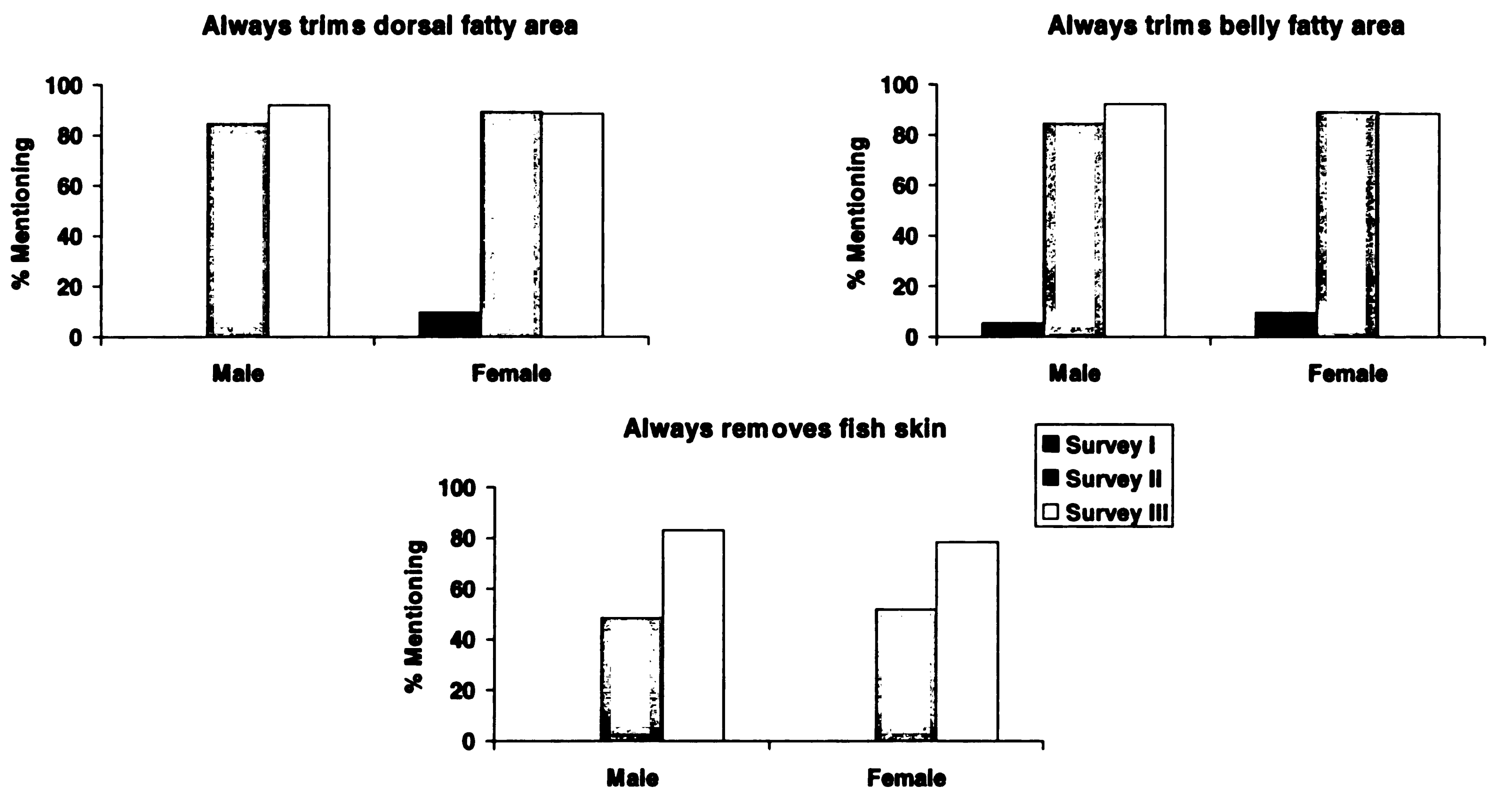


Figure 7. Serum levels of Aroclor 1260, by survey

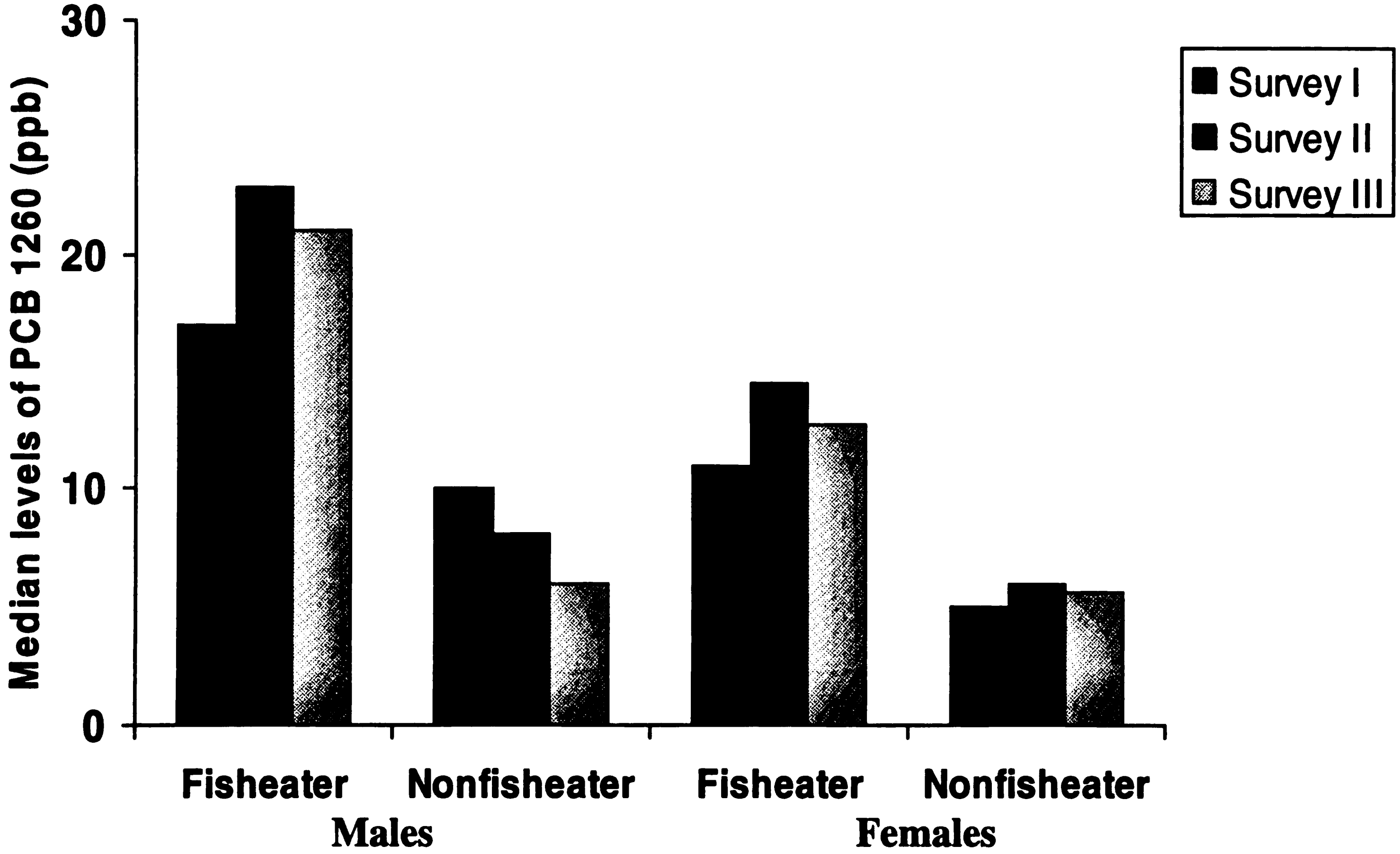
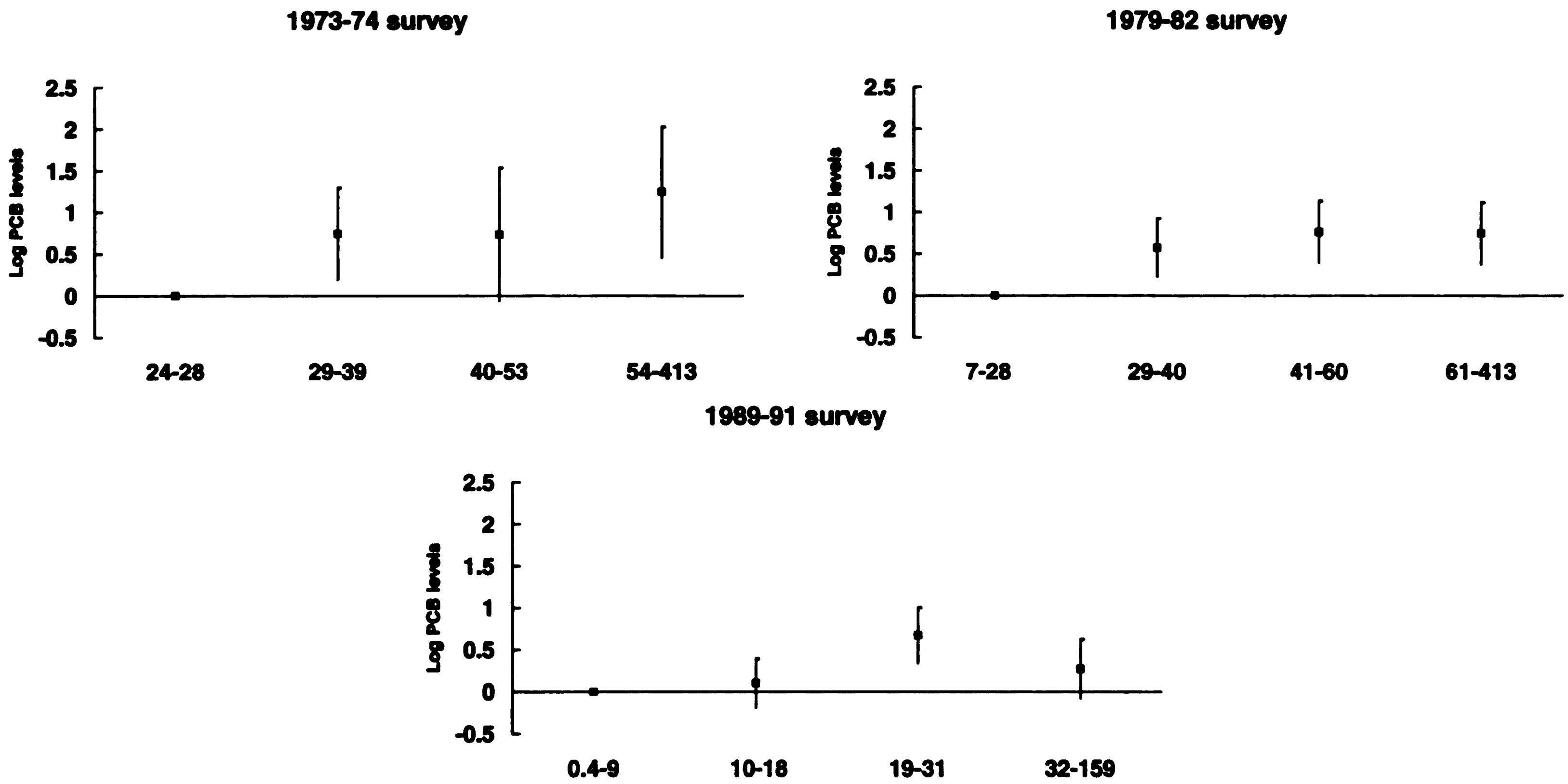
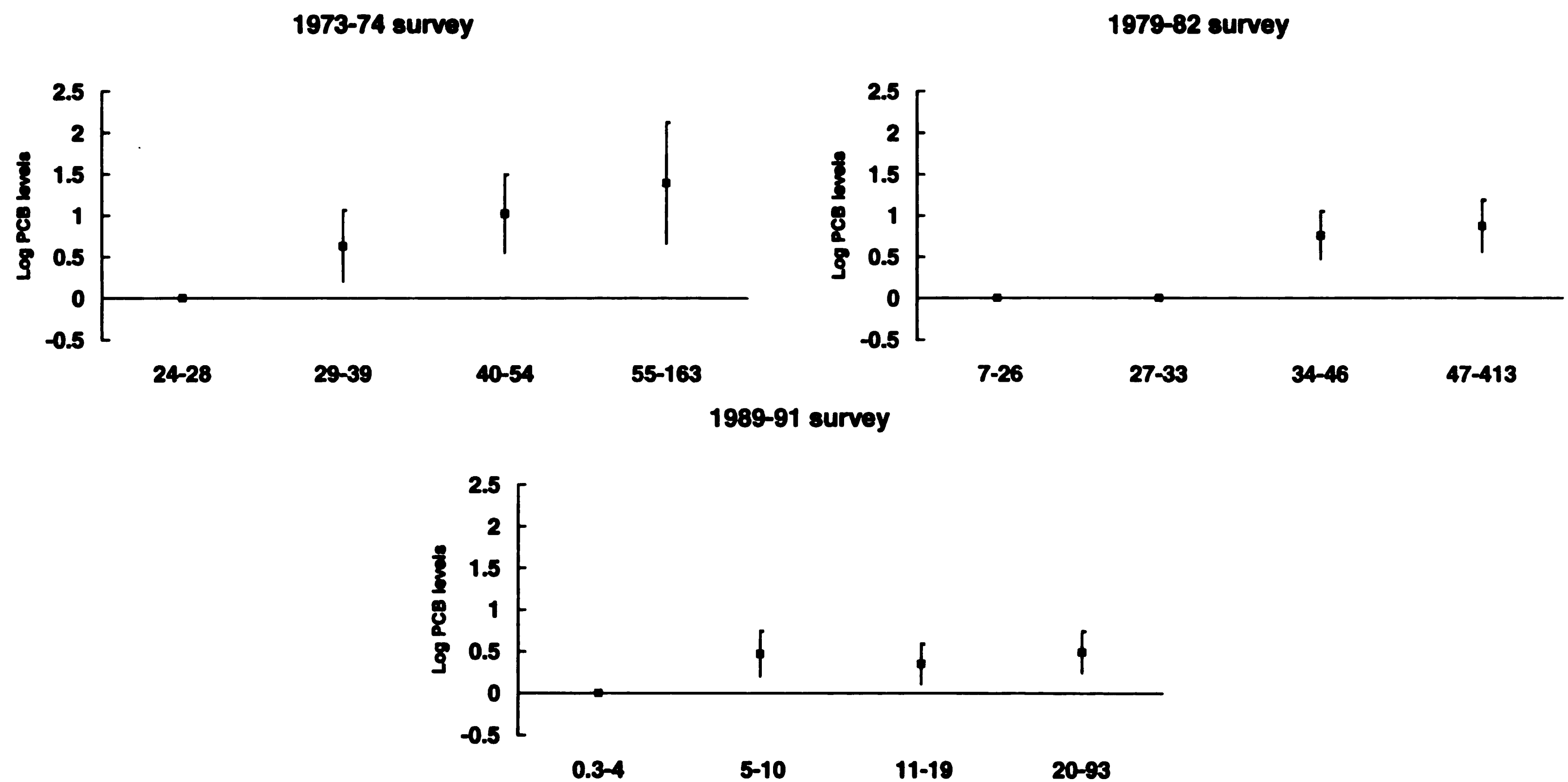


Figure 8. Multiple linear regression of log Aroclor 1260 levels against quartile of total weight of fish consumed in males, by survey



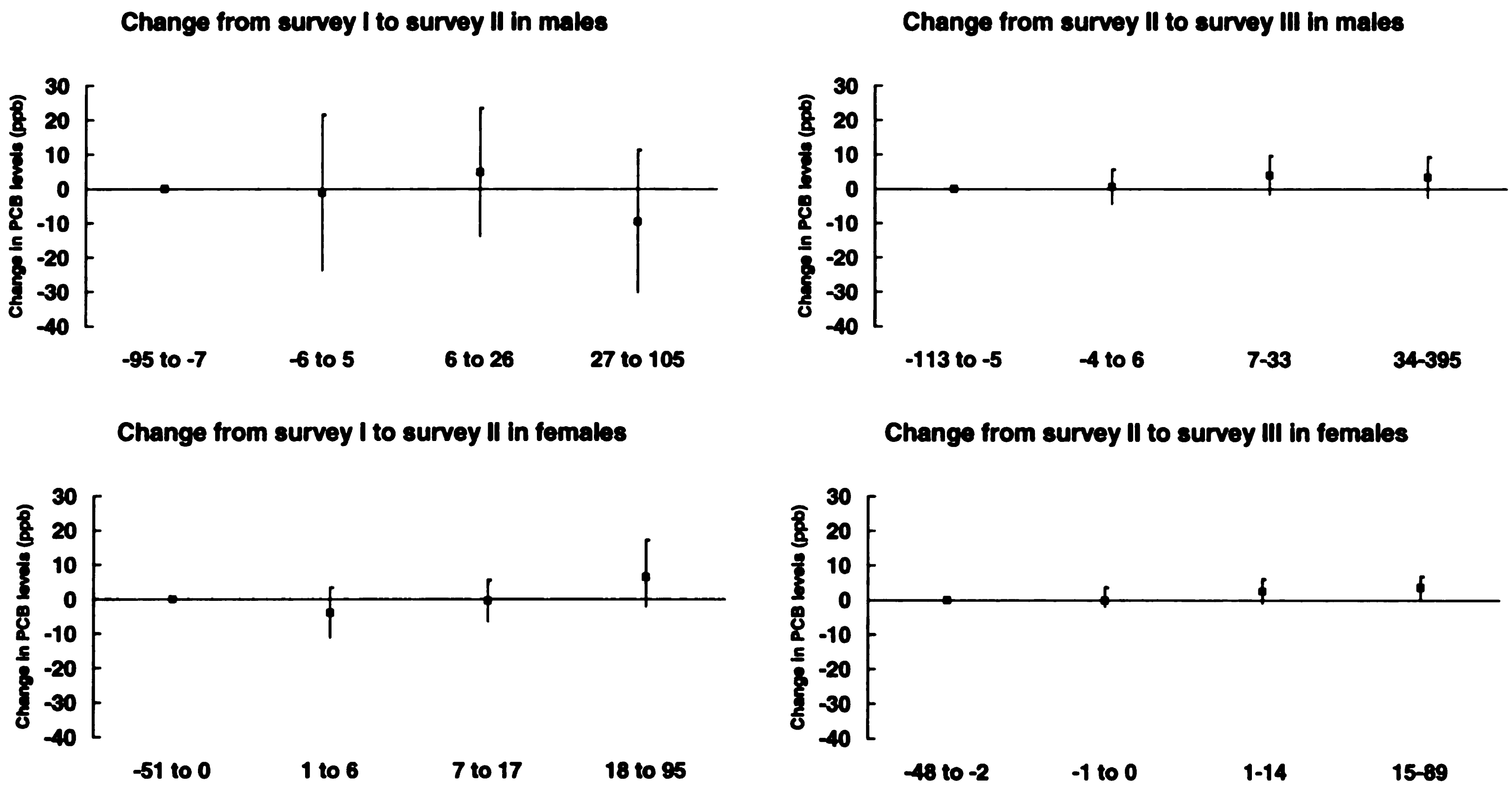
* Adjusted for age education, BMI, fish eating status for 1974-74 survey and 1979-82 survey
Adjusted for age, education, fish eating status for 1989-91 survey

Figure 9. Multiple linear regression of log Aroclor 1260 levels against quartile of total weight of fish consumed in females, by survey



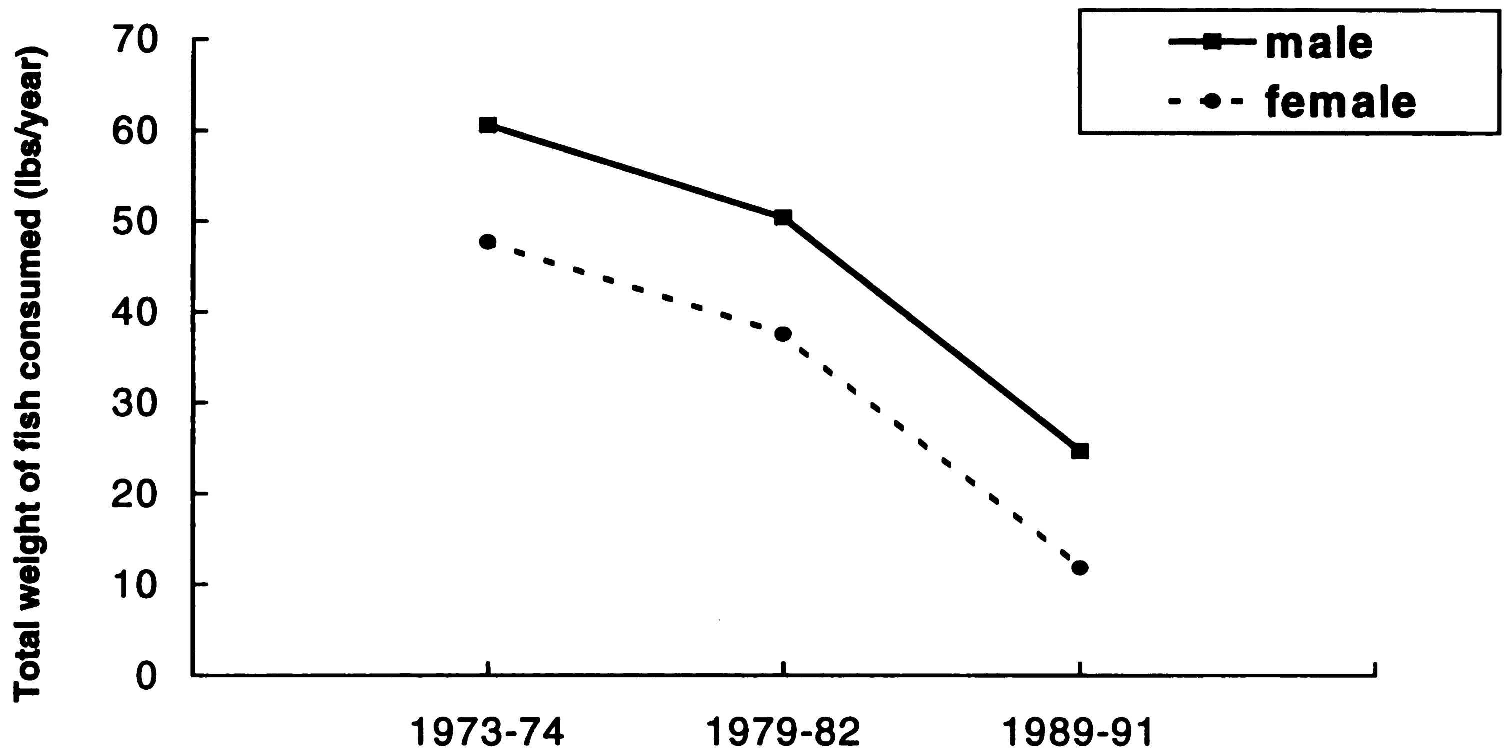
* Adjusted for age education, BMI, fish eating status for 1974-74 survey and 1979-82 survey
Adjusted for age, education, fish eating status for 1989-91 survey

Figure 10. Multiple linear regression of change in Aroclor 1260 levels against quartile of change in total weight of fish consumed



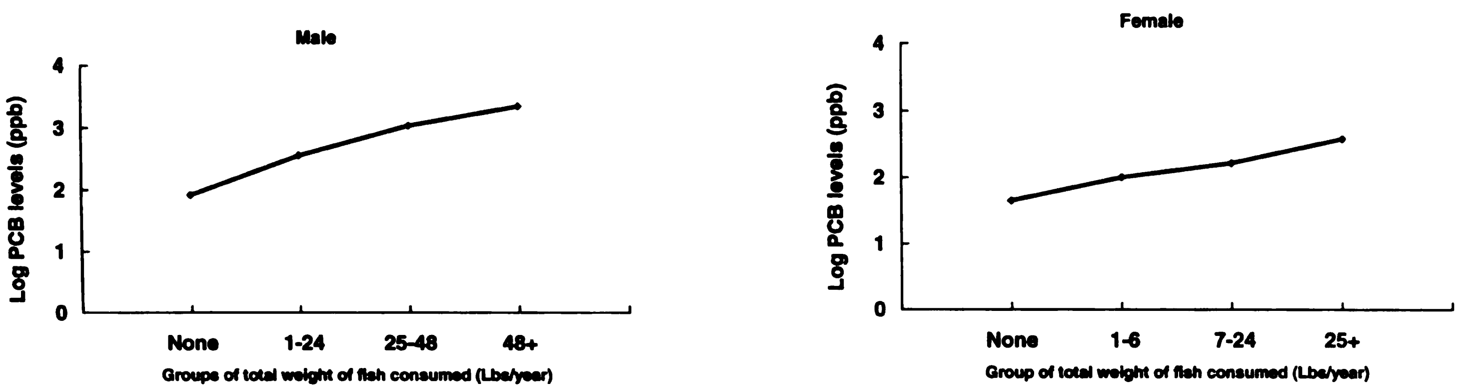
* Adjusted for age, education, region, baseline BMI, baseline Aroclor 1260 levels, fish eating status

Figure 11. Trends in total weight of fish consumed over 3 surveys



* Adjusted for age, education, region based on repeated measure models

Figure 12. Fish consumption and log serum Aroclor 1260 levels



* Adjusted for age, education, region, survey time based on repeated measure models

APPENDICES

Appendix I:

Reproducibility analysis of 1972 and 1974 survey

Variable	Statistic	P-value
Gender	Kappa=1.0	<.001
Height	Pearson r=0.95	<.001
Weight	Pearson r=0.96	<.001
Portion serving size	Spearman r=0.73	<.001
One of 3 top fish species:		
Trout	Kappa=0.6	<.001
Salmon	Kappa=0.6	<.001
Catfish	Kappa=1.0	<.001
Perch	Kappa=0.4	<.001
Whitefish	Kappa=0.9	<.001

Appendix II

Total lipid levels (mg/dl) stratified by gender and fish eating status, 1979-82

	N	Mean±SD	Median	Q25-Q75
Male	615	584.6±141.1	563.0	481.5-660.5
Fisheater	401	602.3±139.9	590.0	496.0-681.0
Nonfisheater	214	551.0±137.5	525.5	456.5-609.8
Female	502	543.8±133.1	523.0	458.0-612.0
Fisheater	205	555.5±139.1	534.0	466.5-630.0
Nonfisheater	297	535.7±128.3	518.5	455.0-600.0

Appendix III

Correlations between total lipids levels (mg/dl) and log levels of Aroclor 1260, DDT, DDE, and PBB, 1979-82

	Correlation Coefficient	p-value
Aroclor 1260	0.36	<.001
DDT	0.34	<.001
DDE	0.34	<.001
PBB	0.09	.002

Appendix IV

Unadjusted regression coefficient of log levels of Aroclor 1260, DDT, DDE, and PBB of predicted against total lipid levels, 1979-82

	Regression coefficient	R square	p-value
Aroclor 1260	.002	.13	<.001
DDT	.003	.12	<.001
DDE	.002	.11	<.001
PBB	<.001	.01	.002

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