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Effects of Cooking on Levels of PCBs in the Fillets of Winter Flounder (Pseudopleuronectes americanus)

T. M. Poston
G. S. Durell[a]
G. Koczwara[a]
A. M. Spellacy[a]

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Pacific Northwest Laboratory
Richland, Washington 99352

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SUMMARY

The Pacific Northwest Laboratory and Battelle Ocean Sciences performed a study to determine the effect of cooking on polychlorinated biphenyl (PCB) levels in the fillets of winter flounder (Pseudopleuronectes americanus). Broiling, pan frying, and deep frying in oil were tested on fillets from 21 fish collected from New Bedford Harbor, Massachusetts, on February 21, 1991. The evaluation involved estimating the change in PCB concentrations using a mass-balance approach that factored the change in fillet weight resulting from cooking with the changes in PCB concentration expressed on a precooked wet-weight basis.

Deep frying in oil resulted in a 47% reduction in total PCB levels in fillet tissue. Additionally, deep frying caused a 40% reduction in fillet mass. Pan frying and broiling resulted in statistically insignificant increases in total PCB levels of 15% and 17%, respectively. Fillet mass reductions resulting from pan frying and broiling were 7% and 15%, respectively. The effects of cooking on 18 individual congeners generally paralleled the results observed for total PCB. All 18 congeners were significantly reduced by deep frying. Congener $Cl_2(08)$ also was significantly reduced by either pan frying or broiling. Congeners $Cl_5(105)$ and $Cl_5(118)$ showed apparent significant increases in concentrations following pan frying. Congeners $Cl_5(105)$, $Cl_5(118)$, and $Cl_6(138)$ showed significant increases in concentration following broiling.

CONTENTS

FIGURE

TABLES

1.0 INTRODUCTION

The consumption of contaminated seafood has been shown to be a significant pathway for human exposure to polychlorinated biphenyls (Cordle et al. 1982). Human health exposure assessments currently conducted by the U.S. Environmental Protection Agency (EPA) often assume that levels of contaminants in edible tissue of fish remain the same after preparation and cooking. This assumption may lead to overestimation or underestimation of risk because a particular cooking method may remove or transform toxic constituents in the tissue by thermal decomposition, volatilization, dissolution in aqueous tissue fluids or lipids that drip off the tissue, or extraction into cooking oil during preparation.

Polychlorinated biphenyls (PCBs) are of particular interest because of their ubiquitous presence in the environment (including commonly consumed seafood), and their documented deleterious environmental and health effects. Although concentration levels and the fate and effects of PCBs in marine resources have been investigated in many earlier studies (e.g., Courtney and Denton 1976; Connolly 1991; Eisenberg et al. 1980; Rusek 1989; Pruell et al. 1988; Kolek and Ceurvels 1981), little information is available on the effects of cooking on PCB levels in seafood. Zabik et al. (1979) attempted to assess the effects of baking, broiling, and microwave preparation on PCB levels in lake trout. The results were inconclusive, and they suggested that cooking did not appear to significantly affect PCB levels in trout. Others have reported both significant decreases and significant increases in PCB levels following cooking of fish muscle (Smith et al. 1973; Cichy et al. 1979; Zabik et al. 1982; Puffer and Gossett 1983; Armbruster et al. 1989; Trotter et al. 1989).

The objective of this study was to quantify the effect of preparation and cooking on incurred PCB contaminants in the edible portion of seafood. The study focused on the effects of three different cooking methods (broiling, deep frying in oil, and pan frying) on concentrations of specific PCB congeners commonly found in fillets of winter flounder (Pseudopleuronectes americanus). The work plan was developed by the Environmental Protection Agency, Exposure Assessment Group in the Office of Research and Development, Washington, D.C.; Pacific Northwest Laboratory (PNL),[a] Richland, Washington; and Battelle Ocean Sciences (BOS),[b] Duxbury, Massachusetts. Sample processing and analysis were performed by Battelle Ocean Sciences.

This report contains four sections. In Section 2, the materials and methods involved in the field and laboratory work and in the data analysis are presented. The results of the study are summarized in Section 3, and Section 4 provides a further discussion of the analytical results. All PCB values are

(a) PNL is operated for the U.S. Department of Energy by Battelle Memorial Institute.
(b) BOS is a component of Battelle Columbus Laboratories, Battelle Memorial Institute.

expressed as nanograms of PCB per precooked wet fillet weight in grams to accommodate the mass-balance approach used to evaluate the data.

2.0 MATERIALS AND METHODS

The winter flounder used for this study were collected in New Bedford Harbor, Massachusetts. The fish were prepared and cooked by three cooking methods: pan frying, broiling, and deep frying. Fillet tissues from each fish were analyzed for total PCB concentrations and 18 specific PCB congeners, before and after cooking (Table 1). The total PCB concentrations in the samples also were determined based on summation and ratios for 17 of the identified congeners. Congener $Cl_7(170)$ was excluded from this determination because sometimes a low-level laboratory interferant coeluted with this congener in the instrumental analysis. The PCB data were generated and compiled with procedures used in the National Status and Trends Mussel Watch Program (Battelle 1990).

2.1 FIELD WORK

Winter flounder were collected on February 21, 1991. The intent was to collect 25 fish in the 25- to 35-cm range to maximize the chances of selectively collecting 3-year-old fish. Winter flounder that hatch in New Bedford Harbor stay in the estuary for approximately 3 to 4 years before beginning their annual migration pattern.(a) Four-year-old fish generally migrate out of the area in the spring and are often of commercial fishing size (larger than 30 cm long). Selecting 3-year-old (rather than older) fish increases the chances of the fish having spent all their lives in the New Bedford Harbor area. Age classification was determined by size, based on information obtained from the Massachusetts Division of Marine Fisheries, and is specific to the Buzzards Bay region (Table 2).

Twenty-one winter flounder were caught by otter trawl. Using polyethylene gloves, researchers removed the live fish from the net and placed them on ice in a thoroughly cleaned cooler. At the end of the day, the fish were transported on ice to the laboratory for storage and processing.

The fish were caught outside the New Bedford Harbor hurricane barrier, and between the hurricane barrier and Clarks Point (Figure 1), in an area roughly 3 km long and 1.5 km wide. This area is within what is commonly referred to as Restricted Area II, the area north of Ricketsons and Wilbur Points and outside the hurricane barrier. Area II is closed to the taking of bottom-feeding finfish (including winter flounder) and lobster.

(a) Telephone conversation between G. Durell (BOS) and A. Kolek and A. Howell, Massachusetts Division of Marine Fisheries, Boston, Massachusetts.

TABLE 1. PCB Analysis Parameters and Their Respective Detection Limits

Analyte Identification			Detection Limit	
PCB	Congener	Cl Substitution	ng/g, dry wt.(a)	ng/g. wet wt.(b)
Cl_2	(08)	2,4'	5.75	1.15
Cl_3	(18)	2,2',5	1.29	0.26
Cl_3	(28)	2,4,4'	0.67	0.13
Cl_4	(44)	2,2',3,5'	1.49	0.30
Cl_4	(52)	2,2',5,5'	0.97	0.19
Cl_4	(66)	2,3',4,4'	1.47	0.29
Cl_5	(101)	2,2',4,5,5'	1.16	0.23
Cl_5	(105)	2,3,3',4,4'	1.16	0.23
Cl_5	(118)	2,3',4,4',5	1.19	0.24
Cl_6	(128)	2,2',3,3',4,4'	0.65	0.13
Cl_6	(138)	2,2',3,4,4',5	1.96	0.39
Cl_6	(153)	2,2',4,4',5,5'	2.39	0.48
Cl_7	(170)	2,2',3,3',4,4',5	0.49	0.10
Cl_7	(180)	2,2',3,4,4',5,5'	0.96	0.19
Cl_7	(187)	2,2',3,4',5,5',6	1.72	0.34
Cl_8	(195)	2,2',3,3',4,4',5,6	0.56	0.11
Cl_9	(206)	2,2',3,3',4,4',5,5',6	0.86	0.17
Cl_{10}	(209)	100% Substitution	1.18	0.24

(a) Determined using oyster tissue (Battelle 1991).
(b) Calculated by multiplying dry-weight detection limit by 0.2.

TABLE 2. Estimated Age of Winter Flounder Based on Length

Age, (yr)	Length, (cm)
2	13 to 25
3	22 to 35(a)
4	27 to 42

(a) Three-year age-class average is 27.5 cm.

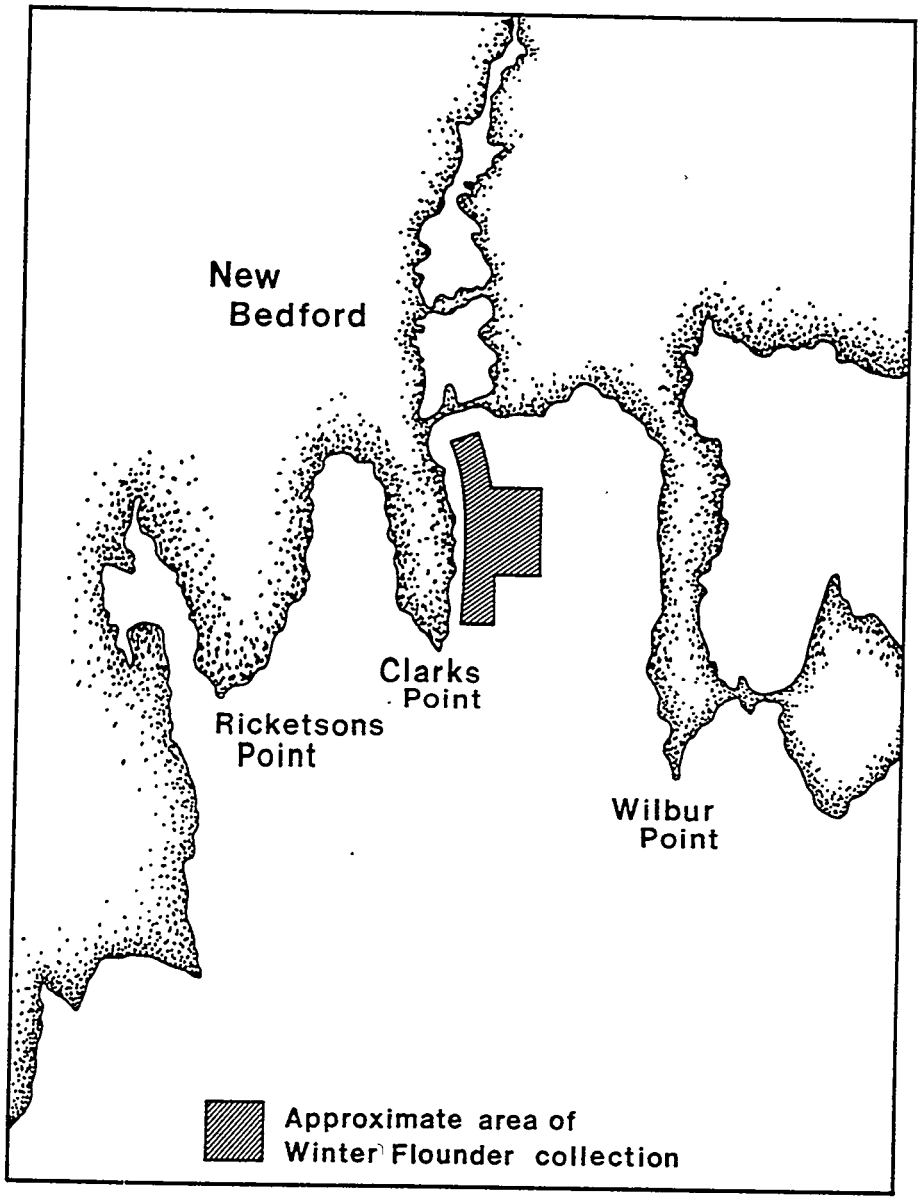

FIGURE 1. New Bedford Harbor Area Map with Approximate Location of Winter Flounder Sample Collection

2.2 LABORATORY WORK

The laboratory work consisted of the initial processing of the samples (filleting and cooking), sample processing for analysis (e.g., extraction, purification), and instrumental analysis. The initial processing of all fish was completed in one day. Sample processing for analysis, the instrumental analysis, and the data reduction were performed in two steps: 1) a pilot study in which five fish, representing the whole range of age/size of the 21 fish caught, were analyzed; and 2) the definitive study in which the remaining fish were analyzed.

2.2.1 Initial Preparation and Cooking

Winter flounder were stored whole on ice and processed within 24 h after collection. The initial processing involved filleting the fish, sectioning the fillets, and cooking the fillet sections according to one of three "treatments": deep frying, pan frying, or broiling. The cooked flesh was homogenized and stored frozen (-20°C) until extraction could begin. Measurements of whole fish length, weight, and fillet section weight before and after cooking were made and recorded during the initial sample preparation.

The sample processing yielded one carcass sample for each fish, and oil/drippings samples from each of the deep-frying and pan-frying treatments. The broiling did not generate enough drippings to collect. Fish carcass and oil/drippings samples were archived at -20°C.

Filleting and Sectioning

Each fish was assigned a unique laboratory identification code when removed from the cooler for processing (e.g., WF01 for winter flounder #1). Weight and fork length (tip of snout to fork in tail) were recorded for all fresh fish before filleting. The fish were examined for external abnormalities (e.g., fin rot and tumors).

During the filleting, care was taken not to disrupt the viscera. All materials coming in contact with the sample (e.g., aluminum foil, sample jars, filleting knife, cutting board, and various laboratory utensils) were cleaned with soap and distilled water, then rinsed with methanol and dichloromethane. Glassware was also baked and rinsed with solvent between samples. Polyethylene gloves were worn at all times when handling fish or tissue.

The fish was removed from the cooler and placed on aluminum foil. A sharp stainless steel filleting knife was used to fillet the fish into two skinfree fillets, one top and one bottom fillet. To reduce bias resulting from the choice of fillet, alternating fillets (top and bottom) were selected for precooking and cooking treatments. The fillet used for background/untreated PCB determination was placed in a prelabeled glass jar immediately after filleting. The fillet used for cooking was placed on a precleaned marble cutting board and was cut on a dorsal-ventral plane into three subsamples of approximately equal size. The anterior (nearest the head) section was Section I, the middle section was Section II, and the posterior section was Section III. The fish subsamples were then placed on a sheet of precleaned aluminum foil that had been prelabeled to identify the fish, fillet (top or bottom), fillet section, and treatment. The carcass, including viscera, was wrapped in precleaned aluminum foil, placed in a prelabeled Ziploc bag, and frozen at or below -20°C should later analysis be of interest.

The choice of fillet used for cooking alternated between top and bottom to reduce bias. For 10 of the 21 fish, the top fillet was used as the treatment fillet; for the other 11 fish, the bottom fillet was

used. Similarly, attempts were made to reduce bias by alternating the section of the treatment fillet (Section I, II, or III) used for the three cooking treatments. An equal number of the three different sections were used for each cooking treatment; i.e., seven were of Section I, seven of Section II, and seven of Section III from the 21 fish used for each of the three cooking methods.

Cooking and Homogenizing

During the cooking of the fish, attempts were made to reproduce restaurant- and home-kitchen cooking and serving techniques. Optimal processing and cooking methods and conditions were determined before processing the fish caught for this study, using store-bought winter flounder of comparable size. The fish were cooked thoroughly but not overcooked. Pre- and post-cooking weights of the treatment sections were recorded to determine weight loss and precooking equivalent weights. Additionally, moisture and lipid content was determined on all background (raw) samples.

Fish samples for deep frying were cooked for approximately 1 min in 200 mL of pure vegetable oil in a fryer that had been preheated for 5 min. Fish samples for pan frying were cooked for approximately 1 min per side in 1 tablespoon of lightly salted butter in a 9-in. "non-stick" frying pan that had been preheated on a portable electric range. Fish samples for broiling were cooked for approximately 2 min on a broiling pan in an oven that had been preheated for broiling. The fryer, the pans, and all utensils that came in contact with the fish were thoroughly cleaned before processing the first fish and between the processing of each succeeding fish. Cleaning involved washing the cooking apparatus with soap and water, then rinsing with methanol and allowing to air dry. Fresh cooking oil was used for each fish. The fish subsamples were handled as during normal cooking and serving. Cooked fillet subsamples were not blotted dry; however, excess oil was allowed to drip off. The cooked subsamples were placed in prelabeled glass jars for storage.

The cooked samples were homogenized within 1 h of filleting and cooking with an Omni homogenizer and were stored frozen at or below -20°C until sample extraction.

2.2.2 Extraction and Preparation for Analysis

Samples were thawed, and approximately 5 to 25 g of tissue homogenate was removed and placed in a Teflon jar for extraction. The subsample was fortified with approximately 60 ng of the surrogate compound dibromooctafluorobiphenyl (DBOFB). Matrix-spike samples were fortified with approximately 50 ng of each of the PCB congener analytes and approximately 60 ng of the surrogate compound. Sodium sulfate was added to absorb water. The sample homogenate was macerated twice for 2 min with a Tissuemizer, using dichloromethane as the extraction solvent. The sample was centrifuged between extractions and the extract decanted. After the two

maceration/extraction steps, dichloromethane was added to the sample and the jar was shaken for approximately 30 min. Again, the sample was centrifuged and the extracts combined.

The extract was passed through 20 g of alumina for preliminary cleanup and concentrated using a Kuderna-Danish apparatus, followed by gentle evaporation with nitrogen gas. The extract was then purified by gel permeation high-performance liquid chromatography (HPLC). The HPLC analyte fraction was concentrated by nitrogen evaporation, solvent exchanged for isooctane, and reduced to a final volume of approximately 200 µL. The sample was then fortified with approximately 50 ng of the recovery internal standard tetrachloro-m-xylene (TCMX), and submitted for analysis by gas chromatography/electron capture detection (GC/ECD).

2.2.3 Instrumental Analysis

The samples were analyzed using a Hewlett-Packard Model 5890A gas chromatograph with a ^{63}Ni electron-capture detector (Battelle 1990). The analytes were separated chromatographically using a 30-m x 0.25-mm-inner-diameter fused-silica capillary column, with a 0.25-µm stationary phase (95% methylsilicone and 5% phenylsilicone) film thickness (J&W Scientific, Folsom, California). Sample injection volume was 2 µL. Hydrogen was used as the carrier gas at a flow rate of approximately 1.5 mL/min. The detector makeup gas was 95% argon and 5% methane at a flow rate of approximately 40 mL/min. Injector and detector temperatures were 280°C and 325°C, respectively. The GC temperature program was as follows: a 1-min hold at 60°C, 60 to 150°C at 15°C/min, 150 to 210°C at 1°C/min, 210 to 280°C at 10°C/min, and a 10-min hold at 280°C.

All chromatographic data were acquired, reduced, and stored using the Beckman PeakPro chromatography software operating on a Hewlett-Packard 1000 A-Series minicomputer. The GC/ECD quantification files were transferred to a personal computer for subsequent manipulation of the data.

The PCB congener concentration data were determined in nanograms per gram on a raw wet-weight basis. The extraction sample wet weights were corrected to raw wet weight for the treatment samples, using the pre- and post-cooking sample weight ratios from the same fish and treatment section (see Appendix A). The extraction sample wet weight was obtained directly for the untreated samples. To determine the concentration of PCB in the cooked fillet, simply multiply the precooked value (Tables A.2 through A.4) by the ratio of the cooked weight to the precooked weight (Table A.6).

The samples were quantified relative to the surrogate compound DBOFB. The recovery internal standard TCMX was used to determine surrogate recoveries in the samples. Four types of PCB data are reported for each field sample (Appendix A): 1) the concentrations of each of the 18

PCB congeners, 2) the sum of the concentrations of the 18 PCB congeners, 3) the total PCB concentration based on the ratio of the sum of the concentrations of the 18 PCB congeners to the total PCB in an equal mix of Aroclors 1242 and 1254, and 4) the total PCB concentration based on the ratio of the sum of the concentrations of 17 PCB congeners [excluding $Cl_7(170)$] to the total PCB in an equal mix of Aroclors 1242 and 1254.

The PCB congeners were quantified using individual response factors for each analyte. The response factors were determined from a three-point calibration curve analyzed with each set of no more than 20 samples. To calculate the total PCB concentration, the average concentration of the 18 PCB congeners in a "total PCB-mix" was determined for a 1:1 mix of Aroclors 1242 and 1254. This Aroclor composition is the approximate composition of the PCBs in the New Bedford Harbor sediment where the fish were collected (EPA, Narragansett, Rhode Island, personal communication). The congener composition was determined by combining approximately 100 ng of the surrogate compound and approximately 1 µg each of Aroclors 1242 and 1254, diluting to approximately 1000 µL with hexane, and performing triplicate analyses. The ratio of the sum of concentrations of the 18 congeners to total PCB concentration was then determined and subsequently used in calculating the total PCB concentration in the winter flounder samples.

2.3 DATA ANALYSIS

All data analysis was conducted with Statview 512+, a statistical software package (Abacus Concepts 1986). Data initially were analyzed as total PCB levels based on estimated levels for 17 congeners. The data were used to determine the fractional change in PCBs as a result of cooking (derived from Skea et al. 1979):

$$F = [(C_r \times M_r) - (C_c \times M_c)]/(C_r \times M_r)$$

where F = the fractional change in PCBs
C_r = concentration of PCBs in raw fillet
M_r = mass of raw fillet
C_c = concentration of PCBs in cooked fillet
M_c = mass of cooked fillet.

The data, which had both positive and negative values, were transformed by raising the fractional change to the natural logarithm (ln; i.e., e^F). This transformation was necessary because of the large range in PCB concentrations and associated high variability. A three-way analysis of

variance (ANOVA) was performed to evaluate differences of cooking treatment, section, and fillet on the transformed data. A oneway ANOVA was performed on treatment effects, and differences between cooking treatments were evaluated with Fisher's Least Significant Differences (LSD) test.

The transformed fractional data also were tested against the null hypothesis (H_0) of no difference by conducting two-tailed t tests.

The null hypothesis was

$$H_0: \quad e^F = 1 \text{ (i.e., transformed } e^0 = 1)$$

The alternative hypotheses (H_a) were

$$H_a: \quad e^F < 1, \text{ or}$$
$$e^F > 1$$

where F represents the change in the transformed treatment sample mean and the transformed control (uncooked) mean.

The same approach was used to evaluate the effects of cooking on individual congeners. Cases in which a congener was at less than detection levels in the raw tissue were deleted from the data sets. When levels in both the cooked and the raw fillet were below detection, the fractional change was recorded as 0% ($e^{0.00} = 1.000$). When a congener was quantified in the raw fillet but below detection in the cooked fillet, the fractional change was entered as 100%, or 2.718 ($e^{1.00} = 2.718$). This modification biased the results low (i.e., it will overestimate PCB reduction) because, in the majority of these cases, the cooking treatment resulted in a less-than-detectable concentration when the raw sample was quantifiable. A small reduction in congener concentration may have resulted in a less-than-detectable amount, but not complete removal. This reanalysis involved congeners $Cl_2(08)$, $Cl_3(18)$, $Cl_8(195)$, $Cl_9(206)$, and $Cl_{10}(209)$.

Additional analysis of variance was conducted on other experimental factors to determine whether there were differences in cooking effects related to precooked-sample weight, change in subsample weight during cooking, fractional change in subsample weight during cooking, or recovery of the internal standard (DBOFB). Additionally, the relationship between lipid content and PCB concentration was evaluated by regression analysis of the ln-transformed total PCB estimates

based on 17 congeners. The ln-transformed total PCB levels were compared with fish mass and length by regression analysis to determine whether there was a relationship between age and PCB tissue burden.

3.0 RESULTS

Twenty-one winter flounder, designated WF01 through WF21, were collected and processed for this study. The lengths of the fish ranged from 25 to 42 cm (Table 3), indicating age classes ranging from 3 to 4 years. The weight of the fish ranged from 223 to 1181 g. All fish appeared healthy, with no external signs (e.g., fin rot or tumors) of environmental effects. Based on the presence of eggs and sperm, it appeared that most of the fish were caught before spring spawning. Regression analyses of ln-transformed total PCB with mass ($P = 0.62$) and length ($P = 0.47$) of the winter flounder were not significant.

Fillet sample size varied considerably because of the variability in the size of the fish (see Appendix A). The experimental design normalized the effects of section location. An analysis of variance was performed to determine whether there were differences in the fillet's raw sample weight, overall change in weight, and fractional change in fillet weight among the three cooking treatments. This analysis was done by section (I, II, or III) and indicated no difference in raw sample weight by treatment or section; however, changes in sample weight resulting from cooking were statistically significant (Table 4; $P = 0.0001$).

Deep-fried fillets showed approximately 40% loss in weight, apparently resulting from loss of water (Table 5). There was less weight loss for pan frying and broiling, and it was more variable. The weight loss averaged approximately 7% and 15% for pan frying and broiling, respectively. The moisture content was fairly constant, approximately 80%, for the 21 fish (see Table 3). The lipid content was more variable but was in the 10- to 20-mg/g range for most of the uncooked fish. A simple regression analysis between lipid content in control fillets and ln-transformed total PCBs showed no significant relationship ($P = 0.385$, $R^2 = 0.042$).

The following sections present the results of the laboratory chemical analyses of these fish.

3.1 QUANTIFICATION OF PCBs

The results of the triplicate analyses of an equal mix of Aroclors 1242 and 1254 are presented in Appendix A. These data indicate that the 18 PCB congeners used in this study constitute approximately 58% of the total PCB in a 1:1 mix of Aroclors 1242 and 1254. This relationship was then used to determine the total PCB concentration, as an equal mix of Aroclors 1242 and 1254, in the fish samples. This relationship also was determined using 17 PCB congeners, after excluding $Cl_7(170)$. The 17 congeners make up approximately 57% of the total PCB [i.e., $Cl_7(170)$ is present

TABLE 3. Length, Weight, Moisture Content, and Lipid Content of Winter Flounder Samples

Fish ID	Length (cm)	Weight (g)	Moisture (%) [a]	Lipid (mg/g wet wt.)[a]
WF01	35.0	716.7	81.7	11.2
WF02	25.0	335.5	81.9	14.8
WF03	27.0	240.9	79.5	15.2
WF04	30.0	304.3	80.7	19.8
WF05	32.0	493.3	81.8	11.5
WF06	34.0	573.3	83.4	13.4
WF07	35.0	688.2	81.7	44.7
WF08	31.0	492.4	79.8	8.5
WF09	30.0	298.7	79.6	10.1
WF10	32.0	512.3	80.7	36.9
WF11	30.0	328.7	81.9	16.9
WF12	27.0	252.7	79.9	24.0
WF13	35.0	500.7	80.9	15.0
WF14	27.0	223.2	80.9	34.7
WF15	28.5	326.7	81.0	8.7
WF16	38.0	537.2	82.2	NR[b]
WF17	38.5	722.3	84.0	14.8
WF18	37.5	658.1	83.1	11.7
WF19	39.0	695.3	83.8	14.9
WF20	40.0	680.3	85.0	19.9
WF21	42.0	1181.2	83.3	14.4

(a) Moisture and lipid measures taken from the raw fillet.
(b) Not reported, sample lost.

in relatively low proportions in these Aroclors]. Sometimes a low-level laboratory interferant coeluted with Cl_7(170) in the instrumental analysis, which could result in unreliable data for Cl_7(170). Consequently, all statistical analyses for total PCB were based on the estimated value derived from the 17-congener estimate. Total PCB levels are reported based on all 18 congeners and on the 17 congeners (see Appendix A). As it turned out, the total PCB data for each set of congeners

TABLE 4. Analysis of Variance of Fractional Change in Fillet Weight by Cooking Treatment

Source	df	Sum of Squares	Mean Square	F-test	P Value
Between treatments	2	1.234	0.617	121.7	0.0001
Within treatments	60	0.304	0.005		
Total	62	1.538			

TABLE 5. Mean Fractional Decreases in Fillet Weight by Section and Cooking Treatment

Section	Cooking Treatment			Total
	Broil	Deep Fry	Pan Fry	
I	0.162	0.379	0.064	0.202 (0.151)[a]
II	0.124	0.410	0.072	0.202 (0.164)
III	0.173	0.416	0.084	0.224 (0.164)
Total	0.153[b] (0.079)	0.402[b] (0.083)	0.073[b] (0.045)	0.209

(a) Standard deviation in parentheses.
(b) Significant at 95% level of confidence.

were similar because the amount of Cl_7(170) and any Cl_7(170) interference were low relative to the concentrations of other congeners in the fish samples.

PCB concentrations are reported in (ng/g) wet weight, on a precooking-weight basis, for the raw, deep-fried, pan-fried, and broiled fish. Some analytes were reported below the previously determined detection limit (see Table 1), but no analytes were quantified unless the analyst had a high degree of confidence in the identification. A signal-to-noise ratio of approximately 5:1 was generally used as the criterion in analyte identification and quantification, and each individual analyte identification was visually confirmed before the data were accepted.

The 21 fish collected showed a large range in PCB concentrations. Total PCB concentration, based on 17 congeners, ranged from 0.014 to 4.0 µg/g wet weight in the untreated fillet. This range is a concentration difference of more than two orders of magnitude. Three of the 21 fish had PCB

concentrations in the untreated fillet that exceeded the Food and Drug Administration action limit of 2 μg/g for seafood.

The PCB congener distributions were similar for most of the fish; Cl_5(118), Cl_6(153), and Cl_6(138) were the most abundant of the 18 congeners. The distribution of PCB congeners observed for the fish samples was quite unlike the expected distribution of congeners in an equal mix of Aroclors 1242 and 1254, based on earlier measurements of PCBs in sediments from this area (see Appendix A). The distribution in the fish looked more like the distribution in Aroclor 1254 alone, based on the relative amounts of PCB congeners by levels of chlorination (Alford-Stevens et al. 1986). Most of the lower-molecular-weight PCB congeners of Aroclor 1242 were detected at relatively low concentrations. The PCB congener distribution in fish may be influenced not only by the distribution in sediment that the fish were exposed to, but also by selective metabolism and bioconcentration.

3.2 EFFECTS OF COOKING ON PCB LEVELS

The primary objective of this study was to determine the effects of cooking on PCB levels in winter flounder fillets. The data were highly variable and covered two orders of magnitude, necessitating that the data be transformed for statistical analyses. The ln transformation for PCB concentrations (ng/g) most closely resembled a normal distribution. The distribution of the fractional change data was also skewed; and the transformed fractional change data (e^F) better represented a normal distribution, particularly for the pan-frying and broiling treatments.

The transformed data were analyzed by a three-way ANOVA for treatment, section, and fillet effects on total PCB (Table 6). In this three-factor ANOVA, only the treatment effects were significant ($a = 0.05$). A one-factor ANOVA of treatments indicated that the differences in cooking treatments between deep frying and either broiling or pan frying were significant (Table 7). The deep-fried fillets showed a 47% decrease ($e^F = 1.605$) in total PCB levels, which was significantly different from the 17% and 15% increases of total PCBs detected in broiled and pan-fried fillets.

The individual cooking results also were tested with two-tailed t tests to determine whether the fractional change resulting from cooking was significantly different from no change, as indicated by a transformed value of 1.00 ($e^{0.00} = 1.00$). Values greater than 1.0 indicate a decrease in PCB levels, and values less than 1.0 indicate an apparent increase in PCB levels. The 47% decrease in the deep-fried fillet was significant; however, the smaller increases in total PCB concentrations for the pan-frying and broiling treatments were not significant ($a = 0.05$). Fisher's Least Significant

TABLE 6. Three-Way Analysis of Variance of Transformed (e^F) Fractional Difference in Total PCB Levels in Cooked Winter Flounder

Source	df	Sum of Squares	Mean Square	F-test	P Value
Treatment (A)	2	8.106	4.053	23.849	0.0001
Section (B)	2	1.105	0.508	2.986	0.0606
AB interaction	4	1.425	0.356	2.096	0.0971
Fillet (C)	1	0.298	0.298	1.753	0.1922
AC interaction	2	0.019	0.010	0.056	0.9456
BC interaction	2	0.509	0.255	1.499	0.2344
ABC interaction	4	0.873	0.218	1.248	0.2904
Error	45	7.647	0.170		

TABLE 7. Fractional Change in Total PCB Levels Resulting from Cooking Based on Transformed Data (e^F)

Cooking Treatment	Mean[a]	Standard Deviation	t Test[b] (Prob.)	Fisher's LSD Test[c]		
				Broil	Deep Fry	Pan Fry
Broil	0.845 (+16.8%)	0.398	0.171	--	0.275[d]	0.275
Deep fry	1.605 (-47.3%)	0.475	0.0001		--	0.275[d]
Pan fry	0.858 (+15.3%)	0.457	0.089			--

(a) A value of 1.0 indicates no fractional change ($e^F = 1.00$); the value in parentheses is the percentage change in PCBs from cooking.
(b) Two-tailed t test for transformed fractional change data ($e^F = 1.00$), n = 21.
(c) LSD = Least Significant Differences.
(d) Indicates significant (95%) differences between cooking treatments listed under LSD heading and under Cooking Treatment.

Differences test indicated that the deep-frying treatment was significantly different from the pan-frying and broiling methods.

Individual congeners were also evaluated for the effects of cooking on congener levels. The initial analysis evaluated only those cases for which quantifiable concentrations of each congener were found in the raw and the cooked fillet (Table 8). The analysis of variance for the three cooking methods was significant for all congeners except Cl_{10}(209).

TABLE 8. Analysis of Variance of Cooking Treatments for Specific Congeners in Fillets of Winter Flounder

	ANOVA			
Congener	Transformed Mean Square	df	F-Value	Prob.
$Cl_2(08)$	3.46	32	16.91	0.0001
$Cl_3(18)$	2.39	60	13.22	0.0001
$Cl_3(28)$	3.01	62	15.20	0.0001
$Cl_4(44)$	1.88	61	15.60	0.0001
$Cl_4(52)$	3.32	62	26.85	0.0001
$Cl_4(66)$	3.08	62	12.27	0.0001
$Cl_5(101)$	3.77	62	25.50	0.0001
$Cl_5(105)$	4.40	62	22.33	0.0001
$Cl_5(118)$	4.18	62	21.01	0.0001
$Cl_6(128)$	4.71	59	23.71	0.0001
$Cl_6(138)$	4.25	62	21.31	0.0001
$Cl_6(153)$	3.71	62	18.48	0.0001
$Cl_7(170)$	4.27	62	17.76	0.0001
$Cl_7(180)$	3.90	62	17.60	0.0001
$Cl_7(187)$	3.97	62	23.89	0.0001
$Cl_8(195)$	3.18	51	12.02	0.0001
$Cl_9(206)$	2.67	49	10.59	0.0002
$Cl_{10}(209)$	0.80	18	3.57	0.0522

Congeners $Cl_2(08)$, $Cl_6(128)$, $Cl_8(195)$, $Cl_9(206)$, and $Cl_{10}(209)$ had cases in which either the raw or the cooked fillet had a non-detectable concentration of that specific congener. These cases were not included in the initial congener-specific analysis; consequently, the estimates of cooking effects are biased low for these congeners. The transformed fractional change (e^F) for each congener was tested with two-tailed t tests to determine whether there was a measurable effect due to cooking (see Section 2.3). The null hypothesis was rejected for all 18 congeners tested for deep frying, indicating significant reductions in each congener (Table 9).

Congeners $Cl_5(105)$ and $Cl_5(118)$ had the only significant fractional increases in congener level with t tests (a = 0.05) in pan-fried samples (Table 10). Inclusion of the 100% reduction values for congener $Cl_2(08)$ indicated a significant decrease (about 49%) for that specific congener. None of the congeners except $Cl_2(08)$ were reduced as a result of pan frying.

TABLE 9. Students t Test for Testing Significance of Cooking on Specific Congeners in Deep-Fried Fillets of Winter Flounder

Congener	Transformed Mean (SD)[a]	% Mean Change	95% CI[b]	df	t Value	Prob.
	Quantifiable concentrations in raw and cooked fillets					
Cl_2(08)	2.10 (0.29)	74	27	11	12.95	0.0001
Cl_3(18)	1.76 (0.35)	57	39	18	9.52	0.0001
Cl_3(28)	1.60 (0.35)	47	43	20	7.87	0.0001
Cl_4(44)	1.65 (0.28)	50	33	19	8.36	0.0001
Cl_4(52)	1.70 (0.32)	53	37	20	9.96	0.0001
Cl_4(66)	1.52 (0.55)	42	71	20	4.31	0.0003
Cl_5(101)	1.67 (0.37)	51	43	20	8.36	0.0001
Cl_5(105)	1.57 (0.50)	45	62	20	5.19	0.0001
Cl_5(118)	1.54 (0.49)	43	62	20	5.03	0.0001
Cl_6 128)	1.81 (0.48)	59	52	19	7.59	0.0001
Cl_6(138)	1.59 (0.50)	46	62	20	5.50	0.0001
Cl_6(153)	1.60 (0.48)	47	59	20	5.72	0.0001
Cl_7(170)	1.63 (0.59)	49	71	20	4.91	0.0001
Cl_7(180)	1.76 (0.48)	57	53	20	7.33	0.0001
Cl_7(187)	1.79 (0.43)	58	47	20	8.45	0.0001
Cl_8(195)	1.71 (0.56)	54	64	15	5.10	0.0001
Cl_9(206)	1.97 (0.46)	68	46	13	7.94	0.0001
Cl_{10}(209)	1.66 (0.37)	51	44	5	4.35	0.0073
	Assumed 100% reduction when cooked fillet was < detection					
Cl_2(08)	2.28 (0.38)	82	33	16	13.92	0.0001
Cl_3(18)	1.85 (0.44)	62	47	20	8.92	0.0001
Cl_4(44)	1.70 (0.36)	53	42	20	8.9	0.0001
Cl_9(206)	2.13 (0.51)	76	47	17	9.39	0.0001
Cl_{10}(209)	1.81 (0.52)	59	56	6	4.11	0.0063

(a) Transformation was e^F, where e is the base of the ln and F is the fraction change; (SD) is the standard deviation. Values greater than 1.0 indicate a decrease in PCB congener concentration; values less than 1.0 indicate an increase.
(b) CI = confidence interval.

Fractional increases in congeners Cl_5(105), Cl_5(118), Cl_6(138), and Cl_9(206) were also significant for broiled samples (a = 0.05; see Table 11). Again, inclusion of the 100% reduction cases for congener Cl_2(08) resulted in a significant t test indicating a loss of about 65% of the congener. The modifications for 100% loss of PCB congeners had little effect on the results as expressed for total PCB because the congeners involved represented only a small fraction of the total PCB when quantified by the ratio of the 17 congeners used in the study.

TABLE 10. Students t Test for Testing Significance of Cooking on Specific Congeners in Pan-Fried Fillets of Winter Flounder

Congener	Transformed Mean (SD)[a]	% Mean Change	95% CI[b]	df	t Value	Prob.
	Quantifiable concentrations in raw and cooked fillets					
Cl_2(08)	1.04 (0.52)	4	98	10	0.23	0.8220
Cl_3(18)	1.23 (0.47)	21	75	20	1.22	0.2365
Cl_3(28)	0.95 (0.52)	-5	107	20	-0.46	0.6541
Cl_4(44)	1.12 (0.40)	11	70	20	1.35	0.1935
Cl_4(52)	1.01 (0.38)	1	74	20	0.09	0.9323
Cl_4(66)	0.88 (0.49)	-13	109	20	-1.14	0.2700
Cl_5(101)	0.94 (0.40)	-6	83	20	-0.68	0.5019
Cl_5(105)	0.78 (0.43)	-25	108	20	-2.41	0.0259
Cl_5(118)	0.79 (0.45)	-24	112	20	-2.19	0.0407
Cl_6(128)	0.95 (0.45)	-5	93	19	-0.52	0.6124
Cl_6(138)	0.82 (0.46)	-20	110	20	-1.82	0.0839
Cl_6(153)	0.88 (0.46)	-13	102	20	-1.23	0.2301
Cl_7(170)	0.89 (0.43)	-12	95	20	-1.23	0.2329
Cl_7(180)	1.02 (0.53)	2	102	20	0.14	0.8916
Cl_7(187)	1.04 (0.43)	4	81	20	0.39	0.6977
Cl_8(195)	0.94 (0.53)	-6	111	17	-0.5	0.6215
Cl_9(206)	1.23 (0.55)	21	88	17	1.78	0.0939
Cl_{10}(209)	1.11 (0.36)	10	64	6	0.8	0.4519
	Assumed 100% reduction when cooked fillet was < detection					
Cl_2(08)	1.63 (0.93)	49	112	17	2.81	0.0127

(a) Transformation was e^F, where e is the base of the ln and F is the fraction change; (SD) is the standard deviation. Values greater than 1.0 indicate a decrease in PCB congener concentration; values less than 1.0 indicate an increase.

(b) CI = confidence interval.

The relationship between the transformed data and other aspects of the analysis was examined by regressing transformed total PCB levels against weight change (g and percentage), initial fillet size before the cooking treatment, and recovery of the internal standard (Table 12). There was no significant relationship except for recovery of the internal standard. This relationship indicated that the higher concentrations of total PCB were generally associated with the lowest recovery levels of DBOFB. Analysis of variance of the data adjusted for recovery did not indicate any significant difference between treatments, and all subsequent analysis used the reported values.

TABLE 11. Students t Test for Testing Significance of Cooking on Specific Congeners in Broiled Fillets of Winter Flounder

Congener	Transformed Mean (SD)[a]	% Mean Change	95% CI[b]	df	t Value	Prob.
	Quantifiable concentrations in raw and cooked fillets					
Cl_2(08)	1.34 (0.52)	29	76	9	2.06	0.0694
Cl_3(18)	1.20 (0.44)	18	72	20	2.04	0.0547
Cl_3(28)	0.94 (0.45)	-6	94	20	-0.65	0.5258
Cl_4(44)	1.23 (0.35)	21	56	20	1.69	0.1069
Cl_4(52)	1.01 (0.35)	1	68	20	0.13	0.8957
Cl_4(66)	0.84 (0.45)	-17	105	20	-1.66	0.1133
Cl_5(101)	0.93 (0.38)	-7	80	20	-0.84	0.4098
Cl_5(105)	0.77 (0.40)	-26	102	20	-2.65	0.0153
Cl_5(118)	0.75 (0.39)	-29	102	20	-2.92	0.0085
Cl_6(128)	0.99 (0.41)	-1	81	19	-0.15	0.8854
Cl_6(138)	0.81 (0.38)	-21	92	20	-2.27	0.0344
Cl_6(153)	0.87 (0.40)	-14	90	20	-1.45	0.1635
Cl_7(170)	0.83 (0.43)	-19	102	20	-1.85	0.0785
Cl_7(180)	1.01 (0.40)	1	78	20	0.15	0.8802
Cl_7(187)	1.03 (0.36)	3	69	20	0.39	0.7028
Cl_8(195)	0.97 (0.46)	-3	93	17	-0.24	0.8134
Cl_9(206)	1.24 (0.48)	22	76	17	2.14	0.0471
Cl_{10}(209)	0.98 (0.65)	-2	130	5	-0.07	0.9499
	Assumed 100% reduction when cooked fillet was < detection					
Cl_2(08)	1.63 (0.93)	49	112	17	2.81	0.0127

(a) Transformation was e^F, where e is the base of the ln and F is the fraction change; (SD) is the standard deviation. Values greater than 1.0 indicate a decrease in PCB congener concentration; values less than 1.0 indicate an increase.

(b) CI = confidence interval.

TABLE 12. Regression Analysis of PCB Concentrations (ln-transformed and adjusted for recovery) Against Changes in Weight, Precooking Weight, and Recovery of the Internal Standard DBOFB

Variable	ANOVA for Regression			Regression Parameters		
	Total df	F-test	Prob.	Slope	Intercept	R^2
Precooking wt.	62	0.167	0.684	-0.01	5.56	0.003
Wt. change (g)	62	1.192	0.279	-0.07	5.63	0.019
Wt. change (%)	62	1.782	0.187	-1.89	5.74	0.028
DBOFB recovery	83	19.321	0.0001	-5.36	9.30	0.191

4.0 DISCUSSION

This section provides further discussion of the analytical results summarized in Section 3, including quantification of PCBs, PCB concentrations in fish from different collection sites, and the effects of cooking on PCB levels.

4.1 PCB QUANTIFICATION

The total PCB quantification method used in this study, in which 17 representative congeners were used for determining total PCB concentrations, is only one of several methods that have been used for determining total PCB concentrations. Other possible methods of quantification include the following:

1. quantify total PCB by Aroclor or Aroclor mix by using a few congeners that constitute a known response per unit concentration of an Aroclor or Aroclor mix
2. identify and sum the responses of each individual congener by level of chlorination, quantify the levels of chlorination separately using an average response factor for each level of chlorination (determined from analysis of several congeners of each level of chlorination), and then sum the concentrations obtained for the different levels of chlorination to yield total PCB
3. identify and quantify as many of the 209 existing PCB congeners as possible using individual standards and response factors, and then sum these values to yield the total PCB concentration.

The first alternative method is probably the most commonly used for quantifying total PCB. When this method is applied, a few congeners (often as few as two or three) are selected to represent total PCB for quantification. This selection is often done with little consideration given to factors other than chromatographic separation and detector response. The second and third alternative methods are generally more accurate but are less frequently used because they are very time consuming.

The method for total PCB determination that was used in this study is an important improvement to the first alternative method because 1) a relatively large set of representative congeners was used that covers the complete range of chlorination levels; 2) the selected congeners are generally among the most abundant congeners in environmental samples; and 3) these congeners are generally relatively free from chromatographic interference, allowing accurate and reproducible determination. However, the method used in this study may not always be as accurate as the other two alternative methods. The higher level of effort required to quantify using either of those two

methods was not considered justifiable for this work, because the primary goal of this work was to provide data to determine relative differences in PCB levels between samples. The total PCB determination method used in this study has been used in the Mussel Watch Program and has been found to be reproducible and suitable for accurate quantification of total PCB concentrations in marine sediment and bivalve tissue (Battelle 1991).

4.2 FISH COLLECTION SITES

The concentrations of PCBs in fish collected from Restricted Area II of New Bedford Harbor generally were in agreement with data from other studies in which fish have been collected from the three restricted areas of New Bedford Harbor. Restricted Area III is south of Ricketsons and Wilbur Points, and Restricted Area I is inside the New Bedford Harbor hurricane barrier (see Figure 1). These designations indicate areas of fishing closure or restricted fishing and were established by the Massachusetts Department of Public Health as a result of PCB levels measured in seafood from New Bedford Harbor and Buzzards Bay. Area I is closed to the taking of all finfish, shellfish, and lobster. Area II is closed to the taking of bottom-feeding finfish (including winter flounder) and lobster. Area III is closed to the taking of lobster.

Connolly (1991) observed greater variability in PCB concentrations in winter flounder collected from Restricted Area II than from Restricted Areas I or III. The PCB levels measured in this study ranged from 0.014 to 7.00 µg/g wet weight (whole body) and were lower than levels reported in several earlier studies. The highly variable results contributed to the non-significant relationship between fish weight or length, and PCB tissue burden. Kolek and Ceurvels (1981) measured levels exceeding 2 µg/g in the majority of the limited number of winter flounder caught in Restricted Area II for their monitoring between 1976 and 1980. Pruell et al. (1988) measured PCB levels ranging from 0.1 to 7 µg/g in winter flounder collected from Restricted Area I. Rusek (1989) reported PCB levels in edible tissue of striped bass that averaged 22 µg/g and 1.1 µg/g in fish collected from Restricted Areas I and III, respectively, in a large 1988 survey. The available data are too few and scattered over time to draw any firm conclusions regarding trends in PCB levels in fish in New Bedford Harbor.

4.3 EFFECTS OF COOKING ON PCB LEVELS

Our results indicated a significant decrease in total PCB levels following deep frying. In contrast, pan frying and broiling resulted in a slight but statistically insignificant increase of around 15 to 17% in total PCB. A possible explanation for increases in PCBs in the pan-fried treatment

would be a contribution to the tissue from the butter if it were contaminated with PCBs. It is also possible that the cooking oil could have been contaminated; however, if true, such contamination was not obvious in the results. This proposition is unlikely and is weakened by the fact that the broiled treatment did not use butter or oil, yet still showed a statistically insignificant net increase in PCB levels. The data analysis was hampered by high variability in the absolute levels of PCBs found in the tissue. Higher concentrations of PCBs also tended to be located in the posterior section (Section III), even though ANOVA for effects due to section were not significant (see Table 6). The differences between top and bottom fillets also were not significant.

Results of the analysis of individual congeners paralleled the results for total PCB. Congener Cl_2(08) was particularly sensitive to reduction by cooking, while congeners Cl_5(105), Cl_5(118), and Cl_6(138) individually showed significant increases following cooking by either pan frying or broiling; increases in PCBs based on estimated total PCB was not significant. Moreover, congener Cl_2(08) has the lowest molecular weight, and is the most volatile and most polar of the congeners included in this study. The assumption that a less-than-detection value in the cooked fillet indicated complete removal of that congener introduces a slight bias for overestimating loss of PCBs during cooking. Moreover, in some cases, quantifiable amounts of specific congeners were reported in cooked fillets where levels were less than detection in the raw fillet. In these cases, the data were not used to estimate fractional change for statistical analyses because the value was undefined (denominator of fractional change was 0) and the congener level in the cooked sample was generally close to the detection limit.

Others also have reported increases in PCB levels following cooking (Table 13). This conclusion is understandable when results are reported on a gravimetric basis without adjusting for loss of water and fat during cooking. Increases in PCBs as high as 36% have been reported in carp when calculated using a mass-balance approach that accounts for weight loss in the fillet (Zabik et al. 1982). Initially, they reported that extractability of PCBs is lower in raw tissue than in cooked tissue and recommended four solvent extractions on raw fish to obtain maximum PCB yields. For our analyses, three extractions were used, with the third extraction lasting for 30 min on a shaker. We believe these three extractions adequately removed the majority of the available PCBs.

Zabik et al. (1982) also suggested that extractability of PCBs was related to a high percentage of lipid in the tissue. Their early work with lake trout indicated significant reductions in total PCBs due to cooking when expressed on a mass basis. The lake trout had a high amount of lipid (25 to 30%) in the fillets. In contrast, carp used in their 1982 study had $7.7 \pm 3.2\%$ lipid. The winter flounder used in this study had lipid levels ranging from 0.8 to 4.5% (mean = 1.8%). While increased lipid content in fish flesh may be associated with greater PCB losses during cooking, there

TABLE 13. Estimates of Cooking Effects on PCB Levels in Fish (wet-weight basis)

Species	Cooking Treatment	Change	Comments	Reference
Bluefish	Baked, 1 h at 325°F	+8% on ppm basis		Trotter et al. 1989
Bluefish	Baked to 80°C it[a]	-7.5%	Average for all four	Armbruster et al.
	Broiled to 75-90°C it	-7.5%	cooking methods	1989
	Pan fried to 80°C it	-7.5%		
	Poached to 80-90°C it	-7.5%		
White croaker	Pan fried 8 min at 190°C	-65% mass balance	Santa Monica Bay	Puffer and Gossett
		-28% mass balance	Orange County, Ca	1983
Lake trout	Roasted to 75°C it	-34% mass balance		Zabik et al. 1979
	Roasted to 75°C it	-40% mass balance	With skin	
	Roasted to 75°C it	-50% mass balance	Without skin	
	Broiled to 75°C it	-53% mass balance		
	Microwaved to 75°C it	-26% mass balance		
Lake trout	Irradiated (gamma, 1000 krad)	-38% mass balance		Cichy et al. 1979
	Irrad. & broiled to 75°C it	-43% mass balance	Combined cooking treatments	
Chinook salmon	Baked to 75°C it	-15.2% fat basis	Arochlor 1248, fat trimmed	Smith et al. 1973
	Baked in bag to 75°C it	-24.2% fat basis	Arochlor 1248, fat trimmed	
	Poached to 75°C it	+1.3% fat basis	Arochlor 1248, fat trimmed	
	Baked to 75°C it	+0.5% fat basis	Arochlor 1254, fat trimmed	
	Baked in bag to 75°C it	-18.1% fat basis	Arochlor 1254, fat trimmed	
	Poached to 75°C it	-1.8% fat basis	Arochlor 1254, fat trimmed	
Coho salmon	Baked to 75°C it	-3.5% fat basis	Arochlor 1248, fat trimmed	Smith et al. 1973
	Baked in bag to 75°C it	-6.1% fat basis	Arochlor 1248, fat trimmed	
	Poached to 75°C it	+8.7% fat basis	Arochlor 1248, fat trimmed	
	Baked to 75°C it	+9.8% fat basis	Arochlor 1254, fat trimmed	
	Baked in bag to 75°C it	+6.7% fat basis	Arochlor 1254, fat trimmed	
	Poached to 75°C it	+13.6% fat basis	Arochlor 1254, fat trimmed	
Carp	Deep fried to 75°C it	+36% mass balance		Zabik et al. 1982
	Poached to 75°C it	+13% mass balance		
	Charbroiled to 75°C it	+33% mass balance		
	Microwaved to 76°C it	-4.3% mass balance		
	Roasted to 75°C it	+8.6% mass balance		

(a) Internal temperature.

are also contrary data. Trotter et al. (1989) reported increases in PCB levels in bluefish (11.8% lipid) following cooking; and decreases in PCB levels following cooking have been reported in salmon, where precooking lipid levels ranged from 2.65 to 3.59% (Smith et al. 1973). Moreover, most weight loss following cooking is due to losses in moisture, either by vaporization or in drippings; there generally is not a significant change in lipid levels on a gravimetric basis following cooking. Deep frying, however, increases the measurable amount of lipid in cooked tissue by absorption of the cooking oil (Zabik et al. 1982).

A direct comparison of our results with others is difficult because of differences in sample processing, cooking methods, and PCB analysis. The factors that contribute to decreases or increases in PCB levels in cooked fillets are complex. It is possible that the cooking oil or butter used for pan frying could have contributed PCBs if it were contaminated, but this proposition is unlikely. Our study, which required that a fillet be sectioned into three subsamples, was designed to prevent any bias from position of the fillets. Our analysis by section was close to showing that section was a significant variable relative to PCB levels. We were not able to demonstrate a relationship between lipid content in the three fillet sections and PCB levels. Other variables include total surface area of the fillet, thickness of the fillet, and interactions of these variables with the cooking methods. Pan-fried fillets have less surface area exposed to air, which might reduce volatilization of PCBs compared with broiled fillets. The deep frying process creates unique cooking conditions that accelerate drying of the fillet compared with broiling and pan frying.

Our data, considered with other published data on the effects of cooking on PCB levels in fish flesh, indicate that the influence of broiling and pan frying on PCB levels in winter flounder fillet is insignificant. Our data indicate that PCB concentrations measured in raw tissue would be suitable for risk assessment of fish consumption when fillets are pan fried or broiled under conditions similar to those used in this study. Deep frying appears to significantly reduce PCB levels. This conclusion is logical because the cooking oil itself could be considered an extraction solvent. However, it should be emphasized that the range in PCB concentrations encountered in winter flounder fillets was very large and a large degree of variability and resulting statistical error was associated with our estimates.

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APPENDIX A

PCB ANALYSIS OF FILLET TISSUE

TABLE A.1. PCB Congener Concentrations in a 1:1 Mix of Aroclor 1242 and Aroclor 1254, and the Ratio of Congener Concentration to Total PCB

Battelle Ocean Sciences
File: AROCLOR
Validated:

Created: BK 03/11/91

PCB Concentration Changes in Cooked Seafood
Phase 1: Winter Flounder
Project Number: G1969-0003
Data reported in ng.

Sample ID	AROCLOR I 1242/1254	AROCLOR II 1242/1254	AROCLOR III 1242/1254	AVERAGE AROCLOR	STD DEV	%RSD
CL2(08)	102.46	101.50	99.05	101.00	1.43	1.4
CL3(18)	97.90	102.27	101.18	100.45	1.86	1.8
CL3(28)	110.10	109.52	108.19	109.27	0.80	0.7
CL4(52)	98.66	101.42	102.06	100.71	1.48	1.5
CL4(44)	72.21	74.62	72.80	73.21	1.03	1.4
CL4(66)	147.48	153.92	152.38	151.26	2.74	1.8
CL5(101)	99.53	107.80	109.15	105.50	4.25	4.0
CL5(118)	98.25	105.16	103.43	102.28	2.94	2.9
CL6(153)	60.21	66.29	66.82	64.44	3.00	4.7
CL5(105)	87.00	92.30	89.44	89.58	2.16	2.4
CL6(138)	87.08	96.69	95.81	93.19	4.34	4.7
CL7(187)	8.54	9.62	7.71	8.62	0.79	9.1
CL6(128)	28.06	28.92	27.54	28.17	0.57	2.0
CL7(180)	16.74	17.33	16.23	16.77	0.45	2.7
CL7(170)	12.82	15.48	11.73	13.34	1.58	11.8
CL8(195)	0.98	0.95	0.72	0.89	0.12	13.1
CL9(206)	0.45	0.35	0.42	0.41	0.04	9.9
CL10(209)	ND	ND	ND	NA	NA	NA
Sum of 18 Congeners	1128.46	1184.14	1164.64	1159.08	23.07	2.0
Total PCB Added	2000.000	2000.000	2000.00	NA	NA	NA
Sum of 18/Total PCB Added	0.564	0.592	0.582	0.580	0.01	2.0
Sum of 17 Congeners	1115.64	1168.66	1152.92	1145.74	22.23	1.9
Total PCB Added	2000.00	2000.00	2000.00	NA	NA	NA
Sum of 17/Total PCB Added	0.558	0.584	0.576	0.573	0.01	1.9

TABLE A.2. PCB Concentrations in the Untreated Samples

Battelle Ocean Sciences
File: PCB_UN
Validated:

Created: GSD 06/11/91
Edited:

PCB Concentration Changes in Cooked Seafood
Phase 1: Winter Flounder
Project Number: G1969-0005
Data reported in ng/g wet weight (procedural blank reported in total ng).

Sample ID	JG24PB	JL16PB	WF01-T -UN	WF02-B -UN	WF03-T -UN	WF04-B -UN	WF05-T -UN	WF06-B -UN	WF07-T -UN	WF08-B -UN	WF09-T -UN	WF10-B -UN	WF11-T -UN
CL2(08)	ND	ND	0.49	1.07	0.92	ND	ND	0.38	0.65	ND	0.79	1.01	0.98
CL3(18)	ND	ND	0.23	2.86	3.71	0.77	7.84	0.34	0.15	7.37	1.99	4.13	1.08
CL3(28)	ND	ND	0.40	17.50	33.04	7.48	160.61	2.69	0.33	47.52	2.80	23.60	1.90
CL4(52)	ND	ND	0.48	7.68	12.43	2.09	11.92	1.78	0.50	32.16	3.90	8.13	1.58
CL4(44)	ND	ND	0.25	2.38	1.60	0.67	2.17	0.38	0.18	2.94	1.23	1.51	0.84
CL4(66)	ND	ND	0.30	58.39	45.69	21.62	272.37	6.73	1.33	53.17	8.75	32.91	2.02
CL5(101)	ND	ND	0.65	21.21	23.09	16.04	44.92	8.40	1.42	33.70	6.62	9.06	1.37
CL5(118)	ND	ND	0.95	258.64	116.80	54.37	605.07	17.45	2.19	112.28	28.94	47.16	2.69
CL6(153)	ND	ND	1.69	365.99	135.55	60.78	541.81	20.17	4.03	134.58	37.77	49.18	3.46
CL5(105)	ND	ND	0.16	51.52	21.77	11.03	103.91	2.77	0.79	26.36	5.47	19.50	0.85
CL6(138)	ND	ND	1.48	286.02	98.08	52.57	393.19	18.74	3.28	107.40	27.64	41.13	2.91
CL7(187)	ND	ND	0.37	6.34	4.61	4.65	20.05	1.96	1.39	7.97	2.18	4.58	0.79
CL6(128)	ND	ND	ND	67.53	17.97	10.22	33.49	1.78	0.66	12.14	5.62	9.92	0.61
CL7(180)	ND	ND	0.48	72.28	21.26	9.56	72.05	2.42	1.95	17.38	5.33	10.26	1.28
CL7(170)	ND	ND	0.15	42.48	12.99	6.46	42.37	1.77	0.77	12.40	3.34	8.33	0.27
CL8(195)	ND	ND	ND	3.82	1.02	0.88	2.69	0.23	0.49	0.74	0.67	1.07	0.16
CL9(206)	ND	ND	ND	3.69	1.14	0.94	2.74	0.26	0.59	1.08	0.95	0.86	0.24
CL10(209)	ND	ND	ND	1.07	ND	ND	ND	ND	0.47	ND	0.53	0.34	0.18
Sum of 18 Congeners	NA	NA	8.07	1270.47	551.66	260.13	2317.19	88.26	21.15	609.19	144.52	272.68	23.21
Total PCB	NA	NA	13.91	2190.47	951.13	448.51	3995.16	152.16	36.47	1050.33	249.17	470.13	40.02
Sum of 17 Congeners	NA	NA	7.92	1227.99	538.67	253.67	2274.83	86.48	20.38	596.79	141.17	264.34	22.94
Total PCB	NA	NA	13.83	2143.09	940.09	442.71	3970.03	150.93	35.57	1041.52	246.37	461.33	40.03

The procedural blank JG24PB was processed with WP07, 10, 11, 14, and 21. JL16PB was processed with the rest of the samples.
The sum of the 17 is the sum of all listed PCB congeners excluding CL7(170).

TABLE A.2. (contd)

Battelle Ocean Sciences
File: PCB_UN
Validated:

Created: GSD 06/11/91
Edited:

PCB Concentration Changes in Cooked Seafood
Phase 1: Winter Flounder
Project Number: G1969-0005
Data reported in ng/g wet weight (procedural blank reported in total ng).

Sample ID	WF12-B -UN	WF13-T -UN	WF14-B -UN	WF15-T -UN	WF16-B -UN	WF17-T -UN	WF18-B -UN	WF19-T -UN	WF20-B -UN	WF21-T -UN
CL2(08)	5.80	0.44	0.96	0.48	0.52	0.35	ND	0.32	0.68	1.13
CL3(18)	13.75	0.52	0.82	0.31	0.90	0.45	0.66	0.14	1.72	1.41
CL3(28)	122.44	1.73	0.82	0.35	0.99	5.86	10.28	1.58	5.82	4.34
CL4(52)	24.62	2.35	1.34	0.32	1.12	4.63	2.54	0.22	5.15	3.88
CL4(44)	5.32	0.62	0.72	0.18	0.49	0.61	0.70	0.15	1.35	1.10
CL4(66)	164,09	3.60	1.89	0.71	1.74	2.15	24.73	4.77	15.40	13.10
CL5(101)	64.47	5.89	1.35	1.18	1.72	29.08	11.91	1.23	21.22	9.60
CL5(118)	259.64	13.94	2.43	2.76	6.16	68.03	130.00	19.28	76.45	25.75
CL6(153)	216.25	22.20	3.47	4.47	10.70	78.57	141.52	23.34	92.23	28.74
CL5(105)	69.92	2.76	0.80	0.48	0.99	6.69	19.03	3.22	10.24	9.76
CL6(138)	181.76	19.27	3.01	3.55	8.06	68.03	101.25	20.77	71.40	27.40
CL7(187)	10.28	2.75	0.90	0.75	0.83	5.66	4.56	1.98	5.93	3.61
CL6(128)	37.62	2.50	0.72	0.32	0.65	4.80	7.45	2.13	3.82	5.11
CL7(180)	25.98	3.55	1.39	0.74	1.61	9.94	17.52	3.49	12.25	7.05
CL7(170)	16.94	2.64	0.42	0.22	0.98	6.80	11.86	2.35	8.11	5.29
CL8(195)	0.89	0.28	0.22	ND	ND	0.30	0.43	0.21	0.50	0.80
CL9(206)	1.18	0.46	0.34	ND	ND	0.35	0.81	0.28	0.55	0.60
CL10(209)	ND	ND	0.25	ND	ND	ND	ND	ND	ND	0.33
Sum of 18 Congeners	1220.94	85.49	21.83	16.80	37.45	292.28	485.24	85.47	332.79	149.00
Total PCB	2105.07	147.40	37.64	28.97	64.57	503.93	836.61	147.36	573.78	256.89
Sum of 17 Congeners	1204.00	82.85	21.41	16.59	36.47	285.48	473.38	83.11	324.69	143.71
Total PCB	2101.23	144.60	37.36	28.95	63.65	498.23	826.14	145.05	566.64	250.80

TABLE A.3. PCB Concentrations in the Deep-Fried Samples

Battelle Ocean Sciences
File: PCB_DF
Validated:

Created: GSD 06/11/91
Edited:

PCB Concentration Changes in Cooked Seafood
Phase 1: Winter Flounder
Project Number: G1969-0005
Data reported in ng/g pre-cooked wet weight (procedural blank reported in total ng).

Sample ID	JG24PB	J175PB	WF01-B-I-DF	WF02-T-II-DF	WF03-B-III-DF	WF04-T-I-DF	WF05-B-II-DF	WF06-T-III-DF	WF07-B-I-DF	WF08-T-II-DF	WF09-B III-DF	WF10-T-I-DF	WF11-B-II-DF
CL2(08)	ND	ND	ND	ND	0.44	ND	ND	ND	0.12	ND	0.25	0.90	0.36
CL3(18)	ND	ND	0.27	2.51	2.83	0.29	6.33	0.19	0.07	9.20	1.04	4.55	0.61
CL3(28)	ND	ND	0.20	17.94	34.47	2.68	176.38	1.39	0.43	76.33	2.77	26.80	0.68
CL4(52)	ND	ND	0.30	8.26	11.64	0.60	9.96	0.88	0.30	46.23	2.90	8.51	1.02
CL4(44)	ND	0.95	0.33	2.35	1.47	0.29	1.22	0.30	0.11	3.05	1.17	1.61	0.42
CL4(66)	ND	ND	0.24	72.80	52.51	5.45	360.91	2.93	0.87	86.89	6.18	35.42	1.14
CL5(101)	ND	ND	0.43	22.31	25.11	4.04	36.49	3.80	1.02	46.95	4.64	8.09	0.82
CL5(118)	ND	ND	0.75	405.48	158.80	12.64	789.88	6.79	1.76	199.68	22.41	50.02	1.62
CL6(153)	ND	ND	1.32	526.54	154.28	11.15	586.33	6.47	3.09	232.43	25.06	54.24	2.61
CL5(105)	ND	ND	0.16	72.07	40.55	2.71	105.63	1.18	0.48	45.51	5.04	21.84	0.47
CL6(138)	ND	ND	0.87	437.00	129.89	10.13	426.59	5.97	2.55	189.22	20.91	46.84	2.02
CL7(187)	ND	ND	0.27	6.19	5.05	0.61	13.78	0.42	1.01	8.81	1.14	4.85	0.44
CL6(128)	ND	ND	0.05	79.50	24.60	1.51	23.17	0.26	0.38	12.38	2.75	9.93	0.29
CL7(180)	ND	ND	0.21	72.84	24.58	1.24	48.77	0.46	1.44	23.15	3.09	11.57	0.81
CL7(170)	ND	3.45	0.39	39.23	15.23	0.79	26.93	0.39	0.45	14.65	2.61	9.41	0.17
CL8(195)	ND	ND	0.03	3.27	0.99	0.08	1.92	ND	0.35	0.96	0.22	1.25	0.09
CL9(206)	ND	ND	0.01	1.91	0.59	0.06	ND	ND	0.47	0.95	0.17	1.00	0.11
CL10(209)	ND	ND	0.08	ND	0.13	0.04	ND	ND	0.39	ND	0.15	0.31	0.21
Sum of 18 Congeners	NA	NA	5.90	1770.19	683.15	54.31	2614.30	31.40	15.27	996.38	102.50	297.14	13.88
Total PCB	NA	NA	10.17	3052.04	1177.85	93.64	4507.42	54.14	26.33	1717.89	176.73	512.30	23.93
Sum of 17 Congeners	NA	NA	5.51	1730.96	667.93	53.52	2587.37	31.01	14.82	981.73	99.89	287.73	13.71
Total PCB	NA	NA	9.61	3020.87	1165.67	93.40	4515.47	54.12	25.86	1713.31	174.33	502.15	23.92

The procedural blank JG24PB was processed with WP07, 10, 11, 14, and 21. J175PB was processed with the rest of the samples.
The sum of the 17 is the sum of all listed PCB congeners excluding CL7(170).

TABLE A.3. (contd)

Battelle Ocean Sciences
File: PCB_DF
Validated:

Created: GSD 06/11/91
Edited:

PCB Concentration Changes in Cooked Seafood
Phase 1: Winter Flounder
Project Number: G1969-0005
Data reported in ng/g pre-cooked wet weight (procedural blank reported in total ng).

Sample ID	WF12-T-III-DF	WF13-B-I-DF	WF14-T-II-DF	WF15-B-III-DF	WF16-T-I-DF	WF17-B-II-DF	WF18-T III-DF	WF19-B-I-DF	WF20-T-II-DF	WF21-B-III-DF
CL2(08)	3.53	0.17	0.21	ND	0.26	ND	ND	0.07	0.25	0.88
CL3(18)	11.38	0.24	0.35	ND	0.71	ND	0.82	0.04	0.85	1.25
CL3(28)	156.01	0.87	0.63	0.38	1.12	6.83	12.03	0.78	4.65	5.36
CL4(52)	22.67	0.77	0.79	0.26	1.03	6.25	3.87	0.12	3.27	3.61
CL4(44)	4.32	0.40	0.35	0.22	0.41	ND	0.78	0.12	1.05	1.11
CL4(66)	183.80	1.47	0.93	0.75	1.55	29.99	65.29	2.69	14.53	12.98
CL5(101)	57.51	1.83	0.79	1.09	1.47	49.87	24.74	0.72	14.74	9.52
CL5(118)	293.79	3.57	1.27	3.09	5.51	137.80	404.70	10.31	69.13	27.24
CL6(153)	227.36	4.80	1.92	4.51	8.46	159.16	397.68	10.44	66.94	28.81
CL5(105)	56.84	0.51	0.36	0.48	0.74	15.22	40.45	1.73	13.33	9.70
CL6(138)	183.06	3.99	1.62	3.53	6.08	135.18	294.02	9.98	64.31	27.28
CL7(187)	7.48	0.41	0.36	0.55	0.44	8.46	8.27	0.67	4.58	3.56
CL6(128)	26.92	0.35	0.29	0.22	0.29	5.78	14.56	0.74	3.48	5.33
CL7(180)	18.52	0.46	0.57	0.56	0.87	15.32	43.52	1.27	11.29	6.78
CL7(170)	11.72	0.52	0.15	0.65	0.60	11.75	29.27	0.94	7.33	4.25
CL8(195)	1.07	0.04	0.10	0.05	0.04	ND	1.48	0.08	0.46	0.64
CL9(206)	ND	0.03	0.12	ND	0.03	ND	1.08	0.07	0.29	0.52
CL10(209)	ND	0.02	0.29	ND	ND	ND	ND	0.04	0.10	0.24
Sum of 18 Congeners	1265.98	20.46	11.09	16.34	29.60	581.60	1342.54	40.80	280.58	149.06
Total PCB	2182.72	35.28	19.11	28.18	51.03	1002.76	2314.73	70.34	483.76	256.99
Sum of 17 Congeners	1254.25	19.94	10.94	15.70	28.99	569.85	1313.27	39.86	273.25	144.80
Total PCB	2188.92	34.80	19.08	27.39	50.60	994.50	2291.92	69.56	476.87	252.71

TABLE A.4. PCB Concentrations in the Pan-Fried Samples

Battelle Ocean Sciences
File: PCB_PF
Validated:

Created: GSD 06/11/91
Edited:

PCB Concentration Changes in Cooked Seafood
Phase 1: Winter Flounder
Project Number: G1969-0005
Data reported in ng/g pre-cooked wet weight (procedural blank reported in total ng).

Sample ID	JG24PB	J179PB	WF01-B-II-PF	WF02-T-III-PF	WF03-B-I-PF	WF04-T-II-PF	WF05-B-III-PF	WF06-T-I-PF	WF07-B-II-PF	WF08-T-III-PF	WF09-B I-PF	WF10-T-II-PF	WF11-B-III-PF
CL2(08)	ND	ND	ND	ND	0.55	0.32	ND	ND	0.76	ND	0.38	2.35	1.98
CL3(18)	ND	ND	0.17	3.55	2.60	0.51	11.61	0.20	0.14	11.95	1.82	5.44	1.68
CL3(28)	ND	ND	0.19	26.86	25.53	5.57	396.81	1.55	0.42	138.42	2.44	33.04	1.52
CL4(52)	ND	ND	0.30	10.24	9.35	1.50	17.74	1.02	0.56	63.24	3.66	9.81	2.54
CL4(44)	ND	0.50	0.12	1.19	1.17	0.34	2.60	0.45	0.25	4.63	0.75	1.89	1.25
CL4(66)	ND	ND	0.14	103.86	38.04	17.81	778.24	3.87	1.65	157.76	7.30	42.29	3.29
CL5(101)	ND	ND	0.39	29.49	17.90	12.75	75.88	5.10	1.83	74.70	6.11	10.66	2.26
CL5(118)	ND	ND	0.60	564.08	105.79	48.56	1758.49	11.52	3.29	353.96	30.05	60.53	5.16
CL6(153)	ND	ND	1.02	689.59	100.93	43.02	1208.86	11.17	5.26	363.73	36.14	60.82	6.84
CL5(105)	ND	ND	0.11	97.47	27.28	13.57	333.11	2.33	0.98	78.02	6.14	24.63	1.30
CL6(138)	ND	ND	0.78	578.91	83.59	44.69	999.68	12.02	4.44	327.48	28.42	50.08	5.47
CL7(187)	ND	ND	0.19	7.69	3.26	3.06	30.91	0.92	1.72	14.91	1.64	5.50	1.20
CL6(128)	ND	ND	0.03	108.98	14.98	8.39	60.75	0.81	0.76	27.01	4.20	11.00	0.93
CL7(180)	ND	ND	0.17	85.12	15.38	6.40	125.61	0.96	2.66	41.06	3.73	13.48	2.45
CL7(170)	ND	3.96	0.22	57.57	8.78	4.31	73.84	1.04	0.86	26.81	3.32	10.71	0.47
CL8(195)	ND	ND	0.03	4.15	0.67	0.47	3.91	0.08	0.58	1.84	0.40	1.47	0.25
CL9(206)	ND	ND	0.03	2.88	0.47	0.39	2.62	0.06	0.71	1.58	0.39	1.37	0.28
CL10(209)	ND	ND	0.03	0.75	0.14	0.18	ND	0.04	0.57	ND	0.28	0.37	0.21
Sum of 18 Congeners	NA	NA	4.52	2372.35	456.43	211.84	5880.66	53.14	27.44	1687.11	137.14	345.44	39.06
Total PCB	NA	NA	7.79	4090.27	786.94	365.24	10139.07	91.62	47.31	2908.81	236.44	595.59	67.34
Sum of 17 Congeners	NA	NA	4.30	2314.78	447.65	207.53	5806.82	52.10	26.58	1660.30	133.82	334.73	38.59
Total PCB	NA	NA	7.50	4039.76	781.23	362.19	10134.06	90.93	46.39	2897.55	233.54	584.17	67.35

The procedural blank JG24PB was processed with WP07, 10, 11, 14, and 21. J179PB was processed with the rest of the samples.
The sum of the 17 is the sum of all listed PCB congeners excluding CL7(170).

TABLE A.4. (contd)

Battelle Ocean Sciences
File: PCB_PF
Validated:

Created: GSD 06/11/91
Edited:

PCB Concentration Changes in Cooked Seafood
Phase 1: Winter Flounder
Project Number: G1969-0005
Data reported in ng/g pre-cooked wet weight (procedural blank reported in total ng).

Sample ID	WF12-T-I-PF	WF13-B-II-PF	WF14-T-III-PF	WF15-B-I-PF	WF16-T-II-PF	WF17-B-III-PF	WF18-T-I-PF	WF19-B-II-PF	WF20-T-III-PF	WF21-B-I-PF
CL2(08)	6.60	0.32	1.66	ND	0.40	ND	ND	0.17	ND	1.87
CL3(18)	18.41	0.45	0.85	0.05	0.83	1.59	0.52	0.07	1.65	1.36
CL3(28)	320.00	1.26	1.73	0.17	1.28	28.84	13.10	1.12	6.86	4.94
CL4(52)	38.92	2.17	1.35	0.21	1.20	17.96	2.95	0.19	5.58	3.55
CL4(44)	7.41	0.54	0.86	0.15	0.45	1.35	0.43	0.13	1.29	1.03
CL4(66)	445.43	3.11	2.16	0.47	1.90	121.74	49.92	5.11	23.85	11.84
CL5(101)	126.00	5.69	1.76	0.81	1.93	153.12	17.01	1.12	25.98	7.98
CL5(118)	735.36	13.76	3.08	2.22	8.73	497.91	266.84	20.84	115.81	22.94
CL6(153)	510.38	20.38	4.37	3.67	13.08	461.43	245.56	21.84	118.49	26.18
CL5(105)	205.87	2.70	0.88	0.29	1.54	60.69	30.03	3.37	19.82	9.10
CL6(138)	484.83	19.02	3.67	2.92	10.97	475.38	194.66	21.85	107.38	25.92
CL7(187)	18.98	2.16	0.84	0.56	0.86	24.53	5.59	1.46	7.56	3.44
CL6(128)	87.66	1.89	0.74	0.18	0.72	24.83	10.35	1.76	5.06	4.92
CL7(180)	57.75	2.67	1.31	0.40	1.88	51.32	22.93	2.88	18.28	6.23
CL7(170)	35.43	2.04	0.31	0.43	1.28	35.81	17.76	1.93	12.24	4.32
CL8(195)	2.38	0.24	0.24	0.07	0.13	2.01	1.05	0.19	0.68	0.70
CL9(206)	1.83	0.19	0.30	0.06	0.11	1.05	0.98	0.15	0.37	0.70
CL10(209)	ND	0.10	0.43	0.05	0.06	ND	ND	0.09	0.10	0.26
Sum of 18 Congeners	3103.23	78.68	26.54	12.69	47.33	1959.55	879.68	84.25	471.00	137.27
Total PCB	5350.39	135.66	45.77	21.88	81.60	3378.54	1516.68	145.25	812.06	236.67
Sum of 17 Congeners	3067.80	76.65	26.23	12.26	46.05	1923.75	861.92	82.32	458.75	132.95
Total PCB	5353.92	133.76	45.78	21.40	80.37	3357.32	1504.22	143.66	800.61	232.02

TABLE A.5. PCB Concentrations in the Broiled Samples

Battelle Ocean Sciences
File: PCB_BR
Validated:

Created: GSD 06/11/91
Edited:

PCB Concentration Changes in Cooked Seafood
Phase 1: Winter Flounder
Project Number: G1969-0005
Data reported in ng/g pre-cooked wet weight (procedural blank reported in total ng).

Sample ID	JG24PB	J191PB	WF01-B-III-BR	WF02-T-I-BR	WF03-B-II-BR	WF04-T-III-BR	WF05-B-I-BR	WF06-T-II-BR	WF07-B-III-BR	WF08-T-I-BR	WF09-B-II-BR	WF10-T-III-BR	WF11-B-I-BR
CL2(08)	ND	ND	ND	ND	0.66	ND	ND	ND	1.11	ND	ND	1.68	0.36
CL3(18)	ND	ND	0.41	2.17	2.78	0.55	7.41	0.26	0.22	10.03	1.36	7.23	0.84
CL3(28)	ND	ND	0.60	19.74	32.03	8.19	243.15	2.68	0.73	99.70	1.80	50.19	1.35
CL4(52)	ND	ND	0.68	8.95	10.29	2.07	11.86	1.86	0.94	51.91	2.91	14.08	1.44
CL4(44)	ND	0.76	0.31	1.25	1.20	0.57	1.88	0.41	0.37	3.27	0.87	2.39	0.71
CL4(66)	ND	ND	0.49	90.50	43.80	24.71	484.06	7.11	2.57	118.55	7.04	57.34	1.59
CL5(101)	ND	ND	1.12	24.82	20.60	19.27	46.96	8.25	2.79	57.21	5.31	16.27	1.11
CL5(118)	ND	ND	1.64	481.80	129.18	81.53	1108.15	20.97	4.58	248.64	27.35	91.63	2.21
CL6(153)	ND	ND	2.86	606.76	118.53	74.62	709.20	19.71	7.50	265.42	31.14	90.97	3.13
CL5(105)	ND	ND	0.22	97.15	33.11	19.41	207.85	4.19	1.46	54.69	4.23	35.76	0.64
CL6(138)	ND	ND	2.11	499.80	102.93	77.09	575.33	21.68	6.39	233.44	25.01	75.51	2.54
CL7(187)	ND	ND	0.51	5.96	4.50	5.14	19.55	1.77	2.32	11.15	1.41	7.84	0.62
CL6(128)	ND	ND	0.11	97.98	20.66	14.05	35.23	1.54	1.13	18.89	3.85	15.85	0.50
CL7(180)	ND	ND	0.57	90.55	18.62	12.13	74.45	2.15	3.70	27.72	3.39	18.47	1.13
CL7(170)	ND	6.28	1.03	52.17	12.68	8.50	42.49	2.22	1.19	18.82	2.94	14.63	0.26
CL8(195)	ND	ND	0.04	4.07	0.97	0.83	2.46	0.16	0.67	1.27	0.38	1.84	0.18
CL9(206)	ND	ND	0.04	3.59	0.66	0.65	2.17	0.12	0.85	0.98	0.33	1.43	0.29
CL10(209)	ND	ND	0.03	ND	0.28	0.29	ND	0.06	0.64	ND	0.22	0.62	0.61
Sum of 18 Congeners	NA	NA	12.76	2087.25	553.45	349.59	3572.20	95.14	39.15	1221.68	119.52	503.72	19.49
Total PCB	NA	NA	21.99	3598.70	954.22	602.73	6158.96	164.04	67.50	2106.35	206.07	868.48	33.60
Sum of 17 Congeners	NA	NA	11.73	2035.08	540.77	341.09	3529.71	92.92	37.96	1202.86	116.58	489.09	19.23
Total PCB	NA	NA	20.47	3551.62	943.76	595.27	6160.05	162.16	66.24	2099.24	203.45	853.56	33.56

The procedural blank JG24PB was processed with WP07, 10, 11, 14, and 21. J191PB was processed with the rest of the samples.
The sum of the 17 is the sum of all listed PCB congeners excluding CL7(170).

TABLE A.5. (contd)

Battelle Ocean Sciences
File: PCB_BR
Validated:

Created: GSD 06/11/91
Edited:

PCB Concentration Changes in Cooked Seafood
Phase 1: Winter Flounder
Project Number: G1969-0005
Data reported in ng/g pre-cooked wet weight (procedural blank reported in total ng).

Sample ID	WF12-T-II-BR	WF13-B-III-BR	WF14-T-I-BR	WF15-B-II-BR	WF16-T-III-BR	WF17-B-I-BR	WF18-T-II-BR	WF19-B-III-BR	WF20-T-I-BR	WF21-B-II-BR
CL2(08)	7.94	ND	0.91	ND	0.25	ND	ND	0.19	0.34	1.03
CL3(18)	24.34	0.51	0.83	0.08	0.58	0.97	0.78	0.12	1.14	1.36
CL3(28)	407.11	1.64	1.38	0.22	0.80	11.03	22.39	1.86	5.22	5.52
CL4(52)	48.65	2.63	1.35	0.23	0.99	8.72	5.39	0.30	4.19	3.86
CL4(44)	9.01	0.57	0.75	0.22	0.41	1.00	0.65	0.21	1.04	1.06
CL4(66)	555.31	4.52	1.88	0.68	1.43	50.76	88.30	9.35	17.18	12.75
CL5(101)	150.39	7.58	1.49	1.19	1.47	69.11	31.93	1.91	18.44	9.40
CL5(118)	755.79	19.04	3.51	3.04	6.36	217.88	508.43	36.47	86.31	26.54
CL6(153)	552.39	27.70	3.67	4.80	9.74	228.28	507.79	35.89	83.60	27.77
CL5(105)	159.62	3.61	0.82	0.45	1.16	22.03	49.83	6.76	14.59	9.51
CL6(138)	467.35	26.77	3.19	3.71	8.15	218.62	374.98	38.31	79.00	26.69
CL7(187)	17.45	2.93	0.90	0.67	0.63	12.19	10.75	2.66	5.77	3.56
CL6(128)	71.84	2.65	0.68	0.22	0.44	13.20	18.75	3.29	3.95	5.24
CL7(180)	44.81	3.58	1.19	0.45	1.31	22.80	46.87	5.20	12.15	6.99
CL7(170)	25.37	4.07	0.28	1.78	1.26	18.08	33.66	4.44	9.51	4.80
CL8(195)	1.51	0.30	0.19	0.07	0.09	1.19	2.42	0.28	0.75	0.68
CL9(206)	1.48	0.23	0.30	0.03	0.08	0.77	1.62	0.19	0.51	0.55
CL10(209)	ND	0.11	0.38	0.05	0.05	ND	ND	0.08	0.18	0.21
Sum of 18 Congeners	3300.34	108.45	23.68	17.88	35.19	896.62	1704.52	147.50	343.87	147.51
Total PCB	5690.24	186.98	40.82	30.83	60.67	1545.90	2938.83	254.31	592.88	254.32
Sum of 17 Congeners	3274.97	104.38	23.40	16.10	33.94	878.54	1670.86	143.06	334.36	142.71
Total PCB	5715.48	182.16	40.84	28.09	59.23	1533.23	2915.99	249.66	583.52	249.06

TABLE A.6. Treatment Section Pre- and Post-Cooking Weight, and Extraction Sample Weight

BATTELLE OCEAN SCIENCES
Saved as: SIZE
Entered by: B.Koczwara 05/02/91
Validated:

Winter Flounder Study
Project #:G1969-0003
G1969-0004

SAMPLE ID	SAMPLE SECTION WEIGHT (g) PRE-COOKING	SAMPLE SECTION WEIGHT (g) POST-COOKING	EXTRACTION SAMPLE WEIGHT (g) WEIGHT USED	EXTRACTION SAMPLE WEIGHT (g) PRE-COOKING EQUIVALENT
WF01-UN	NA	NA	25.2	25.2
WF01-B-I-DF	27.2	21.1	12.7	16.3
WF01-B-II-PF	33.4	30.4	17.0	18.7
WF01-B-III-BR	15.5	14.1	10.1	11.1
WF02-UN	NA	NA	5.4	5.4
WF02-T-I-BR	13.2	11.1	7.0	8.3
WF02-T-II-DF	22.6	14.9	9.0	13.6
WF02-T-III-PF	12.2	10.5	6.1	7.1
WF03-UN	NA	NA	9.9	9.9
WF03-B-I-PF	9.1	8.5	4.4	4.8
WF03-B-II-BR	13.5	11.8	8.2	9.4
WF03-B-III-DF	11.5	8.1	4.2	6.0
WF04-UN	NA	NA	7.7	7.7
WF04-T-I-DF	16.3	10.2	5.6	8.9
WF04-T-II-PF	16.9	16.3	10.1	10.5
WF04-T-III-BR	15.7	14.5	8.4	9.1
WF05-UN	NA	NA	6.1	6.1
WF05-B-I-BR	16.2	14.4	8.7	9.7
WF05-B-II-DF	14.2	9.1	4.9	7.7
WF05-B-III-PF	10.7	10.1	6.1	6.4
WF06-UN	NA	NA	20.9	20.9
WF06-T-I-PF	21.3	21.3	13.5	13.5
WF06-T-II-BR	22.5	21.0	14.4	15.4
WF06-T-III-DF	17.3	10.8	6.7	10.7
WF07-UN	NA	NA	25.1	25.1
WF07-B-I-DF	25.2	15.7	7.1	11.4
WF07-B-II-PF	23.9	22.7	14.1	14.9
WF07-B-III-BR	22.9	21.5	13.6	14.4
WF08-UN	NA	NA	5.6	5.6
WF08-T-I-BR	26.2	20.9	15.0	18.8
WF08-T-II-DF	23.9	13.7	7.8	13.7
WF08-T-III-PF	20.6	18.4	10.5	11.8
WF09-UN	NA	NA	11.0	11.0
WF09-B-I-PF	6.5	6.3	3.7	3.8
WF09-B-II-BR	7.8	6.0	3.5	4.6
WF09-B-III-DF	8.5	4.1	2.4	5.0
WF10-UN	NA	NA	25.3	25.3
WF10-T-I-DF	23.2	15.2	8.1	12.4
WF10-T-II-PF	21.8	19.8	12.3	13.5
WF10-T-III-BR	21.0	17.4	10.4	12.6

TABLE A.6. (contd)

SAMPLE ID	SAMPLE SECTION WEIGHT (g) PRE-COOKING	SAMPLE SECTION WEIGHT (g) POST-COOKING	EXTRACTION SAMPLE WEIGHT (g) WEIGHT USED	EXTRACTION SAMPLE WEIGHT (g) PRE-COOKING EQUIVALENT
WF11-UN	NA	NA	20.1	20.1
WF11-B-I-BR	11.6	8.3	5.1	7.1
WF11-B-II-DF	10.7	5.9	3.1	5.6
WF11-B-III-PF	9.1	8.8	5.1	5.3
WF12-UN	NA	NA	5.9	5.9
WF12-T-I-PF	16.3	14.85	10.1	11.1
WF12-T-II-BR	11.8	9.9	6.7	7.9
WF12-T-III-DF	17.0	10.0	5.3	9.0
WF13-UN	NA	NA	20.1	20.1
WF13-B-I-DF	20.8	9.6	6.0	13.1
WF13-B-II-PF	16.5	15.4	10.0	10.7
WF13-B-III-BR	17.1	11	5.6	8.6
WF14-UN	NA	NA	20.1	20.1
WF14-T-I-BR	14.6	11.9	7.3	9.0
WF14-T-II-DF	13.9	8.5	4.7	7.6
WF14-T-III-PF	10.9	9.2	5.9	7.0
WF15-UN	NA	NA	14.4	14.4
WF15-B-I-PF	12.8	11.1	7.0	8.1
WF15-B-II-BR	10.8	9.9	5.9	6.5
WF15-B-III-DF	10.3	5.0	2.6	5.3
WF16-UN	NA	NA	20.3	20.3
WF16-T-I-DF	24.3	14.1	8.0	13.8
WF16-T-II-PF	26.7	26.2	16.7	17.0
WF16-T-III-BR	22.0	17.4	10.5	13.3
WF17-UN	NA	NA	10.7	10.7
WF17-B-I-BR	18.2	16.2	10.2	11.4
WF17-B-II-DF	19.1	8.2	4.7	10.9
WF17-B-III-PF	25.0	23.9	15.2	15.9
WF18-UN	NA	NA	5.6	5.6
WF18-T-I-PF	21.8	19.7	14.3	15.8
WF18-T-II-BR	27.0	24.3	15.7	17.4
WF18-T-III-DF	17.4	10.0	6.0	10.4
WF19-UN	NA	NA	20.7	20.7
WF19-B-I-DF	36.4	22.7	12.3	19.7
WF19-B-II-PF	24.6	20.9	12.7	15.0
WF19-B-III-BR	13.4	10.1	7.1	9.4
WF20-UN	NA	NA	10.3	10.3
WF20-T-I-BR	30.4	27.9	12.2	13.3
WF20-T-II-DF	36.4	24.2	10.0	15.1
WF20-T-III-PF	32.4	30.8	7.6	8.0
WF21-UN	NA	NA	25.0	25.0
WF21-B-I-PF	41.4	40.1	20.2	20.8
WF21-B-II-BR	44.9	40.3	20.6	23.0
WF21-B-III-DF	32.6	20.4	13.1	21.0

Pre-Cooking Equivalent = Weight Used * (Pre-Cooking Weight / Post Cooking Weight)

APPENDIX B

QUALITY ASSURANCE AND QUALITY CONTROL

APPENDIX B

QUALITY ASSURANCE AND QUALITY CONTROL

A Work Plan describing all pertinent procedures and criteria was written before the start of the field- or laboratory-based project work. Adherence to the Work Plan was monitored by the Project Manager and the Battelle Ocean Sciences (BOS) Quality Assurance Unit. Data quality is defined by comparability, representativeness, completeness, accuracy, and precision in field and laboratory activities. Comparability between this project and earlier studies was ensured by using standard methods that were consistent with those used in other Battelle studies. Representativeness was addressed through the design of the field and analytical program, and by the proper preservation and storage of samples, to ensure that the samples analyzed accurately represent the materials collected. Completeness, defined as the measure of data collected versus the amount expected under ideal conditions, was based 100% on the numbers of fish collected. However, only 21 of the desired 25 fish were collected, and, per mutual agreement among the BOS, PNL, and EPA Project Managers, the field effort was terminated after the 21 fish had been collected. Accuracy and precision were ensured by processing a set of laboratory quality control (QC) samples, as discussed in the following sections.

LABORATORY QC

The laboratory QC program included the processing of one procedural blank, one matrix spike (MS), and one matrix-spike duplicate (MSD) sample with each batch of no more than 20 field samples. There was a total of five analytical batches of samples. The procedural blanks (containing all reagents used in sample processing, carried through all steps and treated as samples) were processed to ensure there were no significant levels of laboratory contamination (see Tables A.2 through A.5 in Appendix A). The MS and MSD samples (field samples amended with the 18 PCB congeners) were used to demonstrate laboratory accuracy and precision (Table B.1). Surrogate standard recoveries were monitored for every sample to provide data on the efficiency of the sample extraction and other sample-processing manipulations (Table B.2). Criteria goals for surrogate (every sample) and PCB analyte (MS and MSD samples) recoveries were between 50 and 150%; precision in the duplicate analyses (MS/MSD) was to be a relative percent difference (%RPD) of no more than 30%; and analyte concentrations measured in the procedural blank were to be less than five times the method detection limit (MDL).

A three-point calibration was analyzed on the analytical instrument (GC/ECD) before each batch of field samples. The three standard solutions in the three-point calibration included all PCB congeners, surrogate, and internal standard analytes, and covered the expected concentration range of the laboratory samples. The initial calibrations were determined by calculating the relative response factors (RRF) of each analyte, relative to the surrogate, for each of the three standards. For the calibration to be valid, the average relative standard deviation in the average RRF for the three concentration levels was to be less than 30% for every analyte. A midlevel calibration standard also was analyzed at least every 12 samples. The %RPD between the RRF of the midlevel check and the average RRF determined from the initial calibration was to be less than 30% for every analyte. Any failure to meet calibration and other quality control criteria goals was brought to the attention of the Project Manager, who determined the appropriate action to be taken.

SAMPLE AND DATA TRACKING

Thorough sample-labeling, chain-of-custody, and log-in procedures were followed. During field collection, field/site forms were completed that included information such as numbers and types of fish collected, location, date, collection method, time, person(s) collecting, and other field observations. In the laboratory, sample-identification/log forms were completed as the individual fish (and subsamples from the fish) were given distinct identifications, and preprinted labels with the same sample identifications were affixed to the sample containers. This procedure created a link between the sample and the data recorded on all laboratory log forms. The sample identifications assigned in the laboratory also were recorded on chain-of-custody forms and were used to track the sample from preparation to final archiving. The samples were in the custody of the field personnel while in the field and during transport to the laboratory, and custody was relinquished to the Laboratory Sample Custodian at the laboratory. Sample storage location, date, and type of analysis also were recorded as the samples progressed through the laboratory. Samples released to other laboratory personnel for analysis were accompanied by sample-transfer documentation.

In the laboratory, all manipulations and processing of the samples were documented on laboratory record forms. Project number, date, and name of the person recording the information were included on the forms. The standard BOS laboratory forms used included forms to record sample identifications, extraction sample weight information, dry weight, lipid weight, spiking, sample cleanup/HPLC, and submission for instrumental analysis. Miscellaneous Documentation Forms were used to record information not covered by standard forms and to record other notable observations/events and deviations from protocol.

Documentation, Data Reduction, and Reporting

All field and laboratory records were maintained on standard forms in three-ring binders. All data were recorded in ink; entries were signed and dated when entered; and any changes were initialed, dated, and explained. Any deviations from Standard Operating Procedures (SOP) or the Work Plan were documented, explained, and approved by the Project Manager. The possible impact of any such deviations on the data was determined by the Project Manager.

Data Validation

Data-validation procedures included checking for accuracy of transcription and calculation, reviewing for conformance with preestablished QC requirements, and evaluating for scientific validity. The Analytical Chemistry Task Leader and Project Manager reviewed the data to ensure conformation with the Work Plan.

Performance and System Audits

The BOS Quality Assurance Unit (QAU) was independent of all work activities pertaining to this study. The QAU monitored the project according to the Work Plan and to existing BOS SOPs to ensure the accuracy, integrity, and completeness of the data. QAU scope included a system inspection, performance and data audits, and document review.

Corrective Action

The Analytical Chemistry Task Leader, Project Manager, Laboratory Manager, and QAU monitored the activities described in this document. All documentation and data were reviewed, and deviations from the Work Plan were recorded. Appropriate corrective action to any identified problems or deviations was addressed by the Project Manager.

QUALITY CONTROL RESULTS

The laboratory quality control data are reported in Tables B.1 and B.2. The matrix-spike surrogate recoveries are reported in Table B.1, and the results are reported in Table B.2. Additionally, procedural-blank data are reported with each set of fish sample data (Tables A.2 through A.5 in Appendix A).

The procedural-blank data are reported in total nanograms. This value can be converted to nanograms per gram by dividing by the appropriate sample weight for comparison to fish sample concentrations. No PCB analytes were detected in the untreated fish batch. Low levels of $Cl_4(44)$ and $Cl_7(170)$ were detected in procedural blanks processed with treatment batches. However, these concentrations were below five times the MDL and were low relative to the concentrations determined in the fish.

Average surrogate recoveries, by analytical batch, ranged from 66 to 87% for the five analytical batches of samples. Surrogate recoveries were slightly below the criteria goal of 50% for 4 of the 99 samples processed in this study, but this condition is not expected to have significantly affected the analytical data.

The precision in the MS/MSD analyses, represented by the %RPD, was good with the exception of one sample. Matrix-spike sample JI76MS, processed with the batch of deep-fried fish samples, appeared to suffer from mass discrimination as a result of poor autosampler sample injection onto the gas chromatograph. This incident was isolated and sample-specific, judging by the GC responses for the analytical standards and all other samples. It resulted in the progressively higher %RPDs with increasing analyte molecular weight, and progressively lower analyte recoveries for JI76MS with increasing molecular weight. Matrix-spike duplicate sample JI77MSD (processed with JI76MS) yielded good recoveries, and other MS/MSD data were good. The MS/MSD recovery data are reported relative to the surrogate compound DBOFB and are not absolute recoveries, allowing a better assessment of the field sample analyte quantification. Absolute recoveries for the MS and MSD samples can be obtained by multiplying the percent recoveries reported by the recovery of the surrogate (see Table B.2) for the sample. There are some analyte-specific deviations from the recovery criteria goal of 50 to 150%; however, these deviations are for analytes [particularly $Cl_5(118)$, $Cl_6(138)$, and $Cl_6(153)$] that were present at high levels in the background sample (relative to the amount spiked into the MS/MSD samples), making the data for these particular analytes unsuitable for assessing accuracy and precision.

TABLE B.1. Laboratory Quality Control Data--Matrix Spike Data

Battelle Ocean Sciences
Matrix Spike Recoveries - Pilot Study Batch
File: QC2

Created: GSD 06/13/91
Validated:

PCB Concentration Changes in Cooked Seafood
Phase 1: Winter Flounder, G1969-0005
Matrix Spike/Spike Duplicate Percent Recovery Data

	Sample Data in ng/g Wet Weight				MS/MSD Corrected for Background in ng/g Wet Weight		% Recovery of MS/MSD Data Background Corrected		
Battelle Lab ID:	WF21-T-UN	JG25MS	JG26MSD	%RPD	JG25MS	JG26MSD	JG25MS	JG26MSD	AVERAGE
Wet Weight:	25.05	15.23	15.04		15.23	15.04	15.23	15.04	
Sample ID									
CL2(08)	1.13	4.76	4.68	1.7	3.63	3.55	106.3	102.7	104.5
HCB	0.22	3.42	3.47	1.5	3.20	3.25	99.0	99.4	99.2
CL3(18)	1.41	4.68	4.71	0.7	3.28	3.31	95.9	95.7	95.8
CL3(28)	4.34	7.28	6.97	4.4	2.94	2.63	86.0	76.0	81.0
CL4(52)	3.88	6.46	6.65	2.9	2.58	2.77	75.6	80.2	77.9
CL4(44)	1.10	4.50	4.57	1.7	3.40	3.48	99.6	100.5	100.1
CL4(66)	13.10	14.95	16.29	8.6	1.85	3.19	54.1	92.3	73.2
OPDDE	1.51	4.85	4.84	0.2	3.34	3.33	103.3	101.8	102.6
CL5(101)	9.60	12.05	12.83	6.3	2.45	3.23	71.7	93.4	82.6
A CHLORDANE	14.21	17.63	18.41	4.3	3.42	4.20	105.7	128.2	116.9
TRANSNONACHLOR	ND	4.42	4.18	5.5	4.42	4.18	135.8	127.0	131.4
PPDDE	6.17	8.90	9.27	4.1	2.73	3.10	83.9	94.1	89.0
OPDDD	ND	2.88	2.82	2.0	2.88	2.82	88.9	86.1	87.5
CL5(118)	25.75	29.64	31.40	5.8	3.89	5.65	113.2	162.6	137.9
PPDDD	1.97	6.22	6.09	2.1	4.25	4.13	131.5	126.0	128.8
OPDDT	5.45	9.43	9.58	1.6	3.99	4.14	123.3	126.4	124.8
CL6(153)	28.74	32.89	34.96	6.1	4.16	6.23	121.1	179.3	150.2
CL5(105)	9.76	13.25	13.35	0.8	3.48	3.59	102.0	103.7	102.9
PPDDT	ND	9.03	8.64	4.4	9.03	8.64	280.6	265.2	272.9
CL6(138)	27.40	31.94	33.67	5.3	4.54	6.27	133.0	181.4	157.2
CL7(187)	3.61	6.39	6.72	5.1	2.78	3.11	80.9	89.6	85.2
CL6(128)	5.11	7.70	8.29	7.4	2.59	3.18	75.9	92.1	84.0
CL7(180)	7.05	9.77	11.14	13.1	2.72	4.09	79.6	118.2	98.9
CL7(170)	5.29	8.13	8.34	2.6	2.84	3.05	82.7	87.8	85.3
CL8(195)	0.80	3.94	3.96	0.6	3.13	3.16	91.8	91.3	91.5
CL9(206)	0.60	3.61	3.68	1.9	3.01	3.08	89.9	90.8	90.4
CL10(209)	0.33	3.42	3.35	2.1	3.10	3.03	90.7	87.5	89.1

Percent Recovery = (Sample Background corrected ng/g * Sample g Wet Weight) / Spike Amount * 100

TABLE B.1. (cont)

Battelle Ocean Sciences
Matrix Spike Recoveries - Untreated Fish Batch
File: QC2

Created: GSD 06/13/91
Validated:

PCB Concentration Changes in Cooked Seafood
Phase 1: Winter Flounder, G1969-0005
Matrix Spike/Spike Duplicate Percent Recovery Data

	Sample Data in ng/g Wet Weight				MS/MSD Corrected for Background in ng/g Wet Weight		% Recovery of MS/MSD Data Background Corrected		
Battelle Lab ID:	WF01-UN	JL17MS	JL18MSD	%RPD	JL17MS	JL18MSD	JL17MS	JL18MSD	AVERAGE
Wet Weight:	25.23	20.38	21.81		20.38	21.81	20.38	21.81	
Sample ID									
CL2(08)	0.49	3.74	3.37	10.4	3.25	2.88	127.3	120.8	124.1
HCB	0.07	2.78	2.54	9.1	2.71	2.47	112.3	109.4	110.9
CL3(18)	0.23	3.50	3.24	7.6	3.27	3.02	128.3	126.5	127.4
CL3(28)	0.40	3.35	3.03	10.1	2.95	2.63	115.6	110.1	112.9
CL4(52)	0.48	3.57	3.25	9.1	3.09	2.78	121.0	116.4	118.7
CL4(44)	0.25	2.96	2.75	7.5	2.71	2.50	106.4	104.9	105.6
CL4(66)	0.30	3.82	3.50	8.6	3.52	3.20	137.9	134.3	136.1
OPDDE	ND	3.13	2.48	23.2	3.13	2.48	129.6	109.9	119.7
CL5(101)	0.65	3.78	3.41	10.3	3.14	2.77	122.9	116.0	119.4
A CHLORDANE	0.15	3.05	2.86	6.6	2.90	2.71	120.0	119.8	119.9
TRANSNONACHLOR	0.20	3.33	3.11	6.9	3.13	2.91	128.9	128.1	128.5
PPDDE	1.04	3.97	3.58	10.2	2.93	2.55	120.7	112.2	116.5
OPDDD	ND	2.70	2.76	2.1	2.70	2.76	111.8	122.2	117.0
CL5(118)	0.95	4.43	4.01	9.8	3.47	3.06	135.4	127.6	131.5
PPDDD	ND	3.34	2.75	19.5	3.34	2.75	138.1	121.6	129.8
OPDDT	ND	3.01	2.87	4.6	3.01	2.87	124.4	127.1	125.7
CL6(153)	1.69	5.59	4.80	15.1	3.90	3.11	152.1	130.0	141.1
CL5(105)	0.16	3.09	3.10	0.5	2.93	2.95	114.8	123.5	119.1
PPDDT	ND	2.96	2.90	2.1	2.96	2.90	123.1	129.0	126.0
CL6(138)	1.48	4.88	4.46	8.9	3.40	2.98	133.4	125.2	129.3
CL7(187)	0.37	3.55	3.33	6.2	3.18	2.96	123.9	123.5	123.7
CL6(128)	ND	3.10	3.04	2.1	3.10	3.04	121.6	127.5	124.6
CL7(180)	0.48	3.86	3.65	5.6	3.38	3.17	132.3	132.7	132.5
CL7(170)	0.15	3.52	3.32	6.0	3.38	3.17	131.7	132.4	132.1
CL8(195)	ND	3.43	3.35	2.5	3.43	3.35	134.5	140.3	137.4
CL9(206)	ND	3.70	3.62	2.2	3.70	3.62	147.8	154.7	151.2
CL10(209)	ND	3.76	3.68	2.1	3.76	3.68	147.4	154.4	150.9

Percent Recovery = (Sample Background corrected ng/g * Sample g Wet Weight) / Spike Amount * 100

TABLE B.1. (cont)

Battelle Ocean Sciences
Matrix Spike Recoveries - Deep Fried Fish Batch
File: QC2

Created: GSD 06/13/91
Validated:

PCB Concentration Changes in Cooked Seafood
Phase 1: Winter Flounder, G1969-0005
Matrix Spike/Spike Duplicate Percent Recovery Data

	Sample Data in ng/g Wet Weight				MS/MSD Corrected for Background in ng/g Wet Weight		% Recovery of MS/MSD Data Background Corrected		
Battelle Lab ID:	WF20-T-II-DF	J176MS	J177MSD	%RPD	J176MS	J177MSD	J176MS	J177MSD	AVERAGE
Wet Weight:	15.1	4.6	4.6		4.6	4.6	4.6	4.6	
Sample ID									
CL2(08)	0.25	10.32	10.61	2.7	10.07	10.36	89.1	91.6	90.3
HCB	0.06	9.20	9.62	4.4	9.14	9.56	85.4	89.3	87.3
CL3(18)	0.85	10.14	11.22	10.1	9.30	10.37	82.2	91.7	87.0
CL3(28)	4.65	14.46	16.64	14.0	9.81	11.99	86.8	106.1	96.4
CL4(52)	3.27	12.09	13.57	11.5	8.82	10.29	78.0	91.0	84.5
CL4(44)	1.05	10.22	12.74	21.9	9.17	11.69	81.1	103.4	92.2
CL4(66)	14.53	21.44	32.06	39.7	6.91	17.54	61.1	155.1	108.1
OPDDE	ND	7.98	10.04	22.9	7.98	10.04	74.5	93.8	84.1
CL5(101)	14.74	17.72	27.51	43.3	2.98	12.77	26.4	113.0	69.7
A CHLORDANE	0.09	8.21	10.93	28.4	8.12	10.84	75.8	101.2	88.5
TRANSNONACHLOR	0.24	8.46	11.52	30.7	8.22	11.28	76.4	104.9	90.6
PPDDE	4.56	10.93	19.07	54.3	6.38	14.52	59.2	134.9	97.1
OPDDD	1.23	7.60	12.60	49.5	6.37	11.37	59.5	106.2	82.8
CL5(118)	69.13	51.08	100.90	65.6	-18.04	31.78	-158.9	279.8	60.5
PPDDD	1.76	7.51	16.95	77.2	5.74	15.18	53.6	141.8	97.7
OPDDT	1.66	7.59	13.63	57.0	5.93	11.97	55.4	111.8	83.6
CL6(153)	66.94	47.20	101.99	73.5	-19.75	35.05	-173.8	308.6	67.4
CL5(105)	13.33	15.36	29.01	61.6	2.03	15.69	18.0	138.8	78.4
PPDDT	0.13	5.54	12.61	77.9	5.41	12.49	50.8	117.2	84.0
CL6(138)	64.31	42.10	99.44	81.0	-22.21	35.12	-196.5	310.7	57.1
CL7(187)	4.58	7.94	17.46	75.0	3.35	12.88	29.5	113.4	71.4
CL6(128)	3.48	7.97	18.77	80.8	4.49	15.29	39.7	135.3	87.5
CL7(180)	11.29	9.60	25.24	89.8	-1.69	13.95	-14.9	123.4	54.2
CL7(170)	7.33	8.29	23.47	95.6	0.96	16.14	8.4	142.1	75.3
CL8(195)	0.46	5.02	13.95	94.2	4.56	13.50	40.3	119.4	79.9
CL9(206)	0.29	4.29	11.78	93.2	3.99	11.48	36.0	103.6	69.8
CL10(209)	0.10	4.59	11.90	88.7	4.49	11.80	39.7	104.4	72.1

Percent Recovery = (Sample Background corrected ng/g * Sample g Wet Weight) / Spike Amount * 100

TABLE B.1. (cont)

Battelle Ocean Sciences
Matrix Spike Recoveries - Pan Fried Fish Batch
File: QC2

Created: GSD 06/13/91
Validated:

PCB Concentration Changes in Cooked Seafood
Phase 1: Winter Flounder, G1969-0005
Matrix Spike/Spike Duplicate Percent Recovery Data

	Sample Data in ng/g Wet Weight				MS/MSD Corrected for Background in ng/g Wet Weight		% Recovery of MS/MSD Data Background Corrected		
Battelle Lab ID:	WF20-T-III-PF	J180MS	J181MSD	%RPD	J180MS	J181MSD	J180MS	J181MSD	AVERAGE
Wet Weight:	8.0	3.5	3.7		3.5	3.7	3.5	3.7	
Sample ID									
CL2(08)	ND	15.05	13.42	11.5	15.05	13.42	101.3	95.5	98.4
HCB	0.13	13.31	11.94	10.9	13.18	11.81	93.7	88.7	91.2
CL3(18)	1.65	15.97	13.67	15.5	14.32	12.02	96.4	85.5	90.9
CL3(28)	6.86	25.73	25.06	2.6	18.87	18.20	127.0	129.5	128.3
CL4(52)	5.58	21.42	18.65	13.8	15.84	13.07	106.6	93.0	99.8
CL4(44)	1.29	16.50	15.30	7.6	15.21	14.01	102.4	99.7	101.0
CL4(66)	23.85	50.59	47.44	6.4	26.75	23.60	180.0	167.9	174.0
OPDDE	ND	15.08	15.05	0.2	15.08	15.05	107.1	113.0	110.1
CL5(101)	25.98	51.25	45.58	11.7	25.27	19.60	170.1	139.5	154.8
A CHLORDANE	0.23	14.73	14.63	0.7	14.51	14.40	103.1	108.2	105.6
TRANSNONACHLOR	0.49	15.07	14.52	3.7	14.58	14.03	103.1	104.9	104.0
PPDDE	7.18	28.30	31.47	10.6	21.13	24.30	149.4	181.6	165.5
OPDDD	2.00	17.10	15.65	8.9	15.10	13.65	107.3	102.6	104.9
CL5(118)	115.81	185.06	169.87	8.6	69.25	54.05	463.9	382.8	423.3
PPDDD	2.47	20.98	23.07	9.5	18.51	20.60	131.6	154.8	143.2
OPDDT	2.59	18.14	18.09	0.3	15.55	15.50	110.5	116.4	113.5
CL6(153)	118.49	191.33	170.49	11.5	72.84	51.99	487.9	368.2	428.1
CL5(105)	19.82	40.16	41.40	3.0	20.35	21.58	136.9	153.6	145.2
PPDDT	ND	14.82	16.13	8.5	14.82	16.13	105.8	121.8	113.8
CL6(138)	107.38	171.54	156.55	9.1	64.16	49.17	431.9	349.9	390.9
CL7(187)	7.56	25.31	23.31	8.2	17.76	15.75	118.9	111.6	115.2
CL6(128)	5.06	24.42	24.33	0.4	19.36	19.27	130.3	137.1	133.7
CL7(180)	18.28	40.89	39.89	2.5	22.61	21.61	152.1	153.8	153.0
CL7(170)	12.24	33.05	31.28	5.5	20.81	19.04	139.4	134.8	137.1
CL8(195)	0.68	16.54	15.09	9.2	15.86	14.41	106.8	102.5	104.6
CL9(206)	0.37	14.54	12.98	11.3	14.17	12.62	97.2	91.5	94.4
CL10(209)	0.10	14.53	12.81	12.6	14.43	12.71	97.1	90.4	93.8

Percent Recovery = (Sample Background corrected ng/g * Sample g Wet Weight) / Spike Amount * 100

TABLE B.1. (cont)

Battelle Ocean Sciences
Matrix Spike Recoveries - Broiled Fish Batch
File: QC2

Created: GSD 06/13/91
Validated:

PCB Concentration Changes in Cooked Seafood
Phase 1: Winter Flounder, G1969-0005
Matrix Spike/Spike Duplicate Percent Recovery Data

	Sample Data in ng/g Wet Weight				MS/MSD Corrected for Background in ng/g Wet Weight		% Recovery of MS/MSD Data Background Corrected		
Battelle Lab ID:	WF20-T-I-BR	J192MS	J193MSD	%RPD	J192MS	J193MSD	J192MS	J193MSD	AVERAGE
Wet Weight:	13.3	4.9	3.7		4.9	3.7	4.9	3.7	
Sample ID									
CL2(08)	0.34	10.27	14.72	35.7	9.93	14.38	93.5	102.3	97.9
HCB	0.08	9.33	13.47	36.3	9.26	13.40	92.1	100.6	96.4
CL3(18)	1.14	10.88	15.36	34.1	9.74	14.22	91.8	101.2	96.5
CL3(28)	5.22	18.52	20.13	8.3	13.31	14.91	125.4	106.1	115.7
CL4(52)	4.19	14.81	19.10	25.3	10.62	14.92	100.1	106.1	103.1
CL4(44)	1.04	12.30	15.94	25.8	11.26	14.90	106.1	106.0	106.1
CL4(66)	17.18	35.18	38.65	9.4	18.00	21.47	169.6	152.8	161.2
OPDDE	ND	9.73	12.78	27.1	9.73	12.78	96.8	96.0	96.4
CL5(101)	18.44	32.80	34.14	4.0	14.35	15.70	135.2	111.7	123.5
A CHLORDANE	0.15	10.15	13.25	26.5	9.99	13.10	99.4	98.4	98.9
TRANSNONACHLOR	0.27	10.43	13.93	28.8	10.17	13.67	100.6	102.2	101.4
PPDDE	4.83	20.25	20.33	0.4	15.42	15.50	152.6	115.9	134.2
OPDDD	1.46	12.16	15.93	26.8	10.71	14.47	106.5	108.7	107.6
CL5(118)	86.31	128.50	112.34	13.4	42.20	26.04	395.7	184.4	290.0
PPDDD	2.12	16.29	18.88	14.7	14.17	16.76	141.0	125.9	133.5
OPDDT	1.77	13.02	15.32	16.2	11.25	13.56	112.0	101.8	106.9
CL6(153)	83.60	131.15	116.45	11.9	47.54	32.85	445.8	232.6	339.2
CL5(105)	14.59	33.89	29.47	13.9	19.31	14.89	181.9	105.9	143.9
PPDDT	ND	11.54	14.62	23.5	11.54	14.62	115.4	110.4	112.9
CL6(138)	79.00	120.99	106.51	12.7	42.00	27.51	395.8	195.8	295.8
CL7(187)	5.77	19.54	21.08	7.5	13.77	15.30	129.1	108.4	118.8
CL6(128)	3.95	18.32	19.92	8.4	14.37	15.97	135.4	113.7	124.5
CL7(180)	12.15	32.92	29.04	12.5	20.76	16.89	195.7	120.2	157.9
CL7(170)	9.51	27.51	27.19	1.2	17.99	17.67	168.7	125.1	146.9
CL8(195)	0.75	13.01	16.11	21.3	12.25	15.35	115.5	109.2	112.3
CL9(206)	0.51	11.24	14.59	25.9	10.74	14.08	103.2	102.2	102.7
CL10(209)	0.18	10.64	14.80	32.7	10.46	14.62	98.5	104.0	101.3

*Recovery = (Sample Background corrected ng/g * Sample g Wet Weight) / Spike Amount * 100

TABLE B.2. Laboratory Quality Control Data--Surrogate Recovery Data

Battelle Ocean Sciences
Surrogate Recoveries - Pilot Study Batch
File: QC1
Created: GSD 06/13/91
Validated:

PCB Concentration Changes in Cooked Seafood
Phase 1: Winter Flounder, G1969-0005

Sample ID	% Recovery DBOFB
JG24PB	91.4
JG25MS	93.0
JG26MSD	88.3
WF07-T-UN	86.3
WF07-B-I-DF	93.1
WF07-B-II-PF	83.3
WF07-B-III-BR	83.3
WF10-B-UN	79.8
WF10-T-I-DF	92.9
WF10-T-II-PF	93.5
WF10-T-III-BR	86.8
WF11-T-UN	80.0
WF11-B-I-BR	88.2
WF11-B-II-DF	92.0
WF11-B-III-PF	84.0
WF14-B-UN	87.9
WF14-T-I-BR	92.0
WF14-T-II-DF	91.0
WF14-T-III-PF	81.7
WF21-T-UN	84.9
WF21-B-I-PF	86.7
WF21-B-II-BR	79.7
WF21-B-III-UN	86.5
Average:	87.2

Battelle Ocean Sciences
Surrogate Recoveries - Untreated Fish Batch

PCB Concentration Changes in Cooked Seafood
Phase 1: Winter Flounder, G1969-0005

Sample ID	% Recovery DBOFB
JL16PB	65.2
JL17MS	67.4
JL18MSD	68.4
WF01-UN	56.8
WF02-UN	66.9
WF03-UN	66.5
WF04-UN	74.6
WF05-UN	71.1
WF06-UN	70.6
WF08-UN	79.5
WF09-UN	67.5
WF12-UN	77.7
WF13-UN	67.1
WF15-UN	65.5
WF16-UN	59.2
WF17-UN	67.3
WF18-UN	61.4
WF19-UN	78.0
WF20-UN	78.8
Average:	68.9

TABLE B.2. (cont)

Battelle Ocean Sciences
Surrogate Recoveries - Deep Fried Fish Batch
File: QC1
Created: GSD 06/13/91
Validated:

PCB Concentration Changes in Cooked Seafood
Phase 1: Winter Flounder, G1969-0005

Sample ID	% Recovery DBOFB
J175PB	56.9
J176MS	88.7
J177MSD	74.3
WF01-B-I-DF	70.5
WF02-T-II-DF	36.1
WF03-B-III-DF	53.0
WF04-T-I-DF	94.9
WF05-B-II-DF	56.5
WF06-T-III-DF	91.5
WF08-T-II-DF	57.3
WF09-B-III-DF	67.1
WF12-T-III-DF	69.7
WF13-B-I-DF	79.0
WF15-B-III-DF	79.9
WF16-T-I-DF	42.3
WF17-B-II-DF	37.5
WF18-T-III-DF	48.5
WF19-B-I-DF	88.9
WF20-T-II-DF	62.7
Average:	66.1

Battelle Ocean Sciences
Surrogate Recoveries - Pan Fried Fish Batch

PCB Concentration Changes in Cooked Seafood
Phase 1: Winter Flounder, G1969-0005

Sample ID	% Recovery DBOFB
J179PB	87.5
J180MS	85.2
J181MSD	90.7
WF01-B-II-PF	75.2
WF02-T-III-PF	58.0
WF03-B-I-PF	85.8
WF04-T-II-PF	84.0
WF05-B-III-PF	58.4
WF06-T-I-PF	96.9
WF08-T-III-PF	60.2
WF09-B-I-PF	72.2
WF12-T-I-PF	62.5
WF13-B-II-PF	72.5
WF15-B-I-PF	90.3
WF16-T-II-PF	89.6
WF17-B-III-PF	52.9
WF18-T-I-PF	55.3
WF19-B-II-PF	74.1
WF20-T-III-PF	69.8
Average:	74.8

TABLE B.2. (cont)

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Surrogate Recoveries - Broiled Fish Batch
File: QC1
Created: GSD 06/13/91
Validated:

PCB Concentration Changes in Cooked Seafood
Phase 1: Winter Flounder, G1969-0005

Sample ID	% Recovery DBOFB
J191PB	77.8
J192MS	79.5
J193MSD	74.5
WF01-B-III-BR	82.6
WF02-T-I-BR	56.8
WF03-B-II-BR	87.2
WF04-T-III-BR	78.0
WF05-B-I-BR	58.7
WF06-T-II-BR	89.1
WE08-T-I-BR	63.0
WF09-B-II-BR	88.9
WF12-T-II-BR	64.5
WF13-B-III-BR	69.7
WF15-B-II-BR	88.5
WF16-T-III-BR	83.7
WF17-B-I-BR	59.3
WF18-T-II-BR	62.1
WF19-B-III-BR	82.5
WF20-T-I-BR	75.8
Average:	74.8

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