Lower Duwamish Waterway Group

Port of Seattle / City of Seattle / King County / The Boeing Company

Lower Duwamish Waterway Remedial Investigation

DATA REPORT:
CHEMICAL ANALYSES OF FISH AND CRAB TISSUE SAMPLES COLLECTED IN 2005
FINAL

For submittal to

The U.S. Environmental Protection Agency
Region 10
Seattle, WA

The Washington State Department of Ecology
Northwest Field Office
Bellevue, WA

April 19, 2006

Prepared by: Windward environmental LLC

200 West Mercer Street, Suite 401 • Seattle, Washington • 98119

Table of Contents

Additional supporting documentation

The following appendices, which consist of detailed validation reports and scanned versions of original field and laboratory documents may be viewed at

http://www.ldwg.org/rifs_docs.htm; the links are found in the Data Report section under the heading Task 10: Results of Phase 2 fieldwork. A compact disc version of these materials is available on request.

Appendix C. Data Validation Reports

Appendix D. Form 1s

Appendix E. Field Form 1s, Field Notes, and Navigation Report

Appendix F. Chain-of-Custody Forms

Appendix G. ARI standard operating procedures

Appendix H. ARI tissue preparation notes

List of Tables

List of Figures

Acronyms

ACRONYM	Definition
ARI	Analytical Resources, Inc.
COC	chain of custody
EPA	US Environmental Protection Agency
ERA	ecological risk assessment
GC/ECD	gas chromatography/electron capture detection
HHRA	human health risk assessment
ID	identification
LDC	Laboratory Data Consultants, Inc.
LDW	Lower Duwamish Waterway
MS/MSD	matrix spike/matrix spike duplicate
PCB	polychlorinated biphenyl
QA/QC	quality assurance/quality control
QAPP	quality assurance project plan
RI	remedial investigation
RM	river mile
RPD	relative percent difference
SDG	sample delivery group
Windward	Windward Environmental LLC
ww	wet weight

1.0 Introduction

This data report presents the results of a sampling event for fish and crab conducted in 2005 as part of the Phase 2 remedial investigation (RI) for the Lower Duwamish Waterway (LDW). Field catch results and the results of the chemical analyses of fish and crab composite tissue samples are provided. Composite samples were analyzed for polychlorinated biphenyls (PCBs) (as Aroclors), total solids, and lipids.

An addendum (Windward 2005) to the fish and crab tissue quality assurance project plan (QAPP) (Windward 2004a) presented the design for this study, including details on project organization, field data collection, laboratory analyses, and data management. In combination with existing data, data from this study will be used to support the ecological risk assessment (ERA), the human health risk assessment (HHRA), and the food web modeling for Phase 2 of the LDW RI, as described in the Phase 2 RI work plan (Windward 2004b).

The remainder of this report is organized into the following sections:

- Section 2 – Fish and crab tissue sampling and processing
- Section 3 – Analytical methods
- Section 4 – Chemical analysis results
- Section 5 – References

The text is supported by the following appendices:

- Appendix A – Compositing information
- Appendix B – Data management
- Appendix C – Data validation reports
- Appendix D – Forms 1s
- Appendix E – Field forms, field notes, and navigation report
- Appendix F – Chain-of-custody forms
- Appendix G – ARI standard operating procedures
- Appendix H – ARI tissue preparation notes

2.0 Fish and Crab Tissue Sampling and Processing

This section describes the methods used to collect and process fish and crab composite tissue samples. The field procedures used to collect the fish and crab samples are described in detail in the QAPP (Windward 2004a) and QAPP addendum (Windward 2005). Section 2.1 presents sampling and processing methods. Section 2.2 describes field deviations from the QAPP. Compositing data are presented in Appendix A. Photocopies of field forms, field notebooks, and the navigation report are presented in Appendix E. Copies of completed chain-of-custody (COC) forms used to track sample custody are presented in Appendix F.

2.1 LDW Tissue Sampling and Processing

Fish and crabs were collected from the LDW from August 29 to September 6, 2005. This section provides a brief overview of the species targeted for collection, sampling areas, sampling methods, and the catch results.

2.1.1 Targeted species and collection areas

As presented in Section 3.1 of the QAPP addendum (Windward 2005), species (and minimum sizes) targeted for collection were English sole (≥ 200 mm), Pacific staghorn sculpin (≥ 120 mm), shiner surfperch (≥ 80 mm), and Dungeness crab (≥ 90 mm). Starry flounder was not listed as a target species in the QAPP addendum; but consistent with the QAPP (Windward 2004a), starry flounder were collected as a potential surrogate species for English sole in case sufficient numbers of English sole were not collected. Slender crab was chosen as a potential surrogate species for Dungeness crab in case sufficient numbers of Dungeness crabs were not collected. The minimum sizes of fish and crabs noted above were selected to represent the preferred prey size of piscivorous wildlife receptors of concern and reasonable sizes of seafood consumed by humans (Windward 2004a).

Fish and crab tissue samples were collected from four distinct tissue sampling areas (Areas T1, T2, T3, and T4) as described in the QAPP (Windward 2004a). Areas T1, T2, and T3 were divided into six subareas (A to F). Area T4 was divided into five subareas (A to E) because of its shape and the difficulty in sampling upstream of river mile (RM) 4.8 (Figure 2-1). As specified in the QAPP addendum (Windward 2005), no sampling was conducted in subarea T4-E in 2005 because only one shiner surfperch of target size was collected in this subarea in 2004. Shiner surfperch and Pacific staghorn sculpin were sampled from smaller subareas of each sampling area, as described in the QAPP.

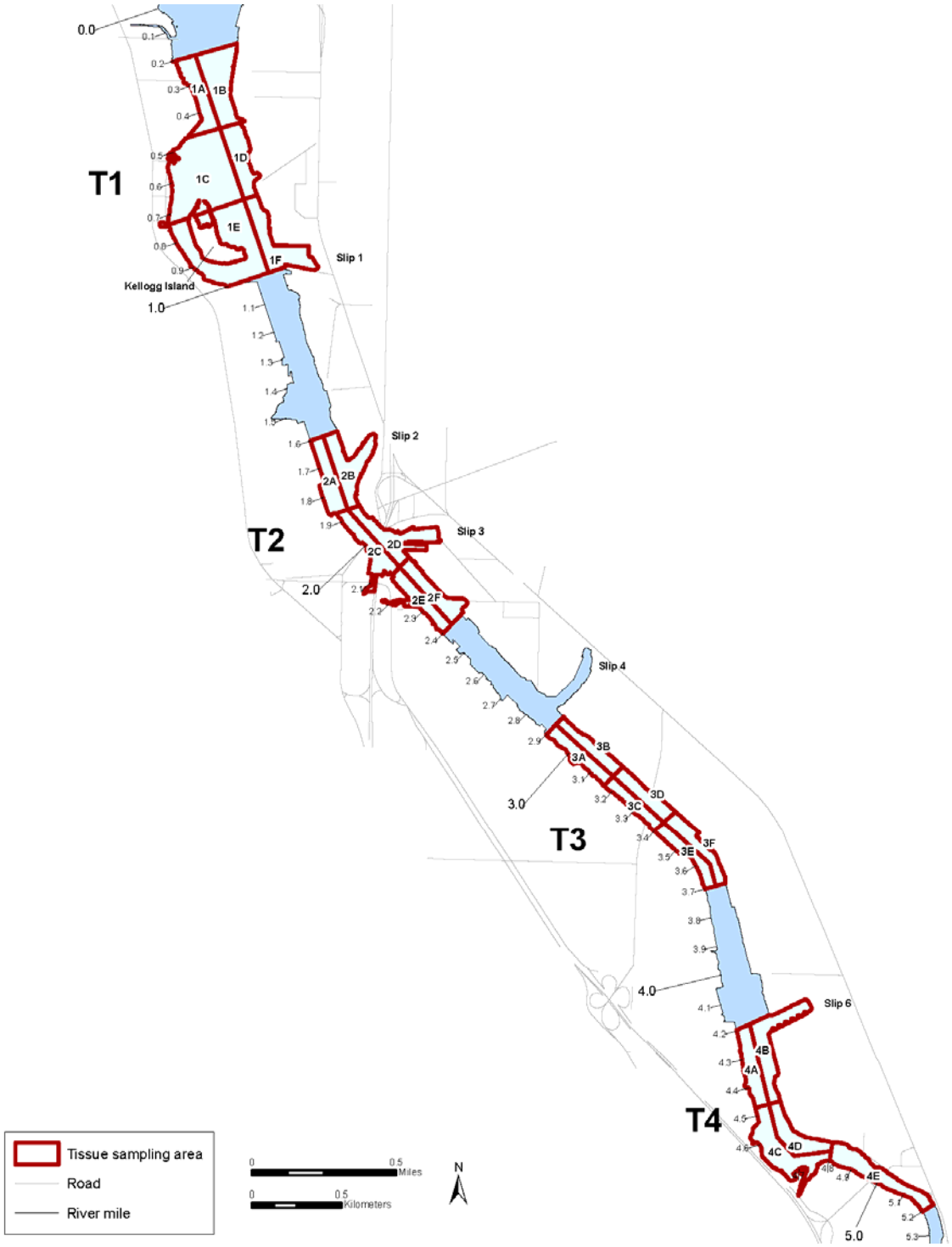

Figure 2-1. Phase 2 fish and crab tissue collection areas in the LDW

2.1.2 Collection methods

Fish and crabs were collected using two different collection methods: a high-rise otter trawl for all fish species, and crab traps for crabs. The rationale for the sampling locations and the field procedures used to collect the fish and crab samples are described in detail in the QAPP (Windward 2004a) and QAPP addendum (Windward 2005).

2.1.2.1 High-rise otter trawl

Trawling was conducted in the LDW for six days from August 29 to September 6, 2005. All trawling was conducted using the research vessel *Kittiwake*, captained by Charles Eaton (Bio-Marine Enterprises). Specifications of the high-rise otter trawl are presented in the QAPP (Windward 2004a).

Trawling began and ended within the boundaries of a given subarea and generally progressed against the flow of the waterway. During ebb tides, trawls were conducted from downstream to upstream. During flood tides that caused flow reversal, trawls were conducted from upstream to downstream. Within each subarea, trawling was focused on areas outside of the navigation channel to capture fish in shallower habitats. However, vessel draft and trawl depth limitations constrained trawling to waters deeper than 6 ft at the time of trawling. If multiple trawls outside the navigation channel failed to yield sufficient numbers of target species, trawls were also conducted within the navigation channel. The numbers of trawls conducted in each subarea, both inside and outside the navigation channel, are presented in Table 2-1, and trawling locations are shown in Figures 2-2 to 2-5.

Table 2-1. Number of trawls conducted inside and outside the navigation channel in each LDW sampling area

Area	Subarea	Number of Trawls[a]		
		Inside Channel	Outside Channel	Total
T1	A	0	3	3
	B	0	5	5
	C	0	2	2
	D	0	5	5
	E	0	2	2
	F	0	2	2
T1 Total		**0**	**19**	**19**
T2	A	1	0	1
	B	0	1	1
	C	2	0	2
	D	1	0	1
	E	3	2	5
	F	0	1	1
T2 Total		**7**	**4**	**11**

Area	Subarea	Number of Trawls[a]		
		Inside Channel	Outside Channel	Total
T3	A	1	1	2
	B	1	2	3
	C	0	3	3
	D	2	2	4
	E	3	1	4
	F	2	4	6
T3 Total		**9**	**13**	**22**
T4	A	15	1	16
	B	14	1	15
	C	4	2	6
	D	1	3	4
T4 Total		**34**	**7**	**41**
Grand Total		**50**	**43**	**93**

[a] The determination of whether trawl transects occurred inside or outside the navigation channel was made in the field by Charles Eaton based on depth sounder measurements and best professional judgment. Because the determinations regarding trawls and traps were made by different people at different times, there may be some discrepancy between co-located trap and trawl locations that are close to the channel edge. The locations of trawl transects in relation to channel bathymetry are shown in Figures 2-2 through 2-5.

2.1.2.2 Crab traps

Crab traps were deployed in the LDW on August 30 and 31, 2005. All traps were Ladner 30-in. rubber-wrapped stainless steel crab traps. Bait was placed in plastic bait jars that were securely fastened to the inside of the trap. The bait containers had numerous holes, which prevented crabs from eating the bait.

Specific trap locations were selected based on Dungeness crab trapping results from 2004 and on Dungeness crab catch results from concurrent trawling efforts. Because no crabs were caught in subareas T4-D or T4-E in the 2004 sampling effort, no traps were deployed in these areas in 2005. Traps were dispersed throughout each subarea in locations outside of the navigation channel to capture crabs in shallower habitats while allowing for vessel navigation. No traps were deployed in Area T1 because sufficient numbers of Dungeness crabs were captured in the trawls from this area. Trap deployment times ranged from approximately 2 to 3.5 hours. The numbers of traps set in each subarea, both inside and outside the navigation channel, are presented in Table 2-2, and locations are shown in Figures 2-6 to 2-8.

Table 2-2. Number of crab traps set inside and outside the navigation channel in each LDW sampling area

Area[b]	Subarea	Number of Traps[a]		
		Inside Channel	Outside Channel	Total
T2	A	0	5	5
	B[c]	0	7	7
	C	0	4	4
	D	0	3	3
	E	0	3	3
	F	0	1	1
T2 Total		**0**	**23**	**23**
T3	A	0	4	4
	B	0	1	1
	C	0	1	1
	D	0	2	2
	E	0	1	1
	F	0	2	2
T3 Total		**0**	**11**	**11**
T4	A	0	5	5
	B[d]	2	10	12
	C	0	3	3
T4 Total		**2**	**18**	**20**
Grand Total		**2**	**52**	**54**

[a] The determination of whether traps were set inside or outside the navigation channel was based on LDW bathymetry contours and best professional judgment. Because these determinations were made by different people at different times, there may be some discrepancy between co-located trap and trawl locations that are close to the channel edge. The locations of traps in relation to bathymetry, area, and subarea boundaries are shown in Figures 2-6 through 2-8.

[b] No traps were deployed in Area T1 because sufficient numbers of Dungeness crabs were captured in the trawls from this area.

[c] Trap CT041 fell approximately 200 feet outside of the sampling area (see Figure 2-6). No specimens were captured in this trap.

[d] Traps CT043 and CT021 fell less than 50 ft outside of the sampling area (see Figure 2-8). The one crab captured in these two traps was not included in any composite samples.

2.1.2.3 Field sample processing

Upon completion of an individual trawl or trap, the catch was sorted by species and size into buckets that contained site water. Prior to release within their area of capture, non-target species were identified to the lowest practical taxonomic level, the lengths of the smallest and largest individuals of a given species were measured, numbers of each species were counted (or estimated if a species was present in large numbers), and these data were recorded on the non-target species tally form.

Individual specimens of target fish or crabs were rinsed in site water to remove any foreign matter from the external surface. Large fish were killed by placing them in a

zip-lock bag and giving them a sharp blow to the head on the side of the processing table. Small fish were killed by placing them on ice, as recommended by the US Environmental Protection Agency (EPA) (EPA 2000). Crabs were not killed in the field but were instead placed in coolers on ice for processing at Windward Environmental LLC (Windward). Individual specimens of the target species were then grouped by species and general size class and placed in clean holding trays to prevent contamination. All fish were inspected carefully to ensure that their skin had not been damaged by the sampling equipment; specimens with broken skin were not included in tissue composite samples. Each fish within the selected target species was measured to determine that the actual total length was greater than the minimum target length for that species.

Pacific staghorn sculpin were specially handled to minimize the number of sculpin taken from the LDW. As Pacific staghorn sculpin were sorted, they were distributed to individual, clean bait canisters with a label including the area, subarea, and trawl number. When sufficient numbers of sculpin from the preferred subarea of a given sampling area were collected (as described in Section 3.1 of the QAPP addendum (Windward 2005), they were bagged using the same methods as for other species, and any additional sculpins were returned to the LDW.

Individual specimens of the same species from a particular sampling area and equipment deployment (i.e., a single trawl or trap) were kept together in one large resealable plastic bag with the date, time, effort number, species, and collection method recorded on the outside in indelible ink. All other pertinent information is traceable through the field notebook and collection forms (Appendix E). The bagged and iced fish and crabs were transported in coolers to Windward or Analytical Resources, Inc. (ARI), for final processing. After target numbers were met in a given area or subarea, additional specimens of target size captured (but not collected) during sampling were measured, enumerated, and returned to the LDW.

The date, time, and location of each effort were recorded in the field notebook, the target species collection form, the non-target species tally form, and the navigation report. Completed field forms are presented in Appendix E.

2.1.3 Catch results

A total of 435 fish and crab specimens of target species and size were collected and processed from 93 successful trawls and 51 successful crab trap sets. Target numbers of fish and crabs specified in the QAPP addendum (Windward 2005) were met or exceeded for all species in each pertinent area or subarea. Catch results for all target fish and crab species collected and processed from each area and subarea of the LDW

are presented in Table 2-3. Catch data, including the specimen identification (ID), length, and weight for each target specimen processed, are presented in Appendix E. [1]

Table 2-3. Target species catch results by area and subarea

Area	Subarea	Number of Specimens Captured					
		English Sole	Pacific Staghorn Sculpin	Shiner Surfperch	Dungeness Crab	Slender Crab	Total
T1	A	9	0	10	1	0	20
	B	9	0	12	2	0	23
	C	3	10	10	2	0	25
	D	3	0	10	0	0	13
	E	4	0	10	1	0	15
	F	2	0	10	0	0	12
T1 Total		**30**	**10**	**62**	**6**	**0**	**108**
T2	A	30	0	10	0	0	40
	B	0	0	10	0	5	15
	C	0	0	10	0	0	10
	D	5	0	10	0	0	15
	E	1	10	10	0	5	26
	F	1	0	10	0	0	11
T2 Total		**37**	**10**	**60**	**0**	**10**	**117**
T3	A	7	0	10	0	4	21
	B	0	0	10	0	1	11
	C	4	0	10	0	2	16
	D	9	0	10	0	1	20
	E	3	2	10	3	1	19
	F	7	13	20	2	1	43
T3 Total		**30**	**15**	**70**	**5**	**10**	**130**
T4	A	8	0	10	5	1	24
	B	8	0	10	0	3	21
	C	0	10	10	0	0	20
	D	0	0	15	0	0	15
T4 Total		**16**	**10**	**45**	**5**	**4**	**80**
Total		**113**	**45**	**237**	**16**	**24**	**435**

Non-target fish and crab species captured in the LDW were identified, recorded and returned to the subareas where they were collected. A total of 24 fish species and 26 types of invertebrates classified to the lowest taxonomic level practicable were

[1] As described in Section 2.1.4.2, the sample ID for each specimen contains characters that identify the area and subarea where the specimen was captured, the collection method, the effort number, and the species.

collected from the LDW, including both target and non-target species. Data on species abundance and occurrence (i.e., number of sampling efforts in which the species was encountered) for each collection method are presented in Table 2-4 for fish and in Table 2-5 for invertebrates.

Table 2-4. Numbers of individual fish species captured in the LDW using trawls and crab traps

Species	Scientific Name	Number of Specimens Captured		
		Otter Trawl	Crab Trap	Total
Brown rock fish	*Sebastes auriculatus*	2	0	2
Buffalo sculpin	*Enophrys bison*	3	0	3
English sole	*Parophrys vetulus*	489	0	489
Flathead sole	*Hippoglossoides elassodon*	2	0	2
Hybrid sole	*Parophrys vetulus/ Platichthys stellatus*	1	0	1
Longfin smelt	*Spirinchus thaleichthys*	30	0	30
Pacific herring	*Clupea pallasii pallasii*	16	0	16
Pacific sand dab	*Citharichthys sordidus*	8	0	8
Pacific staghorn sculpin	*Leptocottus armatus*	812	0	812
Pacific tomcod	*Microgadus proximus*	80	0	80
Padded sculpin	*Artedius fenestralis*	6	0	6
Pile perch	*Rhacochilus vacca*	152	0	152
Prickly sculpin	*Cottus asper*	35	0	35
Rock sole	*Lepidopsetta bilineata*	85	0	85
Roughback sculpin	*Chitonotus pugetensis*	15	0	15
Saddleback gunnel	*Pholis ornata*	1	0	1
Sand sole	*Psettichthys melanostictus*	27	1	28
Shad	*Alosa sapidissima*	8	0	8
Shiner surfperch	*Cymatogaster aggregata*	5,764	0	5,764
Snake prickleback	*Lumpenus sagitta*	13	0	13
Starry flounder	*Platichthys stellatus*	2,668	0	2,668
Striped perch	*Embiotoca lateralis*	18	0	18
Three spine stickleback	*Gasterosteus aculeatus aculeatus*	2	0	1
Unidentified sculpin	*Cottus* sp.	9	0	9
Total		**10,246**	**1**	**10,247**

Table 2-5. Numbers of individual invertebrate species captured in the LDW using trawls and traps

Species	Scientific Name	Number of Specimens Captured		
		Otter trawl	Crab Trap	Total
Cockle clams	*Clinocardium* sp.	5	0	5
Crangon shrimp	*Crangon* sp.	172	0	172
Ctenophore	unknown	1	0	1
Decorator crab	*Loxorhynchus crispatus*	19	0	19
Coonstripe shrimp	*Pandalus danae*	231	0	231
Dungeness crab	*Cancer magister*	28	5	33
Mottled sea star	*Evasterias troschelii*	7	0	7
Hermit crab	*Pagurus* sp.	3	0	3
Jellyfish	unknown	1	0	1
Kelp crab	*Pugettia producta*	11	0	11
Sand star	*Luidia*	2	0	2
Clam, bent-nose	*Macoma* sp.	1	0	1
Moon snail	*Polinices lewisii*	5	0	5
Frilled dogwinkle	*Nucella lamellosa*	2	0	2
Nudibranch	*Armina californica*	118	0	118
Sea star, sunflower	*Pycnopodia helianthoides*	17	1	18
Sea star	*Pisaster* sp.	25	0	25
Plumose anemone	*Metridium senile*	49	0	49
Red rock crab	*Cancer productus*	10	9	19
Sea pen	unknown	8	0	8
Sea star	*Pisaster* sp.	2	0	2
Slender crab	*Cancer gracilis*	323	160	483
Solaster	*Solaster stimpsoni*	1	0	1
Terrebellid (worm)	unknown	1	0	1
Tunicate	unknown	2	0	2
Urchin	unknown	12	0	12
Total		**1,056**	**175**	**1,231**

2.1.4 Sample processing, identification, and compositing

This section presents methods used to process fish and crabs following collection in the field and prior to delivery to the analytical laboratory. Specimen and sample ID numbers for individual fish and crabs and for the tissue composite samples, as well as the compositing scheme for each type of fish or crab tissue sample, are described.

2.1.4.1 Laboratory sample processing

After fish and crabs were collected from the field, target specimens were transported to the Windward laboratory where they were weighed using an analytical scale accurate to 0.1 g, measured, and individually packaged. Each target specimen was

individually wrapped in heavy-duty aluminum foil, enclosed in a resealable plastic bag with an ID label (also enclosed in a resealable bag), and immediately stored in coolers with wet ice. Crabs and fish with spines (e.g., sculpin) were double-wrapped in heavy-duty aluminum foil to minimize punctures prior to placing them in the plastic bag.

All relevant information for each individually wrapped and labeled specimen was recorded on the target fish and crab species collection forms, which are included in Appendix E. Relevant information included the specimen ID, length, weight, gender (when differences between the sexes were visually discernable, such as with gravid females), sample date, time, and location number. The demands of sample processing made a close inspection of all specimens for external abnormalities impossible.

At the end of each day, all sample labels were checked against field forms, and sample ID numbers were recorded on COC forms. COC forms were placed together with samples collected that day into heavy-duty plastic garbage bags, which were then sealed and stored overnight at < 4 °C in the Windward processing laboratory.

In general, samples collected Monday through Thursday were transported the following day in coolers from Windward to ARI. Samples collected on Friday, September 2, 2005, were frozen and held at Windward over the weekend and were transported the following Monday. All samples were frozen within 72 hours of collection. Prior to transport, samples were securely packed inside a cooler with ice packs. The original signed COC forms were placed in a sealable plastic bag, sealed, and taped to the inside lid of the cooler. The coolers were sealed with a custody seal in two locations.

The temperature inside the cooler(s) containing tissue samples was checked upon receipt of the samples at ARI; no coolers exceeded 4° ± 2°C upon receipt. Samples were assigned a specific storage area at ARI. Individual specimens were kept frozen at -20°C until compositing began on October 6, 2005.

All fish and crab tissue preparation, including filleting of fish, dissection of crabs, and homogenization of tissues, was conducted at ARI following standard operating procedures (Appendix G). Specimens were formed into composite samples prior to homogenization. Large fish were chopped into small pieces and combined in their entirety to form the composite sample. For fillet samples, partially thawed whole fish were filleted (skin on), and the fillets were then homogenized. Crabs were dissected, and the hepatopancreas and edible meat tissues were combined into the relevant composite samples prior to homogenization (Appendix H).

2.1.4.2 Sample identification

Unique alphanumeric sample ID numbers were assigned to each individual target fish or crab specimen and recorded on the target fish and crab species form (see

Appendix E for completed forms).[2] Table 2-6 presents the ID scheme for individual fish and crab specimens.

Table 2-6. ID scheme for individual fish and crab specimens

IDENTIFIER	DESCRIPTION
LDW	Identifies the project area.
05	Identifies the year collected.
T1, T2, T3, or T4	Identifies the sampling area.
A, B, C, D, E, or F	Identifies the sampling subarea.
TR or CT followed by sequential three-digit number	Identifies the collection method (trawl or crab trap, respectively) and the effort as a unique number over all areas (e.g., the 15th trawl after the start of sampling would be TR015).
PS, ES, SF, SS, DC, or SC	Identifies the species type (Pacific staghorn sculpin, English sole, starry flounder, shiner surfperch, Dungeness crab, or slender crab, respectively).
Sequential number	Identifies the specimen captured in the sampling event.

Thus, for example, the 28th English sole captured in the 13th trawl of the LDW in subarea T1-A was identified as LDW-05-T1-A-TR013-ES-28. After individual fish and crab specimens were combined to form composite samples, as discussed in Section 2.1.4.3, composite sample IDs were assigned as shown in Table 2-7.

Table 2-7. ID scheme for fish and crab composite tissue samples

IDENTIFIER	DESCRIPTION
LDW	Identifies the project area.
05	Identifies the year collected.
T1, T2, T3, or T4	Identifies the sampling area.
A, B, C, D, E, F, or M	Identifies the sampling subarea; M identifier was used if specimens from multiple subareas were included in the composite sample.
PS, ES, SF, SS, DC, or SC	Identifies the species type (Pacific staghorn sculpin, English sole, starry flounder, shiner surfperch, Dungeness crab, or slender crab, respectively).
WB, FL, RM, EM, or HP	Identifies whole-body, fillet, remainder, edible meat, or hepatopancreas samples, respectively.
comp	Indicates the sample as being composited.
sequential number	Identifies the composite number for a specific species and sampling area combination.

Thus, for example, the second whole-body English sole composite sample, which contained specimens from multiple subareas within Area T1, was identified as LDW-05-T1-M-ES-WB-comp-2. The subareas of specimens in composite samples that contained specimens from multiple subareas can be determined from the individual specimen IDs for those composite samples, which are presented in Appendix A.

[2] No sample ID numbers were assigned to specimens of non-target species.

2.1.4.3 Compositing scheme

Fish and crab tissue samples were chemically analyzed as composite samples, which were created by homogenizing individual specimens together. The compositing plan was reviewed by EPA and their comments were incorporated into the final compositing scheme. Most of the specimens collected were included in composite samples. The numbers and types of composite samples created and chemically analyzed are presented in Table 2-8.

Table 2-8. Numbers of fish and crab composite tissue samples collected from the LDW

Species Collected	Total Length (mm)	Sample Type	Number of Composite Samples by Area			
			T1	T2	T3	T4
English sole	≥ 200	whole body	3	3	3	2
		fillet (skin on)	3	3	3	1
		remainder[a]	3	3	3	1
Pacific staghorn sculpin	≥ 120	whole body	1	1	1	1
Shiner surfperch	≥ 80	whole body	6	6	6	4
Dungeness crab	≥ 90	edible meat	1	0	1	1
		hepatopancreas	1	0	1	1
Slender crab	≥ 90	edible meat	0	1	0	0
		hepatopancreas	0	1	0	0

[a] English sole remainder samples consist of all remaining tissue and fluids after fillets were removed from the specimens used to create English sole fillet composite samples.

The compositing plan took into consideration both sampling area and specimen size. For English sole and crabs, specimens were grouped by area for formation of the composite samples. Pacific staghorn sculpin and shiner surfperch specimens were grouped by subarea. Appendix A presents length and weight data for each individual specimen included in the composite samples as well as gender data for crabs and English sole.3 The following subsections present details on the composite samples created for each target species and tissue type.

English sole

For Areas T1, T2, and T3, three whole-body, three fillet, and three remainder composite samples were created and analyzed, with five English sole per composite. [4] In Area T4, two whole-body, one fillet, and one remainder composite sample were created and analyzed. English sole remainder samples consisted of all remaining

[3] English sole gender data were not considered in the formation of composite samples in order to be consistent with the 2004 compositing scheme.

[4] Starry flounder were collected as a potential surrogate for English sole in case insufficient numbers of English sole were collected in a given area. Because sufficient numbers of English sole were collected in all four areas, no starry flounder composite samples were formed.

tissue and fluids after fillets were removed from the specimens used to create English sole fillet composite samples. The weights of the whole-body fish, the fillet samples, and the remainder samples were all recorded in order to calculate "fillet plus remainder" concentrations using the equation presented in Section 4.1. Through the creation of remainder composite samples, additional total PCB concentrations could be calculated for whole-body fish in each area. Specifically, three additional whole-body concentrations were calculated for Areas T1, T2, and T3, and one additional whole-body concentration was calculated for Area T4 (see Section 4.1.1).

Consistent with the 2004 compositing scheme, fish were classified into one of three size categories based on the length distribution of all English sole collected in a given area. Two randomly selected fish from the small category, one from the medium category, and one from the large category were assigned to each composite sample. The goal of the compositing scheme was to create comparable composite samples with fish of similar weights and lengths for all sampling areas.

Table 2-9 summarizes the average lengths and weights of the resulting composite samples. Appendix A presents a list of sample IDs for the individual specimens that were used to form each composite sample. The particular trawl for each individual specimen can be determined from its sample ID (see Section 2.1.4.2).

Table 2-9. Compositing information for English sole composite samples

Area	Fillet and Whole Body Sample ID	Remainder Sample ID[a]	Average Length (mm) (range)	Average Weight (g) (range)
T1	LDW-05-T1-M-ES-FL-comp1	LDW-05-T1-M-ES-RM-comp1	236 (195 – 350)	166 (76 – 500)
	LDW-05-T1-M-ES-FL-comp2	LDW-05-T1-M-ES-RM-comp2	240 (207 – 295)	141 (85 – 243)
	LDW-05-T1-M-ES-FL-comp3	LDW-05-T1-M-ES-RM-comp3	250 (214 – 326)	176 (96 – 375)
	LDW-05-T1-M-ES-WB-comp1	nr	243 (215 – 270)	147 (95 – 180)
	LDW-05-T1-M-ES-WB-comp2	nr	243 (205 – 305)	153 (95 – 274)
	LDW-05-T1-M-ES-WB-comp3	nr	241 (198 – 305)	157 (79 – 287)
T2	LDW-05-T2-M-ES-FL-comp1	LDW-05-T2-M-ES-RM-comp1	259 (221 – 310)	199 (104 – 343)
	LDW-05-T2-M-ES-FL-comp2	LDW-05-T2-M-ES-RM-comp2	279 (234 – 360)	229 (115 – 500)
	LDW-05-T2-M-ES-FL-comp3	LDW-05-T2-M-ES-RM-comp3	284 (236 – 410)	233 (118 – 525)
	LDW-05-T2-M-ES-WB-comp1	nr	279 (243 – 380)	232 (150 – 515)
	LDW-05-T2-M-ES-WB-comp2	nr	261 (237 – 292)	194 (132 – 343)
	LDW-05-T2-M-ES-WB-comp3	nr	255 (208 – 318)	185 (99 – 365)
T3	LDW-05-T3-M-ES-FL-comp1	LDW-05-T3-M-ES-RM-comp1	270 (214 – 340)	228 (92 – 400)
	LDW-05-T3-M-ES-FL-comp2	LDW-05-T3-M-ES-RM-comp2	256 (215 – 300)	158 (101 – 209)
	LDW-05-T3-M-ES-FL-comp3	LDW-05-T3-M-ES-RM-comp3	255 (210 – 305)	198 (106 – 346)
	LDW-05-T3-M-ES-WB-comp1	nr	270 (225 – 330)	219 (110 – 400)
	LDW-05-T3-M-ES-WB-comp2	nr	257 (198 – 298)	192 (90 – 318)
	LDW-05-T3-M-ES-WB-comp3	nr	263 (194 – 328)	191 (79 – 296)

Area	Fillet and Whole Body Sample ID	Remainder Sample ID[a]	Average Length (mm) (range)	Average Weight (g) (range)
T4	LDW-05-T4-M-ES-FL-comp1	LDW-05-T4-M-ES-RM-comp1	310 (270 – 355)	323 (197 – 425)
	LDW-05-T4-M-ES-WB-comp1	nr	315 (290 – 367)	348 (263 – 520)
	LDW-05-T4-M-ES-WB-comp2	nr	275 (210 – 355)	222 (76 – 470)

[a] English sole remainder samples consist of all remaining tissue and fluids after fillets were removed from the specimens used to create English sole fillet composite samples.

nr – no remainder composite sample was formed

Pacific staghorn sculpin

One whole-body Pacific staghorn sculpin composite sample was created for a single subarea from each of the four sampling areas, for a total of four composite samples. Specimens were collected from the highest-priority subareas, T2E and T3F, as specified in the QAPP addendum (Windward 2005). No priority subareas were specified for Areas T1 or T4. Ten fish were included in each composite sample.

Except for subarea T3-F, all sculpins collected from a subarea were included in the subarea composite sample. Five extra fish were collected in subarea T3-F, for a total of 15 fish. For this subarea, the two largest fish and eight randomly selected smaller fish were included in the composite sample to make the size distribution as similar as possible to the composite samples from other areas.

Table 2-10 summarizes the average lengths and weights of the resulting composite samples. Appendix A presents a list of sample IDs for the individual specimens that were used to form each composite sample. The particular trawl for each individual specimen can be determined from its sample ID (see Section 2.1.4.2).

Table 2-10. Compositing information for Pacific staghorn sculpin composite samples

Area	Subarea	Sample ID	Average Length (mm) (range)	Average Weight (g) (range)
T1	C	LDW-05-T1-C-PS-WB-Comp1	166 (130 – 234)	69 (26 – 175)
T2	E	LDW-05-T2-E-PS-WB-Comp1	168 (115 – 240)	78 (20 – 227)
T3	F	LDW-05-T3-F-PS-WB-Comp1	135 (108 – 170)	35 (16 – 72)
T4	C	LDW-05-T4-C-PS-WB-Comp1	146 (120 – 190)	39 (14 – 102)

Shiner surfperch

One whole-body shiner surfperch composite sample was created for each subarea from each of the four sampling areas, for a total of 22 composite samples. Ten fish were included in each composite sample. All fish collected from within a given subarea were included in the composite samples, except for fish from subareas T1-B, T3-F, and T4-D. For these subareas, extra fish were collected so fish were divided into three size categories based on the length distribution over all shiner surfperch collected in 2005, with equal length intervals in each size category. Size categories

were as follows: small (77 to 98 mm), medium (99 to 121 mm), and large (122 to 144 mm). Fish were randomly selected from each size class to ensure that the size distribution in each sample was similar.

Table 2-11 summarizes the average lengths and weights of the resulting composite samples. Appendix A presents a list of sample IDs for the individual specimens that were used to form each composite sample. The particular trawl for each individual specimen can be determined from its sample ID (see Section 2.1.4.2).

Table 2-11. Compositing information for shiner surfperch composite samples

AREA	SUBAREA	SAMPLE ID	AVERAGE LENGTH (mm) (range)	AVERAGE WEIGHT (g) (range)
T1	A	LDW-05-T1-A-SS-WB-comp1	111 (94 – 138)	21 (12 – 47)
	B	LDW-05-T1-B-SS-WB-comp1	108 (95 – 120)	17 (12 – 24)
	C	LDW-05-T1-C-SS-WB-comp1	111 (95 – 122)	18 (13 – 26)
	D	LDW-05-T1-D-SS-WB-comp1	105 (82 – 134)	16 (6 – 32)
	E	LDW-05-T1-E-SS-WB-comp1	116 (97 – 134)	22 (13 – 32)
	F	LDW-05-T1-F-SS-WB-comp1	108 (80 – 132)	18 (7 – 36)
T2	A	LDW-05-T2-A-SS-WB-comp1	110 (96 – 119)	19 (13 – 24)
	B	LDW-05-T2-B-SS-WB-comp1	109 (95 – 122)	19 (14 – 27)
	C	LDW-05-T2-C-SS-WB-comp1	112 (96 – 137)	19 (12 – 30)
	D	LDW-05-T2-D-SS-WB-comp1	115 (104 – 125)	21 (16 – 27)
	E	LDW-05-T2-E-SS-WB-comp1	106 (95 – 114)	15 (12 – 18)
	F	LDW-05-T2-F-SS-WB-comp1	110 (93 – 122)	19 (11 – 27)
T3	A	LDW-05-T3-A-SS-WB-comp1	101 (78 – 135)	18 (7 – 41)
	B	LDW-05-T3-B-SS-WB-comp1	102 (93 – 118)	16 (12 – 23)
	C	LDW-05-T3-C-SS-WB-comp1	109 (96 – 134)	19 (13 – 33)
	D	LDW-05-T3-D-SS-WB-comp1	104 (80 – 123)	16 (7 – 28)
	E	LDW-05-T3-E-SS-WB-comp1	113 (77 – 125)	20 (7 – 28)
	F	LDW-05-T3-F-SS-WB-comp1	108 (93 – 127)	17 (12 – 25)
T4	A	LDW-05-T4-A-SS-WB-comp1	107 (91 – 137)	18 (11 – 42)
	B	LDW-05-T4-B-SS-WB-comp1	110 (92 – 144)	20 (12 – 42)
	C	LDW-05-T4-C-SS-WB-comp1	114 (99 – 140)	22 (12 – 40)
	D	LDW-05-T4-D-SS-WB-comp1	109 (78 – 130)	18 (6 – 26)

Dungeness crab

Dungeness crabs were collected from Areas T1, T3, and T4. No Dungeness crabs were captured in either trawls or traps within Area T2. One edible meat composite sample and one hepatopancreas composite sample were created for each area, with five crabs per composite sample. Each edible meat sample has a corresponding hepatopancreas sample created from the same crabs.

All Dungeness crabs from Areas T3 and T4 were included in composite samples for these areas. One extra crab was available for T1, so one male crab from this area was randomly eliminated to balance the gender ratio. All composite samples included three male and two female crabs.

Table 2-12 presents the average lengths and weights of the resulting composite samples. Appendix A presents a list of sample IDs for the individual specimens that were used to form each composite sample. The particular trawl or trap for each individual specimen can be determined from its sample ID (see Section 2.1.4.2).

Table 2-12. Compositing information for Dungeness crab composite samples

Area	Edible Meat Sample ID	Hepatopancreas Sample ID	Average Length (mm) (range)	Average Weight (g) (range)
T1	LDW-05-T1-M-DC-EM-Comp1	LDW-05-T1-M-DC-HP-Comp1	129 (103 – 167)	350 (169 – 650)
T3	LDW-05-T3-M-DC-EM-Comp1	LDW-05-T3-M-DC-HP-Comp1	123 (91 – 173)	316 (115 – 710)
T4	LDW-05-T4-M-DC-EM-Comp1	LDW-05-T4-M-DC-HP-Comp1	117 (107 – 127)	242 (189 – 320)

Slender crab

Slender crabs were collected and analyzed from Area T2 because no Dungeness crabs were captured in this area. Five of the 10 slender crabs collected from T2 were included in the single edible meat composite sample. All 10 crabs were included in the hepatopancreas composite sample to ensure sufficient sample mass for analysis.

All slender crabs from Area T2 were divided into three size categories based on length: small (88 to 94 mm), medium (95 to 102 mm), and large (103 to 110 mm). Crabs were randomly selected from each size class to ensure that the size distribution in each sample was similar. All slender crabs collected from T2 were males.

Table 2-13 presents the average lengths and weights of the resulting composite samples. Appendix A presents a list of sample IDs for the individual specimens that were used to form each composite sample. The particular trawl or trap for each individual specimen can be determined from its sample ID (see Section 2.1.4.2).

Table 2-13. Compositing information for slender crab composite samples

Area	Average Length (mm) (range)	Average Weight (g) (range)	Sample ID
T2	98 (94 – 106)	191 (161 – 233)	LDW-05-T2-M-SC-EM-Comp1
	100 (88 – 110)	190 (126 – 233)	LDW-05-T2-M-SC-HP-Comp1[a]

[a] The hepatopancreas sample included the five crabs in the edible meat sample plus an additional five crabs.

2.2 FIELD DEVIATIONS FROM THE QAPP

Field deviations from the QAPP (Windward 2004a) included only slight modifications to collection and processing methods. These field deviations did not affect the data quality and are discussed in detail below.

- Crabs were not killed in the field. They were held on ice in coolers and frozen at Windward after sample processing.
- Starry flounder specimens were collected from Area T4 in the event that insufficient numbers of English sole were collected. However, because sufficient numbers of English sole were collected, the starry flounder specimens were not analyzed.
- Some specimens were remeasured during laboratory processing and found to be smaller than the target size. Undersized specimens included four English sole that ranged from 194 to 198 mm, one 108-mm Pacific staghorn sculpin, one 88-mm slender crab, and three 77- to 78-mm shiner surfperch. Lengths and weights of all fish included in each composite sample are presented in Appendix A.
- Pacific staghorn sculpin of target size were sorted from the trawl and distributed to individual, clean bait canisters that were labeled with the area, subarea, and trawl number rather than being placed in a common bin regardless of the specific trawl as indicated in the QAPP addendum (Windward 2005). In this way, the specific trawl for each fish could be recorded for each fish retained.
- Laboratory processing took place at ARI as well as at Windward.

3.0 Analytical Methods

The methods and procedures used to prepare and chemically analyze the composite samples are described briefly in this section and in detail in the QAPP and QAPP addendum (Windward 2004a, 2005). This section also discusses laboratory deviations from the QAPP.

Individual fish and crab specimens were hand-delivered to ARI where they were homogenized into composite samples according to the compositing scheme presented in Section 2.1.4.3. Windward personnel oversaw the initial homogenization procedures to ensure that the correct specimens were included in the composite samples created at ARI. Data on individual specimens used in each composite sample are presented in Appendix A.

3.1 TISSUE ANALYTICAL METHODS

All composite tissue samples from the LDW were analyzed for PCBs (as Aroclors), lipids, and total solids. Attachment 1 to the data validation report (Appendix C) provides a complete list of the individual samples in each sample delivery group (SDG).

The analytical testing methods followed by ARI adhered to the most recent EPA quality assurance/quality control (QA/QC) guidelines and standard analysis protocols (EPA 2002a; PSEP 1997). The analytical methods are identified in Table 3-1. Aliquots from each composite tissue sample will remain frozen at ARI for 1 year from the collection date. Individual fish and crabs that were not included in composite samples are also being archived frozen at ARI for 1 year from the collection date.

Table 3-1. Analytical methods for fish and crab tissue analyses

PARAMETER	METHOD	REFERENCE
PCBs (as Aroclors)	GC/ECD	EPA 8082
Lipids	gravimetric	NOAA (1993)
Moisture	oven dried	EPA 160.3

GC/ECD – gas chromatography/electron capture detection

3.2 LABORATORY DEVIATIONS FROM THE QAPP

There were no laboratory deviations from the methods and procedures described in the QAPP (Windward 2004a) and QAPP addendum (Windward 2005).

4.0 Chemical Analysis Results

This section presents the chemical analysis results of the fish and crab composite samples collected from the LDW. Form 1s from ARI are presented in Appendix D. The approach used to average laboratory replicates is presented in Appendix B. Methods for calculating concentrations for total PCBs are also presented in Appendix B. The number of significant figures shown for each concentration in all results tables in this section was specified by the analytical laboratory.

QA review of the chemistry data was conducted in accordance with the QA/QC requirements and technical specifications of the methods and the national functional guidelines for organic and inorganic data review (EPA 1999, 2002b). Laboratory Data Consultants, Inc. (LDC), conducted the data validation. The results of the data validation are discussed in Section 4.2 and presented in full in Appendix C.

4.1 LDW FISH AND CRAB TISSUE RESULTS

Composite tissue samples created from fish and crabs collected in the LDW were analyzed for PCBs (as Aroclors), percent moisture, and percent lipids. Table 4-1 presents a summary of the Aroclor and total PCB (Aroclor sum) concentrations for each tissue type. The only Aroclors detected in fish and crab tissue samples were Aroclors 1248, 1254, and 1260. Aroclors 1254 and 1260 were detected in all 57 fish composite samples, all four crab hepatopancreas composite samples, and the one slender crab edible meat composite sample. No Aroclors were detected in the three Dungeness crab edible meat samples. Aroclor 1248 was detected in one shiner surfperch sample.

Table 4-1. Detection frequencies and concentrations of PCBs in fish and crab composite tissue samples

Analyte	Unit	Detection Frequency	Detected Concentration			Reporting Limit[a]	
			Minimum	Maximum	Mean[b]	Minimum	Maximum
English sole – fillet (skin on)							
Aroclor-1016	µg/kg ww	0/10	nd	nd	nd	100	100
Aroclor-1221	µg/kg ww	0/10	nd	nd	nd	100	100
Aroclor-1232	µg/kg ww	0/10	nd	nd	nd	100	100
Aroclor-1242	µg/kg ww	0/10	nd	nd	nd	100	100
Aroclor-1248	µg/kg ww	0/10	nd	nd	nd	100	100
Aroclor-1254	µg/kg ww	10/10	300	1,000	640	na	na
Aroclor-1260	µg/kg ww	10/10	150	470	290	na	na
PCBs (total calc'd)[c]	µg/kg ww	10/10	450	1,450	920	na	na
English sole – remainder[d]							
Aroclor-1016	µg/kg ww	0/10	nd	nd	nd	60	200
Aroclor-1221	µg/kg ww	0/10	nd	nd	nd	60	200
Aroclor-1232	µg/kg ww	0/10	nd	nd	nd	60	200
Aroclor-1242	µg/kg ww	0/10	nd	nd	nd	60	200
Aroclor-1248	µg/kg ww	0/10	nd	nd	nd	60	200
Aroclor-1254	µg/kg ww	10/10	450	1,600	1,070	na	na
Aroclor-1260	µg/kg ww	10/10	280	1,100	640	na	na
PCBs (total calc'd)[c]	µg/kg ww	10/10	730	2,700	1,720	na	na
English sole – whole body							
Aroclor-1016	µg/kg ww	0/11	nd	nd	nd	60	100
Aroclor-1221	µg/kg ww	0/11	nd	nd	nd	60	100
Aroclor-1232	µg/kg ww	0/11	nd	nd	nd	60	120
Aroclor-1242	µg/kg ww	0/11	nd	nd	nd	60	100
Aroclor-1248	µg/kg ww	0/11	nd	nd	nd	60	100
Aroclor-1254	µg/kg ww	11/11	520	1,500	1,050	na	na
Aroclor-1260	µg/kg ww	11/11	300	930	640	na	na
PCBs (total calc'd)[c]	µg/kg ww	11/11	880	2,400	1,690	na	na

Analyte	Unit	Detection Frequency	Detected Concentration			Reporting Limit[a]	
			Minimum	Maximum	Mean[b]	Minimum	Maximum
Pacific staghorn sculpin – whole body							
Aroclor-1016	µg/kg ww	0/4	nd	nd	nd	100	100
Aroclor-1221	µg/kg ww	0/4	nd	nd	nd	100	100
Aroclor-1232	µg/kg ww	0/4	nd	nd	nd	100	100
Aroclor-1242	µg/kg ww	0/4	nd	nd	nd	100	100
Aroclor-1248	µg/kg ww	0/4	nd	nd	nd	100	100
Aroclor-1254	µg/kg ww	4/4	260	380 J	320	na	na
Aroclor-1260	µg/kg ww	4/4	150	340	270	na	na
PCBs (total calc'd)[c]	µg/kg ww	4/4	430	720 J	590	na	na
Shiner surfperch – whole body							
Aroclor-1016	µg/kg ww	0/22	nd	nd	nd	60	200
Aroclor-1221	µg/kg ww	0/22	nd	nd	nd	60	200
Aroclor-1232	µg/kg ww	0/22	nd	nd	nd	60	200
Aroclor-1242	µg/kg ww	0/22	nd	nd	nd	60	200
Aroclor-1248	µg/kg ww	1/22	100	100	100	60	200
Aroclor-1254	µg/kg ww	22/22	340 J	1,200	600	na	na
Aroclor-1260	µg/kg ww	22/22	170	1,500	470	na	na
PCBs (total calc'd)[c]	µg/kg ww	22/22	530 J	2,400	1,070	na	na
Dungeness crab – edible meat							
Aroclor-1016	µg/kg ww	0/3	nd	nd	nd	20	20
Aroclor-1221	µg/kg ww	0/3	nd	nd	nd	20	20
Aroclor-1232	µg/kg ww	0/3	nd	nd	nd	20	20
Aroclor-1242	µg/kg ww	0/3	nd	nd	nd	20	20
Aroclor-1248	µg/kg ww	0/3	nd	nd	nd	20	20
Aroclor-1254	µg/kg ww	0/3	nd	nd	nd	20	20
Aroclor-1260	µg/kg ww	0/3	nd	nd	nd	20	20
PCBs (total calc'd)[c]	µg/kg ww	0/3	nd	nd	nd	nc	nc
Dungeness crab – hepatopancreas							
Aroclor-1016	µg/kg ww	0/3	nd	nd	nd	100	100
Aroclor-1221	µg/kg ww	0/3	nd	nd	nd	100	100
Aroclor-1232	µg/kg ww	0/3	nd	nd	nd	100	100
Aroclor-1242	µg/kg ww	0/3	nd	nd	nd	100	100
Aroclor-1248	µg/kg ww	0/3	nd	nd	nd	100	100
Aroclor-1254	µg/kg ww	3/3	730	830	770	na	na
Aroclor-1260	µg/kg ww	3/3	570	590	580	na	na
PCBs (total calc'd)[c]	µg/kg ww	3/3	1,310	1,420	1,350	na	na
Slender crab – edible meat							
Aroclor-1016	µg/kg ww	0/1	nd	nd	nd	20	20
Aroclor-1221	µg/kg ww	0/1	nd	nd	nd	20	20
Aroclor-1232	µg/kg ww	0/1	nd	nd	nd	20	20

Analyte	Unit	Detection Frequency	Detected Concentration			Reporting Limit[a]	
			Minimum	Maximum	Mean[b]	Minimum	Maximum
Aroclor-1242	µg/kg ww	0/1	nd	nd	nd	20	20
Aroclor-1248	µg/kg ww	0/1	nd	nd	nd	20	20
Aroclor-1254	µg/kg ww	1/1	38	38	38	na	na
Aroclor-1260	µg/kg ww	1/1	26	26	26	na	na
PCBs (total calc'd)[c]	µg/kg ww	1/1	64	64	64	na	na
Slender crab – hepatopancreas							
Aroclor-1016	µg/kg ww	0/1	nd	nd	nd	100	100
Aroclor-1221	µg/kg ww	0/1	nd	nd	nd	100	100
Aroclor-1232	µg/kg ww	0/1	nd	nd	nd	100	100
Aroclor-1242	µg/kg ww	0/1	nd	nd	nd	100	100
Aroclor-1248	µg/kg ww	0/1	nd	nd	nd	100	100
Aroclor-1254	µg/kg ww	1/1	410	410	410	na	na
Aroclor-1260	µg/kg ww	1/1	250	250	250	na	na
PCBs (total calc'd)[c]	µg/kg ww	1/1	660	660	660	na	na

[a] Range of reporting limits for non-detect samples.

[b] Reported mean concentrations are the average of the detected concentrations only; RLs were not included in calculation of the mean concentration.

[c] Methods for calculating total PCBs are presented in Appendix B.

[d] English sole remainder samples consist of all remaining tissue and fluids after fillets were removed from the specimens used to create English sole fillet composite samples.

na – not applicable

nc – not calculated

nd – not detected

J – estimated concentration

ww – wet weight

Total PCB concentrations (based on Aroclor sums) ranged from 430 to 2,400 µg/kg ww in fish whole-body samples, 450 to 1,450 µg/kg ww in English sole fillet composite samples, 730 to 2,700 µg/kg ww in English sole remainder composite samples, 20U to 64 µg/kg ww in crab edible meat composite samples, and 660 to 1,420 µg/kg ww in crab hepatopancreas composite samples.

Table 4-2 presents all Aroclor, total PCB, lipid, and solids data for each fish and crab tissue composite sample analyzed. The highest total PCB concentration in crabs (1,420 µg/kg ww) was detected in the Dungeness crab hepatopancreas composite sample from Area T1. Among the English sole whole-body composite samples, the highest total PCB concentration (2,400 µg/kg ww) was detected in a sample collected from Area T2, and the lowest total PCB concentration (880 µg/kg ww) was detected in a sample collected from Area T3. Total PCB concentrations in all three English sole fillet composite samples collected from each area were lower than those in the corresponding remainder composite samples and were generally lower than concentrations in whole-body samples from the same area.

Table 4-2. Summary of chemistry results for fish and crab composite tissue samples, including lipid-normalized PCB concentrations

Sample ID	Aroclor 1016 (µg/kg ww)	Aroclor 1221 (µg/kg ww)	Aroclor 1232 (µg/kg ww)	Aroclor 1242 (µg/kg ww)	Aroclor 1248 (µg/kg ww)	Aroclor 1254 (µg/kg ww)	Aroclor 1260 (µg/kg ww)	PCBs (total calc'd) (µg/kg ww)[a]	Lipids (% ww)	Lipid-Normalized PCBs (mg PCBs/ kg lipid)[b]	Total Solids (% ww)
English sole – fillet (skin on)											
LDW-05-T1-M-ES-FL-Comp1	100 U	100 U	100 U	100 U	100 U	800	350	1,150	2.95	39	22.64
LDW-05-T1-M-ES-FL-Comp2	100 U	100 U	100 U	100 U	100 U	980	470	1,450	5.09	28	24.36
LDW-05-T1-M-ES-FL-Comp3	100 U	100 U	100 U	100 U	100 U	600	320	920	3.03	30	22.88
LDW-05-T2-M-ES-FL-Comp1	100 U	100 U	100 U	100 U	100 U	640	250	890	3.91	23	24.15
LDW-05-T2-M-ES-FL-Comp2	100 U	100 U	100 U	100 U	100 U	1,000	430	1,400	4.62	30	24.31
LDW-05-T2-M-ES-FL-Comp3	100 U	100 U	100 U	100 U	100 U	570	280	850	3.42	25	22.82
LDW-05-T3-M-ES-FL-Comp1	100 U	100 U	100 U	100 U	100 U	600	260	860	4.12	21	24.90
LDW-05-T3-M-ES-FL-Comp2	100 U	100 U	100 U	100 U	100 U	300	150	450	2.04	22	21.15
LDW-05-T3-M-ES-FL-Comp3	100 U	100 U	100 U	100 U	100 U	500	220	720	3.26	22	22.86
LDW-05-T4-M-ES-FL-Comp1	100 U	100 U	100 U	100 U	100 U	380	150	530	2.82	19	22.73
English sole – remainder											
LDW-05-T1-M-ES-RM-Comp1	100 U	100 U	100 U	100 U	100 U	1,300	750	2,100	7.81	27	27.17
LDW-05-T1-M-ES-RM-Comp2	100 U	100 U	100 U	100 U	100 U	1,200	680	1,900	6.93	27	27.58
LDW-05-T1-M-ES-RM-Comp3	100 U	100 U	100 U	100 U	100 U	900	640	1,540	5.51	28	26.51
LDW-05-T2-M-ES-RM-Comp1	100 U	100 U	100 U	100 U	100 U	1,400	660	2,100	7.03	30	29.36
LDW-05-T2-M-ES-RM-Comp2	100 U	100 U	100 U	100 U	100 U	1,200	690	1,900	5.50	35	22.02
LDW-05-T2-M-ES-RM-Comp3	100 U	100 U	100 U	100 U	100 U	1,100	860	2,000	6.84	29	25.67
LDW-05-T3-M-ES-RM-Comp1	200 U	200 U	200 U	200 U	200 U	1,600	1,100	2,700	10.4	26	32.39
LDW-05-T3-M-ES-RM-Comp2	60 U	60 U	60 U	60 U	60 U	450	280	730	3.92	19	21.24
LDW-05-T3-M-ES-RM-Comp3	200 U	200 U	200 U	200 U	200 U	700	440	1,140	6.67	17	26.15
LDW-05-T4-M-ES-RM-Comp1	60 U	60 U	60 U	60 U	60 U	810	320	1,130	8.24	14	24.47

Sample ID	Aroclor 1016 (µg/kg ww)	Aroclor 1221 (µg/kg ww)	Aroclor 1232 (µg/kg ww)	Aroclor 1242 (µg/kg ww)	Aroclor 1248 (µg/kg ww)	Aroclor 1254 (µg/kg ww)	Aroclor 1260 (µg/kg ww)	PCBs (total calc'd) (µg/kg ww)[a]	Lipids (% ww)	Lipid-Normalized PCBs (mg PCBs/ kg lipid)[b]	Total Solids (% ww)
English sole – whole body											
LDW-05-T1-M-ES-WB-Comp1	60 U	60 U	60 U	60 U	60 U	820	300	1,120	4.01	28	26.09
LDW-05-T1-M-ES-WB-Comp2	100 U	100 U	100 U	100 U	100 U	1,300	890	2,200	4.42	50	23.75
LDW-05-T1-M-ES-WB-Comp3	100 U	100 U	100 U	100 U	100 U	990	640	1,630	3.13	52	20.99
LDW-05-T2-M-ES-WB-Comp1	100 U	100 U	100 U	100 U	100 U	1,300	930	2,200	4.89	45	25.19
LDW-05-T2-M-ES-WB-Comp2	100 U	100 U	100 U	100 U	100 U	1,400	800	2,200	6.83	32	28.57
LDW-05-T2-M-ES-WB-Comp3	100 U	100 U	100 U	100 U	100 U	1,500	920	2,400	6.23	39	27.10
LDW-05-T3-M-ES-WB-Comp1	100 U	100 U	100 U	100 U	100 U	1,300	890	2,200	6.15	36	24.81
LDW-05-T3-M-ES-WB-Comp2	60 U	60 U	120 U	60 U	60 U	520	360	880	4.77	18	25.25
LDW-05-T3-M-ES-WB-Comp3	100 U	100 U	100 U	100 U	100 U	980	650	1,630	4.43	37	24.18
LDW-05-T4-M-ES-WB-Comp1	60 U	60 U	60 U	60 U	60 U	850	330	1,180	5.62	21	26.02
LDW-05-T4-M-ES-WB-Comp2	60 U	60 U	60 U	60 U	60 U	580	360	940	3.85	24	24.26
Pacific staghorn sculpin – whole body											
LDW-05-T1-C-PS-WB-Comp1	100 U	100 U	100 U	100 U	100 U	380 J	340	720 J	2.17	33 J	21.21
LDW-05-T2-E-PS-WB-Comp1	100 U	100 U	100 U	100 U	100 U	350	270	620	1.92	32	19.74
LDW-05-T3-F-PS-WB-Comp1	100 U	100 U	100 U	100 U	100 U	260	330	590	1.34	44	20.73
LDW-05-T4-C-PS-WB-Comp1	100 U	100 U	100 U	100 U	100 U	280	150	430	1.18	36	20.52
Shiner surfperch – whole body											
LDW-05-T1-A-SS-WB-Comp1	100 U	100 U	100 U	100 U	100 U	410	310	720	5.75	13	29.61
LDW-05-T1-B-SS-WB-Comp1	100 U	100 U	100 U	100 U	100 U	400	260	660	6.01	11	26.21
LDW-05-T1-C-SS-WB-Comp1	100 U	100 U	100 U	100 U	100 U	520	360	880	5.08	17	25.63
LDW-05-T1-D-SS-WB-Comp1	100 U	100 U	100 U	100 U	100 U	340 J	190	530 J	6.15	8.6 J	28.30
LDW-05-T1-E-SS-WB-Comp1	100 U	100 U	100 U	100 U	100 U	670 J	290	960 J	6.16	16 J	26.78
LDW-05-T1-F-SS-WB-Comp1	100 U	100 U	100 U	100 U	100 U	570	360	930	4.31	22	28.57
LDW-05-T2-A-SS-WB-Comp1	60 U	60 U	60 U	60 U	60 U	460	310	770	5.70	14	27.31
LDW-05-T2-B-SS-WB-Comp1	100 U	100 U	100 U	100 U	100 U	770	530	1,300	5.79	22	26.62

Sample ID	Aroclor 1016 (µg/kg ww)	Aroclor 1221 (µg/kg ww)	Aroclor 1232 (µg/kg ww)	Aroclor 1242 (µg/kg ww)	Aroclor 1248 (µg/kg ww)	Aroclor 1254 (µg/kg ww)	Aroclor 1260 (µg/kg ww)	PCBs (total calc'd) (µg/kg ww)[a]	Lipids (% ww)	Lipid-Normalized PCBs (mg PCBs/ kg lipid)[b]	Total Solids (% ww)
LDW-05-T2-C-SS-WB-Comp1	200 U	200 U	200 U	200 U	200 U	760	1,200	2,000	4.74	42	26.36
LDW-05-T2-D-SS-WB-Comp1	100 U	100 U	100 U	100 U	100 U	690	470	1,160	5.10	23	26.84
LDW-05-T2-E-SS-WB-Comp1	100 U	100 U	100 U	100 U	100	1,200	640	1,900	5.99	32	26.48
LDW-05-T2-F-SS-WB-Comp1	60 U	60 U	60 U	60 U	60 U	420	240	660	5.26	13	25.37
LDW-05-T3-A-SS-WB-Comp1	100 U	100 U	100 U	100 U	100 U	860	640	1,500	4.98	30	26.51
LDW-05-T3-B-SS-WB-Comp1	60 U	60 U	60 U	60 U	60 U	480	220	700	5.26	13	27.52
LDW-05-T3-C-SS-WB-Comp1	100 U	100 U	100 U	100 U	100 U	620	630	1,250	5.59	22	27.50
LDW-05-T3-D-SS-WB-Comp1	200 U	200 U	200 U	200 U	200 U	910	1,500	2,400	6.92	35	29.96
LDW-05-T3-E-SS-WB-Comp1	60 U	60 U	60 U	60 U	60 U	440	380	820	5.21	16	30.42
LDW-05-T3-F-SS-WB-Comp1	100 U	100 U	100 U	100 U	100 U	1,200	930	2,100	6.70	31	26.33
LDW-05-T4-A-SS-WB-Comp1	60 U	60 U	60 U	60 U	60 U	380	220	600	6.16	9.7	28.14
LDW-05-T4-B-SS-WB-Comp1	60 U	60 U	120 U	60 U	60 U	360	220	580	6.93	8.4	30.28
LDW-05-T4-C-SS-WB-Comp1	60 U	60 U	60 U	60 U	60 U	360	240	600	6.16	9.7	27.39
LDW-05-T4-D-SS-WB-Comp1	60 U	60 U	60 U	60 U	60 U	370	170	540	6.26	8.6	29.69
Dungeness crab – edible meat											
LDW-05-T1-M-DC-EM-Comp1	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U	0.191 J	10 U	17.96
LDW-05-T3-M-DC-EM-Comp1	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U	0.146 J	14 U	15.58
LDW-05-T4-M-DC-EM-Comp1	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U	0.232 J	8.6 U	15.80
Dungeness crab – hepatopancreas											
LDW-05-T1-M-DC-HP-Comp1	100 U	100 U	100 U	100 U	100 U	830	590	1,420	8.14 J	17 J	25.53
LDW-05-T3-M-DC-HP-Comp1	100 U	100 U	100 U	100 U	100 U	740	570	1,310	4.28 J	31 J	14.44
LDW-05-T4-M-DC-HP-Comp1	100 U	100 U	100 U	100 U	100 U	730	590	1,320	5.52 J	24 J	14.20
Slender crab – edible meat											
LDW-05-T2-M-SC-EM-Comp1	20 U	20 U	20 U	20 U	20 U	38	26	64	0.315 J	20 J	18.67

Sample ID	Aroclor 1016 (µg/kg ww)	Aroclor 1221 (µg/kg ww)	Aroclor 1232 (µg/kg ww)	Aroclor 1242 (µg/kg ww)	Aroclor 1248 (µg/kg ww)	Aroclor 1254 (µg/kg ww)	Aroclor 1260 (µg/kg ww)	PCBs (total calc'd) (µg/kg ww)[a]	Lipids (% ww)	Lipid-Normalized PCBs (mg PCBs/ kg lipid)[b]	Total Solids (% ww)
Slender crab – hepatopancreas											
LDW-05-T2-M-SC-HP-Comp1	100 U	100 U	100 U	100 U	100 U	410	250	660	2.47 J	27 J	14.76

[a] Methods for calculating total PCBs are presented in Appendix B.

[b] Lipid-normalized concentrations (in units of mg PCBs/kg lipid) represent the wet-weight total PCB concentration (in units of mg/kg ww) divided by the decimal fraction corresponding to the percent lipid (e.g., 2.0% lipid = 0.02).

J – Estimated concentration

U – Not detected at the reporting limit shown

ww – wet weight

Among the whole-body composite samples of Pacific staghorn sculpin, total PCB concentrations from the four subareas increased in the following order T4-C < T3-F < T2-E < T1-C. Among the whole-body composite samples of shiner surfperch, the highest total PCB concentration was detected in the composite sample from subarea T3-D, and the lowest concentration was detected in the composite sample from subarea T1-D.

Table 4-2 also presents the lipid concentrations (in percent wet weight) and total solids data for each composite sample of each tissue type. Lipid concentrations in whole-body and fillet composite samples ranged from 1.18% in a Pacific staghorn sculpin sample to 6.93% in a shiner surfperch composite sample. The highest lipid content (10.4%) was measured in an English sole remainder composite sample. Lipid concentrations in crab composite samples ranged from 0.146 to 0.315% in edible meat composite samples and from 2.47 to 8.14 in hepatopancreas composite samples. The highest total solids content (32.39%) was measured in an English sole remainder composite sample, and the lowest total solids content (14.20%) was measured in a Dungeness crab hepatopancreas composite sample.

Also reported in Table 4-2 are the lipid-normalized PCB concentrations (in mg PCB/kg lipid) in each fish and crab composite sample. In crabs, lipid-normalized PCB concentrations ranged from < 8.6 to 20 mg/kg lipid in edible meat and from 17 to 31 mg/kg lipid in hepatopancreas composite samples. In fish, lipid-normalized PCB concentrations ranged from 19 to 39 mg/kg lipid in English sole fillets, from 14 to 35 mg/kg lipid in English sole remainder samples, from 18 to 52 mg/kg lipid in English sole whole-body composite samples, from 8.4 to 42 mg PCB/kg lipid in shiner surfperch whole-body composite samples, and from 32 to 44 mg PCB/kg lipid in Pacific staghorn sculpin whole-body composite samples.

Table 4-3 presents the weights of the individual paired (from the same fish) English sole fillet and remainder composite samples that were used to calculate "fillet plus remainder" concentrations of total PCBs, lipids, and total solids. These reconstructed"fillet plus remainder" samples serve as surrogates for additional English sole whole-body composite samples. The "fillet plus remainder" concentrations were calculated according to Equation 1. Table 4-4 presents the results of these calculations.

$$C_{FR} = \frac{(C_{FL} \times W_{FL}) + (C_{RM} \times W_{RM})}{W_{FL} + W_{RM}} \qquad \textbf{Equation 1}$$

Where:

C_{FR} = calculated "fillet plus remainder" concentration of analyte
C_{FL} = concentration of analyte in fillet composite sample
C_{RM} = concentration of analyte in remainder composite sample
W_{FL} = wet weight of fillet composite sample
W_{RM} = wet weight of remainder composite sample

Table 4-3. Weights of the individual paired (from the same fish) English sole fillet and remainder composite samples used in calculating English sole "fillet plus remainder" composite samples

Fillet Composite ID	Fillet Weight (g)	Remainder Composite ID	Remainder Weight (g)	Calculated Whole-Body Composite ID
LDW-05-T1-M-ES-FL-Comp1	917	LDW-05-T1-M-ES-RM-Comp1	1,753	LDW-05-T1-M-ES-WB-Comp1 calculated
LDW-05-T1-M-ES-FL-Comp2	673	LDW-05-T1-M-ES-RM-Comp2	861	LDW-05-T1-M-ES-WB-Comp2 calculated
LDW-05-T1-M-ES-FL-Comp3	532	LDW-05-T1-M-ES-RM-Comp3	914	LDW-05-T1-M-ES-WB-Comp3 calculated
LDW-05-T2-M-ES-FL-Comp1	748	LDW-05-T2-M-ES-RM-Comp1	1,141	LDW-05-T2-M-ES-WB-Comp1 calculated
LDW-05-T2-M-ES-FL-Comp2	818	LDW-05-T2-M-ES-RM-Comp2	975	LDW-05-T2-M-ES-WB-Comp2 calculated
LDW-05-T2-M-ES-FL-Comp3	434	LDW-05-T2-M-ES-RM-Comp3	780	LDW-05-T2-M-ES-WB-Comp3 calculated
LDW-05-T3-M-ES-FL-Comp1	937	LDW-05-T3-M-ES-RM-Comp1	1,111	LDW-05-T3-M-ES-WB-Comp1 calculated
LDW-05-T3-M-ES-FL-Comp2	744	LDW-05-T3-M-ES-RM-Comp2	940	LDW-05-T3-M-ES-WB-Comp2 calculated
LDW-05-T3-M-ES-FL-Comp3	850	LDW-05-T3-M-ES-RM-Comp3	1,044	LDW-05-T3-M-ES-WB-Comp3 calculated
LDW-05-T4-M-ES-FL-Comp1	1,100	LDW-05-T4-M-ES-RM-Comp1	1,900	LDW-05-T4-M-ES-WB-Comp1 calculated

Table 4-4. "Fillet plus remainder" concentrations of total PCBs, lipids, and total solids calculated from paired English sole fillet and remainder composite samples

Sample ID	PCBs (total calc'd) (µg/kg ww)[a,b]	Lipids (% ww)[b]	Lipid-Normalized PCBs (mg PCBs/kg lipid)[c]	Total Solids (% ww)[b]
LDW-05-T1-M-ES-WB-Comp1 calculated	1,800	6.14	29	25.61
LDW-05-T1-M-ES-WB-Comp2 calculated	1,700	6.12	28	26.17
LDW-05-T1-M-ES-WB-Comp3 calculated	1,310	4.60	28	25.17
LDW-05-T2-M-ES-WB-Comp1 calculated	1,600	5.79	28	27.30
LDW-05-T2-M-ES-WB-Comp2 calculated	1,700	5.10	33	23.06
LDW-05-T2-M-ES-WB-Comp3 calculated	1,600	5.62	28	24.65
LDW-05-T3-M-ES-WB-Comp1 calculated	1,900	7.50	25	28.96
LDW-05-T3-M-ES-WB-Comp2 calculated	610	3.09	20	21.20
LDW-05-T3-M-ES-WB-Comp3 calculated	950	5.14	18	24.67
LDW-05-T4-M-ES-WB-Comp1 calculated	910	6.25	15	23.83

[a] Methods for calculating total PCBs are presented in Appendix B.

[b] Total PCBs, lipids, and total solids were calculated using Equation 1.

[c] Lipid-normalized concentrations (in units of mg PCBs/kg lipid) represent the wet weight total PCB concentration (in units of mg/kg ww) divided by the decimal fraction corresponding to the percent lipid (e.g., 2.0% lipid = 0.02).

ww – wet weight

Concentrations of total PCBs calculated in the 10 "fillet plus remainder" composite samples were generally within the range of those in the 11 English sole whole-body composite samples in all sampling areas except Area T2, where the "fillet plus

remainder" total PCB concentrations were consistently lower than the whole body total PCB concentrations.

4.2 DATA VALIDATION RESULTS

Independent data validation of all results was conducted by LDC. The complete data validation report is provided in Appendix C. The following sections summarize the results of the validation but do not list every sample affected by a qualification. Detailed information regarding every qualified sample is included in Appendix C.

4.2.1 Overall data quality

The tissue composite samples were analyzed by ARI in five SDGs.[5] LDC conducted a full validation on one of the SDGs (IQ23). All sample results that were not selected for full validation underwent a summary validation. Table 4-5 provides a summary of the number of samples in each SDG and the level of data validation. The percent of samples submitted for full validation for each analysis is consistent with the QAPP requirements.

Table 4-5. Data validation performed for each SDG

ARI SDG	VALIDATION LEVEL	NUMBER OF SAMPLES
IQ22	summary	8
IQ23	full	20
IQ24	summary	20
IQ25	summary	7
IQ30	summary	10

The majority of the data was either not qualified or had "J" (estimate) qualifiers added. Based on the information reviewed, the overall data quality was considered acceptable for use in the Phase 2 RI as qualified. The results of the validation are summarized below by analyte group.

4.2.2 Sample transport and holding times

All analyses of the tissue samples were conducted within the maximum holding times. The COC documents were reviewed for documentation of cooler temperatures. All cooler temperatures met validation criteria.

4.2.3 PCBs

4.2.3.1 Calibration

Initial calibration and continuing calibration verifications were conducted at the required frequencies. The percent relative standard deviations of the calibration were

[5] Individual samples in each SDG are presented in Attachment B of Appendix C.

less than or equal to 20% for all Aroclors. The percent differences calculated for the continuing calibration verifications were within QC limits of less than 15% for all analyses. The retention times of all compounds were also within the QC limits specified in the QAPP.

4.2.3.2 Blanks

PCBs were not detected in the method blanks. Rinsate blanks of the blender and grinder used during the homogenization and compositing procedures were analyzed to ensure that there was no cross-contamination between samples. PCBs were not detected in any of these blanks.

4.2.3.3 Surrogate recovery

Surrogates were added to all samples and blanks as required by Method EPA 8082. All surrogate recoveries were within QC limits.

4.2.3.4 Matrix spike

Matrix spike (MS) and matrix spike duplicate (MSD) analyses were analyzed in all SDGs. The MS/MSD percent recoveries and relative percent differences (RPDs) were within QC limits in SDGs IQ24 and IQ25. The MS/MSD percent recoveries and RPDs were not within QC limits in SDGs IQ22, IQ23, and IQ30. No data were qualified, however, because the native Aroclor concentrations in these spiked samples were high relative to the spike concentration, and the required analytical dilutions reduced the accuracy of the MS/MSD recovery and RPD calculations.

4.2.3.5 Laboratory control samples

All of the laboratory control sample results were within QC limits.

4.2.3.6 Compound identification and quantification

All PCB compound identification parameters were within validation criteria. Analyst experience in pattern recognition of the individual Aroclors was used in interpreting the PCB results. When samples contained more than one Aroclor, a higher level of analyst expertise and review was necessary to ensure the correct identification and quantification. The analyst noted that the patterns of peaks for detected samples were possibly attributable to weathered Aroclors. The results were quantified based on the Aroclors that provided the best possible match to the observed congener pattern.

All PCB compound quantification parameters were within validation criteria. When detected concentrations exceeded the calibration range of the instrument, extracts were diluted and re-analyzed to obtain results within the calibrated range. The results from the two analytical columns exceeded the RPD QC limit of 40% for Aroclor 1254 in three samples, ranging from 44 to 58%. These results were qualified as estimated (J-qualified). The higher of the two results reported for the two analytical columns was selected as the final result.

4.2.3.7 Internal standards

The laboratory used internal standards for PCB quantification. All internal standard recoveries were within QC limits.

4.2.4 Total solids and lipids

4.2.4.1 Calibration

All calibration criteria were met.

4.2.4.2 Blanks

All four method blanks contained trace lipid concentrations (0.004 to 0.02% ww). All sample results were greater than five times the blank levels, so no data qualification resulted.

4.2.4.3 Laboratory replicates

Laboratory replicate analyses were conducted. All RPDs were within QC criteria, with the following exceptions: the lipid RPDs of 43% for the duplicate and 50% for the triplicate in SDG IQ22 were outside of the QC limit of 30%. The associated lipid results in this SDG were J-qualified.

4.2.4.4 Laboratory replicates

Laboratory replicate analyses were conducted. All RPDs were within QC criteria, with the following exceptions: the lipid RPDs of 4 and 50% for the triplicate in SDG IQ22 were outside of the QC lit associated lipid results in this SDG were J-qualified.

5.0 References

Eaton C. 2004. Personal communication (LDWG, EPA and Ecology fish tissue experts meeting: discussion of English sole, shiner perch, pacific staghorn sculpin, and rockfish in the LDW with Matt Luxon, Windward Environmental). LDWG, Seattle, WA. 3/31/04.

EPA. 1999. USEPA contract laboratory program national functional guidelines for organic data review. EPA-540/R-99/008. Office of Emergency and Remedial Response, US Environmental Protection Agency, Washington, DC.

EPA. 2000. Guidance for assessing chemical contaminant data for use in fish advisories. Volume 1: Fish sampling and analysis. Third ed. EPA 823-B-00-007. US Environmental Protection Agency, Washington, DC.

EPA. 2002a. Guidance for quality assurance project plans. QA/G-5. EPA/240/R-02/009. Office of Environmental Information, US Environmental Protection Agency, Washington, DC.

EPA. 2002b. USEPA contract laboratory program national functional guidelines for inorganic data review. EPA 540-R-01-008. Office of Emergency and Remedial Response, US Environmental Protection Agency, Washington, DC.

NOAA. 1993. Tissue lipid determination method. In: Sampling and analytical methods of the National Status and Trends Program national benthic surveillance and mussel watch projects, 1984-1992. Vol 2: Comprehensive descriptions of complementary measurements. NOAA technical memorandum NOS ORCA 71. National Status and Trends Program, National Oceanic and Atmospheric Administration, Silver Spring, MD.

PSEP. 1997. Recommended guidelines for sampling marine sediment, water column, and tissue in Puget Sound. Final report. Prepared for the US Environmental Protection Agency, Seattle, WA. Puget Sound Water Quality Action Team, Olympia, WA.

Windward. 2004a. Lower Duwamish Waterway remedial investigation. Quality assurance project plan: Fish and crab tissue collection and chemical analyses. Prepared for Lower Duwamish Waterway Group. Windward Environmental LLC, Seattle, WA.

Windward. 2004b. Lower Duwamish Waterway remedial investigation. Task 8: Phase 2 RI work plan. Prepared for Lower Duwamish Waterway Group. Windward Environmental LLC, Seattle, WA.

Windward. 2005. Lower Duwamish Waterway remedial investigation. Quality assurance project plan: Fish and crab tissue collection and chemical analyses. Addendum for additional fish and crab sampling in the Lower Duwamish Waterway. Prepared for Lower Duwamish Waterway Group. Windward Environmental LLC, Seattle, WA.