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Mid-Columbia River Fish Toxics Assessment

EPA Region 10 Report

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U.S. Environmental Protection Agency, Region 10
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List of Abbreviations

Abbreviation	Definition
BZ#	Congener numbers assigned by Ballschmiter and Zell
CDF	Cumulative Distribution Function
CM	Channel marker
CR	Columbia River
DDD	Dichloro-diphenyl-dichloroethane
DDE	Dichloro-diphenyl-dichloroethylene
DDT	Dichloro-diphenyl-trichloroethane
DO	Dissolved Oxygen
ECO	Ecological
EPA	United States Environmental Protection Agency
GIS	Geographic Information System
HH	Human Health
HCB	Hexachlorobenzene
HRGC/HRMS	High Resolution Gas Chromatography / High Resolution Mass Spectrometry
ICPMS	Inductively coupled plasma mass spectrometry
IDEQ	Idaho Department of Environmental Quality
LCR	Lower Columbia River
MCR	Mid-Columbia River
MDL	Minimum detection limit
NA	Not Applicable
ND	Non-detected
ODEQ	Oregon Department of Environmental Quality
ORP	Oxidation-Reduction Potential
PBDE	Polybrominated diphenyl ether
PCB	Polychlorinated biphenyl
QAPP	Quality Assurance Project Plan
QC	Quality Control
RARE	Regional Applied Research Effort
REMAP	Regional Environmental Monitoring and Assessment Program
S.E.	Standard error
SOP	Standard Operating Procedure
SPMD	Semi-Permeable Membrane Device
Std. Dev.	Standard Deviation
SV	Screening Value
TSS	Total Suspended Solids
USGS	United States Geological Survey

List of Units

Abbreviation	Definition
C	centigrade
cm	centimeter
DD	decimal degrees
g	gram
g/day	grams per day
L	liter
M	meter
mg/Kg	milligrams per Kilogram
mg/L	milligrams per Liter
ml	milliliter
mm	millimeter
ng/g	nanograms per gram
ng/Kg	nanograms per kilogram
NTU	nephelometric turbidity units
km	kilometer
ppb	part per billion
ppm	part per million
ppt	part per trillion
RM	river mile
rkm	River kilometer
sq. km	Square kilometer
µg/g	micrograms per gram
µg/L	micrograms per Liter
ww	wet weight

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I. Abstract

The Columbia River Basin is a priority watershed for States, Tribes, federal agencies, and nonprofit organizations and was designated as a 'critical ecosystem' that warrants protection in the Environmental Protection Agency's (EPA's) 2006-2011 Strategic Plan (USEPA 2006a). Past studies by EPA and others have found significant concentrations of toxic contaminants in fish and the waters they inhabit throughout the basin (USEPA 2009). However, the Mid-Columbia River main stem reach, between Bonneville Dam and Grand Coulee Dam, has never been assessed for concentrations of contaminants in fish tissue. This study of the Mid-Columbia River is an effort to fill this information void.

A spatially distributed probabilistic sample design was used to select 42 sample sites along the Mid-Columbia River main stem (MCR) to represent the entire 718 km (440 mile) reach. During the summers of 2008 and 2009, field crews collected two types of fish samples to represent both human health and ecological endpoints. Water quality and physical habitat data were also collected at each site. Fish tissue was analyzed for a variety of toxic contaminants. Water samples were analyzed for physical and chemical characteristics and trace elements.

Toxic contaminants were measured in fillet tissue for the human health endpoint and in whole fish tissue for the ecological endpoint. Using the probabilistic study design, the data were analyzed to produce statistical results that are expressed in terms of the extent of the Mid-Columbia reach (MCR). The results were also compared to literature screening values (SVs) to put the results in context for interpretation. Multiple contaminants were found to exceed SV concentrations. Mercury, PCBs, and DDTs were responsible for most of the exceedances of human health SVs. Trace elements and DDTs were responsible for most of the exceedances of ecological SVs.

Human Health Findings

Tissue contaminant concentrations in fish fillet samples were compared to four types of SVs. Cancer and non-cancer SVs were calculated for two different consumption rates, one representing the general public and one representing people who consume fish at a higher rate. All the contaminants that exceeded human health SVs in fillets were widely detected. However, some widely detected contaminants did not exceed any of these SVs. The following are general results on the extent and magnitude of contaminant concentrations relevant to human health SVs in fish fillet samples collected from the MCR.

• Mercury was detected in all fillet samples, representing 100% of the MCR length. Concentrations exceeded the non-cancer SVs for both the general and the high fish-consuming populations in most of the MCR.

• PCBs exceeded cancer SVs for both the general and the high fish-consuming populations throughout the MCR reach. Non-cancer SVs were exceeded for both types of consumers in a substantial proportion of the reach.

• Total DDTs and DDE exceeded cancer SVs for both the general and high fish-consuming populations in a substantial proportion of the MCR reach.

• Several of the other chlorinated pesticides were frequently detected in tissue samples. Only dieldrin exceeded both of the cancer SVs in a substantial proportion of the MCR reach. Heptachlor epoxide and hexachlorobenzene also exceeded the cancer SVs but to a lesser spatial extent.

• PBDEs were frequently detected in fillet samples, but did not exceed any of the SVs.

• Dioxins and furans were rarely detected. The dioxin congeners with available SVs were not detected in the samples.

Ecological Findings

Tissue contaminant concentrations in whole fish samples were also compared to available SVs. Three types of SVs were compared: piscivorous avian wildlife (kingfisher), piscivorous wildlife (mink and otter), and general aquatic species SVs. The avian SV are generally the lowest (most stringent) and therefore the ones most often exceeded in these tissue samples. The following are general descriptions of the extent and magnitude of contaminant concentrations in ecological SVs from whole fish samples collected from the MCR.

• Total DDTs and DDE exceeded both the kingfisher and general aquatic SVs in much of the MCR reach, while DDD exceedances for kingfisher were more limited in extent.

• Total chlordane exceeded the kingfisher SV in a small percent of the MCR length, and was the only other chlorinated pesticide with an SV exceedance.

• Total PBDEs exceeded the SV for American kestrels (a bird species) in a small percentage of the MCR reach.

• Mercury wildlife SVs were exceeded for kingfisher in much of the MCR reach, and for otter and mink in a smaller proportion.

• Several metals (zinc, copper, and selenium) exceeded the general aquatic SVs in most of the MCR reach, while others (nickel, arsenic, and lead) exceeded them in a smaller proportion of the river.

II. Introduction

The Columbia River is considered one of the great rivers of the world. By volume, the Columbia is the fourth-largest river in the United States, and it has the greatest flow of any North American river draining into the Pacific. The River has immense cultural, environmental, and economic significance for the Pacific Northwest region.
The Columbia River Basin is a priority watershed for agencies, tribes, and other organizations. Multiple locations in the mainstem and tributaries are known to have contaminants in fish and in water at concentrations of concern (USEPA 2009). The amount of data available from the Mid-Columbia River main stem is quite limited compared to other more-studied parts of the basin. This lack of information led us to initiate this study to begin filling data gaps regarding the 718 kilometer (440 mile) reach between the Grand Coulee and Bonneville dams.

EPA Region 10 and Oregon's Department of Environmental Quality (ODEQ) designed the project to meet the goals of both EPA and Oregon, which include improving and protecting water quality by monitoring and controlling pollutants in order to reduce risks to human health and the environment. Analysis of contaminants in fish is the focus of the study. Water quality, biological information, and habitat data are used to provide context. Fish species were selected to represent both human health and ecological endpoints.

Analysis of fillet samples from resident fish consumed by people is used to evaluate the geographic extent of tissue contamination that exceeds concentrations of potential concern for human health. Accumulation of toxics in fish threatens the survival of fish species themselves, as well. Other species, such as fish-eating birds and mammals, can also be harmed by consuming contaminated fish. Analysis of contaminants in whole fish is used to evaluate the geographic extent of tissue contamination that exceeds concentrations of potential concern for ecological receptors.

The assessment reach extends down-river from Grand Coulee Dam in Washington to Bonneville Dam in Oregon. The Washington portion of the reach was sampled in 2008 by EPA and the Oregon portion in 2009 by ODEQ. ODEQ collected data from both the randomly-located sites in Oregon as well as some hand-picked sites (ODEQ 2012). Results from the hand-picked sites are not included in this assessment.

A. Background

1. EPA's Environmental Monitoring Program

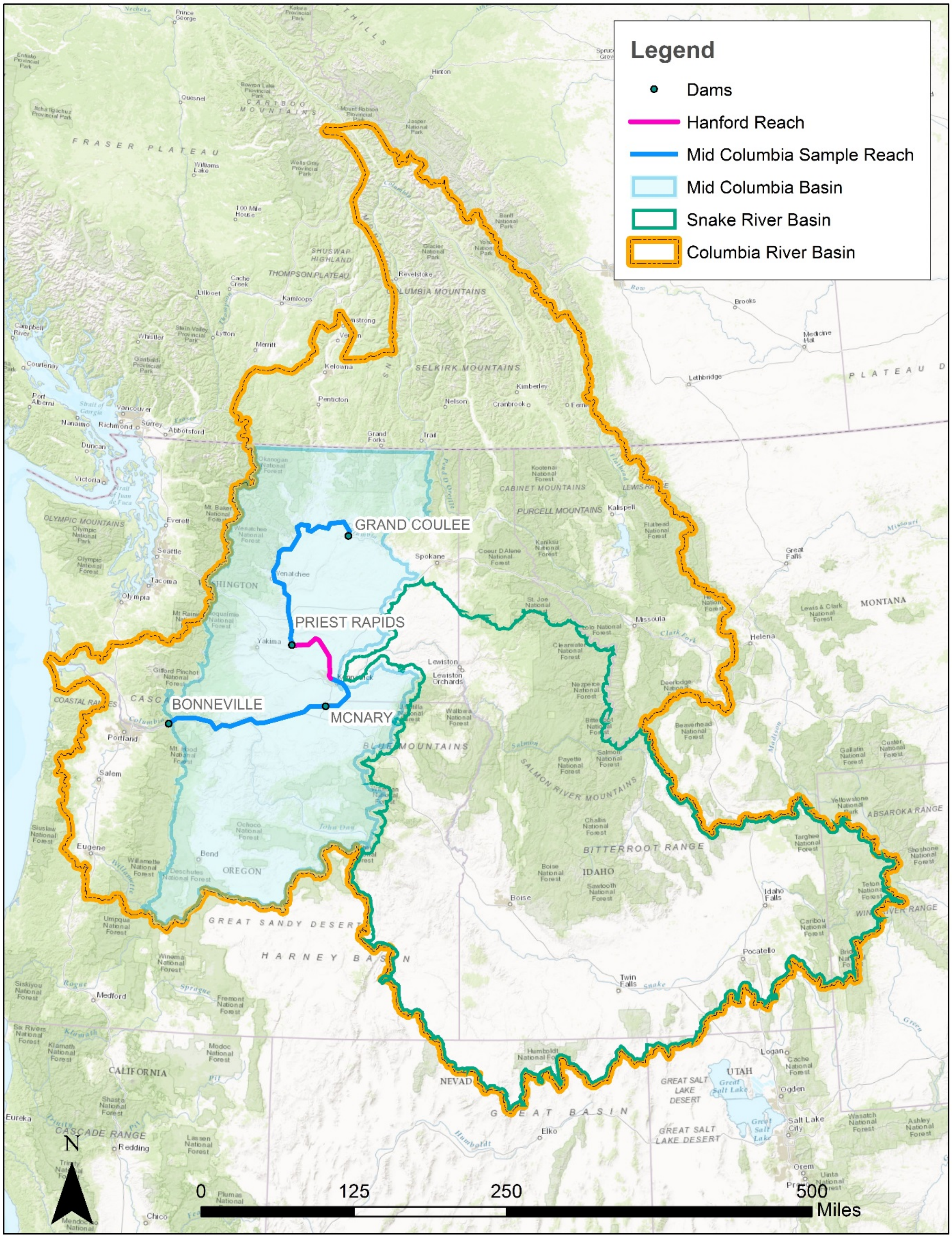
This assessment of the MCR was designed as part of EPA's Environmental Monitoring and Assessment Program (EMAP), a national program of EPA's Office of Research and Development (ORD) to estimate the status and trends in the condition of the nation's ecological resources. These assessments examine associations between indicators of ecological condition and natural and human-caused stressors. This study of the Mid-

Columbia River uses the key feature of all EMAP projects: a probabilistic sample design, which allows a limited number of samples to represent the condition of a relatively large resource with a known degree of statistical confidence.

2. Columbia Geography

With a total length of over 1931 km (1249 miles), the river begins in the Rocky Mountains of British Columbia, Canada, flows southward into Washington State, then turns westward to form the border between the States of Washington and Oregon before discharging to the Pacific Ocean (Map 1). The U.S. portion of the basin is 525,003 sq. km in area (258,000 mi.^{2}, approximately the size of France). Agriculture, livestock grazing, and timber harvest are the primary land uses. Much of the basin is arid, including large areas of plains with annual precipitation of 18-51cm. Portions of the basin are mountainous and the median elevation is 1354 m. The Columbia River is highly developed for hydroelectric production and contains more than 370 dams, including 11 on the Columbia mainstem.

The Mid-Columbia is the river reach from Grand Coulee Dam downstream to Bonneville Dam. It links the upper Columbia reach—Lake Roosevelt plus the free-flowing portion of the river stretching to the Canadian border with the lower Columbia reach—Bonneville Dam to the Pacific Ocean. Major tributaries to the MCR include the Okanogan, Methow, Yakima, Snake, Umatilla, John Day, Deschutes, White Salmon, and Wind rivers. The Snake River is by far the most significant tributary, flowing over a thousand miles before it discharges to the Columbia near the Tri-Cities in eastern Washington. The Snake River subbasin represents 67% of the land area that drains to the Mid-Columbia.



Map 1. Columbia River basin showing major basins and Mid-Columbia reach.

3. Human Uses in the Basin

The Mid-Columbia basin is primarily rural, with scattered regional population centers such as Boise, Yakima, Bend, Wenatchee, and the Tri-Cities area. The Snake River portion of the assessment area contains the highest population, while the highest density of people is found in the upper portion of the reach between Grand Coulee and the Snake confluence.

The basin's land use is dominated by agriculture, especially near the rivers. Details of land use based on a GIS land cover analysis are in Appendix 1. Although land use and land cover are not synonymous, some land uses can be inferred from land cover data, obtained from remote sensing. Although most of the land cover is classified as shrub/grasslands, agricultural land cover makes up 15-24% of the entire MCR basin, and increases to 23-35% in the area within 10 miles of the major rivers. Grazing land is generally not included in the agricultural land cover, so the agricultural land use area is likely underestimated.

The Columbia is one of the most hydroelectrically developed river systems in the world, generating more than 21 million kilowatts, annually. The MCR is bounded by two large federal hydropower dams, and contains nine others (Map 2) which essentially divide the main stem into a series of large reservoirs. The Mid-Columbia also contains the sole remaining free flowing section of the river in the US, the 82 rkm section between Priest Rapids Dam and the city of Richland, known as the Hanford Reach. This reach is also significant as the site of US plutonium production for nuclear weapons for World War II. Post-production clean-up of this site began in 1989. The waste sites and facilities near the River are part of an intensive investigation and clean-up effort including radionuclides, metals, and organic chemicals.

Map 2. Mid-Columbia River showing major dams (red bars) and 42 data collection locations (blue circles).

4. Past Studies of Toxic Contaminants in the Basin

EPA studies and State and federal monitoring programs have found substantial concentrations of contaminants in fish and the water of the Columbia River and its tributaries (Tetra Tech 1996, Williamson et al. 1998, USEPA 2002, Fuhrer et al. 2004, Hinck et al. 2006, ODEQ 2012). Toxic contamination in the Columbia Basin has been documented for many years, but most studies target specific contaminants or focus on specific reaches or tributaries. Studies of contamination have taken place recently in the upper part of the main stem, in support of the Upper Columbia River hazardous waste site (Exponent/Parametrix 2013), and in the upper reaches of the Mid-Columbia, related to the Hanford Site (Hulstrom 2011). The lower Columbia River, below Bonneville Dam, which supports the largest human population in the basin, has also been the focus of numerous studies (Fuhrer et al. 1996, Tetra Tech 1996, Nilsen and Morace 2014). These studies have sampled targeted locations based on a variety of factors, including historical data and site accessibility. One exception is a 1999 EMAP study conducted in the Lower Columbia River (Hayslip et al. 2006). This study used a sample design that made statistical reach-wide estimates, which is comparable to the sample design of this Mid-Columbia study.

USEPA (2009) conducted a basin-wide synthesis of four contaminant groups using existing data. The report focused on mercury, the pesticide DDT and its breakdown products, the polychlorinated biphenyl group of industrial compounds (PCBs), and a class of flame retardants (PBDEs). These contaminants are among those found throughout the basin, including the MCR, and at concentrations that could adversely impact people, aquatic life, and wildlife. The report concluded that although PCB and DDT contamination may be declining over time, they are still present at levels of concern for both human health and fish-eating animals, and that mercury and PBDE contamination may still be increasing.

Aside from the well-studied Hanford Reach, which makes up 12% of the Mid-Columbia main stem, there is a lack of assessments of toxic contamination in this region. Some studies of much larger areas such as USEPA 2002 and Hinck et al. 2006 include a few widely-spaced sample locations in the main stem of the MCR, but do not attempt to characterize or assess the Mid-Columbia in particular.

5. Concerns for Toxics in Fish Tissue

Contaminants have been found in several fish species in rivers throughout the Columbia River Basin as described above. These have the potential to impact people, wildlife, and fish. Public awareness of the condition of Mid-Columbia aquatic resources, including toxic levels in fish, is informed by government sources. Two primary sources of this information are State fish consumption advisories and the Clean Water Act's 303(d) list of impaired waters.

Fish consumption advisories in the Mid-Columbia

To protect people, the State and federal agencies issue fish consumption advisories for specific fish species in water bodies that exceed human health criteria. Advisories are intended to protect the general public or sensitive populations such as women of childbearing age, nursing or pregnant women, and children. State health agencies use human health criteria to determine when and where to issue fish consumption advisories. Whether or not a chemical is of concern depends on the amount of fish consumed from a particular water body. State health agencies take into account many factors as they formulate their health communication for the public. These include the health benefits of eating fish, the availability of less contaminated fish or food from other sources, and background concentrations. Each State determines the methodology and consumption rates they use to derive consumption advisories. These differ among the three States with jurisdiction within the Mid-Columbia (Idaho, Oregon, and Washington).

The Mid-Columbia River and its tributaries have several fish consumption advisories issued by the States of Washington, Oregon, and Idaho, summarized in Table 1. Most fish advisories do not imply that fish from a specific waterbody should not be consumed, but they recommend limiting the amount of specific types of fish consumed. The exceptions are a few noted "do-not-eat" in the list below. Advisories in the Mid-Columbia are for PCBs, DDTs, and mercury. Most of these advisories are for certain fish species within specific water bodies, though some apply to all waters within a State. Because methylmercury affects the developing human nervous system (NRC 2000), advisories based on elevated mercury concentrations have lower consumption recommendations for young children, nursing mothers, and women who are or might become pregnant than they have for the rest of the population.

Table 1. State fish consumption advisories issued for the MCR and tributaries.

Contaminant	Water body	Species	Notes
	Mid-Columbia Basin in Washington[1]		
PCBs	Clark County	clams	applies near and downstream of former Vanalco plant, RM 103
PCBs and mercury	Mid-Columbia mainstem, pool behind Bonneville Dam, up to Ft Raines	all resident fish	joint advisory, Washington and Oregon
PCBs and mercury	Mid-Columbia mainstem from Ft Raines (a mile east of Bonneville Dam) upstream to McNary Dam	multiple resident fish (limited consumption), northern pikeminnow (do-not-eat)	joint advisory, Washington and Oregon
PCBs	Walla Walla River	carp, pikeminnow	
PCBs and mercury	Wenatchee River, Icicle Creek to Columbia River	smallmouth and largemouth bass (limited consumption), mountain whitefish (do-not-eat)	
DDTs	Okanagan River	carp	
PCBs	Yakima River	carp	an advisory based on DDTs in bottom fish was lifted in 2009 since concentrations declined
Mercury	Statewide	smallmouth and largemouth bass (limited consumption)	for women who are or who might become pregnant, nursing mothers, and young children
Mercury	Statewide	northern pikeminnow (do-not-eat)	for women who are or who might become pregnant, nursing mothers, and young children

1. Issued by the Washington State Department of Health, updated at http://www.doh.wa.gov/CommunityandEnvironment/Food/Fish/Advisories.aspx

Table 1, continued. State fish consumption advisories issued for the MCR and tributaries.

Contaminant	Water body	Species	Notes
	Mid-Columbia Basin in Oregon[2]		
PCBs/ mercury	Mid-Columbia mainstem, pool behind Bonneville Dam, up to Ft Raines	all resident fish	Joint advisory for WA and OR. *(note: OR website list only for PCBs)*
PCBs/ mercury	Mid-Columbia mainstem from Ft Raines (a mile east of Bonneville Dam) upstream to McNary Dam	multiple resident fish (limited consumption), northern pikeminnow (do-not-eat)	Joint advisory for WA and OR. *(note: OR website list only for PCBs)*
Mercury	Snake River including Brownlee Reservoir and Powder River Arm	all resident fish	
	Mid-Columbia Basin in Idaho (includes Snake River and tributaries)[3]		
Mercury	Statewide	smallmouth and largemouth bass	
Mercury	American Falls Reservoir	Utah sucker	
Mercury	Boise River	catfish	
Mercury	Brownlee Reservoir	carp, catfish, crappie, perch	
Mercury	Chesterfield Reservoir	rainbow trout	
Mercury	Grasmere Reservoir	Lahontan cutthroat trout	
Mercury	Hells Canyon Reservoir	carp, catfish	
Mercury	Jordan Creek	redband trout	
Mercury	Lake Lowell	sucker, carp	
Mercury	Oakley Reservoir	yellow perch, walleye	
Mercury	Payette River	sucker	
Mercury	Portneuf River	cutthroat, rainbow, and brown trout	
Mercury	Salmon Falls Creek Reservoir	perch, walleye*, rainbow trout, smallmouth bass*	for bass and walleye over 16in, **"do-not-eat"** for women who are or who might become pregnant, nursing mothers, and children under 15 years
Mercury	Shoofly Reservoir	Lahontan cutthroat trout	
Mercury	South Fork Snake River	brown trout	

2. Issued by Oregon Department of Human Services, updated at http://public.health.oregon.gov/healthyenvironments/recreation/pages/fishconsumption.aspx
3. Issued by Idaho Department of Health and Welfare, updated at http://healthandwelfare.idaho.gov/Health/EnvironmentalHealth/FishAdvisories/tabid/180/default.aspx

Water quality impairment list for the Mid-Columbia

Water quality is an important factor in the survival of aquatic life, wildlife, and plants that live in the Columbia River Basin. The Clean Water Act requires each State to track the water quality status of water bodies and to maintain a list of “impaired waters” (also called the 303(d) list) that do not meet State water quality standards. The toxic contaminants that exceed State water quality standards in the Mid-Columbia basin are dioxins, DDT, DDE, other organochlorine and organophosphate pesticides, PCBs, mercury, and other metals (Table 2). It is important to note that States do not comprehensively monitor all waters for all contaminants. Further, each State monitors for different contaminants and each designates their water bodies differently (some by segment, some by river mile) The number of listings is not directly comparable from one part of the basin to another. Additional information and updates to State 303(d) impaired water bodies lists can be found at the web sites maintained by each State’s environmental agency.

Table 2. Summary of MCR and tributaries on State 303d Lists[1] as impaired by toxic contamination.

Tributary	Dioxins	PCBs	DDTs	Other OCPs[2]	OPPs[3]	Total Pesticide	Mercury	Other Metals
Main stem Columbia and tributaries below Snake River conf. (ordered downstream to upstream)								
Columbia: Bonneville Dam to Snake R.	●	●					●	
White Salmon R.		●						
Hood R.					●	●	●	●
Mill Creek					●	●		
Deschutes R.							●	
John Day R.								●
Columbia: Yakima R to John Day Dam	●	●	●	●		●		
Umatilla R.							●	●
Walla Walla R.		●	●	●	●	●		
Main stem Columbia and tributaries above Snake River confluence								
Yakima R.	●	●	●	●		●		
Esquatzal Coulee						●		
Crab Creek	●	●	●	●		●		
Columbia: Rock Island Dam to Yakima R	●	●	●	●		●		
Wenatchee R.		●	●			●		
Chelan R.	●	●	●	●		●	●	●
Columbia: Chelan R to Rock Island Dam		●	●			●		
Methow R.	●		●			●		
Okanogan R.		●	●			●		●
Columbia: below Grand Coulee Dam	●							

Table 2, continued. Summary of MCR and tributaries on State 303d Lists[1] as impaired by toxic contamination.

Tributary	Dioxins	PCBs	DDTs	Other OCPs[2]	OPPs[3]	Total Pesticide	Mercury	Other Metals
Snake Mainstem and tributaries (ordered downstream to upstream)								
Snake, mouth to Palouse R.	●	●	●	●		●		
Palouse R.	●	●	●	●				
Snake: Palouse R. to Clearwater R.	●	●	●	●		●	●	
Clearwater R.						●		●
Grande Ronde R.								●
Snake: the OR - ID border			●	●		●	●	
Salmon R.							●	●
Powder R.							●	●
Burnt R.								●
Payette R.							●	
Malheur R.			●	●		●	●	●
Boise R.					●	●	●	●
Owyhee R.			●	●		●	●	●
Bruneau R.							●	●
Salmon Falls							●	●
Big Wood R.							●	
Goose R.							●	●
Snake: Lake Walcott							●	
Blackfoot								●
Snake: American Falls							●	●
Salt R.								●

1. State 303(d) lists used: Idaho 303(d) 2010 (IDEQ 2010), Oregon 303(d) 2010 list with additions from proposed 2012 list (ODEQ 2010b), WA: 303(d) 2012 list (WA Dept. Ecology 2012)
2. OCPs abbreviation for other organochlorine pesticides (aside from DDTs)
3. OPPs abbreviation for organophosphate pesticides.

B. Purpose and Objectives

The purpose of this assessment is to evaluate the contaminants in fish consumed by both humans and wildlife using concentration data from representative fish tissue collected from the MCR. Four contaminants or groups of contaminants are addressed: mercury/metals, persistent organic pesticides, PCBs, and PBDEs. The data are used to address these questions:

- What are the concentrations of contaminants in fillets of fish species consumed by humans?
- What are the concentrations of contaminants in small prey fish consumed by wildlife and by other fish?
- What is the estimated percentage of the MCR with contaminant concentrations above levels of potential concern for humans and for wildlife species?

Other data, including water quality, physical habitat, and presence of invasive mussel veligers (a larval stage of mussels) data are provided to supplement the current conditions in the Mid-Columbia and to provide context for this toxics assessment.

III. Study Overview

A. Survey Design

Assessing a very large and diverse river reach requires a study design that can describe the condition of the entire resource. There are various statistical design options. A census method, where data are collected from every possible sample site, is impractical (if not impossible). This survey used a probabilistic sampling method where sample sites are selected randomly from the entire pool of possible sites belonging to the resource of interest or "target population". Every river segment of the target population has a known non-zero probability of being selected for sampling. This feature has two advantages: 1) it prevents site selection bias and 2) it enables statistically valid inferences to be made for the entire target population. In other words, because the set of sample sites are representative of the entire study reach or "inference population", data collected from these sites can be used to make estimations of the spatial extent of any measured parameter. This design is used for "EPA's National Aquatic Resource Surveys (NARS), and can be conducted at regional or local scales as well. Additional details are in Diaz-Ramos et al. (1996), Stevens (1997), and Stevens and Olsen (1999). For the Mid-Columbia assessment, 42 random sites were selected from the 718 km (440 mile) target population. Data from these sites are statistically representative of the entire 718 rkm "inference population" and are therefore used to describe the condition for the entire reach with known statistical confidence.

B. Site Selection

The list or map that identifies every unit within the target population is termed the sampling frame. The Mid-Columbia sampling frame was based on a river-center line GIS data layer developed from the National Hydrography Dataset (NHD-Plus). The frame included every km-long segment of the 718 km-long reach river reach from Grand Coulee Dam to Bonneville Dam. The sample sites were randomly selected from this frame in a manner to ensure distribution of sites throughout the entire study reach. In this study, funding dictated an uneven distribution of sites by State with 23 sites in Oregon and 19 in Washington. This was achieved by using an unequal probability sample method for the target population for each of the two States. Site weighting factors are used to compensate for uneven sample probabilities between the two States. Oregon sites are assigned a lower weight because the density of sampled sites in Oregon per river length was higher compared to the density of sites in Washington. The weighting factor is applied in order to make inferences that are valid for the entire target population. Map 2 shows the location of the 42 sample sites, and site locations are listed in Appendix 2.

Of the original sites selected for sampling, all were sampleable and field data and samples were collected (or attempted) at each of the 42 locations. Because none of the sites were omitted or replaced due to access problems (inaccessible due to safety, permission, etc.), the sample set is representative of the entire target population. Therefore, the spatial extent of the river represented by these data from the 42 sites, the 'inference population', is identical to the target population (718 rkm).

C. Assessment Indicators

1. Fish Tissue

Two different endpoints are evaluated in this assessment. The Human Health (HH) endpoint, referred to as "HH-fish" in this report, considers toxic contaminants that are present in fish fillet tissue and reflects the exposure to humans who eat those fish from the Mid-Columbia River. The ecological (ECO) endpoint, referred to as "Eco-fish" in this report, considers toxic contaminants that are present in whole bodies of fish that are consumed by wildlife predators. The chemicals of concern analyzed in both types of samples are generally bioaccumulative and persistent and therefore harmful to fish consumers, whether human or wildlife.

The chemicals that are assessed are described below. The complete lists of analytes for both endpoints and their corresponding analytical methods are in Appendix 3, Appendix 4, and Appendix 5. Some chemicals are actually groups of many individual analytes. Because fillet samples and whole fish samples were analyzed at different laboratories, the analyte lists and the number of actual analytes in each category vary slightly between these two sample types.

<u>Mercury (both fillets and whole fish)</u>

Mercury is an elemental metal that is toxic at low concentrations, affecting the nervous system and brain in both humans and animals. The methylated form of mercury bioaccumulates in the food chain. Atmospheric deposition is believed to be the most significant pathway transporting mercury through the environment (Driscoll et al. 2013). A basin-specific estimate for the Columbia River attributed 84% of the mercury to this pathway (Dwight Atkinson, pers. comm., cited in USEPA 2009). Other basin scale sources are runoff, point discharges, metals mining, and local industries (e.g., cement, ore roasting, coal-fired power plants).

<u>DDT and related compounds (6 analytes in both fillets and whole fish)</u>

DDT is an organochlorine pesticide once widely used in agriculture areas of the Columbia Basin. Highly persistent in the environment, DDT and its breakdown products (i.e., structural analogs), DDE and DDD, bioaccumulate in the food web. We refer to these collectively as DDTs in this document. These chemicals are linked to cancer in humans and neurological and developmental disorders in birds and other animals. Although banned in 1972, DDTs still persist in the environment. The primary source of DDTs to the Columbia River is the large extent of agricultural lands. Soil erosion from wind and water are the primary pathways that move DDTs from fields to the Columbia River and its tributaries.

Chlorinated pesticides (20 analytes in fillets, 17 in whole fish)

Besides DDTs, other organochlorine pesticides are included in this study. Most are cylclodiene pesticides such as aldrin, dieldrin, chlordane, and mirex. Like DDT, these are all highly chlorinated, persistent organic pesticides that degrade slowly and can bioaccumulate in animal tissue. These were once widely used in large quantities in the United States. They were used for a variety of applications, including insect control on agricultural crops and cotton, treatment of livestock, control of ants, termite control in houses, and control of insects that carry human diseases such as malaria. Because of evidence supporting the adverse environmental and human health effects of these substances, including their probable carcinogenicity, the use of these pesticides was phased out in the U.S. during the 1970s and 80s.

Dioxins and furans (18 analytes in fillets only)

Dioxins and furans are formed as a by-product of the manufacture, molding, or burning of organic chemicals and plastics that contain chlorine. Dioxins and furans can cause a number of health effects. The most well-known member of the dioxin/furan family is 2,3,7,8-Tetrachlorodibenzodioxin (TCDD), a likely cancer-causing substance to humans. People exposed to dioxins and furans have experienced changes in hormone levels and high doses of dioxin have caused a skin disease called chloracne. Animal studies show that exposure to dioxins and furans can cause changes in the endocrine system, changes in the development of the fetus, decreased ability to reproduce, and suppressed immune systems.

PCB congeners (172 analytes in fillets, 21 in whole fish)

Polychlorinated biphenyls are synthetic compounds that were widely used in electrical equipment such as electrical transformers. These persistent chemicals bioaccumulate in body fat and biomagnify in the food chain. PCBs have many congeners that vary in degree of toxicity. PCB manufacture was banned in 1979 because the compounds are carcinogenic and pose environmental and human health risks. PCBs have high stability and persist in the environment. Substantial inputs of PCBs to the Columbia River are associated with industrial areas, where spills or leakage of PCBs have occurred.

PBDE congeners (34 analytes in fillet samples, 8 in whole fish)

Polybrominated diphenyl ethers are synthetic flame retardants that are added to plastics and fabrics to reduce flammability. PBDEs are released slowly into the environment from production, use, and disposal of products that contain PBDEs. They are chemically similar to PCBs in that they have many congeners and also bioaccumulate in the freshwater environment. Effects on fish are thought to be similar to those from PCBs, ranging from neurotoxicity to endocrine disruption. Little is known about the health effects of PBDEs on people, but EPA considers neurobehavioral effects to be the endpoint of concern. Recent findings that PBDEs are widely distributed in the environment and are present at increasing concentrations in people have raised concerns about the potential risks of PBDE exposure. Sources of PBDEs to the Columbia River are not well understood, though municipal wastewaters may be a significant pathway.

Other metals/metalloids (8 analytes in whole fish samples only)

In addition to mercury, Eco-fish samples were analyzed for eight other trace elements: arsenic, cadmium, chromium, copper, lead, nickel, selenium, and zinc. Only total concentrations of these elements were analyzed and no speciation data are available (e.g., inorganic arsenic, methylmercury). Fillet samples were not analyzed for metals other than mercury.

2. Other Supporting Data

Although the focus of the assessment is toxic contamination in fish tissue, we also collected some supporting information including a limited amount of data on water quality and physical habitat characteristics. Each category is described briefly below and the data are summarized in Appendix 6.

Water quality

Physiochemical water quality characteristics affect the ability of species to persist in the riverine habitat. Water quality data were collected to determine acid-base status, nutrient enrichment, and chemical stressors. We also collected information on redox potential, total organic carbon, dissolved organic carbon, sulfate, and water hardness. Physical water data parameters collected include light penetration (e.g., turbidity, suspended solids), temperature, and ionic strength (e.g., conductivity). Chemical parameters include the concentrations of dissolved gases, major cations, anions, and nutrients (i.e., nitrogen, phosphorus). Unfiltered samples were analyzed for total metals/metalloids (arsenic, copper, lead, cadmium, selenium, and mercury) and filtered samples were analyzed for dissolved mercury.

Physical habitat

Physical habitat includes all those structural attributes that influence or sustain organisms within the river. The structural complexity of aquatic habitats provides the variety of physical and chemical conditions to support diverse biotic assemblages and maintain long-term stability. Some common physical habitat attributes are stream size, channel gradient, substrate size, fish cover, and riparian vegetation structure. Anthropogenic alterations of riparian areas and stream channels can reduce the complexity of aquatic habitat and result in species loss and ecosystem degradation. The understanding of the physical habitat of an area allows for better assessments of the stream ecosystem and human caused effects. Stressor indicators derived from data collected about physical habitat quality can be used to help explain or diagnose river condition. Observational data on physical characteristics of the riparian and nearshore area are included as a general assessment of habitat characteristics (Appendix 6).

IV. Methods

A. Quality Assurance

Field crews followed protocols described in the Field Methods Manual (USEPA 2008a) to collect field data and to maintain sample integrity. Two separate crews collected the data. An EPA Region 10 crew sampled Washington sites in 2008 and an Oregon DEQ crew sampled Oregon sites in 2009. Consistency and adherence to the field protocols was assured by crew member participation in training sessions and field audits. All data were collected/generated according to procedures described in the project's Quality Assurance Project Plan (QAPP) (USEPA 2008b). A second QAPP describes the analytical work by the Oregon DEQ Laboratory (ODEQ 2010a).

B. Field Sample Collection

Field data were collected during the summer months in 2008 in Washington and in 2009 in Oregon at the random locations selected from the sample frame. The random sample locations designated by the sample frame are mid-channel locations termed "X-sites." The samples were collected shoreward from the X-site. Sample collection alternated between the left and right river bank with the right bank used for even-numbered sites, and the left bank for odd-numbered sites. Fish sampling was conducted within a 500m reach upriver and downriver of the X-site using boat electrofishing gear. Sampling was concentrated along the shoreline within approximately 30m of the designated bank. For the other data collection, the boat was anchored at a point approximately 30m off the bank and data/samples were collected. Further details on field methods and sample preservation and handling are in the Field Operations Manual (USEPA 2008a).

1. Fish Tissue Sampling

Our purpose was to collect fish at each sample site so that the entirety of the fish sampling would represent the reach. Due to different life histories, exposures, and trophic status, fish species vary in their contaminant load and sampling a single species across all sites would yield a different result than if a mix of species were sampled. Therefore, we developed a target fish species list to minimize the effect of sampling different species while still obtaining a representative sample across sites (USEPA 2008a). The target species list incorporated several criteria for fish selection. The criteria common for both the HH and ECO endpoints were 1) the species are distributed throughout the study reach (from Grand Coulee Dam downriver to Bonneville Dam), 2) are catchable using daytime boat electrofishing gear, and 3) are resident (relatively non-migratory), therefore having the potential to accumulate concentrations of chemicals from the local freshwater environment. Human health endpoint target species have the additional criterion of being species that are commonly consumed by humans in the area. A hierarchy of species selection was used to prioritize available human health species by trophic level where piscivorous species were the highest, followed by insectivores and omnivores. If multiple species were available at a site, the highest trophic level species was collected. ECO endpoint target species have the additional criterion of being small-sized (<200 mm) omnivores that are prey species of wildlife (fish, mammals, and birds) of the area.

Crews attempted to retain the highest priority species available at each site according to the target species list. If priority species were not available, crews would select the next best available option. Two fish composite samples were collected at each site, one each for HH and for ECO endpoint tissue analyses. Individuals of the same genus and species and of similar size were combined to form each sample.

Fish tissue samples were processed using similar methods to those described in USEPA 2000a. The HH composite samples consisted of five individuals of similar size (within 75% total length). Each fish was field filleted and both the skin and belly flap were removed. Local consumers are known to prepare fish both with and without skin and belly flaps (CRITFC 1994) so this preparation results in samples that represent tissue that all fish consumers eat but excludes some additional tissue that a subgroup of fish consumers eat. This sample preparation method is consistent with methods used in a significant fish tissue study conducted in the lower Columbia reach (Hayslip et al. 2006), which is used for comparison to these results. Skin removal also facilitates homogenization of the fillets.

For the ECO composite, a variable number of similar-sized individuals (minimum of five) were collected to obtain a minimum weight of 200 grams of whole fish. All samples were preserved and shipped on dry ice. The human health fillet composites were analyzed by Oregon's Department of Environmental Quality laboratory in Hillsboro, Oregon. The ecological endpoint whole fish composites were analyzed at EPA's Office of Research and Development laboratory in Cincinnati, Ohio.

2. Water Quality, Physical Habitat, and Invasive Species Sampling

Field methods are summarized in Table 3. Sampling for most parameters was conducted 30m away from the bank across from the mid-channel X-site. Further discussion of these data is in Appendix 6.

Table 3. Field methods used for MCR data collection.

Metric type	Field method
Water chemistry	Grab sample collected from depth of 0.3m using a peristaltic pump. Water collected for analysis of total organic carbon, nutrients, total suspended solids, metals, sulfate, and alkalinity.
Mercury water sample	Collected using 'clean hands' protocols (EPA method 1669). Unfiltered water sample collected with a peristaltic pump and Teflon tube deployed to 0.3m below surface.
Water quality profile	In situ DO, pH, water temperature, redox potential, turbidity, and conductivity were measured with an electronic meter at the surface and through the water column.
Chlorophyll-*a*	Collected as part of water chemistry sample and field filtered.
Secchi disc transparency	Deployed from shady side of boat. Depth of disappearance recorded.
Rapid habitat visual assessment	Qualitative scoring of crew's observations addressing categories of reach characteristics, fish cover, and general habitat and channel characteristics. Most were recorded based on observations throughout the sample reach. Fish cover observations restricted to near shore (10m) along the 500m fish sampling reach.
Invasive plant species protocols	Visual observations along the 500m fish sampling reach.
Mussel veliger collection	Four vertical plankton tows conducted in various locations (nearshore and open water) in vicinity of X-site to collect juvenile life stage of introduced mussel species (zebra and quagga mussels).

C. Fish Tissue Laboratory Methods

Fish tissue sample preparation and analysis was performed primarily by two laboratories using methods detailed in the project QAPP (Caton 2010) and summarized in Table 4. Fillet samples were analyzed by the ODEQ laboratory in Hillsboro Oregon and whole fish samples were analyzed by EPA's Office of Research and Development, Cincinnati Laboratory (Ahlers 2010). Slight differences in analytical methods for specific analytes are apparent between the human health (fillets) and the eco-samples (whole fish), however sample treatment and analysis were identical within the two tissue types. Fillet samples were homogenized individually and site composites were prepared by combining equal mass from each fish's homogenate. Whole fish samples were homogenized, then aliquots were extracted. Finally, whole fish aliquots were supplied to EPA's Manchester laboratory for analysis of trace elements.

Table 4. Laboratory methods used for MCR fish tissue analyses.

Contaminant	Preparation/Process	EPA method
Human health endpoint fillet samples		
Mercury (total[1])	ICP	EPA method 7374
Chlorinated pesticides	HRGC/HRMS	EPA method 1699
Dioxins/Furans	HRGC/HRMS	EPA method 1613
PCBs	HRGC/HRMS	EPA method 1668
PBDEs	HRGC/HRMS	EPA method 1614
Ecological endpoint whole fish samples		
Pesticides, PCBs and PBDEs	SOP# MIRB-045.4E EPA Method SW3545A for extraction and SW3640A for cleaning. Agilent gas chromatographs with micro-electron capture detectors, GC-µECD	Analysis SOP# MIRB-046: EPA Method SW8081 (pesticides) and SW8082 (PCB and PBDE congeners)
Selenium	Inductively Coupled Argon Plasma Emission Spectroscopy (ICP) and SOP# MIRB 040.2E.	EPA Method 200.7
Total mercury	Milestone DMA-80 and SOP# MIRB-033.1E.	EPA method 7374
Trace elements	3052-M - (MOD) Microwave Assisted Acid Digestion of Siliceous and Organic Matrices	6020 - ICPMS (15 elements)

1. Measurements were of total mercury, rather than methylated mercury because studies have shown that approximately 95% of mercury in fish tissue is methylated (Bloom 1992).

D. Data Analysis Methods

Non-detects were replaced with zeros for organic chemicals data analysis (as in the EMAP estuary study, Hayslip et al. 2006). This can result in biasing summary statistics low. For metals, which occur naturally in water, we used the reporting limit values to replace non-detects, so those summary statistics may be biased high.

1. Application of Weighting Factors and Use of CDFs

Analytical results were extrapolated to describe the entire Mid-Columbia target population. As described in the design section, this is accomplished by assigning a weight to each site as dictated by the random selection design. Results are presented in terms of the estimated proportion of the target reach (e.g., percent of the total river length). The sum of the site weights for all 42 sample sites is the total MCR length (718 rkm).

Any indicator in this study can be expressed in terms of the proportion of the river reach length. This type of result is commonly displayed as a cumulative distribution function (CDF) for indicators with continuous values, which shows the distribution of an indicator accumulated over the entire Mid-Columbia target population. Indicators examined in this report are primarily fish tissue contaminants. As shown in the sample graph below

(Figure 1), if a contaminant concentration above a SV of 25 units is considered "impaired," then approximately 70% of the target population exceeds that threshold (and the other 30% is below that value). Readers who prefer to use a different threshold value simply draw the vertical line in a different location on the graph and project it horizontally to the graph axis to arrive at a different conclusion regarding the percent of the river that they consider impaired. In the example, a higher SV of 50 units results in 50% of the reach exceeding the SV. Confidence bounds can also be calculated for each analyte's CDF.

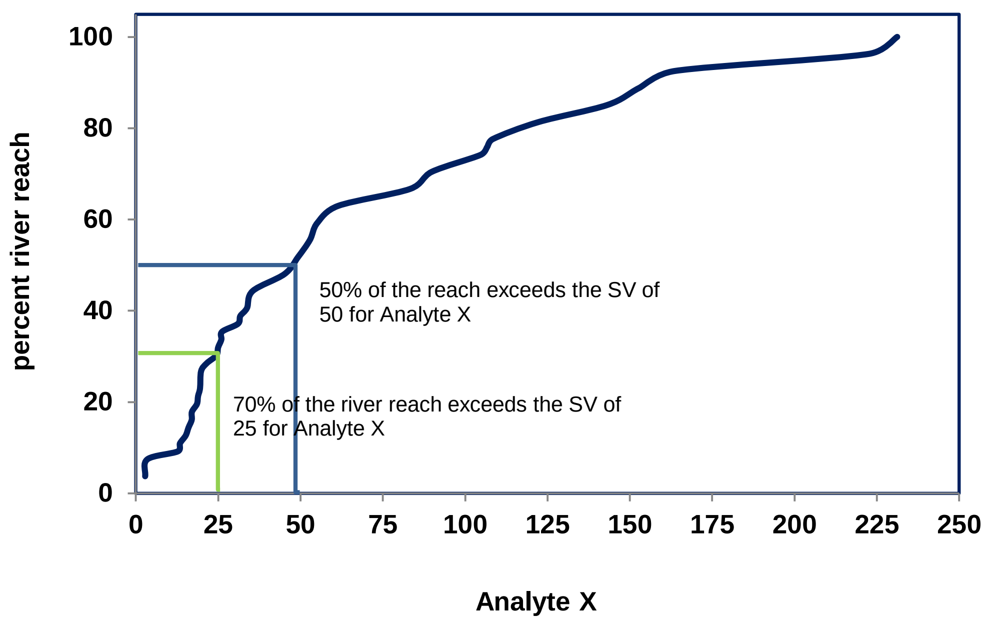


Figure 1. Example of a cumulative distribution function (CDF) graph.

2. Screening for Levels of Concern

SVs are health-based tissue concentrations used to determine whether or not there might be cause for concern for contaminants found in fish. SVs can vary greatly in the amount of uncertainty they reflect. Some have regulatory significance and have gone through rigorous peer review, while others are based on a limited amount of toxicological information available in the literature. In this report we compare the tissue concentrations to SVs determined by EPA and others to be indicative of levels of concern, in order to provide context to our results. Finally, many of the chemicals we analyzed do not have the information available to calculate SVs, thus the results and discussion focus on those analytes that do.

Human health SVs

Human health SVs are derived based on two elements. First is the type of risk/effect. Some contaminants pose an increased risk of cancer, while others have non-cancer effects. These types of risk are discussed in detail in EPA's guidance on fish advisories (USEPA 2000b). For carcinogens, SVs are based on specific risk levels. In this study, we used SVs based on a risk level of one in a million (10^{-6}).

The second element of human health SV calculations is the amount of fish eaten. As consumption rates increase, SVs become lower so a "safe" concentration to use as a SV for concern depends on how much fish we assume people consume. Fish consumption varies greatly among individuals. Studies in the basin revealed that local tribal populations consume considerably more fish than the EPA national average estimate used to calculate values of concern (CRITFC 1994, USEPA 2002). The States have recognized these differences. Oregon has recently revised its water quality standards taking into account a higher consumption rate, which reduces the tissue concentrations that are considered safe for people to eat (ODEQ 2015). Washington and Idaho are currently evaluating existing data and collecting new information to determine what consumption rate to use as they revise their water quality criteria.

We use multiple SVs as comparisons to provide perspective on the extent of contamination. Where possible, four SVs were calculated representing two effects (non-carcinogenic and carcinogenic) at two consumption rates (referred to as "general population" and "high consumers"). SV calculations were provided by Dave McBride, Washington Department of Health, based on toxicity values from USEPA Integrated Risk Information System (IRIS) and Agency for Toxic Substances and Disease Registry (ATSDR). For cancer effects, SV calculations were based on an excess cancer risk of 1 x 10^{-6}. The two consumption rates are defined as follows:

• "General population" rate = eight meals per month or two meals per week (assuming a meal size is 8 ounces). This rate equates to 59.7 grams per day (Washington Department of Health 2012) and is the amount of fish the American Heart Association recommends eating as part of a healthy diet.

• "High consumer" rate = 175 g/day. This is the current rate (2013 revision) used in Oregon's water quality standards, designed to protect people who consume more fish. This rate is only slightly above EPA's subsistence level consumption rate of 142.4 grams per day (USEPA 2000b). In the 1994 CRITFC study, 175 g/day was approximately the 95^{th} percentile consumption rate of those surveyed (CRITFC 1994).

Finally, mercury has an additional SV of 300 ug/g based on a consumption rate of 17.5 g/day. This has been used commonly in the literature, so we include it in the discussion. All SVs used in this assessment are shown in Table 5. Generally, the non-cancer SVs are higher that the cancer SVs. This may seem counter-intuitive, however, the differences are related to chronic versus acute exposure (USEPA 2000b).

Table 5. Human health SVs used to evaluate MCR fillet fish tissue results. SVs for two effects levels with two fish consumption rates. Units are all ng/g (ppb) fillet wet weight.

Analyte[1]	Cancer SV (ng/g ww)		Non-cancer SV (ng/g ww)	
	General population	High consumer	General population	High consumer
Mercury	--	--	120	40
4,4-DDD	4.886	1.667	--	--
4,4-DDE	3.449	1.177	--	--
4,4-DDT	3.449	1.177	--	--
DDT total	3.449	1.177	502.513	171.429
Aldrin	0.069	0.024	35.176	12.000
Chlordane total	3.350	1.143	586.265	200.000
Dieldrin	0.073	0.025	58.627	20.000
Heptachlor	0.261	0.089	586.265	200.000
Heptachlor Epoxide	0.129	0.044	15.243	5.200
Hexachlorobenzene	0.733	0.250	938.024	320.000
Endosulfan I	--	--	7035.176	2400.000
Endosulfan II	--	--	7035.176	2400.000
Endosulfan sulfate	--	--	7035.176	2400.000
Endrin	--	--	351.759	120.000
alpha-BHC	0.186	0.064	--	--
beta-BHC	0.651	0.222	--	--
Lindane (gamma-BHC)	--	--	351.759	120.000
Methoxychlor	--	--	5862.647	2000.000
Mirex	--	--	234.506	80.000
PCB total	0.586	0.200	--	--
PCB total-immun. effects	--	--	23.451	8.000
PCB total-develop. effects	--	--	30.151	10.286
PBDE-47	--	--	117.253	40.000
PBDE-99	--	--	117.253	40.000
PBDE-153	--	--	234.506	80.000
PBDE-209	1675.042	571.429	8207.705	2800.000
PBDE total	--	--	100.000	34.286

1. Dioxin/furan SVs not included as most results are non-detections for these analytes.

Ecological endpoint SVs

We used two different types of SVs for the eco-fish endpoints (Table 6).
General aquatic SVs are concentrations that, if not exceeded in fish tissue, indicate contaminant concentrations that pose little or no unacceptable ecological risk to the fish themselves. These SVs were designed to provide the same level of protection to aquatic species that EPA's water quality criteria for aquatic life provide (i.e. protect 95% of aquatic genera from adverse effects on survival, reproduction, and growth). We note that the general aquatic SV are best looked at as simply a screen and exceedance does

not necessarily indicate a problem. It is also important to note that some of the metals (Cu, Se, Zn) are also essential nutrients, so there are levels that are required by one organism but which would be toxic to another at the same concentration. Methodology for deriving these SVs is described in Dyer et al. 2000. These same methods were used to calculate SVs for several other contaminants of interest using updated toxicological information (Burt Shephard, USEPA, personal communication, 2014).

The second type of ecological endpoint SVs is intended to protect animals that consume those fish, such as predatory fish, fish-eating wildlife, and fish-eating birds. For contaminants that biomagnify as they move up the food chain (e.g., PCB, DDT, Hg, chlordane) the wildlife SVs will be lower than the general aquatic SVs, because they are based on diet. For other non-bioaccumulative contaminants, it will depend on the relative sensitivity of the organism to that specific contaminant.

Kingfisher SVs intended for protecting this common piscivorous bird were available for many of the analytes (Lazorchak et al. 2003). These SVs are based primarily on USEPA guidance (USEPA 1995) that represented an EPA rulemaking involving extensive peer review and a public comment response process. Thus for agency consistency, Lazorchak et al. (2003) is viewed as an extension of this guidance from water to fish tissue. SVs to protect kingfishers from PBDEs in prey fish were not available. However, Environment Canada (2013) developed a PBDE SV for American kestrel, another avian receptor. Mink and otter SVs for protection of these carnivorous mustelids were available for several analytes (Lazorchak et al. 2003). Mustelid SVs are the least conservative of the three ecological endpoints (Table 6).

Table 6. Ecological endpoint SVs used to evaluate MCR whole body fish tissue results. Units are all ng/g (ppb) whole body wet weight (Source: Lazorchak et al. 2003, Dyer et al. 2000 as updated by B. Shephard).

Analyte	General aquatic	Kingfisher	Mink	Otter	General wildlife
Arsenic	227	--	--	--	--
Cadmium	113	--	--	--	--
Chromium	4800	--	--	--	--
Copper	173	--	--	--	--
Lead	189	--	--	--	--
Mercury	60	30	70	100	--
Nickel	390	--	--	--	--
Selenium	560	--	--	--	--
Zinc	5688	--	--	--	--
2,4 DDD	--	20	--	--	--
2,4 DDE	--	20	--	--	--
2,4 DDT	--	20	--	--	--
4,4 DDD	54	20	--	--	--
4,4 DDT	54	20	--	--	--
4,4 DDE	54	20	--	--	--
DDTs total	54	20	360	490	--
Chlordane total	56	5	830	1140	--
Dieldrin	9	360	20	30	--
Hexachlorobenzene	31979	--	--	--	330
PCB total	440	440	130	180	--
PBDE total	--	13(kestrel)[1]	32	--	--

1. Used kestrel as bird ecological endpoint for PBDEs (Source: Environment Canada 2013).

The Eco-fish trace element SVs are developed from testing of the toxic forms of these metals/metalloids. For example, the inorganic form of arsenic (As+3 and As+5) and the methylated fraction of mercury are toxic forms and these are the ones used in the toxicity tests used to establish screening values. Toxic forms are a fraction of the total concentration and the amount of the speciation of toxic forms is variable by chemical. For example, marine species are estimated to have ~2% of arsenic concentrations as inorganic, while the toxic form of mercury, methylmercury, can account for over 90% of mercury concentration in freshwater predator fish species (Eisler1988, USEPA 2006b). The MCR fish samples were analyzed for the total concentration of each of the trace elements (no speciation was analyzed). Therefore, application of some of the trace element screens must be recognized as presenting relatively conservative results.

V. Results

A. Extent of Resource Represented by the Sampling

All of the probabilistic sites were accepted as being part of the sample frame and none were rejected as being ‘unsampleable’ due to physical inaccessibility, safety issues, or access denial. Therefore, the entire target population of 718 river km of the Mid-Columbia is represented by the 42 sampled sites. Table 7 lists the river length represented by sites in each State after applying the site weights. The weighting factor compensates for the fact that the Washington sites were distributed over a longer portion of the MCR reach than the Oregon sites. All 42 sites were sampled. Water quality and habitat data were collected at all sites. HH-fish were not captured at one site and Eco-fish were not captured at five sites.

Table 7. Summary of MCR sampling extent by State.

State	Sites	Site weight	Reach extent (rkm)
Oregon	23	11.2	258.3
Washington	19	24.2	460.2
Totals:	**42**		**718.5**

B. Extent of Fish Species Sampled

1. HH-fish

HH fish species were collected from 18 of the 19 sites in Washington, and from all 23 of the probability sites in Oregon (Figure 2). In the upper portion of the survey reach, largescale suckers (*Catostomus macrocheilus*) were the only sizeable resident fish consumed by people that we were able to capture in sufficient numbers. This was a lower priority species because largescale suckers are benthivorous (consume periphyton and insect larva) rather than piscivorous, which was our preference (USEPA 2008b). Smallmouth bass (*Micropterus dolomieu*) were consistently available in the lower portion of the survey reach and were collected for tissue samples almost exclusively from sites located in the lower half of Hanford Reach (Map 1) downstream. Additional details describing HH fish composite samples are in Appendix 7.

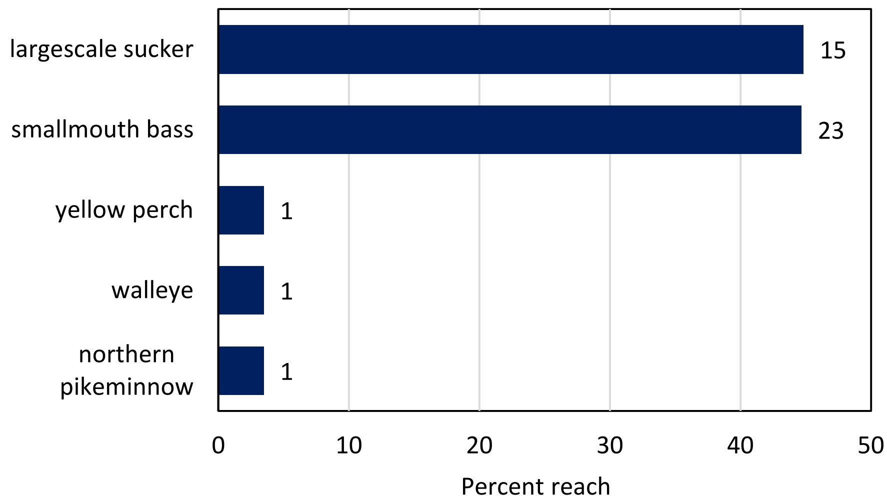


Figure 2. MCR reach extent represented by the species sampled for HH-endpoint tissue with sample counts.

2. Eco-fish

Eco-fish species were collected from 18 of the 19 probability sites in Washington, and from 19 of 23 probability sites in Oregon for a total of 37 sites (Figure 3). Most composite fish samples complied with the similar-size rule, although it was violated at three sites. The maximum-size rule of 200 mm was also violated at three sites. Even when the size rule was violated, fish were still small and the appropriate size for prey items for wildlife. The largest fish sampled was 257mm (10in) total length. Although ODEQ did not record fish minimum and maximum length for the Eco-fish sample, all but three were cottids, which are small fish, (<200 mm). The three non-cottid species included in the sampling were northern pikeminnow (*Ptychocheilus oregonensis*), redside shiner (*Richardsonius balteatus*), and largescale sucker.

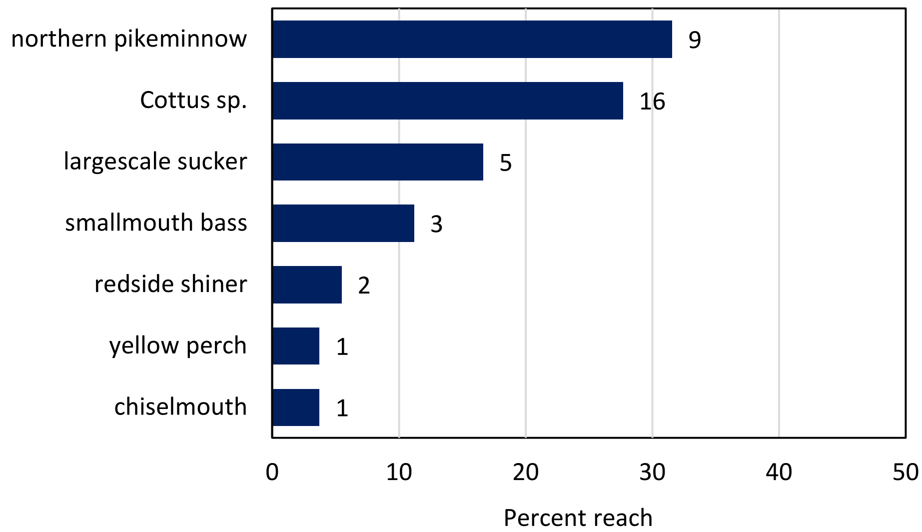


Figure 3. MCR extent represented by the species sampled for eco-endpoint tissue with sample counts.

Sculpin species (family Cottidae), northern pikeminnow, and largescale suckers together represent 76% of the river length in the survey. The small-sized (juvenile) northern pikeminnow and largescale suckers are more available as prey to other species as they are larger and use a wide variety of the riverine habitat. In contrast, sculpins are benthic and therefore not as readily available as a prey species for wildlife and piscivores. Sculpins were therefore considered a lower priority species for this study (USEPA 2008a). Sculpins were collected as the eco-endpoint species by ODEQ at almost all of the Oregon sites, and represent approximately 28% of the river length in the assessment. Details of Eco-fish composite samples by site are in Appendix 8.

C. Fish Tissue Results – Human Health Endpoints

Summary statistics for fillet tissue contaminants include results for all chemicals that have sufficient data for calculating percentiles (< 45% of samples as non-detects). Statistics were calculated using the weighing factors described above. The following apply to these results:

- All results reported as wet weight and expressed as mass of the chemical per unit mass fish tissue in ng/g (ppb) for all chemicals.
- For organic chemicals reported as not detected at the minimum detection limit (MDL) we reported these as zero, although there is a possibility that the chemical is present. This can result in biasing the summary statistics low. For metals, we used the reporting limit values to represent the non-detects, so those summary statistics may be biased high. The rationale for this is that metals do occur naturally in water.

- A number of the chemicals analyzed were not detected in any of the fillet samples (e.g., dioxin/furans) and others were detected infrequently (e.g., aldrin, endosulfan II, and delta- BHC). Percentiles were not calculated for these chemicals that lack sufficient data needed for adequate resolution in a cumulative distribution function.
- Cumulative distribution functions (CDF) plots of chemical concentration (x-axis) versus the cumulative percent of river kilometers (y-axis) from the sampled population were generated for the commonly detected chemicals (Appendix 12). These graphs show the 90% confidence bounds.

Chemicals with both sufficient data above the MDL and SVs available for comparison are presented in greater detail in this section. These include mercury, DDTs, several other chlorinated pesticides, total PCBs, and total PBDEs. R statistics software (version 3.1.1, R Core Team 2013) and the spsurvey package (Kincaid and Olsen 2015) were used to estimate the percentiles and the cumulative distribution of tissue concentrations for each analyte. Summary statistics are shown in Table 8 for the chemicals that have SVs available for comparison. Results are compared to the SVs calculated for each of the two consumption rates described above (Table 5). We calculated the percent of the MCR extent that exceeded human health SVs by comparing each SV to the R output. Using each SV as a cut-off, we reported the reach percentile corresponding to the analyte quantity. Exceedances of the human health SVs are expressed as MCR reach extent (rkm) percentiles (Table 9).

Table 8. Summary statistics and percentile results for HH (fillet) analytes with available SVs, MCR (N=718 rkm).

HH-fish analytes ng/g ww	Min.	10th	25th	50th	75th	90th	Mean	Max.	S.E. of Mean	%Non-detect [1]
Mercury	70	80	120	190	280	450	241	750	6	0
2,4 DDD	0.016	0.103	0.138	0.479	3.010	6.080	1.905	6.980	0.0855	0
2,4 DDE	0.020	0.043	0.081	0.201	0.761	1.500	0.520	1.770	0.0209	0
2,4 DDT	0.015	0.028	0.042	0.127	0.456	0.943	0.311	1.180	0.0127	0
4,4 DDD	0.189	0.703	1.350	3.770	20.100	43.600	13.217	47.200	0.5827	0
4,4 DDE	2.650	7.260	12.400	31.300	92.800	181.000	64.677	226.000	2.4939	0
4,4 DDT	0.099	0.166	0.280	1.010	4.080	8.290	2.676	11.100	0.1155	0
DDTs total [2]	3.191	8.316	15.039	43.621	117.108	234.375	83.306	289.553	3.2826	0
alpha-BHC	0.006	0.007	0.008	0.010	0.014	0.030	0.014	0.050	0.0004	0
beta-BHC	0.000	0.000	0.003	0.004	0.005	0.010	0.005	0.027	0.0002	20
Dieldrin	0.013	0.033	0.070	0.087	0.174	0.476	0.172	1.050	0.0082	0
Endosulfan I	0.000	0.000	0.000	0.150	0.438	0.959	0.405	2.550	0.0245	46
Endosulfan sulfate	0.000	0.000	0.000	0.057	0.125	0.262	0.115	0.915	0.0076	41
Endrin	0.017	0.047	0.068	0.115	0.220	0.407	0.175	0.895	0.0067	0
gamma-BHC (Lindane)	0.000	0.004	0.005	0.008	0.013	0.018	0.010	0.037	0.0003	15
Heptachlor	0.000	0.001	0.001	0.003	0.005	0.015	0.005	0.021	0.0002	7
Heptachlor epoxide	0.003	0.006	0.014	0.024	0.044	0.101	0.039	0.152	0.0014	0
Hexachlorobenzene	0.103	0.122	0.155	0.239	0.394	0.733	0.337	1.120	0.0093	0
Methoxychlor	0.036	0.046	0.072	0.090	0.130	0.342	0.160	1.490	0.0100	0
Mirex	0.003	0.005	0.007	0.014	0.026	0.048	0.018	0.050	0.0005	0
Chlordane total [3]	0.061	0.155	0.242	0.512	0.747	1.566	0.690	2.871	0.0263	0
PCB total[4]	1.372	2.638	5.297	12.409	28.844	70.827	20.985	85.266	0.8867	0
PBDE-047	0.327	0.663	1.690	5.080	7.890	15.600	6.449	34.600	0.2788	0
PBDE-099	0.035	0.054	0.099	0.222	0.375	1.160	0.410	1.780	0.0184	0
PBDE-153	0.016	0.036	0.045	0.070	0.119	0.239	0.108	0.425	0.0037	0
PBDE-209	0.000	0.076	0.099	0.136	0.223	0.248	0.171	1.280	0.0063	5
PBDE total[5]	0.800	1.295	2.779	7.328	10.963	21.368	9.278	47.957	0.3782	0

1. % Non-detect refers to percent of samples analyzed. 2. Total DDTs is the sum of the six analytes
3. Total chlordane is the sum of alpha-chlordane, gamma-chlordane, oxychlordane, cis-nonachlor, and trans-nonachlor.
4. Total PCB is the sum of all 172 congeners analyzed. 5. Total PBDE is the sum of all 34 congeners analyzed.

Table 9. Summary of human health (fillet) SV exceedances expressed as % MCR reach (N=718 rkm).

Analyte	General Population			High Consumer		
	SV (ng/g ww)	SV exceed (% reach)	Std. error	SV (ng/g ww)	SV exceed (% reach)	Std. error
			Non-cancer risk type			
Mercury[1]	120	74.2	6.7	40	100.0	3.9
DDTs total	502.513	0.0	0.0	171.429	17.4	5.6
PCBs total (immune effects)	23.451	26.7	7.1	8.000	60.7	5.7
PCBs total (devel. effects)	30.151	21.4	6.7	10.286	55.4	6.3
PBDEs total	100.000	0.0	0	34.286	3.6	3.1
			Cancer risk type			
4,4-DDD	4.886	44.8	6.4	1.667	67.1	4.9
4,4-DDE	3.449	94.9	3.2	1.177	100.0	0
4,4-DDT	3.449	31.1	6.3	1.177	46.5	6.5
DDTs total	3.449	94.9	3.2	1.177	100.0	0.0
Chlordane total	3.350	0.0	0.0	1.143	16.9	5.2
Dieldrin	0.073	66.9	5.4	0.025	91.7	3.8
Heptachlor epoxide	0.129	3.5	3.0	0.044	23.9	6.2
Hexachlorobenzene	0.733	8.6	4.5	0.250	46.5	6.5
PCBs total	0.586	100.0	3.1	0.200	100.0	3.2

1. The EPA mercury fish tissue residue criterion of 300 ng/g was exceeded in 23.9% of the reach.

1. Mercury

Mercury was detected in all fillet samples. The non-cancer risk general population SV for mercury was exceeded in 74.2% of the river reach and the SV for high fish consumers was exceeded in 100% of the river reach (Figure 4). A third SV is the USEPA recommended fish tissue based water quality criterion of 300 ng/g (ppb) mercury in fish tissue (USEPA 2001), which was exceeded in 23.9% of the reach extent.

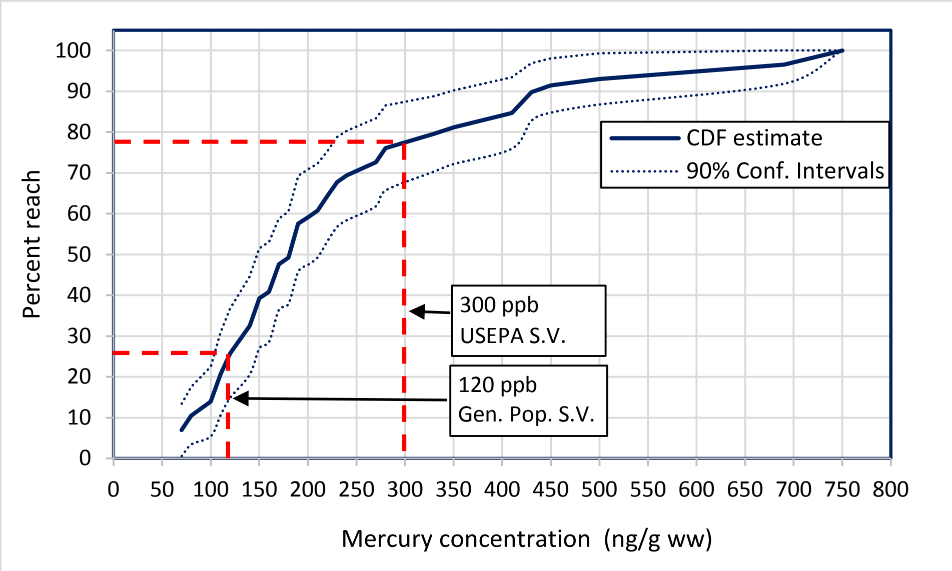


Figure 4. CDF plot of mercury concentrations in fillet fish tissue, MCR reach (N=718).

2. DDT and Related Compounds

Summary statistics for DDT and its breakdown products in fillet tissue are shown in Table 8 and CDFs with 90% confidence bounds are in Appendix 12. All six DDT breakdown products were detected in all samples. Exceedances of cancer risk SVs for total DDT for both consumption rates were ubiquitous (94.9% and 100%). Cancer risk SV exceedances of the individual breakdown products are also generally widespread (Figure 5). A non-cancer SV was available only for total DDT (sum of the six breakdown products). This SV was not exceeded for the general population, but was exceeded for the high fish consumption rate in 17.4% of the river reach.

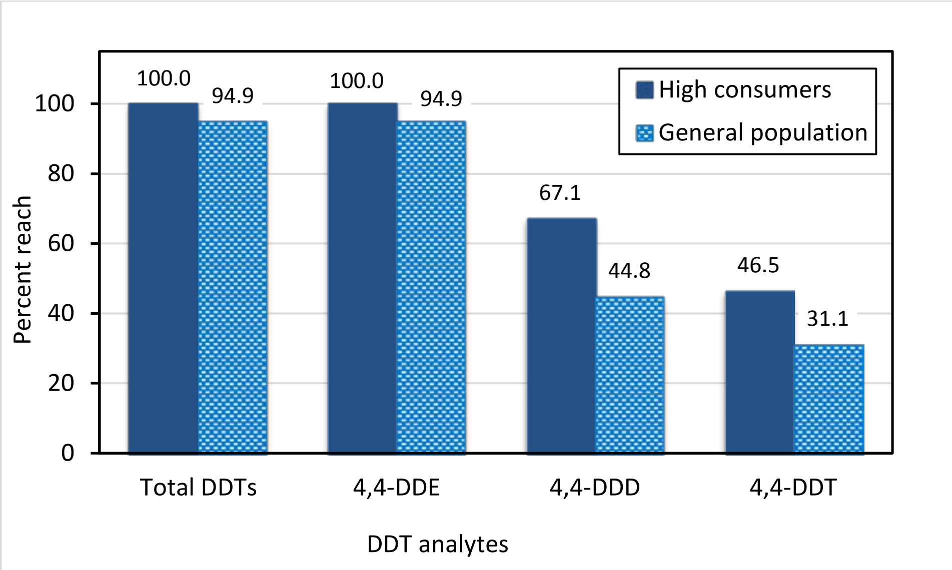


Figure 5. Percent of MCR reach exceeding the DDT and DDT breakdown products human-health cancer SVs in fillet tissue (N=718 rkm).

3. Chlorinated Pesticides

Summary statistics for other chlorinated pesticides in fillet tissue are shown in Table 8 and CDFs with confidence bounds are in Appendix 12. Some compounds such as aldrin, endosulfan II, and delta- BHC were rarely detected and are therefore not included in Table 8. Others such as heptachlor, endrin, and mirex, were widely detected, but not at concentrations above the available SVs for the general population and high consumers.

Four of the tested pesticides exceeded cancer risk SVs: total chlordane, dieldrin, heptachlor epoxide, and hexachlorobenzene (Table 9, Figure 6). Dieldrin showed the most widespread exceedance of the cancer risk SV, at approximately 66.9% and 91.7% of the river reach for general population and high consumers, respectively. For high consumers, the cancer SVs for heptachlor epoxide and hexachlorobenzene were exceeded in 23.9% and 46.5% of the river reach, respectively. The same pesticides exceeded the risk SV for the general population consumption rate in only 3.5% and 8.6% of the reach. Total chlordane (sum of alpha chlordane, cis-nonachlor, trans-nonachlor and oxychlordane --transchlordane is not part of this data set) exceeded the high consumer SV in 16.9% of the reach. None of the pesticides analyzed exceeded the non-cancer risk SVs.

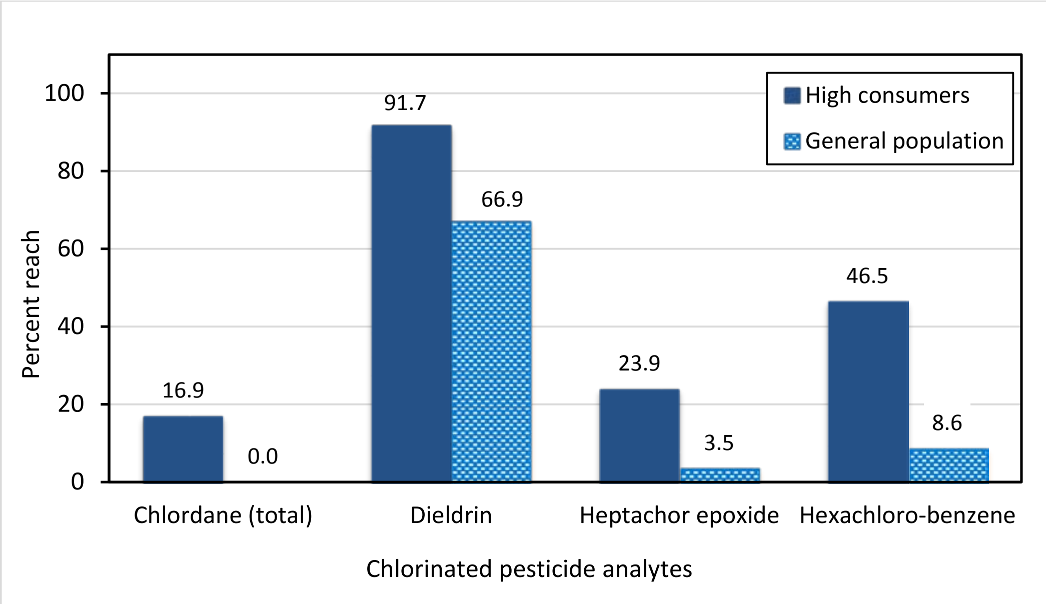


Figure 6. Percent of MCR reach exceeding the four chlorinated pesticides human health cancer SVs in fillet tissue (N=718 rkm).

4. Dioxins and Furans

Eighteen dioxins and furans were analyzed but were all very rare in the fillet samples. (Table 10). Individual analytes that have SVs were not detected.

Table 10. List of Human health (fillet) dioxins and furans included in MCR analysis.

Analyte	%Non-detect[1]	Analyte	%Non-detect[1]
1,2,3,4,6,7,8-HpCDD	98	1,2,3,7,8-PeCDD	98
1,2,3,4,6,7,8-HpCDF	95	1,2,3,7,8-PeCDF	98
1,2,3,4,7,8,9-HpCDF	98	2,3,4,6,7,8-HxCDF	98
1,2,3,4,7,8-HxCDD	98	2,3,4,7,8-PeCDF	98
1,2,3,4,7,8-HxCDF	98	2,3,7,8-Substituted Dioxin/Furans	73
1,2,3,6,7,8-HxCDD	98	2,3,7,8-TCDD	100
1,2,3,6,7,8-HxCDF	98	2,3,7,8-TCDF	76
1,2,3,7,8,9-HxCDD	98	OCDD	90
1,2,3,7,8,9-HxCDF	98	OCDF	98

1. Summary statistics were calculated with non-detects set to zero. 'Non-detect percent observations' refers to the percent of samples analyzed.

5. PCBs

PCB analysis included 172 congeners (Appendix 5). All fillet samples contained measurable PCBs. Summary statistics for 107 PCBs congeners that were commonly detected in the fillet tissue samples are in (Appendix 9) and CDFs with confidence bounds are in Appendix 12. Forty-five PCB congeners were relatively less common in the samples (detected in <45% of the samples) and 20 congeners were not detected in any sample (Appendix 10).

The only PCB SVs available are for 'total' PCBs for cancer risk and for two types of non-cancer risk at both consumption rates (Table 9). We compared these SVs to the calculated sum of all PCBs that the lab analyzed. The total PCB cancer risk SVs for both the general population and high consumers were exceeded for the entire MCR. The screening level for PCB immune effects is slightly lower than that for developmental effects, but both of those non-cancer risk types were exceeded for the general population in 26.7% and 21.4% of the river length, and for the high consumers in 60.7 and 55.4% of the river length. These exceedances are compared in Figure 7.

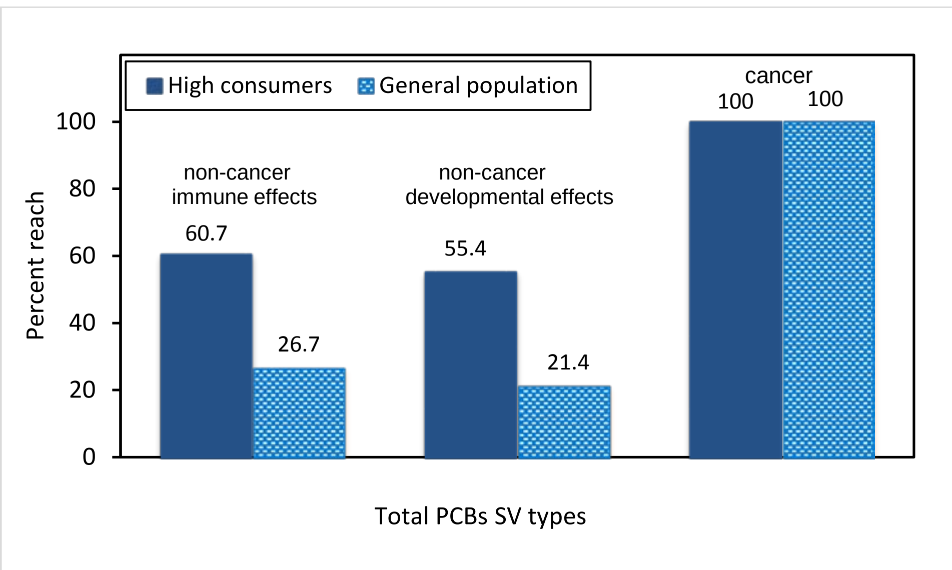


Figure 7. Percent of MCR reach exceeding the total PCBs cancer and non-cancer SVs in fillet tissue (N=718 rkm).

6. PBDEs

Fillet samples were analyzed for 34 PBDE congeners (Appendix 4). Summary statistics for the common PBDEs (detected in > 45% of samples) are in Appendix 9 and CDFs with confidence bounds are in Appendix 12. Ten PBDE analytes were not detected in a majority of samples and CDFs were not generated for those (PBDE 119, 126, 138, 171, 180, 191, 196, 201, 203, 207).

Human health SVs are available for 'total' PBDEs and four congeners (PBDE 47, 99, 153, and 209) (Table 9). As with total PCBs, the total PBDEs SV was compared to the sum of all detected PBDEs found in the samples. The PBDEs with SVs were widely detected, but SV exceedances were minimal (Figure 8). Only the non-cancer high-consumption SV for total PBDEs was exceeded in an estimated 3.6% of the Mid-Columbia.

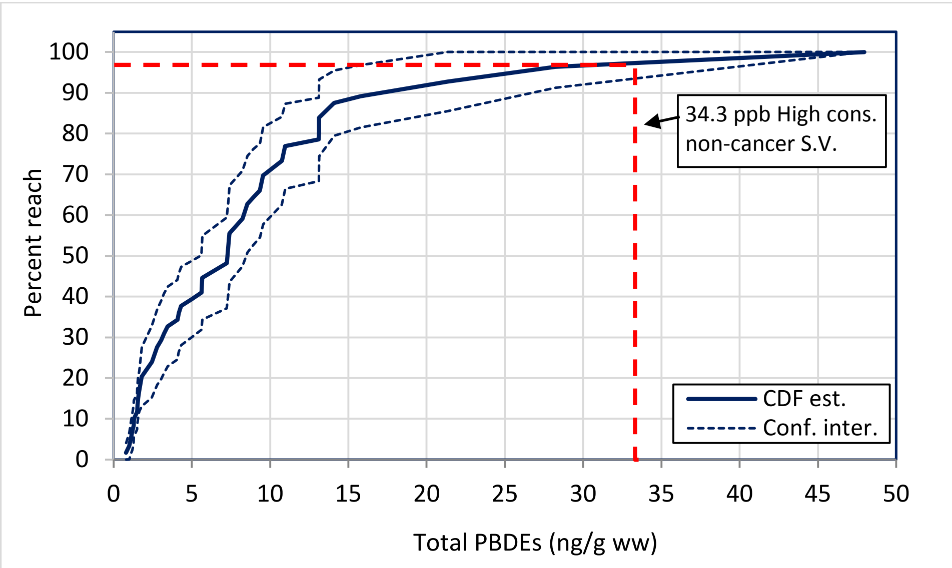


Figure 8. CDF plot of total PBDEs in fillet fish tissue, MCR reach (N=718).

D. Fish Tissue Results– Ecological Endpoints

As with fillet samples, fish tissue data for whole fish samples are described using summary statistics for the entire MCR (Table 11). As noted in the methods, we replaced non-detects with zeros for organic chemicals data analysis (as in the EMAP estuary study). This can result in biasing summary statistics low. For metals, which occur naturally in water, we used the reporting limit values to replace zeros, so statistics may be biased high for lead and zinc. Most analytes are reported in ng/g wet weight except metals (µg/g wet weight). SVs were available for 21 of the ecological endpoint analytes (Table 6). Twelve analytes exceeded one or more SV over some portion of the MCR reach (Table 12). CDF plots with 90% confidence bounds were generated for the commonly detected chemicals (Appendix 13).

Table 11. Summary statistics and percentile results for Eco-fish tissue (whole body), MRC (N=718 rkm).

Analyte	Units	Min.	10th	25th	50th	75th	90th	Mean	Max.	S.E. of Mean	%ND[1]
Arsenic	µg/g ww	0.033	0.042	0.073	0.140	0.231	0.289	0.152	0.384	0.004	0
Cadmium	µg/g ww	0.004	0.012	0.015	0.025	0.045	0.063	0.032	0.083	0.001	0
Chromium	µg/g ww	0.083	0.101	0.168	0.235	0.320	0.359	0.258	0.865	0.006	0
Copper	µg/g ww	0.503	0.661	0.777	0.974	1.501	2.360	1.330	4.298	0.037	0
Lead	µg/g ww	0.036	0.044	0.047	0.050	0.062	0.212	0.105	0.831	0.006	65
Mercury	µg/g ww	0.013	0.019	0.023	0.031	0.045	0.060	0.037	0.118	0.001	0
Nickel	µg/g ww	0.019	0.034	0.086	0.330	0.500	2.047	0.625	5.971	0.046	5
Selenium	µg/g ww	0.103	0.314	0.345	0.374	0.488	0.550	0.412	0.732	0.004	0
Zinc	µg/g ww	12.080	13.882	15.694	19.067	26.394	32.375	21.221	32.804	0.260	0
2,4' DDD	ng/g ww	0.000	0.000	0.225	0.954	2.032	4.256	1.332	5.436	0.058	32
2,4' DDE	ng/g ww	0.000	0.000	0.200	0.521	1.092	1.710	0.658	2.016	0.024	32
2,4' DDT	ng/g ww	0.000	0.000	0.000	0.253	0.337	0.707	0.276	1.232	0.010	38
4,4' DDD	ng/g ww	0.316	1.665	2.509	9.658	18.987	32.905	12.789	41.720	0.470	0
4,4' DDE	ng/g ww	2.811	13.365	19.804	49.273	106.701	163.740	71.218	231.219	2.505	0
4,4' DDT	ng/g ww	0.000	0.000	0.175	0.598	1.127	1.527	0.688	2.131	0.023	16
Total DDTs[2]	ng/g ww	3.127	15.628	22.871	59.411	130.945	207.075	86.962	269.757	2.993	0
Dieldrin	ng/g ww	0.000	0.284	0.328	0.526	0.650	1.012	0.567	1.827	0.012	3
HCBenzene	ng/g ww	0.000	0.000	0.325	0.491	0.627	0.870	0.499	1.584	0.012	8
T_Nonachlor	ng/g ww	0.000	0.000	0.268	0.404	0.688	1.061	0.591	3.924	0.029	8
A_Chlordane	ng/g ww	0.000	0.000	0.000	0.176	0.377	0.551	0.378	5.089	0.037	32
G_Chlordane	ng/g ww	0.000	0.000	0.000	0.000	0.171	0.244	0.161	2.338	0.017	43
Oxychlordane	ng/g ww	0.000	0.000	0.000	0.152	0.196	0.253	0.191	2.458	0.018	43
Chlordane total[3]	ng/g ww	0.000	0.000	0.280	0.634	1.372	2.065	1.357	14.640	0.106	8
PCB-052	ng/g ww	0.000	0.000	0.373	0.448	0.690	1.245	0.560	2.143	0.020	22
PCB-066	ng/g ww	0.000	0.265	0.348	0.471	0.795	1.134	0.611	2.695	0.020	8
PCB-077	ng/g ww	0.000	0.000	0.000	0.233	0.417	0.717	0.301	3.690	0.021	41
PCB-101	ng/g ww	0.000	0.646	0.776	1.694	2.437	3.255	1.849	5.497	0.049	3
PCB-105	ng/g ww	0.000	0.181	0.262	0.383	0.852	1.180	0.548	1.871	0.017	5
PCB-118	ng/g ww	0.498	0.809	1.050	1.453	2.685	3.649	1.878	6.085	0.050	0
PCB-128	ng/g ww	0.000	0.000	0.227	0.323	0.546	0.853	0.394	1.297	0.012	14
PCB-138	ng/g ww	1.303	1.713	2.313	3.109	3.995	4.877	3.349	9.010	0.061	0
PCB-153	ng/g ww	0.691	1.211	1.519	2.050	3.175	4.230	2.439	6.950	0.052	0
PCB-170	ng/g ww	0.000	0.000	0.000	0.269	0.357	0.521	0.224	0.721	0.008	46
PCB-180	ng/g ww	0.000	0.396	0.455	0.638	0.879	1.544	0.846	4.142	0.027	3
PCB-187	ng/g ww	0.000	0.302	0.359	0.537	0.756	1.121	0.623	1.791	0.014	3
PCBs total[4]	ng/g ww	3.600	5.868	8.591	11.869	18.148	26.593	13.912	36.598	0.303	0
PBDE-047	ng/g ww	0.000	3.019	3.600	4.527	5.975	9.363	5.157	13.509	0.102	3
PBDE-100	ng/g ww	0.000	0.000	0.542	0.834	1.277	1.889	0.914	3.176	0.025	19
PBDEs total[5]	ng/g ww	0.542	3.528	4.406	5.253	7.408	11.208	6.227	16.685	0.123	0

1. % Non-detect refers to percent of samples analyzed. **2.** DDT Total is the sum of the six analytes. **3**. Total chlordane is the sum of alpha-chlordane, gamma-chlordane, oxychlordane, cis-nonachlor, and trans-nonachlor concentrations. **4.** Total PCB is the sum of the concentration of 21 congeners analyzed. **5.** Total PBDE is the sum of the concentration of 8 congeners analyzed.

Table 12. Eco-fish tissue (whole body) SV exceedances expressed as % MCR reach (N=718 rkm).

Analyte	General Aquatic			Kingfisher			Mink			Otter		
	SV (ng/g)	reach (%)	Std. error	SV (ng/g)	reach (%)	Std. error	SV (ng/g)	reach (%)	Std. Error	SV (ng/g)	reach (%)	Std. error
Arsenic[2]	227	24.8	4.15	--	--	--	--	--	--	--	--	--
Copper	173	100.0		--	--	--	--	--	--	--	--	--
Lead	189	12.9	5.17				--	--	--	--	--	--
Mercury	60	6.9	2.64	30	48.9	6.88	70	5.2	2.57	100	1.7	1.50
Nickel	390	37.3	6.82	--	--	--	--	--	--	--	--	--
Selenium	560	9.2	4.63	--	--	--	--	--	--	--	--	--
Zinc	5688	100.0		--	--	--	--	--	--	--	--	--
4,4 DDD	54	0.0		20	18.7	5.01	--	--	--	--	--	--
4,4 DDE	54	44.5	5.94	20	73.2	4.37	--	--	--	--	--	--
DDTs total	54	55.7	5.03	20	85.6	4.14	360	0.0		490	0.0	
Chlordane total	56	0.0		5	3.7	3.14	830	0.0		1140	0.0	
PBDEs total	--	--	--	13[1]	5.5	3.46	32	0.0		--	--	--

1. Kestrel as avian ecological endpoint for PBDEs (Source: Environment Canada 2013).
2. Arsenic SV calculated from inorganic fraction while results are total arsenic thus exceedence is an overestimate

1. Inorganics-- Mercury and Trace Metals/metalloids

General aquatic SVs for copper and zinc were exceeded in the entire reach. Several other trace elements exceeded their SVs in a smaller percentage of the river (Table 12, Figure 9). Besides the general aquatic SV, we used three other mercury SVs from the literature for comparison (Table 6). Exceedances of these wildlife SVs are shown in Figure 10. The most stringent of the wildlife SVs is the one for the kingfisher, which is exceeded in almost half of the MCR reach. As discussed in the methods, the SV for arsenic is conservative because it is generated using only inorganic forms (As^+3 and As^+5) while the MCR tissue data is the total arsenic concentration. Thus, the exceedance is likely higher than if speciation data were available for comparison.

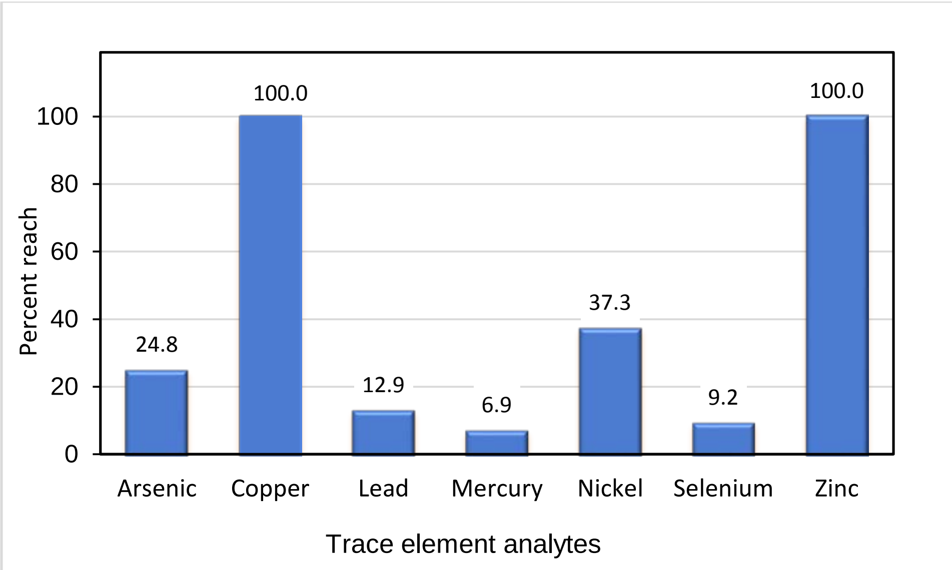


Figure 9. Percent of MCR reach exceeding the trace element general aquatic SVs in whole-fish tissue (N=718 rkm).

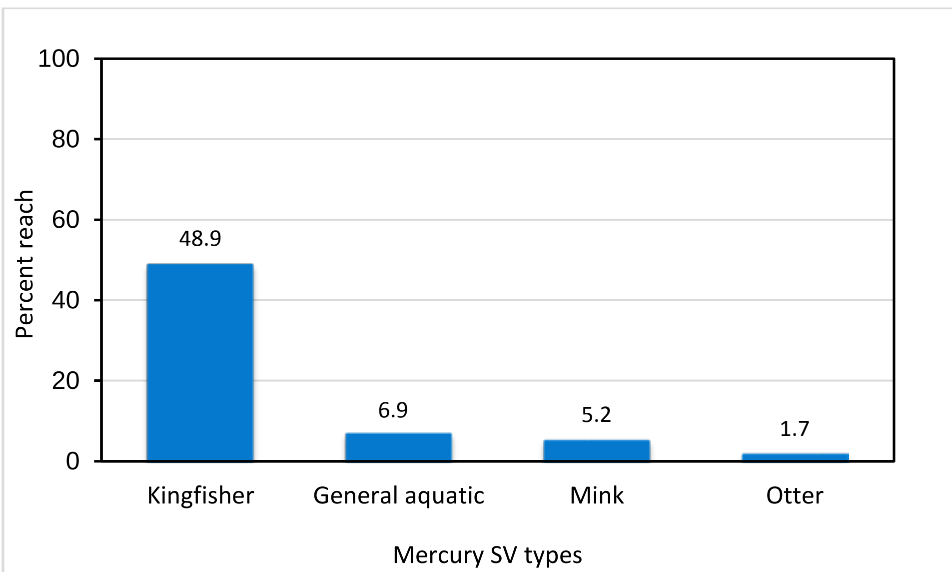


Figure 10. Percent of MCR reach exceeding four mercury SVs in whole-fish tissue (N=718 rkm).

2. DDTs

Summary statistics for DDT and breakdown products in whole fish samples are shown in Table 11 and CDFs with confidence bounds are in Appendix 13. All samples contained DDT and exceedances of SVs were widespread, especially for the most stringent kingfisher SV (Table 12, Figure 11).

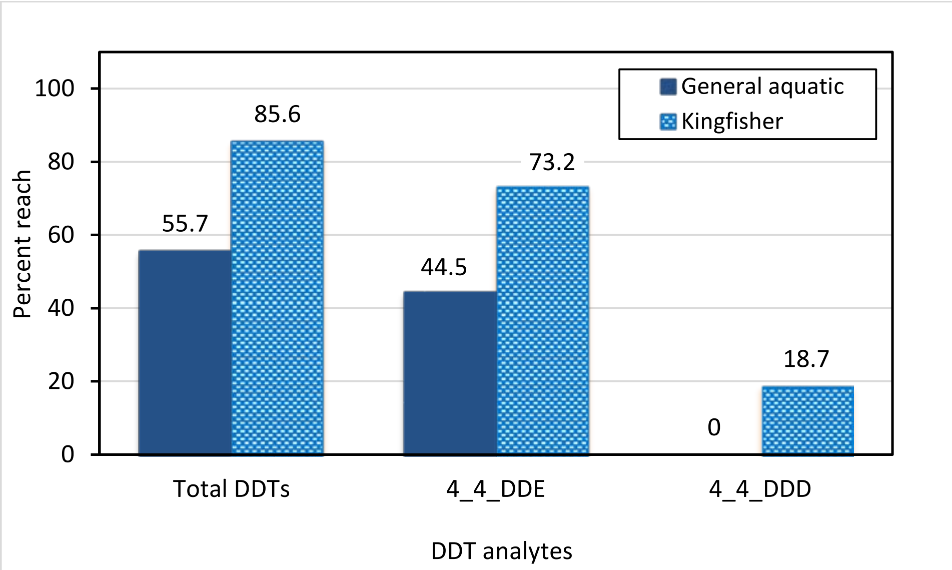


Figure 11. Percent of MCR reach exceeding the DDT SVs in whole fish tissue (N=718 rkm).

3. Chlorinated Pesticides

Besides DDTs, 17 other chlorinated pesticides were analyzed (Table 11). Of these, detection rates ranged from zero for aldrin and heptachlor to 97% for dieldrin. SVs were available for total chlordane, dieldrin and hexachlorobenzene (Table 6). The only SV exceeded was the kingfisher SV (5 ng/g ww) for total chlordane, in 3.7% of the MCR reach (Figure 12).

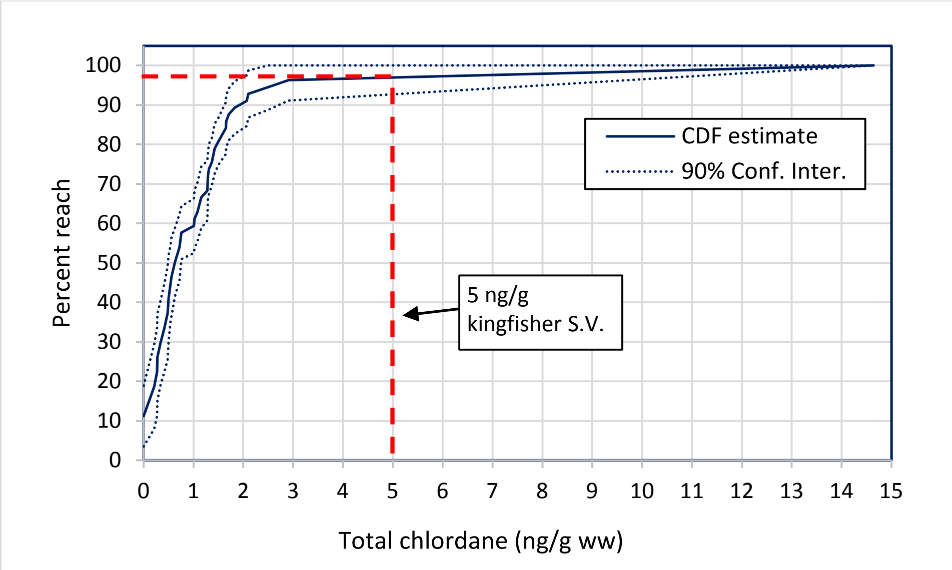


Figure 12. CDF plot of total chlordane concentrations in whole fish tissue, MCR reach (N=718 rkm).

4. PCBs

All but 4 of the 21 PCB congeners analyzed were detected in whole fish samples (Appendix 11) and several were commonly present in the Mid-Columbia Eco-fish (Table 11). Total PCBs were calculated (sum of all PCB analytes) and compared to the available total PCB SVs for general aquatic life, otter, mink, and kingfisher (Table 6). None of these total PCBs SVs were exceeded. The CDF for total PCB is shown in Figure 13.

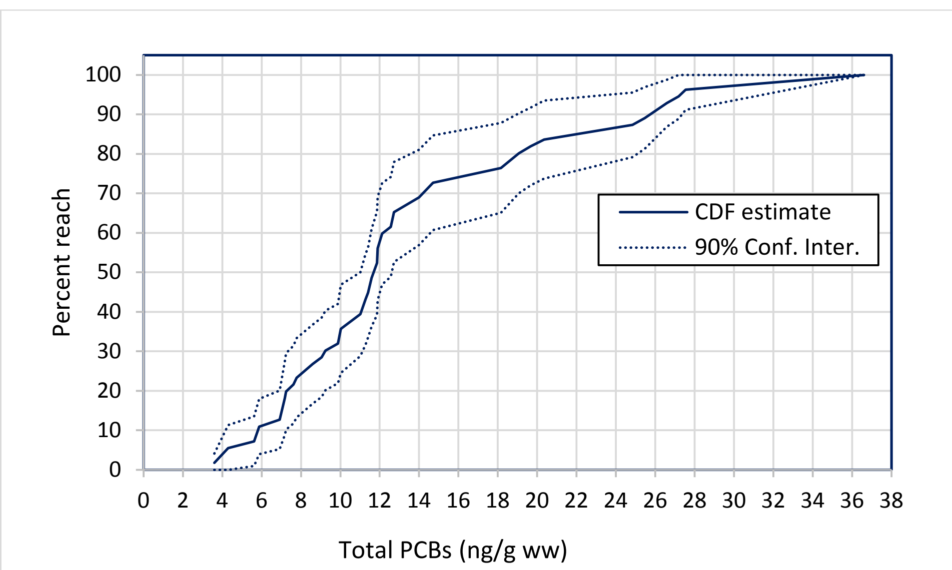


Figure 13. CDF plot of total PCBs concentration in whole fish tissue, MCR (N=718 rkm).

5. PBDEs

Eight PBDE congeners were analyzed in Eco-fish tissue: 47, 66, 99, 100, 138, 153, 154, and 183 (Appendix 11). Only congeners 47 and 100 were commonly detected and five of the eight were not detected in any samples. Summary statistics for these and total PBDE are in Table 11. We compared total PBDEs to the two wildlife SVs available for total PBDE; kestrel at 13 ng/g and mink at 32 ng/g. Only the kestrel SV was exceeded in 5.5 % of the MCR reach (Table 12, Figure 14).

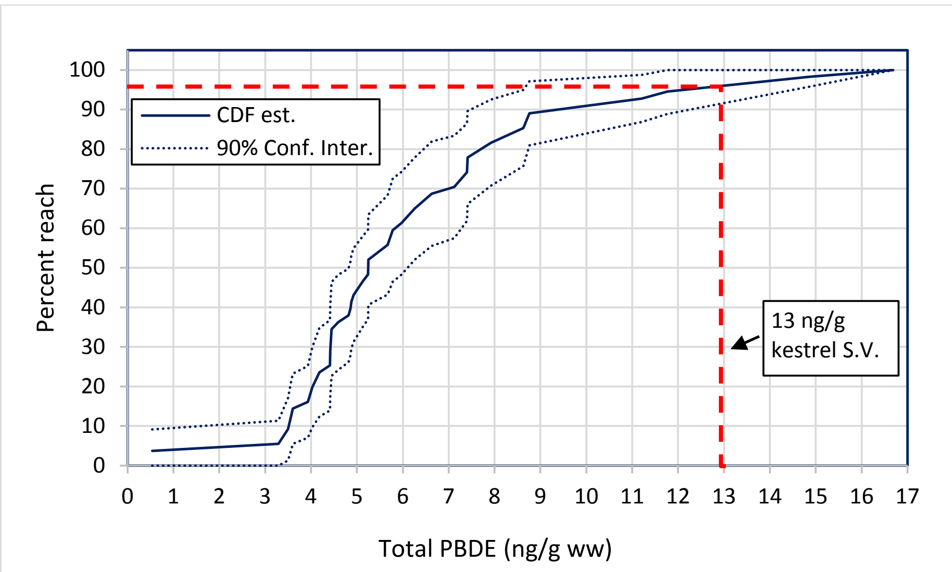


Figure 14. CDF plot of total PBDE concentration in whole fish tissue, MCR (N=718 rkm).

VI. Discussion

A. Relative Extent of Contaminants of Concern (COCs)

We used screening value comparisons to synthesize the Mid-Columbia results. Although screen exceedances do not necessarily mean there is a problem, they are useful for signaling possible concerns, communicating results, and making comparisons between studies. Results of this analysis fell into four types of outcomes: 1) analytes that proved to be COCs in the MCR (SVs exceeded), 2) analytes that are not of concern in the MCR (SVs not exceeded), 3) analytes that are prevalent in tissue samples but cannot be evaluated at the present time due to lack of HH or ECO benchmarks (no SV available), and 4) analytes that were so rare that they were not quantified as COCs.

1) Many of the analytes are well known as human and wildlife contaminants. They have been sufficiently studied and have established SVs useable as benchmarks for comparison. The results of these particular analytes can therefore be quantified and can be placed in order of extend of Mid-Columbia reach that exceeds a particular SV (i.e. relative ranking). For human health, PCBs, DDTs, and mercury are the contaminants that exceed their SVs in the greatest percentage of the MCR, all >70% of the reach (Figure 15). This high ranking is consistent regardless of the consumption rate used--both high consumers and the general population. Several other pesticides are COCs in the MCR but to a lesser extent (chlordane, hexachloro-benzene, and heptachlor epoxide). PBDEs are the lowest ranked of the human health COCs identified in the reach.

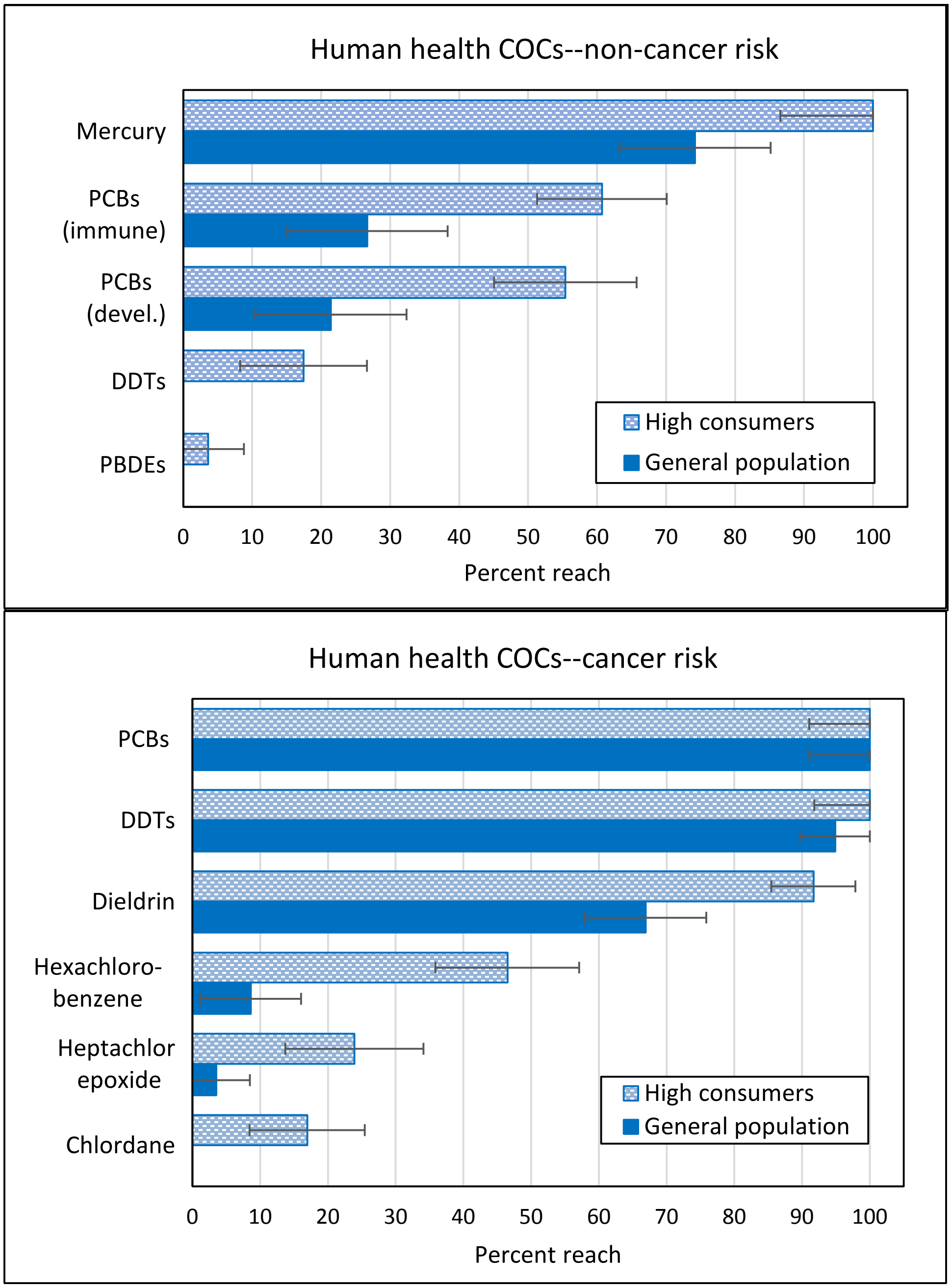


Figure 15. Exceedances of Human Health SVs, cancer and non-cancer with 90% confidence bounds.

For wildlife, copper and zinc are ubiquitous COCs (Figure 16). Mercury is moderately prevalent while the other trace elements are less so. Since the chemicals analyzed vary between the HH and Eco-fish tissue samples, differences in COCs identified and their relative ranking are expected. For example, trace elements were not tested in HH- fish tissue and the list of PCB analytes is very limited for Eco-fish tissue (21) compared to HH-fish tissue (172). However, we do see consistency between ranking of HH and Eco-fish COCs (Figure 15 and Figure 16). DDT and mercury are extensive COCs for both tissue types, while chlordane and PBDEs COCs are limited in extent for both (< 10% of reach exceeding SVs).

2) The second type of result was for chemicals with SVs that did not exceed the SV for any proportion of the reach. For human health tissue, twelve pesticide analytes had low sample concentrations or had a substantial number of non-detects. We also compared results to four individual PBDE congener SVs (PBDE-47, -99, -153, and -209). These SVs were not exceeded, however, PBDE-47 was commonly detected and had relatively high concentrations. PBDE-47 and PBDE-99 are considered the predominant congeners in fish tissue (USEPA 2010b, Stahl et al. 2013).

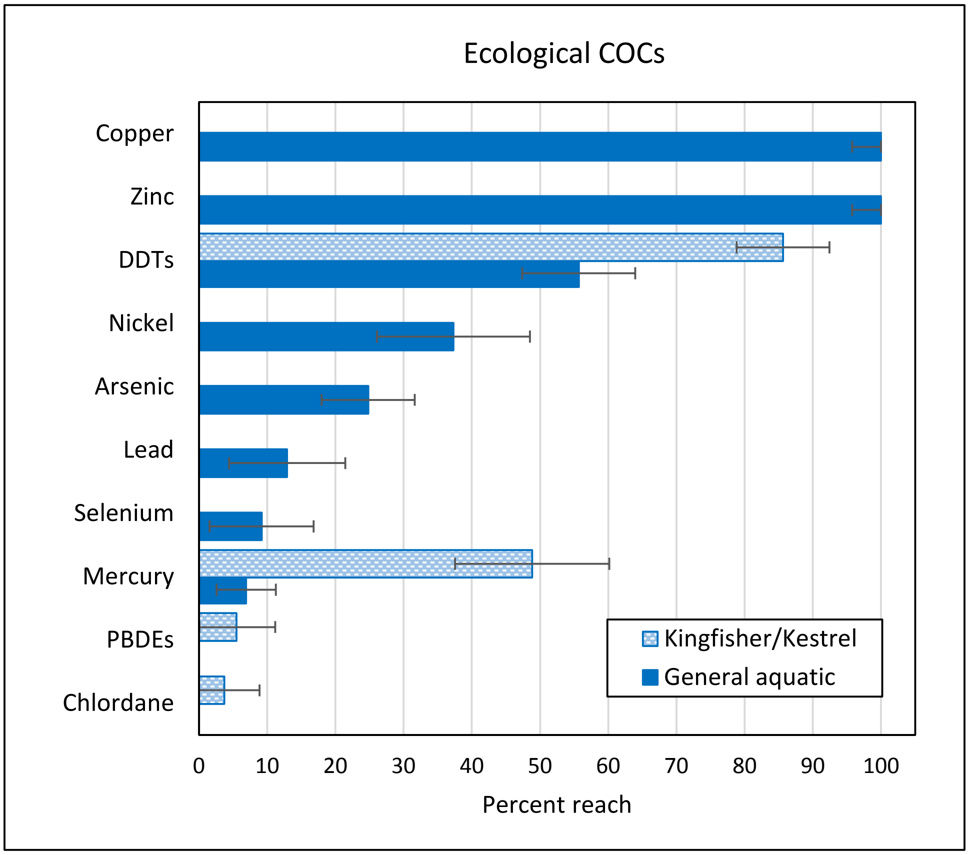


Figure 16. SV exceedence for Eco fish analytes, with 90% confidence bounds.

Eco-fish tissue SVs were available for all of the trace elements tested. Of these, only cadmium and chromium were not identified as COCs (Figure 16). These two metals were commonly detected but concentrations were well below the SVs in all samples. Likewise, the pesticides dieldrin and hexachlorobenzene were detected in most samples yet concentrations were well below SVs. PCB congeners were detected in all Eco-fish samples yet total PCB, the only available SV, was not considered a COC as concentrations were well below even the most stringent total PCB SV (mink). Note that the number of PCB congeners analyzed in Eco-fish tissue was limited compared to HH-fish (21 versus 172). Thus, far fewer analyte results were used to calculate total PCBs for Eco-fish tissue versus HH-fish.

3) The third type of result was for chemicals that do not have screening values for comparison but appear to be prevalent in the MCR reach. Overall, we were able to apply SVs to almost all analytes for both for Eco and HH-fish. Those that did not have an individual SV were covered as part of one of the summation type SVs (total chlordane, total PCBs, total PBDEs).

4) The last result type is chemicals that were rarely detected. The chemicals included in this study are known contaminants and have known presence in the MCR basin. Therefore, we had suspected that these would be measurable in our samples. We had detections for all categories tested except for dioxins/furans. Eighteen of these chemicals were analyzed in HH-fish tissue. These were rarely detected with most only detected in about 2% of the reach extent. All 18 had high percentages of non-detected values (73-100%).

B. Comparisons to Other Mainstem Columbia Results

The contaminants included in this study vary in their signature on the landscape. Some of the contaminants, such as mercury, are known to circulate in the atmosphere from global sources, while others, such as DDTs, have more local sources. In order to understand how the MCR fits into a larger context, results were compared to other Columbia River fish toxics studies. Overall, comparisons are challenging due to differences in design, parameters, fish species, and tissue types. Only one study conducted in the lower Columbia (Hayslip et al. 2007) had similar objectives and design with results that were directly comparable. Other substantial/comprehensive Columbia River fish tissue studies in the Hanford Reach (DOE 2012) and the upper Columbia (Exponent/Parametrics 2013) focus on risk assessment and characterizing the effect of particular impacts yet had some comparable elements. Finally, WA state monitoring efforts have generated fish tissue data from the upper and mid portions of the Columbia River.

1. Lower Columbia River: reach-wide Eco-fish study (Hayslip et al. 2007)

The Lower Columbia River, LCR from here on, is the adjacent downstream reach to the MCR, from Bonneville Dam to the mouth. Unlike the MCR, this reach is tidally influenced and includes a significant estuarine area. The LCR differs substantially in terms of land use. There are two urban centers, Portland, Oregon and Vancouver, Washington as well as numerous smaller towns along the LCR. In addition, a substantial amount of industrial land is adjacent to this portion of the river. Hayslip et al. (2007) quantified fish toxic COCs using a probabilistic design similar to this MCR assessment. Data were collected 1999-2000 from 79 sites distributed in the freshwater, saline, and estuarine portions of the LCR. Eco-fish whole tissue from flatfish and perciform target species was analyzed for trace elements, DDT and other persistent chlorinated pesticides, and PCBs. Results were reported as percent total area (611 sq.km) instead of percent river length because the estuary was included. We compared

SV exceedance results between the two reaches based on Hayslip et al. (2007). We note that the fish species are different between the two studies, thus these comparisons are qualified.

We applied the same Eco-fish SVs (Table 6) to the LCR toxic concentration results to estimate exceedances comparable to our results (Figure 16). For trace elements, there were clear differences for arsenic and nickel (Figure 17). Arsenic exceedances of Eco-fish SV were substantially less in the MCR compared to the LCR (25% versus ~50%). Nickel was substantially more prevalent in the MCR compared to the LCR where it was rarely detected in Eco-fish (87% non-detects). Results were relatively consistent between the two reaches for the other seven trace elements. There were slight differences in exceedances (≤10%) between the two reaches for cadmium, lead, mercury, and selenium, and exceedances were identical for chromium (0%) and copper and zinc (100%).

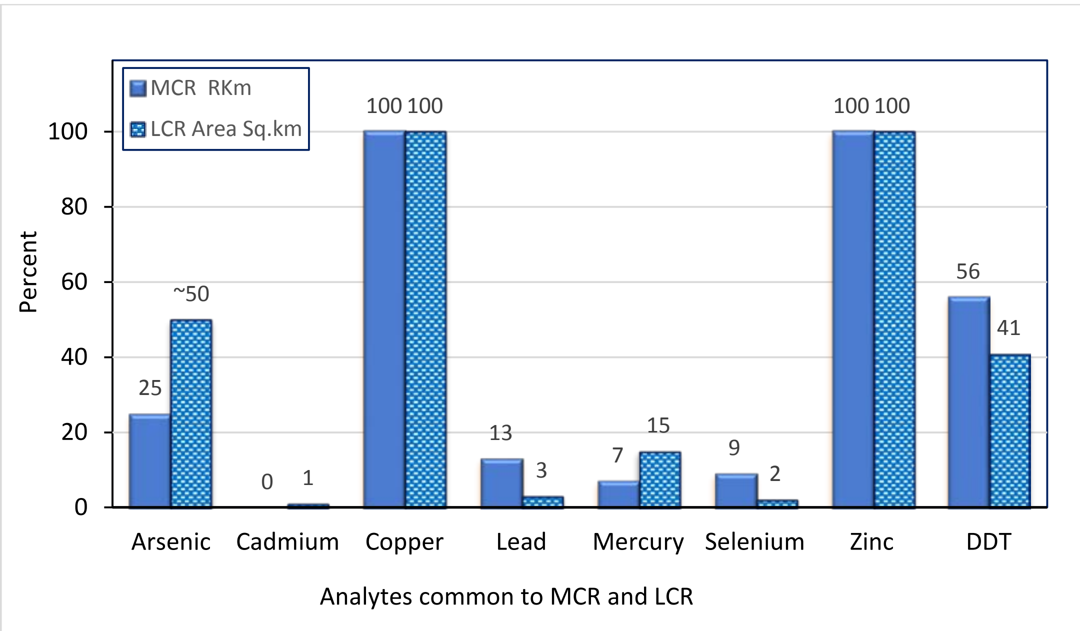


Figure 17. Comparison of MCR (N=718 rkm) and LCR (N= 611 sq.km) percent exceedances of the general aquatic SV in whole-fish tissue for eight analytes (Source: Hayslip et al. 2007).

Total DDT exceedances were more prevalent in the MCR than in the LCR (56% rkm, S.E. 5.03 versus 41% sq.km). Both studies reported on three other pesticides, total chlordane, hexachlorobenzene, and dieldrin. The chlordane and hexachlorobenzene results are consistent, being below the SVs in both studies. Dieldrin results were similar with no exceedance in MCR and minor exceedances in the LCR (1%). All three of these chemicals had low detection frequencies in the LCR study (8-16%).

Total PCB data for Eco-fish is comparable between the two studies as both analyzed the same 21 PCB congeners. The MCR had no total PCB exceedance for Eco-fish. LCR reach exceedances of the 440 ng/g SV appear minor based on summary statistics provided (mean, min, median, max of 52, 2, 17, and 691 ng/g ww, respectively, in Hayslip et al. 2007). Overall, these results show consistency in trace elements, as expected. DDTs have a long history of use in the agricultural areas of the MCR so higher concentrations in the MCR compared to the LCR would be expected. Likewise, we would expect higher PCB concentrations in fish tissue in the lower reach due to more urban and industrial land uses.

2. Lower Columbia River: select sites HH fish study (Nilsen et al. 2014)

Nilsen et al. (2014) analyzed HH-fish tissue contaminant concentrations in the LCR as part of a food web study. They collected largescale sucker fillet composites (15 fish each) from three sites spaced along the LCR in 2009. Analytes that were common between this LCR study and MCR were DDTs and several other persistent pesticides, PCBs, and PBDEs. Although these data do not statistically represent the entire LCR reach, results are useful for general comparisons to the MCR results.

Comparing Nilsen et al. (2014) results to the HH-fish SVs for cancer (Table 5) and the MCR summary statistics (Appendix 9), we conclude the following:

1) These LCR HH-fish results were similar to the MCR in that all three sites exceeded the SVs for total DDT and total PCBs (Table 13). The concentrations were generally lower than the MCR. All three sites were below the MCR total DDT and total PCB median values of 43.6 ng/g ww and 12.4 ng/g ww, respectively.

2) Total PBDEs at the two lower sites were similar to the high end of the range of values in the MCRT (90th percentile), while the upper Skamania site was below the range of MCR values.

3) LCR sites were similar to the MCR median values for chlordane and HCB. Dieldrin was not detected in the LCR but was common in the MCR HH fish (detected in all samples).

Table 13. Chemical concentrations (ng/g ww) in largescale sucker fillet tissue composites from three LCR sites (Source: Nilsen et al. 2014).

Site Name	Chlordane	Dieldrin	hexachloro-benzene	Total DDT	Total PCB	Total PBDE
Skamania (upper)	0.687	ND	0.300	**23.0**	**4.61**	0.416
Columbia City (mid)	0.477	ND	0.286	**27.0**	**6.67**	21.2
Longview (lower)	0.610	ND	0.347	**28.2**	**10.4**	21.6

Bold values indicate exceedance of HH-fish general population cancer SV.

3. Mid-Columbia River: select sites HH fish study (Washington Department of Ecology)

Seiders et al. (2015) analyzed skin-on fillet samples from 54 fish collected from six handpicked sites within the upper portion of the Mid-Columbia reach (Wanapum Dam near Vantage upstream to Grand Coulee Dam). This study is marginally comparable due to numerous differences including design, reach length, tissue preparation, and species. For 4,4' DDE, the Washington report summary statistics indicate that concentrations are higher than our MCR reach-wide results. The mean and maximum values are substantially higher in these sites and the 50th and 90th percentiles were both higher than the confidence intervals of the MRC. The difference in reach length would be a factor, as the MCR reach includes a substantial reach that is less influenced by agricultural land use. Also, species differences are a likely factor. The Washington State study included some carp samples which were highest in contaminant concentrations for DDE. We did not include any carp in our analysis. Also, fillet samples were processed skin on by Ecology as compared to no skin in this MCR study.

One interesting comparison is that of longitudinal patterns in tissue concentrations. Seiders et al. (2015) noted a pattern of relatively low concentrations of 4,4’ DDE in the two sites above the confluence of the Okanogan River. Concentrations were relatively higher at the two sites below the confluence, then diminishing in the lower two sites near Wenatchee. They observed a similar yet weaker pattern for PCBs and PBDE for various species. A State Fish Advisory was issued in 2011 for the Okanogan River for DDT in common carp (Table 1). In the MCR data, we noted a similar pattern for total DDTs in Eco-fish samples (Figure 18). Our Eco-fish concentrations were relatively low at the three sites upstream of the Okanogan confluence, sharply higher at sites below the Okanogan confluence, and then progressively lower downstream. Sites below Vernita Bridge were relatively low compared to the upper sites. This pattern was similar but less distinct for our HH-fish (fillet) samples. We did explore the data for reach-wide spatial patterns for all other analytes. None showed a clear pattern as seen in the total DDT and 4,4’ DDE data.

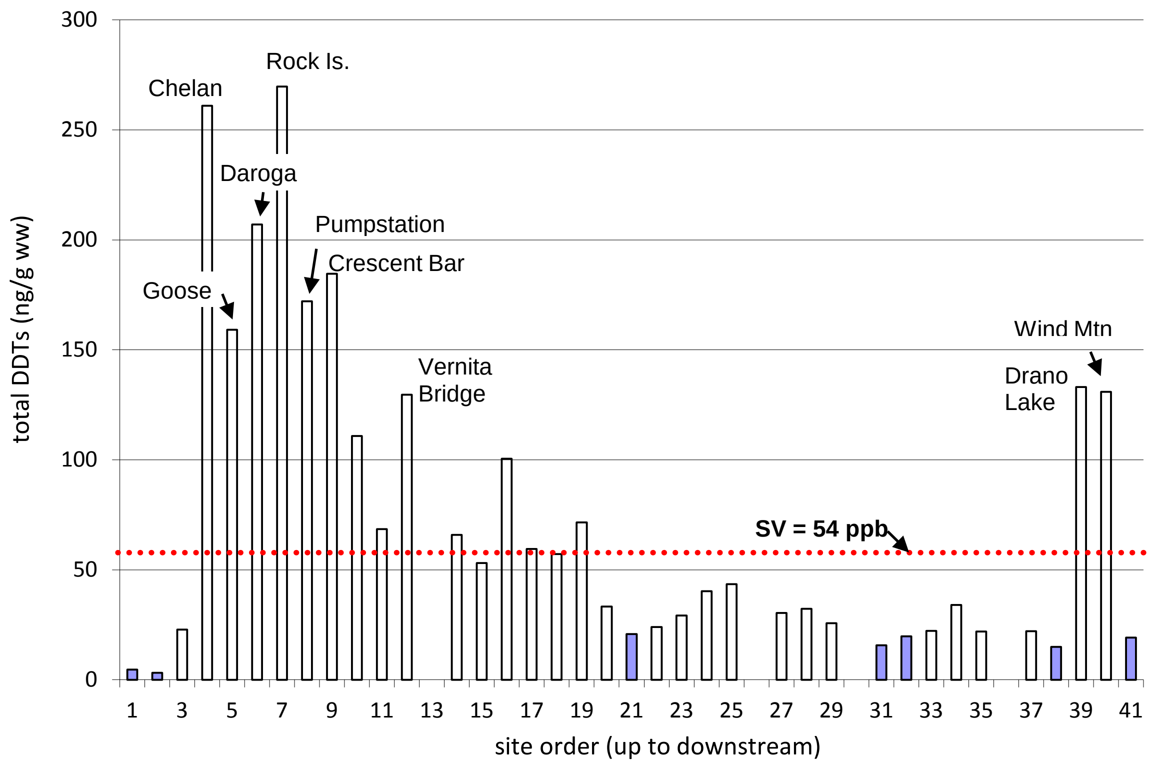


Figure 18. Total DDTs concentrations in Eco-fish composite samples at each sample site, MCR.

4. Mid-Columbia River: select sites HH and Eco fish study Hanford Reach

The Hanford Project Area is located in the Washington portion of the MCR. This reach has been studied extensively to support environmental remediation of the US Department of Energy's Hanford Site (DOE 2012). Fish tissue analysis has been conducted in this reach to determine human health and ecological risk related to the disposal of hazardous wastes. Extensive sampling took place during 2009-2010. They collected a variety of species (common carp, mountain whitefish, walleye, smallmouth bass, bridgelip sucker, and white sturgeon) from sites above and below the Hanford facility, extending from McNary Dam upstream to Wanapum Dam (Map 2). The samples collected above Priest Rapids Dam were used to represent the un-impacted condition for comparison to the impacted portion of the reach. Both HH and Eco-fish tissue samples (fillets and whole fish) were analyzed for metals, pesticides and PCB congeners.

Fillet (skin-on) analysis showed PCBs, organochlorine pesticides (DDTs and others), and several trace elements (As, Ad, Co, Li, Hg, Se, U, Z, and Zn) were elevated in fillet composites and exceeded human health SVs. They concluded that the mercury and PCB concentrations were consistent with concentrations from reference sites sampled above the facility. Likewise, organochlorine pesticides were similar to the reference sites and concentrations were attributed to agricultural applications rather than from the Hanford Facility. In comparison with ecological SVs, the greatest number and magnitude of exceedances in Hanford Eco-fish tissue were for cadmium, copper, selenium, and zinc. They concluded that these exceedances were not believed to be site-related contaminants.

PCBs were also studied, because this site was known to have use of equipment and practices associated with these pollutants (Hermann 2007 as in Delistraty 2013). Fillet mean total PCBs ranged from 270 ng/g ww (n=29) at the upper site to 130 ng/g ww (n=31) at the lowest site (Delistraty 2013). These values were not significantly different among locations. The mean values reported at all four sites were substantially higher than the range of values in this MCR reach-wide study, which ranged from min 1.4 ng/g to 85.3 ng/g (median 12.4 ng/g). We note the sites with the highest total PCBs in our data set are in the vicinity of the Hanford facility (from two sites near Vernita Bridge area below Priest Rapids Dam and the site just above the Snake River confluence). Washington Department of Health will be issuing a fish consumption advisory for the Hanford reach in 2017, which will restrict consumption of all resident fish species primarily due to PCB concentrations (David McBride, WDOH, pers. comm., Feb. 2017).

5. Upper Columbia River: select sites HH and Eco-fish tissue risk assessment

The Upper Columbia River (UCR from here on) is the adjacent upstream reach that extends from Grand Coulee Dam upstream to the Canadian border, about 150 river miles. This reach is being studied as part of a remedial investigation into environmental impacts from a metal smelter in British Columbia. It addresses questions specific to risk assessment and clean-up/disposal of hazardous wastes (Exponent/Parametrix 2013, USEPA 2007). Fish were collected in 2005 and 2009 from six handpicked locations. Species sampled included yellow perch, kokanee, walleye, whitefish, burbot, smallmouth bass, rainbow trout, and largescale suckers. Both HH and Eco-fish endpoints were analyzed for many analytes including potential smelter-related metals, mercury, dioxins/furans, and PCBs. “Comparison values” or CVs, were developed for both humans and ecological receptors, and exceedance ratios were calculated. The metals that most often exceeded CVs were total Hg, As, Se, Cr, Cu, Zn, Al, Pb, and Cd. PCBs and dioxins/furans also exceeded CVs.

Incompatibility of study designs and data synthesis methods limits the depth of comparisons between the two studies. However, it is interesting to qualitatively compare results. General conclusions of the UCR study were; 1) mercury was detected in all species and concentrations increase significantly in a downstream direction, 2) PCBs are widespread and total PCB concentrations were similar across species, and 3) slag-related metals, especially zinc, were elevated in various fish, particularly in the most upstream reaches.

The MCR results are consistent with these UCR findings in that PCBs and mercury are widespread and are present at levels of concern. DDT is consistently higher in the MCR. Mean DDT was an order of magnitude greater for the MCR (83.3 ng/g HH and

59.4 ng/g ECO) than the UCR (7.6 ng/g HH and 4.4 ng/g Eco-fish) (Exponent/ Parametrix 2013).

Also, several Eco-fish trace element SVs were exceeded with copper and zinc concentrations high for the entire MCR reach. Looking at individual sites, we note that sites in the extreme upper end of the MCR study reach (top 3-5 sites) had relatively higher Eco-fish concentrations for nickel, copper, and lead relative to the rest of the sites sampled. Finally, zinc concentrations in the upper reaches from Okanogan River confluence to Vernita Bridge were higher than the lower sample sites. Again, these are qualitative comparisons based on a single Eco-fish composite for each of the MCR sites.

C. Comparisons to Other Regions

1. Mid-continent Large Rivers: reach-wide HH and Eco fish study

The 2010 study of three great rivers of the mid–continent assessed fish tissue for toxics (Blocksom et al. 2010). They used a probability design comparable to the one used in this MCR study where sites were randomly selected so that results could be extrapolated to un-sampled sites and reported at a reach-wide scale for the Upper and Lower Missouri River, upper free flowing Mississippi River (above Ohio River confluence), upper impounded Mississippi, and the Ohio River. Both large and small fish were collected in 2004-2005 from these five reaches. Whole fish tissue was analyzed for mercury, legacy organochlorines (chlordane, DDT, and dieldrin), PCBs (20 congeners), and PBDEs (6 congeners). Small-sized whole fish were the ecological endpoint. Large-sized whole fish were analyzed as the human health end-point (conversion factors were used to estimate fillet concentrations). We focus our comparisons on small whole fish for the Eco-fish endpoint. Note some comparisons were not possible because both large and small whole body fish results were combined in some of the Blocksom et al. (2010) analyses while our MCR study only had small whole body fish samples.

For pesticides, there are similarities between the MCR and the Great Rivers (Blocksom et al. 2010). DDT, chlordane, and dieldrin, were detected in most samples in both studies. However, the pesticides of highest concern vary between the two studies. In the MCR, the mean DDT reach-wide value is an order of magnitude higher than in the Great Rivers reaches (Table 14). Also, MCR Eco-fish chlordane and dieldrin reach mean concentrations are lower than the Great Rivers reach means. In the MCR, DDT is the most extensive pesticide COC (Figure 16) while in the Great Rivers chlordane poses the greater risk to wildlife (Blocksom et al. 2010).

Table 14. Comparison of small whole fish mean chemical concentrations (ng/g ww) for five Mid-continent large river reaches from Blocksom et al. (2010) and the MCR mean reported at reach-scale. Standard error of mean in parens.

River reach	DDT total	Dieldrin	Chlordane total	PCB total	PBDE total
Upper Mississippi	6.57 (0.37)	3.10 (0.18)	2.31 (0.23)	19.67 (0.93)	5.31 (0.39)
Impounded Mississippi	6.54 (0.37)	2.66 (0.11)	1.39 (0.14)	7.41 (0.84)	4.43 (0.28)
Missouri	5.47 (0.38)	3.19 (0.25)	4.54 (0.40)	7.41 (0.74)	12.72 (2.08)
Lower Missouri	6.14 (0.43)	3.59 (0.27)	5.14 (0.46)	8.43 (0.85)	14.18 (2.39)
Ohio	15.6 (0.62)	4.75 (0.32)	19.41 (0.73)	90.31(3.66)	28.1 (1.47)
Mid-Columbia	**86.96** (3.00)	**0.57** (0.01)	**1.36** (0.11)	**13.91** (0.30)	**6.23** (0.12)

For PCBs and PBDEs, MCR mean reach-wide concentrations in Eco-fish are within the range of the Great Rivers (Table 14). The results are most similar to the Mississippi and Missouri river reaches as the Ohio mean concentrations are much higher.

Finally, Mercury is identified as an extensive COC in both studies. In the Great Rivers, mean reach concentrations for small whole fish were approximately 28 ng/g in the Missouri, 38 ng/g in the Mississippi, and 52 ng/g in the Ohio. (see Figure 1 in Walters et al. 2010). This is similar to the MCR mean of 37 ng/g ww (Table 11).

Similarities to the human health results were also found. The Great rivers study identified PCBs (up to 98% of river reach) and dieldrin (range 26-54% of reach length among the 3 rivers) as the most important COCs in terms of risk of exposure. Besides DDT, these were also identified as substantial COCs in the MCR (Figure 15).

2. National Rivers and Streams Assessment (NRSA): nation-wide HH fish study

The USEPA conducted a nationwide study of streams 5th order and larger for ecological condition (USEPA 2016). This study had a probability design where analytical results were used to generate statistical estimates for the entire resource of 83,144 rkm. This is a similar and therefore comparable design to the MCR study. Fish samples were collected in 2008 and 2009 from 541 sites and analyzed as fillet tissue for human health endpoints. Published results are available for mercury (Wathen et al. 2014).

In both studies, mercury was detected in all fillet samples. Mean concentrations of mercury were very similar, with the NRSA reporting a national weighted mean of 229 ng/g compared to MCR mean of 240 ng/g. Approximately 25.4% of the NRSA rkm exceeded the EPA 300 ng/g SV, which is very similar to the 23.9% exceedance in the MCR study reach. Also, the NRSA study exceeded the more stringent SV of 120 ng/g in approximately 65% of the rkm compared to 74.2% in the MCR.

Finally, we compared unpublished USEPA data from the NRSA 2008-2009 for DDT and total PBDE and from the most recent NRSA 2013-2014 for total PCBs (Provided by Leanne Stahl, pers. comm., May 2016). Some notable similarities and differences were found.

Concentrations of DDTs in the Mid-Columbia are significantly higher than those reported nation-wide (Table 15). Our mean total DDT concentration of 83.3 ng/g in fillets is about 6 times the mean in the NRSA. The mean concentrations of total PBDEs were very similar (9.3 vs 11.6 ng/g). For total PCBs, the MCR mean concentration was actually much lower than the national mean (21.0 ng/g as compared to 68.0 ng/g).

Table 15. Comparison of HH fish results for NRSA and MCR for DDT, PBDE and PCB (Source: unpublished EPA data, L. Stahl, pers. comm., May 2016).

Statistic	DDT total (ng/g)		PBDE total (ng/g)		PCB total(ng/g)	
	NRSA	MCR	NRSA	MCR	NRSA	MCR
mean	13.77	83.31	11.57	9.28	67.99	20.99
SE mean	1.15	3.28	1.02	0.38	9.41	0.89
10th	0.68	8.32	0.07	1.30	0.90	2.64
25th	1.81	15.04	1.18	2.78	3.53	5.30
50th	6.31	43.62	4.66	7.33	11.26	12.41
75th	15.19	117.11	11.45	10.96	41.16	28.84
90th	31.90	234.38	26.92	21.37	149.10	70.83

VII. Conclusions and Recommendations

- Bioaccumulative contaminants are an ongoing problem in the Mid-Columbia River as in many other parts of the US. Nationally, the number of fish advisories for Hg, PCBs, and DDTs continues to increase (USEPA 2011).

- Elevated mercury concentrations are very similar to those found in rivers across the US. Likewise, PBDE levels were reflective of other large US river systems (Blocksom et al. 2010).

- MCR fish tissue concentration of DDTs stand out as being extremely elevated compared to what is found in the rest of the US, even in other agriculturally intense locations. Although DDTs and the other persistent chlorinated pesticides are likely related to historical agricultural applications, efforts can be made to reduce their mobilization and transport into the MCR. Improved land management practices have significantly reduced concentrations of DDT in fish tissue in some portions of the Columbia Basin (Washington Department of Ecology 2014).

- Important fish tissue contaminants of concern and their ranking are virtually the same for both the general and high fish consumers. This suggests the same triggers for improving environmental conditions/reducing contaminants are present regardless of the intensity of use of the fisheries resource.

- This study establishes a baseline for toxic contamination in fish tissue in the Mid-Columbia. Repeated at intervals, studies of this type would help to determine trends in contamination so that future assessments of the Columbia River will be able to provide more robust understanding of the relationship between contaminants and associated human activity, natural phenomena, and environmental change.

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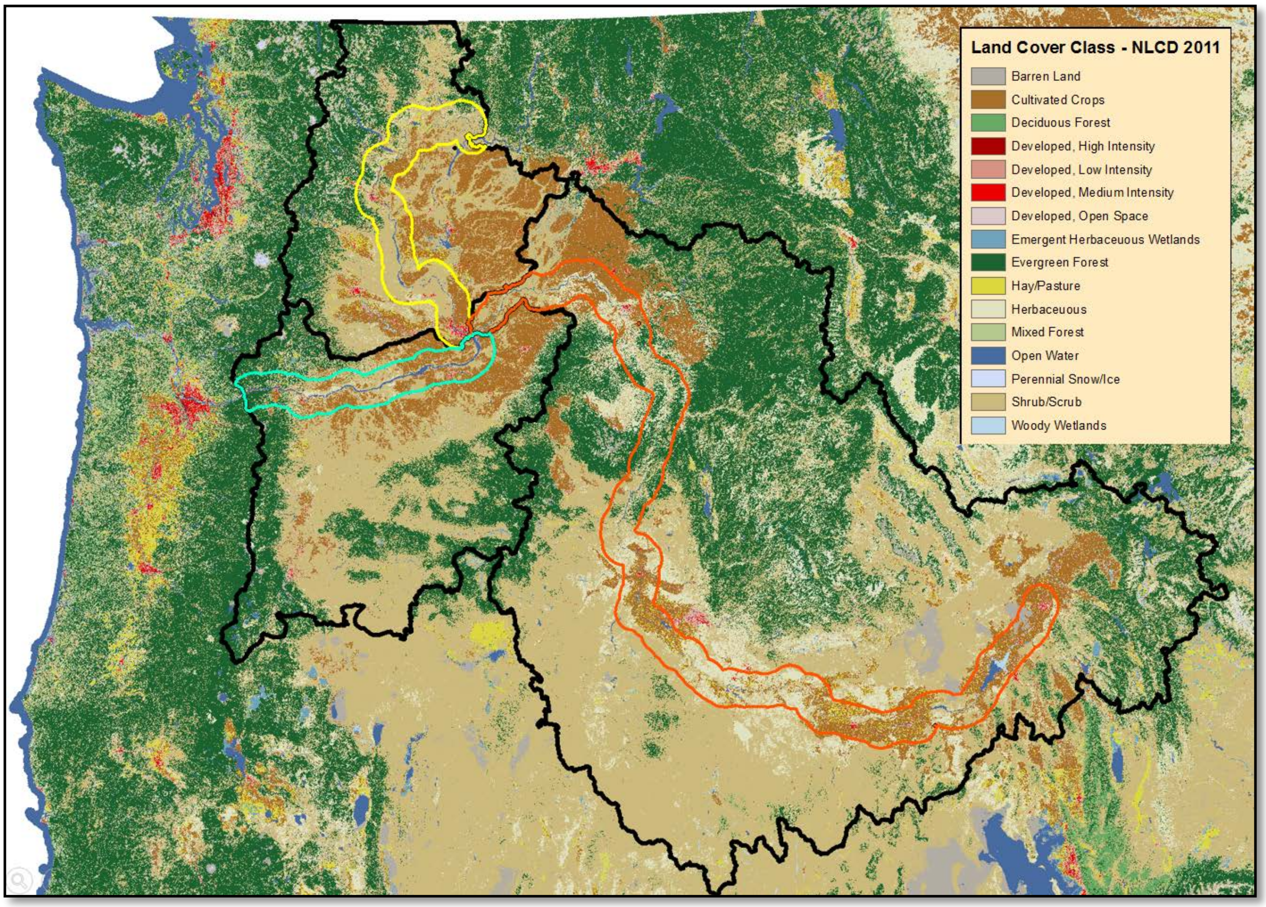
X. Appendices

Appendix 1. Land cover conditions within assessment areas.

Two GIS datasets were used to generate estimates of land cover and human population in the basin: The 2011 National Land Cover (NLCD) dataset (www.mrlc.gov) and the 2010 Census of the human population were used in this analysis and obtained from the USEPA server (i.e., the Navteq dataset). Watershed areas associated with the Columbia and Snake Rivers were derived from the National Hydrologic Dataset (NHD) (nhd.usgs.gov). Ten mile-wide sampling buffers for the Columbia and Snake Rivers were created in ArcGIS.

Land cover and population datasets were summarized for three assessment units; the black polygons in Figure A1 are the "watershed" areas associated with each evaluation river segment. The assessment units are 1) the Middle Columbia River reach (Bonneville Dam to the confluence with the Snake River), 2) Upper Middle Columbia River Reach (confluence with Snake River to the Grand Coulee dam), and 3) the Snake River reach. In addition, the land cover dataset was sampled at a 10-mile river buffer resolution (e.g., turquoise, yellow and orange polygons for the Middle Columbia River, Upper Middle Columbia River, and the Snake River reaches, respectively) (Figure A1).

Figure A1. Land Cover Conditions in the Project Area



Land cover is shown for the entire basin area that drains to the study reach as well as separately for the areas of the basin that drain to the Snake River and to the Mid-Columbia reaches above and below the confluence with the Snake River. Because land use is often different near water sources, conditions were also summarized for the zone within 10 miles of the large rivers. The comparison shows that agriculture is more focused in lower elevations closer to the rivers. Results indicate that most people live in the Snake River portion of the assessment area, however the highest density of people is observed in the Upper Middle Columbia River Reach.

Table A1-1. MCR basin area proportions by land cover class.

Land Cover group	Lower Mid-Columbia	Upper Mid-Columbia	Snake River	Entire area
Entire watershed				
Shrub/Grasslands	52%	45%	59%	56%
Agriculture	15%	24%	11%	14%
Forest	29%	23%	26%	26%
Developed	3%	5%	3%	3%
"Other"	2%	3%	2%	2%
Within 10 mile river buffer within watershed				
Shrub/Grasslands	44%	61%	50%	51%
Agriculture	32%	23%	35%	32%
Forest	13%	7%	9%	9%
Developed	5%	5%	5%	5%
"Other"	5%	4%	2%	3%

Table A1-2. Population density by MCR sub-basin.

Assessment area	Population (Million)	Average population density (People/Mile^2)
Middle Columbia	0.44	37
Upper Middle Columbia	0.79	84
Snake River	1.53	35
Entire Basin Area	2.77	43

Appendix 2. Description of Mid-Columbia sample sites.

Site_ID	ST	ECO	HH	Latitude (DD)[1]	Longitude (DD)[1]	Location	Downstream dam
CR206637-001	OR	•	•	45.675508	-121.8954	Cascade Locks	Bonneville
CR206637-002	OR	•	•	45.709947	-121.6155	Drano Lake	Bonneville
CR206637-003	OR	•	•	45.71942	-120.28788	Lake Umatilla Ch. Marker 18	John Day
CR206637-004	OR	•	•	45.841641	-119.83513	Crow Butte Powerline	John Day
CR206637-005	OR	•	•	45.70413	-121.82329	Trotter Point	Bonneville
CR206637-006	OR	•	•	45.697336	-121.76106	Wind Mountain	Bonneville
CR206637-007	OR	•	•	45.739881	-120.56969	Lake Umatilla Ch. Marker 6	John Day
CR206637-008	OR	•	•	45.909436	-119.6153	Big Blalock Island	John Day
CR206637-009	OR	•	•	45.626801	-121.11545	Lake Celilo	The Dalles
CR206637-010	OR	•	•	45.653876	-120.88012	Miller Island East	The Dalles
CR206637-011	OR	•	•	45.736789	-120.19939	Arlington	John Day
CR206637-012	OR	•	•	45.912465	-119.45946	Irrigon	John Day
CR206637-013	OR	no	•	45.703909	-121.3631	Memaloose	Bonneville
CR206637-014	OR	no	•	45.690345	-120.77742	Rufus	The Dalles
CR206637-015	OR	no	•	45.793259	-120.04913	Hepner Junction	John Day
CR206637-016	OR	•	•	45.936969	-119.26824	McNary Dam	McNary
CR206637-017	OR	•	•	45.719027	-121.50281	Hood River	Bonneville
CR206637-018	OR	•	•	45.843338	-119.81013	Crow Butte Ch. Marker 35	John Day
CR206637-019	OR	•	•	45.609188	-121.18829	The Dalles	Bonneville
CR206637-020	OR	•	•	45.638964	-120.91346	Miller Island South	The Dalles
CR206637-021	OR	no	•	45.697051	-120.49116	Lake Umatilla Ch. Marker 10	John Day
CR206637-022	OR	•	•	45.87463	-119.6757	Blalock Island	John Day
CR206637-023	OR	•	•	45.622764	-121.12081	Dalles Locks Ch. Marker 1	The Dalles
CR206637-063	WA	•	•	46.637915	-119.74405	Vernita Bridge	McNary
CR206637-064	WA	•	•	46.235222	-119.19375	Kennewick-Wade Island	McNary
CR206637-065	WA	•	•	48.016566	-119.67988	Bridgeport	Wells
CR206637-066	WA	•	•	47.904925	-119.91118	Chelan	Rocky Reach
CR206637-067	WA	no	•	46.646822	-119.6817	East Vernita Bridge	McNary
CR206637-068	WA	•	•	46.014435	-118.96892	Port Kelley	McNary
CR206637-069	WA	•	•	47.746484	-120.21002	Daroga	Rocky Reach
CR206637-070	WA	•	•	46.841179	-119.94845	Beverly	Priest Rapids
CR206637-071	WA	•	•	46.557892	-119.3214	Savage Island	McNary
CR206637-072	WA	•	no	48.133643	-119.05287	Coyote Creek	Chief Joseph
CR206637-073	WA	•	•	47.379405	-120.23408	Rock Island Wenatchee	Rock Island
CR206637-074	WA	•	•	47.127049	-120.00402	Babcock Bench	Wanapum

1. Latitude and longitude are in decimal degrees using the North American Datum of 1983 (NAD83).

Appendix 2, cont. Description of Mid-Columbia sample sites.

Site_ID	ST	ECO	HH	Latitude (DD)[1]	Longitude (DD)[1]	Location	Downstream dam
CR206637-075	WA	•	•	46.369823	-119.26536	Johnson Island	McNary
CR206637-076	WA	•	•	48.115615	-119.21621	Rufus Wood	Chief Joseph
CR206637-077	WA	•	•	47.374159	-120.19171	Pumpstation Wenatchee	Rock Island
CR206637-078	WA	•	•	47.22414	-120.05618	Crescent Bar	Wanapum
CR206637-079	WA	•	•	46.194433	-119.04389	Snake Confluence	McNary
CR206637-080	WA	•	•	47.772996	-120.14471	Goose Falls	Rocky Reach
CR206637-081	WA	•	•	46.082414	-118.94324	Lake Wallula Gap	McNary

1. Latitude and longitude are in decimal degrees using the North American Datum of 1983 (NAD83).

Appendix 3. Fish tissue analytes and associated methods and detection limits.

BZ #	Analyte name	Eco-fish	HH- fish	Detection Limits
PCB Congeners (Accelerated Solvent Extraction/Solvent Cleanup/Lipid partitioning/ Electron Capture)				
8	2,4-Dichlorobiphenyl, #8 (34883-43-7)	Yes	N/A see HH PCB in Appendix 5.)	0.625 µg/Kg
18	2,2',5-Trichlorobiphenyl, #18 (37680-65-2)	Yes		
28	2,4,4'-Trichlorobiphenyl, #28 (7012-37-5)	Yes		
44	2,2',3,5'-Tetrachlorobiphenyl, #44 (41464-39-5)	Yes		
52	2,2',5,5'-Tetrachlorobiphenyl, #52 (35693-99-3)	Yes		
66	2,3',4,4'-Tetrachlorobiphenyl, #66 (32598-10-0)	Yes		
77	3,3',4,4' Tetrachlorobiphenyl, #77* (32598-13-3)	Yes		
81	3,4,4,5- Tetrachlorobiphenyl, #81 (70362-50-4)	No		
101	2,2',4,5,5'-Pentachlorobiphenyl, #101 (37680-73-2)	Yes		
105	2,3,3',4,4'-Pentachlorobiphenyl, #105 (32598-14-4)	Yes		
110	2,3,3',4',6-pentachlorobiphenyl	No		
118	2,3',4,4',5-Pentachlorobiphenyl, #118 (31508-00-6)	Yes		
126	3,3',4,4',5 Pentachlorobiphenyl, #126	Yes		
128	2,2',3,3',4,4'-Hexachlorobiphenyl, #128 (38380-07-3)	Yes		
138	2,2',3,4,4',5-Hexachlorobiphenyl, #138 (35065-28-2)	Yes		
153	2,2',4,4',5,5'-Hexachlorobiphenyl, #153 (35065-27-1)	Yes		
169	3,3',4,4',5,5' Hexachlorobiphenyl, #169 (32774-16-6)	Yes		
170	2,2',3,3',4,4',5-Heptachlorobiphenyl, #170 (35065-30-6)	Yes		
180	2,2',3,4,4',5,5'-Heptachlorobiphenyl, #180 (35065-29-3)	Yes		
187	2,2',3,4',5,5',6-Heptachlorobiphenyl, #187 (52663-68-0)	Yes		
195	2,2',3,3',4,4',5,6-Octachlorobiphenyl, #195 (52663-78-2)	Yes		
206	2,2',3,3',4,4',5,5',6-Nonachlorobiphenyl, #206 (40186-72-9)	Yes		
209	Decachlorobiphenyl, #209 (2051-24-3)	Yes		
Chlorinated Pesticides (Accelerated Solvent Extraction/Solvent Cleanup/Electron Capture)				
	Aldrin (309-00-2)	Yes	Yes	Detection limit (ppb) µg/Kg wet weight variable, approx. 0.12 - 0.73
	Alpha-Chlordane (Chlordane-cis 5103-71-9)	Yes	Yes	
	Alpha-BHC	Yes	Yes	
	beta-BHC [Hexachlorocyclohexane, beta-]	No	Yes	
	Chlordane-trans (5103-74-2)	Yes	Yes	
	delta-BHC [Hexachlorocyclohexane, delta-]	No	Yes	
	Dieldrin (60-57-1)	Yes	Yes	
	Endosulfan I (959-98-8)	Yes	Yes	
	Endosulfan II (33213-65-9)	Yes	Yes	
	Endosulfan sulfate	No	Yes	
	Endrin (72-20-8)	Yes	Yes	
	Endrin Ketone	Yes	No	

Appendix 3, cont. Fish tissue analytes and associated methods and detection limits.

BZ #	Analyte name	Eco-fish	HH- fish	Detection Limits
	Heptachlor (76-44-8)	Yes	Yes	
	Heptachlor Epoxide (1024-57-3)	Yes	Yes	
	Hexachlorobenzene (118-74-1)	Yes	Yes	
	Hexachlorocyclohexane [Gamma-HC/Lindane] (58-89-87)	Yes	Yes	
	Methoxychlor	No	Yes	
	Mirex (2385-85-5)	Yes	Yes	
	trans-Nonachlor (3765-80-5)	Yes	Yes	
	cis-Nonachlor (5103-73-1)	Yes	Yes	
	Oxychlordane (27304-13-8)	Yes	Yes	
DDT & related compounds (Accelerated Solvent Extraction/Solvent Cleanup/Electron Capture)				
	2,4'-DDD (53-19-0)	Yes	Yes	Detection limit (ppb) µg/Kg wet weight approx. 0.12 -0.73
	4,4'-DDD (72-54-8)	Yes	Yes	
	2,4'-DDE (3424-82-6)	Yes	Yes	
	4,4'-DDE (72-55-9)	Yes	Yes	
	2,4'-DDT (789-02-6)	Yes	Yes	
	4,4'-DDT (50-29-3)	Yes	Yes	
PBDE Congeners				
28	2,4,4'-Tribromodiphenyl ether	No	N/A (HH PBDEs listed in Appendix 4.)	
47	2,2',4,4'-Tetrabromodiphenyl ether	Yes		
66	2,3',4,4'-Tetrabromodiphenyl ether	Yes		
85	2,2',3,4,4'-Pentabromodiphenyl ether	No		
99	2,2',4,4',5-Pentabromodiphenyl ether	Yes		
100	2,2',4,4',6-Pentabromodiphenyl ether	Yes		
138	2,2',3,4,4',5'-Hexabromodiphenyl ether	Yes		
153	2,2',4,4',5,5'-Hexabromodiphenyl ether	Yes		
154	2,2',4,4',5,6'-Hexabromodiphenyl ether	Yes		
183	2,2',3,4,4',5',6-Heptabromodiphenyl ether	Yes		
209	Decabromodiphenyl ether	No		

Appendix 3, cont. Fish tissue analytes and associated methods and detection limits.

BZ #	Analyte name	Eco-fish	HH- fish	Detection Limits
***Dioxins and Furans** (HRGC/HRMS EPA method 1613)*				
	dioxin Heptachlorodibenzo-p-dioxin 1,2,3,4,6,7,8-	No	Yes	
	dioxin Hexachlorodibenzo-p-dioxin 1,2,3,4,7,8- (1,2,3,4,7,8-HxCDD)	No	Yes	
	dioxin Hexachlorodibenzo-p-dioxin 1,2,3,6,7,8- (1,2,3,6,7,8-HxCDD)	No	Yes	
	dioxin Hexachlorodibenzo-p-dioxin 1,2,3,7,8,9- (1,2,3,7,8,9-HxCDD)	No	Yes	
	dioxin Pentachlorodibenzo-p-dioxin 1,2,3,7,8- (1,2,3,7,8-PeCDD)	No	Yes	
	2,3,7,8-Substituted Dioxin/Furans	No	Yes	
	Dioxin Tetrachlorodibenzodioxin 2,3,7,8 (2,3,7,8-TCDD)	No	Yes	
	dioxin Octachlorodibenzo-p-dioxin 1,2,3,4,6,7,8,9-	No	Yes	
	furan Heptachlorodibenzofuran 1,2,3,4,6,7,8- (1,2,3,4,6,7,8-HpCDF)	No	Yes	
	furan Heptachlorodibenzofuran 1,2,3,4,7,8,9- (1,2,3,4,7,8,9-HpCDF)	No	Yes	
	furan Hexachlorodibenzofuran 1,2,3,4,7,8- (1,2,3,4,7,8-HxCDF)	No	Yes	
	furan Hexachlorodibenzofuran 1,2,3,6,7,8- (1,2,3,6,7,8-HxCDF)	No	Yes	
	furan Hexachlorodibenzofuran 1,2,3,7,8,9- (1,2,3,7,8,9-HxCDF)	No	Yes	
	furan Pentachlorodibenzofuran 1,2,3,7,8- (1,2,3,7,8-PeCDF)	No	Yes	
	furan Hexachlorodibenzofuran 2,3,4,6,7,8- (2,3,4,6,7,8-HxCDF)	No	Yes	
	furan Pentachlorodibenzofuran 2,3,4,7,8- (2,3,4,7,8-PeCDF)	No	Yes	
	furan Tetrachlorodibenzofuran 2,3,7,8- (2,3,7,8-TCDF)	No	Yes	
	furan Octachlorodibenzofuran 1,2,3,4,6,7,8,9-	No	Yes	
Trace metals/metalloids (method 6020 – ICPMS)				
	Arsenic	Yes	No	
	Cadmium	Yes	No	
	Chromium	Yes	No	
	Copper	Yes	No	
	Lead	Yes	No	
	Nickel	Yes	No	
	Zinc	Yes	No	
Mercury and Selenium				
	Mercury (7439-97-6) (via ICP Methods)	Yes	Yes	0.01 µg/g ww
	Selenium (SOP# ECCB 032.0 Revision MIRB 040.2E) (via ICP Methods)	Yes	No	0.034 µg/g ww
Additional Measurements				
	Percent Moisture (Karl-Fisher Titration) or Percent Solids	Yes	Yes	
	Lipids (Gravimeteric Method)	Yes	Yes	

Appendix 4. Human health endpoint PBDE analytes. Method HRGC/HRMS EPA method 1614 for PBDEs.

BZ #	Analyte name	BZ #	Analyte name
PBDE-15	4,4'-Dibromodiphenyl	PBDE-154	2,2',4,4',5,6'-Hexabromodiphenyl
PBDE-17	2,2',4-Tribromodiphenyl ether	PBDE-156	2,3,3',4,4',5-Hexabromodiphenyl
PBDE-28	2,4,4'-Tribromodiphenyl ether	PBDE-171	2,2',3,3',4,4',6-Heptabromodiphenyl
PBDE-47	2,2',4,4'-Tetrabromodiphenyl	PBDE-180	2,2',3,4,4',5,5'-Heptabromodiphenyl
PBDE-49	2,2',4,5'-Tetrabromodiphenyl	PBDE-183	2,2',3,4,4',5',6-Heptabromodiphenyl
PBDE-66	2,3',4,4'-Tetrabromodiphenyl	PBDE-184	2,2',3,4,4',6,6'-Heptabromodiphenyl
PBDE-71	2,3',4',6-Tetrabromodiphenyl	PBDE-191	2,3,3',4,4',5',6-Heptabromodiphenyl
PBDE-77	3,3',4,4'-Tetrabromodiphenyl	PBDE-196	2,2',3,3',4,4',5,6'-Octabromodiphenyl
PBDE-85	2,2',3,4,4'-Pentabromodiphenyl ether	PBDE-197	2,2',3,3',4,4',6,6'-Octabromodiphenyl
PBDE-99	2,2',4,4',5-Pentabromodiphenyl ether	PBDE-201	2,2',3,3',4,5',6,6'-Octabromodiphenyl
PBDE-100	2,2',4,4',6-Pentabromodiphenyl	PBDE-203	2,2',3,4,4',5,5',6-Octabromodiphenyl
PBDE-119	2,3',4,4',6-Pentabromodiphenyl	PBDE-204	2,2',3,4,4',5,6,6'-Octabromodiphenyl
PBDE-126	3,3',4,4',5'-Pentabromodiphenyl	PBDE-205	2,3,3',4,4',5,5',6-Octabromodiphenyl
PBDE-138	2,2',3,4,4',5'-Hexabromodiphenyl	PBDE-206	2,2',3,3’,4,4’,5,5',6-Nonabromodiphenyl
PBDE-139	2,2',3,4,4',6-Hexabromodiphenyl	PBDE-207	2,2',3,3’,4,4’,5,6,6'-Nonabromodiphenyl
PBDE-140	2,2',3,4,4',6'-Hexabromodiphenyl	PBDE-208	2,2',3,3’,4,5,5',6,6'-Nonabromodiphenyl
PBDE-153	2,2',4,4',5,5'-Hexabromodiphenyl	PBDE-209	Decabromodiphenyl

Appendix 5. Human health endpoint fillet tissue PCBs analytes (method HRGC/HRMS EPA method 1668).

BZ #	BZ #	BZ #	BZ #	BZ #	BZ #	BZ #
PCB-16	PCB-44	PCB-73	PCB-100	PCB-132	PCB-159	PCB-187
PCB-17	PCB-45	PCB-74	PCB-101	PCB-134	PCB-161	PCB-188
PCB-18	PCB-46	PCB-77	PCB-102	PCB-135	PCB-162	PCB-189
PCB-19	PCB-47	PCB-78	PCB-103	PCB-136	PCB-164	PCB-190
PCB-20	PCB-48	PCB-79	PCB-104	PCB-137	PCB-165	PCB-191
PCB-22	PCB-49	PCB-80	PCB-105	PCB-138	PCB-166	PCB-192
PCB-23	PCB-50	PCB-81	PCB-106	PCB-139	PCB-167	PCB-194
PCB-24	PCB-51	PCB-82	PCB-107	PCB-140	PCB-168	PCB-195
PCB-25	PCB-53	PCB-83	PCB-108	PCB-141	PCB-169	PCB-196
PCB-26	PCB-54	PCB-84	PCB-109	PCB-142	PCB-170	PCB-197
PCB-27	PCB-55	PCB-85	PCB-110	PCB-143	PCB-171	PCB-198
PCB-28	PCB-56	PCB-86	PCB-112	PCB-144	PCB-172	PCB-199
PCB-29	PCB-57	PCB-87	PCB-114	PCB-145	PCB-173	PCB-200
PCB-30	PCB-58	PCB-88	PCB-115	PCB-146	PCB-174	PCB-201
PCB-31	PCB-59	PCB-89	PCB-118	PCB-147	PCB-175	PCB-202
PCB-34	PCB-60	PCB-90	PCB-120	PCB-148	PCB-176	PCB-203
PCB-35	PCB-61	PCB-91	PCB-122	PCB-149	PCB-177	PCB-204
PCB-36	PCB-62	PCB-92	PCB-124	PCB-150	PCB-178	PCB-205
PCB-37	PCB-63	PCB-93	PCB-125	PCB-151	PCB-179	PCB-206
PCB-38	PCB-64	PCB-94	PCB-126	PCB-152	PCB-180	PCB-207
PCB-39	PCB-65	PCB-95	PCB-127	PCB-154	PCB-181	PCB-208
PCB-40	PCB-66	PCB-96	PCB-128	PCB-155	PCB-183	PCB-209
PCB-41	PCB-69	PCB-97	PCB-129	PCB-156	PCB-184	
PCB-42	PCB-70	PCB-98	PCB-130	PCB-157	PCB-185	
PCB-43	PCB-71	PCB-99	PCB-131	PCB-158	PCB-186	

Appendix 6. Summary of habitat and water chemistry data. Methods used for chemical analysis is in the QAPP (ODEQ 2010a). Summarized results with summary statistics to provided general description of conditions.

Table A6-1. Water physical properties and in situ measurements summary statistics for MCR reach (N=718 rkm).

Metric	units	Mean	Median	Min.	Max.
Temperature	°C	19.0	18.9	14.5	24.4
Specific Conductance	(Us/cm)	150	150	142	172
Dissolved Oxygen	mg/L	9.5	9.4	8.4	10.9
ORP	millivolts	166	139	76	428
Secchi depth*	M	3.2	2.9	0.8	8.5
Turbidity	NTU	2.3	2.0	0.5	7.0
pH	-log [H]	8.0	8.0	6.8	8.9

*Secchi values omitted from summary statistics if clear to bottom. Secchi Depth data not collected at 5 of the Oregon sites.

Table A6-2. Water quality metrics summary statistics for Mid-Columbia River (N=718 rkm).

Metric	units	Mean	Median	Min.	Max.
Calcium	mg/L	17.41	17.40	15.10	19.10
Sulfate	mg/L	8.68	8.09	6.89	11.10
Total Suspended Solids	mg/L	3.06	2.00	1.00	11.80
Nitrate+Nitrite (as N)	mg/L	0.07	0.06	0.04	0.33
Total Phosphorus	mg/L	0.02	0.02	0.02	0.04
Total Organic Carbon	mg/L	1.67	1.58	1.23	2.00
Chlorophyll a	µg/L	3.56	3.02	0.70	15.10

Table A6-3. Water trace element summary statistics for Mid-Columbia River (N=718 rkm).

Metric	units	Mean	Median	Min.	Max.	Non-detects (% Obs.)[1]
Antimony	µg/L	1.36	1.00	1.00	2.00	100
Arsenic	µg/L	1.18	0.73	0.63	2.00	71
Barium	µg/L	30.35	31.50	20.70	34.20	0
Beryllium	µg/L	0.14	0.05	0.05	0.30	98
Cadmium	µg/L	0.19	0.13	0.13	0.30	98
Chromium	µg/L	1.19	1.30	1.00	1.30	100
Cobalt	µg/L	0.11	0.06	0.04	0.20	64
Copper	µg/L	1.37	1.30	1.30	1.50	100
Lead	µg/L	0.17	0.15	0.13	0.27	81
Molybdenum	µg/L	1.43	0.59	0.45	3.00	55
Nickel	µg/L	0.85	0.77	0.69	1.00	55
Selenium	µg/L	1.55	1.30	1.30	2.00	100
Silver	µg/L	0.44	0.63	0.10	0.63	100
Thallium	µg/L	0.44	0.63	0.10	0.63	100
Vanadium	µg/L	2.16	1.00	1.00	4.00	100
Zinc	µg/L	3.16	3.00	2.50	4.40	67
Mercury_dissolved	ng/L	0.500	0.500	0.500	0.521	98
Mercury_total	ng/L	0.655	0.564	0.500	1.900	26

1. All variables except barium had values at the detection limit included in summary statistical calculations. Statistics are therefore biased towards high. Non-detect percent observations refers to the percent of samples analyzed not percent of inference rkm.

Physical Habitat

The general physical characteristics of the riparian zone, littoral zone (fish habitat), and overall condition were captured using visual quantification based on observations of the field crew. Observations were collected at each sample reach and by inference calculated for the survey reach.

1. Reach characteristics

Observations limited to the area immediate adjacent to the river were used to characterize the reach. The most commonly observed vegetation types in the riparian zone were shrubs and grasses. Bare ground was also common due to the abundance of rocky outcrops of basalt, rip rap (particularly in the lower portion of the middle Columbia) and simply the arid conditions that are dominant in the basin. Macrophytes were sparse or rare with occasional sites with some abundance. The presence of wetlands was extremely rare. Land use types observed in riparian zone of the sample reaches were generally low. There was some urban and residential development but overall this was sparse. Other forms of land use by humans in the riparian zone were sparse or rare.

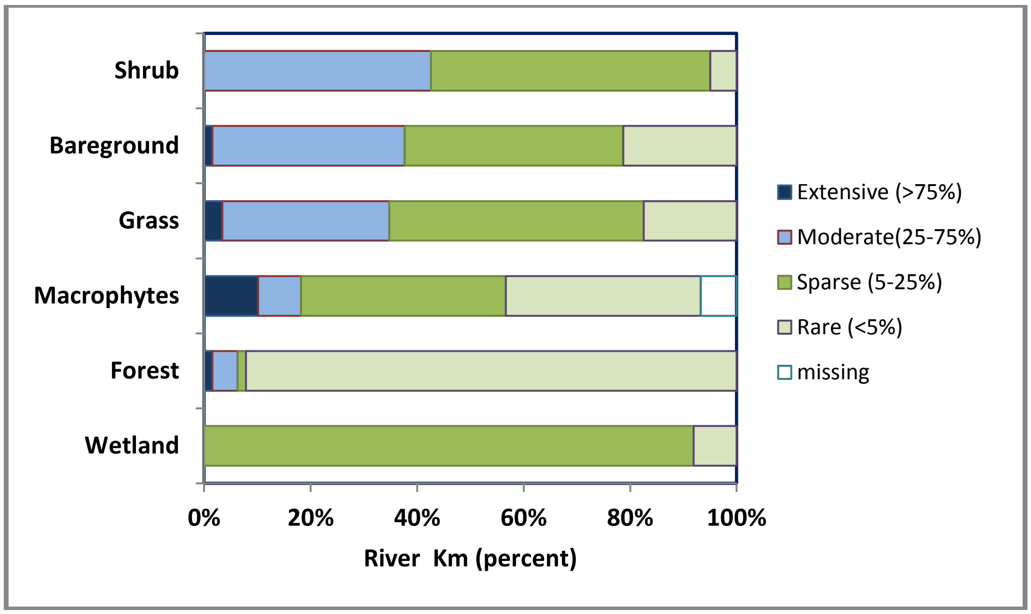


Figure A6-1. Extent of riparian cover classes in the MCR.

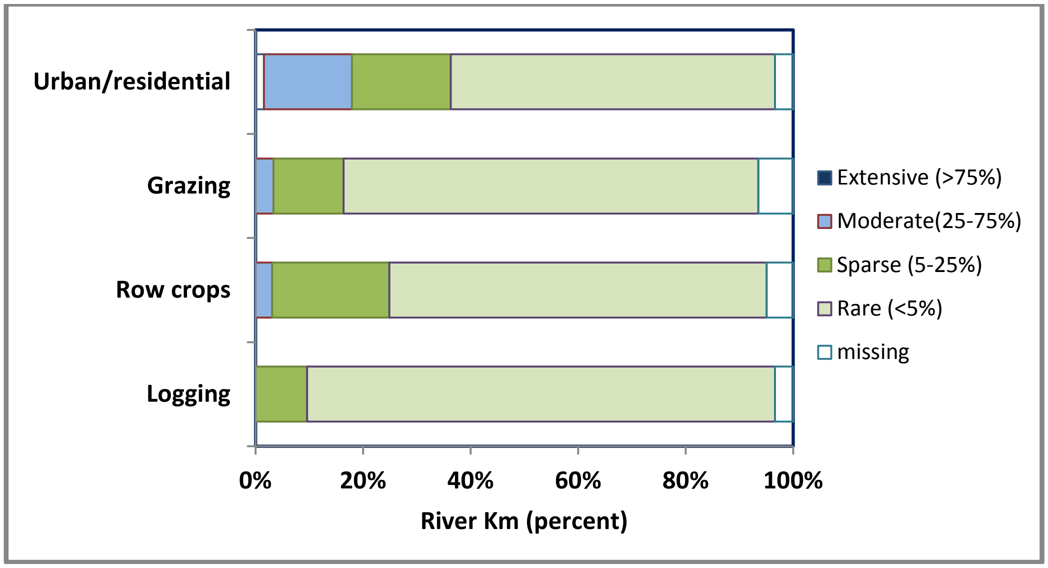


Figure A6-2. Extent of general human use categories, MCR.

2. Fish cover

Fish cover in the form of boulders/ledges and macrophytes was fairly abundant across the study area. Both of these are likely related to inundation due to the dams inundate rocky areas and create the slack water conditions that are favorable to macrophytes and filamentous algae. The observed low abundance of brushy and woody debris is also expected as these are not substantial components of the riparian zone of the Mid-Columbia River.

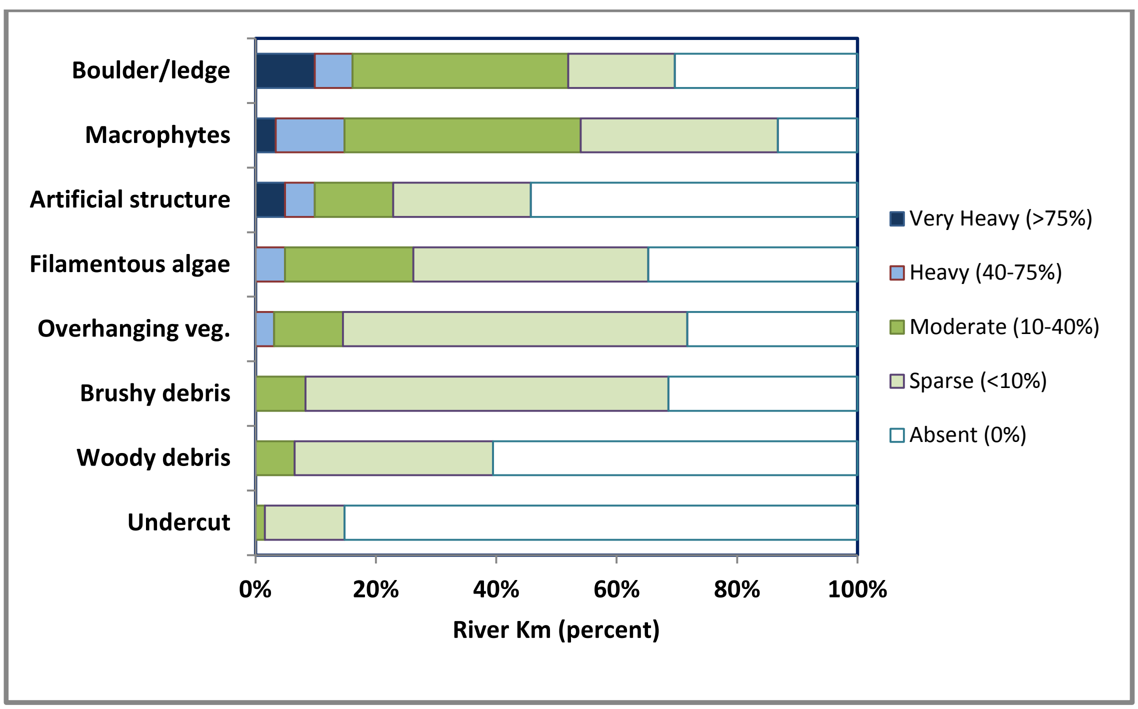


Figure A6-3. Extent of fish cover classes in the MCR.

3. General habitat assessment

The general habitat was evaluated using a quality rating based on visual observation of six habitat parameters (see QAPP). Bank stability was the only parameter that showed a majority of the study area to be in good/excellent condition. The narrow riparian zone, limited off-channel areas, and low diversity of cover are reflected in the overall limited quality of the aquatic habitat. Frankly, expectation of habitat quality is low due to the highly altered state of the MCR. Water velocity is low in the inundated area and water levels fluctuate highly as a result of dams and their water level modifications and controls.

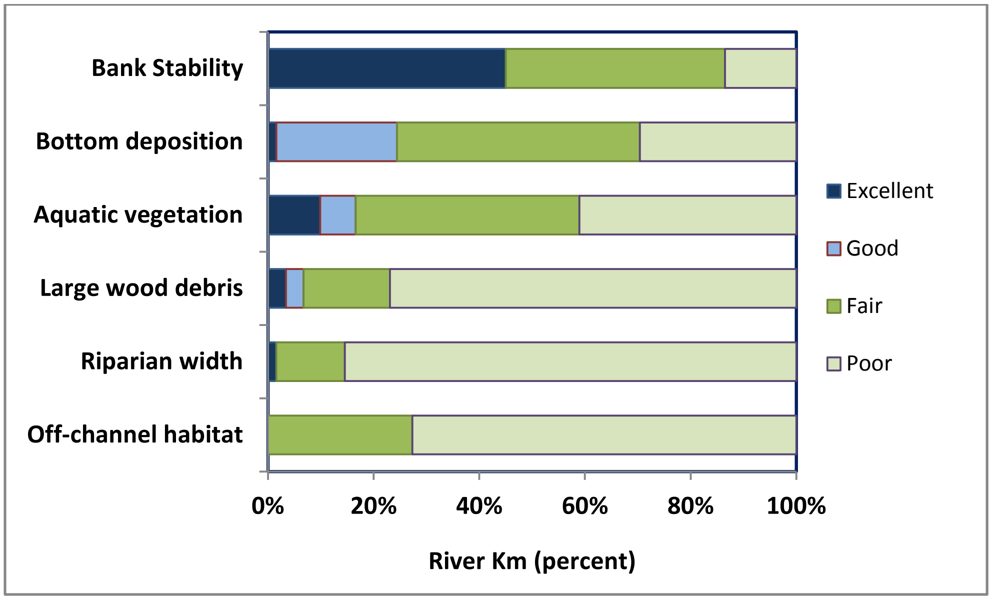


Figure A6-4.

G. Invasive mussels

Veliger tow samples from the 19 Washington sites were submitted to Portland State University for analysis. Veligers were not detected in any of the samples. Although this does not prove that there are no mussel veligers in the sampled reach, it does contribute to the effort to search for introduced species when possible as part of early detection efforts (Wells, et al. 2011). The latest information from PSU indicates that invasive mussel veligers are still unknown in the Columbia River (IEAB 2013). However, research has established that Columbia River water quality would probably support these invasive mussels (IEAB 2013) which require adequate temperature and concentrations of dissolved calcium for growth and shell development.

Appendix 7. Description of human health endpoint fish composite samples collected from 41 probability sampling sites Mid-Columbia River.

Site ID	State	Location	Common name	Taxon	Fish Count	Mean lgth (mm)	Mean wt (g)	Lipid (%)
CR206637-001	OR	Cascade Locks	smallmouth bass	Micropterus dolomieui	4	265	335	<1.0
CR206637-002	OR	Drano Lake	smallmouth bass	Micropterus dolomieui	5	315	466	<1.0
CR206637-003	OR	Lake Umatilla CM 18	smallmouth bass	Micropterus dolomieui	5	302	316	<1.0
CR206637-004	OR	Crow Butte Powerline	smallmouth bass	Micropterus dolomieui	5	397	862	<1.0
CR206637-005	OR	Trotter Pt	smallmouth bass	Micropterus dolomieui	5	373	772	<1.0
CR206637-006	OR	Wind Mtn	smallmouth bass	Micropterus dolomieui	3	373	793	<1.0
CR206637-007	OR	Lake Umatilla CM 6	smallmouth bass	Micropterus dolomieui	5	258	218	<1.0
CR206637-008	OR	Big Blalock Island	smallmouth bass	Micropterus dolomieui	4	364	640	<1.0
CR206637-009	OR	Lake Celilo	smallmouth bass	Micropterus dolomieui	5	484	1370	<1.0
CR206637-010	OR	Miller Island East	smallmouth bass	Micropterus dolomieui	5	277	274	<1.0
CR206637-011	OR	Arlington	smallmouth bass	Micropterus dolomieui	3	360	560	<1.0
CR206637-012	OR	Irrigon	smallmouth bass	Micropterus dolomieui	5	262	251	<1.0
CR206637-013	OR	Memaloose	largescale sucker	Catostomus macrocheilus	5	524	1586	<1.0
CR206637-014	OR	Rufus	smallmouth bass	Micropterus dolomieui	5	296	333	<1.0
CR206637-015	OR	Hepner Junction	largescale sucker	Catostomus macrocheilus	5	554	1450	4.9
CR206637-016	OR	McNary Dam	largescale sucker	Catostomus macrocheilus	5	547	1640	2.7
CR206637-017	OR	Hood River	smallmouth bass	Micropterus dolomieui	5	409	992	<1.0
CR206637-018	OR	Crow Butte CM 35	smallmouth bass	Micropterus dolomieui	5	371	630	<1.0
CR206637-019	OR	The Dalles	smallmouth bass	Micropterus dolomieui	5	252	206	<1.0
CR206637-020	OR	Miller Island South	smallmouth bass	Micropterus dolomieui	5	262	254	<1.0
CR206637-021	OR	Lake Umatilla CM 10	smallmouth bass	Micropterus dolomieui	5	230	276	<1.0
CR206637-022	OR	Blalock Island	smallmouth bass	Micropterus dolomieui	5	402	850	<1.0
CR206637-023	OR	Dalles Locks CM1	largescale sucker	Catostomus macrocheilus	5	302	364	3.3
CR206637-063	WA	Vernita Bridge	largescale sucker	Catostomus macrocheilus	5	540	1501	4.2
CR206637-064	WA	Kennewick-Wade island	largescale sucker	Catostomus macrocheilus	3	535	1581	2.1
CR206637-065	WA	Bridgeport	largescale sucker	Catostomus macrocheilus	5	478	907	<1.0
CR206637-066	WA	Chelan	largescale sucker	Catostomus macrocheilus	5	456	907	1.7
CR206637-067	WA	Port Kelley	largescale sucker	Catostomus macrocheilus	5	446	1120	4.3

Appendix 7, cont. Description of human health endpoint fish composite samples collected from 41 probability sampling sites Mid-Columbia River.

Site ID	State	Location	Common name	Taxon	Fish Count	Mean lngth (mm)	Mean wt (g)	Lipid (%)
CR206637-068	WA	Daroga	smallmouth bass	*Micropterus dolomieui*	4	391	945	<1.0
CR206637-069	WA	Beverly	yellow perch	*Perca flavescens*	3	297	401	<1.0
CR206637-070	WA	Savage Island	largescale sucker	*Catostomus macrocheilus*	5	482	1042	2.2
CR206637-071	WA	Coyote creek	smallmouth bass	*Micropterus dolomieui*	5	267	314	<1.0
CR206637-073	WA	Rock Island Wenatchee	largescale sucker	*Catostomus macrocheilus*	5	488	1092	1.5
CR206637-074	WA	Babcock Bench	largescale sucker	*Catostomus macrocheilus*	3	482	1157	2.6
CR206637-075	WA	Johnson Island	smallmouth bass	*Micropterus dolomieui*	5	295	414	<1.0
CR206637-076	WA	Rufus Wood	walleye	*Sander vitreum*	2	420	756	2.7
CR206637-077	WA	Pumpstation Wenatchee	largescale sucker	*Catostomus macrocheilus*	4	416	693	<1.0
CR206637-078	WA	Crescent Bar	largescale sucker	*Catostomus macrocheilus*	5	432	784	1.5
CR206637-079	WA	Snake Confluence	largescale sucker	*Catostomus macrocheilus*	5	516	1394	3.2
CR206637-080	WA	Goose Falls	northern pikeminnow	*Ptychocheilus oregonensis*	5	309	280	<1.0
CR206637-081	WA	Lake Wallula Gap	smallmouth bass	*Micropterus dolomieui*	4	436	896	<1.0

Appendix 8. Description of Eco-fish composite samples collected from 37 probability sampling sites in the Mid-Columbia River.

Site Id.	State	Location	Common name	Taxon	Fish Count	Mean lngth (mm)	Mean wt. (g)	Lipid (%)
CR206637-001	OR	Cascade Locks	Cottus sp.	Family Cottidae	17	380	22.4	2.28
CR206637-002	OR	Drano Lake	Cottus sp.	Family Cottidae	11	260	23.6	2.01
CR206637-003	OR	Lake Umatilla CM 18	Cottus sp.	Family Cottidae	19	250	13.2	3.97
CR206637-004	OR	Crow Butte Powerline	Cottus sp.	Family Cottidae	23	295	12.8	3.84
CR206637-005	OR	Trotter Pt	redside shiner	*Richardsonius balteatus*	12	210	17.5	3.40
CR206637-006	OR	Wind Mtn	northern pikeminnow	*Ptychocheilus oregonensis*	16	310	19.4	8.39
CR206637-007	OR	Lake Uma. CM 6	Cottus sp.	Family Cottidae	17	250	14.7	4.18
CR206637-008	OR	Big Blalock Island	Cottus sp.	Family Cottidae	27	470	17.4	3.17
CR206637-009	OR	Lake Celilo	Cottus sp.	Family Cottidae	8	220	27.5	2.48
CR206637-010	OR	Miller Island East	Cottus sp.	Family Cottidae	13	440	33.8	2.03
CR206637-011	OR	Arlington	Cottus sp.	Family Cottidae	10	210	21.0	3.21
CR206637-012	OR	Irrigon	Cottus sp.	Family Cottidae	9	250	27.8	2.23
CR206637-016	OR	McNary Dam	Cottus sp.	Family Cottidae	16	400	25.0	3.54
CR206637-017	OR	Hood River	Cottus sp.	Family Cottidae	71	620	8.7	2.51
CR206637-018	OR	Crow Butte CM 35	Cottus sp.	Family Cottidae	17	250	14.7	3.64
CR206637-019	OR	The Dalles	largescale sucker	*Catostomus macrocheilus*	na	missing	na	5.30
CR206637-020	OR	Miller Island South	Cottus sp.	Family Cottidae	12	300	25.0	1.94
CR206637-022	OR	Blalock Island	Cottus sp.	Family Cottidae	23	420	18.3	3.44
CR206637-023	OR	Dalles Locks CM1	Cottus sp.	Family Cottidae	12	160	13.3	2.61
CR206637-063	WA	Vernita Bridge	redside shiner	*Richardsonius balteatus*	10	56	5.6	7.16
CR206637-064	WA	Kennewick-Wade Is.	northern pikeminnow	*Ptychocheilus oregonensis*	5	280	56.0	4.64
CR206637-065	WA	Bridgeport	largescale sucker	*Catostomus macrocheilus*	24	308	12.8	3.41
CR206637-066	WA	Chelan	northern pikeminnow	*Ptychocheilus oregonensis*	5	364	72.8	2.92
CR206637-068	WA	Port Kelley	smallmouth bass	*Micropterus dolomieu*	10	210	21.0	2.74
CR206637-069	WA	Daroga	northern pikeminnow	*Ptychocheilus oregonensis*	8	252	31.5	3.20

Appendix 8, cont. Description of Eco-fish composite samples collected from 37 probability sampling sites in the Mid-Columbia River.

Site ID	State	Location	Common name	Taxon	Fish Count	Mean lngth (mm)	Mean wt. (g)	Lipid (%)
CR206637-070	WA	Beverly	northern pikeminnow	*Ptychocheilus oregonensis*	19	196	10.3	4.05
CR206637-071	WA	Savage Island	smallmouth bass	*Micropterus dolomieu*	9	196	21.8	3.23
CR206637-072	WA	Coyote Creek	largescale sucker	*Catostomus macrocheilus*	5	616	123.2	3.26
CR206637-073	WA	Rock Island Wenatchee	northern pikeminnow	*Ptychocheilus oregonensis*	8	252	31.5	3.34
CR206637-074	WA	Babcock Bench	northern pikeminnow	*Ptychocheilus oregonensis*	6	280	46.7	3.06
CR206637-075	WA	Johnson Island	largescale sucker	*Catostomus macrocheilus*	5	504	100.8	4.23
CR206637-076	WA	Rufus Wood	largescale sucker	*Catostomus macrocheilus*	6	476	79.3	2.46
CR206637-077	WA	Pumpstation Wenatchee	chiselmouth	*Acrocheilus alutaceus*	9	280	31.1	4.23
CR206637-078	WA	Crescent Bar	northern pikeminnow	*Ptychocheilus oregonensis*	7	280	40.0	3.10
CR206637-079	WA	Snake Confluence	yellow perch	*Perca flavescens*	6	252	42.0	4.68
CR206637-080	WA	Goose Falls	northern pikeminnow	*Ptychocheilus oregonensis*	7	196	28.0	2.79
CR206637-081	WA	Lake Wallula Gap	smallmouth bass	*Micropterus dolomieu*	5	336	67.2	3.34

Appendix 9. Human health endpoint fish fillet tissue summary statistics. Units in ng/g ww.

HH-fish analytes (ng/g ww)	Min.	10th	25th	50th	75th	90th	Mean	Max.	S.E. of mean	% ND[1]
Mercury	70	80	120	190	280	450	241	750	6	0
2,4`-DDD	0.016	0.103	0.138	0.479	3.010	6.080	1.905	6.980	0.0855	0
2,4`-DDE	0.020	0.043	0.081	0.201	0.761	1.500	0.520	1.770	0.0209	0
2,4`-DDT	0.015	0.028	0.042	0.127	0.456	0.943	0.311	1.180	0.0127	0
4,4`-DDD	0.189	0.703	1.350	3.770	20.100	43.600	13.217	47.200	0.5827	0
4,4`-DDE	2.650	7.260	12.400	31.300	92.800	181.000	64.677	226.000	2.4939	0
4,4`-DDT	0.099	0.166	0.280	1.010	4.080	8.290	2.676	11.100	0.1155	0
total DDTs	3.191	8.316	15.039	43.621	117.108	234.375	83.306	289.553	3.2826	0
alpha Chlordane	0.006	0.013	0.019	0.071	0.165	0.364	0.140	0.687	0.0063	0
alpha-BHC	0.006	0.007	0.008	0.010	0.014	0.030	0.014	0.050	0.0004	0
beta-BHC	0.000	0.000	0.003	0.004	0.005	0.010	0.005	0.027	0.0002	20
cis-Nonachlor	0.013	0.033	0.047	0.096	0.146	0.298	0.134	0.559	0.0051	0
Dieldrin	0.013	0.033	0.070	0.087	0.174	0.476	0.172	1.050	0.0082	0
Endosulfan I	0.000	0.000	0.000	0.150	0.438	0.959	0.405	2.550	0.0245	46
Endosulfan sulfate	0.000	0.000	0.000	0.057	0.125	0.262	0.115	0.915	0.0076	41
Endrin	0.017	0.047	0.068	0.115	0.220	0.407	0.175	0.895	0.0067	0
gamma-BHC (Lindane)	0.000	0.004	0.005	0.008	0.013	0.018	0.010	0.037	0.0003	15
gamma-Chlordane/ trans-nonachlor	0.030	0.084	0.134	0.267	0.385	0.780	0.360	1.470	0.0135	0
Heptachlor	0.000	0.001	0.001	0.003	0.005	0.015	0.005	0.021	0.0002	7
Heptachlor epoxide	0.003	0.006	0.014	0.024	0.044	0.101	0.039	0.152	0.0014	0
Hexachlorobenzene	0.103	0.122	0.155	0.239	0.394	0.733	0.337	1.120	0.0093	0
Methoxychlor	0.036	0.046	0.072	0.090	0.130	0.342	0.160	1.490	0.0100	0
Mirex	0.003	0.005	0.007	0.014	0.026	0.048	0.018	0.050	0.0005	0
Oxychlordane	0.000	0.006	0.021	0.037	0.072	0.138	0.056	0.201	0.0019	2
Total chlordane	0.061	0.155	0.242	0.512	0.747	1.566	0.690	2.871	0.0263	0
PCB-016	0.000	0.000	0.000	0.011	0.029	0.072	0.027	0.196	0.0018	38
PCB-017	0.000	0.000	0.000	0.010	0.027	0.061	0.023	0.142	0.0014	40
PCB-018	0.000	0.003	0.004	0.018	0.046	0.100	0.039	0.246	0.0022	13
PCB-020	0.002	0.003	0.005	0.019	0.056	0.121	0.057	0.481	0.0039	0
PCB-022	0.000	0.002	0.004	0.019	0.052	0.093	0.039	0.231	0.0023	5
PCB-026	0.000	0.000	0.003	0.008	0.020	0.044	0.017	0.092	0.0009	18
PCB-028	0.005	0.008	0.016	0.055	0.125	0.282	0.124	0.982	0.0081	0
PCB-031	0.004	0.006	0.010	0.035	0.088	0.186	0.074	0.442	0.0038	0
PCB-037	0.000	0.000	0.002	0.008	0.022	0.030	0.014	0.070	0.0006	23
PCB-040	0.000	0.000	0.002	0.007	0.023	0.056	0.020	0.147	0.0012	25

1. List restricted to analytes with detection in majority of samples. Cut off at about 45% of samples with non-detects.

Appendix 9, cont. Human health endpoint fish fillet tissue summary statistics. Units in ng/g ww.

HH-fish analytes (ng/g ww)	Min.	10th	25th	50th	75th	90th	Mean	Max.	S.E. of mean	% ND[1]
PCB-041	0.000	0.000	0.000	0.006	0.020	0.045	0.017	0.142	0.0011	35
PCB-042	0.000	0.002	0.007	0.019	0.104	0.229	0.080	0.493	0.0045	13
PCB-043	0.008	0.025	0.039	0.205	0.346	1.070	0.312	1.550	0.0147	0
PCB-044	0.008	0.012	0.024	0.100	0.273	0.719	0.231	1.160	0.0117	0
PCB-045	0.000	0.000	0.000	0.006	0.014	0.029	0.012	0.085	0.0008	43
PCB-048	0.000	0.000	0.002	0.009	0.045	0.102	0.038	0.257	0.0023	18
PCB-049	0.005	0.011	0.030	0.090	0.228	0.599	0.200	1.050	0.0102	0
PCB-053	0.000	0.000	0.000	0.005	0.017	0.038	0.014	0.080	0.0008	40
PCB-056	0.002	0.003	0.007	0.029	0.118	0.267	0.084	0.507	0.0045	0
PCB-058	0.000	0.000	0.000	0.004	0.010	0.017	0.006	0.029	0.0003	35
PCB-059	0.000	0.000	0.001	0.003	0.017	0.035	0.013	0.087	0.0007	30
PCB-060	0.005	0.008	0.016	0.049	0.126	0.336	0.107	0.649	0.0055	0
PCB-063	0.000	0.002	0.004	0.008	0.026	0.061	0.020	0.119	0.0010	8
PCB-064	0.005	0.007	0.019	0.044	0.141	0.331	0.116	0.645	0.0060	0
PCB-065	0.004	0.007	0.016	0.039	0.081	0.197	0.077	0.386	0.0038	0
PCB-066	0.020	0.034	0.066	0.179	0.544	1.380	0.434	2.330	0.0213	0
PCB-070	0.018	0.026	0.068	0.244	0.421	0.893	0.336	1.500	0.0139	0
PCB-071	0.000	0.001	0.003	0.011	0.043	0.102	0.038	0.298	0.0025	13
PCB-074	0.010	0.019	0.036	0.109	0.289	0.841	0.247	1.340	0.0123	0
PCB-077	0.001	0.002	0.004	0.016	0.036	0.078	0.025	0.100	0.0010	0
PCB-081	0.000	0.000	0.002	0.005	0.017	0.032	0.010	0.034	0.0004	20
PCB-082	0.000	0.004	0.010	0.057	0.082	0.260	0.075	0.306	0.0035	10
PCB-083	0.000	0.002	0.007	0.016	0.037	0.091	0.026	0.098	0.0011	13
PCB-084	0.000	0.007	0.012	0.062	0.122	0.349	0.098	0.385	0.0043	5
PCB-085	0.014	0.021	0.055	0.172	0.285	0.884	0.246	1.030	0.0111	0
PCB-087	0.000	0.024	0.044	0.247	0.396	1.320	0.347	1.610	0.0170	3
PCB-089	0.012	0.017	0.052	0.119	0.257	0.708	0.189	0.749	0.0081	0
PCB-091	0.000	0.007	0.013	0.050	0.121	0.350	0.094	0.394	0.0043	8
PCB-095	0.019	0.026	0.068	0.232	0.530	1.450	0.387	1.650	0.0175	0
PCB-097	0.018	0.028	0.050	0.259	0.610	1.950	0.477	2.200	0.0238	0
PCB-099	0.035	0.056	0.150	0.433	0.787	2.260	0.617	2.530	0.0269	0
PCB-101	0.058	0.083	0.223	0.777	1.540	4.540	1.182	5.370	0.0553	0
PCB-105	0.039	0.055	0.119	0.418	0.643	1.900	0.554	2.420	0.0240	0
PCB-107	0.000	0.000	0.024	0.089	0.172	0.477	0.136	0.603	0.0062	23
PCB-110	0.051	0.069	0.153	0.653	1.370	3.910	1.026	4.330	0.0465	0

1. List restricted to analytes with detection in majority of samples. Cut off at about 45% of samples with non-detects.

Appendix 9, cont. Human health endpoint fish fillet tissue summary statistics. Units in ng/g ww.

HH-fish analytes (ng/g ww)	Min.	10th	25th	50th	75th	90th	Mean	Max.	S.E. of mean	% ND[1]
PCB-112	0.000	0.000	0.007	0.024	0.045	0.127	0.034	0.138	0.0015	15
PCB-114	0.000	0.007	0.013	0.032	0.062	0.168	0.051	0.200	0.0021	3
PCB-115	0.000	0.000	0.003	0.015	0.035	0.115	0.031	0.139	0.0015	20
PCB-118	0.110	0.239	0.404	1.200	2.230	6.260	1.807	8.560	0.0808	0
PCB-124	0.000	0.004	0.008	0.033	0.058	0.153	0.043	0.180	0.0019	5
PCB-128	0.022	0.030	0.080	0.184	0.339	0.942	0.289	1.450	0.0130	0
PCB-129	0.000	0.000	0.006	0.023	0.046	0.112	0.039	0.257	0.0021	18
PCB-130	0.000	0.009	0.027	0.074	0.185	0.472	0.126	0.634	0.0061	8
PCB-132	0.159	0.376	0.713	1.590	4.200	8.450	2.755	12.700	0.1182	0
PCB-134	0.003	0.004	0.010	0.036	0.082	0.234	0.060	0.267	0.0029	0
PCB-135	0.006	0.009	0.021	0.058	0.170	0.402	0.105	0.433	0.0048	0
PCB-137	0.000	0.005	0.017	0.041	0.079	0.200	0.072	0.440	0.0036	10
PCB-138	0.132	0.222	0.515	1.230	2.610	6.500	1.975	9.560	0.0868	0
PCB-140	0.000	0.000	0.000	0.003	0.008	0.016	0.005	0.024	0.0002	35
PCB-141	0.000	0.013	0.031	0.084	0.162	0.346	0.125	0.661	0.0055	5
PCB-142	0.000	0.005	0.012	0.021	0.054	0.136	0.039	0.170	0.0017	5
PCB-144	0.000	0.004	0.010	0.026	0.070	0.172	0.049	0.216	0.0084	3
PCB-146	0.019	0.042	0.091	0.218	0.458	0.985	0.319	1.290	0.0020	0
PCB-147	0.000	0.004	0.009	0.020	0.044	0.088	0.033	0.181	0.0084	3
PCB-148	0.000	0.006	0.015	0.045	0.119	0.286	0.078	0.328	0.0032	3
PCB-149	0.018	0.063	0.142	0.463	1.250	3.570	0.923	4.590	0.0005	0
PCB-151	0.003	0.025	0.060	0.138	0.349	0.654	0.221	0.882	0.0048	0
PCB-154	0.000	0.002	0.005	0.011	0.025	0.054	0.017	0.059	0.0015	3
PCB-156	0.004	0.030	0.055	0.127	0.207	0.535	0.188	1.030	0.0021	0
PCB-157	0.000	0.003	0.011	0.026	0.044	0.126	0.042	0.240	0.0015	10
PCB-158	0.002	0.013	0.031	0.083	0.181	0.595	0.169	0.932	0.0808	0
PCB-164	0.000	0.005	0.013	0.044	0.087	0.210	0.067	0.357	0.0019	8
PCB-166	0.000	0.000	0.004	0.009	0.016	0.042	0.013	0.053	0.0130	15
PCB-167	0.000	0.013	0.027	0.055	0.138	0.321	0.100	0.570	0.0021	5

1. List restricted to analytes with detection in majority of samples. Cut off at about 45% of samples with non-detects.

Appendix 9, cont. Human health endpoint fish fillet tissue summary statistics. Units in ng/g ww.

HH-fish analytes (ng/g ww)	Min.	10th	25th	50th	75th	90th	Mean	Max.	S.E. of mean	% ND[1]
PCB-170	0.020	0.038	0.062	0.129	0.289	0.527	0.200	0.799	0.0074	0
PCB-171	0.006	0.012	0.026	0.063	0.129	0.234	0.089	0.296	0.0032	0
PCB-172	0.004	0.008	0.016	0.026	0.059	0.099	0.042	0.158	0.0015	0
PCB-174	0.009	0.011	0.030	0.080	0.157	0.314	0.107	0.394	0.0042	0
PCB-175	0.000	0.000	0.003	0.008	0.016	0.032	0.011	0.039	0.0004	13
PCB-176	0.000	0.002	0.005	0.012	0.048	0.080	0.028	0.117	0.0012	3
PCB-177	0.000	0.016	0.049	0.126	0.313	0.586	0.205	0.753	0.0082	3
PCB-178	0.002	0.009	0.020	0.047	0.122	0.226	0.084	0.319	0.0033	0
PCB-179	0.006	0.009	0.020	0.054	0.136	0.239	0.092	0.373	0.0037	0
PCB-180	0.042	0.121	0.213	0.367	0.894	1.320	0.603	1.860	0.0197	0
PCB-181	0.000	0.000	0.000	0.002	0.006	0.018	0.011	0.195	0.0014	43
PCB-183	0.013	0.029	0.053	0.115	0.290	0.459	0.185	0.627	0.0066	0
PCB-184	0.000	0.000	0.000	0.001	0.002	0.003	0.001	0.007	0.0001	13
PCB-185	0.000	0.002	0.006	0.016	0.033	0.056	0.023	0.082	0.0008	3
PCB-187	0.031	0.093	0.141	0.339	0.644	1.240	0.477	1.650	0.0167	0
PCB-188	0.000	0.000	0.000	0.001	0.002	0.002	0.001	0.006	0.0000	25
PCB-189	0.001	0.002	0.003	0.005	0.012	0.022	0.008	0.038	0.0003	0
PCB-190	0.006	0.014	0.025	0.055	0.110	0.182	0.074	0.227	0.0024	0
PCB-191	0.000	0.002	0.004	0.008	0.015	0.025	0.011	0.037	0.0004	3
PCB-194	0.002	0.012	0.024	0.036	0.110	0.222	0.076	0.246	0.0028	0
PCB-195	0.003	0.011	0.013	0.028	0.075	0.111	0.044	0.134	0.0015	0
PCB-196	0.004	0.009	0.013	0.022	0.069	0.102	0.041	0.136	0.0014	0
PCB-197	0.001	0.001	0.002	0.004	0.008	0.011	0.005	0.017	0.0002	0
PCB-199	0.010	0.020	0.032	0.050	0.147	0.235	0.097	0.311	0.0033	0
PCB-200	0.001	0.001	0.002	0.005	0.011	0.018	0.008	0.029	0.0003	0
PCB-201	0.002	0.003	0.006	0.013	0.027	0.042	0.019	0.065	0.0007	0
PCB-202	0.003	0.007	0.009	0.029	0.065	0.097	0.042	0.151	0.0015	0
PCB-203	0.008	0.018	0.027	0.055	0.149	0.239	0.099	0.341	0.0034	0
PCB-205	0.000	0.001	0.002	0.004	0.010	0.014	0.006	0.019	0.0002	8
PCB-206	0.003	0.006	0.011	0.022	0.049	0.088	0.036	0.106	0.0012	0
PCB-207	0.001	0.002	0.002	0.005	0.008	0.015	0.006	0.019	0.0002	0
PCB-208	0.001	0.003	0.004	0.008	0.017	0.027	0.013	0.037	0.0004	0
PCB-209	0.001	0.003	0.005	0.009	0.015	0.033	0.012	0.043	0.0004	0
Sum_PCBs	1.372	2.638	5.297	12.409	28.844	70.827	20.985	85.266	0.8867	0
PBDE-015	0.001	0.002	0.003	0.006	0.011	0.035	0.013	0.074	0.0006	0

1. List restricted to analytes with detection in majority of samples. Cut off at about 45% of samples with non-detects.

Appendix 9, cont. Human health endpoint fish fillet tissue summary statistics. Units in ng/g ww.

HH-fish analytes (ng/g ww)	Min.	10th	25th	50th	75th	90th	Mean	Max.	S.E. of Mean	% ND[1]
PBDE-017	0.000	0.004	0.006	0.044	0.078	0.233	0.080	0.622	0.0052	3
PBDE-028	0.006	0.021	0.039	0.285	0.401	0.640	0.307	1.890	0.0153	0
PBDE-047	0.327	0.663	1.690	5.080	7.890	15.600	6.449	34.600	0.2788	0
PBDE-049	0.010	0.029	0.081	0.192	0.298	0.513	0.242	1.420	0.0106	0
PBDE-066	0.000	0.007	0.013	0.020	0.040	0.129	0.044	0.236	0.0023	5
PBDE-085	0.000	0.000	0.000	0.002	0.004	0.034	0.007	0.048	0.0005	28
PBDE-099	0.035	0.054	0.099	0.222	0.375	1.160	0.410	1.780	0.0184	0
PBDE-100	0.076	0.175	0.239	0.903	1.690	2.360	1.164	5.890	0.0472	0
PBDE-139	0.000	0.000	0.000	0.001	0.001	0.003	0.001	0.006	0.0001	43
PBDE-140	0.000	0.000	0.000	0.002	0.002	0.004	0.002	0.008	0.0001	30
PBDE-153	0.016	0.036	0.045	0.070	0.119	0.239	0.108	0.425	0.0037	0
PBDE-154	0.023	0.035	0.053	0.130	0.262	0.412	0.195	0.961	0.0075	0
PBDE-183	0.000	0.001	0.001	0.002	0.002	0.003	0.002	0.006	0.0000	13
PBDE-184	0.000	0.000	0.000	0.001	0.001	0.002	0.001	0.003	0.0000	33
PBDE-197	0.000	0.000	0.000	0.001	0.002	0.002	0.001	0.005	0.0000	40
PBDE-206	0.000	0.000	0.000	0.009	0.013	0.019	0.009	0.067	0.0004	40
PBDE-209	0.000	0.076	0.099	0.136	0.223	0.248	0.171	1.280	0.0063	5
Sum_PBDEs	0.800	1.295	2.779	7.328	10.963	21.368	9.278	47.957	0.3782	0

1. List restricted to analytes with detection in majority of samples. Cut off at about 45% of samples with non-detects.

Appendix 10. List of other human health endpoint fish fillet tissue PCBs analyzed but with insufficient detections for CDF calculations.

analyte	% non-detects	analyte	% non-detects	analyte	% non-detects
PCB-019	58	PCB-073	98	PCB-126	53
PCB-023	98	PCB-078	98	PCB-127	100
PCB-024	85	PCB-079	98	PCB-131	50
PCB-025	48	PCB-080	100	PCB-136	55
PCB-027	53	PCB-086	100	PCB-139	100
PCB-029	70	PCB-088	98	PCB-143	100
PCB-030	100	PCB-090	48	PCB-145	80
PCB-034	85	PCB-092	100	PCB-150	58
PCB-035	68	PCB-093	98	PCB-152	68
PCB-036	93	PCB-094	60	PCB-155	63
PCB-038	100	PCB-096	68	PCB-159	98
PCB-039	50	PCB-098	90	PCB-161	100
PCB-046	60	PCB-100	68	PCB-162	93
PCB-047	100	PCB-102	53	PCB-165	95
PCB-050	95	PCB-103	55	PCB-168	100
PCB-051	53	PCB-104	100	PCB-169	60
PCB-054	100	PCB-106	100	PCB-173	50
PCB-055	75	PCB-108	75	PCB-186	98
PCB-057	60	PCB-109	100	PCB-192	100
PCB-061	100	PCB-120	80	PCB-198	100
PCB-062	100	PCB-122	88	PCB-204	100
PCB-069	90	PCB-125	73		

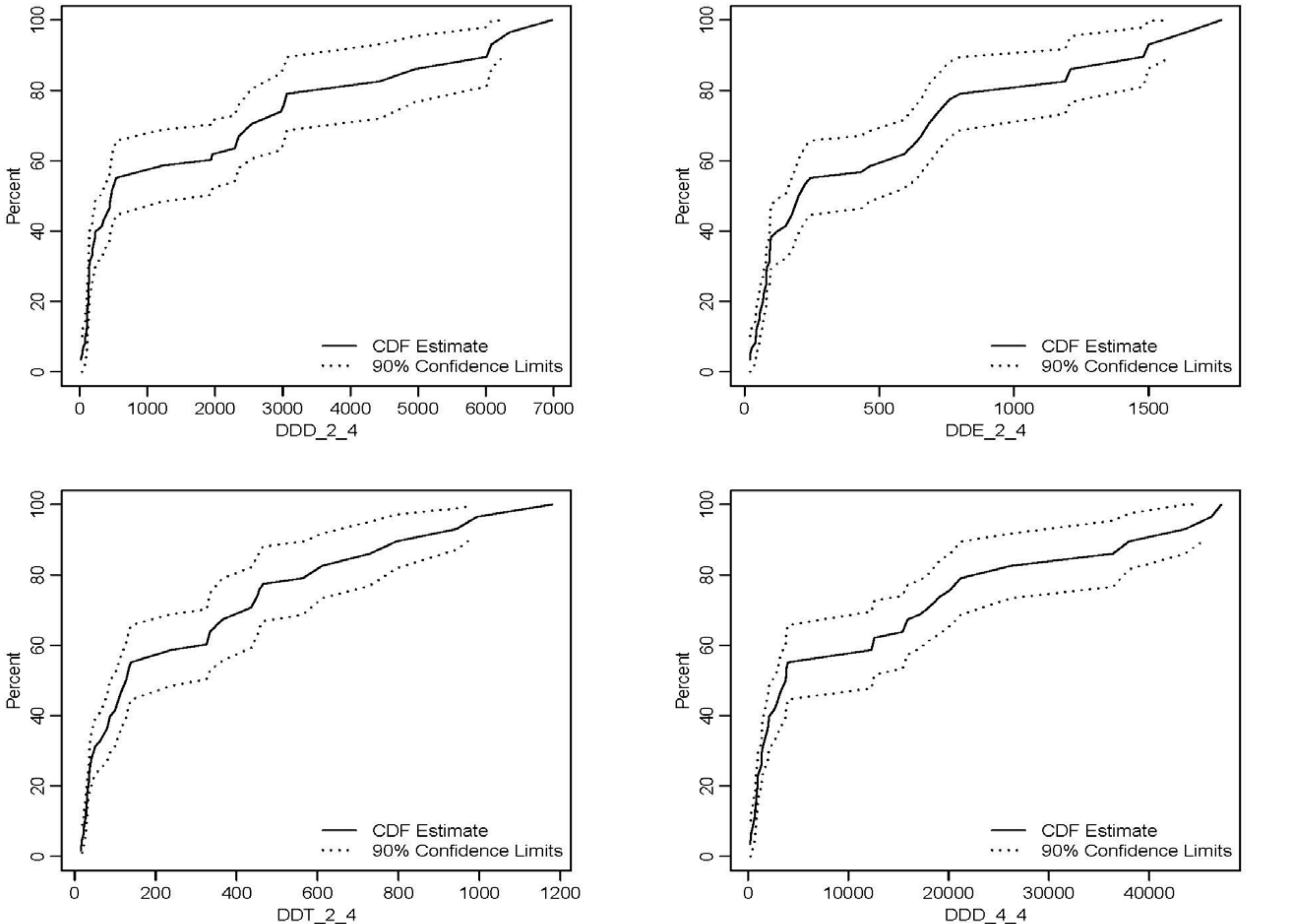
Appendix 11. List of Eco-endpoint whole fish analytes with summary statistics and % non-detects.

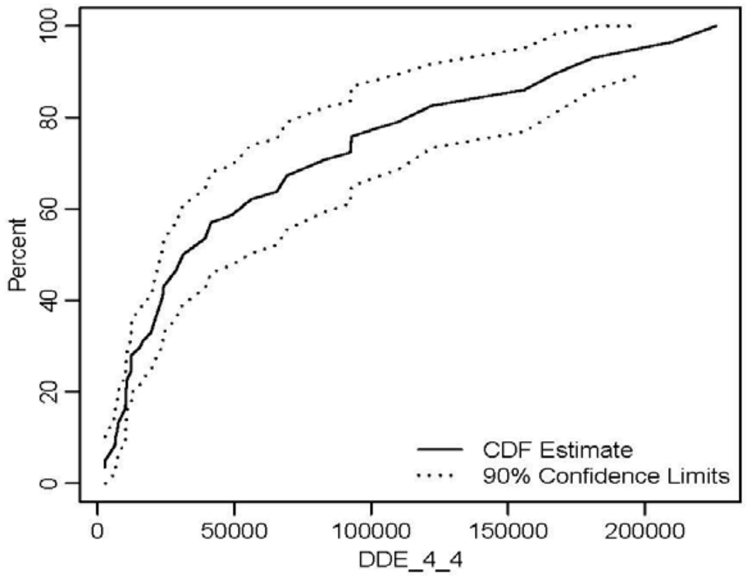
Analytes	Units	Median	Minimum	Maximum	% ND
Arsenic	µg/g ww	0.140	0.033	0.384	0
Cadmium	µg/g ww	0.025	0.004	0.083	0
Chromium	µg/g ww	0.235	0.083	0.865	0
Copper	µg/g ww	0.974	0.503	4.298	0
Lead	µg/g ww	0.050	0.036	0.831	65
Mercury	µg/g ww	0.031	0.013	0.118	0
Nickel	µg/g ww	0.330	0.019	5.971	5
Selenium	µg/g ww	0.374	0.103	0.732	0
Zinc	µg/g ww	19.067	12.080	32.804	0
2,4'-DDE	ng/g ww	0.52	0.2	2.02	32
4,4'-DDE	ng/g ww	49.27	2.81	231.22	0
2,4'-DDD	ng/g ww	0.95	0.22	5.44	32
4,4'-DDD	ng/g ww	9.66	0.32	41.72	0
4,4'-DDT	ng/g ww	0.6	0.12	2.13	16
2,4'-DDT	ng/g ww	0.25	0.21	1.23	38
total DDTs	ng/g ww	59.41	3.13	269.76	0
Total chlordane	ng/g ww	0.63	0	14.64	8
Alpha-BHC	ng/g ww	0	1.32	1.32	97
HC benzene	ng/g ww	0.49	0.21	1.58	8
Lindane	ng/g ww	0	0.2	0.2	97
Heptachlor	ng/g ww	0	0	0	100
Aldrin	ng/g ww	0	0	0	100
H Epoxide	ng/g ww	0	0.18	0.19	92
Oxychlordane	ng/g ww	0.15	0.15	2.46	43
G Chlordane	ng/g ww	0	0.12	2.34	43
Endosulfan 1	ng/g ww	0	0.33	3.48	81
A Chlordane	ng/g ww	0.18	0.17	5.09	32
T Nonachlor	ng/g ww	0.4	0.19	3.92	8
Dieldrin	ng/g ww	0.53	0.26	1.83	3
Endrin	ng/g ww	0.45	0.24	1.18	57
Endosulfan II	ng/g ww	0	0.3	1.76	84
Cis Nonachlor	ng/g ww	0	0.15	0.83	95
Endrin Ketone	ng/g ww	0	0.23	0.23	97
Mirex	ng/g ww	0	0	0	100

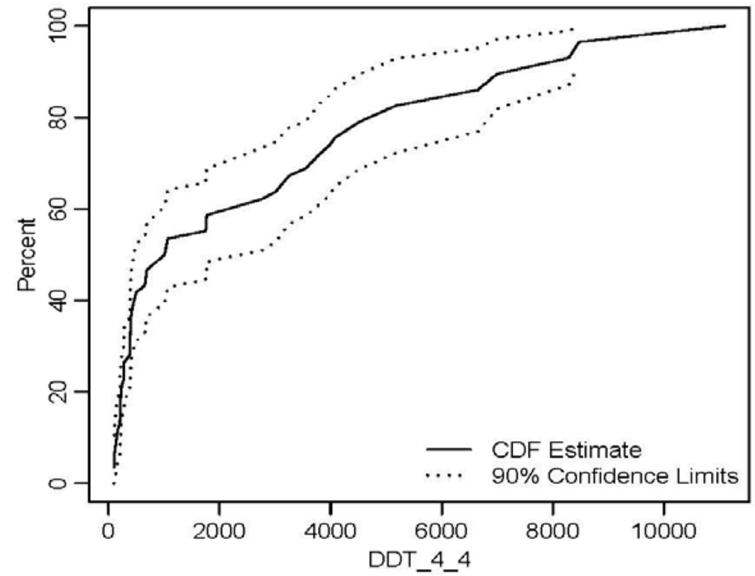
Appendix 11, cont. List of eco-endpoint whole fish analytes with summary statistics and % non-detects.

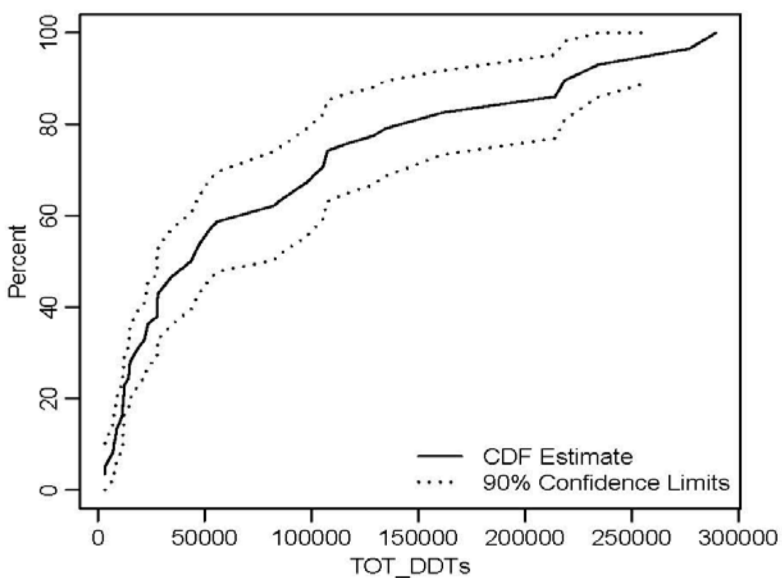
Analytes	Units	Median	min detected value	maximum	% non-detects
PCB-8	ng/g ww	0	0.64	0.64	97
PCB-18	ng/g ww	0	0	0	100
PCB-28	ng/g ww	0	2.16	2.16	97
PCB-44	ng/g ww	0	0.27	1.62	68
PCB-52	ng/g ww	0.45	0.32	2.14	22
PCB-66	ng/g ww	0.47	0.21	2.69	8
PCB-77	ng/g ww	0.23	0.23	3.69	41
PCB-101	ng/g ww	1.69	0.51	5.5	3
PCB-105	ng/g ww	0.38	0.14	1.87	5
PCB-118	ng/g ww	1.45	0.5	6.08	0
PCB-126	ng/g ww	0	0.19	0.19	97
PCB-128	ng/g ww	0.32	0.2	1.3	14
PCB-138	ng/g ww	3.11	1.3	9.01	0
PCB-153	ng/g ww	2.05	0.69	6.95	0
PCB-169	ng/g ww	0	0	0	100
PCB-170	ng/g ww	0.27	0.23	0.72	46
PCB-180	ng/g ww	0.64	0.28	4.14	3
PCB-187	ng/g ww	0.54	0.28	1.79	3
PCB-195	ng/g ww	0	0.2	0.2	97
PCB-206	ng/g ww	0	0	0	100
PCB-209	ng/g ww	0	0	0	100
PCB sum	ng/g ww	11.87	3.6	36.6	0
PBDE-47	ng/g ww	4.53	2.75	13.51	3
PBDE-66	ng/g ww	0	0	0	100
PBDE-99	ng/g ww	0	0.31	1.73	84
PBDE-100	ng/g ww	0.83	0.41	3.18	19
PBDE-138	ng/g ww	0	0	0	100
PBDE-153	ng/g ww	0	0	0	100
PBDE-154	ng/g ww	0	0	0	100
PBDE-183	ng/g ww	0	0	0	100
PBDE sum	ng/g ww	5.25	0.54	16.69	0

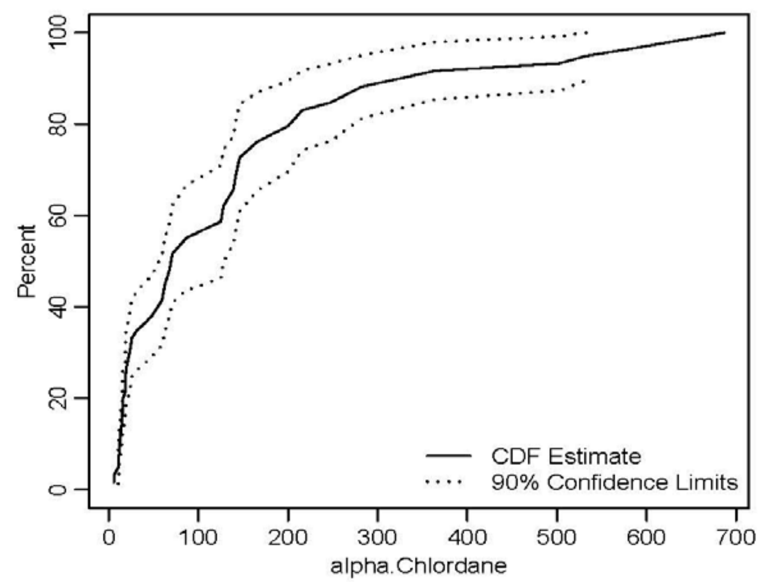
Appendix 12. Fillet tissue concentration cumulative distribution frequency (CDF) estimates for analytes detected at >40% of MCR sites. Upper and lower 90% confidence bounds are shown. Units are ng/kg ww except mercury is mg/kg ww.

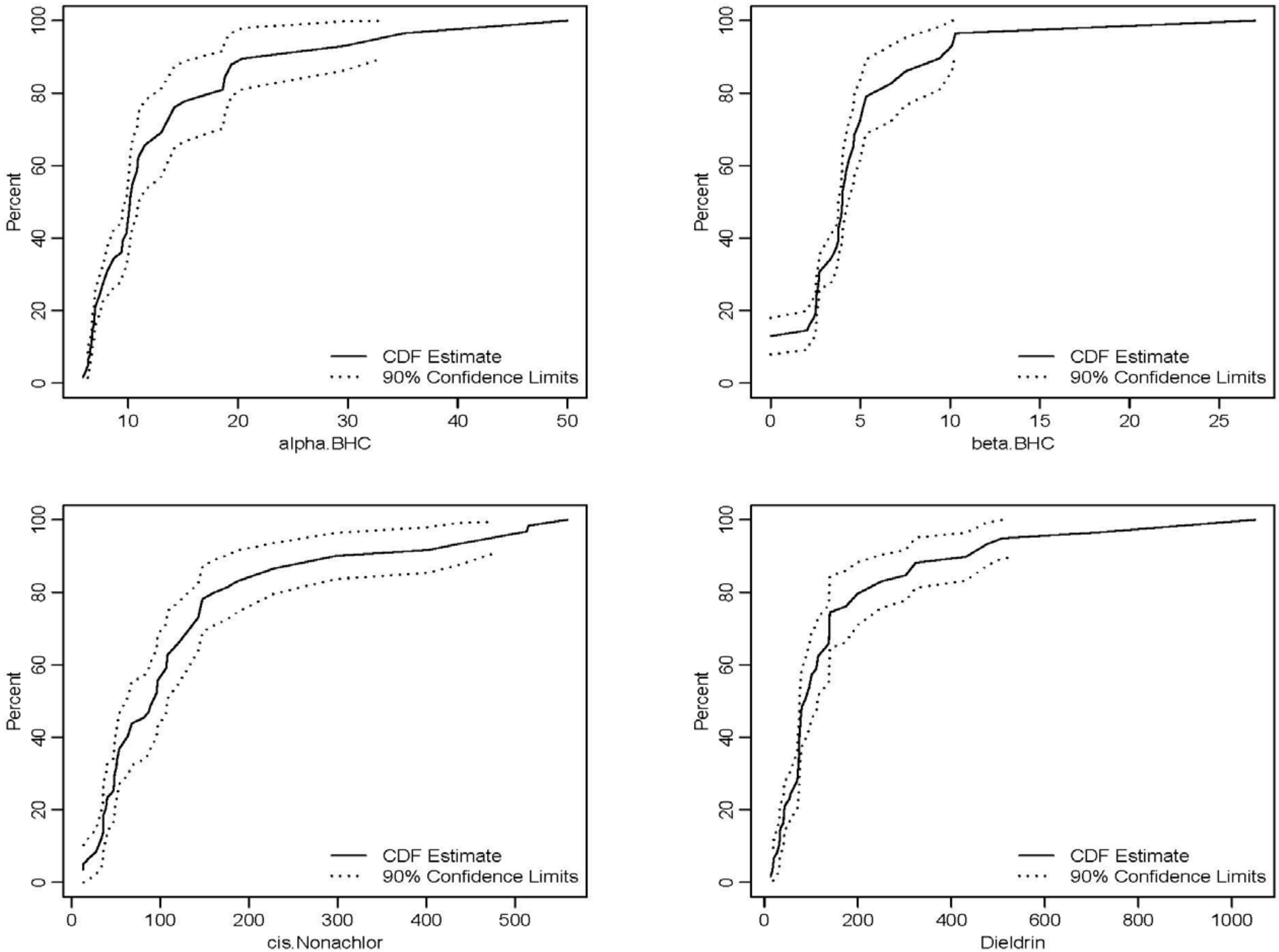

Percent
DDD_2_4
DDE_2_4
DDT_2_4
DDD_4_4
CDF Estimate
90% Confidence Limits

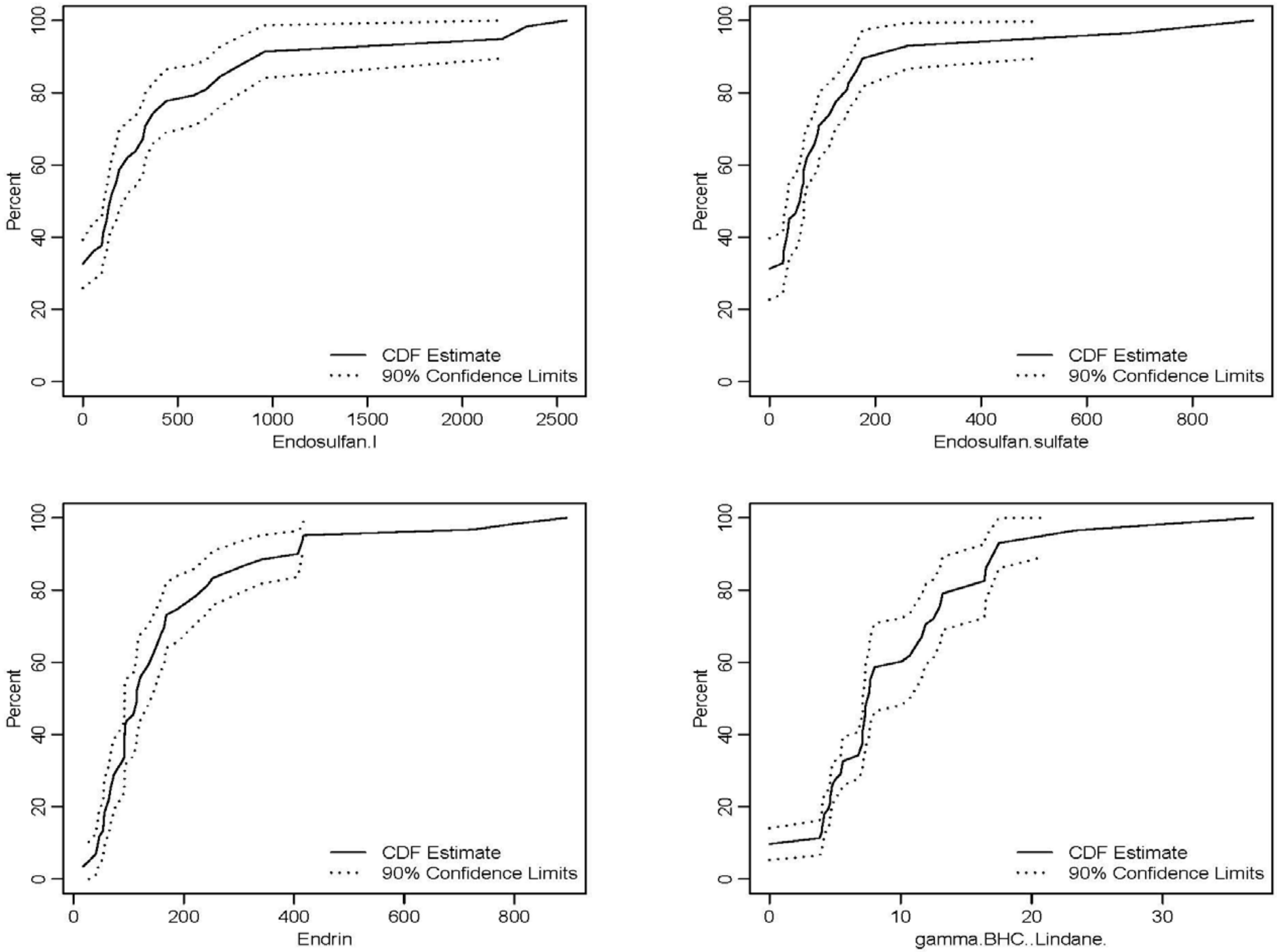

Percent
0
20
40
60
80
100
0
50000
100000
150000
200000
DDE_4_4
CDF Estimate
90% Confidence Limits

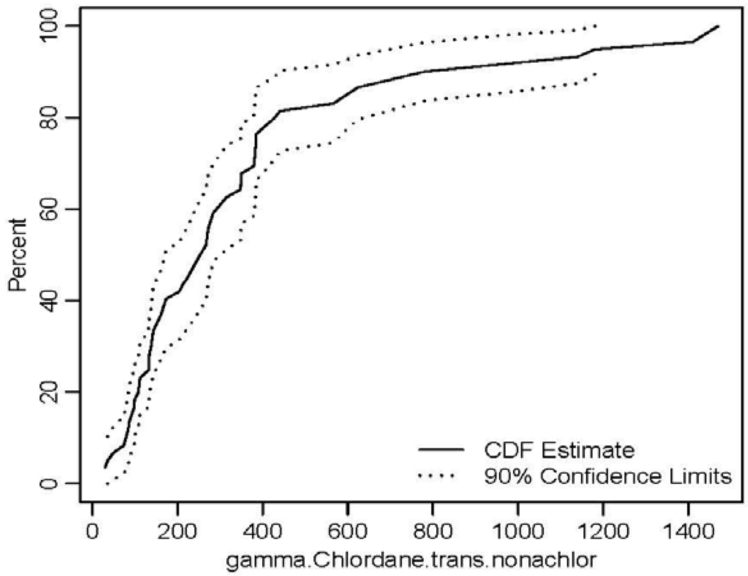

Percent
0
20
40
60
80
100
0
2000
4000
6000
8000
10000
DDT_4_4
CDF Estimate
90% Confidence Limits

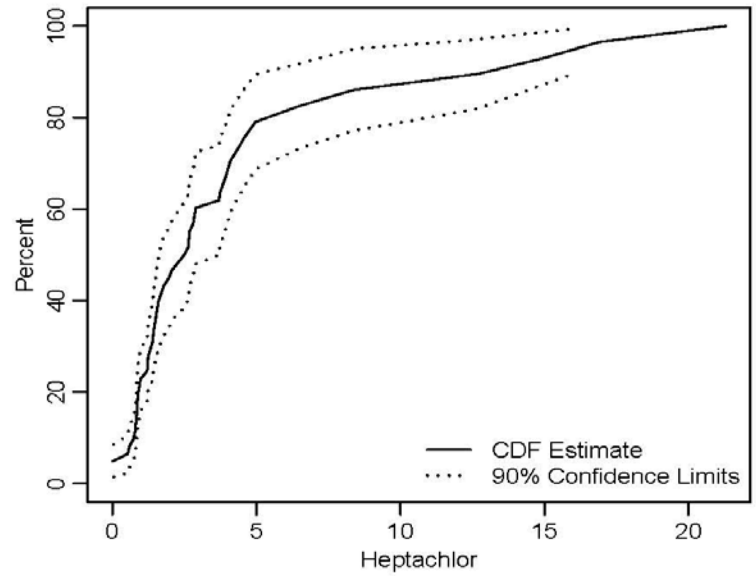

Percent
0
20
40
60
80
100
0
50000
100000
150000
200000
250000
300000
TOT_DDTs
CDF Estimate
90% Confidence Limits

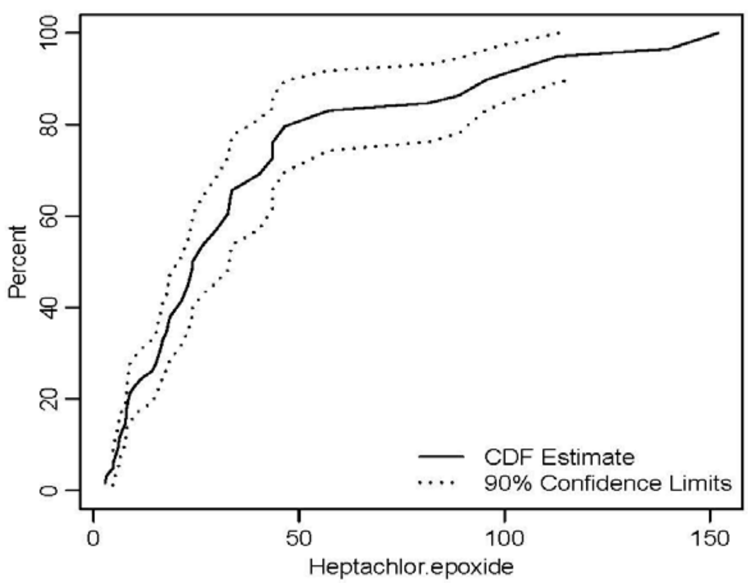

Percent
0
20
40
60
80
100
0
100
200
300
400
500
600
700
alpha.Chlordane
CDF Estimate
90% Confidence Limits

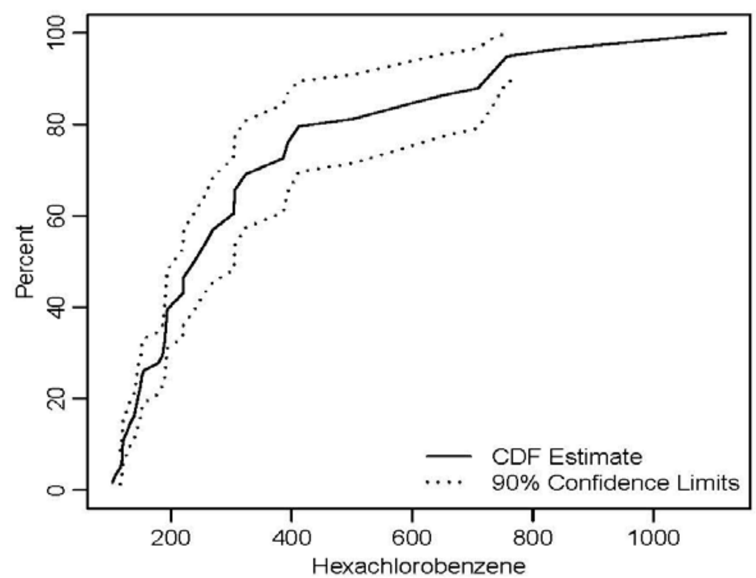

Percent
CDF Estimate
90% Confidence Limits
alpha.BHC
beta.BHC
cis.Nonachlor
Dieldrin

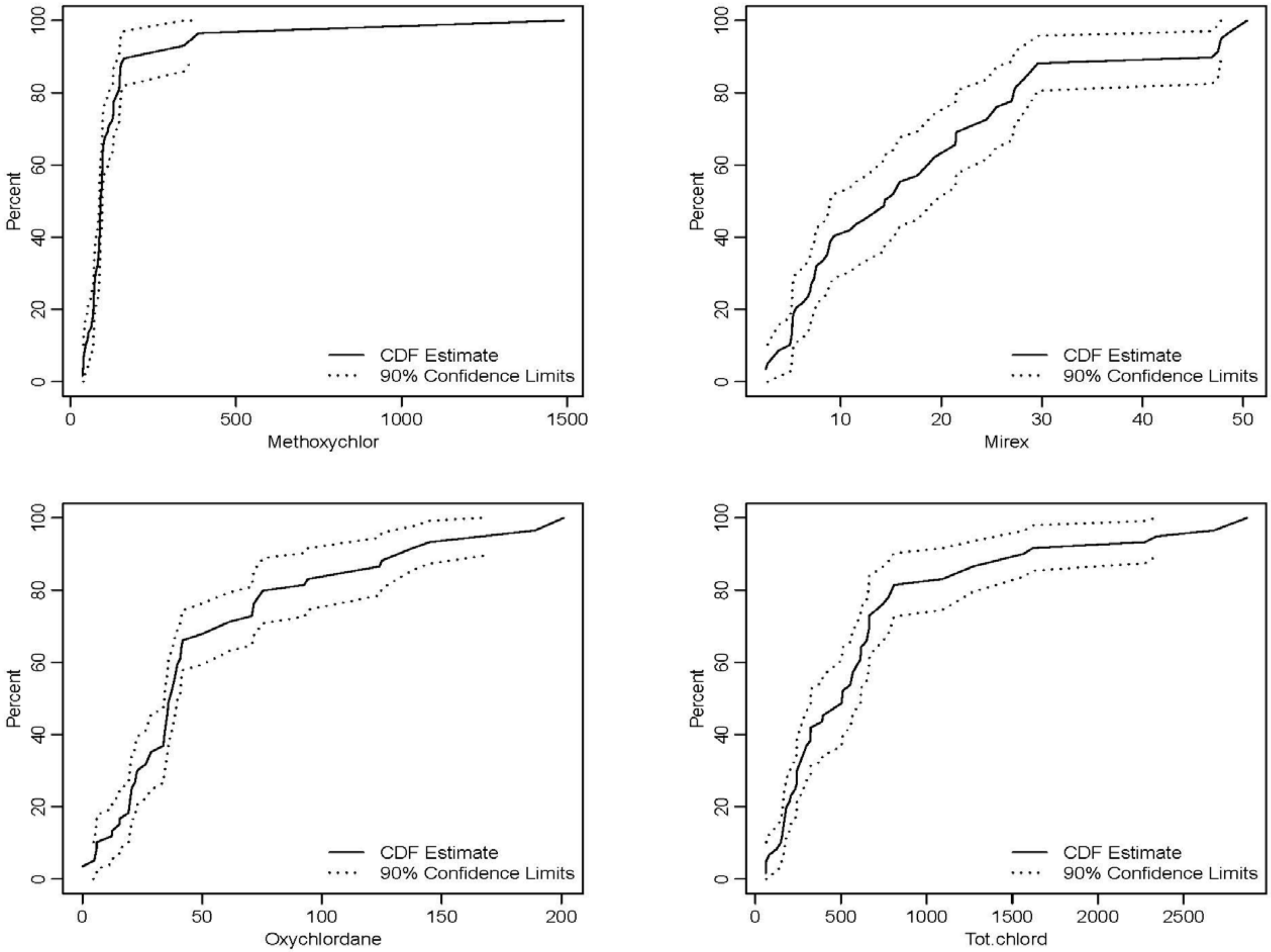

Percent
0
20
40
60
80
100
CDF Estimate
90% Confidence Limits
0
500
1000
1500
2000
2500
Endosulfan.I
Percent
0
20
40
60
80
100
CDF Estimate
90% Confidence Limits
0
200
400
600
800
Endosulfan.sulfate
Percent
0
20
40
60
80
100
CDF Estimate
90% Confidence Limits
0
200
400
600
800
Endrin
Percent
0
20
40
60
80
100
CDF Estimate
90% Confidence Limits
0
10
20
30
gamma.BHC..Lindane.

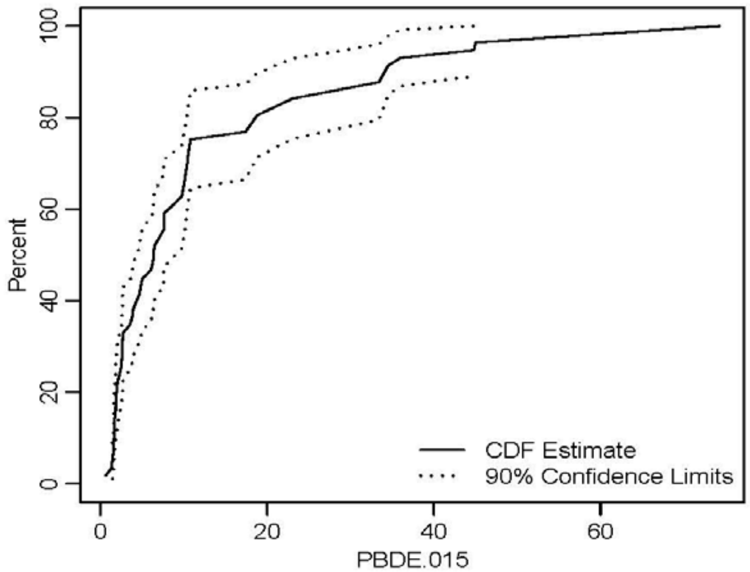

Percent
0
20
40
60
80
100
0
200
400
600
800
1000
1200
1400
gamma.Chlordane.trans.nonachlor
CDF Estimate
90% Confidence Limits

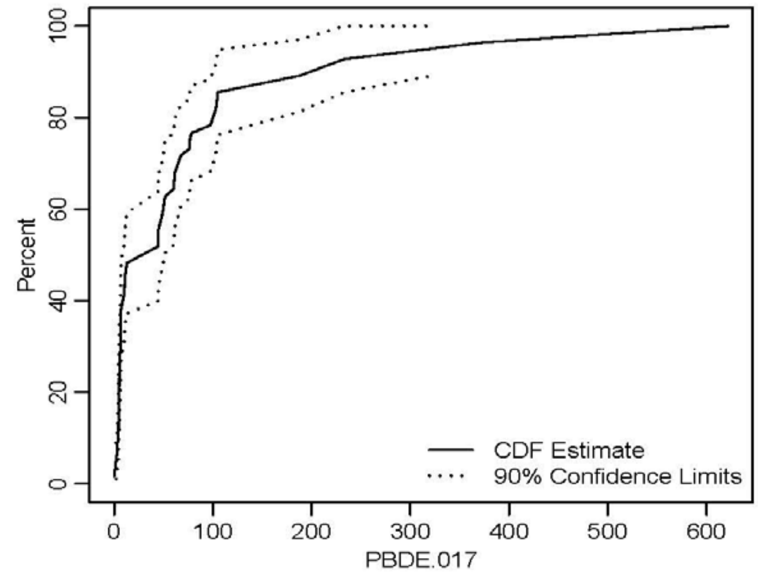

Percent
0
20
40
60
80
100
0
5
10
15
20
Heptachlor
CDF Estimate
90% Confidence Limits

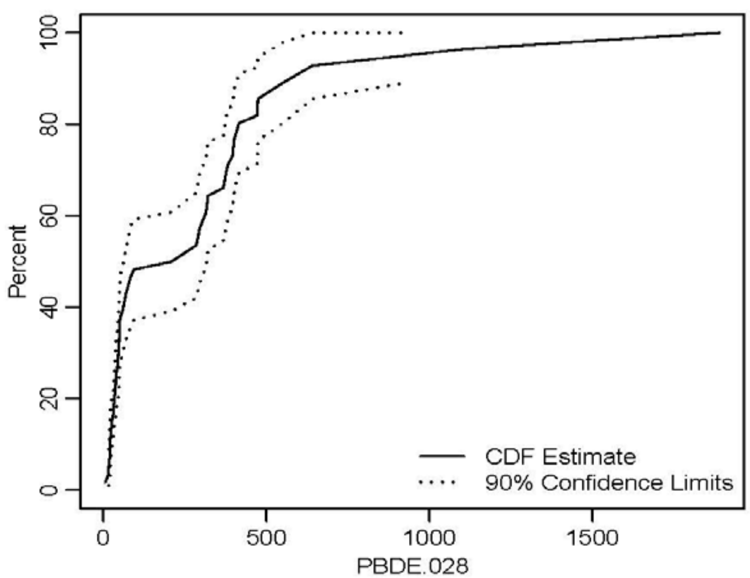

Percent
0
20
40
60
80
100
0
50
100
150
Heptachlor.epoxide
CDF Estimate
90% Confidence Limits

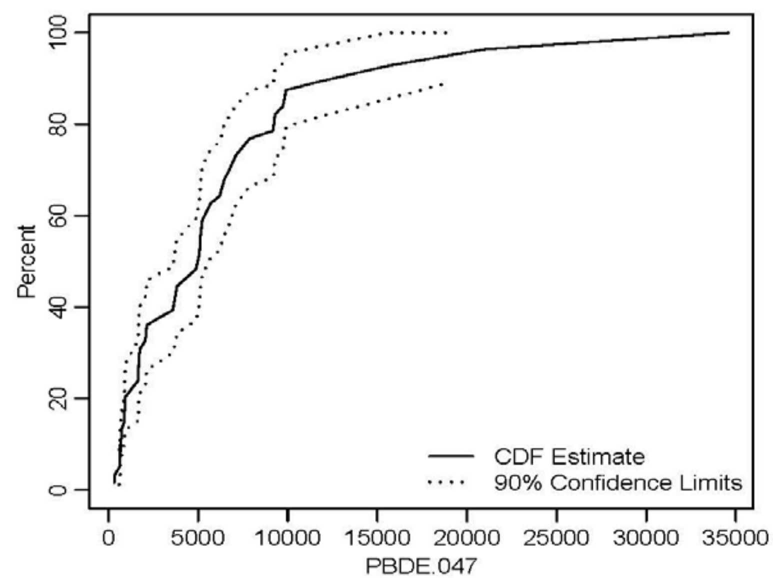

Percent
0
20
40
60
80
100
200
400
600
800
1000
Hexachlorobenzene
CDF Estimate
90% Confidence Limits

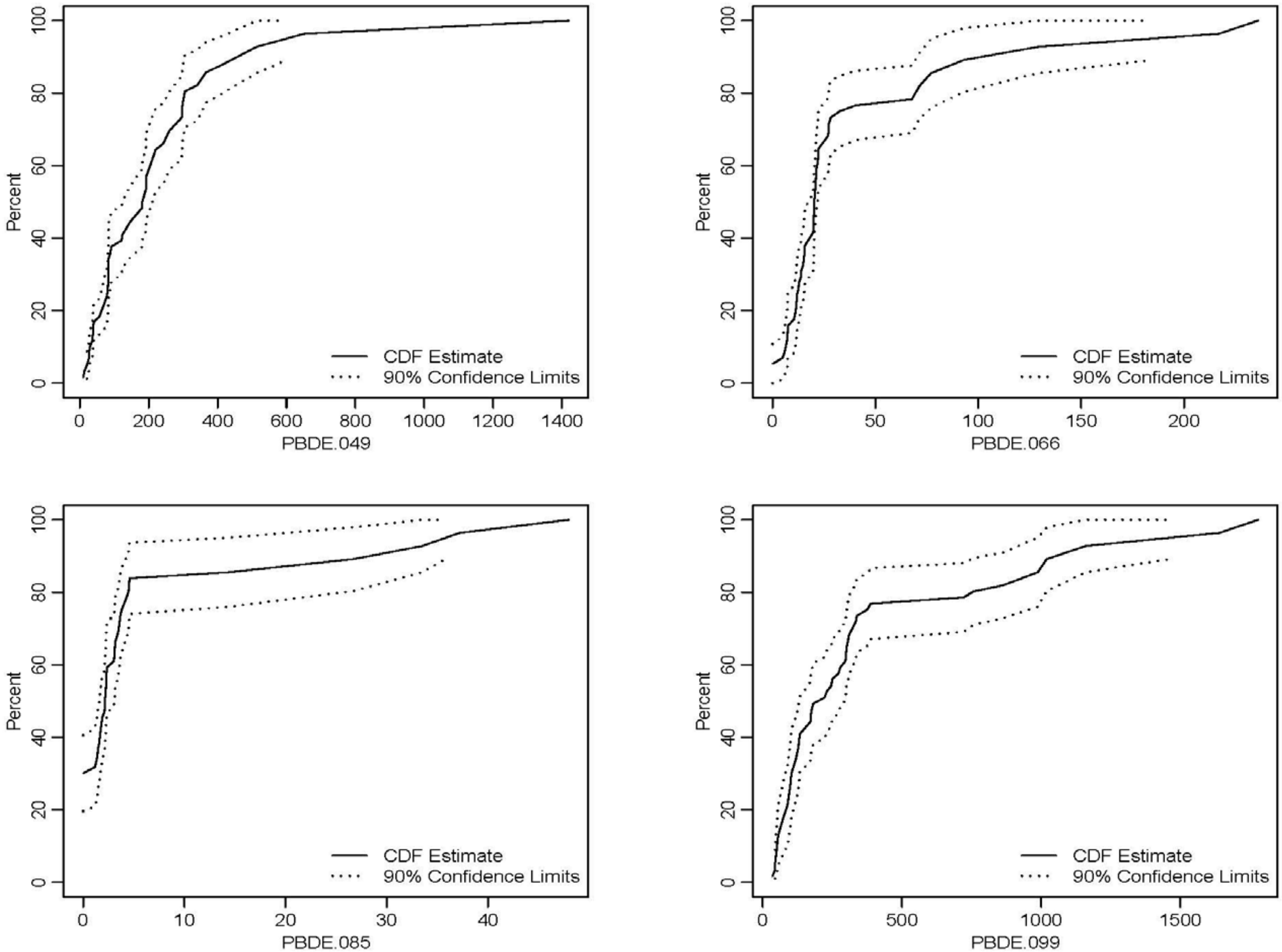

Percent
Methoxychlor
CDF Estimate
90% Confidence Limits
Percent
Mirex
CDF Estimate
90% Confidence Limits
Percent
Oxychlordane
CDF Estimate
90% Confidence Limits
Percent
Tot.chlord
CDF Estimate
90% Confidence Limits

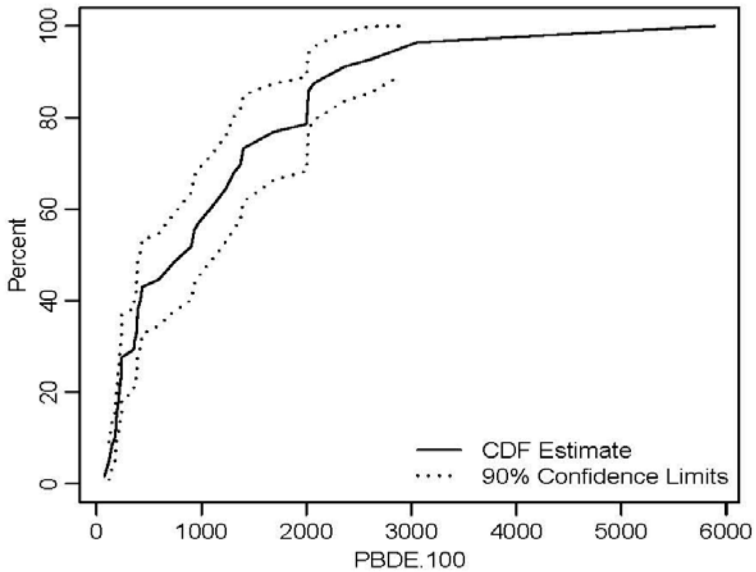

Percent
0
20
40
60
80
100
0
20
40
60
PBDE.015
CDF Estimate
90% Confidence Limits

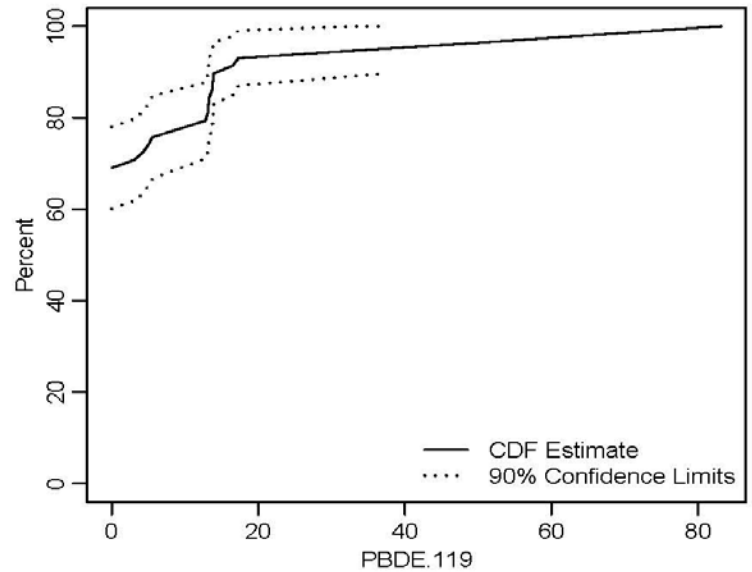

Percent
0
20
40
60
80
100
0
100
200
300
400
500
600
PBDE.017
CDF Estimate
90% Confidence Limits


Percent
0
20
40
60
80
100
0
500
1000
1500
PBDE.028
CDF Estimate
90% Confidence Limits


Percent
0
20
40
60
80
100
0
5000
10000
15000
20000
25000
30000
35000
PBDE.047
CDF Estimate
90% Confidence Limits


Percent
PBDE.049
PBDE.066
PBDE.085
PBDE.099
CDF Estimate
90% Confidence Limits
0
20
40
60
80
100
200
400
600
800
1000
1200
1400
50
150
10
30
500
1500


Percent
0
20
40
60
80
100
0
1000
2000
3000
4000
5000
6000
PBDE.100
CDF Estimate
90% Confidence Limits


Percent
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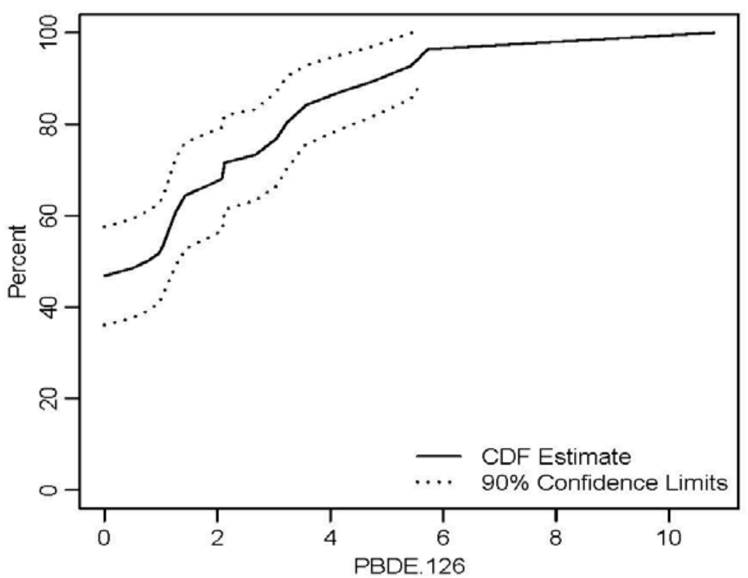
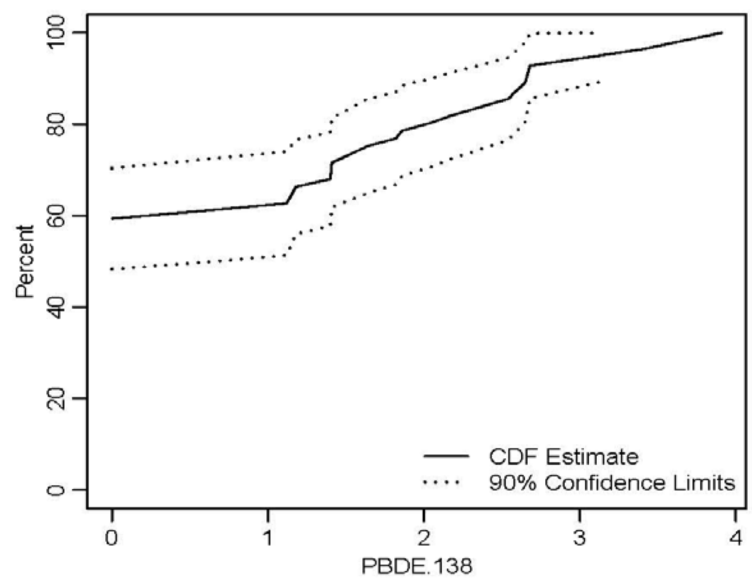
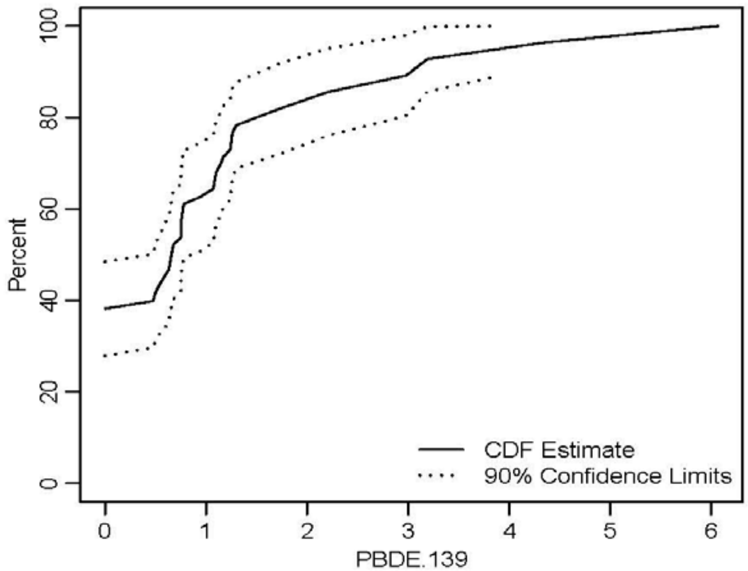
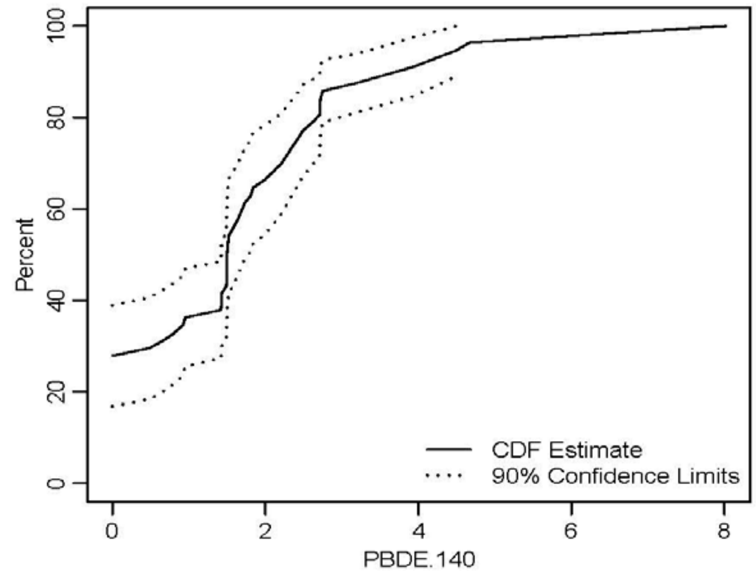
20
40
60
80
100
0
20
40
60
80
PBDE.119
CDF Estimate
90% Confidence Limits


Percent
0
20
40
60
80
100
0
2
4
6
8
10
PBDE.126
CDF Estimate
90% Confidence Limits


Percent
0
20
40
60
80
100
0
1
2
3
4
PBDE.138
CDF Estimate
90% Confidence Limits


Percent
0
20
40
60
80
100
0
1
2
3
4
5
6
PBDE.139
CDF Estimate
90% Confidence Limits


Percent
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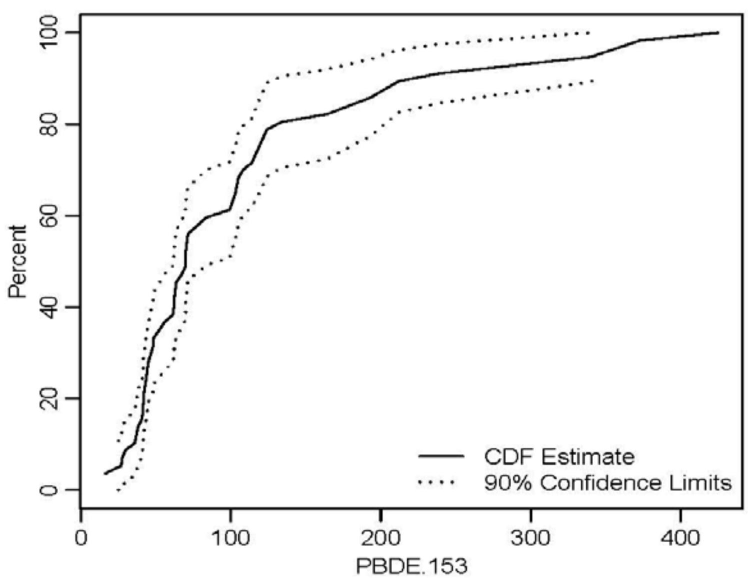
20
40
60
80
100
0
2
4
6
8
PBDE.140
CDF Estimate
90% Confidence Limits


Percent
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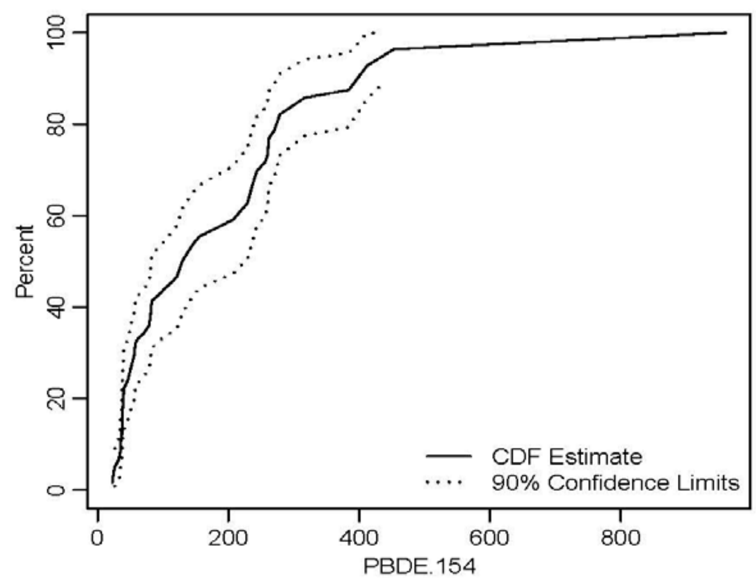
20
40
60
80
100
0
100
200
300
400
PBDE.153
CDF Estimate
90% Confidence Limits


Percent
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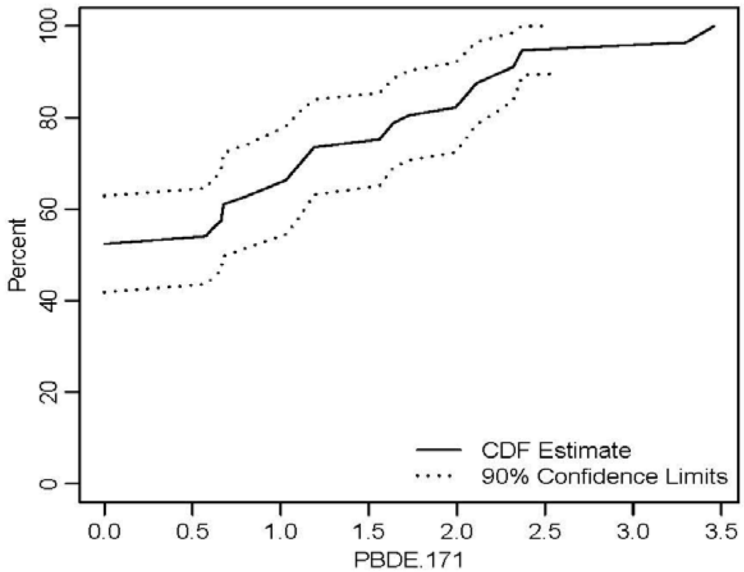
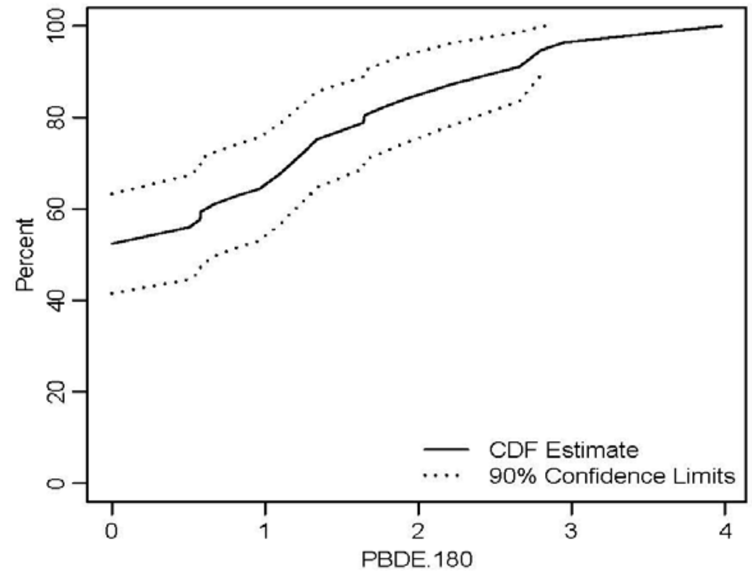
40
60
80
100
0
200
400
600
800
PBDE.154
CDF Estimate
90% Confidence Limits


Percent
0
20
40
60
80
100
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
PBDE.171
CDF Estimate
90% Confidence Limits


Percent
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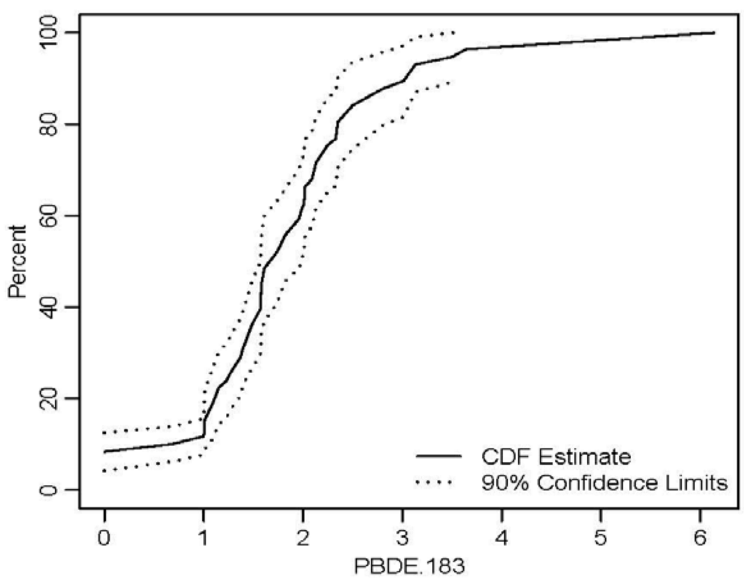
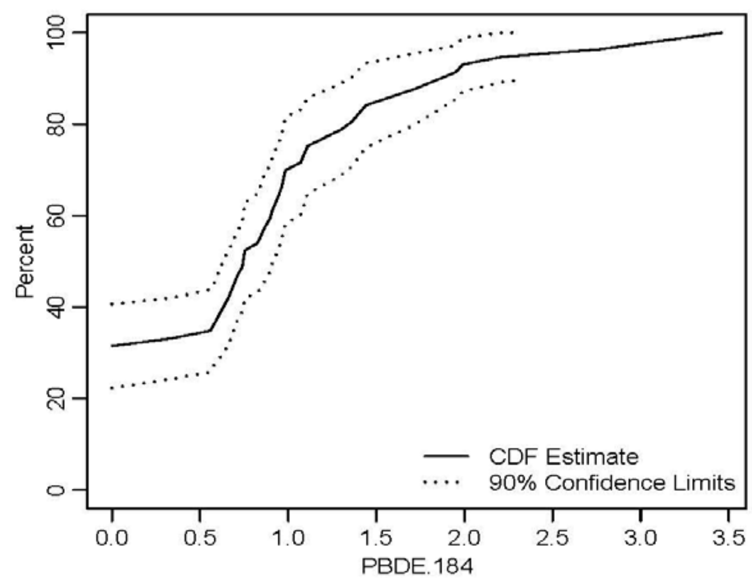
20
40
60
80
100
0
1
2
3
4
PBDE.180
CDF Estimate
90% Confidence Limits


Percent
0
20
40
60
80
100
0
1
2
3
4
5
6
PBDE.183
CDF Estimate
90% Confidence Limits


Percent
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20
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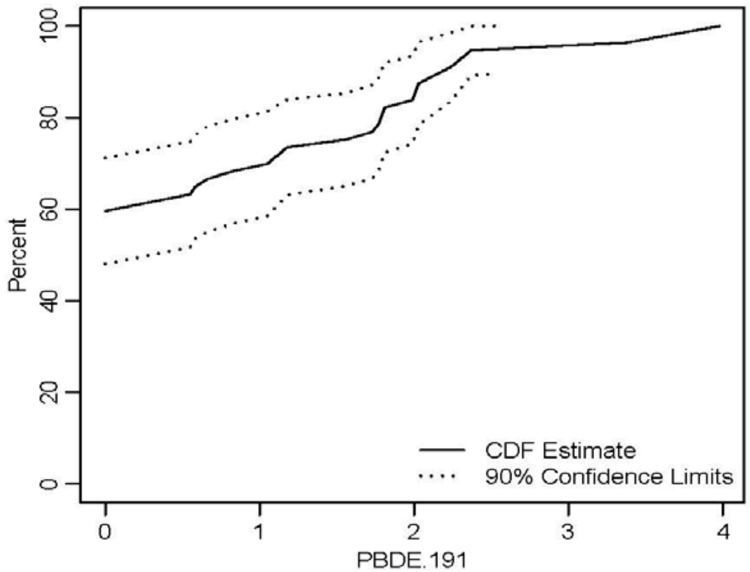
60
80
100
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
PBDE.184
CDF Estimate
90% Confidence Limits


Percent
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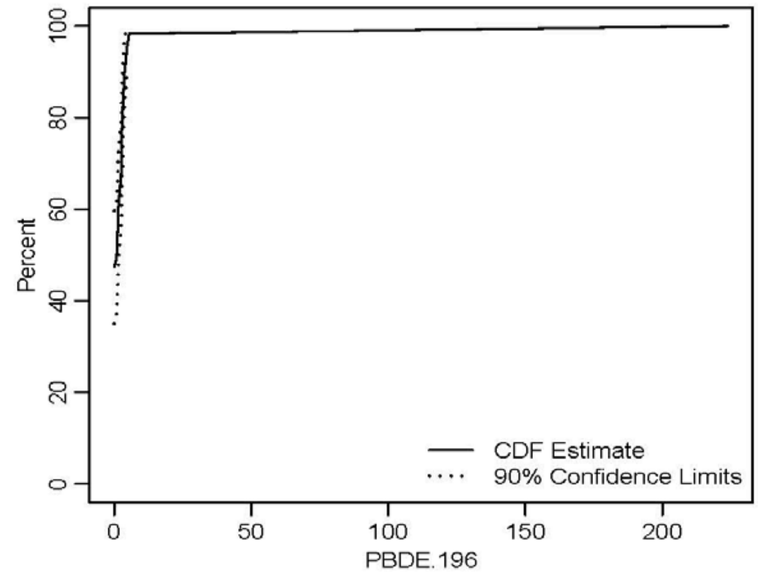
20
40
60
80
100
0
1
2
3
4
PBDE.191
CDF Estimate
90% Confidence Limits


Percent
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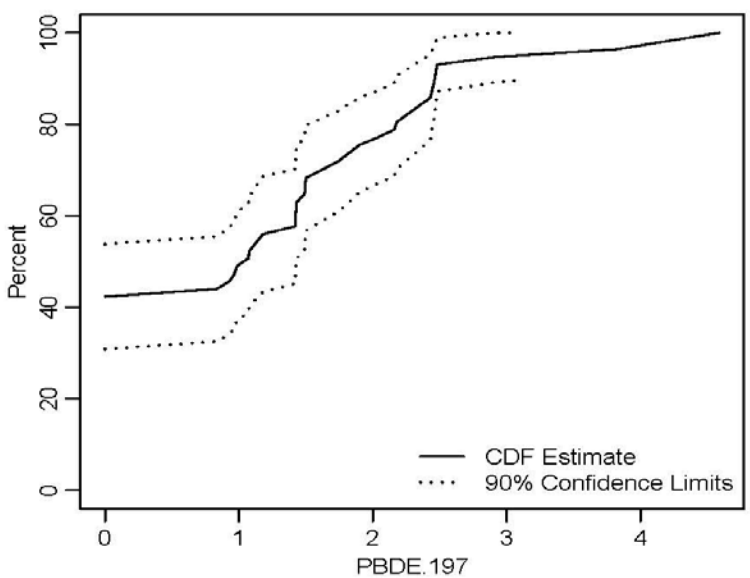
20
40
60
80
100
0
50
100
150
200
PBDE.196
CDF Estimate
90% Confidence Limits


Percent
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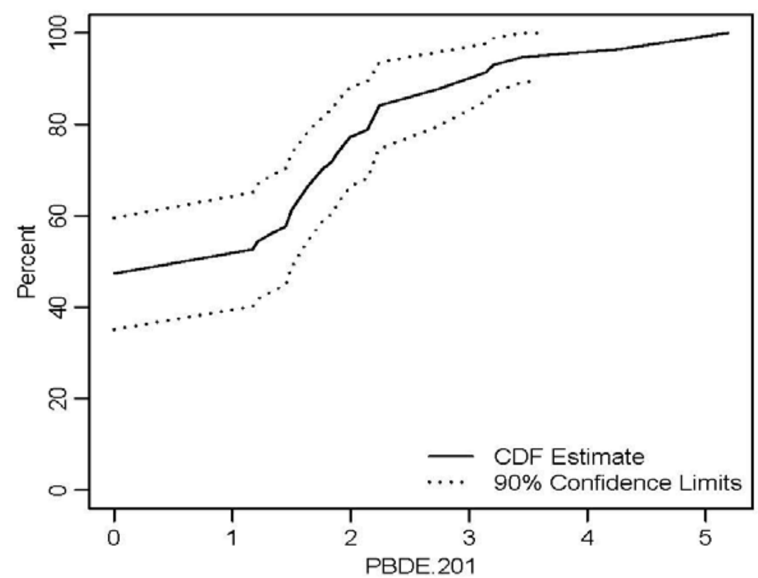
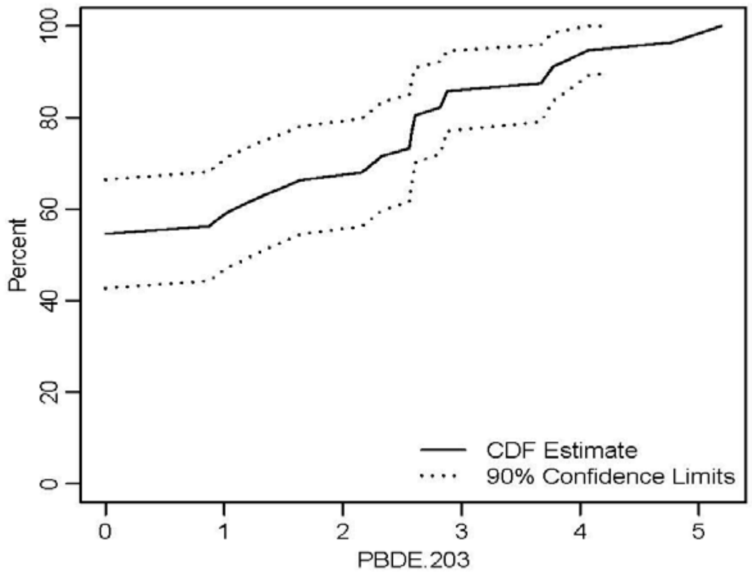
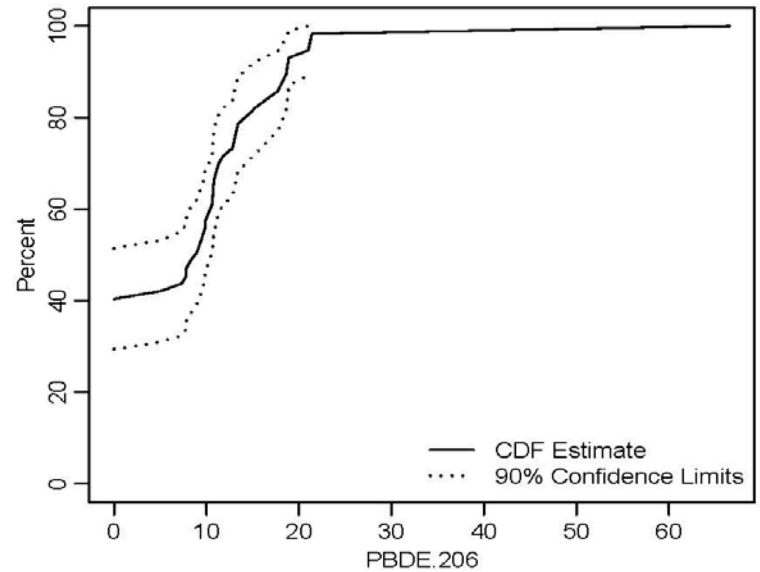
20
40
60
80
100
0
1
2
3
4
PBDE.197
CDF Estimate
90% Confidence Limits


Percent
0
20
40
60
80
100
0
1
2
3
4
5
PBDE.201
CDF Estimate
90% Confidence Limits


Percent
0
20
40
60
80
100
0
1
2
3
4
5
PBDE.203
CDF Estimate
90% Confidence Limits


Percent
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20
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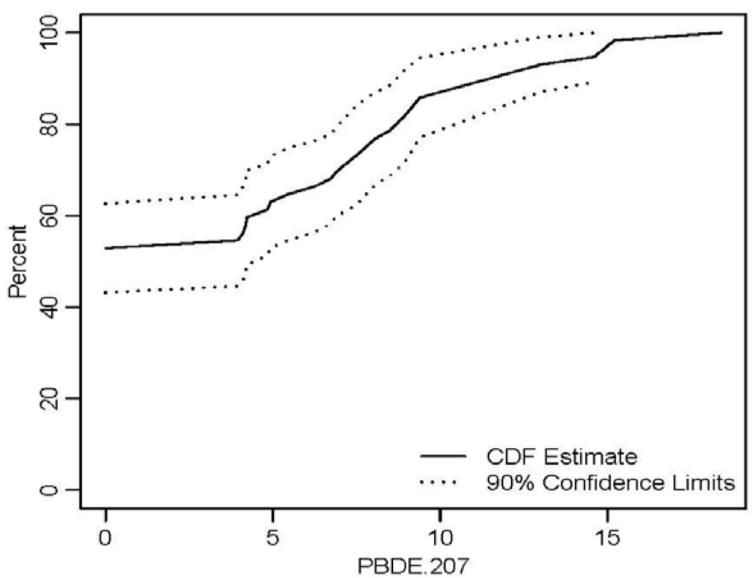
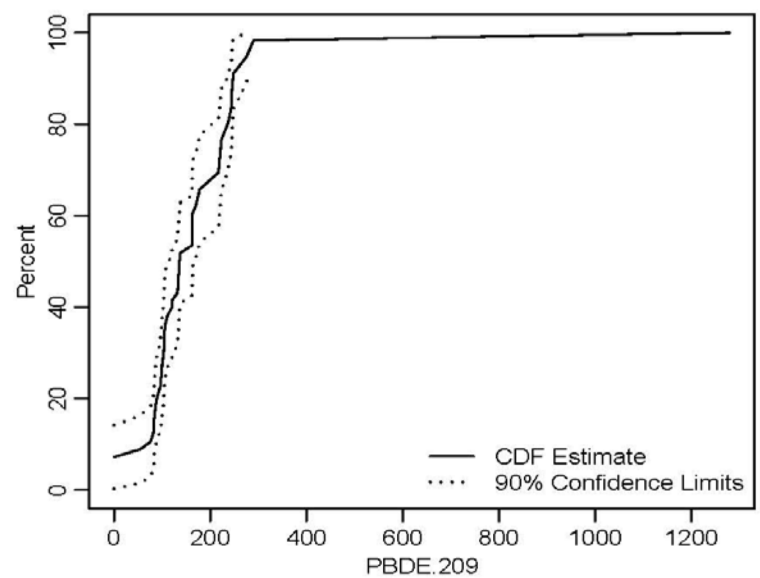
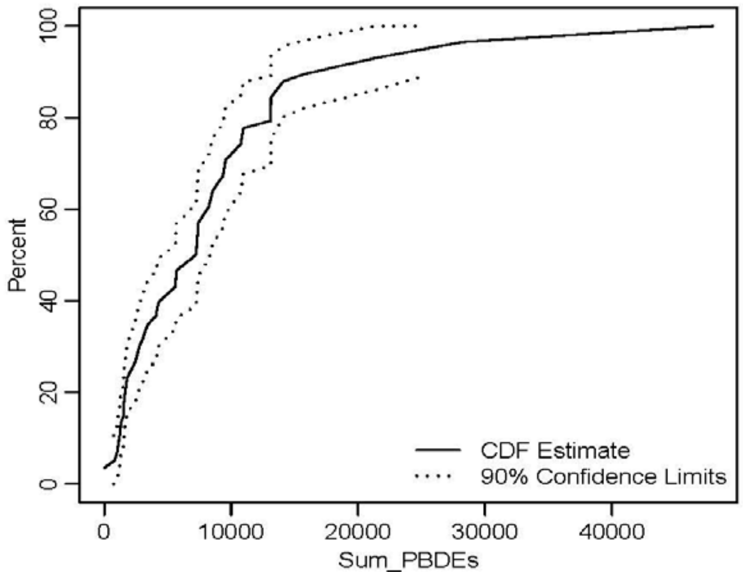
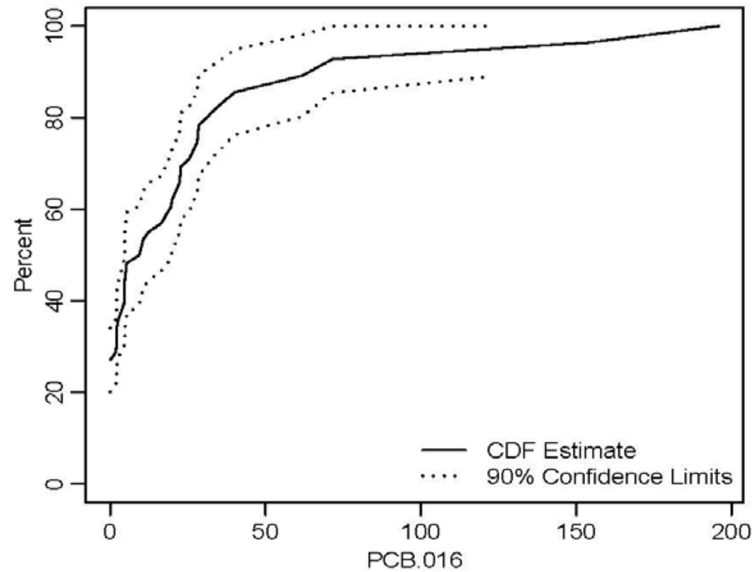
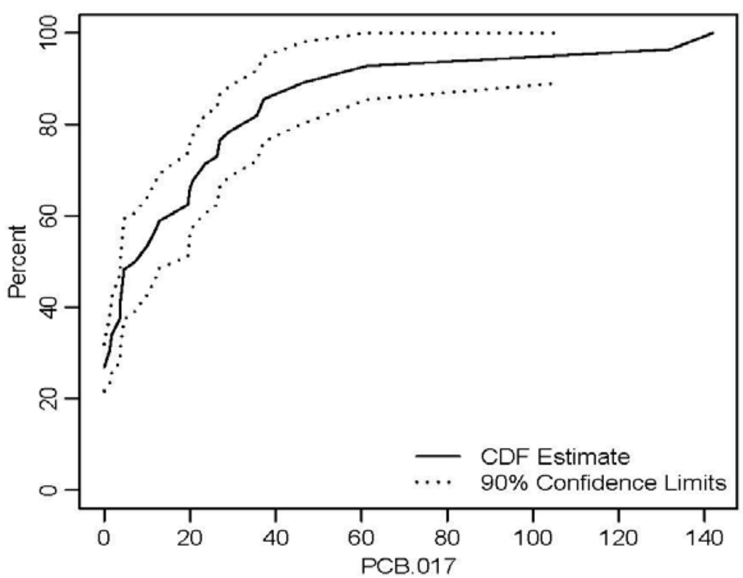
60
80
100
0
10
20
30
40
50
60
PBDE.206
CDF Estimate
90% Confidence Limits

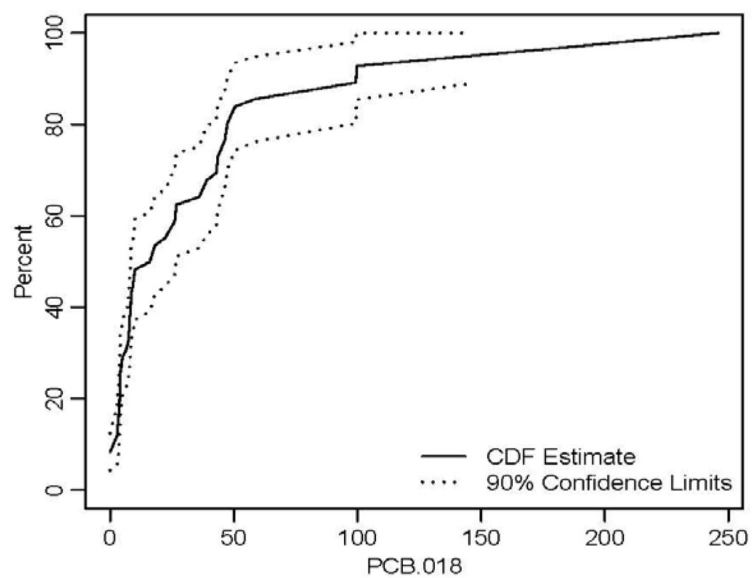

Percent
0
20
40
60
80
100
0
5
10
15
PBDE.207
CDF Estimate
90% Confidence Limits

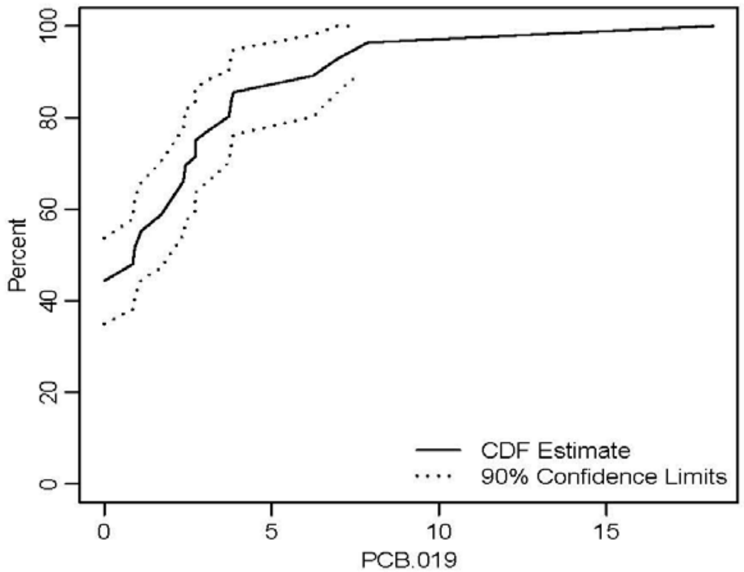

Percent
0
20
40
60
80
100
0
200
400
600
800
1000
1200
PBDE.209
CDF Estimate
90% Confidence Limits

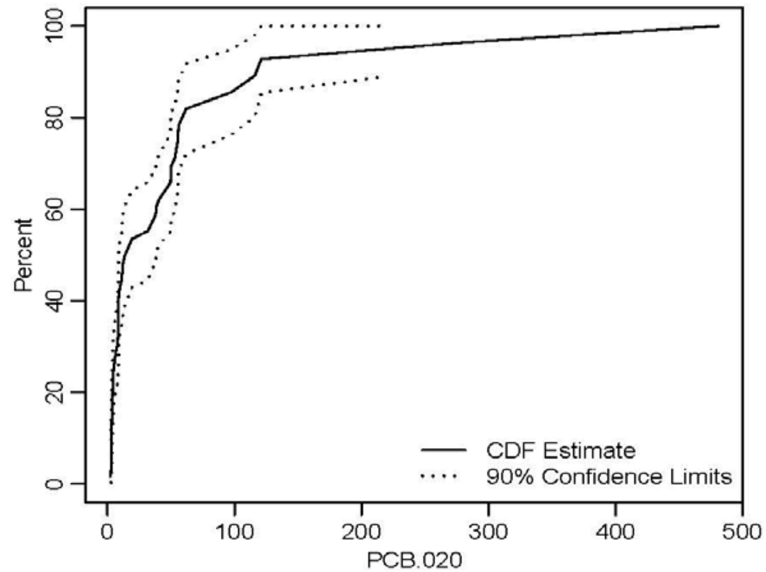

Percent
0
20
40
60
80
100
0
10000
20000
30000
40000
Sum_PBDEs
CDF Estimate
90% Confidence Limits

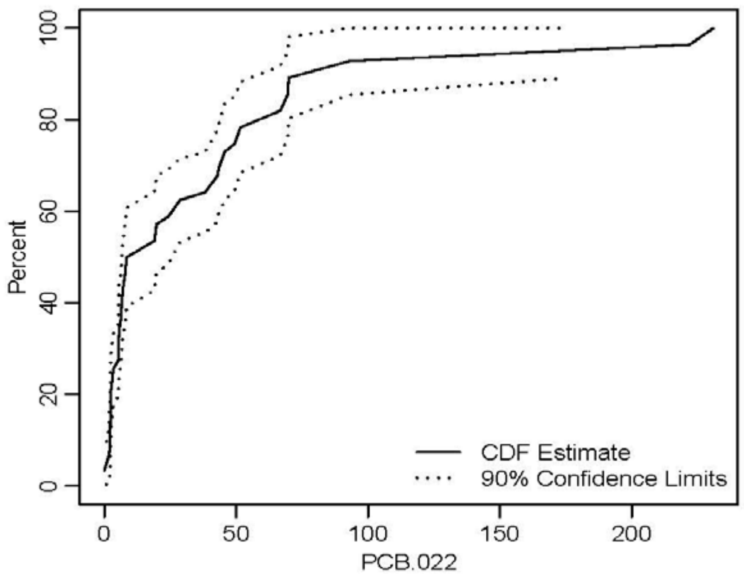

Percent
0
20
40
60
80
100
0
50
100
150
200
PCB.016
CDF Estimate
90% Confidence Limits

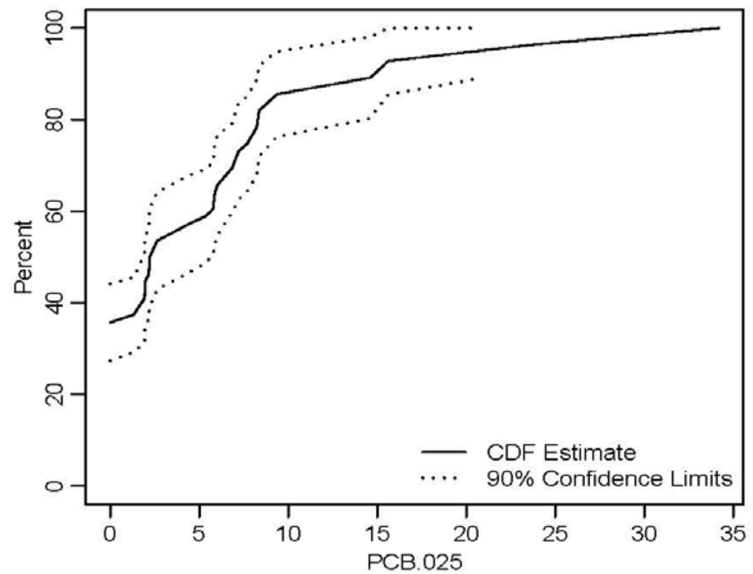

Percent
0
20
40
60
80
100
0
20
40
60
80
100
120
140
PCB.017
CDF Estimate
90% Confidence Limits

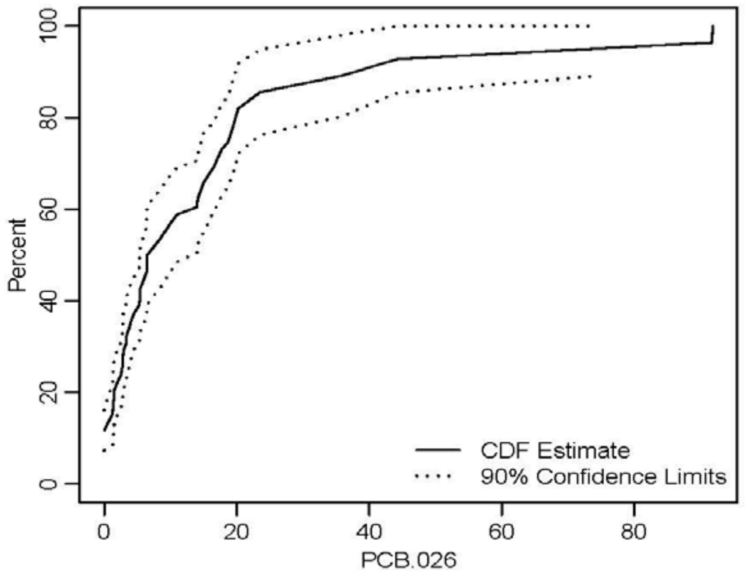

Percent
0
20
40
60
80
100
0
50
100
150
200
250
PCB.018
CDF Estimate
90% Confidence Limits

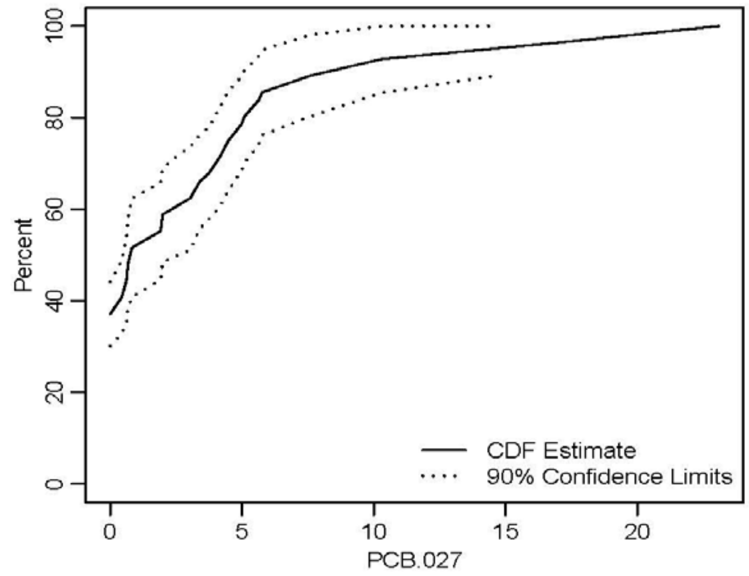

Percent
PCB.019
CDF Estimate
90% Confidence Limits

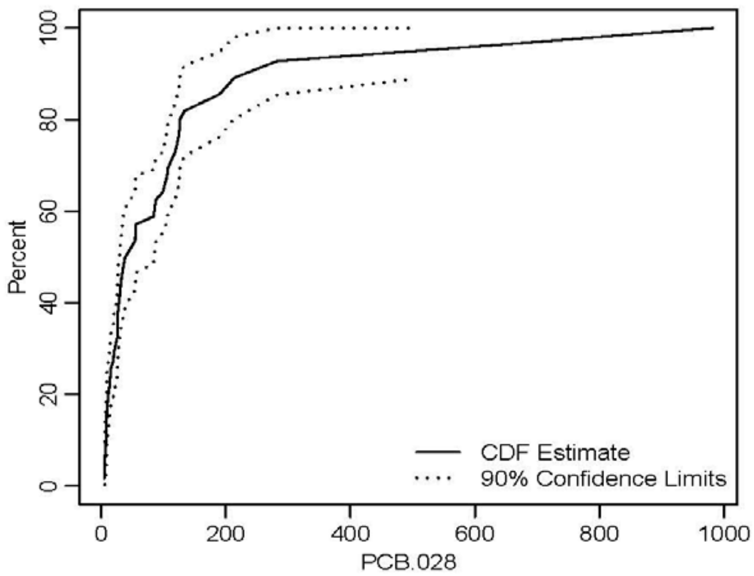

Percent
PCB.020
CDF Estimate
90% Confidence Limits

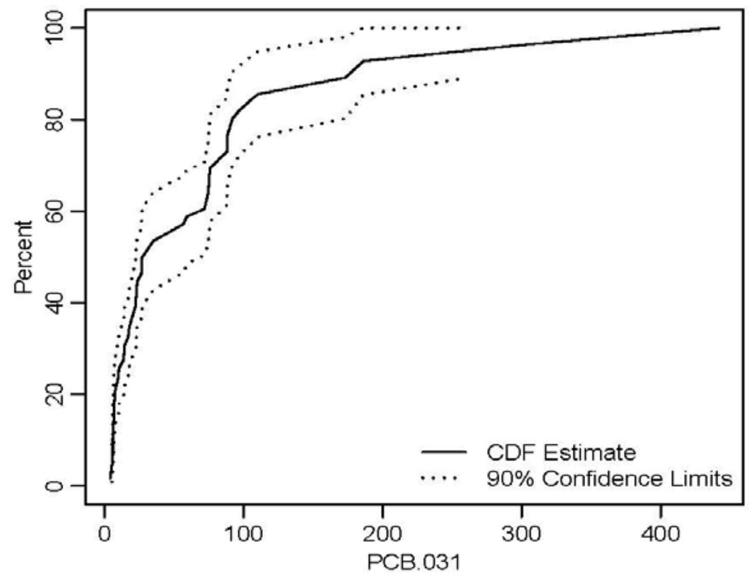

Percent
PCB.022
CDF Estimate
90% Confidence Limits

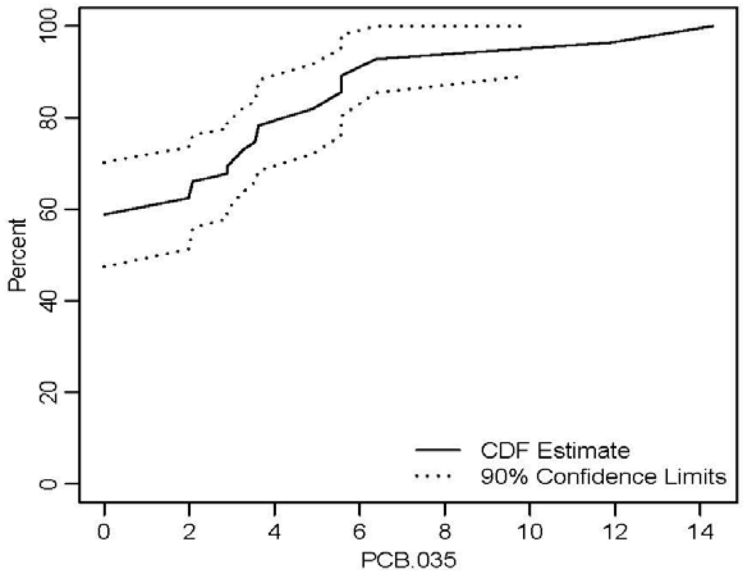

Percent
PCB.025
CDF Estimate
90% Confidence Limits

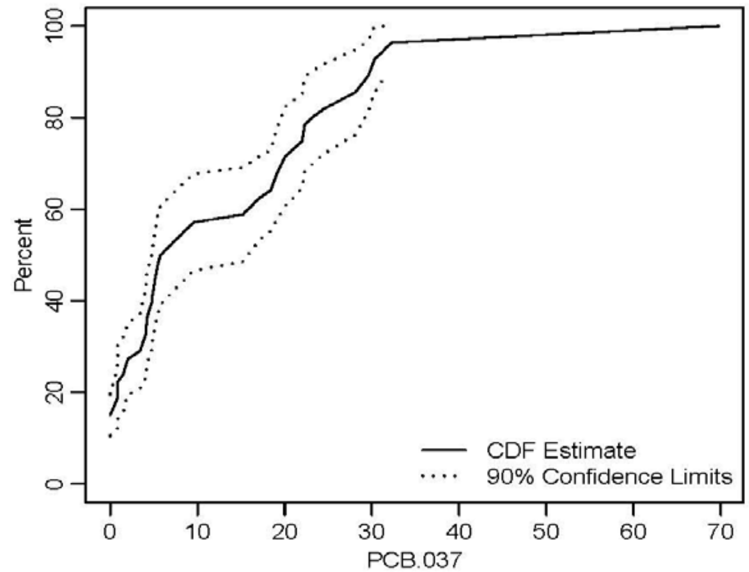

Percent
PCB.026
CDF Estimate
90% Confidence Limits

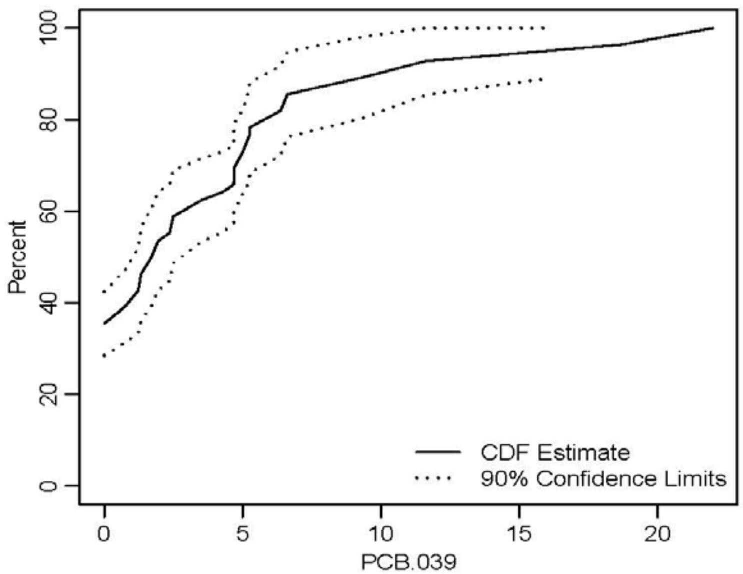

Percent
PCB.027
CDF Estimate
90% Confidence Limits

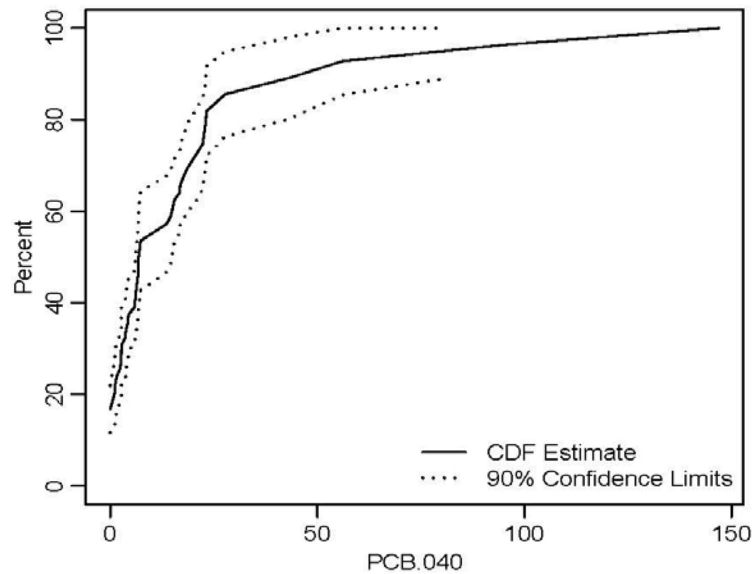

Percent
PCB.028
CDF Estimate
90% Confidence Limits

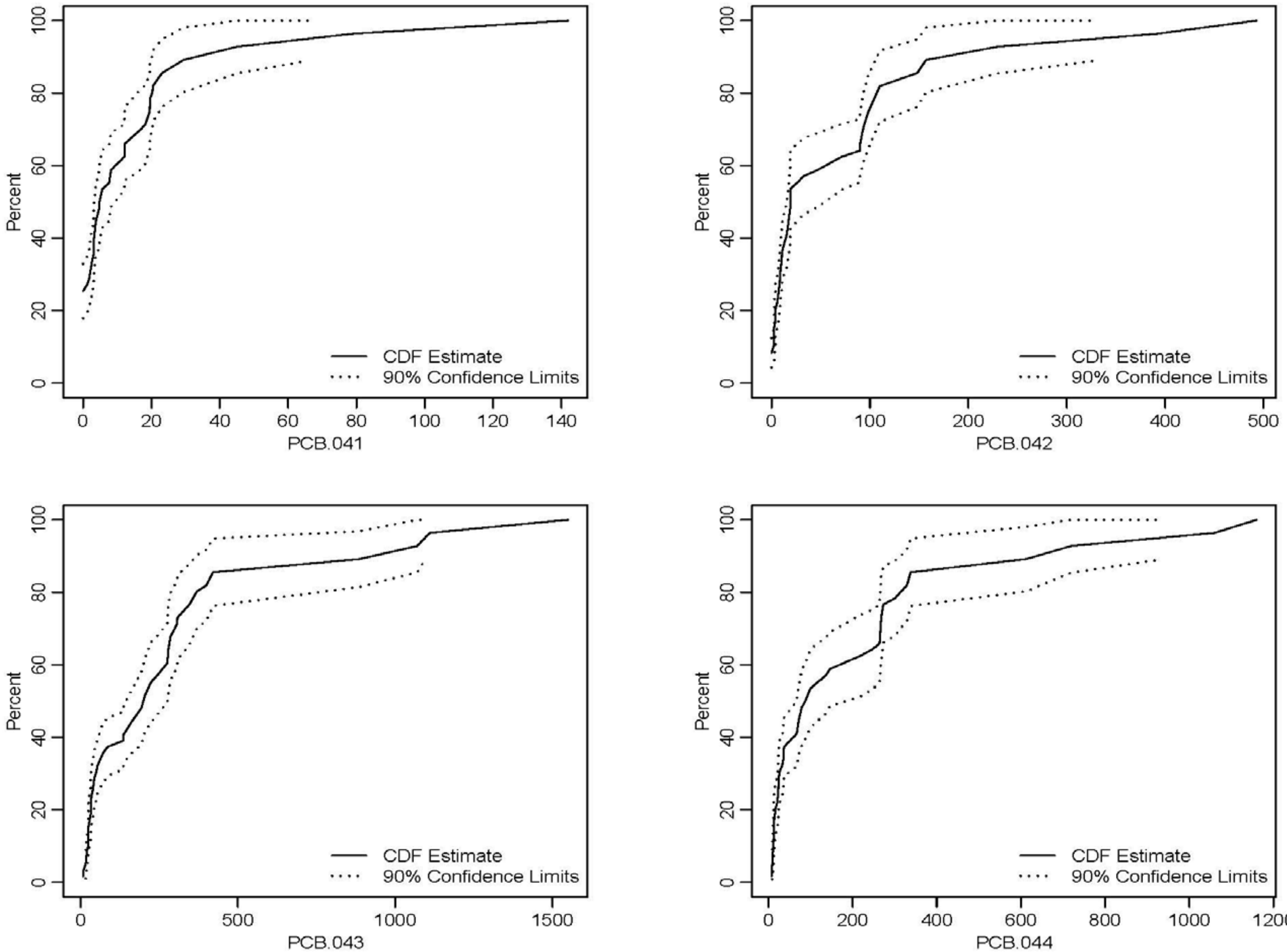

Percent
PCB.031
CDF Estimate
90% Confidence Limits


Percent
PCB.035
CDF Estimate
90% Confidence Limits


Percent
PCB.037
CDF Estimate
90% Confidence Limits


Percent
PCB.039
CDF Estimate
90% Confidence Limits


Percent
PCB.040
CDF Estimate
90% Confidence Limits


Percent
CDF Estimate
90% Confidence Limits
PCB.041
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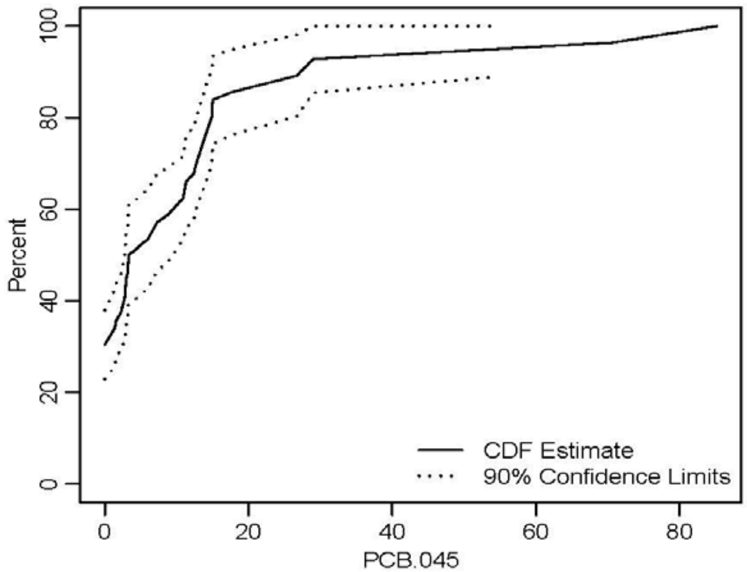
0 20 40 60 80 100
PCB.042
0 100 200 300 400 500
PCB.043
0 500 1000 1500
PCB.044
0 200 400 600 800 1000 1200



Percent
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20
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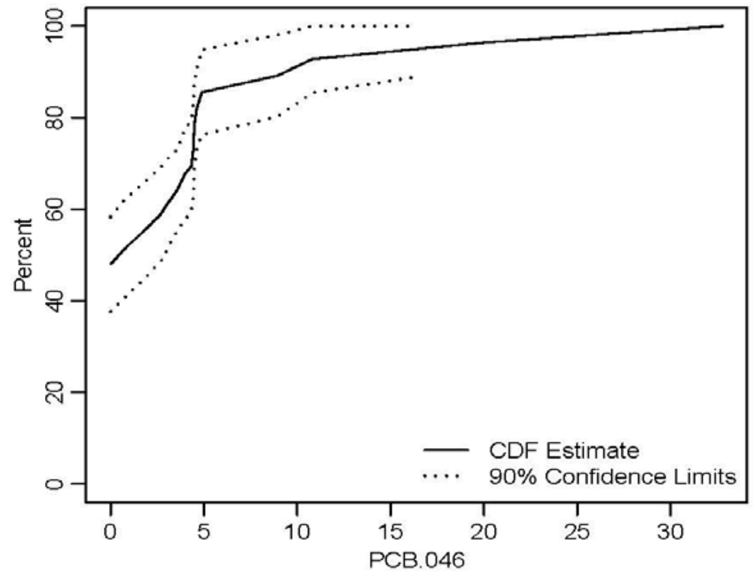
60
80
PCB.045
CDF Estimate
90% Confidence Limits



Percent
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15
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25
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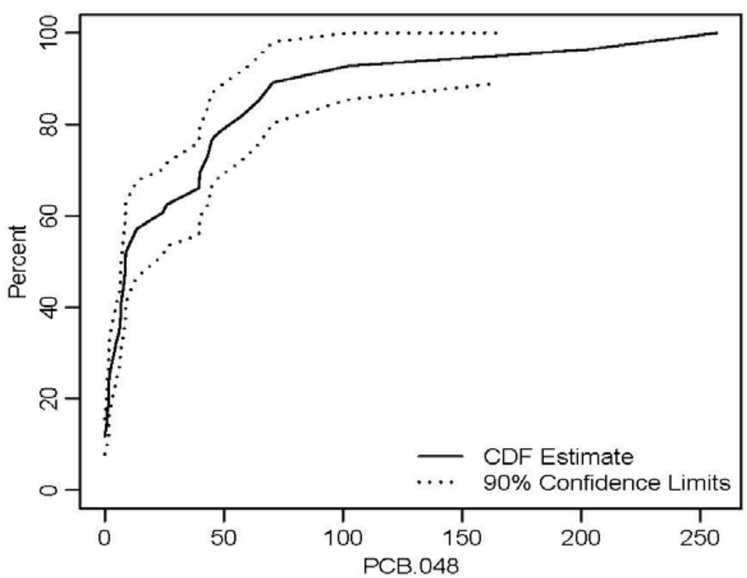
PCB.046
CDF Estimate
90% Confidence Limits



Percent
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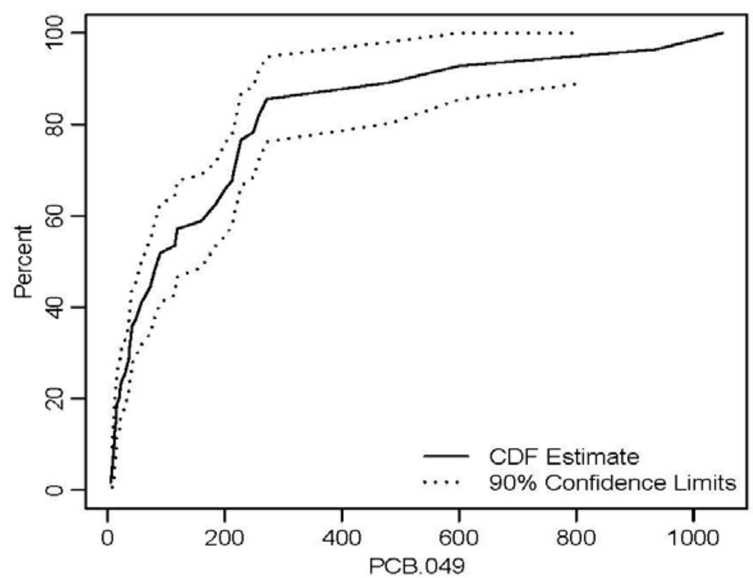
200
250
PCB.048
CDF Estimate
90% Confidence Limits



Percent
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800
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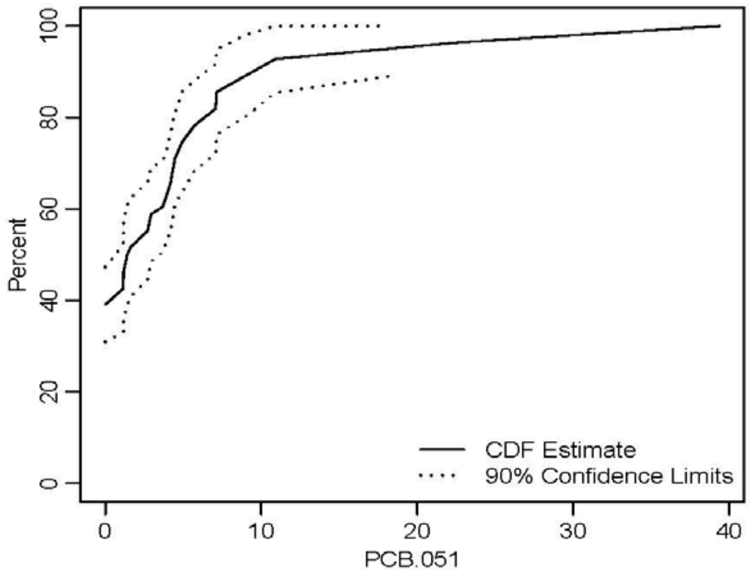
PCB.049
CDF Estimate
90% Confidence Limits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30
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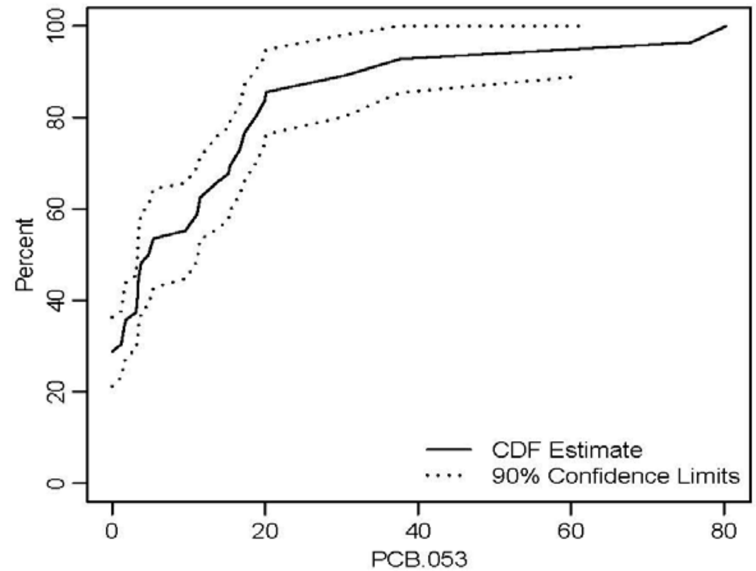
CDF Estimate
90% Confidence Limits


Percent
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60
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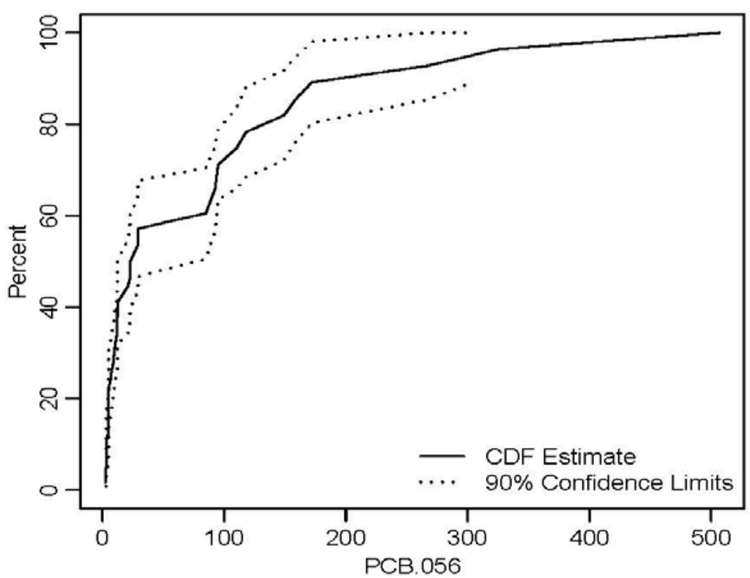
PCB.053
CDF Estimate
90% Confidence Limits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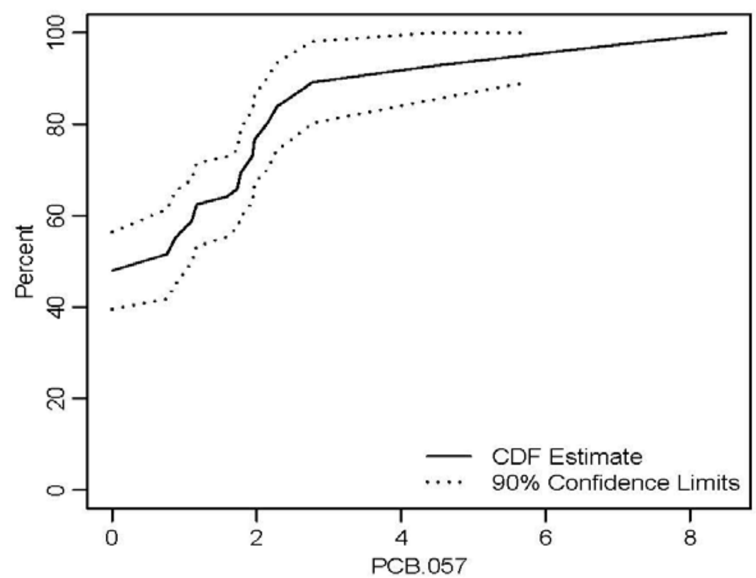
PCB.056
CDF Estimate
90% Confidence Limits


Percent
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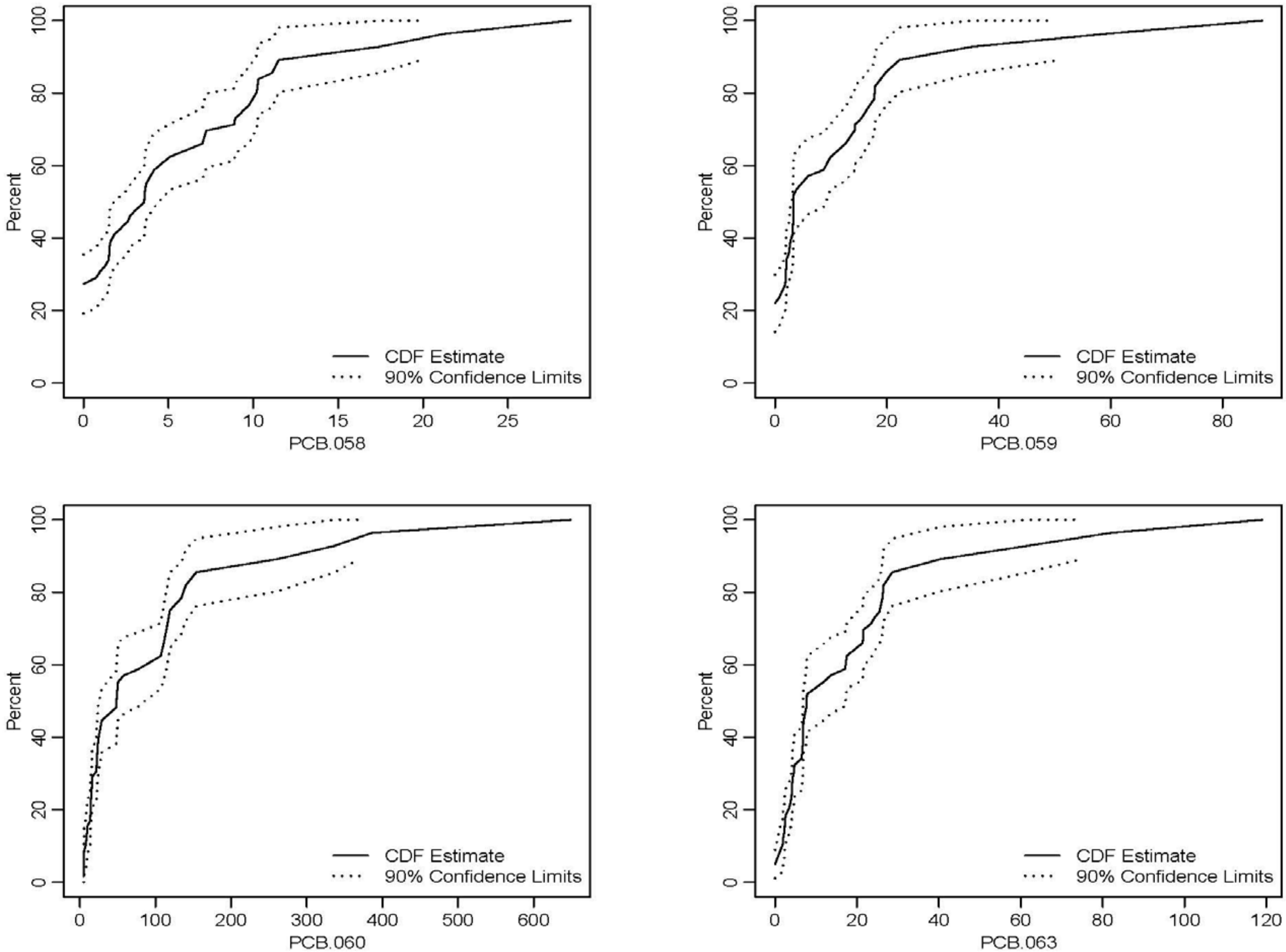
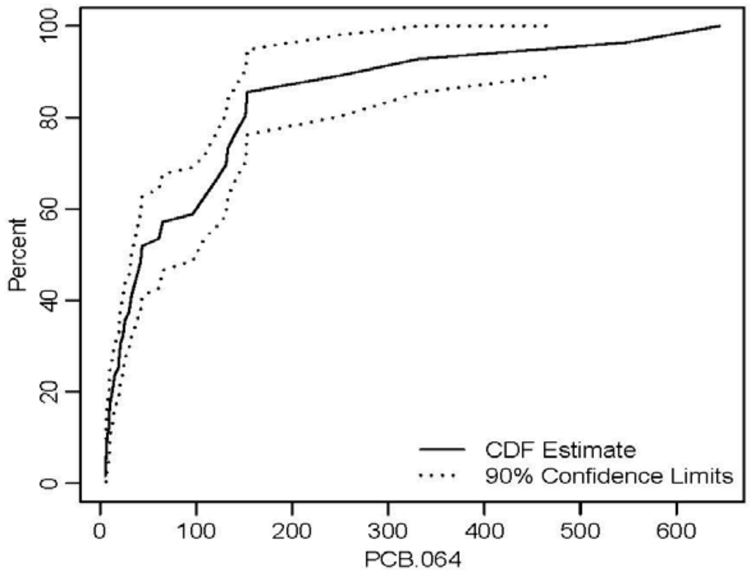
2
4
6
8
PCB.057
CDF Estimate
90% Confidence Limits


Percent
PCB.058
PCB.059
PCB.060
PCB.063
CDF Estimate
90% Confidence Limits


Percent
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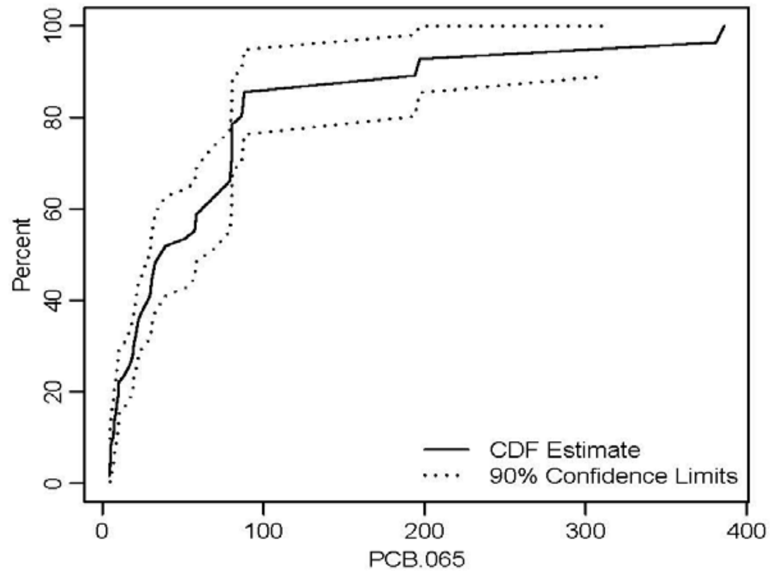
PCB.064
CDF Estimate
90% Confidence Limits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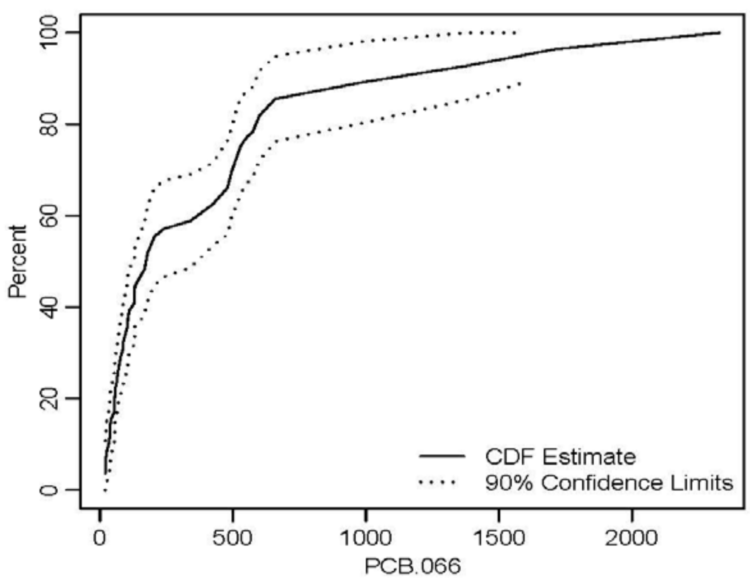
PCB.065
CDF Estimate
90% Confidence Limits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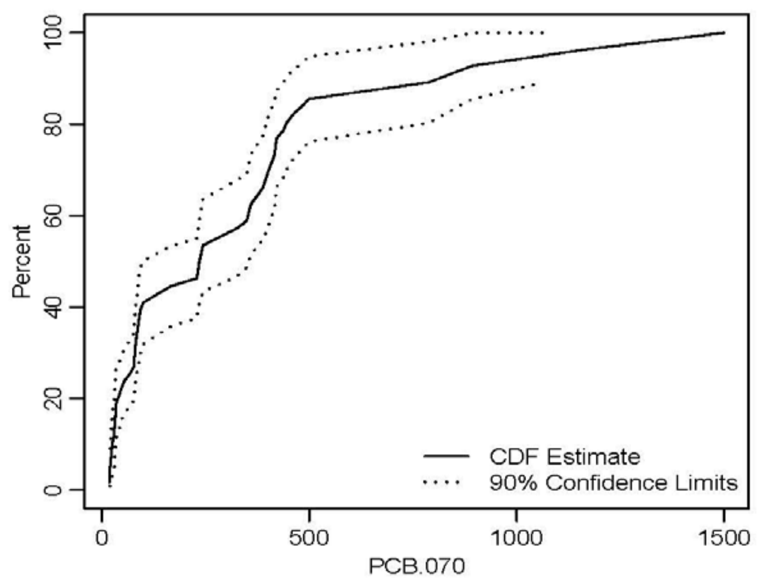
CDF Estimate
90% Confidence Limits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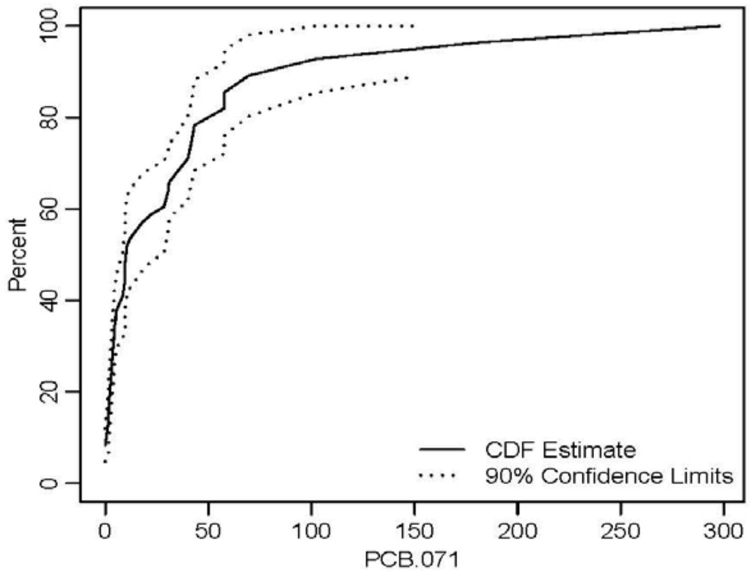
PCB.070
CDF Estimate
90% Confidence Limits


Percent
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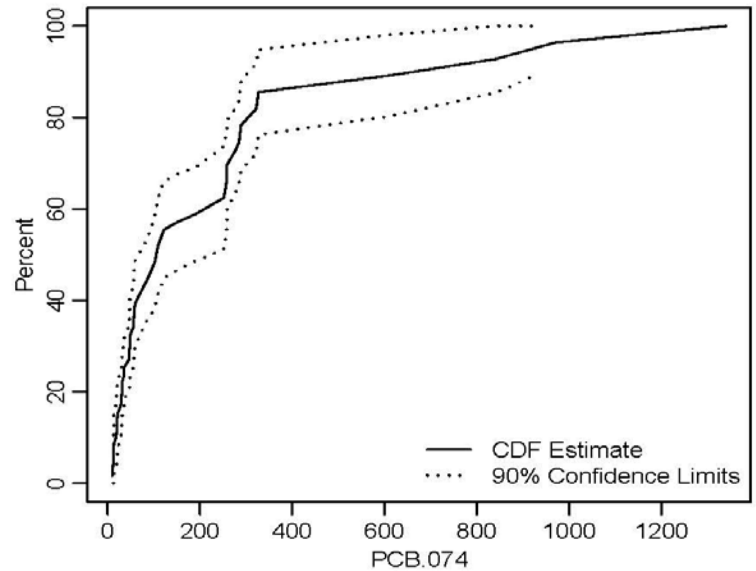
PCB.071
CDF Estimate
90% Confidence Limits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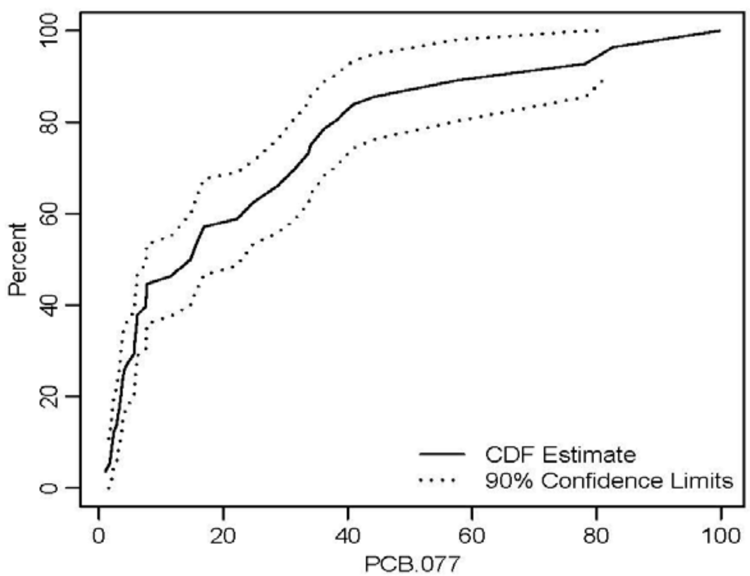
PCB.074
CDF Estimate
90% Confidence Limits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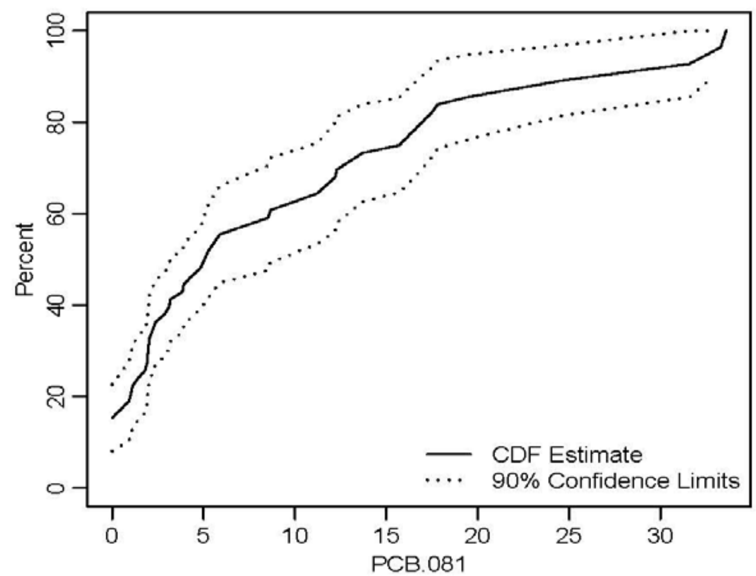
PCB.077
CDF Estimate
90% Confidence Limits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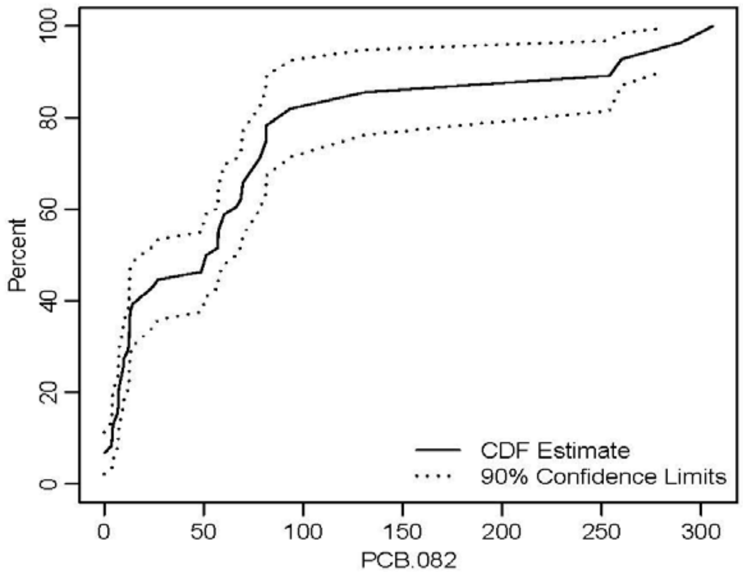
PCB.081
CDF Estimate
90% Confidence Limits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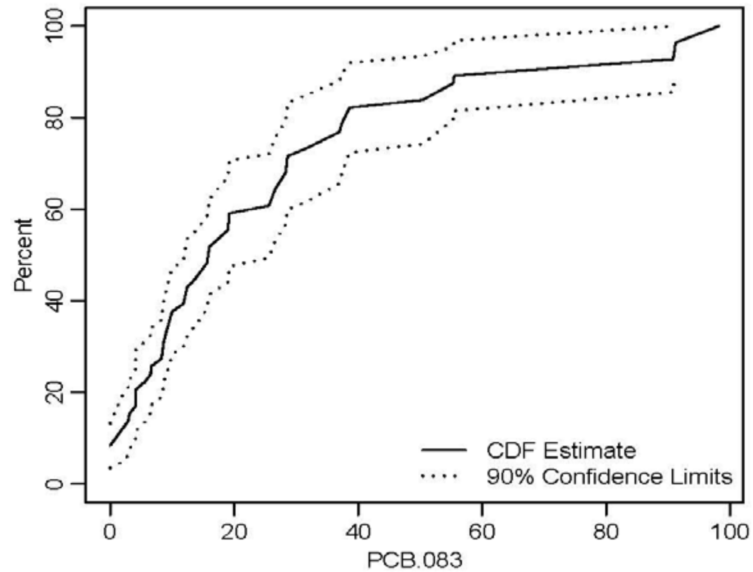
PCB.082
CDF Estimate
90% Confidence Limits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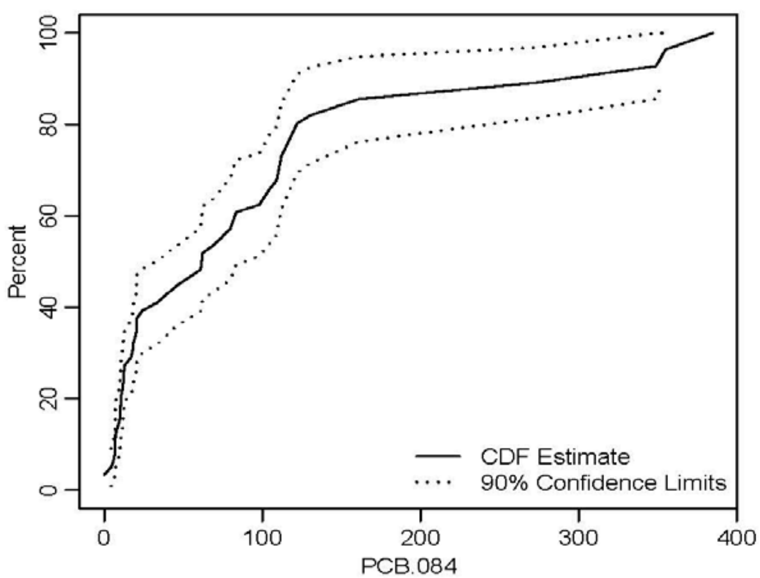
PCB.083
CDF Estimate
90% Confidence Limits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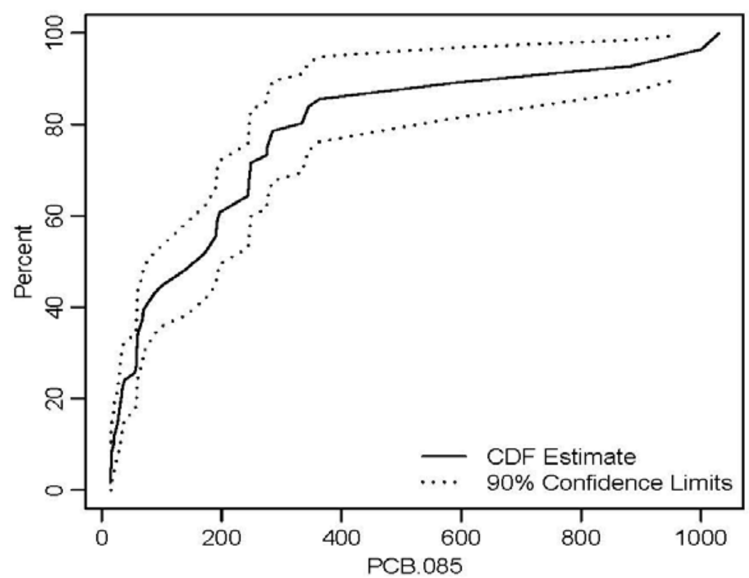
CDF Estimate
90% Confidence Limits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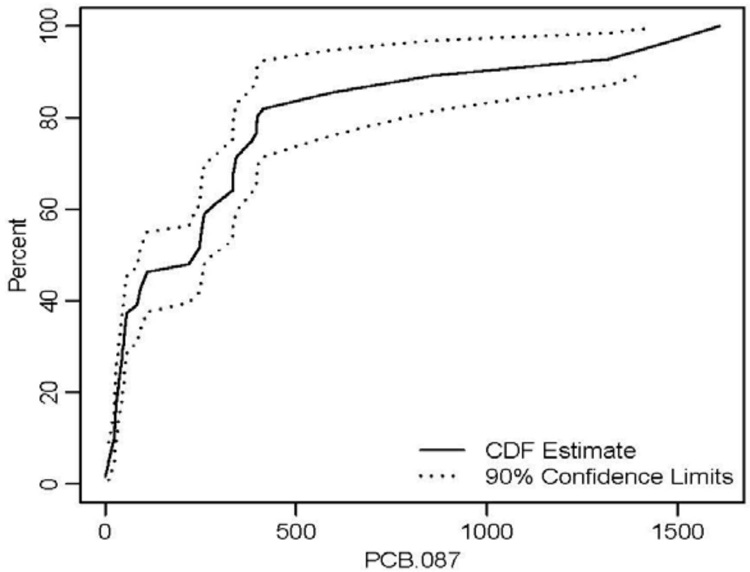
PCB.085
CDF Estimate
90% Confidence Limits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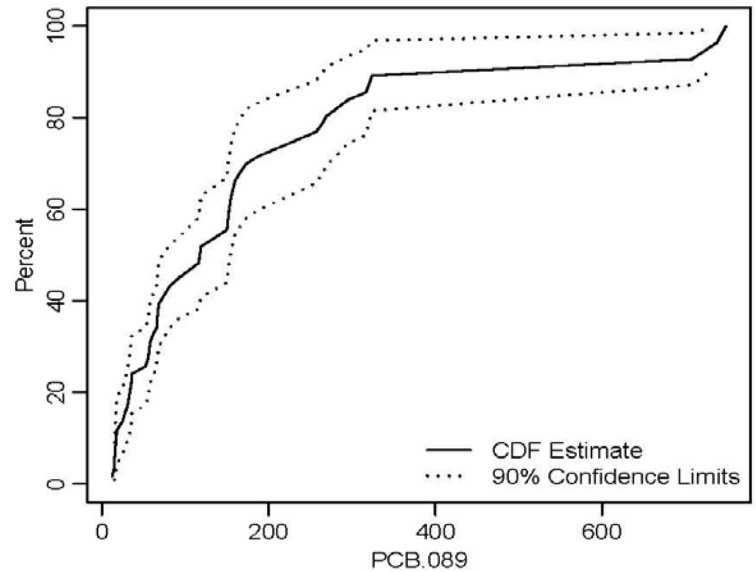
CDF Estimate
90% Confidence Limits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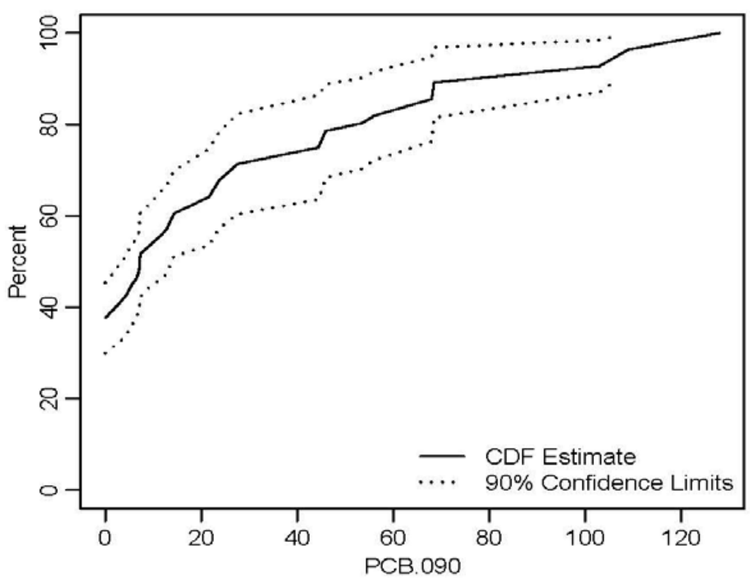
CDF Estimate
90% Confidence Limits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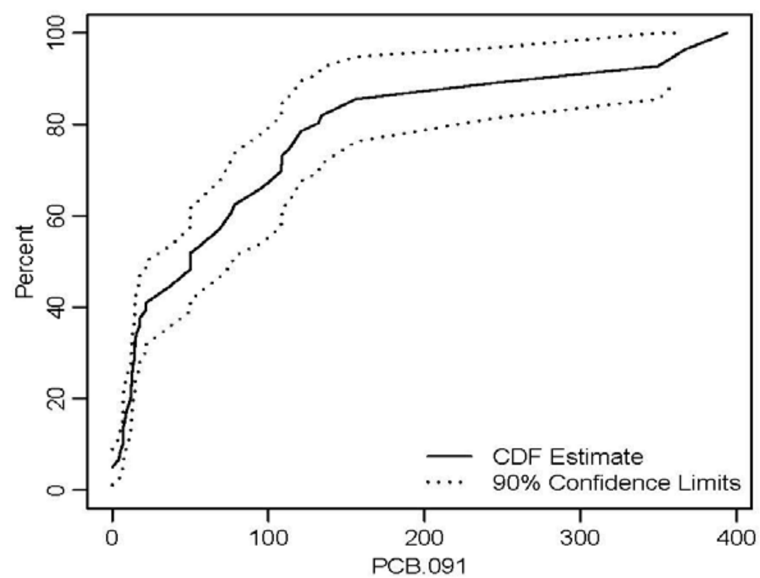
CDF Estimate
90% Confidence Limits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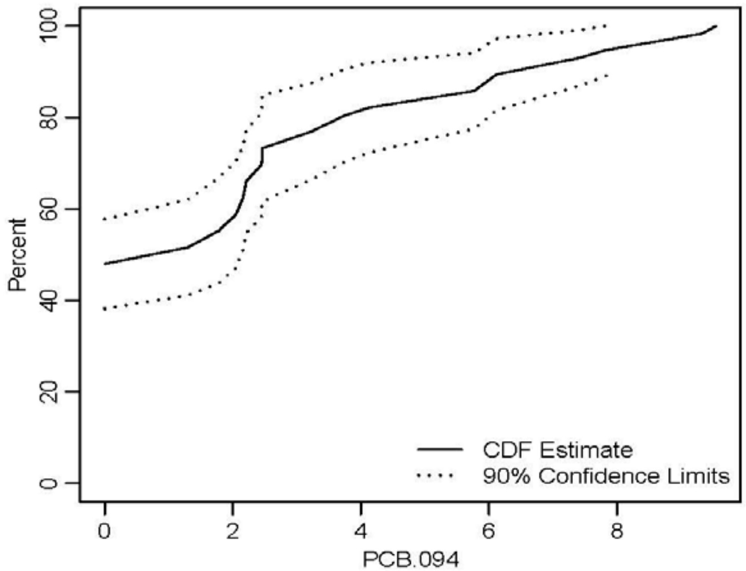
CDF Estimate
90% Confidence Limits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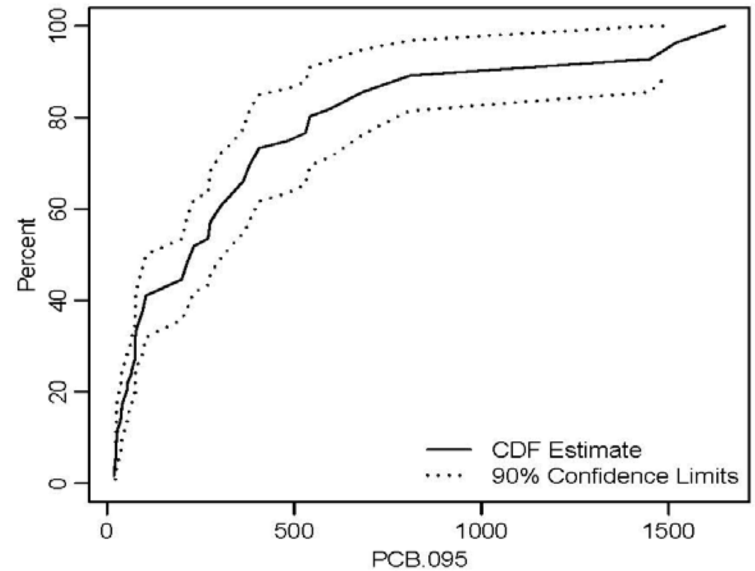
PCB.094
CDF Estimate
90% Confidence Limits


Percent
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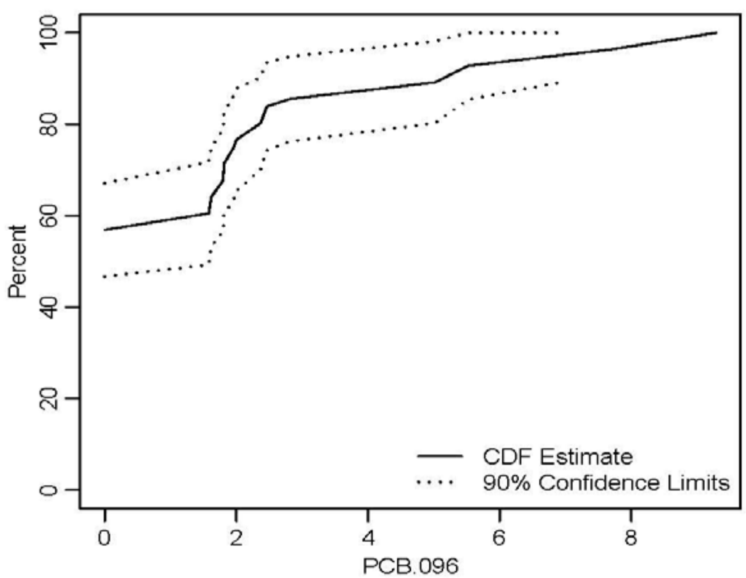
CDF Estimate
90% Confidence Limits


Percent
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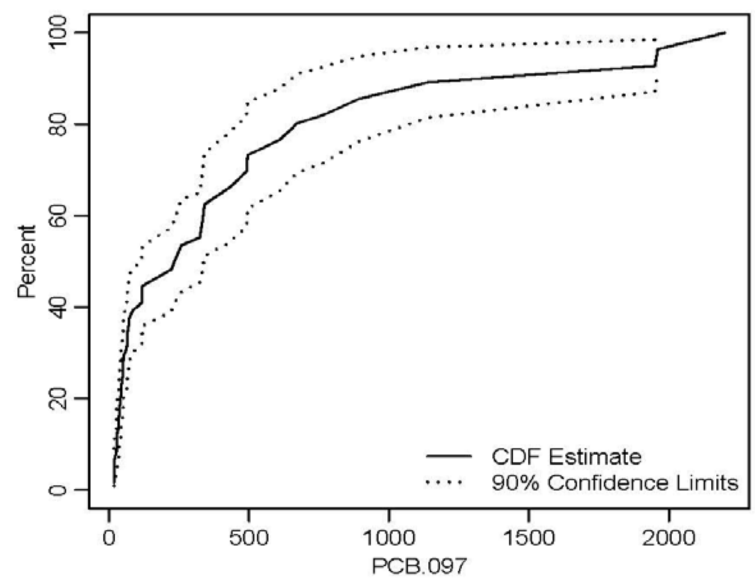
CDF Estimate
90% Confidence Limits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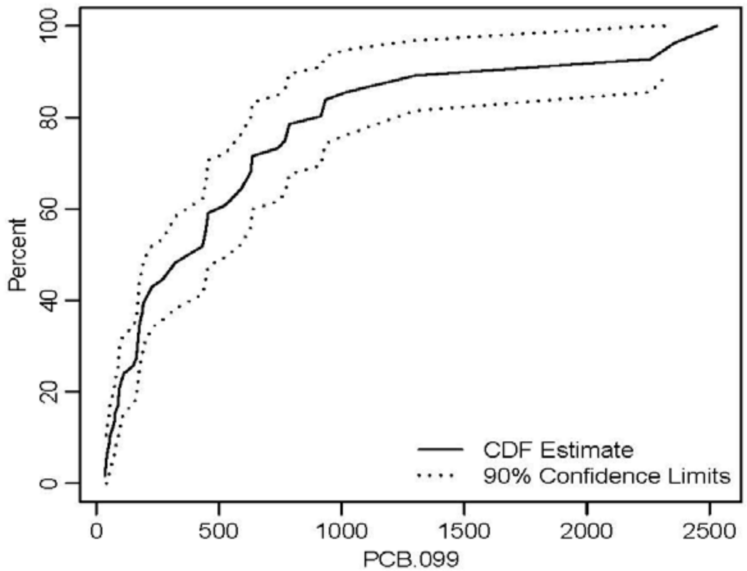
CDF Estimate
90% Confidence Limits


Percent
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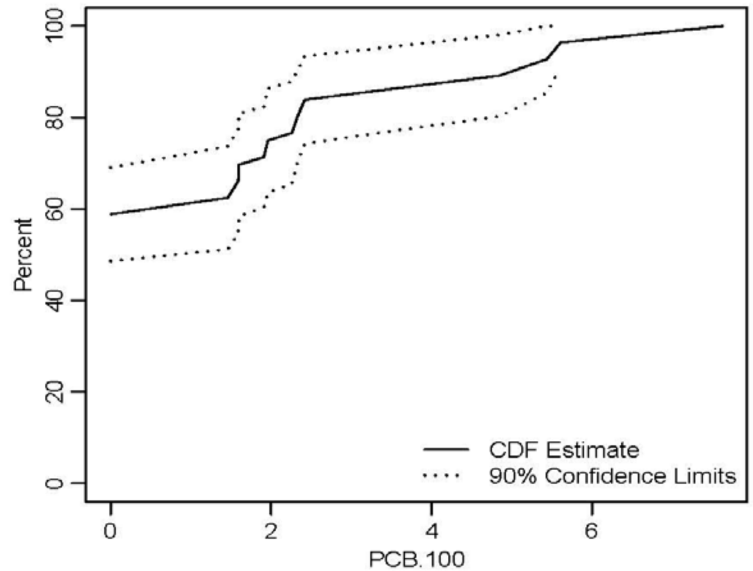
CDF Estimate
90% Confidence Limits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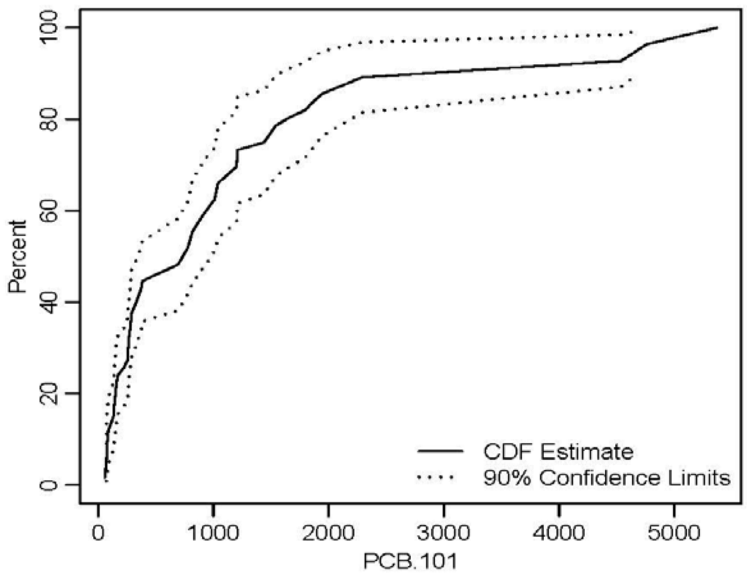
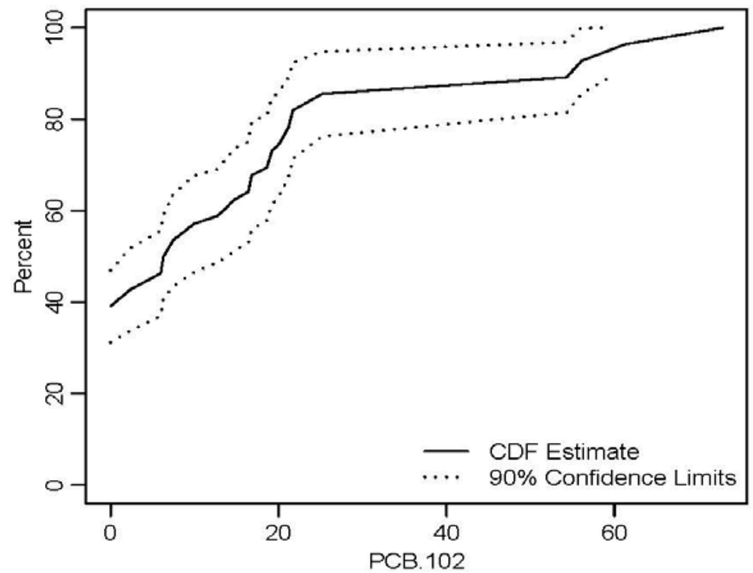
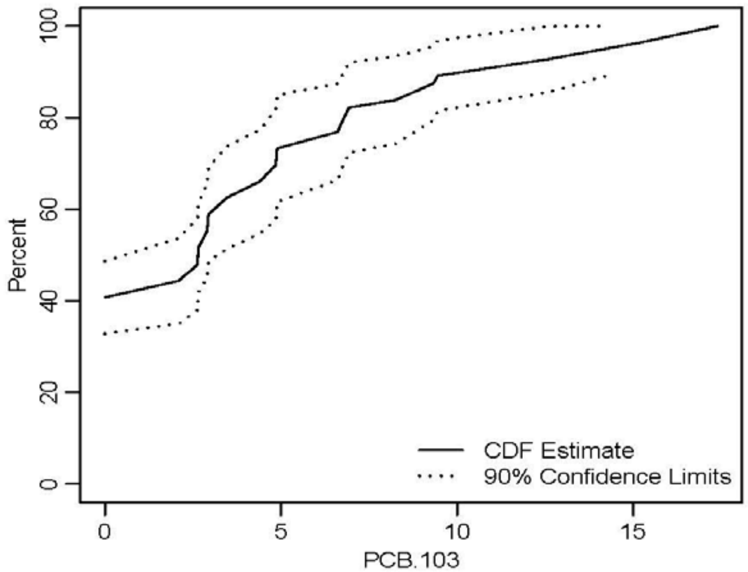
PCB.100
CDF Estimate
90% Confidence Limits


Percent
PCB.101
CDF Estimate
90% Confidence Limits


Percent
PCB.102
CDF Estimate
90% Confidence Limits


Percent
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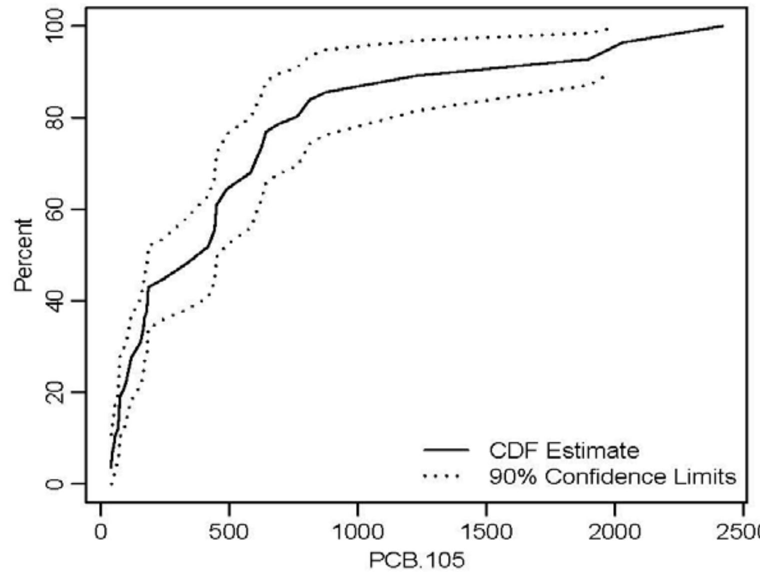
CDF Estimate
90% Confidence Limits


Percent
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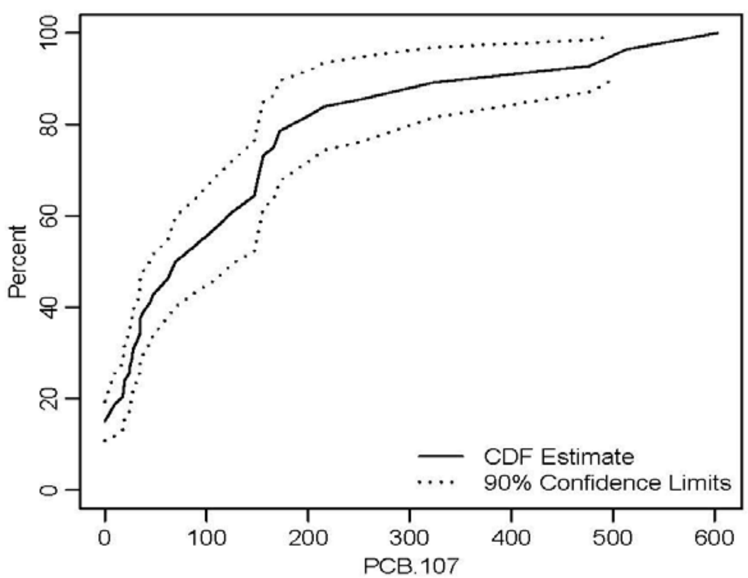
CDF Estimate
90% Confidence Limits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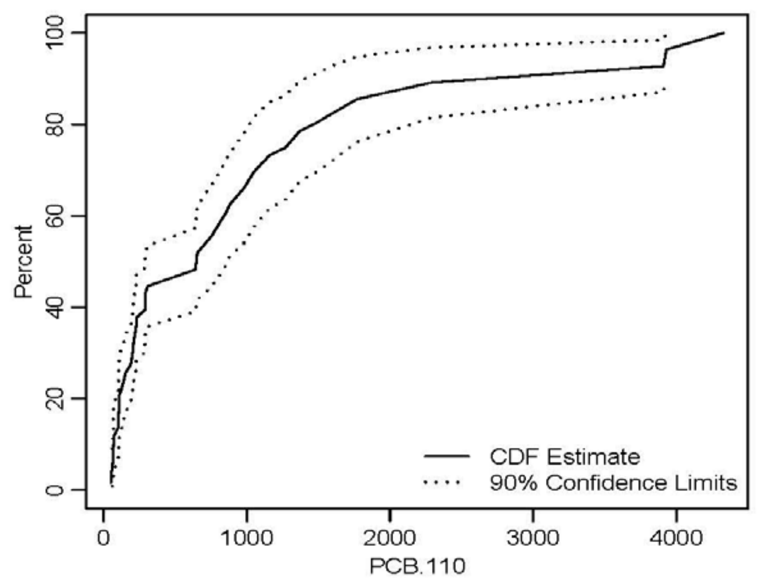
CDF Estimate
90% Confidence Limits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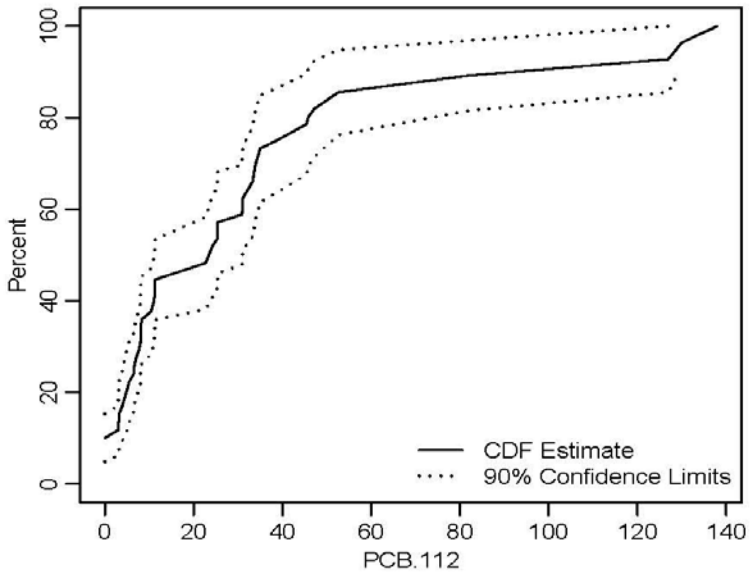
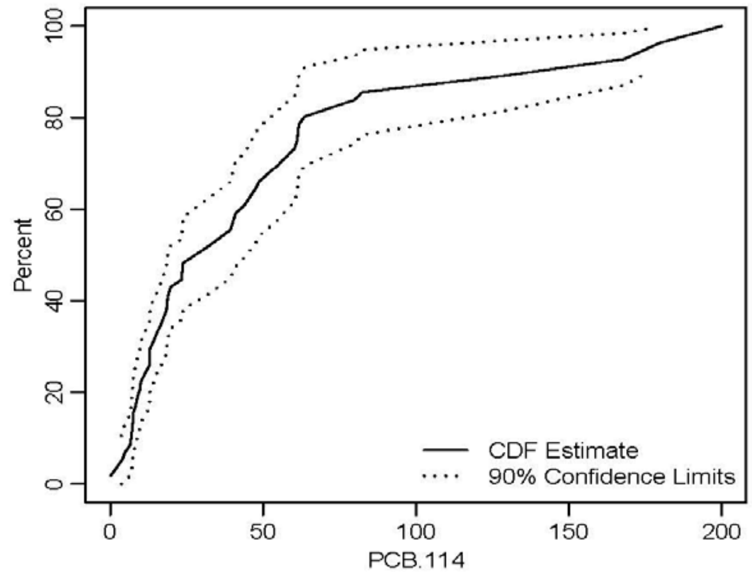
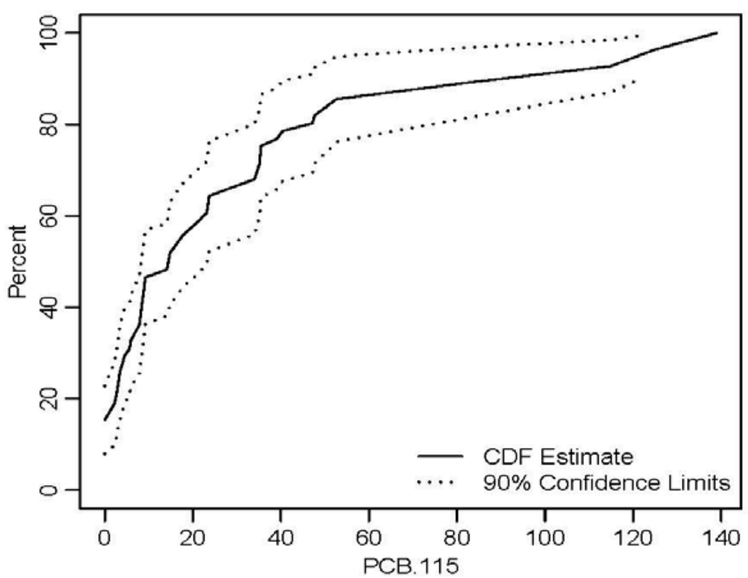
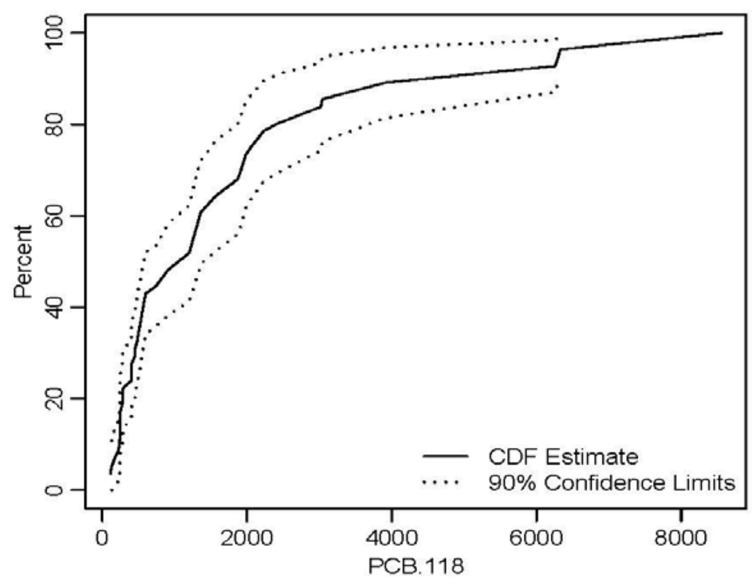
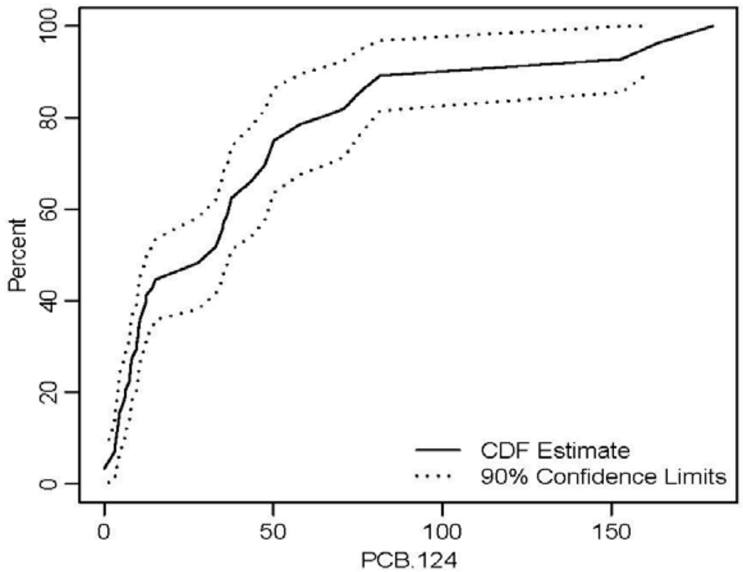
PCB.110
CDF Estimate
90% Confidence Limits


Percent
CDF Estimate
90% Confidence Limits
PCB.112


Percent
CDF Estimate
90% Confidence Limits
PCB.114


Percent
CDF Estimate
90% Confidence Limits
PCB.115


Percent
CDF Estimate
90% Confidence Limits
PCB.118


Percent
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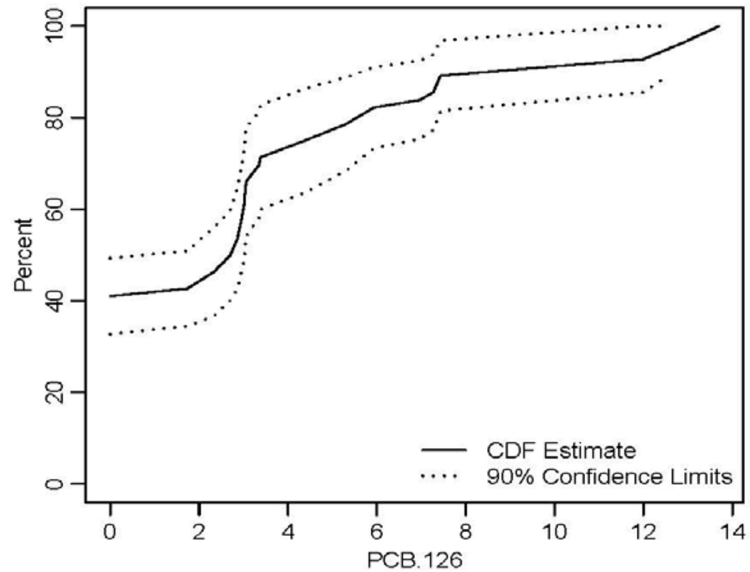
PCB.124
CDF Estimate
90% Confidence Limits


Percent
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14
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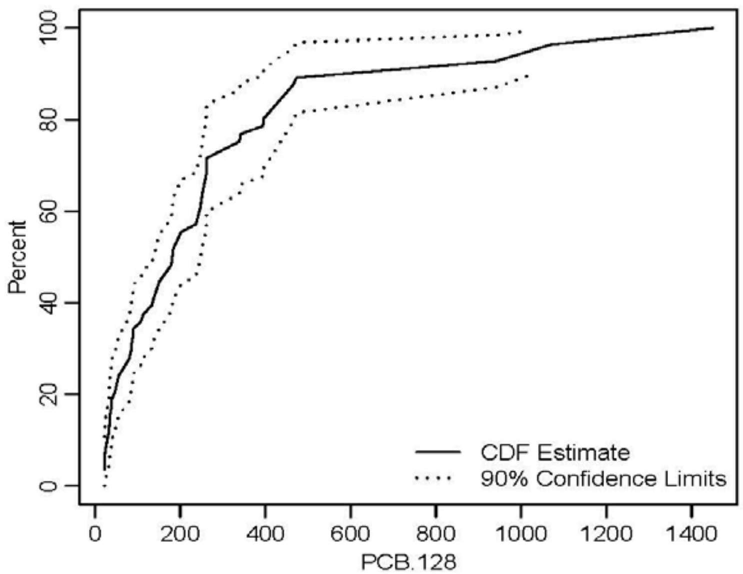
CDF Estimate
90% Confidence Limits


Percent
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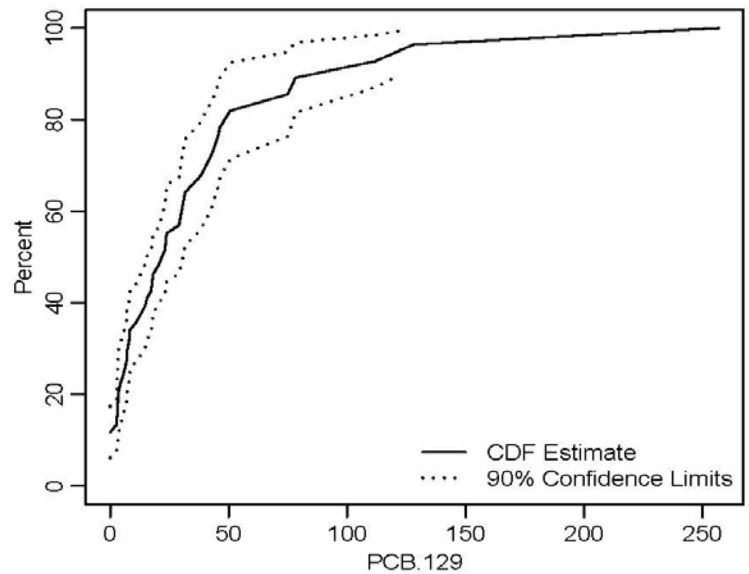
CDF Estimate
90% Confidence Limits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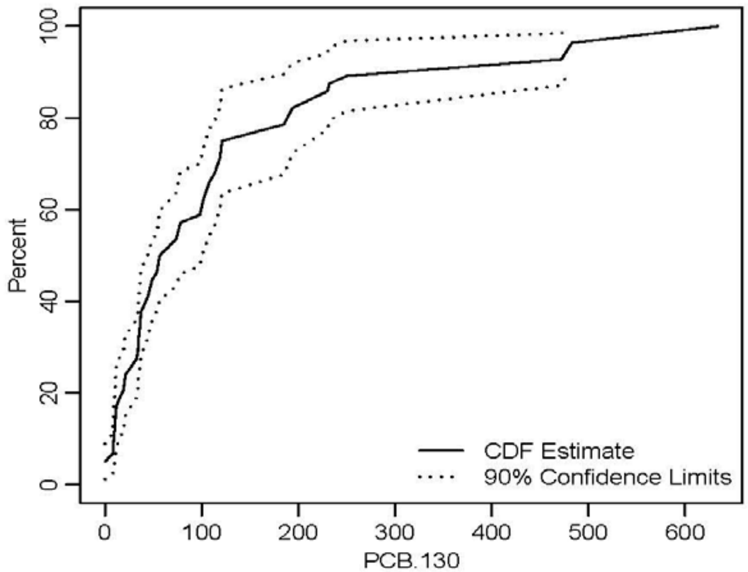
CDF Estimate
90% Confidence Limits


Percent
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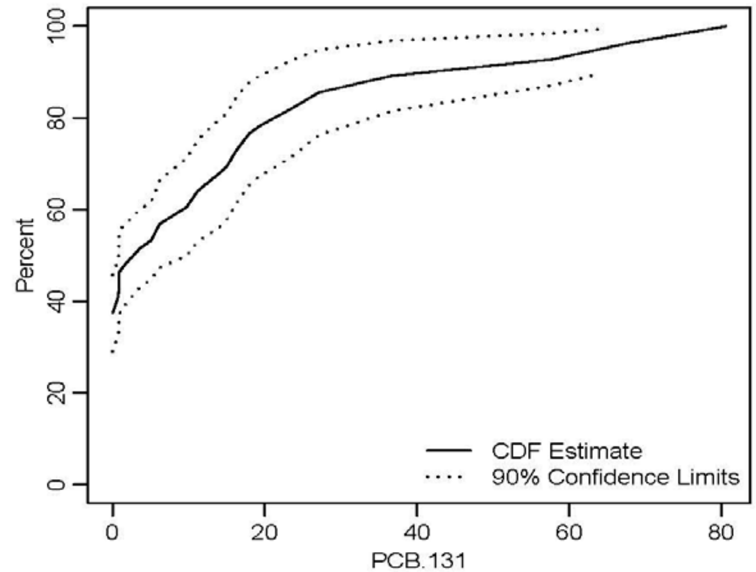
600
PCB.130
CDF Estimate
90% Confidence Limits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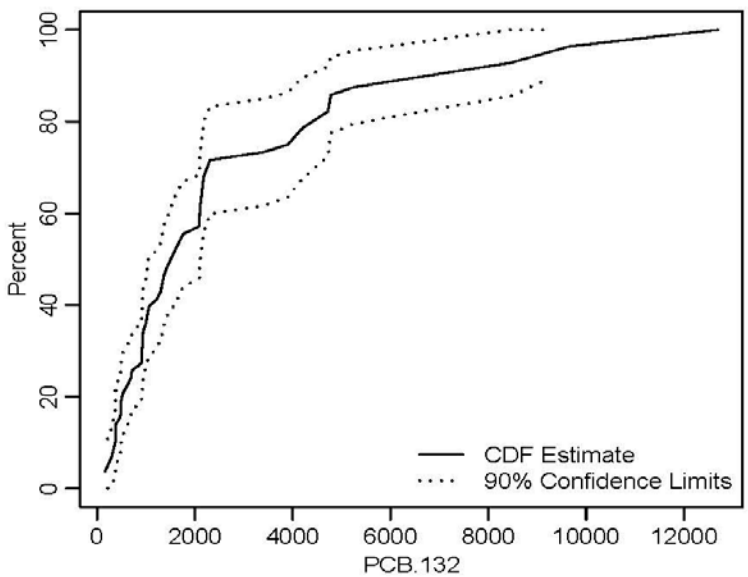
60
80
PCB.131
CDF Estimate
90% Confidence Limits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10000
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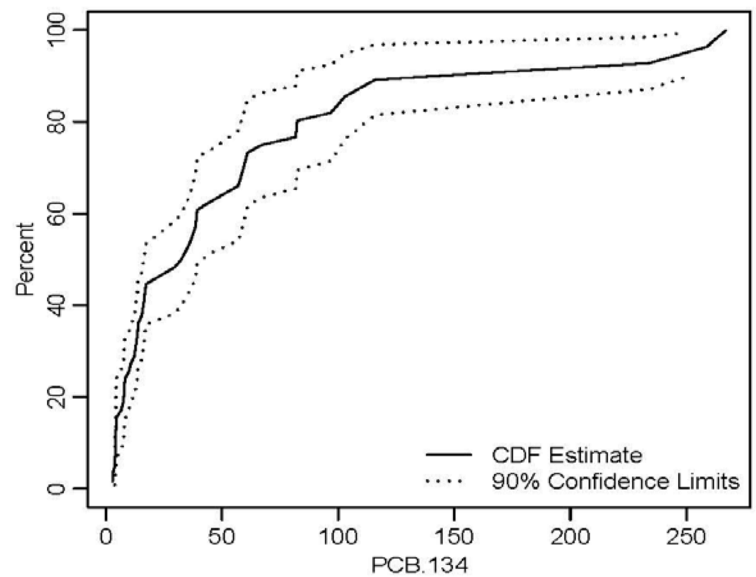
PCB.132
CDF Estimate
90% Confidence Limits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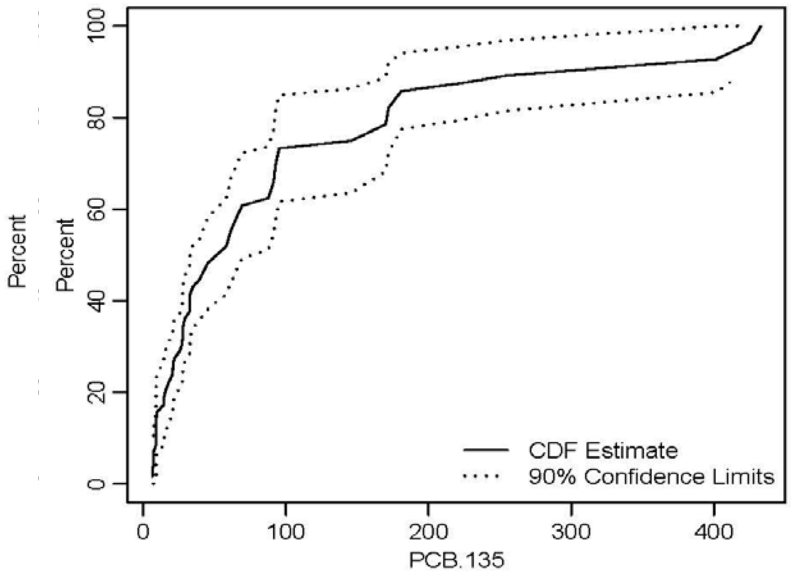
PCB.134
CDF Estimate
90% Confidence Limits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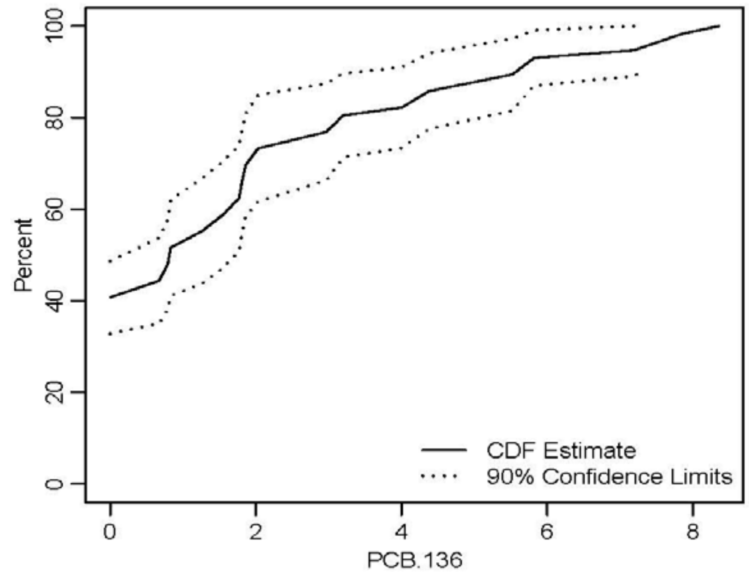
PCB.135
CDF Estimate
90% Confidence Limits


Percent
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2
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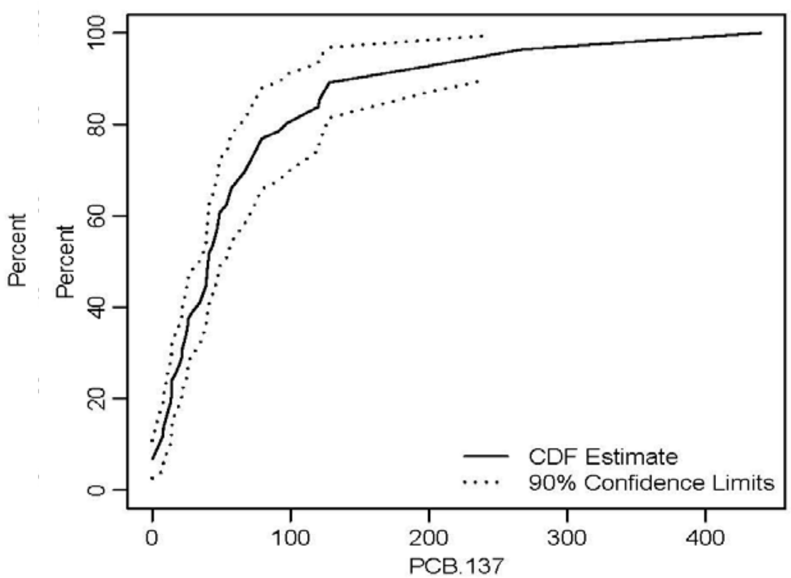
8
PCB.136
CDF Estimate
90% Confidence Limits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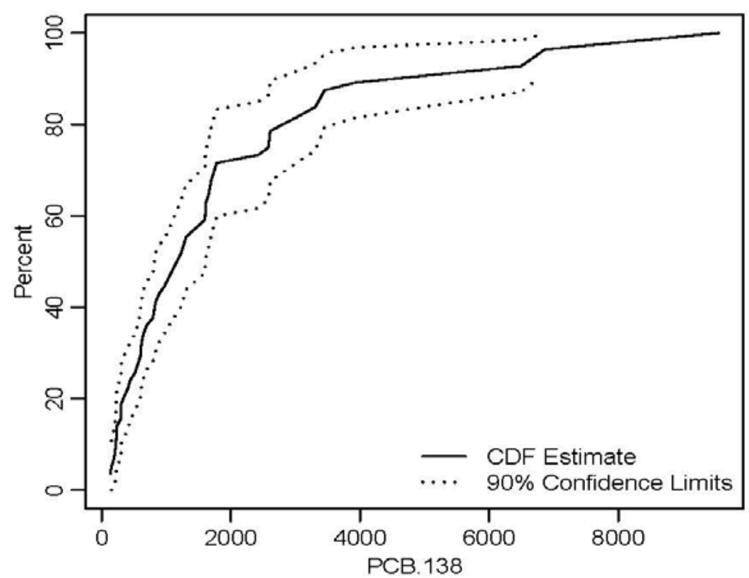
PCB.137
CDF Estimate
90% Confidence Limits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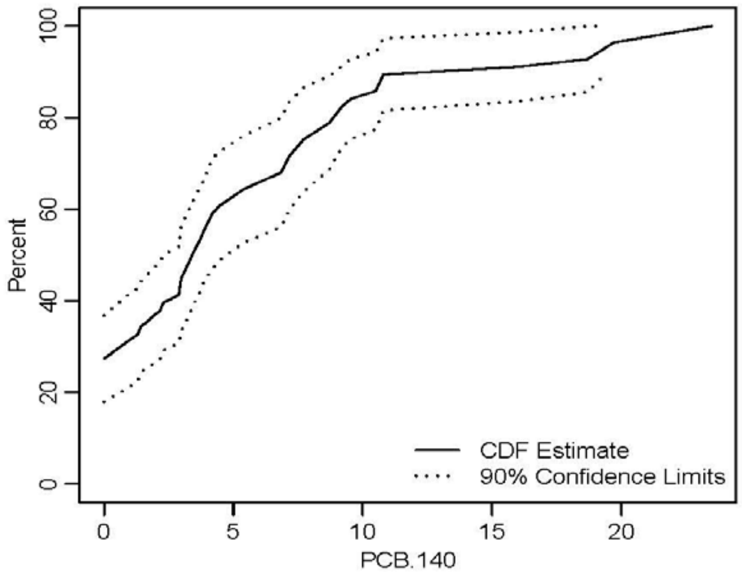
PCB.138
CDF Estimate
90% Confidence Limits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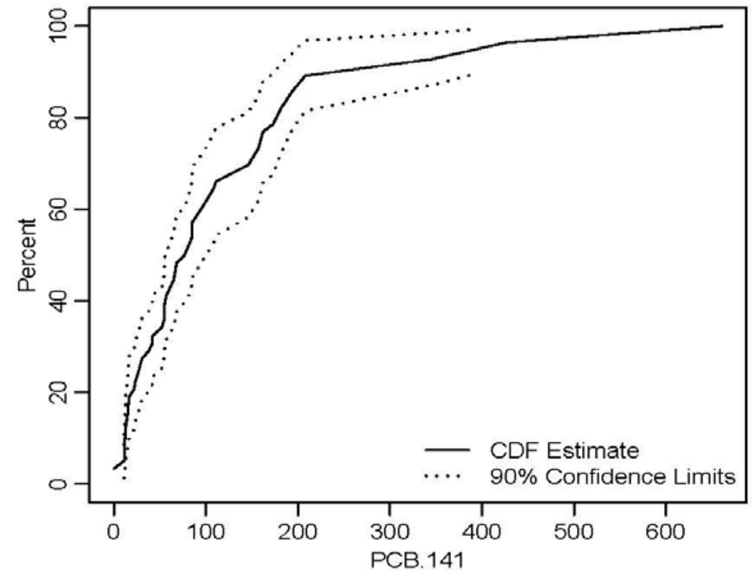
PCB.140
CDF Estimate
90% Confidence Limits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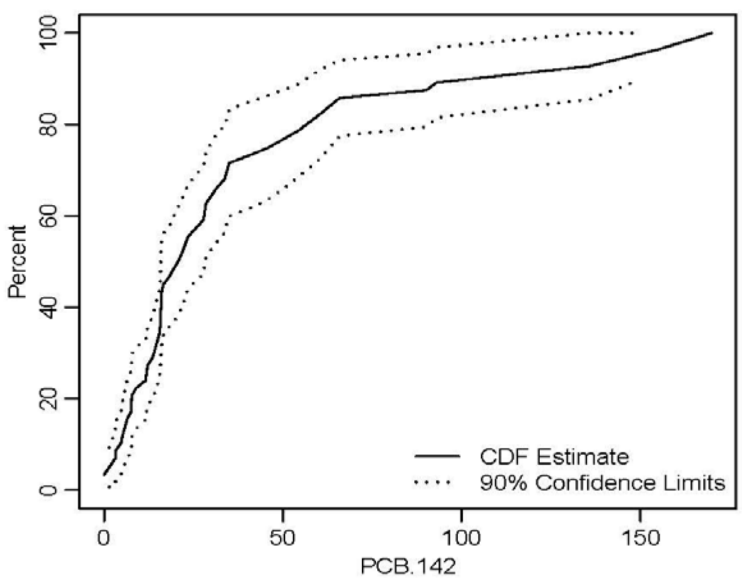
PCB.141
CDF Estimate
90% Confidence Limits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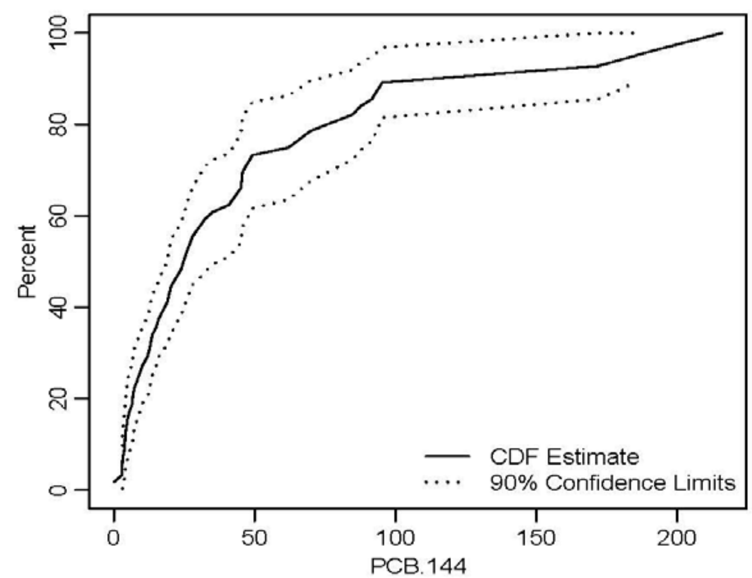
PCB.142
CDF Estimate
90% Confidence Limits


Percent
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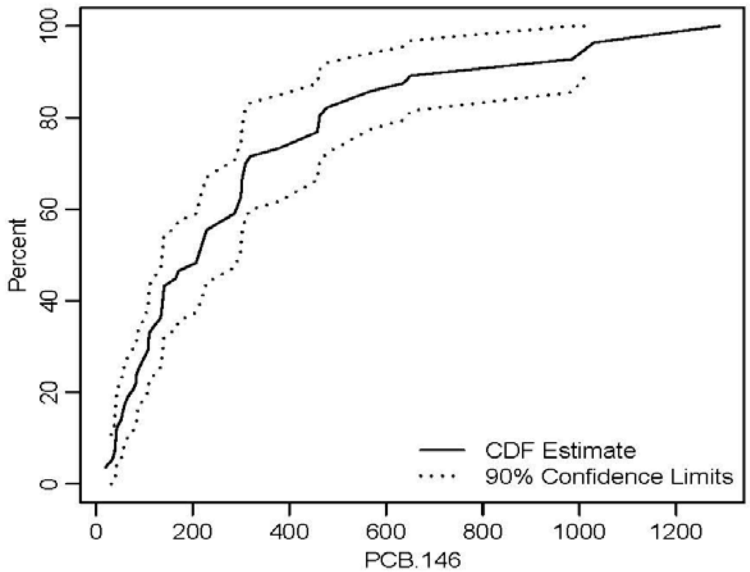
PCB.144
CDF Estimate
90% Confidence Limits


Percent
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600
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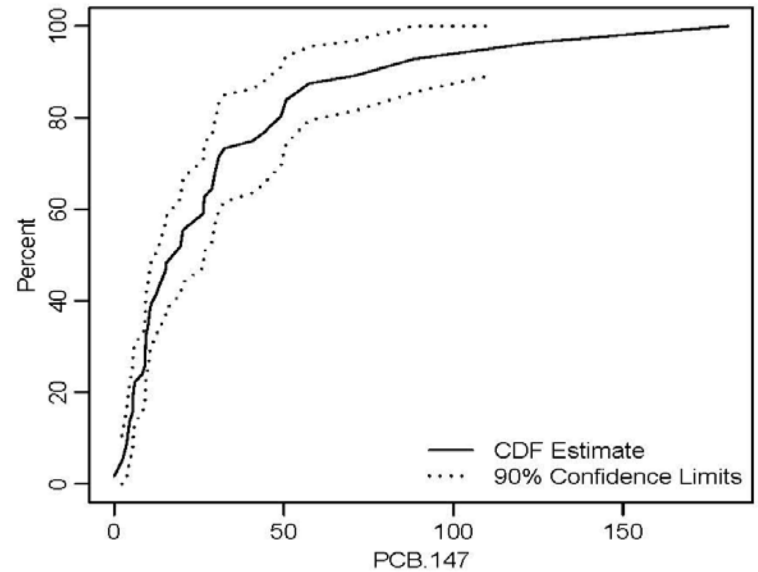
1000
1200
PCB.146
CDF Estimate
90% Confidence Limits


Percent
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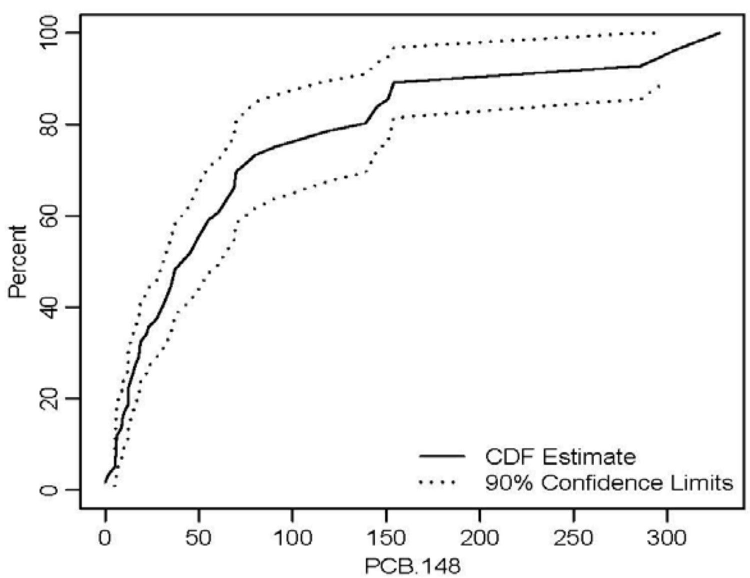
PCB.147
CDF Estimate
90% Confidence Limits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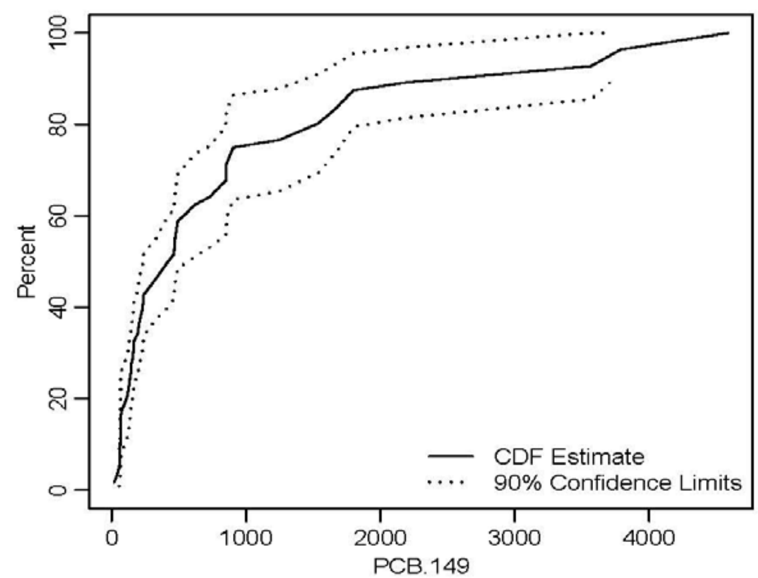
PCB.148
CDF Estimate
90% Confidence Limits


Percent
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60
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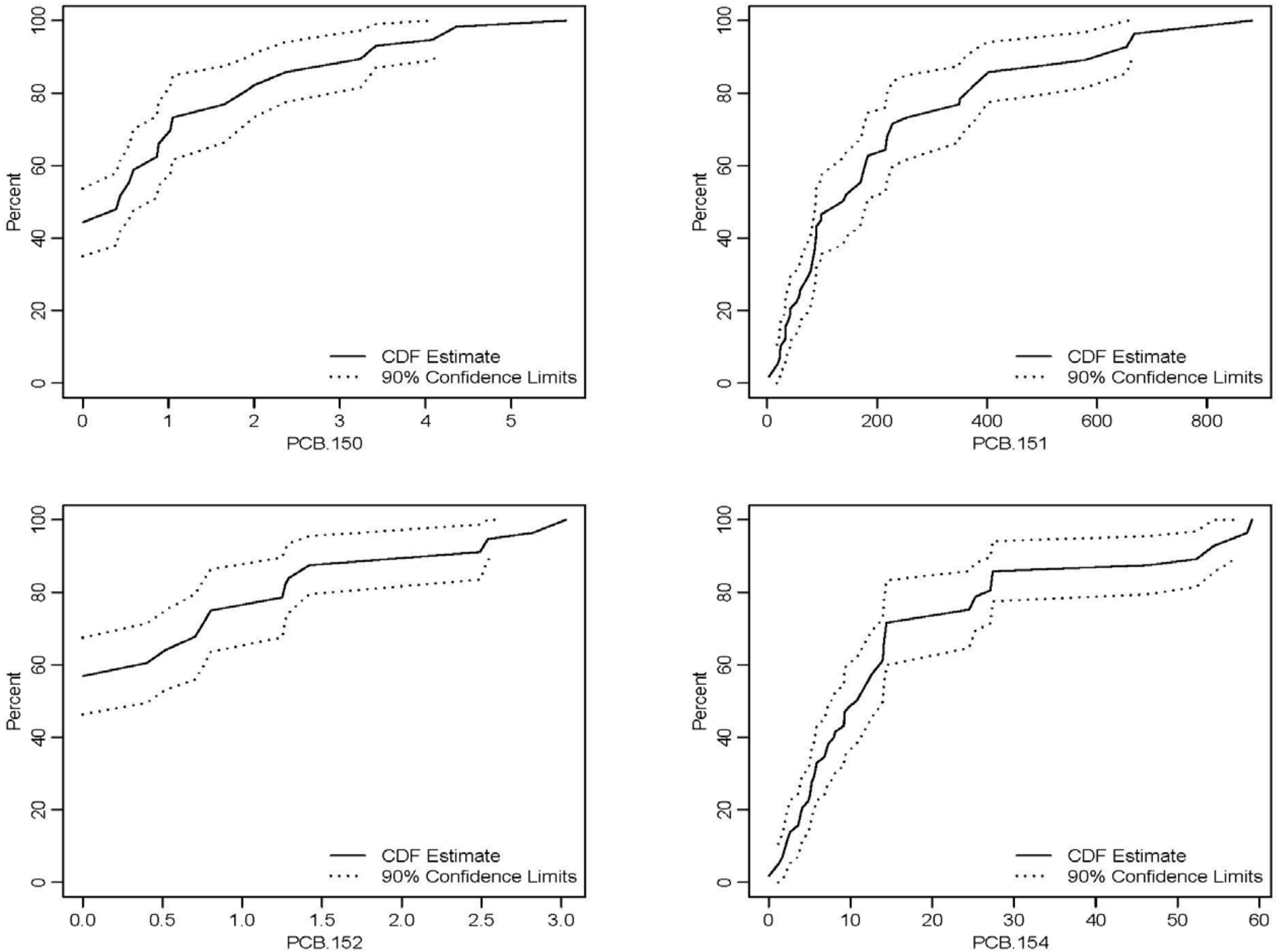
4000
PCB.149
CDF Estimate
90% Confidence Limits



Percent
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20
40
60
80
100
0
1
2
3
4
5
PCB.150
CDF Estimate
90% Confidence Limits
Percent
0
20
40
60
80
100
0
200
400
600
800
PCB.151
CDF Estimate
90% Confidence Limits
Percent
0
20
40
60
80
100
0.0
0.5
1.0
1.5
2.0
2.5
3.0
PCB.152
CDF Estimate
90% Confidence Limits
Percent
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80
100
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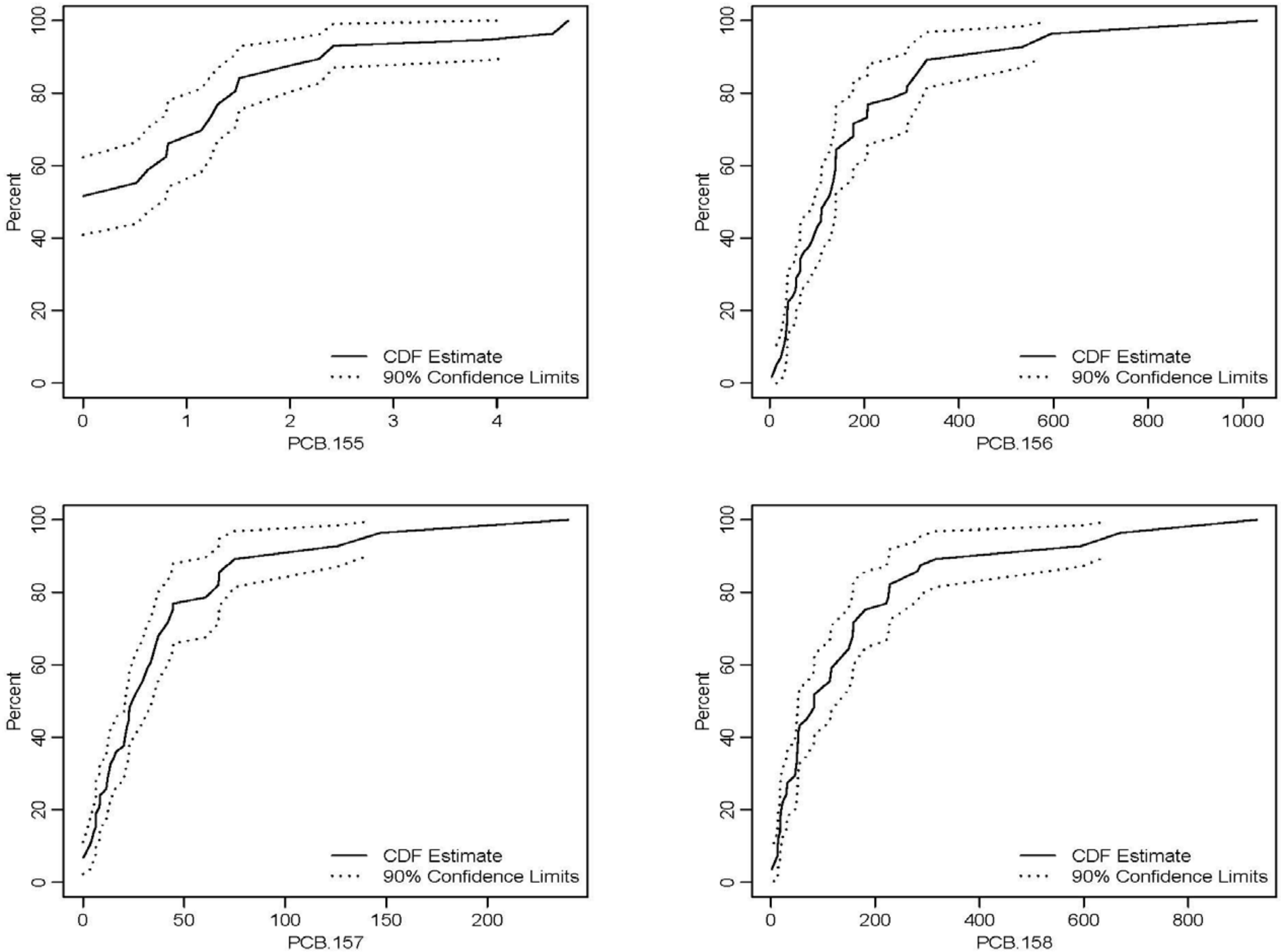
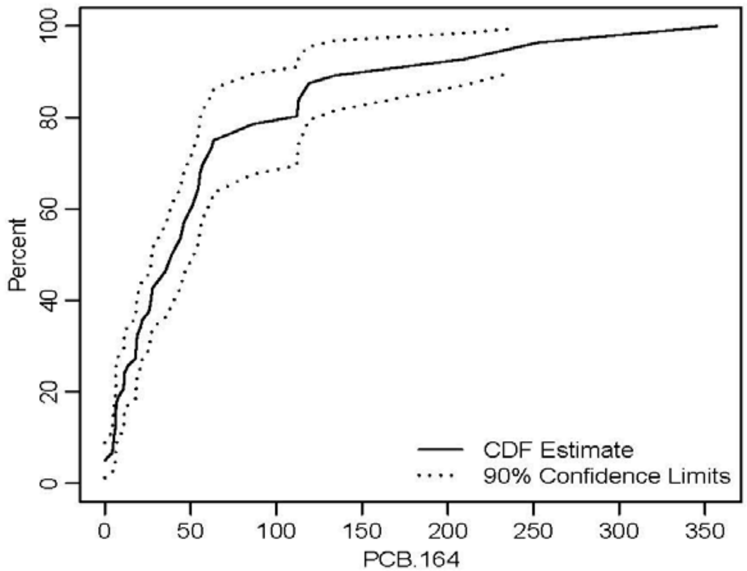
10
20
30
40
50
60
PCB.154
CDF Estimate
90% Confidence Limits


Percent
PCB.155
CDF Estimate
90% Confidence Limits
Percent
PCB.156
CDF Estimate
90% Confidence Limits
Percent
PCB.157
CDF Estimate
90% Confidence Limits
Percent
PCB.158
CDF Estimate
90% Confidence Limits


Percent
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100
150
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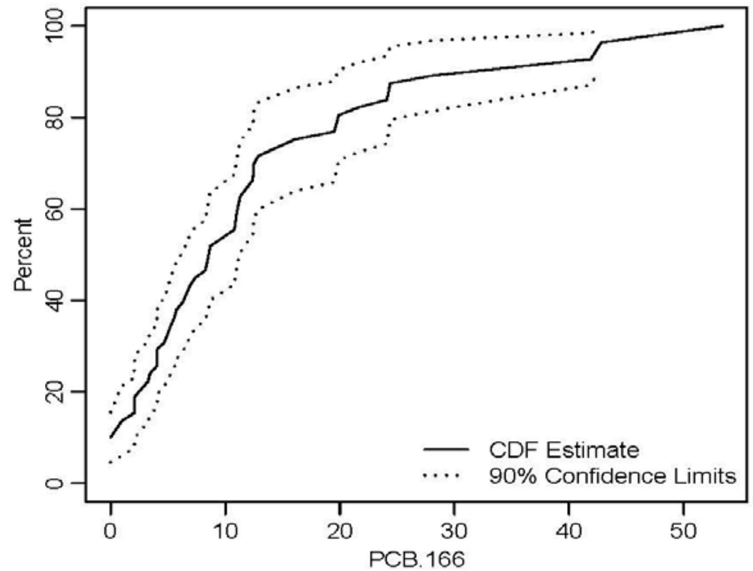
350
PCB.164
CDF Estimate
90% Confidence Limits


Percent
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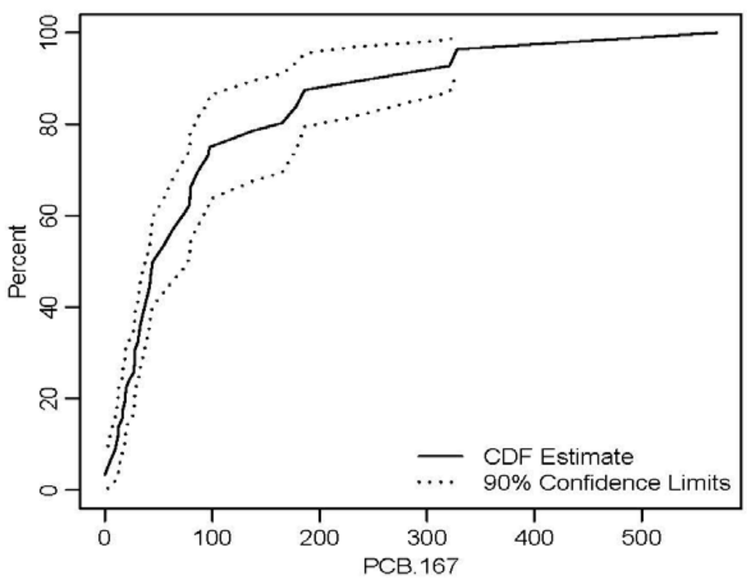
50
PCB.166
CDF Estimate
90% Confidence Limits


Percent
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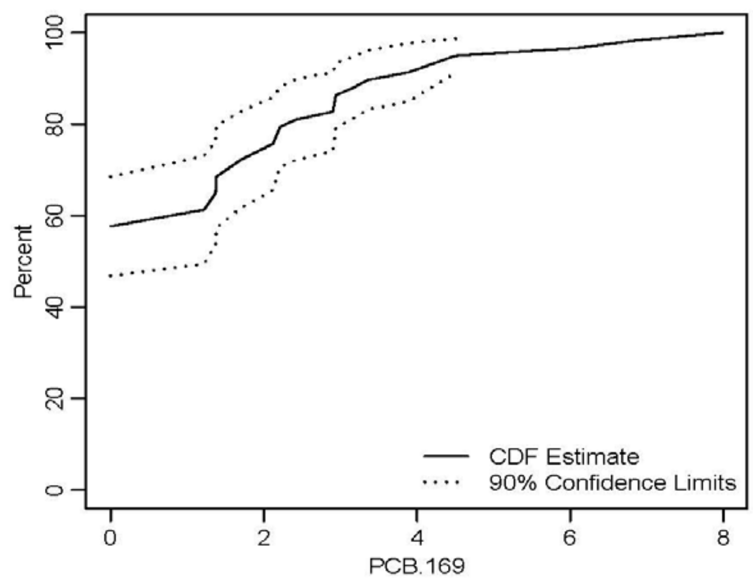
PCB.167
CDF Estimate
90% Confidence Limits


Percent
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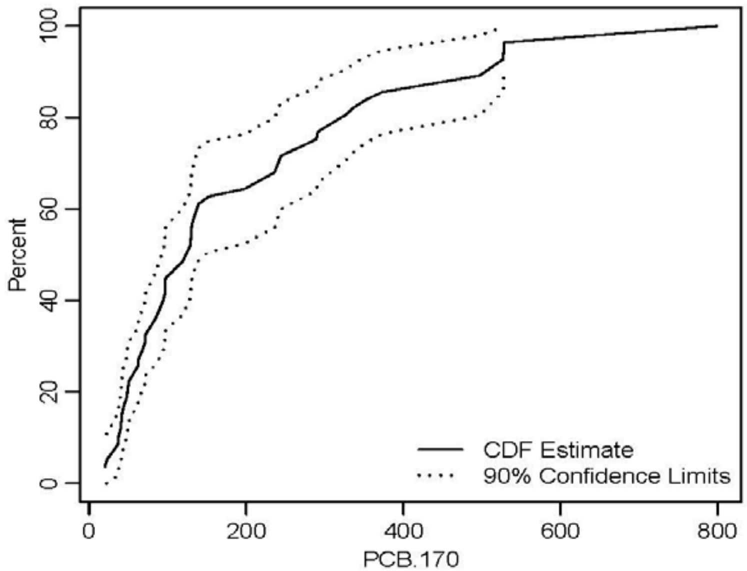
2
4
6
8
PCB.169
CDF Estimate
90% Confidence Limits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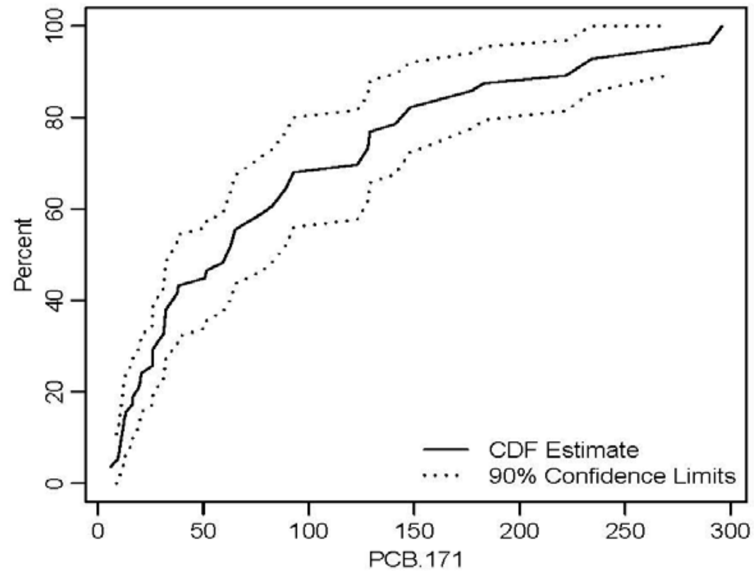
800
PCB.170
CDF Estimate
90% Confidence Limits


Percent
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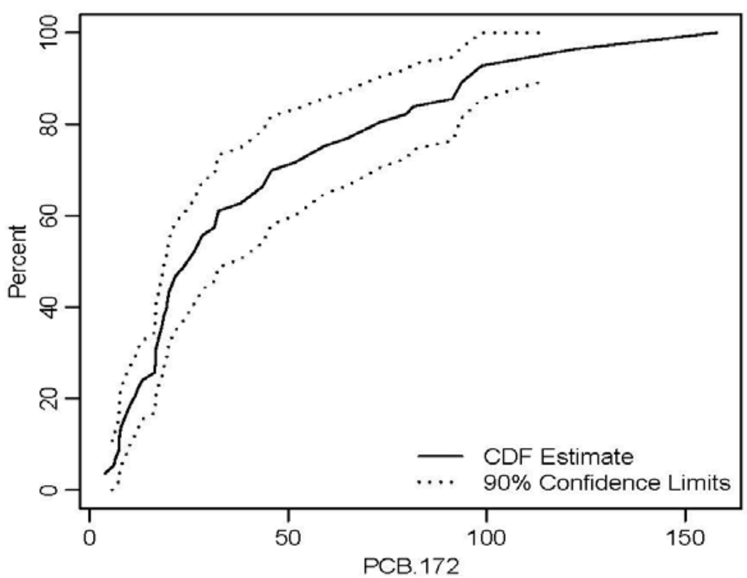
PCB.171
CDF Estimate
90% Confidence Limits


Percent
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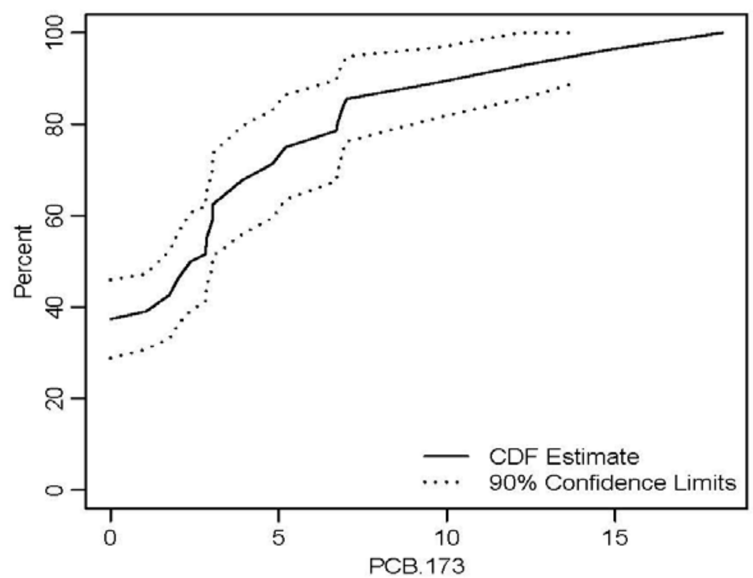
PCB.172
CDF Estimate
90% Confidence Limits


Percent
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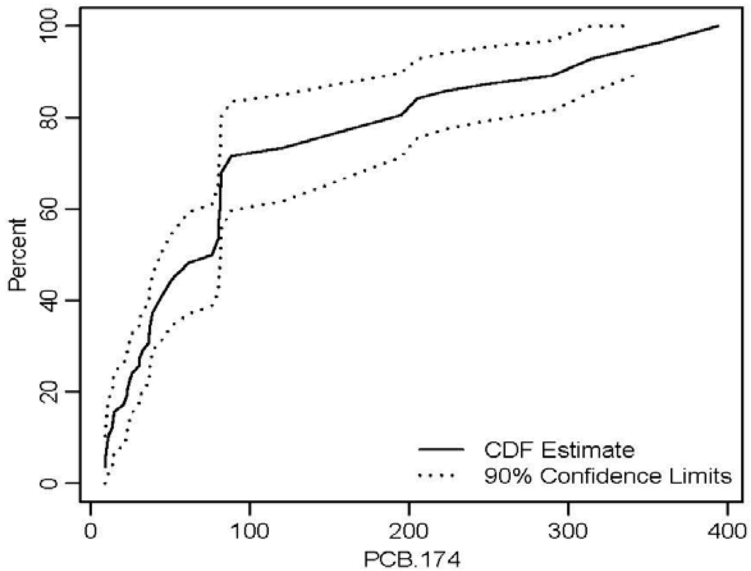
10
15
PCB.173
CDF Estimate
90% Confidence Limits


Percent
PCB.174
CDF Estimate
90% Confidence Limits
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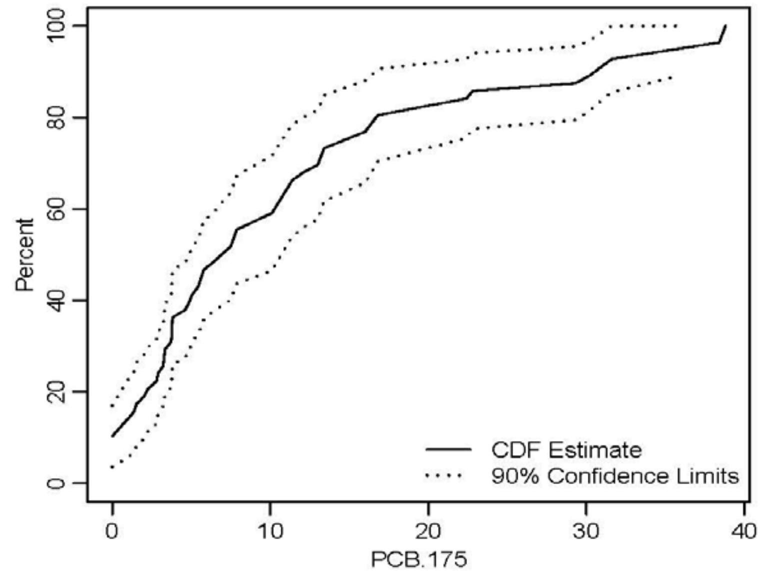
0
100
200
300
400


Percent
PCB.175
CDF Estimate
90% Confidence Limits
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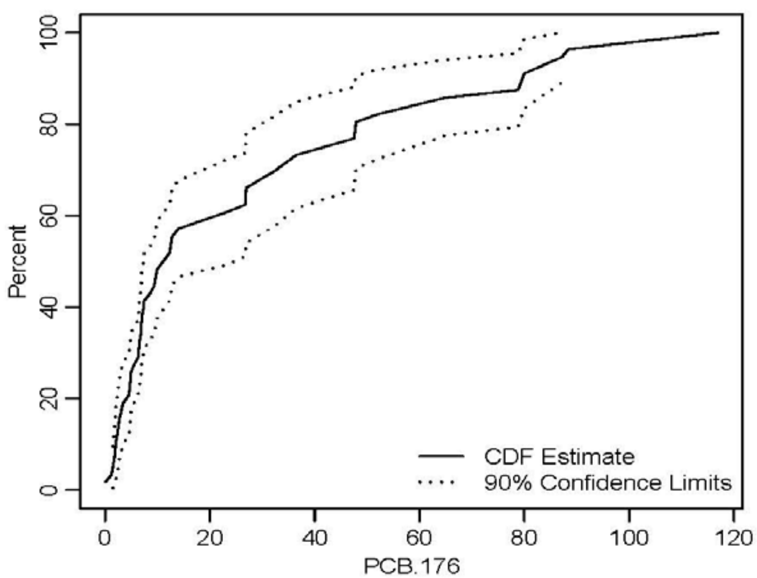
10
20
30
40


Percent
PCB.176
CDF Estimate
90% Confidence Limits
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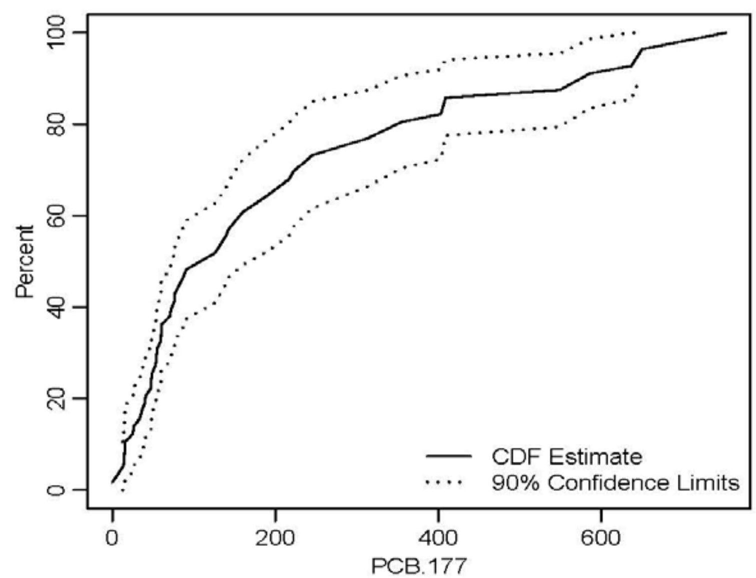
60
80
100
120


Percent
PCB.177
CDF Estimate
90% Confidence Limits
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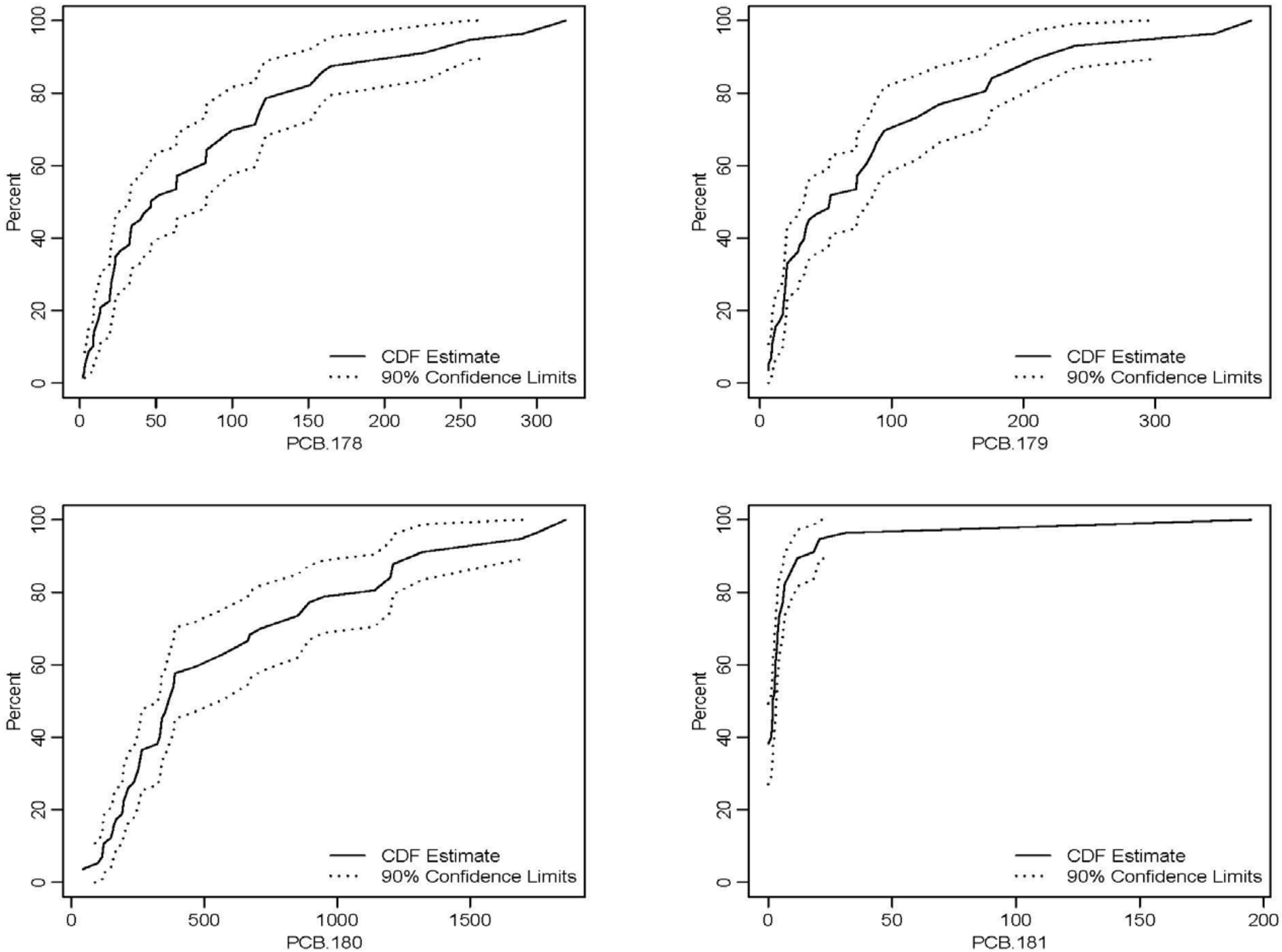
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CDF Estimate
90% Confidence Limits
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PCB.178
Percent
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80
100
CDF Estimate
90% Confidence Limits
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200
300
PCB.179
Percent
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60
80
100
CDF Estimate
90% Confidence Limits
0
500
1000
1500
PCB.180
Percent
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80
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CDF Estimate
90% Confidence Limits
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150
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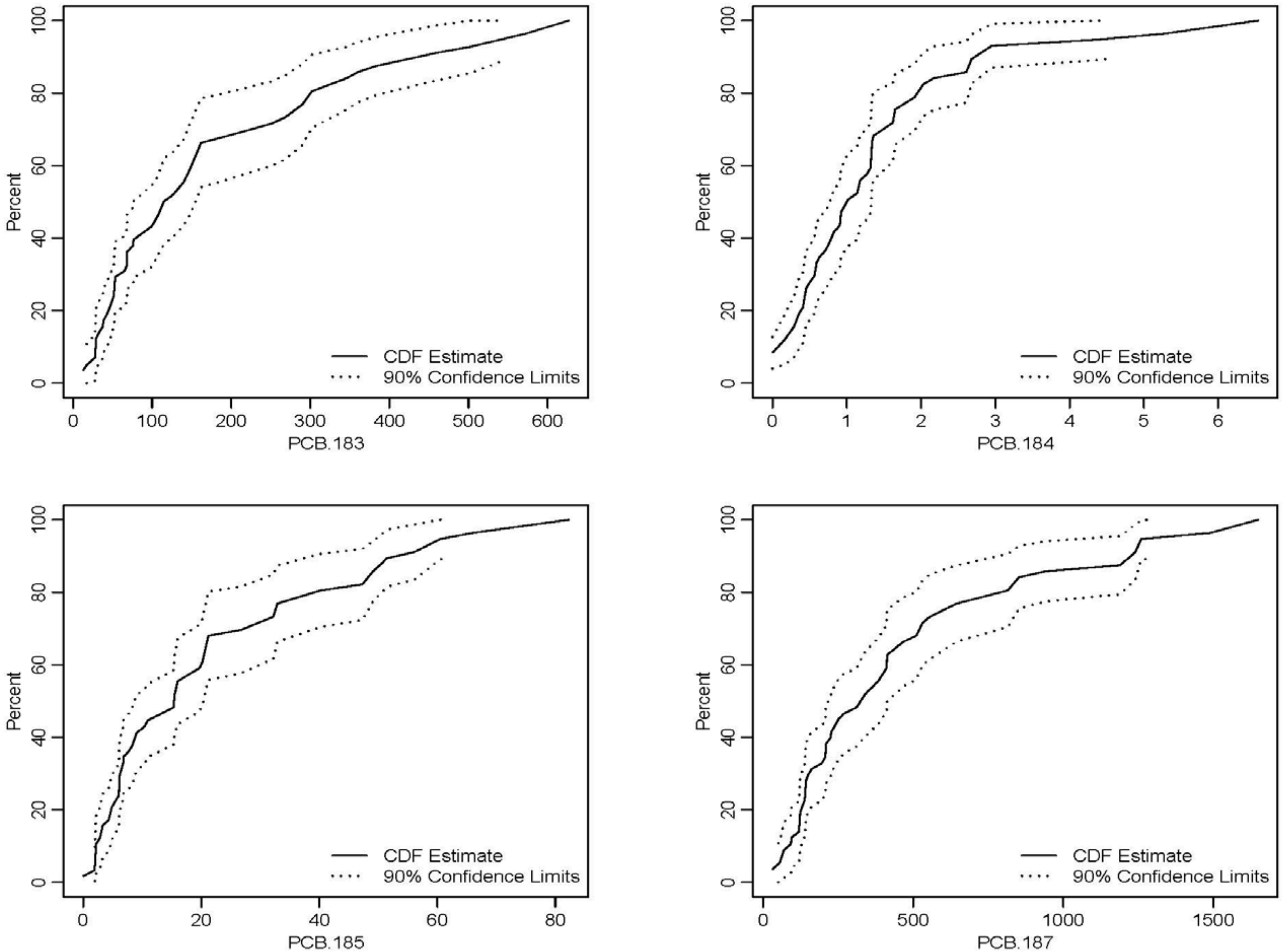
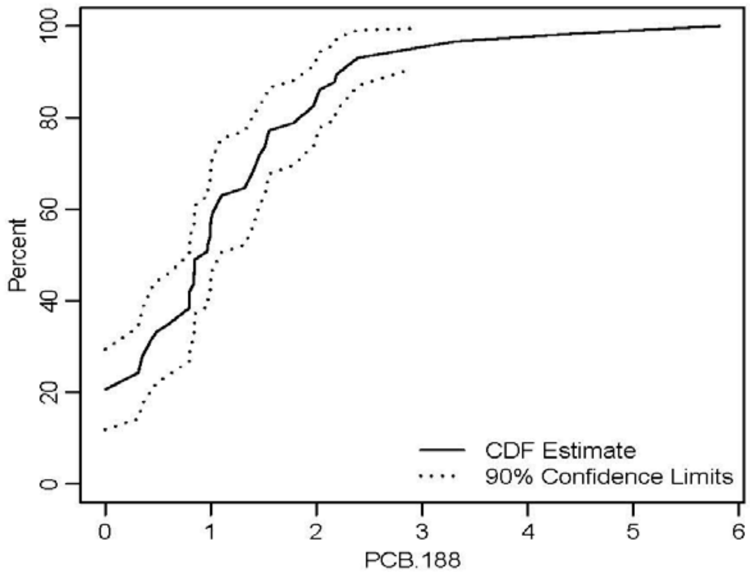
PCB.181


Percent
PCB.183
CDF Estimate
90% Confidence Limits
Percent
PCB.184
CDF Estimate
90% Confidence Limits
Percent
PCB.185
CDF Estimate
90% Confidence Limits
Percent
PCB.187
CDF Estimate
90% Confidence Limits


Percent
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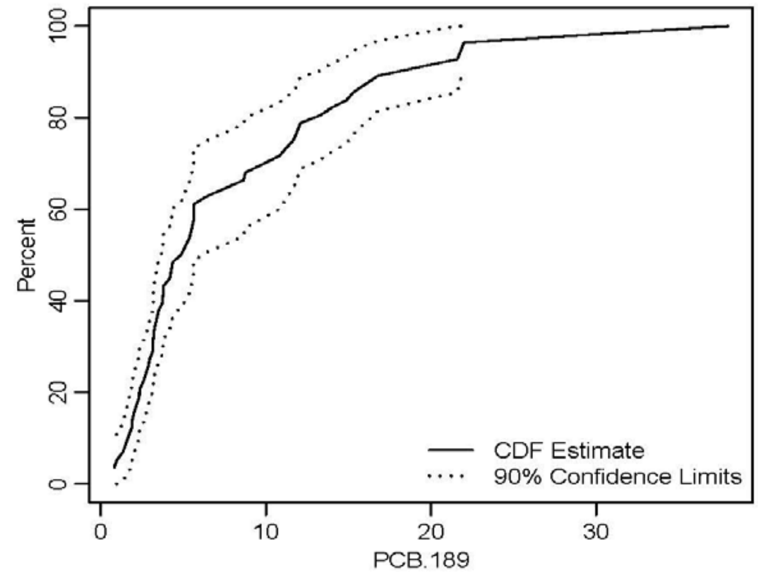
PCB.188
CDF Estimate
90% Confidence Limits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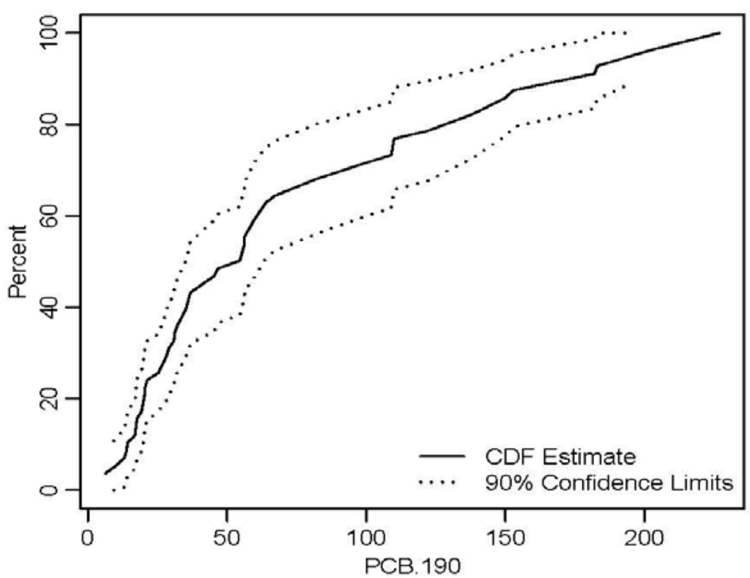
PCB.189
CDF Estimate
90% Confidence Limits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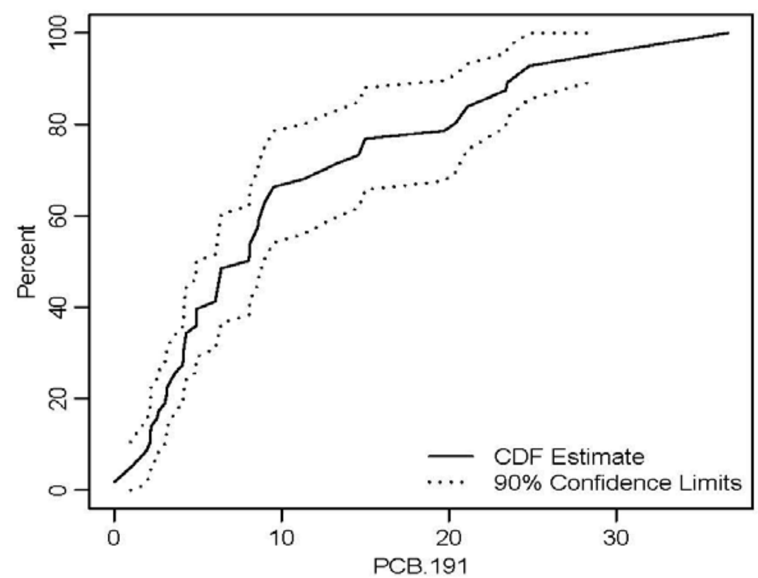
PCB.190
CDF Estimate
90% Confidence Limits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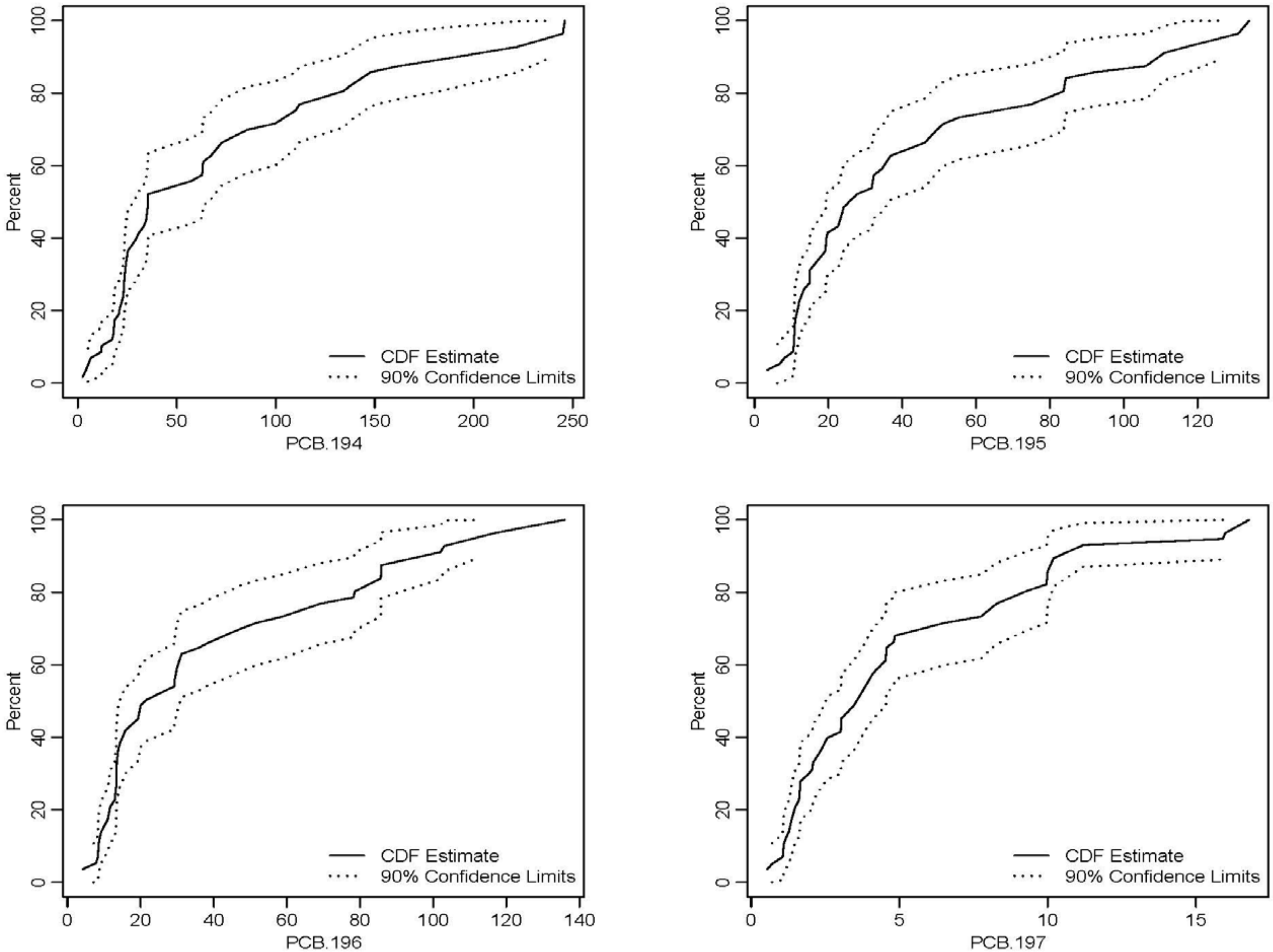
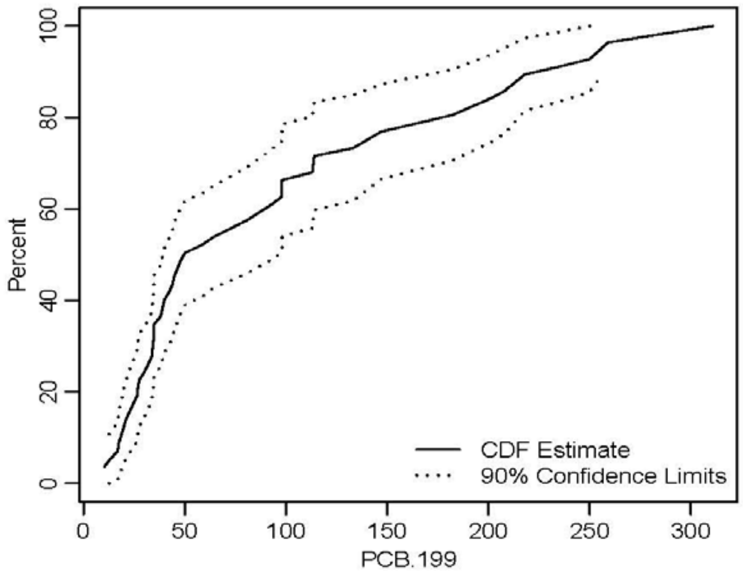
PCB.191
CDF Estimate
90% Confidence Limits


Percent
PCB.194
CDF Estimate
90% Confidence Limits
Percent
PCB.195
CDF Estimate
90% Confidence Limits
Percent
PCB.196
CDF Estimate
90% Confidence Limits
Percent
PCB.197
CDF Estimate
90% Confidence Limits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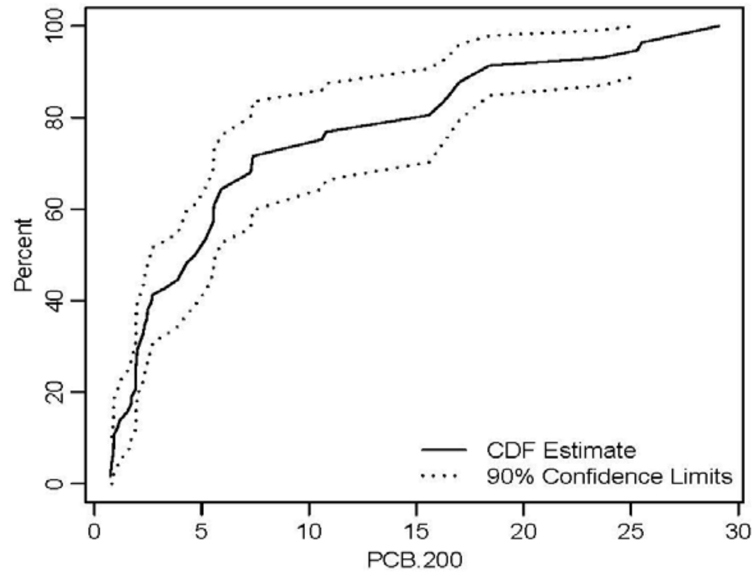
PCB.199
CDF Estimate
90% Confidence Limits


Percent
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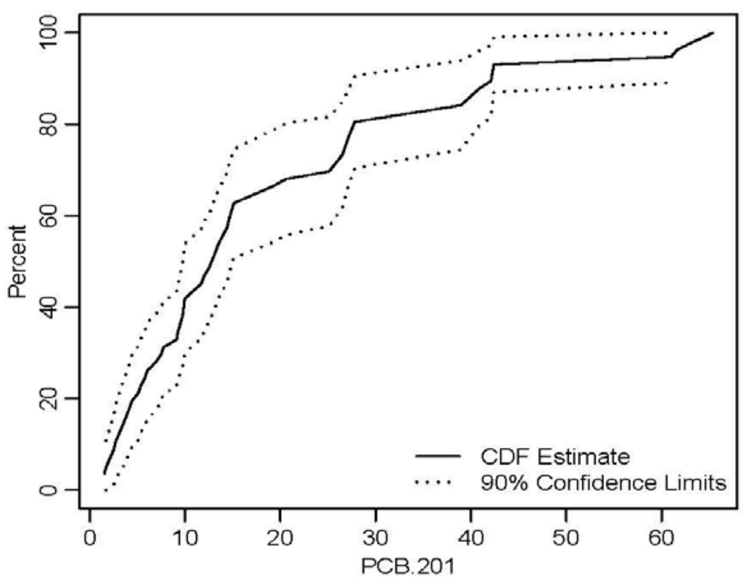
PCB.200
CDF Estimate
90% Confidence Limits


Percent
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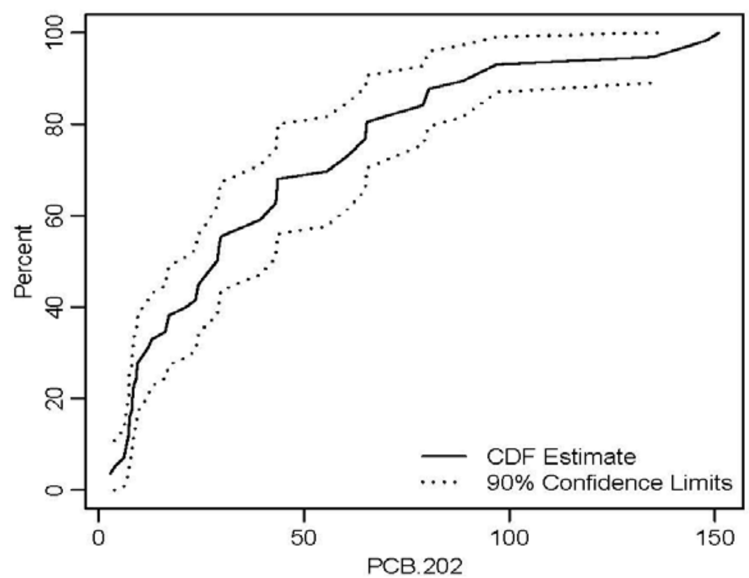
PCB.201
CDF Estimate
90% Confidence Limits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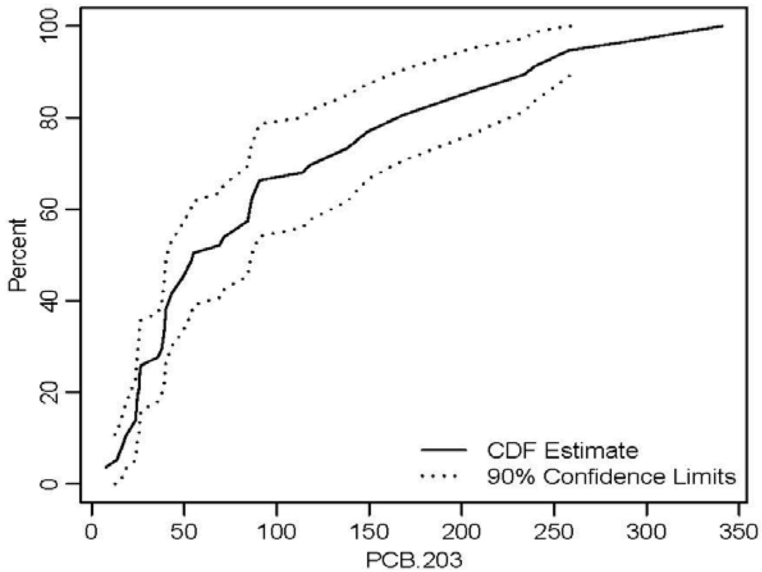
PCB.202
CDF Estimate
90% Confidence Limits


Percent
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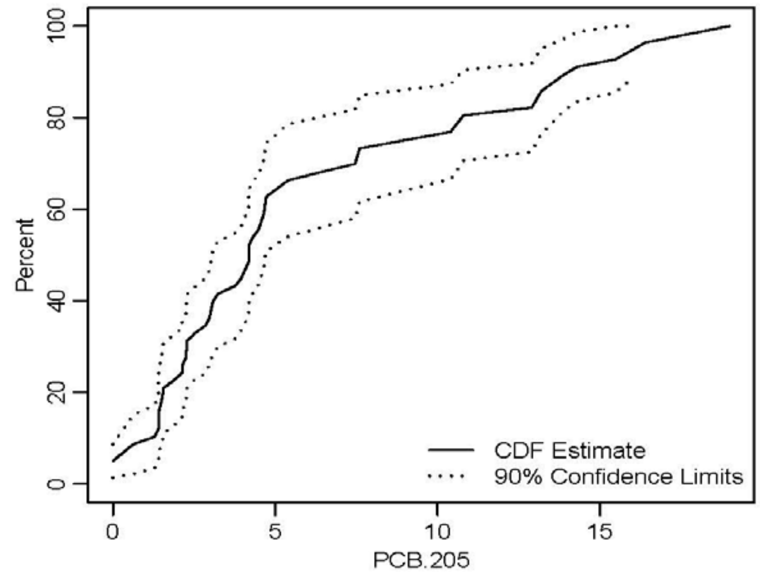
350
PCB.203
CDF Estimate
90% Confidence Limits


Percent
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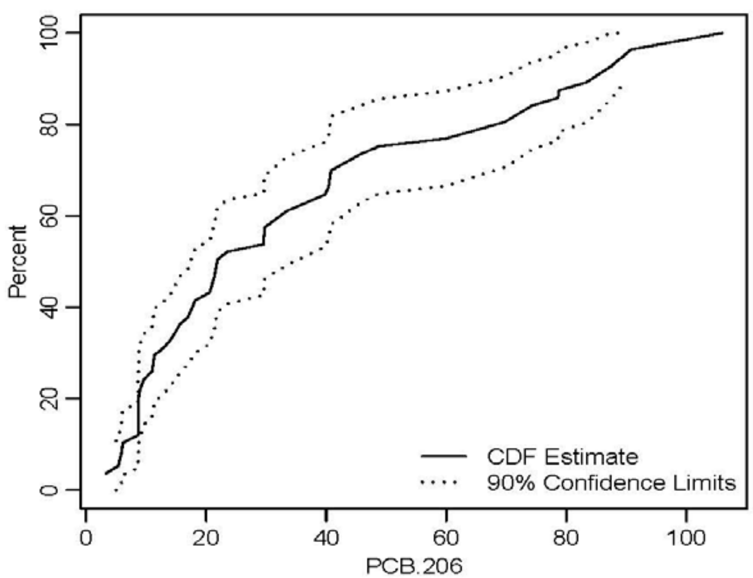
10
15
PCB.205
CDF Estimate
90% Confidence Limits


Percent
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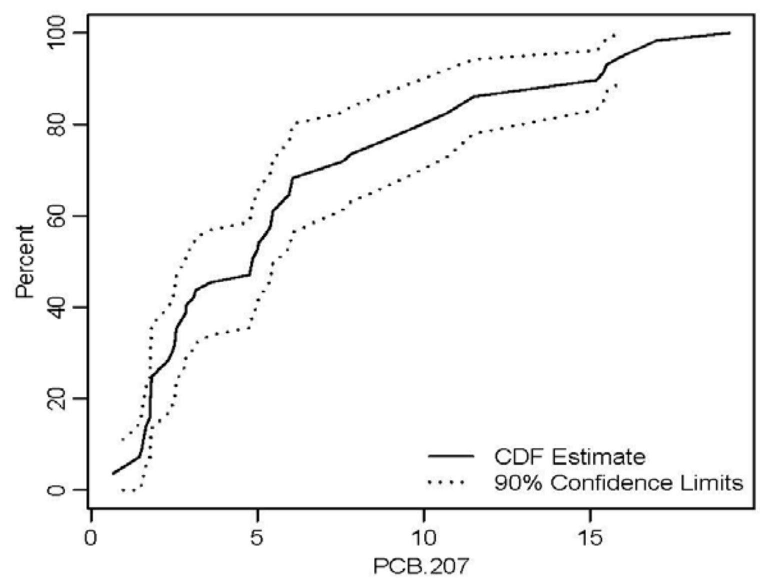
80
100
PCB.206
CDF Estimate
90% Confidence Limits


Percent
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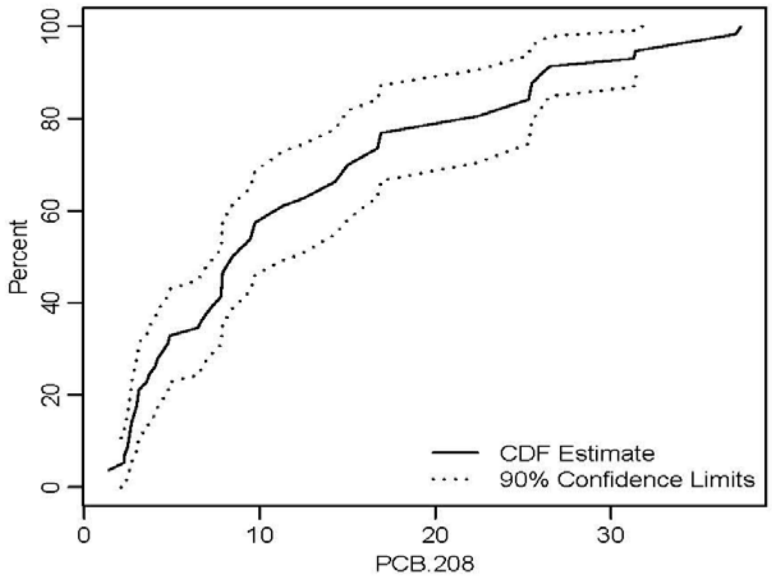
10
15
PCB.207
CDF Estimate
90% Confidence Limits


Percent
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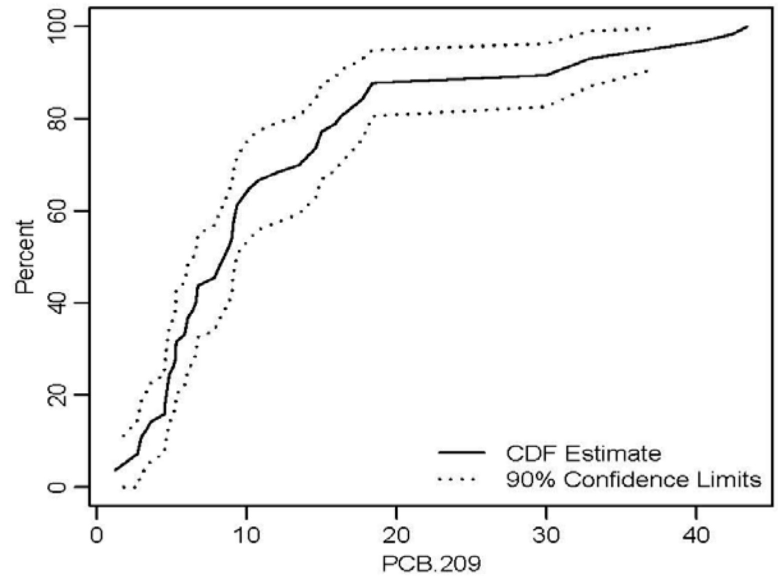
PCB.208
CDF Estimate
90% Confidence Limits


Percent
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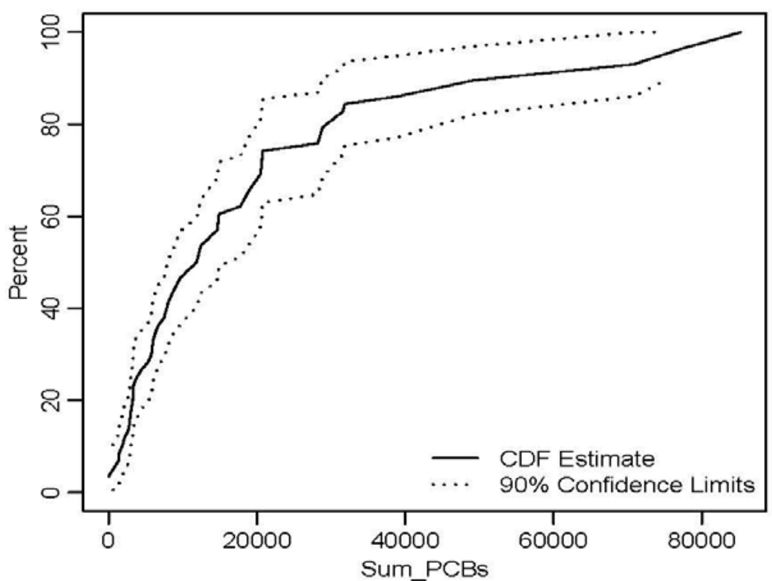
PCB.209
CDF Estimate
90% Confidence Limits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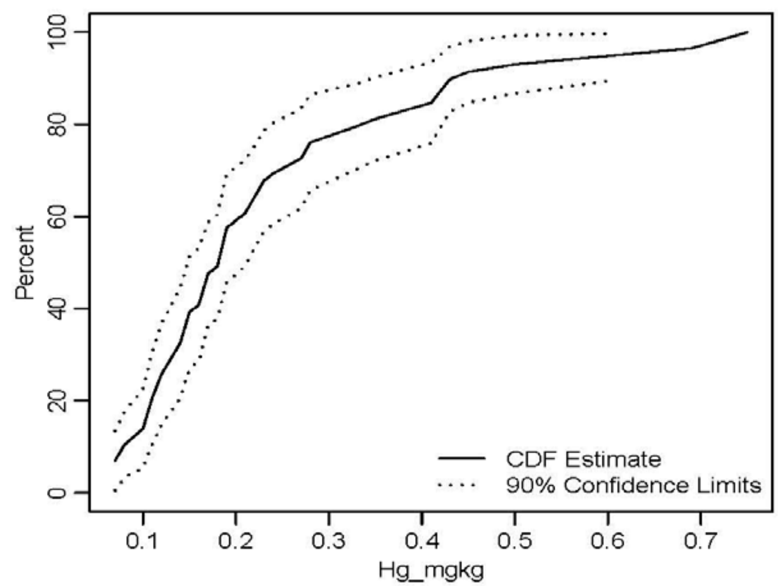
40000
60000
80000
Sum_PCBs
CDF Estimate
90% Confidence Limits


Percent
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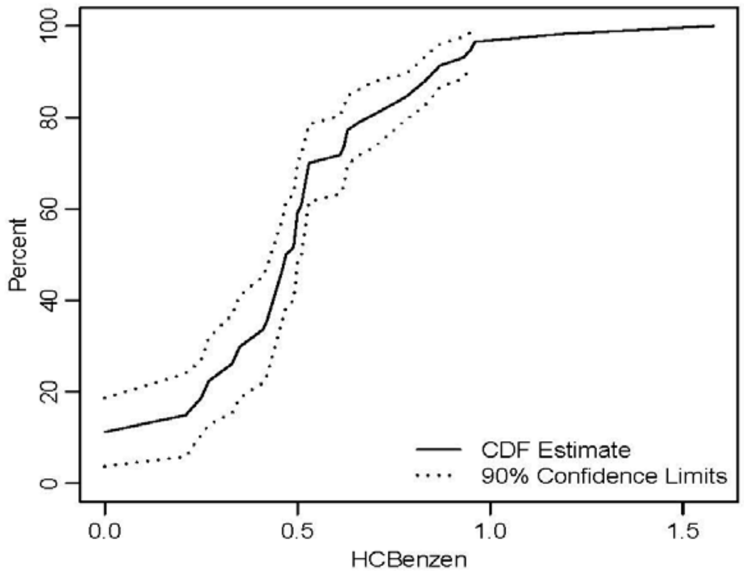
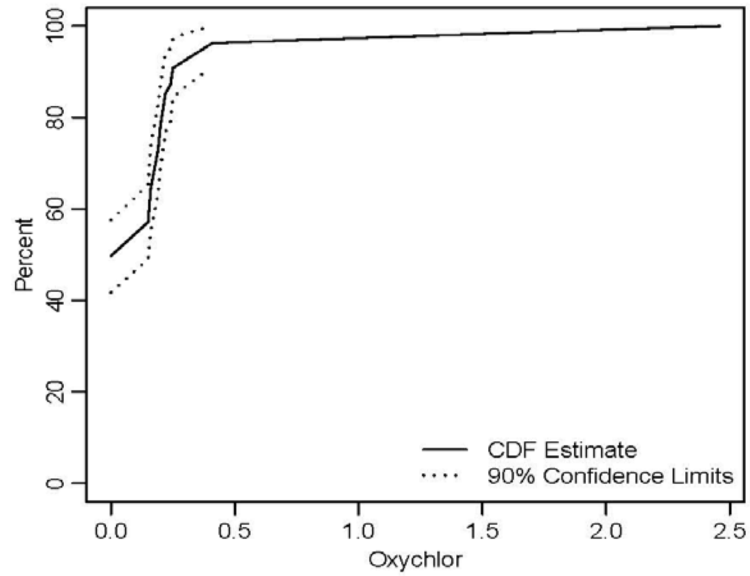
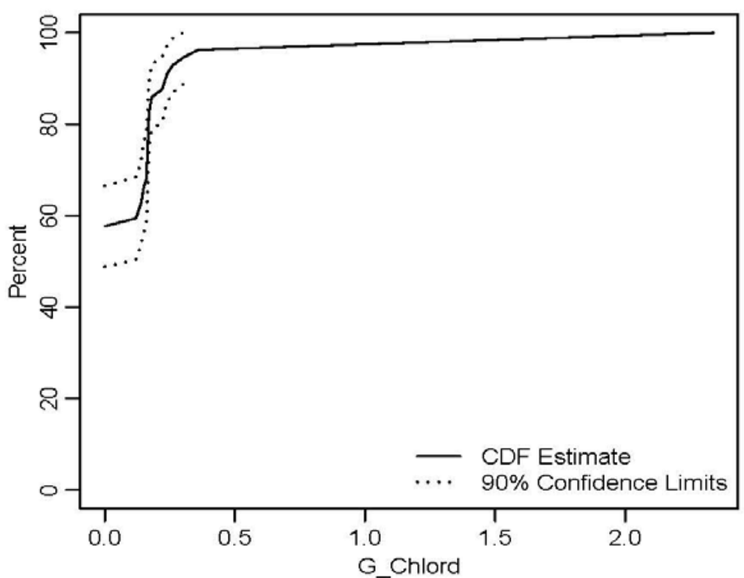
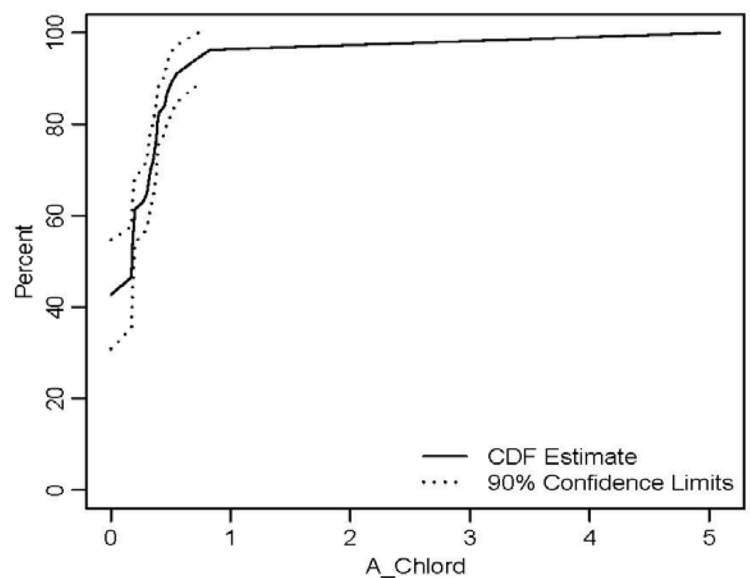
80
100
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Hg_mgkg
CDF Estimate
90% Confidence Limits

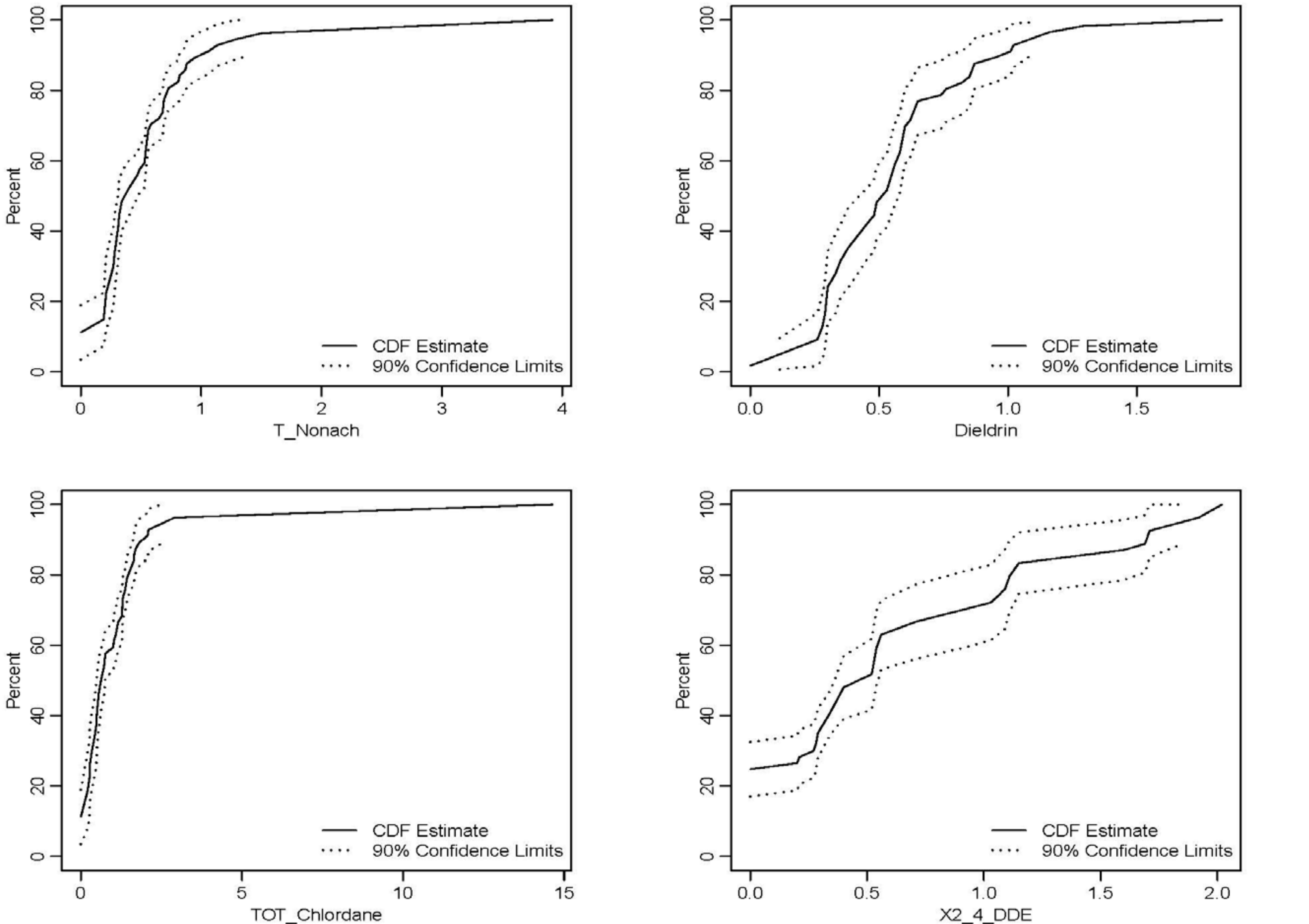
Appendix 13. Whole fish tissue concentration cumulative distribution frequency (CDF) estimates for analytes detected at >40% of MCR sites. Upper and lower 90% confidence bounds are shown. Units are ng/g ww except trace elements are in mg/kg ww.

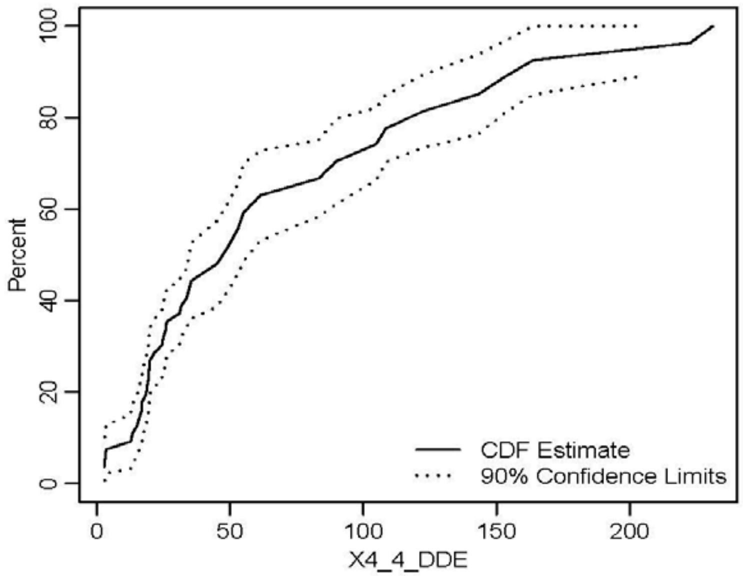

Percent
0
20
40
60
80
100
0.0
0.5
1.0
1.5
HCBenzen
CDF Estimate
90% Confidence Limits

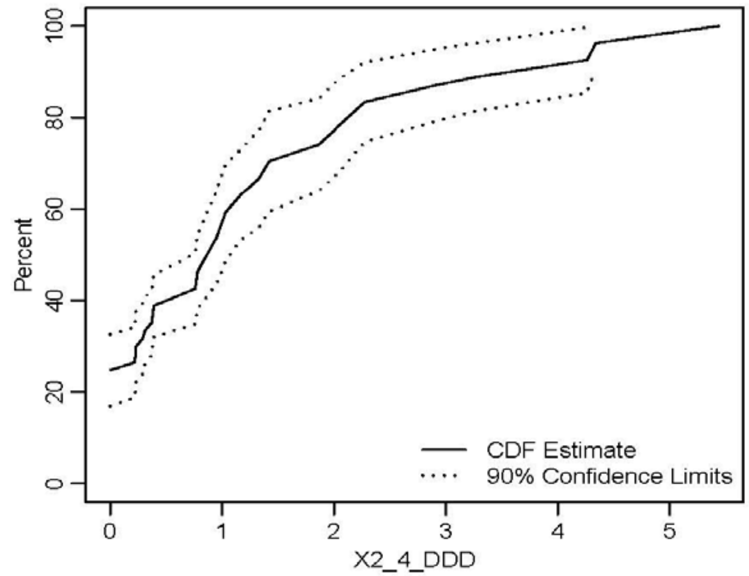

Percent
0
20
40
60
80
100
0.0
0.5
1.0
1.5
2.0
2.5
Oxychlor
CDF Estimate
90% Confidence Limits

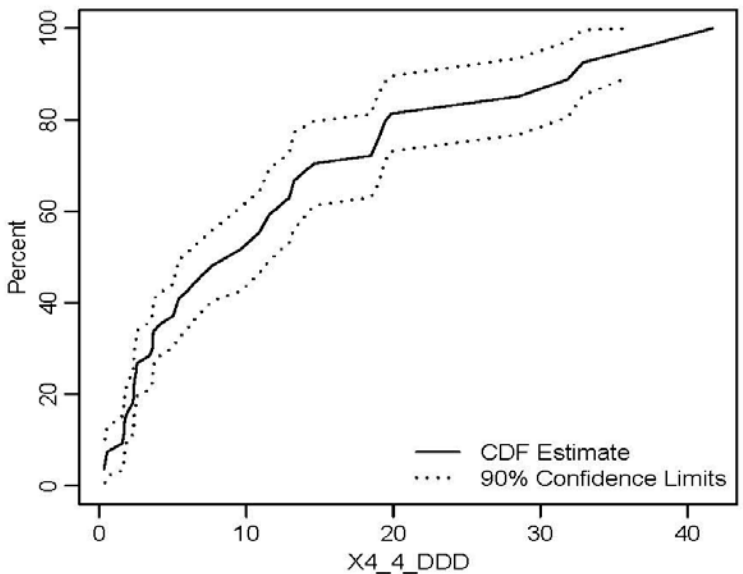

Percent
0
20
40
60
80
100
0.0
0.5
1.0
1.5
2.0
G_Chlord
CDF Estimate
90% Confidence Limits

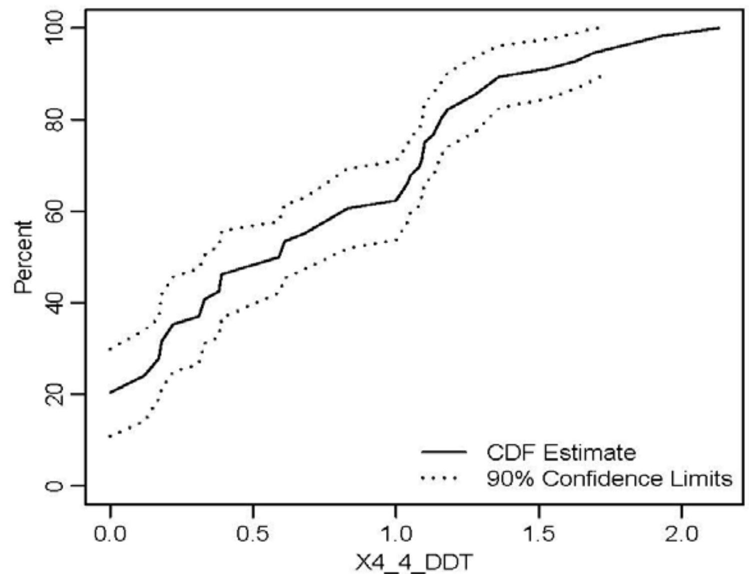

Percent
0
20
40
60
80
100
0
1
2
3
4
5
A_Chlord
CDF Estimate
90% Confidence Limits

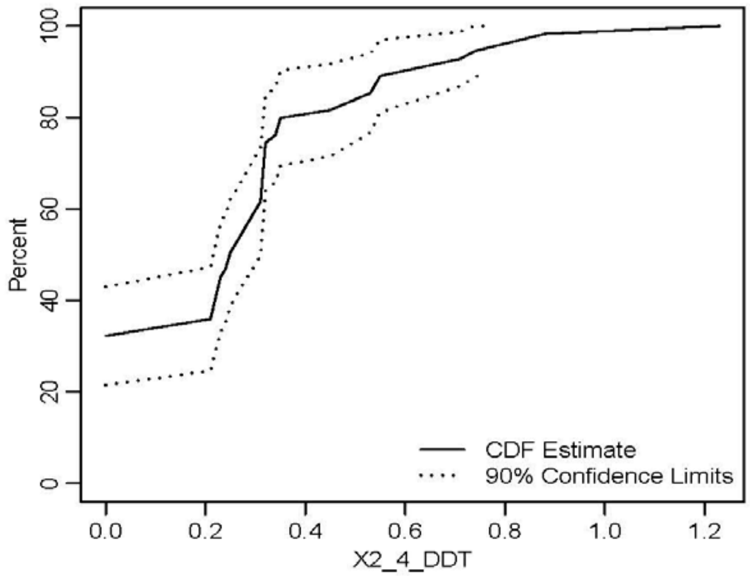

Percent
T_Nonach
CDF Estimate
90% Confidence Limits
Dieldrin
TOT_Chlordane
X2_4_DDE
0
20
40
60
80
100
1
2
3
4
0.0
0.5
1.0
1.5
2.0
5
10
15

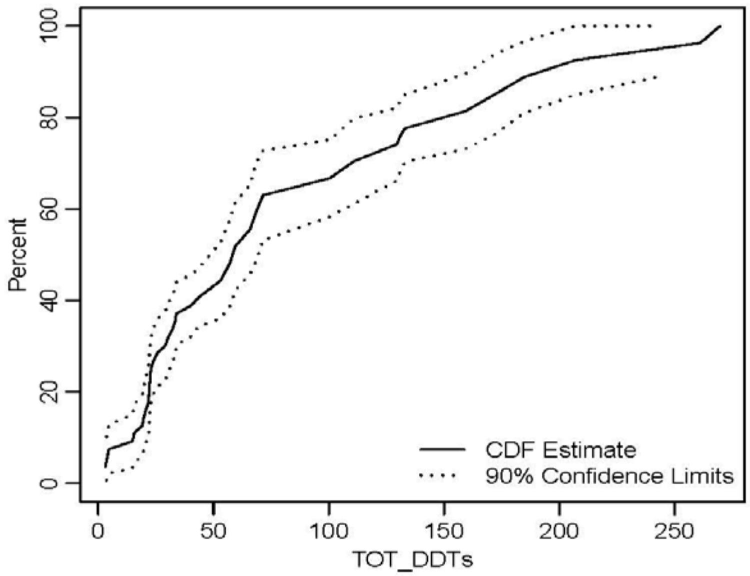

Percent
X4_4_DDE
CDF Estimate
90% Confidence Limits

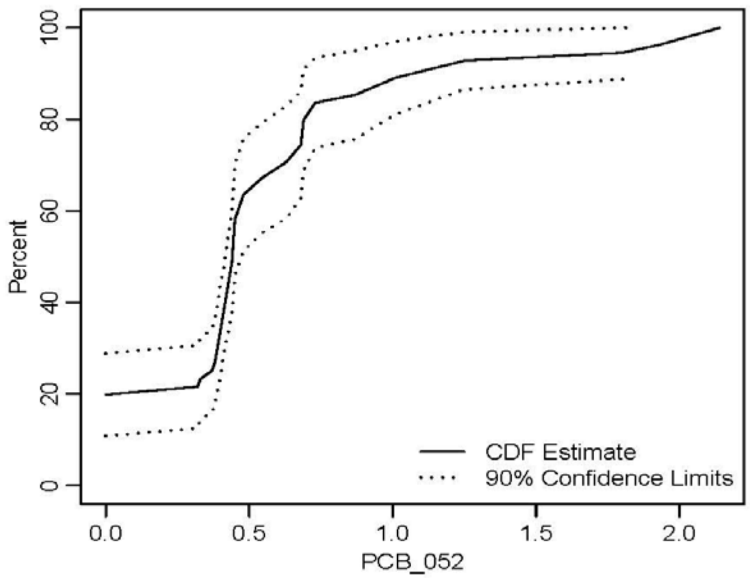

Percent
X2_4_DDD
CDF Estimate
90% Confidence Limits

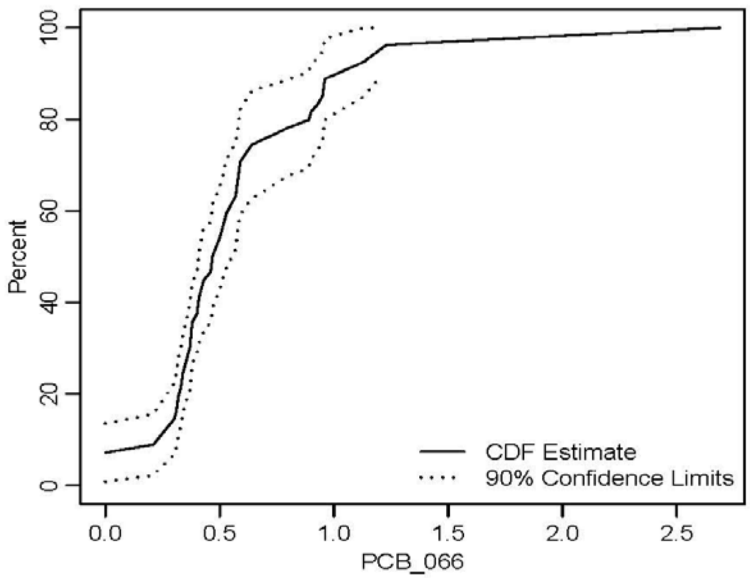

Percent
X4_4_DDD
CDF Estimate
90% Confidence Limits

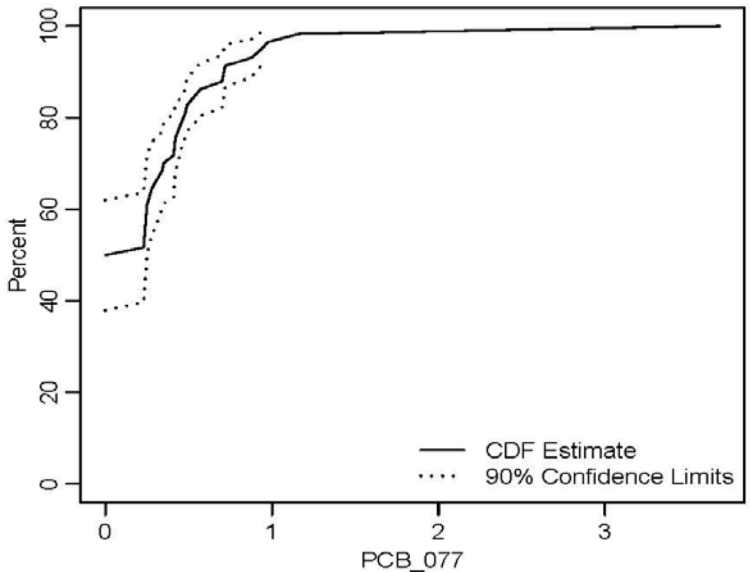

Percent
X4_4_DDT
CDF Estimate
90% Confidence Limits

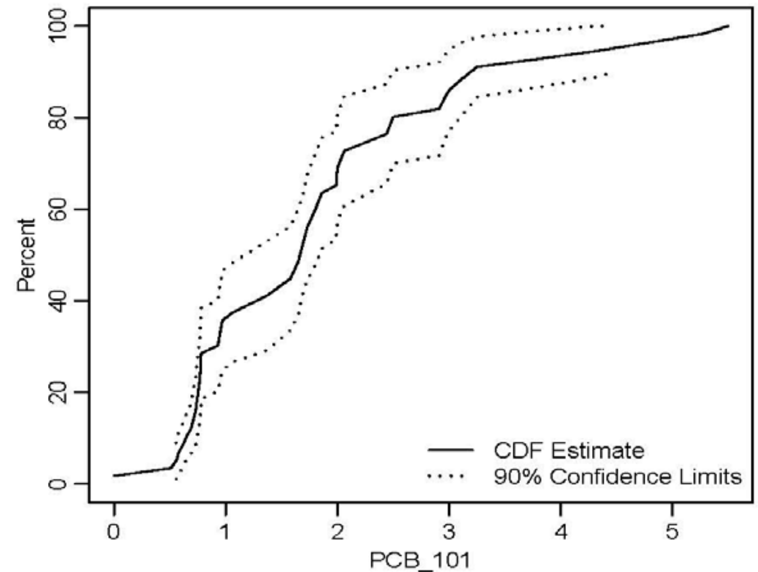

Percent
0
20
40
60
80
100
0.0
0.2
0.4
0.6
0.8
1.0
1.2
X2_4_DDT
CDF Estimate
90% Confidence Limits

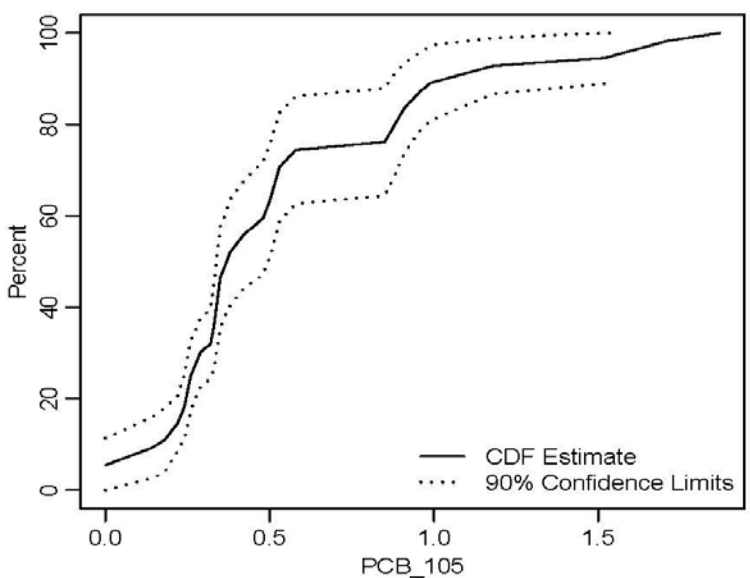

Percent
0
20
40
60
80
100
0
50
100
150
200
250
TOT_DDTs
CDF Estimate
90% Confidence Limits

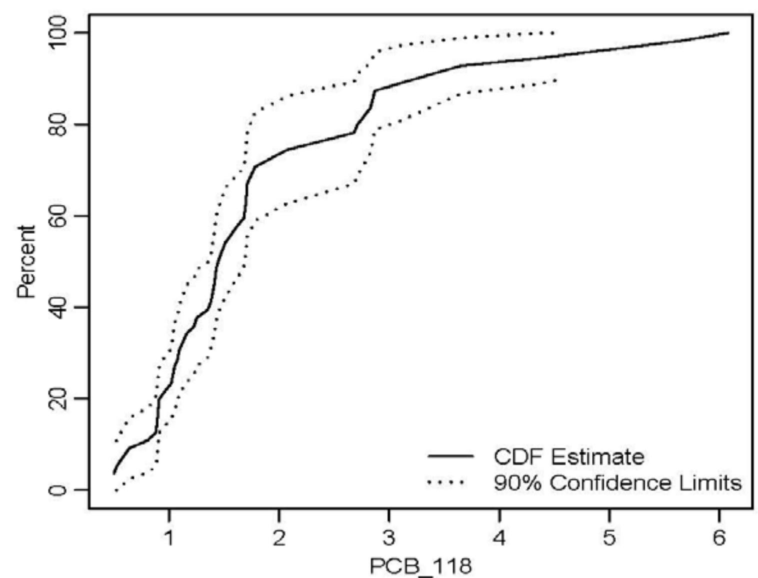

Percent
0
20
40
60
80
100
0.0
0.5
1.0
1.5
2.0
PCB_052
CDF Estimate
90% Confidence Limits

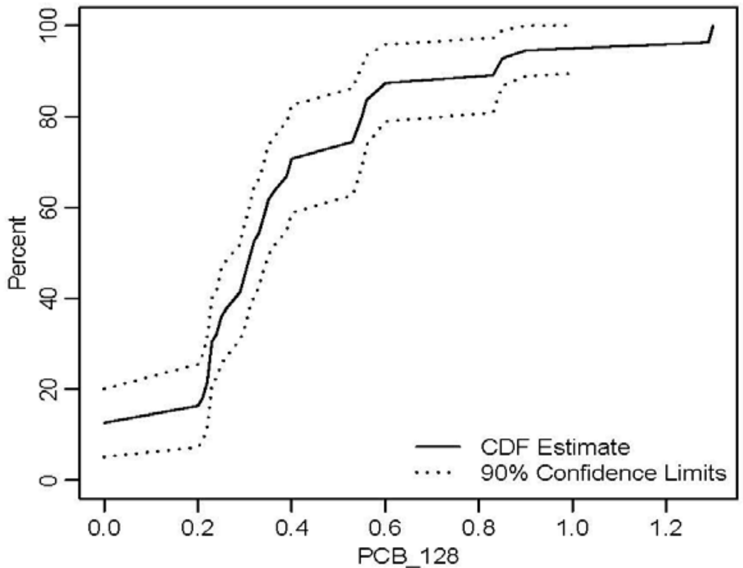

Percent
0
20
40
60
80
100
0.0
0.5
1.0
1.5
2.0
2.5
PCB_066
CDF Estimate
90% Confidence Limits

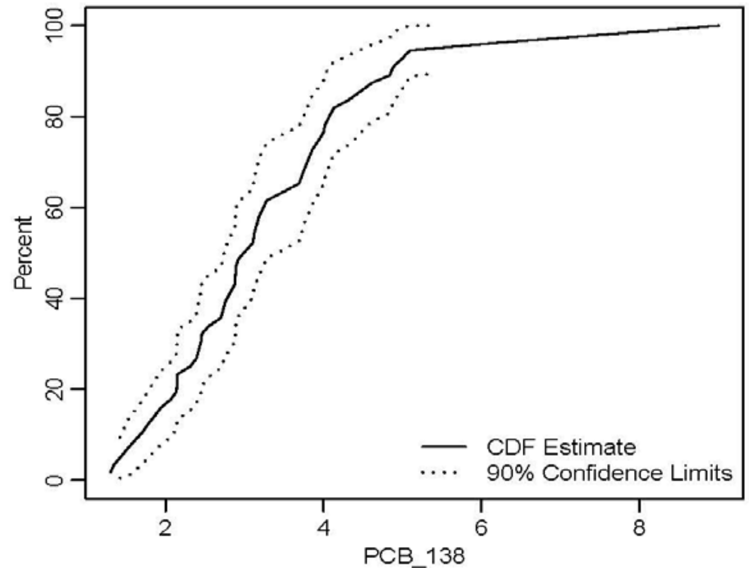

Percent
0
20
40
60
80
100
0
1
2
3
PCB_077
CDF Estimate
90% Confidence Limits

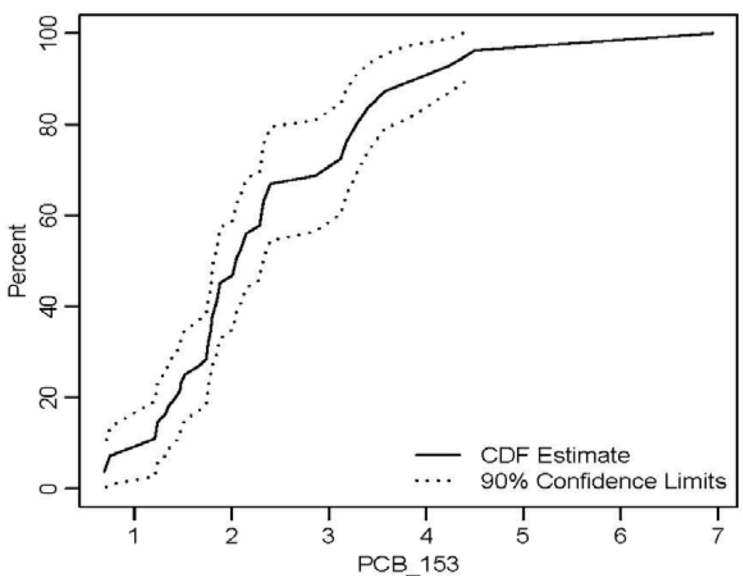

Percent
0
20
40
60
80
100
0
1
2
3
4
5
PCB_101
CDF Estimate
90% Confidence Limits

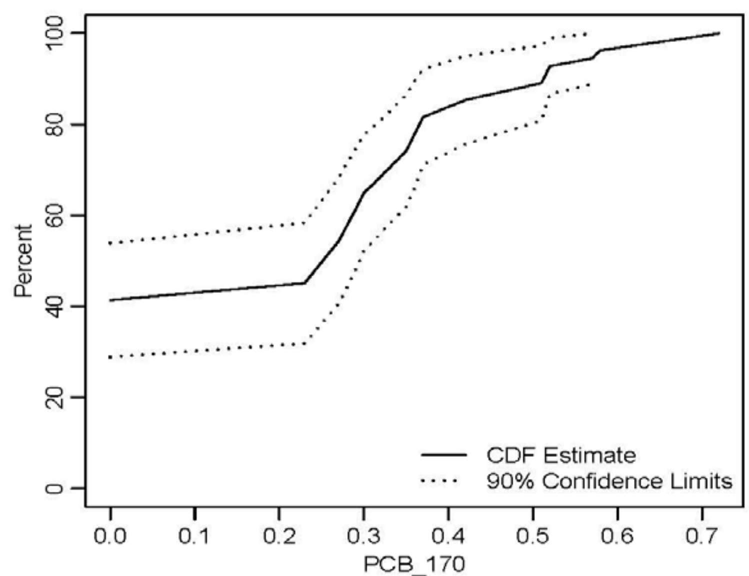

Percent
0
20
40
60
80
100
0.0
0.5
1.0
1.5
PCB_105
CDF Estimate
90% Confidence Limits

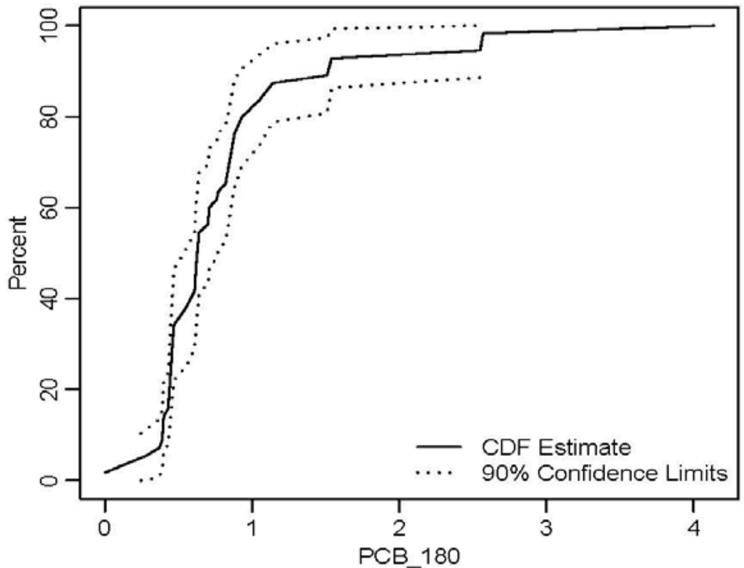

Percent
0
20
40
60
80
100
1
2
3
4
5
6
PCB_118
CDF Estimate
90% Confidence Limits

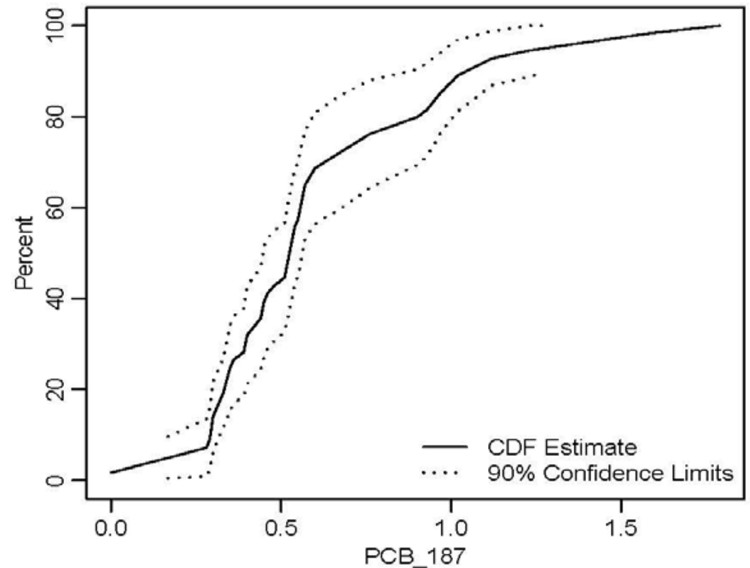

Percent
0
20
40
60
80
100
0.0
0.2
0.4
0.6
0.8
1.0
1.2
PCB_128
CDF Estimate
90% Confidence Limits

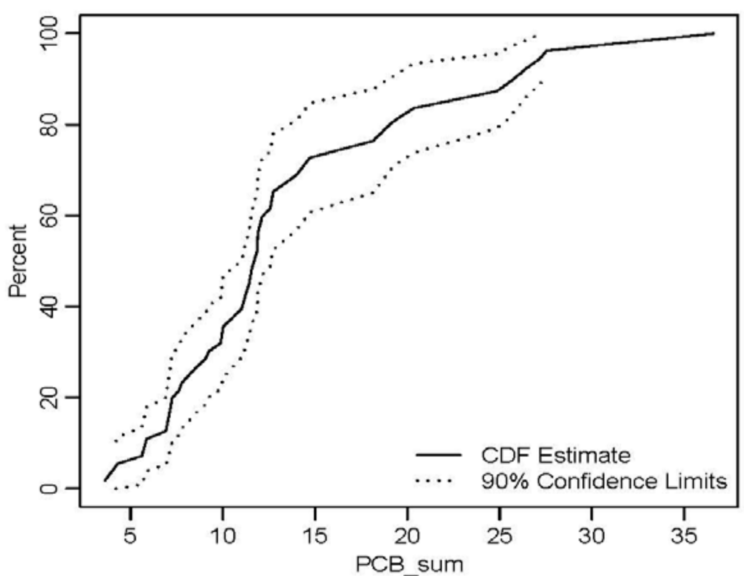

Percent
0
20
40
60
80
100
2
4
6
8
PCB_138
CDF Estimate
90% Confidence Limits

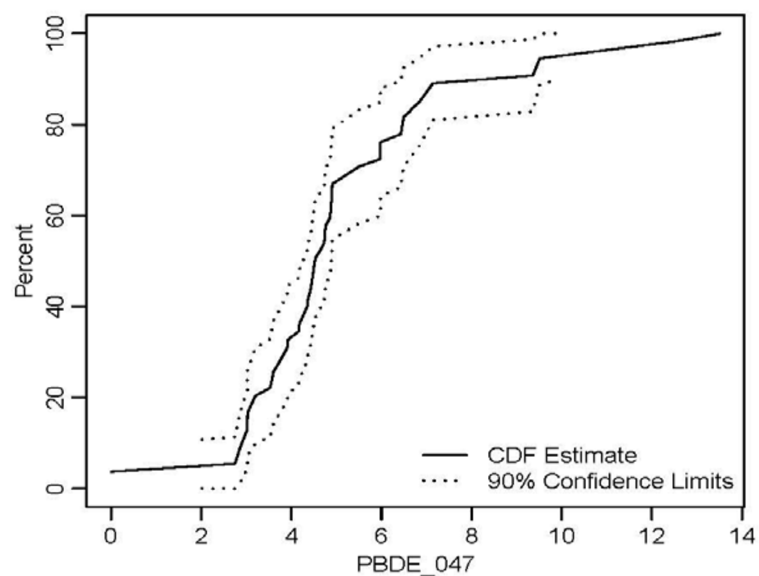

Percent
0
20
40
60
80
100
1
2
3
4
5
6
7
PCB_153
CDF Estimate
90% Confidence Limits

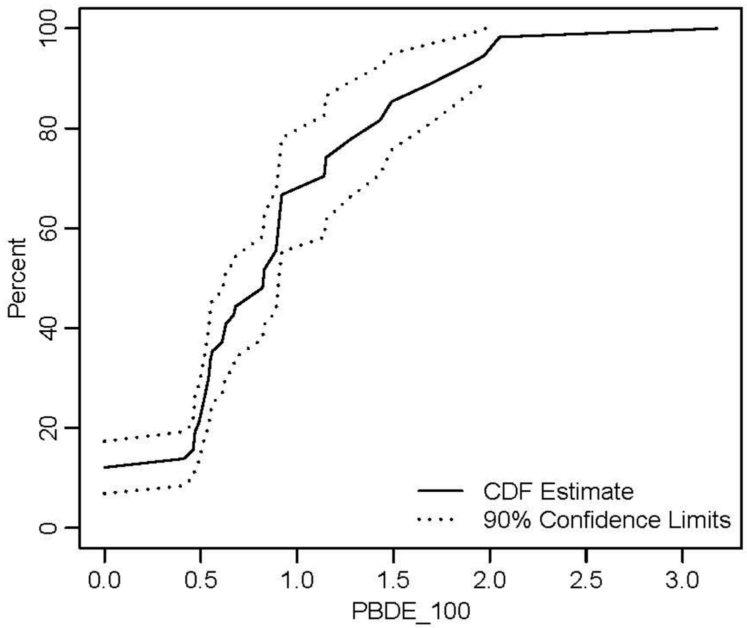

Percent
0
20
40
60
80
100
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
PCB_170
CDF Estimate
90% Confidence Limits


Percent
0
20
40
60
80
100
0
1
2
3
4
PCB_180
CDF Estimate
90% Confidence Limits

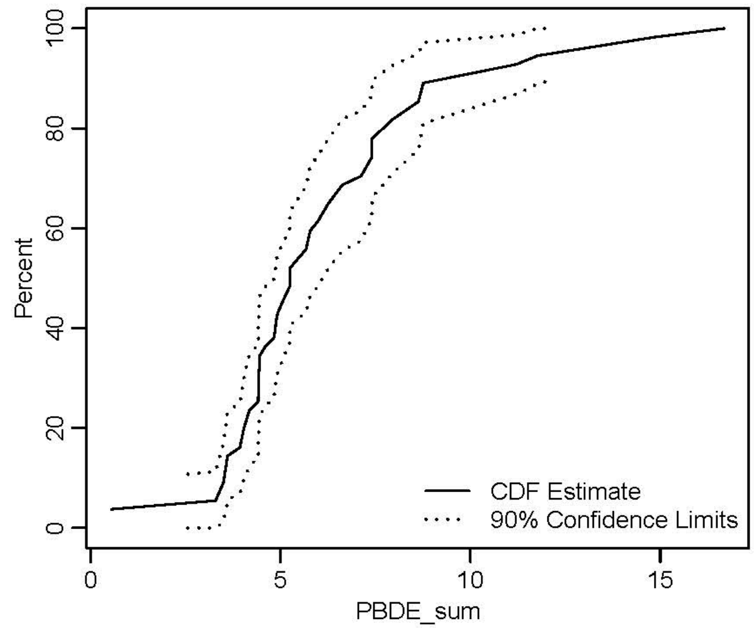

Percent
0
20
40
60
80
100
0.0
0.5
1.0
1.5
PCB_187
CDF Estimate
90% Confidence Limits


Percent
0
20
40
60
80
100
5
10
15
20
25
30
35
PCB_sum
CDF Estimate
90% Confidence Limits

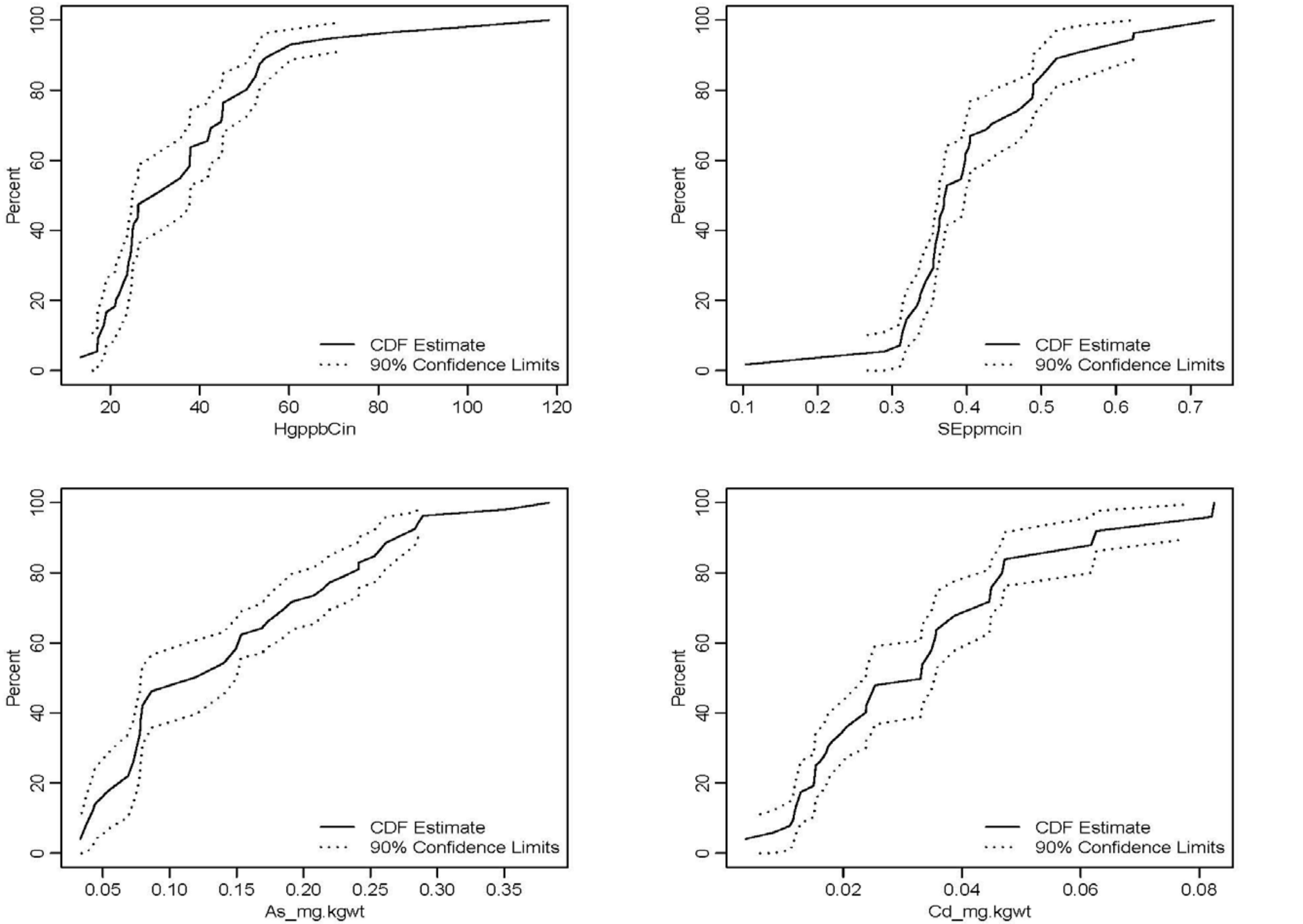

Percent
0
20
40
60
80
100
0
2
4
6
8
10
12
14
PBDE_047
CDF Estimate
90% Confidence Limits

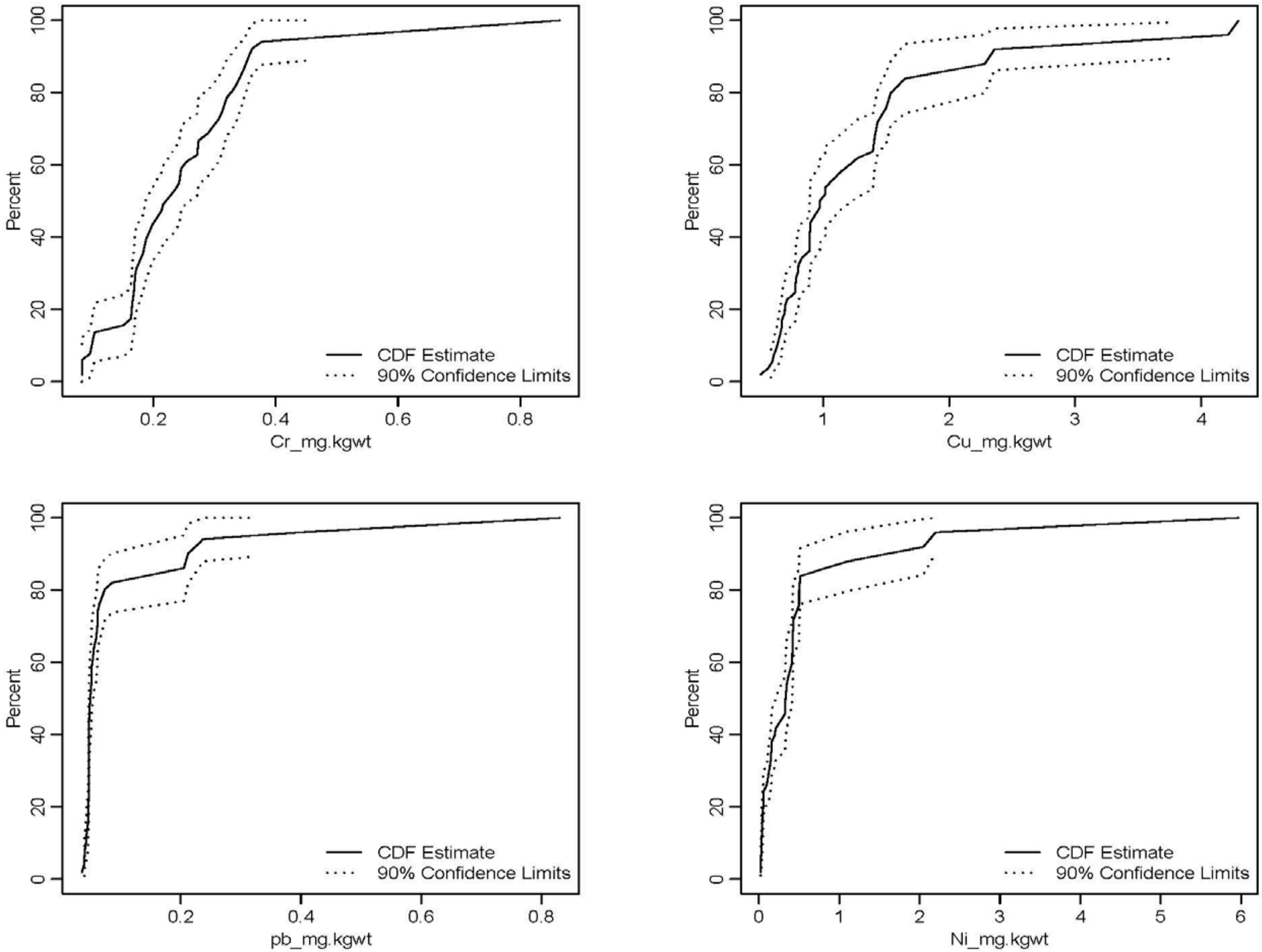


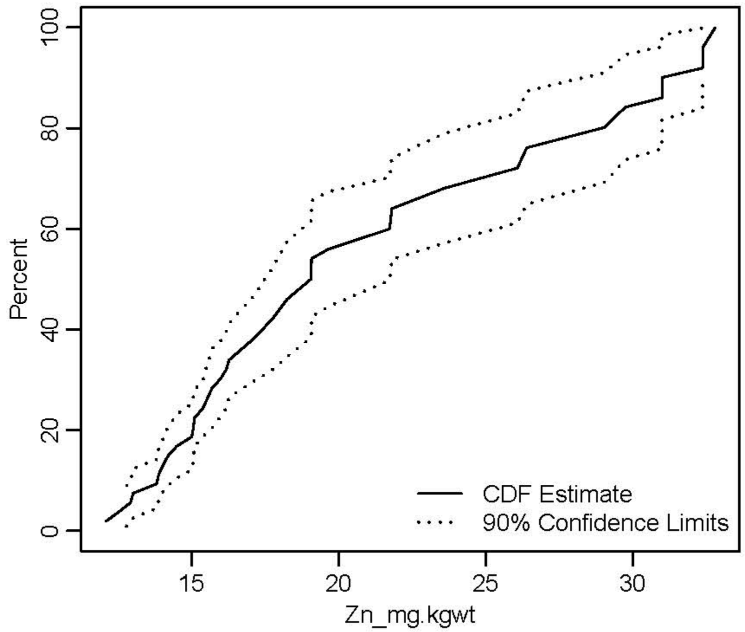
Percent
0
20
40
60
80
100
0.0
0.5
1.0
1.5
2.0
2.5
3.0
PBDE_100
CDF Estimate
90% Confidence Limits



Percent
0
20
40
60
80
100
0
5
10
15
PBDE_sum
CDF Estimate
90% Confidence Limits


Percent
HgppbCin
CDF Estimate
90% Confidence Limits
SEppmcin
As_mg.kgwt
Cd_mg.kgwt


Percent
0
20
40
60
80
100
0.2
0.4
0.6
0.8
Cr_mg.kgwt
CDF Estimate
90% Confidence Limits
Percent
0
20
40
60
80
100
1
2
3
4
Cu_mg.kgwt
CDF Estimate
90% Confidence Limits
Percent
0
20
40
60
80
100
0.2
0.4
0.6
0.8
pb_mg.kgwt
CDF Estimate
90% Confidence Limits
Percent
0
20
40
60
80
100
0
1
2
3
4
5
6
Ni_mg.kgwt
CDF Estimate
90% Confidence Limits



Percent
0
20
40
60
80
100
15
20
25
30
Zn_mg.kgwt
CDF Estimate
90% Confidence Limits

--end--

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