2006 Southern Resident Killer Whale Symposium
NOAA Fisheries Service Northwest Regional Office
April 3-5, 2006, Seattle WA 98103
Extended Abstract

Regional patterns of persistent organic pollutants in five Pacific salmon species (*Oncorhynchus spp*) and their contributions to contaminant levels in northern and southern resident killer whales (*Orcinus orca*)

O'Neill, Sandra M.[1]*; Ylitalo, Gina M.*[2]*; West, James, E.*[1]*; Bolton, Jennie*[2]*; Sloan, Catherine A.*[2]*; Krahn, Margaret M.*[2]

[1]*Washington Department of Fish and Wildlife, 600 Capitol Way North, Olympia WA 98501-1091*
[2] *NOAA Fisheries, Northwest Fisheries Science Center, 2725 Montlake Blvd. E., Seattle, WA 98112*

Previous studies on killer whales (*Orcinus orca*) have shown that southern residents contain higher concentrations of persistent organic pollutants (POPs) than northern residents (Ross *et al.*, 2000; Rayne *et al.*, 2004) and other North Pacific resident killer whale populations (Ylitalo *et al.*, 2001; Herman *et al.*, 2005). Elevated contaminant exposure in southern residents may be attributed to dietary differences between the two whale populations or to regional differences in concentrations of POPs in their prey. Based on observational data and stomach contents analyses, Ford *et al.* (1998) identified Pacific salmon (*Oncorhynchus spp*), especially Chinook salmon (O. *tshawytscha*), as the primary prey of southern and northern resident killer whales in their summer feeding ranges. The main objective of this study was to determine if Pacific salmon had species-specific regional body burdens of contaminants that could differentially affect contaminant levels is northern and southern residents. An additional objective was to measure proximate composition (amount of protein, lipid and carbohydrate) and estimate caloric content of Pacific salmon as an indicator of species- and regionally-specific variation in nutritional quality of prey to killer whales.

Free-ranging populations of anadromous Pacific salmon are generally assumed to have low levels of POPs because the majority of their growth (and therefore contaminant uptake) occurs in open water of the Pacific Ocean. However, the oceanic distributions of the five Pacific salmon species (*i.e.*, Chinook, coho, chum, pink, sockeye) differ and, as a result, can influence their exposure to contaminants. For example, when pink, chum and sockeye salmon enter the marine environment, they rapidly migrate northward and westward through coastal waters of North America and are found in the open waters of the North Pacific, Gulf of Alaska and Bering Sea by the end of their first year at sea (Quinn, 2005). In contrast, Chinook and coho, have a more coastal marine distribution along the continental shelf compared to other salmon populations, although, populations within these two species can also differ in their marine distribution (Quinn, 2005).

To determine if Pacific salmon populations present in the summer feeding areas of northern and southern resident whales had species- and regionally-specific body burdens of contaminants, we analyzed POPs in whole body samples of five species of Pacific

salmon collected from northern British Columbia to the central California coast. All five species were each sampled in two regions, the non-urbanized north-central coast of British Columbia that is frequented by northern resident killer whales and in the urbanized Puget Sound - Strait of Juan de Fuca region that is frequented more by southern resident killer whales (Table 1). Additionally, Chinook salmon were sampled in the coastal waters on the inside of Vancouver (near Robson Bight), the Lower Columbia River (spring and fall runs) and central coast of California (Table 1). We sampled terminal marine and in-river fisheries, at times aligned with the return time for specific salmon stocks, to increase the likelihood of sampling particular stocks of fish returning to a specific river. The presumed river-stock associated with each sampling location is noted in Table 1.

Table 1. Number of individual fish of each species collected at each sampling location for chemical, proximate and stable isotope analyses. Contaminants samples were based on whole body samples of individual Chinook salmon and composite samples (5-6 individuals) for other salmon species. Proximate analyses were based on composite samples of males or females, each with 2-3 fish per composite. Note: Only 13 of the Fraser and 20 of the Columbia River Fall Chinook were analyzed for contaminants but proximate analyses were based on all fish collected.

			Species						
			Chinook						
Region	Sampling Location	River Stock Origin	Fall	Spring	Resident	Sockeye	Pink	Chum	Coho
North/ central coast BC	Chatam Sound	Skeena	30			29	30		
	Dean Channel	Kimsquit						30	30
East coast Vancouver Island	near Robson Bight	Fraser/ Nimpkish	30						
Strait of Juan de Fuca/ Puget Sound	Lopez Sound	Fraser				30			
	Skagit River	Skagit					30		
	near Apple Cove Point	Puget Sound mixed			34			30	11
	Nooksack/ Duwamish/ Nisqually rivers	Puget Sound mixed	36						29
Columbia River	Lower Columbia River	Columbia	30	20					
Central coast of California	near Point Arena	Sacramento/ Joaquin	29						

Overall, concentrations of POPs were higher in coho and Chinook populations that have more coastal distributions than those measured in salmon species (e.g., chum, pink, sockeye) with more oceanic distributions. For pink, chum, and sockeye salmon, PCB levels were higher for fish caught in the more urbanized region of Puget Sound/Strait of Juan de Fuca region than in the less urbanized north/central coast of British Columbia area, whereas concentrations of DDTs were similar between regions. PBDEs were below the limit of quantitation in all pink, chum and sockeye sampled in this study. Concentrations of PCBs, PBDEs and DDTs were higher in coho salmon from Puget Sound compared to coho from the central BC coast. Regional variation in POP exposure was also evident in Chinook salmon (Figure 1) and appears to be associated with differences in marine distribution of these species. For example, Chinook salmon returning to Puget Sound had significantly higher concentrations of PCBs and PBDEs

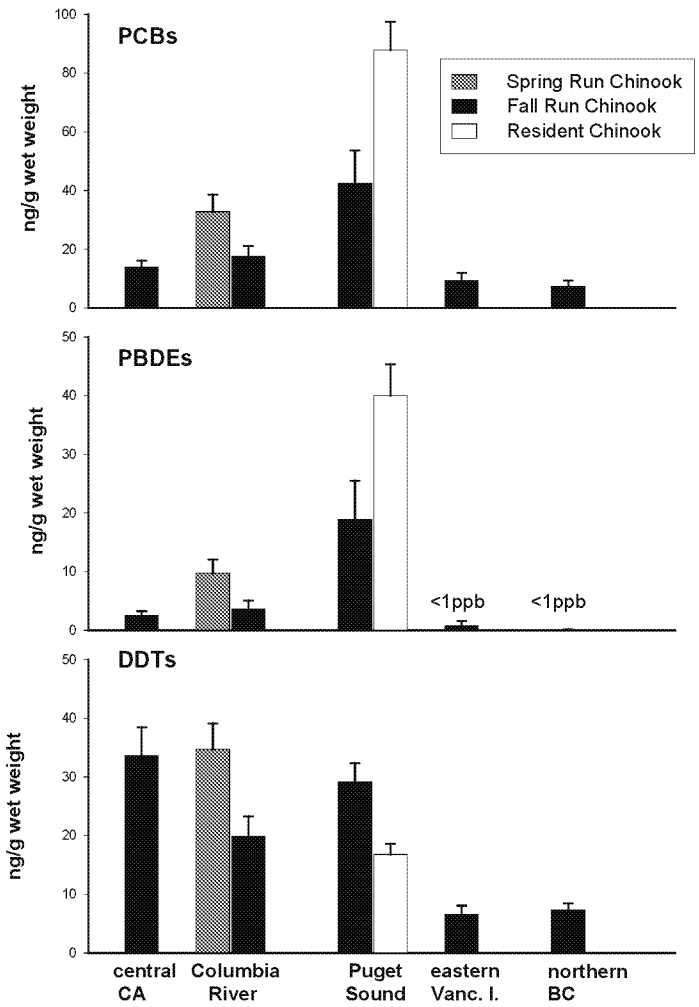

Figure 1. Concentrations of persistent organic pollutants (± 95% CI) in whole body samples of individual Chinook salmon caught in terminal fishing areas. River populations represented include fish returning to the Sacramento/San Joaquin (central CA; n = 29), the Columbia River (spring run n = 20; fall run n = 17), the Nooksack, Duwamish and Nisqually (Puget Sound; n = 36), the Fraser and Nimpkish (eastern coast Vancouver Island; n = 13;Georgia Basin) and the Skeena rivers (northern BC; n= 30). Additionally data are

shown for sub-adult chinook salmon that were resident in Puget Sound in the winter months (termed "resident chinook" n= 34).

compared to other Pacific coast salmon populations we sampled. Furthermore, Chinook salmon that resided in Puget Sound in the winter rather than migrate to the Pacific Ocean ("residents") had the highest concentrations of POPs, followed by Puget Sound fish populations believed to be more ocean-reared. Fall Chinook from Puget Sound have a more localized marine distribution in Puget Sound and the Georgia Basin than other populations of Chinook from the west coast of North America and are more contaminated with PCBs (2 to 6 times) and PBDEs (5 to 17 times).

Overall, the total caloric content per kg of fish was higher for Chinook and sockeye salmon than the other salmon species we sampled, due to their higher fat content. Moreover, because of their greater size, the total Kcal per fish was highest for Chinook salmon. Regional differences in caloric content among Chinook populations were also observed. Puget Sound Chinook had lower caloric content (total Kcals per fish) than summer/fall run of Chinook salmon from all regions we sampled (Figure 2). Assuming that the fish we sampled were representative of the sizes of fish available for killer whale consumption, whales feeding on non-resident Chinook salmon in Puget Sound would need to eat 1.5 to 1.8 times as many Chinook salmon as animals feeding outside Puget Sound to obtain the same caloric content.

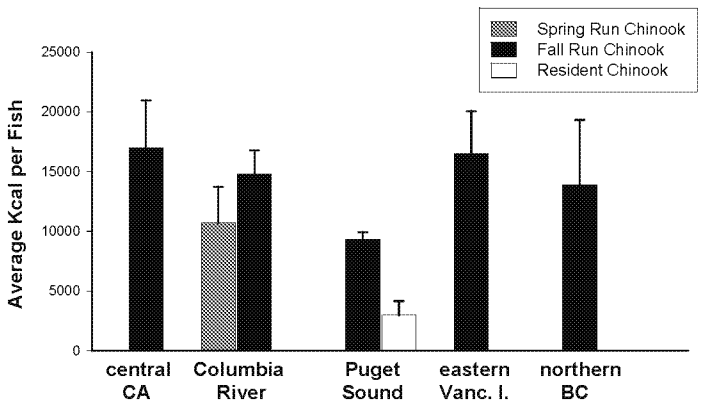

Figure 2. Average estimated caloric content (± 95% CI) of whole body samples of individual Chinook salmon caught in terminal fishing areas. River populations represented include fish returning to the Sacramento/San Joaquin (central CA), the Columbia River (spring and fall runs), the Nooksack, Duwamish and Nisqually (Puget Sound), the Fraser and Nimpkish (eastern coast Vancouver Island) and the Skeena rivers (northern BC).

In summary, regional body burdens of contaminants in Pacific salmon, and Chinook salmon in particular, could contribute to the higher levels of contaminants in southern resident killer whales. In addition to contamination, regional differences in caloric content of Chinook salmon from Puget Sound further reduce their quality as prey to southern resident killer whales.

References

Ford JKB, Ellis GM, Barrett-Lennard LG, Morton AB, Palm RS, Balcomb III KC. 1998. Dietary specialization in two sympatric populations of killer whales (*Orcinus orca*) in coastal British Columbia and adjacent waters. *Can. J. Zool.* 76(8): 1456-1471.

Herman, D.P., Burrows, D.G., Wade, P.R., Durban, J.W., LeDuc, R.G., Matkin, C.O., & Krahn, M.M. (2005) Feeding ecology of eastern North Pacific killer whales from fatty acid, stable isotope, and organochlorine analyses of blubber biopsies. *Mar. Ecol. Prog. Ser.* 302: 275-291.

Quinn TP, 2005. The Behavior and Ecology of Pacific Salmon and Trout. American Fisheries Society, University of Washington Press, Seattle, Washington. 378 pp.

Rayne S, Ikonomou MG, Ross PS, Ellis GM, Barrett-Lennard LG. 2004. PBDEs, PBBs, and PCNs in three communities of free-ranging killer whales (*Orcinus orca*) from the northeastern Pacific Ocean. *Environ. Sci. Technol.* 38(16): 4293-4299.

Ross PS, Ellis GM, Ikonomou MG, Barrett-Lennard LG, Addison RF. 2000. High PCB concentrations in free-ranging Pacific killer whales, *Orcinus orca*: Effects of age, sex and dietary preference. *Mar. Pollut. Bull.* 40(6): 504-515.

Ylitalo, GM, Matkin CO, Buzitis J, Krahn MM, Jones LL, Rowles T, Stein JE. 2001. Influence of life-history parameters on organochlorine concentrations in free-ranging killer whales (*Orcinus orca*) from Prince William Sound, AK. Sci. Total Environ. 281: 183-203.