

Development of a Comprehensive Allozyme Baseline for Pacific Rim Chum Salmon

by

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Abstract

This document presents a new allozyme database for chum salmon populations from throughout the Pacific Rim for use in genetic stock identification (GSI) of complex mixtures. These data represent the summation of two decades of research investigating the population structure of chum salmon from North America and Asia. The database has been used extensively by NPAFC researchers, but has not been significantly updated since 1995. During the spring of 2002, researchers met to standardize and refine the database and to enlarge it to include over 200 new populations. The resulting database now includes 356 individual populations ranging from the Columbia River to Kotzebue Sound in North America and from Honshu to the Anadyr River in Asia. Major changes in the 2002 database are: (1) inclusion of individual locations rather than larger pooled groups for Northwest Alaska, (2) inclusion of individual populations rather than representative populations for Southeast Alaska, British Columbia, and Washington, and (3) exclusion of the majority of Japanese populations from a 1994 publication. Japanese populations are now represented by newly-collected data from the National Salmon Resources Center. Simulation analyses supported six broad-scale reporting regions as well as 19 fine-scale reporting groups using the criteria of 90% correct allocation in a 100% simulation. A variety of applications are now possible throughout the species' range including both near-shore and high-seas mixtures of chum salmon in all life history stages. The current database is available from the authors.

Background and Introduction

In this document we present a new allozyme baseline for chum salmon populations (*Oncorhynchus keta*) from throughout the Pacific Rim for use in genetic stock identification (GSI) of complex mixtures. These data represent the summation of two decades of research investigating the population structure of chum salmon from North America and Asia. Genetic stock identification studies for chum salmon requiring a Pacific Rim-wide database began in the mid-1980s with an interest in identifying the origin of illegally harvested chum salmon in the high seas and incidentally-caught chum salmon in high-seas driftnet fisheries for flying squid (*Ommastrephes bartrami*) (Seeb and Seeb 1986; Winans et al. 1989; Smouse et al. 1990). Agencies using protein electrophoresis to estimate genetic population structure in chum salmon began efforts early in their research programs to collect information on a common set of allozyme loci and to standardize alleles scored. These efforts evolved into an informal coastwide GSI consortium with a goal to standardize allozyme data for Pacific salmon to facilitate data sharing and the creation of large databases for application to complex fisheries.

During the 1990's, large data sets of allele frequency information for chum salmon from Washington, British Columbia, Alaska, Canada, Russia, and Japan were completed. These data were collected by Washington Department of Fish and Wildlife (WDFW), National Marine Fisheries Service (NMFS)-Seattle, NMFS-Auke Bay Laboratory, Alaska Department of Fish and Game (ADF&G), US Fish and Wildlife Service (USFWS), Kamchatka Branch of Pacific Research Institute of Fisheries and Oceanography (KoTINRO), Russian Academy of Sciences,

Chinese Academy of Fisheries Science, National Salmon Research Center (NASREC), and Kitasato University. Primary data sources include Kondzela et al. (1994), Phelps et al. (1994), Seeb and Crane (1999a), Wilmot et al. (1994), and Winans et al. (1994).

Throughout much of the 1990's, applications were based on the database derived by Seeb and Crane (1999b) developed to estimate the origin of chum salmon harvested in fisheries occurring off the south Alaska Peninsula. Researchers from contributing agencies met in Anchorage, Alaska, to finalize allele standardization and to discuss control of bias through pooling populations or using populations representative of a region. Preliminary analyses of the mixture samples suggested that Asia and western Alaska were the largest contributors to the fishery; therefore, most of the available data for these areas were included in the baseline. Southeast Alaska, British Columbia, and Washington were small contributors; therefore, only populations representative of these regions were used. Preliminary stock groups that could be identified in mixtures were selected from heterogeneity and multidimensional scaling analyses and were refined using simulation studies of artificial mixtures created 100% from a single stock group under study (Seeb and Crane 1999b). Contribution estimates to south Alaska Peninsula fisheries for chum were presented for the following groups: Japan, Russia, Northwestern Alaska summer, Fall Yukon, Alaska Peninsula/Kodiak Island, British Columbia, and Washington (Seeb and Crane 1999b); the baseline used data for 20 allozyme loci from 164 collections of chum salmon.

As new population data became available, researchers independently updated the original baseline used by Seeb and Crane (1999b). Wilmot et al. (1995) added new data from Asia; this baseline was used to estimate the origin of chum salmon sampled from the Bering Sea trawl fishery for walleye pollock (*Theragra chalcogramma*) (Wilmot et al. 1995; Wilmot et al. 1996, Wilmot et al. 1998), high seas test fisheries (Urawa et al. 1997; Urawa et al. 1998; Winans et al. 1998; Urawa et al. 2000), and confiscated fishery samples from illegal fishing (Wilmot et al. 1999; Wilmot et al. 2000). Seeb et al. (1997) and Crane and Seeb (2000) added new Alaskan data and estimated the stock contribution of Japan, Northern Russia, China/Southern Russia, Northwest Alaska summer, Fall Yukon, Alaska Peninsula/Kodiak Island, Susitna River, Prince William Sound, Southeast Alaska/Northern British Columbia, and Southern British Columbia/Washington to commercial catches from the south Alaska Peninsula.

Expanded Allozyme Baseline

During the spring of 2002, researchers met to standardize and refine the database and to enlarge it to include newly-collected populations based on the preliminary compilation of Crane et al. (2001). The resulting database includes 356 individual populations ranging from the Columbia River to Kotzebue Sound in North America and from Honshu to the Anadyr River in Asia (Appendix 1). Populations were selected for inclusion in the baseline if they were consistently scored for a common set of 20 characters: *ALAT**, *mAAT-1**; *sAAT-1,2**; *mAH-3**; *ESTD**; *G3PDH-2**; *GPI-A**, *GPIB-1,2*; *mIDHP-1**; *sIDHP-2**; *LDH-A1**; *LDHB-2**; *sMDHA-1**; *sMDHB-1,2**; *mMEP-2**; *sMEP-1**; *MPI**; *PEPA**; *PEPB-1**; and *PGDH*. Alleles were pooled as described in Table 1. Data from samples collected in more than a single year at a location were pooled following the recommendations of Waples (1990) to counter the effects of drift and sampling error.

Major changes in the 2002 database are: 1) inclusion of individual locations rather than larger pooled groups for Northwest Alaska, 2) inclusion of individual populations rather than representative populations for Southeast Alaska, British Columbia, and Washington, and 3) exclusion of the majority of Japanese populations from Winans et al. (1994). Japanese populations are now represented by newly-collected data from NASREC.

Database Evaluation

Potential reporting groups for fishery analyses were identified from previous studies of chum salmon population structure and by multidimensional scaling analyses of genetic distances. Potential reporting groups were evaluated further using simulation studies. Simulations were performed using the Statistics Program for Analyzing Mixtures developed by ADF&G (SPAM ver. 3.2, Debevec et al. 2000) based on the GIRLS (Masuda et al. 1991) and CONJA-S (Pella et al. 1996) algorithms. In each simulation, baseline and mixture genotypes were randomly generated from the baseline allele frequencies using Hardy-Weinberg expectations. Each simulated mixture (N=400) was composed 100% of the reporting group under study, with each population in the reporting group contributing equally to the mixture. Average estimates of mixture proportions were derived from 1000 simulations. Individual population estimates were first calculated, and then summed into reporting groups (allocate-sum procedure). Reporting groups were enlarged until approximately 90% of the mixture on average was allocated to the correct reporting group. We tested fine- to broader-scale groupings with the same methods.

Results and Recommendations

We report both fine-scale and broad-scale reporting groups (Table 2, Figures 1 and 2). Simulation analyses supported six broad-scale reporting regions as well as 19 fine-scale reporting groups using the criteria of 90% correct allocation in a 100% simulation. Broad-scale reporting groups are recommended for mixtures estimated to contain fish from a large number of genetic groups. Fine-scale reporting groups are more appropriate for mixtures estimated to originate from a smaller number of genetic groups. The reporting groups can be easily modified for specific applications by individual investigators.

This allozyme database provides exhaustive coverage of chum salmon spawning populations throughout the Pacific Rim. A variety of applications are now possible throughout the species' range including both near-shore and high-seas mixtures of chum salmon in all life history stages. Efforts are also underway to expand the locus character set to 33 for a subset of the collections.

The current database is available from the authors.

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Table 1. Loci and alleles pooled for Pacific Rim baseline for chum salmon. Alleles separated by a “/” have been pooled. Parentheses indicate synonymous alleles that differ in mobility based on electrophoretic condition.

Locus	Allele								
	1	2	3	4	5	6	7	8	9
sAAT-1,2*	100/113	120/125	65		84/80/95				
mAAT-1*	-100	-120/-110	-70						
mAH-3*	100/140/115	124							
ALAT*	100/98/fast	93/90	78						
ESTD*	100	91/80	110/106						
G3PDH-2*	100/132	90							
GPI-B1,2*	100	fast	40						
GPI-A*	100	slow	fast						
mIDHP-1*	100	60	140	20	85				
sIDHP-2*	100/65	35	85	25	20	110	28		45
LDH-A1*	-100(100)	50(130)	110/0						
LDH-B2*	100/60	120/115							
sMDH-A1*	100	200	400	10					
sMDH-B1,2*	100/110	72/85/95	50/20/65	fast>110					
mMEP-2*	100/75	122							
sMEP-1*	100	90							
MPI*	100	94/91/95/97	110	80/86		74			
PEPA*	100	90	113						
PEPB-1*	-100	-146	-126	-127	-72/-50				
PGDH*	100	88/84	104/106/110	95					

Table 2. Broad- and fine-scale regional groups of Pacific Rim chum salmon. Population number refer to collections described in Appendix 1.

Broad Scale	Fine Scale	Included Regions	Pop. #
Northwest Alaska			
	Northwest Alaska Summer		
		Kotzebue Sound	1-3
		Norton Sound	4-6
		Yukon River Summer	7-17
		Kuskokwim Bay and Lower Kuskokwim River	18-32,41
		Bristol Bay	33-40,53-54
	Yukon River Fall		42-50
	Kuskokwim River-Upper		51-52
Alaska Peninsula, Gulf of Alaska			
	Alaska Peninsula and Kodiak Island		
		North Alaska Peninsula	55-67
		South Alaska Peninsula	68-93
		Kodiak Island	94-99
	Susitna River		100-101
	Prince William Sound		102-106
Southeast Alaska, Northern British Columbia			
	Southeast Alaska, Northern British Columbia		
		Northern Southeast Alaska	107-143
		Mainland Southeast Alaska	144-160
		Northern British Columbia	161-169
		Georgia Strait	193-204
	Prince of Wales Island		170-181
	Queen Charlotte Island		182-192
Southern British Columbia, Pacific Northwest			
	Puget Sound, Southern British Columbia		
		Fraser River	205-214
		West Coast Vancouver Island	215-217
		Strait of Juan de Fuca	218-221
		Northern Puget Sound	222-239
		Southern Puget Sound	240-260
		Hood Canal	261-276
	Hood Canal Summer		277-285
	Coastal Washington, Columbia River		286-294
Japan			
	Honshu		
		Pacific Coast of Honshu	294-305,312
		Japan Sea Coast of Honshu	306-311,313
	Hokkaido		
		Pacific Coast of Hokkaido	314-321
		Nemuro Coast	322-323

Broad Scale	Fine Scale	Included Regions	Pop. #
		Okhotsk Coast of Hokkaido	324-328
		Japan Sea Coast Hokkaido	329-333
Russia, China			
	Amur River China		334-335
	Kuril Islands		336-338
	Premorye/Suifen		339-340
	Sakhalin Island		341-343
	Northern Russia		
		Anadyr River	344
		Eastern Kamchatka Peninsula	345-347, 349,354
			348-351, 355-
		Western Kamchatka Peninsula	356
		Magadan	352-353

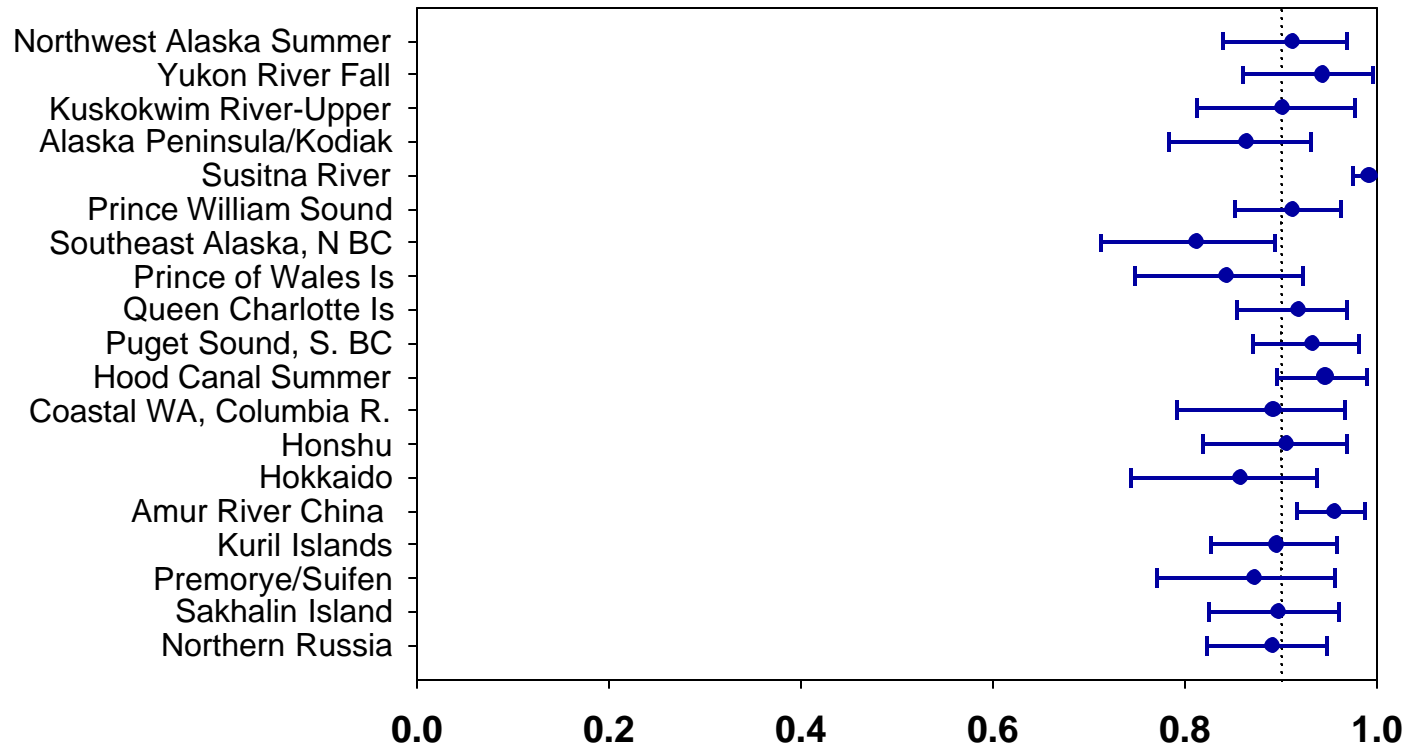


Figure 1. Simulation results for fine-scale reporting groups for chum salmon. Point estimates and 90% bootstrap confidence intervals are given.

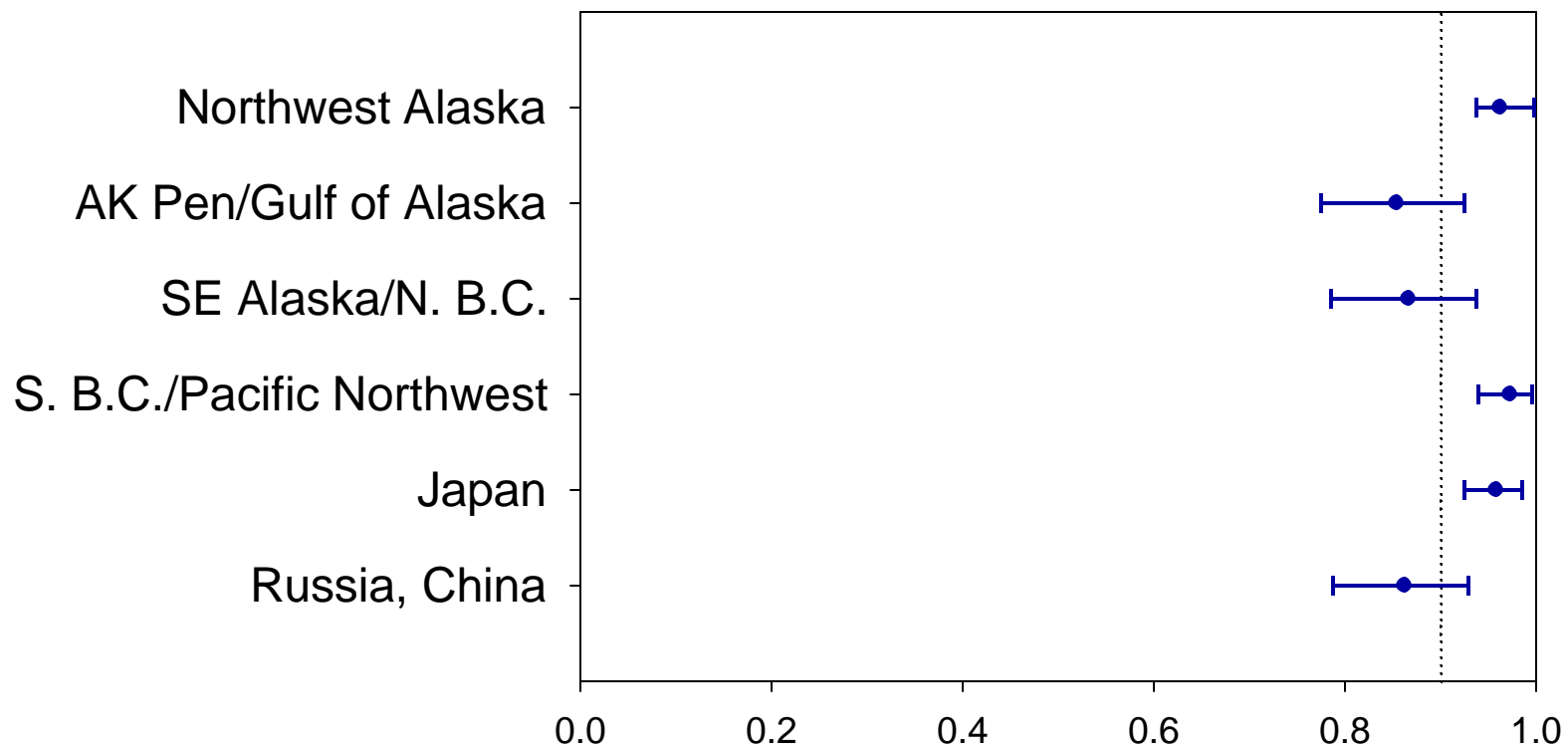


Figure 2. Simulation results for broad-scale reporting groups for chum salmon. Point estimates and 90% bootstrap confidence intervals are given.

Appendix 1. Collections of chum salmon assayed for genetic variation. Population number, laboratory sample number (if applicable), collection date (if available), sample size and data source are given. Collections labeled "NA" under population number were not included in the mixture analyses due to small sample sizes or missing loci. Abbreviations for unpublished data sources: NMFS-ABL: National Marine Fisheries Service, Auke Bay Laboratory, Auke Bay, Alaska, USA; ADFG: Alaska Department of Fish and Game, Anchorage, Alaska, USA; USFWS: U. S. Fish and Wildlife Service, Anchorage, Alaska, USA , KamchatNIRO: Kamchatka Research Institute of Fisheries and Oceanography, Petropavlovsk-Kamchatsky, Russia ; IMB RAN: Institute of Marine Biology, Russian Academy of Sciences, Vladivostok, Russia, TINRO-center – Pacific Ocean Research Institute of Fisheries and Oceanography, Vladivostok, Russia.

Geographic Area	Pop Number	Laboratory Sample Number	Population	Collection Date	N	Source
Arctic	NA	peel98.frq	Peel River	1998	38	NMFS-ABL unpublished
Kotzebue Sound	1	Kotzebue.frq,cmsik91,93,cmnoa91	Noatak River	1989,1991,1993,1991	400	Seeb and Crane 1999a, NMFS-ABL unpublished
	2	cmkel91	Kelly Lake	1991	100	Seeb and Crane 1999a
	3	cmkob91, cmsel94	Kobuk River	1991, 1994	206	Seeb and Crane 1999a
Norton Sound	4	cmpil94	Pilgrim River	1994	90	Seeb and Crane 1999a
	5	cmsna92,93,94,95;cmnom91,92,93,94,95,cmsol95	N. Norton Sound	1992,1993,1994,1990	404	Seeb and Crane 1999a, Seeb et al. 1997
Yukon River-Summer	6	cmfis94,cmkwi94,cmuna92	SW Norton Sound	1992,1994	300	Seeb and Crane 1999a
	7	cmand93w,93e	Andreafsky River	1993	200	Seeb and Crane 1999a
	8	cminn93	Innoko River	1993	88	Seeb and Crane 1999a
	9	cmbea92,93;cmyel92;cmwi92,93;cmcan93;cmott93	Anvik	1992,1993	650	Seeb and Crane 1999a
	10	kalt_92	Kaltag River	1992	100	Crane et al. 2001
	11	cmnul94	Nulato River	1994	100	Seeb et al. 1997
	12	ekoy,lkoy,cmhen95,cmsfko95	Upper Koyukuk River	1995,1996	362	Seeb et al. 1997, USFWS, NMFS/ABL-unpublished
	13	cmgis94cmhus93,dakli92,cmcle95	Lower Koyukuk River	1992,1993,1994,1995	400	Seeb et al. 1997, Seeb and Crane 1999a,Crane et al. 2001
	14	cmmel94	Melozitna River	1994	100	Seeb et al. 1997
	15	toz_92	Tozitna River	1992	71	USFWS unpublished
Yukon River-Fall Run	16	cmche92,94	Chena River	1992,1994	186	Seeb et al. 1997,Seeb and Crane 1999a
	17	cmsal92,94	Salcha River	1992,1994	200	Seeb and Crane 1999a, Seeb et al. 1997
	NA	blackyuk	Black River	1995	96	USFWS/NMFS-ABL unpublished
	42	cmtok91,92,93,a94,b94,g94,s94	Toklat River	1991,1992,1993,1994	815	Sarafin, 1995; Seeb et al. 1997; Seeb and Crane 1999a

Geographic Area	Pop Number	Laboratory Sample Number	Population	Collection Date	N	Source
	43	cmtan92,93;cmblu92,cmdel91,92,94	Upper Tanana River	1991,1992,1993,1994	597	Seeb et al. 1997;Seeb and Crane 1999a
	44	cmshe92,93	Sheenjek River	1992,1993	164	Seeb and Crane 1999a
	45	fish_92,cmfbr94	Fishing Branch	1992,1994	200	Crane et al. 1992;Seeb et al. 1997
	46	big_92,cmcbck95	Big Creek	1992,1995	200	Crane et al. 1992;Seeb et al. 1997
	47	tatn_92	Tatchun	1992	98	Crane et al. 1992
	48	cmpel93	Pelly River	1993	84	Seeb et al. 1997
	49	klu_92,cmdon94	White River	1992,1994	174	Seeb et al. 1997; Crane et al. 1992
	50	tes_92	Teslin River	1992	100	Crane et al. 1992
Kuskokwim Bay and Lower River						
	18	cmkwe94	Kwethluk River	1994	100	Seeb and Crane 1999a
	19	cmkas94	Kasigluk River	1994	70	Seeb et al. 1997
	20	cmkis94	Kisaralik River	1994	100	Seeb et al. 1997
	21	cmtul93	Tuluksak River	1993	100	Seeb and Crane 1999a
	22	cmani92	Aniak River	1992	100	Seeb and Crane 1999a
	23	cmhol95	Holokuk River	1995	48	Seeb et al. 1997
	24	cmosk94	Oskawalik River	1994	58	Seeb et al. 1997
	25	cmgeo96	George River	1996	100	Seeb et al. 1997
	26	cmkog92, 93	Kogrukuk River	1992, 1993	125	Seeb and Crane 1999a
	27	cmsto94e, 94l	Stoney River early and late	1994	156	Seeb et al. 1997
	28	cmtal94	Tatlawiksuk River	1994	100	Seeb and Crane 1999a
	29	cmnun94	Nunsatuk River	1994	100	Seeb et al. 1997
	30	cmtak94	4th of July Creek	1994	100	Seeb and Crane 1999a
	41	cmmcg94	Kuskokwim River at McGrath	1994	100	Seeb et al. 1997
	31	cmkan92, 93,94	Kanektok River	1989, 1993, 1994	214	Wilmot et al. 1994; Seeb et al. 1997; Seeb and Crane 1999a
	32	cmgoo91	Goodnews River	1991	100	Seeb and Crane 1999a
Kuskowkwim River--Upper						
	51	cmsfku95	South Fork Kuskokwim-late	1995	100	Seeb et al. 1997
	52	cmkus96l	Big River	1996	100	Seeb et al. 1997
Bristol Bay						
	33	cmtog93, 94	Togiak River	1993,1994	200	Seeb and Crane 1999a
	34	cmnuu92, 93	Upper Nushagak River	1992,1993	103	Seeb and Crane 1999a
	35	cmmul94	Mulchatna River	1994	100	Seeb and Crane 1999a
	36	cmstuy92, 93	Stuyahok River	1992,1993	88	Seeb and Crane 1999a
	37	cmala92	Alagnak River	1992	84	Seeb and Crane 1999a
	38	cmbigc93	Naknek/Big Creek	1993	80	Seeb and Crane 1999a
	39	cmwha93	Egegik Bay/Whale Mountain Creek	1993	98	Seeb and Crane 1999a
	40	cmpum93	Ugashik Bay/Pumice Creek	1993	100	Seeb and Crane 1999a
	53	cmmes93	Meshik/Plenty Bear Creek	1993	93	Seeb and Crane 1999a

Geographic Area	Pop Number	Laboratory Sample Number	Population	Collection Date	N	Source
North Alaska Peninsula	54	cmmes92	Meshik/Braided Creek	1992	78	Seeb and Crane 1999a
	55	cmwes93c	Wiggly Creek	1993	100	Seeb et al. 1997
	56	cmnpen01	First stream N. of Cape Seniavin	2001	55	ADFG unpublished
	57	cmnpe98b	Franks Lagoon	1998	18	ADFG unpublished
	58	cmnpe98a	Right Hand Moller Bay	1998	100	ADFG unpublished
	59	cmlaw92	Lawrence Valley Creek	1992	100	Seeb and Crane 1999a
	60	cmmof96	Moffitt Creek	1996	100	Seeb et al. 1997
	61	cmjos92	Joshua Green River	1992	80	Seeb and Crane 1999a
	62	cmjos94	Joshua Green River	1994	100	Seeb et al. 1997
	63	cmfro92	Frosty Creek	1992	100	Seeb and Crane 1999a
	64	cmall96	Alligator Hole	1996	100	Seeb et al. 1997
	65	cmtra92	Trader's Cove Creek	1992	100	Seeb and Crane 1999a
	66	cmstc92	St. Catherine's Cove	1992	80	Seeb and Crane 1999a
	67	cmpet92	Peterson Lagoon	1992	86	Seeb and Crane 1999a
South Alaska Peninsula	68	cmlij92	Little John Lagoon	1992	87	Seeb and Crane 1999a
	69	cmsanc96	Sandy Cove	1996	100	Seeb et al. 1997
	70	cmrus92,93	Russell Creek	1992,1993	200	Seeb and Crane 1999a, Seeb et al. 1997
	71	cmdel96	Delta Creek	1996	100	Seeb et al. 1997
	72	cmbel92	Belkofski River	1992	87	Seeb and Crane 1999a
	73	cmvol92, 96	Volcano Bay	1992,1996	106	Seeb et al. 1997
	74	cmrub96	Ruby's Lagoon	1996	100	Seeb et al. 1997
	75	cmcan92	Canoe Bay	1992	100	Seeb and Crane 1999a
	76	cmzac92	Zachary Bay	1992	80	Seeb et al. 1997
	77	cmcol96	Coleman Creek	1996	100	Seeb et al. 1997
	78	cmbal92	Foster Creek (Balboa Bay)	1992	100	Seeb et al. 1997
	79	cmchi96	Chichigof Bay	1996	100	Seeb et al. 1997
	80	cmste92	Stepovak Bay	1992	50	Seeb et al. 1997
	81	cmste93	Stepovak River	1993	100	Seeb and Crane 1999a
	82	cmiva93	Ivanoff River	1993	94	Seeb and Crane 1999a
	83	cmwes93j	Portage Creek	1993	100	Seeb et al. 1997
	84	cmwes93k	North Fork River	1993	72	Seeb et al. 1997
	85	cmwes93e	North Fork Creek	1993	100	Seeb et al. 1997
	86	cmwes93n	Main Creek	1993	92	Seeb et al. 1997
	87	cmchi93	Chiginigak River	1993	75	Seeb and Crane 1999a
	88	cmwid93	Wide Bay	1993	100	Seeb and Crane 1999a
	89	cmwes93d	E. Bear Bay Creek	1993	100	Seeb et al. 1997
	90	cmala93	Alagoshak River	1993	95	Seeb and Crane 1999a
	91	cmwes93p	Gull Cape Creek	1993	100	Seeb et al. 1997

Geographic Area	Pop Number	Laboratory Sample Number	Population	Collection Date	N	Source
Kodiak Island	92	cmbigr93	Big River	1993	100	Seeb and Crane 1999a
	93	cmmcn94, 96	McNeil River	1994, 1996	109	Seeb et al. 1997
	94	cmame92,95	American River	1992,1995	145	Seeb et al. 1997
	95	chdog92	Dog Bay	1992	100	Seeb et al. 1997
	96	cmsuk92	Big Sukhoi Creek	1992	100	Seeb and Crane 1999a
	97	cmstu92, cmkit93	Sturgeon River	1992, 1993	171	Seeb and Crane 1999a, Seeb et al. 1997
	98	chuga92	Uganik River	1992	100	Seeb et al. 1997
Susitna River	99	Khizuyak.frq,cmkiz92	Kizhuyak	1989, 1992	138	NMFS-ABL unpublished, Seeb and Crane 1999a
	NA	lsusitna.frq	Little Susitna	1989,1990	79	NMFS-ABL unpublished
	100	cmlak96	Yentna/Lake Creek	1996	100	Seeb et al. 1997
Prince William Sound	101	cmchu93, cmsus96, cmtalk95	Susitna River	1993, 1995, 1996	237	Seeb et al. 1997; Seeb and Crane 1999a
	102	cmwhn91	WHN Hatchery	1992	92	Seeb and Crane 1999a
	103	cmwel96	Wells River	1996	100	Seeb et al. 1997
	104	5p92eolm,pws95,olsen.frq	Olsen Creek	1992, 1995,1997	350	Seeb et al. 1997, NMFS-ABL unpublished
Northern Southeast Alaska	105	pws94b	Constantine Creek	1994	100	Seeb et al. 1997
	106	5p92ekee	Keta Creek	1992	100	Seeb et al. 1997
	107	Alsek.frq	Alsek River, lower river slough	2000	100	NMFS-ABL unpublished
	108		Lynn Brothers	1988	50	Kondzela et al. 1994
	109	Excurs.frq	Excursion River			NMFS-ABL unpublished
	110	20TY	Tyndall	1992	102	NMFS-ABL unpublished
	NA	20VI	Vivid	1990,1993	100	NMFS-ABL unpublished
	111	Wellsb.frq	Well's Bridge	1991, 2000	90	NMFS-ABL unpublished
	112		Herman Creek	1987, 1990	159	Kondzela et al. 1994
	113	sawmill.frq	Sawmill Creek	1993	100	NMFS-ABL unpublished
	114	eagle.frq	Eagle River	1997	54	NMFS-ABL unpublished
	115	taku.frq	Taku River, lower river slough	2000	45	NMFS-ABL unpublished
	116	lace.frq	Lace River	1995	25	NMFS-ABL unpublished
	117		Donkey Creek	1986,1990	162	Kondzela et al. 1994
	118		Pybus Bay East	1989	65	Kondzela et al. 1994
119		Eliza Harbor	1989	61	Kondzela et al. 1994	
120	chaik.frq	Chaik Bay	1995	100	NMFS-ABL unpublished	
121	hoodbay.frq	Hood Bay, N arm, E head	1992	110	NMFS-ABL unpublished	
122	green.frq	Greens Creek	1995	100	NMFS-ABL unpublished	
123	humpback.frq	Humpback Creek	1994	102	NMFS-ABL unpublished	

Geographic Area	Pop Number	Laboratory Sample Number	Population	Collection Date	N	Source
	124	spasski.frq	Spasski Creek	1991,1992	145	NMFS-ABL unpublished
	125	saltery.frq	Saltery River	1991,1992	101	NMFS-ABL unpublished
	126	black.frq	Black Bay, N head	1991,1992	200	NMFS-ABL unpublished
	127		Ford Arm	1992	71	NMFS-ABL unpublished
	128	ushk.fr	Ushk Bay	1991,1992	145	NMFS-ABL unpublished
	129	kennel.frq	Kennel Creek	1995	100	NMFS-ABL unpublished
	130	longbay.frq	Long Bay	1991,1992	169	NMFS-ABL unpublished
	131		Lover's Cove Creek	1987,1990	131	Kondzela et al. 1994
	132	saook.frq	Saook Bay	1994	103	NMFS-ABL unpublished
	133	crawfish.frq	W. Crawfish Inlet	1993,1994	105	NMFS-ABL unpublished
	134	whalebay.frq	Whale Bay, head of Great Arm	1993	100	NMFS-ABL unpublished
	135		Irish Creek	1986	98	Kondzela et al. 1994
	136	saginaw.frq	Saginaw Creek	1995	97	NMFS-ABL unpublished
	137	pcamden.frq	Port Camden	1995	100	NMFS-ABL unpublished
	138	noname.frq	No Name Bay	1995	84	NMFS-ABL unpublished
	139	pbeau.frq	Port Beauclerc	1995	100	NMFS-ABL unpublished
	140	dipac.frq	Gastineau Hatchery	1987,1998	300	NMFS-ABL unpublished
	141	sheep.frq	Sheep Creek Hatchery	1997	100	NMFS-ABL unpublished
	142	hidden.frq	Hidden Falls Hatchery	1997	150	NMFS-ABL unpublished
	143	medvejie.frq	Medvejie Hatchery	1997	150	NMFS-ABL unpublished
Southeast Mainland Alaska						
	144		Herman River	1986	100	Kondzela et al. 1994
	145		North Arm Creek	1987	81	Kondzela et al. 1994
	146		Harding River	1986	95	Kondzela et al. 1994
	147		Fish Creek	1986,1987,1988	202	Kondzela et al. 1994
	148		Tombstone River	1986	98	Kondzela et al. 1994
	149		Marten River	1986	105	Kondzela et al. 1994
	150		Keta River	1986	101	Kondzela et al. 1994
	151		Blossom River	1986	101	Kondzela et al. 1994
	152		Wilson River	1986	103	Kondzela et al. 1994
	153		Traitor River		100	Kondzela et al. 1994
	154		Carroll River	1986	100	Kondzela et al. 1994
	155		Portage Creek	1986,1988	173	Kondzela et al. 1994
	156		King Creek	1986,1988	152	Kondzela et al. 1994
	157		Klahini River	1986	102	Kondzela et al. 1994
	158		Eulachon Creek	1986	90	Kondzela et al. 1994
	159		Grant Creek	1986	127	Kondzela et al. 1994
	160	neets1.frq	Neets Bay Hatchery (summer)	1997	150	NMFS-ABL unpublished
Prince of Wales Island						
	170		Kugel Creek	1986	104	Kondzela et al. 1994

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	171		Aiken Creek	1986	100	Kondzela et al. 1994
	172	dis98.frq	Disappearance Creek	1986,1988, 1998	300	Kondzela et al. 1994, NMFS-ABL unpublished
	173		Lagoon Creek	1986	102	Kondzela et al. 1994
	174	otom98.frq	Old Tom Creek	1986,1988,1998	195	Kondzela et al. 1994, NMFS-ABL unpublished
	175		Cabin Creek	1986	103	Kondzela et al. 1994
	176		Karta River	1986	100	Kondzela et al. 1994
	177	20coco.frq	Coco Harbor	1987,1998	200	Kondzela et al. 1994, NMFS-ABL unpublished
	178		Breezy Bay	1986,1987,1988	254	Kondzela et al. 1994
	179	preal98.frq	Port Real Marina	1998	58	NMFS-ABL unpublished
	180	cruz98.frq	Cruz Cove	1986,1987, 1988,1998	258	Kondzela et al. 1994, NMFS-ABL unpublished
Queen Charlotte Islands	181	neets2.frq	Neets Bay Hatchery (fall)	1997	150	NMFS-ABL unpublished
	182		Awun River	1989	75	Kondzela et al. 1994
	183		Mace Creek	1989	100	Kondzela et al. 1994
	184		Peel Creek	1989	75	Kondzela et al. 1994
	185		Tasu Creek	1989	100	Kondzela et al. 1994
	186		Lagins Creek	1989	91	Kondzela et al. 1994
	187		Deena River	1989	82	Kondzela et al. 1994
	188		Lagoon Creek	1989	83	Kondzela et al. 1994
	189		Salmon River	1989	57	Kondzela et al. 1994
	190		Sedgewick Creek	1989	74	Kondzela et al. 1994
	191		Bag Harbor Creek	1989	89	Kondzela et al. 1994
Northern British Columbia	192		Surprise Creek	1989	85	Kondzela et al. 1994
	161		Kshwan River	1988	88	Kondzela et al. 1994
	162		Kitsault River	1988	95	Kondzela et al. 1994
	163		Stagoo Creek	1988,1989	128	Kondzela et al. 1994
	164		Khutzeymateen River	1989	94	Kondzela et al. 1994
	165		Toon River	1989	98	Kondzela et al. 1994
	166		Kitimat River/Mussel River	1988, 1989	123	Kondzela et al. 1994
	167		Neekas Creek	1989	54	Kondzela et al. 1994
	168		Klownik Creek	1989	100	Kondzela et al. 1994
Georgia Strait	169		Nekite River and Channel	1989	197	Kondzela et al. 1994
	193		Nanaimo River		100	Phelps et al. 1994
	194		Cowichan River		100	Phelps et al. 1994
	195		Chemainus River		100	Phelps et al. 1994

Geographic Area	Pop Number	Laboratory Sample Number	Population	Collection Date	N	Source
	196		Goldstream river		100	Phelps et al. 1994
	197		Big Qualicum FH		200	Phelps et al. 1994
	198		Little Qualicum		100	Phelps et al. 1994
	199		Puntledge FH		100	Phelps et al. 1994
	200		Cheakamus River		100	Phelps et al. 1994
	201		Indian Arm		100	Phelps et al. 1994
	202		Mamquam River		100	Phelps et al. 1994
	203		Tzoonie River		100	Phelps et al. 1994
Fraser River	204		Sliammon FH		100	Phelps et al. 1994
	205		Alouette River		100	Phelps et al. 1994
	206		Stave River		100	Phelps et al. 1994
	207		Chilliwack-Vedder FH		100	Phelps et al. 1994
	208		Chehalis at Harrison FH		100	Phelps et al. 1994
	209		Inch Creek FH		100	Phelps et al. 1994
	210		Weaver River		100	Phelps et al. 1994
	211		Chehalis FH		100	Phelps et al. 1994
	212		Harrison River		100	Phelps et al. 1994
	213		Squakum Creek		100	Phelps et al. 1994
West Coast Vancouver Island	214		Wahleach Creek		100	Phelps et al. 1994
	215		Nitinat River and FH		380	Phelps et al. 1994
	216		Nahmint River		100	Phelps et al. 1994
	217		Sarita River		127	Phelps et al. 1994
Strait of Juan de Fuca						
	218		Sooke River		100	Phelps et al. 1994
	219		Deep Creek		100	Phelps et al. 1994
	220		Lyre River		100	Phelps et al. 1994
	221		Pysht River		255	Phelps et al. 1994
Northern Puget Sound						
	222		Squire Creek		140	Phelps et al. 1994
	223		Jim Creek		151	Phelps et al. 1994
	224		Fortson Creek		211	Phelps et al. 1994
	225		N.F. Stillaguamish River		140	Phelps et al. 1994
	226		Skagit River		100	Phelps et al. 1994
	227		Illabot Creek		98	Phelps et al. 1994
	228		Dan Creek		153	Phelps et al. 1994
	229		Finney Creek		41	Phelps et al. 1994
	230		Samish FH		100	Phelps et al. 1994
	231		Thomas Creek		101	Phelps et al. 1994
	232		Bob Smith Creek		100	Phelps et al. 1994

Geographic Area	Pop Number	Laboratory Sample Number	Population	Collection Date	N	Source
	233		Nooksack River		36	Phelps et al. 1994
	234		Kendall FH		200	Phelps et al. 1994
	235		Maple Creek		100	Phelps et al. 1994
	236		Chuckanut Creek		35	Phelps et al. 1994
	237		Schoolhouse Slough		100	Phelps et al. 1994
	238		Wallace River		144	Phelps et al. 1994
	239		Skykomish River		200	Phelps et al. 1994
Southern Puget Sound						
	240		Swift Creek		250	Phelps et al. 1994
	241		Perry Creek		350	Phelps et al. 1994
	242		Elson Creek		350	Phelps et al. 1994
	243		Carbon River		150	Phelps et al. 1994
	244		Fennel Creek		100	Phelps et al. 1994
	245		Skookum Creek		100	Phelps et al. 1994
	246		Little Creek		51	Phelps et al. 1994
	247		Reitdorf Creek		50	Phelps et al. 1994
	248		Upper Skookum Creek		100	Phelps et al. 1994
	249		Sherwood, Rocky, Coulter Cks,		106	Phelps et al. 1994
	250		Mill Creek		179	Phelps et al. 1994
	251		Kennedy Creek		200	Phelps et al. 1994
	252		Goldsborough Creek		200	Phelps et al. 1994
	253		Chico Creek		196	Phelps et al. 1994
	254		Gorst Creek		100	Phelps et al. 1994
	255		Johns Creek FH		100	Phelps et al. 1994
	256		Sherwood Creek		100	Phelps et al. 1994
	257		Coulter Creek FH		100	Phelps et al. 1994
	258		Blackjack Creek		100	Phelps et al. 1994
	259		Chambers Creek FH		100	Phelps et al. 1994
	260		Nisqually River		300	Phelps et al. 1994
Hood Canal						
	261		Big Mission Creek		67	Phelps et al. 1994
	262		Little Mission Creek		53	Phelps et al. 1994
	263		Big Beef Creek		100	Phelps et al. 1994
	264		Dewatto River		263	Phelps et al. 1994
	265		Tahuya River		83	Phelps et al. 1994
	266		Enetai FH		100	Phelps et al. 1994
	267		Hood Canal FH		450	Phelps et al. 1994
	268		Lilliwaup Creek		100	Phelps et al. 1994
	269		Walcott FH		100	Phelps et al. 1994
	270		McKernan FH		100	Phelps et al. 1994
	271		Big Quilcene FH		100	Phelps et al. 1994

Geographic Area	Pop Number	Laboratory Sample Number	Population	Collection Date	N	Source
	272		Vance		101	Phelps et al. 1995
	273		NF. Skokomish		111	Phelps et al. 1996
	274		Hamma Hamma River		186	Phelps et al. 1994
	275		Dosewallips River		105	Phelps et al. 1994
	276		Tulalip FH GM		197	Phelps et al. 1994
Hood Canal Summer						
	277		Salmon Creek		50	Phelps et al. 1994
	278		Snow Creek		50	Phelps et al. 1994
	279		Jimmycomelately Creek		100	Phelps et al. 1994
	280		Union River Summer		103	Phelps et al. 1997
	281		Duckabush River Summer		125	Phelps et al. 1998
	282		Dosewallips River Summer		102	Phelps et al. 1994
	283		Hamma Hamma River Summer		37	Phelps et al. 1994
	284		Quilcene Bay & FH		240	Phelps et al. 1994
	285		Lilliwaup Creek Summer		120	Phelps et al. 1994
Coastal, Columbia River						
	286		Satsop River		100	Phelps et al. 1994
	287		Wynoochee River		22	Phelps et al. 1994
	288		Stevens Creek		100	Phelps et al. 1994
	289		Ellsworth Creek		100	Phelps et al. 1994
	290		Bitter Creek		100	Phelps et al. 1994
	291		Hamilton Creek		100	Phelps et al. 1994
	292		Grays River		100	Phelps et al. 1994
	293		Coal Creek		100	Phelps et al. 1994
	294					
ASIA						
Japan						
Pacific Coast of Honshu						
	294		Kido River	1994	80	Urawa et al. (2002)
	295		Kuji River	1994	69	Urawa et al. (2002)
	296		Koizumi River	1996	80	Urawa et al. (2002)
	297		Naruse River	1995	80	Urawa et al. (2002)
	298		Hazama River	1994	80	Urawa et al. (2002)
	299	Kata.frq	Katagishi River	1991	40	NMFS-ABL unpublished
	300		Katagishi River	1995	79	Urawa et al. (2002)
	312		Hei River	1996	45	Urawa et al. (2002)
	301		Tsugaruishi River Late Run	1995	80	Urawa et al. (2002)
	302	Tsug.frq	Tsugaruishi River	1991	40	NMFS-ABL unpublished
	303		Orikasa River	1996	80	Urawa et al. (2002)

Geographic Area	Pop Number	Laboratory Sample Number	Population	Collection Date	N	Source
	304		Akka River	1995	80	Urawa et al. (2002)
Japan Sea Coast of Honshu	305		Mabechi River	1994	40	Urawa et al. (2002)
	306		Tedori River	1994	40	Urawa et al. (2002)
	307		Sho River	1994	80	Urawa et al. (2002)
	308		Kurobe River	1996	80	Urawa et al. (2002)
	309		Kawabukuro River	1994	80	Urawa et al. (2002)
	310		Uono River	1995	80	Urawa et al. (2002)
	311		Gakko River Early	10/21/1997, 10/31/2000	120	Urawa et al. (2002)
	313		Gakko River Late	12/8/1994, 12/3/97, 12/7/00	186	Urawa et al. (2002)
Pacific Coast of Hokkaido						
	314		Yurrapu River Early	9/24/97	80	Urawa et al. (2002)
	315		Yurrapu River Mid	10/15/97	80	Urawa et al. (2002)
	316		Yurrapu River Late	11/17/97	80	Urawa et al. (2002)
	317		Shikiu River	1991	80	Urawa et al. (2002)
	318		Shizunai River	1991	80	Urawa et al. (2002)
	319		Tokachi River Early Run	9/26/97	80	Urawa et al. (2002)
	320		Tokachi River Late Run	11/20/97	80	Urawa et al. (2002)
	321		Kushiro River	10/22/98	80	Urawa et al. (2002)
Nemuro Coast						
	322		Nishibetsu River Early Run	9/25/97	80	Urawa et al. (2002)
	323		Nishibetsu River Late Run	11/17/97	80	Urawa et al. (2002)
Okhotsk Sea Coast of Hokkaido						
	324		Abashiri River	1998	80	Urawa et al. (2002)
	325		Tokushibetsu River	9/23/1997, 9/24/97	120	Urawa et al. (2002)
	326		Yubetsu River	1992	40	Urawa et al. (2002)
	327		Shokotsu River	1992	80	Urawa et al. (2002)
	328		Shari River	10/11/2001, 10/31/01	78	Urawa et al. (2002)
Japan Sea Coast of Hokkaido						
	329		Assabu River	1990	79	Urawa et al. (2002)
	330		Toshibetsu River	1990	80	Urawa et al. (2002)
	331		Chitose River Early run	9/17/97	80	Urawa et al. (2002)
	332		Chitose River mid run	10/17/97	40	Urawa et al. (2002)
	333		Chitose River Late run	11/10/97	80	Urawa et al. (2002)
Russia/China Amur River						

Geographic Area	Pop Number	Laboratory Sample Number	Population	Collection Date	N	Source
	334	cmamu97	Amur River fall run, Heilong	6/1/1997, 1994, 9/1/00	150	Wilmot et al. 1995, ADF&G-KamchatNIRO unpublished, Urawa et al. (2002)
	335		Amur River Summer	2001	100	Urawa et al. (2002)
Kuril Islands	336	cmrei98r	Reidova River, Kuril Is.	1998	77	ADF&G-KamchatNIRO unpublished
	337	cmreib98	Reidova Bay	1998	76	ADF&G-KamchatNIRO unpublished
	338	cmkons98	Kons Bay	1998	35	ADF&G-KamchatNIRO unpublished
Premorye/Suifen	339		Ryzanovka	1994	51	Wilmot et al. 1995, IMB RAN, TINRO-center unpublished
	340	suifen.frq	Suifen (Dongning Hatchery)	1994	25	Wilmot et al. 1995, NMFS/ABL unpublished
	NA		Avakumovka	1994	35	Wilmot et al. 1995, IMB RAN, TINRO-center unpublished
	NA	narva.frq	Narva	1994	18	Wilmot et al. 1995, IMB RAN, TINRO-center unpublished
Sakhalin Island	341		Kalininka	1994	49	Wilmot et al. 1995, IMB RAN, TINRO-center unpublished
	342	naiba.frq	Naiba River	1994, 1995	100	Wilmot et al. 1995, NMFS-ABL-KamchatNIRO-TINRO-center unpublished
	343		Udarnitsa	1994	98	Wilmot et al. 1995, TINRO-center, IMB RAN unpublished
Anadyr River	NA	tym.frq	Tym River	1995	56	NMFS-ABL-KamchatNIRO unpublished,
	344		Anadyr River	1991	183	Winans et al. 1994, Wilmot et al. 1994
Eastern Kamchatka	345		Ossora	1990, 1996	90	Winans et al. 1994, NMFS--KamchatNIRO unpublished
	346		Nerpichi Lake	1991	40	Winans et al. 1994
	347		Kamchatka River	1990, 1991	120	Winans et al. 1994
	354	cmbol97	Bolshaya River	1997	102	ADF&G-KamchatNIRO unpublished,
	NA	cmpara98	Paratunka River	1998	100	ADF&G-KamchatNIRO unpublished,
Western Kamchatka	348		Utka River 1991	1991	79	Winans et al. 1994
	NA		Kikchik River 1991	1991	40	Winans et al. 1994

Geographic Area	Pop Number	Laboratory Sample Number	Population	Collection Date	N	Source
Sea of Ohkotsk	349	pymta.frq	Pymta River 1990	1990, 1991, 1993	80	Winans et al. 1994, NMFS-ABL-KamchatNIRO unpublished
	350		Kol River 1990	1990	93	Winans et al. 1994
	NA	Vorovsk.frq	Vororskaya	1993	146	NMFS-ABL-KamchatNIRO unpublished
	351	harusova.frq	Harusova River	1990, 1993	202	Winans et al. 1994, NMFS-ABL-KamchatNIRO unpublished
	355	cmbist98, cmozer98	Bistraya River , Ozerki Hatchery	1998	150	ADF&G-KamchatNIRO unpublished
	356	cmpala98	Palana River 1998	1998	98	ADF&G-KamchatNIRO unpublished
	352		Tumani River 1991	1991	66	Winans et al. 1994
	353		Ola River	1990, 1991	80	Winans et al. 1994
	NA	Oklan.frq	Oklan	1993	77	NMFS-ABL-KamchatNIRO unpublished
	NA	Penzhina.frq	Penzhina	1993	50	NMFS-ABL-KamchatNIRO unpublished
	NA	Belaya.frq	Belaya	1993	40	NMFS-ABL-KamchatNIRO unpublished