Salmon Harvests to the Year 2050: A Predictive Model for the Yukon, Kuskokwim, and Norton Sound Drainages in Alaska

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Introduction

This paper predicts potential future salmon harvests to the year 2050 in the Yukon, Kuskokwim, and Norton Sound drainages of Alaska. The predictions derive from models of salmon runs, subsistence salmon demand, and commercial salmon production developed by an expert panel of fisheries biologists, anthropologists, and economists. The work addresses research questions about the future of salmon fisheries posed by the Arctic-Yukon-Kuskokwim Sustainable Salmon Initiative (AYK-SSI), a research-restoration organization concerned with the sustainability of salmon fisheries in Alaska.

The Arctic-Yukon-Kuskokwim region (AYK) includes the Yukon, Kuskokwim, and Norton Sound drainages of Alaska (Krueger and Zimmerman 2009) (Map 1). Salmon and other wildlife have been critical to the survival of the people in the AYK region for thousands of years. In recent decades, residents of about eighty communities have harvested salmon for subsistence purposes in this region, primarily as food for families and secondarily for feeding sled dogs (Wolfe and Spaeder 2009). The salmon runs also have been harvested for commercial sales and sport use (Knapp 2009). The commercial fisheries have generated income to local residents through the sale of fish to middlemen buyers and through employment in fish processing. Historically, the AYK region has had a mixed, subsistence-cash economy where many families survive through subsistence harvests, commercial fishing, and wage employment.

Salmon returns to the AYK region have been variable in recent decades. Between 1997 and 2002, unexpected declines in salmon runs prompted fifteen disaster declarations within local watersheds by the governor of Alaska and federal agencies (Krueger et al. 2009). While some runs have improved since 2002, others have remained at low or uncertain levels. These conditions have created hardships for the people and communities dependent on salmon. Commercial salmon production has fallen with fewer active commercial fishers and buyers, and reduced earnings. Subsistence production for dog food also has fallen substantially with less available salmon and fewer local dog teams. Subsistence production for human food has continued, albeit with greater costs and local shortages for fishing families.

In response to salmon declines, Alaska Native regional organizations joined with state and federal agencies to form the AYK Sustainable Salmon Initiative (AYK-SSI), a partnership for research and restoration[7]. To understand trends and causes of variation in salmon fisheries, the

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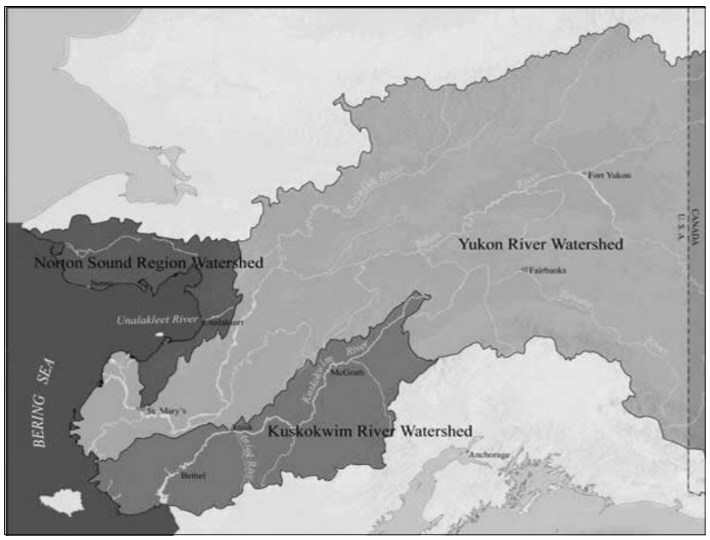
[7] The partnership includes the Association of Village Council Presidents, Tanana Chiefs Conference, Kawerak, Inc., Bering Sea Fishermen's Association, Alaska Department of Fish and Game, National Oceanic and Atmospheric Administration, and U.S. Fish and Wildlife Service.

AYK-SSI Research and Restoration Program advanced a general hypothesis about future harvests for additional study:

> In the AYK region, human populations will increase over the next fifty years, but alternative affordable food resources will become more available, causing fishing and harvest to remain the same or to decline. (*AYK-SSI Research Framework No. 2, Human Systems and Sustainable Salmon: Social, Economic, and Political Linkages*).

This hypothesis asserts that future harvests will be influenced by increasing human populations and greater availability of store-bought foods, with overall stable or downward trends in subsistence salmon harvests in the AYK region.



Map. 1. Arctic-Yukon-Kuskokwim (AYK) Region in Alaska

The AYK-SSI Research Program charged a nine-member expert panel to examine the future of salmon fisheries in the AYK region with this hypothesis as a starting point. The panel consisted of the authors of this paper, as well as Caroline Brown and James Magdanz of the Alaska Department of Fish and Game, Division of Subsistence, and Joseph Spaeder of AYK-SSI. The charge was to develop a model that might describe future harvests in the AYK region.

This paper presents the results of that work, including a predictive model of factors and conditions that potentially affect future salmon harvests in the AYK region. As illustrated in Fig. 1, the predictive model contains three main components: (1) salmon run simulations, (2) a subsistence demand component, and (3) a commercial harvest component. The *salmon run simulations* provide scenarios for future run returns based on annual variation of past runs and assumed mean abundance levels. The *subsistence demand component* predicts future demand for subsistence salmon based on anticipated changes in community populations, mean incomes, and other factors. The *commercial harvest component* predicts future commercial harvests for years with harvestable surpluses (after escapement and subsistence demand is sufficiently met). Each component of the predictive model is described below. Findings of the predictive model are then presented, representing scenarios of potential future salmon harvests in the AYK region under alternative conditions. The paper ends with a discussion of the findings and conclusions.

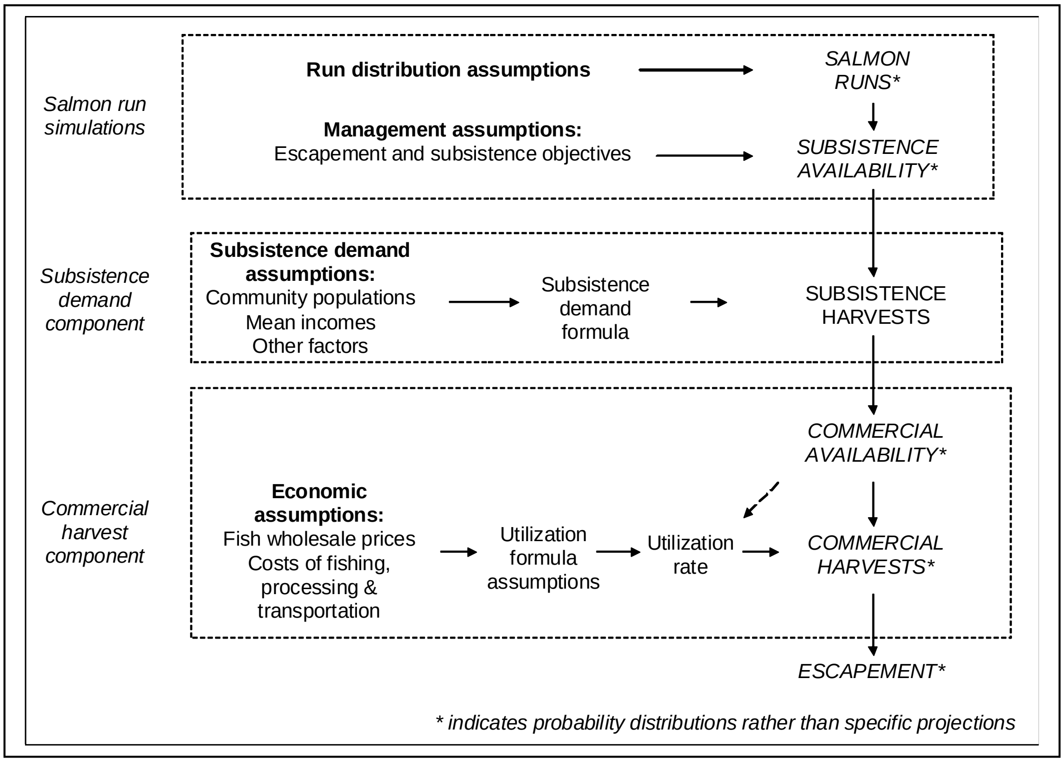


Fig. 1. Conceptual Framework for Analysis

Salmon Run Simulations

Paramount to future salmon harvests in the AYK region is the availability of salmon. If salmon runs are insufficient to provide harvestable surpluses, fishing must be restricted to achieve escapement goals. Historically, the AYK region has supported harvestable runs of six salmon varieties – Chinook (Kuskokwim, Yukon, Norton Sound), summer chum (Kuskokwim, Yukon, Norton Sound), fall chum (Yukon), sockeye (Kuskokwim, Norton Sound), coho (Kuskokwim, Yukon, Norton Sound), and pink (Kuskokwim, Yukon, Norton Sound). Run abundance has varied by area, year, and variety. Overall, the region's commercial fisheries have primarily targeted Chinook and chum with a lesser focus on sockeye, coho, and pink. Commercial fisheries generally have been larger in downriver areas than upriver areas. The Yukon and Kuskokwim systems have been substantially more productive than the Norton Sound systems. All salmon varieties are harvested within local subsistence fisheries, but the species composition and volume of harvests vary substantially by area. Sport fishing has primarily targeted Chinook and coho, with catches relatively modest compared with subsistence and commercial takes.

The run simulations divide the salmon runs in the AYK region into 28 salmon stocks defined by area, species, and run timing (Table 1). For our purposes, "stock" simply refers to a salmon variety within a management area (a river segment or combination of subdistricts). Our analysis assumes that the current general geographic distribution of salmon varieties continues into the future. The Lower Kuskokwim includes harvests from Eek to Tuluksak. The Lower Yukon includes harvests in management subdistricts Y1-Y3. Northern Norton Sound includes harvests from Elim to Brevig Mission, including Port Clarence.

Table 1. Salmon Stocks Represented in Run Simulations

Area	Chinook	Summer Chum	Fall Chum	Sockeye	Coho	Pink
Lower Kuskokwim	X	X		X	X	
Middle-Upper Kuskokwim	X	X		X	X	
Kuskokwim Bay	X	X		X	X	
Lower Yukon	X	X	X		X	
Middle-Upper Yukon	X	X	X		X	
Southern Norton Sound	X	X			X	X
Northern Norton Sound		X		X	X	X

The data used for simulating future salmon returns was compiled from published reports and personal communications on harvests and escapements in the AYK region[8]. Time series of potential total returns were reconstructed using the available data. Run reconstructions (e.g., Starr and Hilborn 1988; Mundy et al. 1993) are summations of observed or estimated escapements and fishing removals of particular stocks throughout their drainage:

$$(Total\ Return)_{it} = \Sigma(esc)_{ijt} + \Sigma(sub)_{ikt} + \Sigma(com)_{ikt} + \Sigma(rec)_{ikt}.$$

where *i* indexes a stock of salmon in a particular area, *j* indexes the tributaries for which escapement estimates are tracked, *k* indexes fishing zones for which subsistence, commercial, and sport catches are tracked, and *t* indexes the year. Because some of the time series were inconsistent and discontinuous (i.e., the tributaries monitored and methods used to estimate escapement within management areas were not consistent and catches were subject to management decisions to open or close the fisheries), reconstructing the runs required two modifications to the basic equation. Inconsistencies in the escapement data were addressed by replacing missing values with random draws from log-normal distributions based on the means and standard deviations of log-transformed values of available data in each time series. Binomial distributions were used to characterize the frequency that fisheries were not opened and normal distributions were used to characterize catches in years when the fishery was open. Run reconstructions for each stock were iterated 5,000 times. The means and standard deviations of the log-transformed total returns were estimated from these iterations and used to parameterize the run simulations.

The simulation model was initialized with random draws from a binomial distribution to represent the frequency of run failures. If the binomial random value did not indicate a run failure, the simulation proceeded to draw a random value from the distribution of log-normal total returns. The variance of the random draw was constrained for a few highly variable stocks to prevent unrealistic values (e.g., negative total returns). However, a given iteration of the synthesized total return as constructed in this model was allowed to exceed historical bounds of reconstructed total returns.

[8] Sources included ADF&G 2004; Bergstrom et al. 2009; Borba et al. 2009; Brannian et al. 2006; Brase 2010; Burr 2009; Busher et al. 2009; Chythlook 2009; Estensen et al. 2009; Hayes et al. 2008; Howe et al. 1995, 1996; JTC 2010; Kent and Bergstrom 2009; Linderman and Bergstrom 2006; Menard and Bergstrom 2009a, 2009b; Menard et al. 2009; Mill 1989, 1990, 1991, 1992, 1993, 1994; Parker 1991, 2009; Parker and Viavant 2000; Soong et al. 2008; Volk et al. 2009; Whitmore et al. 2008; K. Howard, ADF&G, pers. comm.; J. Menard, ADF&G, pers. comm.

Once the simulation was initialized, the synthesized total return was subjected to a fishery management simulation regime (e.g., Criddle 1996; Criddle and Streletzki 2000.) The primary management objective was to meet escapement goals. For some stocks, the Alaska Board of Fisheries has adopted formal escapement goals (Brannian et al. 2006; Volk et al. 2009), but has not done so for all of the stocks modeled in our simulations. Because we also wanted to consider tributaries for which goals are not formally adopted, we used the median of the log-transformed historical data as an escapement goal, which was summed with formalized escapement goals. Escapement goals for each stock were pooled across tributaries within a management area or district. The simulation protocol apportioned this summed escapement goal from the total return, which is initially unknown in the protocol. Goals for passage of Chinook salmon and fall chum salmon up the Yukon River into Canada are established through international treaty. In our simulation, we regarded treaty-directed passage into Canada as an escapement goal for Canada[9].

The second highest management objective was to assign sufficient catch to meet subsistence demand. To capture uncertainty in implementation of subsistence harvests, subsistence removals were modeled as random draws from a binomial distribution of the historical mean and standard deviation of subsistence removals, scaled relative to the simulated total run strength. In the case of an exceptionally small total return, both escapement and subsistence harvests might be less than targeted levels. Given the gauntlet characteristic of some river systems, under simulated low total returns, lower river subsistence harvests were restricted in order to provide for sufficient upriver escapement (Starr and Hilborn 1988; Criddle 1996).[10]

Sport harvests were assumed to occur in the same proportions as the historical sport harvests relative to the reconstructed total run. This was done because larger total returns were assumed to generate greater opportunistic sport catches, and in-season adjustments of sport harvests have been relatively infrequent in most management segments, with the primary exception occurring under extremely small total returns that have not provided for subsistence demands. For simulation iterations in which the subsistence harvests were curtailed, sport harvests were set to zero.

Commercial availability was calculated as the difference between the simulated total return and the sum of escapements, subsistence harvests, and sport harvests. Because actual commercial harvests also depend on economic considerations, some or all of the commercial availability might not be harvested in some years. Fish not harvested were treated as additional escapement. Based on discussions with managers, near-term commercial harvests were not anticipated in the Kuskokwim River above District 1, so we allowed for no commercial harvests in the middle or upper Kuskokwim River.

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[9] Historically, passage goals into Canada have not been consistently met. Our simulation rule results in more conservative future harvestable surpluses (compared with historical runs) because it assumes that passage goals would be consistently met.

[10] If the index of run strength was less than one half of a scaled estimate of the historical average escapement, no subsistence fishery was allowed. If the indexed run exceeded one half of the scaled historical escapement, the subsistence goal was set to the smaller of either: (1) the subsistence demand under a given subsistence scenario, or (2) the remainder between the indexed run strength and sum of the escapement goal scaled to run strength plus one half of the upstream subsistence demands. The subsistence goal was given a random implementation error based on the mean and distribution of historical subsistence harvests. Thus, if run strength was sufficiently large enough, then actual subsistence harvest might be slightly larger or smaller than demand.

Given the above rules, we created a total of 1,000 iterations of each synthesized harvest return and fishery management simulation for each stock. Each iteration simulated the total return, escapement, subsistence harvest, sport harvest, and potential commercial availability for the years 2010 to 2050. As part of this, we examined subsistence scenarios based on potential changes in subsistence demand: (1) Low; (2) Intermediate One; (3) Intermediate Two; and (4) High (as defined below in the subsistence demand component). For each stock, we simulated three potential levels of total returns: (1) the historical mean (the random draw of the total run was based on the mean of the reconstructed log-transformed total return); (2) a decreased mean (the random draw of the total run was based on the first quartile of the reconstructed log-transformed total return); and (3) an increased mean (the random draw of the total run was based on the third quartile of the reconstructed log-transformed total return).

Our analysis assumed that the historic annual variability of returns of these salmon stocks would continue into the future. That is, we assumed that the observed annual variability of historic salmon abundance was the best indication of annual variability expected for future years. Under such an assumption, the large historic Chinook salmon and chum salmon runs that supported substantial commercial fisheries for two decades (1970s-80s) would be statistical possibilities for repeating in the future; similarly, substantial low years of abundance (the crashes of the late 1990s-2003) would be statistical possibilities for repeating.

In simulated returns, our model treated each return year as independent of any other. That is, the model assumed that there is no significant serial correlation and instead, between-year variability could be randomly apportioned across years. This means our model did not consider spawner-recruit relationships or capture other factors that could lead to extended periods of low and high annual runs observed historically, periods of salmon productivity probably linked to environmental and stock conditions. The model includes no assumptions about the causes of between-year variability.

The simulations assumed that current management priorities would continue into the future. Currently, the first management priority is escapement for spawning. In addition, on the Yukon River, there are trans-boundary passage goals for Chinook salmon and fall chum (as required by U.S.-Canada treaties). If there is no expected harvestable surplus considering escapement needs, no fisheries are opened. Subsistence fisheries are given the next highest priority after escapement. Commercial and sport fisheries are opened when surpluses are expected above subsistence demand. Because of sequential fishing from the mouth to upstream in the Yukon and Kuskokwim rivers, management attempts to provide for upstream escapement and subsistence harvests through constraints of downstream harvests. One might imagine different management priorities at some future time. If that happened, the simulation rules would change.

Subsistence Demand for Human Food

The second component of the predictive model is the Subsistence Demand Component. This component was designed to predict future subsistence demand for salmon in the AYK region. Subsistence salmon primarily are harvested for local uses as human food in rural communities. In some communities, subsistence salmon also are harvested for feeding sled dogs. Our analysis predicts demand for human food separately from dog food, with total subsistence demand representing their sum. "Demand" is defined as the amount of salmon that local residents would harvest in years with sufficient salmon runs.

Subsistence salmon production occurs within local mixed subsistence-cash economies (Wolfe and Walker 1987). In mixed economies, families invest labor and income into traditional fishing and hunting pursuits to produce wild foods for local consumption. The organization of mixed economies of rural communities differs substantially from that of Alaska's urban areas where wage sectors are central and most foods derive from non-local sources. Over the past century, production of wild foods (on a per capita basis) has decreased in rural Alaska communities as incomes have increased and the cost of store-bought foods has become less prohibitive. This has been a general trend throughout rural Alaska. At the same time, families continue to produce subsistence foods in substantial amounts in places where store-bought foods are relatively expensive to families, lower in quality, or have unreliable availability compared with local wild foods. Higher wild food production occurs especially in villages off the road system where incomes are modest and insecure. Because of these relationships, the relative mix of wild and store-bought foods is sensitive to mean incomes within communities (Wolfe and Walker 1987). As mean incomes increase or fall within communities, diets shift to include more or less store-bought foods. If general trends continue, wild food production will continue to decrease as mean incomes increase in AYK communities, representing strengthening of local monetary sectors and shifts by households to more store-bought foods.

In addition to income, cultural factors also influence wild food production at the village level (Wolfe and Walker 1987). The press of culture affects dietary preferences, including preferred types of food and quantities consumed[11]. Cultural obligations within extended families promote the production and sharing of wild foods in villages. Traditional preferences about kinds of activities (indoors or outdoors, at camp or in communities, among others) also reflect cultural patterns. The cultural composition of a population (the percentage of Alaska Natives) represents, in a general way, the influence of cultural factors on wild food harvest patterns. In particular, communities with higher percentages of Alaska Natives tend to produce and consume larger amounts of wild foods (Wolfe and Walker 1987).

Because wild food production at the village level is related to income, culture, and geography in Alaska, statistical equations can be created for estimating (that is, inferring) subsistence production based on these factors. The statistical equations can be developed into predictive models of demand, assuming that past relationships among factors continue into the future. As a basis for our predictive model of subsistence food demand, data from a set of 149 communities in Alaska with wild food harvest information were analyzed to assess the statistical relationships among factors (Table 2). The data set derives from Wolfe and Fischer (2003); harvest data were originally collected through face-to-face household surveys or mailed post-season harvest surveys/tickets by the Alaska Department of Fish and Game. The set of communities was selected to represent local economies outside of the AYK region, including rural Southeast Alaska (25 places), rural Gulf of Alaska-Bristol Bay (35 places), rural road-connected Interior Alaska (25 places), and urban and urban-rural fringe areas (64 places).

The presumption is that this set of communities presents a range of socioeconomic and geographic conditions (affecting wage employment, stores, wild food harvests, and other community factors) that may represent AYK communities in the future. As a group, the communities produced negligible harvests for feeding sled dogs, so the analysis can be used to represent wild food harvests for human consumption. AYK communities were excluded from the data set because human and dog consumption cannot be separated out from most community-based studies.

[11] Notable examples of culturally-based food preferences are marine mammal products which are primarily consumed within Alaska Native groups but not non-Native groups.

Table 2. Community Data Set for Regression Analysis of Relationships Between Income, Culture, Roads, and Geography on Wild Food Harvest Levels

	Area and Population	Wild Food Harvest	Population in 2000	Percent Native in 2000	Per Cap Income (x$1,000)	Harvest Year
	Interior Road					
1	Sutton-Alpine	24.06	1,080	25.8	20.436	2000
2	S. Parks Highway	58.01	367	11.0	23.695	1985
3	Gakona	95.31	215	17.7	18.143	1987
4	Glennallen	99.51	554	12.1	17.084	1987
5	Skwentna	100.85	148	8.1	23.995	2000
6	Tazlina	107.46	149	30.2	23.992	1987
7	Cantwell	111.53	222	27.0	22.615	1982
8	Mentasta Lake	125.48	142	71.1	11.274	1987
9	Healy	132.06	1,000	5.3	18.160	1987
10	Kenny Lake	136.25	410	13.4	13.121	1987
11	Anderson	139.20	367	6.5	23.837	1987
12	Tok	149.18	1,393	19.0	18.521	1987
13	Gulkana	152.59	88	73.9	13.548	1987
14	Tonsina	155.68	92	9.8	13.390	1987
15	Slana	173.77	124	15.3	20.019	1987
16	Copper Center	174.33	362	50.6	15.152	1987
17	Lake Louise	179.18	88	3.0	11.056	1987
18	Tetlin	213.93	117	97.4	7.371	1987
19	Chickaloon	223.58	213	16.9	14.755	1982
20	McKinley Park	242.06	142	3.5	27.255	1987
21	Tanacross	249.85	140	90.0	9.429	1987
22	Tyonek	259.95	193	95.3	11.261	1983
23	Chistochina	261.54	93	65.6	12.362	1987
24	Northway	278.07	95	82.1	10.300	1987
25	Chitina	342.35	123	48.8	10.835	1987
	Pacific-Gulf-Bristol Bay					
26	Seldovia	54.16	430	28.8	23.669	2000
27	Kodiak City	151.05	6,334	13.1	21.522	1993
28	Kodiak Road	168.13	3,991	18.3	21.522	1991
29	Cordova	178.91	2,454	15.0	25.256	1997
30	Naknek	188.19	678	47.1	21.182	1983
31	Unalaska	194.53	4,283	9.3	24.676	1994
32	Chignik Lagoon	211.36	103	82.5	19.604	1989
33	King Salmon	220.32	442	30.1	26.755	1983
34	Dillingham	242.03	2,466	60.9	21.537	1984
35	Port Graham	253.41	171	88.3	13.666	1997
36	Nanwalek	253.93	177	93.2	10.577	1997
37	Nelson Lagoon	254.01	83	81.9	27.596	1987
38	Sand Point	255.69	952	44.2	21.954	1992

	Area and Population	Wild Food Harvest	Population in 2000	Percent Native in 2000	Per Cap Income (x$1,000)	Harvest Year
	Pacific-Gulf-Bristol Bay (cont.)					
39	King Cove	256.07	792	47.9	17.791	1992
40	Ouzinkie	263.98	225	87.6	19.324	1997
41	Saint Paul	267.47	532	86.5	18.408	1994
42	Chenega Bay	275.26	86	77.9	13.381	1993
43	South Naknek	296.82	137	83.9	13.019	1992
44	Old Harbor	300.36	237	85.7	14.265	1997
45	Akhiok	321.75	80	93.8	8.472	1992
46	Port Lions	331.46	256	63.7	17.492	1993
47	Chignik Bay	357.51	79	60.8	16.166	1991
48	Clark's Point	362.94	75	92.0	10.989	1989
49	Larsen Bay	370.48	115	79.1	16.227	1997
50	Aleknagik	379.23	221	84.6	10.973	1989
51	Pilot Point	383.74	100	86.0	12.627	1987
52	Manokotak	384.09	399	94.7	9.294	1985
53	Egegik	384.33	116	76.7	16.352	1984
54	Perryville	394.36	107	98.1	20.935	1989
55	Tatitlek	406.37	107	85.0	13.014	1997
56	Port Heiden	407.62	119	78.2	20.532	1987
57	False Pass	412.58	64	65.6	21.465	1988
58	Atka	439.31	92	91.3	17.079	1994
59	Chignik Lake	442.34	145	87.6	13.843	1991
60	Akutan	466.17	713	85.4	12.259	1990
	Southeast Region					
61	Petersburg	161.35	3,224	12.0	25.827	2000
62	Wrangell	167.44	2,308	23.8	21.851	2000
63	Hollis	169.26	139	9.4	17.278	1998
64	Whitestone	178.42	116	6.9	21.810	1996
65	Kake	179.09	710	74.6	17.411	1996
66	Thorne Bay	179.22	557	4.8	20.836	1998
67	Whale Pass	184.96	58	3.4	24.041	1998
68	Haines	195.80	1,811	18.5	22.505	1996
69	Sitka	205.02	8,835	24.7	23.622	1996
70	Angoon	224.42	572	86.4	11.357	1996
71	Craig	231.93	1,397	30.9	20.176	1997
72	Gustavus	240.82	429	8.2	21.089	1987
73	Naukati Bay	241.54	135	9.6	15.949	1998
74	Coffman Cove	276.15	199	6.0	23.249	1998
75	Port Alexander	311.75	81	13.6	14.767	1987
76	Klawock	320.33	854	58.1	14.621	1997

Table 2 (cont). Community Data Set for Regression Analysis of Relationships Between Income, Culture, Roads, and Geography on Wild Food Harvest Levels

	Area and Population	Wild Food Harvest	Population in 2000	Percent Native in 2000	Per Cap Income (x$1,000)	Harvest Year
	Southeast Region (cont.)					
77	Tenakee	329.94	104	4.8	20.483	1987
78	Hyder	345.28	97	4.1	11.491	1987
79	Sitka Tribe	350.18	2,095	99.0	23.622	1996
80	Pelican	355.12	163	25.8	15.201	1987
81	Hoonah	372.04	860	69.4	16.097	1996
82	Hydaburg	384.09	382	89.5	11.401	1997
83	Yakutat	385.51	680	46.8	21.330	2000
84	Port Protection	450.85	63	11.1	12.057	1996
85	Klukwan	608.27	139	88.5	11.612	1996
	Urban-Urban Fringe					
86	D-town Anchorag	8.04	1,458	26.7	25.287	2000
87	Avenue Fifteen	8.77	12,288	12.5	25.287	2000
88	North Fairbanks	10.05	8,253	7.0	19.814	2000
89	Merrill Field	10.16	4,128	23.8	25.287	2000
90	Hope	11.22	155	6.4	9.079	2000
91	Houston	11.56	1,202	12.1	17.213	2000
92	Ship Creek	11.96	6,727	23.4	25.287	2000
93	MidFork-RusJack	12.12	10,105	16.2	25.287	2000
94	Russian Jack	12.15	4,084	14.5	25.287	2000
95	Lake Otis	12.19	5,275	7.1	25.287	2000
96	University	12.26	4,633	13.1	25.287	2000
97	Spenard	12.59	14,939	9.9	25.287	2000
98	Delaney Lake	12.99	2,917	11.1	25.287	2000
99	Midtown	13.61	12,687	15.5	25.287	2000
100	Northfork	13.74	4,324	14.9	25.287	2000
101	Little Campbell Cl	15.09	23,581	10.5	25.287	2000
102	Fort Richardson	15.14	5,470	1.7	25.287	2000
103	Campbell Creek	15.48	9,245	8.6	25.287	2000
104	NW Fairbanks	15.90	5,127	9.3	23.381	2000
105	Muldoon	16.64	36,961	12.2	25.287	2000
106	Nikiski	16.83	4,327	10.1	20.129	2000
107	Central Fairbanks	17.09	16,788	17.7	19.814	2000
108	Elmendorf	18.01	6,626	1.3	25.287	2000
109	Airport	18.30	18,626	8.4	25.287	2000
110	Girdwood	18.39	2,091	3.0	25.287	2000
111	Fort Wainwright	19.09	7,381	2.8	19.814	2000
112	SW Fairbanks	19.31	17,574	11.7	19.814	2000
	Urban-Urban Fringe (cont.)					
113	Big Lake	19.88	2,635	10.3	19.285	2000
114	OMalley	21.34	6,000	5.5	25.287	2000
115	Lk. OMalley	21.35	12,697	9.5	25.287	2000
116	Coastal Refuge	21.35	8,612	7.0	25.287	2000
117	Upper OMalley	22.06	4,574	3.2	25.287	2000
118	Eielson AFB	22.59	5,400	1.4	19.814	2000
119	Rabbit Creek	22.64	12,318	4.0	25.287	2000
120	Willow	23.24	2,614	7.8	22.323	2000
121	Wasilla	24.10	29,618	8.0	21.127	2000
122	Juneau	25.29	30,711	16.6	26.719	2000
123	Palmer	26.95	15,000	7.7	20.672	2000
124	Eagle River	27.34	20,610	5.1	25.287	2000
125	North Pole Area	27.48	16,295	7.4	21.426	2000
126	Seward	28.42	4,670	18.4	20.360	2000
127	NE Fairbanks	33.22	4,894	7.3	19.814	2000
128	Ketchikan	34.37	7,922	22.2	22.484	2000
129	Glacier View	35.78	249	10.4	14.855	2000
130	Kenai	36.18	9,828	12.2	20.789	2000
131	Chugiak	36.67	4,472	6.8	25.287	2000
132	Homer	38.97	8,472	5.3	21.823	2000
133	Eklutna	41.97	4,835	8.0	25.287	2000
134	Soldotna	42.00	14,946	6.1	21.740	2000
135	Moose Pass	44.02	374	8.8	28.147	2000
136	Salcha-Harding	47.38	1,128	4.9	22.616	2000
137	Trapper Creek	50.74	423	11.3	18.247	1985
138	Anchor Point	54.98	2,334	6.7	18.668	2000
139	Talkeetna	55.38	813	8.1	23.695	2000
140	Kasilof	60.25	1,639	7.0	21.211	2000
141	Fritz Creek	72.14	1,603	5.1	18.937	1998
142	Cooper Landing	77.16	369	4.9	24.795	1990
143	Whittier	79.94	182	12.6	25.700	1990
144	Nikolaevsk	88.45	345	4.9	10.390	1998
145	Clam Gulch	99.14	173	5.8	17.983	2000
146	Valdez	103.45	4,036	10.2	27.341	1992
147	Ninilchik	134.66	772	16.6	18.463	1998
148	Kenai Tribe	141.00	1,149	99.0	20.789	1993
149	Saxman	210.54	431	70.1	15.642	1999

A multiple regression analysis of this data set identified four community-level variables as significantly related to total wild food harvests (lbs per capita per year)[12] within a community – income (mean per capita income in thousands of dollars), cultural composition of a community (percentage Alaska Native), and binary variables reflecting road-connectedness and urban location (in or out of an urban/urban-rural fringe). The relationships are expressed in the following equation:

[12] Total wild food production (lbs per capita) is more predictable at the community level than the constituent food species. Species composition varies substantially between communities due to ecological differences in community harvest areas, so it is more difficult to predict. (Wolfe 2004).

Harvests = 329 – (5.276 x Income) + (1.067 x Cultural Composition),

with the subsistence harvest adjusted downward if the community is road-connected (reduced by 114 lbs) or if the community is located in an urban/urban-rural fringe area (reduced by 188 lbs). In this equation, "Income" is measured in thousands of dollars and "Cultural Composition" is measured as the percentage of Alaska Natives in a community. Based on this equation, for every $1,000 increase in mean per capita income in a community, wild food harvests decrease by 5.276 lbs per capita. For every one percent increase of Alaska Natives in a community, wild food harvests increase by 1.067 lbs per capita. If a community becomes part of an urban or urban-rural fringe area, wild food harvests decrease substantially (to avoid negative harvests under alternative scenarios, 10.0% of predicted harvest was substituted in the equation for the 188 lbs adjustment factor for urban/urban-rural fringe populations). The regression equation is robust and accounts for 80.9% of the variation in wild food harvests within this set of 149 communities (R = 0.902; Rsq = 0.809; sig. <.000 for each variable).[13]

Table 3. Predicted Wild Food Demand for Human Consumption By Community Type and Area, AYK Region (Base Year 2000)

Community Type/Area	Mean Per Capita Income (2000)	Alaska Native (2000)	Wild Food Demand (Lbs per Capita) (Predicted)
Villages			
Lower Yukon River	$9,163	94.8%	381.8
Upper Yukon River	$11,812	78.6%	350.6
Lower Kuskokwim	$7,877	96.7%	390.6
Middle-Upper Kuskokwim	$10,164	80.2%	360.9
South Kuskokwim Bay	$7,537	94.7%	390.3
Bering Sea Coast	$8,990	94.0%	380.8
South Norton Sound	$11,553	92.1%	366.3
North Norton Sound	$10,142	91.8%	373.4
Regional Centers			
Bethel	$20,267	68.0%	176.8
Nome	$23,402	58.0%	107.0
Urban Area			
Fairbanks (NWTractFAI13)	$23,381	9.6%	21.6

Applying this multiple regression equation to AYK areas with community values from the 2000 U.S. Census, per capita demand for wild foods for human consumption was estimated (Table 3). Demand ranged from about 350.6 lbs to 390.6 lbs per capita per year in AYK villages. Demand in urban Fairbanks was estimated at 21.6 lbs per capita. Demand in regional centers was intermediate (Bethel, 176.8 lbs; Nome, 107.0 lbs)[14]. These estimates of demand represented all wild foods consumed by residents, of which salmon was a component.

[13] Standard errors and t statistics were: Constant 30.095, 10.959; Income 1.232, -4.281; Cultural Composition 0.210, 5.074; Roads 15.293, -7.448; Urban/Urban Fringe 13.545, -13.867 (all sig. <.000).

[14] Adjustments to the equation were required in its application to these two regional centers to match observed harvest levels – Bethel (0.600 of predicted) and Nome (0.400 of predicted). The data set of 149 places included only one regional center (Dillingham), which limited the predictive capacity of the multiple regression equation for regional centers.

To calculate the demand for salmon only, the estimated total wild food demand was multiplied by the assumed percentage of salmon in the total wild food harvest of an area (Table 4). By weight, salmon was estimated to comprise from 40.7% to 46.1% of wild food harvests in particular Yukon and Kuskokwim areas, and 21.5% or 33.3% in Norton Sound areas[15]. Yukon drainage salmon comprised 3.0% of wild food harvests in the Fairbanks area (residents typically catch salmon from the Copper River and Kenai Peninsula rivers, not the Yukon River). In the predictive model, this percentage can be varied to examine effects. As shown below, our simulations assumed no or only slight changes in the percentage of salmon in the total wild food harvest within communities[16].

Table 4. Estimated Contribution of AYK Salmon to Total Subsistence Harvests for Human Food

Community Type/Area	Salmon Contribution
Villages	
Lower Yukon River	40.70%
Upper Yukon River	46.10%
Lower Kuskokwim	46.03%
Middle-Upper Kuskokwim	44.81%
South Kuskokwim Bay	44.57%
Bering Sea Coast	5.21%
South Norton Sound	33.33%
North Norton Sound	21.51%
Regional Centers	
Bethel	76.61%
Nome	13.89%
Urban Area	
Fairbanks	3.02%

Using these estimates, the demand for subsistence salmon (lbs) in an area for human consumption was calculated by multiplying the per capita demand for salmon by the area's human population. We used population projections produced by the Alaska Department of Labor (ADL), calculated from trends in fertility rates and migration (Bishop et al. 2007). The population projections include low, medium, and high estimates to represent the uncertainty of inputs (Fig. 2). Our predictive model adjusts these population projections to exclude places marginally connected to AYK salmon[17]. The populations of McGrath, Nikolai, Takotna, and Telida were moved from the Yukon-Koyukuk CA (Census Area) to the Middle-Upper Kuskokwim area. We extended the projected population trends to the year 2050.

[15] Estimates of the percentage of salmon in total wild food harvests derived from community subsistence harvest surveys in selected years: Lower Yukon River (Alakanuk 2007); Middle-Upper Yukon River (the mean of Anvik 1990, 2007; Grayling 1990, 2007; Tanana 1987, 2007; and Stevens Village 1984, 2007); Bethel (the mean of 1993-96 salmon harvests divided by estimated total harvest of 170.15 lbs/capita); Lower Kuskokwim River (the mean of Nunapitchuk 1983, Kwethluk 1986, and Akiachak 1998); Middle-Upper Kuskokwim (the mean of Nikolai and McGrath for 1984); South Kuskokwim Bay (Quinhagak 1982); and Bering Sea Coast (Tununak 1984). For the Norton Sound area, mean per capita salmon from post-season salmon surveys in 2000-2003 was divided by the total per capita wild food harvest predicted by the regression equation.

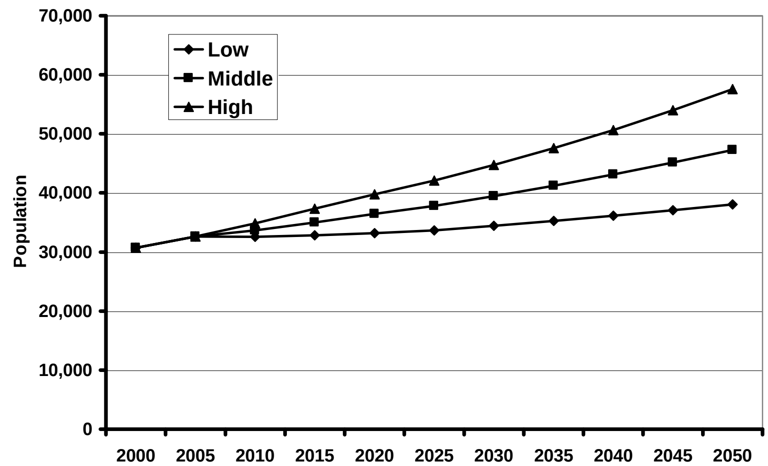
[16] In the set of 149 communities in Table 2, the percentage of salmon decreases slightly as total per capita wild food harvests decrease; however, the relationship is weak (Rsq = 0.1073).

[17] The adjustments removed Bering Sea coastal communities not usually included in the Yukon drainage statistics (Hooper Bay, Chevak, and Scammon Bay), as well as Arctic Village, Central, Coldfoot, Flat, Four Mile Road, Lake Minchumina, Livengood, and Wiseman. Upper Yukon River villages that harvest salmon comprised 77.69% of the Yukon-Koyukuk CA population in 2000. Lower Yukon River villages that harvest salmon comprise 67.57% of the Wade Hampton CA population.

Overall, population projections indicate growing rural populations in the AYK region (Fig. 2). Populations of villages that take salmon are projected to increase from about 30,682 (2000) to 47,282 (2050) (middle projection), an increase of 54.1% (see Fig. 2). The low estimate shows a more modest increase of 24.0% (to 38,057), while the high estimate shows a larger increase of 87.6% (to 57,573). An exception is the Middle-Upper Yukon, where villages that take salmon are projected to decline from 4,899 (2000) to 3,342 (2050), a decrease of 31.8% (middle case). Urban populations in the AYK region also are expected to increase. The Fairbanks area population is projected to increase from 82,840 (2000) to 127,817(2050), an increase of 54.3% (middle case).

Based on these population trends, we can expect more potential human consumers of subsistence salmon in the AYK region (an exception being the villages of the Middle-Upper Yukon). Other things being equal, as population increases, so will demand for salmon.[18]

Fig. 2. Population Projections to 2050 of Villages Harvesting Salmon, AYK Region (Alaska Department of Labor Adjusted Data)



Demand by salmon variety was calculated by multiplying the total salmon harvest by the percentage of each salmon type in an area's catch (Table 5). The percentages of salmon varieties were based on the means since the 1990s, as counted by post-season subsistence salmon surveys of ADF&G. Finally, each salmon variety was divided by a mean fish weight to calculate numbers of fish. These values can be changed in simulations to examine effects; however, for our projections, most are assumed to remain unchanged to 2050.

[18] The ADL population projections are an important driving variable in our subsistence demand equations. If trends differ from these projections, our subsistence projections would also change correspondingly. We made no attempt to evaluate the assumptions on which the population trends are based and have no reason to argue with them. But we note that making long-term regional population projections is difficult due to their sensitivity to in-migration or out-migration, which change in response to many factors including future economic conditions and, potentially, availability of subsistence foods.

Table 5. Assumed Species Composition (by Weight) of
AYK Salmon Harvested for Human Food

Community Type/Area	Chinook	Summer Chum	Fall Chum	Coho	Pink	Sockeye
Villages						
Lower Yukon River	43.50%	48.50%	4.90%	3.10%	0.00%	0.00%
Upper Yukon River	80.00%	7.00%	12.00%	1.00%	0.00%	0.00%
Lower Kuskokwim	63.18%	18.54%	0.00%	6.66%	0.09%	11.52%
Middle-Upper Kuskokwim	55.11%	20.06%	0.00%	12.60%	0.04%	12.18%
South Kuskokwim Bay	65.24%	9.50%	0.00%	12.01%	0.07%	13.18%
Bering Sea Coast	23.05%	58.67%	0.00%	9.72%	0.41%	8.15%
South Norton Sound	20.86%	29.98%	0.00%	23.59%	24.46%	1.11%
North Norton Sound	8.05%	29.80%	0.00%	19.36%	27.06%	15.74%
Regional Centers						
Bethel	64.01%	12.04%	0.00%	12.81%	0.08%	11.05%
Nome	2.22%	37.71%	0.00%	20.50%	19.97%	19.60%
Urban Area						
Fairbanks	75.53%	0.05%	4.12%	20.30%	0.00%	0.00%

Subsistence Demand for Dog Food

In addition to the human consumption of salmon, dogs are consumers of salmon in portions of the AYK region. Dog teams continue to be maintained for sport and utility purposes by some households, particularly in the Middle-Upper Yukon area. Many households also retain dogs as scrap dogs and pets. Numerous species of fish, including several species of salmon, have long provided locally-available and relatively cost-effective food sources for feeding dogs (Andersen 1992, Andersen and Scott 2010). Information on dogs and feeding patterns are the most robust for the Yukon drainage. Data on the use of fish to feed dogs in other portions of the AYK region are less detailed but suggest that these Yukon-based findings are more broadly applicable in the region.

Many households keep *pets or scrap dogs*. These dogs often serve as watchdogs to warn of the presence of bears, and also serve as consumers of family table scraps. The term “scrap dog” has become a more formal designation in some western Alaska communities where the feeding of fish cutting scraps to dogs is considered a culturally respectful way to dispose of fish waste. Households sometimes maintain a number of dogs for this specific purpose. Dogs categorized as scrap/pet dogs are primarily fed using scraps and commercially manufactured dog food. In addition, it is common for fish, including small numbers of whole salmon, to be used as a dietary supplement by some owners. While their individual use of salmon is minimal, the large number of dogs falling into this category can make them significant consumers in aggregate.

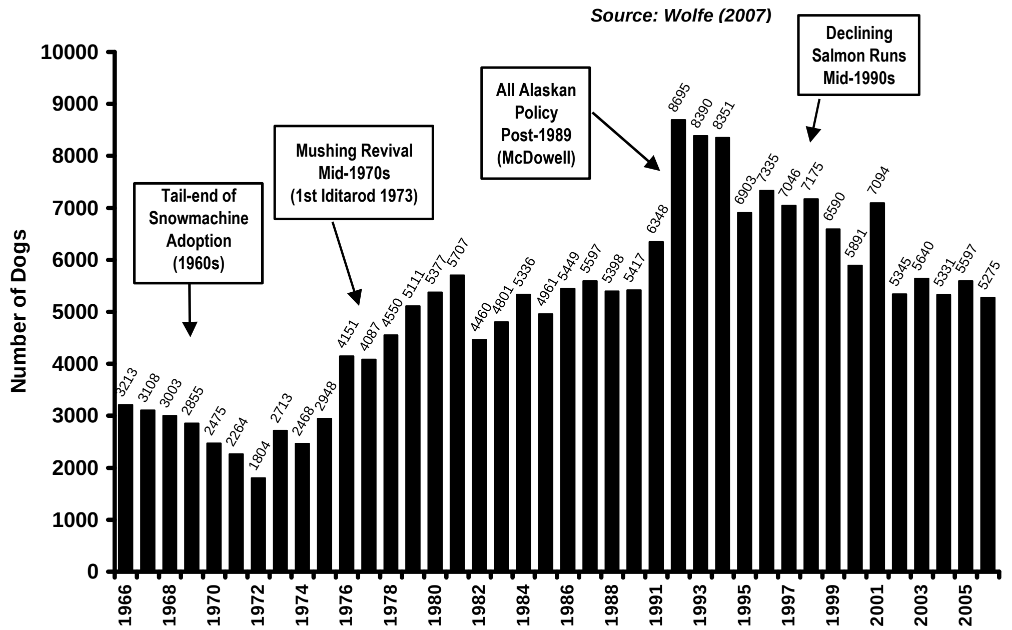
Sled dogs in small lots (less than 25 dogs) represent another dog category. Most dog teams in the AYK region fall into this category. Small yards or kennels of sled dogs are maintained for general winter transportation, trapping, and racing during village carnivals. The kennels commonly consist of a core team of seven to 10 dogs with smaller numbers of younger and older dogs held as spares or in development for eventual placement in the core team. Owners of dogs in small lots tend to be highly reliant on fish for feeding dogs. In some AYK areas, small lot dogs have been major consumers of chum and coho salmon. Mushers maintaining small kennels of sled dogs primarily for racing tend to be less reliant on fish for food than utility teams, but locally-caught fish are often used to supplement the dog’s diets.

Sled dogs in large lots (25 dogs or more) represent a third dog category. In the Upper Yukon River area, some sled dog kennels range in size from 25 to 80 dogs. These large kennels tend to be associated with competitive dog racing. To field a competitive team of 10 to 14 dogs, elite racers will maintain large kennels. Dogs are selected to match specific race distances, trails, and weather conditions. Competitive dog racing requires careful breeding and training regimens. The large kennels typically support one or more “puppy teams” in stages of development, as well as a stable of older dogs that may be past their racing prime but have utility for training and breeding. Dogs in large lots tend to be less reliant on fish as a source of food than smaller lots due to both the special nutritional demands of competitive racing and the monumental tasks of fishing to feed large numbers of dogs. Fish may represent an off-season food staple or in-season food supplement for the most elite dogs, with high-energy commercially manufactured dog foods and supplements serving as their primary food sources.

Before the introduction of snowmachines, virtually every rural household in the AYK region relied on small family-owned teams of sled dogs for winter transportation. Dogs declined with the shift to snowmachines for winter transportation in the early to late 1960s. Dog numbers rebounded during the 1970s following a resurgent interest in dog racing (Fig. 3). While no data sources offer a complete or systematic inventory of historic dog numbers, there are enough community studies that include information on dogs to support these general trends. Sled dog numbers peaked in the early 1990s and have subsequently declined with decreasing interest in racing and increasing costs of dog food. Andersen (2010) associated the most recent decline in sled dog use with the magnified economic stresses being felt in Alaska’s rural communities that make the maintenance of dog teams untenable, and a lack of interested young people to replace aging and retiring mushers. In addition, Wolfe and Scott (2010) found fewer sled dogs on the Middle-Upper Yukon alongside declining uses of fish wheels and decreasing supplies of cheap chum and coho salmon for dog food.

Fig. 3. Dog Population Counts, Yukon Drainage, 1966 - 2006

Source: Wolfe (2007)



To predict future demand for dog food, we estimated the numbers of the three categories of dogs – sled dogs in small yards (less than 25 dogs), sled dogs in large yards (25 or more dogs), and scrap/pet dogs. Counts of dogs owned by salmon fishing households were derived from the post-season surveys of the Alaska Department of Fish and Game. For scrap/pet dogs, we assumed an average of one dog per household, calculated by dividing the area's projected population by mean household size (2000 census values). Residents in the AYK region owned about 12,300 dogs in 2005 (Table 6). The large majority of these dogs (75.35%) fell into the category of scrap/pet dogs. While representing a smaller segment of the dog population, sled dog numbers largely drive scenarios of future salmon consumption by dogs in the region.

To calculate the demand for salmon for dog food, we multiplied the number of dogs by the mean number of salmon consumed per dog, assuming a certain proportion of the diet was salmon for each dog category (Table 7). We assumed that a dog almost exclusively fed salmon would consume at most 200 small salmon per year (chum, coho, or sockeye). On average, dogs are fed considerably less. Estimates for the mean amount of salmon in a dog's diet by area were derived from ADF&G post-season surveys for representative years (shown in parentheses): the Kuskokwim area (1995-99), the Norton Sound area (2000-02), the Fairbanks area (1991-95, 2002-06), and the Yukon villages (1995, 1996, and 1999). The mean contribution of salmon ranged from 10.4 salmon per dog (5.18% of the annual diet) in North Norton Sound to 60.0 salmon per dog (30.0% of the annual diet) in the Upper Yukon area (Table 7). Some owners fed their dogs substantially above the mean, while many others fed their dogs substantially less, particularly on years of low run abundance (see Wolfe et al. 2001). Owners fed other products to sled dogs above those amounts. For the diets of scrap/pet dogs, we assumed nominal amounts of whole salmon (0.5 salmon per dog, except for the Yukon River at 3.0 salmon per dog).

Table 6. Estimated Number of Dogs in the AYK Region, 2005

Community Type/Area	Sled Dogs in Lots <25	Sled Dogs in Lots >25	Scrap/Pet Dogs	Total Dogs
Villages				
Lower Yukon River	90	0	1,524	1,614
Upper Yukon River	731	598	2,396	3,724
Lower Kuskokwim	497	0	1,371	1,868
Middle-Upper Kuskokwim	395	0	719	1,114
South Kuskokwim Bay	21	0	338	359
Bering Sea Coast	0	0	771	771
South Norton Sound	115	0	-	115
North Norton Sound	45	0	-	45
Regional Centers				
Bethel	273	0	2,156	2,429
Nome	-	-	-	-
Urban Area				
Fairbanks	270	0	-	270
Total Dogs	2,436	598	9,275	12,310
	19.79%	*4.86%*	*75.35%*	*100.00%*

Finally, demand by salmon variety for dog food was calculated by multiplying the total salmon harvest by the assumed proportion of each salmon type in an area's catch that is fed to dogs (Table 8). The proportion is based on ADF&G post-season subsistence salmon surveys.

Table 7. Estimated Mean Amounts of Salmon in the Diets of Dogs in the AYK Region, 2000

Community Type/Area	Percentage of Salmon in Dog's Diet: Sled Dogs in Lots <25	Sled Dogs in Lots >25	Scrap/Pet Dogs	Salmon per Dog per Year: in Lots <25	in Lots >25	Scrap/Pet Dogs
Villages						
Lower Yukon River	6.00%	*	1.50%	12.0	*	3.0
Upper Yukon River	30.00%	15.00%	1.50%	60.0	30.0	3.0
Lower Kuskokwim	5.30%	*	0.25%	10.6	*	0.5
Middle-Upper Kuskokwim	11.20%	*	0.25%	22.4	*	0.5
South Kuskokwim Bay	8.80%	*	0.25%	17.6	*	0.5
Bering Sea Coast	0.00%	*	0.25%	0.0	*	0.5
South Norton Sound	7.35%	*	0.25%	14.7	*	0.5
North Norton Sound	5.18%	*	0.25%	10.4	*	0.5
Regional Centers						
Bethel	5.30%	*	0.25%	10.6	*	0.5
Nome	7.35%	*	0.25%	14.7	*	0.5
Urban Area						
Fairbanks	15.00%	*	*	30.0	*	*

* *It is assumed that there are no dogs in this category that consume whole salmon.*

Table 8. Assumed Species Composition of AYK Salmon Harvested for Dog Food, 2000

Community Type/Area	Chinook	Summer Chum	Fall Chum	Coho	Pink	Sockeye
Villages						
Lower Yukon River	0.0%	60.0%	29.8%	10.0%	0.2%	0.0%
Upper Yukon River	0.0%	31.8%	60.0%	8.0%	0.2%	0.0%
Lower Kuskokwim	0.0%	65.8%	0.0%	24.7%	0.0%	9.6%
Middle-Upper Kuskokwim	0.0%	67.6%	0.0%	24.6%	0.0%	7.9%
South Kuskokwim Bay	0.0%	14.0%	0.0%	53.2%	0.0%	32.9%
Bering Sea Coast	0.0%	65.8%	0.0%	24.7%	0.0%	9.6%
South Norton Sound	5.0%	48.2%	0.0%	18.0%	28.4%	0.4%
North Norton Sound	0.1%	31.5%	0.0%	12.8%	45.5%	10.1%
Regional Centers						
Bethel	0.0%	65.8%	0.0%	24.7%	0.0%	9.6%
Nome	0.1%	31.5%	0.0%	12.8%	45.5%	10.1%
Urban Area						
Fairbanks	0.0%	41.8%	50.0%	8.0%	0.2%	0.0%

Subsistence Demand Scenarios

Altogether, our model predicts future subsistence demand for salmon based on ten different factors (Table 9). Six factors are used to predict demand for human food, while four factors are used to predict demand for dog food. Each factor acts as a variable in the predictive model insofar as its value can change over time, potentially affecting future levels of demand for subsistence uses. No one can predict with surety trends of human population, dog numbers, incomes, the relative composition of salmon varieties, and other factors. Accordingly, the model allows for varied assumptions on potential future conditions of these factors and projects what the future demand for salmon would be conditional on those assumptions.

Table 9. Factors Related to Subsistence Salmon Demand for Human Food and Dog Food

<u>Human Food Factors</u>
Population Size (Number of People)
Monetary Incomes (Mean Per Capita)
Cultural Composition (Percent Native)
Community Type (Village, Regional Center, Urban Area)
Salmon in Wild Food Harvests (Percentage)
Salmon Varieties in Harvest (Percentage)
<u>Dog Food Factors</u>
Sled Dogs in Community (Number)
Scrap Dogs in Community (Number)
Salmon in Dog Diets (Percentage)
Salmon Varieties in Harvest (Percentage)

Table 10. Scenarios for Predicted Demand for Subsistence Salmon

	Scenarios (Change Each 5-Yr Period)			
Model Factor	Low	Intermediate One	Intermediate Two	High
1. Per Capita Income (Villages)	+8.0%	+5.0%	+3.0%	0.0%
2. Per Capita Income (Bethel, Nome, Fairbanks)	+6.0%	+5.0%	+3.0%	0.0%
3. Community Cultural Composition	-1.0%	-1.0%	0.0%	0.0%
4. Salmon Contribution in Wild Food Harvest	0.0%	0.0%	+1.0%	+1.0%
5. Human Population Projection in Region	Low	Middle	Middle	High
6. Salmon Species Composition (Human Food)	0.0%	0.0%	0.0%	0.0%
7. Number of Sled Dogs in Small Yards (<25 dogs)	-2.0%	-2.0%	+2.0%	+10.0%
8. Number of Sled Dogs in Large Yards (>25 dogs)	-2.0%	-2.0%	+2.0%	+10.0%
9. Number of Scrap Dogs (Human Population/HH size)	Low	Middle	Middle	High
10. Percentage of Salmon in Diet of Sled Dogs in Small Yards (<25 dogs)	-1.0%	0.0%	+1.0%	+2.0%
11. Percentage of Salmon in Diet of Sled Dogs in Large Yards (>25 dogs)	-1.0%	0.0%	+1.0%	+2.0%
12. Percentage of Salmon in Diet of Scrap Dogs	0.0%	0.0%	0.0%	0.0%
13. Salmon Species Composition of Dog Food Harvest	0.0%	0.0%	0.0%	0.0%

To examine potential futures in regards to subsistence salmon demand, we examined four scenarios, each with a different set of assumptions about future conditions (Table 10). We named the scenarios (*Low*, *Intermediate One*, *Intermediate Two*, and *High*) based on their relative levels of demand for subsistence salmon (low to high). The scenarios were chosen to illustrate just four potential futures for subsistence demand.

The two intermediate scenarios shown in Table 10 assumed human populations would change at the rates of the middle projection of the Alaska Department of Labor. Income (per capita) was assumed to increase by 3.0% or 5.0% each five-year period, representing modest gains by households in employment. The cultural composition (percentage of Alaska Natives) of communities was assumed to either decrease by 1.0% or remain unchanged each five-year period, representing no or modest in-migration or out-migration into the AYK region. Sled dog populations were assumed to either decrease or increase by 2.0% each five-year period, representing modest changes in sled dog numbers. The relative proportion of salmon in wild food diets was assumed to either stay the same or increase by 1.0% each five-year period, representing no or small changes in preference for salmon over other wild foods. The relative composition of salmon species was left unchanged.

By contrast, the low scenario assumed that human populations would change at the rates of the low projection of the Alaska Department of Labor. Incomes were assumed to substantially increase (8.0% per five-year period in villages and 6.0% per five-year period in Bethel, Nome, and Fairbanks), representing substantially higher employment and earnings in villages, town, and cities. The cultural composition (percent Alaska Natives) of rural communities was assumed to decrease by 1.0% each five-year period, representing modest in-migration of non-Natives into the AYK region. The numbers of sled dogs were assumed to decrease by 2.0% each five-year period, representing modest declines. The contribution of salmon in dog diets was assumed to decrease by 1.0% each five-year period, representing modest shifts to store-bought dog food. The relative proportion of salmon in wild food diets was assumed to stay the same, representing no change in preference for salmon over other wild foods. The relative composition of salmon species was left unchanged.

The high scenario assumed that human populations would increase at the rates of the high projection of the Alaska Department of Labor. Incomes were assumed to remain unchanged, representing unchanged employment patterns in villages, town, and cities. The cultural composition (percent Alaska Natives) of communities was assumed to remain unchanged, representing no net gains through in-migration or out-migration into the AYK region. The numbers of sled dogs was assumed to increase by 10.0% each five-year period, representing a resurgent interest in dog racing and transport, similar to the trends of the 1970s. The contribution of salmon in dog diets was assumed to increase by 2.0% each five-year period, representing shifts away from store-bought dog food due to lower disposable incomes. Salmon’s contribution in wild food diets was assumed to increase by 1.0% each five-year period, representing shifts in food preferences toward salmon over other wild foods. The relative composition of salmon species was left unchanged.

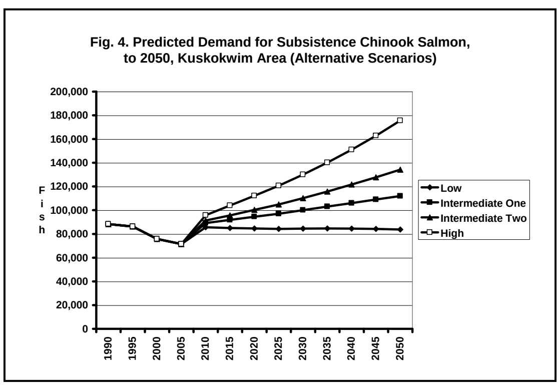
Findings: Subsistence Demand to 2050

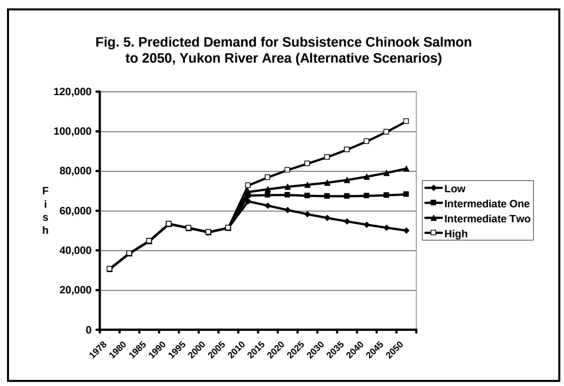
Subsistence demand for salmon to 2050 in the Kuskokwim, Yukon, and Norton Sound areas displays a range of predicted values, depending upon assumed future conditions (Figs. 4 to 15). Predicted demand is shown for each five-year period from 2010 to 2050. Numbers before 2010 are reported subsistence salmon harvests. More details of the predictions (harvests by species, area, human food, and dog food) are summarized in Appendix A.

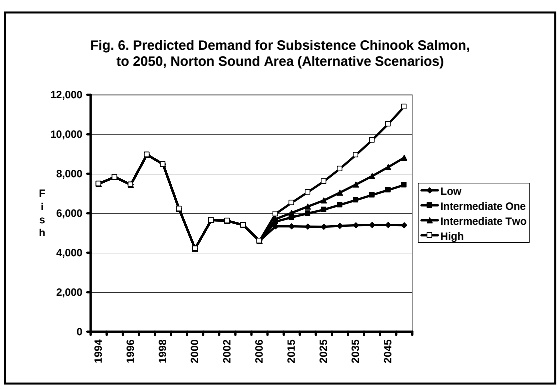
According to our model’s outcomes, the ranges of potential demand for subsistence salmon depend on assumed future conditions, salmon variety, and area. The predictive model of subsistence demand provides a way to assess the initial research hypothesis that predicts subsistence fishing in the AYK region will “remain the same or decline”.

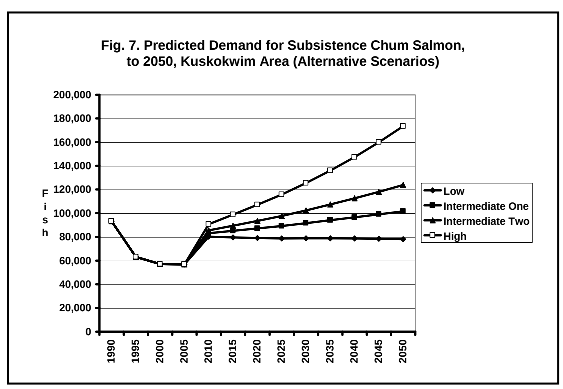
In the Kuskokwim area, demand for Chinook, chum, sockeye, and coho remains the same or declines slightly under the low scenario conditions. This is true for all Kuskokwim areas and species. Demand increases for all salmon species and Kuskokwim areas under the other scenarios. The greatest increase (in terms of numbers of fish) occurs on the lower Kuskokwim River, an area with the most villages and village population. Harvest for dog food is largest on the middle-upper river, representing from 16% to 22% of the harvest. Otherwise, the increased demand for salmon is primarily for human food in the Kuskokwim area.

In the Yukon area, demand for Chinook, summer chum, fall chum, and coho remains the same or declines slightly under the low scenario conditions. Under most other scenarios, demand increases for Chinook and summer chum, fall chum, and coho, due primarily to increased demand for food along the lower river (Subdistricts Y1-Y3) for growing human populations. Along the middle-upper river, demand for salmon as human food declines under all scenarios, principally due to falling human populations. Under most scenarios, total demand for salmon for human food increases in the Yukon area. Demand for summer chum, fall chum, and coho along the middle-upper river is sensitive to dog populations as dog food remains a significant component of subsistence demand for small salmon species. If dog populations increase substantially, as in the high scenario, demand for small salmon also increases substantially. Otherwise, dog food demand changes slightly up or down to 2050 along the middle-upper river. Along the lower river, demand for dog food remains relatively low under all scenarios.









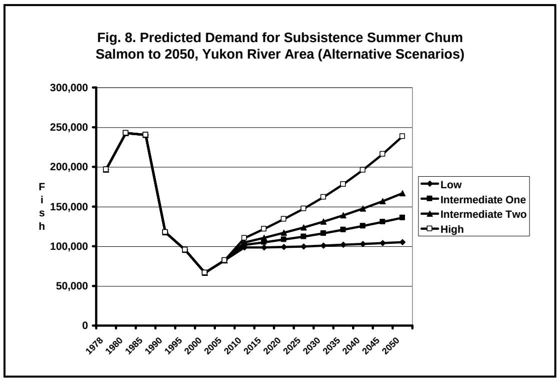


Fig. 8. Predicted Demand for Subsistence Summer Chum Salmon to 2050, Yukon River Area (Alternative Scenarios)
Fish
Low
Intermediate One
Intermediate Two
High

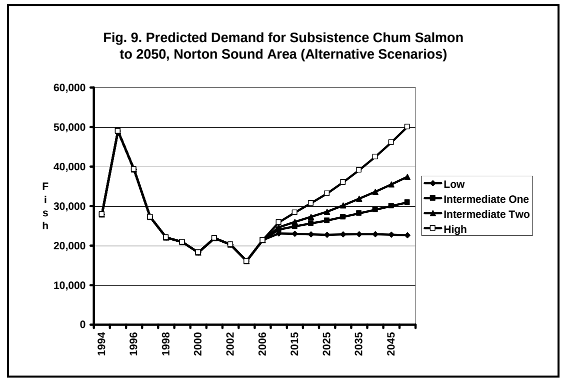


Fig. 9. Predicted Demand for Subsistence Chum Salmon to 2050, Norton Sound Area (Alternative Scenarios)
Fish
Low
Intermediate One
Intermediate Two
High

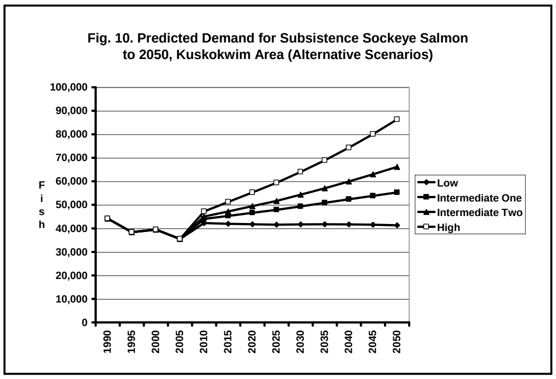


Fig. 10. Predicted Demand for Subsistence Sockeye Salmon to 2050, Kuskokwim Area (Alternative Scenarios)
Fish
Low
Intermediate One
Intermediate Two
High

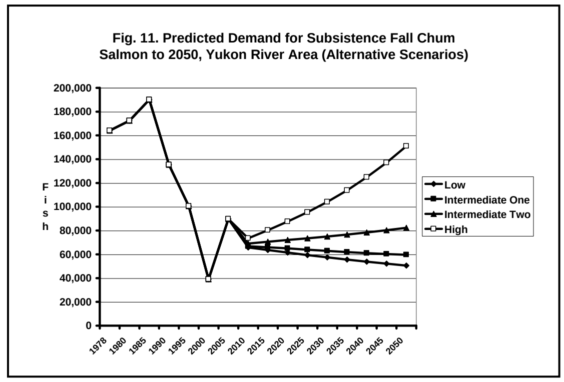


Fig. 11. Predicted Demand for Subsistence Fall Chum Salmon to 2050, Yukon River Area (Alternative Scenarios)
Fish
Low
Intermediate One
Intermediate Two
High

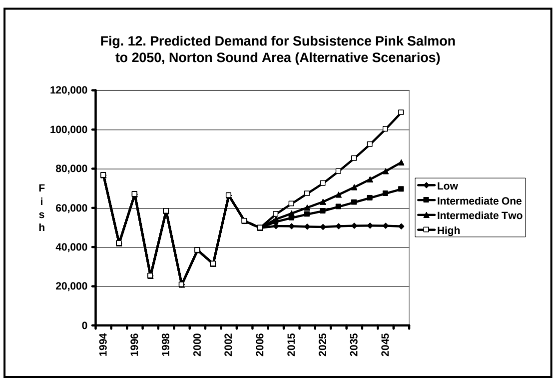


Fig. 12. Predicted Demand for Subsistence Pink Salmon to 2050, Norton Sound Area (Alternative Scenarios)
Fish
Low
Intermediate One
Intermediate Two
High

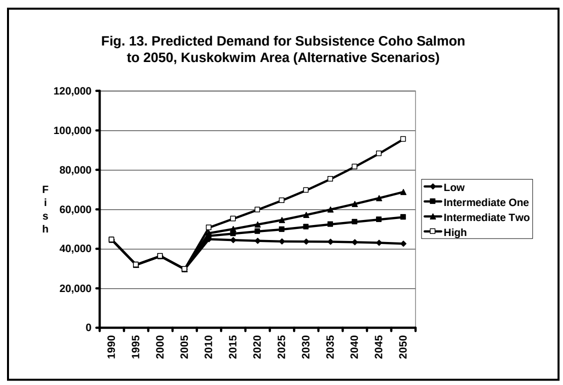


Fig. 13. Predicted Demand for Subsistence Coho Salmon to 2050, Kuskokwim Area (Alternative Scenarios)
Fish
Low
Intermediate One
Intermediate Two
High

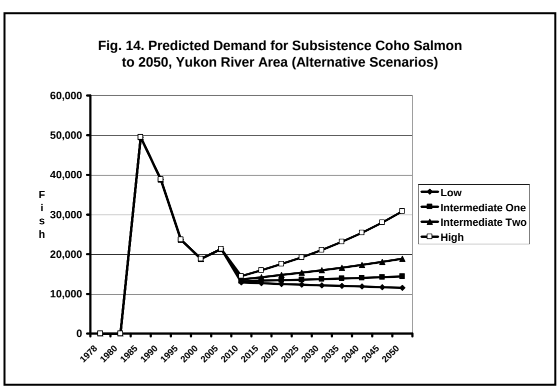


Fig. 14. Predicted Demand for Subsistence Coho Salmon to 2050, Yukon River Area (Alternative Scenarios)
Fish
Low
Intermediate One
Intermediate Two
High

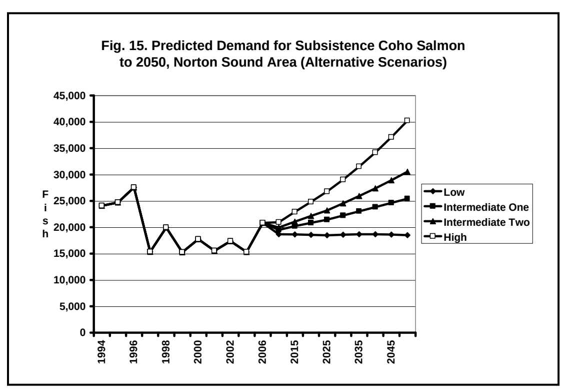


Fig. 15. Predicted Demand for Subsistence Coho Salmon to 2050, Norton Sound Area (Alternative Scenarios)
Fish
Low
Intermediate One
Intermediate Two
High

In the Norton Sound area, demand for Chinook, chum, sockeye, coho, and pink remains stable under the low scenario (with slight declines for Nome). Demand for these species increases under all other scenarios, primarily for human food in the villages. Demand for salmon for dog food changes with trends in sled dog numbers, but remains a relatively small component of the area's salmon harvests.

Overall, demand for subsistence salmon increases under most future scenarios examined for the AYK region. Among this range of potential futures, there are fewer cases where subsistence demand "remains the same or declines."

Table 11. Predicted Subsistence Demand in 2020 and 2050 Compared with the Amounts Necessary for Subsistence (ANS) as Determined by the Alaska Board of Fisheries *

ANS Stock		Amount Necessary for Subsistence	Predicted Subsistence Demand for ANS Stock by Scenario							
			Low		Intermediate 1		Intermediate 2		High	
Area	Variety		2020	2050	2020	2050	2020	2050	2020	2050
Norton Sound, Subdistrict 1	Chum	3,430 - 5,716	3,077	2,608	3,461	3,635	3,768	4,864	4,366	7,040
Norton Sound - Port Clarence Area	Salmon	96,000 - 160,000	101,819	101,674	114,316	139,470	121,387	167,473	136,105	220,338
Yukon-Northern Area	Chinook	45,500 - 66,704	60,364	49,965	67,866	68,231	72,076	81,232	89,436	104,981
	Summer chum	83,500 - 142,192	98,983	105,024	108,882	137,213	117,034	166,678	134,128	238,338
	Fall chum	89,500 - 167,100	61,473	50,595	65,589	61,704	72,104	82,305	87,627	151,029
	Coho	20,500 - 51,980	12,494	11,539	13,548	14,697	14,766	18,856	17,538	30,822
Kuskokwim River Drainage	Chinook	64,500 - 83,000	77,932	76,649	87,099	102,660	92,464	123,414	103,632	161,950
	Chum	39,500 - 75,500	70,259	68,760	77,436	89,377	83,222	109,619	95,773	155,515
	Sockeye	27,500 - 39,500	37,875	39,614	42,337	49,919	44,921	59,893	50,313	78,446
	Coho	24,500 - 35,000	39,614	37,913	43,899	49,951	47,141	61,697	54,004	86,393
Kuskokwim Area Remainder	Salmon	7,500 - 13,500	23,709	25,037	26,376	32,987	27,746	38,289	30,721	48,595

* *5AAC 01,186, 01,236, 01.286*

In Table 11, our model's predictions for subsistence demand (for the four scenarios in 2020 and 2050) are compared with the amounts necessary for subsistence (ANS) set by the Alaska Board of Fisheries in regulation for 11 salmon stocks (5AAC 01.186, 01.236, and 01.286). In the low subsistence scenario, predicted subsistence demand falls within the ANS ranges for 6 of 11 stocks, falls below for 3 stocks, and exceeds it for 2 stocks. In the high scenario, subsistence demand (by 2050) exceeds the high range of the ANS for 9 of 11 stocks, and falls within it for 2 stocks (fall chum and coho in the Yukon-Northern Area). For the two intermediate scenarios, subsistence demand within the Kuskokwim River Drainage and Kuskokwim Area Remainder exceeds the ANS ranges by 2020 for all stocks. For the two intermediate scenarios, predicted subsistence demand within the Norton Sound and Yukon-Norton areas tends to fall within the ANS ranges for most salmon stocks, with the exception of Chinook salmon in the Yukon-Northern area where predicted demand exceeds the ANS range. Overall, predictions such as these suggest that changes in subsistence demand over time may lead to requests by salmon users for revisions of ANS determinations by the Alaska Board of Fisheries.

Overview of Commercial Harvest Analysis

The Commercial Harvest Component is the third component of the predictive model. This component was designed to project future harvests of commercial salmon in the AYK region. We begin our analysis with a brief overview of the methodology for projecting future commercial harvests. We then discuss, in turn (a) historical AYK commercial harvests; (b) our assumptions about future harvestable commercial surpluses; (c) factors affecting future utilization of harvestable commercial surpluses; (d) our formula for projecting future utilization; and (e) our projections of future commercial harvests.

Future salmon harvests for commercial sale will be constrained by the harvestable *surpluses* for each stock. The *surplus* is the number of fish available for commercial harvest after escapement, subsistence demand, and other priorities are sufficiently met.

For each stock, we project the commercial harvest in any given year as the *surplus* multiplied by *utilization*, the share of the surplus which is harvested:

$$\text{Harvest} = \text{Surplus} \times \text{Utilization}$$

Future surpluses will be driven by returns, subsistence demand, and management actions to achieve escapement and subsistence goals. Future utilization will be driven by economic factors including wholesale prices of AYK salmon products and costs of harvesting, processing, and transporting salmon to markets, which ultimately determine the potential for both harvesting and processing to be profitable. Surpluses also affect utilization, because the size, variability, and uncertainty of surpluses affect both unit costs of harvesting and processing as well as risks associated with investments in harvesting and processing.

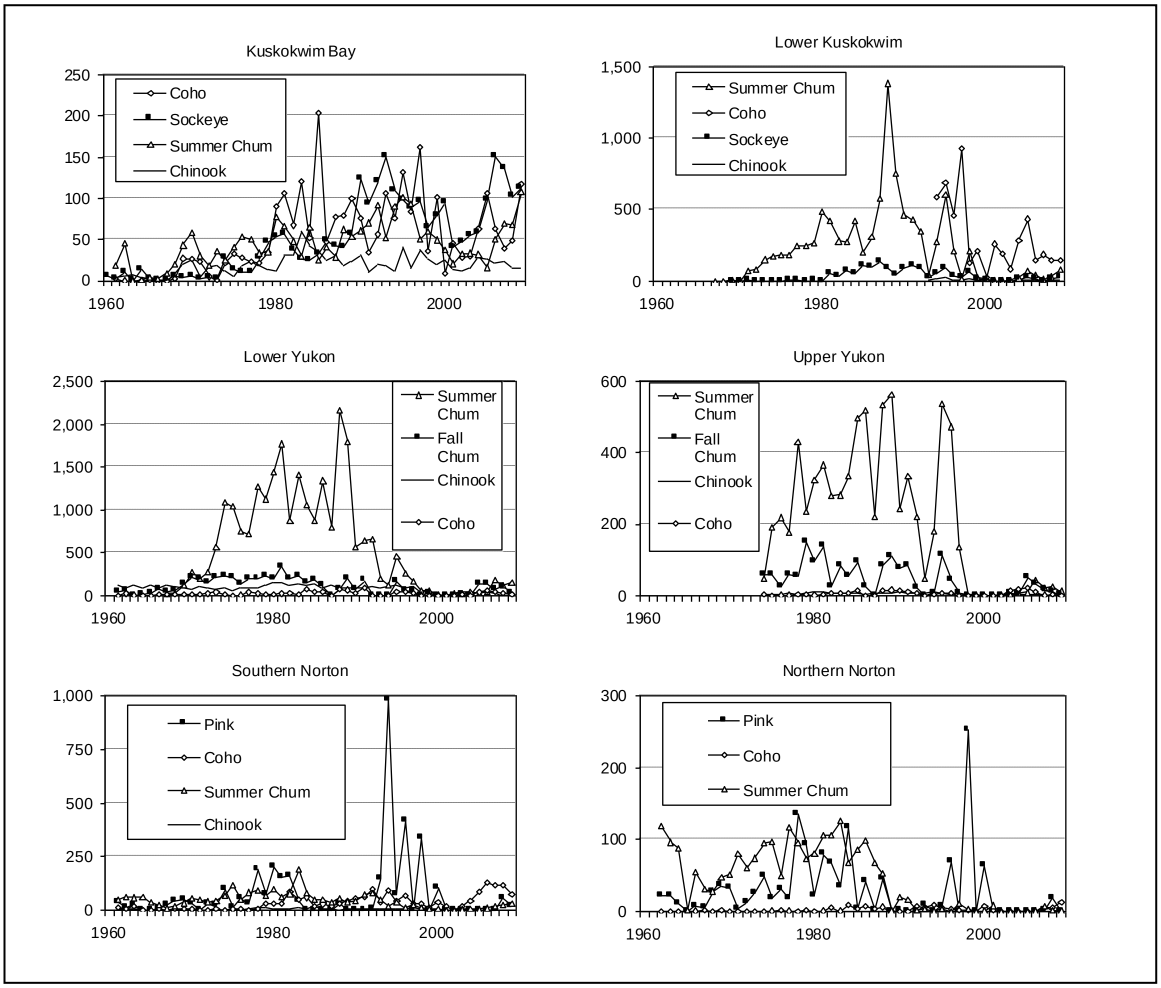
For each stock, we estimated probability distributions for future surpluses by subtracting escapement goals and projected subsistence demand from our estimated probability distributions for future runs. We developed a formula for utilization as a function of assumptions about future economic conditions and surpluses. We then examined the implications of different assumptions about surpluses and economic conditions for the probability distribution of future harvests.

Our commercial harvest projections are inherently much more uncertain than our subsistence demand projections. It is reasonable to project specific levels of future subsistence demand for future years, such as those discussed above. In contrast, given the inherent uncertainty and variability of future salmon returns, it is impossible to project specific levels of future commercial harvestable surpluses or commercial harvests for future years. We can only think of future harvestable surpluses and harvests as *probability distributions*, as ranges within which harvestable surpluses are likely to lie. Although we can describe these with probability distributions with statistical indicators such as the mean, maximum, 10^{th} and 90^{th} percentiles, we cannot predict what harvests will be in any given year.

Historical Commercial Harvests

Historical commercial salmon harvests for the years 1961-2009 are summarized in Fig. 16. Note that over these five decades, for each stock, commercial harvests varied widely both from year to year as well as over longer-term periods. Different stocks showed different trends over time. The scale of harvests varied widely for different species within an area, as well as between areas. Put simply, there is no obvious or common pattern or trend in commercial harvests.

Fig. 16. AYK Commercial Salmon Harvests, by Area 1961-2009 (Thousands of Fish).



If we had enough data, and talked with fishermen, processors and managers familiar with the specific historical circumstances for each stock over time, we could develop explanations for the year-to-year and longer-term changes in commercial harvests for each stock. These would include changes in the commercially *harvestable surpluses* for each stock as a result of changes in returns, management policies, and subsistence harvests. They would also include changes in numbers of buyers, ex-vessel prices, costs of fishing, and other factors that affected the historical *utilization* of harvestable surpluses.

For this analysis, we have not attempted to develop explanations for historical changes in harvests for AYK salmon stocks. One important reason is that no data are available for historical harvestable surpluses or utilization rates. Further, only limited data are available for economic factors affecting utilization rates. Lack of data makes it impossible to develop a formal statistical model of the factors driving historical harvests. Even if data were available to develop such a model, it would be of limited value for projecting future harvests given the uncertainty associated with changes in future salmon returns, subsistence demand, and economic factors affecting utilization of harvestable surpluses.

Consider how difficult it would have been in 1970 to predict specifically how and why AYK commercial salmon harvests of each stock would change over the four decades between 1970 and 2010. It would have been impossible to predict the varying trends in returns and harvestable surpluses for different AYK stocks. Similarly, it would have been impossible to predict the dramatic changes in utilization over time driven by factors such as competition from farmed salmon, competition from other regions of Alaska, changes in the Japanese economy, and (most recently) growing demand for wild salmon (Knapp 2009).

In thinking about how AYK commercial salmon harvests may change over the next four decades, we should recognize that we face similar fundamental uncertainties as we would have faced in 1970. Any long-term projections of future AYK commercial salmon harvests are inherently highly uncertain. Most fundamentally, this uncertainty derives from uncertainty about future returns, exacerbated by the uncertain future effects of climate change. It is compounded by uncertainties associated with subsistence demand and economic conditions. The uncertainty increases the farther we attempt to project into the future. For these reasons, it is important to think of our commercial harvest projections not as predictions but rather as illustrations of what future harvest trends might look like under different assumptions about future returns, subsistence demand, and economic conditions.

The most certain thing we can say about AYK commercial salmon harvests over the next four decades is the same basic points that applied for historical harvests. Commercial harvests are likely to vary widely from year to year, average commercial harvests are likely to vary widely over longer periods, and long-term trends in commercial harvests are likely to vary widely between stocks.

Commercial Harvestable Surpluses

The starting point for our projections of future AYK commercial harvests was the development of *harvestable surplus scenarios*: sets of simulations of potential future harvestable surpluses. As discussed above, we calculated these simulations as the difference between the simulations of total returns and the sum of assumed escapements, subsistence harvests, and "other priorities" (fish reserved for other parts of the river system):

Harvestable surplus = Total return – Escapement – Subsistence harvests – Other priorities

For each stock, three sets of probability distributions were developed for future returns to the system for each year between 2010 and 2050: "Historic," "Low," and "High". The "historic" distributions were based on the assumption that future runs would have the same probability distribution as was estimated for past runs. The "low" and "high" probability distributions were illustrative of alternative distributions which would generate higher or lower future harvests, on average. Based on these probability distributions, three sets of 1,000 “run simulations” for the period 2010-2050 were generated for each stock.

For each set of run simulations, four sets of harvestable surplus simulations were calculated, corresponding to four different assumptions about future subsistence demand. Thus for each stock, 12 sets of 1,000 harvestable surplus simulations were generated (Table 12). We refer to each of these sets of simulations as a “harvestable surplus scenario” or simply a “scenario.”

Table 12. Harvestable Surplus Scenarios

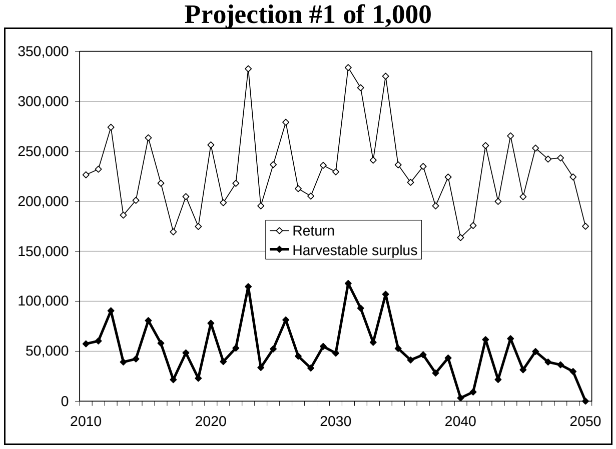
			Assumptions about Probability Distribution of Future Returns *Higher Surplus →*		
			Low	*Historic*	*High*
Assumptions about Future Subsistence Demand	*Lower Surplus→*	*Historic*	Low Return- Low Subsistence	Historic Return- Low Subsistence	High Return- Low Subsistence
		Int1	Low Return- Int1 Subsistence	Historic Return- Int1 Subsistence	High Return- Int1 Subsistence
		Int2	Low Return- Int2 Subsistence	Historic Return- Int2 Subsistence	High Return- Int2 Subsistence
		High	Low Return- High Subsistence	**Historic Return- High Subsistence**	High Return- High Subsistence

Note: We use the “Historic Return-High Subsistence” scenario to illustrate our discussion.

For our discussion below, we use the “Historic Return-High Subsistence” scenarios to illustrate our projection methodology. In using this scenario we do not mean to imply that this scenario is more “likely”: it is very difficult to say very much about the relatively likelihood of our twelve scenarios. However, it is useful to use the “high future subsistence demand” assumptions for purposes of illustration because it makes it easier to see how growth in subsistence demand might affect projected harvestable surpluses over time.

For each harvestable surplus scenario, the 1,000 projections together describe, in effect, a probability distribution for harvestable surpluses for each year, derived from the probability distribution for future returns. Figure 17 shows the projected return and harvestable surplus corresponding to one simulation for this stock and scenario. Each of the 999 other simulations for this stock and scenario shows a different random pattern of year-to-year variation, although they all vary within similar ranges.

Fig. 17. Lower Yukon Chinook: Projected Return and Harvestable Surplus (Historic Return-High Subsistence Scenario), Projection #1 of 1,000



Our assumed probability distributions for future returns do not assume any trend over time or any relationship between individual years. In effect, each year's return is considered a random draw from a stationary probability distribution. As discussed above, the probability distribution for future returns was estimated based on available historical data for several decades. This means that for those stocks for which runs and harvestable surpluses for a stock have been relatively low for the most recent historical decade (since 2000), our projections will tend to show an immediate increase in projected future harvests, while for those stocks for which runs and harvestable surpluses have been relatively high for the most recent historical decade, our projections will tend to show an immediate decrease in projected future harvests.

In contrast to future returns, future harvestable surpluses may show a trend over time if projected subsistence harvests show a trend over time. In Fig. 17, for Lower Yukon Chinook, harvestable surplus exhibits a downward trend over time. This is because in the "high subsistence" scenario, projected Lower Yukon Chinook subsistence demand increases over time which results in a decreasing projected commercial harvestable surplus after subsistence demand is subtracted from the projected return.

Figure 18 compares historical harvests of Lower Yukon Chinook for several different measures of the probability distribution for projected future harvestable surpluses for the years 2011-2050. The figure also shows the first of the 1,000 simulations for the harvestable surplus. Note that most, but not all of the projected harvestable surpluses fall within the 10th percentile to 90th percentile band, and all are well below the maximum.

Fig. 18. Lower Yukon Chinook, Historic Harvests and Selected Indicators of Projected Harvestable Surplus (Historic Return-High Subsistence Scenario).

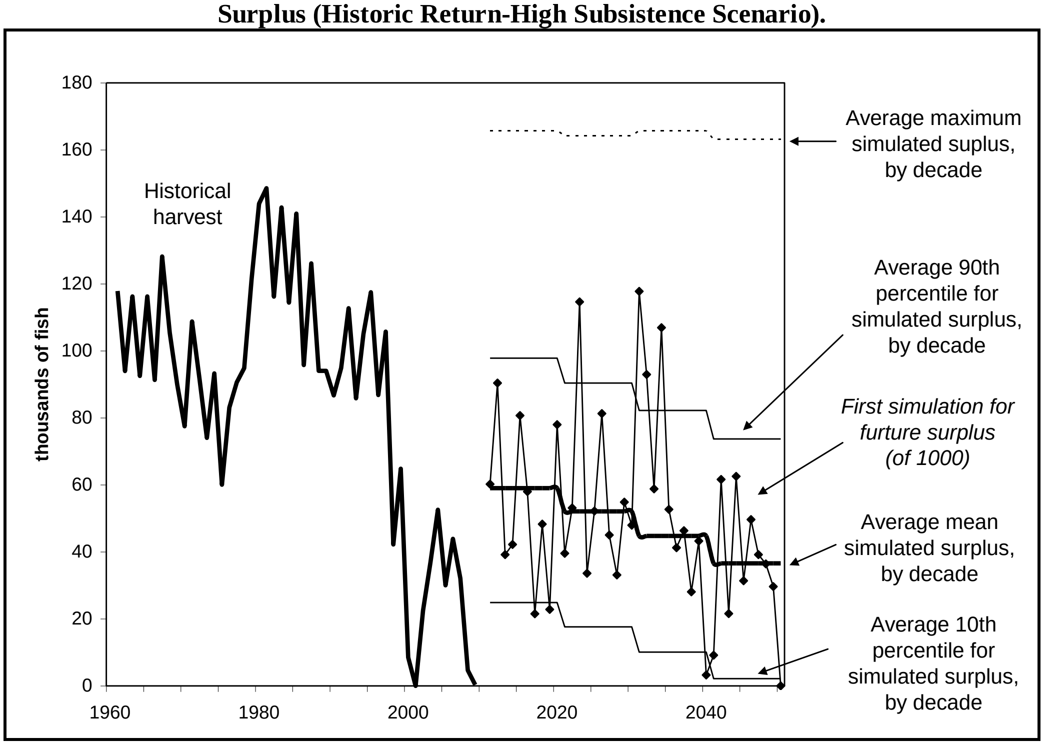
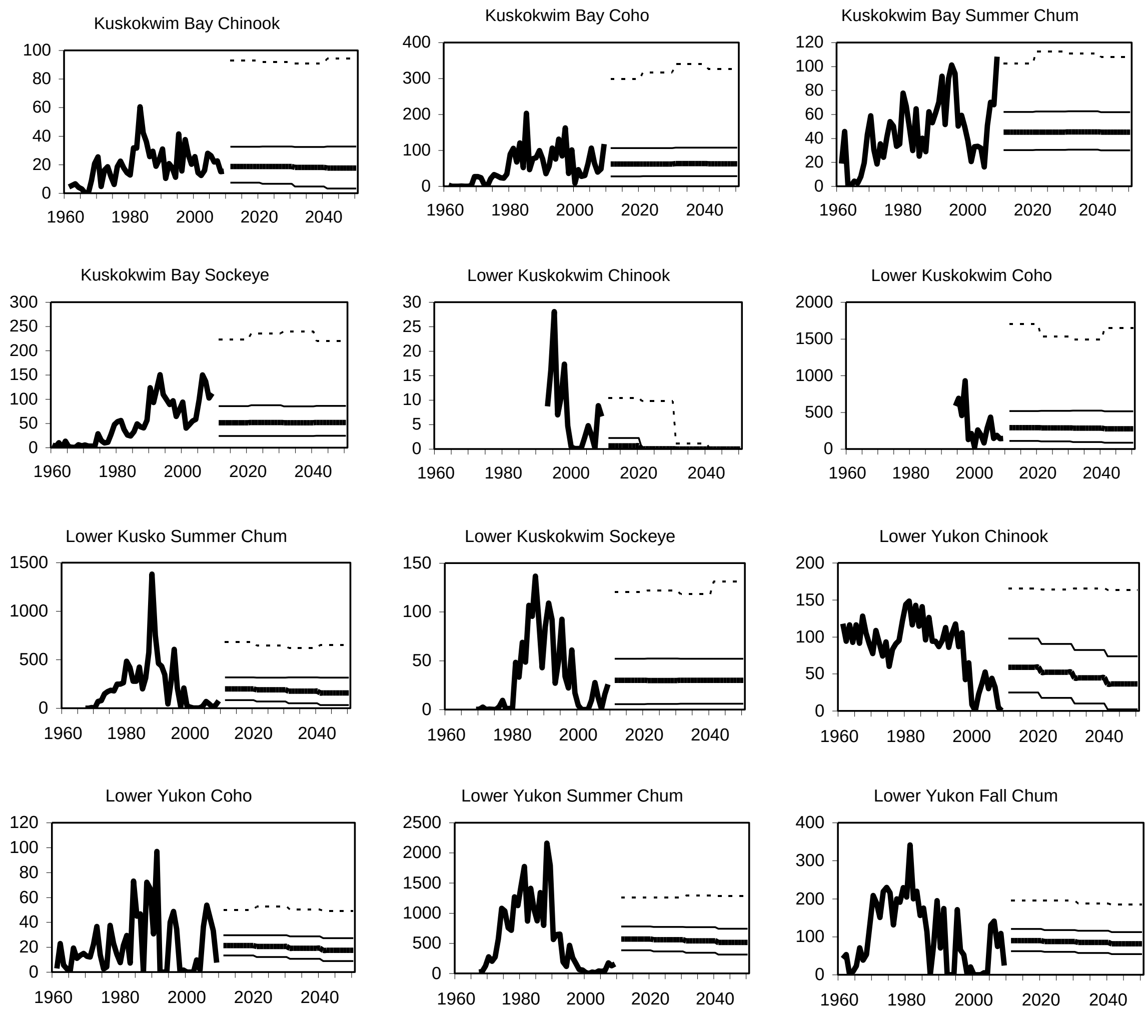


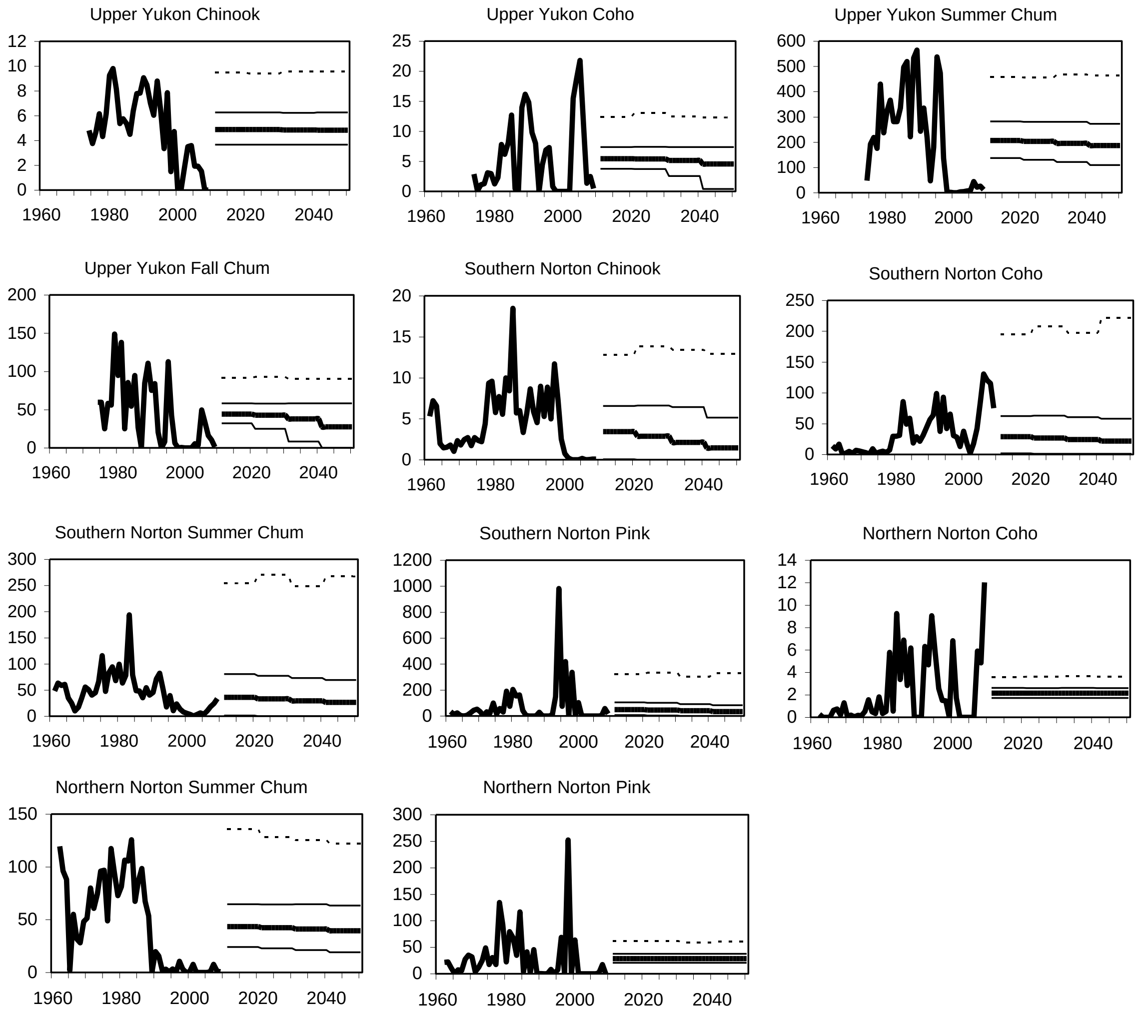
Figure 19 shows, for each stock, similar comparisons of historical harvests with the same four measures of the probability distribution for projected future harvestable surpluses for the years 2011-2050 for the "Historic Return-High Subsistence" scenarios. For each scenario, these projections of harvestable surplus were the starting point for our projections of future commercial harvests. They reflect the assumptions and methodologies (discussed above) used to develop probability distributions for future returns and to predict subsistence demand. Any limitations to those assumptions and methodologies are incorporated in these projections of harvestable surpluses.

Fig. 19. Historic Harvests and Selected Indicators of Projected Harvestable Surplus, by Stock (Historic Return-High Subsistence Scenario).



Note: Scales vary widely for different stocks. Data for the full historical period 1961-2009 were not available for some stocks. Figure continues on next page.

Fig. 19 (continued).



As discussed above, we developed twelve different scenarios corresponding to twelve different sets of assumptions about the probability distribution of future returns (Low, Historic, and High) and four sets of assumptions about the future subsistence demand (Low, Intermediate One, Intermediate Two, and High). Rather than presenting twelve similar sets of figures illustrating projected harvestable surpluses for each scenario, below we compare these projections only in terms of the mean harvestable surplus for the period 2011-2050 and the mean harvestable surplus by decade. However, note that all projections have similarly wide ranges for the probability distributions of projected surpluses, so they should not be viewed as point estimates.

Table 13 shows the mean projected harvestable surplus (averaged across all 1,000 runs and all years) for all 12 scenarios for all stocks.

Table 13. Mean Harvestable Surplus, 2011-2050, by Return and Subsistence Demand Scenarios (thousands of fish)

		Historic return				High return				Low return			
		Subsistence demand scenario				Subsistence demand scenario				Subsistence demand scenario			
Area	Species	Low	Int 1	Int 2	High	Low	Int 1	Int 2	High	Low	Int 1	Int 2	High
Kuskokwim Bay	Chinook	18.8	18.8	18.5	18.3	21.1	20.3	19.7	18.6	14.6	13.6	12.9	11.7
	Coho	62.3	62.4	62.3	62.5	71.3	71.9	71.9	71.7	67.2	66.3	66.4	65.0
	Summer Chum	45.2	45.2	45.2	45.2	47.0	46.9	46.9	47.0	46.9	46.9	47.0	47.0
	Sockeye	51.4	51.5	51.2	51.6	58.6	58.8	58.7	59.0	57.5	57.3	57.1	57.5
Lower Kuskokwim	Chinook	4.4	1.2	0.6	0.2	4.9	1.6	0.8	0.2	4.7	1.4	0.7	0.2
	Coho	296.9	294.8	292.7	285.5	344.6	345.8	347.0	345.3	188.5	184.1	180.4	170.0
	Summer Chum	205.7	201.3	197.3	180.6	239.8	239.8	239.3	235.1	231.9	226.1	217.6	198.8
	Sockeye	29.8	29.8	29.9	29.9	36.3	36.3	36.4	36.3	18.0	18.2	18.1	18.2
Lower Yukon	Chinook	76.8	67.7	60.9	48.1	85.2	80.8	76.1	65.0	71.4	60.9	53.9	40.6
	Coho	21.6	21.0	20.5	19.6	22.7	22.5	22.2	21.4	22.7	22.4	22.0	21.1
	Summer Chum	574.7	565.7	560.4	546.4	596.2	593.7	588.5	579.9	594.0	594.9	591.1	586.8
	Fall Chum	91.1	89.3	88.3	85.8	101.3	99.9	98.9	96.5	90.3	88.7	87.9	85.6
Upper Yukon	Chinook	4.9	4.9	4.9	4.9	5.0	5.0	5.0	5.0	5.0	5.0	5.0	4.9
	Coho	5.5	5.5	5.4	5.1	5.8	5.8	5.8	5.6	5.8	5.8	5.8	5.6
	Summer Chum	209.1	208.2	207.7	198.1	216.3	216.4	215.8	211.2	215.1	215.6	213.6	202.8
	Fall Chum	44.7	44.7	44.6	38.1	45.3	45.4	44.8	32.8	45.4	45.4	45.5	44.6
Southern Norton	Chinook	4.0	3.5	3.1	2.5	4.6	4.5	4.3	3.8	3.3	2.5	2.1	1.5
	Coho	31.4	29.3	27.9	25.3	41.5	41.0	40.3	39.4	21.3	18.9	17.4	15.3
	Summer Chum	39.9	36.5	34.8	31.2	53.7	53.2	53.0	51.1	29.1	26.2	24.6	21.3
	Pink	55.3	50.2	47.7	42.3	73.2	70.7	69.5	67.1	37.8	32.4	29.5	24.4
Northern Norton	Coho	2.2	2.2	2.1	2.1	2.3	2.3	2.3	2.3	2.3	2.3	2.2	2.3
	Summer Chum	44.0	43.5	42.8	41.6	47.4	47.1	47.3	47.2	40.8	39.8	38.7	37.0
	Pink	28.5	28.1	27.8	28.6	29.5	29.5	29.4	29.5	28.9	28.4	27.8	28.6

Note that the relative differences in mean harvestable surplus among the “Historic return,” “High return,” and “Low return” scenarios varies by stock. This is because the relative size of escapement and subsistence demand in relation to the total return varies among stocks. The higher escapement and subsistence demand are relative to the total return, the greater the *relative* effect of a change in the total return on the residual portion of the run available for commercial harvest.

As can be seen in Table 13, the higher subsistence demand, the lower the harvestable surplus available for commercial harvests, and vice versa. In general, for each return scenario, as subsistence demand increases from “low” to “high,” the mean harvestable surplus decreases.[19]

As shown in Table 14, the relative effects of subsistence on mean harvestable surplus over time vary by stock. For example, in the “high” subsistence scenario, the Lower Kuskowim mean harvestable surplus of coho declines by 5% between 2011-20 and 2041-50, while the Lower Kuskokwim mean harvestable surplus of summer chum declines by 20%. The relative percentage decline depends upon both the relative size of the surplus and the relative change in subsistence demand; the smaller the stock, the greater the relative effect of a given change in subsistence demand over time.

[19] There are a few stocks and scenarios for which this does not consistently hold, such as for the Kuskokwim Bay coho historic run scenarios, on the second row of the table at the left. This is because the data for each cell of the table are means of 1,000 projections from a probability distribution. When differences in subsistence demand between scenarios is low, random variation in the means of projected harvestable surpluses may outweigh the effects of small changes in subsistence demand.

Table 14. Mean Harvestable Surplus by Decade, Historic Return Scenarios (thousands of fish)

		Mean harvstable surplus, 2011-20				Mean harvestable surplus, 2041-50				Percent change, 2011-20 to 2041-50			
		Subsistence demand scenario				Subsistence demand scenario				Subsistence demand scenario			
Area	Species	Low	Int1	Int2	High	Low	Int1	Int2	High	Low	Int1	Int2	High
Kuskokwim Bay	Chinook	18.9	18.8	18.8	18.7	18.7	18.6	18.2	17.6	-1%	-1%	-3%	-6%
	Coho	62.8	62.9	62.5	62.1	62.2	62.7	62.6	62.8	-1%	0%	0%	1%
	Summer Chum	45.0	45.3	45.2	45.2	45.3	44.8	45.2	45.1	1%	-1%	0%	0%
	Sockeye	51.2	51.6	51.2	51.5	50.9	51.6	51.4	51.8	0%	0%	0%	1%
Lower Kuskokwim	Chinook	4.3	2.5	1.7	0.6	4.6	0.3	0.0	0.0	8%	**-87%**	**-99%**	**-100%**
	Coho	295.7	299.0	296.0	292.0	298.1	292.5	291.0	276.6	1%	-2%	-2%	-5%
	Summer Chum	205.1	203.9	204.2	198.6	205.4	198.9	189.6	158.1	0%	-2%	-7%	**-20%**
	Sockeye	29.8	29.7	30.0	29.8	29.9	29.9	30.2	30.0	0%	1%	1%	1%
Lower Yukon	Chinook	72.1	67.4	64.0	59.0	80.5	67.6	56.4	36.6	12%	0%	**-12%**	**-38%**
	Coho	21.8	21.5	21.4	21.2	21.4	20.2	19.4	17.5	-2%	-6%	**-9%**	**-17%**
	Summer Chum	574.4	571.9	571.9	571.1	575.8	555.7	545.9	515.7	0%	-3%	-5%	**-10%**
	Fall Chum	92.0	91.2	90.7	89.7	90.0	87.4	85.6	81.5	-2%	-4%	-6%	-9%
Upper Yukon	Chinook	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.8	0%	0%	0%	-1%
	Coho	5.5	5.5	5.4	5.4	5.5	5.5	5.4	4.6	0%	0%	0%	**-16%**
	Summer Chum	208.4	207.8	207.8	206.9	210.2	208.1	208.1	186.4	1%	0%	0%	**-10%**
	Fall Chum	44.8	44.7	44.6	44.1	44.6	44.7	44.5	27.6	0%	0%	0%	**-37%**
Southern Norton	Chinook	4.0	3.8	3.7	3.4	4.0	3.1	2.5	1.4	0%	**-18%**	**-33%**	**-58%**
	Coho	31.4	30.4	30.0	28.7	31.2	27.8	25.8	21.6	0%	**-9%**	**-14%**	**-25%**
	Summer Chum	40.3	38.1	37.6	36.2	39.7	35.4	31.7	26.2	-2%	**-7%**	**-16%**	**-28%**
	Pink	56.0	53.1	52.7	49.6	55.2	47.6	42.2	33.6	-2%	**-10%**	**-20%**	**-32%**
Northern Norton	Coho	2.1	2.1	2.2	2.2	2.2	2.1	2.1	2.1	1%	0%	0%	0%
	Summer Chum	44.0	43.9	43.4	43.4	43.7	43.7	41.9	39.4	-1%	-1%	-3%	-9%
	Pink	28.4	28.2	28.3	28.6	28.5	28.0	27.2	28.6	0%	-1%	-4%	0%

Note: **Bold** indicates percentage change exceeds -10%.

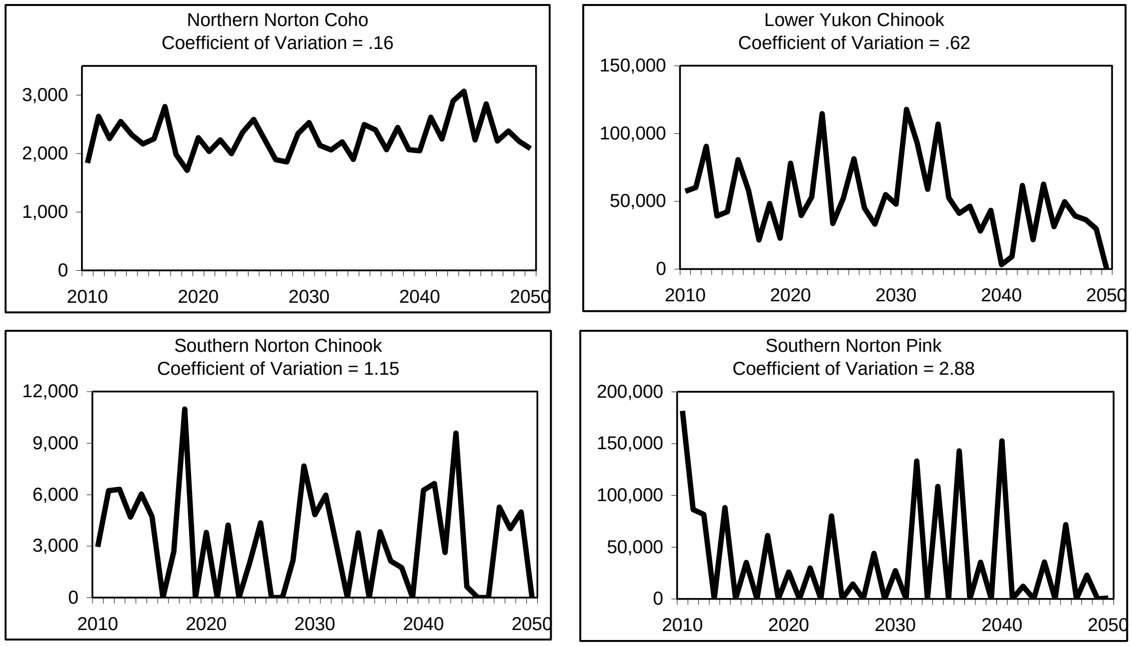
For the "low" subsistence demand scenario, no stocks experience more than a 2% decline in mean harvestable commercial surpluses between 2011-20 and 2041-50. In contrast, for the high subsistence demand scenario, mean harvestable surpluses decline by more than 10% between the two periods for about half the stocks. The five stocks experiencing the greatest relative decline in harvestable surpluses (more than 30%) are Lower Kuskokwim Chinook, Southern Norton Sound Chinook, Lower Yukon Chinook, Southern Norton Sound Pink, and Upper Yukon Fall Chum.

The farther we project into the future, the more important what we assume about how subsistence demand will change in the future becomes for projected commercial harvestable surpluses.

As we discuss below, future commercial harvests of AYK salmon will likely depend not only on the mean level of harvestable surpluses but also on the *variability* of harvestable surpluses. For example, mean commercial harvests are likely to be higher for a stock for which the harvestable surplus is 100,000 fish every year than for a stock for which the harvestable surplus is zero for two-thirds of the years and 300,000 fish every third year. This is because harvesters and processors are more likely to invest in capacity for harvesting and processing a stock with a predictable and consistent surplus than for one with an unpredictable and only occasional surplus.

One simple measure of variability is the coefficient of variation, which is defined as the ratio of the standard deviation to the mean. Figure 20 illustrates harvestable surplus projections with increasing coefficients of variation of 0.16, 0.62, 1.15 and 2.88.

Fig. 20. Projected Harvestable Surpluses for Selected Stocks (Historic Return-High Subsistence Scenario), Projection #1 of 1,000



The harvestable surplus projections in the two bottom figures help to illustrate why variability matters in thinking about future AYK commercial harvests. For these two projections, there are a substantial number of years in which harvestable surpluses are zero. This means that any investment in harvesting or processing capacity, gearing up for the season, or developing markets would provide zero revenue for those years, a major financial risk and disincentive to investing in harvesting or processing.

Harvestable Surpluses for Commercial Fisheries

An important question for this analysis is whether there will be harvestable surpluses for AYK commercial salmon fisheries in the future. The answer to this question depends on what we assume about the distribution of future returns for each stock and subsistence demand for each stock.

Table 15 shows the percentage of our simulations for which our projections of the harvestable surplus were zero or low (<= 5000 fish) for the final decade (2041-2050) of four different harvestable surplus scenarios. Harvestable surpluses are most likely to be zero or low for the “Low Return-High Subsistence Demand” scenario shown in the fourth and eighth columns of Table 15. For this scenario, harvestable surpluses were zero at least 10% of the time from 2041-50 for the following six stocks: Kuskokwim Bay Chinook, Lower Kuskokwim Chinook, Lower Yukon Chinook, Southern Norton Chinook, Southern Norton Summer Chum, and Southern Norton Pink. However, with the exception of these stocks, assuming the distribution of returns and subsistence demand projections for these scenarios, there would be at least some commercial harvestable surpluses for most salmon stocks in most years in the AYK area.

Table 15. Selected Indicators of the Availability of Harvestable Surpluses for Commercial Harvests

Area	Species	Percentage of years between 2041 and 2050 for which harvestable surplus = 0				Percentage of years between 2041 and 2050 for which harvestable surplus <=5000			
		Low susbsistence demand		High subsistence demand		Low susbsistence demand		High subsistence demand	
		Historic return	Low return	Historic return	Low return	Historic return	Low return	Historic return	Low return
Kuskokwim Bay	Chinook	0%	2%	4%	**18%**	4%	**18%**	**14%**	**42%**
	Coho	0%	0%	0%	0%	0%	0%	0%	0%
	Summer Chum	0%	0%	0%	0%	0%	0%	0%	0%
	Sockeye	0%	0%	0%	0%	0%	0%	0%	0%
Lower Kuskokwim	Chinook	**26%**	**24%**	**100%**	**100%**	**45%**	**42%**	**100%**	**100%**
	Coho	0%	0%	0%	2%	0%	0%	0%	2%
	Summer Chum	0%	0%	4%	3%	0%	0%	4%	4%
	Sockeye	0%	1%	0%	1%	9%	**29%**	9%	**30%**
Lower Yukon	Chinook	0%	0%	9%	**14%**	0%	0%	**13%**	**20%**
	Coho	0%	0%	0%	0%	0%	0%	2%	1%
	Summer Chum	0%	0%	0%	0%	0%	0%	0%	0%
	Fall Chum	0%	0%	0%	0%	0%	0%	0%	0%
Upper Yukon	Chinook	0%	0%	2%	4%	**57%**	**54%**	**57%**	**55%**
	Coho	0%	0%	8%	5%	**42%**	**33%**	**45%**	**35%**
	Summer Chum	0%	0%	0%	0%	0%	0%	0%	0%
	Fall Chum	0%	0%	**20%**	3%	0%	0%	26%	4%
Southern Norton	Chinook	4%	**11%**	**56%**	**75%**	**69%**	**75%**	**89%**	**96%**
	Coho	0%	0%	3%	7%	**11%**	**23%**	**39%**	**58%**
	Summer Chum	9%	**20%**	**20%**	**36%**	9%	**20%**	**36%**	**50%**
	Pink	**34%**	**32%**	**58%**	**68%**	**38%**	**38%**	**60%**	**71%**
Northern Norton	Coho	0%	0%	0%	0%	**100%**	**100%**	**100%**	**100%**
	Summer Chum	0%	0%	0%	0%	0%	0%	0%	0%
	Pink	1%	0%	1%	0%	2%	3%	1%	1%

Note: **Bold font** indicates percentage is greater than or equal to 10%.

It is important to recognize that we cannot give any *definitive* answer to the question "will there be harvestable commercial surpluses for AYK salmon?" Our simulations are based on the assumption that run distributions will be similar over the next four decades to what they were over the past five decades. Clearly, if runs are significantly larger, harvestable commercial surpluses will be larger. If runs are significantly smaller, harvestable commercial surpluses will be smaller, with more years with no commercially harvestable surplus.

Commercial Harvests

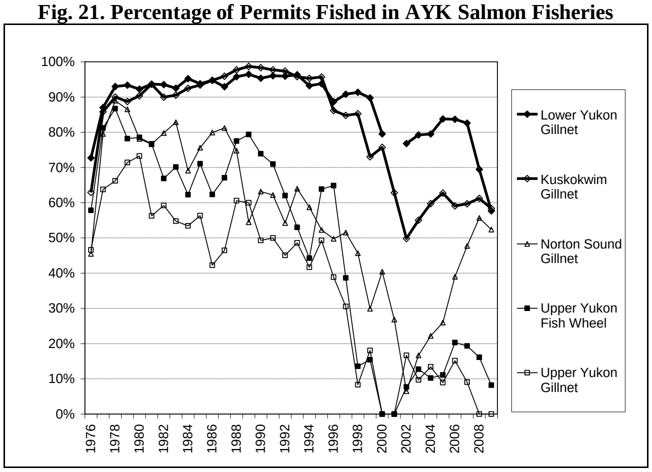
Having discussed potential harvestable surpluses which may be available for future commercial AYK commercial salmon harvests, we next discuss the extent to which these surpluses are likely to be utilized for commercial harvests. We use the term "utilization" to refer to the percentage of a surplus actually harvested during a year.

No data are available to estimate the annual historical utilization of AYK commercially harvestable salmon surpluses. No data have been collected systematically or estimated for how many salmon have historically returned each year to AYK systems, or were potentially available for commercial harvest each year. We cannot tell the extent to which historical changes in harvests from year to year resulted from changes in surpluses or changes in utilization rates.

Lack of data made it impossible for us to develop a formal statistical model of how different factors have affected utilization historically.

One potential indicator of historical utilization of AYK salmon harvests is *fishery participation*. Historical data for the five AYK limited entry permit types (which are differentiated only by area, not species) show the fishery participation was relatively high in all areas in the 1990s, but declined in all fisheries during the 1990s (Fig. 21). The decline was particularly sharp for Norton Sound gillnet and the Upper Yukon fish wheel and gillnet fisheries.

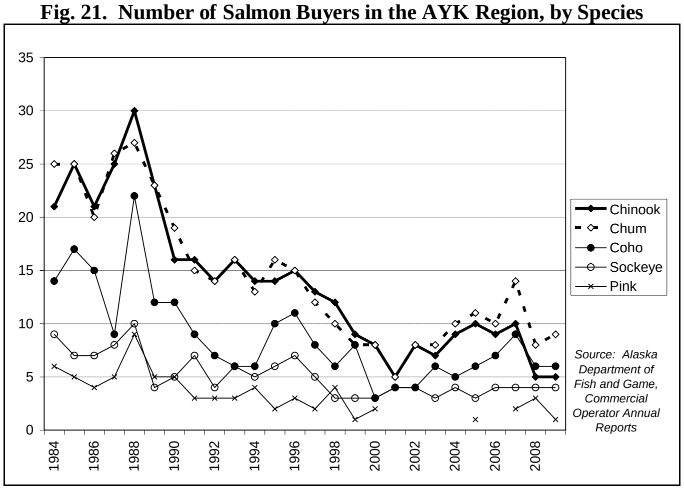
Fig. 21. Percentage of Permits Fished in AYK Salmon Fisheries



The decline in fishery participation could partly reflect lower harvestable surpluses. If there are few or no fish to be caught, fewer permit holders will participate in a fishery. But the fact that the decline in participation is correlated with falling prices in the 1990s (discussed below) suggests that it was attributable in part to market conditions, and declining participation resulted in lower utilization of harvestable surpluses (although lower participation could be offset in part by higher catches by the remaining fishermen).

Another potential indicator of lower utilization is the number of *salmon buyers*. Commercial harvesters will not harvest fish without buyers. A dramatic decline in the number of buyers in the AYK region occurred during the 1990s for all species (Fig. 22). Again, the decline in buyers could partly result from lower harvestable surpluses. If there are fewer fish to be bought, fewer buyers are likely to participate. But the fact that the number of buyers dropped so sharply, and that there were no buyers in large areas of the AYK region, is a strong indicator of declining utilization.

Fig. 21. Number of Salmon Buyers in the AYK Region, by Species



A variety of studies, as well as anecdotal evidence, describe underutilization of specific stocks in particular years. Consider, for example, the following discussions of commercial harvests for selected AYK salmon stocks:

> Kuskokwim River: "The lack of markets, buyers and processing capacity for chum salmon has been a major impediment in recent years for the commercial fisheries . . . Although a harvestable surplus existed each year 2001-2005, no market existed for chum salmon in the Kuskokwim River fishery from 2001 through 2003, and only modest commercial fisheries were prosecuted from 2004 through 2005. . . Given the scale of record Chinook, chum and sockeye salmon escapements observed from 2004 through 2005 in the Kuskokwim River, large surpluses of these species were available for commercial harvest. These surpluses were unexploited and contributed, in part, to the record escapements in these years. Given the poor market conditions which have persisted in the Kuskokwim Area for almost a decade, full exploitation of the large harvestable surpluses is unlikely. Along with harvest, the average number of permit holders participating in the fishery has declined significantly to approximately 20% of historical highs. Even if effort had been at, or near, historical highs, market interest in large harvests from the Kuskokwim Area did not exist, especially for chum salmon" (Linderman and Bergstrom, 2009).

> Norton Sound: "Beginning in the early 2000s, no market interest existed for chum or pink salmon, and the commercial fishery targeted Chinook and coho salmon . . ." (Menard, Krueger and Hilsinger, 2009).

> Yukon River: "Given the improved total return in recent years, greater commercial harvest of salmon might have been expected. The decline of salmon stocks from 1998 through 2002 changed the character of the fisheries. Many fishers moved away from using long established fish camps, fishing gear fell into disrepair or was replaced with other types, prices for salmon fell, and market interest shifted to other available fisheries outside the region. With the return of the salmon, fishers and markets are slowly returning and may improve in the future . . ." (Bue et al, 2009).

Note that none of these sources attempt to estimate specific utilization rates, or how utilization may have varied from year to year. However, they do convey that harvestable commercial surpluses for many AYK salmon stocks have been significantly underutilized since the late 1990s, particularly for chum and pink salmon.

Factors Affecting Utilization of Harvestable Surpluses

In any given year, a very wide variety of factors may *appear* to determine the extent to which harvestable surpluses of a given stock are utilized. Examples include:

- The ex-vessel prices processors offer to fishermen.
- The cost of fuel for fishermen.
- Whether buyers or processors choose to operate in the region for a salmon species.
- How much of the season processors or buyers operate.
- The extent to which processors offer tendering to fishermen.
- Whether processors put fishermen on "limits".
- The extent to which transportation is available to ship whole or processed fish out of the region.

All of these factors are manifestations of market or cost conditions which together determine economic conditions for the stock. "Economic conditions" refer broadly to factors affecting the potential total profitability of harvesting and processing salmon (the wholesale value that could potentially be derived from commercial salmon products minus all the costs of harvesting salmon and processing and transporting salmon products to the wholesale point of sale).

Stocks will not be harvested unless fishing and processing are profitable for both fishermen and processors. Potential total profitability limits the extent to which both fishing and harvesting can be profitable.

Extremely favorable economic conditions (i.e., when potential total profitability is very high) are likely to be reflected in the types of factors listed above. For example, if economic conditions are extremely favorable:

- Processors are likely to offer higher ex-vessel prices to fishermen.
- Fishermen are likely to fish even if the cost of fuel is high.
- More processors and buyers are likely to operate in the region.
- Fishermen are likely to fish, and processors are likely to buy, for more of the run.
- Processors are more likely to offer tendering over greater distances.
- More transportation options will be economically profitable.
- Utilization is likely to be high.

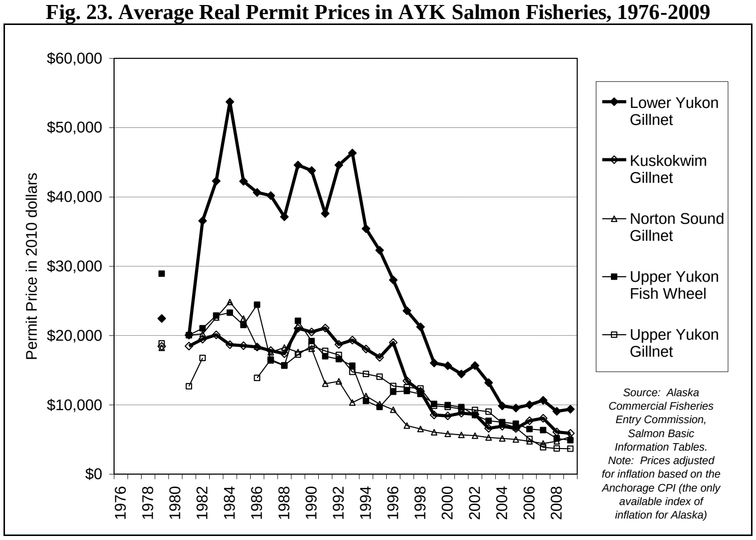
Conversely, if economic conditions are extremely unfavorable:

- Processors are likely to offer lower ex-vessel prices to fishermen.
- Fishermen are less likely to fish if the cost of fuel is high.
- Fewer processors and buyers are likely to operate in the region.
- Fishermen are likely to fish, and processors are likely to buy, for less of the run.
- Processors are less likely to offer tendering, or to offer it for shorter distances.
- Fewer transportation options will be economically profitable.

- Utilization is likely to be low.

Real (inflation-adjusted) limited entry permit prices declined sharply in all AYK salmon fisheries during the 1990s (Fig. 23). Since permit prices are an indicator of expected future profits, this suggests that fishery profitably declined very sharply during this period. In part this would be an expected result of lower harvestable surpluses. But it likely to some extent also reflects lower prices, which would have contributed to lower utilization.

Fig. 23. Average Real Permit Prices in AYK Salmon Fisheries, 1976-2009



A wide variety of factors affect potential total profitability of a fishery. We briefly review some of the most important factors below.

Market Conditions

Market conditions are reflected in wholesale prices paid for products produced from AYK salmon fisheries, and also in the ex-vessel prices processors pay fishermen. Figures 24-28 show average real (inflation-adjusted) ex-vessel prices paid by processors to fishermen for AYK salmon, as well as the corresponding average statewide ex-vessel prices. Note that these prices are weighted averages of prices from different regions, so part of the changes in prices over time (particularly for Chinook) derive from changes in the relative share of differently-priced AYK fisheries in the total catch.

Real prices declined dramatically in the 1990s and early 2000s, both in the AYK region and statewide, for all species except Chinook. Similar declines occurred in the wholesale prices of most of the frozen, fresh and roe products made from these species, although the specific price changes varied by product and species. A wide variety of factors contributed to the price declines, including growth in worldwide farmed salmon production, large world harvests of wild salmon (including Japanese and Alaska chum salmon hatchery production), changes in the Japanese economy, and changes in the seafood distribution and retailing industries (Knapp 2009). The AYK Chinook salmon, which enjoyed a niche-market reputation as a very high-quality product, was less dramatically affected by these market changes than other species and suffered a less dramatic price decline. These market changes during the 1990s contributed to, and were reflected in, declining processor interest in buying AYK salmon and operating in the high-cost AYK region. They are probably the most significant factor contributing to reduced utilization during this period.

Since about 2003, real prices have been rising for all species, both in the AYK region and statewide. Although real ex-vessel prices have more than doubled for all species, they remain well below real price levels of the 1980s for all species except Chinook. The improvement in prices reflect a variety of continuing changes in world salmon markets, including strong growth in world salmon demand, market differentiation of wild salmon from farmed salmon, generic marketing efforts for wild salmon, development of new wild salmon products, and development of new domestic and European markets for Alaska wild salmon resulting in diversification of markets and reduced dependence on the Japanese market.

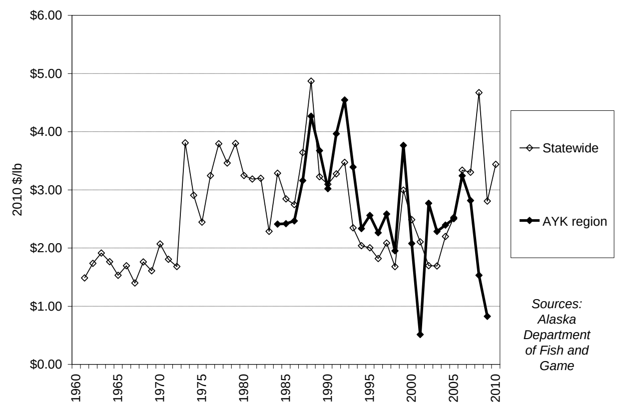
It is difficult to predict how AYK wild salmon prices will change in the future, particularly over the extremely long time period of the next four decades. History strongly suggests that price cycles will continue to occur. There will be periodic periods of higher or lower prices due to periods of relatively lower or higher world supply relative to demand. However, several factors suggest that over the long-term, real prices for AYK wild salmon may trend upward, continuing the trend of recent years.

The most fundamental factor is that world demand for salmon is likely to grow more rapidly than supply. Factors contributing to likely long-term growth in world salmon demand include continued growth in the world population; rising global incomes, particularly for emerging middle classes in populous Asian countries such as China and India; and the likelihood that real prices of meat and poultry will increase due to constraints on the supply of feeds, land, and water. Another favorable factor is that wild salmon, limited in supply by nature, is likely to become increasingly differentiated from farmed salmon and appreciated for unique “wild” characteristics. At the same time, there are substantial differences in the value of different salmon species; pink and chum are unlikely to command prices comparable to those of Chinook, sockeye, or coho. The limited sizes of the Chinook, coho, and sockeye runs in the AYK region also limits the potential value of commercial salmon harvests.

Potentially offsetting these generally favorable market factors (limiting and at times reversing long-term positive trends in real prices) is the potential for continued dramatic technological advances in aquaculture contributing to lower costs of production and increased supply of farmed salmon and other species (potentially including species not yet farmed in significant volumes). As for any other commodity, future price increases for salmon will be limited by the incentives they create for producers to expand production of farmed salmon and other competing species, and for consumers to shift to other, lower-priced alternatives.

It would have been impossible in 1970 to predict the price trends over the next four decades illustrated by Figs. 24-28. Although it is always tempting to assume that the trends of the past few years will continue indefinitely, in reality it is just as impossible to predict what will actually happen to AYK salmon prices over the next four decades as it would have been in 1970. Although our best guess would be that AYK salmon prices will trend upwards over the next four decades, it should be recognized that any projection for this long a time period is ultimately only a guess.

Fig. 24. Selected Chinook Salmon Real Average Ex-Vessel Prices (adjusted for inflation)



Note: Steep drops in AYK region average price in 2001 and 2008-09 likely reflect declines in the share of higher-priced Yukon Chinook to total AYK catches.

Fig. 25. Selected Sockeye Salmon Real Average Ex-Vessel Prices (adjusted for inflation)

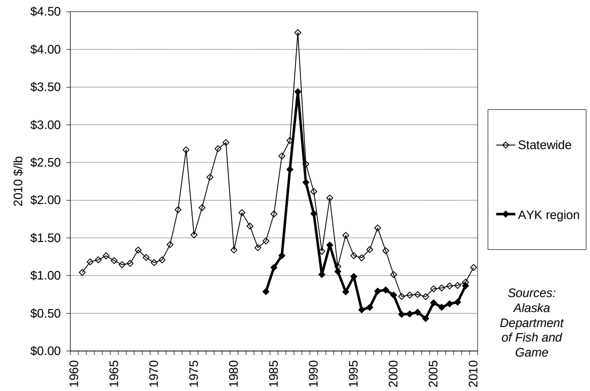


Fig. 26. Selected Coho Salmon Real Average Ex-Vessel Prices (adjusted for inflation)

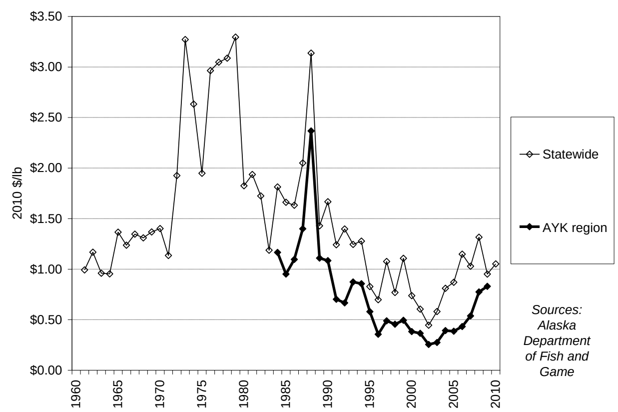


Fig. 27. Selected Chum Salmon Real Average Ex-Vessel Prices (adjusted for inflation)

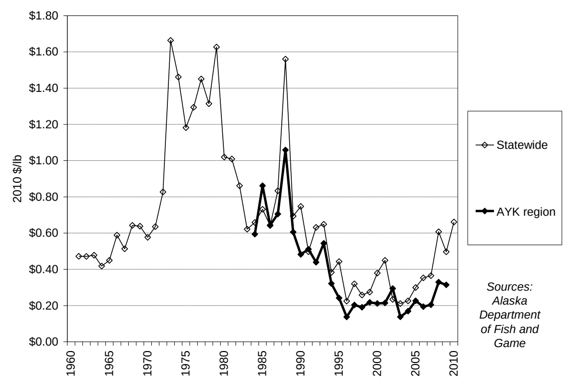
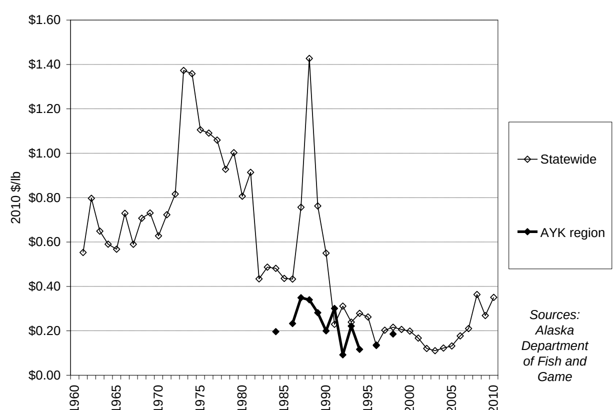


Fig 28. Selected Pink Salmon Real Average Ex-Vessel Prices (adjusted for inflation)



Transportation Infrastructure

Among the most important factors which could affect the future profitability of utilizing AYK salmon is the future development of transportation infrastructure. One of the most important differences between AYK salmon fisheries and other AYK fisheries is the much higher costs of transporting supplies into the region and transporting fish products out of the region. Most other salmon-producing areas of Alaska have access to roads, jet air service, or large ocean-going vessels. In contrast, fisheries in much of the AYK region are accessible only by small aircraft or shallow-draft boats. This increases the relative costs of everything associated with fishing and processing and transporting fish to market, such as fuel, fishing gear, processing labor, utilities, machinery maintenance, packaging, and transporting processed frozen and fresh fish. Transportation limitations also reduce the reliability of services for getting fresh products to market.

Over the longer term, it is possible that new transportation infrastructure, particularly roads, could be built to parts of the AYK region. Road connections to western Alaska have been discussed for decades, but they have yet to be built because of extremely high costs and ambivalence within the region about the desirability of road access. In general, road connections to the Kuskokwim, Lower Yukon, or Seward Peninsula could change the cost structure of AYK fisheries and would likely result in greater utilization of harvestable surpluses.

It is also possible that transportation services to the AYK region could decline and costs of transportation could increase, if energy costs increase significantly or if changes in national and state political priorities result in reductions in the significant subsidies to air transportation to the region, such as for bypass mail and airport construction, maintenance, and operation. This would tend to reduce future utilization of AYK salmon.

Variability and Uncertainty of Harvestable Surpluses

For any given market conditions and cost conditions, utilization will be affected by the variability and uncertainty of harvestable surpluses. Commercial fishing cannot occur (and will not be allowed) unless there are processors willing to buy and process commercial harvests. Processors will not buy or process salmon unless they have a reasonable expectation, prior to the season, that they will make money. The more likely they think it is that there will not be enough fish for them to make processing worthwhile (or worse, no fish at all to process) the lower the chance that they will choose to operate in an area.

The amount of fish processors can buy is also affected by longer-term investments that they make in processing facilities and equipment in a region. This is central for the economics of AYK commercial salmon fisheries. Successful commercial salmon fisheries depend on markets: processors willing and able to pay fishermen enough to make commercial fishing worthwhile for fishermen. Processing requires long-term investments in facilities and equipment within a region, as well as annual pre-season investments in bringing in labor, packaging, and other supplies. The less frequently facilities and equipment are used, the more favorable economic conditions need to be to justify investing in them. The more variable and uncertain the processors expect future harvestable surpluses to be, the less profitable long-term investments in processing capacity will appear, and the less they will invest. The more uncertain processors are prior to a season about whether there will be a harvestable surplus, the less likely they are to make the necessary investments to be ready to buy if a harvestable surplus occurs.

For this reason, a critical factor affecting the utilization of future AYK salmon harvests will be how often the harvestable surpluses are very low or zero. The effects of low or zero harvestable surpluses go beyond the year in which they occur. If they lead to expectations that low or zero harvestable surpluses are likely in the future, then buyers are less likely to be present in years when surpluses *are* available, reducing future utilization.

This has an important policy implication. Managers should recognize that how they manage commercial fisheries when runs are weak may affect the extent to which they will have a commercial fishery in years when runs are strong. While meeting subsistence and escapement goals are clearly very important, the more that managers fully close commercial fishing when runs are weak, the fewer commercial buyers there are likely to be when runs are strong.

What will matter for investment in processing and utilization of future AYK salmon harvestable surpluses will be not just the percentage of years over the entire period for which surpluses are low or zero, but the extent to which years of low or zero surpluses are bunched together so that an extended period occurs of low or zero surpluses. Put simply, processors may not leave because of one bad year, but are more likely to leave if they encounter or expect multiple bad years in a row.

Our methodology for simulating future salmon returns for this study is limited in that it assumes that returns are not governed by predictable spawner-recruit relationships but are instead characterized as independent draws from a stationary distribution of run sizes. Consequently, the model does not provide a way of projecting how often “multiple bad years in a row” may occur. Thus, an important question for the future of AYK commercial salmon harvests, which we do not address in this study, is the extent to which extended periods of low salmon returns may occur. Utilization of harvestable surpluses is likely to be higher, with higher commercial salmon harvests on average, if the next four decades are characterized by relatively stable returns and surpluses than if they are characterized by varying multi-year periods of low and high returns and surpluses.

Economies of Scale and Fishery Synergies

In general, unit costs of processing and harvesting tend to decline as volume increases, as long as there is sufficient harvesting and processing capacity. This suggests that all else equal, harvesting and processing is more likely to be profitable for larger-scale fisheries.

However, smaller stocks may be profitable to harvest if runs overlap with larger-scale fisheries. Similarly, if investments in processing capacity are justified by larger-scale fisheries, plants may stay open to take advantage of other, smaller runs which would not have been profitable on their own.

An important limitation of our modeling for this analysis is that we treat each stock within a region separately. In reality, within each AYK region, future utilization of different species will be interdependent. The profitability of processing any particular species will depend on the profitability of harvesting other species and the extent to which they can help to offset fixed costs of harvesting and processing.

Fishery Management

The potential profitability of a commercial fishery depends in part on how it is managed (that is, when and how fish may be harvested and who may harvest them). Management regulations can dramatically affect both costs of harvesting and processing as well as potential market value.

Current management regulations strictly limit the types of gear which may be used in AYK salmon fisheries. Regulations are intended, in part, to achieve social goals such as widespread participation in fish harvesting. Despite drastic changes in technology in other food-producing industries, relatively little has changed over the past fifty years in how AYK salmon (and other Alaska salmon) are harvested.

It is possible to imagine very different management regulations for AYK commercial fisheries which could result in very different ways of harvesting fish. For example, fish could be harvested in fish traps (as are common in the Russian Far East) or by other gear types from larger vessels. Fishing could be organized cooperatively, or conducted by companies rather than individuals. Such changes could, in theory, lead to significantly more efficient and profitable fisheries which would utilize available commercial surpluses more intensively.

We are not advocating or predicting such changes, and they seem unlikely given the policy goals for AYK fisheries. But over a long time frame, they are theoretically possible, particularly if significant economic and social changes occur in the AYK region that lead to declining interest in traditional commercial fishing.

CDQ Program

A unique factor affecting western Alaska salmon fisheries is the Community Development Quota program. In general, commercial salmon fisheries are economically sustainable over the long-term only if they are economically profitable. The exception to this principle is if subsidies are available to offset losses on a long-term basis. Community Development Quota groups have been subsidizing some AYK salmon processing operations to a significant scale. This has likely increased the utilization of salmon in the areas from which these processing operations are buying. It also may have contributed to a decline in other private processing operations which cannot compete with subsidized CDQ operations.

Examples of significant AYK salmon processing operations operated or subsidized by CDQ groups include Norton Sound Economic Development Corporation’s joint ventures with Glacier Fish Company, Yukon Delta Fisheries Development Association’s Kwik’pak Fisheries, and Coastal Villages Region Fund’s large new processing facility in Platinum. These operations buy significant volumes of fish and provide markets in their regions.

The future scale of AYK commercial salmon fisheries will partly depend on how the CDQ program evolves in the future, and particularly, the extent to which large revenues continue to be generated, whether CDQ groups are mandated to invest revenues in fisheries-related economic development within the region, and whether CDQ groups choose to subsidize salmon processing operations.

Utilization Formula and Assumptions

As the above discussion suggests, a wide variety of factors will affect future utilization commercial harvestable surpluses of AYK salmon. We cannot accurately predict how these factors will combine to determine actual utilization. It is plausible to imagine very different futures for AYK commercial salmon fisheries, particularly over the longer term.

For this reason we do not attempt to predict future utilization. Rather, our goal is to illustrate different potential futures, that is, what long-term trends in commercial harvests might look like under different assumptions about future trends in utilization. To do this we developed a simple utilization formula to calculate utilization rates as a function of two main factors: (1) general economic conditions affecting utilization; and (2) variability of harvestable surpluses. The formula is based on a "logistic function" which calculates an annual utilization value between 0% and 100% based on the values of two variables:

Table 16. Utilization Formula Variables

Variable	Definition	Scale	Assumed or calculated?	How utilization changes as the variable increases
Utilization index	An assumed annual index of utilization for the stock	1-10	Assumed	Increases
Coefficient of variation of the harvestable surplus	The annual ratio of the standard deviation to the mean for 1,000 simulations of harvestable surplus	0-infinity	Calculated	Decreases

The formula is:

$$U = 1/(1+EXP(-(-3 + 0.6\ I - 0.7V)))$$

where

U = Utilization (the proportion of harvestable surplus which is harvested),
I = Utilization index, and
V = Coefficient of variation of the harvestable surplus.

Table 17 shows utilization for several different combinations of the utilization index and the coefficient of variation of the harvestable surplus which result from this formula:

Table 17. Utilization with Selected Combinations of Utilization Index and Coefficient of Variation

		Utilization Index									
		1	2	3	4	5	6	7	8	9	10
Coefficient of Variation	0.0	8%	14%	23%	35%	50%	65%	77%	86%	92%	95%
	0.5	6%	10%	18%	28%	41%	56%	70%	81%	89%	93%
	1.0	4%	8%	13%	21%	33%	48%	62%	75%	85%	91%
	1.5	3%	5%	10%	16%	26%	39%	54%	68%	79%	88%
	2.0	2%	4%	7%	12%	20%	31%	45%	60%	73%	83%
	2.5	2%	3%	5%	9%	15%	24%	37%	51%	66%	78%
	3.0	1%	2%	4%	6%	11%	18%	29%	43%	57%	71%

Note that at a utilization index of 5, utilization is 50% if the coefficient of variation is zero (implying that the projected harvestable surplus is the same for each of 1,000 simulations). Utilization falls to 33% for a coefficient of variation of 1 and to 31% for a coefficient of variation of 2.

The coefficients of the formula were chosen so that it would calculate: (a) the utilization rates shown in the first row of the table for a coefficient of variation of 0; and (b) the changes in utilization rates shown in the table columns as the coefficient of variation increases. Note that the formula is *not* based on economic analysis. It only provides a simple way of combining assumptions about long-term trends in factors affecting utilization with assumptions about how variability in harvestable surpluses may affect utilization. This is useful because of the potential importance of variability for utilization, the wide differences in variability between stocks, and the changes in variability that may occur over time as harvestable surpluses increase or decrease.

The purpose of the formula and our analysis is to illustrate potential long-term trends in harvests under alternative assumptions. As historical experience clearly shows, shorter-term increases and decreases in utilization in response to shorter-term trends in economic conditions and harvestable surpluses are clearly possible or probable.

Another important limitation is that the formula treats each stock separately: it does not take account of the clear synergies between commercial harvests of different species within a given geographic area. As noted above, it is likely that utilization will be correlated for different species within a given area, but we do not attempt to account for this correlation in our projections.

For the purposes of our analysis, we developed six sets of assumptions about utilization indexes, by species. For each set of assumptions, we assumed a "starting" value of the index in 2010 and an "ending" value in 2050. When the starting and ending values differed, we assumed that the index changes by a constant annual amount between the starting and ending year.

Table 18 summarizes our utilization index assumptions. For the "Same" assumptions we assume the same indexes for all species; for the "Varied" assumptions we assume different indexes for each species. For the "Low" assumptions we assume a "low" utilization index over the entire period; for the "High" assumptions we assume a "high" utilization index for the entire period, and for the "Rising" assumptions we assume the index rises from "low" to "high" over the period.

Table C-7. Utilization Index Assumptions, by Species

	Same-Low		Same-High		Same-Rising		Varied-Low		Varied-High		Varied-Rising	
Species	2010	2050	2010	2050	2010	2050	2010	2050	2010	2050	2010	2050
Chinook	5	5	8	8	5	8	7	7	9	9	7	9
Sockeye	5	5	8	8	5	8	5	5	9	9	5	9
Coho	5	5	8	8	5	8	5	5	9	9	5	9
Summer Chum	5	5	8	8	5	8	4	4	8	8	4	8
Fall Chum	5	5	8	8	5	8	4	4	8	8	4	8
Pink	5	5	8	8	5	8	3	3	8	8	3	8

Note: "Same" or "Varied" indicates whether the assumptions are the same for all species or vary across species. "Low," "High," and "Rising" indicate whether the assumptions are low across the projection period, high across the projection period, or rising across the projection period.

It is important to understand that we are *not* arguing that any of these sets of utilization index assumptions are "best" or "most likely" or "most realistic." As discussed above, due to both lack of historical data about utilization and our uncertainty about the factors which may affect utilization in the future, it would be impossible to predict with any certainty how utilization will change. Rather, our purpose is to illustrate the implications of different sets of assumptions about utilization.

Commercial Harvest Projection Scenarios

For each stock, we calculated 72 sets of 1,000 simulations of future commercial salmon harvests, corresponding to the 48-possible combinations of 3 sets of assumptions about future returns (Historic, Low, High), 4 sets of assumptions about future subsistence demand (Low, Int1, Int2, High), and 6 sets of assumptions about utilization indexes (Same-Low, Same-High, Same-Rising, Varied-Low, Varied-High, Varied-Rising). We refer to each of these sets of simulations as a commercial "harvest projection scenario."

In discussing our harvest projection scenarios, we begin by describing the "Historic Return-High Subsistence-Varied-Rising Utilization" scenario projections as an example. Figure 29 (on the following two pages) shows four indicators of projected harvestable surpluses and harvests for each stock for the years 2011-2050 for this scenario. Recall that the assumptions for this scenario imply that:

- Future salmon returns will be drawn from the same probability distribution as that which we estimated drove historic salmon returns ("historic return" assumption),

- Future subsistence demand will reflect a combination of assumptions leading to relatively high future subsistence demand ("high subsistence" assumption), and

- Utilization indexes will vary between species and will be rising over the period 2010-2050 ("varied-rising utilization" assumption). In particular starting (2010) and ending (2050) utilization indexes will be 7 and 9 for Chinook; 5 and 9 for sockeye and coho; 4 and 8 for chum; and 3 and 8 for pink salmon.

Each graph in the figure has four lines:

- A light line showing the projected annual surplus for simulation #1 of 1,000 simulations.
- A dark line showing the projected annual harvest for simulation #1 of 1,000 simulations.
- A light line showing the average projected surplus by decade.
- A dark line showing the average projected harvest by decade.

The differences between the light lines (surplus) and dark lines (harvest) are an indicator of utilization: the closer projected harvests are to projected surpluses, the greater utilization is.

Fig. 29. Projected Harvestable Surpluses and Commercial Harvests:
Averages by Decade and Simulation #1 of 1000
(Historic Return-High Subsistence-Varied-Rising Utilization Scenario)

Note: Light lines show surpluses, heavy lines show harvests; graphs continue on next page.

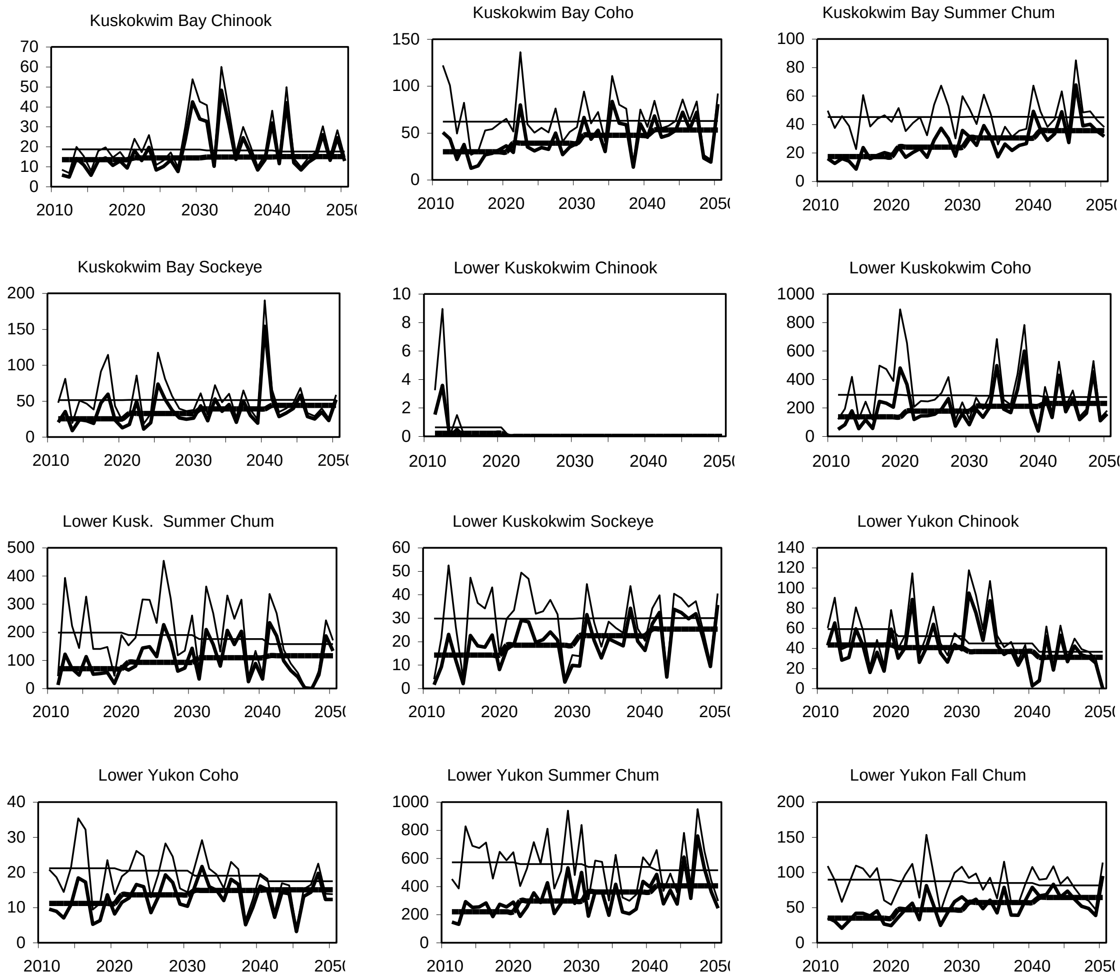
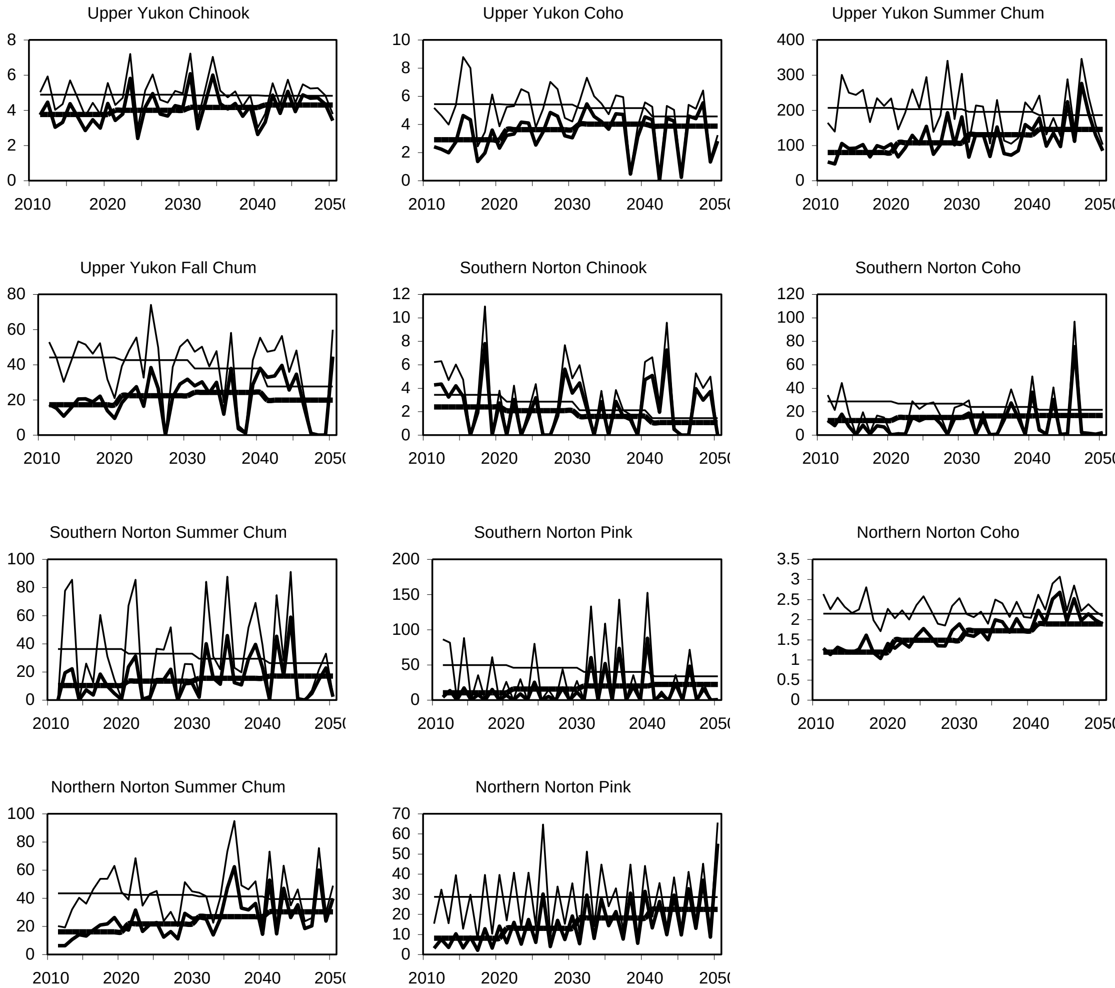


Fig. 29 (continued).



For each of the 23 stocks, future projected harvest trends reflect the effects of two trends over time: changes in subsistence demand (increases in subsistence demand result in lower harvestable surpluses) and assumed increasing utilization indexes. Whether future projected harvests increase, decrease, or stay about the same depends on the relative strength of these two trends.

We may divide the stocks into five different groups based upon the relative effects of the two different trends on trends in projected harvests (Table 19).

Table 19. Grouping of Stocks Based on Trends in Projected Surpluses and Commercial Harvests

Trend in Projected Surpluses	Assumed Increase in Utilization Index	Trend in Projected Commercial Harvests	Stocks
Relatively stable surplus reflecting relatively stable subsistence demand	Relatively small	Relatively Stable	Kuskokwim Bay Chinook Upper Yukon Chinook
	Relatively large	Increasing	Kuskokwim Bay Coho Kuskokwim Bay Summer Chum Kuskokwim Bay Sockeye Lower Kuskokwim Coho Lower Kuskokwim Sockeye Lower Yukon Summer Chum Lower Yukon Fall Chum Upper Yukon Coho Upper Yukon Summer Chum Northern Norton Coho Northern Norton Summer Chum Northern Norton Pink
Declining surplus reflecting increasing subsistence demand	Relatively small	Decreasing	Lower Kuskokwim Chinook Lower Yukon Chinook Southern Norton Chinook
	Relatively large: Utilization increases about as much as needed to offset the projected decline in harvestable surplus	Relatively Stable	Upper Yukon Fall Chum Southern Norton Coho
	Relatively large: Utilization increases sufficiently to more than offset the projected decline in harvestable surplus	Increasing	Lower Kuskokwim Summer Chum Lower Yukon Coho Southern Norton Summer Chum Southern Norton Pink

Note that this grouping reflects the specific assumptions of the “Historic Return-High Subsistence-Varied-Rising Utilization” scenario. Different scenarios would result in different sets of groupings.

Appendix B provides tables illustrating how projected harvests change for different sets of assumptions about returns, subsistence demand, and utilization. In general, the projections suggest that for most AYK stocks there are likely to be commercial harvestable surpluses, and that commercial harvests are likely to rise over time if improving economic conditions lead to higher utilization rates. However, for a few stocks, increasing subsistence demand may reduce harvestable surpluses significantly, resulting in decreasing commercial harvests.

Discussion

Our predictive model of subsistence demand provides a basis for assessing the initial research hypothesis that subsistence fishing in the AYK region will "remain the same or decline" in the future. The model's findings show a range of future outcomes depending upon future conditions of human populations, dog populations, household incomes, community cultural composition, and other factors. Under many plausible future scenarios, subsistence demand for salmon remains the same or increases in the AYK region according to the model. There are also future conditions where subsistence demand decreases, particularly if human populations decrease in the AYK region. It is safe to conclude that the initial hypothesis that predicts stable or decreasing subsistence harvests is not a sound prediction. Our model of subsistence demand portrays a range of potential outcomes in subsistence demand for salmon depending upon future conditions.

In our model, the size of the population of consumers has a major affect on local subsistence salmon harvests. Growing human populations in the villages of the AYK region will result in growing subsistence demand for salmon, provided that other aspects of the mixed economy and culture do not change radically in the area. Overall, village populations are growing in the AYK area according to Alaska Department of Labor projections. These population trends would result in increased subsistence demand for salmon according to our model. Based on our model, declining village populations would result in declining demand for salmon, but this scenario is probably less likely than others in the AYK region.

Our model suggests there may be "upriver-downriver" shifts in the location of subsistence demand for salmon because of human population trends. On the Yukon River, demand would disproportionately shift from upriver areas to lower river areas because village populations are growing at greater rates along the lower river while village populations are stable or declining in some upper river areas. Similarly, as Lower Kuskokwim and Bethel populations are increasing at greater rates than upriver areas, demand for salmon will increase more in lower river areas compared with upriver areas according to the model.

Trends in dog populations are less predictable than human populations in the AYK area. The populations of dogs significantly affect the subsistence demand for chum and coho salmon in upriver areas on the Yukon and Kuskokwim rivers. A resurgent interest in dog mushing would mean increased demand for chum and coho. But such resurgence may be unlikely. On the racing circuit, newer dog breeds and more expensive diets give outside dog teams a competitive advantage over local teams. This creates disincentives to local racers to compete. However, interest in local dog racing might increase once again. Race sponsorship and race reward monies affect participation. Increased fuel prices in villages might lead to increased use of dogs for transportation. But at the same time, dog food may also increase as an expense with low salmon runs and decreased supplies of cheap salmon. These factors make it difficult to predict trends in dog populations. Overall, the model suggests that fishing for dog food will continue as a significant component of the subsistence demand for chum and coho in upriver areas.

Trends in income (per capita) affect subsistence harvests in rural areas. Constraints on the growth in mean per capita incomes (due to underdeveloped wage sectors, low employment, and poor commercial fisheries, among other factors) tend to be associated with higher overall subsistence demand in AYK communities. At the same time, increasing costs of imported products to households (especially fuel, boat motors, and nets used for fishing) strain the capacity of households to catch and process wild foods. To deal with such potential economic conditions, some households may adopt fishing strategies that require lower monetary costs (because households may have less income to invest in fishing) and that involve strategic applications of labor (because local labor is comparatively more available). It can be expected that core households with access to income, fuel, and equipment will continue to link with households of kinsmen (in extended family networks) to share capital and labor in the production and distribution of salmon. This has been a central economic strategy for producing wild foods by family groups in the AYK area.

Roads are a potential factor affecting subsistence demand. According to the model, if roads push into the AYK region, socioeconomic changes may substantially lower salmon harvests for subsistence. Elsewhere in the state, roads have been associated with lower food costs in stores, greater mean incomes, in-migration by non-Natives, out-migration by Natives, greater competition between rural and urban fishers and hunters, and more restrictive regulations for fishing and hunting. Roads tend to be associated with lower harvests for local subsistence use.

Urban transformation is another potential future factor. If the industrial capitalism of urban areas transforms the local economies of communities in the AYK area, lower subsistence harvests are predicted by the model. But this seems unlikely, short of large-scale mineral development in the region. It is more likely that household incomes in villages will change incrementally over time, allowing for more or less purchases of imported food. The effects of these income changes are shown in the range of potential outcomes of subsistence demand.

The model of subsistence demand says nothing about other kinds of transforming events that might occur in the next several decades in the AYK region. During the previous fifty years, snowmachines and ATVs replaced sled dogs for everyday winter transportation, a technological transformation that substantially decreased local demand for chum and coho salmon. Is there another technological change in the offing? It is difficult to see any of such a magnitude. Another transforming event during the previous century was the development of commercial fisheries on AYK stocks. That event may have permanently altered the potential productivity of the AYK drainages in ways not understood. Examples of potential future transforming events might be fish hatcheries in the AYK region, or changes in fish productivity due to global warming, or an unprecedented disinterest by young people in traditional culture. Our model of subsistence demand does not account for effects of these types of potentially transforming factors.

In the commercial salmon fisheries, the fundamental constraint to future salmon harvests will be future salmon returns to the AYK region. As is clear from historical experience, returns may vary dramatically from year to year and over longer-term periods. There may be years or extended periods of very low returns, and years or extended periods of very high returns.

Potential future changes to management control rules are also not predictable. The primary management policy has been, and will likely continue to be, to ensure escapement that will provide reproductive output sufficient to provide for a desired level of future returns. However, long periods with reduced run strength (returns) for a particular salmon stock can result in more conservative management measures in an effort to boost spawning escapements. The relatively recent recognition of long-term shifts in productivity, likely driven by environmental changes, may also result in re-defined escaped goals. The goals may be reduced in acknowledgement of lower sustainable productivity for a particular stock. Although our run strength model applied the most recent accepted escapement goals on systems for which formal escapement goals have been adopted (Brannian et al. 2006; Volk et al. 2009), these goals are likely to be amended over the next four decades as additional information becomes available. Ultimately, changes to the escapement goals will affect both subsistence and commercial harvests.

Because future returns are highly uncertain, any long-term projections of future AYK commercial salmon harvests are inherently highly uncertain. Our "projections" of future returns are not predictions of actual returns, or even of the range within which actual returns will fall. Rather, they should be interpreted as illustrations or examples of the range within which returns might fall, if the distribution of future returns is similar to that of the past five decades.

Because subsistence harvests have, and will likely retain, priority over commercial harvests, growing subsistence demand could affect commercial harvestable surpluses for some stocks over time. In general, assuming that the distribution of future returns is similar to that of past returns, it appears likely that there will be at least some commercial harvestable surpluses for most stocks in most years. Assuming the distribution of future returns is similar to that of the past five decades, for the "low" subsistence demand scenario, no stocks would experience more than a 2% decline in mean harvestable commercial surpluses between 2011-20 and 2041-50. However, for the high subsistence demand scenario, harvestable surpluses could decline by more than 10% between the two periods for about half the stocks. The five stocks experiencing the greatest relative decline in harvestable surpluses (more than 30%) are Lower Kuskokwim Chinook, Southern Norton Chinook, Lower Yukon Chinook, Upper Yukon Fall Chum, and Southern Norton Pink. However, if future returns are significantly lower than past returns, harvestable commercial surpluses will be smaller, with more stocks experiencing more years with no commercially harvestable surplus.

Future AYK commercial salmon harvests will depend not only on harvestable surpluses but also the extent to which those surpluses are utilized. A wide variety of factors may affect future utilization. Among the most important of these are likely to be market trends, the development of transportation infrastructure, variability and uncertainty of harvestable surpluses, synergies between harvests of different species within the same area, fisheries management regulations, and the future evolution of the Community Development Quota program. The uncertainty associated with these factors make it impossible to predict with any certainty how utilization will change over the long term.

In general, long-term market trends may be favorable for AYK wild salmon. Following a drastic decline in the 1990s and early 2000s, market conditions have been generally improving for wild salmon over the past decade, particularly for higher-valued species (Chinook, coho, and sockeye). Major contributing factors have been strong growth in world demand for salmon, differentiation in market demand for wild salmon, and a slowdown in the growth of production of farmed salmon due to constraints of disease, feed costs, availability of sites, and the potential for technological improvements. All of these may continue over the long term, although there is clearly potential for periods of lower prices should farmed salmon production increase too rapidly. Unique characteristics of Yukon and Kuskokwim salmon could become long-term marketing advantages in niche markets. If market conditions for AYK salmon improve, this would tend to increase utilization of AYK salmon commercial harvestable surpluses may over time.

More general factors contributing to a positive long-term outlook for market conditions include growing world demand for protein as populations and incomes expand, and constraints to corresponding increases in protein production including availability of water and farmland.

Because of significantly higher costs and lack of transportation infrastructure, AYK salmon will nevertheless likely remain "last in, first out" in comparison with salmon from other areas of Alaska in the event of future market downturns, particularly for lower-valued species (pink and chum). Although the long-term outlook is favorable, increases in utilization are more likely to occur gradually rather than rapidly or dramatically. Moreover, likely future increases in fuel costs could make fishing, processing, and transportation increasingly less affordable in the AYK region.

Variability and uncertainty of harvestable surpluses have been and are likely to remain important factors limiting utilization in some AYK commercial salmon fisheries. Processors are less likely to plan to buy and process salmon during a season unless they are reasonably certain there will be a harvestable surplus for them to process. There may not be investment in facilities and equipment to buy and process salmon in the future unless processors are reasonably certain there will be harvestable surpluses to buy and process in most years. Managers should recognize that how they manage commercial fisheries when runs are weak may affect the extent to which they will have a commercial fishery in years when runs are strong. The more years that there are no commercial harvestable surpluses, the fewer commercial buyers there are likely to be when runs are strong. Future AYK commercial salmon harvests will depend in part on the extent to which management policies can reduce the variability and uncertainty of harvestable surpluses.

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Appendix A. Subsistence Demand Scenario Details

Fig. A1. Subsistence Demand Scenario, Yukon River Area (High)

Subsistence Salmon Demand Model

High Scenario: Yukon River Area (Lower Yukon, Middle-Upper Yukon, Fairbanks)

Subsistence Salmon Demand (All Species and Uses)

	L Yukon	M-U Yukon	Fairbanks	Total
2010	115,188	141,416	14,326	270,930
2015	127,997	150,827	15,922	294,746
2020	141,864	160,257	17,608	319,729
2025	156,504	169,691	19,438	345,633
2030	172,760	179,824	21,432	374,016
2035	190,706	191,415	23,645	405,765
2040	210,517	204,638	26,100	441,256
2045	232,389	219,688	28,826	480,903
2050	256,534	236,783	31,854	525,171

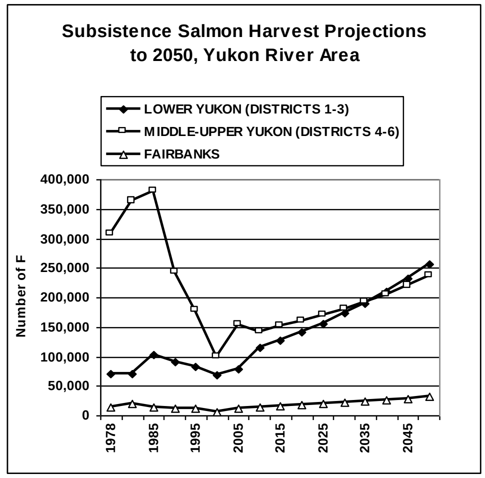
Subsistence Salmon Demand by Species

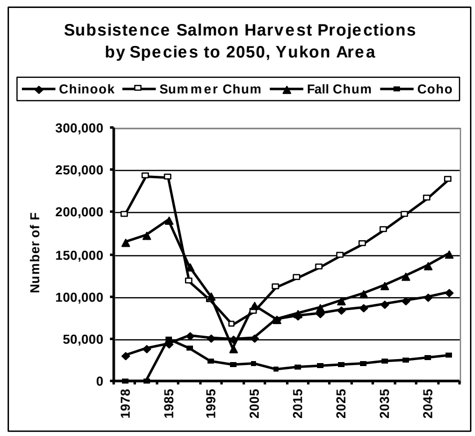
	Chinook	S Chum	Fall Chum	Coho	Total
2010	72,684	110,243	73,513	14,489	270,930
2015	76,730	121,729	80,322	15,965	294,746
2020	80,436	134,128	87,627	17,538	319,729
2025	83,675	147,281	95,457	19,220	345,633
2030	86,968	161,866	104,113	21,069	374,016
2035	90,700	178,076	113,861	23,129	405,765
2040	94,914	196,089	124,830	25,423	441,256
2045	99,657	216,104	137,165	27,977	480,903
2050	104,981	238,338	151,029	30,822	525,171

Subsistence Salmon Demand for Human or Dog Food*

	L Yukon Human Food	L Yukon Dog Food	M-U Yukon Human Food	M-U Yukon Dog Food
2010	109,052	6,143	66,353	75,110
2015	121,219	6,786	67,445	83,436
2020	134,391	7,482	67,643	92,673
2025	148,296	8,218	66,820	102,937
2030	163,738	9,032	65,477	114,419
2035	180,790	9,928	64,161	127,335
2040	199,616	10,914	62,872	141,857
2045	220,403	12,000	61,608	158,181
2050	243,355	13,195	60,370	176,526

** Urban Fairbanks not shown.*





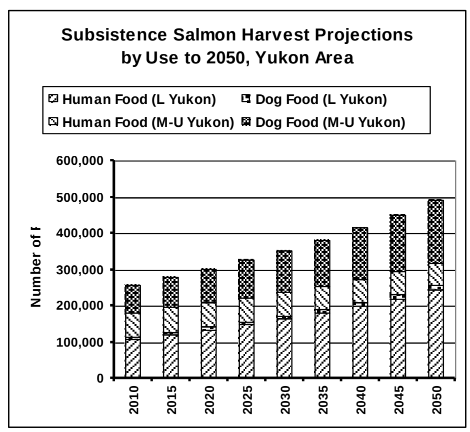


Fig. A2. Subsistence Demand Scenario, Yukon River Area (Intermediate Two)

Subsistence Salmon Demand Model
Intermediate Two Scenario: Yukon River Area (Lower Yukon, Middle-Upper Yukon, Fairbanks)

Subsistence Salmon Demand (All Species and Uses)

	L Yukon	M-U Yukon	Fairbanks	Total
2010	110,338	133,237	13,309	256,884
2015	118,557	133,812	13,773	266,142
2020	127,812	133,963	14,205	275,981
2025	137,513	133,400	14,628	285,541
2030	148,394	132,649	15,043	296,086
2035	160,116	132,072	15,463	307,651
2040	172,741	131,666	15,887	320,294
2045	186,334	131,430	16,314	334,078
2050	200,967	131,361	16,743	349,071

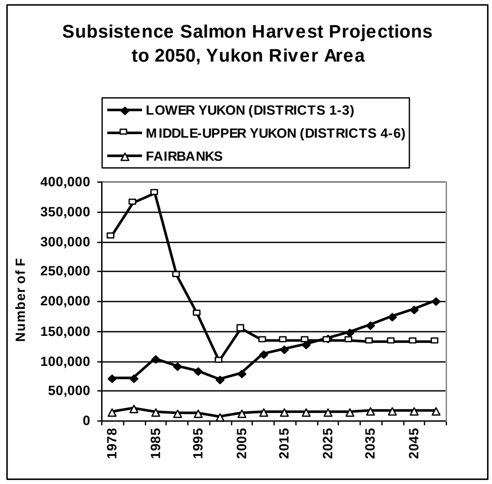
Subsistence Salmon Demand by Species

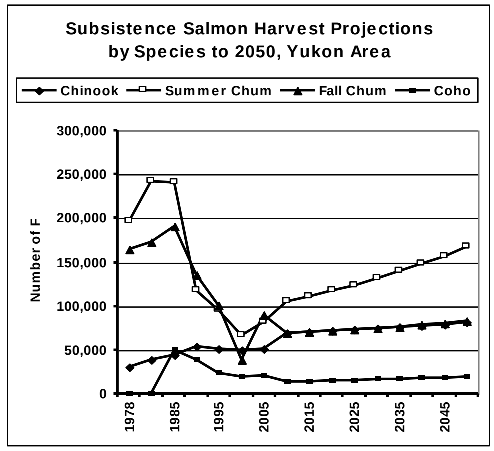
	Chinook	S Chum	Fall Chum	Coho
2010	69,413	104,817	69,011	13,643
2015	70,770	110,616	70,563	14,193
2020	72,076	117,034	72,104	14,766
2025	73,035	123,647	73,519	15,339
2030	74,125	131,008	74,999	15,955
2035	75,477	138,950	76,613	16,612
2040	77,103	147,513	78,365	17,313
2045	79,017	156,741	80,260	18,060
2050	81,232	166,678	82,305	18,856

Subsistence Salmon Demand for Human or Dog Food*

	L Yukon Human Food	L Yukon Dog Food	M-U Yukon Human Food	M-U Yukon Dog Food
2010	104,461	5,885	63,358	69,924
2015	112,316	6,248	62,191	71,666
2020	121,166	6,653	60,589	73,421
2025	130,445	7,076	58,286	75,161
2030	140,857	7,546	55,757	76,941
2035	152,076	8,050	53,324	78,798
2040	164,162	8,590	50,985	80,733
2045	177,178	9,167	48,736	82,746
2050	191,193	9,786	46,574	84,841

** Urban Fairbanks not shown.*





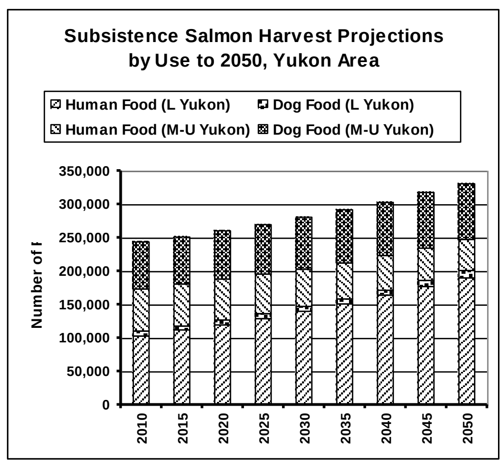


Fig. A3. Subsistence Demand Scenario, Yukon River Area (Intermediate One)

Subsistence Salmon Demand Model

Intermediate One Scenario: Yukon River Area (Lower Yukon, Middle-Upper Yukon, Fairbanks)

Subsistence Salmon Demand (All Species and Uses)

	L Yukon	M-U Yukon	Fairbanks	Total
2010	107,149	129,373	12,807	249,329
2015	113,392	126,277	12,806	252,475
2020	120,369	122,765	12,751	255,885
2025	127,482	118,583	12,666	258,731
2030	135,382	114,249	12,549	262,180
2035	143,704	110,099	12,412	266,215
2040	152,462	106,126	12,250	270,839
2045	161,665	102,321	12,063	276,049
2050	171,323	98,676	11,846	281,844

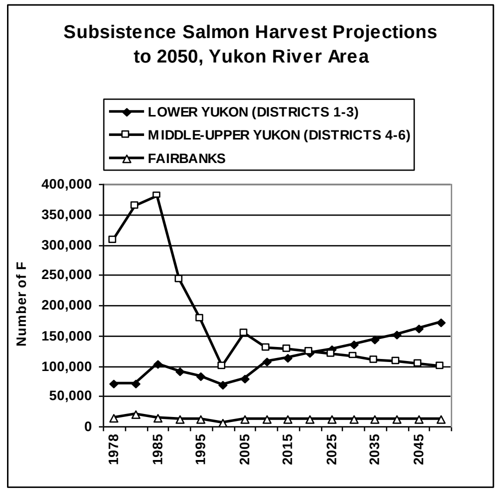
Subsistence Salmon Demand by Species

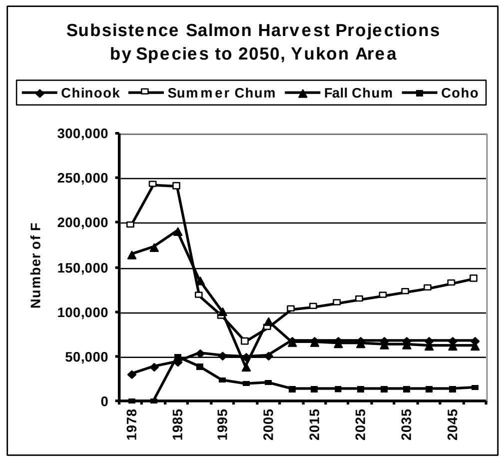
	Chinook	S Chum	Fall Chum	Coho
2010	67,631	101,660	66,828	13,211
2015	67,799	105,065	66,233	13,378
2020	67,866	108,882	65,589	13,548
2025	67,559	112,690	64,784	13,699
2030	67,328	116,982	64,002	13,868
2035	67,284	121,574	63,304	14,053
2040	67,423	126,474	62,689	14,253
2045	67,740	131,685	62,156	14,468
2050	68,231	137,213	61,704	14,697

Subsistence Salmon Demand for Human or Dog Food*

	L Yukon Human Food	L Yukon Dog Food	M-U Yukon Human Food	M-U Yukon Dog Food
2010	101,315	5,842	61,960	67,456
2015	107,239	6,161	59,810	66,509
2020	113,855	6,521	57,278	65,529
2025	120,593	6,898	54,137	64,487
2030	128,069	7,322	50,855	63,434
2035	135,936	7,778	47,732	62,407
2040	144,204	8,268	44,762	61,403
2045	152,880	8,796	41,937	60,423
2050	161,970	9,364	39,249	59,465

** Urban Fairbanks not shown.*





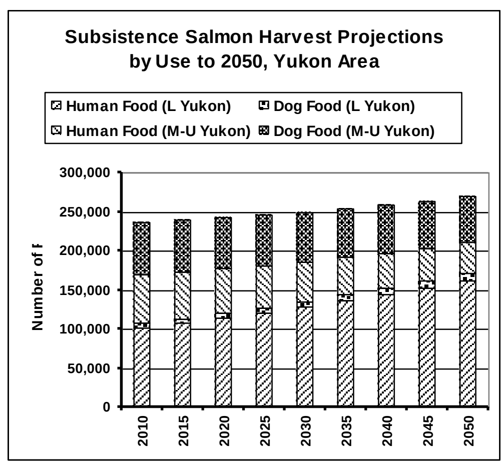


Fig. A4. Subsistence Demand Scenario, Yukon River Area (Low)

Subsistence Salmon Demand Model
Low Scenario: Yukon River Area
(Lower Yukon, Middle-Upper Yukon, Fairbanks)

Subsistence Salmon Demand (All Species and Uses)

	L Yukon	M-U Yukon	Fairbanks	Total
2010	102,881	126,408	12,587	241,876
2015	105,058	120,072	12,245	237,374
2020	107,756	113,693	11,865	233,314
2025	110,718	107,243	11,482	229,444
2030	114,406	101,062	11,091	226,560
2035	118,037	95,228	10,685	223,949
2040	121,572	89,718	10,260	221,550
2045	124,971	84,514	9,815	219,299
2050	128,181	79,595	9,347	217,123

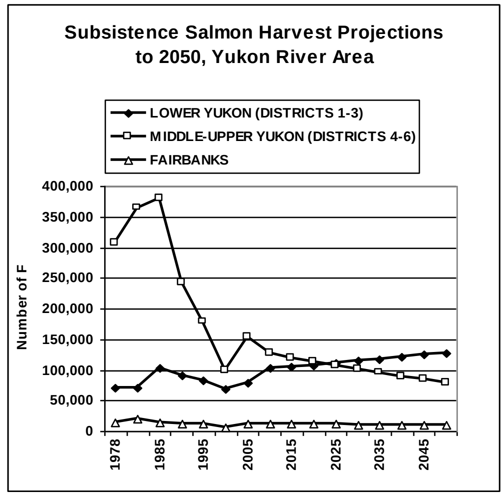
Subsistence Salmon Demand by Species

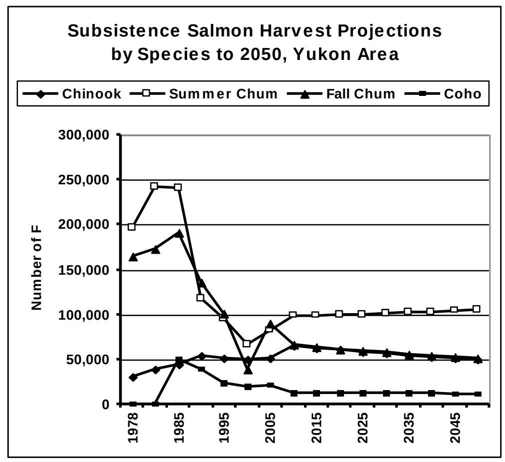
	Chinook	S Chum	Fall Chum	Coho
2010	64,734	98,487	65,757	12,898
2015	62,527	98,565	63,591	12,692
2020	60,364	98,983	61,473	12,494
2025	58,191	99,569	59,377	12,307
2030	56,307	100,672	57,426	12,154
2035	54,565	101,798	55,581	12,004
2040	52,944	102,921	53,833	11,853
2045	51,418	104,007	52,174	11,700
2050	49,965	105,024	50,595	11,539

Subsistence Salmon Demand for Human or Dog Food*

	L Yukon Human Food	L Yukon Dog Food	M-U Yukon Human Food	M-U Yukon Dog Food
2010	97,202	5,686	59,225	67,226
2015	99,243	5,822	55,041	65,072
2020	101,770	5,994	50,777	62,956
2025	104,536	6,190	46,410	60,872
2030	107,977	6,437	42,245	58,854
2035	111,346	6,699	38,354	56,910
2040	114,604	6,976	34,717	55,036
2045	117,708	7,271	31,318	53,230
2050	120,606	7,584	28,139	51,488

** Urban Fairbanks not shown.*





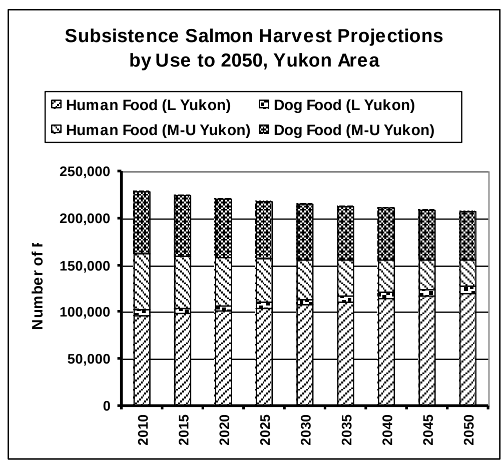
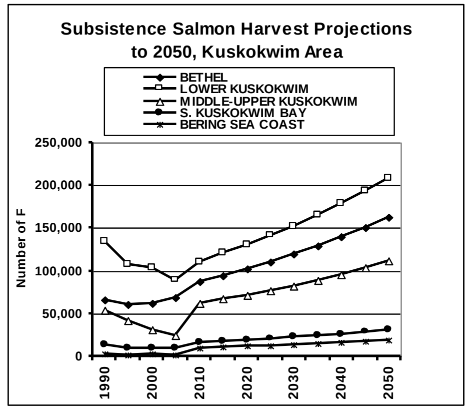


Fig. A5. Subsistence Demand Scenario, Kuskokwim Area (High)

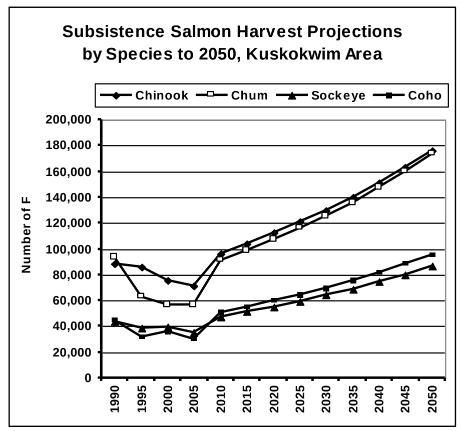
Subsistence Salmon Demand Model

High Scenario: Kuskokwim Area
(Bethel, Lower Kuskokwim, Middle-Upper Kuskokwim, South Kuskokwim Bay, Bering Sea Coast)



Subsistence Salmon Demand (All Species and Uses)

	Bethel	L Kusk	Mid-U Kusk	S Kusk B	Bering SC	Total
2010	86,844	110,580	61,529	16,204	10,057	285,213
2015	94,513	120,420	66,576	17,629	10,923	310,062
2020	102,334	130,471	71,691	19,079	11,803	335,378
2025	110,350	140,795	76,895	20,561	12,700	361,302
2030	119,296	152,316	82,651	22,215	13,702	390,180
2035	128,976	164,792	88,949	24,003	14,783	421,503
2040	139,450	178,306	95,840	25,935	15,950	455,480
2045	150,784	192,944	103,381	28,024	17,209	492,341
2050	163,050	208,802	111,631	30,282	18,568	532,333



Subsistence Salmon Demand by Species

	Chinook	Chum	Sockeye	Coho
2010	95,780	90,702	47,216	50,713
2015	103,981	98,805	51,242	55,166
2020	112,263	107,152	55,305	59,724
2025	120,668	115,797	59,424	64,412
2030	130,024	125,437	64,008	69,636
2035	140,132	135,940	68,961	75,314
2040	151,054	147,385	74,313	81,487
2045	162,852	159,861	80,095	88,199
2050	175,597	173,462	86,342	95,498

Subsistence Salmon Demand for Human or Dog Food

	L Kusk-Bet Human Food	L Kusk-Bet Dog Food	M-U Kusk Human Food	M-U Kusk Dog Food	SK Bay-Cst Human Food	SK Bay-Cst Dog Food
2010	187,641	10,819	52,216	10,107	25,507	984
2015	204,084	11,999	56,153	11,311	27,743	1,059
2020	220,763	13,317	60,024	12,661	30,012	1,143
2025	237,775	14,787	63,833	14,174	32,326	1,234
2030	256,747	16,440	68,024	15,873	34,907	1,337
2035	277,233	18,287	72,567	17,777	37,694	1,450
2040	299,354	20,351	77,491	19,912	40,704	1,574
2045	323,239	22,659	82,826	22,305	43,953	1,711
2050	349,031	25,239	88,603	24,989	47,463	1,862

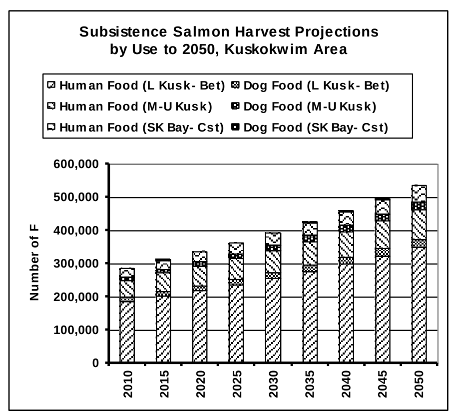


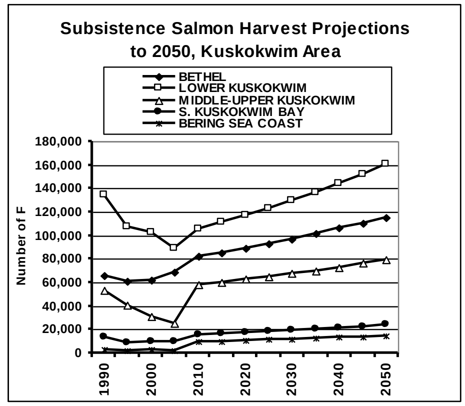
Fig. A6. Subsistence Demand Scenario, Kuskokwim Area (Intermediate Two)

Subsistence Salmon Demand Model

Intermediate Two Scenario: Kuskokwim Area
(Bethel, Lower Kuskokwim, Middle-Upper Kuskokwim, South Kuskokwim Bay, Bering Sea Coast)

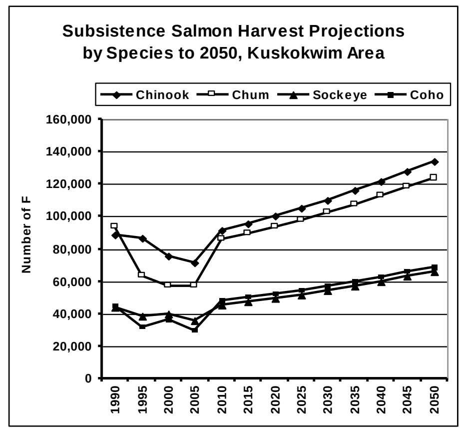
Subsistence Salmon Demand (All Species and Uses)

	Bethel	L Kusk	Mid-U Kusk	S Kusk B	Bering SC	Total
2010	81,796	105,563	58,006	15,523	9,650	270,538
2015	85,354	111,019	60,227	16,339	10,151	283,090
2020	89,084	116,825	62,529	17,207	10,684	296,329
2025	92,791	122,742	64,777	18,092	11,226	309,628
2030	97,066	129,560	67,361	19,114	11,853	324,953
2035	101,480	136,743	70,102	20,191	12,512	341,028
2040	106,032	144,310	73,005	21,327	13,207	357,880
2045	110,717	152,278	76,077	22,523	13,938	375,533
2050	115,530	160,669	79,325	23,784	14,706	394,014



Subsistence Salmon Demand by Species

	Chinook	Chum	Sockeye	Coho
2010	91,334	85,511	45,041	47,887
2015	95,679	89,405	47,178	50,029
2020	100,267	93,511	49,433	52,282
2025	104,875	97,646	51,697	54,539
2030	110,204	102,386	54,316	57,133
2035	115,794	107,362	57,066	59,849
2040	121,654	112,583	59,950	62,690
2045	127,791	118,058	62,973	65,661
2050	134,216	123,795	66,139	68,763



Subsistence Salmon Demand for Human or Dog Food

	L Kusk-Bet Human Food	L Kusk-Bet Dog Food	M-U Kusk Human Food	M-U Kusk Dog Food	SK Bay-Cst Human Food	SK Bay-Cst Dog Food
2010	178,714	9,560	49,950	8,743	24,457	927
2015	187,442	9,878	51,922	9,013	25,744	964
2020	196,679	10,208	53,967	9,291	27,115	1,003
2025	205,996	10,546	55,951	9,578	28,511	1,043
2030	216,763	10,907	58,260	9,876	30,124	1,087
2035	228,023	11,280	60,718	10,183	31,824	1,134
2040	239,792	11,668	63,329	10,500	33,615	1,183
2045	252,083	12,069	66,100	10,827	35,502	1,234
2050	264,910	12,484	69,037	11,164	37,489	1,288

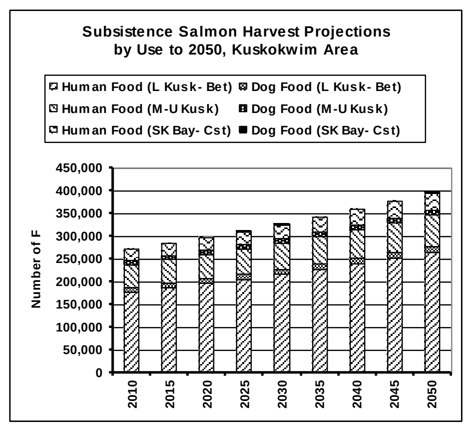


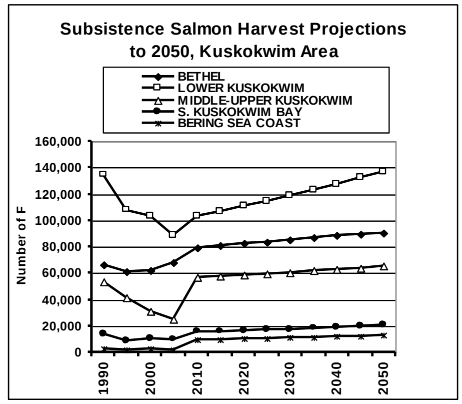
Fig. A7. Subsistence Demand Scenario, Kuskokwim Area (Intermediate One)

Subsistence Salmon Demand Model

Intermediate One Scenario: Kuskokwim Area (Bethel, Lower Kuskokwim, Middle-Upper Kuskokwim, South Kuskokwim Bay, Bering Sea Coast)

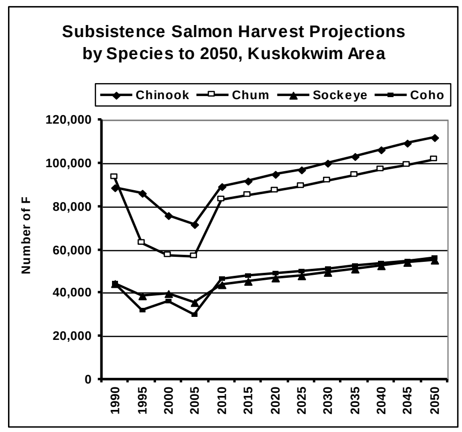
Subsistence Salmon Demand (All Species and Uses)

	Bethel	L Kusk	Mid-U Kusk	S Kusk B	Bering SC	Total
2010	79,245	103,253	56,375	15,213	9,462	263,548
2015	80,873	106,827	57,375	15,769	9,805	270,649
2020	82,465	110,575	58,382	16,351	10,164	277,936
2025	83,820	114,255	59,266	16,924	10,514	284,778
2030	85,448	118,591	60,383	17,596	10,926	292,945
2035	86,926	123,055	61,556	18,289	11,349	301,175
2040	88,222	127,643	62,780	19,002	11,781	309,428
2045	89,300	132,351	64,050	19,735	12,223	317,659
2050	90,122	137,175	65,360	20,486	12,674	325,816



Subsistence Salmon Demand by Species

	Chinook	Chum	Sockeye	Coho
2010	89,206	83,059	44,004	46,532
2015	91,833	85,105	45,300	47,643
2020	94,522	87,221	46,629	48,776
2025	97,049	89,222	47,878	49,822
2030	100,042	91,632	49,359	51,081
2035	103,048	94,084	50,849	52,340
2040	106,051	96,569	52,342	53,589
2045	109,034	99,076	53,830	54,820
2050	111,977	101,593	55,303	56,022



Subsistence Salmon Demand for Human or Dog Food

	L Kusk-Bet Human Food	L Kusk-Bet Dog Food	M-U Kusk Human Food	M-U Kusk Dog Food	SK Bay-Cst Human Food	SK Bay-Cst Dog Food
2010	174,391	8,967	48,912	8,099	23,977	900
2015	179,645	8,909	50,038	7,962	24,858	920
2020	185,030	8,859	51,168	7,829	25,779	942
2025	190,106	8,813	52,171	7,699	26,683	965
2030	196,097	8,784	53,403	7,575	27,744	992
2035	202,056	8,764	54,686	7,455	28,835	1,021
2040	207,951	8,752	56,017	7,339	29,953	1,052
2045	213,741	8,748	57,390	7,228	31,099	1,084
2050	219,383	8,753	58,799	7,120	32,271	1,119

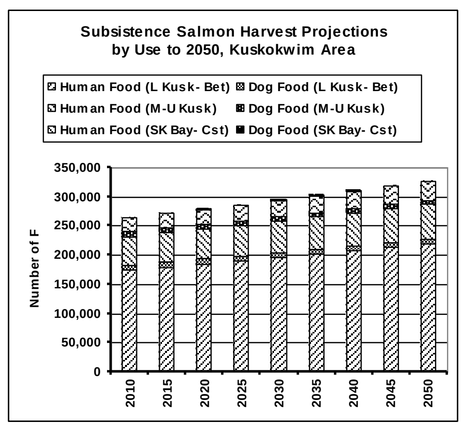
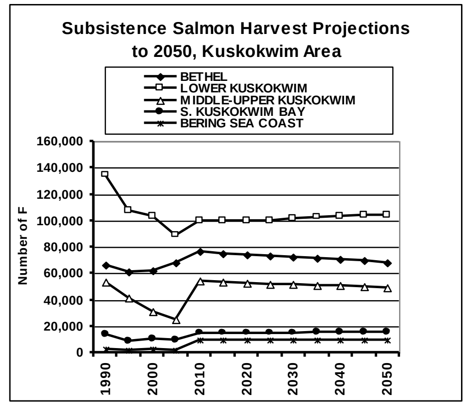


Fig. A8. Subsistence Demand Scenario, Kuskokwim Area (Low)

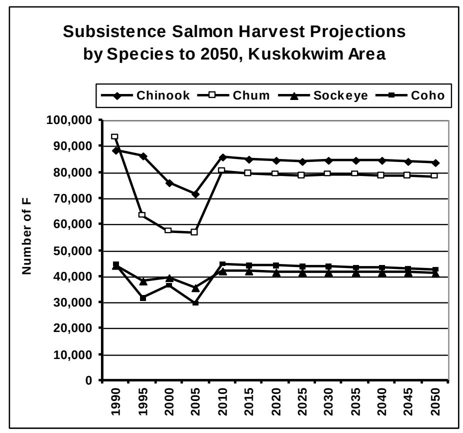
Subsistence Salmon Demand Model

Low Scenario: Kuskokwim Area
(Bethel, Lower Kuskokwim, Middle-Upper Kuskokwim, South Kuskokwim Bay, Bering Sea Coast)



Subsistence Salmon Demand (All Species and Uses)

	Bethel	L Kusk	Mid-U Kusk	S Kusk B	Bering SC	Total
2010	76,180	99,382	54,319	14,632	9,094	253,607
2015	75,097	99,389	53,467	14,655	9,105	251,713
2020	74,047	99,559	52,656	14,703	9,130	250,094
2025	73,065	99,963	51,909	14,786	9,174	248,897
2030	72,495	101,106	51,467	14,983	9,286	249,337
2035	71,689	102,140	50,990	15,164	9,385	249,367
2040	70,619	103,043	50,463	15,326	9,470	248,921
2045	69,257	103,794	49,871	15,467	9,537	247,926
2050	67,569	104,367	49,197	15,582	9,585	246,300



Subsistence Salmon Demand by Species

	Chinook	Chum	Sockeye	Coho
2010	85,628	80,188	42,236	44,837
2015	85,062	79,574	41,957	44,408
2020	84,589	79,053	41,724	44,022
2025	84,264	78,666	41,563	43,702
2030	84,517	78,774	41,690	43,653
2035	84,612	78,784	41,740	43,529
2040	84,524	78,675	41,704	43,319
2045	84,226	78,428	41,566	43,010
2050	83,690	78,021	41,314	42,586

Subsistence Salmon Demand for Human or Dog Food

	L Kusk-Bet Human Food	L Kusk-Bet Dog Food	M-U Kusk Human Food	M-U Kusk Dog Food	SK Bay-Cst Human Food	SK Bay-Cst Dog Food
2010	167,454	8,967	46,855	8,099	23,028	900
2015	166,494	8,839	46,199	7,886	23,046	917
2020	165,719	8,723	45,578	7,681	23,101	936
2025	165,239	8,613	45,013	7,483	23,212	956
2030	165,892	8,525	44,745	7,294	23,498	980
2035	166,189	8,448	44,435	7,113	23,755	1,007
2040	166,083	8,382	44,069	6,939	23,977	1,035
2045	165,521	8,328	43,631	6,772	24,158	1,065
2050	164,446	8,284	43,104	6,612	24,293	1,098

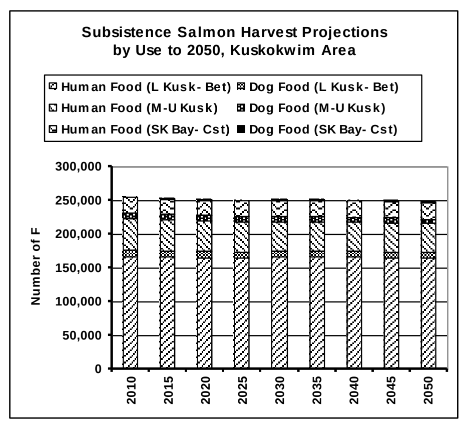


Fig. A9. Subsistence Demand Scenario, Norton Sound Area (High)

Subsistence Salmon Demand Model

High Scenario: Norton Sound Area (South Norton Sound, Nome, North Norton Sound-Port Clarence)

Subsistence Salmon Demand (All Species and Uses)

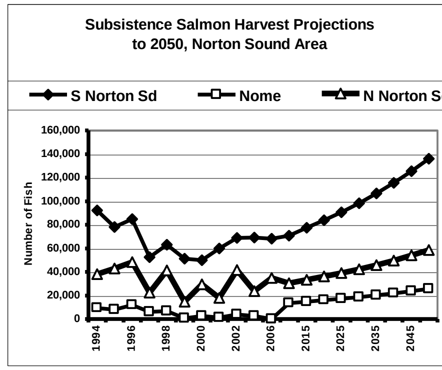
	S Norton Sd	Nome	N Norton Sd	Total
2010	70,836	13,453	30,543	114,831
2015	77,501	14,711	33,407	125,619
2020	83,988	15,929	36,188	136,105
2025	90,596	17,167	39,016	146,779
2030	98,280	18,608	42,308	159,196
2035	106,619	20,170	45,877	172,666
2040	115,669	21,863	49,748	187,280
2045	125,491	23,698	53,947	203,135
2050	136,151	25,687	58,500	220,338

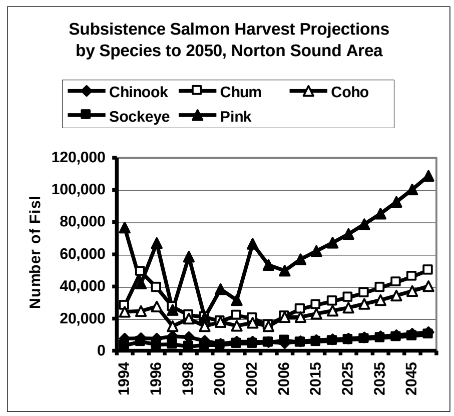
Subsistence Salmon Demand by Species

	Chinook	Chum	Coho	Sockeye	Pink
2010	5,967	25,883	20,940	5,255	56,787
2015	6,524	28,333	22,909	5,746	62,106
2020	7,065	30,727	24,825	6,222	67,266
2025	7,614	33,174	26,776	6,705	72,510
2030	8,253	36,015	29,045	7,268	78,614
2035	8,946	39,102	31,507	7,878	85,233
2040	9,697	42,456	34,179	8,539	92,409
2045	10,511	46,099	37,078	9,256	100,191
2050	11,393	50,059	40,225	10,033	108,628

Subsistence Salmon Demand for Human or Dog Food

	S Norton Sd Human Food	S Norton Sd Dog Food	Nome Human Food	Nome Dog Food	N Norton Sd Human Food	N Norton Sd Dog Food
2010	69,350	1,493	13,453	0	30,242	352
2015	75,835	1,675	14,711	0	33,070	395
2020	82,118	1,880	15,929	0	35,810	443
2025	88,498	2,109	17,167	0	38,592	497
2030	95,926	2,366	18,608	0	41,832	558
2035	103,978	2,655	20,170	0	45,343	626
2040	112,705	2,979	21,863	0	49,149	703
2045	122,165	3,342	23,698	0	53,274	788
2050	132,420	3,750	25,687	0	57,746	884





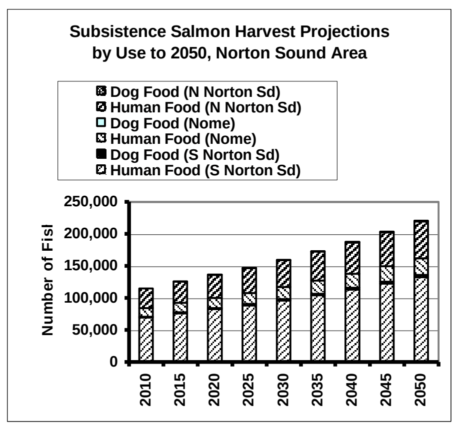


Fig. A10. Subsistence Demand Scenario, Norton Sound Area (Intermediate Two)

Subsistence Salmon Demand Model

Intermediate Two Scenario: Norton Sound Area (South Norton Sound, Nome, North Norton Sound-Port Clarence)

Subsistence Salmon Demand (All Species and Uses)

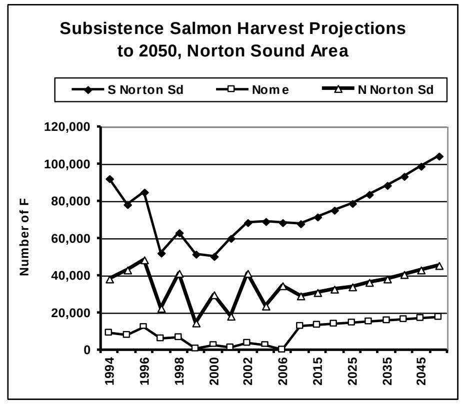
	S Norton Sd	Nome	N Norton Sd	Total
2010	67,649	12,622	29,219	109,490
2015	71,424	13,202	30,881	115,508
2020	75,125	13,748	32,514	121,387
2025	78,849	14,278	34,160	127,287
2030	83,418	14,940	36,180	134,538
2035	88,235	15,620	38,312	142,167
2040	93,309	16,315	40,563	150,188
2045	98,655	17,025	42,938	158,618
2050	104,282	17,747	45,444	167,473

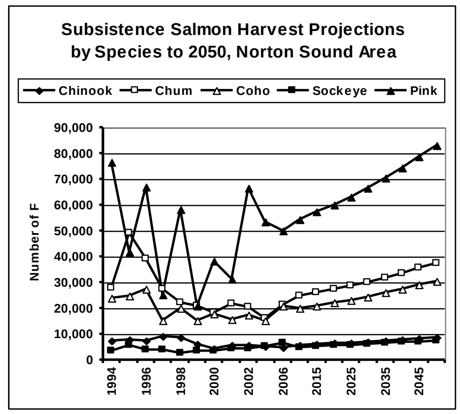
Subsistence Salmon Demand by Species

	Chinook	Chum	Coho	Sockeye	Pink
2010	5,701	24,648	19,965	4,995	54,181
2015	6,022	25,980	21,061	5,261	57,184
2020	6,336	27,281	22,132	5,519	60,118
2025	6,652	28,586	23,208	5,777	63,065
2030	7,040	30,186	24,528	6,095	66,688
2035	7,450	31,868	25,918	6,429	70,502
2040	7,882	33,635	27,379	6,778	74,514
2045	8,336	35,491	28,915	7,143	78,734
2050	8,815	37,437	30,528	7,524	83,169

Subsistence Salmon Demand for Human or Dog Food

	S Norton Sd Human Food	S Norton Sd Dog Food	Nome Human Food	Nome Dog Food	N Norton Sd Human Food	N Norton Sd Dog Food
2010	66,271	1,384	12,622	0	28,941	327
2015	70,005	1,426	13,202	0	30,594	336
2020	73,663	1,469	13,748	0	32,218	347
2025	77,343	1,514	14,278	0	33,855	357
2030	81,867	1,559	14,940	0	35,866	368
2035	86,636	1,606	15,620	0	37,989	379
2040	91,663	1,655	16,315	0	40,230	390
2045	96,958	1,705	17,025	0	42,595	402
2050	102,534	1,756	17,747	0	45,090	414





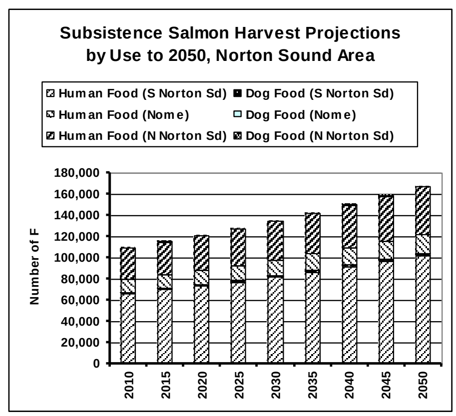


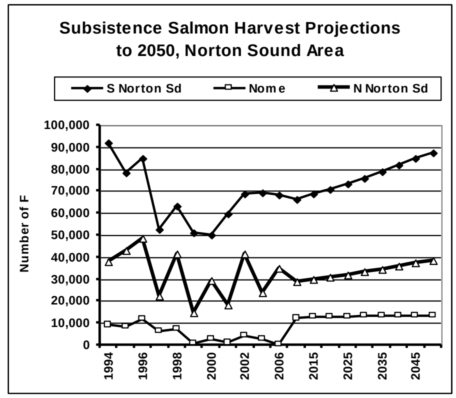
Fig. A11. Subsistence Demand Scenario, Norton Sound Area (Intermediate One)

Subsistence Salmon Demand Model

Intermediate One Scenario: Norton Sound Area
(South Norton Sound, Nome,
North Norton Sound-Port Clarence)

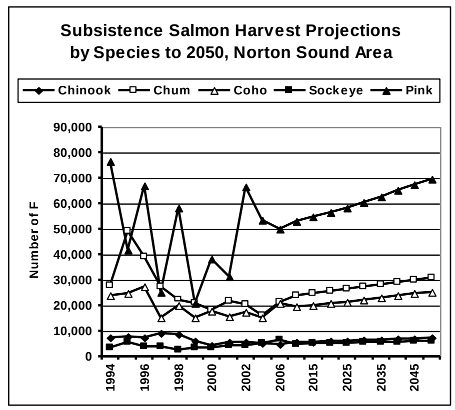
Subsistence Salmon Demand (All Species and Uses)

	S Norton Sd	Nome	N Norton Sd	Total
2010	66,126	12,191	28,599	106,916
2015	68,615	12,444	29,734	110,793
2020	70,902	12,626	30,788	114,316
2025	73,081	12,753	31,800	117,634
2030	75,894	12,951	33,099	121,944
2035	78,762	13,109	34,430	126,301
2040	81,677	13,219	35,792	130,688
2045	84,630	13,273	37,182	135,086
2050	87,611	13,262	38,597	139,470



Subsistence Salmon Demand by Species

	Chinook	Chum	Coho	Sockeye	Pink
2010	5,574	24,050	19,495	4,867	52,929
2015	5,790	24,876	20,199	5,031	54,896
2020	5,988	25,623	20,839	5,176	56,690
2025	6,177	26,323	21,442	5,309	58,383
2030	6,420	27,238	22,225	5,484	60,577
2035	6,668	28,160	23,017	5,658	62,798
2040	6,919	29,086	23,815	5,828	65,039
2045	7,174	30,011	24,615	5,995	67,291
2050	7,431	30,930	25,413	6,155	69,542



Subsistence Salmon Demand for Human or Dog Food

	S Norton Sd Human Food	S Norton Sd Dog Food	Nome Human Food	Nome Dog Food	N Norton Sd Human Food	N Norton Sd Dog Food
2010	64,803	1,330	12,191	0	28,331	314
2015	67,318	1,304	12,444	0	29,472	307
2020	69,631	1,277	12,626	0	30,531	301
2025	71,835	1,252	12,753	0	31,548	295
2030	74,674	1,227	12,951	0	32,852	289
2035	77,566	1,202	13,109	0	34,188	284
2040	80,505	1,178	13,219	0	35,555	278
2045	83,481	1,155	13,273	0	36,950	272
2050	86,485	1,132	13,262	0	38,369	267

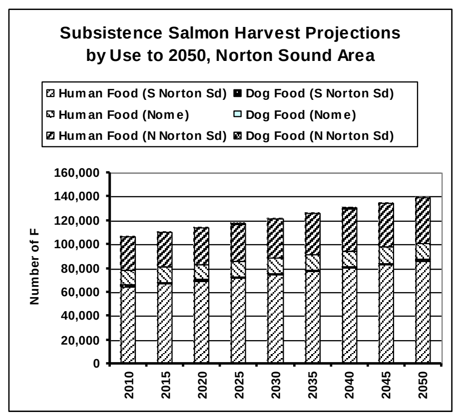


Fig. A12. Subsistence Demand Scenario, Norton Sound Area (Low)

Subsistence Salmon Demand Model

Low Scenario: Norton Sound Area
(South Norton Sound, Nome,
North Norton Sound-Port Clarence)

Subsistence Salmon Demand (All Species and Uses)

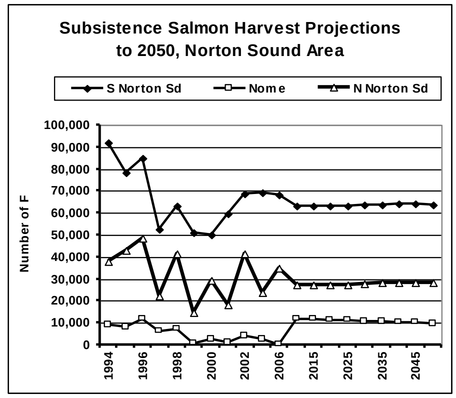
	S Norton Sd	Nome	N Norton Sd	Total
2010	63,330	11,672	27,419	102,421
2015	63,328	11,476	27,489	102,293
2020	63,118	11,226	27,476	101,819
2025	62,975	10,970	27,501	101,445
2030	63,460	10,801	27,814	102,076
2035	63,800	10,578	28,077	102,455
2040	63,970	10,295	28,280	102,544
2045	63,944	9,943	28,413	102,300
2050	63,692	9,516	28,466	101,674

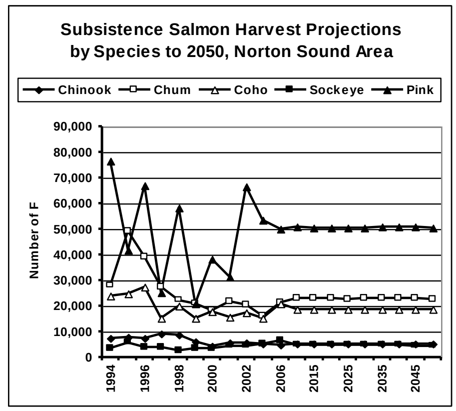
Subsistence Salmon Demand by Species

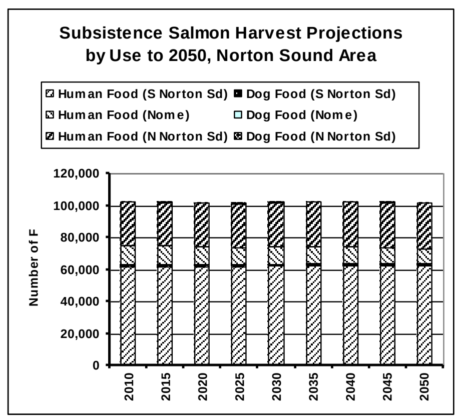
	Chinook	Chum	Coho	Sockeye	Pink
2010	5,335	23,064	18,677	4,662	50,683
2015	5,337	23,012	18,652	4,644	50,648
2020	5,322	22,883	18,565	4,609	50,441
2025	5,312	22,775	18,495	4,577	50,285
2030	5,356	22,886	18,608	4,590	50,635
2035	5,388	22,941	18,676	4,590	50,861
2040	5,405	22,930	18,690	4,575	50,944
2045	5,406	22,844	18,643	4,542	50,864
2050	5,388	22,673	18,528	4,490	50,597

Subsistence Salmon Demand for Human or Dog Food

	S Norton Sd Human Food	S Norton Sd Dog Food	Nome Human Food	Nome Dog Food	N Norton Sd Human Food	N Norton Sd Dog Food
2010	62,007	1,330	11,672	0	27,151	314
2015	62,030	1,304	11,476	0	27,227	307
2020	61,847	1,277	11,226	0	27,219	301
2025	61,729	1,252	10,970	0	27,249	295
2030	62,240	1,227	10,801	0	27,567	289
2035	62,603	1,202	10,578	0	27,835	284
2040	62,797	1,178	10,295	0	28,043	278
2045	62,795	1,155	9,943	0	28,181	272
2050	62,566	1,132	9,516	0	28,239	267







Appendix B:
Comparison of Projections of Mean Commercial Harvests and Mean Utilization for Selected Combinations of Scenario Assumptions and Time Periods

The tables in this appendix provide summary comparisons of projections of mean harvests and mean utilization for the following combinations of scenario assumptions and time periods:

Table B-1.Overview of Appendix B Tables

Tables	Assumptions about probability distribution of future returns	Assumptions about future subsistence demand	Utilization assumptions	Time periods
B-2, B-3	Historic, Low, High	Low, Int1, Int2, High	Varied-Rising	2011-2050
B-4, B-5	Historic	Low, High	Varied-Rising	2011-20 2021-30 2031-40 2041-50
B-6, B-7	Historic	High	Same-Low Same-High Same-Rising Varied-Low Varied-High Varied-Rising	2011-20 2041-50
B-8, B-14	Historic	Low	"	2011-2050
B-9, B-15	Historic	High	"	"
B-10, B-16	Low	Low	"	"
B-11, B-17	Low	High	"	"
B-12, B-18	High	Low	"	"
B-13, B-19	High	High	"	"

Table B-2. Mean Projected Commercial Harvest, 2011-2050, with "Varied-Rising" Utilization (000 fish)

		Historic return				High return				Low return			
		Subsistence demand:				Subsistence demand:				Subsistence demand:			
Area	Species	Low	Int 1	Int 2	High	Low	Int 1	Int 2	High	Low	Int 1	Int 2	High
Kuskokwim Bay	Chinook	15.0	14.9	14.7	14.5	16.6	15.8	15.3	14.2	11.3	10.4	9.8	8.8
	Coho	42.4	42.5	42.4	42.5	48.2	48.6	48.6	48.6	45.6	44.9	44.9	43.9
	Summer Chum	26.9	26.9	26.9	26.9	27.9	27.9	27.9	27.9	27.9	28.0	28.0	28.0
	Sockeye	35.2	35.2	35.1	35.3	40.0	40.2	40.1	40.2	39.3	39.2	39.1	39.4
Lower Kuskokwim	Chinook	3.4	0.7	0.3	0.1	3.9	1.0	0.4	0.1	3.7	0.8	0.3	0.1
	Coho	199.5	197.5	196.0	189.7	231.3	232.2	233.2	231.6	125.3	121.7	118.6	110.5
	Summer Chum	118.1	114.5	110.8	97.4	138.3	138.1	137.7	133.7	133.1	128.1	121.6	106.8
	Sockeye	20.1	20.1	20.2	20.1	25.2	25.2	25.3	25.2	11.1	11.2	11.2	11.2
Lower Yukon	Chinook	63.4	55.3	49.2	38.0	70.9	66.7	62.4	52.3	58.8	49.5	43.3	31.7
	Coho	15.4	14.9	14.5	13.7	16.3	16.1	15.8	15.1	16.3	16.0	15.7	14.9
	Summer Chum	344.0	336.5	332.2	320.7	357.0	354.2	350.1	342.6	356.2	356.3	353.4	349.0
	Fall Chum	54.5	53.3	52.5	50.8	60.6	59.6	58.9	57.2	54.1	52.9	52.3	50.7
Upper Yukon	Chinook	4.1	4.1	4.1	4.1	4.2	4.1	4.1	4.1	4.1	4.2	4.1	4.1
	Coho	3.9	3.9	3.9	3.6	4.1	4.1	4.1	4.0	4.2	4.2	4.2	3.9
	Summer Chum	125.4	124.7	124.3	116.1	129.6	129.5	129.1	124.9	129.0	129.2	127.6	118.8
	Fall Chum	26.9	26.9	26.8	20.9	27.3	27.3	26.8	16.5	27.4	27.4	27.4	26.6
Southern Norton	Chinook	3.2	2.7	2.4	1.8	3.8	3.6	3.4	3.0	2.5	1.8	1.5	1.0
	Coho	20.2	18.5	17.2	15.1	27.5	27.0	26.4	25.5	13.1	11.2	10.0	8.3
	Summer Chum	20.3	18.0	16.7	14.1	28.6	28.2	27.9	26.4	14.2	12.2	11.0	8.8
	Pink	25.5	22.3	20.5	17.1	35.2	33.7	32.7	31.1	16.3	12.9	11.2	8.3
Northern Norton	Coho	1.6	1.6	1.6	1.6	1.7	1.6	1.7	1.6	1.7	1.6	1.6	1.7
	Summer Chum	25.6	25.3	24.7	23.7	27.6	27.5	27.6	27.5	23.6	22.9	22.1	20.9
	Pink	15.3	15.0	14.7	15.4	15.9	15.9	15.8	15.9	15.5	15.1	14.7	15.5

Note: ##### indicates value is very low or zero.

Table B-3. Mean Projected Average Utilization, 2011-2050, with "Varied-Rising" Utilization

		Historic return				High return				Low return			
		Subsistence demand:				Subsistence demand:				Subsistence demand:			
Area	Species	Low	Int 1	Int 2	High	Low	Int 1	Int 2	High	Low	Int 1	Int 2	High
Kuskokwim Bay	Chinook	80%	79%	79%	79%	79%	78%	77%	77%	77%	77%	76%	75%
	Coho	68%	68%	68%	68%	68%	68%	68%	68%	68%	68%	68%	68%
	Summer Chum	60%	59%	60%	60%	59%	59%	59%	59%	60%	60%	60%	60%
	Sockeye	69%	68%	69%	68%	68%	68%	68%	68%	68%	68%	68%	68%
Lower Kuskokwim	Chinook	77%	55%	45%	31%	79%	60%	51%	38%	78%	58%	48%	35%
	Coho	67%	67%	67%	66%	67%	67%	67%	67%	66%	66%	66%	65%
	Summer Chum	57%	57%	56%	54%	58%	58%	58%	57%	57%	57%	56%	54%
	Sockeye	68%	67%	67%	67%	69%	69%	69%	69%	62%	62%	62%	62%
Lower Yukon	Chinook	83%	82%	81%	79%	83%	83%	82%	80%	82%	81%	80%	78%
	Coho	71%	71%	71%	70%	72%	71%	71%	70%	72%	71%	71%	70%
	Summer Chum	60%	59%	59%	59%	60%	60%	59%	59%	60%	60%	60%	59%
	Fall Chum	60%	60%	59%	59%	60%	60%	60%	59%	60%	60%	60%	59%
Upper Yukon	Chinook	83%	83%	83%	83%	83%	83%	83%	83%	83%	83%	83%	83%
	Coho	72%	72%	72%	70%	72%	72%	72%	71%	72%	72%	72%	71%
	Summer Chum	60%	60%	60%	59%	60%	60%	60%	59%	60%	60%	60%	59%
	Fall Chum	60%	60%	60%	55%	60%	60%	60%	50%	60%	60%	60%	60%
Southern Norton	Chinook	80%	78%	76%	73%	81%	81%	80%	78%	77%	74%	71%	65%
	Coho	64%	63%	62%	60%	66%	66%	66%	65%	62%	59%	57%	54%
	Summer Chum	51%	49%	48%	45%	53%	53%	53%	52%	49%	46%	45%	41%
	Pink	46%	44%	43%	40%	48%	48%	47%	46%	43%	40%	38%	34%
Northern Norton	Coho	73%	73%	73%	73%	73%	73%	73%	73%	73%	73%	73%	73%
	Summer Chum	58%	58%	58%	57%	58%	58%	58%	58%	58%	57%	57%	56%
	Pink	54%	53%	53%	54%	54%	54%	54%	54%	54%	53%	53%	54%

Note: ##### indicates value is very low or zero.

Table B-4. Mean Projected Commercial Harvests by Decade, with "Varied-Rising" Utilization (000 fish)

		Low subsistence demand				High subsistence demand			
		Decade ending:				Decade ending:			
Area	Species	2020	2030	2040	2050	2020	2030	2040	2050
Kuskokwim Bay	Chinook	13.6	14.7	15.5	16.2	13.5	14.5	14.9	15.0
	Coho	30.5	39.3	47.0	52.8	30.0	39.2	47.7	53.2
	Summer Chum	17.4	24.0	30.4	35.8	17.4	24.0	30.5	35.6
	Sockeye	25.2	32.7	39.5	43.4	25.4	32.9	39.0	44.1
Lower Kuskokwim	Chinook	2.9	3.3	3.4	3.9	0.2	0.0	0.0	0.0
	Coho	140.6	182.7	223.1	251.4	137.6	177.7	211.7	231.6
	Summer Chum	74.5	104.5	134.5	158.9	70.4	93.2	109.5	116.4
	Sockeye	14.2	18.6	22.4	25.3	14.2	18.5	22.5	25.3
Lower Yukon	Chinook	54.2	61.2	66.9	71.4	43.4	40.7	36.7	31.0
	Coho	11.6	14.6	16.8	18.6	11.2	13.6	14.9	15.1
	Summer Chum	224.0	308.3	388.1	455.5	220.9	297.3	360.7	404.0
	Fall Chum	35.9	49.0	61.8	71.3	34.9	46.8	57.3	64.3
Upper Yukon	Chinook	3.7	4.0	4.2	4.4	3.8	4.0	4.2	4.3
	Coho	2.9	3.7	4.3	4.8	2.9	3.6	4.0	3.9
	Summer Chum	81.3	112.2	141.6	166.6	80.0	107.8	130.8	145.7
	Fall Chum	17.6	24.1	30.5	35.5	17.2	22.4	24.3	19.8
Southern Norton	Chinook	2.9	3.1	3.3	3.4	2.4	2.1	1.6	1.1
	Coho	13.8	18.8	22.5	25.8	12.3	15.0	16.3	16.7
	Summer Chum	12.1	17.4	23.3	28.5	10.3	13.4	15.5	17.0
	Pink	12.2	20.6	29.6	39.6	10.4	15.7	20.0	22.3
Northern Norton	Coho	1.2	1.5	1.7	1.9	1.2	1.5	1.7	1.9
	Summer Chum	16.3	22.9	29.3	34.1	16.0	21.7	26.9	30.3
	Pink	8.0	12.8	18.0	22.3	8.1	13.0	18.1	22.4

Note: ##### indicates value is very low or zero.

Table B-5. Mean Projected Average Utilization by Decade, with "Varied-Rising" Utilization

		Low subsistence demand				High subsistence demand			
		Decade ending:				Decade ending:			
Area	Species	2020	2030	2040	2050	2020	2030	2040	2050
Kuskokwim Bay	Chinook	72%	78%	83%	86%	72%	77%	82%	85%
	Coho	48%	63%	76%	85%	48%	63%	76%	85%
	Summer Chum	39%	53%	67%	79%	39%	53%	67%	79%
	Sockeye	49%	64%	76%	85%	49%	63%	76%	85%
Lower Kuskokwim	Chinook	69%	75%	80%	85%	33%	1%	13%	#DIV/0!
	Coho	48%	62%	75%	84%	47%	62%	74%	84%
	Summer Chum	36%	51%	65%	77%	35%	49%	62%	74%
	Sockeye	48%	62%	75%	85%	48%	62%	75%	84%
Lower Yukon	Chinook	75%	81%	85%	89%	74%	78%	82%	85%
	Coho	53%	67%	79%	87%	53%	66%	78%	86%
	Summer Chum	39%	54%	68%	79%	39%	53%	67%	78%
	Fall Chum	39%	54%	68%	79%	39%	54%	68%	79%
Upper Yukon	Chinook	77%	82%	86%	89%	77%	82%	86%	89%
	Coho	53%	68%	79%	87%	53%	67%	78%	85%
	Summer Chum	39%	54%	68%	79%	39%	53%	67%	78%
	Fall Chum	39%	54%	68%	79%	39%	53%	64%	72%
Southern Norton	Chinook	73%	78%	83%	87%	70%	73%	75%	75%
	Coho	44%	59%	72%	83%	43%	56%	68%	77%
	Summer Chum	30%	44%	59%	72%	29%	41%	53%	65%
	Pink	22%	37%	55%	72%	21%	34%	50%	66%
Northern Norton	Coho	55%	69%	80%	88%	55%	69%	80%	88%
	Summer Chum	37%	52%	66%	78%	37%	51%	65%	77%
	Pink	28%	45%	63%	78%	28%	45%	63%	78%

Note: #DIV/0! indicates projected mean harvestable surplus is zero.

Table B-6. Mean Projected Commercial Harvest, by Utilization Assumptions (000 fish)

		Same-Low		Same-High		Same-Rising		Varied-Low		Varied-High		Varied-Rising	
		Decade ending:		Decade ending:		Decade ending:		Decade ending:		Decade ending:		Decade ending:	
Area	Species	2020	2050	2020	2050	2020	2050	2020	2050	2020	2050	2020	2050
Kuskokwim Bay	Chinook	7.4	6.7	15.0	13.8	8.6	13.2	12.8	11.8	16.5	15.3	13.5	15.0
	Coho	24.9	25.2	49.8	50.4	28.7	48.2	24.9	25.2	54.7	55.3	30.0	53.2
	Summer Chum	20.4	20.3	37.6	37.5	23.1	36.1	14.0	14.0	37.6	37.5	17.4	35.6
	Sockeye	21.2	21.1	41.6	41.8	24.3	40.0	21.2	21.1	45.5	45.8	25.4	44.1
Lower Kuskokwim	Chinook	0.1	0.0	0.3	0.0	0.1	0.0	0.2	0.0	0.4	0.0	0.2	0.0
	Coho	113.9	105.8	232.1	218.3	131.6	208.1	113.9	105.8	255.8	241.3	137.6	231.6
	Summer Chum	83.0	60.1	161.4	124.5	95.1	118.6	56.1	39.8	161.4	124.5	70.4	116.4
	Sockeye	11.8	11.8	23.8	23.9	13.6	22.9	11.8	11.8	26.2	26.3	14.2	25.3
Lower Yukon	Chinook	24.6	13.5	47.9	28.5	28.1	27.1	41.5	24.2	52.3	31.7	43.4	31.0
	Coho	9.5	7.5	17.6	14.3	10.8	13.7	9.5	7.5	19.1	15.6	11.2	15.1
	Summer Chum	258.1	227.8	475.7	426.6	293.2	410.1	177.9	156.1	475.7	426.6	220.9	404.0
	Fall Chum	40.8	36.7	74.8	67.8	46.3	65.2	28.2	25.3	74.8	67.8	34.9	64.3
Upper Yukon	Chinook	2.3	2.2	4.1	4.0	2.6	3.9	3.6	3.5	4.4	4.4	3.8	4.3
	Coho	2.5	1.8	4.5	3.7	2.8	3.5	2.5	1.8	4.9	4.0	2.9	3.9
	Summer Chum	93.4	81.9	172.3	153.9	106.2	147.9	64.4	56.0	172.3	153.9	80.0	145.7
	Fall Chum	20.1	10.0	36.9	21.4	22.8	20.3	13.9	6.6	36.9	21.4	17.2	19.8
Southern Norton	Chinook	1.3	0.3	2.7	0.9	1.5	0.9	2.3	0.7	3.0	1.1	2.4	1.1
	Coho	10.1	6.3	22.0	15.4	11.7	14.4	10.1	6.3	24.6	17.7	12.3	16.7
	Summer Chum	12.4	7.6	27.5	18.6	14.5	17.4	8.1	4.8	27.5	18.6	10.3	17.0
	Pink	17.7	10.5	37.9	24.5	20.8	23.2	7.1	4.1	37.9	24.5	10.4	22.3
Northern Norton	Coho	1.0	1.0	1.8	1.8	1.1	1.7	1.0	1.0	2.0	1.9	1.2	1.9
	Summer Chum	18.8	16.6	35.7	32.2	21.5	30.8	12.8	11.3	35.7	32.2	16.0	30.3
	Pink	13.1	13.1	23.9	23.9	14.9	23.1	5.8	5.8	23.9	23.9	8.1	22.4

Note: All projections are for Historic Return-High Subistence Demand assumptions. ##### indicates harvest is very low or zero.

Table B-7. Mean Projected Average Utilization, by Utilization Assumptions

		Same-Low		Same-High		Same-Rising		Varied-Low		Varied-High		Varied-Rising	
		Decade ending:		Decade ending:		Decade ending:		Decade ending:		Decade ending:		Decade ending:	
Area	Species	2020	2050	2020	2050	2020	2050	2020	2050	2020	2050	2020	2050
Kuskokwim Bay	Chinook	40%	38%	80%	79%	46%	75%	69%	67%	88%	87%	72%	85%
	Coho	40%	40%	80%	80%	46%	77%	40%	40%	88%	88%	48%	85%
	Summer Chum	45%	45%	83%	83%	51%	80%	31%	31%	83%	83%	39%	79%
	Sockeye	41%	41%	81%	81%	47%	77%	41%	41%	89%	88%	49%	85%
Lower Kuskokwim	Chinook	13%	######	44%	######	14%	######	32%	######	58%	######	33%	######
	Coho	39%	38%	79%	79%	45%	75%	39%	38%	88%	87%	47%	84%
	Summer Chum	42%	38%	81%	79%	48%	75%	28%	25%	81%	79%	35%	74%
	Sockeye	40%	39%	80%	80%	46%	76%	40%	39%	88%	88%	48%	84%
Lower Yukon	Chinook	42%	37%	81%	78%	48%	74%	70%	66%	89%	87%	74%	85%
	Coho	45%	43%	83%	82%	51%	78%	45%	43%	90%	89%	53%	86%
	Summer Chum	45%	44%	83%	83%	51%	80%	31%	30%	83%	83%	39%	78%
	Fall Chum	45%	45%	83%	83%	52%	80%	31%	31%	83%	83%	39%	79%
Upper Yukon	Chinook	46%	46%	84%	83%	52%	80%	74%	73%	90%	90%	77%	89%
	Coho	45%	40%	83%	80%	51%	77%	45%	40%	90%	88%	53%	85%
	Summer Chum	45%	44%	83%	83%	51%	79%	31%	30%	83%	83%	39%	78%
	Fall Chum	46%	36%	84%	77%	52%	73%	31%	24%	84%	77%	39%	72%
Southern Norton	Chinook	38%	24%	78%	65%	43%	60%	67%	51%	87%	77%	70%	75%
	Coho	35%	29%	76%	71%	41%	67%	35%	29%	86%	82%	43%	77%
	Summer Chum	34%	29%	76%	71%	40%	66%	22%	18%	76%	71%	29%	65%
	Pink	36%	31%	76%	73%	42%	69%	14%	12%	76%	73%	21%	66%
Northern Norton	Coho	47%	47%	84%	84%	53%	81%	47%	47%	91%	91%	55%	88%
	Summer Chum	43%	42%	82%	82%	49%	78%	30%	29%	82%	82%	37%	77%
	Pink	46%	46%	84%	84%	52%	81%	20%	20%	84%	84%	28%	78%

Note: All projections are for Historic Return-High Subistence Demand assumptions. ##### indicates harvest is very low or zero.

Table B-8. Mean Commercial Harvest, 2011-2050, Historic Return-Low Subsistence Scenario

		Utilization Assumptions					
		Same-Low	Same-High	Same-Rising	Varied-Low	Varied-High	Varied-Rising
Kuskokwim Bay	Chinook	7,483	15,047	11,601	12,920	16,540	14,983
	Coho	25,209	50,133	38,807	25,209	54,992	42,409
	Summer Chum	20,332	37,579	29,985	14,003	37,579	26,905
	Sockeye	21,036	41,496	32,256	21,036	45,446	35,210
Lower Kuskokwim	Chinook	1,598	3,399	2,575	2,872	3,780	3,390
	Coho	116,753	236,553	181,961	116,753	260,437	199,482
	Summer Chum	87,712	168,266	132,246	59,607	168,266	118,114
	Sockeye	11,842	23,846	18,390	11,842	26,221	20,140
Lower Yukon	Chinook	34,050	63,584	50,815	55,716	68,927	63,435
	Coho	9,671	17,922	14,264	9,671	19,401	15,416
	Summer Chum	260,817	479,317	383,216	180,001	479,317	343,996
	Fall Chum	41,426	76,025	60,719	28,604	76,025	54,473
Upper Yukon	Chinook	2,252	4,093	3,287	3,612	4,415	4,077
	Coho	2,474	4,555	3,638	2,474	4,925	3,928
	Summer Chum	95,136	174,548	139,681	65,698	174,548	125,442
	Fall Chum	20,504	37,400	29,975	14,190	37,400	26,930
Southern Norton	Chinook	1,607	3,194	2,476	2,751	3,503	3,181
	Coho	11,345	24,322	18,276	11,345	27,091	20,229
	Summer Chum	14,289	30,783	23,068	9,353	30,783	20,329
	Pink	20,360	42,789	32,572	8,321	42,789	25,487
Northern Norton	Coho	1,016	1,817	1,468	1,016	1,954	1,578
	Summer Chum	19,212	36,280	28,674	13,128	36,280	25,648
	Pink	12,945	23,742	19,057	5,722	23,742	15,286

Table B-9. Mean Commercial Harvest, 2011-2050, Historic Return-High Subsistence Scenario

		Utilization Assumptions					
		Same-Low	Same-High	Same-Rising	Varied-Low	Varied-High	Varied-Rising
Kuskokwim Bay	Chinook	7,131	14,522	11,107	12,425	16,005	14,456
	Coho	25,175	50,196	38,890	25,175	55,088	42,530
	Summer Chum	20,348	37,606	29,990	14,013	37,606	26,901
	Sockeye	21,108	41,655	32,370	21,108	45,623	35,336
Lower Kuskokwim	Chinook	20	70	23	50	91	53
	Coho	110,551	226,277	172,706	110,551	249,630	189,658
	Summer Chum	72,631	144,936	110,615	48,715	144,936	97,393
	Sockeye	11,818	23,838	18,377	11,818	26,221	20,133
Lower Yukon	Chinook	19,184	38,488	28,784	33,064	42,299	37,967
	Coho	8,576	16,155	12,644	8,576	17,541	13,695
	Summer Chum	244,438	453,757	359,133	168,077	453,757	320,723
	Fall Chum	38,869	71,549	56,824	26,809	71,549	50,819
Upper Yukon	Chinook	2,232	4,070	3,262	3,589	4,393	4,054
	Coho	2,239	4,232	3,321	2,239	4,599	3,604
	Summer Chum	88,395	164,346	130,002	60,747	164,346	116,067
	Fall Chum	16,197	31,071	23,860	11,022	31,071	20,937
Southern Norton	Chinook	809	1,829	1,252	1,515	2,067	1,789
	Coho	8,210	18,799	13,434	8,210	21,259	15,056
	Summer Chum	9,978	23,063	16,354	6,405	23,063	14,064
	Pink	14,237	31,592	22,913	5,648	31,592	17,103
Northern Norton	Coho	1,013	1,813	1,464	1,013	1,950	1,574
	Summer Chum	17,804	34,080	26,660	12,109	34,080	23,727
	Pink	13,073	23,900	19,200	5,790	23,900	15,402

Table B-10. Mean Commercial Harvest, 2011-2050, Low Return-Low Subsistence Scenario

		Utilization Assumptions					
		Same-Low	Same-High	Same-Rising	Varied-Low	Varied-High	Varied-Rising
Kuskokwim Bay	Chinook	8,062	16,664	12,690	14,198	18,420	16,587
	Coho	28,527	57,150	44,090	28,527	62,779	48,240
	Summer Chum	21,098	39,048	31,119	14,523	39,048	27,908
	Sockeye	23,809	47,173	36,647	23,809	51,707	40,032
Lower Kuskokwim	Chinook	1,888	3,887	2,983	3,315	4,294	3,876
	Coho	135,138	274,289	210,917	135,138	302,086	231,315
	Summer Chum	102,908	196,549	154,747	70,042	196,549	138,269
	Sockeye	15,256	29,548	23,136	15,256	32,247	25,179
Lower Yukon	Chinook	38,891	71,207	57,088	62,722	76,919	70,940
	Coho	10,217	18,874	15,052	10,217	20,420	16,260
	Summer Chum	270,613	497,295	397,612	186,764	497,295	356,963
	Fall Chum	46,070	84,548	67,536	31,811	84,548	60,592
Upper Yukon	Chinook	2,297	4,174	3,351	3,684	4,503	4,158
	Coho	2,600	4,792	3,826	2,600	5,182	4,132
	Summer Chum	98,252	180,464	144,327	67,821	180,464	129,588
	Fall Chum	20,755	37,908	30,370	14,356	37,908	27,284
Southern Norton	Chinook	1,964	3,769	2,961	3,278	4,106	3,753
	Coho	15,882	32,771	25,040	15,882	36,212	27,539
	Summer Chum	20,540	42,407	32,334	13,622	42,407	28,630
	Pink	28,314	57,772	44,590	11,760	57,772	35,154
Northern Norton	Coho	1,062	1,902	1,536	1,062	2,046	1,651
	Summer Chum	20,688	39,037	30,867	14,141	39,037	27,613
	Pink	13,477	24,670	19,806	5,964	24,670	15,885

Table B-11. Mean Commercial Harvest, 2011-2050, Low Return-High Subsistence Scenario

		Utilization Assumptions					
		Same-Low	Same-High	Same-Rising	Varied-Low	Varied-High	Varied-Rising
Kuskokwim Bay	Chinook	6,669	14,336	10,605	12,074	15,979	14,223
	Coho	28,675	57,453	44,410	28,675	63,113	48,600
	Summer Chum	21,129	39,083	31,154	14,548	39,083	27,941
	Sockeye	23,965	47,501	36,820	23,965	52,070	40,218
Lower Kuskokwim	Chinook	36	116	41	85	146	90
	Coho	135,552	274,940	211,247	135,552	302,760	231,623
	Summer Chum	99,481	191,885	150,086	67,479	191,885	133,672
	Sockeye	15,260	29,558	23,155	15,260	32,259	25,203
Lower Yukon	Chinook	27,169	52,807	40,454	45,770	57,676	52,285
	Coho	9,450	17,709	13,944	9,450	19,210	15,098
	Summer Chum	260,615	482,232	383,000	179,412	482,232	342,621
	Fall Chum	43,672	80,436	63,896	30,115	80,436	57,159
Upper Yukon	Chinook	2,281	4,157	3,332	3,666	4,487	4,140
	Coho	2,465	4,617	3,650	2,465	5,008	3,955
	Summer Chum	94,942	175,643	139,600	65,364	175,643	124,929
	Fall Chum	13,149	26,191	19,263	8,845	26,191	16,525
Southern Norton	Chinook	1,472	3,024	2,258	2,580	3,341	2,997
	Coho	14,578	30,734	23,128	14,578	34,114	25,533
	Summer Chum	18,903	39,869	29,997	12,455	39,869	26,394
	Pink	25,454	52,365	39,933	10,521	52,365	31,107
Northern Norton	Coho	1,061	1,899	1,534	1,061	2,044	1,649
	Summer Chum	20,599	38,904	30,761	14,076	38,904	27,518
	Pink	13,481	24,681	19,820	5,964	24,681	15,897

Table B-12. Mean Commercial Harvest, 2011-2050, High Return-Low Subsistence Scenario

		Utilization Assumptions					
		Same-Low	Same-High	Same-Rising	Varied-Low	Varied-High	Varied-Rising
Kuskokwim Bay	Chinook	5,350	11,357	8,560	9,602	12,623	11,305
	Coho	26,955	53,874	41,661	26,955	59,152	45,568
	Summer Chum	21,149	39,027	31,137	14,574	39,027	27,933
	Sockeye	23,468	46,381	36,015	23,468	50,814	39,326
Lower Kuskokwim	Chinook	1,775	3,702	2,822	3,146	4,100	3,689
	Coho	72,573	149,132	114,063	72,573	164,655	125,342
	Summer Chum	98,745	189,616	149,056	67,082	189,616	133,131
	Sockeye	5,996	13,544	9,959	5,996	15,261	11,122
Lower Yukon	Chinook	31,183	58,849	46,957	51,421	63,916	58,764
	Coho	10,233	18,878	15,058	10,233	20,419	16,264
	Summer Chum	270,506	495,986	396,740	186,845	495,986	356,198
	Fall Chum	41,128	75,381	60,243	28,412	75,381	54,057
Upper Yukon	Chinook	2,290	4,162	3,341	3,673	4,489	4,145
	Coho	2,641	4,858	3,881	2,641	5,251	4,190
	Summer Chum	97,893	179,573	143,631	67,606	179,573	128,962
	Fall Chum	20,848	37,978	30,457	14,435	37,978	27,368
Southern Norton	Chinook	1,190	2,534	1,911	2,140	2,818	2,525
	Coho	7,066	15,990	11,741	7,066	18,024	13,115
	Summer Chum	9,732	21,890	16,173	6,291	21,890	14,215
	Pink	12,715	28,334	21,082	5,043	28,334	16,338
Northern Norton	Coho	1,063	1,900	1,535	1,063	2,044	1,650
	Summer Chum	17,586	33,478	26,395	11,983	33,478	23,597
	Pink	13,125	24,117	19,353	5,796	24,117	15,529

Table B-13. Mean Commercial Harvest, 2011-2050, High Return-High Subsistence Scenario

		Utilization Assumptions					
		Same-Low	Same-High	Same-Rising	Varied-Low	Varied-High	Varied-Rising
Kuskokwim Bay	Chinook	3,995	8,876	6,427	7,402	9,966	8,788
	Coho	25,988	52,098	40,146	25,988	57,237	43,933
	Summer Chum	21,188	39,108	31,206	14,600	39,108	27,998
	Sockeye	23,465	46,398	36,061	23,465	50,837	39,379
Lower Kuskokwim	Chinook	30	98	33	71	125	75
	Coho	63,597	133,175	100,230	63,597	147,608	110,468
	Summer Chum	79,789	159,430	121,394	53,490	159,430	106,781
	Sockeye	6,062	13,690	10,065	6,062	15,425	11,239
Lower Yukon	Chinook	15,808	32,220	23,784	27,555	35,524	31,719
	Coho	9,330	17,469	13,746	9,330	18,947	14,879
	Summer Chum	265,164	488,794	389,510	182,797	488,794	349,000
	Fall Chum	38,772	71,351	56,677	26,745	71,351	50,691
Upper Yukon	Chinook	2,240	4,101	3,281	3,612	4,430	4,085
	Coho	2,462	4,615	3,643	2,462	5,007	3,948
	Summer Chum	90,484	168,279	133,057	62,176	168,279	118,773
	Fall Chum	20,201	37,179	29,648	13,935	37,179	26,557
Southern Norton	Chinook	403	1,018	620	813	1,186	975
	Coho	4,387	10,814	7,339	4,387	12,451	8,317
	Summer Chum	6,211	15,149	10,329	3,932	15,149	8,755
	Pink	7,096	17,106	11,658	2,714	17,106	8,330
Northern Norton	Coho	1,064	1,902	1,536	1,064	2,045	1,651
	Summer Chum	15,664	30,187	23,485	10,628	30,187	20,854
	Pink	13,127	23,960	19,272	5,820	23,960	15,474

Table B-14. Mean Commercial Utilization, 2011-2050, Historic Return-Low Subistence Scenario

		Utilization Assumptions					
		Same-Low	Same-High	Same-Rising	Varied-Low	Varied-High	Varied-Rising
Kuskokwim Bay	Chinook	40%	80%	62%	69%	88%	80%
	Coho	40%	80%	62%	40%	88%	68%
	Summer Chum	45%	83%	66%	31%	83%	60%
	Sockeye	41%	81%	63%	41%	88%	69%
Lower Kuskokwim	Chinook	37%	78%	59%	66%	86%	77%
	Coho	39%	80%	61%	39%	88%	67%
	Summer Chum	43%	82%	64%	29%	82%	57%
	Sockeye	40%	80%	62%	40%	88%	68%
Lower Yukon	Chinook	44%	83%	66%	73%	90%	83%
	Coho	45%	83%	66%	45%	90%	71%
	Summer Chum	45%	83%	67%	31%	83%	60%
	Fall Chum	45%	83%	67%	31%	83%	60%
Upper Yukon	Chinook	46%	84%	67%	74%	90%	83%
	Coho	45%	83%	67%	45%	90%	72%
	Summer Chum	45%	83%	67%	31%	83%	60%
	Fall Chum	46%	84%	67%	32%	84%	60%
Southern Norton	Chinook	40%	80%	62%	69%	88%	80%
	Coho	36%	77%	58%	36%	86%	64%
	Summer Chum	36%	77%	58%	23%	77%	51%
	Pink	37%	77%	59%	15%	77%	46%
Northern Norton	Coho	47%	84%	68%	47%	91%	73%
	Summer Chum	44%	82%	65%	30%	82%	58%
	Pink	45%	83%	67%	20%	83%	54%

Table B-15. Mean Commercial Utilization, 2011-2050, Historic Return-High Subsistence Scenario

		Utilization Assumptions					
		Same-Low	Same-High	Same-Rising	Varied-Low	Varied-High	Varied-Rising
Kuskokwim Bay	Chinook	39%	79%	61%	68%	88%	79%
	Coho	40%	80%	62%	40%	88%	68%
	Summer Chum	45%	83%	66%	31%	83%	60%
	Sockeye	41%	81%	63%	41%	88%	68%
Lower Kuskokwim	Chinook	12%	41%	13%	29%	54%	31%
	Coho	39%	79%	60%	39%	87%	66%
	Summer Chum	40%	80%	61%	27%	80%	54%
	Sockeye	40%	80%	62%	40%	88%	67%
Lower Yukon	Chinook	40%	80%	60%	69%	88%	79%
	Coho	44%	82%	65%	44%	90%	70%
	Summer Chum	45%	83%	66%	31%	83%	59%
	Fall Chum	45%	83%	66%	31%	83%	59%
Upper Yukon	Chinook	46%	84%	67%	74%	90%	83%
	Coho	44%	82%	65%	44%	89%	70%
	Summer Chum	45%	83%	66%	31%	83%	59%
	Fall Chum	43%	82%	63%	29%	82%	55%
Southern Norton	Chinook	33%	74%	51%	62%	84%	73%
	Coho	32%	74%	53%	32%	84%	60%
	Summer Chum	32%	74%	52%	21%	74%	45%
	Pink	34%	75%	54%	13%	75%	40%
Northern Norton	Coho	47%	84%	68%	47%	91%	73%
	Summer Chum	43%	82%	64%	29%	82%	57%
	Pink	46%	84%	67%	20%	84%	54%

Table B-16. Mean Commercial Utilization, 2011-2050, Low Return-Low Subsistence Scenario

		Utilization Assumptions					
		Same-Low	Same-High	Same-Rising	Varied-Low	Varied-High	Varied-Rising
Kuskokwim Bay	Chinook	38%	79%	60%	67%	87%	79%
	Coho	40%	80%	62%	40%	88%	68%
	Summer Chum	45%	83%	66%	31%	83%	59%
	Sockeye	41%	81%	63%	41%	88%	68%
Lower Kuskokwim	Chinook	38%	79%	61%	67%	87%	79%
	Coho	39%	80%	61%	39%	88%	67%
	Summer Chum	43%	82%	65%	29%	82%	58%
	Sockeye	42%	81%	64%	42%	89%	69%
Lower Yukon	Chinook	46%	84%	67%	74%	90%	83%
	Coho	45%	83%	66%	45%	90%	72%
	Summer Chum	45%	83%	67%	31%	83%	60%
	Fall Chum	45%	83%	67%	31%	83%	60%
Upper Yukon	Chinook	46%	84%	67%	74%	90%	83%
	Coho	45%	83%	67%	45%	90%	72%
	Summer Chum	45%	83%	67%	31%	83%	60%
	Fall Chum	46%	84%	67%	32%	84%	60%
Southern Norton	Chinook	43%	82%	64%	71%	89%	81%
	Coho	38%	79%	60%	38%	87%	66%
	Summer Chum	38%	79%	60%	25%	79%	53%
	Pink	39%	79%	61%	16%	79%	48%
Northern Norton	Coho	47%	84%	68%	47%	91%	73%
	Summer Chum	44%	82%	65%	30%	82%	58%
	Pink	46%	84%	67%	20%	84%	54%

Table B-17. Mean Commercial Utilization, 2011-2050, Low Return-High Subsistence Scenario

		Utilization Assumptions					
		Same-Low	Same-High	Same-Rising	Varied-Low	Varied-High	Varied-Rising
Kuskokwim Bay	Chinook	36%	77%	57%	65%	86%	77%
	Coho	40%	80%	62%	40%	88%	68%
	Summer Chum	45%	83%	66%	31%	83%	59%
	Sockeye	41%	81%	62%	41%	88%	68%
Lower Kuskokwim	Chinook	15%	48%	17%	35%	61%	38%
	Coho	39%	80%	61%	39%	88%	67%
	Summer Chum	42%	82%	64%	29%	82%	57%
	Sockeye	42%	81%	64%	42%	89%	69%
Lower Yukon	Chinook	42%	81%	62%	70%	89%	80%
	Coho	44%	83%	65%	44%	90%	70%
	Summer Chum	45%	83%	66%	31%	83%	59%
	Fall Chum	45%	83%	66%	31%	83%	59%
Upper Yukon	Chinook	46%	84%	67%	74%	90%	83%
	Coho	44%	83%	65%	44%	90%	71%
	Summer Chum	45%	83%	66%	31%	83%	59%
	Fall Chum	40%	80%	59%	27%	80%	50%
Southern Norton	Chinook	38%	79%	59%	67%	87%	78%
	Coho	37%	78%	59%	37%	87%	65%
	Summer Chum	37%	78%	59%	24%	78%	52%
	Pink	38%	78%	60%	16%	78%	46%
Northern Norton	Coho	47%	84%	68%	47%	91%	73%
	Summer Chum	44%	82%	65%	30%	82%	58%
	Pink	46%	84%	67%	20%	84%	54%

Table B-18. Mean Commercial Utilization, 2011-2050, High Return-Low Subsistence Scenario

		Utilization Assumptions					
		Same-Low	Same-High	Same-Rising	Varied-Low	Varied-High	Varied-Rising
Kuskokwim Bay	Chinook	37%	78%	59%	66%	86%	77%
	Coho	40%	80%	62%	40%	88%	68%
	Summer Chum	45%	83%	66%	31%	83%	60%
	Sockeye	41%	81%	63%	41%	88%	68%
Lower Kuskokwim	Chinook	38%	78%	60%	67%	87%	78%
	Coho	38%	79%	61%	38%	87%	66%
	Summer Chum	43%	82%	64%	29%	82%	57%
	Sockeye	33%	75%	55%	33%	85%	62%
Lower Yukon	Chinook	44%	82%	66%	72%	90%	82%
	Coho	45%	83%	66%	45%	90%	72%
	Summer Chum	46%	83%	67%	31%	83%	60%
	Fall Chum	46%	84%	67%	31%	84%	60%
Upper Yukon	Chinook	46%	84%	67%	74%	90%	83%
	Coho	45%	83%	67%	45%	90%	72%
	Summer Chum	46%	83%	67%	31%	83%	60%
	Fall Chum	46%	84%	67%	32%	84%	60%
Southern Norton	Chinook	36%	78%	59%	66%	86%	77%
	Coho	33%	75%	55%	33%	85%	62%
	Summer Chum	33%	75%	56%	22%	75%	49%
	Pink	34%	75%	56%	13%	75%	43%
Northern Norton	Coho	47%	84%	68%	47%	91%	73%
	Summer Chum	43%	82%	65%	29%	82%	58%
	Pink	45%	83%	67%	20%	83%	54%

Table B-19. Mean Commercial Utilization, 2011-2050, High Return-High Subsistence Scenario

		Utilization Assumptions					
		Same-Low	Same-High	Same-Rising	Varied-Low	Varied-High	Varied-Rising
Kuskokwim Bay	Chinook	34%	76%	55%	63%	85%	75%
	Coho	40%	80%	62%	40%	88%	68%
	Summer Chum	45%	83%	66%	31%	83%	60%
	Sockeye	41%	81%	63%	41%	88%	68%
Lower Kuskokwim	Chinook	14%	46%	16%	33%	59%	35%
	Coho	37%	78%	59%	37%	87%	65%
	Summer Chum	40%	80%	61%	27%	80%	54%
	Sockeye	33%	75%	55%	33%	85%	62%
Lower Yukon	Chinook	39%	79%	59%	68%	88%	78%
	Coho	44%	83%	65%	44%	90%	70%
	Summer Chum	45%	83%	66%	31%	83%	59%
	Fall Chum	45%	83%	66%	31%	83%	59%
Upper Yukon	Chinook	46%	84%	67%	74%	90%	83%
	Coho	44%	83%	65%	44%	90%	71%
	Summer Chum	45%	83%	66%	31%	83%	59%
	Fall Chum	45%	83%	66%	31%	83%	60%
Southern Norton	Chinook	27%	68%	41%	54%	79%	65%
	Coho	29%	71%	48%	29%	82%	54%
	Summer Chum	29%	71%	49%	18%	71%	41%
	Pink	29%	70%	48%	11%	70%	34%
Northern Norton	Coho	47%	84%	68%	47%	91%	73%
	Summer Chum	42%	82%	64%	29%	82%	56%
	Pink	46%	84%	67%	20%	84%	54%