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As previously observed, increases in the values of demand variables (e.g. income and population) coupled with a predicted decrease in wild stocks led to an upward price trend over the 15 year future time horizon. These price increases would be dampened if farmed salmon producers increased supplies in response to the higher prices.

One factor that detracts from the predictive power of the model is that the Atlantic salmon portion of Bloc 1 is not included in the future simulations. Time constraints were too severe to get this section to simulate after initial problems were encountered. Consequently, future prices were set equal to the 1991 third quarter price of Norwegian salmon to the EEC and North America. Fine tuning of the model will continue into the future and, hopefully, this problem will be solved. Nonetheless, this model shortcomings should not seriously affect the results presented for the cases examined in this section.

Predicted Revenue Effects of Cases 1-11

On pages 3 and 4 of this report the 11 cases to be analyzed were presented. These cases were put forward in the original RFP. At the September meeting with Ginny Fay and Jeff Hartman it was decided that cases 1-6 would be simulated with the average, high, and low prices, and cases 7-11 would be simulated with the average prices. Forecasted revenue averages for the time period of 1997-2006 will be presented. The revenue figures represent 10-year averages which are based on the changes specified in the case scenarios for hatchery production and the associated changes in harvest (except chinook which starts in 1998).

Recall, in bloc 1 estimation it was necessary that chinook, coho, and sockeye be aggregated and that pink and chum be aggregated. These aggregations imposed on the model the use the assumption that chinook, coho, and sockeye salmon were perfect substitutes, and that chum and pink salmon were perfect substitutes. The overly restrictive nature of these assumptions are partially alleviated in Bloc 2 by correlating predicted North America high-valued and low-valued exvessel prices with species specific Alaska regional exvessel prices. Nevertheless, we cannot state, *a priori*, what the cross-price effects are within the high-valued and low-valued salmon groupings. Cross price effects could range from zero if species are not substitutes in the salmon markets, to the actual substitution effect indicated by the model if the species within the high-valued grouping and those within the low-valued grouping are strong substitutes for one another.

Therefore, only upper and lower bounds can be placed on the cross-price effects within salmon groupings. The lower bound would generate expected exvessel prices in the absence of any substitution effect. The upper-bound results in the initial model predicted exvessel prices, which are associated with a strong substitution effect. Both upper bound and lower bound exvessel prices are provided for each of the considered case scenarios.

For certain species, such as chinook and coho. There is expected to be a strong substitution effect because the species fill similar market niches. It should be noted that the substitution effect problems occur between species within the high-valued or low-valued grouping, and not between high-valued species and low-valued species.

As noted, the difficulty in sorting out the substitution effects within a Pacific salmon category are mitigated by placing bounds on the substitution effects. Therefore, special

care should be taken when interpreting cases 2-4. Unfortunately, this is not possible when changes in production at multiple hatcheries are considered. i.e., case scenarios 2-4. Bounds cannot be specified in these scenarios because exvessel price changes will depend on own-price effects, in addition, to cross-price substitution effects. The results for cases 7-11 are the easiest to interpret, and, therefore, are presented first, following the base case. Cases 5-6 are presented next, with cases 2-4 provided last.

Case 1 -- Base Case Scenario

Table 30 Predicted Average Annual Harvests, Real Revenue, and Real Exvessel Prices for Prince William Sound Sockeye (PWR), Cook Inlet Sockeye (CIR), Southeast Sockeye (SER), Kodiak Sockeye (KKR), Other Alaska Regional Sockeye (AKOR), and All Alaska Sockeye (AKR), for 1997-2006.

	Harvests (lbs.)	Price (\$/lbs.)	Revenue (dollars)
PWR	16,223,684	1.699	27,562,709
CIR	26,893,398	1.451	38,983,260
SER	9,693,268	1.570	15,218,431
KKR	21,278,567	1.461	31,067,467
AKOR	172,005,487	1.174	201,984,575
AKR	246,094,406	1.279	314,820,833

Table 31 Predicted Average Annual Harvests, Real Revenue, and Real Exvessel Prices for Prince William Sound Pink (PWP), Cook Inlet Pink (CIP), Southeast Pink (SEP), Kodiak Pink (KKP), Other Alaska Regional Pink (AKOP), and All Alaska Pink (AKP), for 1997-2006.

	Harvests (lbs.)	Price (\$/lbs.)	Revenue (dollars)
PWP	124,099,162	0.301	37,270,908
CIP	15,687,819	0.263	4,125,1089
SEP	108,661,448	0.312	33,873,455
KKP	44,796,114	0.290	13,022,112
AKOP	33,476,156	0.299	10,009,330
AKP	326,720,701	0.301	98,300,914

Table 32 Predicted Average Annual Harvests, Real Revenue, and Real Exvessel Prices for Prince William Sound Chum (PWC), Cook Inlet Chum (CIC), Southeast Chum (SEC), Kodiak Chum (KKC), Other Alaska Regional Chum (AKOC), and All Alaska Chum (AKC), for 1997-2006.

	Harvests (lbs.)	Price (\$/lbs.)	Revenue (dollars)
PWC	24,739,905	0.432	10,683,775
CIC	6,788,449	0.430	2,920,517
SEC	66,726,067	0.497	33,164,835
KKC	13,388,277	0.396	5,325,693
AKOC	36,113,753	0.350	12,631,744
AKC	147,756,451	0.436	64,726,666

Table 33 Predicted Average Annual Harvests, Real Revenue, and Real Exvessel Prices for Prince William Sound Coho (PWS), Cook Inlet Coho (CIS), Southeast Coho (SES), Kodiak Coho (KKS), Other Alaska Regional Coho (AKOS), and All Alaska Coho (AKS), for 1997-2006.

	Harvests (lbs.)	Price (\$/lbs.)	Revenue (dollars)
PWS	6,649,055	0.987	6,561,277
CIS	4,085,305	0.748	3,056,781
SES	16,824,809	1.336	22,483,893
KKS	2,214,332	0.757	1,677,025
AKOS	13,281,378	0.793	10,533,505
AKS	43,054,879	1.029	44,312,483

Table 34 Predicted Average Annual Harvests, Real Revenue, and Real Exvessel Prices for Prince William Sound Chinook (PWK), Cook Inlet Chinook (CIK), Southeast Chinook (SEK), Kodiak Chinook (KKK), Other Alaska Regional Chinook (AKOK), and All Alaska Chinook' (AKK), for 1997-2006.

	Harvests (lbs.)	Price (\$/lbs.)	Revenue (dollars)
PWK	1,512,850	1.906	2,883,069
CIK	686,856	1.223	840,649
SEK	7,329,879	2.484	18,204,606
KKK	130,865	1.100	143,890
AKOK	6,422,050	1.510	9,699,213
AKK	16,082,501	1.976	31,771,429

The predicted average harvests and real prices and revenues for 1997-2006 are within the bounds that have been historically observed in the past decade. The average sockeye salmon harvest is 246 million pounds and the average exvessel price is \$1.28 per pound. The average predicted real revenue of 314 million dollars is approximately 60 million higher than those found in the 1980s, although lower than those found from 1987 to 1991.

The predicted average annual pink harvest for Alaska is 326 million pounds. Predicted average real exvessel price and revenues are \$0.30 per pound and 98 million pounds, respectively. Both the predicted average revenue and harvest are slightly above those observed in the 1980s (the predicted price is 1 cent lower than the average 1980s price). The predicted price is also below actual 1987 to 1990 prices but well above the 1991 price.

The predicted average Alaska chum harvest, exvessel price, and exvessel revenue are 147 million pounds, \$0.436 per pound, and \$64 million, respectively. The predicted average Alaska harvest and exvessel revenue are nearly twice those of the 1980 to 1991 averages. The predicted price of \$0.44 is 3 cents per pound under the 1980-1991 average.

The predicted coho harvest, revenue, and prices are all above the averages for the 1980 to 1991. The predicted average Alaska annual real exvessel price of \$1.03 is 6 cents per pound above the average prices found from 1980-1991. The predicted average Alaska chinook harvest and revenues are also above the 1980 to 1991 averages. The predicted average Alaska annual price of \$1.98 is 32 cents per pound above the 1980-1991 average.

Case 7 -- Production from Pink Salmon Enhancement Increases/Decreases 15 percent

Table 35 Base Scenario 7 (Increase) Predicted Average Annual Harvests, Real Revenue, and Real Prices for Prince William Sound Pink (PWP), Cook Inlet Pink (CIP), Southeast Pink (SEP), Kodiak Pink (KKP), Other Alaska Regional Pink (AKOP), Alaska Pink (AKP), Alaska Sockeye (AKR), Alaska Chum (AKC), Alaska Coho (AKS) and Alaska Chinook (AKK), for 1997-2006.

	Harvests (lbs.)	Price (\$/lbs.)	Revenue (dollars)
PWP	140,600,522	0.276	38,780,767
CIP	17,577,819	0.244	4,291,210
SEP	109,956,746	0.288	31,624,326
KKP	46,565,542	0.267	12,434,105
AKOP	33,476,158	0.280	9,357,526
AKP	348,176,789	0.277	96,487,936
AKR	246,094,406	1.278	314,611,908
AKC	147,756,451	0.414	61,239,262
AKS	43,054,879	1.029	44,285,778
AKK	16,082,501	1.975	31,760,907

Table 36 Scenario 7 (Decrease) Predicted Average Annual Harvests, Real Revenue, and Real Prices Base for Prince William Sound Pink (PWP), Cook Inlet Pink (CIP), Southeast Pink (SEP), Kodiak Pink (KKP), Other Alaska Regional Pink (AKOP), Alaska Pink (AKP), Alaska Sockeye (AKR), Alaska Chum (AKC), Alaska Coho (AKS) and Alaska Chinook (AKK), for 1997-2006.

	Harvests (lbs.)	Price (\$/lbs.)	Revenue (dollars)
PWP	108,265,361	0.324	35,089,014
CIP	13,797,819	0.281	3,880,719
SEP	107,366,150	0.335	35,988,917
KKP	43,033,080	0.313	13,515,655
AKOP	<u>33,476,155</u>	0.318	<u>10,643,472</u>
AKP	305,938,565	0.324	99,117,779
AKR	246,094,406	1.280	315,040,732
AKC	147,756,451	0.461	68,117,239
AKS	43,054,879	1.030	44,340,597
AKK	16,082,501	1.976	31,782,508

Table 37 Case 7 (Increase) Predicted Changes in Total Annual Real Revenue from Base Scenario 1 for Prince William Sound Pink (PWP), Cook Inlet Pink (CIP), Southeast Pink (SEP), Kodiak Pink (KKP), Other Alaska Regional Pink (AKOP), Alaska Pink (AKP), Alaska Sockeye (AKR), Alaska Chum (AKC), Alaska Coho (AKS) and Alaska Chinook (AKK), for 1997-2006.

	Revenue Changes Production Increase		
	(L. Bound) (\$/lbs)	(U. Bound) (\$/lbs)	(Expected) (\$/lbs)
PWP	1,509,859	1,509,859	1,509,859
CIP	166,102	166,102	166,102
SEP	-2,249,129	-2,249,129	-2,249,129
KKP	-588,007	-588,007	-588,007
AKOP	<u>-651,804</u>	<u>-651,804</u>	<u>-651,804</u>
AKP	-1,812,978	-1,812,978	-1,812,978
AKR	-208,925	-208,925	-208,925
AKC	0	-3,487,404	-871,851
AKS	-26,705	-26,705	-26,705
AKK	<u>-10,522</u>	<u>-10,522</u>	<u>-10,522</u>
TOTAL	<u>-2,059,130</u>	<u>-5,546,534</u>	<u>-2,930,981</u>

Table 38 Case 7 (Decrease) Predicted Changes in Total Annual Real Revenue from Base Scenario 1 for Prince William Sound Pink (PWP), Cook Inlet Pink (CIP), Southeast Pink (SEP), Kodiak Pink (KKP), Other Alaska Regional Pink (AKOP), Alaska Pink (AKP), Alaska Sockeye (AKR), Alaska Chum (AKC), Alaska Coho (AKS) and Alaska Chinook (AKK), for 1997-2006.

	<u>Revenue Changes</u>		
	<u>Production Decrease</u>		
	(L. Bound)	(U. Bound)	(Expected)
	(\$/lbs)	(\$/lbs)	(\$/lbs)
PWP	-2,181,894	-2,181,894	-2,181,894
CIP	-244,389	-244,389	-244,389
SEP	2,115,462	2,115,462	2,115,462
KKP	493,543	493,543	493,543
AKOP	634,142	634,142	634,142
AKP	816,865	816,865	816,865
AKR	219,899	219,899	219,899
AKC	0	3,390,573	874,643
AKS	28,114	28,114	28,114
AKK	11,079	11,079	11,079
TOTAL	<u>1,075,957</u>	<u>4,466,530</u>	<u>1,923,600</u>

The forecast results indicate that a 15 percent increase in pink enhancement product will result in revenue losses between \$2 and \$5.5 million with an expected loss of \$2.9 million. The losses are not shared equally. Prince William Sound, which gets the largest increase in harvest under scenario 7, gains \$1.5 million a year. In contrast, gains from slight harvest increases in Southeast and Kodiak are more than offset by the price declines which accompany the higher statewide harvest. Southeast and Kodiak experience harvest declines of \$2.249 million and \$588,007, respectively. Additionally, the All-Other Alaska region, which does not experience a harvest increase, suffers a revenue decline of \$651,804. The potential revenue decrease encountered in the Statewide chum fishery range from zero (no substitution effect) to 3.487 million (if the substitution effect is very strong). The expected revenue loss for chum salmon is \$874,643 million. All other species experience negligible revenue decline.

In contrast to the previous results, a 15 percent decrease in the hatchery produced pink salmon leads to forecasted Alaska average annual exvessel revenue increasing between \$1 million and \$4.5 million, with an expected value of \$1.9 million. As previously found, the revenue changes are not equally distributed across fishery regions. In both Prince William Sound and Cook Inlet gains from exvessel price increases, which accompany the lower harvests, are more than offset by harvest declines. Prince William Sound suffers a revenue decline of \$2.8 million, while Cook Inlet exvessel revenues decline by \$244,389. Southeast, Kodiak and the aggregate All-Other Alaska region experiences gains in exvessel revenues. These regions suffer only slight or no decrease in harvest while enjoying the benefit of the exvessel price increase.

The forecast results for Case 7 show that pink exvessel prices are very sensitive to changes in Pink harvest, given current harvest levels, demand conditions, and market structure. The proportional increase (decrease) in harvest associated with increases (decreases) in hatchery production will be less than the proportional decrease (increase)

in pink exvessel prices. Thus, in the absence of any factors which expand demand for pink salmon, an increase (decrease) in hatchery production of pink salmon is expected to decrease (increase) Alaska exvessel revenues.

Case 8 -- Production from Sockeye Salmon Enhancement Increases/Decreases 15 percent

Table 39 Scenario 8 (Increase) Predicted Average Annual Harvests, Real Revenue, and Real Prices Base for Prince William Sound Sockeye (PWR), Cook Inlet Sockeye (CIR), Southeast Sockeye (SER), Kodiak Sockeye (KKR), Other Alaska Regional Sockeye (AKOR), Alaska Sockeye (AKR), Alaska Pink (AKP), Alaska Chum (AKC), Alaska Coho (AKS) and Alaska Chinook (AKK), for 1997-2006.

	Harvests (lbs.)	Price (\$/lbs.)	Revenue (dollars)
PWR	17,420,271	1.684	29,329,776
CIR	27,479,609	1.440	39,528,439
SER	9,857,337	1.556	15,337,104
KKR	22,150,370	1.448	32,056,224
AKOR	<u>172,005,487</u>	1.164	<u>200,164,266</u>
AKR	248,913,075	1.271	316,415,811
AKP	326,720,701	0.300	98,151,858
AKC	147,756,451	0.438	64,658,696
AKS	43,054,879	1.021	43,955,087
AKK	16,082,501	1.967	31,630,526

Table 40 Scenario 8 (Decrease) Predicted Average Annual Harvests, Real Revenue, and Real Prices Base for Prince William Sound Sockeye (PWR), Cook Inlet Sockeye (CIR), Southeast Sockeye (SER), Kodiak Sockeye (KKR), Other Alaska Regional Sockeye (AKOR), Alaska Sockeye (AKR), Alaska Pink (AKP), Alaska Chum (AKC), Alaska Coho (AKS) and Alaska Chinook (AKK), for 1997-2006.

	Harvests (lbs.)	Price (\$/lbs.)	Revenue (dollars)
PWR	15,027,098	1.714	25,762,647
CIR	26,331,976	1.463	38,468,677
SER	9,529,200	1.585	15,105,873
KKR	20,379,710	1.474	30,016,855
AKOR	<u>172,005,485</u>	1.185	<u>203,832,851</u>
AKR	243,273,470	1.287	313,186,905
AKP	326,720,701	0.301	98,451,189
AKC	147,756,451	0.439	64,795,170
AKS	43,054,879	1.038	44,675,371
AKK	16,082,501	1.984	31,914,516

Table 41 Case 8 (Increase) Predicted Changes in Total Annual Real Revenue from Base Scenario 1 for Prince William Sound Sockeye (PWR), Cook Inlet Sockeye (CIR), Southeast Sockeye (SER), Kodiak Sockeye (KKR), Other Alaska Regional Sockeye (AKOR), Alaska Sockeye (AKR), Alaska Pink (AKP), Alaska Chum (AKC), Alaska Coho (AKS) and Alaska Chinook (AKK), for 1997-2006.

	<u>Revenue Changes</u>		
	<u>Production Increase</u>		
	(L. Bound)	(U. Bound)	(Expected)
	(\$/lbs)	(\$/lbs)	(\$/lbs)
PWR	1,767,067	1,767,067	1,767,067
CIR	545,179	545,179	545,179
SER	114,284	114,284	114,284
KKR	988,757	988,757	988,757
AKOR	<u>-1,820,309</u>	<u>-1,820,309</u>	<u>-1,820,309</u>
AKR	1,594,978	1,594,978	1,594,978
AKP	-114,944	-114,944	-114,944
AKC	-67,970	-67,970	-67,970
AKS	0	-357,396	-89,349
AKK	0	<u>-140,903</u>	<u>-35,226</u>
TOTAL	<u>1,412,064</u>	<u>913,765</u>	<u>1,287,489</u>

Table 42 Case 8 (Decrease) Predicted Changes in Total Annual Real Revenue from Base Scenario 1 for Prince William Sound Sockeye (PWR), Cook Inlet Sockeye (CIR), Southeast Sockeye (SER), Kodiak Sockeye (KKR), Other Alaska Regional Sockeye (AKOR), Alaska Sockeye (AKR), Alaska Pink (AKP), Alaska Chum (AKC), Alaska Coho (AKS) and Alaska Chinook (AKK), for 1997-2006.

	<u>Revenue Changes</u>		
	<u>Production Decrease</u>		
	(L. Bound)	(U. Bound)	(Expected)
	(\$/lbs)	(\$/lbs)	(\$/lbs)
PWR	-1,800,062	-1,800,062	-1,800,062
CIR	-514,583	-514,583	-514,583
SER	-18,768	-18,768	-18,768
KKR	-1,050,612	-1,050,612	-1,050,612
AKOR	<u>1,848,276</u>	<u>1,848,276</u>	<u>1,848,276</u>
AKR	-1,633,928	-1,633,928	-1,633,928
AKP	150,275	150,275	150,275
AKC	68,504	68,504	68,504
AKS	0	363,888	90,972
AKK	0	<u>143,087</u>	<u>35,772</u>
TOTAL	<u>-1,415,149</u>	<u>-908,174</u>	<u>-1,288,405</u>

Each of the individual sockeye fishery regions, Prince William Sound, Cook Inlet, Kodiak, and Southeast experience increases in exvessel revenues when future sockeye

hatchery production is increased by 15 percent, and incur decreases in exvessel revenue when sockeye hatchery production is reduced by 15 percent. The Prince William Sound sockeye fishery experiences the greatest changes in exvessel revenue. A 15 percent increase in sockeye hatchery production results in this fishery's exvessel revenues increasing by an average of \$1.767 million annually for the 1997-2006 time period, whereas a 15 percent reduction in sockeye hatchery production results in an average \$1.8 million annual decline in exvessel revenue.

The 15 percent increase in sockeye hatchery production increases average annual exvessel revenues to the Cook Inlet, Southeast, and Kodiak sockeye fisheries by \$545,179, \$114,284, and \$988,757, respectively, for the 1997-2006 time period. In contrast, a 15 percent reduction in sockeye salmon hatchery production results in average annual exvessel revenues declines to the Cook Inlet, Southeast, and Kodiak sockeye fisheries of \$514,583, \$18,768, and \$1.050 million, respectively, for the 1997-2006 time period.

The aggregate All-Other-Alaska-Regions harvest is not impacted by changes in sockeye salmon hatchery production. Yet, the exvessel revenues of the fisheries within this group are impacted by the changes in sockeye exvessel prices which accompany the changes in hatchery production. A 15 percent increase in hatchery production reduces average annual exvessel price by one cent per pound, reducing exvessel revenue to this group of fisheries by an annual average of \$1.820 million for the 1997-2006 time period. These losses accrue primarily to the Bristol Bay fishery, which is the dominant sockeye fishery within this aggregate group. Sockeye exvessel prices increase if sockeye hatchery production is reduced, and this results in average annual exvessel revenue increases for All-Other-Alaska-Regions of \$1.848 million.

The changes in exvessel revenues to the other high-valued salmon species associated with changes in sockeye salmon hatchery production vary depending on the strength of the substitution effect. In the absence of any substitution effect between sockeye salmon and coho and chinook salmon, exvessel revenues to the coho and chinook fisheries would not be affected by the changes in sockeye hatchery production. If the substitution effect is the expected effect, a 15 percent increase in sockeye salmon hatchery production results in coho and chinook salmon exvessel revenue declining by an annual average of \$89,349 and \$35,226, respectively, for the 1997-2006 time period. A 15 percent reduction in sockeye hatchery production would increase average annual exvessel revenues to the chinook and coho fisheries, given an expected substitution effect, by \$90,972 and \$35,772.

The exvessel revenues of the low-valued salmon fisheries are moderately impacted by the changes in sockeye salmon hatchery production. The state-wide pink and chum fisheries experience average annual exvessel revenue declines of \$114,944 and \$67,970, respectively, given a 15 percent increase in sockeye salmon hatchery production. A 15 percent reduction in sockeye salmon hatchery production results in average annual revenue increases to the pink and chum fisheries of \$150,275 and \$68,504, respectively.

Case 9 – Production from Chum Salmon Enhancement Increases/Decreases 15 percent

Table 43 Scenario 9 (Increase) Predicted Average Annual Harvests, Real Revenue, and Real Prices Base for Prince William Sound Chum (PWC), Cook Inlet Chum (CIC), Southeast Chum (SEC), Kodiak Chum (KKC), Other Alaska Regional Chum (AKOC), Alaska Chum (AKC), Alaska Sockeye (AKR), Alaska Pink (AKP), Alaska Coho (AKS) and Alaska Chinook (AKK), for 1997-2006.

	Harvests (lbs.)	Price (\$/lbs.)	Revenue (dollars)
PWC	27,064,972	0.419	11,330,018
CIC	6,788,449	0.422	2,863,036
SEC	74,694,744	0.483	36,103,049
KKC	14,318,612	0.381	5,484,173
AKOC	<u>36,115,385</u>	0.344	<u>12,422,375</u>
AKC	158,982,161	0.429	68,202,653
AKR	246,094,406	1.279	314,801,492
AKP	326,720,701	0.289	94,552,703
AKS	43,054,879	1.029	44,310,017
AKK	16,082,501	1.975	31,770,457

Table 44 Scenario 9 (Decrease) Predicted Average Annual Harvests, Real Revenue, and Real Prices Base for Prince William Sound Chum (PWC), Cook Inlet Chum (CIC), Southeast Chum (SEC), Kodiak Chum (KKC), Other Alaska Regional Chum (AKOC), Alaska Chum (AKC), Alaska Sockeye (AKR), Alaska Pink (AKP), Alaska Coho (AKS) and Alaska Chinook (AKK), for 1997-2006.

	Harvests	Price	Revenue
PWC	22,414,838	0.445	9,977,026
CIC	6,788,449	0.439	2,978,387
SEC	58,757,388	0.510	30,010,878
KKC	12,457,941	0.411	5,139,671
AKOC	<u>36,112,122</u>	0.356	<u>12,841,784</u>
AKC	136,530,740	0.446	60,947,747
AKR	246,094,406	1.279	314,841,988
AKP	326,720,701	0.312	102,061,423
AKS	43,054,879	1.029	44,315,182
AKK	16,082,501	1.976	31,772,493

Table 45 Case 9 (Increase) Predicted Changes in Total Annual Real Revenue from Base Scenario 1 for Prince William Sound Chum (PWR), Cook Inlet Chum (CIR), Southeast Chum (SER), Kodiak Chum (KKR), Other Alaska Regional Chum (AKOR), Alaska Chum (AKC), Alaska Sockeye (AKP), Alaska Pink (AKP), Alaska Coho (AKS) and Alaska Chinook (AKK), for 1997-2006.

	<u>Revenue Changes</u>		
	<u>Production Increase</u>		
	(L. Bound)	(U. Bound)	(Expected)
	(\$/lbs)	(\$/lbs)	(\$/lbs)
PWC	646,243	646,243	646,243
CIC	-57,581	-57,581	-57,581
SEC	2,938,214	2,938,214	2,938,214
KKC	158,480	158,480	158,480
AKOC	<u>-209,369</u>	<u>-209,369</u>	<u>-209,369</u>
AKC	3,475,987	3,475,987	3,475,987
AKR	-19,341	-19,341	-19,341
AKP	0	-3,748,211	-937,053
AKS	-2,466	-2,466	-2,466
AKK	<u>-972</u>	<u>-972</u>	<u>-972</u>
TOTAL	<u>3,453,208</u>	<u>-295,003</u>	<u>2,516,155</u>

Table 46 Case 9 (Decrease) Predicted Changes in Total Annual Real Revenue from Base Scenario 1 for Prince William Sound Chum (PWR), Cook Inlet Chum (CIR), Southeast Chum (SER), Kodiak Chum (KKR), Other Alaska Regional Chum (AKOR), Alaska Chum (AKC), Alaska Sockeye (AKR), Alaska Pink (AKP), Alaska Coho (AKS) and Alaska Chinook (AKK), for 1997-2006.

	<u>Revenue Changes</u>		
	<u>Production Decrease</u>		
	(L. Bound)	(U. Bound)	(Expected)
	(\$/lbs)	(\$/lbs)	(\$/lbs)
PWC	-706,749	-706,749	-706,749
CIC	57,770	57,770	57,770
SEC	-3,153,957	-3,153,957	-3,153,957
KKC	-186,022	-186,022	-186,022
AKOC	<u>210,040</u>	<u>210,040</u>	<u>210,040</u>
AKC	-3,778,919	-3,778,919	-3,778,919
AKR	21,155	21,155	21,155
AKP	0	3,760,509	940,127
AKS	2,699	2,699	2,699
AKK	<u>1,064</u>	<u>1,064</u>	<u>1,064</u>
TOTAL	<u>-3,764,001</u>	<u>-3,492</u>	<u>-2,823,874</u>

Case 9 involved increasing/decreasing state enhancement chum hatchery production by 15 percent beginning in 1993, and continuing through 2006. The increased/decreased

hatchery production impacts state chum harvests beginning in 1997, when the adult chum return to the state fisheries. The impact of changes in chum hatchery production to statewide exvessel revenues depends on the strength of the substitution effect between chum and pink salmon. In the absence of any substitution effect, a 15 percent increase in chum hatchery production increases average annual state exvessel revenues by \$3.456 million for the 1997-2006 time period. A 15 percent decrease in hatchery chum production reduces average annual statewide exvessel revenues by \$3.778 million. For an expected substitution effect, a 15 percent increase in chum hatchery production increases average annual Alaska exvessel revenues by \$2.516 million. A reduction in chum hatchery production of 15 percent leads to a decrease in average annual Alaska exvessel revenue of 2.823 million.

Exvessel revenues in three of the four individual chum fishery regions, Prince William Sound, Southeast, and Kodiak, vary directly with changes in chum hatchery production, i.e., increases in chum hatchery production leads to increases in exvessel revenues in these fisheries, and decreases in chum hatchery production lead to decreases in exvessel revenues in these fisheries. The changes in the Southeast chum fishery are particularly noteworthy. A 15 percent increase in chum hatchery production increases average annual Southeast chum exvessel revenues by \$2.938 million, for the 1997-2006 time period. Reducing chum hatchery production by 15 percent decreases average annual Southeast exvessel revenues by \$3.764 million.

The Cook Inlet chum fishery and the aggregate All-Other-Alaska-Regions suffer decreases in average annual exvessel revenues when chum hatchery production is increased, and increases in average annual exvessel revenue when chum hatchery production is reduced. The chum harvests in these two regions are not impacted by the changes in enhancement hatchery chum production. But the regions exvessel revenues are impacted by the changes in exvessel prices which accompany the changes in statewide chum harvests.

The impacts of changes in chum hatchery production to Alaska pink exvessel revenues depend on the strength of the substitution effect between chum and pink salmon (a similar outcome was reported with respect to changes in pink hatchery production). If the two salmon species are not substitutes in the market place, then changes in chum hatchery production will not impact Alaska pink exvessel revenues. If the two species are strong substitutes, then increasing chum hatchery production by 15 percent reduces average annual Alaska pink exvessel revenue by \$3.748 million, for the 1997-2006 time period; and a 15 percent reduction in chum salmon hatchery production increases average annual Alaska pink exvessel revenue by \$3.476 million.

The average annual Alaska exvessel revenue to the high-valued salmon fisheries are only mildly impacted by the changes in chum hatchery production. For example, average annual Alaska sockeye exvessel revenue increase by \$19,341 given a 15 percent reduction in chum hatchery production, and decrease by \$21,155 given a 15 percent increase in chum hatchery production.

Case 10 – Production from Coho Salmon Enhancement Increases/Decreases 15 percent

Table 47 Scenario 10 (Increase) Predicted Average Annual Harvests, Real Revenue, and Real Prices Base for Prince William Sound Coho (PWS), Cook Inlet Coho (CIS), Southeast Coho (SES), Kodiak Coho (KKS), Other Alaska Regional Coho (AKOS), Alaska Coho (AKS), Alaska Sockeye (AKR), Alaska Pink (AKP), Alaska Chum (AKC) and Alaska Chinook (AKK), for 1997-2006.

	Harvests (lbs.)	Price (\$/lbs.)	Revenue (dollars)
PWS	6,950,788	0.985	6,844,023
CIS	4,109,651	0.747	3,068,723
SES	17,513,662	1.333	23,347,979
KKS	2,227,020	0.756	1,683,947
AKOS	<u>13,281,380</u>	0.791	<u>10,510,551</u>
AKS	44,082,501	1.031	45,455,225
AKR	246,094,406	1.276	314,034,797
AKP	326,720,701	0.301	98,270,643
AKC	147,756,451	0.438	64,712,858
AKK	16,082,501	1.971	31,706,444

Table 48 Scenario 10 (Decrease) Predicted Average Annual Harvests, Real Revenue, and Real Prices Base for Prince William Sound Coho (PWS), Cook Inlet Coho (CIS), Southeast Coho (SES), Kodiak Coho (KKS), Other Alaska Regional Coho (AKOS), Alaska Coho (AKS), Alaska Sockeye (AKR), Alaska Pink (AKP), Alaska Chum (AKC) and Alaska Chinook (AKK), for 1997-2006.

	Harvests	Price	Revenue
PWS	6,347,323	0.989	6,277,580
CIS	4,060,959	0.750	3,044,924
SES	16,135,957	1.340	21,616,701
KKS	2,201,643	0.759	1,670,140
AKOS	<u>3,281,376</u>	0.795	<u>10,557,048</u>
AKS	42,027,258	1.027	43,166,395
AKR	246,094,406	1.283	315,627,667
AKP	326,720,701	0.301	98,333,701
AKC	147,756,451	0.438	64,741,589
AKK	16,082,501	1.978	31,812,063

Table 49 Case 10 (Increase) Predicted Changes in Total Annual Real Revenue from Base Scenario 1 for Prince William Sound Coho (PWS), Cook Inlet Coho (CIS), Southeast Coho (SES), Kodiak Coho (KKS), Other Alaska Regional Coho (AKOS), Alaska Coho (AKS), Alaska Sockeye (AKR), Alaska Pink (AKP), Alaska Chum (AKC), and Alaska Chinook (AKK), for 1997-2006.

	Revenue Changes		
	Production Increase		
	(L. Bound)	(U. Bound)	(Expected)
	(\$/lbs)	(\$/lbs)	(\$/lbs)
PWS	282,746	282,746	282,746
CIS	11,942	11,942	11,942
SES	864,086	864,086	864,086
KKS	6,922	6,922	6,922
AKOS	<u>-22,954</u>	<u>-22,954</u>	<u>-22,954</u>
AKS	1,142,742	1,142,742	1,142,742
AKP	-30,271	-30,271	-30,271
AKR	0	-786,036	-196,509
AKC	-13,808	-13,808	-13,808
AKK	0	<u>-64,985</u>	<u>-32,492</u>
TOTAL	<u>1,098,663</u>	<u>247,642</u>	<u>869,662</u>

Table 50 Case 10 (Decrease) Predicted Changes in Total Annual Real Revenue from Base Scenario 1 for Prince William Sound Coho (PWS), Cook Inlet Coho (CIS), Southeast Coho (SES), Kodiak Coho (KKS), Other Alaska Regional Coho (AKOS), Alaska Coho (AKS), Alaska Sockeye (AKR), Alaska Pink (AKP), Alaska Chum (AKC), and Alaska Chinook (AKK), for 1997-2006.

	Revenue Changes		
	Production Decrease		
	(L. Bound)	(U. Bound)	(Expected)
	(\$/lbs)	(\$/lbs)	(\$/lbs)
PWS	-283,697	-283,697	-283,697
CIS	-11,857	-11,857	-11,857
SES	-867,192	-867,192	-867,192
KKS	-6,885	-6,885	-6,885
AKOS	<u>23,543</u>	<u>23,543</u>	<u>23,543</u>
AKS	-1,146,088	-1,146,088	-1,146,088
AKP	32,787	32,787	32,787
AKR	0	806,834	201,709
AKC	14,923	14,923	14,923
AKK	0	<u>40,634</u>	<u>20,317</u>
TOTAL	<u>-1,098,378</u>	<u>-250,910</u>	<u>-876,352</u>

Case 10 examines impacts to Alaska fisheries of increasing/decreasing state enhancement coho hatchery production by 15 percent annually, beginning in 1993. Alaska exvessel revenues varies directly with the changes in coho hatchery production. The changes in revenue are moderate. A 15 percent increase in coho hatchery production results in average annual statewide exvessel revenue increasing by an expected \$869,662. Reducing the coho hatchery production by 15 percent results in statewide exvessel revenue decreasing by an expected \$876,352.

The average annual exvessel revenues for each of the four individually modelled coho fishery regions, Prince William Sound, Cook Inlet, Southeast, and Kodiak, vary directly with changes in coho hatchery production. A 15 percent increase in coho hatchery production results in increases in average annual exvessel revenues for the coho fishery regions which range from \$864,086, for the Southeast coho fishery, to \$11,942 for the Cook Inlet coho fishery. The reduction in average annual exvessel revenues in these fisheries associated with a 15 percent decrease in coho hatchery production range from \$867,192, for the Southeast coho fishery, to \$11,857, for the Cook Inlet coho fishery.

The harvest of the aggregate All-Other-Alaska-Regions coho fisheries is not impacted by changes in coho hatchery production. As noted in conjunction with the previous cases, this results in average annual exvessel revenues for this region varying indirectly with changes in hatchery production. Average annual exvessel revenues decrease by \$22,954 when coho hatchery production is increased by 15 percent, and increase by \$23,543 when coho hatchery production is reduced by 15 percent.

Impacts of the changes in coho hatchery production to exvessel revenues in the other high-valued salmon fisheries depend on the strength of the substitution effect between coho salmon and chinook and sockeye salmon. If the substitution effect is as expected, a 15 percent increase in coho hatchery production decreases average annual sockeye and chinook revenues by \$196,509 and \$32,492, respectively; and a 15 percent decrease in coho hatchery production increases average annual exvessel revenue of the sockeye and chinook fisheries by \$201,709 and \$20,317, respectively. The impacts of changes in coho hatchery production to average annual exvessel revenue in the low-valued salmon species, pink and chum salmon, are negligible.

Case 11 – Production from Chinook Salmon Enhancement Increases/Decreases 15 percent

Table 51 Base Scenario 11 (Increase) Predicted Average Annual Harvests, Real Revenue, and Real Prices for Prince William Sound Chinook (PWK), Cook Inlet Chinook (CIK), Southeast Chinook (SEK), Kodiak Chinook (KKK), Other Alaska Regional Chinook (AKOK), Alaska Chinook (AKK), Alaska Sockeye (AKR), Alaska Pink (AKP), Alaska Chum (AKC) and All Alaska Coho (AKS), for 1997-2006.

	Harvests (lbs.)	Price (\$/lbs.)	Revenue (dollars)
PWK	1,576,047	1.902	2,998,993
CIK	691,599	1.223	845,771
SEK	7,778,562	2.481	19,308,447
KKK	130,865	1.099	143,770
AKOK	<u>6,423,383</u>	1.509	<u>9,690,762</u>
AKK	16,600,456	1.987	32,987,745
AKR	246,094,406	1.276	314,122,807
AKP	326,720,701	0.301	98,252,861
AKC	147,756,451	0.438	64,704,704
AKS	43,054,879	1.027	44,223,197

Table 52 Scenario 11 (Decrease) Predicted Average Annual Harvests, Real Revenue, and Real Prices Base for Prince William Sound Chinook (PWK), Cook Inlet Chinook (CIK), Southeast Chinook (SEK), Kodiak Chinook (KKK), Other Alaska Regional Chinook (AKOK), Alaska Chinook (AKK), Alaska Sockeye (AKR), Alaska Pink (AKP), Alaska Chum (AKC) and Alaska Coho (AKS), for 1997-2006.

	Harvests (lbs.)	Price (\$/lbs.)	Revenue (dollars)
PWK	1,442,630	1.909	2,754,076
CIK	681,587	1.225	834,840
SEK	6,922,257	2.486	17,206,528
KKK	130,865	1.100	144,001
AKOK	<u>6,420,804</u>	1.512	<u>9,706,924</u>
AKK	15,598,143	1.965	30,646,370
AKR	246,094,406	1.282	315,459,772
AKP	326,720,701	0.301	98,346,712
AKC	147,756,451	0.438	64,747,560
AKS	43,054,879	1.031	44,394,266

Table 53 Case 11 (Increase) Predicted Changes in Total Annual Real Revenue from Base Scenario 1 for Prince William Sound Chinook (PWK), Cook Inlet Chinook (CIK), Southeast Chinook (SEK), Kodiak Chinook (KKK), Other Alaska Regional Chinook (AKOK), Alaska Chinook (AKK), Alaska Sockeye (AKR), Alaska Pink (AKP), Alaska Chum (AKC), and Alaska Coho (AKS) for 1997-2006.

	<u>Revenue Changes</u> <u>Production Increase</u>		
	(L. Bound) (\$/lbs)	(U. Bound) (\$/lbs)	(Expected) (\$/lbs)
PWK	115,924	115,924	115,924
CIK	5,122	5,122	5,122
SEK	1,103,841	1,103,841	1,103,841
KKK	-120	-120	-120
AKOK	-8,451	-8,451	-8,451
AKK	1,216,316	1,216,316	1,216,316
AKR	0	-698,026	-174,507
AKP	-48,053	-48,053	-48,053
AKC	-21,692	-21,692	-21,692
AKS	0	-89,286	-22,321
TOTAL	<u>1,146,571</u>	<u>359,259</u>	<u>949,743</u>

Table 54 Case 11 (Decrease) Predicted Changes in Total Annual Real Revenue from Base Scenario 1 for Prince William Sound Chinook (PWK), Cook Inlet Chinook (CIK), Southeast Chinook (SEK), Kodiak Chinook (KKK), Other Alaska Regional Chinook (AKOK), Alaska Chinook (AKK), Alaska Sockeye (AKR), Alaska Pink (AKP), Alaska Chum (AKC), and Alaska Coho (AKS) for 1997-2006.

	<u>Revenue Changes</u> <u>Production Decrease</u>		
	(L. Bound) (\$/lbs)	(U. Bound) (\$/lbs)	(Expected) (\$/lbs)
PWK	-128,993	-128,993	-128,993
CIK	-5,809	-5,809	-5,809
SEK	-998,078	-998,078	-998,078
KKK	111	111	111
AKOK	<u>7,711</u>	<u>7,711</u>	<u>7,711</u>
AKK	-1,125,059	-1,125,059	-1,125,059
AKR	0	638,939	159,734
AKP	45,798	45,798	45,798
AKC	20,894	20,894	20,894
AKS	0	<u>81,783</u>	<u>20,446</u>
TOTAL	<u>-1,058,367</u>	<u>-337,645</u>	<u>878,187</u>

Case 11 examines impacts to Alaska fisheries of increasing/decreasing state enhancement chinook hatchery production by 15 percent annually, beginning in 1993. As with the coho scenario, revenue changes are moderate. A 15 percent increase in chinook hatchery production results in average annual statewide exvessel revenue

increasing by an expected \$949,743. Reducing the chinook hatchery production by 15 percent results in statewide exvessel revenue decreasing by an expected \$878,187.

The average annual exvessel revenues for each of the four individually modelled chinook fishery regions, Prince William Sound, Cook Inlet, Southeast, and Kodiak, vary directly with changes in chinook hatchery production. A 15 percent increase in chinook hatchery production results in increases in average annual exvessel revenues for the chinook fishery regions which range from \$1,103,841, for the Southeast chinook fishery, to a loss of \$120 for the Kodiak chinook fishery. The reduction in average annual exvessel revenues in these fisheries associated with a 15 percent decrease in chinook hatchery production range from \$998,078, for the Southeast chinook fishery, to a gain of \$111, for the Kodiak chinook fishery.

The harvest of the aggregate All-Other-Alaska-Regions chinook fisheries is not impacted by changes in chinook hatchery production. As noted in conjunction with the previous cases, this results in average annual exvessel revenues for this region varying indirectly with changes in hatchery production. Average annual exvessel revenues decrease by \$22,954 when chinook hatchery production is increased by 15 percent, and increase by \$23,543 when chinook hatchery production is reduced by 15 percent.

Impacts of the changes in chinook hatchery production to exvessel revenues in the other high-valued salmon fisheries depend on the strength of the substitution effect between chinook salmon and coho and sockeye salmon. If the substitution effect is as expected, a 15 percent increase in chinook hatchery production decreases average annual sockeye and coho revenues by \$196,509 and \$32,492, respectively; and a 15 percent decrease in chinook hatchery production increases average annual exvessel revenue of the sockeye and coho fisheries by \$201,709 and \$20,317, respectively. The impacts of changes in chinook hatchery production to average annual exvessel revenue in the low-valued salmon species, pink and chum salmon, are negligible.

Case 5 -- Pink Salmon Program is Eliminated

Table 55 Base Scenario 5 Predicted Average Annual Harvests, Real Revenue, and Real Prices for Prince William Sound Pink (PWP), Cook Inlet Pink (CIP), Southeast Pink (SEP), Kodiak Pink (KKP), Other Alaska Regional Pink (AKOP), Alaska Pink (AKP), Alaska Sockeye (AKR), Alaska Chum (AKC), Alaska Coho (AKS) and All Alaska Chinook (AKK), for 1997-2006.

	Harvests (lbs.)	Price (\$/lbs.)	Revenue (dollars)
PWP	13,266,300	0.463	6,139,691
CIP	3,087,819	0.398	1,197,710
SEP	100,026,126	0.472	47,199,026
KKP	33,450,037	0.447	15,010,679
AKOP	<u>33,476,146</u>	0.429	<u>14,333,512</u>
AKP	183,306,430	0.458	83,880,620
AKR	246,094,406	1.288	317,047,026
AKC	147,756,451	0.595	87,874,981
AKS	43,054,879	1.036	44,597,032
AKK	16,082,501	1.982	31,883,543

Table 56 Case 5 Base Scenario 1 Predicted Changes in Total Annual Real Revenue for Prince William Sound Pink (PWP), Cook Inlet Pink (CIP), Southeast Pink (SEP), Kodiak Pink (KKP), Other Alaska Regional Pink (AKOP), Alaska Pink (AKP), Alaska Sockeye (AKR), Alaska Chum (AKC), Alaska Coho (AKS) and Alaska Chinook (AKK), for 1997-2006.

	<u>Revenue Changes</u>		
	<u>Production Decrease</u>		
	(L. Bound)	(U. Bound)	(Expected)
	(\$/lbs)	(\$/lbs)	(\$/lbs)
PWK	-31,131,217	-31,131,217	-31,131,217
CIK	-2,927,398	-2,927,398	-2,927,398
SEK	13,325,571	13,325,571	13,325,571
KKK	1,988,567	1,988,567	1,988,567
AKOK	<u>4,324,181</u>	<u>4,324,181</u>	<u>4,324,181</u>
AKP	-14,420,294	-14,420,294	-14,420,296
AKR	2,226,193	2,226,193	2,226,193
AKC	0	23,148,315	5,787,079
AKS	284,549	284,549	284,549
AKK	<u>112,114</u>	<u>112,114</u>	<u>112,114</u>
TOTAL	<u>-11,797,440</u>	<u>11,350,875</u>	<u>-6,010,361</u>

Case 5 examines impacts to Alaska fisheries of eliminating the pink salmon enhancement program beginning in 1993. Under this scenario the revenue losses that would occur to the pink salmon fishery are sizeable. An elimination of the pink salmon hatchery production results in average annual statewide expected exvessel revenue reduction of \$6,010,361.

The average annual exvessel revenues for each of the four individually modelled pink fishery regions, Prince William Sound, Cook Inlet, Southeast, and Kodiak, differ widely in the expected revenue changes under an elimination of the pink salmon enhancement program. An elimination of the pink salmon enhancement program results in decreases in average annual exvessel revenues for Prince William Sound of \$31.1 million. Cook Inlet loses nearly \$3 million dollars. The largest gainer is the Southeast pink salmon fishery which takes advantage of an expected 16 cent per pound increase in exvessel price while losing very little harvest. Expected gains to Southeast is \$13 million. The harvest of the aggregate All-Other-Alaska-Regions pink fisheries is also impacted by changes in pink hatchery production. The expected increase in revenues to other Alaska regions is \$4.3 million.

Impacts of the changes in pink salmon hatchery production to exvessel revenues in the chum fishery depends on the strength of the substitution effect between pink and chum salmon. The expected revenue effect is for approximately a \$5.8 million increase in the chum fishery revenues. Other salmon fisheries are also expected to see revenue increases. The revenue increase to the sockeye, coho, and chinook fishery is expected to be \$2.2 million, \$284,549, and \$112,114, respectively.

Case 6 -- Sockeye Salmon Program is Eliminated

Table 57 Case Scenario 6 (Average Prices) Predicted Average Annual Harvests, Real Revenue, and Real Prices for Prince William Sound Sockeye (PWR), Cook Inlet Sockeye (CIR), Southeast Sockeye (SER), Kodiak Sockeye (KKR), Other Alaska Regional Sockeye (AKOR), Alaska Sockeye (AKR), Alaska Pink (AKP), Alaska Chum (AKC), Alaska Coho (AKS) and Alaska Chinook (AKK), for 1997-2006.

	Harvests (lbs.)	Price (\$/lbs.)	Revenue (dollars)
PWR	8,246,440	1.808	14,907,251
CIR	23,173,027	1.535	35,446,854
SER	8,599,481	1.674	14,396,447
KKR	15,044,037	1.554	23,303,507
AKOR	<u>172,005,481</u>	1.250	<u>214,962,961</u>
AKR	227,068,467	1.334	303,017,022
AKP	326,720,701	0.304	99,359,937
AKC	147,756,451	0.441	65,209,081
AKS	43,054,879	1.088	46,860,638
AKK	16,082,501	2.038	32,776,090

Table 58 Case Scenario 6 (Average Prices) Predicted Changes in Total Annual Real Revenue for Prince William Sound Sockeye (PWR), Cook Inlet Sockeye (CIR), Southeast Sockeye (SER), Kodiak Sockeye (KKR), Other Alaska Regional Sockeye (AKOR), Alaska Sockeye (AKR), Alaska Pink (AKP), Alaska Chum (AKC), Alaska Coho (AKS) and Alaska Chinook (AKK), for 1997-2006.

Revenue Changes -- Average Prices			
Production Decrease			
	(L. Bound) (\$/lbs)	(U. Bound) (\$/lbs)	(Expected) (\$/lbs)
PWR	-12,655,458	-12,655,458	-12,655,458
CIR	-3,536,406	-3,536,406	-3,536,406
SER	-826,373	-826,373	-826,373
KKR	-7,763,960	-7,763,960	-7,763,960
AKOR	<u>12,978,386</u>	<u>12,978,386</u>	<u>12,978,386</u>
AKR	-11,803,811	-11,803,811	-11,803,811
AKP	1,059,023	1,059,023	1,059,023
AKC	482,415	482,415	482,415
AKS	0	2,548,155	637,039
AKK	0	<u>1,004,666</u>	<u>251,165</u>
TOTAL	<u>-10,262,373</u>	<u>-6,709,552</u>	<u>-9,374,169</u>

Table 59 Case Scenario 6 (High Prices) Predicted Average Annual Harvests, Real Revenue, and Real Prices for Alaska Sockeye (AKR), Alaska Pink (AKP), Alaska Chum (AKC), Alaska Coho (AKS) and All Alaska Chinook (AKK), for 1997-2006.

	Harvests (lbs.)	Price (\$/lbs.)	Revenue (dollars)
AKR	227,068,467	1.858	368,584,313
AKP	326,720,701	0.324	105,806,173
AKC	147,756,451	0.461	68,147,380
AKS	43,054,879	1.303	56,104,930
AKK	16,082,501	2.265	36,421,291

Table 60 Case Scenario 6 (Low Prices) Predicted Average Annual Harvests, Real Revenue, and Real Prices for Alaska Sockeye (AKR), Alaska Pink (AKP), Alaska Chum (AKC), Alaska Coho (AKS) and All Alaska Chinook (AKK), for 1997-2006.

	Harvests (lbs.)	Price (\$/lbs.)	Revenue (dollars)
AKR	227,068,467	1.165	264,514,534
AKP	326,720,701	0.288	94,108,878
AKC	147,756,451	0.425	62,816,098
AKS	43,054,879	0.962	41,432,268
AKK	16,082,501	1.905	30,635,571

Table 61 Case Scenario 6 (High/Low) Predicted Changes in Total Annual Real Revenue for Alaska Sockeye (AKR), Alaska Pink (AKP), Alaska Chum (AKC), Alaska Coho (AKS) and Alaska Chinook (AKK), for 1997-2006.

<u>Revenue Changes - Expected High-Low Prices</u>		
	(Expected High) (dollars)	(Expected Low) (dollars)
AKR	-12,850,034	-11,062,803
AKP	321,257	1,329,445
AKC	374,157	605,504
AKS	821,118	532,995
AKK	323,737	210,146
TOTAL	-10,509,765	-8,384,712

Case 6 examines impacts to Alaska fisheries of eliminating the sockeye salmon enhancement program beginning in 1993. Under this scenario the revenue losses that would occur to the sockeye salmon fishery are dramatic. An elimination of the sockeye salmon hatchery production results in average annual statewide expected exvessel revenue reduction of \$9,374,169.

The average annual exvessel revenues for each of the four individually modelled sockeye fishery regions, Prince William Sound, Cook Inlet, Southeast, and Kodiak would also suffer revenue decreases under the elimination of the sockeye enhancement program. An elimination of the sockeye salmon enhancement program results in decreases in average annual exvessel revenues for Prince William Sound, Cook Inlet,

Southeast, and Kodiak of \$12.6 million, \$3.5 million, \$826,373, and \$7.76 million, respectively. The harvest of the aggregate All-Other-Alaska-Regions sockeye fisheries is also impacted by changes in sockeye hatchery production. The expected increase in revenues to other Alaska regions is nearly \$13 million. This sizeable increase would accrue mainly to Bristol Bay. The increase is an result of an increase in exvessel price of nearly 8 cents per pound.

Impacts of the changes in sockeye salmon hatchery production to exvessel revenues in the coho and chinook fisheries depend on the strength of the substitution effect between sockeye and coho and chinook salmon. The expected revenue increase is \$637,039 and a \$251,165. Other salmon fisheries are also expected to see revenue increases. The revenue increase to the pink and chum is expected to be \$1,059,023 and \$482,415, respectively.

When demand is stronger than the predicted demand then total revenue losses accruing to the Alaska salmon fisheries will increase to \$10.5 million. When demand is weaker than expected losses decrease to \$8.3 million.

Case 2 -- State Enhancement Program Continues at State and PNP Projected Production Levels.

Table 62 Case Scenario 2 (Average Prices) Predicted Average Annual Harvests, Real Revenue, and Real Prices, Alaska Sockeye (AKR), Alaska Pink (AKP), Alaska Chum (AKC) and All Alaska Coho (AKS), Alaska Chinook (AKK), for 1997-2006.

	Harvests (lbs.)	Price (\$/lbs.)	Revenue (dollars)
AKR	259,353,687	1.243	322,287,029
AKP	333,650,263	0.287	95,788,118
AKC	151,630,219	0.426	64,546,534
AKS	43,258,370	0.970	42,842,911
AKK	16,187,568		31,347,465

Table 63 Case Scenario 3 (Average Prices) Predicted Average Annual Harvests, Real Revenue, and Real Prices, Alaska Sockeye (AKR), Alaska Pink (AKP), Alaska Chum (AKC) and All Alaska Coho (AKS), Alaska Chinook (AKK), for 1997-2006.

	Harvests (lbs.)	Price (\$/lbs.)	Revenue (dollars)
AKR	259,353,687	1.501	389,260,481
AKP	333,650,263	0.307	102,521,014
AKC	151,630,219	0.446	67,643,112
AKS	43,258,370	1.177	50,897,653
AKK	16,187,568	2.133	34,527,425

Table 64 Case Scenario 2 (Low Prices) Predicted Average Annual Harvests, Real Revenue, and Real Prices, Alaska Sockeye (AKR), Alaska Pink (AKP), Alaska Chum (AKC) and All Alaska Coho (AKS), Alaska Chinook (AKK), for 1997-2006.

	Harvests (lbs.)	Price (\$/lbs.)	Revenue (dollars)
AKR	259,353,687	1.090	282,732,400
AKP	333,650,263	0.270	90,165,870
AKC	151,630,219	0.409	61,961,440
AKS	43,258,370	0.880	38,085,840
AKK	16,187,568	1.820	29,469,402

Table 65 Case 2 (High/Low Prices) Predicted Changes in Total Annual Real Revenue from Base Scenario 1 for Average, High, and Low Prices for Alaska Sockeye (AKR), Alaska Pink (AKP), Alaska Chum (AKC), Alaska Coho (AKS), and All Alaska Chinook (AKK), for 1997-2006.

	(Ave. Price) (dollars)	<u>Revenue Changes</u> (High Price) (dollars)	(Low Price) (dollars)
AKR	7,466,196	7,825,820	7,155,063
AKP	-2,512,796	-2,463,902	-2,613,563
AKC	-180,132	-130,111	-249,154
AKS	-1,469,572	-1,922,807	-1,214,446
AKK	-423,964	-598,917	-325,583
TOTAL	2,879,732	2,710,083	2,752,726

Because all the changes take place simultaneously in scenario 2, it is impossible to separate out expected cross-price effects from own-price effects. Furthermore, bounds on cross-price effects cannot be determined. So some of the negative effects from the competing species may be over-stated. **Therefore, the above results are probably a minimum gain for sockeye salmon and maximum losses for the other fisheries. These results are not deemed overly reliable.**

Under the projected enhancement levels for future production the revenue to Alaska salmon fisheries increases from the base-line scenario. The increases in annual revenue ranges from \$2.7 million to \$2.8 million depending on the price scenario, however, only the sockeye fishery shows increases in revenue. The sockeye fishery gains an annual real revenue of over \$7 million dollars. The largest decreases is to the pink salmon fishery which loses an annual real revenue of \$2.5 million dollars.

Case 3 -- The Salmon Enhancement Program is Eliminated in Fiscal Year 1993.

Table 66 Case 3 Predicted Average Annual Harvests, Real Revenue, and Real Prices Base, Alaska Sockeye (AKR), Alaska Pink (AKP), Alaska Chum (AKC) and All Alaska Coho (AKS), Alaska Chinook (AKK), for 1997-2006.

	Harvests (lbs.)	Price (\$/lbs.)	Revenue (dollars)
AKR	227,068,467	1.40	317,195,053
AKP	183,306,430	0.54	99,041,218
AKC	72,918,371	0.59	43,375,225
AKS	36,204,066	1.10	39,672,013
AKK	12,486,955	1.95	24,354,094

Table 67 Case 3 Predicted Changes in Total Annual Real Revenue from Base Scenario 1 for Average, High, and Low Prices for Alaska Sockeye (AKR), Alaska Pink (AKP), Alaska Chum (AKC), Alaska Coho (AKS), and All Alaska Chinook (AKK), for 1997-2006.

	<u>Revenue Changes</u> (dollars)
AKR	2,374,220
AKP	740,304
AKC	-21,351,441
AKS	-4,640,470
AKK	-7,417,335
TOTAL	-30,294,722

To predict this case is really beyond the limits of this program. The problem is that econometrics estimates cause and effect relationships between explanatory and dependent variables. These relationships are estimated around a set of historical data points. When shocks to the system lead to data which is well beyond historically observed data the model's findings become suspect. In this case, with all enhancement eliminated, harvests for average annual harvests, sockeye salmon harvests are well below record levels every year and average annual harvest for pink salmon are close to record low levels. In addition, the predicted harvests for chum are less than half of the base scenario. If these shocks were just for one or two years the model could probably handle it. But these shocks are for every year. If this scenario were to happen it would drastically change the structure of salmon markets and any structural deviation from the historical pattern, in which the model was estimated, makes it extremely difficult to make accurate predictions.

Again, these scenarios are simultaneously determined. This does not allow bounds to be placed on the cross-price effects. This will overstate the benefit of the increases within the high- and low-valued salmon categories for species when competing species decline in production. Therefore, the increases to salmon species prices because of competing species decline in harvest will be the upper bound on price increases and the resulting numbers will be understate the loss to the fishery. Therefore, the estimated loss of \$30 million is probably underestimated and, in actuality, all species will most likely lose from elimination of the enhancement program.

Because of the unreliability of the modelling effort dealing with case 3 -- the discussion of individual effects is meaningless.

Case 4 -- Salmon Production from Enhancement is Increased/Decreased by 15 percent.

Table 68 Case Scenario 4 -- Increase -- (Average Prices) Predicted Average Annual Harvests, Real Revenue, and Real Prices, Alaska Sockeye (AKR), Alaska Pink (AKP), Alaska Chum (AKC) and All Alaska Coho (AKS), Alaska Chinook (AKK), for 1997-2006.

	Harvests (lbs.)	Price (\$/lbs.)	Revenue (dollars)
AKR	248,913,075	1.264	314,698,647
AKP	348,176,789	0.265	92,245,925
AKC	158,982,163	0.404	64,287,728
AKS	44,082,501	1.020	44,968,100
AKK	16,600,456	1.975	32,789,061

Table 69 Case Scenario 2 -- Increase -- (High Prices) Predicted Average Annual Harvests, Real Revenue, and Real Prices, Alaska Sockeye (AKR), Alaska Pink (AKP), Alaska Chum (AKC) and All Alaska Coho (AKS), Alaska Chinook (AKK), for 1997-2006.

	Harvests (lbs.)	Price (\$/lbs.)	Revenue (dollars)
AKR	248,913,075	1.530	380,851,326
AKP	348,176,789	0.283	98,654,304
AKC	158,982,163	0.423	67,273,155
AKS	44,082,501	1.215	53,543,491
AKK	16,600,456	2.181	36,204,966

Table 70 Case Scenario 2 -- Increase -- (Low Prices) Predicted Average Annual Harvests, Real Revenue, and Real Prices, Alaska Sockeye (AKR), Alaska Pink (AKP), Alaska Chum (AKC) and All Alaska Coho (AKS), Alaska Chinook (AKK), for 1997-2006.

	Harvests (lbs.)	Price (\$/lbs.)	Revenue (dollars)
AKR	248,913,075	1.108	275,690,690
AKP	348,176,789	0.250	86,874,376
AKC	158,982,163	0.389	61,786,235
AKS	44,082,501	0.905	39,911,496
AKK	16,600,456	1.854	30,774,835

Table 71 Case 2 -- Increase -- (High/Low Prices) Predicted Changes in Total Annual Real Revenue from Base Scenario 1 for Average, High, and Low Prices for Alaska Sockeye (AKR), Alaska Pink (AKP), Alaska Chum (AKC), Alaska Coho (AKS), and All Alaska Chinook (AKK), for 1997-2006.

	(Ave. Price) (dollars)	<u>Revenue Changes</u> (High Price) (dollars)	(Low Price) (dollars)
AKR	-122,186	-1,520,152	-496,492
AKP	-6,045,989	-6,368,395	-5,969,431
AKC	-438,938	-517,353	-435,805
AKS	655,578	603,193	533,199
AKK	1,017,632	1,938,427	1,719,881
TOTAL	-4,933,903	-5,864,280	-4,648,648

Table 72 Case Scenario 4 -- Increase -- (Average Prices) Predicted Average Annual Harvests, Real Revenue, and Real Prices, Alaska Sockeye (AKR), Alaska Pink (AKP), Alaska Chum (AKC) and All Alaska Coho (AKS), Alaska Chinook (AKK), for 1997-2006.

	Harvests (lbs.)	Price (\$/lbs.)	Revenue (dollars)
AKR	243,273,470	1.294	314,789,244
AKP	321,772,368	0.319	102,585,890
AKC	136,530,740	0.452	61,777,802
AKS	42,027,258	1.038	43,620,364
AKK	15,550,595	1.974	30,699,935

Table 73 Case Scenario 2 -- Increase -- (High Prices) Predicted Average Annual Harvests, Real Revenue, and Real Prices, Alaska Sockeye (AKR), Alaska Pink (AKP), Alaska Chum (AKC) and All Alaska Coho (AKS), Alaska Chinook (AKK), for 1997-2006.

	Harvests (lbs.)	Price (\$/lbs.)	Revenue (dollars)
AKR	243,273,470	1.569	381,781,704
AKP	321,772,368	0.340	109,475,655
AKC	136,530,740	0.474	64,675,601
AKS	42,027,258	1.238	52,045,372
AKK	15,550,595	2.185	33,982,864

Table 74 Case Scenario 2 -- Increase -- (Low Prices) Predicted Average Annual Harvests, Real Revenue, and Real Prices, Alaska Sockeye (AKR), Alaska Pink (AKP), Alaska Chum (AKC) and All Alaska Coho (AKS), Alaska Chinook (AKK), for 1997-2006.

	Harvests (lbs.)	Price (\$/lbs.)	Revenue (dollars)
AKR	243,273,470	1.132	275,356,028
AKP	321,772,368	0.301	96,933,746
AKC	136,530,740	0.435	59,400,922
AKS	42,027,258	0.920	38,661,247
AKK	15,550,595	1.850	28,767,507

Table 75 Case 2 -- Increase -- (High/Low Prices) Predicted Changes in Total Annual Real Revenue from Base Scenario 1 for Average, High, and Low Prices for Alaska Sockeye (AKR), Alaska Pink (AKP), Alaska Chum (AKC), Alaska Coho (AKS), and All Alaska Chinook (AKK), for 1997-2006.

	(Ave. Price) (dollars)	<u>Revenue Changes</u> (High Price) (dollars)	(Low Price) (dollars)
AKR	-31,589	-589,774	-831,154
AKP	4,284,976	4,452,956	4,089,939
AKC	-2,948,864	-3,114,907	-2,839,118
AKS	-692,119	-894,926	-717,050
AKK	-1,071,494	-283,367	-287,447
TOTAL	-459,090	-429,988	-584,830

As in scenario 2, all the changes in scenario 4 take place simultaneously and it is impossible to separate out expected cross-price effects from own-price effects. Again, bounds on cross-price effects cannot be determined. So some of the negative effects from the competing species may be overstated. Because of these drawbacks, scenario 4 cannot be used with any degree of confidence and will not be further discussed here.

Conclusion

The salmon marketing model was constructed to predict a 15-year exvessel price stream under various enhancement scenarios. The accuracy of the long term price predictions will depend on several factors including: (1) the specified future values of salmon price determinants; (2) the accuracy of the underlying salmon exvessel price models; and (3) the extent to which the current structure of the international salmon market continues into the future. The model were specifically designed to capture long-run price trends. Thus, even though actual outcomes may vary from those predicted through the model, the model results may still be valid in terms of projecting the direction of future price movements.

The model performed best when the enhancement changes were examined in isolation. This was due to the fact that it was difficult to separate out the true substitution effects between coho, chinook, and sockeye salmon and pink and chum salmon. An ad hoc procedure was used to estimate the substitution effect between the species in the high-valued salmon grouping and the low-valued salmon grouping. This ad hoc procedure could not be used when there were simultaneous changes in the enhancement program.

The results of the model simulations indicate that Alaska average annual exvessel revenues will increase over the 1997-2006 time period when sockeye, coho, chinook, and chum enhancement hatchery production are increased. However, these increases are moderate, and the actual profitability of increasing hatchery production of these species can only be determined when the revenue increase are compared to the costs of the enhancement program. Costs considerations and determination of producer surpluses from the enhancement program are provided in a separate report.

The future simulation results for variation in the pink salmon enhancement program indicate that there is currently an over production of pink salmon. Reducing pink salmon production by 15 percent results in average annual exvessel revenue gains in both the statewide pink fisheries and the overall statewide salmon fisheries. However, there are distributional impacts which must be considered in conjunction with this result. The Prince William Sound pink fishery suffers a significant reduction in exvessel revenue when pink hatchery production is reduced by 15 percent.

The model results do not suggest that the pink salmon enhancement program should be eliminated. The large declines in pink salmon harvest that accompany this action depress statewide average annual exvessel revenues. This indicates that there is some exvessel revenue maximizing level of pink salmon enhancement which lies somewhere between the 15 percent reduction in pink hatchery production and the complete elimination of the enhancement program. Costs must be considered prior to determination of the profitability of the various future pink salmon enhancement programs.

Four points, which are not discussed elsewhere in the market or policy analyses, should be noted in evaluating the economic viability of various enhancement programs. Returns to only the commercial fleet are considered in the economic analysis. Increased enhancement production of some salmon species, e.g. chinook and coho, will increase sport-fishing harvests. Thus, the reported revenue increases provided in this report (which are confined to exvessel revenue) will understate actual benefits associated with increased salmon hatchery production. It may be useful in the future to consider incorporating economic impacts of the sport segment of the fishery industry into the economic analysis of the salmon enhancement program.

Second, variation in salmon hatchery production may affect prices and/or recruitment/survivability of other fish species. Considerations of salmon enhancement impacts to other fisheries is beyond the scope of this analysis.

Third, it is clear from the model results that, across salmon species, increases in production/harvests will have only moderate impacts on salmon fisheries exvessel revenues, at best. Current high levels of world salmon supplies severely hamper the ability of increased production to bolster economic returns to the salmon fisheries. It may be prudent to increase efforts aimed at expanding world demand for Pacific wild salmon. This would increase prices at all harvest levels, and increase the ability of the world salmon market to absorb additional salmon production.

Represented in Figure 45 are demand curves (in the upper graph) and associated total revenues curves (in the lower graph). In order to illustrate the previous discussion, assume that the current demand for pink salmon is represented by the demand curve D_0 and supply is represented by S_0 . Given these demand and supply curves the current quantity is Q_0 and the current price is P_0 . The total revenue curve to the fishery is represented by TR_0 . Current production levels occur where the total revenue curve is downward sloping. This implies that the revenue associated with the last unit of fish harvested was negative. Therefore, decreasing harvest will increase total revenue. However, there is a range, beyond which this will no longer be true. If harvest is cut beyond Q_1 total revenue will decline.

If demand can be expanded to D_1 , the total revenue curve will be shifted up to TR_1 , as more salmon are demanded at each price level. In addition to increasing profits to the industry, the expanded demand may also lead to a situation where further increase in pink salmon production lead to increases in fishery revenues. Therefore, it may be advisable to increase efforts aimed at increasing demand for salmon, particularly pink salmon, through increased marketing and promotion, product development, market expansion, and the development of new markets. This investment may provide greater returns to the salmon industry than investment in increasing salmon hatchery production.

Finally, an increase or decrease in the production of any salmon species may trigger a counter move by competitors in the world salmon industry which may offset any potential gain from the production change. For example, a decrease in pink salmon harvest could provide incentive for the Japanese to invest in the potentially large Russian pink salmon industry. Thus, possible reactions of other participants in the world salmon industry must be considered when evaluating salmon enhancement policy.

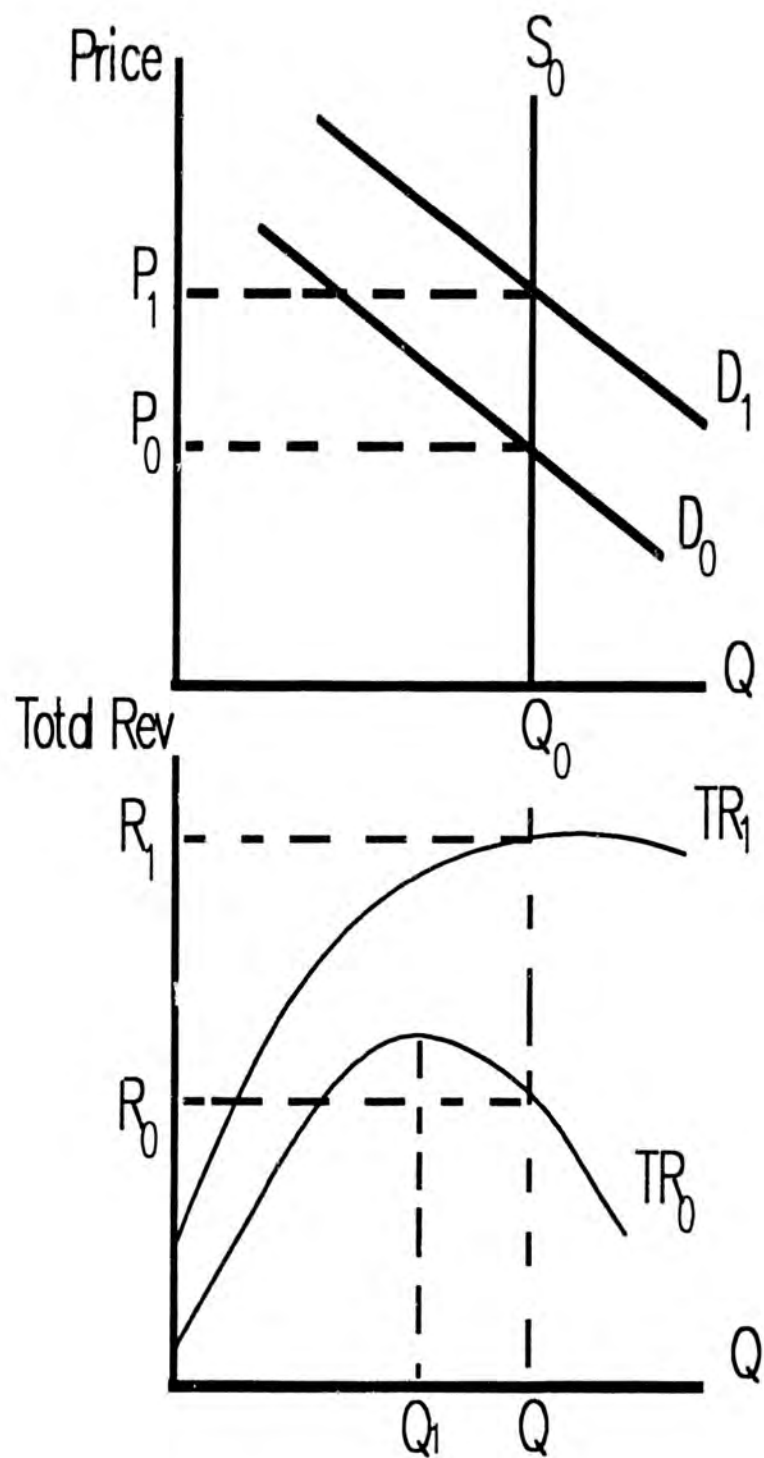


Figure 45. Supply, Demand, and Revenue Illustration

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An International Marketing Model for Alaskan Salmon
Executive Summary

December 15, 1992

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This report is for the purpose of giving the final report on the demand component of the Legislative Review of Alaska's Fisheries Enhancement Program. This report was made possible by a grant received from the Alaska State Legislature and is the result of research sponsored by Alaska Sea Grant with funds from the National Oceanic and Atmospheric Administration, Office of Sea Grant, Department of Commerce, under grant no. NA90AA-D-SG066, project # R/14-13, and from the University of Alaska with funds appropriated by the state.

Introduction

This report is designed to address potential impacts of future changes in the state and PNP salmon enhancement program to the economic returns from Alaska salmon fisheries. These impacts are analyzed through a econometric supply and demand equilibrium model of the world salmon market. This report represents one part of a cost/benefit analysis of the state and PNP salmon enhancement program. **The revenue projections from this model provide the benefits of the enhancement program. They are compared to estimated costs in a separate report.**

The econometric model is divided into two components: Component one provides a model of historical, international, salmon wholesale price formation. The model encompasses the wholesale salmon markets of North America, Japan, the European Economic Community, Chile, Australia, and New Zealand. In the second component, the historical relationship between North American wholesale prices and regional Alaska exvessel prices for the five salmon species harvested in Alaska (sockeye, coho, chinook, pink, and chum) are modelled.

The estimated econometric models are combined in model simulations. The simulations provide the vehicle for examining impacts of future changes in state and PNP enhancement salmon hatchery production to Alaska statewide and regional salmon exvessel revenues and prices. Eleven different future scenarios are simulated. These scenarios involve various adjustments to state and PNP hatchery production levels of the different salmon species. The future simulation time period is 1992-2006.

The econometric models in this study estimate the historical structure of the international salmon markets. Future revenue projections are based on the assumption that this historical structure continues into the future. In addition, the future simulations depend on specified future salmon harvests. Harvests of wild stock are

based on a ten-year average, while harvest of state and PNP hatchery stocks are based on projections provided by either Dr. Jerome Collie (University of Alaska Fairbanks, School of Fisheries) or state salmon hatchery operators. **Additionally, the models are designed to project average revenue changes over the 15-year future time horizon, and not the returns to the Alaska salmon fisheries in any single year.**

Estimation Results

This study is designed specifically to project future Alaska salmon exvessel prices through the year 2006 under varying state and PNP hatchery production levels.

Alaska exvessel prices are going to depend, in part, on wholesale prices. Thus, the economic model must consist of a system of equations that model salmon price formation at both the wholesale and exvessel levels. This modelling framework is considered particularly critical for this study, where the modelling emphasis is placed on projecting long-term price movements, rather than simply forecasting exvessel prices one-year into the future.

A model designed to project exvessel prices one year into the future might include ADF&G forecasted run sizes, current U.S., Canadian, and Japanese wholesale prices and inventories, and other supply and demand determinants. However, these variables are not available beyond the current time period. Thus, these variables must be internally generated within a model designed to project exvessel prices 15-years into the future (1992-2006). This model must explicitly account for the interlinkages which exist between the various salmon markets at the wholesale level, as well as the interlinkages between the wholesale and exvessel levels. Model performance is evaluated on the basis of the model's ability to predict long-term average price movements, rather than to predict exvessel prices in any single year.

The international salmon econometric model may be divided into two components, referred to in this report as Bloc 1 and Bloc 2. Bloc 1 provides a system of 23 equations that models the international salmon market. The complexity of this submodel reflects the highly integrated nature of world salmon markets. The flow chart provided in Figure 1 provides a representation of the structure of the international salmon market, that is modelled in Bloc 1. The arrows designate direction of trade flows.

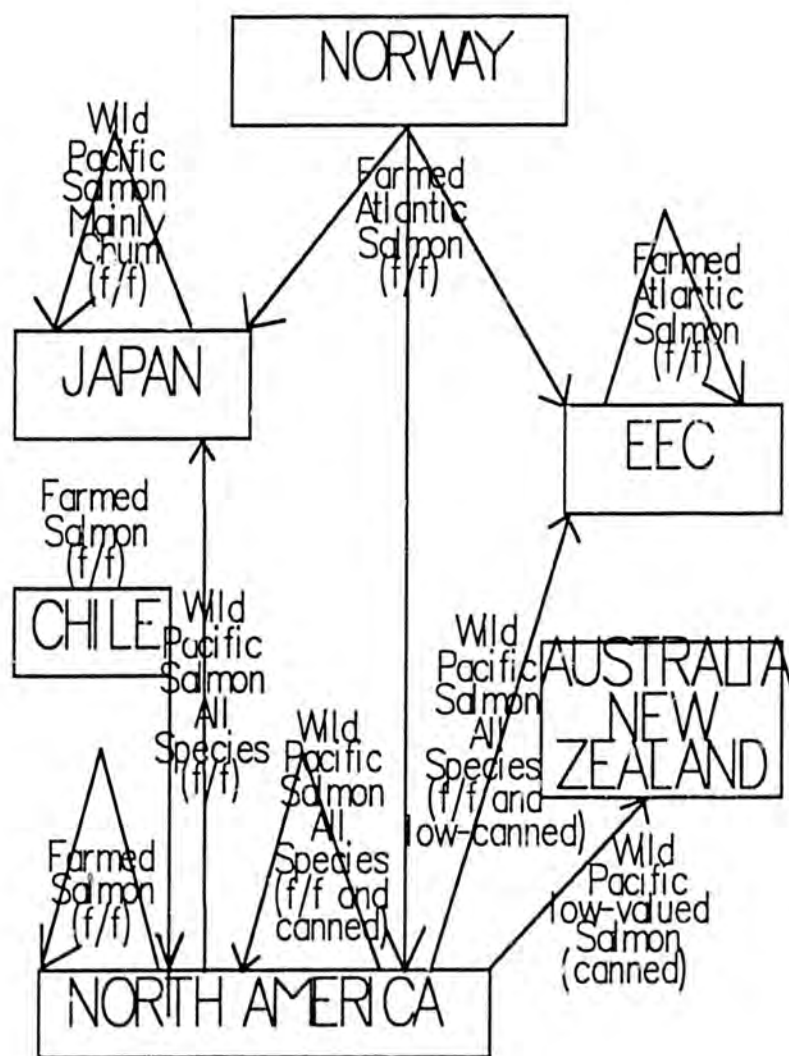


Figure 1. International Salmon Flow Chart

The final component of the Bloc 1 submodel is North American exvessel price formation. Exvessel prices depend on the current wholesale salmon prices and, therefore, are modelled recursively--wholesale prices feed into exvessel price formation. Two aggregate exvessel price equations are modelled in Bloc 1: North American high-valued salmon exvessel price, and North American low-valued salmon exvessel price. The North American high-valued exvessel price is a weighted average of Canadian and U.S. exvessel prices of high-valued salmon species: sockeye, coho, and chinook. The North American low-valued exvessel price is a weighted average of Canadian and U.S. exvessel prices of low-valued salmon species: pink and chum. These exvessel price equations are modelled in reduced form, based on derived demand theory.

Listed below are the dependent variables that are modelled in Bloc1. All quantities are fresh/frozen, unless otherwise noted as canned.

1. Norwegian allocation of farm-raised Atlantic salmon

- Quantity allocated to the EEC
- Quantity allocated to the Japan
- Quantity allocated to the United States

2. EEC demand for salmon

- Quantity demanded of Norwegian farmed Atlantic salmon
- Quantity demanded of North American wild high-valued Pacific salmon
- Quantity demanded of North American wild low-valued Pacific salmon
- Quantity demanded of North American wild low-valued canned Pacific salmon (combined demand with Australia and New Zealand)

3. Japanese demand for salmon

- Quantity demanded of Norwegian farmed Atlantic salmon
- Quantity demanded of North American wild high-valued Pacific salmon
- Quantity demanded of North American wild low-valued Pacific salmon

4. North American demand
 - Quantity demanded of Norwegian farmed Atlantic salmon
5. Australia and New Zealand Demand
 - Quantity demanded of North American low-valued canned salmon.
(combined demand with the EEC)
6. North American allocation of wild high-valued Pacific Salmon
 - Quantity allocated to Japan
 - Quantity allocated to the EEC
7. North American allocation of wild low-valued Pacific salmon
 - Quantity allocated to Japan
 - Quantity allocated to the EEC
8. North American allocation of wild canned low-valued Pacific salmon
 - Quantity allocated to the EEC, Australia, and New Zealand
9. North American inventory holdings
 - Quantity of wild high-valued salmon inventory
 - Quantity of wild low-valued salmon inventory
 - Quantity of canned wild low-valued salmon inventory
10. North American exvessel prices
 - Price of wild high-valued salmon
 - Price of wild low-valued salmon

The model includes flows of farmed salmon from Norway, Scotland, Chile, British Columbia, Ireland, and the United States. The farmed salmon from Norway, Ireland, and Scotland is exclusively Atlantic salmon. Farmed salmon from the United States, British Columbia, and Chile are a mixture of Pacific and Atlantic salmon. North American salmon exports include all species of Pacific salmon. Japanese landings of salmon also include all species of Pacific salmon, although most Japanese landings are chum salmon.

Data limitations, coupled with the need to keep this complex model tractable, require that certain countries and species be aggregated, and that some markets be omitted. Aggregated markets include the United States and Canada (designated as North America), and European Countries (designated as the EEC). Omitted countries include the Soviet Union, which historically supplied salmon only to Eastern Bloc countries. Even with these modifications, the model is sufficiently detailed to provide insight into price formation in the world salmon markets.

Alaska regional and statewide exvessel prices are modelled in Bloc 2. Within this submodel, exvessel prices are estimated for all Pacific salmon species (sockeye, coho, chinook, pink and chum) in four regions: Prince William Sound, Cook Inlet, Kodiak, and Southeast. In addition, exvessel prices for all other Alaska fishery regions are modelled as a single aggregate group. The Alaska regional exvessel prices are estimated on the basis of the econometrically identified relationship between the regional exvessel prices and relevant North American high-valued salmon exvessel price (sockeye, coho and chinook salmon) or low-valued salmon exvessel price (pink and chum salmon), which are modelled in Bloc 1.

The Bloc 1 submodel was constructed specifically to model the linkages between the international salmon wholesale market and exvessel price formation. This linkage occurs through the estimated North American high-valued and low-valued salmon exvessel price equations. These two exvessel price equations form the basis for subsequent estimation of Alaska regional salmon exvessel prices. Therefore, the discussion of Bloc 1 estimation results will focus on the North American high-valued and low-valued salmon exvessel price equations (the reader is referred to the full report for complete Bloc 1 estimation results).

The model results for the North American high-valued exvessel price equation indicated that 91.6 percent of the variation in North American high-valued exvessel prices, over the historical time period 1982-1991, were explained by variation in the equations explanatory variables. The predicted versus actual North American high-valued exvessel prices are provided in Figure 2. **One key finding from the Bloc 1 estimation was that there is a 99.6 percent probability that farmed Atlantic salmon is a substitute for sockeye, chinook, and coho salmon.**

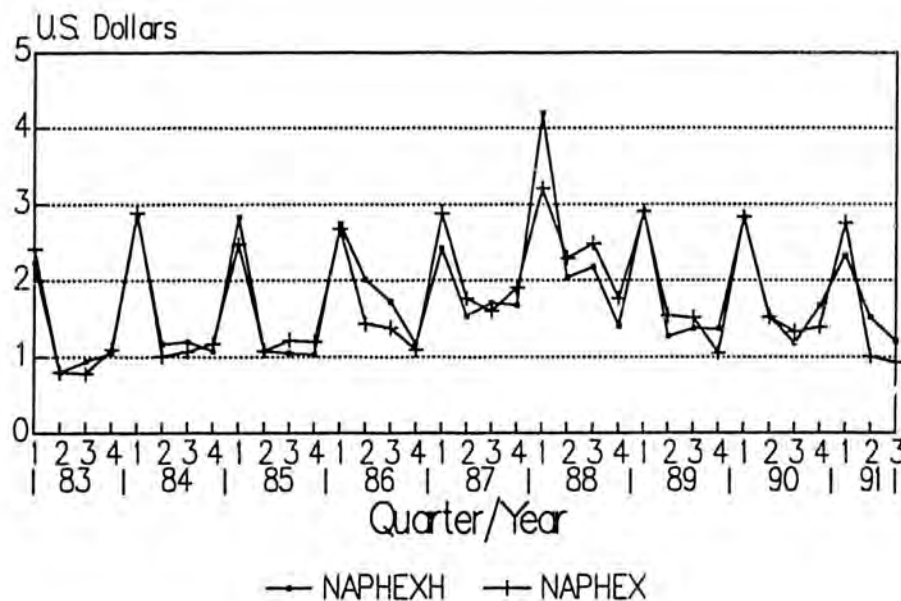


Figure 2. Predicted (NAPHEXH) vs. actual (NAPHEX) North American high-valued salmon exvessel price (1983 to 1991)

The variation in the explanatory variables within the North American low-valued salmon exvessel price equation explained 86.9 percent of the variation in North American low-valued exvessel prices over the historical time period. Actual versus

predicted North American low-valued salmon exvessel prices for the 1983-1991 time period are provided in Figure 3.

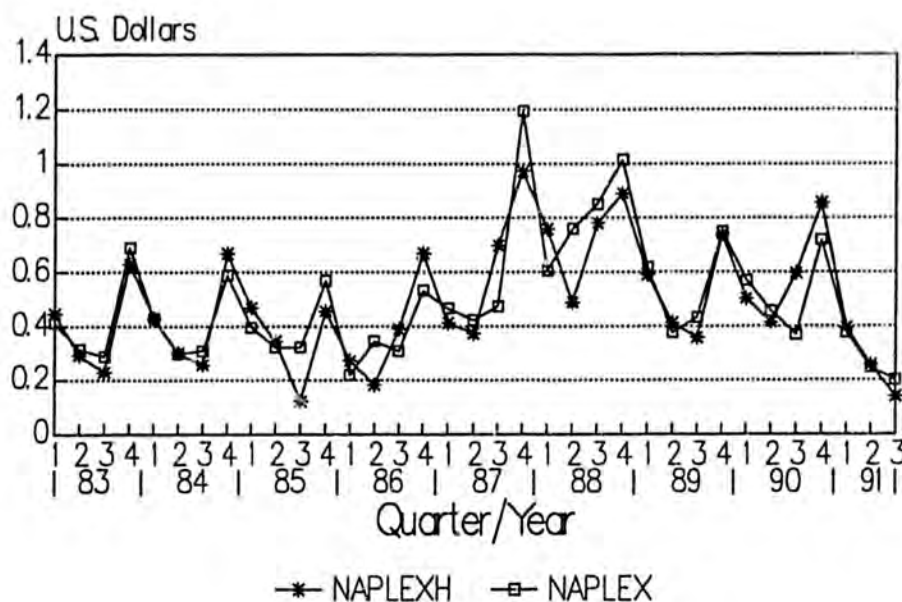


Figure 3. Predicted (NAPLEXH) vs. actual (NAPLEX) North American low-valued salmon exvessel price (1983 to 1991)

The Bloc 2 submodel included 20 equations within which regional Alaska exvessel prices across Pacific salmon species were regressed against the appropriate North American high-valued exvessel price or North American low-valued exvessel price. The correlation between the North American exvessel prices and the regional exvessel prices were in general quite strong. The strongest relationships occurred between Alaska regional sockeye salmon exvessel price and North American high-valued salmon exvessel price, and pink salmon exvessel price and North American low-valued salmon exvessel price. For example, 90 percent of the variation in Cook Inlet sockeye exvessel price was captured by variation in North American high-valued exvessel price.

The predicted versus actual Cook Inlet sockeye exvessel prices are provided in Figure 4.

The chinook salmon regional exvessel price equations generally had the poorest fits. This outcome was generally attributed to chinook salmon not being the target species in several Alaska fisheries, which resulted in regional chinook exvessel prices being based on few observations. The reader is referred to the full report for estimation results of all Alaska regional exvessel price equations.

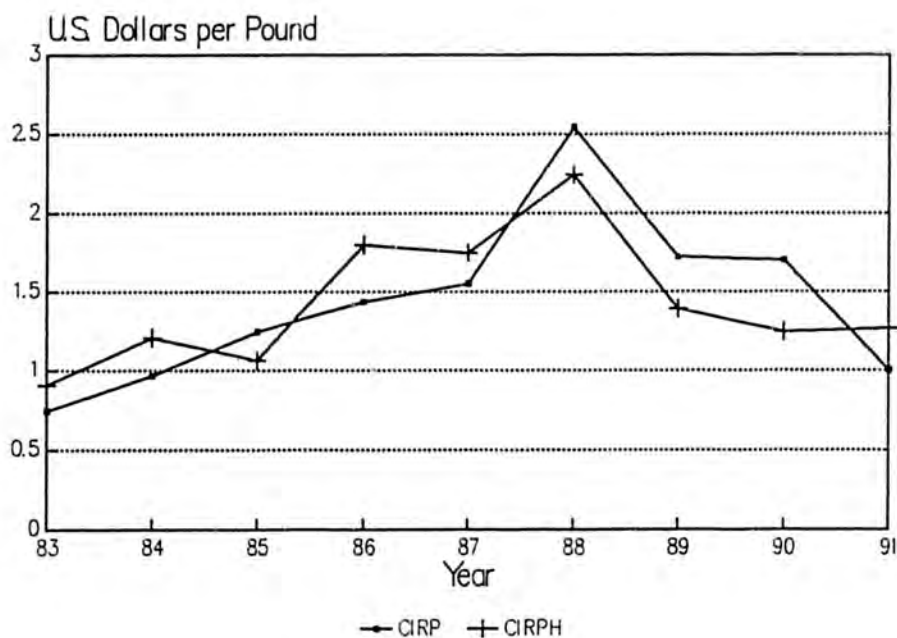


Figure 4. Predicted (CIRPH) vs. actual (CIRP) Cook Inlet sockeye salmon exvessel price (1983 to 1991).

Simulation Results

The estimated system of equations from Bloc 1 and Bloc 2 are combined in simulation to forecast future economic returns to the Alaska salmon industry. A variety of future

case scenarios were simulated. The various scenarios assumed different future state and PNP salmon hatchery production levels for the 1992-2006 time period. The base scenario, to which other scenarios were compared in deriving changes in exvessel revenues, assumes that state and PNP salmon hatchery production will continue at levels consistent with current production practices.

Forecasting future values of the variables determined within the system of equations (endogenous variables) requires specifying future values of the variables set outside the system of equations (exogenous variables) for the 1992-2006 time period. For example, values must be set for Japanese-U.S. exchange rates and Japanese personal income. A variety of techniques were used in specifying future values of the exogenous variables, including holding variable values constant at their most recently observed values, extrapolating future values from historic movements in the variables, and expert opinion. In addition to specifying their expected values, upper and lower bounds were specified for each of the exogenous variables. And, each scenario, for cases 1-6, was simulated for all three values, providing an expected, an optimistic, and a pessimistic set of simulation results. Only those simulation results using expected exogenous variable values are discussed in this report. A full listing of all simulation results are provided in the full report.

Although, the case scenarios involve altering state and PNP salmon hatchery production beginning in 1992, salmon harvests are not impacted until several years later, when the adult salmon return to the Alaska fisheries. Therefore, revenue and exvessel price impacts for the various case scenarios were reported for the 1997-2006 time period. All revenues and prices were reported in constant 1992 dollars (referred to as real revenues and prices).

The results presented in this section represent the 1997-2006 average annual real exvessel revenue changes from the base scenario that accompany some specific change in state and PNP salmon hatchery production. Two sets of results are provided for each of the case scenarios. Average real exvessel revenue changes are reported for each regional fishery harvesting the salmon species for which hatchery production is altered. In addition, Alaska statewide exvessel revenue changes are reported across all salmon species.

The aggregation of exvessel prices in Bloc 1 estimation (necessitated by data limitations and the need to maintain model tractability) resulted in the model providing the most reliable results when a change in the state and PNP hatchery production involves only a single salmon species. For this reason, only case scenarios 5-11 are reported in this summary document (refer to the full report for results of all case scenarios).

Tables 1-7 provide the expected average annual exvessel revenue changes for case scenarios 5-11.

Table 1 -- Case 5 (Pink Salmon Program Eliminated) Predicted Changes in Total Annual Real Revenue from Base Scenario 1 for Prince William Sound Pink (PWP), Cook Inlet Pink (CIP), Southeast Pink (SEP), Kodiak Pink (KKP), All All-Other-Regions Pink (AKOP), Alaska Pink (AKP), Alaska Sockeye (AKR), Alaska Chum (AKC), Alaska Coho (AKS) and Alaska Chinook (AKK), for 1997-2006.

Annual Revenue Changes
(Total 1992 Dollars)

PWP	-31,131,217
CIP	-2,927,398
SEP	13,325,571
KKP	1,988,567
AKOP	<u>4,324,181</u>
AKP	-14,420,296
AKR	2,226,193
AKC	5,787,079
AKS	284,549
AKK	<u>112,114</u>
TOTAL	<u>-6,010,361</u>

Table 2 -- Case 6 (Sockeye Salmon Enhancement Program is Eliminated) Predicted Changes in Total Annual Real Revenue from Base Scenario 1 for Prince William Sound Sockeye (PWR), Cook Inlet Sockeye (CIR), Southeast Sockeye (SER), Kodiak Sockeye (KKR), All All-Other-Regions Sockeye (AKOR), Alaska Sockeye (AKR), Alaska Pink (AKP), Alaska Chum (AKC), Alaska Coho (AKS) and Alaska Chinook (AKK), for 1997-2006.

Annual Revenue Changes
(Total 1992 Dollars)

PWR	-12,655,458
CIR	-3,536,406
SER	-826,373
KKR	-7,763,960
AKOR	<u>12,978,386</u>
AKR	-11,803,811
AKP	1,059,023
AKC	482,415
AKS	637,039
AKK	<u>251,165</u>
TOTAL	<u>-9,374,169</u>

Table 3 -- Case 7 (Production from Pink Enhancement Changes by 15%) Predicted Changes in Total Annual Real Revenue from Base Scenario 1 for Prince William Sound Pink (PWP), Cook Inlet Pink (CIP), Southeast Pink (SEP), Kodiak Pink (KKP), All All-Other-Regions Pink (AKOP), Alaska Pink (AKP), Alaska Sockeye (AKR), Alaska Chum (AKC), Alaska Coho (AKS) and Alaska Chinook (AKK), for 1997-2006.

Annual Revenue Changes
(Total 1992 Dollars)

	<u>Increase Production</u>	<u>Decrease Production</u>
PWP	1,509,859	-2,181,894
CIP	166,102	-244,389
SEP	-2,249,129	2,115,462
KKP	-588,007	493,543
AKOP	<u>-651,804</u>	<u>634,142</u>
AKP	-1,812,978	816,865
AKR	-208,925	219,899
AKC	-871,851	874,643
AKS	-26,705	28,114
AKK	<u>-10,522</u>	<u>11,079</u>
TOTAL	<u>-2,930,981</u>	<u>2,584,019</u>

Table 4 -- Case 8 (Production from Sockeye Enhancement Changes by 15%)
 Predicted Changes in Total Annual Real Revenue from Base Scenario 1 for Prince William Sound Sockeye (PWR), Cook Inlet Sockeye (CIR), Southeast Sockeye (SER), Kodiak Sockeye (KKR), All All-Other-Regions Sockeye (AKOR), Alaska Sockeye (AKR), Alaska Pink (AKP), Alaska Chum (AKC), Alaska Coho (AKS) and Alaska Chinook (AKK), for 1997-2006.

	<u>Annual Revenue Changes</u> (Total 1992 Dollars)	
	<u>Increase</u> <u>Production</u>	<u>Decrease</u> <u>Production</u>
PWR	1,767,067	-1,800,062
CIR	545,179	-514,583
SER	114,284	-18,768
KKR	988,757	-1,050,612
AKOR	-1,820,309	1,848,276
AKR	1,594,978	-1,633,928
AKP	-114,944	150,275
AKC	-67,970	68,504
AKS	-89,349	90,972
AKK	-35,226	35,772
TOTAL	<u>1,287,489</u>	<u>-1,288,405</u>

Table 5 -- Case 9 (Production from Chum Enhancement Changes by 15%)
 Predicted Changes in Total Annual Real Revenue from Base Scenario 1 for Prince William Sound Chum (PWC), Cook Inlet Chum (CIC), Southeast Chum (SEC), Kodiak Chum (KCC), All All-Other-Regions Chum (AKOC), Alaska Chum (AKC), Alaska Sockeye (AKR), Alaska Pink (AKP), Alaska Coho (AKS) and Alaska Chinook (AKK), for 1997-2006.

	<u>Annual Revenue Changes</u> (Total 1992 Dollars)	
	<u>Increase</u> <u>Production</u>	<u>Decrease</u> <u>Production</u>
PWC	646,243	-706,749
CIC	-57,581	57,770
SEC	2,938,214	-3,153,957
KCC	158,480	-186,022
AKOC	-209,369	210,040
AKC	3,475,987	-3,778,919
AKR	-19,341	21,155
AKP	-937,053	940,127
AKS	-2,466	2,699
AKK	-972	1,064
TOTAL	<u>2,516,155</u>	<u>-2,813,874</u>

Table 6 -- Case 10 (Production from Coho Enhancement Changes by 15%)
 Predicted Changes in Total Annual Real Revenue from Base Scenario 1 for Prince
 William Sound Coho (PWS), Cook Inlet Coho (CIS), Southeast Coho (SES), Kodiak
 Coho (KKS), All All-Other-Regions Coho (AKOS), Alaska Coho (AKS), Alaska
 Sockeye (AKR), Alaska Pink (AKP), Alaska Chum (AKC), and Alaska Chinook
 (AKK), for 1997-2006.

	<u>Annual Revenue Changes</u> (Total 1992 Dollars)	
	<u>Increase</u> <u>Production</u>	<u>Decrease</u> <u>Production</u>
PWS	282,746	-283,697
CIS	11,942	-11,857
SES	864,086	-867,192
KKS	6,922	-6,885
AKOS	-22,954	23,543
AKS	1,142,742	-1,146,088
AKP	-30,271	32,787
AKR	-196,509	201,709
AKC	-13,808	14,923
AKK	-32,492	20,317
Total	<u>869,662</u>	<u>-876,352</u>

Table 7 -- Case 11 (Production from Chinook Enhancement Changes by 15%)
 Predicted Changes in Total Annual Real Revenue from Base Scenario 1 for Prince
 William Sound Chinook (PWK), Cook Inlet Chinook (CIK), Southeast Chinook (SEK),
 Kodiak Chinook (KKK), All All-Other-Regions Chinook (AKOK), Alaska Chinook
 (AKK), Alaska Sockeye (AKR), Alaska Pink (AKP), Alaska Chum (AKC), and Alaska
 Coho (AKS) for 1997-2006.

	<u>Annual Revenue Changes</u> (Total 1992 Dollars)	
	<u>Increase</u> <u>Production</u>	<u>Decrease</u> <u>Production</u>
PWK	115,924	-128,993
CIK	5,122	-5,809
SEK	1,103,841	-998,078
KKK	-120	111
AKOK	-8,451	7,711
AKK	1,216,316	-1,125,059
AKR	-174,507	159,734
AKP	-48,053	45,798
AKC	-21,692	20,894
AKS	-22,321	20,446
TOTAL	<u>949,743</u>	<u>-878,187</u>

Tables 1 and 3 provide the simulation results for those case scenarios where future hatchery pink salmon production are varied. Complete elimination of the pink hatchery program results in Alaska statewide average annual exvessel revenues decreasing by \$6.01 million (see Table 1). However, a 15 percent reduction in pink salmon hatchery production increases statewide average annual exvessel revenues by \$2.93 million, whereas increasing pink hatchery production by 15 percent results in statewide average annual exvessel revenues declining by \$2.58 million (Table 3).

The results indicate that given current market conditions and market structure, pink salmon are over produced. Reductions in pink salmon hatchery production provides economic gains to the state fisheries. However, these revenue gains occur only over some defined range of reductions in pink salmon hatchery production. A reduction in pink salmon hatchery production beyond this range will reduce statewide salmon exvessel revenues. This is demonstrated by statewide exvessel revenues decreasing when the pink salmon enhancement program is eliminated.

The revenue impacts of changes in the pink salmon state and PNP hatchery production are not equally distributed across Alaska regional pink fisheries. The two fisheries which have harvests significantly impacted by pink salmon hatchery production, Prince William Sound and Cook Inlet, experience increases in exvessel revenues when pink hatchery production is increased, and decreases in exvessel revenues when pink hatchery production is reduced. Exvessel revenues in the other pink fisheries, in which only a minor portion of harvest is comprised of pink salmon from the hatcheries, exhibit an inverse relationship with pink hatchery production--exvessel revenues increase when pink hatchery production is reduced, and decrease when pink salmon hatchery production is increased.

The impacts of changes in sockeye hatchery production to exvessel revenues are provided in Tables 2 and 4. Table 2 provides revenue impacts of eliminating the sockeye enhancement program, whereas Table 4 provides the impacts to fishery revenues of increasing/decreasing salmon sockeye hatchery production by 15 percent. **In all cases, statewide exvessel revenues decrease when sockeye hatchery production is reduced, and increase when sockeye hatchery production is increased.** Elimination of the sockeye enhancement program results in statewide average annual exvessel revenues decreasing by \$9.37 million; and reducing sockeye hatchery production by 15 percent results in statewide average annual exvessel revenues decreasing by \$1.29 million. A 15 percent increase in sockeye hatchery production increases statewide average annual exvessel revenues by \$1.29 million.

The principal beneficiary of an increase in sockeye hatchery production is the Prince William Sound fishery. The fifteen percent increase in hatchery production leads to a \$1.77 million increase in this fishery's average annual exvessel revenues. The largest losses from the 15 percent increase in sockeye hatchery production are incurred by the aggregate Alaska-Other-Regions sockeye fisheries (AKOR). These losses accrue primarily to the Bristol Bay fishery, which is the dominant fishery within this aggregate group.

Table 5 provides the predicted revenue impacts of increasing/decreasing chum hatchery production by 15 percent. Alaska statewide average annual exvessel revenues are projected to vary directly with changes in chum hatchery production. **Increasing chum hatchery production by 15 percent increases statewide exvessel revenues by \$2.52 million. Reducing chum hatchery production by 15 percent decreases statewide exvessel revenues by \$2.81 million.**

Average annual exvessel revenues in three of the modelled chum fisheries, Prince William Sound, Southeast, and Kodiak, vary directly with changes in chum hatchery production. Exvessel revenues in the Southeast fishery show the greatest variation, increasing \$2.94 million when chum hatchery production is increased by 15 percent, and decreasing by \$3.15 million when chum hatchery production is decreased by 15 percent. Average exvessel revenues in the other two chum fisheries, Cook Inlet and Alaska-Other-Regions, have an indirect relationship with changes in chum hatchery production.

The changes in average annual exvessel revenues associated with a 15 percent increase/decrease in coho hatchery production are provided in Table 6. Increasing hatchery production by 15 percent boosts statewide average annual exvessel revenues by \$869,662. The 15 percent reduction in hatchery production leads to statewide average annual exvessel revenues declining by \$876,352.

Exvessel revenues in only two of the coho fisheries, Southeast and Prince William Sound, are significantly impacted by the variations in coho hatchery production. The 15 percent increase in coho hatchery production increases average annual exvessel revenues in the Southeast and Prince William Sound coho fisheries by \$864,086 and \$282,746, respectively. Decreasing coho hatchery production by 15 percent reduces average annual exvessel revenues in the Southeast and Prince William Sound coho fisheries by \$867,192 and \$283,697, respectively.

The final case scenario involves increasing/decreasing chinook hatchery production by 15 percent. The exvessel revenue impacts of the variations in hatchery production are provided in Table 7. Statewide exvessel revenues vary directly with the changes in chinook hatchery production. **A 15 percent increase in chinook hatchery production results in statewide average annual exvessel revenues increasing by \$949,743. A 15**

percent reduction in chinook hatchery production leads to a \$867,352 decrease in statewide average annual exvessel revenues.

The primary beneficiary of an increase in chinook hatchery production is the Southeast chinook fishery. A \$1.10 million increase in this fishery's average annual exvessel revenues accompany the 15 percent increase in chinook hatchery production.

Conversely, this fishery's exvessel revenues decline by \$998,078 when chinook hatchery production is reduced by 15 percent.

Conclusion

The salmon marketing model was constructed to predict a 15-year exvessel price stream under various enhancement scenarios. The accuracy of the long term price predictions will depend on several factors including: (1) the specified future values of salmon price determinants; (2) the accuracy of the underlying salmon exvessel price models; and (3) the extent to which the current structure of the international salmon market continues into the future. The model was specifically designed to capture long-run price trends. Thus, even though actual outcomes may vary from those predicted through the model, the model results may still be valid in terms of projecting the direction of future price movements.

The results of the model simulations indicate that Alaska average annual exvessel revenues will increase over the 1997-2006 time period when sockeye, coho, chinook, and chum enhancement hatchery production are increased. However, these increases are moderate, and the actual profitability of increasing hatchery production of these species can only be determined when the revenue increase are compared to the costs of the enhancement program. Costs considerations and

determination of producer surpluses from the enhancement program are provided in a separate report.

The future simulation results for variation in the pink salmon enhancement program indicate that there is currently an over production of pink salmon. Reducing pink salmon production by 15 percent results in average annual exvessel revenue gains in both the statewide pink fisheries and the overall statewide salmon fisheries. However, there are distributional impacts which must be considered in conjunction with this result. The Prince William Sound pink fishery suffers a significant reduction in exvessel revenue when pink hatchery production is reduced by 15 percent.

The model results do not suggest that the pink salmon enhancement program should be eliminated. The large declines in pink salmon harvest that accompany this action depress statewide average annual exvessel revenues. This indicates that there is some exvessel revenue maximizing level of pink salmon enhancement which lies somewhere between the 15 percent reduction in pink hatchery production and the complete elimination of the enhancement program. Costs must be considered prior to determination of the profitability of the various future pink salmon enhancement programs.

Four points, which are not discussed elsewhere in this report, should be noted in evaluating the economic viability of various enhancement programs. Returns to only the commercial fleet are considered in the economic analysis. Increased enhancement production of some salmon species, e.g. chinook and coho, will increase sport-fishing harvests. Thus, the reported revenue increases provided in this report (which are confined to exvessel revenue) will understate actual benefits associated with increased salmon hatchery production. It may be useful in the future

to consider incorporating economic impacts of the sport segment of the fishery industry into the economic analysis of the salmon enhancement program.

Second, variation in salmon hatchery production may affect prices and/or recruitment/survivability of other fish species. Considerations of salmon enhancement impacts to other fisheries is beyond the scope of this analysis.

Third, it is clear from the model results that, across salmon species, increases in production/harvests will have only moderate impacts on salmon fisheries exvessel revenues, at best. **Current high levels of world salmon supplies severely hamper the ability of increased production to bolster economic returns to the salmon fisheries. It may be prudent to increase efforts aimed at expanding world demand for Pacific wild salmon. This would increase prices at all harvest levels, and increase the ability of the world salmon market to absorb additional salmon production.**

Represented in Figure 5 are demand curves (in the upper graph) and associated total revenues curves (in the lower graph). In order to illustrate the previous discussion, assume that the current demand for pink salmon is represented by the demand curve D_0 and supply is represented by S_0 . Given these demand and supply curves the current quantity is Q_0 and the current price is P_0 . The total revenue curve to the fishery is represented by TR_0 . Current production levels occur where the total revenue curve is downward sloping. This implies that the revenue associated with the last unit of fish harvested was negative. Therefore, decreasing harvest will increase total revenue. However, there is a range, beyond which this will no longer be true. If harvest is cut beyond Q_1 total revenue will decline.

If demand can be expanded to D_1 , the total revenue curve will be shifted up to TR_1 , as more salmon are demanded at each price level. In addition to increasing profits to the

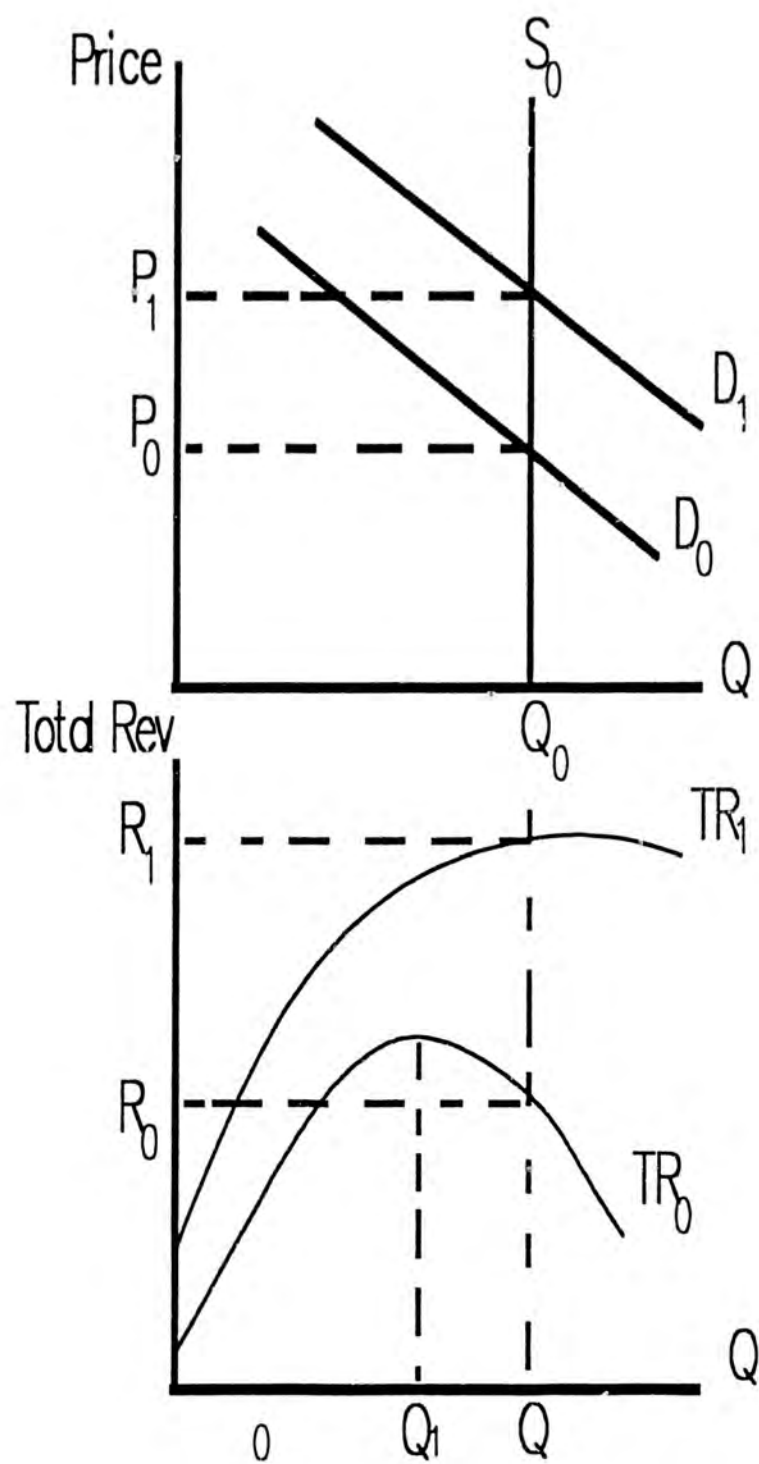


Figure 5. Supply, Demand, and Revenue Illustration

industry, the expanded demand may also lead to a situation where further increase in pink salmon production lead to increases in fishery revenues. Therefore, it may be advisable to increase efforts aimed at increasing demand for salmon, particularly pink salmon, through increased marketing and promotion, product development, market expansion, and the development of new markets. This investment may provide greater returns to the salmon industry than investment in increasing salmon hatchery production.

Finally, an increase or decrease in the production of any salmon species may trigger a counter move by competitors in the world salmon industry which may offset any potential gain from the production change. For example, a decrease in pink salmon harvest could provide incentive for the Japanese to invest in the potentially large Russian pink salmon industry. Thus, possible reactions of other participants in the world salmon industry must be considered when evaluating salmon enhancement policy.

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Salmon Population and Exploitation Modeling

by

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For the
Alaska State Legislature
Senate Special Committee on Domestic and
International Commercial Fisheries

As part of the
Legislative Review of the Alaska Salmon Enhancement Program
Benefit-Cost Analysis

December 1992

Introduction

The objective of the salmon population and exploitation modeling was to project Alaska salmon production levels by region to the year 2021. For each region, projections were made of expected wild and enhanced production based on current facility capacity. Estimates of commercial salmon harvests are based on present fisheries management practices.

Background

In the early 1970s, the state of Alaska began a salmon enhancement and rehabilitation program through the Alaska Department of Fish and Game (ADF&G), Division of Fisheries Rehabilitation, Enhancement, and Development (FRED). Salmon production through enhancement efforts was to compensate for extremely low wild salmon returns in the 1970s.

The hatchery (or ocean ranching) component is the largest part of the enhancement program. There are two categories of hatcheries: 1) state hatcheries, which are state funded and operated by FRED, and 2) private non-profit (PNP) hatcheries. Private non-profit hatcheries include regional aquaculture association facilities, which can collect salmon enhancement tax receipts from fishermen in the region, and "mom and pop" operations working independently from the regional associations. The independent operations cannot collect enhancement taxes. All PNPs can sell cost-recovery harvest fish to pay for operating costs. They may apply for state enhancement loans through the Alaska Department of Commerce and Economic Development, Division of Investments.

During the past 20 years, the state of Alaska has invested extensively in hatcheries, providing capital construction costs and operating costs to state facilities and loans to PNPs. In addition, FRED provides administrative, technical, research, and planning support to PNP facilities. However, due to declining state revenues, the state has encouraged privatization of state-owned and operated facilities, primarily through contracts in which regional aquaculture associations operate state-owned facilities. Support to PNPs through FRED and salmon enhancement loans also has declined.

In general, the enhancement program has been very successful in producing salmon. Recent annual harvests from the hatchery program range from 15-23 million fish. It is now recognized that the early 1970s were years of low productivity for salmon and other fishes in the North Pacific Ocean. Productivity has increased since then, resulting in record salmon harvests in the 1980s. It is presently uncertain whether ocean productivity will remain high or cycle back to the lower level prevalent in the 1970s.

Enhancement Program Review

In May 1991 the Senate Special Committee on Domestic and International Commercial Fisheries initiated an extensive review of the Alaska salmon hatchery and enhancement program. The purpose of the overall study is to:

- 1) Review the history and legislative intent of the program.
- 2) Analyze the current status of the program.
- 3) Consider future options for the program ranging from fine tuning to possible redirection.

Part of the program review is an economic analysis. An economics study group was formed to address questions raised by the Committee, including:

- if the present levels of Alaska salmon harvest are over- or under-supplied from a world market perspective, and
- if increased enhanced salmon production will raise or lower prices, fishing revenues, and the total net benefits of Alaska's salmon fisheries.

A benefit-cost analysis is required to answer these two questions. My salmon population and exploitation modeling project is one part of this benefit-cost analysis. The results of the benefit-cost analysis are reported in Boyce et al. 1992.

Fisheries Modeled

To bound the modeling project, a subset of regions and species was selected by legislative and FRED representatives and the author to be intensively modeled:

Kodiak pink salmon
 Kodiak sockeye
 Cook Inlet sockeye
 Prince William Sound pink salmon
 Southeast Alaska chinook salmon

This set includes most of the enhanced salmon production harvested by commercial fleets (Figure 1). The models aggregate production over the region of interest. We agreed that the remainder of the commercial salmon population and exploitation estimates (the non-intensively modeled set) would be based on projections of state and PNP hatchery managers and ADF&G, Division of Commercial Fisheries historical records of wild-stock harvests. Only the intensively modeled fisheries are discussed in this report.

Modeling Methodology

The modeling effort followed the standard approach to estimating the catch of enhanced fish:

$$\text{Hatchery Catch} = \text{Fry released} * \text{Survival} * \text{Exploitation Rate}$$

Refinements were made to the model by estimating survival rates and variance from past releases, and by considering constraints on the exploitation rate imposed by mixed fisheries.

The flow chart (Figure 2) illustrates the steps involved in the simulation model. The first step was to estimate the model parameters from historical data. If there were insufficient data to quantify a relationship, the effect could not be included in the model. Thus, genetic effects were not included, even though they may potentially

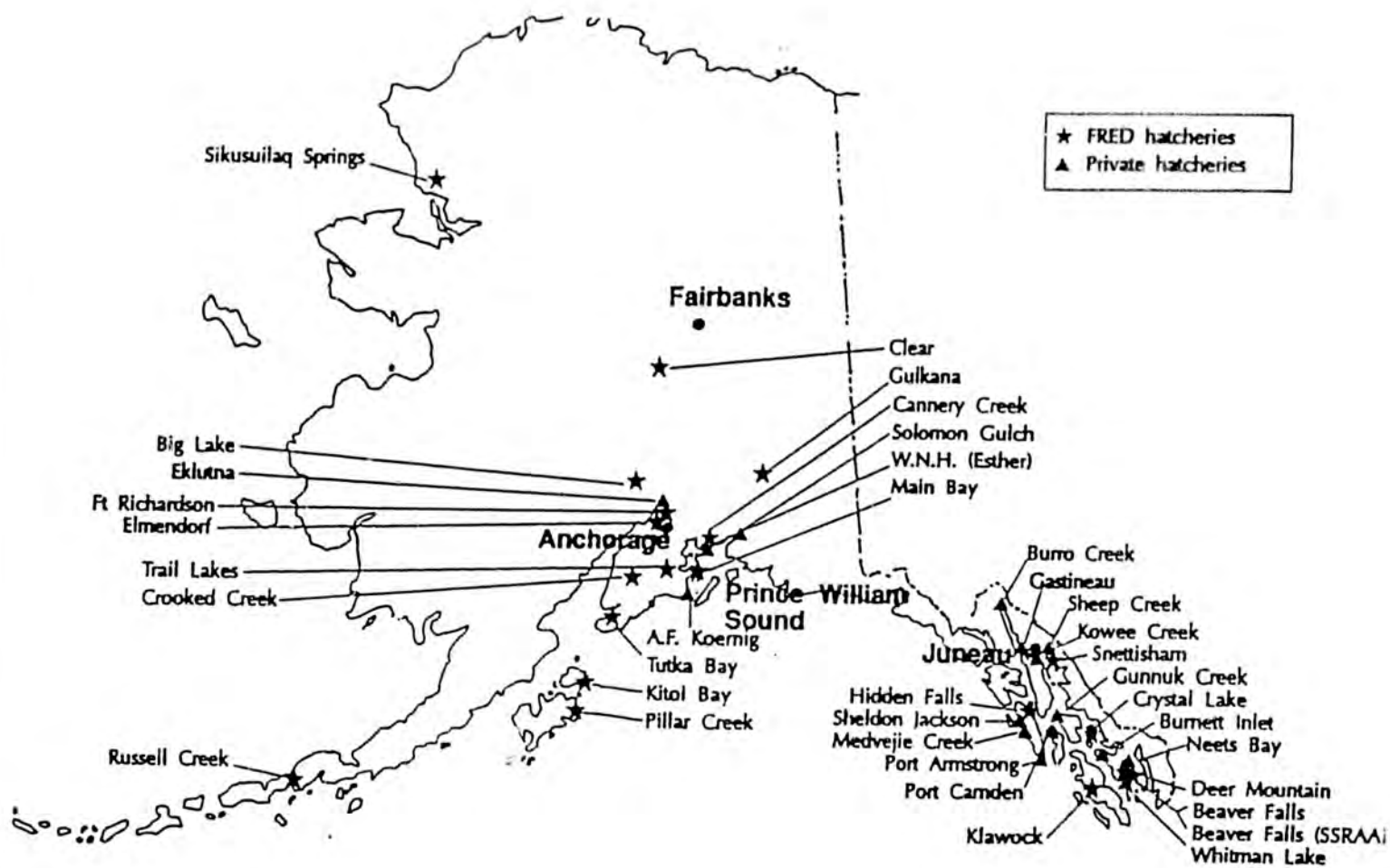


Figure 1. Locations of hatcheries in Alaska.

Salmon Simulation Model

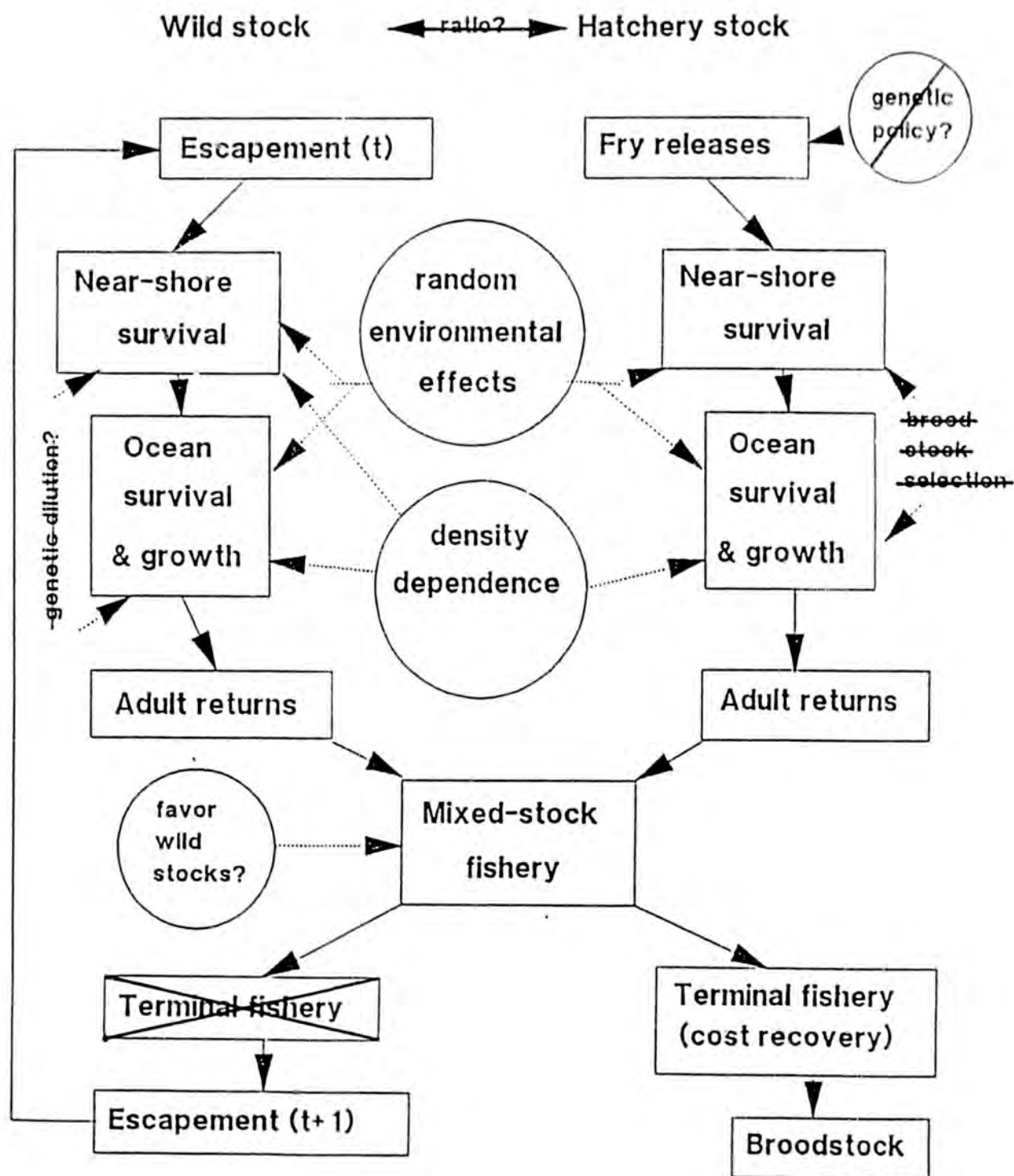


Figure 2. Flow chart of salmon simulation model. Components deleted with an "X" were considered in model development but not included in the final models.

affect salmon production. Initial attempts to intensively model the Prince William Sound chum salmon fishery and the Southeast Alaska coho salmon fishery were discontinued because of inadequate data.

Release data for enhanced stocks were obtained by surveying hatchery managers. This survey was conducted jointly by legislative and FRED effort. Survey results were provided to the author. Most of the survey results indicated that fry and smolt releases will change very little after the initial survey years. Although the hatchery managers' planning horizon is relatively short, investment decisions must be made with a longer planning horizon. In most cases, planned releases are the same as current releases. The exception was Cook Inlet sockeye salmon; hatchery operators there are planning significant production expansion.

Wild-stock recruitment and escapement data, future escapement targets, and mixed-fisheries management constraints were provided by ADF&G, Division of Commercial Fisheries.

Monte Carlo Simulations

The purpose of the simulations is not to *predict* catch in each year, but to *project* the most likely level of production and upper and lower confidence levels. In these Monte Carlo simulations, random variability was introduced into the survival rates to indicate the level of natural variability to expect around the median estimates. Mean survival rates and their variances were calculated from spawner-recruit data for wild stocks, and from historical release data for hatchery stocks. The inputs for the Monte Carlo simulations included enhanced fry and smolt releases, wild-stock escapements during the initialization years, and the escapement target for future years. Wild-stock preference was built into the exploitation sub-model such that the harvest rate of hatchery fish in the mixed-stock fishery was conditional on the escapement target for the wild stock. Excess hatchery fish were assumed to be harvested in the terminal areas. Broodstock requirements were backcalculated from projected fry and smolt releases, assuming a 50:50 sex ratio, average fecundities from literature, 10% more fish collected than required, and egg-to-release survivals as listed in the surveys. Initial simulation runs indicated that the return of hatchery fish would very seldom be less than brood stock requirements. Therefore it was assumed that the fry and smolt releases listed on the surveys would actually occur and not be constrained by adult return rates.

The simulation outputs were adult returns, divided into the various harvest and escapement boxes (Figure 2). One hundred stochastic replicates of the 30-year simulations were run. The 100 replicates were then sorted by total return for each year to obtain median, 10%, and 90% quantiles. The quantiles of the return distribution provide an empirical confidence interval around the median; 80% of the replicates lie between the 10% and 90% quantiles.

As part of the benefit-cost analysis public policy simulation, hatchery production was hypothetically altered to estimate how net benefits would change under different production scenarios. To develop accurate population and exploitation estimates for these simulations, the population models were run using the production scenarios listed below. Changes in production refer to numbers of returning adult salmon available for harvest by commercial fisheries. The first five changes were specified by the legislature. The sixth was added to compare enhanced production with increased wild salmon production through increased escapement targets. The

results of the latter scenario are referred to as the "management" option in the figures. Only the first five scenarios were included in the complete benefit-cost analysis.

Production Scenarios

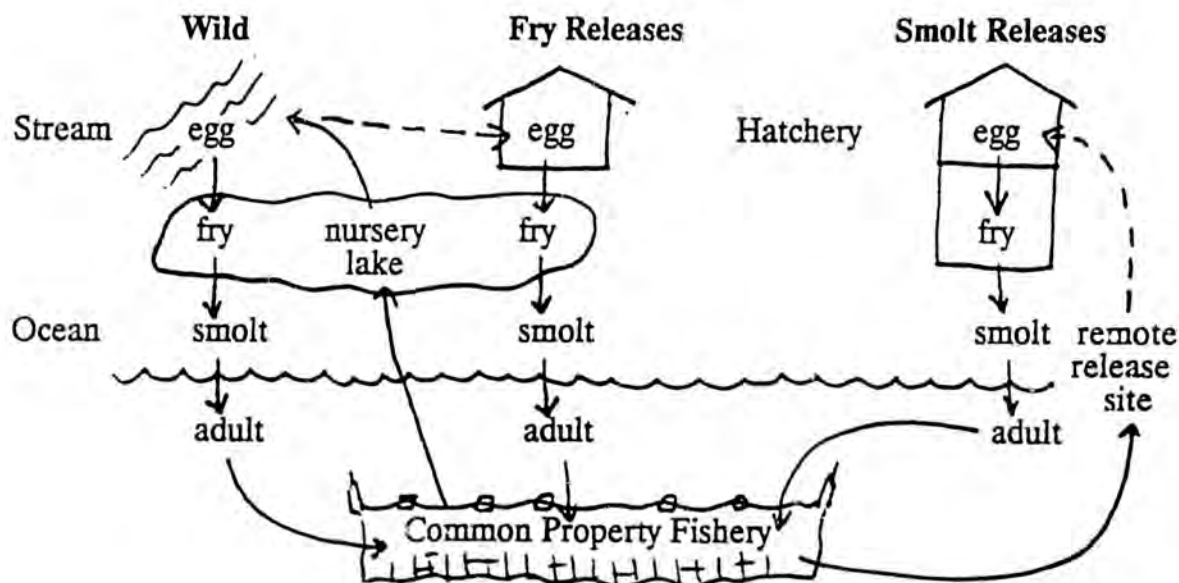
1. Hatchery production continues at current permitted levels (Base Case)
2. Hatchery production continues at planned (unconstrained) levels.
3. Hatchery production is eliminated (no egg take in 1993)
4. Hatchery production is increased 15% over the Base Case
5. Hatchery production is decreased 15% from the Base Case
6. Hatchery production is eliminated and escapement targets are increased.

The next sections provide information on modeling methodology and results for the Cook Inlet sockeye, Prince William Sound pink, and Southeast Alaska chinook salmon fisheries. Results for Kodiak pink and sockeye salmon are not included in this report. Methods for Kodiak were the same as for Cook Inlet sockeye and Prince William Sound pink salmon. In fact, the Kodiak and Prince William Sound pink salmon simulations were combined in a single program.

Cook Inlet Sockeye Salmon

Considerable research has been conducted in Alaska on sockeye salmon dynamics. Cook Inlet is the region of Alaska producing the most enhanced sockeye. The Cook Inlet Regional Salmon Enhancement Plan projected a harvest of 1 million enhanced sockeye by the year 2000. Cook Inlet also supports large natural runs of sockeye. From 1968 through 1985, the median return of wild sockeye was 4 million fish. During a visit to Soldotna in May 1992, the author consulted limnologist Dana Schmidt and other ADG&G staff to obtain information needed for the Cook Inlet and Kodiak regions.

Figure 3. Sockeye salmon life history



Sockeye enhancement, consisting primarily of fry lake releases, fish passes, and lake fertilization has until recently been relatively "benign." This is for the most part because the enhanced stocks are from wild egg takes that are transported to nursery lakes and harvested with wild stocks rather than creating new, separate stocks. These enhancement methods, however, provide no mechanism for generating cost-recovery revenue because the fry releases do not return to a hatchery facility. For this reason, most of the initial sockeye fry enhancement in Cook Inlet was conducted by FRED. In contrast, smolts released directly into salt water return as adults to the release sites, where cost recovery harvests can be conducted. It is likely that remote smolt release will provide for cost-recovery sales harvest but it will also complicate management.

Spawner-Recruit Data

The escapement data include all surveyed streams in Upper Cook Inlet; data values streams not surveyed in a given year were interpolated. The return data include only the dominant age categories. The percentages of these age categories, calculated over all years, were used to project the age compositions in the simulation model.

Age	1.2	1.3	2.2	2.3
%	18.3	62.6	7.9	11.2

Escapement targets and returns have both increased since 1971 (Figure 4). I used an escapement target of 1.06 million in the simulations, the midrange of escapement goals for Upper Cook Inlet, inflated to include Lower Cook Inlet stocks. The fitted spawner-recruit curve is a straight line with a slope of 4.2 returning adults per spawner. There is relatively little scatter in the data point around the straight line, compared with typical spawner-recruit data. It is uncertain what level of escapement will lead to diminishing returns per spawner. One possible reason for this linear relationship is that the return data contain a small but unknown number of hatchery released sockeye salmon, which cannot presently be distinguished from the wild sockeye. Based on the estimated survival of past releases, the hatchery contribution to these return data is at most 1 million and probably much less in most years. The 1992 return of approximately 10 million adult salmon, primarily from the 1987 escapement of 2.3 million, will indicate the degree of density-dependent survival for Cook Inlet sockeye. In addition, the 1989 escapement, also 2.3 million, will test whether such high returns are sustainable.

Sockeye life-stage survivals are summarized in Figure 5 from Koenings and Kyle (1991). Lake Tustumena, in particular, has been the site of fry tagging and smolt enumeration (Kyle 1992).

Residuals from log survival rates were used to estimate the variance of the random deviations in survival (Figure 6). The residuals from the combined Cook Inlet spawner-recruit data (Figure 4) have an increasing trend which reflects the increased productivity since the 1970s. The data for fry and smolt releases are all from Lake Tustumena (Kyle 1992). Deviations in survival for the different life stages are not in phase, nor does the variance in survival decrease for partial life stages, compared with the entire life span. This lack of coherence could indicate compensatory survival during the smolt-adult stage, or imprecision in measuring smolt abundance.

Upper Cook Inlet Sockeye Salmon (data labels are brood years)

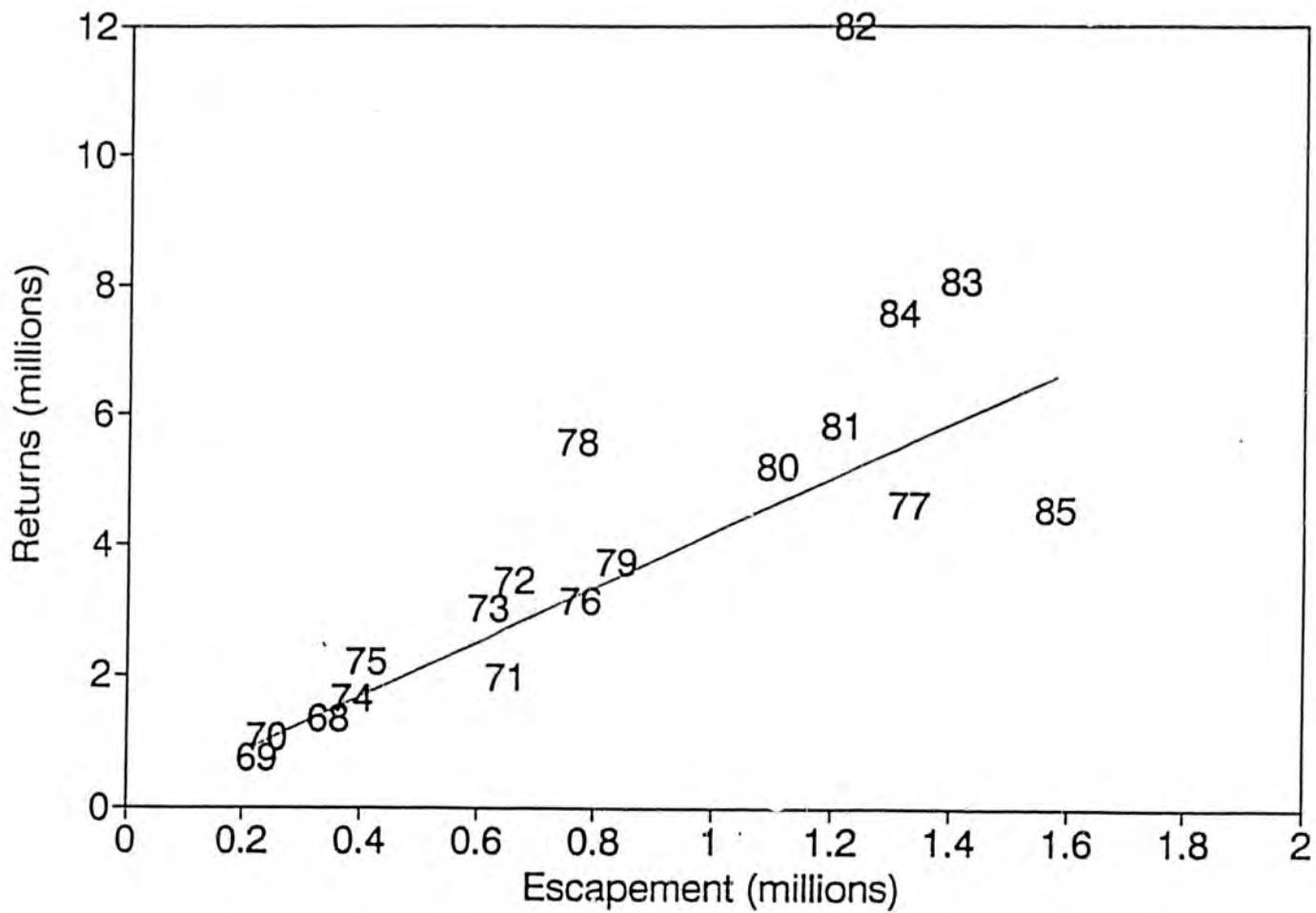


Figure 4. Upper Cook Inlet sockeye salmon spawner-recruit data.

***Sockeye Salmon Life-Stage Survivals at Rearing
Limitation Based on Euphotic Volume (EV)***

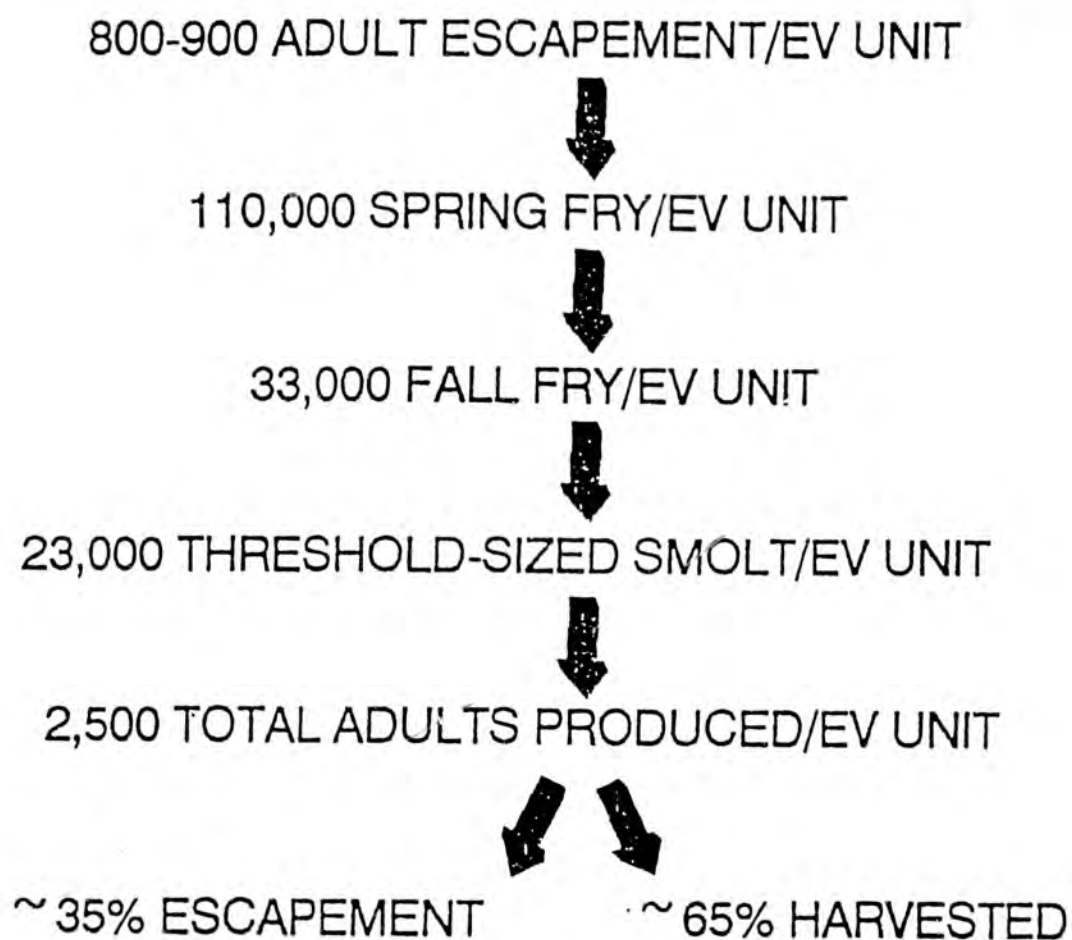


Figure 5. Sockeye salmon survival by life stage (from Koenings and Kyle 1991).

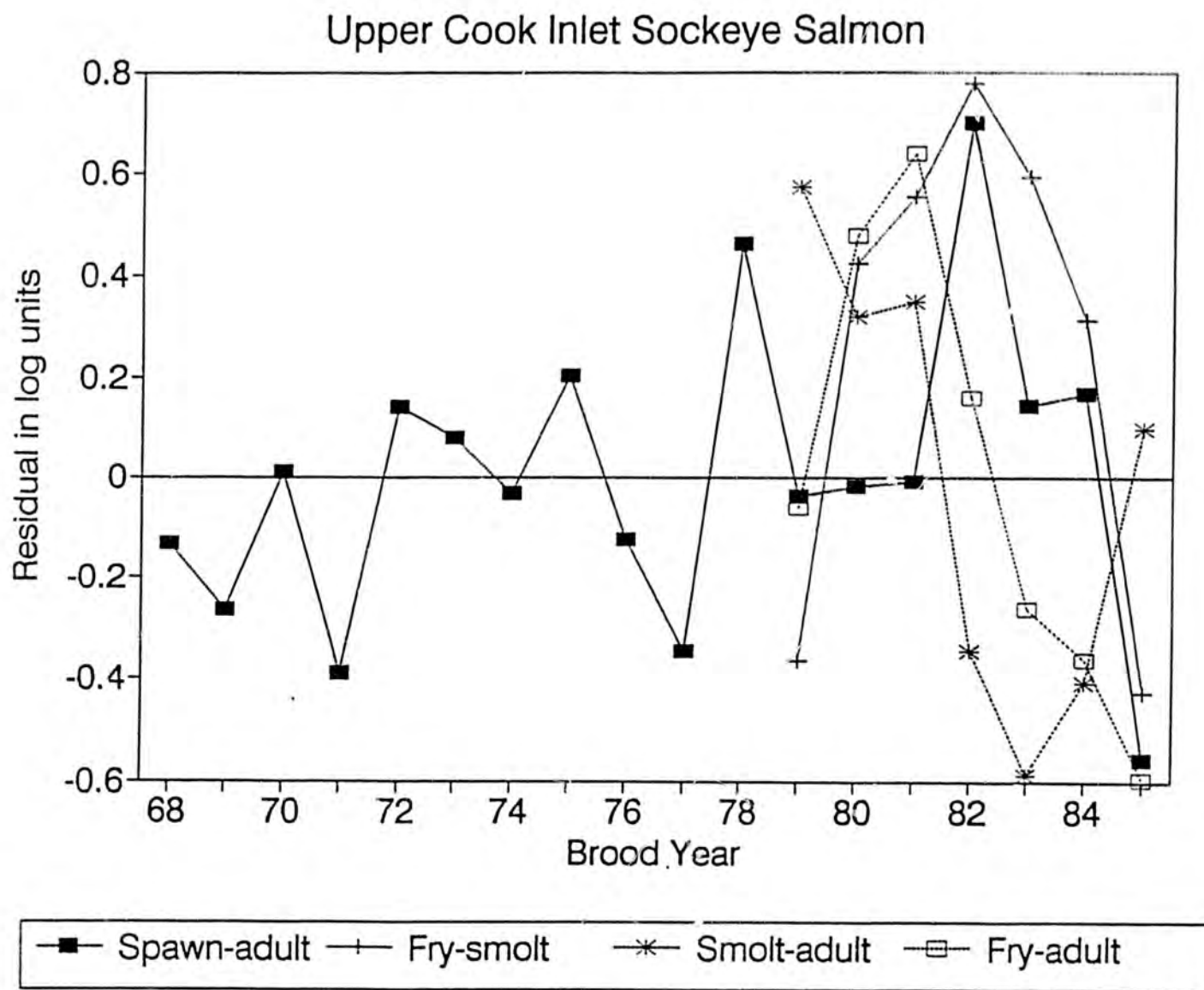


Figure 6. Residual deviations from mean log survival rates.

Cook Inlet Sockeye Releases

Fry are released into about a dozen lakes. Figure 7 shows historic fry releases as well as current, planned, and the 15% increase and decrease production scenarios. Changes in production are assumed to begin with the 1993 egg take and thus the 1994 releases. Planned releases would be almost double the currently permitted levels. In the simulations, I used a fry-adult survival rate of 2.2%.

Smolt releases are the latest trend in sockeye salmon enhancement (Figure 8). Smolts are being released both at age-0 and age-1. Four facilities plan to release a total of over 5 million sockeye smolts. The smolt-adult survival rate used in the simulations was 15.1%.

Results

Figure 9 shows commercial catch from current releases and wild stocks with 10%, median, 90% levels, and the actual 1992 catch. The range between the 10 and 90 percent levels is approximately 1-2 million fish from the median estimate. Projected catches are initially high because of high escapements in the late 1980s. Escapement was 2.3 million in 1987 and again in 1989. In the model, escapement is maintained at the target of 1.06 million, so there are approximately half as many fish returning. It appears that high catches in the 1990s are realistic--the model predicted exactly the 1992 catch.

Commercial Catch Estimates for Production Scenarios

Planned increases in hatchery fry and smolt releases add about 1 million returning adult salmon to be harvested by the common property commercial fishery by the year 2000 (Figure 10). Eliminating hatchery production reduces catches by approximately 1/2 million annually. Doubling the escapement target to 2 million results in an initial decrease of 1 million salmon annually (a total reduction in harvests of 4 million sockeye over the four year period 1993-1996). This increased escapement would result in an eventual annual payoff of 3.5 million sockeye salmon. The management option exceeds harvest levels of planned sockeye enhancement by approximately 2.5 million annually. The prospect of such high catches may be overoptimistic if possibility of brood-year interactions occur. There is evidence that strong year-classes may decrease the survival of following cohorts by heavy grazing of zooplankton populations in the nursery lakes (Koenings and Kyle 1991). Lake rearing capacity may therefore set upper bounds on escapement targets and fry stocking densities.

Terminal sockeye harvests will increase with increases in smolt production (Figure 11). If hatcheries close, there would be a short burst of terminal catch followed by declines. The number of sockeye harvested in the terminal areas is about two orders of magnitude lower than the number harvested in the common property fishery. It would be very difficult for managers to ensure that this relatively small number of smolt-released sockeye was available for cost-recovery harvest. Thus, sockeye smolt releases will further complicate fisheries management in Cook Inlet, which is already adversarial.

Cook Inlet Sockeye Salmon

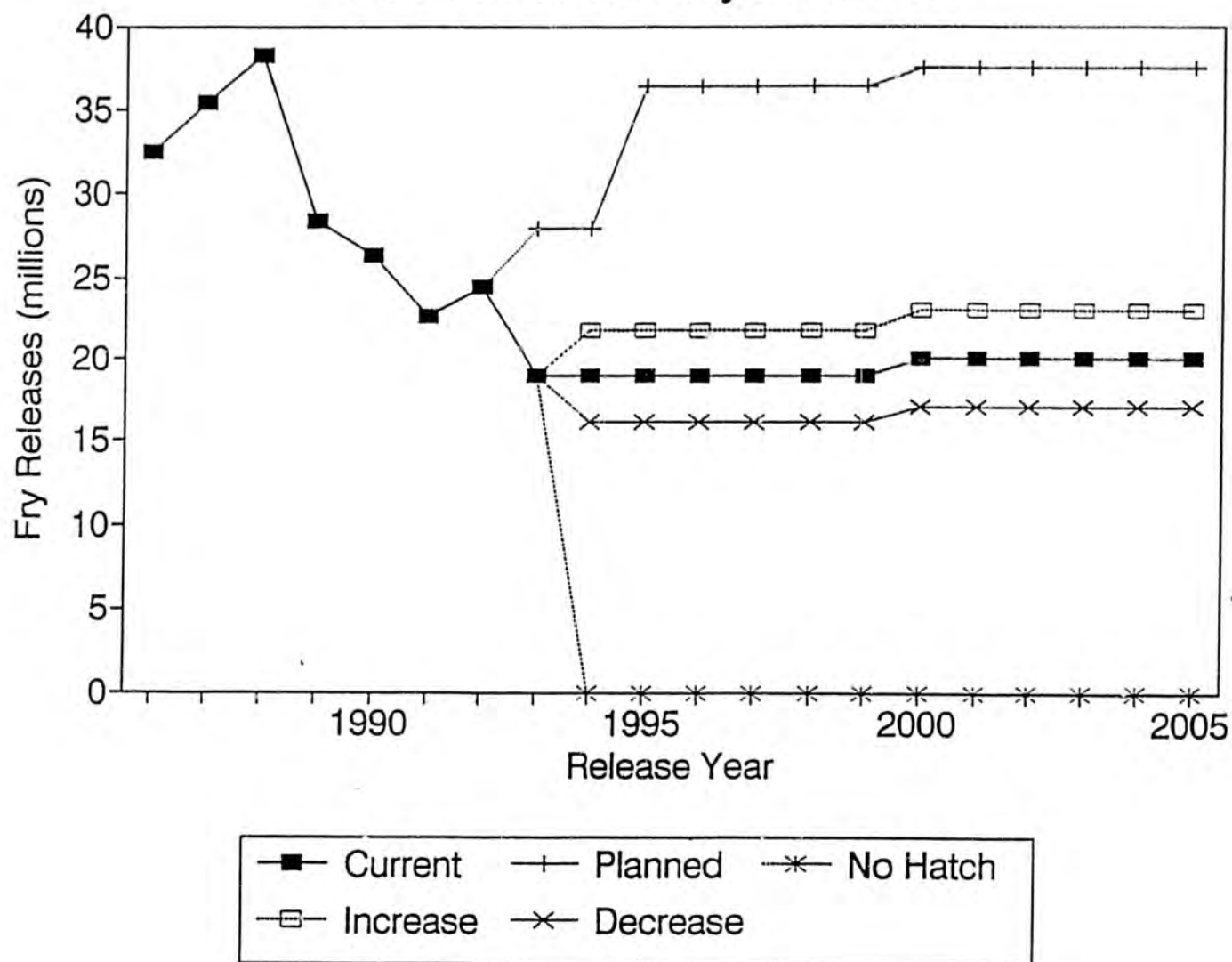


Figure 7. Cook Inlet sockeye salmon fry releases. "Current" releases are actual releases until 1991 and projected releases starting in 1992.

Cook Inlet Sockeye Salmon

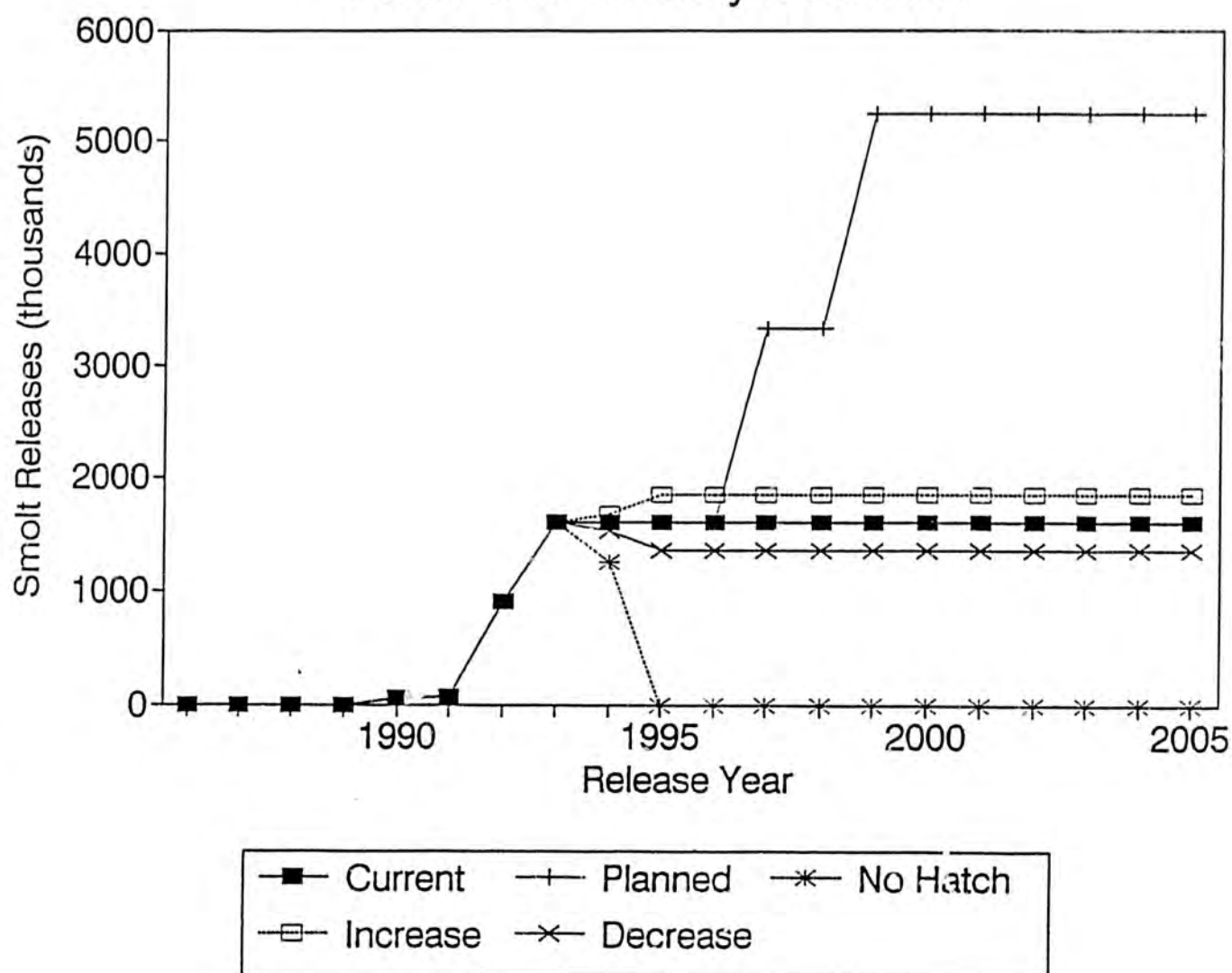


Figure 8. Cook Inlet sockeye salmon smolt releases. "Current" releases are actual releases until 1991 and projected releases starting in 1992.

Figure 9. Projected commercial catches of Cook Inlet sockeye salmon. The solid line is the median or 50% quantile of 100 replicates. The broken lines are the 10% and 90% quantiles of the distributions of catch each year.

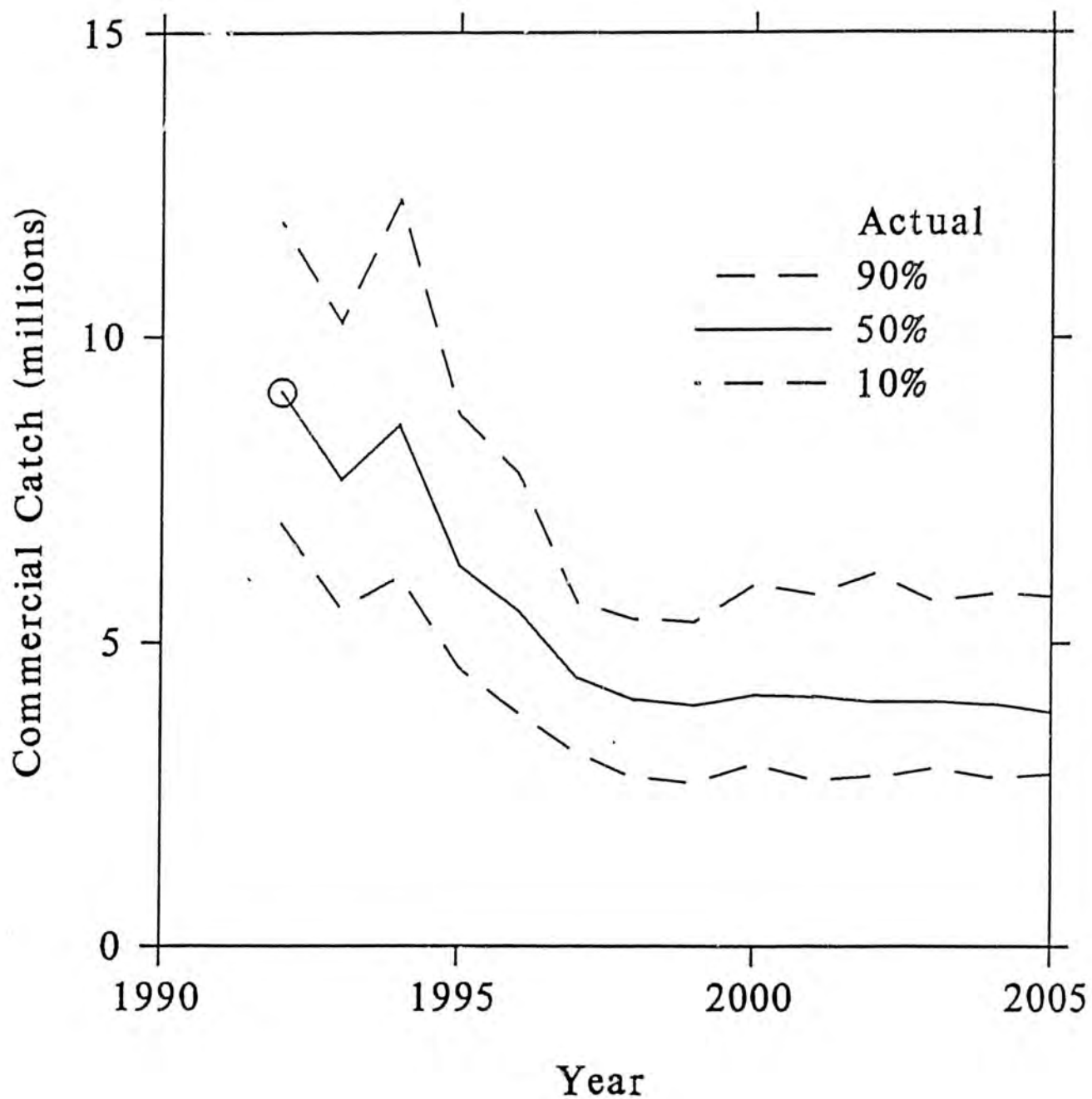


Figure 10. Projected common-property catches of Cook Inlet sockeye salmon for four production scenarios: Current releases, Planned releases, No hatchery releases, and a doubling of the escapement target ("Manage").

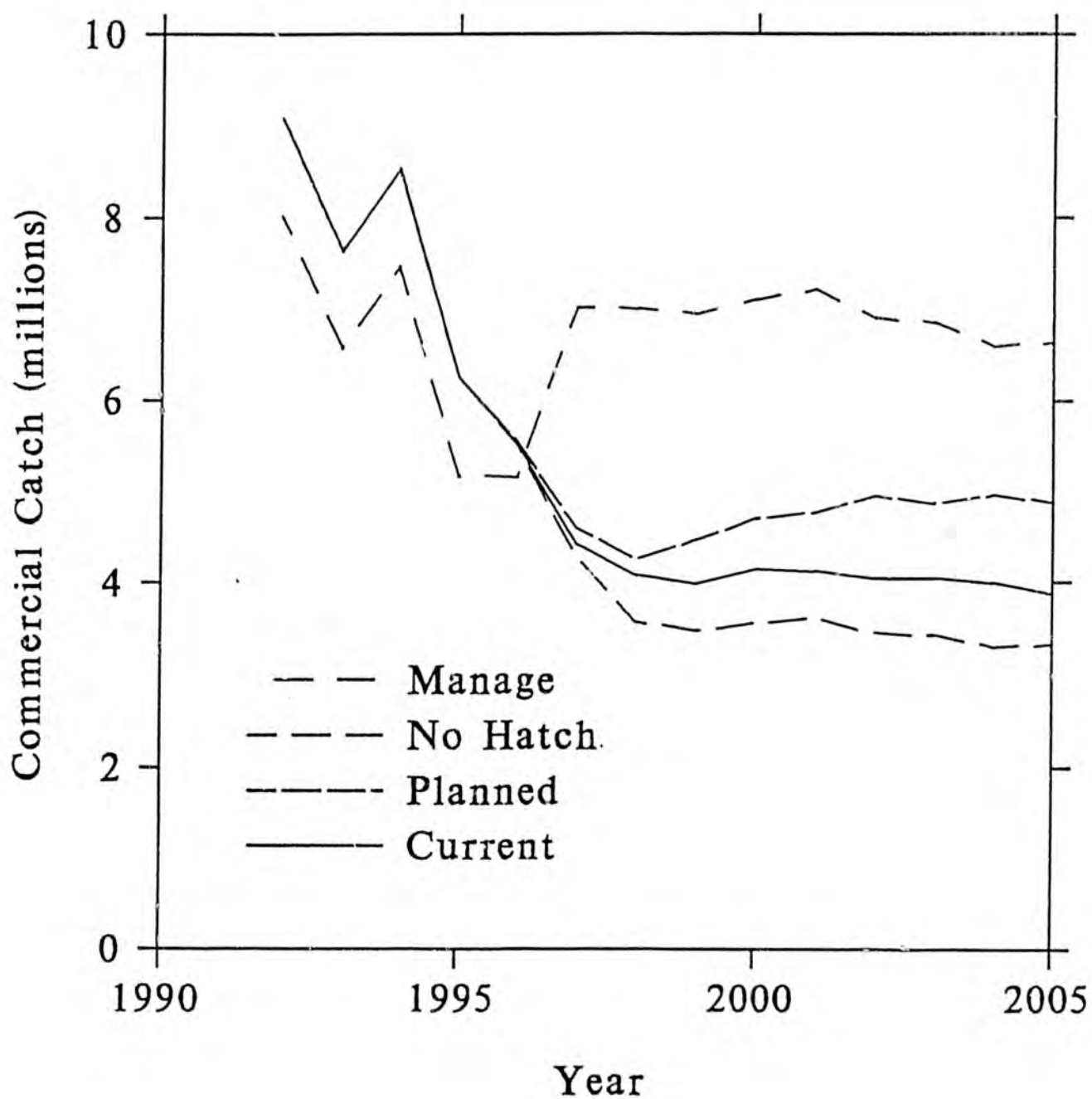
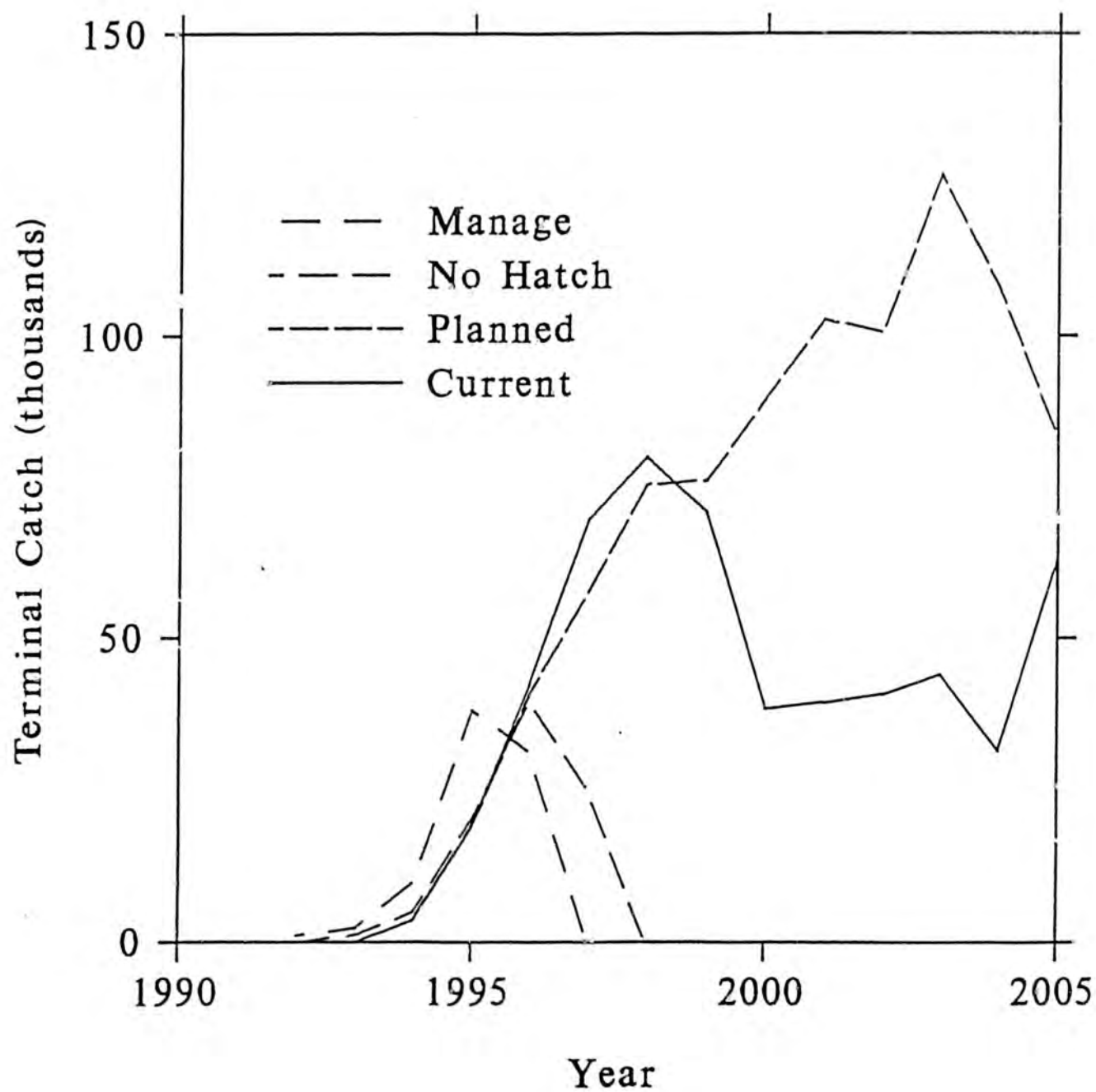


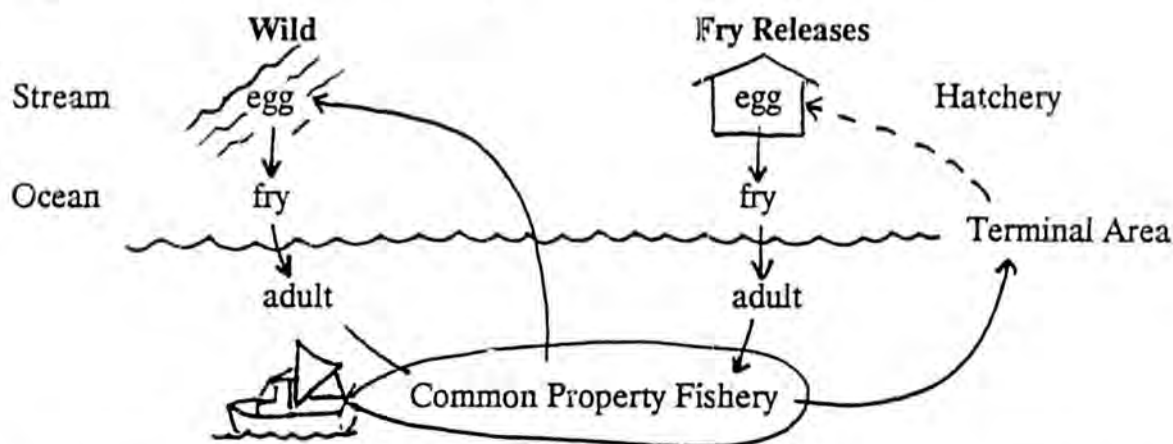
Figure 11. Projected terminal-area catches of Cook Inlet sockeye salmon for four production scenarios: Current releases, Planned releases, No hatchery releases, and a doubling of the escapement target ("Manage").



Prince William Sound Pink Salmon

My pink salmon model is based on a 1991 paper by Eggers et al. entitled, "Trends in abundance of hatchery and wild stocks of pink salmon in Cook Inlet, Prince William Sound, and Kodiak, Alaska." The relationships described in this paper were used to simulate salmon abundance in the future.

Figure 12. Pink salmon life history



For Prince William Sound there exist the perennial problems of trying to optimize the escapement of wild and hatchery fish in the common property fishery. In the model simulations, the harvest rate is conditioned on the strength of the wild stock.

Spawner-Recruit Data

In general, increased escapement has brought greater returns of adult pink salmon with the exception of 1984 (Figure 13). The Ricker curve passes through the center of the data, which fall into two clusters—good years and bad years. The Ricker curve gives fairly conservative predictions of adult returns. The present escapement target is about 1.5 million; the apparent optimum is 5 million.

Hatchery survival rates have averaged 5% (Figure 14). There is not yet evidence of density-dependent survival, but the low return of the 1990 releases is a break from the linear relationship that prevailed up to now.

Deviations in survival rates are correlated between 1) Prince William Sound hatchery and wild pink salmon and 2) Prince William Sound hatchery and Kodiak hatchery survival (Figure 15). The covariance and autocorrelation structure illustrated in Figure 15 was programmed into the model simulations.

Average body weight appears to decrease as a function of the combined run of Kodiak and Prince William Sound pink salmon (Figure 16). However, there is plenty of scatter because the weights were derived from fish ticket data, not measurements of individual fish. This body weight relationship was modeled with a log-log function so that body weight decreases asymptotically with changing run size.

Fry releases were initiated in 1976, and jumped to over 1/2 million in 1988 (Figure 17). Current Prince William Sound fry production capacity is 650 million. Planned capacity is approximately 700 million. It does not appear that releases will reach the 1 billion level.

Prince William Sound Wild Pink Salmon (data labels are brood years)

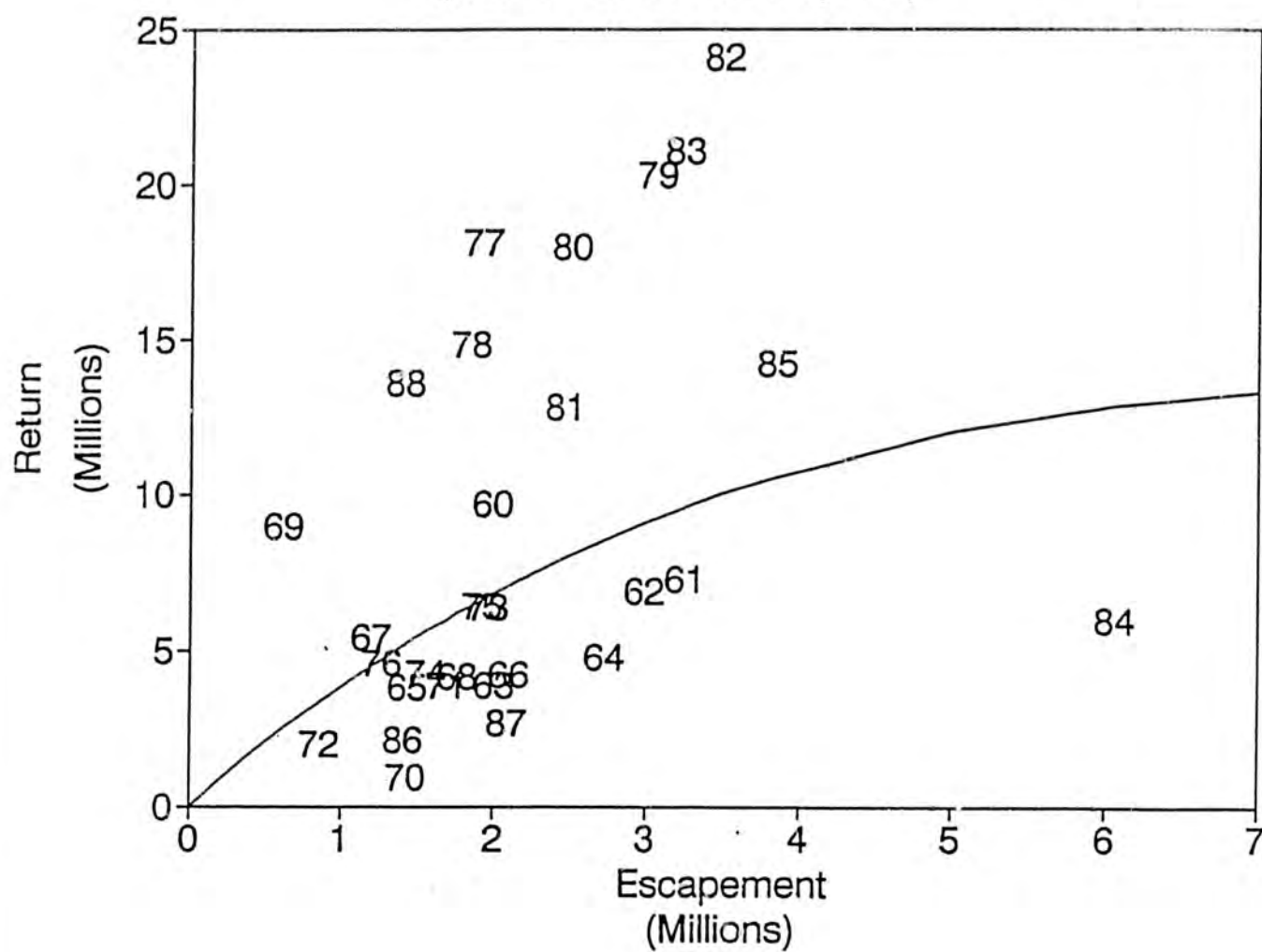


Figure 13. Prince William Sound wild pink salmon spawner-recruit data, and fitted Ricker curve.

PWS Hatchery Pink Salmon (data labels are brood years)

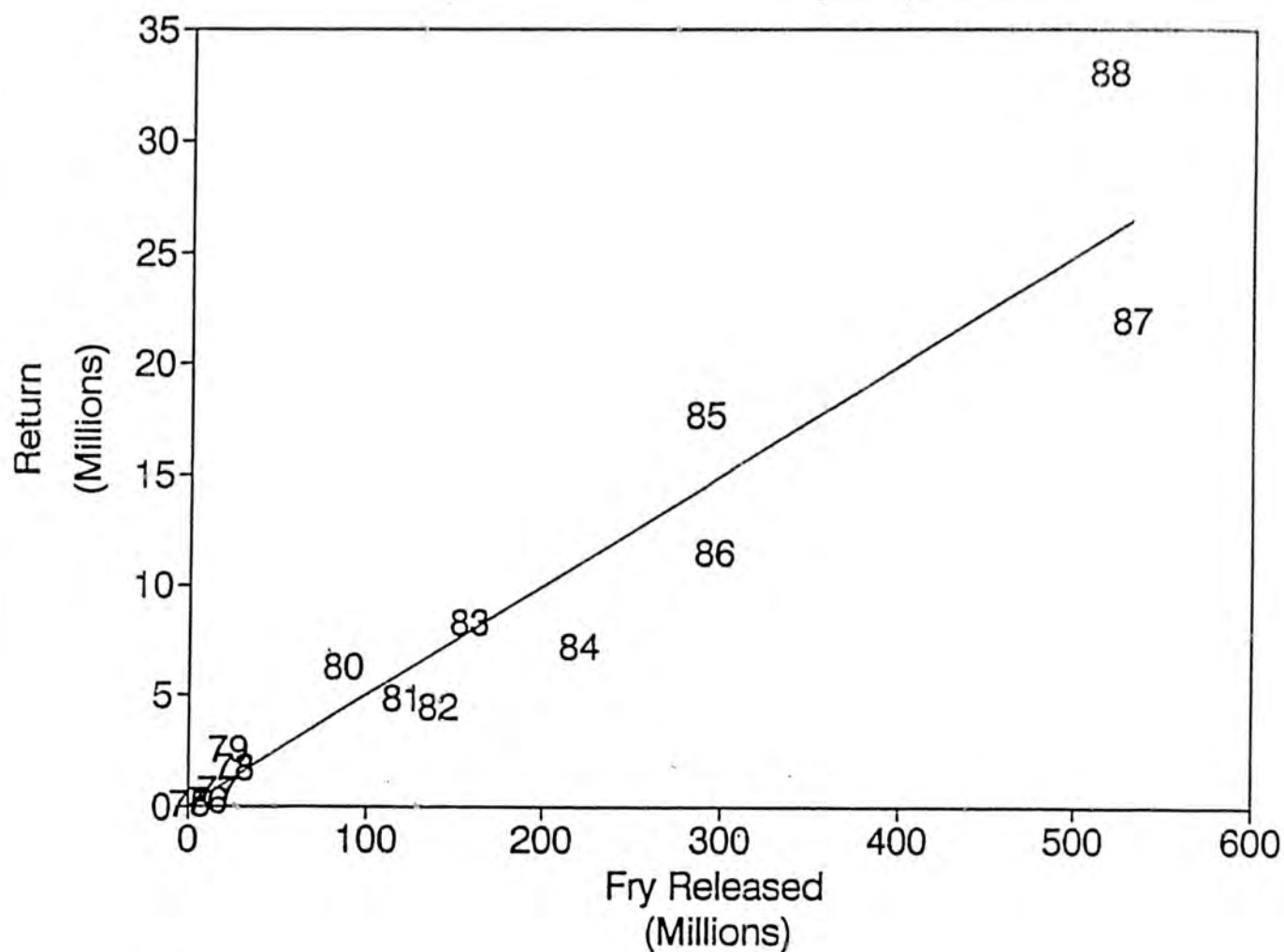


Figure 14. Prince William Sound hatchery pink salmon release-return data, and linear fit.

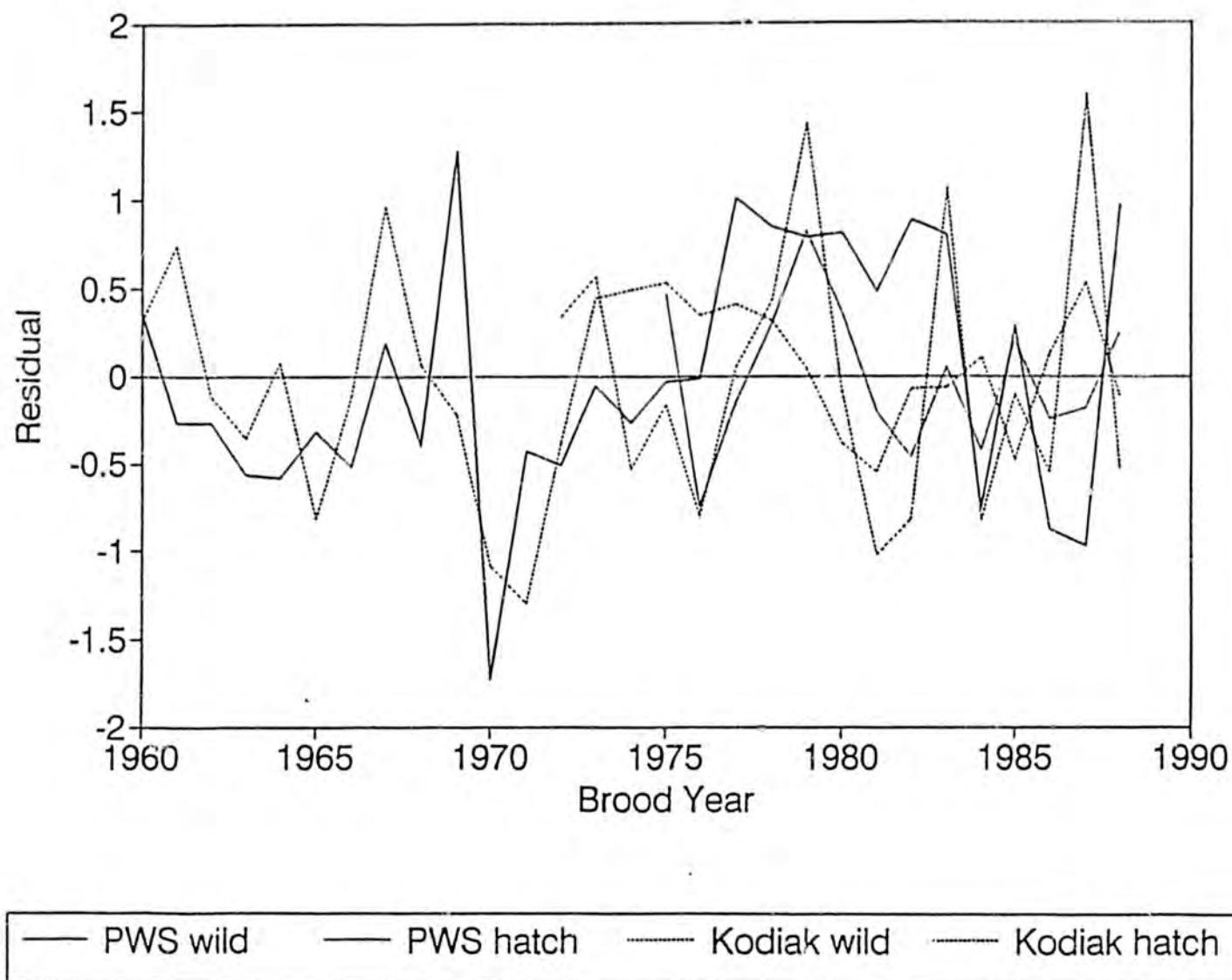


Figure 15. Residual deviations from log survival rates for Kodiak and Prince William Sound pink salmon. The wild salmon residuals are from spawner-recruit data (e.g. Fig. 13); the hatchery data are from release-return data (e.g. Fig. 14)

PWS and Kodiak Pink Salmon

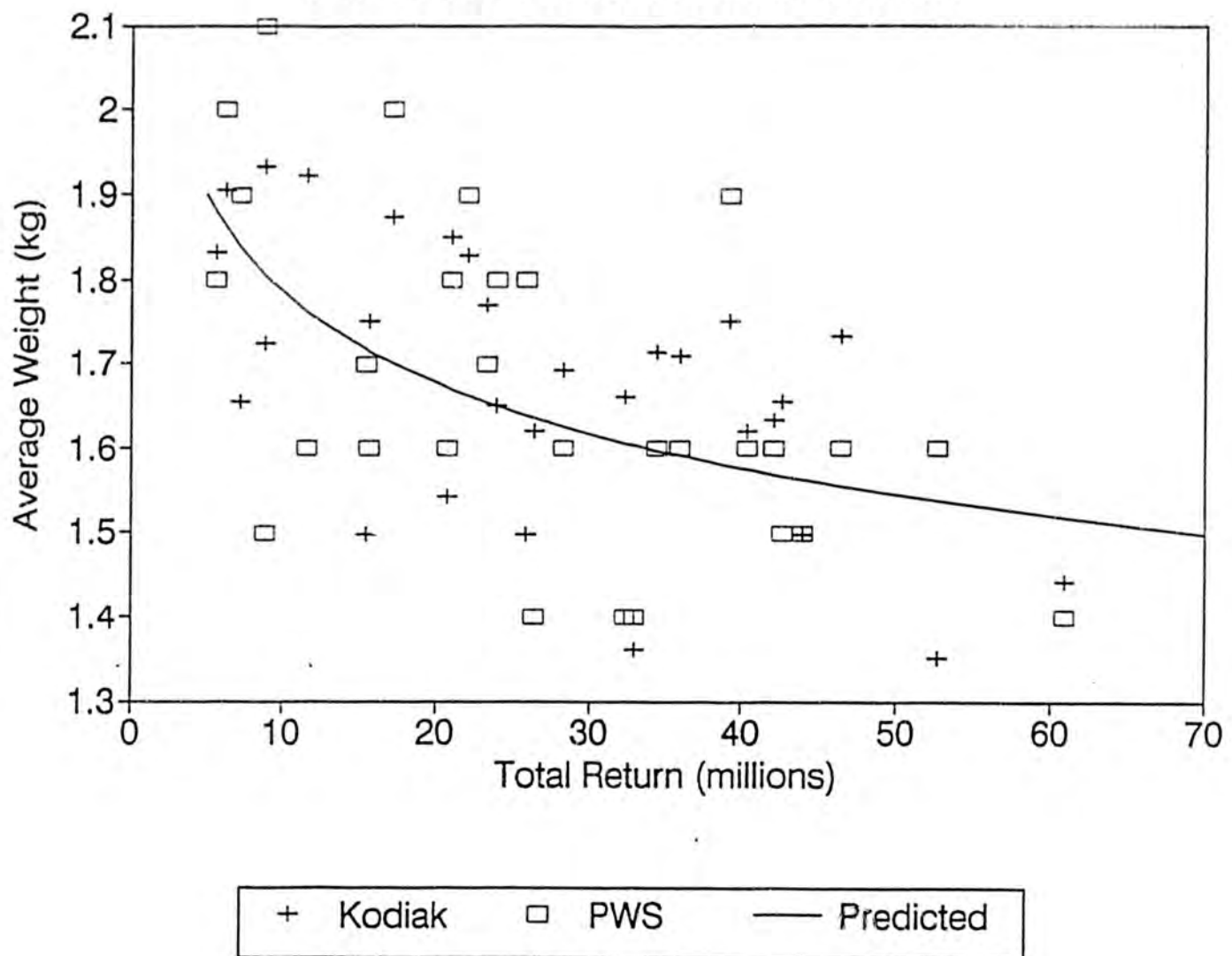


Figure 16. Average weight of Prince William Sound and Kodiak pink salmon, and a fitted log-log relationship.

Prince William Sound Pink Salmon

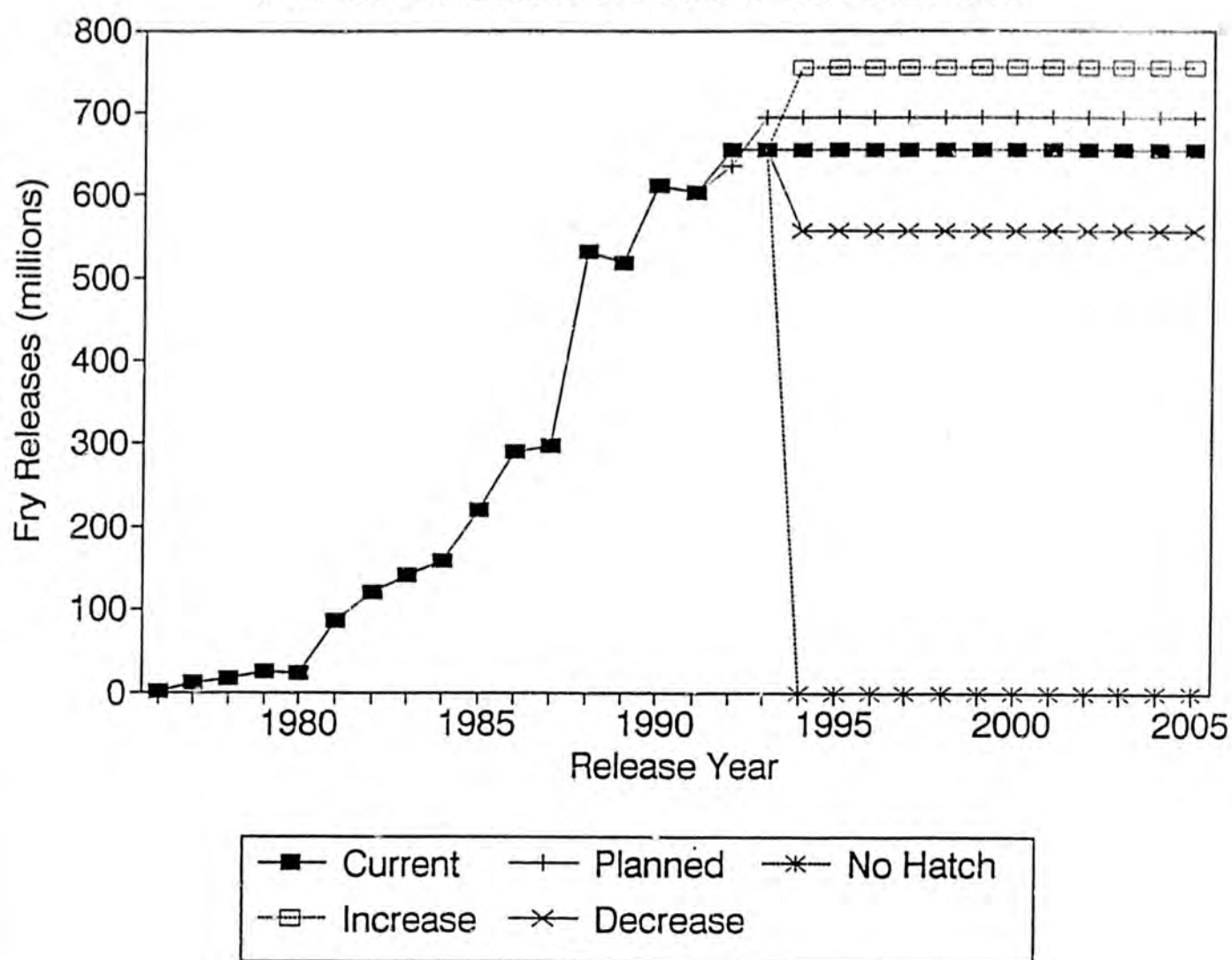


Figure 17. Prince William Sound pink salmon fry releases. "Current" releases are actual releases until 1991 and projected releases starting in 1992.

Results

Total annual adult returns of hatchery and wild salmon are projected at approximately 40 million, which is consistent with the 1990-91 returns (Figure 18). Eighty percent of the model realizations fall between the upper and lower broken lines. Actual 1992 adult returns were only approximately 10 million fish, a value below even the 10% quantile projection. The survival rate experienced by the 1990 year-class appears to be on the very low end of the range of historical survival rates.

Common property catch is highly variable because, if the wild stock return is weak, the fishery is closed, resulting in a lower harvest of hatchery stocks (Figure 19). This pattern is apparent for the Current and Increase cases. In these cases, the extra fish are harvested in the hatchery terminal areas where the enhanced stocks are no longer mixed with wild stocks. In the case of decreased production, median catches are more constant across years. If hatcheries are eliminated the wild stocks produce a median catch of about 4 million annually. If the escapement goal were raised to 5 million (the "Manage" scenario), an annual catch of 7.5 million could be obtained. This is still a small fraction of the harvest level with hatchery production.

Terminal cost recovery harvests are equal in magnitude to common property harvest. As fry releases increase, more of the salmon must be caught in terminal areas to protect wild stocks. The simulated management is only an approximation of actual pink salmon management. In practice it has not been possible to completely curtail the harvest of wild stocks when the runs are less than the escapement target. Some wild pink salmon are harvested even in the designated terminal areas (Hal Gieger, ADF&G, pers. comm.). At this point in time, the wild runs could only be built up to an escapement level of 5 million by leaving some hatchery fish unharvested.

Southeast Alaska Chinook Salmon

The chinook salmon model was the most challenging to construct because of the more complex life history and the trans-boundary nature of the fisheries. Alaska hatchery chinook salmon are caught along with other hatchery and wild chinook stocks mainly from British Columbia, Washington and Oregon. The abundance of these other stocks (referred to here as non-Alaska hatchery chinook) in southeast Alaska waters was projected with an existing coastwide chinook salmon model. Abundance indices for the years 1979-2005 were provided by John Carlile (ADFG, Douglas, AK). For this reason, projections of southeast Alaska chinook catch end in 2005.

Figure 18. Prince William Sound wild and hatchery pink salmon returns. The solid line indicates actual returns until 1991 and projected median returns starting in 1992. The broken lines are the 10% and 90% quantiles of the distributions of 100 replicates.

Prince William Sound Pink Salmon

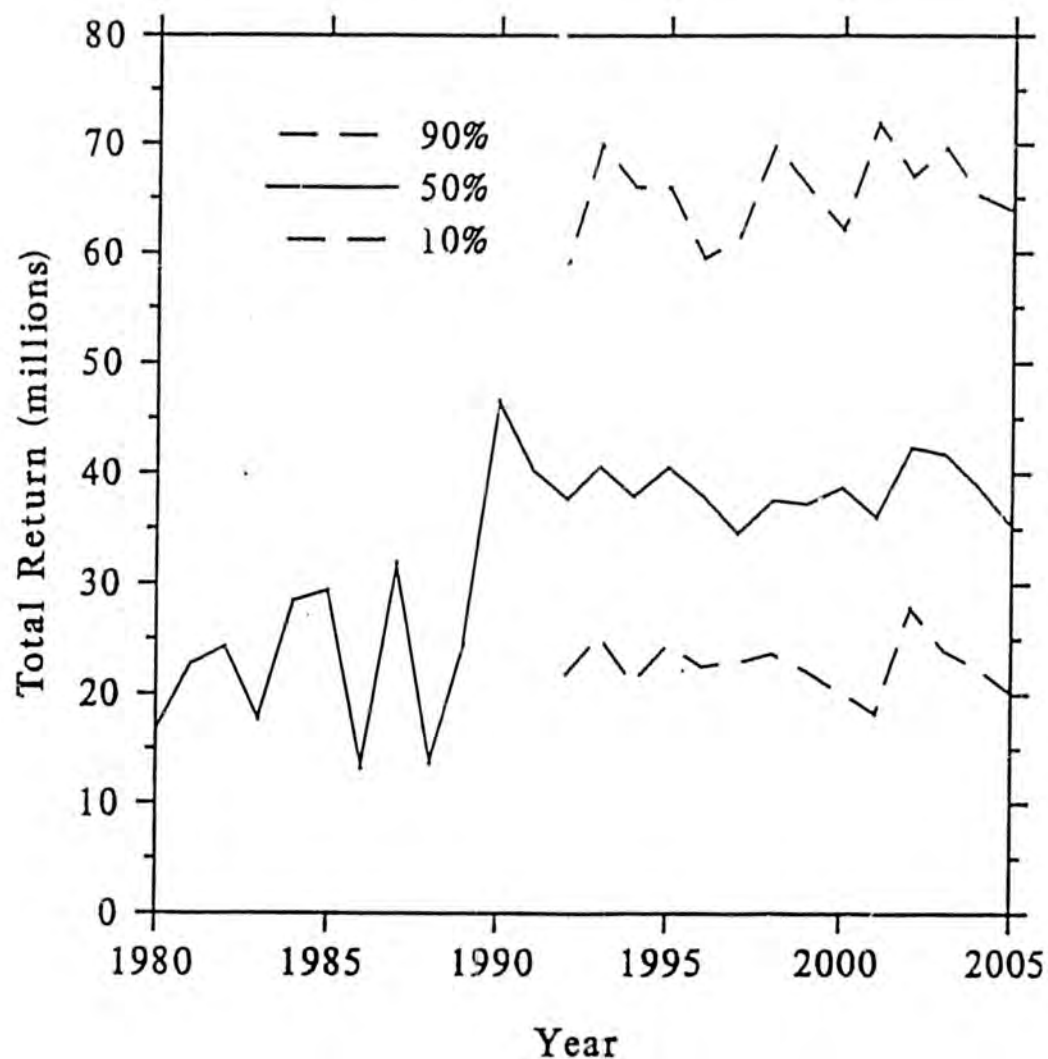


Figure 19. Projected common-property and terminal area catches of Prince William Sound pink salmon for five production scenarios: Current releases, 15% Increase, 15% Decrease, No hatchery releases, and increasing the escapement target to 5 million ("Manage").

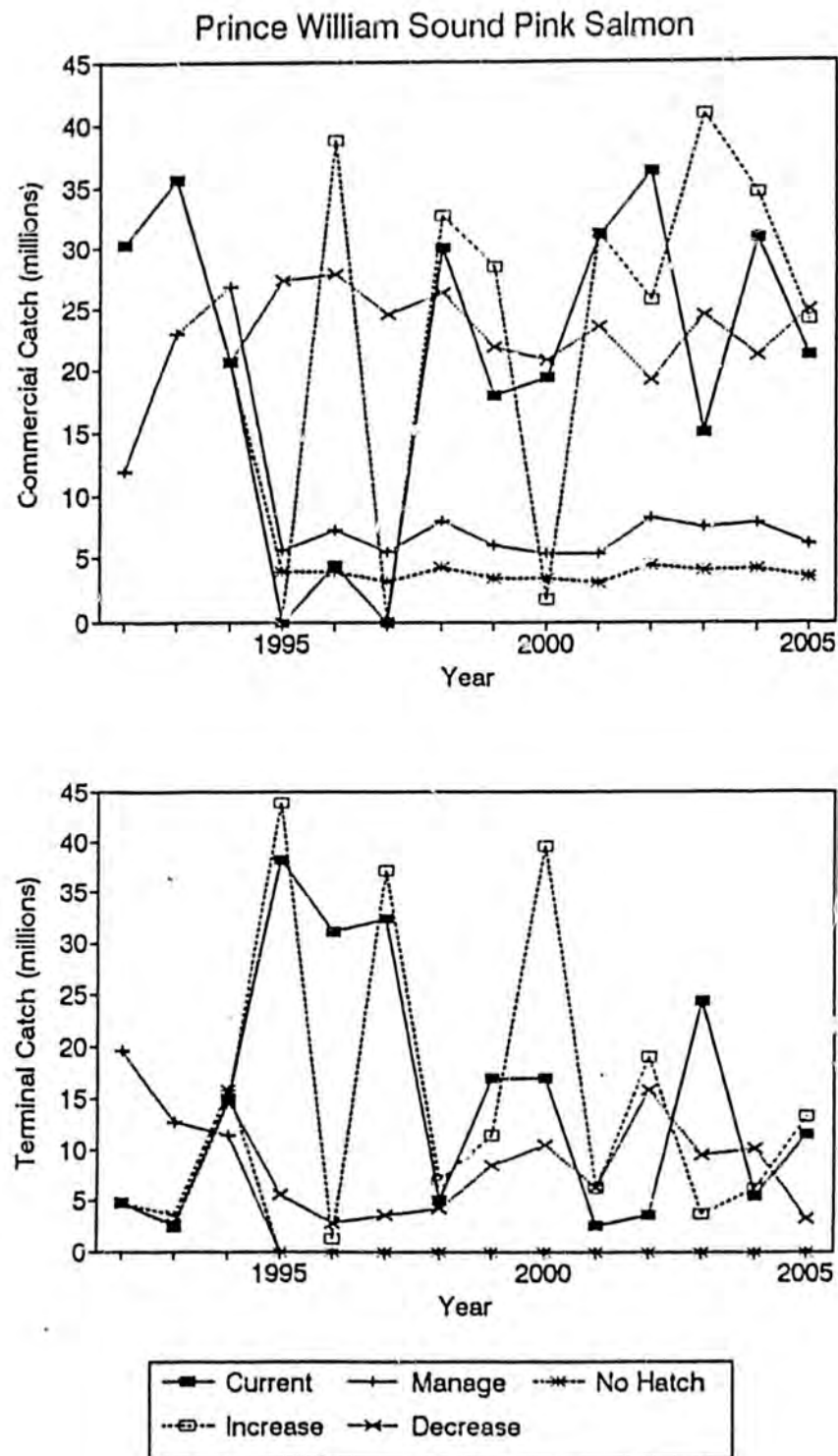
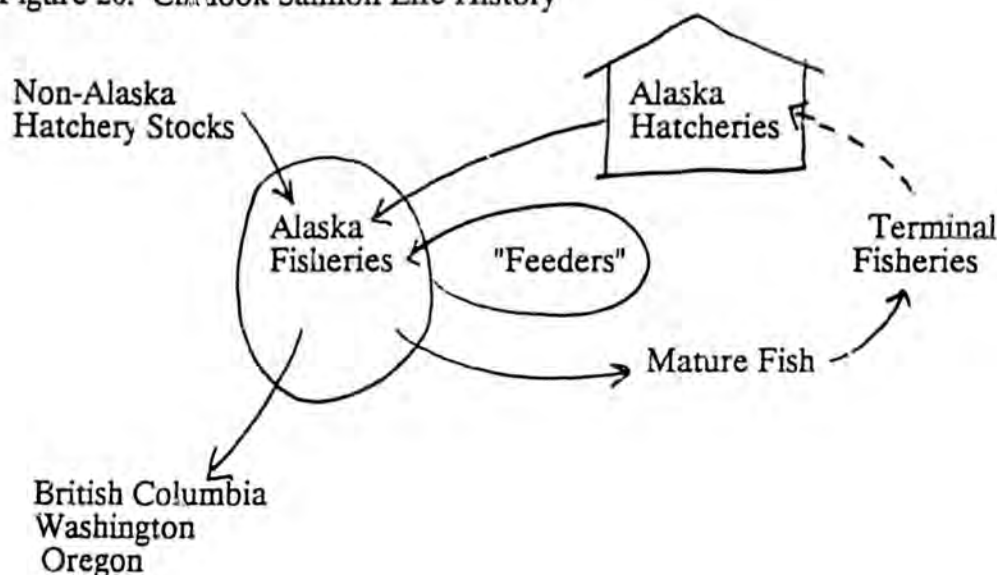


Figure 20. Chinook Salmon Life History



Fisheries Management

The chinook salmon fishery is governed by the US-Canada Pacific Salmon Treaty. Provisions of the treaty include a quota of chinook salmon, to be caught in waters adjacent to southeast Alaska, of 263,000 non-AK hatchery fish. This quota applies to all commercial gear types and user groups. Alaska hatchery fish can be taken in addition to the quota provided that their contribution is estimated in-season from coded-wire tags (CWT). This Alaska hatchery "add on" is calculated as the lower 90% confidence interval of the estimated hatchery contribution. The original plan was to produce 100,000 harvestable chinook salmon adults for the troll fishery (McGee et al. 1991). Under treaty stipulation, even if the hatchery fish are produced, they may not be harvestable if the treaty quota is exceeded.

The treaty quota of 263,000 chinook was allocated by the Alaska Board of Fish in March 1992. On a percentage basis the allocation was 77% troll, 16% sport and 7% net fisheries. Each gear group can supplement its catch of treaty fish according to its hatchery contribution rate. The hatchery contribution rate depends on the production of AK-hatchery chinook (P_H) and the abundance of non-AK hatchery chinook (P_N).

$$\frac{CH_g}{CN_g} = a_g + b_g \frac{P_H}{P_N}$$

$$CN_g = A_g Q$$

$$CH_g = [a_g + b_g \frac{P_H}{P_N}] A_g Q$$

where:

g = gear type

CH = Alaska hatchery catch

CN = Non-Alaska hatchery catch

a, b = parameters

A_g = gear allocation

Q = Treaty Quota

Hatchery contribution rates have increased as hatchery production increased (Figure 21). The sport fishery has the highest hatchery catch ratio, because the effort is in inside waters where the hatchery chinook congregate. The troll fleet has the lowest contribution because much of its effort is in outside waters where there are more non-Alaska hatchery fish and it is more difficult for the fleet to target the hatchery fish. Chinook are caught mainly as bycatch in seine and gillnet fisheries.

Southeast Alaska Chinook Salmon AK-hatchery-catch/Non-AK-hatchery-catch

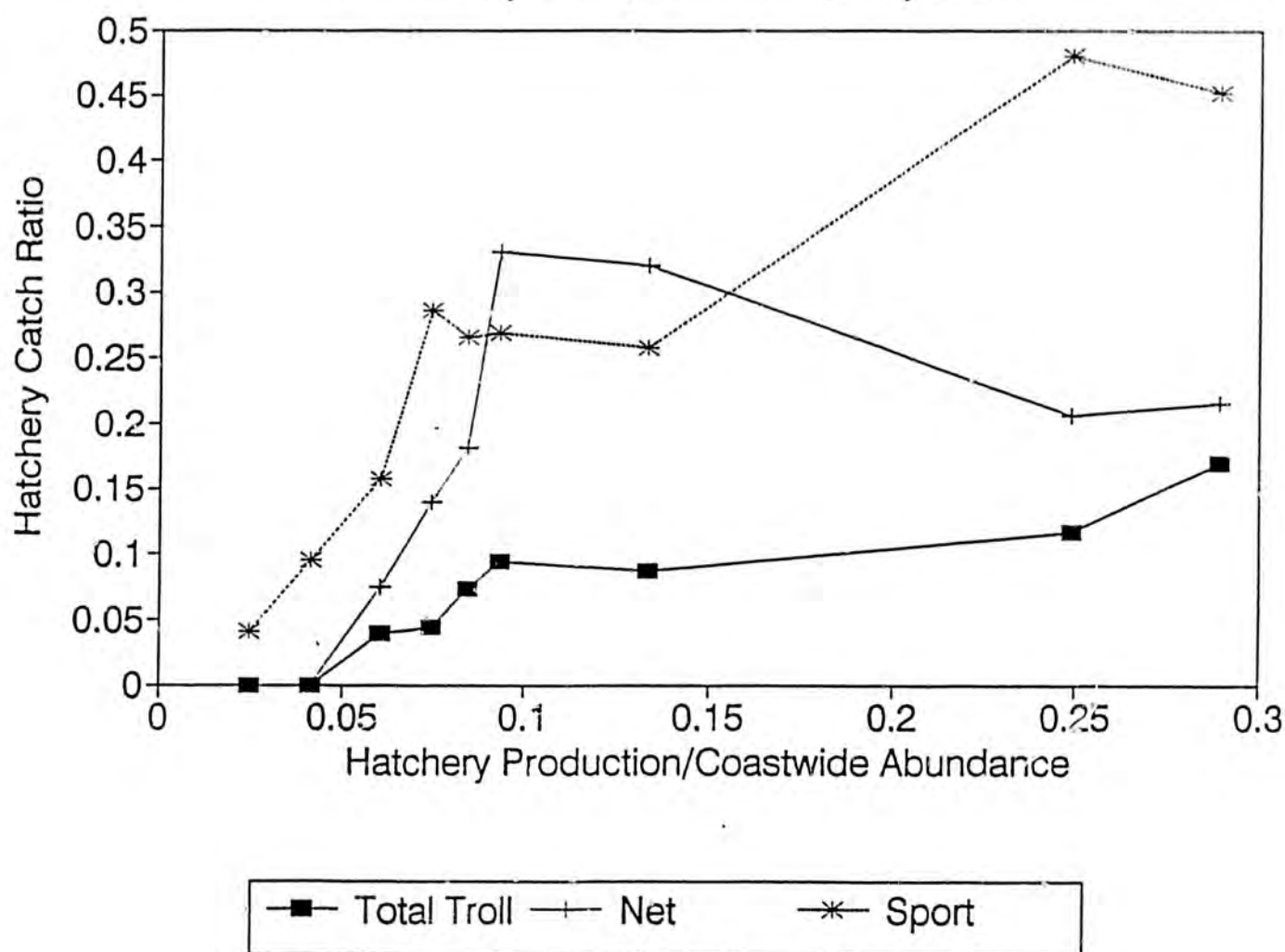


Figure 21. Contribution rates of Alaska hatchery chinook salmon to the Southeast Alaska chinook fishery. The ordinate is the ratio of Alaska hatchery chinook to non-Alaska chinook in the commercial catch.