A SALMON MANAGEMENT PLAN FOR CUMSHEWA INLET

by

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ABSTRACT

This document is a plan for salmon management and enhancement strategies in Cumshewa Inlet, on the Queen Charlotte Islands. It provides background information on the salmon stocks, the fisheries and the existing enhancement facilities. Several management and enhancement strategies are identified and evaluated, and one is recommended.

Chum, pink and coho salmon are produced in Cumshewa Inlet, with chum salmon most abundant. Pallant and Mathers Creeks support the major populations. Commercial fisheries targetting on Cumshewa Inlet stocks have been irregular in the past. However a major enhancement facility for chum salmon was constructed on Pallant Creek in 1978 and a small experimental hatchery was developed on Mathers Creek in 1980. Hatchery returns have provided a surplus for harvesting since 1984. There was not a long-term management strategy for harvesting these fish.

The three management options that were evaluated addressed the issues regarding mixed-stock fisheries, uncertainties of inseason run size estimates and fish quality. The four enhancement options addressed issues regarding species mix and strategies for enhancing the Mathers Creek chum salmon stock.

The option involving the expansion of the Pallant Creek facility for the purpose of enhancing the Mathers Creek chum salmon stock in combination with the management strategy of an early fishery with area restrictions is recommended. This option provides the potential for relatively high benefits

and is very cost effective. Although there is the risk that this management strategy may deplete the Mathers Creek stock, there is the opportunity to revert to another management strategy if the assumptions prove false. In this case the benefits would be significantly lower but the possibility of attaining the higher benefits would have been tested with minimal costs. This option is also flexible and provides the opportunity to consider other options in the future.

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1.0 INTRODUCTION

Cumshewa Inlet is located on the east coast of the Queen Charlotte Islands in British Columbia (Figure 1). The streams in the area support chum, pink, coho and sockeye salmon as well as steelhead and cutthroat trout. In the past, commercial salmon fisheries in Cumshewa Inlet have been irregular because of low and fluctuating fish abundance. In 1978 a major hatchery was constructed at Pallant Creek and in 1980 a pilot facility was built at Mathers Creek. Commercial fisheries targetting on the enhanced production have operated in the Inlet since 1984. Currently, harvesting strategies are identified on an annual basis and there is no long term management plan for harvesting these fish. In addition, further enhancement has been proposed for the area.

This planning document presents background information on the fish stocks in Cumshewa Inlet, the fisheries, and the existing enhancement facilities. Several management and enhancement options are identified and evaluated. The recommended plan is based on consideration of the evaluation criteria, and is subject to revision by the Department of Fisheries and Oceans (DFO) in consultation with user groups.

2.0 FISH STOCKS

Chum, pink, coho and sockeye salmon spawn in streams in Cumshewa Inlet. Pallant and Mathers creeks are the major salmon producing systems. Smaller escapements have been reported in Chadsey, Carmichael, Aero and Braverman creeks (Figure 2). Escapement, timing and migration of each species is described in the following sections. The escapement data are from Orman and Hansen (1986).

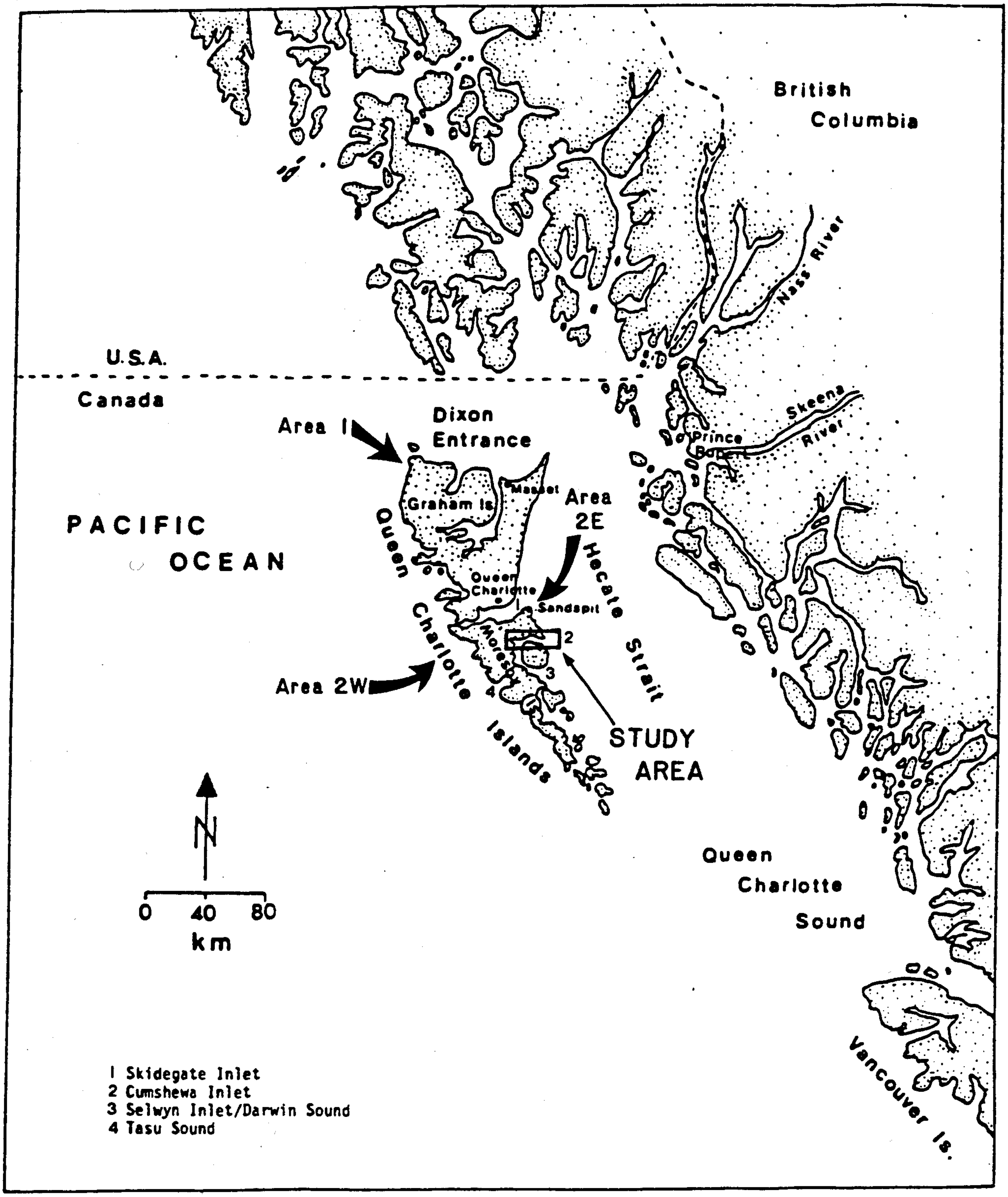


Figure 1. Location of Queen Charlotte Islands and study area (adapted from Orman and Hansen, 1986. Figure 2.).

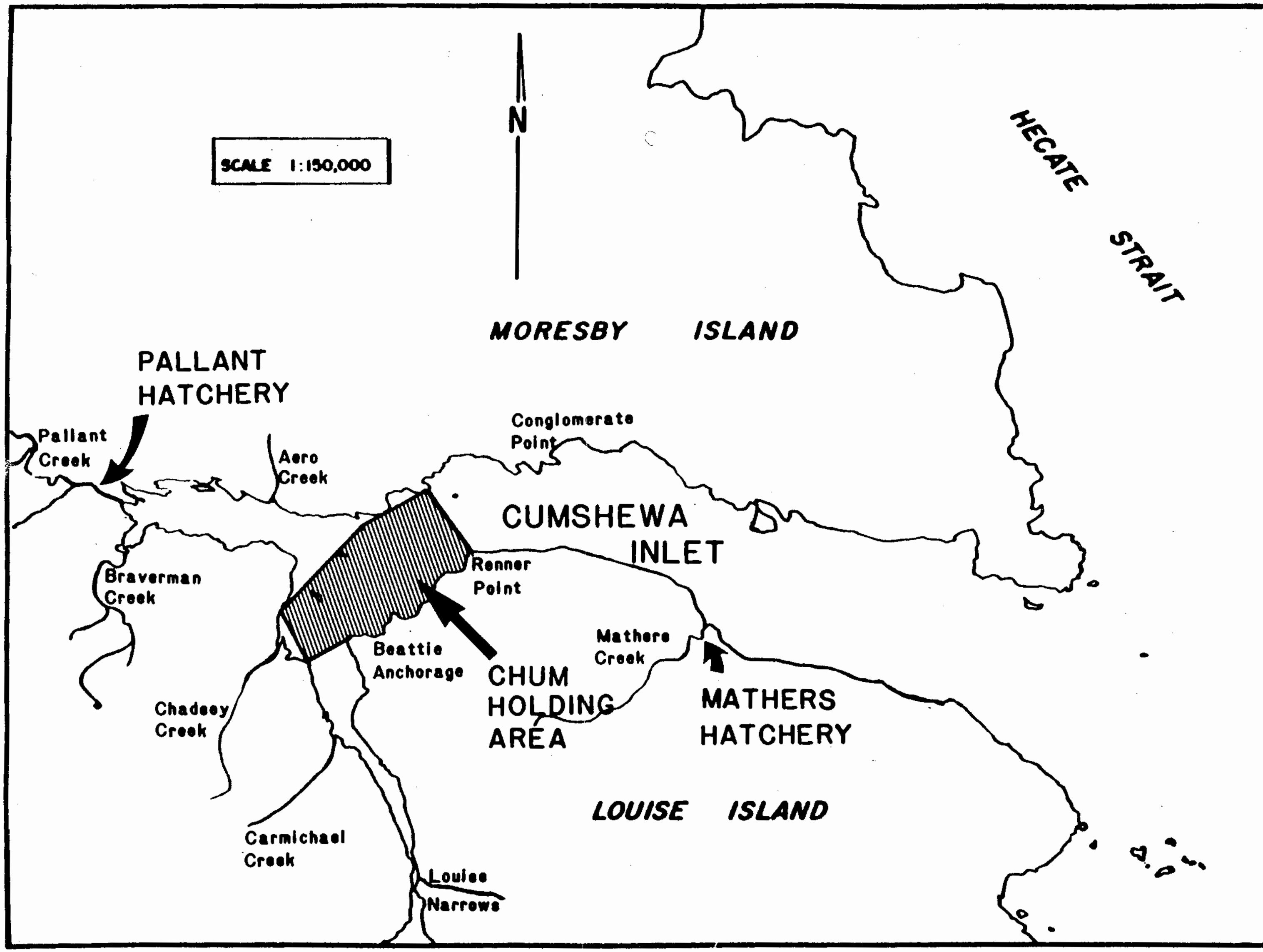


Figure 2. Cumshewa Inlet and streams (adapted from Aquatic Resources Ltd., 1982 Figure 3.2-1.).

2.1 Chum Salmon

Chum salmon escapements to Cumshewa Inlet streams have fluctuated substantially ranging from 850 to 57,500 in 1979 and 1952 respectively (Table 1). Average escapements by decade have remained relatively constant at about 20,000 spawners.

Pallant Creek is the major chum salmon producing stream in the inlet with average escapements of 16,000 in the 1950's, 13,500 in the 1960's, 12,000 in the 1970's and 20,500 in the early 1980's. The increased escapements in the 1980's reflects additional production from the Pallant Creek hatchery. Mathers Creek has consistently supported a moderate run of chum salmon with escapements averaging 4500, 7000, 5500 and 2000 for the 1950's, 1960's, 1970's, and early 1980's, respectively. Escapements to Chadsey Creek have averaged about 500 spawners except in the 1950's when escapements as high as 10,000 fish were reported. Records for Carmichael Creek are only available since 1969. In the 1970's, escapements averaged 600 fish but declined in the early 1980's to average less than 200 spawners.

The route of chum salmon migration to Cumshewa Inlet is not well understood. Three possible approach routes have been proposed: 1) from the north via Alaska, the north end of the Charlottes (Statistical Area 1),and Skidegate Inlet 2) from the west via Area 2W, around the southern end of the Charlottes and north along Area 2E and 3) from the east (Hecate Strait) directly into the terminal areas (Charles and Henderson, 1985).

There are limited data from chum salmon tagging studies and mark-recovery studies that provide some indication of chum salmon routings. Chum salmon tagging studies conducted in Skidegate Inlet in 1971, 1974, 1975 and

Table 1. Chum salmon escapements to Cumshewa Inlet streams.

	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	Mean
Aero											
Braverman											
Carmichael	N/O	N/O	N/O	N/O	N/O	N/O	N/O	N/O	N/O	N/O	
Chadsey	10000	9000	7500	750	750	750	750	400	1500	75	3148
Mathers	5000	9000	15000	1500	3500	750	750	7500	400	1500	4490
Pallant	15000	32250	35000	1500	3500	750	1500	35000	35000	400	15990
Total	30000	50250	57500	3750	7750	2250	3000	42900	36900	1975	23628

	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	Mean
Aero											
Braverman											
Carmichael	N/O	N/O	N/O	N/O	N/O	N/O	N/O	N/O	N/O	750	75
Chadsey	200	200	400	N/O	800	400	1500	750	750	75	508
Mathers	3500	3500	15000	15000	6000	7000	8000	750	7500	3500	6975
Pallant	35000	7500	15000	15000	8000	8000	9000	7500	15000	15000	13500
Total	38700	11200	30400	30000	14800	15400	18500	9000	23250	19325	21058

	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	Mean
Aero											
Braverman											
Carmichael	3000	900	350	500	400	400	150	100	200	50	605
Chadsey	500	600	2400	1000	400	100	100	300	230	75	571
Mathers	8000	500	15000	3000	10000	1000	16500	2000	1000	75	5708
Pallant	35000	20000	10000	25000	8000	5000	150	3000	12000	650	11880
Total	46500	22000	27750	29500	18800	6500	16900	5400	13430	850	18763

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	Mean
Aero						N/O					
Braverman						N/O					
Carmichael	675	15	12	200	90	50					116
Chadsey	630	925	140	265	340	200					417
Mathers	1700	2500	75	3000	1000	2800					1846
Pallant	10000	28600	2300	25000	26464	32000					20727
Total	13005	32040	2527	28465	27894	35050					15442

Note: N/O None Observed.

1981 suggest that Skidegate Inlet is not a major migration route for Cumshewa Inlet chum salmon because only a few of the fish tagged in Skidegate Inlet were recovered in Cumshewa Inlet (Dickson, 1971, 1974 and 1975; Aquatic Resources, 1982). In 1971, tagging studies in Selwyn Inlet, south of Cumshewa Inlet, indicated that a substantial portion of Cumshewa Inlet stocks migrated north through Louise Narrows (Dickson, 1971). The results of subsequent tagging studies in Cumshewa Inlet and adjacent areas in 1974, 1975, 1980 and 1981 did not support this conclusion. The general conclusion drawn from the tagging studies is that chum salmon returning to Cumshewa Inlet appear to approach directly from the east in Hecate Strait (Aquatic Resources,1982).

Since 1984, the return of hatchery fish from Pallant and Mathers creeks has been monitored in a mark-recovery program (McKenzie and Thomas,1985). In 1984 the distribution of catch of enhanced Cumshewa chum salmon was estimated at 5% in Skidegate Inlet, 2% in Area 2W (Tasu Sound and West Skidegate Inlet), 2% in Darwin Sound/Selwyn Inlet and the majority (91%) in Cumshewa Inlet. The 1985 results were similar with 10% of the catch in Skidegate Inlet, less than 1% in Area 2W,and the remainder were caught in the Cumshewa/Selwyn and Darwin fisheries. Mark- recovery data are based on sales slip information and the location of catch cannot always be identified to a specific location. For example, boats fishing in Cumshewa, Selwyn and Darwin may deliver to the same packer, and catches are not kept separate. Therefore, the results of the mark-recovery program are inconclusive and do not necessarily reflect the catch distribution between Cumshewa, Selwyn and Darwin fishing areas.

Chum salmon begin arriving in Cumshewa Inlet in early September (unpublished test fishing data 1982, 1984 and 1985). Tagging studies indicated that peak abundance occurred between September 24 and October 2 during 1980 and 1982 (Aquatic Resources,1982). These studies also indicated that most chum salmon hold in the inlet for 2 to 4 weeks before heading upstream (Figure 2). Counting fence data from Pallant and Mathers Creeks show that some spawners begin entering the streams in early September but most arrive between early and late October. Chum salmon migration into the streams appears to be strongly related to flow conditions. In 1985, water levels were very low and the majority of spawners did not enter the streams until flows increased.

2.2 Pink Salmon

The dominant pink salmon run occurs in even years. Escapements to the inlet have fluctuated substantially over the period of record, ranging from 14,500 in 1964 to 220,000 in 1950 (Table 2). Average escapements have increased over time from 90,000 in the 1950's to 104,000 in the 1960's and 139,000 in the 1970's. However, escapements in the early 1980's have averaged only 28,000 spawners. The two major pink salmon spawning streams are Pallant and Mathers creeks. Pink salmon escapements to other streams in the inlet have only been reported periodically in Braverman and Chadsey creeks. Generally, escapements to Pallant Creek have been slightly higher than to Mathers Creek (Table 2).

The odd-year pink salmon run is relatively small compared to the even-year run, with a peak escapement of 45,000 recorded in 1963 (Table 2).

Table 2. Pink salmon escapements to Cumshewa Inlet streams.

Even Year Pink Salmon Escapements

	1950	1952	1954	1956	1958	Mean
Braverman						
Chadsey	N/0	N/0	N/0	N/0	200	40
Mathers	20000	75000	1500	3500	/500	21500
Pallant	200000	100000	15000	15000	15000	69000
Total	220000	1/5000	16500	18500	22/00	90540
	1960	**1962**	**1964**	**1966**	**1968**	**Mean**
Braverman						
Chadsey	N/0	N/0	N/0	N/0	N/0	0
Mathers	35000	100000	7500	25000	/5000	48500
Pallant	50000	100000	7000	45000	/5000	55400
Total	85000	200000	14500	70000	150000	103900
	1970	**1972**	**1974**	**1976**	**1978**	**Mean**
Braverman						
Chadsey	N/0	500	N/0	N/0	N/0	100
Mathers	75000	75000	20000	47500	50000	53500
Pallant	100000	130000	5000	90000	100000	85000
Total	175000	205500	25000	13/500	150000	138600
	1980	**1982**	**1984**			**Mean**
Braverman	100	20	100			73
Chadsey	N/0	N/0	N/0			0
Mathers	8000	15500	2000			8500
Pallant	10000	10330	391/5			19835
Total	18100	25850	412/5			28408

Odd Year Pink Salmon Escapements

	1951	1953	1955	1957	1959	Mean
Braverman						
Chadsey	N/0	N/0	N/0	N/0	N/0	0
Mathers	2000	400	N/0	3500	400	1260
Pallant	1000	750	200	3500	3500	1790
Total	3000	1150	200	7000	3900	3050
	1961	**1963**	**1965**	**1967**	**1969**	**Mean**
Braverman						
Chadsey	N/0	N/R	N/0	N/0	N/0	0
Mathers	15000	30000	13000	7500	1500	13400
Pallant	3500	15000	4000	3500	35000	12200
Total	18500	45000	17000	11000	36500	25600
	1971	**1973**	**1975**	**1977**	**1979**	**Mean**
Braverman						
Chadsey	N/0	N/0	75	N/0	N/0	15
Mathers	1000	N/0	2500	1000	150	930
Pallant	8000	1500	3500	400	3000	3280
Total	9000	1500	6075	1400	3150	4225
	1981	**1983**	**1985**			**Mean**
Braverman	1100	500	N/0			533
Chadsey	2	34	N/0			12
Mathers	1/00	200	/00			867
Pallant	3550	7/00	4300			5183
Total	6352	8434	5000			6595

Note: N/0 None observed.

With the exception of the 1960's, pink salmon escapements to Cumshewa Inlet streams have been less than 10,000 spawners. Average escapements to Pallant and Mathers Creeks were similar in the 1950's and 1960's, but escapements to Pallant Creek have generally been higher in recent years (1971-1985)(Table 2).

Information on Area 2E pink salmon migration is limited to a small number of recoveries from the International Tagging Program in 1984 (English et al.,1985). Most tags recovered in Area 2E were released from Area 1 (n=7) at the north end of the Queen Charlotte Islands. However, 2 of the recovered fish were tagged in Area 3 and Area 4 suggesting that a minor percentage of the Area 2E pink salmon stocks may be intercepted in those fisheries. None of the tagged fish were recovered in Area 2E in the 1982 study.

No studies have been directed at pink salmon stocks in Cumshewa Inlet but observations by fishery officers suggest that pink salmon arrive in Cumshewa Inlet during early August. Incidental information collected during chum salmon tagging studies indicates that peak abundance of pink salmon in Cumshewa Inlet occurs in the first week of September and that the fish have left the inlet by the end of the second week (Aquatic Resources, 1982). Counting fences on Pallant and Mathers creeks are not usually installed early enough to monitor the beginning of pink salmon migration into the creeks. The available fence data and historic escapement records indicate that pink salmon begin to arrive in Pallant Creek in mid-August, with peak spawning usually occurring in early to mid-September and die-off is complete in early October (Aquatic Resources, 1982). Pink salmon timing in Mathers Creek is similar (Shepherd, 1978).

2.3 Coho Salmon

Coho salmon escapements to Cumshewa Inlet have been reported to range between 475 in 1958 and 20,000 in 1965 (Table 3). Average escapement to the inlet has been relatively consistent ranging between 6200 to 10,800. Pallant and Mathers Creeks are the major producers and had similar escapements prior to 1970. During the mid 1970's, Mathers Creek escapements were about twice that in Pallant Creek. However in recent years, coho salmon escapements to Mathers Creek declined while escapements to Pallant Creek have increased. The increase in Pallant Creek coho salmon escapements can be attributed to hatchery enhancement. Chadsey Creek is the only other system in Cumshewa Inlet in which coho salmon escapements are reported consistently; recent estimates indicate less than 200 spawners.

There is little known about the migration of coho salmon originating in the Queen Charlotte Islands. The only available information is from the coded-wire tag recoveries from enhanced Pallant Creek coho salmon. The three years of available data (1983-85, unpublished mark recovery data) indicate that Pallant Creek coho salmon are intecepted in Alaskan fisheries (5%) and in northern Canadian troll fisheries (35%).

The timing of coho salmon to Pallant Creek is earlier than for most other QCI coho salmon stocks. Pallant Creek coho salmon arrive from mid to late August, peak about the third week in September, and continue spawning in October (Aquatic Resources, 1982). Coho salmon timing in Mathers Creek is later with arrival beginning in early September, the peak occurring in early to mid-October and spawning continuing to November (Hawkshaw, 1985). Coho salmon timing in Cumshewa Inlet overlaps with both pink and chum salmon timing because of their longer migration period.

Table 3. Coho salmon escapements to Cumshewa Inlet streams.

	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	Mean
Aero											
Braverman											
Carmichael											
Chadsey	750	200	1500	200	200	400	N/O	750	200	N/O	420
Mathers	7500	5500	7500	750	3500	1500	3500	3500	75	1500	3483
Pallant	3500	4000	7500	3500	3500	1500	1500	3500	200	400	2910
Total	11750	9700	16500	4450	7200	3400	5000	7750	475	1900	6813

	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	Mean
Aero											
Braverman											
Carmichael											
Chadsey	N/O	N/O	75	N/O	N/O	40	75	200	75	25	49
Mathers	3500	3500	3500	3500	5000	10000	4000	3500	7500	7500	5150
Pallant	3500	3500	750	7500	5000	10000	13000	3500	1500	7500	5575
Total	7000	7000	4325	11000	10000	20040	17075	7200	9075	15025	10774

	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	Mean
Aero											
Braverman											
Carmichael											
Chadsey	100	N/O	N/O	N/O	N/O	150	150	200	150	180	93
Mathers	7500	N/O	N/O	10000	UNK	5000	10000	5500	10000	2000	5000
Pallant	8000	N/O	4000	4500	2000	4000	2000	2000	2000	1300	2980
Total	1 5600	0	4000	14500	2000	9150	12150	7700	12150	3480	8073

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	Mean
Aero		58			N/O	N/O					19
Braverman	25	N/O	N/O	N/O	2	N/O					5
Carmichael				1	N/O	N/O					0
Chadsey	200	75	80	200	80	N/O					106
Mathers	3000	2500	5000	3500	2000	1400					2900
Pallant	2500	1650	2100	4100	3742	5300					3232
Total	5725	4283	7180	7801	5824	6700					6252

Note: N/O None observed.

2.4 Other Species

Spawning records indicate periodic escapements of sockeye salmon to Pallant and Mathers creeks. Maximum reported escapement of sockeye salmon to Pallant Creek was 200 in 1959 and 1960. Maximum reported sockeye salmon escapement to Mathers Creek was 15,000 spawners in 1967 but escapements were generally less than 5000. Sockeye salmon escapement estimates in 1985 were 30 for Pallant Creek and 1000 for Mathers Creek. Sockeye salmon spawning occurs from April to June.

No chinook salmon stocks are produced from Cumshewa Inlet, although strays are occasionally reported.

Pallant Creek supports one of the most important steelhead stocks in the Charlottes. These winter run steelhead enter the river from September through to the end of May, with spawning occurring throughout the spring. Average run strength is estimated at 360 fish. Estimates of the steelhead stock in Mathers Creek indicate a similar size run, but difficult access limits sport fishing effort on that stock (B.C.MOE unpublished,1985).

There is an important stock of cutthroat trout in Mosquito Lake on the Pallant Creek system. Abundance is estimated in excess of 3000 fish. Spawning occurs in the small tributaries to the lake from April to June. Juvenile cutthroat trout spend one to four years in the tributaries prior to migrating to the lake (B.C.MOE unpublished, 1985).

3.0 FISHERIES MANAGEMENT

3.1 Net fisheries

3.1.1 Pink Salmon

Pink salmon fisheries in Cumshewa Inlet are managed to escapement targets of 75,000 spawners in Pallant Creek and 50,000 spawners in Mathers Creek (Orman and Hansen, 1986). Pink salmon fisheries were conducted in Cumshewa Inlet during the 1970's on the even year stocks. These fisheries occurred in late August and early September. Catches were 160,400 in 1972, 26,000 in 1974, 334,600 in 1976 and 15,600 in 1978. There have not been any pink salmon fisheries held in Cumshewa Inlet since 1978 because stocks have been at relatively low levels.

3.1.2 Chum Salmon

Chum salmon fisheries in Cumshewa Inlet are managed to escapement targets of 30,000 for Pallant Creek and 20,000 for Mathers Creek (Orman and Hansen, 1986). However, since the stocks cannot be managed separately because they mix in the inlet, the fishery is managed to an aggregate escapement target of 50,000 spawners (D.F.O., 1985).

Chum salmon fisheries in Cumshewa Inlet have been minor in the past because the abundance of chum salmon has been low. Brief openings in some years during the 1970's resulted in catches less than 5000 pieces (unpublished catch records). However, in 1984 and 1985, chum salmon fisheries were held in Cumshewa Inlet to harvest the enhancement-related surplus. Catches were in the order of 50,000 pieces in 1984 (Orman, 1984) and 85,000 pieces in 1985 (Enderud et al., 1985). It is anticipated that Cumshewa Inlet will support consistent chum salmon fisheries in the future because of the surplus available from enhancement. Fishery openings have generally occurred from mid-September to early October.

The fishery is driven by the abundance of chum salmon in the inlet, which is dominated by the enhanced Pallant Creek stock. Time and area restrictions have been used in an attempt to protect the Mathers Creek stock which is also enhanced but at lower levels. These restrictions involve closing the outside area in the vicinity of Mathers Creek later in the season. Poor escapement to Mathers Creek indicates that these measures have not been effective. The unenhanced Chadsey and Carmichael Creek stocks are relatively minor and management is not altered to protect those stocks.

The major difficulty in managing the Cumshewa Inlet chum salmon fishery is the difficulty in obtaining timely estimates of stock abundance. Enumeration data from the Pallant and Mathers Creek counting fences are not available in time to make management decisions because the fish hold in the inlet for 2-4 weeks before migration into their spawning streams (Aquatic Resources, 1982; Webb, 1984). Another complicating factor is that fish quality deteriorates during this holding period. The incentive is to harvest the fish early to obtain better quality and thus higher values, but this strategy results in greater risks of not achieving the escapement targets.

In 1982, 1984 and 1985, test fishing programs were conducted in Cumshewa Inlet as a method of assessing chum salmon abundance (Webb, 1984 and 1986). The studies are based on gillnet catch per unit effort at standardized sites at set times. The objective of the studies was to develop an index to relate the catch per unit effort to actual escapement counts. However, the gillnet catch per unit effort had a wide variance and could not be correlated to escapement of fish into Pallant Creek because the fish do not move as a steady stream through the inlet and up the rivers, but rather hold in the inlet and mill about prior to migrating to the rivers (Webb, 1984). It was recommended that one site outside the holding area such as Conglomerate Point be used to index movement of the fish into the holding area. Several years of data are required to determine the effectiveness of this test fishery as an index of stock abundance.

In 1982 and 1985, mark-recapture studies were conducted in Cumshewa Inlet to determine chum salmon abundance using Jolly-Seber and Petersen population estimates (Webb, 1984 and 1986). The Jolly-Seber method provides point estimates through the season, but cannot be calculated until after all the data are available and therefore is not useful as an inseason tool. Simple Petersen estimates were also calculated but overestimated the abundance of fish because it could not account for tag losses (Webb, 1985). These marking studies also indicated that Mathers Creek chum salmon mix with Pallant Creek chum in the holding area, although it is not known what proportion of the run is present in the holding area.

3.2 Sport Fishery

The tidal sport fishery for coho salmon occurs from mid-August to mid-September. The non-tidal sport fishery is later occurring from early September to early October. Historically, the Pallant Creek coho salmon and steelhead trout stocks were subject to relatively heavy angling pressure during the period that Moresby Camp was in operation (Shepherd, 1978). Improved access resulted in continued sport fishing effort after the camp was closed in 1970 (Shepherd,1978). Mathers Creek was historically subject to a small sport fishery from anglers based at Moresby Camp (Shepherd,1978).

Sport fishing in Mathers Creek has increased in recent years since the Beatty Anchorage logging camp has been operating.

The tidal sport fishery has also been developing with effort from resident and non-resident anglers. The 1985 run of coho salmon to Cumshewa Inlet was relatively high because of the return from a large release group from the hatchery in 1982. It was estimated that the tidal anglers launching from Moresby Camp caught 250 fish, anglers from the two charter boats caught 200 fish and river anglers caught 25 coho salmon (Enderud et al., 1985). The unusually low river flows during 1985 resulted in relatively poor non-tidal coho salmon catches.

4.0 ENHANCEMENT ACTIVITIES

4.1 Background

In 1976, Pallant and Mathers Creeks were identified by DFO as having a high potential for chum salmon enhancement (Shepherd, 1978). Bioreconnaissance studies were conducted in 1977 and 1978 (Shepherd, 1978; Glova et al., 1979; Northern Natural Resource Services Ltd., 1979). In 1978, a modified Japanese-style hatchery was constructed at Pallant Creek. Japanese-style hatcheries are usually supplied with ground water and the process involves bulk incubation of eggs and transfer of the eggs to shallow gravel channels just prior to hatch so the fry emerge in a semi-natural environment. The Pallant Creek facility was modified because ground water was not available and space at the site was limited. Since the surface water supply had a high level of suspended solids, the bulk incubators could not be used for the entire incubation period. At Pallant Creek Hatchery, eggs are incubated during the sensitive period from fertilization to just prior to hatch in Heath trays, and then transferred to shallow matrix gravel incubators until emergence. It was originally intended that the fry would be released unfed because there was limited space available to install rearing channels on the site. However, in 1979, sea pens were installed to improve survival since this rearing strategy was proving successful in Japan.

The original plans included equal enhancement of Pallant Creek and Mathers Creek chum salmon stocks and some enhancement of Pallant Creek coho salmon to offset the anticipated interception of coho salmon in the chum salmon fishery. In 1978, the capacity of the Pallant Creek Hatchery was 5 million chum salmon and 100,000 coho salmon eggs. Development of the Mathers facility was delayed because water quality testing conducted between 1976 and 1979 indicated potential problems for fish culture. The ground water had marginally high ammonia levels and nitrogen supersaturation and the surface water periodically had high suspended solids levels (Fedorenko and Shepherd, 1985).

The Pallant Creek Hatchery was expanded in 1979 with a doubling of the incubation capacity and the addition of sea-pens and four concrete raceways for chum salmon rearing. The additional incuation capacity was to enable satelliting of 5 million Mathers chum salmon eggs to the Pallant Creek facility. Satelliting is an enhancement strategy whereby fertilized eggs from a particular salmonid stock are incubated and reared in a central facility and then fry are released in the donor stream. In 1979, satelliting of the Mathers Creek chum salmon stock was attempted on a small scale, one million eggs, and failed because not enough eggs could be collected due to a low abundance of brood stock (Grant and McCart, 1980).

Failure of the satelliting option lead to reconsideration of development of a Mathers Creek facility. It was suggested that water quality conditions would not necessarily preclude successful incubation and short term rearing of chum salmon. Construction of a pilot hatchery was recommended to test the feasibility of enhancing chum salmon at the Mathers Creek site prior to developing a full scale production facility (Fedorenko and Shepherd, 1985). The pilot project objectives were to compare survival of fry reared on the two separate ground and surface water supplies. A pilot hatchery with rearing capacity for about one million fry was constructed at Mathers Creek in 1980 and incubation capacity for one million fry was added in 1981 (Fedorenko and Shepherd, 1985).

Since development of the pilot facility, the enhancement strategy for Mathers Creek chum salmon has been variable from year to year. Budgetary constraints have limited operation of the pilot facility in 1980, 1983 and 1985 and the satelliting approach was adapted instead. In years when the pilot facility operated, 1981 and 1982, the original objectives were lost and the facility was run using mixed water supplies to maximize survival rather than test the suitability of each water supply. The result of these mixed strategies is that no conclusion can be drawn regarding the suitability of the two water supplies at the Mathers Creek site (Fedorenko and Shepherd, 1985).

4.2 Production Targets and Status

The current capacity of Pallant Creek hatchery is about 11.5 million chum salmon and 350,000 coho salmon eggs. However, this estimate includes 2 million chum salmon eggs satellited from Mathers Creek in some years. The current egg target for Pallant Creek chum salmon is 9.5 million eggs. The expected production from this target is 171,000 adults, based on the Salmonid Enhancement Program (S.E.P.) biostandards for sea pen rearing of chum salmon. The S.E.P. biostandards are standardized criteria used to estimate production of salmonid reproduction in the wild or in various types of enhancement facilities. The current egg target for Pallant coho salmon is 350,000 which would result in returns of about 7500 adults.

The current capacity of the Mathers Creek pilot facility is 1.1 million eggs. Egg targets have varied because of the alternate strategies used. Assuming that the stock should be enhanced at the pilot facility, the egg target would be 1.1 million and the expected adult production would be 15,800 based on S.E.P. biostandards for freshwater rearing of chum salmon fry.

Actual production status of the facilities is shown in Table 4. Egg targets for Pallant Creek have been exceeded since 1984 for chum salmon and 1982 for coho salmon. The egg take at Mathers Creek in 1985 exceeded the target by double the capacity of the site, but incubation was conducted at the Pallant Creek facility. In the early years of operation, some pink salmon eggs were taken from Pallant and Mathers Creeks because the facilities had extra space since the chum salmon egg takes were limited by low numbers of broodstock. Some steelhead eggs were also taken but the provincial fishery managers do not encourage further enhancement of steelhead.

5.0 MANAGEMENT ALTERNATIVES

5.1 Issues

A regular chum salmon fishery is anticipated in the future to harvest the surplus hatchery returns to Cumshewa Inlet. This fishery was initiated

Table 4. Ehancement production status of Pallant and Mathers Creek stocks.

Stock	Brood Year	Number of Eggs Taken	Number of Fry Released	Expected Adult Returns	Estimated Adult Returns	Comments
Pallant Creek Chum Salmon	1978	1172568	990030	24284	4975	
	1979	329433	298354	7459	1550	
	1980	2985982	3011512	75288	51851	
	1981	8230781	7207389	180185	158867	
	1982	4516900	3847537	96188	b	
	1983	7650917	7211290	180282	b	
	1984	11496989	10333847	244412	b	
	1985	10770000	a	193860	b	
Mathers Creek Chum Salmon	1980	385533	391905	7836	2875	Incubated at Pallant, reared at Mathers
	1981	678576	518552	10371	11664	Incubated and reared at Mathers
	1982	298798	267500	5350	b	Incubated and reared at Mathers
	1983	679867	608948	12179	b	Incubated at Pallant, reared at Mathers
	1984	0	0	0	0	No brood stock collected
	1985	2130000	a	30672	b	Incubated at Pallant, reared at Mathers
Pallant Creek Coho Salmon	1979	9581	9120	109	c	
	1980	91067	73230	1098	1937	
	1981	223901	192857	2893	1736	
	1982	459817	447973	6720	1736	
	1983	339382	249171	3701	b	
	1984	372812	349762	4197	b	
	1985	428000	a	9245	b	
Pallant Creek Pink Salmon	1979	9620	6760	169	c	
	1980	1164785	951699	23792	c	
	1983	511485	485867	12147	486	Fed and unfed release groups equal
Mathers Creek Pink Salmon	1980	55974	44941	1124	c	
Pallant Creek Steelhead Trout	1982	10410	5129	51		
	1983	24303	15458	155		

Notes: a) data not available at time of printing
b) total estimates not possible because not all age classes returned
c) no groups were marked

in 1984, the first year of significant returns to the hatchery, and it continued in 1985. Full production from the enhancement facility has not yet been realized but is expected in 1987.

Several issues need consideration in choosing the best management strategy for this fishery. First, it is a mixed stock fishery and will likely have effects on unenhanced chum, pink and coho salmon stocks depending on when the fishery occurs. Second, it is difficult to estimate stock size inseason because the chum salmon hold in the inlet for several weeks prior to entering the streams. Therefore, escapement information is not a useful inseason estimate of run strength. Without accurate abundance estimates, the managers risk the possibility of opening a fishery which could over-harvest the escapement target. Third, fish quality deteriorates during this holding period and value of the catch declines. In summary, the problem facing fisheries managers in Cumshewa Inlet is to develop a management strategy which will minimize the interception of less productive stocks while providing maximum value from the fishery and ensuring that the major stocks remain at adequate levels to provide genetic diversity.

5.2 Identification of Options

Several fisheries management options could be considered for Cumshewa Inlet. Three options chosen for this analysis were status quo management, a quota fishery with a terminal fishery to harvest any surplus, and an early fishery to harvest fish as they arrive. The third option was modified to include restrictions which were intended to minimize negative impacts. These options are described in the following sections.

5.2.1 Option 1: Status Quo

The management strategy used in 1984 and 1985 could be continued in the future. This involves opening the fishery when chum salmon are at their peak abundance in the inlet. The fisheries managers have reasonable confidence that there is an abundance of fish based on test fishing and tagging studies. However, there is some risk that the commercial fishery could over harvest the run and the target escapement would not be met. Under the status quo management scenario, the quality of the fish would be medium with an average grade of dark red. The Mathers, Chadsey and Carmichael chum salmon stocks would also be caught, and because they are less productive than the enhanced Pallant Creek stock, they would likely be over harvested.

5.2.2 Option 2: Quota and Terminal Fishery

This option attempts to reduce the harvest of Mathers chum salmon by setting a quota of 30,000 pieces on the fishery during mid-September in the early part of the run and then harvesting the surplus Pallant Creek fish terminally in the later part of the run. The 30,000 piece quota was arbitrarily chosen with consideration given to providing enough catch to attract a fleet while limiting the harvest rate to minimize impacts to the Mathers Creek stock. Although some Mathers fish would be intercepted in the early fishery, a good portion of the run may escape and the stock could rebuild. The surplus Pallant Creek fish would be harvested later at the head of the inlet to minimize interception of Mathers Creek fish. The fish caught in the quota fishery would be better quality than in the status quo option with an average grade of semi bright, while fish caught in the later fishery would be poorer quality dark pale.

5.2.3 Option 3 : Early Fishery

This management option involves opening the fishery early in the run to maximize catch of better quality fish. Most of the fish entering the inlet would be of silverbright quality. However, since some of the catch may have entered the inlet in previous weeks, the quality was assumed semi bright as a conservative position. Fisheries would be open for 1 to 2 days each week of the chum salmon run. This would enable the fleet to capture fish that had arrived within the week and were still of prime quality. The fleet would likely concentrate on the outer portion of the inlet to intercept arriving fish. This reaction of the fleet would negatively affect the Mathers Creek stock. Harvesting pressure would be heavier on the Mathers stock since it would be fished on arrival to the inlet and again while approaching the stream mouth. Some of the Pallant Creek stock would escape the fishery and hold at the head of the inlet away from the harvesting pressure.

This management strategy would also have implications on pink and coho salmon in Cumshewa Inlet. With earlier fishing of chum salmon, there would be more interception of coho, except for the Mathers Creek coho salmon stock which has a later timing. Interceptions of pink salmon would also increase with the early fishing option.

This approach also results in a greater risk of not achieving target escapements of chum salmon in Pallant and Mathers Creeks. The fish are being harvested continually so there is no guarantee that the required number will filter through the fishery. This factor could be addressed by ensuring adequate broodstock to the hatchery by seining them in the inlet prior to the fishery.

5.2.4 Option 3A: Early Fishery with Restrictions

The third option was modified slightly to include restrictions which may reduce the interception of Mathers Creek chum salmon in the Cumshewa fishery. Although there is no conclusive evidence at this time, results from tagging studies and electrophoretic analysis suggest that a relatively higher proportion of Mathers Creek fish are located along the north shore of Louise Island. This option assumes that a ribbon boundary along the north shore of Louise Island imposed to restrict fishing in the area would result in Mathers Creek chum being harvested at the same rate as Pallant Creek chum.

6.0 ENHANCEMENT ALTERNATIVES

6.1 Issues

Further enhancement has been proposed for Cumshewa Inlet (DFO, 1985). The original S.E.P. plans involved equal enhancement of Pallant and Mathers Creek chum salmon stocks. However, because of the uncertainty associated with water supplies at Mathers, and the testing of the satelliting option whereby eggs from the Mather Creek stock are incubated at the Pallant Creek facility, the Mathers Creek stock has received only minor enhancement while the Pallant Creek stock has been fully enhanced as originally planned. Several factors should be considered in deciding the best strategy for future enhancement in Cumshewa Inlet.

The question of whether to satellite the Mathers Creek stock from the Pallant Creek hatchery, or to develop a separate facility, has not been resolved. Despite several attempts to operate the pilot facility, the suitability of the water supply has not been determined (Fedorenko and Shepherd, 1985). Testing of the satelliting option has been limited by the low broodstock numbers in most years that this option has been adapted. This strategy is also complicated by difficulties associated with rough weather which commonly occurs at the time of egg transfer.

The other major factor to consider in planning an enhancement strategy for the inlet, is the species mix. Should all stocks and species be enhanced, or should production primarily focus on chum salmon? Currently, Pallant Creek coho salmon are also being enhanced. Originallly the coho enhancement was meant to offset interceptions in the Cumshewa chum salmon fishery. In 1985, there was an overescapement of coho to Pallant Creek, and this trend is expected to continue if production levels are maintained. Continual excessive escapement to the system is not acceptable since it represents foregone benefits or unneccessary costs. Either production must be reduced to maintain the stock at a level that the habitat can support, or these fish should be harvested. Harvesting surplus coho in Cumshewa Inlet would result in increased interception of pink salmon.

Enhancement proposals in the area have also included pink salmon, although this adds another level of complexity to the problem. First, pink salmon enhancement was not successful in the previous attempts at the Pallant Creek hatchery. Pink salmon enhancement has had variable success at other facilities. Survival at Puntledge hatchery was consistently low while survival at the Quinsam facility was initially low but improved over time and was extremely good in 1986. The low pink salmon returns to the Pallant Creek hatchery may represent either poor years of marine survival or unsuitable conditions for pink salmon enhancement. Second, enhancement of three species adds considerable complexity to the operation of the facility. With timing and spacing requirements of several species overlapping during various lifestages, enhancement objectives for one may only be met at the expense of the others. Finally, the available area at the Pallant Creek site is limited. Any major expansion would require use of the area on the other side of Pallant Creek from the existing facility. This would involve considerable expense since a bridge would be necessary to cross the stream and the area would have to be cleared to prepare the site for development.

Managers are unable to determine their goals for total potential production from Cumshewa Inlet. At present existing enhancement measures are projected to produce catches of about 300,000 pieces. However, since some Cumshewa fish are captured in other areas of the Charlottes, a greater abundance of Cumshewa fish could create management problems. Management in these areas is based on observed fish abundance, and high numbers of Cumshewa fish may mask a low abundance of the local wild fish. This problem can only be resolved by improving the estimation of the proportion of Cumshewa fish migrating through other areas. However, because of uncertainty associated with the manageability of major increases in Cumshewa chum salmon abundance, enhancement plans should not involve major expansions until this problem is resolved.

6.2 Identification of Enhancement Options

Four enhancement options, which would address these concerns were selected for analysis. The options are discussed below and the adult production targets are outlined in Table 5.

Table 5.

Total production targets for Pallant and Mathers Creek stocks with each enhancement option.

	Chum Salmon		Coho Salmon		Pink Salmon (even year)	
	Eggs	Adults	Eggs	Adults	Eggs	Adults
Current Facilities						
Pallant Creek	9500000	171000	350000	7600	0	0
Mathers Creek	1100000	15800	0	0	0	0
Option E1 (Expand both facilities)						
Pallant Creek	13500000	243000	550000	12000	5000000	100000
Mathers Creek	3900000	55800	164000	2000	2500000	50000
Braverman Creek	0	0	164000	2000	0	0
Option E2 (Expand Mathers Creek facility)						
Pallant Creek	11000000	198000	158000	3400		
Mathers Creek	10000000	144000	200000	2440		
Braverman Creek			200000	2440		
Option E3 (Expand Pallant Creek facility to satellite Mathers Creek stocks)						
Pallant Creek	9500000	171000	158000	3400	0	0
Mathers Creek	5000000	72000	200000	2440	0	0
Braverman Creek	0	0	200000	2440	0	0
Option E4 (Expand Pallant Creek facility to satellite Mathers Creek stocks and increase coho salmon production)						
Pallant Creek	8700000	157000	925000	20000		
Mathers Creek	5000000	72000	200000	2440		
Braverman Creek			200000	2440		

6.2.1 Enhancement Option E1: Original Expansion Proposal

This option is the proposal for expansion identified in the Salmon Resource Management Plan (DFO, 1985). It involves expansion of both Pallant and Mathers Creek facilities. Chum, coho and pink salmon from both systems would be enhanced, and coho salmon from Pallant Creek would be used to colonize Braverman Creek. The enhancement focus is on chum and pink salmon. Additional chum salmon production would supplement production from the existing facilities, although the relative production of Pallant and Mathers Creeks would continue to be imbalanced. Enhancement of pink salmon would extend the fishing period in the area since pink salmon arrive a month earlier than chum salmon. Coho salmon production was included to compensate for the projected increase in interceptions of coho in both pink and chum salmon fisheries.

6.2.2 Enhancement Option E2: Mathers Creek Expansion

The second enhancement option involves expansion of Mathers Creek hatchery only. It would focus on chum salmon to provide a more balanced enhancement of Pallant and Mathers Creek chum salmon stocks. Mathers Creek coho salmon would also be enhanced to withstand increased interceptions. Pink salmon are not included in this enhancement option. There would also be a minor amount of increased production of Pallant Creek chum salmon because some of the current capacity at the Pallant Creek facility has been used for satelliting Mathers stocks. Some coho salmon production at the Pallant Creek facility would be redistributed to colonize Braverman Creek.

6.2.3 Enhancement Option E3: Pallant Creek Expansion

This enhancement option involves expansion of the existing Pallant Creek facility. The expansion is limited by the available space at the site. It is not cost effective to build on the other side of the river until a major expansion is proposed. However, since fisheries managers are uncertain as to whether a substantial increase in Cumshewa chum salmon would create management problems in other areas of the Charlottes, a major expansion is not advisable.

In this option, expansion of the Pallant Creek facility is focussed on increasing the capacity for satelliting Mathers chum salmon on the existing site. This strategy is meant to provide a better balance between Pallant and Mathers stocks, allowing the Mathers stock to increase. Mathers coho would also be enhanced and satellited to the Pallant Creek facility. Some Pallant Creek coho salmon would be transplanted to Braverman Creek, to reduce excessive escapement to Pallant Creek. Experimental small scale pink salmon enhancement of the Pallant Creek even year stock is also included in this proposal. The rationale for including pink salmon in this proposal is to determine the feasibility of enhancing this species.

6.2.4 Enhancement Option E4: Coho Salmon Production

This option tests the proposal to increase coho salmon production from Pallant Creek to a level where a net fishery could be targetted on these fish. Production of Pallant chum salmon would have to be reduced to accommodate the additional coho salmon because of the limited space for expansion at Pallant Creek. This option involves a management decision to forgo pink salmon production in Cumshewa Inlet, since it is likely that pink salmon stocks would decline due to interceptions in the coho salmon fishery. Since coho and chum salmon would be the major species harvested in the area, it was decided that the Mathers Creek chum salmon stock should also be enhanced further to ensure its viability. Therefore, the satelliting option involving incubation of Mathers Creek salmon eggs at the Pallant Creek hatchery was included in this example.

Fisheries management would involve a small coho net fishery in Cumshewa Inlet in late August. The fleet would be drawn to the area slightly earlier than normal for the chum salmon fishery, and would then be present for an early chum fishery. The coho fishery could also provide information regarding arrival of the chum stocks. Since pink salmon interceptions are not a concern with this management approach, the early chum salmon fishery would be acceptable except for problems associated with the Mathers chum stock.

7.0 EVALUATION METHODS AND CRITERIA

7.1 Biological Modelling

A mixed-stock fisheries computer model was used to simulate the stock and fisheries dynamics associated with each of the management and enhancement options identified for Cumshewa Inlet (Staley, 1985). It includes several aspects of the population biology of salmon, such as simple stock-recruitment relationships, age structure, migration, and relative vulnerabilities of stocks to various fishing strategies. The major dynamics of fisheries such as their gauntlet behavior, the interception of non target stocks and the relative price and quality of various harvesting strategies are also represented in the model. The model was used to project catch by stock in each fishery and escapement by stock over a 40-year period.

The model can account for the effects of enhanced production on natural stocks in a fishery. If several stocks are vulnerable to the fishery, and the fishery is managed to harvest the enhanced fish, as is the case in Cumshewa Inlet, the wild stocks with lower productivities will likely be overharvested. This presumed reduction in wild populations results in foregone production and represents some of the opportunity cost of enhancement.

The model also accounts for uncertainty in both the biological and harvest dynamics. The productivity of the stocks includes a stochastic component which is based on the variance of the estimated recruits per spawner. This simulates recruitment variability similar to that which would occur in response to variable environmental conditions.

Uncertainty in fisheries management can result in either over harvesting or over escapement of stocks. The model simulates the uncertainty in management by incorporating a fishery with a variable harvest rate depending on fish abundance. With low fish abundance, stocks would be over harvested and future production would be forgone. If fish abundance is high, there may be over escapement of some stocks. The surplus escapement would represent foregone catch and would not contribute to future production since it presumably exceeds the capacity of the system.

The Cumshewa Inlet analysis model is based on 15 stocks and 9 fisheries. The stock information is summarized in Table 6. The wild and enhanced components of the Pallant and Mathers Creek salmon stocks are treated separately to reflect their different productivities. It was assumed that the surplus escapement of enhanced stocks would spawn with the wild

Table 6. Summary of stock data used for biological modelling.[a]

Salmon Stock Name	Average Productivity[b]	Variance in Productivity	Target Escapement[c]
Pallant Creek Chum	1.53	2.00	30000
Pallant Creek Enhanced Chum	21.15	1.00	8085
Mathers Creek Chum	1.53	2.00	20000
Mathers Creek Enhanced Chum	16.92	1.50	934
Other Chum	1.53	2.00	6000
Pallant Creek Pink	1.7	1.90	75000
Pallant Creek Enhanced Pink	13.2	1.00	0
Mathers Creek Pink	1.7	1.90	50000
Mathers Creek Enhanced Pink	13.2	1.00	0
Pallant Creek Coho	2.25	2.00	4000
Pallant Creek Enhanced Coho	27	1.00	280
Mathers Creek Coho	2.25	2.00	7500
Mathers Creek Enhanced Coho	15.25	1.00	0
Other Coho	2.25	2.00	200
Other Enhanced Coho	15.25	1.00	0

Notes:

[a] Escapement data for each stock were also input to the model based on escapements in Table 1. Escapement of enhanced stocks were based on number of eggs taken, divided by average fecundity and doubled assuming a one to one sex ratio.

[b] Age structure of all chum salmon stocks was assumed to be 27% age 3, 71% age 4, and 2% age 5. Age structure of all coho salmon stocks was assumed to be 99% age 3 and 1% age 4.

[c] Target escapements for enhanced stocks reflect the status quo option. These targets were modified as necessary for each option.

stock in the river of origin. The productivity of these surplus fish was assumed equal to that of the wild stock.

The first three fisheries represent interceptions of Cumshewa stocks in other fisheries. Management strategies used in the model are based on average estimates of harvest rates on the Cumshewa stocks. The first is the Alaskan fishery where harvest rates of 10%, 5% and 1% occur on Cumshewa pink, coho and chum salmon respectively. The second fishery represents interceptions in Canadian troll and net fisheries in Areas 1 and 3. Harvest rates in this fishery were assumed to be 23% on coho salmon, 6% on pink salmon and 1% on chum salmon. The third fishery accounts for interceptions of Cumshewa chum salmon in other Area 2E and 2W fisheries. Mark-recovery information suggests a harvest rate in the order of 10% on Cumshewa chum salmon.

The next two fisheries represent the Cumshewa Inlet pink salmon fishery. However, since pink salmon stocks are at low levels, this fishery has not operated recently and is not expected to in the future unless pink salmon stocks are rebuilt or enhanced. These fisheries were set to harvest rates of zero for the management options.

The sixth fishery is the coho salmon sport fishery in Cumshewa Inlet and in the rivers. Based on limited data, harvest rate on coho salmon was estimated at 10% in the sport fishery.

The last three fisheries represent the Cumshewa Inlet chum salmon fishery. Different strategies were used for these three fisheries to reflect the various management strategies associated with each option. In the status quo option, the seventh fishery is a variable test fishery which simulates the uncertainty in estimating fish abundance. The eighth fishery is managed to an escapement target of 50,000 chum salmon. Pink salmon are not susceptible to these fisheries, but coho salmon are assummed to have a vulnerability of 0.4. Quality of the chum salmon in these fisheries is dark red. In option 2, there is no test fishery and the eighth fishery is the quota fishery, which is managed to a catch limit of 30000 chum salmon. The last fishery is the terminal fishery which harvests to the escapement target of 38000, to provide adequate escapement to Pallant Creek for natural spawning and broodstock for the hatchery. Only wild and enhanced Pallant Creek chum salmon are susceptible to this terminal fishery. Quality of the catch is semi bright in the quota fishery and dark pale in the terminal fishery. Option 3 management strategies resemble the status quo, except that since the fisheries occur earlier they are more likely to intercept pink and coho salmon. The vulnerability of pink salmon was estimated at 0.5. The vulnerability of Pallant and the other smaller coho salmon stocks was estimated at 0.6 while the vulnerabililty of Mathers Creek coho salmon remained at 0.4 as in the status quo because it has a later timing and would not likely have increased interceptions. The quality of the chum salmon catch in these fisheries was conservatively estimated as semi bright.

7.2. Benefit Cost Analysis

7.2.1. Price Projections

Prices were based on price projections from a computer model developed by the Regional Planning and Economics Branch of DFO. This model considers price as a function of world supply of salmon from major salmon producing countries, change in consumer incomes and price of competing products. Consumer incomes were found to be the major factor driving demand. Since

Canada is a price-taker in the world market, it was assumed that incremental production from stock rebuilding or enhancement would not affect price.

Net wholesale prices were used in this benefit cost analysis. This net wholesale price represents the gross wholesale price minus harvesting and processing costs. Harvesting and processing costs varied by species and grade but were assumed constant over time. These costs were based on average variable costs because it was assumed that the existing capital investment in boats and processing facilities was adequate to handle the incremental catch.

Net wholesale prices were considered to be the best estimate of total benefit to Canadians, since the majority of the product is exported and this price captures net benefits accruing to fishermen and processors.

Prices are estimated by species and broad product categories (fresh/frozen or cannned) and then by grade for chum salmon: silver bright, semi bright, dark red and dark pale. Estimation of these prices is difficult because processors are very secretive about product type and grading, since they want the flexibility to make inseason adjustments depending on the supply of fish and market demand. The model does not account for these changes in product shares whether a fish is sold as frozen or canned.

Although prices are generally projected to increase over 15 years, the forecasting model includes a random variable which generates unexpected fluctuations. These fluctuations could result due to unexpected changes in supply of other major producers. The stochastic component of the economic model adds variability to production from the Alaskan market because Alaska produces about half of the world's salmon and its production has a significant affect on world prices.

The price for sport caught coho salmon was estimated from average willingness to pay per angler day ($40/day) and the average catch per angler day (1/2 fish /day). There are no sport fishery effort data available for Cumshewa Inlet so averages for the B.C.coast were used. This estimate is likely high since it applies average price rather than marginal price and because the limited incidental information from sport fishermen in the area suggest that average catch is more than half a fish per day.

7.2.2. Benefit Projections

Estimates of projected catch from the mixed stock fishery model and estimates of net wholesale prices from the econometric demand model were used to estimate the value of benefits expected from each option. The results of the biological modelling provided catch by species by quality projected for 40 years.

Since prices represent dollars per kilogram, average weight of each species was used to convert commercial catch into kilograms:

$$VB(t) = C(s,q,t) \times W(s) \times P(s,q,t)$$

where VB(t) is value of benefits in year t

C(s,q,t) is catch by species by quality in year t

W(s) is average weight by species

P(s,q,t) is price by species by quality in year t

Values for sport caught coho salmon were based on a price of $80 per fish.

The incremental value of each option was determined by subtracting the benefits expected with the status quo from the benefits expected with each option.

VB(opt) = VB(opt) - VB(status quo)

The present value of the incremental benefit of each option was calculated using discount rates of 5, 10, and 15 %.

7.2.3 Cost Analysis

It is difficult to assess management costs associated with Cumshewa Inlet fisheries management since it is part of a statistical area and costs are not easily separated for individual components within an area. Although costs should be separated to determine the cost effectiveness of current management of the fisheries, this was not within the scope of this analysis. Here, it is assumed that the same amount of dollars will continue to be spent in Cumshewa Inlet. Each option is evaluated with respect to the incremental change in costs compared to current management. The results of the cost analysis will indicate whether more or less dollars will be required for management associated with each option. All analysis is relative since some management action will be taken in this study area.

7.2.4. Benefit Cost Analysis

The net value of each option was calculated by subtracting the incremental costs from the incremental benefits. The net present value (NPV) of each option was determined using 5, 10 and 15% discount rates.

Rank ratios were also calculated for each option and discount rate as an indication of cost effectiveness. Rank ratios represent the ratio between value of benefits and government dollar spent. The ratio can be used in choosing among several projects when there are budget constraints.

7.3 Evaluation Criteria

The objective of this management plan is to provide direction for fisheries managers to effectively manage the salmon resources of Cumshewa Inlet providing maximum long-term economic benefits to Canadians. This broad statement involves two major components: the status of the resource, and the economic value received from it. These two criteria were used to evaluate the various management and enhancement options.

Each management and enhancement option is evaluated based on the results of the biological modelling and benefit cost analysis as well as consideration of other factors which were not accounted for by these more quantitative methods. The most critical results of the analysis are the projected escapement trends for each stock and the net present value estimated from the benefit cost analysis. Stock escapement trends reflect the condition of the stock and its ability to provide future benefits. Under escapement indicates a loss of future production from a stock and over escapement represents foregone catch. The economic value of the options reflects the relative benefits to be achieved from each option.

This analysis considers these indicators and other relevant factors in recommending the option which best meets the objectives. There are trade-offs that also have to be considered.

Specific evaluation criteria used in this analysis are:

1) the benefit cost analysis as measured by the incremental change in net present value (NPV) from the status quo,
2) cost effectiveness as measured by the rank ratio,
3) the ability to achieve target escapements in both Pallant and Mathers Creek stocks as measured by the projected escapement as a percent of target,
4) the fishing season characteristics including average catch, timing and duration, and fish quality, and
5) the risks involved with each option.

8.0 EVALUATION OF MANAGEMENT OPTIONS

8.1 Results of Biological Modelling

Results of the simulation modelling indicate that the management strategies associated with each option had different effects on escapement trends projected for Cumshewa Inlet stocks. Pallant Creek chum salmon were predicted to exceed target escapement under the status quo (option 1) and early fishery (option 3 and 3A) options but would have an average escapement at the target level of 30,000 spawners with option 2, which includes the quota and terminal fisheries (Figure 3). Escapement of Mathers chum salmon was predicted to average less than 5,000 spawners with status quo management (Figure 4). In option 2, Mathers chum salmon stocks would rebuild within 5 years and continue to increase, exceeding the target of 20,000 spawners (Figure 4). The management strategy of harvesting the fish as they arrive in the inlet (option 3)is projected to rapidly drive the Mathers chum salmon stock to extinction unless area restictions prove to be successful (option

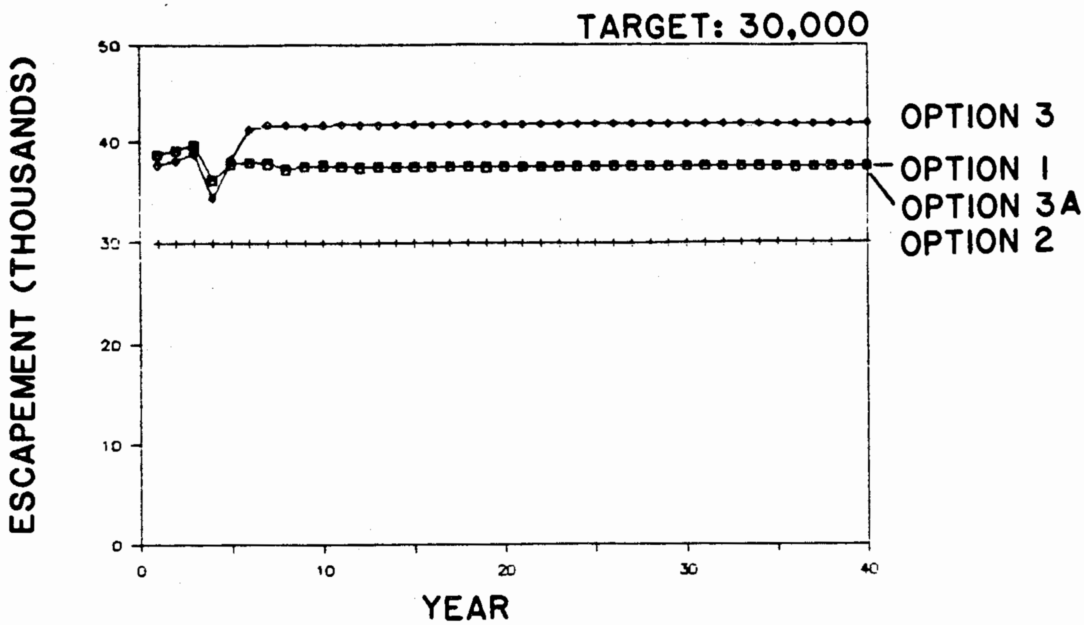


Figure 3. Pallant Creek chum salmon escapements projected over the next 40 years for each management option.

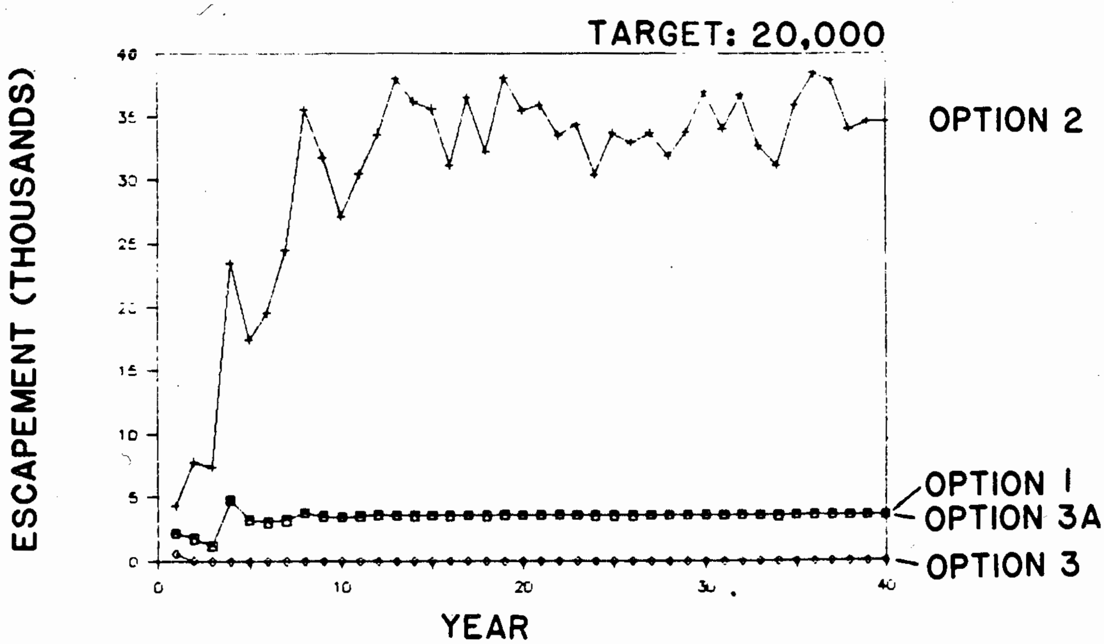


Figure 4. Mathers Creek chum salmon escapements projected over the next 40 years for each management option.

3A) in reducing harvest rates on Mathers chum salmon (Figure 4). The Carmichael and Chadsey chum salmon stocks are predicted to become extinct in options 1 and 3, but would be maintained at low levels in option 2.

Pink salmon stocks are not likely to be affected by options 1 and 2 because the Cumshewa chum salmon fisheries occur after the pink salmon have entered their spawning streams. Under these management conditions, even year pink salmon escapements to Pallant Creek are projected to average 62,000 spawners compared to a target of 75,000 (Figure 5). Mathers even year pink salmon escapements are predicted to increase but would not achieve their target of 50,000 spawners within 40 years (Figure 6). Pink salmon escapements to both systems are projected to decline under the management conditions in option 3 and 3A (Figures 5 and 6). The model projects rebuilding of the odd year pink salmon stocks in both Pallant and Mathers Creeks. However, rebuilding of the odd year stocks is unlikely since these stocks have not had significant harvest pressures in the past and have not shown any indication of rebuilding. These stocks may have lower productivity rates than the even-year stocks, but the model assumes the same rate of return for both runs. Therefore, the projected trend is not likely representative of future odd-year pink salmon production.

The projected coho salmon escapements to Pallant Creek are different for each option. Under status quo conditions, escapement would average about 7,500 spawners (Figure 7). In option 2, coho salmon escapements would be higher, averaging 10,500 spawners, since the main chum salmon fishery would occur at the end of the coho salmon run. Coho salmon escapement is projected to average 6,000 spawners under the option 3 management scenario and 5,800 if

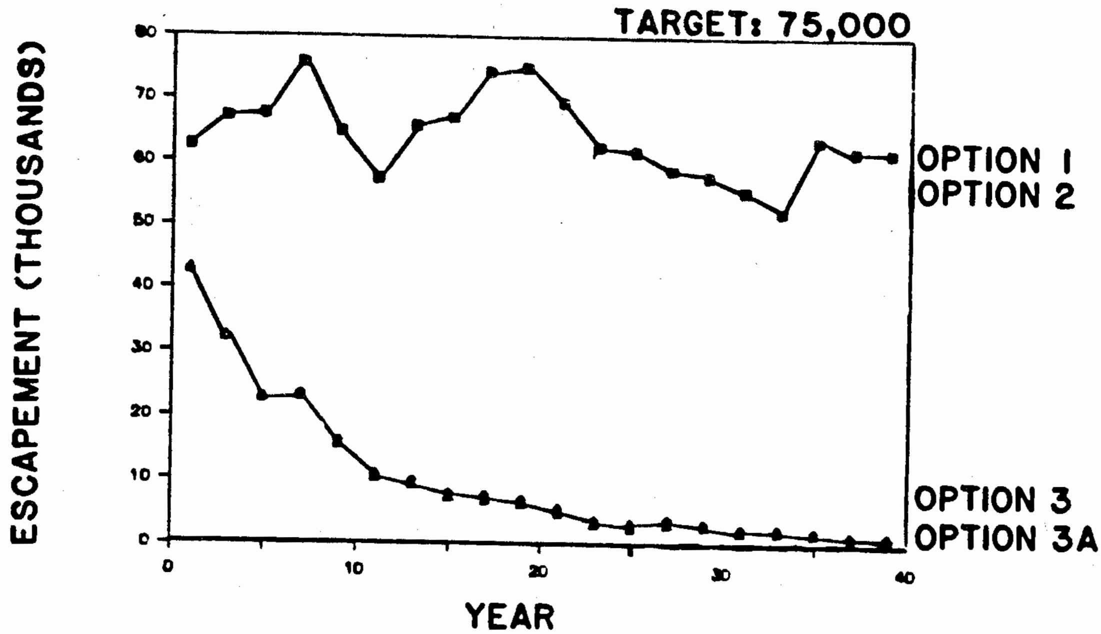


Figure 5. Pallant Creek even year pink salmon escapements projected over the next 40 years for each management option.

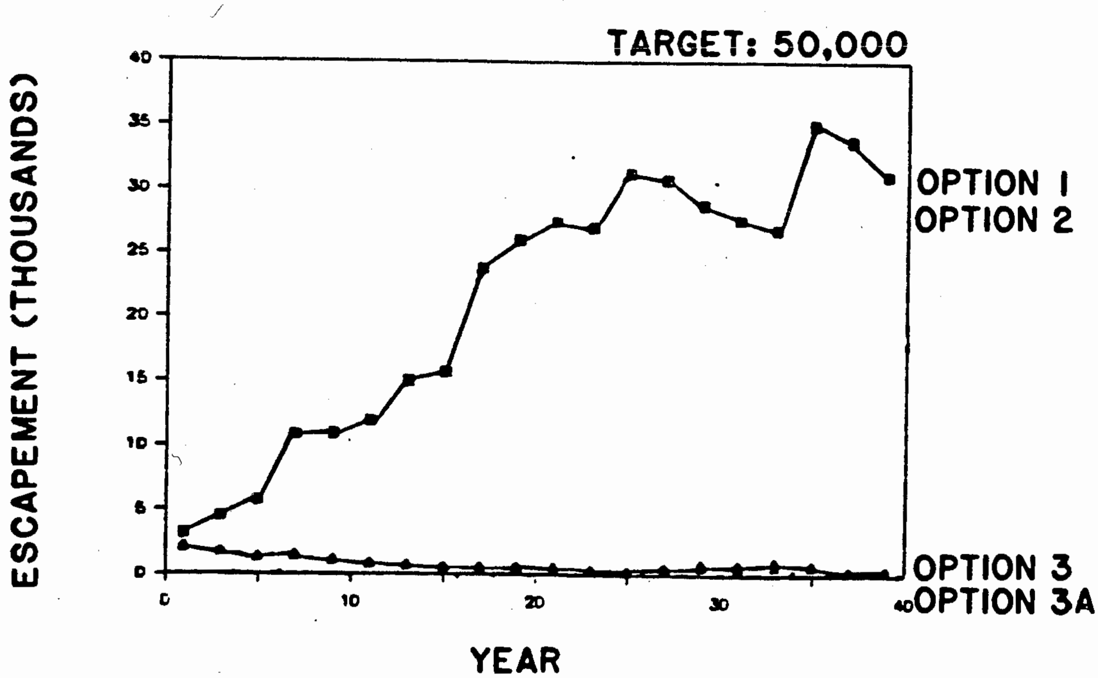


Figure 6. Mathers Creek even year pink salmon escapements projected over the next 40 years for each management option.

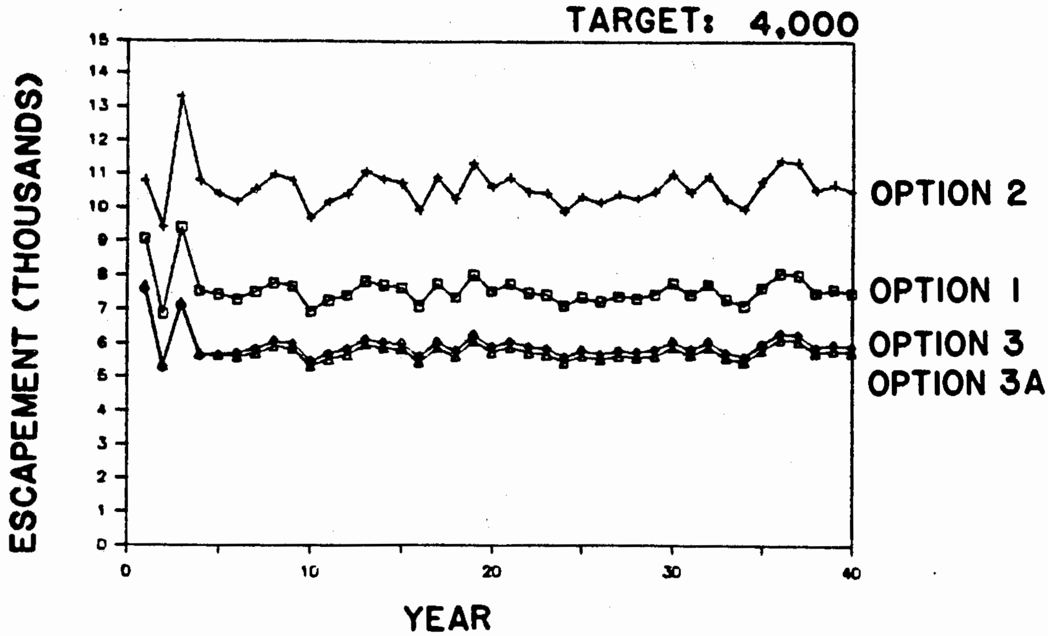


Figure 7. Pallant Creek coho salmon escapements projected over the next 40 years for each management cycle.

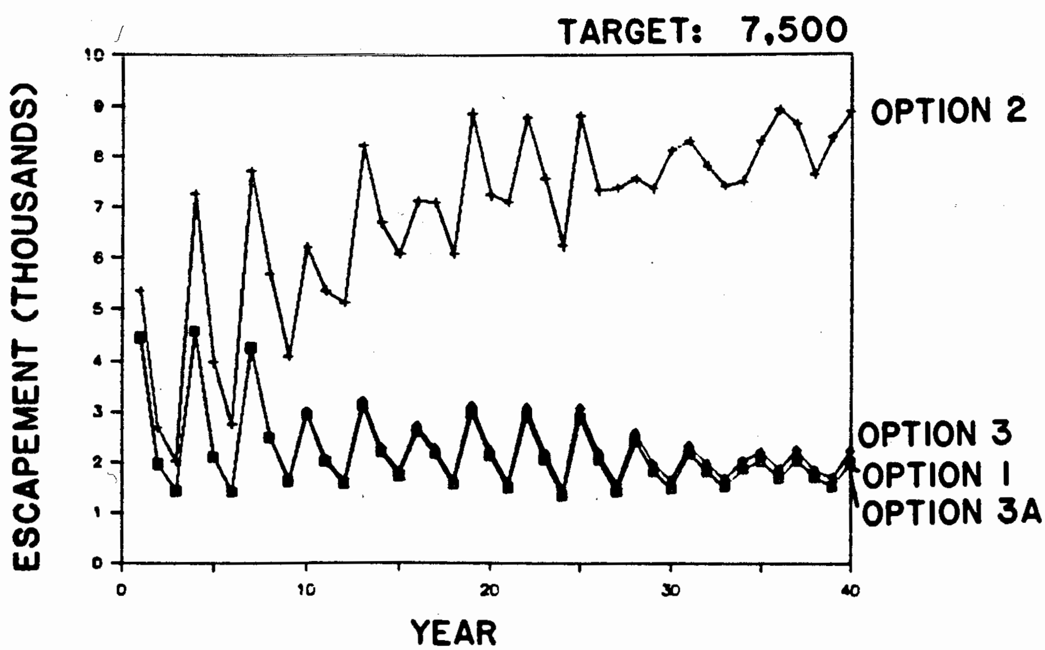


Figure 8. Mathers Creek coho salmon escapements projected over the next 40 years for each management option.

the restriction option is imposed (Figure 7). Escapement of coho salmon to Mathers Creek is projected to be similar in options 1, 3 and 3A, averaging about 2,200 spawners (Figure 8). Under option 2, Mathers Creek coho salmon escapements increase over time, averaging 7,000 over the 40 year period. The other minor coho salmon stocks are projected to gradually decline with options 1 and 3 but would be maintained at relatively low levels (<200) in option 2. Escapement targets for coho salmon have not been identified for Cumshewa Inlet streams. However, based on observations in recent years, Pallant Creek appears to have a capacity for about 4,000 coho salmon. In the past Mathers has supported populations in the order of 7,500 coho salmon spawners. Other streams in the area have not supported significant populations in the past but may through the aid of colonization. Since there is no evidence to support an estimate of the optimum, the escapement to these streams is not evaluated with respect to a target.

The projected catch of chum salmon was the same for option 1, 2 and 3A averaging 186,000 pieces annually (Figure 9). The quality of catch was quite different between these three options, with the majority of the catch varying in quality from dark red in option 1, dark pale in option 2 amd semi bright in option 3A. Projected catch of chum salmon in option 3, without area restrictions, averaged 168,000 pieces and was estimated to be mostly semi bright quality (Figure 9).

The projected catch of even-year pink salmon averaged 15,000 in both option 1 and 2 (Figure 10). All these pink salmon were intercepted in fisheries outside of Cumshewa Inlet. Under option 3 and 3A, catch of pink salmon was projected to be substantially higher (30,000 pieces) than with the

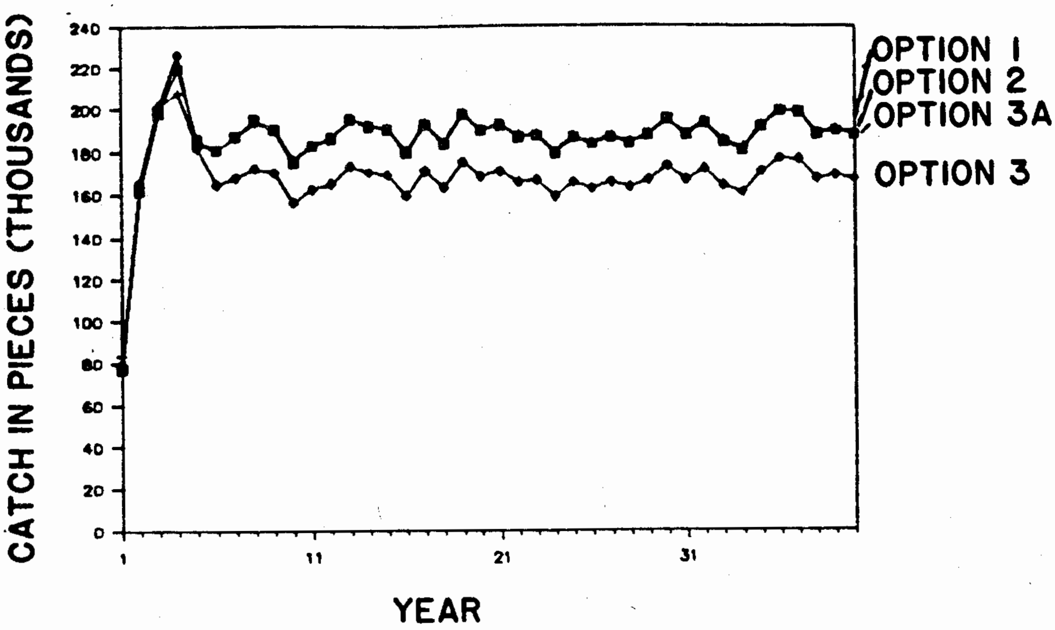


Figure 9. Total catch of Cumshewa Inlet chum salmon in all fisheries projected over the next 40 years for each management option.

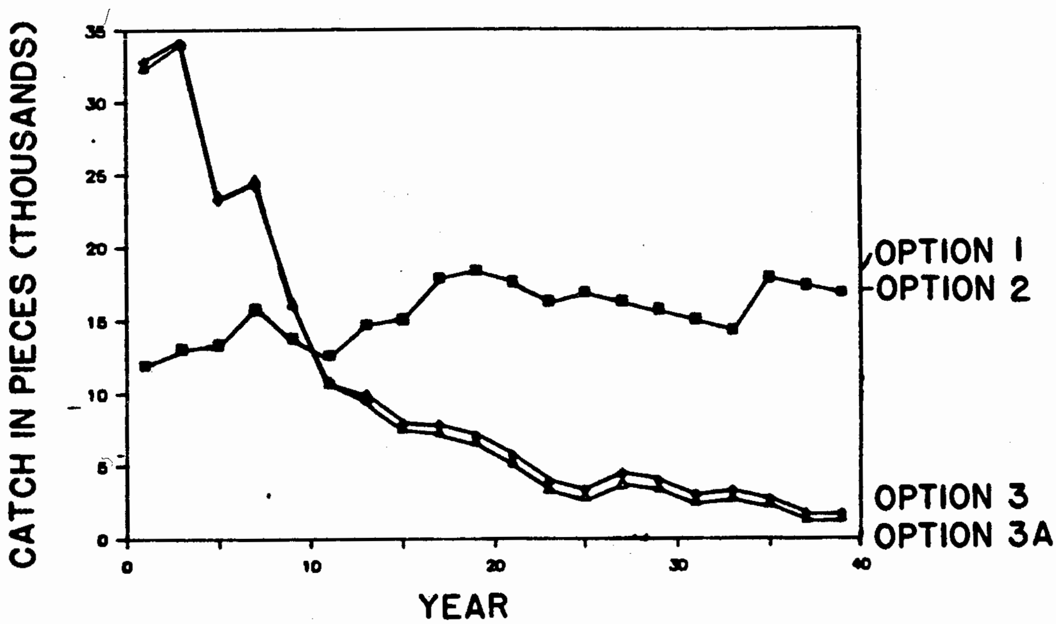


Figure 10. Total catch of Cumshewa Inlet even year pink salmon in all fisheries projected over the next 40 years for each management option.

other two options in the first few years because of increased interceptions in Cumshewa Inlet, but then rapidly declined as the stocks were depleted due to over harvesting (Figure 10).

Total coho salmon catch was projected to average 11,000 pieces in option 1, 10,000 pieces in option 2, 8,000 pieces in option 3 and 13,000 pieces in option 3A (Figure 11). Sport catch in all options was projected to be substantially higher than the current estimates of 500 coho salmon. Sports catch in options 1, 3, and 3A was predicted to be about 1,600 fish while catch in the option 2 scenario was estimated at 2,100 pieces. The net catch of coho salmon in Cumshewa Inlet varied because of differential interceptions with each management strategy with 1,000 pieces projected for option 2 to 4,800 pieces for option 1 and 6,100 pieces for options 3 and 3A. The remainder of the catch in each option was caught in the troll fishery.

8.2 Benefit Cost Analysis

Benefits of each option were estimated using the projections of the biological simulation model and the price projections. The estimated value of the catch and incremental benefits of each option compared to the status quo (option 1) are shown in Table 7.

In assessing costs associated with each option, only variable costs were considered. The relative time that fishery officers and management biologists spend in the management of Cumshewa Inlet fishery was assumed to remain the same for each option. Costs associated with the existing enhancement activities were also assumed constant for each option. The variable costs include the costs for the operation of the test fishery and for monitoring the fishery with patrolmen and guardians.

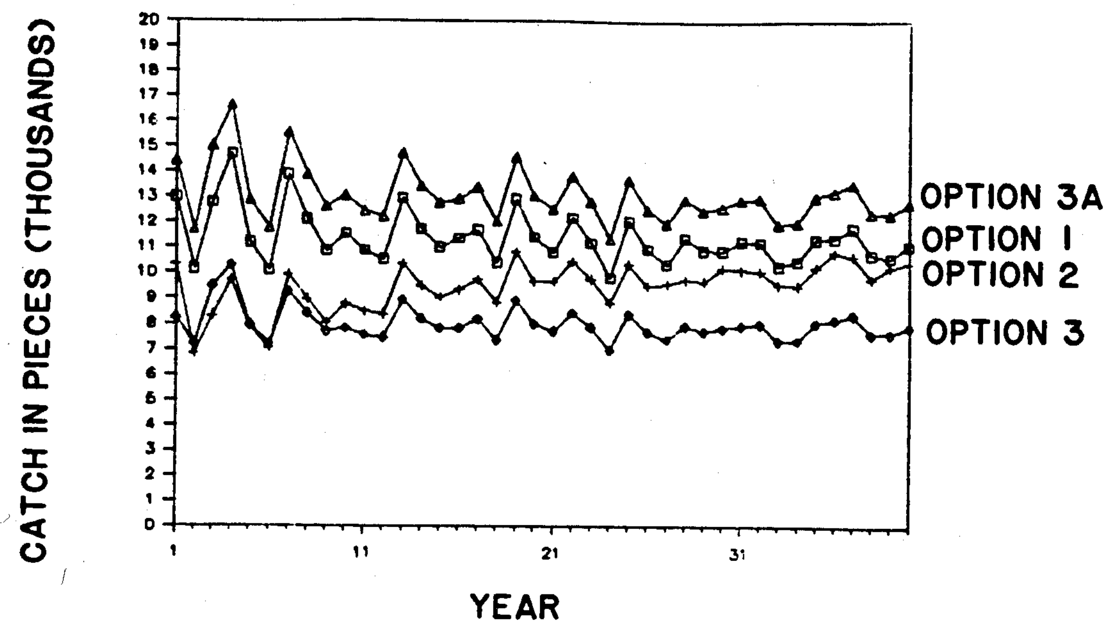


Figure 11. Total catch of Cumshewa Inlet coho salmon in all fisheries projected over the next 40 years for each management option.

Table 7. Projected value of benefits (dollars) for each management option.

Year	TOTAL VALUE OF BENEFITS				INCREMENTAL BENEFIT FROM STATUS QUO			
	OPT1	OPT2	OPT3	OPT3A	OPT1	OPT2	OPT3	OPT3A
1	604880	600534	841953	824078	0	-4345	237074	219199
2	172675	33882	418696	414017	0	-138792	246021	241343
3	1981498	1518584	2790236	2754013	0	-462914	808738	772514
4	392227	162955	763583	751940	0	-229272	371357	359713
5	1175153	864397	1658982	1689228	0	-310755	483829	514076
6	242564	71516	489297	514430	0	-171048	246734	271866
7	1298160	991047	1653159	1803369	0	-307113	354999	505209
8	361547	185930	623510	671074	0	-175617	261963	309527
9	1055837	789233	1383370	1512623	0	-266604	327533	456786
10	1176522	920180	1525602	1680317	0	-256342	349080	503794
11	905853	680989	1171319	1281342	0	-224864	265466	375488
12	1051028	803907	1383934	1526939	0	-247122	332905	475911
13	3291492	2741597	3830451	4263330	0	-549895	538959	971838
14	2608313	2140850	3145706	3498907	0	-467463	537393	890594
15	3237042	2694945	3782385	4220241	0	-542097	545343	983199
16	3001840	2512227	3559915	3975768	0	-489613	558075	973928
17	3307468	2759469	3830115	4272647	0	-547999	522647	965179
18	3041851	2539539	3615254	4039663	0	-502311	573404	997813
19	3402907	2838217	3936234	4386993	0	-564690	533327	984086
20	3161006	2632419	3744147	4182824	0	-528587	583141	1021818
21	3278330	2749586	3796067	4237481	0	-528744	517736	959151
22	3158200	2648109	3708233	4139008	0	-510091	550033	980809
23	3202113	2692109	3708609	4139022	0	-510004	506496	936910
24	2975300	2507756	3512692	3927329	0	-467544	537392	952029
25	3207731	2701639	3702905	4129194	0	-506092	495174	921463
26	3063704	2574312	3612594	4035686	0	-489392	548890	971983
27	3165285	2675029	3667496	4094301	0	-490256	502211	929016
28	3072834	2574397	3628982	4051187	0	-498437	556148	978353
29	3185345	2681577	3694103	4121851	0	-503768	508758	936506
30	3240189	2716845	3820408	4266405	0	-523344	580219	1026216
31	3187402	2689653	3700204	4128726	0	-497749	512802	941325
32	3212503	2688545	3794800	4237870	0	-523958	582297	1025367
33	3115268	2636578	3624238	4046198	0	-478690	508970	930930
34	3007113	2540669	3546205	3961677	0	-466444	539092	954564
35	3272942	2759129	3773425	4212150	0	-513813	500484	939209
36	3327156	2792575	3902276	4356160	0	-534580	575120	1029004
37	3377617	2830976	3906619	4358402	0	-546641	529002	980785
38	3153229	2653835	3689262	4120890	0	-499394	536033	967661
39	3224476	2731455	3726215	4161415	0	-493021	501740	936939
40	3148656	2662992	3695311	4126365	0	-485663	546656	977709
NPV@5%	33696468	27423729	41373940	45362850	0	-6272739	7677472	11666382
NPV@10%	15011134	11963880	19108466	20645424	0	-3047254	4097332	5634290
NPV@15%	8280190	6470346	10941925	11632626	0	-1809844	2661735	3352436

The difference in costs between the status quo option and the other options are identified in Table 8. Under the status quo scenarios it was assumed that the test fishery would be operated each season for about 40 days similar to past operations. It was estimated that a patrolboat would be required for 6 weeks.

Under option 2, operation of the test fishery would be extended to 50 days to provide better information for the early part of the run. A patrol boat would be required for one week early in the chum fishing season and again for 3 weeks late in the fall. A guardian would also be required to monitor fish abundance and enforce the closure during the period between the quota fishery and the terminal fishery.

The test fishery would not be required with option 3 and 3A because inseason abundance estimates are not necessary since the fisheries are open to catch newly arriving fish and are not designed to wait for a build up of abundance. A patrol boat would be required on a regular basis for the 6 week period of the fishery.

The variable costs for each option are assumed to remain constant from year to year (Table 8). Option 2 has the highest variable costs with a present value of about $555,000 discounted at 10% over 40 years while options 3 and 3A have the lowest variable costs at $189,000. The present value of variable costs associated with the status quo option were estimated at $483,000.

The incremental change in the net present value (NPV) from the status quo is shown for each option in Table 9. Option 1 is the status quo and therefore does not have any change in NPV since it is being compared to

Table 8. Projected costs (dollars) for each management option.

	Annual Variable Costs			
	Option 1	Option 2	Option 3	Option 3A
Test Fishery				
Days	40	50	0	0
Cost*	30000	37500	0	0
Patrol Boat				
Days	30	20	30	30
Cost**	19350	12900	19350	19350
Guardian				
Days	0	30	0	0
Cost***	0	6300	0	0
Total Variable Cost	49350	56700	19350	19350
Present Value of Costs Discounted over 40 Years				
Discount rate at 5%	774183	889487	303555	303555
Discount rate at 10%	452138	519477	177282	177282
Discount rate at 15%	316739	363913	124192	124192
Incremental Costs Compared to Status Quo				
Discount rate at 5%	0	115304	-470628	-470628
Discount rate at 10%	0	67340	-274856	-274856
Discount rate at 15%	0	47174	-192546	-192546

Notes
* Cost of test fishery estimated at $750/day from previous years.
** Standard cost of patrol boat is $645/day.
*** Standard cost of guardian is $210/day.

Table 9. Benefit cost analysis of management options.

Incremental Benefits (dollars) Compared to Status Quo

	Option 1	Option 2	Option 3	Option 3A
Discount rate at 5%	0	-6272739	7677472	11666382
Discount rate at 10%	0	-3047254	4097332	5634290
Discount rate at 15%	0	-1809844	2661735	3352436

Incremental Costs (dollars) Compared to Status Quo

	Option 1	Option 2	Option 3	Option 3A
Discount rate at 5%	0	115304	-470628	-470628
Discount rate at 10%	0	67340	-274856	-274856
Discount rate at 15%	0	47174	-192546	-192546

Incremental Change in Net Present Value Compared to Status Quo

	Option 1	Option 2	Option 3	Option 3A
Discount rate at 5%	0	-6388043	8148100	12137010
Discount rate at 10%	0	-3114594	4372187	5909145
Discount rate at 15%	0	-1857018	2854282	3544982

itself. A lower NPV in the order of $3.1 million (at 10% discount rate) is projected in option 2. Option 3 and 3A are projected to have net benefits over the status quo in the order of $4.4 and $5.9 million respectively.

Cost effectiveness of the options was analyzed using incremental benefits and costs. Option 2 is the least cost effective because it results in fewer benefits than in the status quo scenario yet requires higher costs for management of the fishery. Option 3 and 3A are most cost effective because they result in greater benefits and lower costs than projected in the status quo option.

8.3 Other Considerations

Other factors considered in the evaluation of the options include the period of the fishing season, fish quality and risks. The fishing season duration would be about the same for all options at about one and a half months except for Option 2 in which the fishing period would be only 1 month. The timing of the fisheries varies between options. In the status quo option, the fishery would occur between mid-September and late October. In option 2, the fishing period would be split between early September for the quota fishery and late October for the terminal fishery. The fishing season would be from early September to mid-October under options 3 and 3A. Fishermen prefer earlier fisheries because weather conditions deteriorate during the fall.

Fishermen's preference for early fisheries is also related to fish quality and the landed value of the product. Price of the catch at the end of the season can vary depending on the success of the commercial fishery during earlier openings. Although fish quality is reflected in the benefit cost analysis, it is also included in this section because of fishermen's concerns. In option 1 the majority of the catch is dark red quality, in option 2 it is dark pale and in options 3 and 3A it is semi bright chum salmon.

The biological risk associated with each management strategy varies. In the status quo option, the risk factor is rated as moderate because uncertainties associated with managing the fishery could result in greater impact on the Mathers Creek chum salmon stock than projected. In option 2, the risk factor is low because the fishery will be delayed until there is a good indication that escapement targets would be met. However, although the biological risk is low, there is a good possibility with this option that the stocks may be under harvested and some catch would be foregone if the fish move into the streams before the fishery is open. The risks in managing the fisheries in option 3 and 3A are high because of uncertainty in estimating stock size. There is a high risk that the Mathers chum salmon stock could be depleted. Although it is assumed in option 3A that the area restrictions reduce the harvest rate on the Mathers chum salmon stock it is questionable whether this assumption is valid. There is also a risk that escapement targets to Pallant Creek may not be achieved. Since most of the production is from enhanced stocks, this is not considered a significant concern unless the brood stock requirements are not met. As indicated previously, this risk could be reduced by seining the broodstock prior to fishery openings.

8.4 Summary

The evaluation of each option is summarized in Table 10. All results should be compared to option 1 , which represents the status quo.

In option 2, the Mathers Creek chum and coho salmon stocks rebuild to much higher levels than projected in the status quo option. However, this management strategy results in a much lower NPV than option 1. The estimated difference in NPV is $3.1 million. This option is not likely to receive support from the industry because fish quality would be poor and the fishing season would be split into two time periods, one of which would be late in the season. This is the safest option in terms of minimizing risk to stocks in the area although the cost of rebuilding these stocks is high.

Option 3 is projected to result in an increase in NPV of $4.4 million over that projected in option 1. However, this is a high risk management scenario and is projected to result in the decline of the Mathers chum stock, both salmon stocks and minor coho stocks in the inlet. Although catch would be lower than projected in the status quo option, it would still support a good size chum salmon fishery, averaging 168,000 pieces relatively early in the season, with a good quality of catch.

The highest increase in NPV ($5.9 million) is projected in option 3A. The Mathers chum salmon stock is maintained at a low level similar to that projected under status quo management. Pink salmon stocks and the other coho salmon stocks are projected to decline. Chum salmon catch is projected at similar levels as for the base case but the quality would be much better since the fishery is earlier. The benefits of this option over option 3 are based on the assumption that the area restrictions would keep harvest rates

Table 10. Evaluation of management options.

Evaluation Criteria	Options			
	Status Quo	Quota/Terminal	Early Fishery	Early with Restrictions
Change in Net Present Value ($ in millions)	0	-3.1 M $	+4.4 M $	+5.9 M $
Cost Effectiveness	M	L	H	H
Salmon Escapement as a Percentage of Target after 40 years				
Pallant Creek Chum	125	100	140	125
Mathers Creek Chum	20	150	0	20
Pallant Creek Pink	85	85	0	0
Mathers Creek Pink	60	60	0	0
Pallant Creek Coho	190	265	150	140
Mathers Creek Coho	30	90	30	30
Average Salmon Catch				
Chum	186000	186000	16800	186000
Pink	15000	15000	declines	declines
Coho	11000	3000	8000	13000
Fishing Season				
Duration (months)	1 1/2	1	1 1/2	1 1/2
Timing	late	split early/late	early	early
Quality of Chum Salmon Catch	dark red	dark pale	semi bright	semi bright
Risks	moderate	low	high	high

on Mathers stocks at a similar level as on Pallant Creek stocks. This is a high risk option because of the uncertainty regarding this assumption and the uncertainty associated with the management strategy fishing before knowing the abundance.

It is evident that there are tradeoffs associated with all the options. The high cost to industry of foregoing better quality fish in order to rebuild the Mathers Creek chum salmon stock through management (option 2) precludes it from being an acceptable solution. The increased values associated with the early fishery options (3 and 3A) are countered by the high risk of depleting the Mathers chum salmon stock and the pink salmon stocks. The status quo is a compromise which may not be the best choice because stocks are held at relatively low levels; much greater value or higher stock levels could be achieved through alternative management strategies.

9.0 EVALUATION OF ENHANCEMENT OPTIONS

9.1 Results of Biological Modelling

The management strategy used to evaluate the different enhancement strategies varied with each option (Table 11). In the first enhancement option (E1) in which both Pallant and Mathers Creek facilities are expanded for production of pink and chum salmon, it was assumed that there would be both pink and chum salmon fisheries in Cumshewa Inlet. In the second enhancement (E2) option which involves only the expansion of the Mathers facility, two management strategies were evaluated, the normal chum salmon

Table 11. Enhancement options and associated management strategies.

Option	Enhancement Strategy	Management Strategy
E1	-expansion of both Pallant and Mathers Creek facilities -includes increased chum, pink and coho salmon	-Cumshewa Inlet would be open for a pink salmon fishery in late August and a chum salmon fishery in late September -chum salmon management strategy is same as in the Status Quo option
E2A	-expansion of Mathers Creek pilot into a major facility for chum salmon production and some coho salmon enhancement	-chum salmon fishery in Cumshewa Inlet as in the Status Quo option
E2B	-expansion of Mathers Creek pilot into a major facility for chum salmon production and some coho salmon enhancement	-chum salmon fishery in Cumshewa Inlet would be open earlier (early to mid-September) to obtain better quality catch -area restrictions would be imposed to ensure Mathers Creek chum salmon are not being harvested at a higher rate than Pallant Creek chum salmon
E3A	-expansion of Pallant Creek facility to incubate and rear (satellite) Mathers Creek chum and coho salmon -experimental pink and chinook salmon enhancement	-chum salmon fishery in Cumshewa Inlet would be open earlier (early to mid-September) to obtain better quality catch -area restrictions would be imposed to ensure Mathers Creek chum salmon are not being harvested at a higher rate than Pallant Creek chum salmon
E3B	-expansion of Pallant Creek facility to incubate and rear (satellite) Mathers Creek chum and coho salmon -experimental pink and chinook salmon enhancement	-chum salmon fishery in Cumshewa Inlet would be open earlier (early to mid-September) to obtain better quality catch -area restrictions would be imposed to ensure Mathers Creek chum salmon are not being harvested at a higher rate than Pallant Creek chum salmon
E4B	-expansion of Pallant Creek facility to increase coho salmon production and also provide increased capacity for satelliting of Mathers Creek chum and coho salmon -also some experimental chinook salmon enhancement	-a coho salmon net fishery would be open in Cumshewa Inlet in early September followed by an early chum salmon fishery with area restrictions as described above -no conservation concerns for pink salmon

fishery (E2A) and an early chum salmon fishery with restrictions (E2B) to give added protection to the Mathers Creek stock. If the Mathers Creek stock is not given this added protection it would be harvested to extinction before the enhancement was on line. These same two management strategies of normal and early timing fisheries were analyzed with the third enhancement option (E3A and E3B, respectively) of an expansion at Pallant Creek to service the Mathers Creek chum salmon stock through a satelliting strategy. In the fourth enhancement option (E4B) which involves increased coho salmon production, an early coho salmon fishery and an early chum salmon fishery are assumed. Since the objective of this option is to provide a small commercial coho salmon fishery, which will likely have a negative effect on the pink salmon stocks, it is pointless to delay the chum salmon fishery to its normal timing for the benefit of the pink salmon stocks. Again, the early chum salmon fishery assumes restrictions which are successful at providing some protection for the Mathers stocks.

The biological modelling results indicate that the escapement of Pallant Creek chum salmon stocks would be less than under status quo conditions with all the enhancement options (Figure 12). Escapement would stabilize slightly above target at 32,000 with E1, under target at 20,000 spawners with E2A and E2B, and just below the target of 30,000 with E3A, E3B and E4B. All enhancement options are projected to increase escapements to Mathers Creek but levels are predicted to remain below the 20,000 target (Figure 13). Under option E1, chum salmon escapement to Mathers would increase to about 7,000 spawners, while under the other three enhancement options, escapements would average between 10,000 and 12,000 spawners. The other minor chum salmon stocks in Cumshewa Inlet are projected to decline in all cases.

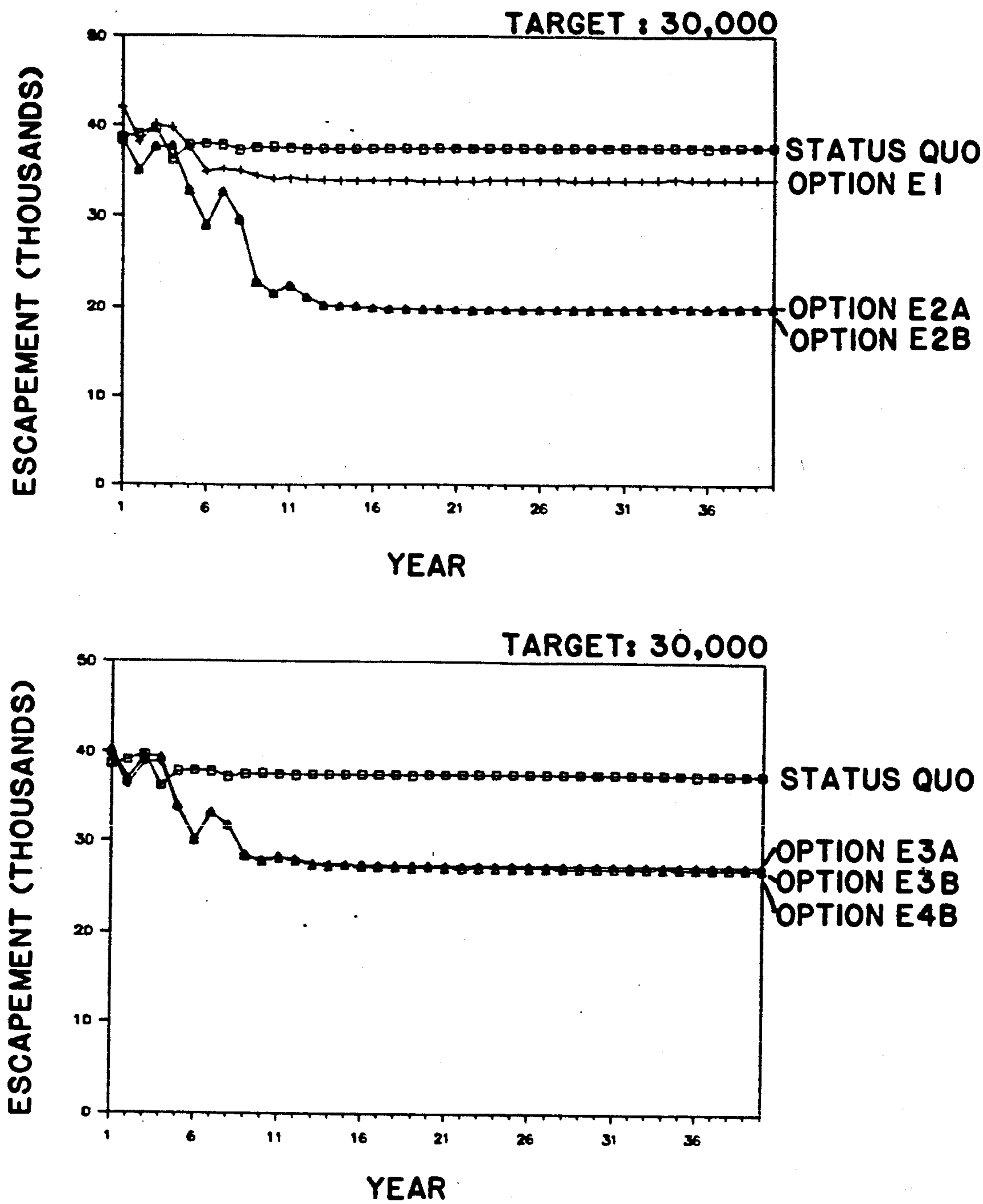


Figure 12. Pallant Creek chum salmon escapements projected over the next 40 years for each enhancement option compared to the status quo.

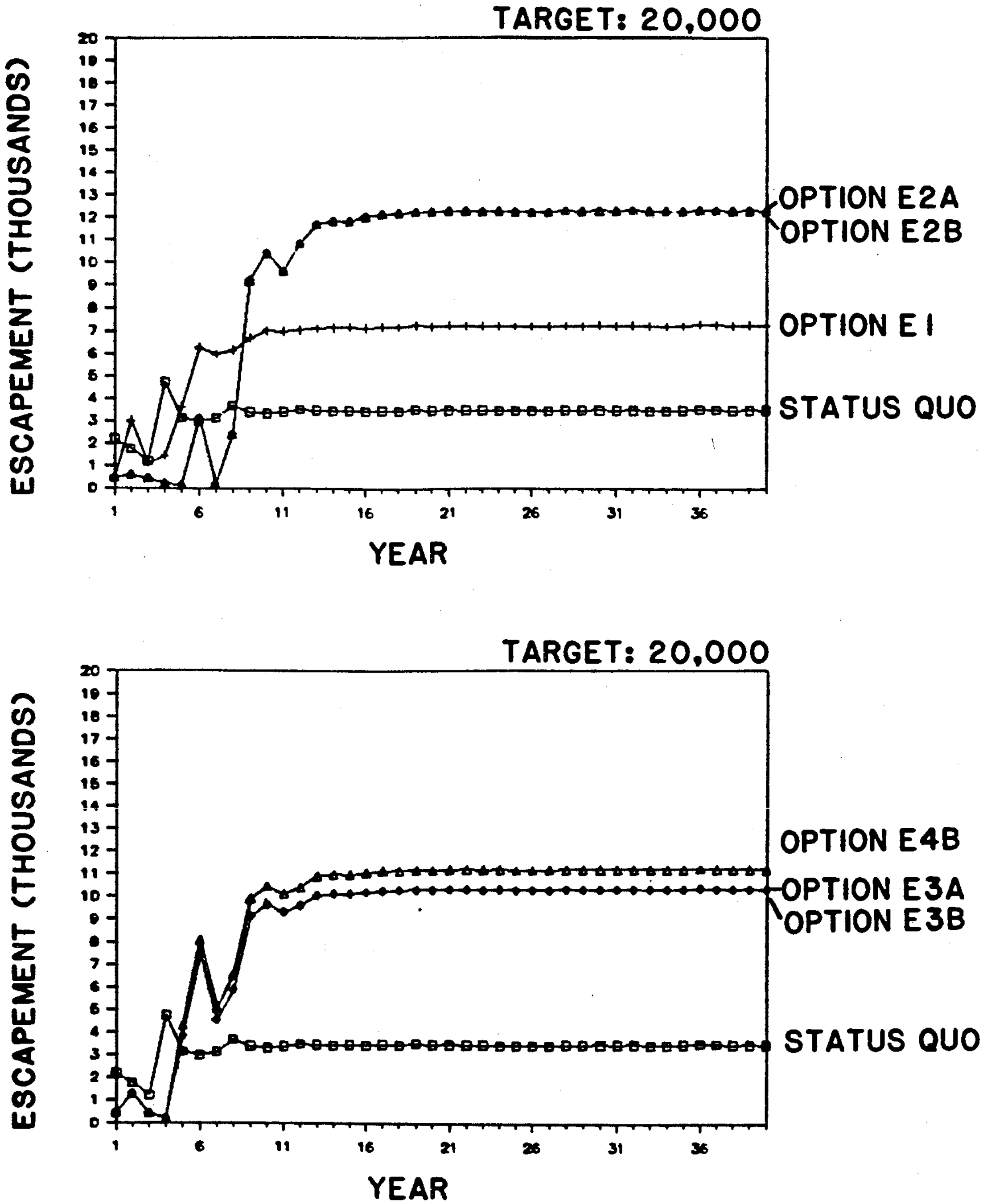
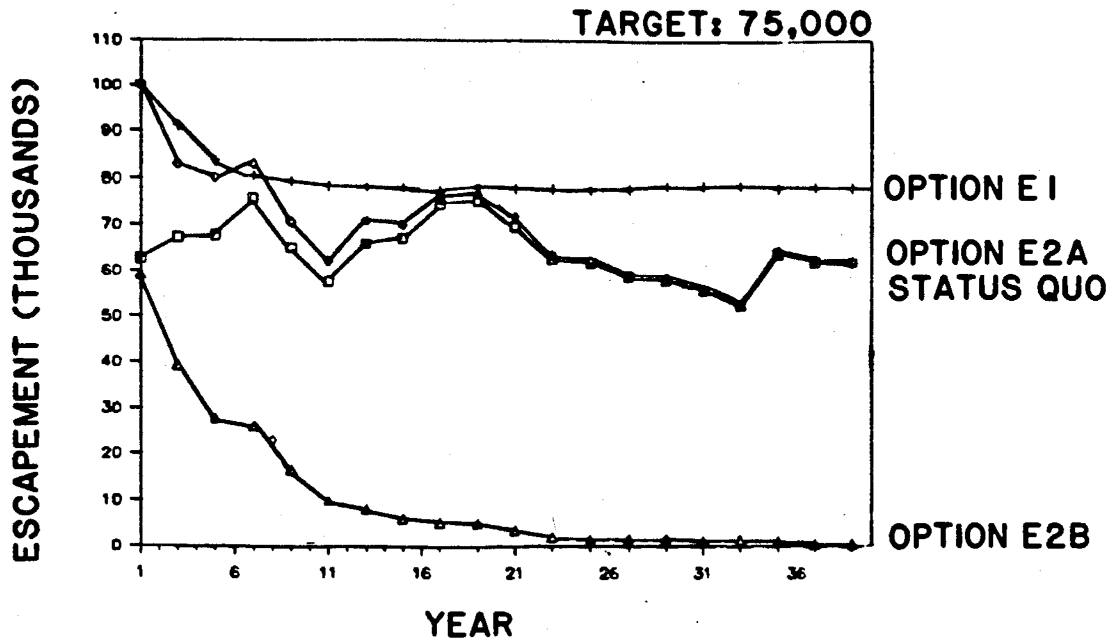


Figure 13. Mathers Creek chum salmon escapements projected over the next 40 years for each enhancement option compared to the status quo.

The projected trends in even year pink salmon escapements in Pallant Creek varied between enhancement options and were dependant on the management strategies (Figure 14). The only enhancement option involving significant enhancement of pink salmon was E1, for which escapements of Pallant Creek pink salmon were projected to remain constant near the target of 75,000 spawners. Escapements were predicted to follow similar trends as projected under the status quo option with E2A and E3A which assume that the chum salmon fishery is held during the normal period to avoid interception of pink salmon. However, when the enhancement options include the management strategy of an early fishery for chum salmon as in E2B, E3B and E4B, the pink salmon escapements in Pallant Creek are projected to decline rapidly. Escapement of pink salmon to Mathers Creek followed similar trends (Figure 15). However, the target level of 50,000 was not achieved in any of the options, the closest being the projected escapement of 35,000 with E1, the option which includes enhancement of Mathers pink salmon. As discussed previously, the trends in odd year pink salmon escapements are not representative since they are based on an assumed productivity similar to the even year stocks.

Under the status quo option, coho salmon escapements to Pallant Creek are projected to be in the order of 7,500 spawners (Figure 16). Recent escapements have been about 4,000 spawners, a number considered adequate for the creek. Under E1, the escapement of coho salmon to Pallant Creek is expected to increase to about 9,500 fish. Coho salmon escapements under the other enhancement options is projected to be less than under the status quo. With enhancement options E2A and E3A, and the management strategy of normal



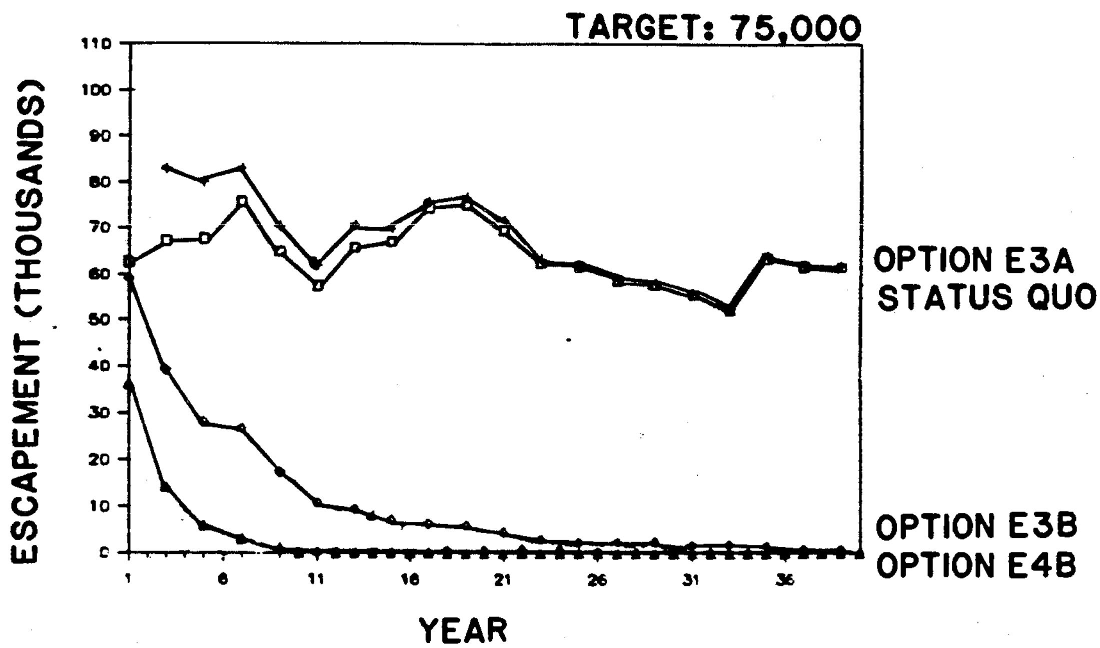
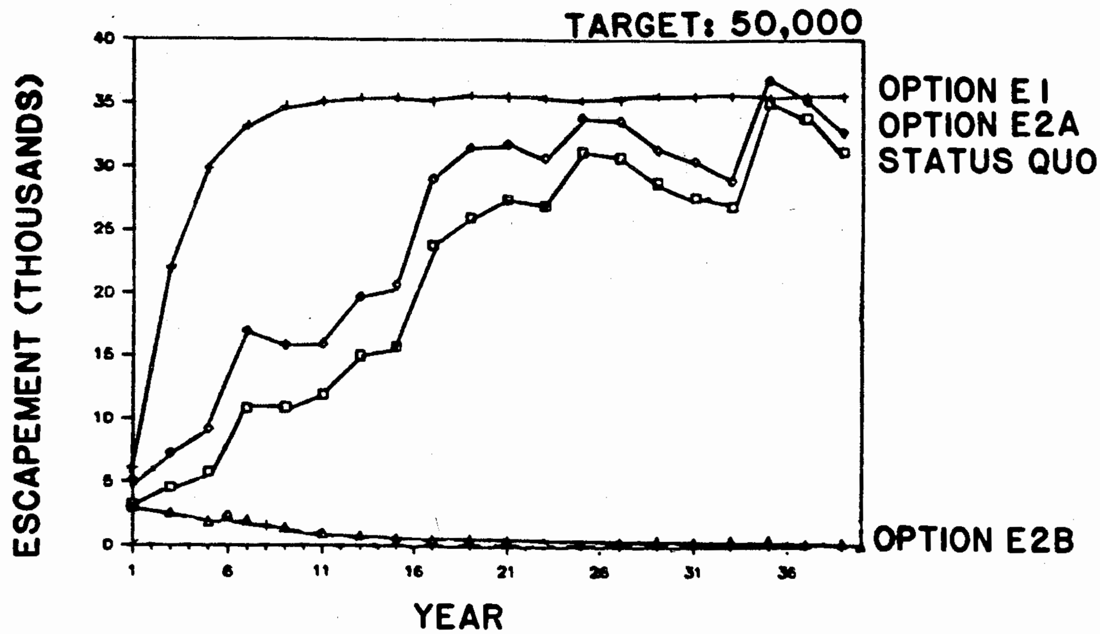


Figure 14. Pallant Creek even year pink salmon escapements projected over the next 40 years for each enhancement option compared to the status quo.



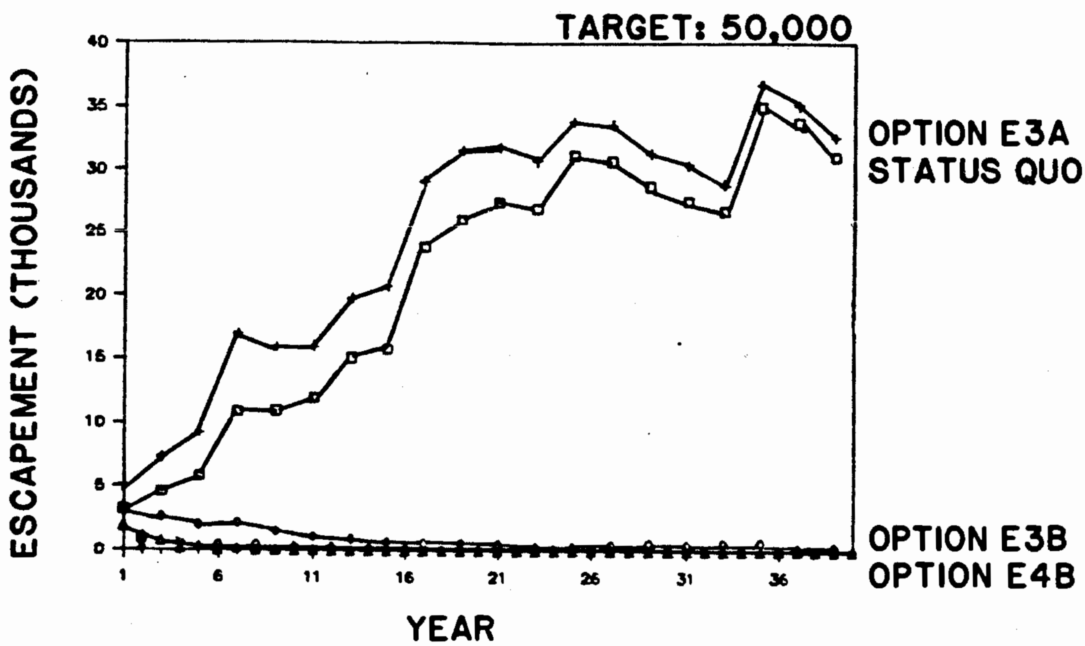
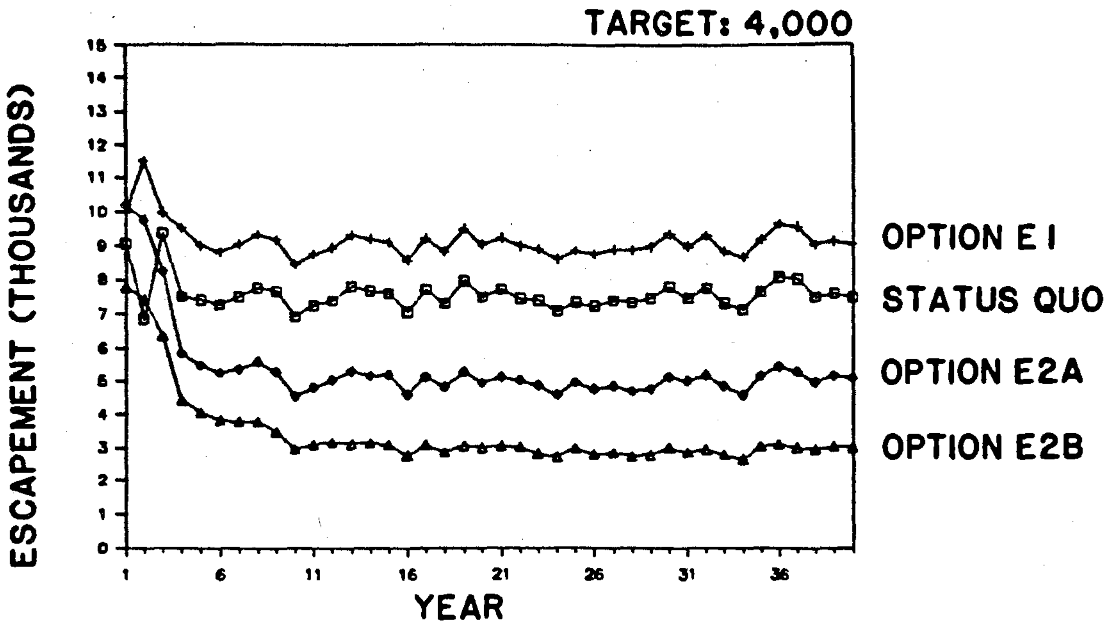


Figure 15. Mathers Creek even year pink salmon escapements projected over the next 40 years for each enhancement option compared to the status quo.



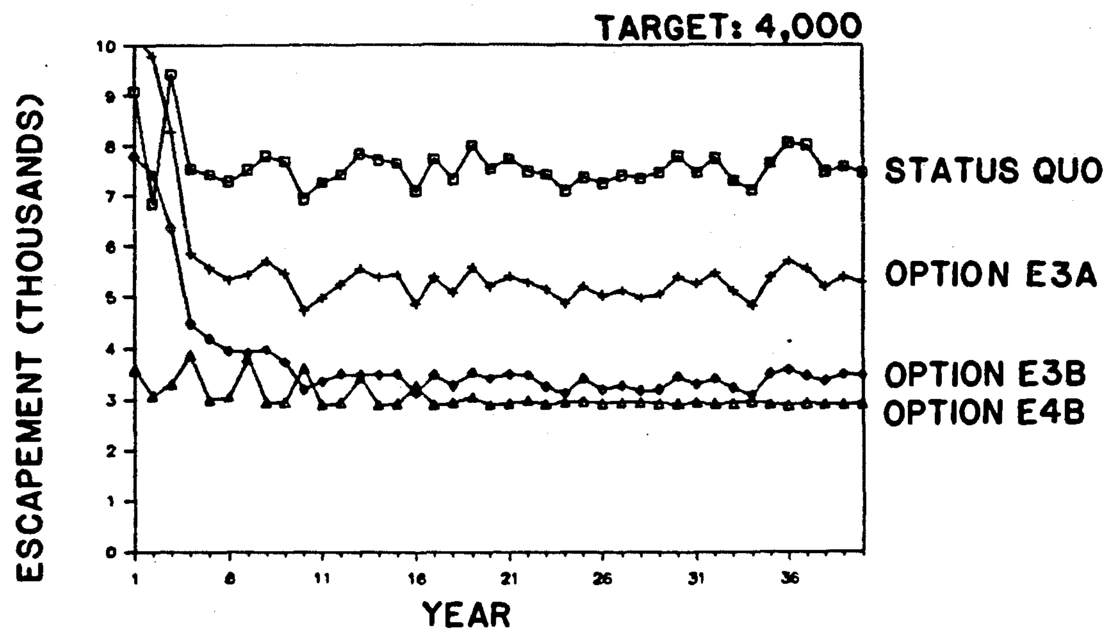


Figure 16. Pallant Creek coho salmon escapements projected over the next 40 years for each enhancement option compared to the status quo.

timing chum fisheries, coho salmon escapements to Pallant Creek are projected to be about 5,000. In the options including earlier fisheries -- E2B, E3B and E4B -- coho salmon escapements are predicted to be 3,000 to 4,000 fish. Coho salmon escapements to Mathers Creek are projected to fluctuate around 2,000 spawners under the status quo, well below historic levels of 7,500. Under the condition of the other enhancement options, with the exception of E4B, coho salmon escapements are projected to increase to about 5,000 (Figure 17). With option E4B, escapements are projected to be similar to the status quo. In the other streams, coho salmon escapements are projected to remain less than 200 with the status quo option but would increase to between 800 and 1,200 with the first three enhancement options (Figure 18).

The catch of chum salmon was projected to be higher for all the enhancement options than with the status quo option (Figure 19). Under status quo conditions, total catch of chum salmon would average 186,000 pieces compared to 231,000 with E4B, 243,000 with E3A and E3B, 289,000 with E1 and 318,000 with E2A and E2B.

The total catch of even year pink salmon was projected to average 15,000 pieces with the status quo, and enhancement options E2A and E3A (Figure 20). These catches are attributable to outside inteceptions since the Cumshewa chum salmon fishery would be delayed until after the pink salmon migration in these options. In options E2B, E3B and E4B, catch of pink salmon would initially be higher because of increased interceptions in the early Cumshewa chum and coho salmon fisheries. However, catches would decline rapidly as the pink salmon stocks were depleted. With option E1, which includes enhancement of pink salmon, catch of even year pink salmon are projected to increase to about 200,000 pieces.

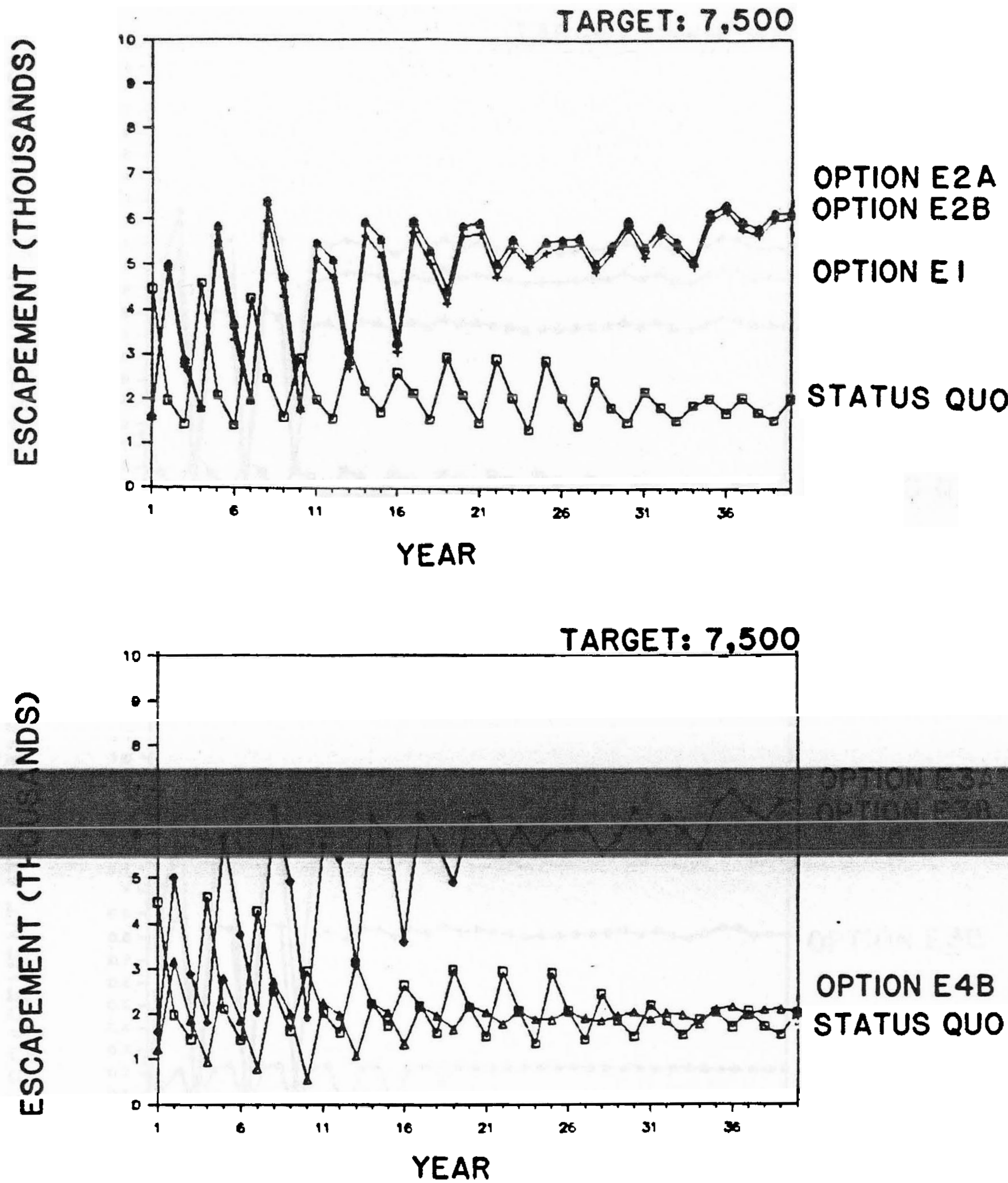


Figure 17. Mathers Creek coho salmon escapements projected over the next 40 years for each enhancement option compared to the status quo.

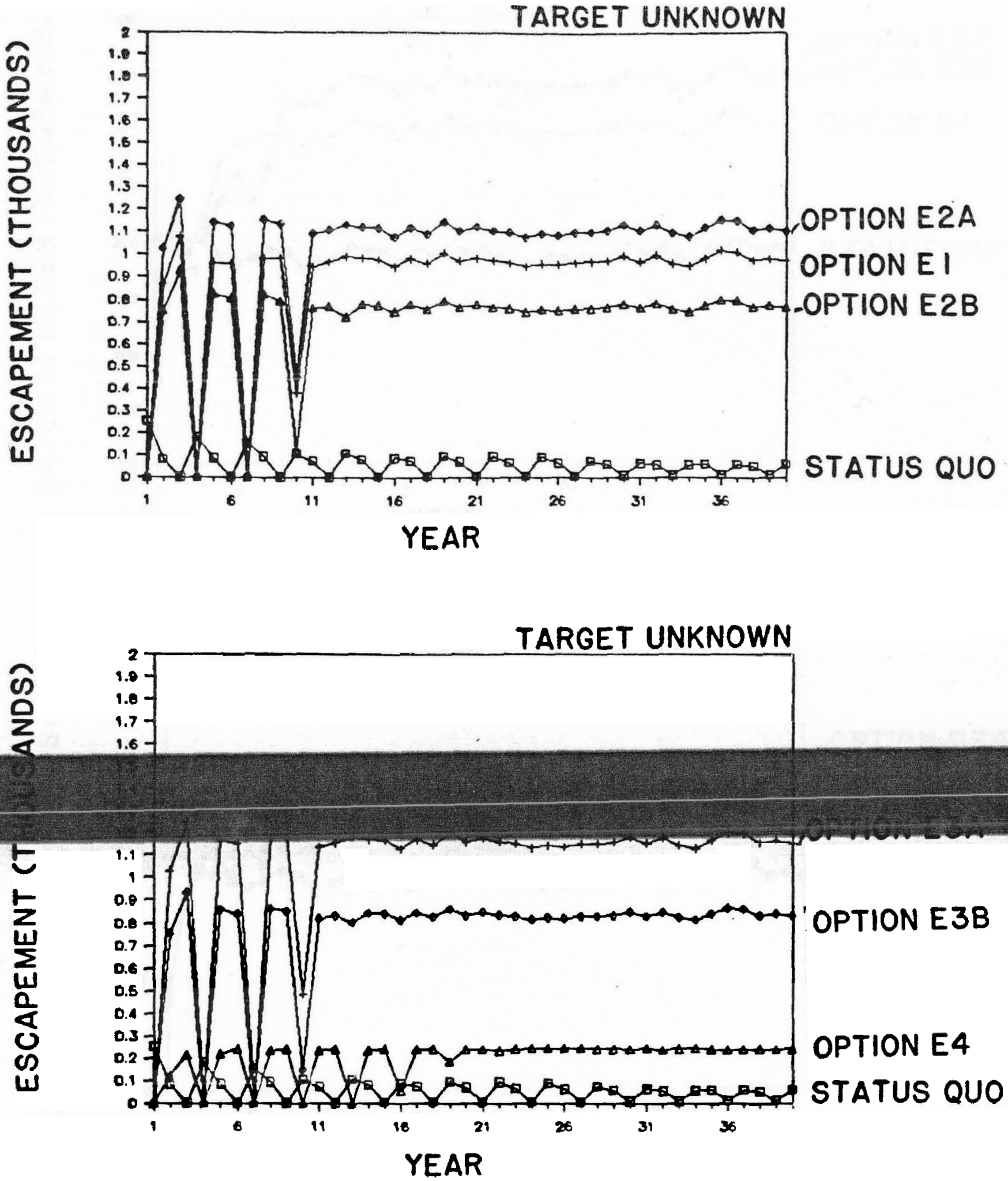


Figure 18. Other coho salmon stock escapements projected over the next 40 years for each enhancement option compared to the status quo.

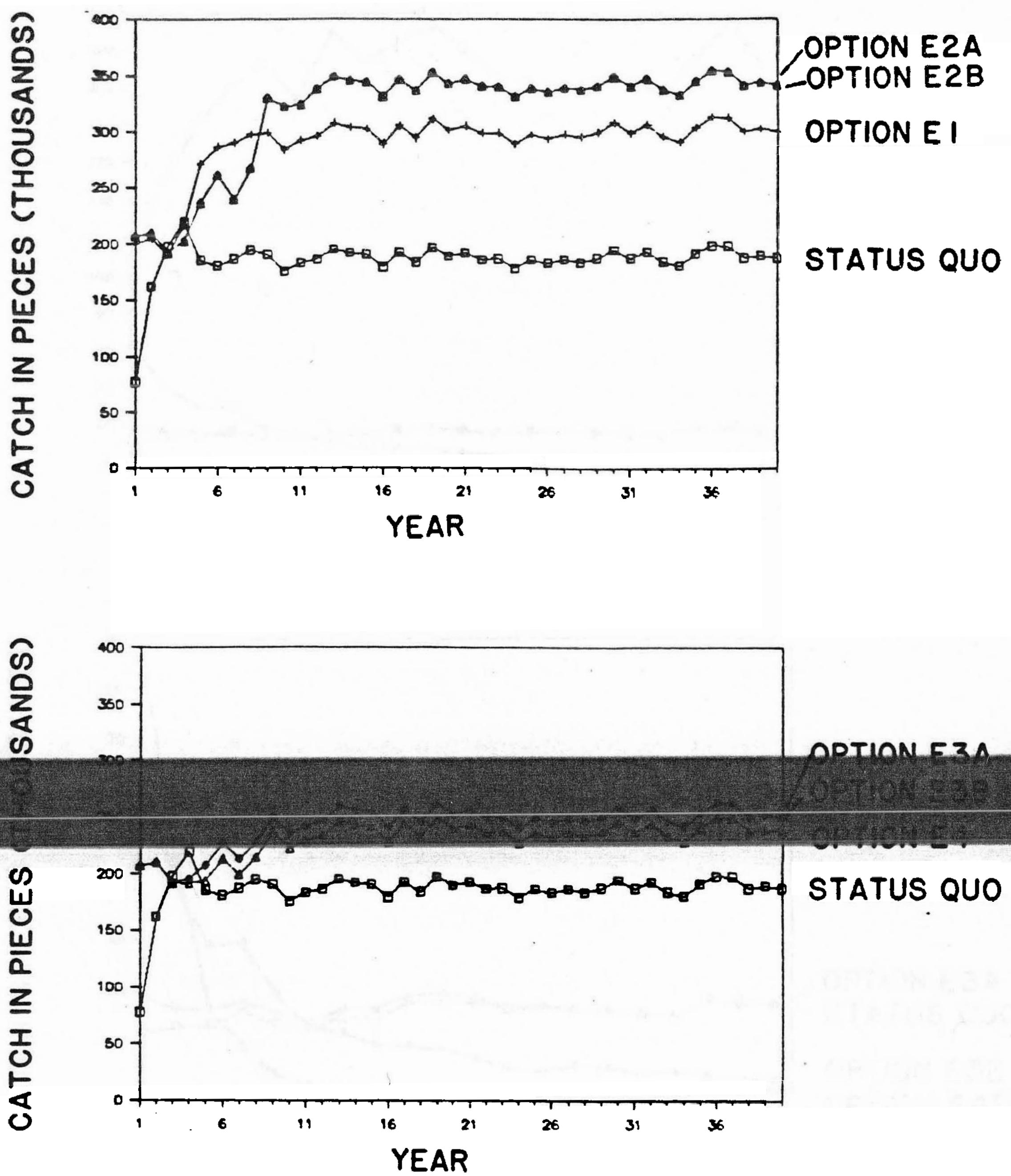
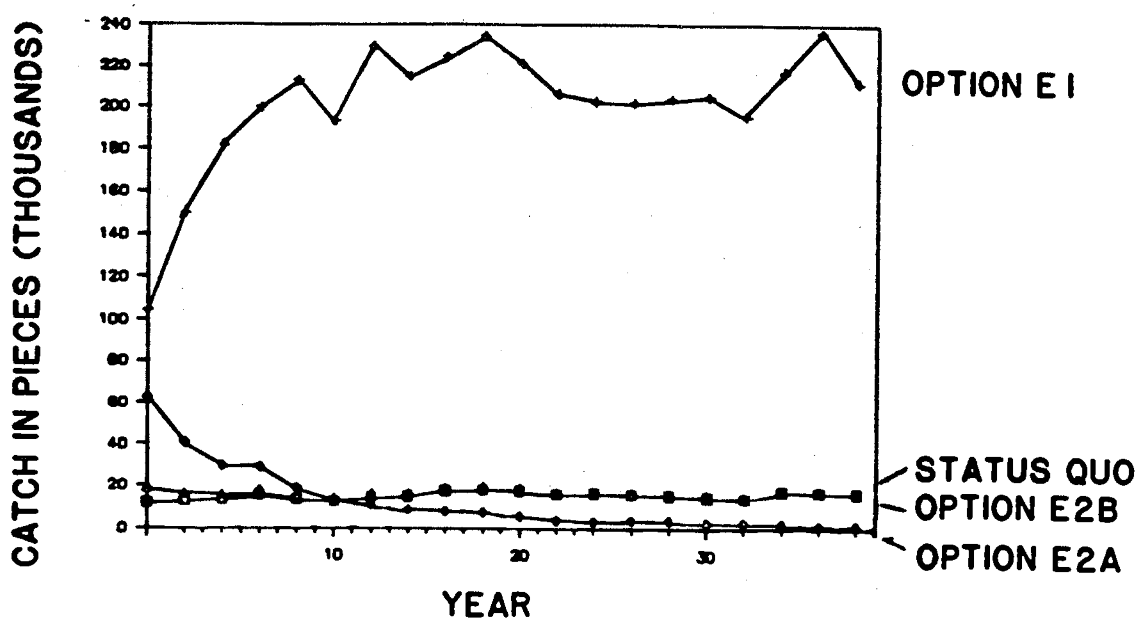


Figure 19. Total catch of Cumshewa Inlet chum salmon in all fisheries projected over the next 40 years for each enhancement option and compared to the status quo.



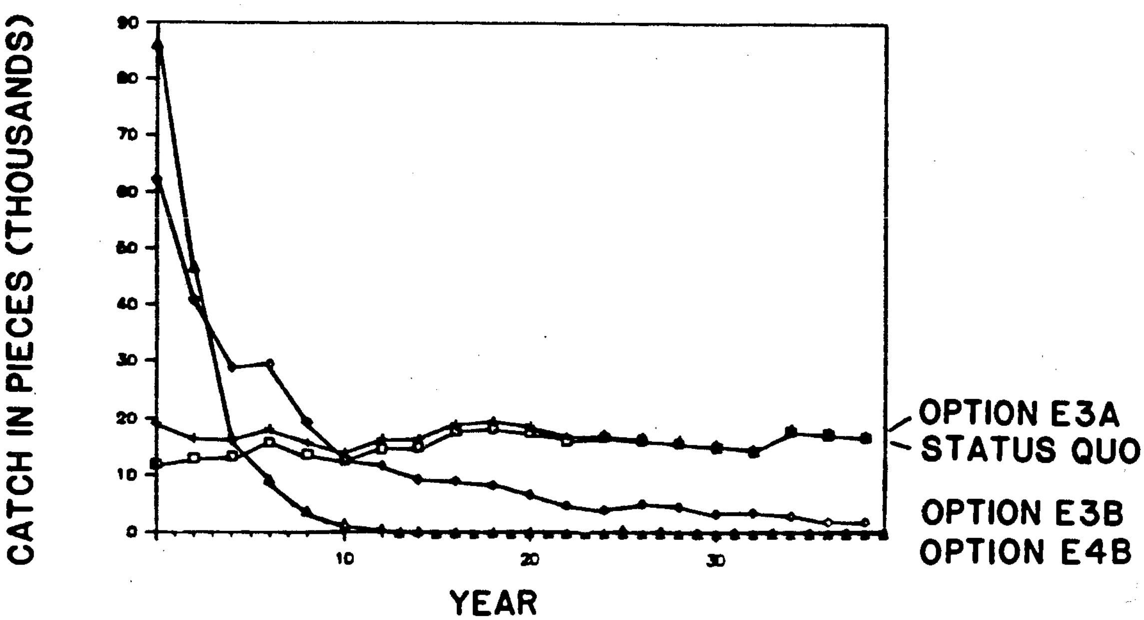


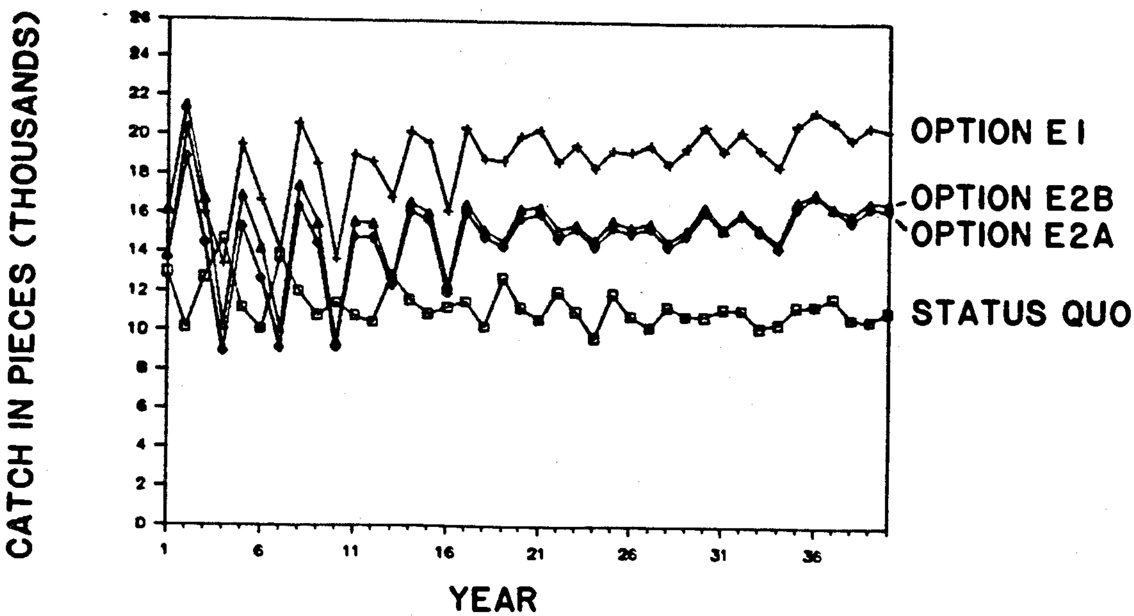
Figure 20. Total catch of Cumshewa Inlet even year pink salmon in all fisheries projected over the next 40 years for each enhancement option and compared to the status quo.

Total catch of coho salmon is projected to increase from 4,000 to 8,000 pieces over the average of 11,000 projected in the status quo option with options E1, E2A, E2B, E3A and E3B (Figure 21). As expected, the highest catch of coho salmon is projected with E4B, the option which includes significant coho enhancement. Total catch with this option would average 30,000 pieces. The distribution of coho salmon catch between sport, net and troll fisheries was similar with enhancement options E2 and E3 with about 2,000 fish caught in the sport fishery, 6,500 to 7,500 caught in the net fishery and the remainder in the troll fishery. With E1 catch of coho salmon would be slightly higher in each of the fisheries. The catch distribution would change dramatically with E4B since it includes a net fishery targetting on coho salmon. Sports catch would be in the order of 1,200 pieces while net catch would be about 21,000 pieces and troll catch would be 8,000 pieces.

9.2 Benefit Cost Analysis

The benefits in terms of estimated value of the catch associated with each enhancement option and the incremental benefits of each option compared to the status quo are shown in Table 12. The analysis indicates that option E2B would provide the highest benefits, with catch values in the order of $16 million based on a 10% discount rate over a 40 year period. The fewest benefits from increased catch were associated with option E3A since it involves the lowest increment in production and a relatively low quality of chum salmon in the catch.

There are three components to the costs associated with the enhancement options, the capital and operating costs of the enhancement facilities and



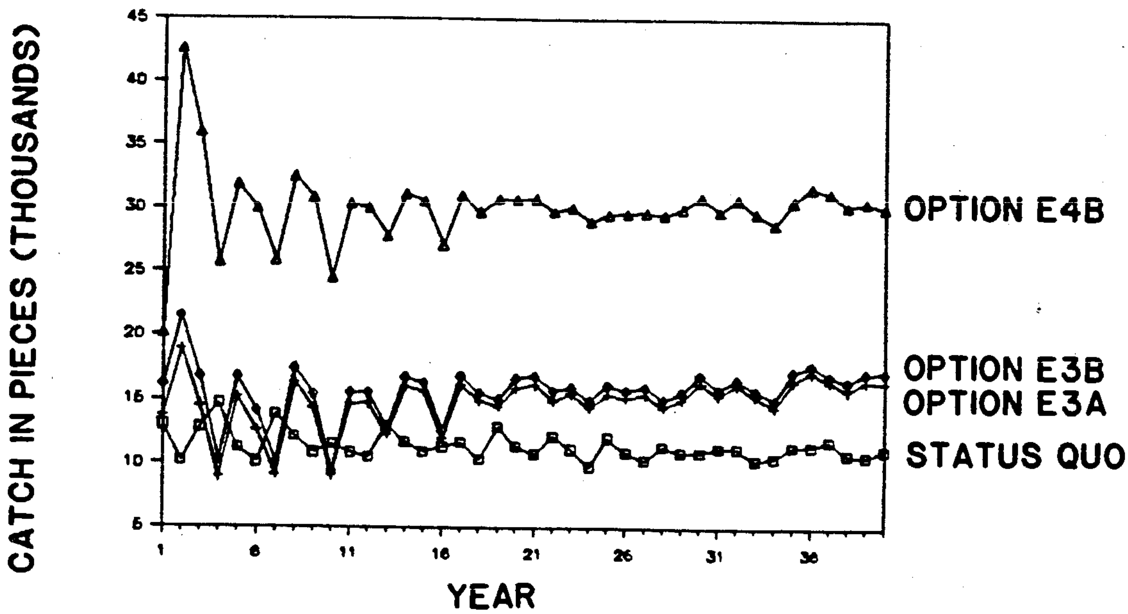


Figure 21. Total catch of Cumshewa Inlet coho salmon in all fisheries projected over the next 40 years for each enhancement option and compared to the status quo.

Table 12. Projected value of benefits for each enhancement option (dollars).

Year	Total Value of Benefits							Incremental Benefit from Status Quo					
	Status Quo	Option E1	Option E2A	Option E2B	Option E3A	Option E3B	Option E4B	Option E1	Option E2A	Option E2B	Option E3A	Option E3B	Option E4B
1	604880	604880	604880	604880	604880	604880	604880	0	0	0	0	0	0
2	172675	172675	172675	172675	172675	172675	172675	0	0	0	0	0	0
3	1981498	2253293	2089192	2905665	2089192	2905665	2981916	271795	107694	924166	107694	924166	1000418
4	392227	516364	476094	832412	476094	832412	991288	124138	83868	440185	83868	440185	599061
5	1175153	1726365	1282128	1828263	1282128	1828263	2033540	551213	106976	653110	106976	653110	858387
6	242564	321204	213763	516493	213659	505474	678601	78641	-28801	273930	-28904	262911	436038
7	1298160	2646685	1565500	2223282	1423251	1995498	2017641	1348525	267340	925123	125091	697339	719481
8	361547	491417	393209	810915	378217	740223	844646	129870	31662	449368	16670	378676	483099
9	1055837	2608435	1228389	1799810	1126513	1628353	1684479	1552597	172552	743973	70676	572516	628642
10	1176522	1997173	1743204	2505198	1542138	2186253	2167412	820651	566682	1328676	365616	1009730	990889
11	905853	2837023	1447605	2156703	1200470	1720022	1753070	1931169	541752	1250850	294617	814169	847216
12	1051028	1514672	1563803	2385348	1208295	1795960	1891279	463644	512775	1334320	157266	744932	840251
13	3291492	6830056	5166338	6873148	3981272	5220670	5026775	3538565	1874846	3581656	689780	1929178	1735284
14	2608313	3975707	4366259	5959402	3302908	4449840	4388409	1367394	1757947	3351089	694595	1841528	1780096
15	3237042	6965136	5612578	7478441	4283521	5633948	5475174	3728094	2375536	4241399	1046479	2396906	2238132
16	3001840	5053903	5562058	7465354	4233509	5618806	5443190	2052063	2560219	4463515	1231669	2616966	2441350
17	3307468	6844393	5612689	7446589	4278844	5595370	5403477	3536925	2305221	4139121	971377	2287902	2096009
18	3041851	4722285	5256673	7081293	3921213	5225625	5084395	1680434	2214823	4039443	879363	2183775	2042544
19	3402907	6972924	5667268	7484080	4343105	5646514	5454638	3570018	2264361	4081174	940199	2243607	2051731
20	3161006	4847720	5388722	7239722	4055382	5386770	5218869	1686714	2227716	4078716	894376	2225763	2057863
21	3278330	7119583	5731882	7575602	4397236	5722833	5560291	3841253	2453552	4297272	1118906	2444503	2281961
22	3158200	4990802	5513037	7391914	4186471	5548550	5373691	1832603	2354837	4233714	1028272	2390351	2215492
23	3202113	6942652	5667720	7482122	4334866	5631768	5438483	3740540	2465607	4280009	1132753	2429656	2236371
24	2975300	4990246	5481072	7321294	4143328	5463603	5291699	2014946	2505772	4345994	1168028	2488303	2316399
25	3207731	6701821	5543008	7327182	4218448	5487956	5309298	3494090	2335277	4119451	1010716	2280225	2101567
26	3063704	4782442	5318598	7123529	3977170	5259721	5092996	1718738	2254895	4059825	913467	2196017	2029292
27	3165285	6641543	5520946	7293802	4197582	5457226	5271079	3476258	2355661	4128517	1032297	2291941	2105794
28	3072834	4837867	5394261	7213780	4066974	5369383	5200505	1765033	2321427	4140946	994140	2296549	2127671
29	3185345	6645493	5521135	7298918	4192915	5456129	5272974	3460147	2335790	4113573	1007570	2270784	2087629
30	3240189	4843664	5402434	7242158	4058065	5373393	5213103	1603475	2162245	4001969	817876	2133204	1972914
31	3187402	6678202	5532275	7324589	4198900	5473163	5300518	3490801	2344874	4137187	1011498	2285761	2113116
32	3212503	5077385	5627649	7511313	4301560	5669003	5491106	1864882	2415146	4298810	1089058	2456500	2278603
33	3115268	6680100	5527919	7318795	4199366	5474465	5295556	3564832	2412651	4203527	1084098	2359197	2180288
34	3007113	5060886	5588991	7470378	4257379	5620398	5446711	2053773	2581877	4463264	1250266	2613284	2439598
35	3272942	6546759	5470606	7252536	4136279	5400105	5221506	3273817	2197664	3979595	863338	2127163	1948564
36	3327156	4800500	5329754	7133276	3997087	5281854	5115276	1473345	2002599	3806120	669932	1954699	1788120
37	3377617	6885249	5638328	7436231	4310301	5592975	5401417	3507632	2260712	4058614	932684	2215359	2023800
38	3153229	5241928	5740342	7631770	4405418	5777599	5593853	2088699	2587113	4478541	1252189	2624370	2440624
39	3224476	7184853	5757471	7602877	4427926	5755864	5577139	3960378	2532995	4378401	1203451	2531389	2352664
40	3148656	4924620	5517778	7341618	4185844	5490892	5316215	1775964	2369122	4192963	1037188	2342236	2167559
NPV@5%	33696468	60867410	54165819	73294005	42691546	57123823	56395957	27170943	20469351	39597537	8995079	23427355	22699488
NPV@10%	15011134	26292895	22685228	30976983	18449967	24948509	24967783	11281761	7674094	15965848	3438833	9937374	9956649
NPV@15%	8280190	13866201	11668546	16044043	9848017	13421404	13619516	5586011	3388356	7763852	1567827	5141214	5339326

the variable management costs associated with the specific management strategy. The capital costs are based on estimates made by DFO engineers. The cost of expansions at the existing Pallant Creek site are all about $1 million (Table 13). There is slight variation between options because the coho salmon production option is only viable if a ground water source is found, a condition which entails exploration and well development. The capital costs for expanding the Mathers facility are dependant on the capacity. With a smaller scale expansion as in option E1, the capital costs at Mathers Creek would be in the order of $1.25 million while the costs of a larger facility as in option E2, would be in the order of $2 million. The costs at Mathers Creek are higher than at Pallant Creek because the Mathers Creek facility infrastructure needs to be replaced since it was installed as a temporary pilot facility. It is assumed that 75% of the capital cost would be spent in the first year and the remainder in the second year.

The operational costs in Table 13 represent the incremental expense associated with the enhancement options. A detailed breakout of the expense for each option are outlined in Appendix 1. The highest operational costs are associated with the Mathers Creek hatchery because a full staff would be required to run the facility. It was estimated that the requirements would be similar to the existing Pallant Creek hatchery, regardless of capacity, with an additional 20% increase on expenses because the site is more isolated and not accessible by road. The operational costs for the Pallant Creek expansion depend on the capacity and species mix of the option. In the option including pink salmon, costs are lower because the fry are not reared, whereas in the coho salmon production option, costs are

Table 13. Estimated capital and operational costs for the enhancement options.

		Capital Cost	Annual Operating Costs Even-Year	Annual Operating Costs Odd-Year
E1	Expansion at Pallant Creek	1015000	86000	40000
	Expansion at Mathers Creek	1245000	536000	353760
	Total	2260000	622000	393760
E2	Expansion at Mathers Creek	2000000	536000	536000
E3	Expansion at Pallant Creek to Satellite Mathers Creek Stocks	1015000	194000	194000
E4	Expansion at Pallant Creek for Coho Salmon Production	1065000	225000	225000

Present value of costs discounted over 40 years	Option E1	Option E2	Option E3	Option E4
Discount rate at 5%	9939742	10082712	3923296	4444638
Discount rate at 10%	6136702	6088183	2462198	2755968
Discount rate at 15%	4488633	4371033	1826945	2024504

higher because the coho salmon fry are reared for a longer time. In option E1, which includes pink salmon enhancement, the operational costs at both Pallant and Mathers Creek facilities would be lower in the odd years when pink salmon would not be enhanced. The estimate of present value of the costs assumes that the incremental operational costs would not be incurred during the two years of construction.

Incremental management costs are based on the variable costs associated with the management strategy described in the analysis of the management options (Table 14). In E1 it is assumed that the patrol boat would be required for a longer period to monitor the pink salmon fishery and therefore a net increase in management costs is expected. No incremental cost is expected with option E2A and E3A because the fishing strategy is assumed to be status quo even though there are more fish available. In options E2B and E3B, the management costs would be the same as for management option 3, the early fishery option (Table 8) but less than in the status quo option. Management costs for the coho salmon production option, E4B, was assumed to be similar to the early fishing option but would include an additional 15 days of patrol boat time to monitor the newly established coho salmon fishery. Management costs would still be less than in the status quo option.

The incremental change in NPV from the status quo is shown for each option in Table 15 at each of the three discount rates. The highest NPV of $10.2 million discounted at 10% over 40 years is projected with E2B, the option involving a major expansion of the Mathers facility and a management strategy of fishing chum salmon when the quality is highest. However, if this facility were built and the management strategy remained the same as

Table 14. Estimated management costs associated with each enhancement option (dollars).

	Annual Variable Costs						
	Status Quo	Option E1	Option E2A	Option E2B	Option E3A	Option E3B	Option E4B
Test Fishery							
Days	40	40	40	0	40	0	0
Cost*	30000	30000	30000	0	30000	0	0
Patrol Boat							
Days	30	50	30	30	30	30	45
Cost**	19350	32250	19350	19350	19350	19350	29025
Guardian							
Days	20	0	20	0	20	0	0
Cost***	4200	0	4200	0	4200	0	0
Total variable cost	53550	62250	53550	19350	53550	19350	29025
Present value of costs discounted over 40 Years							
Discount rate at 5%	918869	1068153	918869	332028	918869	332028	498042
Discount rate at 10%	523668	608746	523668	189225	523668	189225	283837
Discount rate at 15%	355667	413451	355667	128518	355667	128518	192778
Incremental costs compared to status quo							
Discount rate at 5%	0	149284	0	-586841	0	-586841	-420827
Discount rate at 10%	0	85078	0	-334444	0	-334444	-239831
Discount rate at 15%	0	57783	0	-227149	0	-227149	-162890

Notes
* Cost of test fishery estimated at $750/day from previous years
** Standard cost of patrol boat is $645/day
*** Standard cost of guardian is $210/day

Table 15. Benefit cost analysis of enhancement options.

Incremental Benefits Compared to Status Quo

	Option E1	Option E2A	Option E2B	Option E3A	Option E3B	Option E4B
Discount rate at 5%	27170943	20469351	39597537	8995079	23427355	22699488
Discount rate at 10%	11281761	7674094	15965848	3438833	9937374	9956649
Discount rate at 15%	5586011	3388356	7763852	1567827	5141214	5339326

Incremental Costs Compared to Status Quo

Capital and Operating Costs	Option E1	Option E2A	Option E2B	Option E3A	Option E3B	Option E4B
Discount rate at 5%	9939742	10082712	10082712	3923296	3923296	4444638
Discount rate at 10%	6136702	6088183	6088183	2462198	2462198	2755968
Discount rate at 15%	4488633	4371033	4371033	1826945	1826945	2024504

Management Costs	Option E1	Option E2A	Option E2B	Option E3A	Option E3B	Option E4B
Discount rate at 5%	149284	0	-586841	0	-586841	-420827
Discount rate at 10%	85078	0	-334444	0	-334444	-239831
Discount rate at 15%	57783	0	-227149	0	-227149	-162890

Total Incremental Costs	Option E1	Option E2A	Option E2B	Option E3A	Option E3B	Option E4B
Discount rate at 5%	10089026	10082712	9495872	3923296	3336455	4023811
Discount rate at 10%	6221779	6088183	5753739	2462198	2127754	2516137
Discount rate at 15%	4546416	4371033	4143884	1826945	1599797	1861614

Incremental Change in Net Present Value Compared to the Status Quo

	Option E1	Option E2A	Option E2B	Option E3A	Option E3B	Option E4B
Discount rate at 5%	17081916	10386639	30101665	5071783	20090900	18675677
Discount rate at 10%	5059981	1585912	10212109	976635	7809620	7440512
Discount rate at 15%	1039595	-982677	3619968	-259118	3541417	3477711
Rank Ratio*						
Discount rate at 5%	2.69	2.03	4.17	2.29	7.02	5.64
Discount rate at 10%	1.81	1.26	2.77	1.40	4.67	3.96
Discount rate at 15%	1.23	0.78	1.87	0.86	3.21	2.87

*Denotes NPV/government cost.

status quo, E2A, the potential value would be substantially less at about $1.6 million. Options E3B and E4B would provide the next highest values with $7.8 and $7.4 millions, respectively. Both these options involve expansion of the Pallant Creek facility for the purpose of satelliting Mathers Creek chum salmon and include early chum salmon fisheries in Cumshewa Inlet. Option E4 also involves transferring some of the Pallant Creek chum salmon production into coho salmon production. However, if Mathers chum salmon are satellited from the Pallant Creek facility, and the management strategy is to allow chum salmon abundance to build before harvesting (E3A), the potential value of this option declines to $1 million. The value of option E1, which involves expansion of both facilities is estimated at $5.1 million.

The cost effectiveness of the enhancement options as measured by the rank ratio (NPV/government cost) varies substantially between options (Table 15). Options E3B and E4B provide the highest value received for government dollars spent, followed by E2B, E1, E3A and E2A, respectively.

9.3 Other Considerations

The social factors from the fishermen's perpective, and risks associated with each option are also considered in the evaluation of the options. The fishermen would be concerned with the duration and timing of the fishing season and the quality of the catch. Options E2A and E3A are based on the status quo management strategy and therefore are the same in terms of fishing season and catch quality. Option E1 would be more appealing to fishermen because it would provide a slightly longer fishing season in even-years with a pink salmon fishery. Both options E2B and E3B would provide slightly shorter fishing seasons, but would be more desirable than the status quo because the fishery would be in early September and fish quality would be prime. Option E4B would be appealing since the chum salmon fishery is early as in E2B and E3B but there is the added bonus of a coho salmon net fishery in late August.

Risks associated with each option should be compared to the status quo which is rated as moderate. Option E1 is considered a high risk because it includes pink salmon enhancement, which has not been successful on previous attempts at Pallant Creek hatchery, and because it involves expansion of the Mathers Creek facility which has a questionable water supply. Option E2A also rates a high risk factor because of the uncertainty with regards to water supply suitability. Option E2B is a high risk option because of uncertainties with both the enhancement and management strategies. The risk of over harvesting the Mathers Creek stock in this early fishing option is high. Option E3A involves a similar management strategy as the status quo, does not have any more risk associated with the enhancement strategy and is rated moderate. However, option E3B involves the early fishing strategy which has a high risk of over harvesting Mathers Creek chum salmon stock. Option E4B is rated as very high risk because of the uncertainties with the management strategy of an early chum salmon fishery, and because feasibility of this option is dependant on finding a ground water supply at the Pallant Creek site. Preliminary well exploration has been unsuccessful.

9.4 Summary

The evaluation of each of the enhancement options is summarized in Table 16. All results should be compared to the status quo.

Table 16. Evaluation of enhancement options.

Evaluation Criteria	Options						
	Status Quo	Option E1	Option E2A	Option E2B	Option E3A	Option E3B	Option E4B
Change in Net Present Value ($ in millions)	0	5.0	1.6	10.2	1.0	7.8	7.4
Cost Effectiveness (Rank ratio)	n/a	1.8	1.3	2.8	1.4	4.7	4.0
Government Cost ($ in millions)	n/a	6.2	6.1	5.7	2.5	2.1	2.5
Salmon Eşcapement as a Percentage of Target after 40 years							
Pallant Creek Chum	125	115	70	75	90	90	90
Mathers Creek Chum	20	35	60	60	50	50	50
Pallant Creek Pink	85	100	85	0	85	0	0
Mathers Creek Pink	60	70	65	0	65	0	0
Pallant Creek Coho	190	230	130	85	140	85	75
Mathers Creek Coho	30	65	65	80	70	80	25
Average Salmon Catch							
Chum	186000	289000	318000	318000	243000	243000	231000
Pink (Even year)	15000	200000	15000	/000	15000	7000	4500
Coho	11000	19000	15000	15000	15000	16000	30000
Fishing Season							
Duration (months)	1 1/2	2	1 1/2	1	1 1/2	1	1 1/2
Timing	late	early & late	late	early	late	early	early
Chum Salmon Quality	dark red	dark red	dark red	semi bright	dark red	semi bright	semi bright
Risks	moderate	high	high	very high	moderate	high	very high

In the first enhancement option, E1, the escapement of even year pink salmon stocks is projected to improve over that expected with the status quo strategy. Mathers Creek chum salmon escapements are projected to increase marginally but would remain well below the target. The catch of chum salmon would increase by about 100,000 and a new even year pink salmon fishery with catches on the order of 200,000 would be developed in Cumshewa Inlet. This option would probably receive industrial support because it would extend the fishing season and provide new opportunities with the pink salmon fishery. This option would provide additional benefits in the order of $5 million, discounted at 10% over 40 years. It is a cost effective option, and is projected to provide $1.8 of benefit for each government dollar spent in development of this option. Even though the projected benefits are high, it should be noted that there is a high risk that these projections may not be achieved because of limited success in enhancement of pink salmon, and uncertainties regarding the suitability of the water supply at Mathers Creek.

The projected consequences for the second enhancement option, E2, are dependant on the associated management strategy. Although, the trend in chum salmon escapement is similar under both management strategies, E2A and E2B with escapements to Pallant and Mathers Creeks becoming more balanced than under status quo conditions, the trend in pink salmon escapements is opposite. With option E2A, the escapements of pink salmon are projected to increase over time similar to projections in the status quo option, while with option E2B, both pink salmon stocks would decline. Coho salmon escapements are projected to achieve a better balance than in the status quo, with some over escapement to Pallant Creek and under escapement to Mathers

Creek in E2A, and both stocks approching target in E2B. Both management strategies would result in catches of about 130,000 more chum salmon than projected with the status quo. However, the catch quality is significantly different between options, with an average grade of dark red expected with E2A and semi bright with E2B. This variation in quality has a substantial affect on the projected value of each option. The increase in NPV from status quo conditions would be $1.6 million with E2A compared to $10.2 million with E2B. The cost effectiveness of E2B would also be higher than for E2A. Since both E2A and E2B involve a major expansion of the Mathers Creek facility, there is a high risk that projections may not be achieved because of the potential unsuitablility of the water supply. The early fishing management strategy E2B has more risk because of the potential for driving the Mathers Creek chum salmon stock to extinction.

As with enhancement option E2, the projections for the third enhancement option are very dependant on the management strategy. The projected escapement trends for chum salmon are similar, with the Pallant Creek stock at target and the Mathers Creek stock at about half its target. Pink salmon stocks would increase as in the status quo in E3A and would decline in E3B. In the late fishing option, coho salmon escapements would exceed target in Pallant Creek, while in the early fishing option coho salmon escapements in both Pallant and Mathers Creeks would be near target. In both E3A and E3B catch of chum salmon would be about 60,000 more than in the status quo but quality would be very different. The value of the options are estimated at $1 million for E3A and $7.8 million for E3B. Option E3B is the most cost effective of all options analyzed with an estimated $4.7 of benefit for each dollar of government expenditure. As with the status quo, risk is rated as moderate for E3A. However, E3B has a high risk factor because of the potential for overharvesting the Mathers Creek chum stock in the early fishery.

The enhancement option of increasing coho salmon production and satelliting Mathers Creek chum salmon, E4B, results in similar escapement trends as observed for E3B, with the exception that the Mathers Creek coho salmon remain at a relatively low level. Catch is projected to increase by about 45,000 chum salmon and 20,000 coho salmon. This option would meet approval with the industry because it provides additional fishing opportunities with the addition of the coho salmon net fishery, and improves the chum salmon fishery in terms of timing and catch quality. The projected benefits from this option are estimated at $7.4 million. It is a highly cost effective option with a rank ratio of 4. The risk associated with this option is very high because of the potential for overharvesting the Mathers Creek chum and coho salmon stocks, and because the Pallant Creek facility may not be suitable for large scale coho salmon production due to lack of ground water.

As with the management options, it is apparent that no one enhancement option is the obvious choice. Each involves tradeoffs. The potential benefits from rebuilding pink salmon stocks (E1) are offset by the high risk that it may not be a feasible option and the likelihood that the Mathers Creek chum salmon stocks would remain at low levels. The relatively good escapement levels for all stocks as projected in E2A and E3A are countered by the marginal benefits that would be received over 40 years. The high values associated with the options involving early fisheries -- E2B,E3B and E4B -- are offset by the high risk of depleting the Mathers Creek stock, and the various concerns regarding the potential success of the enhancement strategy.

10.0 RECOMMENDATIONS

In evaluating these options it is apparent that there are two main issues regarding biological stability of the stocks that require consideration before any option can be recommended. First, are the pink salmon worth saving, and second, is the Mathers Creek chum salmon stock worth saving?

The Cumshewa pink salmon are believed to be intercepted in outside fisheries and have therefore been contribution to catch. However they have not recently been at a high enough abundance to be fished locally in Cumshewa Inlet. There is some speculation that pink salmon production may be limited by chum salmon production in the same stream and fishery officers indicated that the target escapements set for pink and chum salmon are not based on consideration of the abundance of the other species. Since chum salmon are currently being enhanced, it is likely that chum salmon targets could be met consistently in the future and pink salmon production may be limited.

Model projections that indicate management actions to rebuild or maintain pink salmon stocks including the status quo and quota/terminal fishery option will require forgoing options which could provide benefits in the order of $4 to $5 million. On the other hand, the enhancement option which could rebuild pink salmon (E1) is projected to provide benefits in the order of $5 million. However, there is uncertainty as to the potential success of this particular option since there is doubt regarding the feasibility of enhancing pink salmon. Even if the option were feasible, it is questionable whether Canada would receive the benefits since the fish may be intercepted in Alaskan fisheries. Unless the fish were identified by code-wire tags, Canada would not receive credit. Also, considering the limited budget and Federal Government policies regarding restraint, E1 is the most costly option but is not the most cost effective.

Should options that do not rebuild pink salmon stocks be rejected on that basis? Pink salmon are not a threatened species and there are numerous pink salmon stocks in the Queen Charlotte Islands. The costs of maintaining the pink salmon stocks in Cumshewa Inlet are high, both from the perspective of foregone opportunities and enhancement costs. Therefore, it is recommended that pink salmon be considered a passively managed species in Cumshewa, and that the fishery and enhancement strategies be primarily directed at chum salmon.

The issue of conserving Mathers Creek chum salmon is another question. The costs of rebuilding through management actions seem unreasonably high, yet there is biological value in maintaining this stock for genetic reasons. This stock is not currently rebuilding and is projected to remain at relatively low levels if the current balance in enhancement continues. Because of biological concerns for maintaining this stock, it would be worthwhile concentrating enhancement efforts on the Mathers Creek chum salmon stock to give it a boost in rebuilding. Enhancement options E2A, E2B, E3A, E3B and E4B all increase the chum salmon escapement to Mathers Creek over that expected in the status quo.Although escapement would only reach about half the target, it is recommended that one of these options be chosen since they would be a step in the direction of improving the status of the Mathers Creek chum salmon stock.

The choice as to which of these options to recommend is difficult. The greatest potential benefits are with E2B. However the risk is very high that with the strategy of fishing the chum salmon early, the Mathers Creek stock may be depleted before enhancement can contribute to its rebuilding. If it became apparent that the boundary restrictions did not adequately protect the Mathers Creek fish, the managers would revert back to the status quo management with later chum salmon fisheries (E2A). This would provide significantly fewer benefits and it is only marginally cost effective. These options both require building a facility at the Mathers Creek site which involves considerable expense and has a risk of failure.

Both options E3B and E4B offer relatively high benefits and are the most cost effective options. However, both these also have a high risk of depleting the Mathers Creek chum salmon stock if the assumptions regarding restrictions prove false. In this case, the managers could revert back to the status quo management with E3A, but would not be able to with E4B because an early fishery for coho salmon fishery is the basis for this option. Therefore, considering the risks associated with developing the Pallant Creek site as a coho salmon facility because of ground water considerations, and the potential for depleting the Mathers Creek chum salmon stock, option E4B is not recommended at this time.

In conclusion, it is recommended that option E3B be implemented. It has the potential to provide relatively high benefits very cost effectively. Although there is a risk that the restrictions imposed to protect the Mathers Creek stock may not be effective, the status quo management strategy (E3A) could be implemented as an alternative. In this case the benefits would be marginal, but the overall costs would be minimal compared to the other options.

Option E3B could be viewed as an experimental approach. It provides the opportunity to test the assumptions associated with the early fishery strategy and also provides a means for rebuilding the Mathers stock. It also provides an option for testing the feasibility of pink salmon enhancement. Because of the uncertainties, the management in Cumshewa Inlet would have to be adaptive and respond to indications in the initial years so as to not risk eliminating the Mathers Creek chum salmon stock. Managers should monitor the early fishery carefully and evaluate the effectiveness of the restrictions by comparing harvest rates between the Pallant and Mathers Creek chum salmon stocks.

Proceeding with option E3B does not require foregoing the opportunities of other options at a later date. Rather it would eliminate some uncertainties and identify other potential options in the future. If the area restrictions prove successful, and the Mathers Creek stock rebuilds, it may be worthwhile re-evaluating the option for a major Mathers Creek facility. During the next few years, studies could be directed at testing the water supplies at Mathers Creek, and in identifying whether Cumshewa fish are a major concern in other fishing areas. However, if the assumptions prove false, it would be apparent that the projected benefits of Options E2B, E3B and E4B are not achievable. Other strategies may be necessary to assist the Mathers Creek stock in rebuilding.

Appendix 1

Summary of incremental operations cost estimates for each enhancement option

Table 1.1 Incremental Operations Cost Estimates for Option E1
Hatchery Expansions at Pallant and Mathers Creeks

PALLANT CREEK FACILITY COSTS	Incremental costs associated with increased egg capacity at Pallant Creek — Even Year: Chum Salmon (4M eggs)	Pink Salmon (5M eggs)	Coho Salmon (364K eggs)	Total costs for Pallant Creek expansion: Even Year	Odd Year
Labour Requirements					
1) Incubation					
Persons	0	0	0	0	0
Weeks	0	0	0	0	0
2) Rearing					
Persons	3	0	0	3	3
Weeks	8	0	0	8	8
3) Brood collection					
Persons	1	1	n/a	2	1
Weeks	8	8	n/a	16	8
Total Person Weeks	32	8	0	40	32
Labour Costs[a]	24000	6000	0	30000	24000
Fish Food[b]	6612	0	4814	11426	11426
Marking[c]	0	40000	0	40000	0
Fry Transport[d]	n/a	n/a	4550	4550	4550
Total Costs for Pallant Creek Expansion	30612	46000	9364	85976	39976

Notes
[a]Labour costs based on ($650/wk wages & $100/wk support).
[b]Fish food costs based on conversions of 1.5 for chum, 1.6 for chinook and coho, and food costs of $.75/lb.
[c]Marking cost based on $100/1000 fish.
[d]Transport costs based on $455/hr and 1/2 hr turn around.

MATHERS CREEK FACILITY COSTS

Assume costs will be similar to the existing Pallant Creek facility since capacity is slightly less with 6.4 M eggs chum and pink salmon combined. Facility will require full staff and expenses to operate except in odd years when requirements would be about 2/3 the cost because no pink salmon would be incubated.

Expenses are increased by 20% to account for increased costs due to isolation.

	Even Year $	Odd Year $
Wages	200000	133000
Expenses	280000	187000
Isolation Factor	56000	37000
Total Cost of Mathers Creek Expansion	536000	357000

TOTAL ANNUAL COST FOR
EXPANSION OF BOTH FACILITIES

Pallant Creek Expansion	85976	39976
Mathers Creek Expansion	536000	357000
Total	621976	396976

Table 1.2 Incremental Operational Cost Estimates for Option E2: Hatchery Expansion at Mathers Creek

Capacity 10 million chum and 200,000 coho salmon eggs

Assume similar costs as at the Pallant Creek facility since capacity is similar. However expenses are increased 20% to account for isolation costs.

Wages	200000
Expenses	280000
Isolation Factor	56000
Total Annual Cost	536000

Table 1.3 Incremental operations cost estimates for option E3 expansion at Pallant Creek to satellite Mathers Creek stocks.

	Incremental costs associated with increased egg capacity					
Labour Requirements	Mathers Ck. Chum Salmon (3.9M eggs)	Pallant Ck. Chum Salmon (seapen rearing)	Chinook Salmon (100K eggs)	Pallant Ck. Pink Salmon (600K eggs)	Mathers Ck. Coho Salmon (200K eggs)	Total Costs ($)
1) Incubation						
Persons	0	0	0	1	0	1
Weeks	0	0	0	1	0	1
2) Rearing						
Persons	3	1	0	1	0	5
Weeks	8	8	0	4	0	20
3) Brood collection						
Persons	n/a	n/a	n/a	2	0	2
Weeks	n/a	n/a	n/a	3	0	3
Total Person Weeks	24	8	0	11	0	43
Labour Costs[a]	18000	6000	0	8250	0	32250
Fish Food[b]	6447	8000	1322	1000	2645	19414
Marking[c]	5000	0	10000	10000	2000	27000
Fry Transport[d]	22/50	n/a	n/a	n/a	4550	27300
Broodstock						
Contract	85000	n/a	n/a	n/a	2000	87000
Shipping			1000			1000
Total Costs for Pallant Creek Expansion	13/19/	14000	12322	19250	11195	193964

Notes
[a]Labour costs based on ($650/wk wages & $100/wk support).
[b]Fish food costs based on conversions of 1.5 for chum, 1.6 for chinook and coho, and food costs of $.75/lb.
[c]Marking cost based on $100/1000 fish.
[d]Transport costs based on $455/hr and 1/2 hr turn around.

Table 1.4 Incremental Operations Cost Estimates for Option E4 Expansion for Coho Salmon Production at Pallant Creek

	Incremental costs associated with increased egg capacity				
	Mathers Ck. Chum Salmon	Chinook Salmon	Mathers Ck. Coho Salmon	Pallant Ck. Coho Salmon	Total
Labour Requirements	(3.9M eggs)	(100K eggs)	(200K eggs)	(775K eggs)	Costs
1) Incubation					
Persons	0	0	0	0	0
Weeks	0	0	0	0	0
2) Rearing					
Persons	3	0	0	1	4
Weeks	8	0	0	52	60
3) Brood collection					
Persons	n/a	n/a	0	0	0
Weeks	n/a	n/a	0	0	0
Total Person Weeks	24	0	0	52	76
Labour Costs*	18000	0	0	39000	57000
Fish Food	6447	1322	2645	20497	30911
Marking	5000	10000	2000	0	17000
Fry Transport	22750	n/a	4550	4550	31850
Broodstock Collection					
Contract	85000	n/a	2000	n/a	87000
Shipping		1000		n/a	1000
Total Costs for Pallant Creek Expansion	137197	12322	11195	64047	224761

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