

An Evaluation of the Strait of Georgia Mark Selective Coho Fishery

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ABSTRACT

After a period of decreasing abundance and the closure of all directed coho fisheries in 1998, the Strait of Georgia recreational coho fishery reopened in 2002 with Mark Selective Fishery (MSF) regulations. The MSF regulations allow the harvest of hatchery-marked fish but require the release of unmarked (wild) coho. MSF are thought to provide fishing opportunity while protecting wild stocks. This document presents the analysis of the Strait of Georgia MSF coho fishery to determine if the fishery is meeting its objectives.

1 INTRODUCTION

From 1952 to 1990 the Strait of Georgia (SoG) Coho fisheries maintained a catch of between 500,000 and 2 million pieces (Figure 1). Catches peaked in 1978 but have declined since the late 1980's. Commercial troll fisheries for coho in the SoG have been closed since 1995. Escapement to SoG wild streams peaked in 1964, estimated at 450,000 (Farlinger et al 1990) and declined to their current low levels; the 2011 estimate is 35,228 (NuSEDS DFO escapement database).

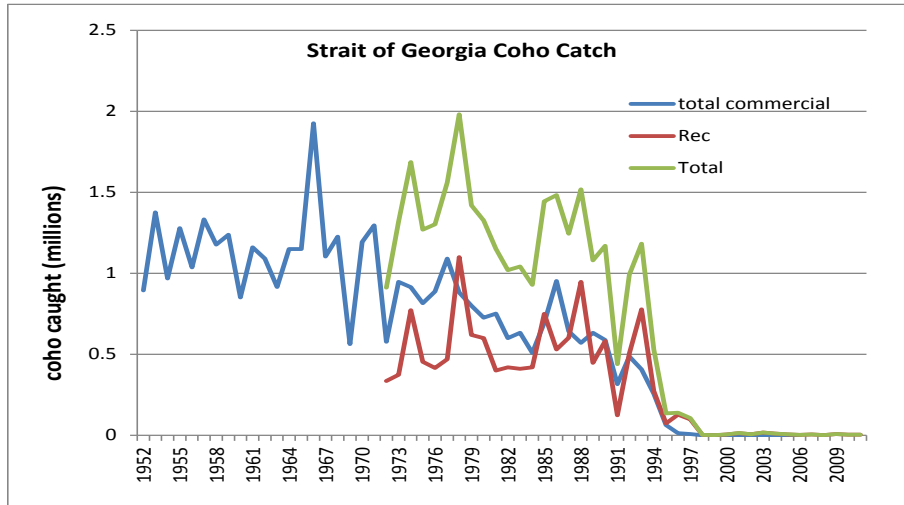


Figure 1. Total Strait of Georgia coho catch over time. Data from FOS, South Coast Creel survey, and Milne 1964.

The cause of this decline in both catches and escapement was attributed to overexploitation during a period of decreasing marine survival (Figure 2) as reported in a series of departmental workshops. A Pacific Science Advisory (PSARC) workshop was held in 1988 with the goal to establish stock monitoring and assessment requirements for coho salmon in B.C. (Anon 1988). In the spring of 1989 PSARC recommended that exploitation rates on wild Strait of Georgia coho stocks be reduced by approximately 10 percentage points to between 65% and 75% (Farlinger et al 1990). A subsequent DFO publication (Anon 1990) documented escapement and catch of many Strait of Georgia wild coho stocks were declining at a disturbing rate. In response to these declines, a coho salmon workshop was held in 1992 to improve the understanding and management of coho stocks (Berg and Delaney 1993).

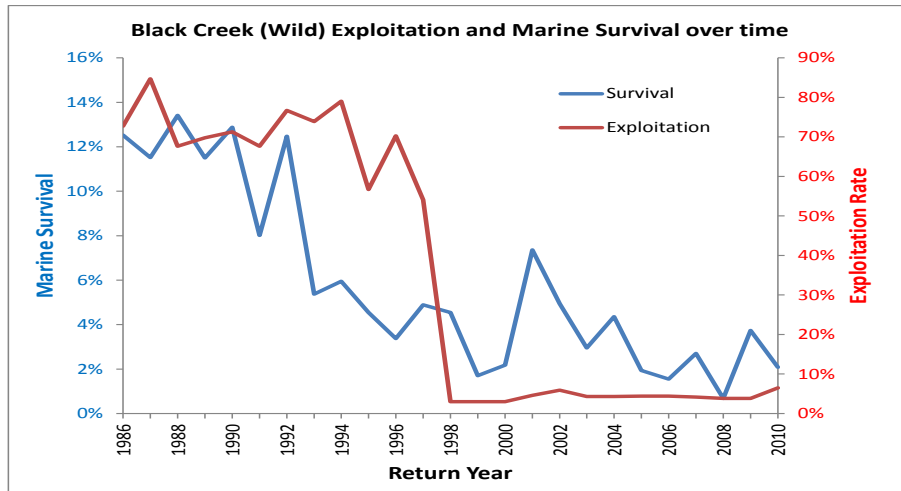


Figure 2. Black Creek Marine Survival and Exploitation, 1986-2010.

During most of this period of decline the coho fisheries in British Columbia were managed with the global objective of maximizing benefits to all Canadians and the only management action was the gradual reduction of directed net fisheries on coho (Kadowaki 1992). PSARC agreed with the need for harvest measures on coho in late 1992 and identified a need to reduce the exploitation rate below 60% (Kadowaki and Ryall 1995). In 1995 the recreational bag limit in the Strait of Georgia was reduced from 4 to 2 with an increase in the minimum size from 30 to 41 cm. and the Strait of Georgia troll fishery was restricted to non-retention for coho salmon. Due to conservation concerns, an exploitation rate range of 20% -25% was established for Strait of Georgia coho in 1997 (Anon 1998).

In 1998 salmon fisheries were restricted over the entire B.C. coast to protect Thompson and Skeena coho with the establishment of Red and Yellow Zones. In the South Coast, Red Zones were areas where Thompson coho were expected to be prevalent. Yellow Zones were areas where Thompson coho were not expected to be prevalent. Only a small number of restricted experimental and test fisheries were allowed in Red Zones and these were closely monitored. In Yellow Zones, the only salmon fisheries permitted were directed on salmon species other than coho. In 1998 all South Coast fisheries were coho non-retention (Irvine 1999, Anon 1998b).

In 1999 the Red Zones were replaced with Special Management Zones (SMZ) to allow for flexibility in managing the fisheries where Thompson and Skeena coho stocks are prevalent. Opportunity for marine fisheries on surplus coho (primarily from hatcheries) was allowed at the mouth of the Capilano River and in the vicinity of the mouth of the Qualicum River (Anon 1999). Since 2000, Strait of Georgia coho fisheries have been restricted to hatchery retention only, with some terminal fisheries allowing limited wild coho harvest, and managed to a maximum total fishing mortality rate of 3% on Thompson coho, effectively limiting the impacts on other Strait of Georgia wild stocks.

2 MARK SELECTIVE FISHERIES

In response to declining wild coho stocks Mark-Selective Fisheries (MSF) were proposed as a strategy to permit harvest while reducing impacts on stocks needing protection. The Pacific Salmon Commission (PSC) established the Ad-hoc Selective Fishery Evaluation Committee (ASFEC) in October, 1993 to complete an assessment of selective fisheries. The assessment focused on two general questions: (1) Can selective fishery regulations reduce harvest rates on unmarked salmon and (2) Can the viability of the existing coast wide CWT program for stock assessment and management planning be maintained if selective fisheries are implemented.

The general conclusions of the ad-hoc committee were: 1) MSF can reduce harvest rates on unmarked salmon and 2) the overall effects of coho MSF on the CWT program will be negative, most notably the assessment of wild (unmarked) coho (Ad-hoc Selective Fishery Evaluation Committee (ASFEC) 1995). The sequestering of the adipose fin clip to identify hatchery coho for MSF, as opposed to identifying the presence of a CWT, has decreased the ability to monitor exploitation and survival of wild (unmarked) coho stocks based on hatchery indicators.

2.1 DOUBLE INDEX TAGGING (DIT)

In response to the loss of wild coho stock assessment capabilities, Double Index Tagging (DIT) programs were implemented. Paired CWT release groups, one with adipose clips (marked) and one without (unmarked), are used to assess the effect of MSF on unmarked fish. The implicit assumption in the DIT analysis is the CWT unmarked hatchery fish are representative of wild stocks.

The DIT analysis compares the ratio of unmarked / marked fish at release with the ratio of unmarked / marked fish in the escapement. If MSF are effective in their goal of reducing harvest on unmarked fish, more unmarked DIT fish should be present in the escapement.

In 1998 seven coho DIT stocks were implemented in British Columbia: Big Qualicum (East Coast Vancouver Island), Goldstream (East Coast Vancouver Island), Quinsam (North Vancouver Island), Chilliwack (Lower Fraser), Inch (Lower Fraser), and Sooke (West Coast Vancouver Island). In 2001 Spius Creek (Thompson River) was added.

Most of these programs were discontinued in 2004; currently, only Quinsam and Inch maintain DIT programs. The analysis in this paper will only include data from the Quinsam and Inch DIT programs.

2.2 IMPLEMENTATION OF MSF

Coho MSF were initially implemented in select recreational fisheries but over time have been applied to all southern BC recreational salmon fisheries as well as WCVI troll. In 2000 retention

of hatchery marked coho was permitted for some local and hatchery stocks and retention of hatchery marked coho was allowed in a pilot selective mark fishery in Area 13 (lower Johnstone Strait) and Area 23 (Barkley Sound / Alberni Inlet) for part of the season. (Anon 2000)

In 2001 coho MSF were allowed in lower Johnstone Strait and Upper Georgia Strait (Areas 13 and 14). (Anon 2001)

In 2002 coho MSF were expanded to all Southern B.C. marine recreational fisheries (Anon 2002) and continue in most areas through 2012. Since 2002, a number of “mixed bag” fisheries have been implemented where the retention of 1 or 2 unmarked coho are allowed. (Anon 2012)

3 OBJECTIVE

The question addressed in this paper:

Is the Georgia Strait hatchery mark selective coho fishery meeting its objectives to reduce exploitation rates and/or relative mortality rates on wild coho populations and maintain or increase harvest opportunities for marked coho?

4 HATCHERY PRODUCTION

Hatchery production of chinook and coho salmon on a routine basis dates from 1971 when the Big Qualicum and Capilano hatcheries began operating. There were 11 chinook and coho hatcheries by 1977, the year the Salmon Enhancement Program (SEP) began. (Cross et al 1991)

SEP has two operational divisions: the Enhancement Operations Division runs large government-owned hatcheries and the Community Programs Division is responsible for hatcheries developed in cooperation with community and public groups. By 1988 there were 111 coho producing facilities located in the SoG or Johnstone Straits. Of the 111, 7 are large government owned facilities: Capilano, Tenderfoot, Big Qualicum, Chemainus, Little Qualicum, Puntledge, and Quinsam. Currently, there are 69 coho producing facilities in the SoG or Johnstone Straits, of these 5 are large government owned facilities: Capilano, Tenderfoot, Big Qualicum, Puntledge, and Quinsam.

Figure 3 shows the time series of hatchery releases and marine survival for SoG coho.

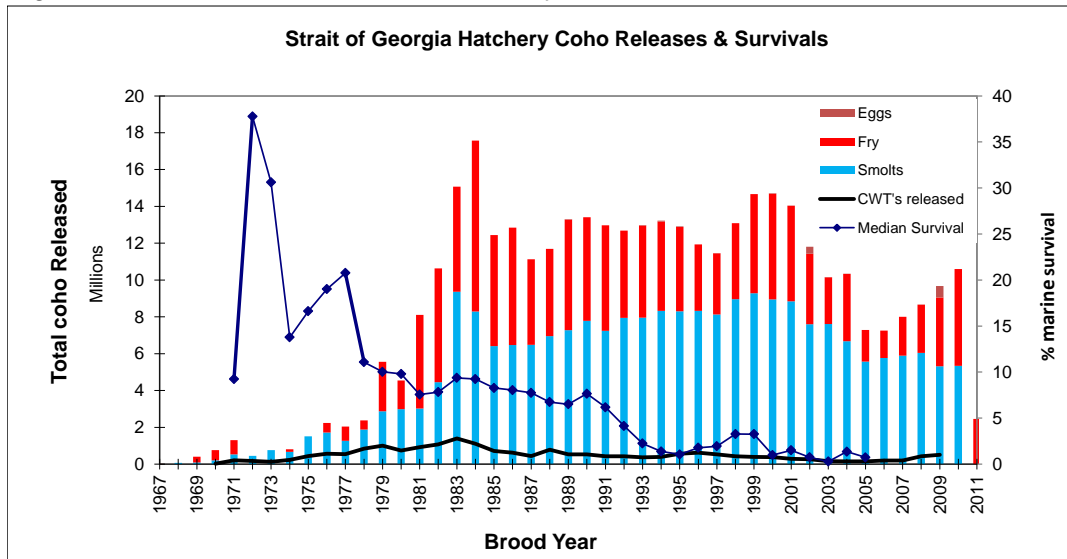


Figure 3. Strait of Georgia hatchery coho releases by stage, marine survivals, and number of CWT releases

5 DATA SOURCES

Data were obtained from the following sources: SEP provided the hatchery coho releases, CWT recovered in hatchery escapement and hatchery marine survival data. South Coast Stock Assessment provided the Black Creek indicator stock data, the SoG recreational creel survey data, and the freshwater creel survey data from the Campbell / Quinsam Rivers. The Inch Creek freshwater creel survey data were provided by Lower Fraser Stock Assessment staff. CWT data were retrieved from the Mark Recovery Program (MRP) and Regional Mark Information System (RMIS) databases. Commercial catch data were obtained from the Fishery Operations System (FOS). North Coast Stock Assessment provided catch data for North and Central Coast fisheries. Historic data were obtained from Milne (1964)

6 METHODS

6.1 DIT ANALYSIS

DIT analysis was performed using a SAS program developed by the Selective Fishery Evaluation Committee of the Pacific Salmon Commission (Pacific Salmon Commission 2002, Joint Coho DIT Analysis Workgroup 2003).

The method used for this DIT analysis is known as the Equal Marine Survival Method (EMS) and has the following assumptions:

1. There are no differential sources of mortality between the unmarked and marked fish before the first mark-selective fishery.

2. All fisheries and escapement of both unmarked and marked fish are adequately sampled
3. There are no non-fishing sources of mortality (i.e. natural mortality) of three year old fish.
4. Effects of multiple mark-selective fisheries do not need to be separated by fishery

The analysis estimates the total impact on unmarked fish summed over all mark-selective fisheries by subtracting the number of fish accounted for (in either escapement or in non-selective fisheries) from an initial abundance estimate. This method does not produce fishery-specific estimates of mortalities. The analysis determines if the ratio of unmarked / marked fish changes between hatchery release and escapement. If MSF are effective in their purpose of allowing harvest of marked fish while reducing the harvest of unmarked fish, this ratio will increase between release and escapement.

A Z- test was used to assess statistical significance

6.2 MSF EFFECTS ON WILD COHO ESCAPEMENT

The pre (1986-1997) and post MSF (2002-2011) escapement to the Black Creek indicator stock were compared to determine if the MSF had a significant effect on wild coho escapement.

6.3 EFFECTIVENESS OF MSF ON HARVEST OPPORTUNITIES FOR COHO.

The pre and post MSF coho catch information from the SoG creel survey were compared to determine if the MSF has increased harvest opportunities for coho.

7 RESULTS

7.1 MARK SELECTIVE FISHERY

7.1.1 DIT Analysis

The DIT analysis on the paired releases from the Quinsam River showed significantly greater numbers of unmarked CWT coho in the escapement in only 6 of 13 years. Significant results were observed in 2002-2005, 2007 and 2010. In comparison, Inch Creek had significantly greater numbers of unmarked CWT coho in all years (Table 1).

Table 1. Double Index Tag (DIT) analysis for Quinsam River and Inch Creek. Pm = marked escapement / marked released, Pu= unmarked escapement / unmarked released.

Return Year	Stock	Pm	Pu	Z stat	P value for Z	Significance
1999	Quinsam R	0.010	0.010	0.406	0.685	NS
2000	Quinsam R	0.017	0.018	0.437	0.662	NS
2001	Quinsam R	0.020	0.020	-0.253	0.800	NS
2002	Quinsam R	0.018	0.020	2.726	0.006	Y
2003	Quinsam R	0.011	0.014	4.101	0.000	Y
2004	Quinsam R	0.012	0.014	2.269	0.023	Y
2005	Quinsam R	0.006	0.007	2.272	0.023	Y
2006	Quinsam R	0.003	0.003	0.148	0.882	NS
2007	Quinsam R	0.008	0.009	1.960	0.050	Y
2008	Quinsam R	0.008	0.009	1.263	0.207	NS
2009	Quinsam R	0.017	0.017	0.689	0.491	NS
2010	Quinsam R	0.011	0.013	2.559	0.011	Y
2011	Quinsam R	0.012	0.013	1.397	0.162	NS
1999	Inch Cr	0.017	0.020	3.194	0.001	Y
2000	Inch Cr	0.013	0.019	7.589	0.000	Y
2001	Inch Cr	0.044	0.060	9.887	0.000	Y
2002	Inch Cr	0.016	0.023	7.463	0.000	Y
2003	Inch Cr	0.006	0.011	7.127	0.000	Y
2004	Inch Cr	0.021	0.024	2.630	0.009	Y
2005	Inch Cr	0.013	0.023	10.448	0.000	Y
2006	Inch Cr	0.007	0.011	5.257	0.000	Y
2007	Inch Cr	0.011	0.017	5.147	0.000	Y
2008	Inch Cr	0.007	0.010	3.620	0.000	Y
2009	Inch Cr	0.009	0.013	4.835	0.000	Y
2010	Inch Cr	0.027	0.041	10.978	0.000	Y
2011	Inch Cr	0.013	0.015	2.863	0.004	Y

7.1.2 Black Creek (wild) Coho Indicator Stock

The escapement estimates for Black Creek are not significantly different for the 1986 -1997 (pre-MSF) period compared to the 2002-2011(MSF) period (t-test P=0.44, df=17) (Figure 4). Data from the years when the coho fishery was closed were excluded from the analysis

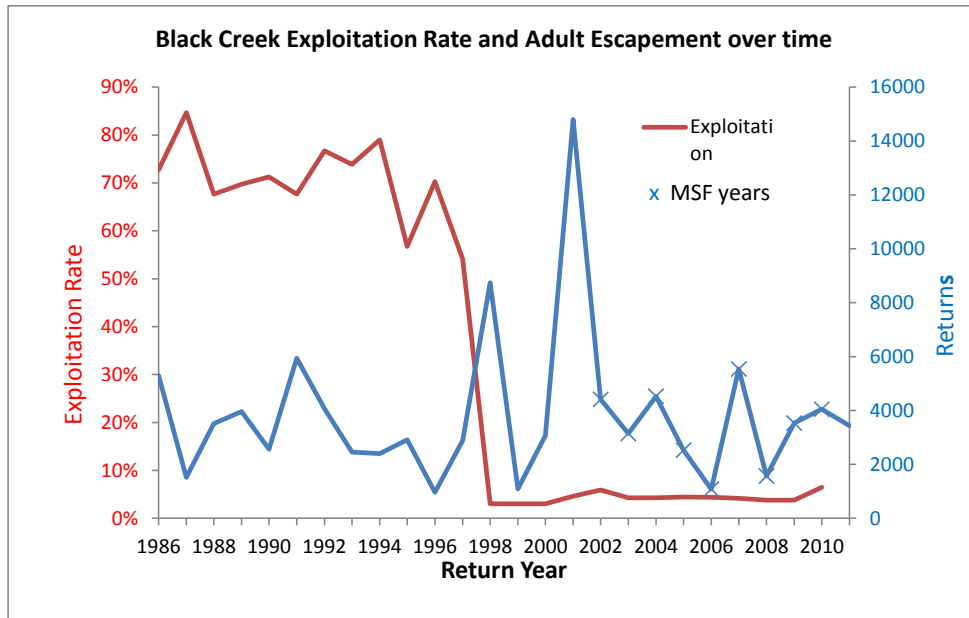


Figure 4. Black Creek exploitation and adult escapement over time

7.2 STRAIT OF GEORGIA RECREATIONAL COHO CATCH

7.2.1 Marine

The MSF in the SoG has provided opportunities for the harvest of marked coho. However, due to low marine survival rates, the MSF in the SoG has done little to maintain or increase harvest of marked coho. The average annual catch of coho for the 2002-2011 MSF years was 6,148 fish (SE=1,452) compared to the years preceding the MSF (1988-1997) average catch was 395,519 (SE=97,344) (Figure 5).

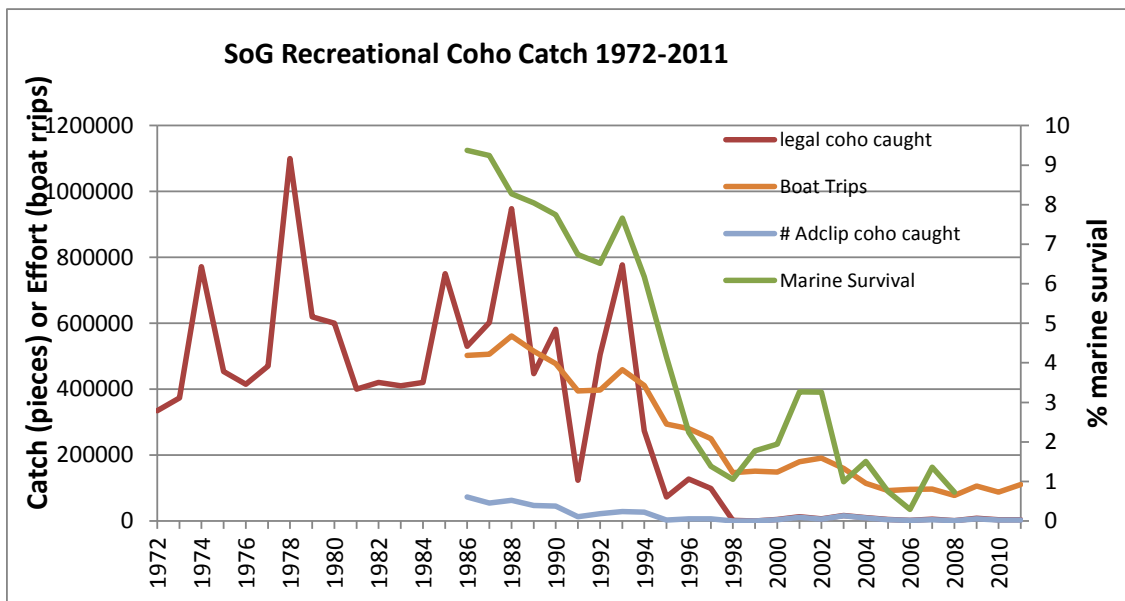


Figure 5. Strait of Georgia Recreational coho catch, 1972-2011, effort in boat trips, % marine survival and adclip coho caught.

The average CPUE (kept coho / boat trip) during the MSF years was 0.05 (SE=0.009). This translates to 1 coho kept for 20 boat trips (Figure 6). The releases of legal and sublegal coho far exceed the retained catch (Figure 7).

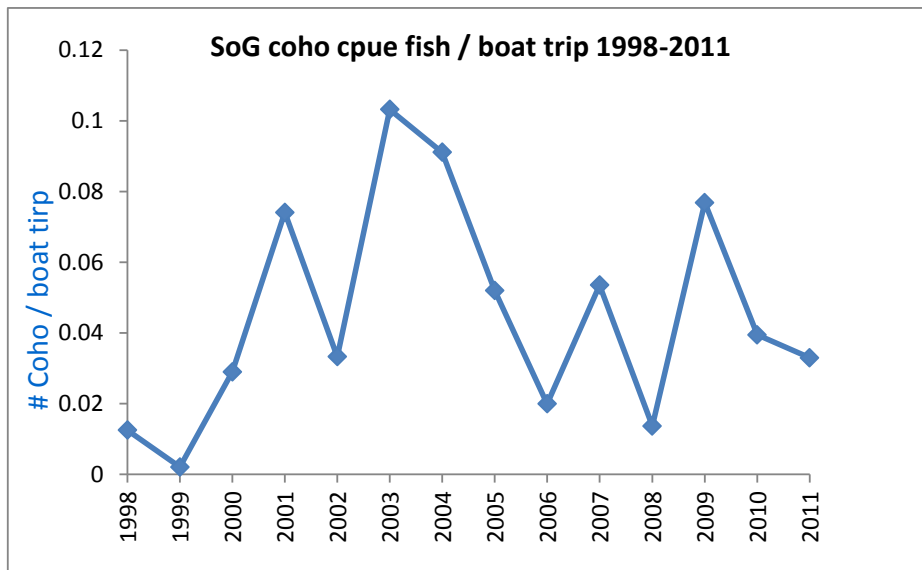


Figure 6. Strait of Georgia coho CPUE (fish / boat trip) for 1998-2011

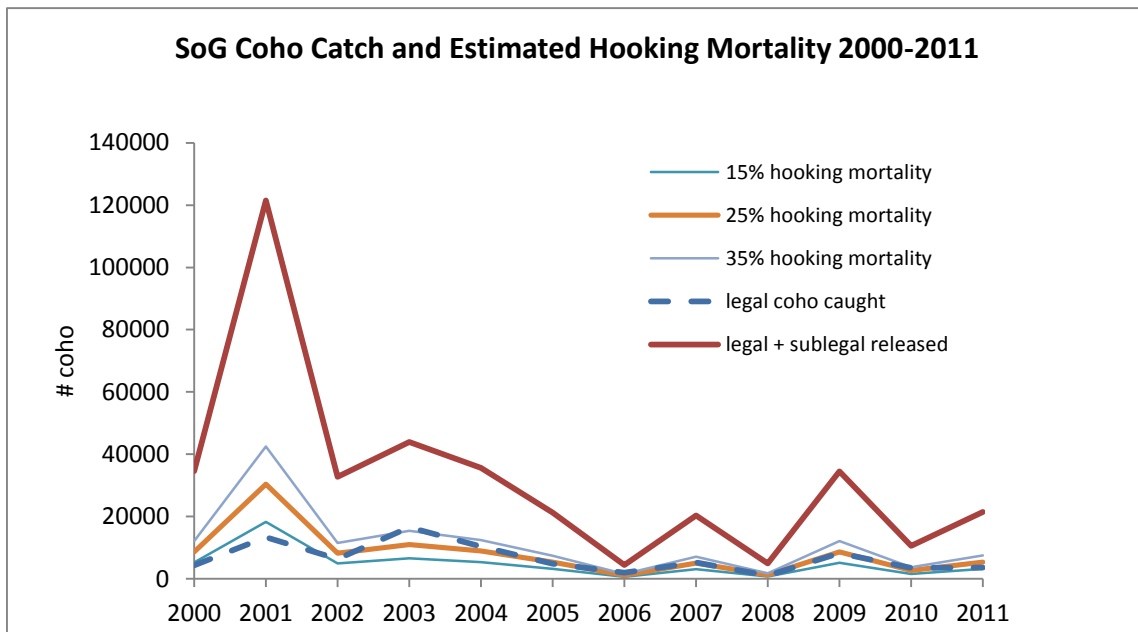


Figure 7. Legal coho caught, legal and sublegal coho released and estimated hooking mortality.

There is no relationship between coho catch and fishing effort (correlation; $r = 0.59$, $df=8$, ns) but a relationship exists between Chinook salmon catch and fishing effort (correlation; $r = 0.89$, $df=8$, $P < 0.01$) (Figure 8 and Figure 9).

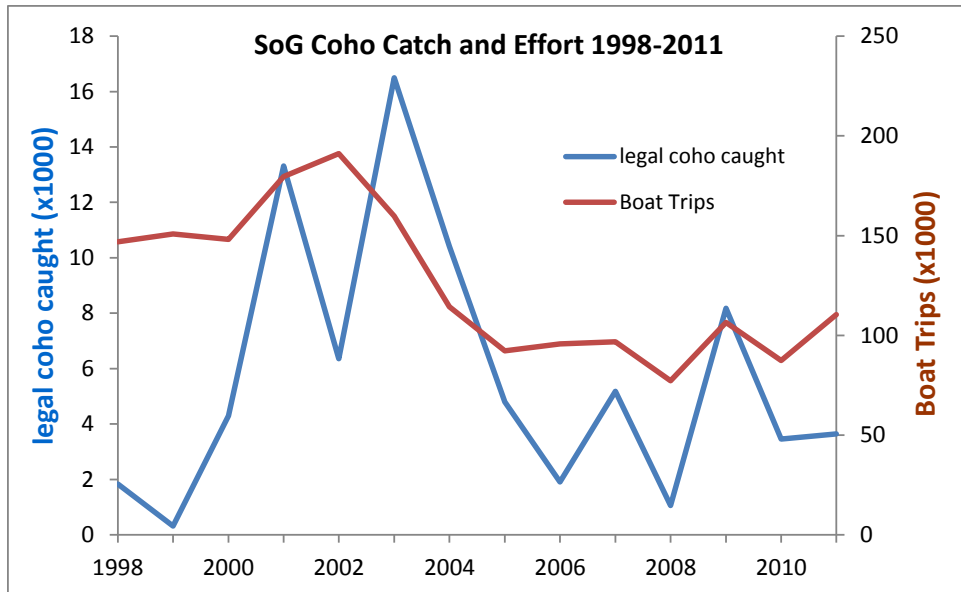


Figure 8. Strait of Georgia coho catch and effort (boat trips) 1998-2011.

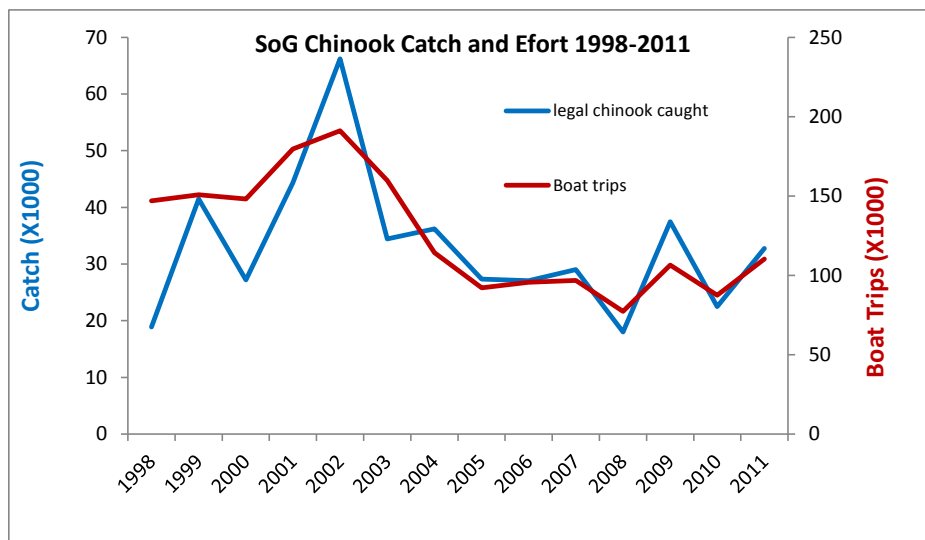


Figure 9. Strait of Georgia Chinook salmon catch and effort 1998-2011.

7.2.2 Freshwater

The creel survey data for the Campbell /Quinsam freshwater fishery from 2007-2011 is listed in Table 2. CPUE (fish / rod hour) ranges from 0.02 in 2007 to 0.22 in 2009. This translates to 1 fish in 64 hours of fishing in 2007 to 1 fish in 4 hours of fishing in 2009. Over a wide range of catches, observed effort is stable (Figure 10).

Table 2. Freshwater creel survey for the Campbell - Quinsam Rivers 2007-2011

	2007	2008	2009	2010	2011
marked fish caught and released	62	566	801	539	233
rod hours	3971	3982	3591	3466	2948
CPUE (fish / rod hour)	0.02	0.14	0.22	0.16	0.08
# hours / fish	64.04	7.04	4.48	6.43	12.65

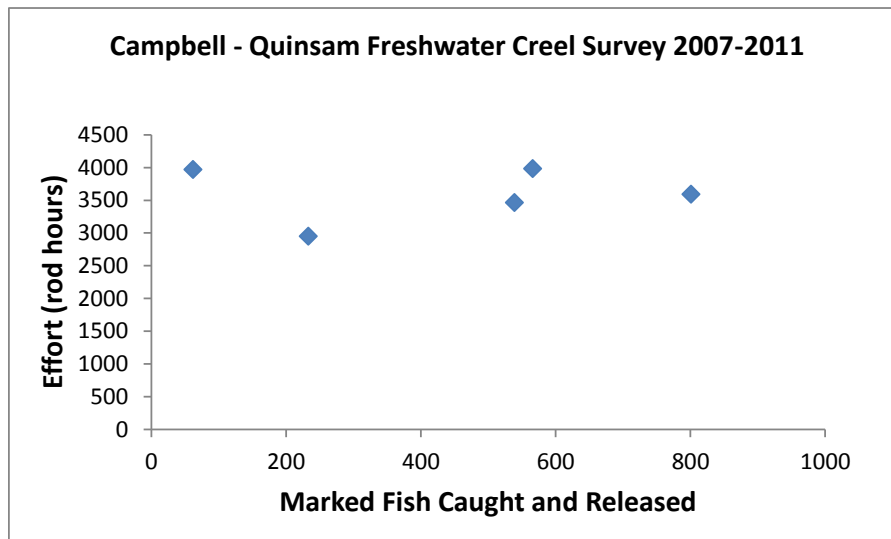


Figure 10. Marked fish caught and released vs effort (rod hours) for the Campbell - Quinsam Rivers 2007-2011.

8 DISCUSSION

Reviewing the objective of this paper:

Is the Georgia Strait hatchery mark selective coho fishery meeting its objectives to reduce exploitation rates and/or relative mortality rates on wild coho populations and maintain or increase harvest opportunities for marked coho?

The results of DIT analysis for Quinsam showed significantly higher escapement of marked fish in only 6 of 13 years (Table 1). In the remaining 7 years, there was no significant difference in the escapement of marked and unmarked fish. In these years the MSF did not reduce the mortality rate of unmarked (a surrogate of wild) fish compared to marked fish. This result, viewed in concert with the pre and post MSF escapement to Black Creek, demonstrate the MSF is not having the desired effect of reduced exploitation or mortality rates on wild coho populations in 7 of 13 years.

The failure of the Strait of Georgia MSF to protect unmarked coho is puzzling and demonstrates the shortcomings of using unmarked DIT stocks as surrogates for wild indicator stocks. Our ability to calculate empirical exploitation rates on wild stocks has been lost. The higher than

expected mortality on unmarked fish could be due to the number of fish harvested in non-selective fisheries. Another source of mortality on unmarked fish is hooking mortality on the large number of coho caught and released in the SoG recreational fishery. Cox-Rogers et al (1999) observed a mean short term (0-24 h) hooking mortality of 25.5% (range 17.2%-35.6%) for legal (>30 cm) coho in the North Coast recreational fishery. If a hooking mortality value of 25% is used, the numbers of released fish killed is similar to the retained catch. Other sources of mortality on unmarked fish include the mixed-bag fisheries and illegal or unmonitored catch.

The DIT analysis for Inch Creek showed significantly higher escapement for unmarked fish in all years. Examination of the CWT recoveries for both Quinsam and Inch show different ocean distributions; Inch is more southern and is harvested primarily in MSF fisheries. Quinsam has a more northern distribution and has a higher number of fish harvest in non-selective fisheries. Note the low observed CWT recoveries in all years. (Appendix 1)

The restrictions on wild coho harvest may have had a positive an effect on Thompson River / Interior Fraser coho. Escapement has increased since 1997 (Figure 11).

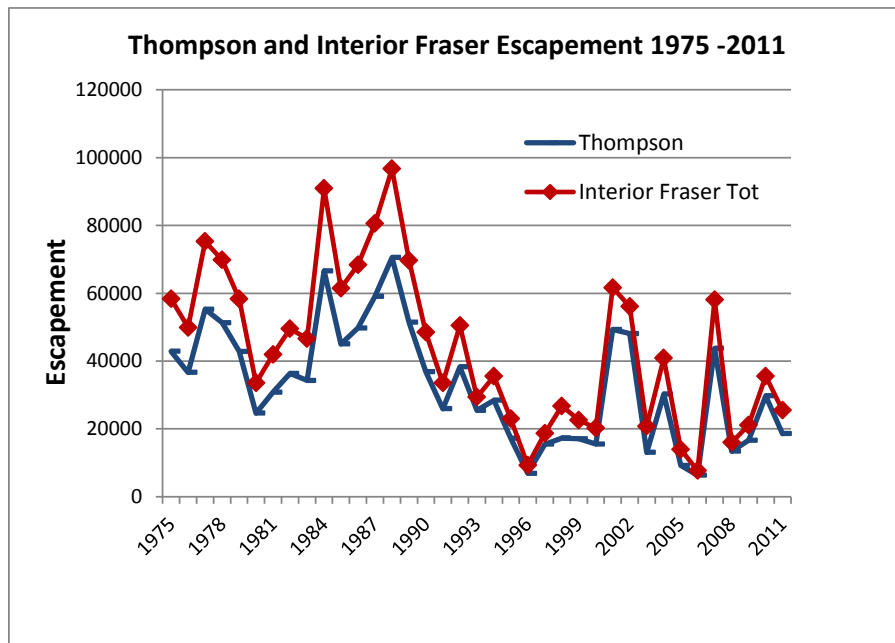


Figure 11. Thompson and Interior Fraser coho escapement 1975-2011.

9 CONCLUSIONS AND RECOMMENDATIONS

The MSF provides opportunities for coho fisheries but the MSF is not having the desired effect of reducing exploitation or mortality rates of wild coho populations in the SoG in 7 of 13 years. The DIT analysis for Inch Creek showed significantly higher escapement for unmarked fish in all years. The termination of the DIT program at the Robertson Creek Hatchery precludes any analysis of the impact of the MSF on WCVI wild coho stocks.

Coho appears to be bycatch in the SoG recreational fishery for Chinook. Coho marine survival and CPUE are so low that a reduction in coho hatchery releases may have little effect on the SoG recreational fishery.

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APPENDIX

Inch AFC-CWT releases and "Estimated Number" ("Observed Number") in retained catch by Release Year and Catch Region. MS= mark selective fishery, NS= non-selective fishery.

Release Year	Adclip CWT Releases	Freshwater Sport (MS)	JST,GST,Jdf Sport (MS)	WCVI Sport (MS)	Northern Sport (NS)	Fraser GN & FN Fall Winter Below Harrison	Northern Troll (NS)	Alaska (NS)	WDFW (MS)	Oregon (MS)	Total
1998	41918	93.84 (24)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	55.61 (21)	0 (0)	149.45 (45)
1999	40206	23.46 (6)	159.08 (1)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	40.74 (11)	0 (0)	223.28 (18)
2000	40201	19.55 (5)	41.14 (5)	124.6 (1)	0 (0)	0 (0)	0 (0)	0 (0)	119.12 (37)	0 (0)	304.41 (48)
2001	39911	0 (0)	9.58 (1)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	53.52 (16)	1.85 (1)	64.95 (18)
2002	39998	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	52.11 (17)	2.93 (1)	55.04 (18)
2003	39819	0 (0)	51.45 (3)	14.69 (1)	0 (0)	0 (0)	0 (0)	0 (0)	212.77 (78)	0 (0)	278.91 (82)
2004	39595	3.19 (1)	22.73 (1)	14.42 (1)	0 (0)	0 (0)	0 (0)	0 (0)	37.87 (18)	0 (0)	78.21 (21)
2005	39986	0 (0)	0 (0)	19.88 (1)	0 (0)	0 (0)	0 (0)	0 (0)	78.18 (25)	0 (0)	98.06 (26)
2006	39724	30.29 (9)	0 (0)	0 (0)	10.9 (1)	1 (1)	4.43 (1)	18.79 (5)	88.69 (26)	0 (0)	154.1 (43)
2007	39035	11.99 (3)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	3.09 (1)	25.32 (8)	1.63 (1)	42.03 (13)
2008	40117	14.07 (1)	19.26 (2)	0 (0)	8.77 (1)	0 (0)	0 (0)	5.79	29.2 (9)	10.03	87.12 (19)

								(1)		(5)	
2009	40306	29.33 (19)	6.78 (2)	15 (3)	0 (0)	0 (0)	0 (0)	0 (0)	39.31 (14)	0 (0)	90.42 (38)
2010	39197	9.52 (7)	0 (0)	47.16 (5)	0 (0)	0 (0)	0 (0)	0 (0)	19.48 (9)	0 (0)	76.16 (21)
Total	520013	235.24 (75)	310.02 (15)	235.75 (12)	19.67 (2)	1 (1)	4.43 (1)	27.67 (7)	851.92 (289)	16.44 (8)	1702.14 (410)

Quinsam AFC-CWT releases and "Estimated Number" ("Observed Number") in retained catch by Release Year and Catch Region.
MS= mark selective fishery, NS= non-selective fishery.

Release Year	Adclipped CWT	Freshwater Sport (MS)	IDE Sport South, JST and South (MS)	GST South, JST and South (MS)	WCVI Sport (MS)	Central Sport (NS)	Northern Sport (NS)	Johnstone Strait Net (NS)	Troll (MS)	Northern and North Central (NS)	Alaska (NS)	WDFW (MS)	Oregon (MS)	Total
1998	39813	0	46.6 (2)	0	0	0	0	0	0	2.6 (1)	0	0	0	49.22 (3)
1999	39322	0	109.3 (2)	0	0	0	0	1 (1)	0	16.2 (6)	14.2 (4)	0	0	140.68 (13)
2000	42352	0	25.3 (3)	0	0	0	0	0	0	1 (1)	8.8 (2)	0	0	35.18 (6)
2001	42996	2.1 (1)	4 (1)	16.8 (1)	8.5 (2)	0	0	0	5.7 (1)	0	18.2 (6)	4 (1)	4 (1)	59.17 (13)
2002	42665	0	8.1 (2)	0	24.4 (5)	0	0	0	0	0	6.4 (3)	0	0	38.91 (10)
2003	42914	0	56.4 (6)	0	49.5 (3)	0	0	0	0	14.1 (4)	14.1 (5)	0	0	134.08 (18)
2004	43430	0	14 (3)	0	10.3 (2)	0	0	0	4.5 (1)	3.8 (1)	2.6 (1)	0	0	35.18 (8)
2005	3799	0	0	16.9 (1)	0	0	0	0	5 (1)	12.4 (3)	4.7 (2)	0	0	38.96 (7)

	8											
2006	4367 2	2.1 (1)	24 (2)	8.7 (1)	19.7 (2)	32.7 (3)	0	13.3 (6)	12.9 (3)	10 (4)	0	123.32 (22)
2007	4444 8	8.7 (3)	0	0	0	0	0	0	12 (4)	0	2.7 (1)	23.46 (8)
2008	4427 0	12.1 (5)	0	53.2 (5)	3.9 (1)	0	0	23.5 (9)	23.8 (5)	18.3 (4)	0	134.7 (29)
2009	4460 0	2.1 (1)	15.9 (2)	0	0	7.3 (1)	0	3.9 (1)	10.3 (4)	3.6 (1)	0	43.16 (10)
2010	4339 4	14.1 (3)	9.3 (2)	0	11.4 (2)	0	0	0	0	2.2 (1)	0	36.99 (10)
Total	5518 74	41.18 (14)	312.9 (25)	95.61 (8)	127.67 (17)	39.97 (4)	1 (1)	55.79 (20)	109.13 (33)	103.1 (33)	6.66 (2)	893.01 (157)