

The purpose of this note is to identify impediments to Cultus sockeye recovery, quantify the productivity response to predator control and examine the impact of harvest restrictions versus productivity improvements.

The Cultus Sockeye Recovery Team (CSRT 2004) assessed the biological feasibility of recovery of the Cultus sockeye population using a simulation model based on the historical stock-recruitment relationship. Applying the exploitation rates estimated for the last 10 years to this model predicts substantial rebuilding with successful spawners averaging about 26,000 fish over the last generation (2001 to 2004). Obviously, this recovery did not happen and mortality other than fishing has caused the stock to decline to endangered levels. (There was an average of 1,500 successful spawners, approximately, over the 2001-2004 period). The suspects are as follows: (1) high pre-spawning mortality (PSM) from early migration particularly over the period 1999-2001, (2) poor marine survival and (3) poor fresh water production.

Pre-Spawning Mortality

For Cultus, PSM refers to the fraction of fish that were counted at Sweltzer Creek but failed to spawn. Any non-route mortalities from early migration are reflected in the marine mortality estimates because marine mortality is measured as the fraction of outmigrating smolts that return as adults (catch and escapement counted at the fence). The high PSM attributed to the 1999-2001 broods (93%, 93% and 67% for the three years) is based entirely on low smolt-to-spawner ratios and the difficulty in finding spawners in the lake. No direct measures of spawning success were obtained in the 1999-2001 period. It is likely that PSM was overestimated for the 1999-2001 period. Confounding factors include the revelation that lake spawners were not easy to find because of displacement into deeper water by milfoil encroachment on the traditional spawning grounds and the low smolt-to-spawner ratios could have been caused by poor egg to smolt (i.e., freshwater) survival. Detailed observations were taken of successful spawning in 2002 and 2003 by the Coast Guard using remotely operated underwater vehicles. They documented extensive deep water spawning. It is well known that sockeye hold in the cooler (deeper) water in Cultus Lake for extensive periods until they are ready to spawn in the fall.

If the accepted PSM estimates for 1999 to 2004 (1999-2001 extreme values were used and 2002-2004 were based on observed spawning success) are incorporated into the simulation model described above, then an average of about 12,000 successful spawners are predicted. While the model reconstruction was substantially less than the 26,000 using just historical exploitation rates, the prediction is still substantially larger than the observed 1,500 average. Thus, even extreme PSM 1999-2001 events are not sufficient to explain the observed decline. We acknowledge that PSM may have had significant impact on the population; however, we believe the effect has been overstated in the status reports (Schubert et al. 2002 and COSEWIC 2003). Additional sources of mortality are required to explain the decline in the last decade.

Marine Survival

The COSEWIC status report (COSEWIC 2003) and the Recovery plan (CSRT 2004) identify poor marine survival in the early to mid 1990's as one of the main causes for the populations decline. However, this claim is made without empirical evidence. Figure 1 plots the marine survival of the 1952 to 2000 brood years based on fraction of out migrating smolts that returned as adults. The only brood years with available data pertinent to the poor survival claim are 1988 to 1990 (returns during 1992 to 1994, primarily) which turn out to be some of the higher survival rates observed.

The only evidence for the poor survival statements are based on Chilko sockeye smolt survival; however, in the 23 years (previous to 1977) where synoptic data were collected there is no correlation between Chilko and Cultus in the survival estimates. In other words, there is not an empirical basis for attributing poor marine survival as causing the decline.

Fresh Water Production

Since smolts are enumerated at the Sweltzer Creek fence at out-migration, fresh water productivity can be characterized by the number of smolts per spawner. Figure 2 plots the smolts-per-successful-adult. The only recent brood years with smolt enumeration free of confounding by PSM and predator control are 1988 and 2002. Both exhibit consistently low productivity that is statistically lower than the historical measures. Using this low productivity measure and observed exploitation rates over the last decade in the simulation model is sufficient to explain (mimic) the observed decline in the Cultus escapement.

Predator Control Programs

Mossop et al. (2004) reviewed the predator control programs (1935 to 1941 and 1989 to 1990 brood years) and provided the following synopsis:

“Exceptional sockeye survival during three of the predator control years in the 1930’s provides the only empirical evidence for benefits to sockeye. However, removals could potentially have an incremental benefit to sockeye survival, provided pikeminnow continue to feed on sockeye when sockeye abundance is very low. Given the constraints of future pikeminnow removals and the potential for complex ecosystem responses following intensive pikeminnow removals, directed efforts at suspected predation ‘hot-spots’ may provide a beneficial action over the short term, while Eurasian watermilfoil control may be effective over the longer term. Trapnets can be used to target pikeminnow that aggregate at the outlet of the lake during the smolt outmigration (mid-March to mid-June).”

Annex 1 in the Recovery plan (CSRT 2004) points out that there also appears to be depensatory predation, where the predator consumes a relatively constant number of prey even when prey abundance is low. Figure 3 plots smolts-per-spawner as a function of spawners to illustrate the phenomena. Six historical brood years with less than 6,000 escapement form a separate group with a production of 34 smolts-per-spawner as compared to 67 smolts-per-spawner in the rest of the historical broods with escapement greater than 6,000. (Usually, productivity decreases as escapement increases – the so called compensation effect). The productivity difference between the two groups is statistically significant (we would be pleased to provide the analysis on request). Note that, under the depensatory predation hypothesis, the recent depressed fresh water productivity occurs because the escapement is small and not because of any habitat or ecosystem changes.

The three predator control brood years with escapement lower than 6,000 fish had higher productivity than any of the historical broods. Even the relatively modest 1989-1990 predator control program appears to have produced positive results with about a doubling of the productivity (67 smolts-per-spawner mean for the 1989 and 1990 broods).

Impact of Harvest Restrictions and Productivity Improvements

Table 1 lists the 2005 Cultus sockeye preseason run size predictions (provided by Charles Parken, DFO). Since 10,698 smolts outmigrated in 2003, marine survival is predicted to range between 1.7% and 2.1%. Inspection of Fig. 1 implies these predictions underestimate the size and overestimate the precision of the return. Nevertheless, using the mid point (50% P level) of 201 fish, Table 2 lists the number of number of spawners under various exploitation and PSM rates. Only 20 to 32 additional fish are saved when harvest is reduced to 10% from 30% dependent on the PSM assumption. Even these savings are overstated because the harvest will be directed mainly at the early part of the Cultus run (the commercial fishery will target summer run fish) where higher PSM rates occur (i.e., there will be a tendency to catch fish that have a higher likelihood of dying).

In contrast, if we assume that the current freshwater productivity, characterized by 1988 and 2002 broods (23 smolts-per-spawner), can be improved to 67 smolts-per-spawner through a predator control program then better results can be obtained. Table 3 provides the percent generational growth assuming mean marine survival and 30% SPR under current (23) and projected with predator control (67) smolts per spawner and various exploitation rates. To illustrate some absolute numbers assume the parameters in Table 3 and harvest at 10% in 2005 so that escapement is 127 fish. If a predator program is not implemented and harvest is maintained at 10% in 2009 then 120 fish will escape. On the other hand if harvest is increased to 30% but a predator program is implemented then 98 fish escape in 2005 but 209 fish in 2009.

Conclusions

Low fresh water productivity is identified as the main impediment to Cultus sockeye recovery over the last decade. The causal mechanism is believed to be depensatory predation and not habitat degradation. The primary mitigative measure should be a predator control program to enable the population to escape the "predator pit".

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Table 1. Pre-season forecast for 2005 Cultus sockeye return.

P Level ¹	Return
0.95	177
0.90	183
0.75	191
0.50	201
0.25	210
0.10	219
0.05	224
¹ Probability of a larger run size	

Table 2. Number of Cultus sockeye spawners under various exploitation and pre-spawning mortality rates assuming a return of 201 fish.

PSM ¹ (%)	Exploitation Rate (%)			
	10	15	20	30
20	145	137	129	113
30	127	120	113	98
40	109	103	96	84
50	90	85	80	70
¹ Pre-spawning mortality				

Table 3. Percent generational growth assuming mean marine survival (6.5%) and 30% PSM under recent (23) and mean (67) smolts per spawner and various exploitation rates.					
Smolts per Spawner	Exploitation Rate (%)				
	10	15	20	30	
23	-5.8	-11.0	-16.3	-26.7	
67	174.4	159.1	143.9	113.4	

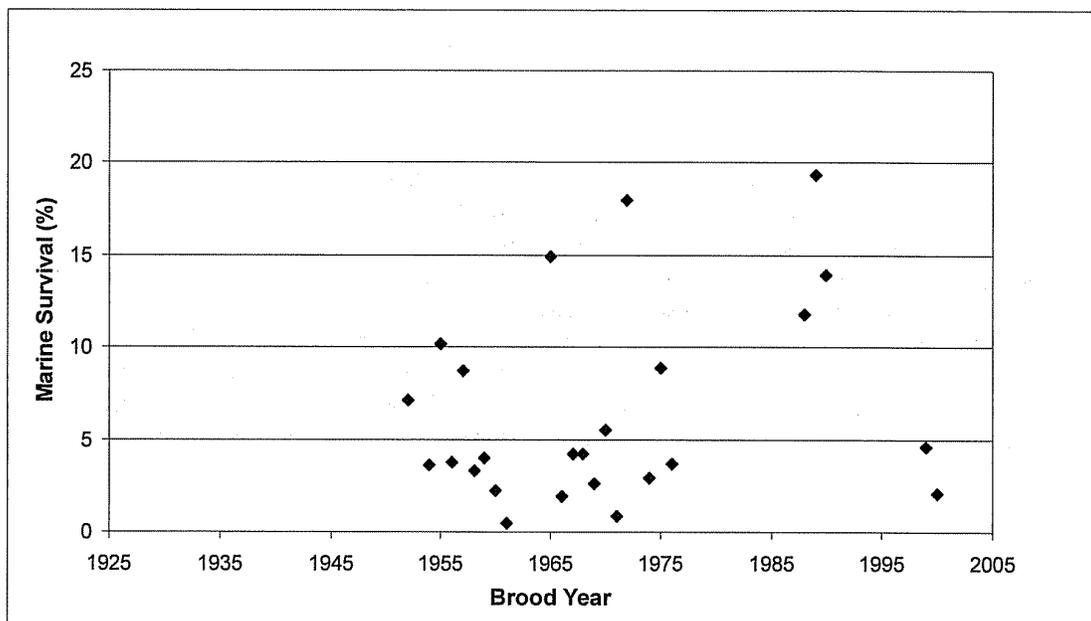


Figure 1. Marine survival of the 1952 to 2000 brood years based on fraction of out migrating smolts that returned as adults. Notes: (1) 1951 was excluded because a survival of 43.9% was not considered credible; (2) five year old returns are not included in the 2000 brood year which will result in a small underestimate; and (3) here are two long periods when smolt enumeration was not conducted (1977 to 1987 and 1991 to 1998)

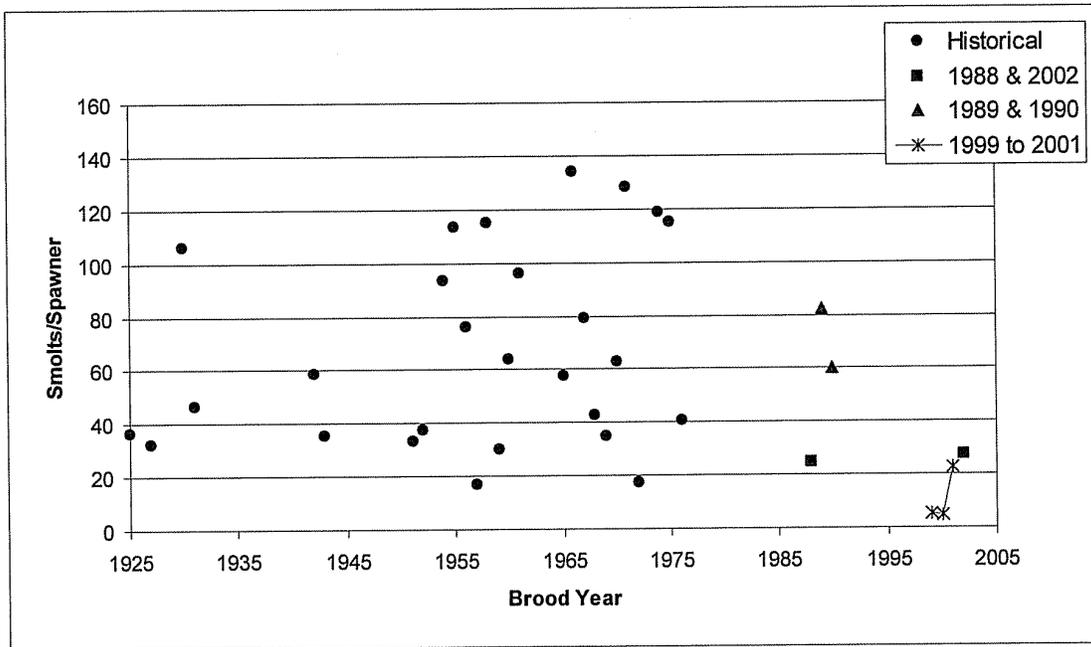


Figure 2. Smolts per successful spawner (the large scale hatchery operation and large scale predator removal 1935-1941 brood years are excluded). Notes: (1) successful adult estimates were calculated using successful spawning fractions where available and the mean historical PSM of 6.6% for all other years; (2) brood years (1926, 28, 29, 32, 33) were not used because natural spawning was not allowed (all eggs were stripped); (3) brood years 1935 to 1941 were not used because of the large scale predator control program; (4) brood year escapements for 1988 to 1991 were expanded to account for truncated fence operation; (5) the 1989 and 1990 broods are plotted but they were affected by a predator control program; and (6) the 1999 to 2001 broods are plotted using spawner counts not corrected for PSM (no measure of spawning success is available but large PSM events are suspected).

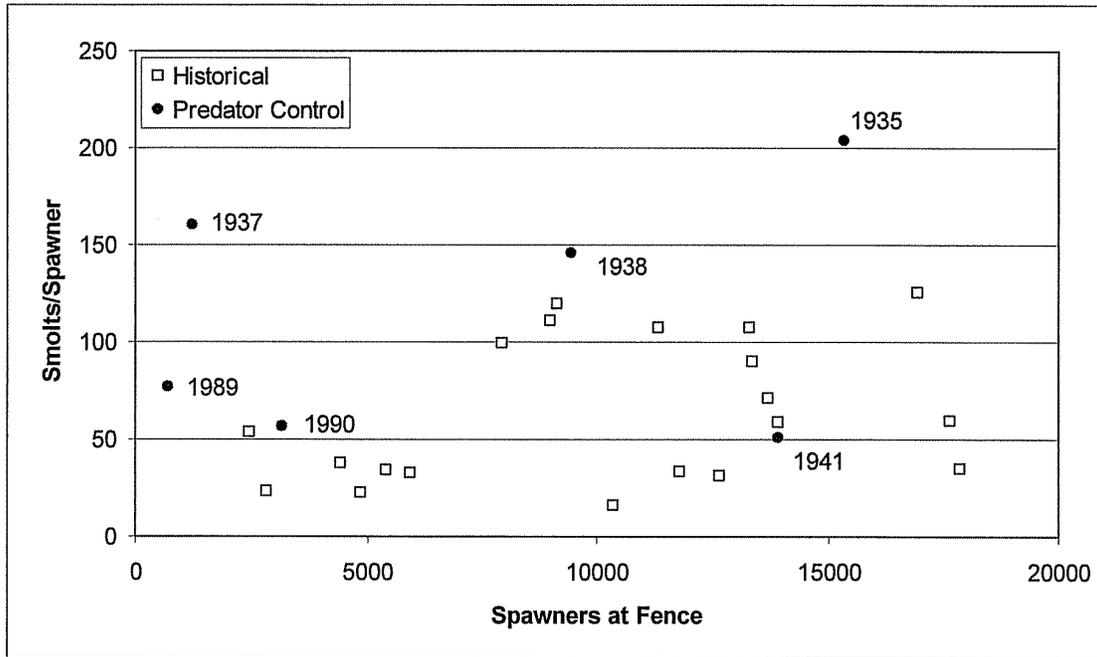


Figure 3. Smolts per spawner as a function of spawners enumerated at Sweltzer Creek fence. Corrections for PSM were not made. Notes: (1) brood years (1926, 28, 29, 32, 33) were not used because natural spawning was not allowed (all eggs were stripped); (2) brood years 1991 to 2001 were not included because of confounding with possibly large PSM events; (3) brood years with associated predator control programs are plotted and identified; (4) the plot is truncated at 20,000 spawners to focus on the lower abundance behavior (9 historical and 2 predator control points not shown – the 9 historical points are included in the average calculation).