Technical Review of the CWT Program and its Use for coho and Chinook Management

Part I

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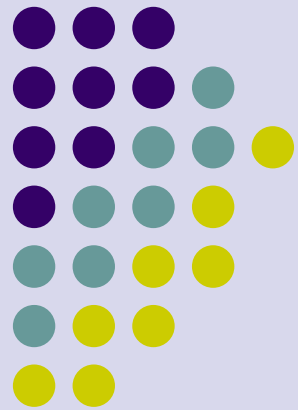
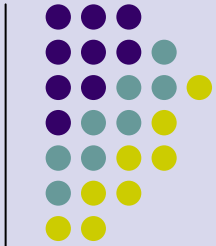


What will these talks be about?

- ***Sample design***
- *Tagging and sampling programs*
- ***Estimation of exploitation rates and their uncertainty***
- *Simple exploitation rates and uncertainty*
  - *Estimation of tagged harvest and escapement*
  - *Precision – sampling variances*
  - *Factors that impact variance of SER*
    - *Tagging rates*
    - *Sample rates*
    - *Fishery resolution*
  - *Estimates of total harvest and escapement*

  - *Bias in estimates of tagged harvest and escapement*
  - *Bias in SER when fisheries or escapement locations are not sampled*
- ***Some conclusions***
  - *Reliability of estimates of exploitation rates for management*
    - *Viability of the CWT program*
  - *Sample design issues*
    - *CWT program tune-up*

Sample design



- The CWT program consists of two major components, the tagging and the sampling programs.
- The parties to the PSC treaty have agreed to maintain a coded-wire tagging and recovery program designed to provide statistically reliable data for stock assessments and fishery evaluations.
- Quality control is the responsibility of the agencies carrying out the tagging and sampling tasks.

Tagging program

- Chinook and coho salmon tagging programs are carried out by agencies coast wide.
- The tag groups are hatchery juveniles and wild or naturally spawned juveniles.
- The tag code provides information on
  - the origin of the fish
  - the age of the fish in the tag group

Tagging program

- In 1985, the Chinook and coho technical committees (CTC and CoTC) of the Pacific Salmon Commission initiated the Chinook and Coho Indicator Stock programs.

Tagging program

- Stocks were selected that were representative of particular basins or regions of production

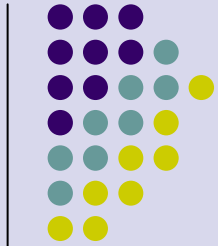
Tagging program

- The intent was to utilize indicator stocks to monitor and evaluate the effectiveness of the management measures prescribed by the PSC

Tagging program

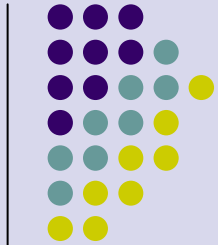
- Additional CWT groups are used to describe the historical fishery distributions and estimate exploitation rates for stocks of interest.

Sampling program



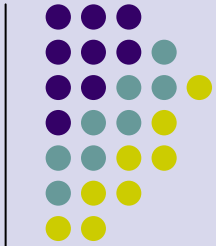
- The basic design for the CWT sampling program is a stratified sample design.
- Fisheries are stratified and each stratum is sampled by week, month or year.
- The definition of the spatial-time strata for sampling is determined by the conduct of the fisheries.

Basic Sampling Guidelines



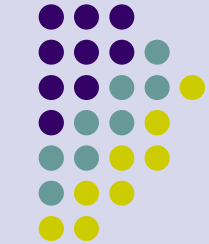
- Fisheries should be sampled at 20%
- Hatcheries are sampled, most at 100%
- Spawning grounds should be sampled.

Assumptions necessary for estimation of tagged harvest and escapement



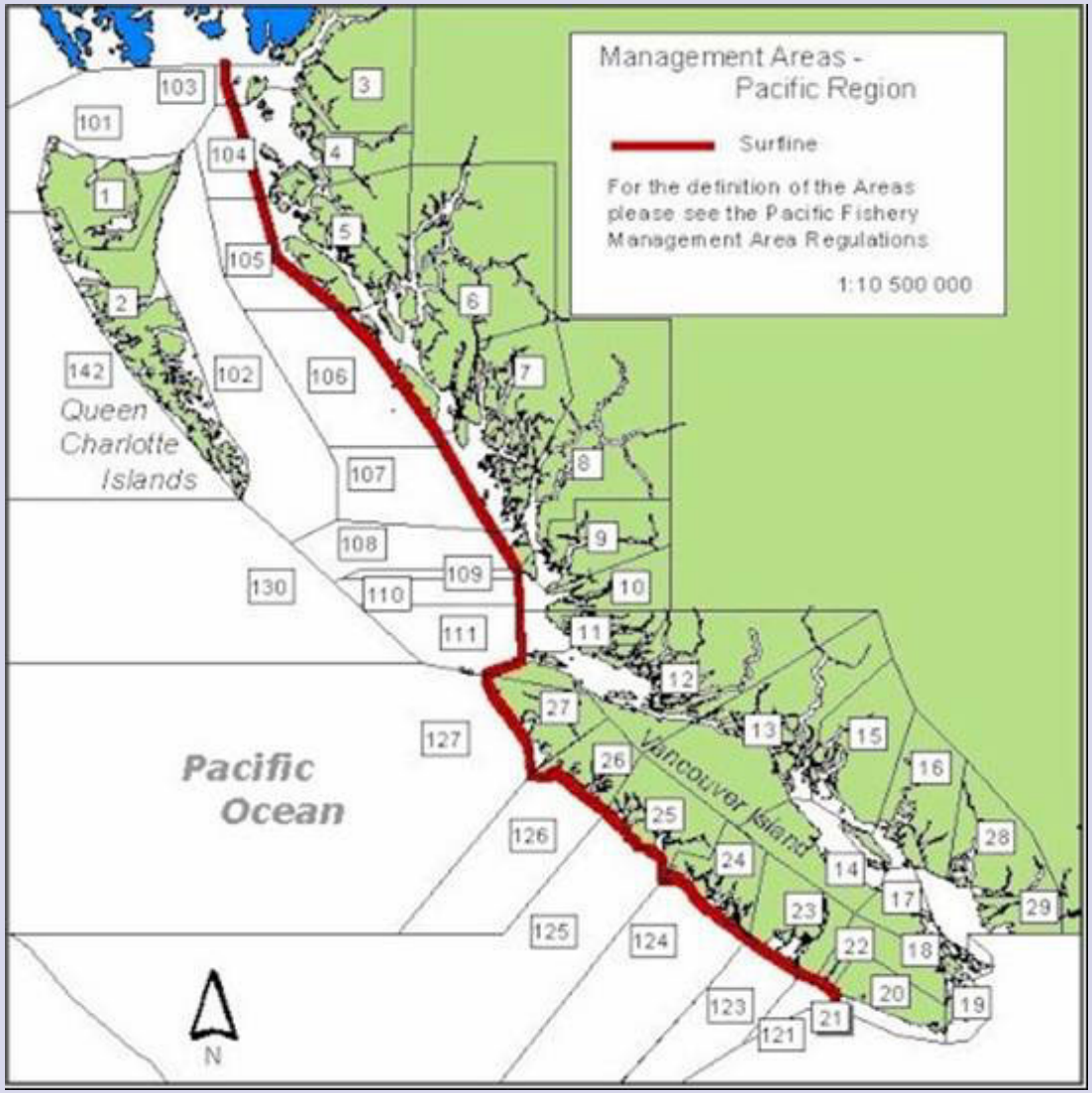
- Sampling in each stratum is random or representative.
- The total harvest or escapement is known or estimated without bias for the purposes of expanding the observed tagged fish to total tagged fish harvested or in the escapement.
- All tagged fish in the sample are identified.

Assumptions necessary for estimation of unbiased exploitation rates

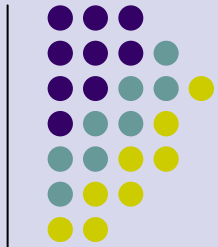


- All strata represented in a fishery and all locations of escapement (hatcheries, spawning grounds) are sampled, that is sampling coverage is complete.

Canadian Sampling Strata

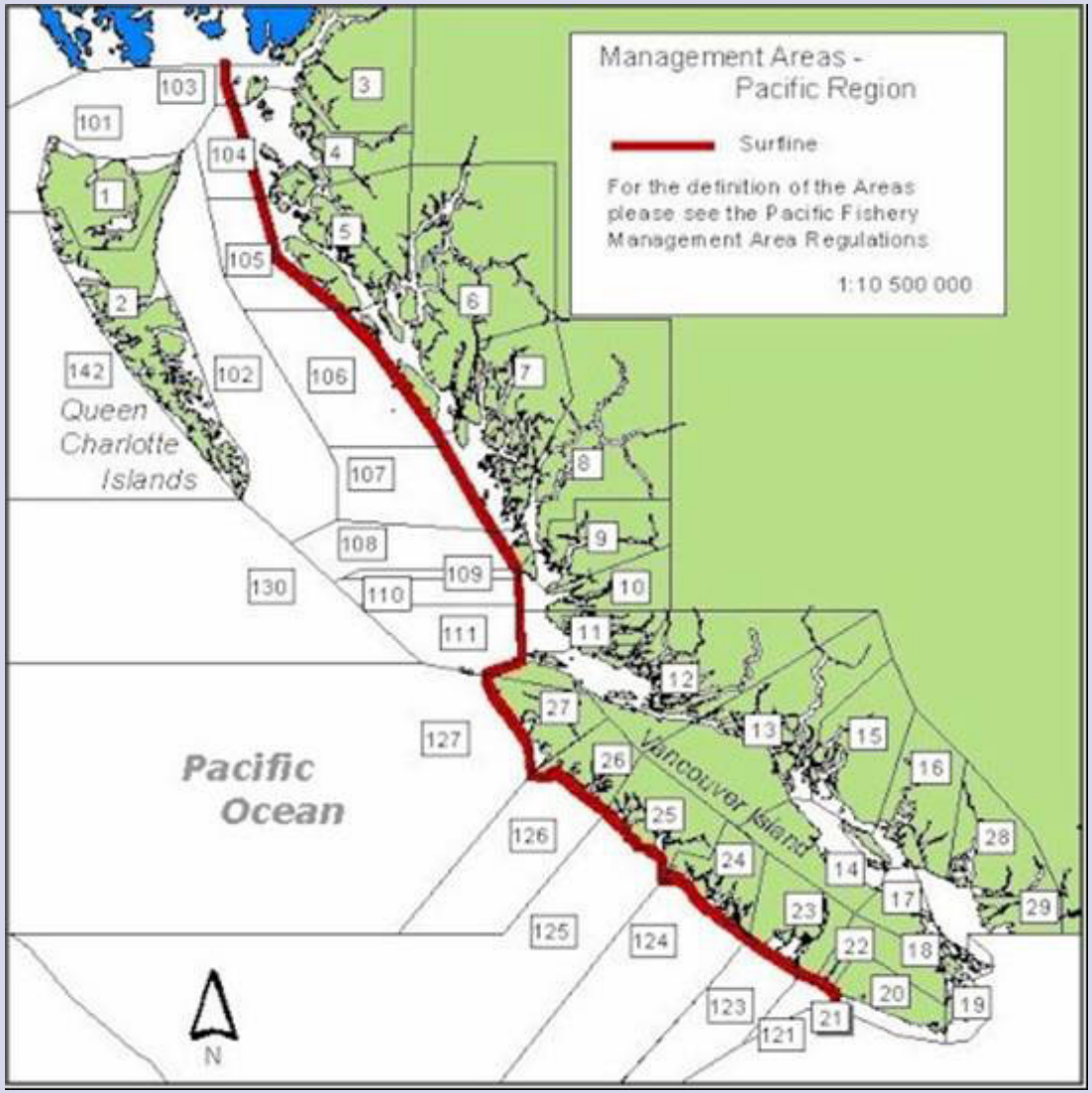


Canadian Commercial Fisheries

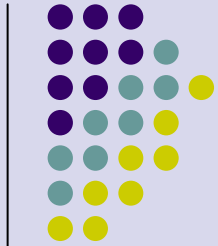


Name of Fishery Catch Region	Acronym	Included Statistical Areas
Northern Troll	NTR	1 - 5
North Central Troll	NCTR	6 - 9, 30
South Central Troll	SCTR	10 - 12
Northwest Vancouver Island Troll	NWTR	25 - 27
Southwest Vancouver Island Troll	SWTR	21, 23, 24
Georgia Strait Troll	GSTR	13 - 18, 29A
Juan de Fuca Troll	JFTR	20
Northern Net	NN	1 - 5
Central Net	CN	6 - 11
Northwest Vancouver Island Net	NWVN	25 - 27
Southwest Vancouver Island Net	SWVN	21 - 24
Johnstone Strait Net	JSN	12 - 13
Georgia Strait Net	GSN	14 - 18
Fraser Gillnet	FGN	29A - E
Fraser Seine Net	FSN	29A
Juan de Fuca Net	JFN	20
Alaska Net	AN	Southeast Alaska

Canadian Sampling Strata



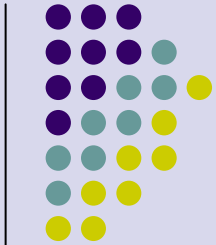
Sampling program and assumptions



There are some logistic problems in meeting the assumption that sampling is representative,

- Commercial fisheries where all harvesters do not land catch at docks In some cases the harvest may be processed onboard.
- Fishers sell harvest directly to consumers (over the bank or at the dock)

Example - Canadian Troll Fisheries



- Freezer boats process harvest onboard, bring in heads, but
  - May not bring in all or any heads
  - Heads brought in may not match number landed by boat
  - Recovery information may be missing
- Sample landed catch to make up 20%.
  - If freezer boats and boats landing do not fish on same population, estimates of tagged harvest is biased

Sampling program and assumptions

- There are limitations to moneys available for sampling fisheries and escapement and there is not complete coverage. In particular:
  - Freshwater sport fisheries are not generally sampled for CWT.
  - Spawning grounds where tagged fish may be present are not consistently sampled.

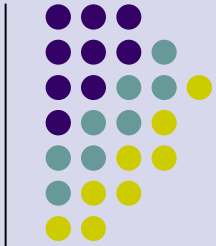
Example - Washington Coho Salmon 1998-2000

(Joint Coho DIT Analysis Workgroup, 2003)

Fishery type		1998	1999	2000
Commercial net and troll	Strata	341	260	376
	Harvest	184,129	161,787	452,598
	Sample	71,030	62,057	119,487
	% sample	39%	38%	26%
	Strata not sampled	135	103	162
	Harvest not sampled	13,028	13,219	37,315
	% not sampled	7%	8%	8%
Ocean Sport	Strata	27	59	55
	Harvest	25,713	47,491	83,829
	Sample	12,205	19,817	37,344
	% sample	47%	42%	45%
	Strata not sampled	3	5	7
	Harvest not sampled	296	300	498
	% not sampled	1%	1%	1%
Puget Sound Sport	Strata	66	45	53
	Harvest	62,456	18,697	77,910
	Sample	12,811	3,901	16,891
	% sample	21%	21%	22%
	Strata not sampled	25	11	4
	Harvest not sampled	922	558	154
	% not sampled	1%	3%	0%
Freshwater sport that impact Puget Sound coho salmon tag groups	Strata	24	24	24
	Harvest	15,824	15,457	23,509
	Strata sampled	1	1	1
	Sample	287	1,979	1,541
	% not sampled	98%	87%	93%
All Washington fisheries Combined (excl. Col. R.)	Total Harvest	288,122	243,432	637,846
	% not sampled	5.4%	5.5%	3.4%

Example - Washington Coho Salmon 1998-2000

(Joint Coho DIT Analysis Workgroup, 2003)



- Escapement – Out of 17 indicator stocks
  - 7 had sampling on spawning grounds
  - 2 were net pens
  - 8 had no sampling on spawning grounds

Sampling program and assumptions

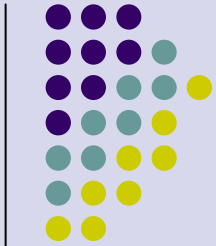
- Some marine sport fisheries are not sampled for CWTs, but tags returned by anglers voluntarily are used.
  - This relies on the “awareness factor”, or the probability that an angler will return the head of a tagged fish.
    - Currently still used in BC, was used for Puget Sound

Estimation of exploitation rates

$$ER_{i,j} = \frac{(F_{i,j} + IM_{i,j})}{\sum_{f}^{F}\sum_{a}^{A}(F_{f,a} + IM_{f,a}) + \sum_{a}^{A}(NM_a + PSM_a + E_a + S_a)}$$

Cohort	=Recruitment cohort for brood, sum of all mortalities and escapement
$F_{f,a}$	=Landed mortalities estimated using tagged fish recovered in fishery *f* and for age *a*
$IM_{f,a}$	=Incidental mortalities in fishery *f* and for age *a*, i.e., catch and release, sub-legal release, drop-off and mark-selective fishery mortalities
NM_a	=Natural mortality occurring prior to recruitment for age *a*
PSM_a	=Pre-spawning mortality for age *a*, occurring after fish exit last fishery, e.g. interdam mortalities
E_a	=Escapement to hatcheries for age *a*
Sa	=Escapement to spawning grounds for age *a*

The components necessary for estimation of the exploitation rates



- ***Landed mortality and escapement estimated directly from tagged fish recovered in fisheries, hatcheries and on spawning grounds.***
- Non-landed mortalities including sub-legal, species catch and release (CNR, e.g., release of Chinook in coho fishery), mark-selective fishery release and drop-off. These are estimated indirectly as some function of landed mortalities, or in a few cases from independent sampling.
- Natural mortality which is estimated using an assumed rate (CTC, 2003).

CTC, 2003. Annual Exploitation Rate Analysis and Model Calibration, November 2003. TCCHINOOK (03)-2.

Simple Exploitation Rates

- What is the SER and why we are using it for this review?
- Precision of estimates of tagged harvest and escapement
- Precision of estimates of SERs
- Examples for coho and Chinook salmon
- What are the factors that impact precision of SER?

Simple Exploitation Rates

$$SER\left(\hat{F}^{C}_{0,P,A}\right) = \frac{\hat{F}^{C}_{0,P,A}}{\sum_{i=fisheries}\sum_{j=period}\sum_{a=ages}\hat{F}^{C}_{i,j,a} + \hat{E}_C + \hat{S}_C}$$

$F^{C}_{0,P,A}$	=	number of tagged fish from group *C* harvested in fishery O, period P and age A
$F_{i,j,a}{}^{C}$	=	number of tagged fish from group *C* harvested in fishery *i*, period *j* and age *a*,
E_C	=	number of tagged fish of group *C* that escaped to the hatchery, and
S_C	=	number of tagged fish of group *C* that strayed to spawning grounds.

Simple Exploitation Rates

$$Var(SER) \cong \frac{Var\left(\hat{F}_0^C\right)}{\left(\sum_i \hat{F}_i^C + \hat{E}_C + \hat{S}_C\right)^2} + \left(SER(\hat{F}_0^C)\right)^2 \left(\frac{Var\left(\sum_i \hat{F}_i^C + \hat{E}_C + \hat{S}_C\right)}{\left(\sum_i \hat{F}_i^C + \hat{E}_C + \hat{S}_C\right)^2} \right)$$

$$PSE\left(SER\left(\hat{F}_0^C\right)\right) = \left[\frac{\sqrt{VAR\left(SER\left(\hat{F}_0^C\right)\right)}}{SER\left(\hat{F}_0^C\right)} \right]$$

Estimating variances for the estimates of tagged harvest and escapement

When the total harvest or escapement is known:

$$\hat{F}_0^C = \frac{m_0^C}{\varphi_0}$$

$$\varphi_0 = \frac{n_0}{N_0}$$

$$V(\hat{F}_0^C) = \frac{\hat{F}_0^C}{\varphi_0}(1-\varphi_0)$$

F^C_0	= Number of tagged fish harvested in stratum 0 from tag group C
m^C_0	= tagged fish recovered in stratum 0 from tag group C
φ_0	= sample fraction in C or where n_0 is the number sampled and N_C is the total catch or escapement

Bernard, D.R. and J.E. Clark. 1996. Estimating salmon harvest with coded-wire tagged fish. Can.J.Fish.Aquat.Sci. 53: 2323-2332.

Estimating variances for the estimates of tagged harvest and escapement

When the total harvest or escapement is estimated:

$$\hat{p}_0^C = \frac{m_0^C}{n_0} \qquad V(\hat{p}_0^C) = \frac{\hat{p}_0^C}{n_0}(1-\hat{\varphi}_0)$$

$$\hat{F}_0^C = \hat{N}_0 \hat{p}_0^C$$

$p^C{}_0$ = proportion of sample in stratum 0 that is tagged from tag group C

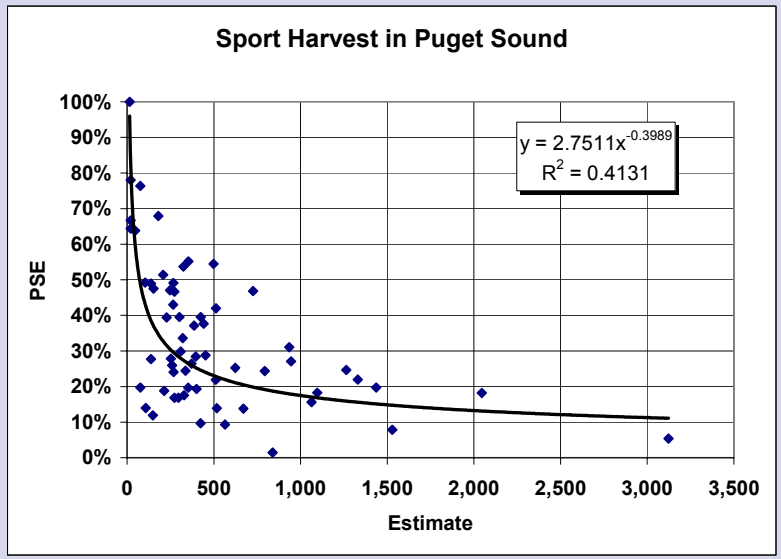
$$V(\hat{F}_0^C) = \hat{F}_0^{C^2}(G(\hat{p}_0^C) + G(\hat{N}_0) - G(\hat{p}_0^C)G(\hat{N}_0))$$

$$G(\hat{X}) = \left[\frac{SE(\hat{X})}{\hat{X}}\right]^2$$

Bernard, D.R. and J.E. Clark. 1996. Estimating salmon harvest with coded-wire tagged fish. Can.J.Fish.Aquat.Sci. 53: 2323-2332.

Estimating variance of total harvest or escapement or N_0

Sport Harvest



Escapement – PSE = 40%

Estimating variances for the estimates of tagged harvest and escapement

When the CWTs are returned voluntarily by anglers:

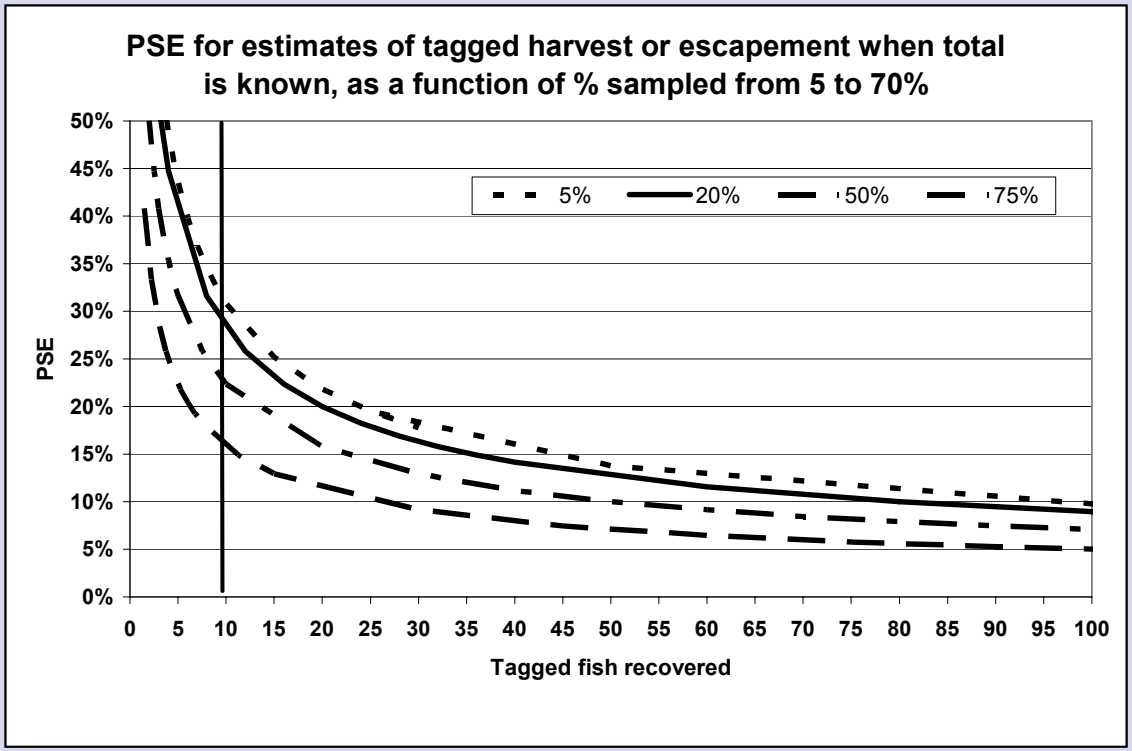
$$\hat{F}_o^C = \frac{m_o^r + m_o^v}{\frac{n_0}{\hat{N}_0} + (1 - \frac{n_0}{\hat{N}_0})\hat{P}_A^o}$$

P_A^i which is the probability that a tagged fish caught in fishery *i* will be returned by the angler (Kimura, 1976).

Kimura, D.K. 1976. Estimating the Total Number of Marked Fish Present in a Catch. *Transactions of the American Fisheries Society:* Vol. 105, No. 6, pp. 664–668.

Precision of estimates of tagged fish, when total is known

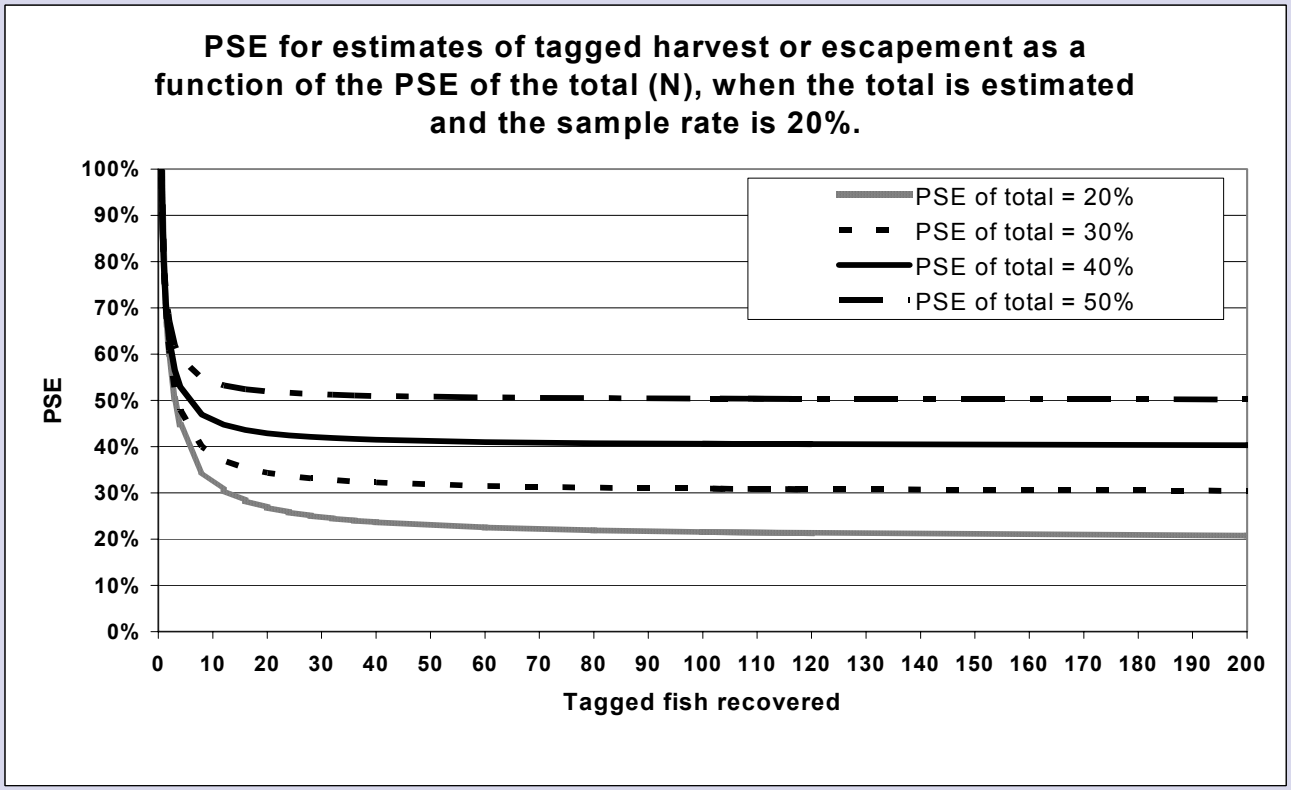
$$V(\hat{F}_0^C) = \frac{m_0^C}{\varphi_0^2}(1-\varphi_0)$$



Precision of estimates of tagged fish, when total is estimated

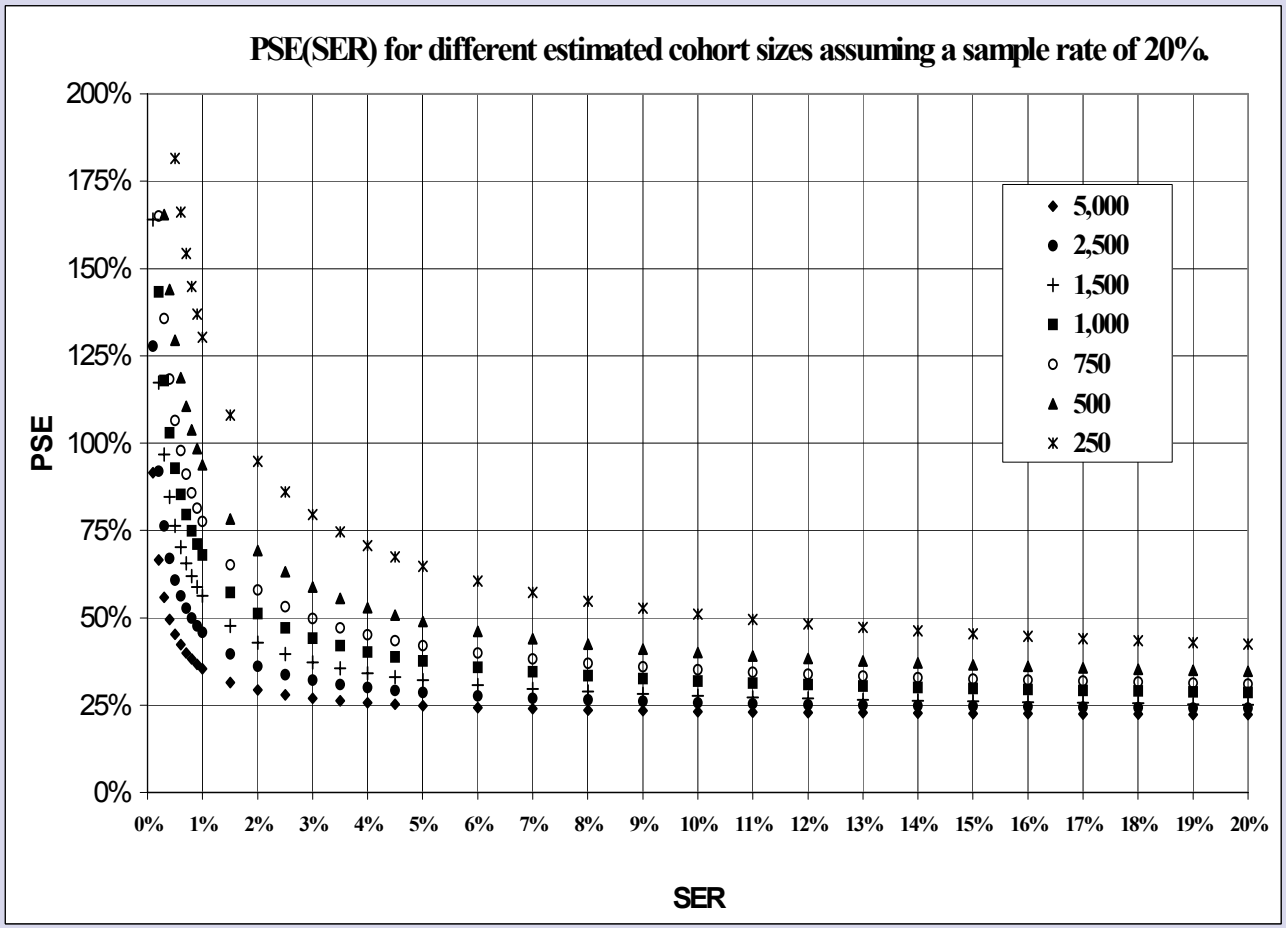
$$V(\hat{F}_0^C) = \frac{{m_0^C}^2}{\varphi_0^2}(G(\hat{p}_0^C) + G(\hat{N}_0) - G(\hat{p}_0^C)G(\hat{N}_0))$$

$$V(\hat{p}_0^C) = \frac{(1-\hat{\varphi}_0)}{m_0^C}$$



Precision of estimates of SER

$$PSE\left(SER\left(F_0^C\right)\right) = \frac{\sqrt{Var\left(SER\left(F_0^C\right)\right)}}{SER\left(F_0^C\right)} = \sqrt{\frac{1-\varphi_0}{\hat{T}^C \bullet SER(\hat{F}_o^C) \bullet \varphi_0} + PSE(\hat{T}^C)}$$



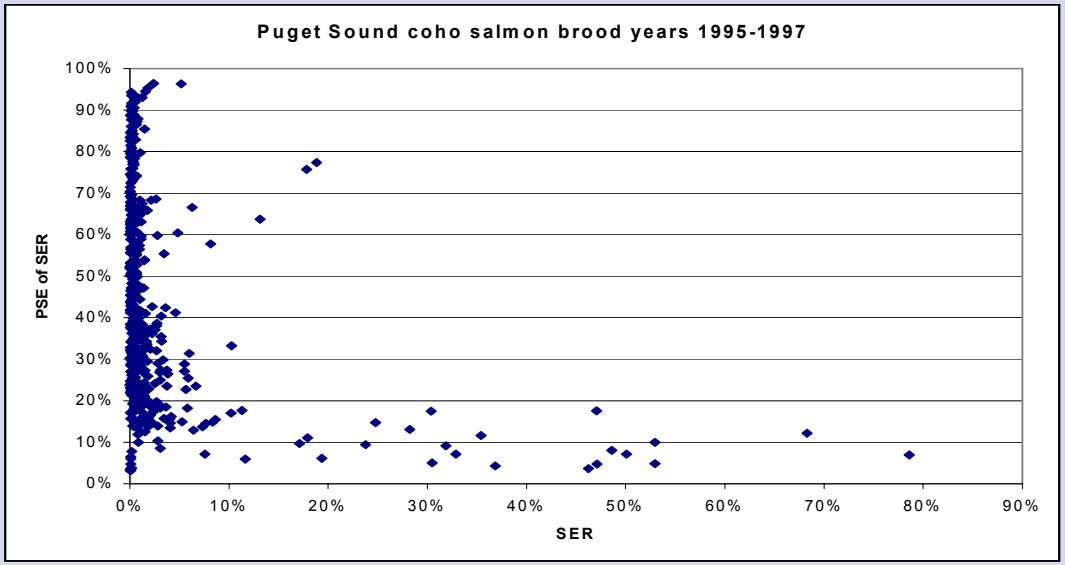
T^C = Cohort Size

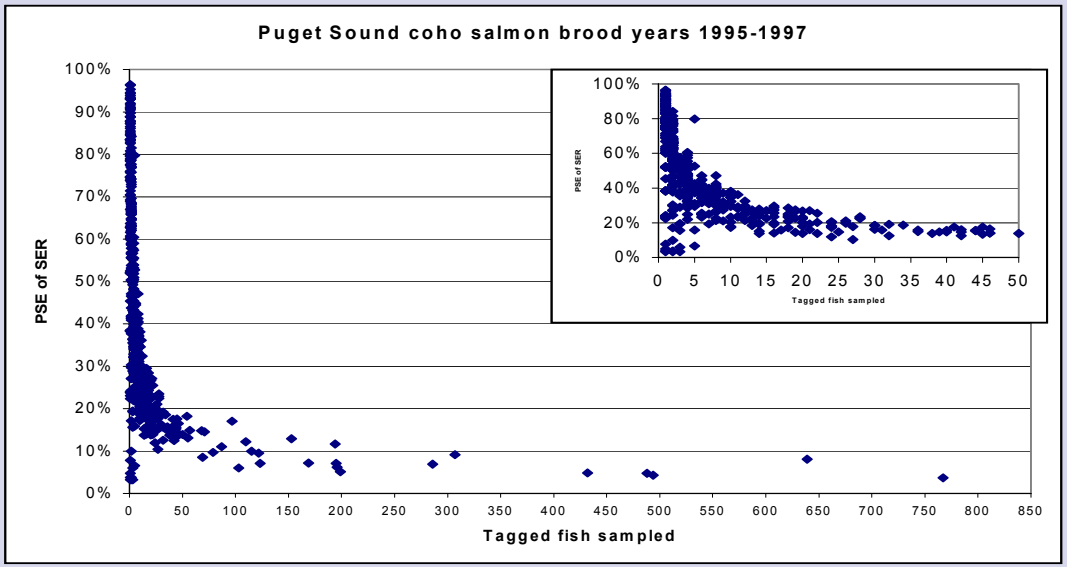
Φ_0 = Sample Rate

Simple Exploitation Rates

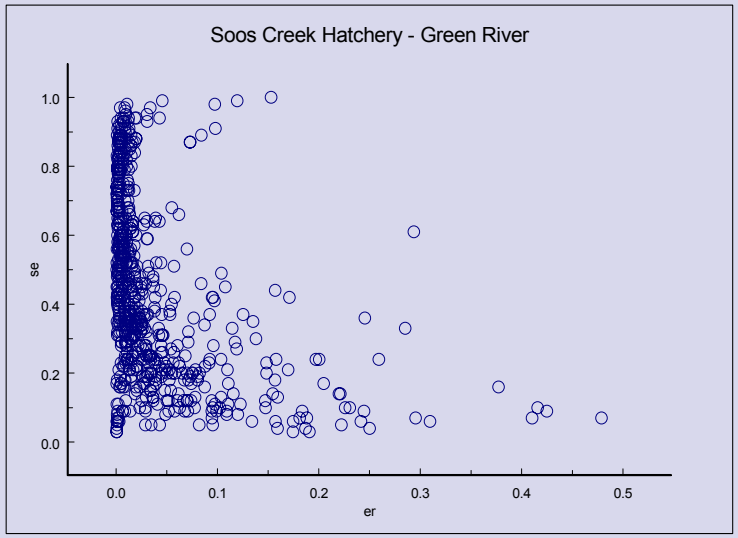
- What is the SER and why we are using it for this review?
- Precision of estimates of tagged harvest and escapement
- Precision of estimates of SERs
- Examples for coho and Chinook salmon
- What are the factors that impact precision of SER?

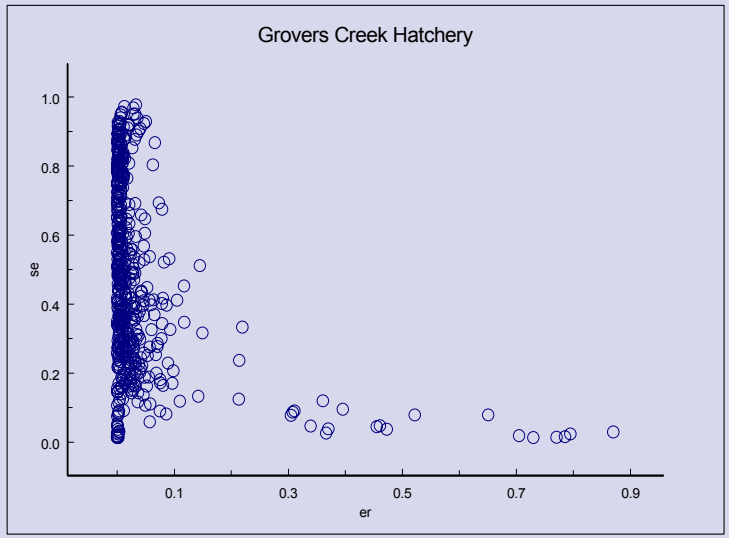
Example – Puget Sound Coho Salmon, brood year 1995-1998

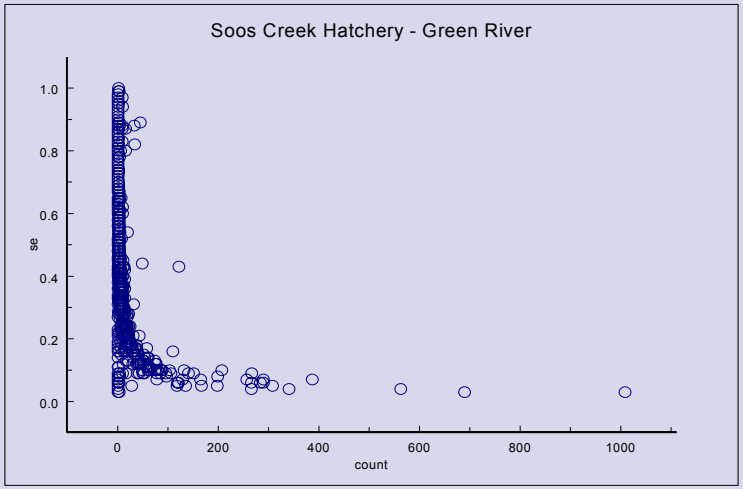


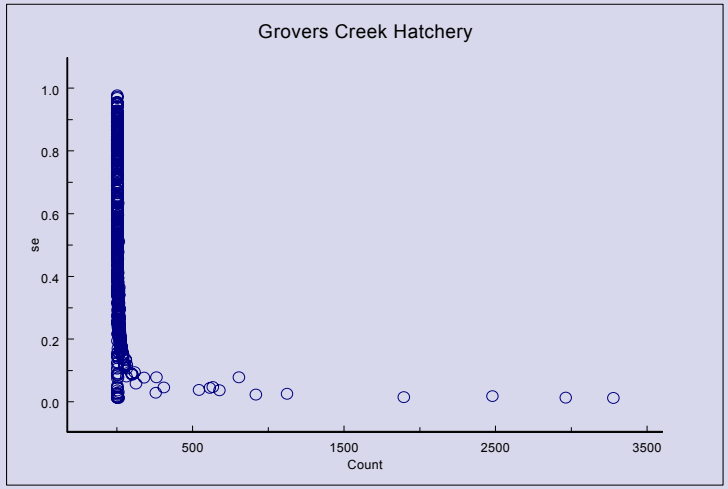


Example – Chinook Salmon









Average PSE(SER)

	SER	PSE
Coho	0-1%	54%
	1-5%	57%
	>5%	37%
Chinook	0-1%	64%
	1-5%	47%
	>5%	25%

Simple Exploitation Rates

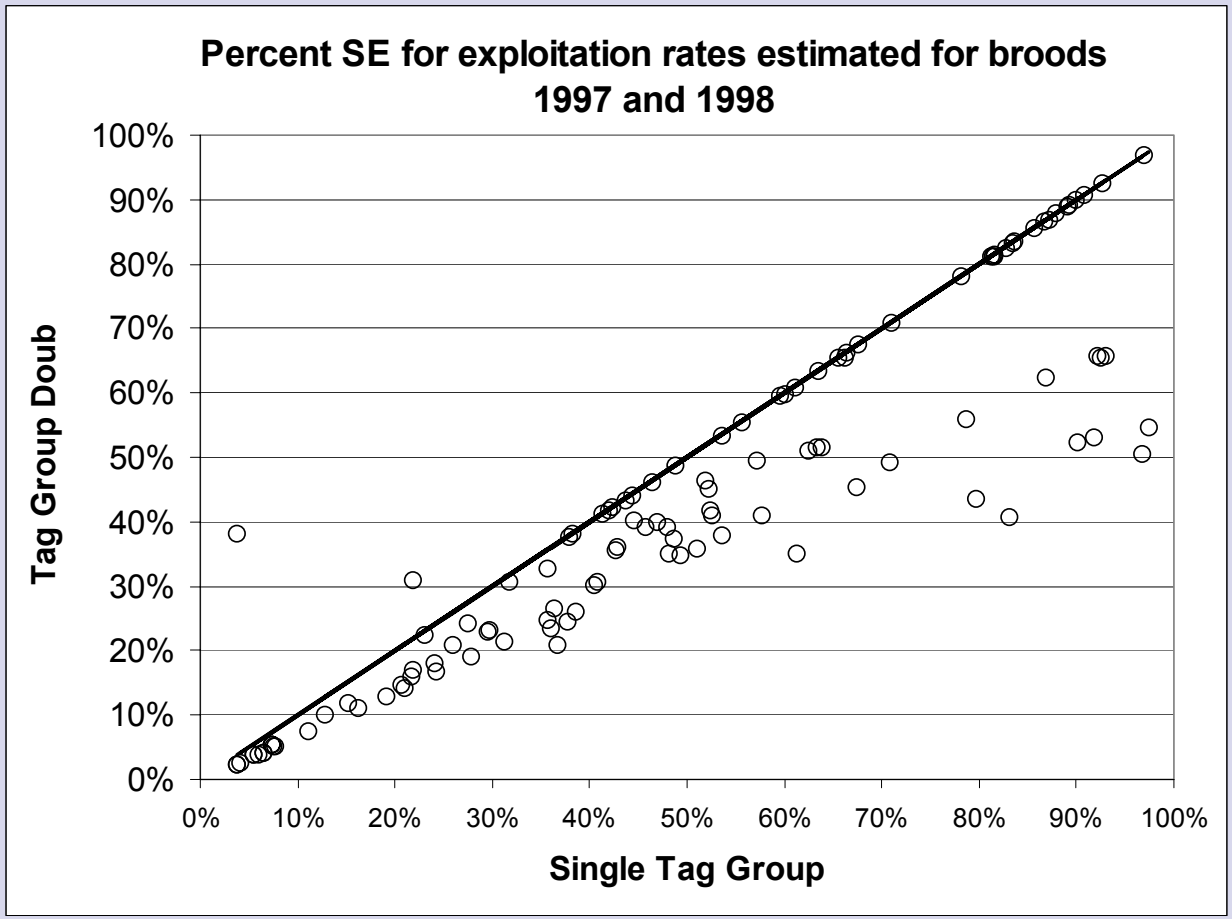
- What is the SER and why we are using it for this review?
- Precision of estimates of tagged harvest and escapement
- Precision of estimates of SERs
- Examples for coho and Chinook salmon
- *What are the factors that impact precision of SER?*

Factors that influence precision of SER

- Number of tags
  - Tagging Rate
  - Sample Rate
  - Fishery Resolution

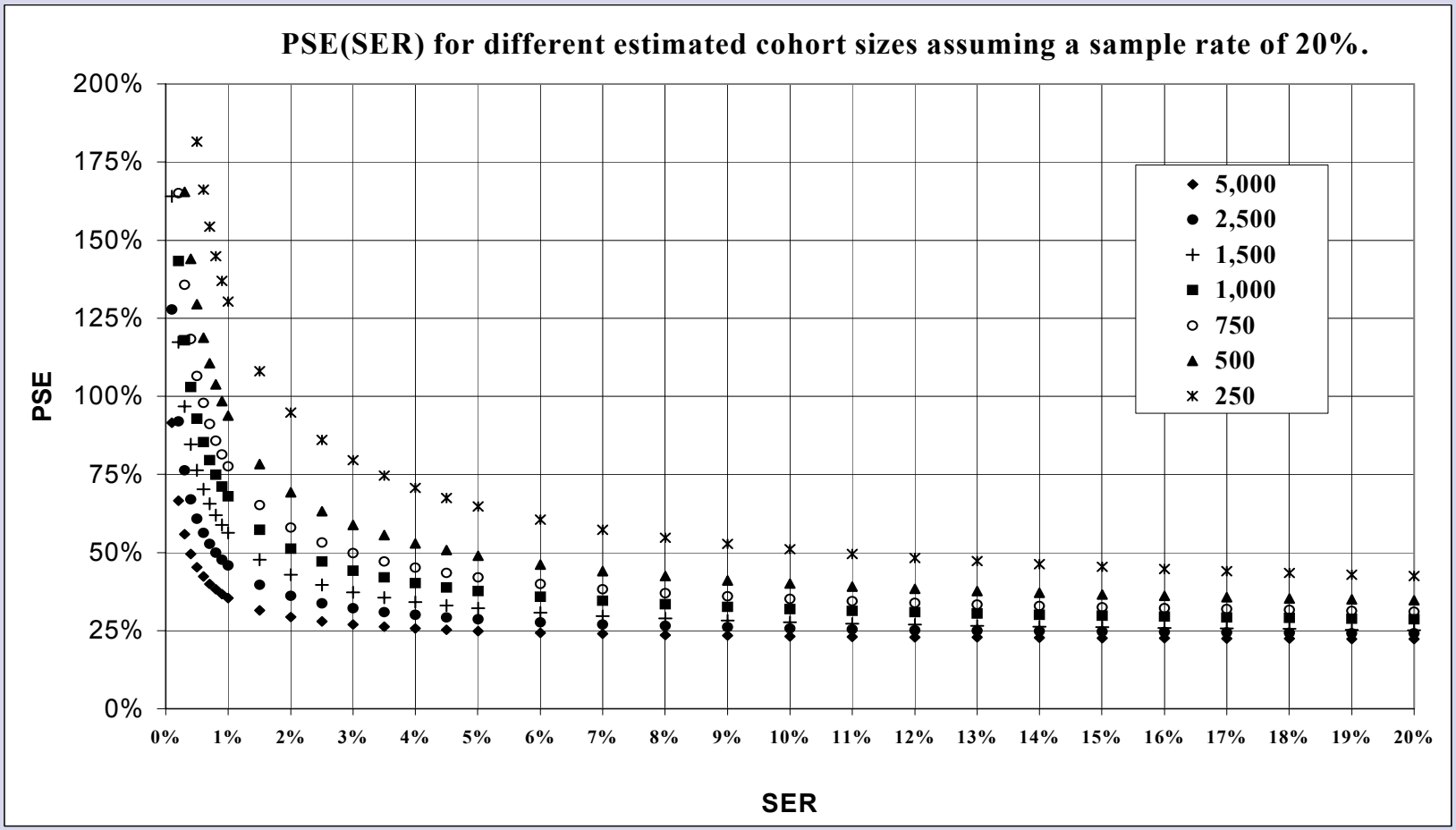
- Precision of estimates of total harvest and escapement

Tagging Rate – Chinook Data

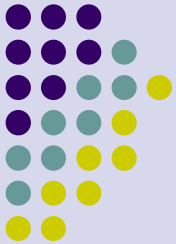


Tagging Rate

$$= \sqrt{\frac{1-\varphi_0}{\hat{T}^C \bullet SER(\hat{F}_o^C) \bullet \varphi_0} + PSE(\hat{T}^C)}$$

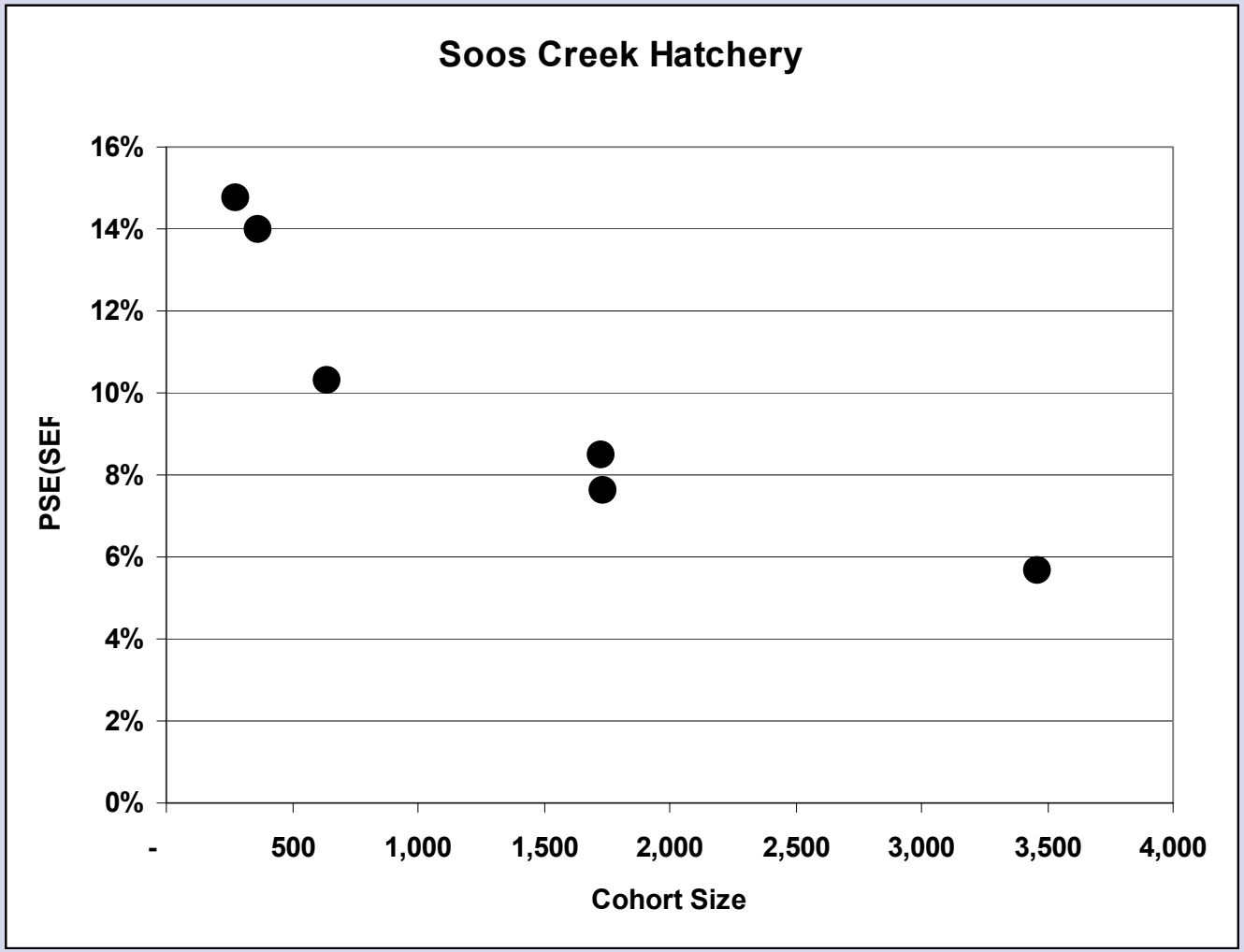


Cohort Sizes → Number Tagged

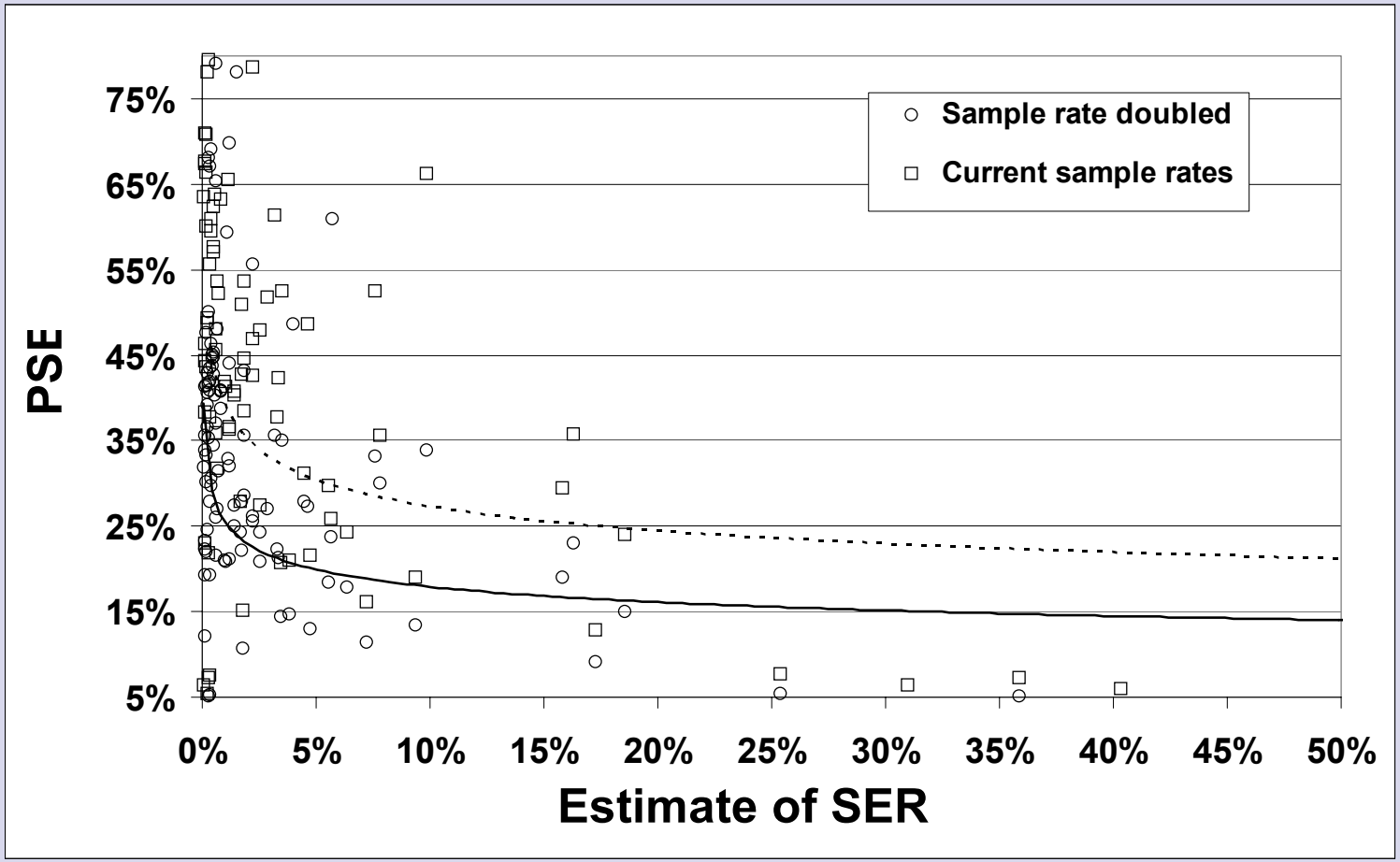


Brood Year	Big Qualicum River		Kitsumkalum River		Grovers Creek Hatchery		Soos Creek Hatchery	
	Cohort	PSE	Cohort	PSE	Cohort	PSE	Cohort	PSE
1973	3,107	3.0%					985	5.3%
1974	8,062	4.9%	1,618	13.8%			566	8.6%
1975	3,698	6.1%	444	8.3%			4,047	2.6%
1976	8,690	1.8%	2,278	3.8%			708	5.9%
1977	2,326	4.3%	1,257	17.6%			2,522	3.5%
1978	1,758	6.2%	1,205	6.1%				
1979	868	6.3%	656	6.8%				
1980	397	9.8%	1,182	7.3%			2,121	5.1%
1981	756	7.7%	2,053	4.8%	1,515	3.7%	1,704	4.9%
1982	860	5.5%	707	7.1%	326	8.7%	208	12.2%
1983	1,921	3.7%	829	7.3%	300	9.4%	1,454	4.4%
1984	358	7.5%	2,468	5.6%	596	7.7%		
1985	299	9.7%	662	13.4%	1,373	4.7%		
1986	851	5.6%	838	5.9%	3,007	2.6%		
1987	365	7.7%	1,073	9.2%	902	4.7%	623	9.0%
1988	954	5.1%	607	8.5%	129	12.0%	5,348	2.9%
1989	435	7.1%	110	13.8%	299	9.0%	179	13.6%
1990	483	6.2%	372	13.1%	1,423	3.7%	1,827	5.9%
1991	261	7.1%	478	11.8%	505	7.8%	250	13.7%
1992	80	12.0%	476	11.9%	3,866	1.4%	1,112	5.5%
1993	417	5.9%	626	9.0%	4,478	1.3%	299	16.1%
1994	257	7.2%	689	11.1%	1,166	2.3%	1,002	6.4%
1995	161	8.5%	348	16.9%	297	2.8%	1,138	7.6%
1996	265	6.6%	1,280	10.1%	2,414	1.5%	1,068	5.8%
1997	391	5.7%	879	12.3%	1,281	7.8%	653	9.5%
1998	295	6.9%	736	22.7%	3,560	1.9%	974	5.4%
Average 1973-78	4,607	4.4%	1,360	9.9%			1,766	5.2%
Average 1979-88	763	6.9%	1,107	7.6%	1,019	6.7%	1,910	6.4%
Average 1989-98	304	7.3%	599	13.3%	1,929	4.0%	850	8.9%

Tagging Rate – Brood SER



Sample Rates

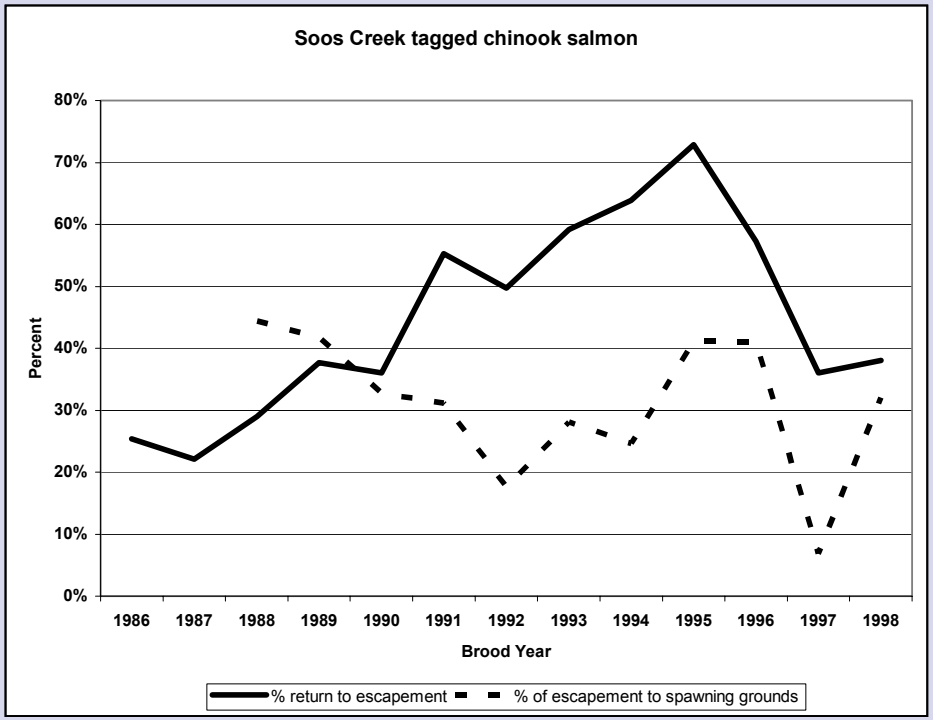


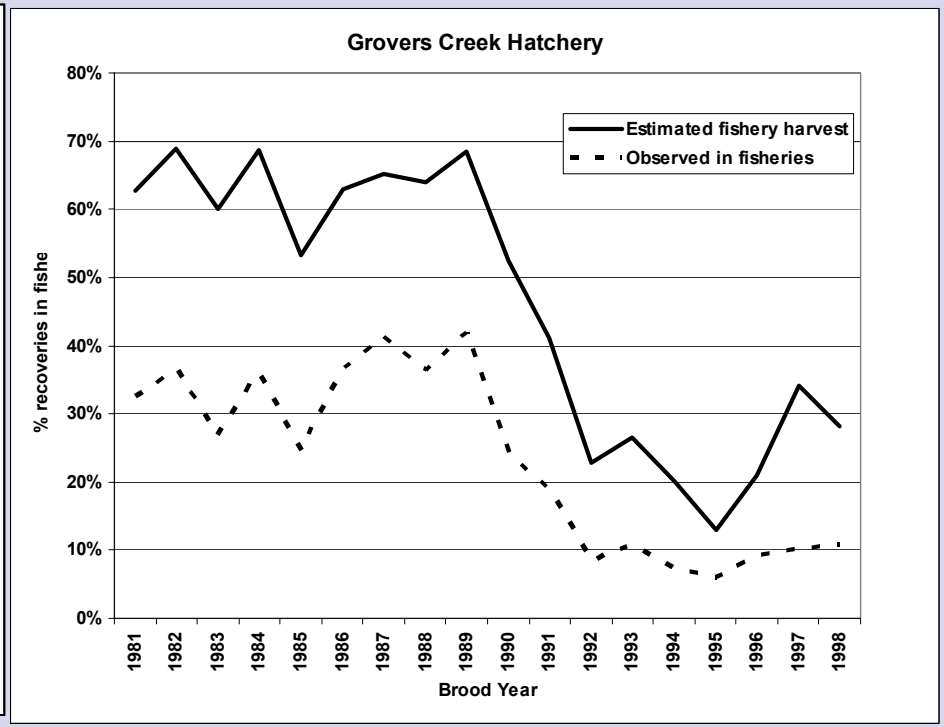
Fishery Resolution

SER	*Chinook salmon*				*Coho Salmon*
	Big Qualicum	Kitsumkalum	Soos Creek	Grovers Creek	Puget Sound
0-0.5%	15	7	20	33	18
0.5-1%	6	3	9	11	8
1-2%	6	1	19	5	10
2-3%	2	1	5	6	3
3-4%	1	1	2	6	2
4-5%	2	0	1	0	0
5-10%	2	7	3	1	1
>10%	1	2	1	0	4

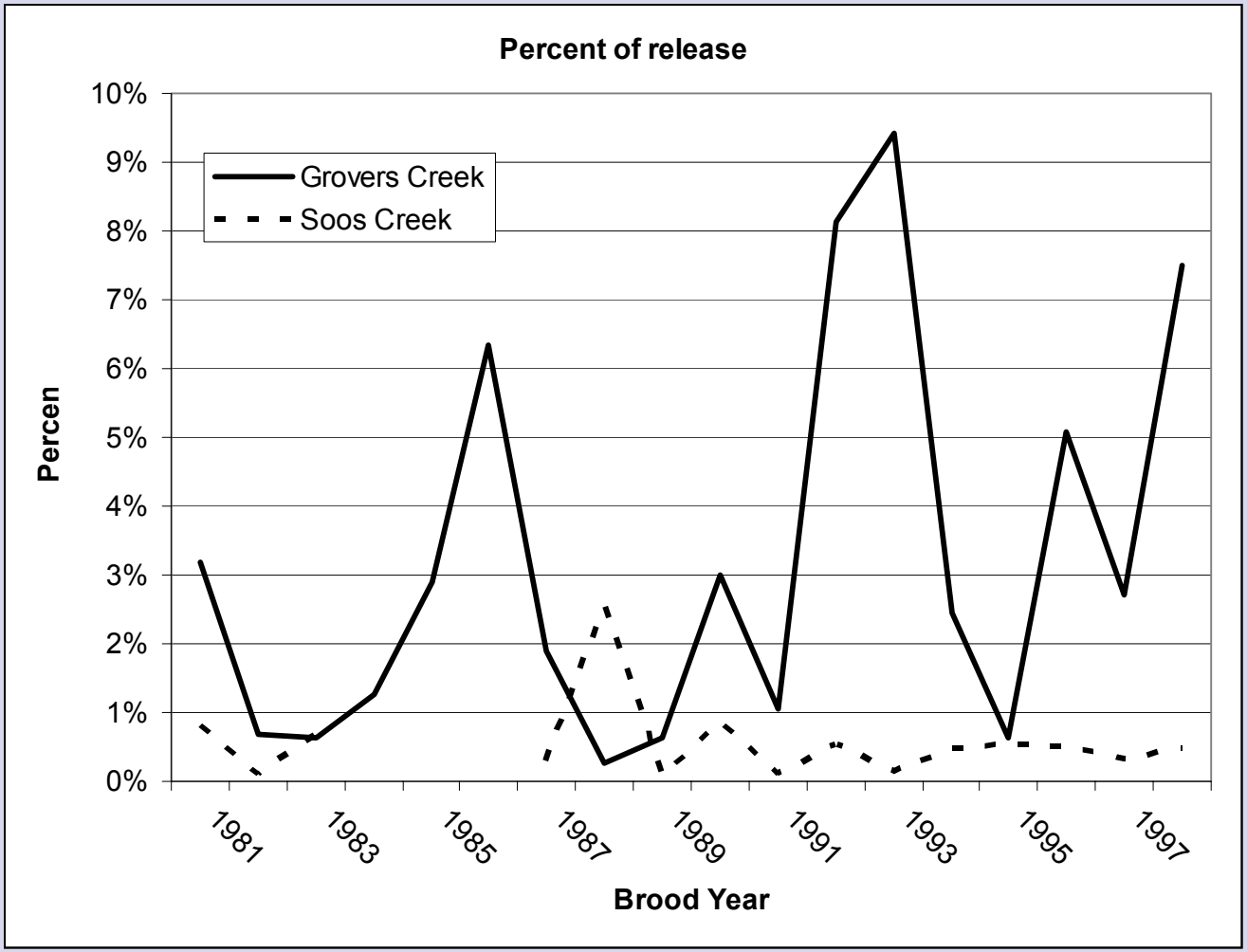
	SER	PSE
Coho	0-1%	54%
	1-5%	57%
	>5%	37%
Chinook	0-1%	64%
	1-5%	47%
	>5%	25%

Total harvest and escapement is estimated





Percent of tagged release harvested or in escapement



Escapement – Soos Creek.

Brood Year	Total Tagged fish	Tagged Escapement				Total % to escapement	Escapement	
		Hatchery	Big Soos Creek	Mainstem and Newaukum	Total		% to hatchery	% to mainstem and Newaukum
1986	5,347	1,019	50	287	1,355	25.3%	75.2%	21.2%
1988	1,827	287	8	231	526	28.8%	54.6%	43.9%
1989	250	55	-	39	94	37.7%	58.3%	41.7%
1990	1,112	268	1	130	400	36.0%	67.1%	32.6%
1991	299	113	1	52	165	55.3%	68.2%	31.2%
1992	1,005	412	-	57	470	46.7%	87.8%	12.2%
1993	1,138	483	1	189	674	59.2%	71.7%	28.1%
1994	1,068	511	3	165	680	63.6%	75.2%	24.3%
1995	653	271	9	192	472	72.3%	57.5%	40.6%
1996	974	301	28	227	556	57.1%	54.2%	40.8%
1997	438	129	18	11	158	36.1%	81.9%	6.8%
1998	2,254	563	19	274	856	38.0%	65.8%	32.0%
Average	1,273	343	11	143	496	44.5%	70.6%	27.3%

Impact depends on proportion of cohort returning to escapement