Special Publication No. 05-21

Stock Status and Recommended Escapement Goals for Coho Salmon in Selected Waters Along the Juneau Road System, 1981-2004

by

Robert A. Clark

November 2005

Alaska Department of Fish and Game **Divisions of Sport Fish and Commercial Fisheries**

Symbols and Abbreviations

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Weights and measures (metric)

centimeter	cm
deciliter	dL
gram	g
hectare	ha
kilogram	kg
kilometer	km
liter	L
meter	m
milliliter	mL
millimeter	mm

Weights and measures (English)

cubic feet per second	ft^3/s
foot	ft
gallon	gal
inch	in
mile	mi
nautical mile	nmi
ounce	oz
pound	lb
quart	qt
yard	yd

Time and temperature

day	d
degrees Celsius	°C
degrees Fahrenheit	°F
degrees kelvin	K
hour	h
minute	min
second	s

Physics and chemistry

all atomic symbols	
alternating current	AC
ampere	A
calorie	cal
direct current	DC
hertz	Hz
horsepower	hp
hydrogen ion activity (negative log of)	pH
parts per million	ppm
parts per thousand	ppt, ‰
volts	V
watts	W

General

Alaska Administrative Code	AAC
all commonly accepted abbreviations	e.g., Mr., Mrs., AM, PM, etc.
all commonly accepted professional titles	e.g., Dr., Ph.D., R.N., etc.
at	@
compass directions:	
east	E
north	N
south	S
west	W
copyright	©
corporate suffixes:	
Company	Co.
Corporation	Corp.
Incorporated	Inc.
Limited	Ltd.
District of Columbia	D.C.
et alii (and others)	et al.
et cetera (and so forth)	etc.
exempli gratia (for example)	e.g.
Federal Information Code	FIC
id est (that is)	i.e.
latitude or longitude	lat. or long.
monetary symbols (U.S.)	$, ¢
months (tables and figures): first three letters	Jan,...,Dec
registered trademark	®
trademark	™
United States (adjective)	U.S.
United States of America (noun)	USA
U.S.C.	United States Code
U.S. state	use two-letter abbreviations (e.g., AK, WA)

Measures (fisheries)

fork length	FL
mideye-to-fork	MEF
mideye-to-tail-fork	METF
standard length	SL
total length	TL

Mathematics, statistics

all standard mathematical signs, symbols and abbreviations	
alternate hypothesis	H_A
base of natural logarithm	*e*
catch per unit effort	CPUE
coefficient of variation	CV
common test statistics	(F, t, χ^2, etc.)
confidence interval	CI
correlation coefficient (multiple)	R
correlation coefficient (simple)	r
covariance	cov
degree (angular)	°
degrees of freedom	df
expected value	*E*
greater than	>
greater than or equal to	≥
harvest per unit effort	HPUE
less than	<
less than or equal to	≤
logarithm (natural)	ln
logarithm (base 10)	log
logarithm (specify base)	$\log_2$, etc.
minute (angular)	'
not significant	NS
null hypothesis	H_O
percent	%
probability	P
probability of a type I error (rejection of the null hypothesis when true)	α
probability of a type II error (acceptance of the null hypothesis when false)	β
second (angular)	"
standard deviation	SD
standard error	SE
variance	
population	Var
sample	var

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by

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November 2005

Development of this manuscript was partially financed by the Federal Aid in Sport Fish Restoration Act (16 U.S.C. 777-777K).

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This document should be cited as:
Clark, R. A. 2005. Stock status and recommended escapement goals for coho salmon in selected waters along the Juneau road system, 1981-2004. Alaska Department of Fish and Game, Special Publication No. 05-21, Anchorage.

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ABSTRACT

In preparation for the January 2006 Board of Fisheries meeting, a team of fishery biologists and scientists from Alaska Department of Fish and Game (ADF&G) Divisions of Sport Fish and Commercial Fisheries was assembled to review escapement goals for salmon stocks in southeast Alaska and revise or develop new goals where appropriate. As part of this effort, escapement goals for five coho salmon *Oncorhynchus kisutch* stocks along the Juneau road system were selected for review and revision by Sport Fish Division staff. Cluster analysis of temporal patterns of escapement indicated very little correlation in foot surveys among the five systems, with the exception of Jordan and Montana creeks (r = 0.608). Two systems (Montana and Petersen) were recommended for further analysis and development of an escapement goal based on availability of escapement data from these systems and exploitation rate data from the full indicator system at nearby Auke Creek. Based on a theoretical spawner-recruit analysis, sustainable escapement goals (SEGs) were recommended for Montana Creek (foot survey count of 400-1,200 fish) and Petersen Creek (foot survey count of 100 to 250 fish). Existing escapement goals for Jordan, Steep, and Switzer creeks were recommended for elimination.

Key words: coho salmon, *Oncorhynchus kisutch*, escapement goal, cluster analysis, spawner-recruit analysis, exploitation rate, foot surveys, Montana Creek, Petersen Creek, southeast Alaska, Juneau road system

INTRODUCTION

In preparation for the January 2006 Board of Fisheries meeting, a team of fishery biologists and scientists from Alaska Department of Fish and Game (ADF&G) Divisions of Sport Fish and Commercial Fisheries was assembled to review and attempt to revise escapement goals for salmon stocks in southeast Alaska (Geiger and Der Hovanisian *In prep*). As part of this effort, escapement goals for five coho salmon *Oncorhynchus kisutch* stocks along the Juneau road system (Figure 1) were selected for review and revision by ADF&G Division of Sport Fish staff. This report details the review and recommendations made to the escapement goal team for these coho salmon stocks.

Holmes et al. (2003) describes the assessment of coho salmon fisheries along the Juneau road system with time series of foot surveys conducted on five creeks (Figure 1). Peterson Creek runs parallel to the Glacier Highway north of the city of Juneau, emptying into Eagle Harbor. Montana Creek parallels the Montana Creek Road and is a westside tributary of the Mendenhall River. Steep Creek is also a tributary of the Mendenhall River, draining into Mendenhall Lake from the east. Jordan and Switzer creeks drain into Gastineau Channel near the Juneau Airport. Assessment of productivity of these stocks was last performed in 1994 by Clark (1995).

METHODS

DATA SOURCES

Coho salmon escapements in five drainages along the Juneau road system were enumerated by peak foot survey (see Clark 1995 for a description of these foot surveys). These data were available from 1981 to 2004 (Shaul et al. 2003 and unpublished data) and represent partial counts of escapement that are thought to range from 20% to 40% (π = 2.5 to 5.0) of actual escapement based on limited validation studies (Steep Creek in 1994) and expert opinion (Clark 1995). Stock specific harvests were estimated from recreational harvest in freshwater (see Jennings et al. 2004). Although there are no stock specific harvest information available for marine recreational and commercial fisheries, marine exploitation rates of a nearby indicator stock (coho salmon in Auke Creek; Figure 1) are available for 1981 to 2004 (Shaul et al. 2003 and unpublished data).

CLUSTER ANALYSIS OF ESCAPEMENTS

To investigate potential spatial relationships between escapement survey counts in the five Juneau roadside coho salmon systems, cluster analysis was performed on the untransformed and log-transformed escapements. The distance metric used was the Pearson product-moment correlation and clusters were formed using single linkages (Everett 1981).

THEORETICAL SPAWNER-RECRUIT ANALYSIS

Theoretical spawner-recruit (S-R) relationships were investigated for two systems (Montana and Petersen creeks) along the Juneau road system. Given that the long-term marine exploitation rate of the indicator stock at Auke Creek has been fairly stable (Figure 2), indicating an equilibrium situation, it seemed reasonable to assume that harvests and escapements in Montana and Petersen creeks were also in equilibrium. Assuming peak foot surveys represent an index of annual escapement and exploitation rates are similar to those of the indicator stock, the indexed escapement and indexed run averaged over a long time period likely represent x-y coordinates on the indexed S-R relationship. Assuming that the S-R relationship follows the form of Ricker (Ricker 1975), several S-R relationships can be realized that encompass a range of productivity commonly seen for coho salmon. Defensible escapement goal ranges that incorporate exploitation rate, stock productivity, data uncertainty, and maximization of yields can be developed from this analysis.

Average escapement survey counts $(\bar{s})$ were estimated from available data for each creek (i = 1981-2004):

$$\bar{s} = \frac{1}{n}\sum_{i}^{n} s_i \tag{1}$$

Annual foot surveys (s_i) do not count all salmon that are in the escapement to these creeks, but were considered an index of escapement based on the opinion of the local area management biologist. To make harvests comparable to the index of escapement, "indexed" harvests were estimated from total exploitation rates derived from marine exploitation rates (U_i) of Auke Creek coho salmon (Shaul et al. 2003 and unpublished data) and freshwater harvest from each creek (f_i) estimated from the Statewide Harvest Survey (Jennings et al. 2004). Utilizing assumed expansion factors (π) for each creek (Montana = 5 and Petersen = 4 from Clark 1995), creek-specific exploitation rate (u_i) was estimated as:

$$u_i = U_i + f_i \Big/ \left[\frac{s_i \pi + f_i}{1 - U_i} \right] \tag{2}$$

Indexed harvest (h_i) was then calculated and averaged $(\bar{h})$ as:

$$h_i = \frac{s_i u_i}{(1 - u_i)} \text{ and } \bar{h} = \frac{1}{n}\sum_{i}^{n} h_i \tag{3}$$

Assuming that harvest and escapements are in equilibrium, average exploitation rate $(\bar{u})$ was estimated as:

$$\bar{u} = \frac{\bar{h}}{\left(\bar{s} + \bar{h}\right)} \tag{4}$$

Exploitation rate at maximum sustained yield (MSY) depends solely on the Ricker productivity parameter α (Ricker 1975). The productivity of coho salmon stocks in the indicator streams of southeast Alaska, including Auke Creek, was previously investigated by Clark et al. (1994). A range of productivity parameter was chosen (4.4 to 9) that represents the range of productivity observed in Auke Creek coho salmon by Clark et al. (1994). Assuming α was known and the observed average exploitation rate and the average foot survey count over a number of years were in equilibrium, an estimate of escapement in terms of foot survey units that will produce MSY (from Hilborn and Walters (1992) and Ricker (1975)) was calculated as:

$$s_{MSY} = \bar{s}\,\frac{0.5\ln(\alpha) - 0.07\ln(\alpha)^2}{\ln\left(\alpha\left(1-\bar{u}\right)\right)} \tag{5}$$

To compare estimates of s_{MSY} and S-R relationships derived from different assumed α's, the β parameter was estimated for each S-R relationship by first estimating the exploitation rate at MSY by solving:

$$\ln(\alpha) = u_{MSY} - \ln(1 - u_{MSY}) \tag{6}$$

for u_{MSY} (from Ricker 1975). The β parameter was then calculated from (Ricker 1975):

$$\beta = \frac{u_{MSY}}{s_{MSY}} \tag{7}$$

From these S-R relationships the range around s_{MSY} that produces 90% or more of MSY was also calculated. This procedure has been used previously by Clark et al. (*In prep*) to develop escapement goals for coho stocks along the Kodiak road system. Since the resulting ranges were based on foot surveys (an index of escapement) rather than the actual escapement they were considered sustainable escapement goal (SEG) ranges.

RESULTS AND DISCUSSION

CLUSTER ANALYSIS OF ESCAPEMENTS

Results for the untransformed escapement counts were identical to the log-transformed data so results are presented for the untransformed data only (Table 1). Overall, there was fairly low correlation amongst foot survey counts across combinations of all surveyed streams, with only Montana Creek highly correlated (> 0.5) with Jordan Creek (Table 2). Escapement trends in Petersen Creek were least similar to the other four systems (Figure 3).

After preliminary review of the available data and discussion among staff, it was decided to review and attempt to revise escapement goals for coho salmon in the Montana and Petersen creeks, and drop existing escapement goals (see Clark 1995) for Jordan, Steep, and Switzer creeks.

MONTANA CREEK

The biological escapement goal (BEG) range in Montana Creek has been 200 to 500 coho salmon enumerated by foot survey. This goal range was established in 1994 (Clark 1995). Since

1981 the BEG range has been achieved 3 times, has been underachieved twice and exceeded 19 times (Table 3).

Theoretical Spawner-Recruit Analysis

Average foot survey count from 1981-2004 was 958 fish and average indexed harvest was 783 fish (Table 3 and Figure 4). Assuming Ricker α for coho salmon ranges from 4.4 to 9 ($\ln(\alpha)$ ranges from 1.49 to 2.20) and the average survey count and average harvest represented an equilibrium exploitation rate of 0.450, two theoretical S-R relationships that have these same equilibrium values were calculated. In addition, from the two theoretical S-R relationships, escapements (based on the surveys) that would produce MSY and a range of escapements that produce 90% or more of MSY were also calculated (Table 4). In addition, there appeared to be a shift in the magnitude of foot survey counts that indicated a change in either productivity or the fraction observed in foot surveys had occurred after 1988 so that this time period (1989-2004) was analyzed separately from data gathered prior to this time to see if this changed the outcome based on this method (Figure 4). Average foot survey from 1989-2004 was 1,229 fish and average indexed harvest was 1,009 fish for an exploitation rate of 0.451. Results from the two S-R relationships are shown in Figure 5 and Table 4.

Foot surveys of 400 to 1,200 appeared to theoretically provide for nearly 90% of MSY given α may have actually ranged from 4.4 to 9 and average indexed harvests and foot surveys represented an equilibrium situation (Figure 5, lower panel). Foot surveys have been below this range in 5, within this range in 13, and above this range in 6 of the 24 years (Table 3). Foot surveys have never been below 400 in four consecutive years, but have been below 400 in three consecutive years once (1986-1988). The existing BEG for Montana Creek was recommended for change to a SEG of 400 to 1,200 fish by foot survey.

PETERSEN CREEK

The BEG range in Petersen Creek has been 100 to 350 coho salmon enumerated by foot survey. This goal range was established in 1994 (Clark 1995). Since 1981 the BEG range has been achieved 20 times, has never been underachieved, and has been exceeded 4 times (Table 5).

Theoretical Spawner-Recruit Analysis

Average foot survey from 1981-2004 was 260 fish and average indexed harvest was 227 fish (Table 5 and Figure 6). Assuming Ricker α for coho salmon ranges from 4.4 to 9 ($\ln(\alpha)$ ranges from 1.49 to 2.2) and that the average survey count and average harvest represent an equilibrium exploitation rate of 0.466, two theoretical S-R relationships that have these same equilibrium values were calculated (Figure 7). In addition, from the two theoretical S-R relationships escapements (based on the surveys) that would produce MSY and a range of escapements that produce 90% or more of MSY were also calculated (Table 4). These reference points were then compared to the average escapements based on surveys to help identify a potential SEG range that was robust to differences in the shape of the S-R relationship.

Foot surveys of 100 to 250 appeared to theoretically provide for nearly 90% MSY given α may have actually ranged from 4.4 to 9 and average indexed harvests and foot surveys represented an equilibrium situation (Figure 7). Foot surveys have never been below this range, within this range in 12, and above this range in 12 of the 24 years (Table 5). Foot surveys have never been below 100 in four consecutive years. The existing BEG for Peterson Creek was recommended for change to a SEG of 100 to 250 fish by foot survey.

RECOMMENDATIONS

- Escapement trends are dissimilar among all surveyed streams except Montana and Jordan creeks. Escapement goal reviews were recommended for two systems (Montana and Petersen) where management of the inriver recreational fishery is possible. Formal escapement goals were not needed for the remaining systems, although these other systems may need to be monitored to gain an understanding of escapement trends in these systems.
- The existing escapement goal for Montana Creek should be changed to a SEG of 400 to 1,200 fish by foot survey. Assuming exploitation rates are similar to those estimated for Auke Creek, the current range of escapements into Montana Creek should provide for high to maximum sustainable yields in the future.
- The existing escapement goal for Petersen Creek should be changed to a SEG of 100 to 250 fish by foot survey. Assuming exploitation rates are similar to those estimated for Auke Creek, the current range of escapements into Petersen Creek should provide for high to maximum sustainable yields in the future.

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FIGURES AND TABLES

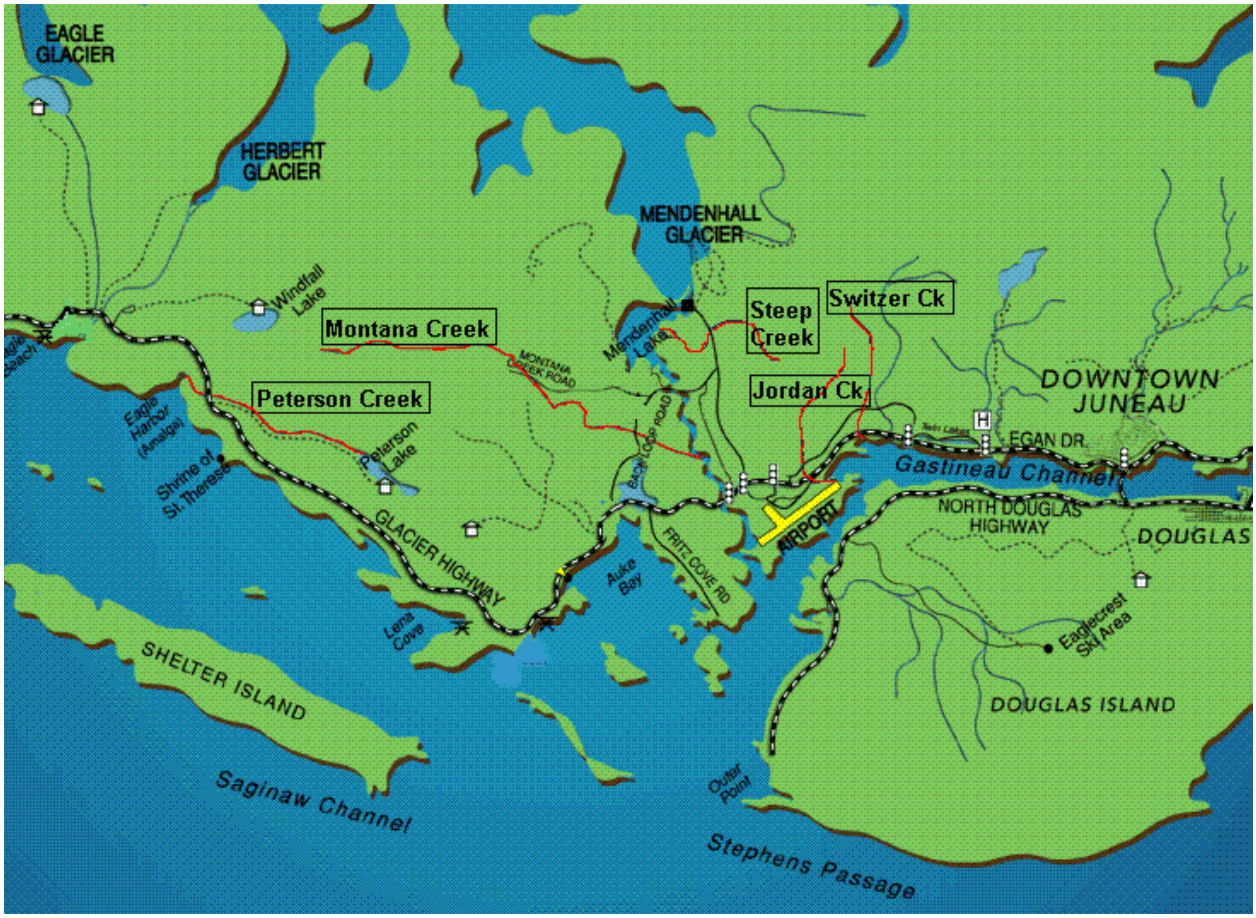


Figure 1.–The Juneau road system with systems surveyed for coho salmon shown in text boxes.

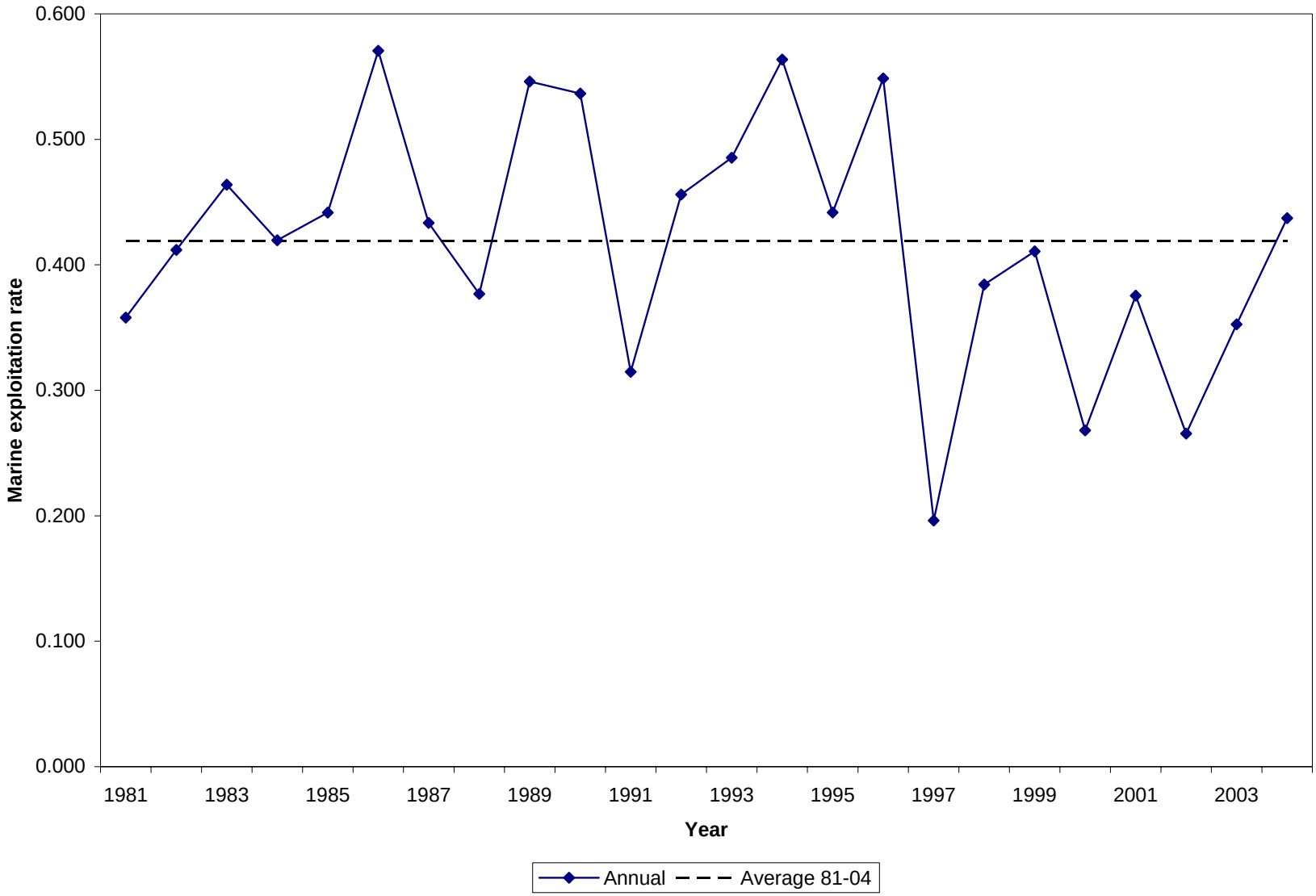


Figure 2.–Annual and average marine exploitation rate of coho salmon from production in Auke Creek, 1981-2004.

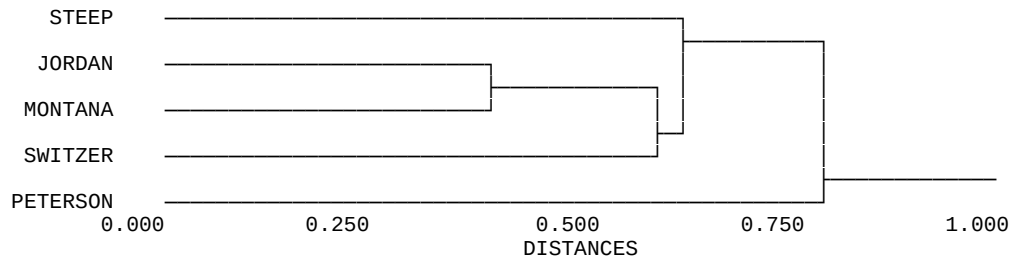


Figure 3.–Cluster diagram of distances (1 – correlations) between time series of coho salmon escapement indices in five systems along the Juneau road system (1981-2004).

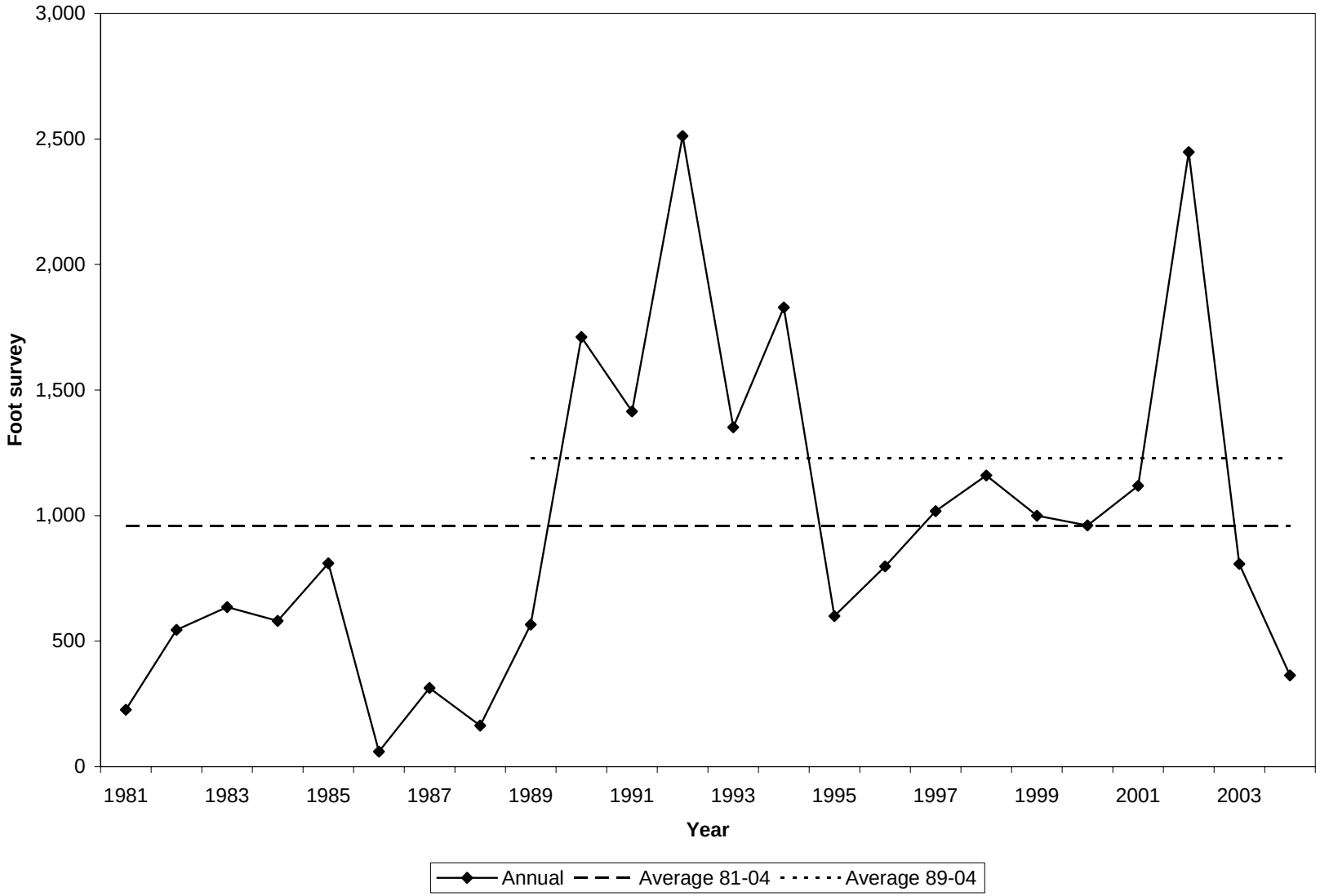
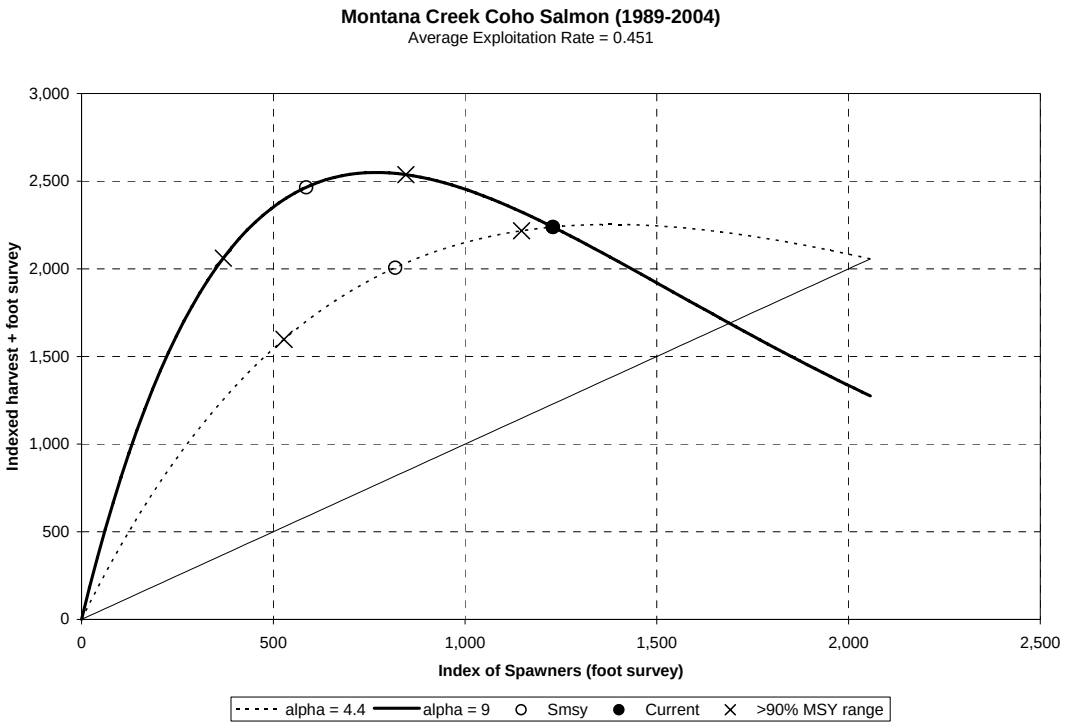


Figure 4.–Annual foot survey (solid line) and average foot survey (1981-2004 = dashed line; 1989-2004 =dotted line) of coho salmon in Montana Creek, 1981-2004.



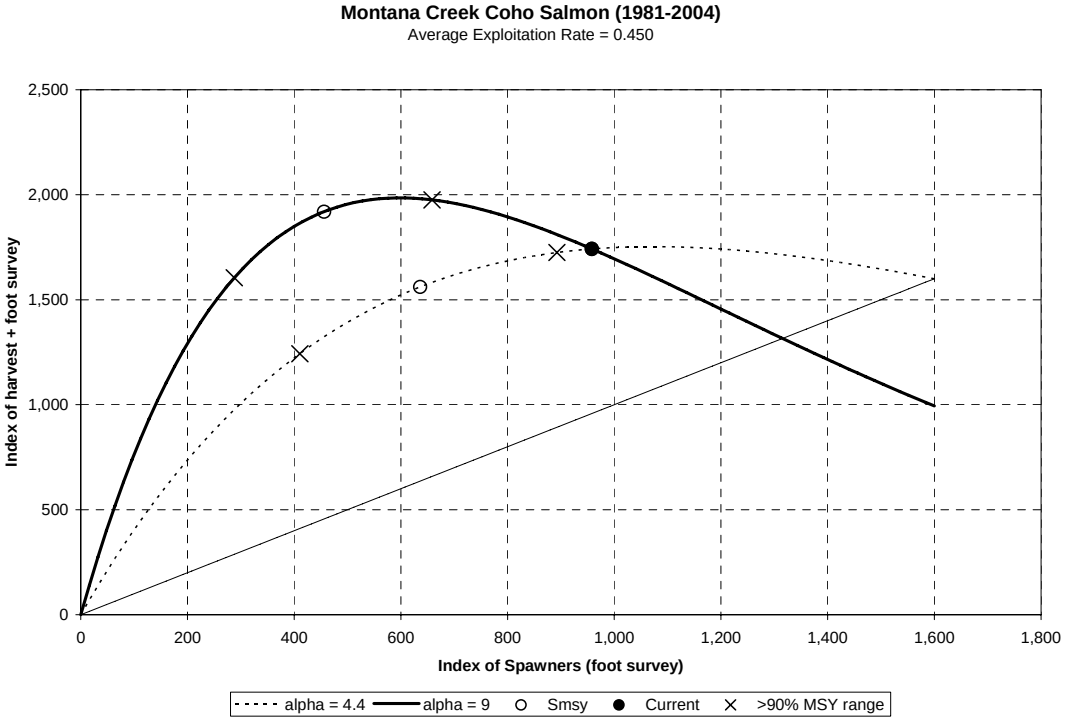


Figure 5.–Theoretical Ricker stock-recruitment relationships based on: upper panel) an average foot survey of 958 and average indexed harvest of 783 coho salmon (1981-2004; •); and, lower panel) an average foot survey of 1,229 and average indexed harvest of 1,009 coho salmon (1989-2004; •) in Montana Creek. The dotted line represents the Ricker curve with an α-parameter of 4.4; the solid line represents the Ricker curve with an α-parameter of 9, and the solid straight line represents replacement. Smsy (o) and escapements that produce 90% of MSY (×) are also shown.

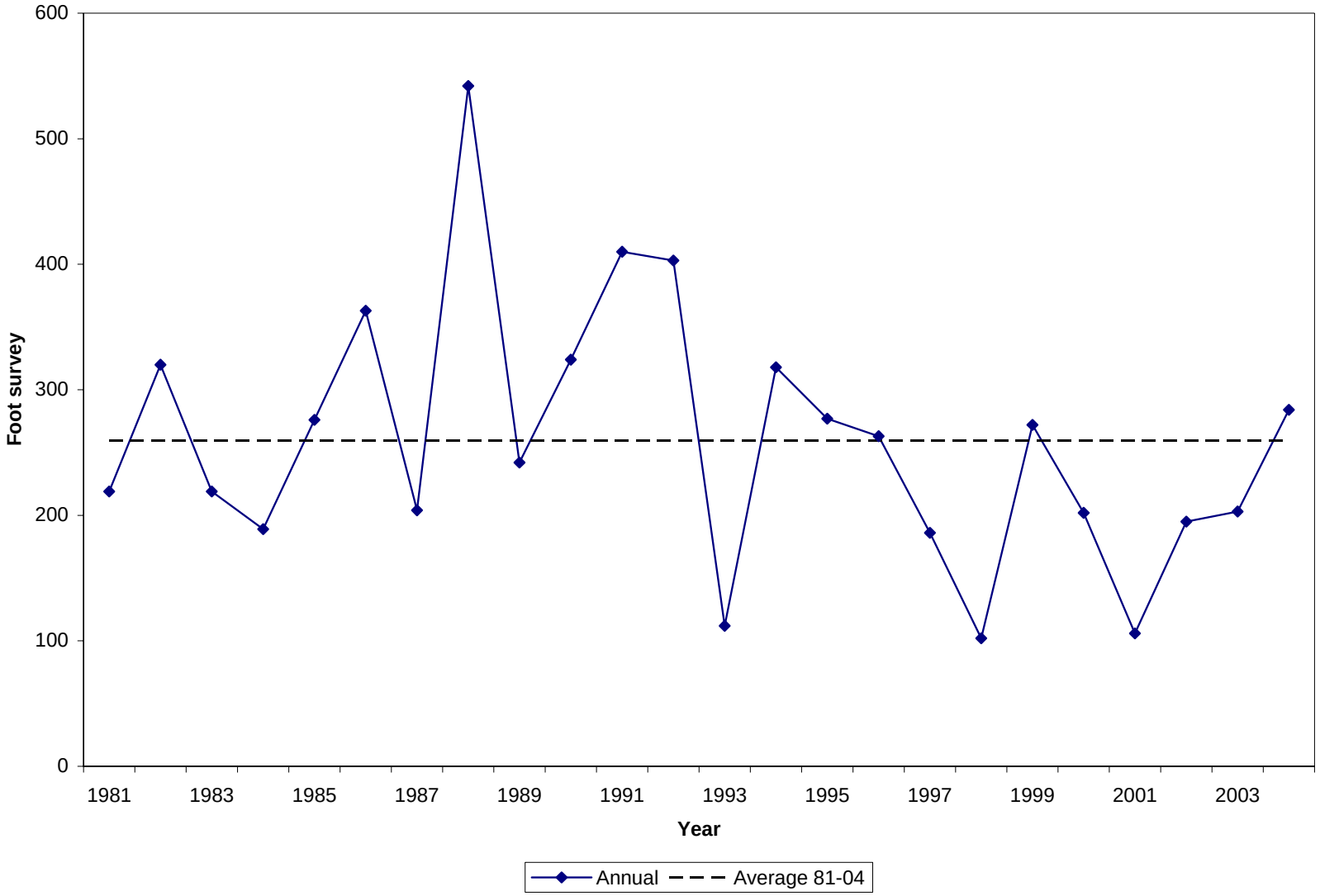


Figure 6.–Annual foot survey (solid line) and average foot survey (dashed line) of coho salmon in Peterson Creek, 1981-2004.

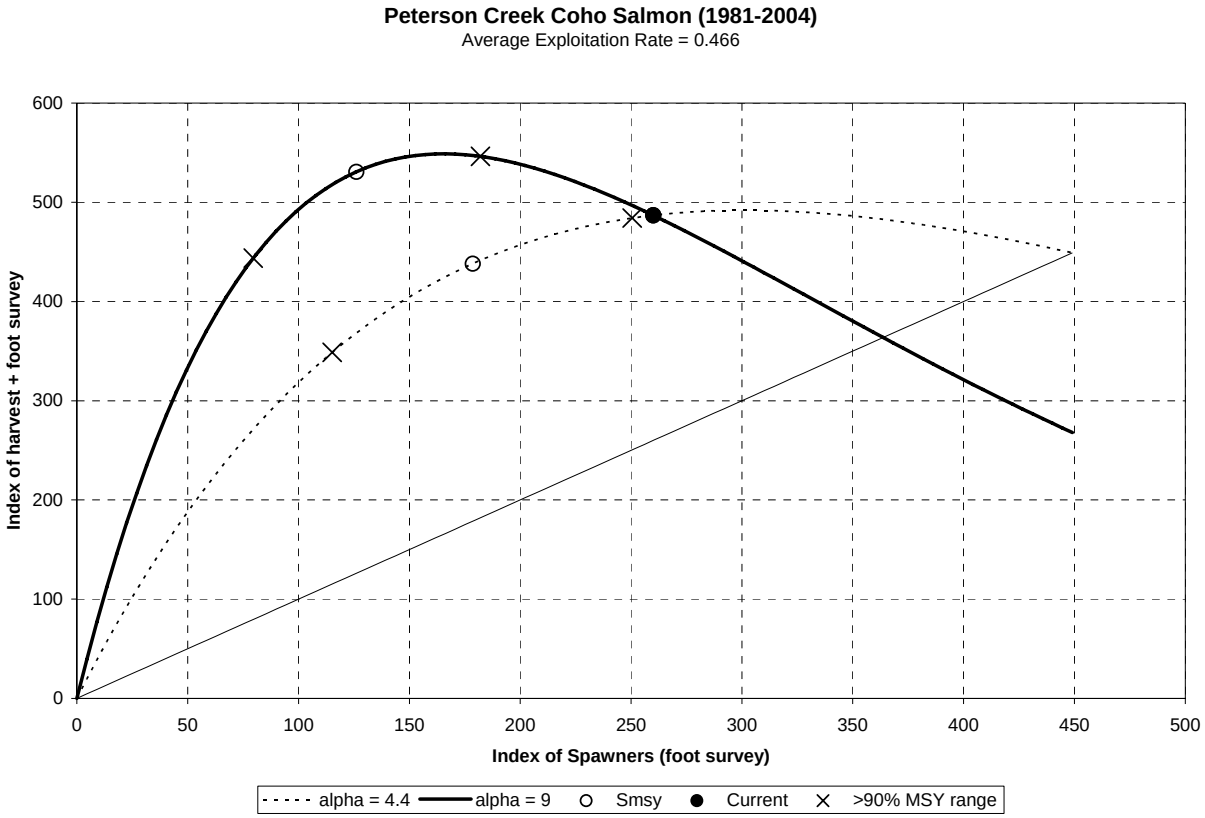


Figure 7.–Theoretical Ricker stock-recruitment relationships based on an average foot survey of 260 and average indexed harvest of 227 coho salmon (1981-2004; •) in Peterson Creek. The dotted line represents the Ricker curve with an α-parameter of 4.4; the solid line represents the Ricker curve with an α-parameter of 9, and the solid straight line represents replacement. Smsy (o) and escapements that produce 90% of MSY (×) are also shown.

Table 1.–Foot surveys of coho salmon escapement in five creeks along the Juneau road system, 1981-2004.

Year	Montana	Steep	Jordan	Switzer	Peterson
1981	227	515	482	109	219
1982	545	232	368	80	320
1983	636	171	184	77	219
1984	581	168	251	123	189
1985	810	186	72	122	276
1986	60	247	163	54	363
1987	314	128	251	48	204
1988	164	155	215	51	542
1989	566	222	133	78	242
1990	1,711	185	216	82	324
1991	1,415	267	322	227	410
1992	2,512	312	785	93	403
1993	1,352	471	322	94	112
1994	1,829	200	371	198	318
1995	600	409	77	42	277
1996	798	134	54	42	263
1997	1,018	182	18	67	186
1998	1,160	149	63	42	102
1999	1,000	392	47	51	272
2000	961	88	30	74	202
2001	1,119	366	119	50	106
2002	2,448	380	1,396	124	195
2003	808	400	78	100	203
2004	364	82	38	69	284
Avg	958	252	252	87	260
SD	656	124	301	47	103
Min	60	82	18	42	102
Max	2,512	515	1,396	227	542
Contrast	42	6	78	5	5
Existing Goal	450	150	150	50	200
Lower	200	100	75	25	100
Upper	500	300	200	75	350

Table 2.–Pearson product-moment correlations between time series of foot survey counts of coho salmon escapement in five creeks along the Juneau road system, 1981-2004.

System	Jordan	Montana	Peterson	Steep	Switzer
Jordan	1				
Montana	**0.608**	1			
Peterson	0.088	-0.043	1		
Steep	0.383	0.176	-0.163	1	
Switzer	0.373	0.417	0.220	0.086	1

Table 3.–Marine exploitation of Auke Creek coho salmon, and freshwater harvests, foot survey counts of escapement, total exploitation, and indexed harvests of coho salmon in Montana Creek, 1981-2004.

	Auke Creek	Montana Creek			
Year	Marine Exploitation	Freshwater Harvest	Foot Survey	Total Exploitation[b]	Indexed Harvest
1981	0.358	ND[a]	227	0.358	127
1982	0.412	ND	545	0.412	382
1983	0.464	ND	636	0.464	550
1984	0.420	93	581	0.438	452
1985	0.442	ND	810	0.442	641
1986	0.571	89	60	0.669	121
1987	0.433	0	314	0.433	240
1988	0.377	127	164	0.460	140
1989	0.546	126	566	0.565	737
1990	0.537	256	1,711	0.550	2,092
1991	0.315	42	1,415	0.319	662
1992	0.456	97	2,512	0.460	2,141
1993	0.485	134	1,352	0.495	1,327
1994	0.564	208	1,829	0.573	2,457
1995	0.442	255	600	0.485	566
1996	0.549	353	798	0.585	1,126
1997	0.196	218	1,018	0.229	303
1998	0.384	274	1,160	0.412	813
1999	0.411	230	1,000	0.437	775
2000	0.268	324	961	0.314	441
2001	0.375	301	1,119	0.407	769
2002	0.266	658	2,448	0.303	1,064
2003	0.353	361	808	0.406	551
2004	0.437	90	364	0.464	315
81-04	0.419	212	958	0.450	783
89-04	0.411	245	1,229	0.451	1,009

[a] ND = no data available to estimate harvest.

[b] Total exploitation rate was assumed to equal marine exploitation rate in years when there were no data on freshwater harvest.

Table 4.–Value of β, and sMSY and range of sMSY given the average exploitation rate $(\bar{u})$ and assumed α-parameter for Ricker spawner-recruit relationship of coho salmon in Montana and Peterson creeks.

System	$\bar{u}$	α	β	s_{MSY}	s_{MSY} range
Montana	0.450	4.4	9.31×10^{-4}	636	410 – 893
(all years)	0.450	9	1.67×10^{-3}	456	288 – 658
Montana	0.451	4.4	7.24×10^{-4}	818	528 – 1,147
(1989-2004)	0.451	9	1.30×10^{-3}	586	370 – 846
Peterson	0.466	4.4	3.32×10^{-3}	179	115 – 251
	0.466	9	6.05×10^{-3}	126	80 – 182

Table 5.–Marine exploitation of Auke Creek coho salmon, and freshwater harvests, foot survey counts of escapement, total exploitation and indexed harvests of coho salmon in Peterson Creek, 1981-2004.

	Auke Creek	Petersen Creek			
Year	Marine Exploitation	Freshwater Harvest	Foot Survey	Total Exploitation[b]	Indexed Harvest
1981	0.358	ND[a]	219	0.358	122
1982	0.412	ND	320	0.412	224
1983	0.464	ND	219	0.464	189
1984	0.420	0	189	0.420	137
1985	0.442	ND	276	0.442	218
1986	0.571	0	363	0.571	482
1987	0.433	0	204	0.433	156
1988	0.377	109	542	0.407	371
1989	0.546	0	242	0.546	291
1990	0.537	0	324	0.537	375
1991	0.315	0	410	0.315	188
1992	0.456	65	403	0.477	368
1993	0.485	276	112	0.682	240
1994	0.564	124	318	0.602	482
1995	0.442	38	277	0.460	236
1996	0.549	0	263	0.549	320
1997	0.196	131	186	0.317	86
1998	0.384	6	102	0.393	66
1999	0.411	11	272	0.417	194
2000	0.268	63	202	0.321	96
2001	0.375	19	106	0.402	71
2002	0.266	178	195	0.402	131
2003	0.353	158	203	0.458	172
2004	0.437	0	284	0.437	221
81-04	0.419	59	260	0.466	227

[a] ND = no data available to estimate harvest.

[b] Total exploitation rate was assumed to equal marine exploitation rate in years when there were no data on freshwater harvest.