Fishery Data Series No. 14-41

Stock Assessment of Buskin River Coho Salmon, 2008–2010

by

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and

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October 2014

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)

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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ABSTRACT

Since 1985, the Alaska Department of Fish and Game Division of Sport Fish has assessed the annual runs of coho salmon (*Oncorhynchus kisutch*) to the Buskin River on Kodiak Island. This report presents weir counts, harvest, and age composition data collected between 2008 and 2010 as well as a spawner–recruit analysis. In 2008, the estimated Buskin River weir count was 9,028 coho salmon, the estimated sport harvest was 4,259, the reported subsistence harvest was 1,232, and the commercial harvest was 137 coho salmon. Age-2.1 fish composed 68% of the total run, and the male-to-female ratio was 1.3:1. Estimated escapement was 8,176 coho salmon. In 2009, the estimated weir count was 10,624 coho salmon, the estimated sport harvest was 5,207, the reported subsistence harvest was 987, and the commercial harvest was 299. Age-2.1 fish made up 81% of the total run, and the male-to-female ratio was 1.0:1. Estimated escapement was 9,583 coho salmon. In 2010, the estimated weir count was 6,808 coho salmon, the estimated sport harvest was 2,846, the reported subsistence harvest was 717, and the commercial harvest 127. Age-2.1 fish composed 71% of the escapement, and the male-to-female ratio was 1.3:1. Estimated escapement was 6,239 coho salmon. A full probability spawner–recruit analysis of all relevant data was performed. This analysis accounted for uncertainty in escapement of spawners, sport fish harvest above the weir, and non-returned subsistence permits. The estimated spawning escapement at maximum sustainable yield (MSY) is approximately 7,300 coho salmon (90% credibility interval of 5,450–13,600). The inriver run estimated for MSY is about 8,100 coho salmon, and the exploitation rate estimated for MSY is 43%.

Key words: coho salmon, *Oncorhynchus kisutch*, escapement, Buskin River, age, length, sex composition, ASL composition, sport harvest, subsistence harvest, stock assessment, spawner–recruit analysis.

INTRODUCTION

The Buskin River drainage, located on the northeast end of Kodiak Island (Figure 1), contains one of the largest wild populations of coho salmon (*Oncorhynchus kisutch*) found on the Kodiak road system. The drainage also supports the largest reported subsistence coho salmon fishery in the Kodiak Archipelago. Buskin River coho salmon typically make up 17% of the total Buskin River subsistence salmon harvest, with reported harvests ranging from approximately 1,309 to 2,505 fish and averaging 1,654 fish from 1998 to 2007 (Schmidt and Evans 2012). Harvest in this fishery is documented through subsistence permits issued by the Alaska Department of Fish and Game (ADF&G) Division of Commercial Fisheries (CF).

The Buskin River is the most popular recreational fishing stream on Kodiak Island, recently representing 37% of the total freshwater recreational fishing effort in the Kodiak Management Area (Jennings et al. 2004, 2006 a-b, 2007, 2009 a-b, 2010 a-b, 2011 a-b). Recreational fishing effort on the Buskin River is directed primarily toward coho salmon and sockeye salmon (*O. nerka*), but some effort is also directed at steelhead and rainbow trout (*O. mykiss*), pink salmon (*O. gorbuscha*), and Dolly Varden (*Salvelinus malma*). From 1998 through 2007, estimated sport harvests of coho salmon from the Buskin River ranged from 2,332 to 6,567 fish and averaged 3,646 fish (Schmidt and Evans 2012). Sport harvest of coho salmon and fishing effort on the Buskin River are estimated annually by the ADF&G Division of Sport Fish (SF) Statewide Harvest Survey (SWHS).

A relatively minor commercial harvest of Buskin River coho salmon periodically occurs in adjacent marine waters of Chiniak Bay. These harvests are typically small, even nonexistent during some years. Fish ticket harvest receipts available from CF indicate that between 1998 and 2007, the average annual commercial harvest of Buskin River coho salmon was 163 fish (Schmidt and Evans 2012).

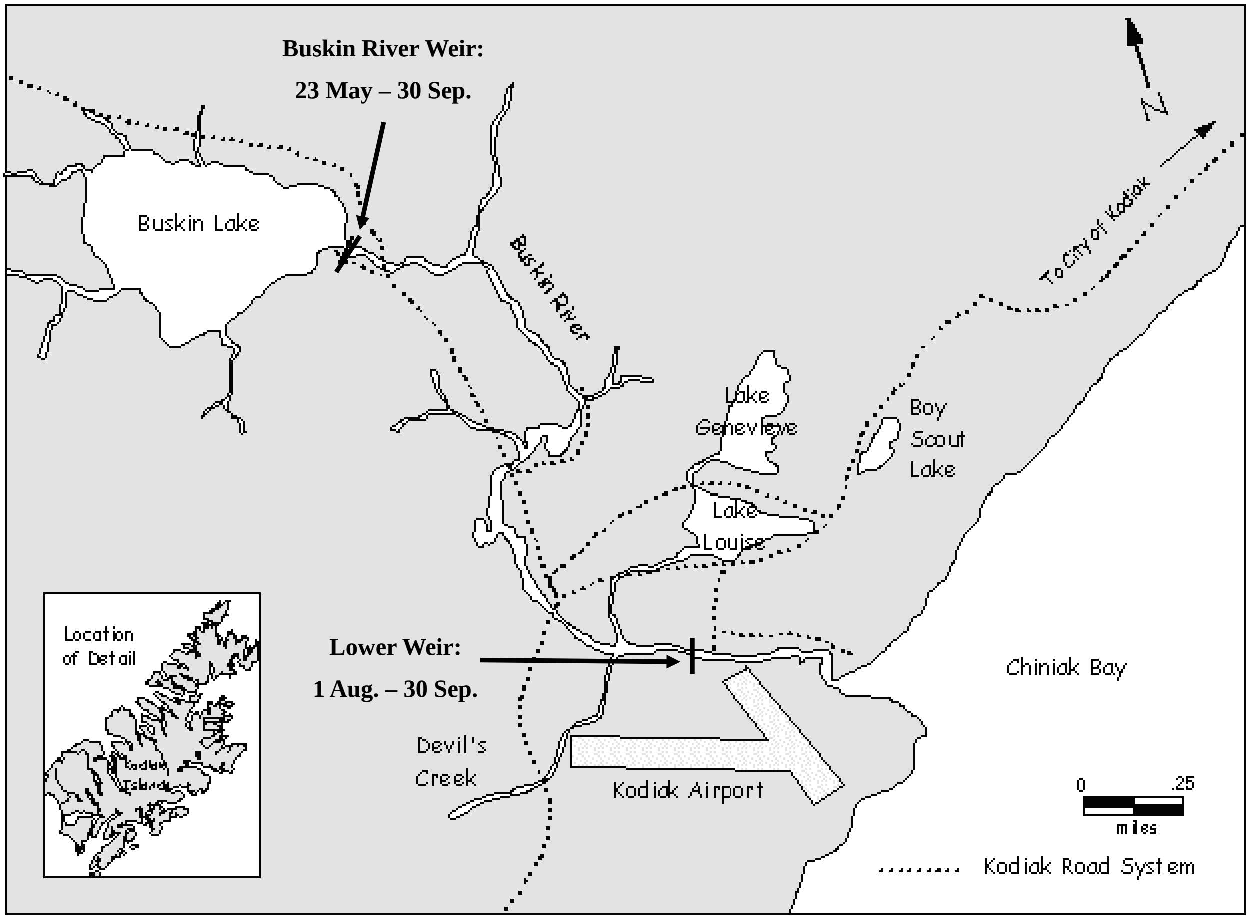

Figure 1.–Map of the Buskin River drainage.

Inriver runs of Buskin River coho salmon have been monitored at a salmon counting weir operated annually by ADF&G at the lower weir site since 1985. The aim of this program is to ensure the sustainability and long-term health of the stock. Between 1989 and 2007, the average weir count was 9,862 coho salmon, and weir counts have ranged from 6,222 to 16,596 fish (2011–2012). More recently, inriver runs of Buskin River coho salmon at the weir were very strong; the average between 2003 and 2007 was 12,339 fish. Through 2007, five of the highest Buskin river weir counts ever documented occurred between 2001 and 2007. Weir counts of adult fish entering Buskin River are obtained from early August through September, with peak coho salmon daily counts typically occurring during the third week of September.

Historically, the Buskin River coho salmon escapement goal has been based on the magnitude of long-term estimated escapements, derived by subtraction of estimated upriver sport harvests from inriver runs (weir counts). The current coho salmon escapement goal range of 3,200–7,200 fish was established in 2005 using a Ricker stock–recruitment model (Clark et al. 2006; Ricker 1954). The escapement goal influences inseason management of the subsistence, sport, and commercial fisheries. Periodic refinement of the escapement goal is possible through continued estimation of total annual run, which requires estimation of age composition to identify brood year contributions. The ongoing coho salmon project has facilitated the collection of data necessary for this purpose by providing a census of the inriver run at the weir (weir counts) and total run age composition estimates. This report presents data results from 2008 through 2010 and includes estimates of coho salmon age composition by sex and mean length, derived from sampling the inriver run and sport harvest. A spawner–recruit analysis is presented that uses spawning escapement and adult age data (ages 1.1, 2.1, and 3.1) from 1989 through 2010; the age data is derived from brood years 1984 through 2007.

STUDY OBJECTIVES

The 2008–2010 stock assessment study of Buskin River coho salmon had the following objectives:

1. Census the coho salmon inriver run at the Buskin River weir from 1 August to 1 October each year.
2. Estimate the age, sex, and length (ASL) composition of the coho salmon run.

An overarching objective for this data series is to construct a brood table for Buskin river coho salmon in order to estimate population characteristics such as spawning escapement, inriver run, and exploitation rate at maximum sustainable yield.

METHODS

INRIVER RUN

During the three years of this study, up to 2 weirs were operated each season: one at the outlet to Buskin Lake (referred to hereafter as the lake weir), and one 2 km upstream of the Buskin River mouth (referred to as the lower weir) (Figure 1). During each year, both weirs were monitored daily. Fish passage was only allowed when counts were conducted, and all immigrant and emigrant anadromous fishes passing through the weirs were enumerated and identified by species.

From 2008 through 2010, ADF&G operated a conventional weir at the lower weir site that was constructed across a channel approximately 40 m wide where the predominately small rock substrate was suitable for holding a weir. In 2009 and 2010, ADF&G operated an additional weir at the outlet of Buskin Lake. The lake weir was of conventional design spanning 38 m. Both weirs were constructed with a superstructure framework of wooden tripods (weighted with sandbags), aluminum cross stringers, and a boardwalk. Rigid aluminum panels provided structural continuity; these measured 2.01 m in height and 0.76 m in width and were made of 2.54 cm diameter schedule-40 pipe sections spaced 2.54 cm apart welded into an aluminum T-bar channel. These structures created a barrier to control passage of fish and allow free passage of water. Four counting gates integrated into the panel array allowed for the controlled passage of fish over a submerged, white-colored background medium to visually assist in species identification and fish enumeration. A trap constructed of aluminum panels with a funnel-shaped entrance and attached to a counting gate was installed to capture immigrating coho salmon.

The lower weir was designed to operate continuously from the beginning of August through the end of September, although every year a portion of the inriver run was estimated, usually on more than one occasion when high water levels precluded the controlled passage of fish. The lake weir was installed annually to monitor sockeye salmon returns in mid-May and was typically pulled at the end of July, before coho salmon runs can be enumerated. However, in 2009 and 2010, the lake weir was kept installed through the end of September and remained continuously operational even during high water events. Estimates of coho salmon passing the lower weir during periods of high water were calculated using a variety of methods described in Table 1. As a result of periodic interruptions in lower weir counts from high water events and also variability in the annual duration of weir operations, the weir count in a given year should be considered a minimal indicator of inriver run. The inriver run obtained from the weir should also not be considered the escapement because sport fishery harvest of coho salmon occurs upstream of the lower weir.

Table 1.–Methods used to interpolate Buskin River coho salmon lower weir counts during high water events, 2008–2010.

Year	Dates weir tended	Dates weir out	Total days weir out	Estimated number per incident	Percent of weir count estimated	Estimation method[a]
2008	30 Jul–29 Sep	13–14 Aug	1.25	30		From 1998–2007 average weir count.
		18–21 Aug	2.80	257		From 1998–2007 average weir count.
		6–9 Sep	3.00	993		From 1998–2007 average weir count.
		Total	7.05	1,280	14.0%	
2009	3 Aug–16 Sep	4-6 Aug	1.9	–		Lake weir counts used.
		27 Aug	–	5		Small hole in weir; estimated 5 coho salmon.
		28–30 Aug	2.6	743		From 1999–2008 average weir count.
		8–13 Sep	4.5	1,606		From 1999–2008 average weir count.
		16–30 Sep	–	5,022		Estimates for 16–30 Sep based on ratio of total count of the lower weir to total count of the lake weir as of 16 Sep multiplied by the daily count for the lake weir.
		Total	6.0	7,376	69.4%	
2010	29 Jul–29 Sep	15–17 Aug	2.4	79		From 2000–2009 average weir count.
		29 Sep–7 Oct	–	3,501		Estimates for 30 Sep–7 Oct based on ratio of total count of the lower weir as of 29 Sep to total count of the lake weir as of 1 Oct multiplied by the daily count for the lake weir.
		Total	2.4	3,580	52.6%	

[a] The lake weir was only operated in 2009–2010; this is the first time the lake weir was also operated during coho salmon immigration.

FISHERY HARVESTS

Annual subsistence harvests of Buskin drainage coho salmon were estimated from returns of subsistence fishing permits received by the CF Kodiak Office. From 2001 through 2007, annual return rates of permits ranged between 85% and 92% and averaged 90% (J. Shaker, Alaska Department of Fish and Game, Kodiak, personal communication). It was not possible to adequately determine the proportion of permit holders harvesting Buskin River coho salmon who failed to return permits.

The sport fishery harvest of coho salmon in 2008 through 2010 was estimated by the SWHS (Jennings et al. 2004, 2006 a-b, 2007, 2009 a-b, 2010 a-b, 2011 a-b).

Commercial harvests were obtained from the CF Statewide Harvest Receipt (fish ticket) database. Reported catches of coho salmon only from ADF&G Kodiak Salmon Statistical Chart area 259-22 (Womens Bay) were assumed to be of Buskin River origin.

Age, Sex, and Length Composition Sampling

In 2008 and 2010, samples of coho salmon ASL were obtained solely from the inriver run; in 2009, ASL samples were obtained from both the inriver run and the sport fishery harvest. ASL samples from the inriver run were taken only from live fish captured at the lower weir. The sampling period at the weir was stratified into weekly intervals between 16 August and 30 September. Whenever possible, all coho salmon captured in the weir trap were sampled. Sampling was typically conducted 3 days per week. In 2009, ASL sampling from the sport harvest was also required due to low water levels and difficulty capturing coho salmon at the weir. The sport harvest sampling was opportunistic, and the entire sample was collected only over the period 16–30 September.

Subsistence and commercial harvests were not sampled for ASL composition; samples from the inriver run and sport harvest (when available) were used as proxies for each of these run components.

Length from mid eye to tail fork (METF) was recorded to the nearest millimeter for each fish sampled, and sex was determined through external characteristics. Whenever possible, 4 scales were removed as described by Welander (1940). Sampled scales were taken from the preferred area on the left side of the fish, 3 or 4 scale rows above the lateral line, and placed on a gum card for subsequent analysis. Scales not available from the preferred area were taken in the same linear plane but from the third or fourth row below the lateral line. If it was not possible to take scales from the left side of the fish, scales were collected from the opposite side in the same manner as described above. Ages of sampled coho salmon were determined from scales using criteria described in Mosher (1969).

DATA ANALYSIS

Total Run and Escapement

For E = escapement, Sub = subsistence, CF = commercial harvest, and SF = sport harvest, the number of coho salmon in the total run (T) was estimated as follows:

$$\hat{N}_T = \hat{N}_E + N_{Sub} + N_{CF} + \hat{N}_{SF} . \tag{1}$$

Subsistence, sport, and commercial harvests were assumed known, with zero variance, and $\hat{N}_{SF}$ and $\text{var}(\hat{N}_{SF})$ were provided by the SWHS. Because sport fishery harvest of coho salmon is not reported by area and harvest occurs upriver of the weir, escapement was estimated as follows:

$$\hat{N}_E = N_{IR} - \tilde{p}_{Ab}\hat{N}_{SF} \tag{2}$$

where N_{IR} is the inriver run and $\tilde{p}_{Ab}$ is the assumed proportion of the sport harvest occurring above the weir; this quantity originates from a creel survey conducted in 1986 (Murray 1987) and more recent field observations. We assumed a value of 0.2 for $\tilde{p}_{Ab}$, with the understanding that bias may be introduced. The bias is not expected to be serious; there is only a 10% increase between escapement estimates over the last 7 years if a value for $\tilde{p}_{Ab}$ of 0.1 versus 0.5 is used.

The variances of $\hat{N}_E$ and $\hat{N}_T$ were estimated as follows:

$$\text{var}(\hat{N}_E) = \tilde{p}_{Ab}^2 \, \text{var}(\hat{N}_{SF}) \text{ and} \tag{3}$$

$$\text{var}(\hat{N}_T) = \text{var}(\hat{N}_{SF})(1 - \tilde{p}_{Ab})^2 . \tag{4}$$

Exploitation Rate

The exploitation rate for fishery *i* was estimated as follows:

$$\hat{U}_i = \frac{\hat{N}_i}{\hat{N}_T} \tag{5}$$

where $\hat{N}_i$ is N_{Sub}, N_{CF}, or $\hat{N}_{SF}$ for the subsistence, commercial, or sport fishery, respectively. For *i* = subsistence or commercial fishery, the variance of the exploitation rate was estimated as follows:

$$\text{var}(\hat{U}_i) = N_i^2 \frac{\text{var}(\hat{N}_T)}{\hat{N}_T^4} . \tag{6}$$

For *i* = sport fishery, the variance of the exploitation rate was estimated as follows:

$$\text{var}(\hat{U}_{SF}) = \frac{\left[N_{IR} + N_{Subs} + N_{CF}\right]^2 \text{var}(\hat{N}_{SF})}{\left[N_{IR} + N_{Subs} + N_{CF} + (1 - \tilde{p}_{Ab})\hat{N}_{SF}\right]^4} . \tag{7}$$

Total exploitation rate was estimated as follows:

$$\hat{U}_T = \frac{\sum_{i=1}^{3} \hat{N}_i}{\hat{N}_T} \tag{8}$$

with variance estimated by simulation.

Age–Sex Composition

For each year, a contingency table analysis was used to test for differences in age and sex composition of the inriver run over 2 time strata. Due to sample size considerations, each stratum was constructed of a set of contiguous weekly sampling strata. The contingency table analysis was also performed for the sport fish harvest sampled in 2009, when the lower weir was removed early. These analyses provided baseline information for future sampling designs; there are currently no reasonable weights available for use in a time-stratified analysis. For the sport harvest, there is only one estimate provided annually by the SWHS. For the inriver run, there are weir counts, but a significant sport harvest occurs above the weir, which complicates any stratified estimate. The inriver run sample is a hybrid sample of the escapement and sport harvest.

A second contingency table analysis was used to test for differences in age and sex composition between the inriver run and sport harvest populations for the 2009 data only. This analysis was used to determine whether the sport harvest sample could be used to augment the inriver run sample; it is noted that the inriver run sample is assumed to be representative of the total run as a result of its nonselective sampling technique (weir trap). Stratification by inriver run and sport harvest is impossible because of the upriver harvest and because the sport harvest is estimated with considerable error, violating the assumption required of a traditional stratified analysis that the stratum populations are known.

Proportions and variances of age or sex class *j* for the run were estimated from the inriver run sample in 2008 and 2010 and from a pooled sample of the inriver run and sport sample in 2009:

$$\hat{p}_j = \frac{n_j}{n} \tag{9}$$

and

$$\mathrm{var}(\hat{p}_j) = \frac{\hat{p}_j\left(1-\hat{p}_j\right)}{n-1}, \tag{10}$$

where

n_j = the number of coho salmon in the sample that were in age or sex class *j*, and

n = the number of coho salmon sampled.

The finite population correction factor was negligible (population > sample) and there was also uncertainty in the total population size because of the estimation of the sport harvest. Therefore, no correction factor was calculated.

The number of coho salmon of age or sex class *j* in the population of interest *i* (*i* = E, IR, SF, Sub, CF, or T) and its variance were estimated as follows:

$$\hat{N}_{ij} = \hat{N}_i\,\hat{p}_j \tag{11}$$

and

$$\mathrm{var}(\hat{N}_{ij}) = \hat{N}_i^{\,2}\,\mathrm{var}(\hat{p}_j) + \hat{p}_j^2\,\mathrm{var}(\hat{N}_i) - \mathrm{var}(\hat{p}_j)\,\mathrm{var}(\hat{N}_i)\,. \tag{12}$$

Length

Mean length-at-age and its standard error were estimated for each age class of the run.

Spawner–Recruit Analysis

A Bayesian spawner–recruit analysis based on an underlying Ricker-type relationship was performed. This analysis is better able to incorporate any uncertainty and autocorrelation in the data than traditional spawner–recruit analyses, which assume known spawning escapements and zero autocorrelation. Examples of the Bayesian approach can be found in Ericksen and Fleischman (2006), Szarzi et al. (2007), Fleischman and Borba (2009), and McPherson et al. (2010).

Traditional Approach

The traditional approach is based on simple linear regression techniques that fit the linearized Ricker stock–recruitment function:

$$\ln(R_y / S_y) = \ln\alpha - \beta S_y + \varepsilon_y, \tag{13}$$

where R_y and S_y are the return and spawning abundance, respectively, relevant to brood year y; α and β describe the shape of the Ricker stock–recruitment relationship (Ricker 1975); and $\{\varepsilon_y\}$~$N(0,\sigma^2)$, with ε_y representing process error. Spawning abundance yielding maximum sustained yield, S_{MSY}, is typically modeled using the approximation of Hilborn and Walters (1992):

$$S_{MSY} = \frac{\ln(\alpha)'}{\beta}(0.5 - 0.07\ln(\alpha)'), \tag{14}$$

where

$$\ln(\alpha)' = \ln(\alpha) + \sigma^2/2. \tag{15}$$

Spawning abundance for which $R = S$ is modeled as

$$S_{EQ} = \frac{\ln(\alpha)'}{\beta}. \tag{16}$$

Estimates of the quantities above are obtained by plugging in the simple linear regression estimates of $\ln(\alpha)$, β,and σ^2.

Confidence intervals for S_{MSY} are typically estimated using the bootstrap method (Efron 1982); each iteration of the bootstrap is conducted by resampling the residuals from the regression, creating a bootstrap dataset, and then refitting the regression model to the bootstrapped dataset. A sustained yield probability profile can also be created that describes the probability of attaining 90% of maximum sustained yield as a function of spawning escapement. A 'horsetail' plot of the Ricker relationship can also be created from the first 20 bootstrap datasets.

Serial correlation can be examined through inspection of the autocorrelation and partial autocorrelation functions of the residuals and by the Durbin–Watson statistic, although it cannot be directly accounted for in the traditional analysis. The traditional analysis is also only useful for brood years for which a large majority of the return is complete (complete brood years).

Bayesian Analysis

The Bayesian method used in this report has several potential advantages over the traditional stock–recruitment model described above. The method is capable of incorporating into parameter estimation the uncertainty associated with incomplete stock–recruitment datasets (such as the missing age composition data for the 1990 calendar year), error in spawning escapement measurements (considered substantial for some years of this study), sampling variability in age composition estimation, serial correlation in returns, and other ad hoc sources of variability such as the error in sport harvest and subsistence harvest estimation. The Bayesian method also allows use of incomplete brood year data.

Markov Chain Monte Carlo (MCMC) methods, which are especially well-suited for modeling complex population and sampling processes, were used to obtain the Bayesian estimates. The MCMC algorithms were implemented in OpenBUGS[1] (Gilks et al. 1994).

The Bayesian MCMC analysis considers all the data simultaneously in the context of the following "full-probability" statistical model. Returns of coho salmon originating from spawning escapement in brood years *y*, where *y* equals 1989 through 2007, are modeled as a Ricker stock–recruitment function with autoregressive lognormal errors:

$$\ln(R_y) = \ln(S_y) + \ln(\alpha) - \beta S_y + \phi \nu_{y-1} + \varepsilon_y \tag{17}$$

where α and β are Ricker parameters, ϕ is the autoregressive coefficient, $\{\nu_y\}$ are the model residuals

$$\nu_y = \ln(R_y) - \ln(S_y) - \ln(\alpha) + \beta S_y, \tag{18}$$

and $\{\varepsilon_y\}$ are independently and normally distributed process errors with mean zero and variance σ^2_{SR}.

Age proportion vectors $\underline{\boldsymbol{p}}_{\boldsymbol{y}}$ = (p_{y3}, p_{y4}, p_{y5}) from brood year *y* returning at ages 3–5 are drawn from a common Dirichlet distribution (multivariate analogue of the beta). The Dirichlet is re-parameterized such that the usual parameters

$$D_a = \pi_a D \tag{19}$$

are written in terms of location (overall age proportions π_a) and inverse scale (*D*, which governs the inverse dispersion of the $\underline{\boldsymbol{p}}_{\boldsymbol{y}}$ age proportion vectors among brood years).

The abundance *N* of age-*a* sockeye salmon in calendar year *t* ($t \in$ 1989–2010) is the product of the age proportion scalar *p* and the total return *R* from brood year $y = t - a$:

$$N_{ta} = R_{t-a}\, p_{t-a,a}\,. \tag{20}$$

Total run during calendar year *t* is the sum of abundance-at-age across ages:

$$N_{t\cdot} = \sum_a N_{ta}\,. \tag{21}$$

The weir counts were modeled as the total run minus all subsistence harvest and the sport harvest occurring below the inriver weir:

$$W_t = N_{t\cdot} - HSub_t - p_{t,Below} HSF_t \tag{22}$$

where $p_{t,Below}$ is the proportion of the sport harvest occurring below the inriver weir (the prior distribution on $p_{t,Below}$ was set as a beta [4.5,1.125], an informative prior with mean 0.8), and where HSF_t is the product of the annual exploitation rate μ_t and total run:

[1] Product names are used for completeness but do not constitute endorsement.

$$HSF_t = \mu_t N_t \tag{23}$$

and where subsistence harvest was modeled as follows:

$$HSub_t = HSub_{t,K} + \left[\frac{HSub_{pt}}{p_{rt}} - HSub_{pt} \right] p_h \tag{24}$$

where $HSub_{pt}$ is the (known) harvest from returned permits in year t, p_{rt} is the proportion of issued permits returned, and p_h is a discounting proportion accounting for the reduction in harvest rate associated with unreturned permits. The prior distribution on p_h was set as a beta (5,1), an informative prior with mean 0.8.

Spawning abundance was modeled as the weir count minus the sport harvest occurring above the inriver weir:

$$S_t = W_t - (1 - p_{t,Below}) HSF_t \,. \tag{25}$$

Spawning abundance yielding peak return S_{MAX} is the inverse of the Ricker β parameter. Equilibrium spawning abundance S_{EQ} and spawning abundance leading to maximum sustained yield S_{MSY} are obtained using equations 14 and 16, except that ln(α) is corrected for AR1 serial correlation as well as lognormal process error:

$$\ln(\alpha') = \ln(\alpha) + \frac{\sigma_{SR}^2}{2(1-\phi^2)} \,. \tag{26}$$

Expected sustained yield at a specified escapement S was calculated by subtracting spawning escapement from the expected return, again incorporating corrections for lognormal process error and AR1 serial correlation:

$$SY = E[R] - S = Se^{\ln(\alpha') - \beta S} - S \,. \tag{27}$$

Probability that a given level of escapement would produce average yields exceeding 90% of MSY was obtained by calculating the expected sustained yield (*SY*; Equation 27) at the considered level of *S* for each MCMC sample. The calculated *SY* was then compared to 90% of the value of MSY for that MCMC sample. The desired probability is the proportion of MCMC samples in which *SY* exceeded 0.9 MSY.

Observed data include estimates of inriver run (weir counts), estimates of sport and subsistence harvest, and scale age counts. Likelihood functions for the data follow.

Weir counts were modeled as follows:

$$\hat{W}_t = W_t e^{\varepsilon_{Wt}} \tag{28}$$

where $\{\varepsilon_{Wt}\}$ are normal (0,σ^2_{Wt}) with measurement error variance σ^2_{Wt} and the estimated portions of the weir counts (flooding periods) were assumed to have a coefficient of variation of 50%.

Estimated sport harvest was modeled as

$$\hat{HSF}_t = HSF_t e^{\varepsilon_{Ht}} \tag{29}$$

where $\{\varepsilon_{Ht}\}$ are normal (0,σ^2_{Ht}) with individual variances σ^2_{Ht} assumed known from the Statewide Harvest Survey.

Numbers of fish sampled for scales (n) that were classified as age-a in calendar year t (x_{ta}) are assumed multinomially (r_{ta},n) distributed, with proportion parameters as follows:

$$r_{ta} = \frac{N_{ta}}{N_{t\cdot}}. \tag{30}$$

Bayesian analyses require that prior probability distributions be specified for all unknowns in the model. Non-informative priors (chosen to have a minimal effect on the posterior) were used almost exclusively. Initial returns R_{1984}–R_{1988} (those with no linked spawner abundance) were modeled as drawn from a common lognormal distribution with median μ_{LOGR} and variance σ^2_{LOGR}. Normal priors constrained to be positive with mean zero and very large variances were used for ln(α) and β (Millar 2002), as well as for μ_{LOGR}. The initial model residual ν_0 was given a normal prior with mean zero and variance $\sigma^2_{SR}/(1-\phi^2)$. Diffuse conjugate inverse gamma priors were used for σ^2_{SR} and σ^2_{LOGR}. Annual exploitation rates $\{\mu_t\}$ were given uninformative beta (0.1,0.1) prior distributions. The parameters p_t and $p_{t,Below}$ were given informative beta (5,1) and beta (4.5,1.125) priors, respectively, reflecting prior knowledge.

MCMC samples were drawn from the joint posterior probability distribution of all unknowns in the model. For each of two Markov chains initialized, a 100,000-sample burn-in period was discarded, after which each chain ran for an additional 190,000 iterations. After thinning by a factor of 10, a total of approximately 30,000 samples were used to estimate the marginal posterior means, standard deviations, and percentiles. The diagnostic tools in OpenBUGS assessed mixing and convergence, and no major problems were encountered. Interval estimates were obtained from the percentiles of the posterior distributions.

RESULTS

YEAR 2008

Total Run, Harvest, and Escapement

The lower weir was installed on 30 July and was tended through 29 September. High water conditions interrupted operation of the weir on 3 occasions: 13–14 August, 18–21 August, and 6–9 September (Table 1).

The weir remained operational until 3:00 AM on 13 August, when half the panels were pulled due to high water conditions. The weir was fish tight again on 14 August at 9:40 AM. An estimated 30 coho salmon were added to the weir count based on the recent 10-year average (1998–2007) count for 13 and 14 August. The weir was completely pulled at 2:55 PM on

18 August due to rising waters. On 19 August, 2.5 inches of rain fell in 24 hours, and the tripods were washed out and swung to the sides of the river while tethered on cables. Water levels receded enough to reinstall the weir by 11:45 AM on 21 August. An estimated 257 coho salmon were added to the weir count; this estimate was based on the 10-year average count during the dates the weir was out. The water levels rose again, and on 6 September the weir was pulled at 2:00 PM and remained inoperable until 2:00 PM on 9 September. Missed salmon were estimated as before, adding 993 coho salmon to the weir count.

The inriver run (weir count) of coho salmon in the Buskin River for 2008 was estimated to be 9,028 fish, 50% of which were enumerated by 9 September (Appendix A1). Approximately 14% of the 2008 reported weir count was estimated, with 7,748 coho salmon actually counted at the weir (Table 1, Appendix A1). Anglers fishing the Buskin River drainage caught an estimated 6,469 and harvested 4,259 (SE 760) coho salmon, expending 15,068 angler-days of effort (Table 2). The reported coho salmon subsistence harvest was 1,232, and the commercial harvest of Buskin River coho salmon was 137. The estimated spawning escapement was 8,176 (SE 152) (Equation 2). The estimated total run was 13,804 (SE 608) coho salmon (Equation 1).

Table 2.–Buskin River coho salmon weir counts, and subsistence, commercial, and sport harvests, 2001–2010.

				Sport estimate[d]			
Year	Weir count[a]	Commercial harvest[b]	Subsistence harvest[c]	Harvest	SE	Catch	Angler-days
2001	13,494	0	1,457	2,332	477	3,928	9,539
2002	10,649	0	1,582	2,497	532	4,388	18,450
2003	13,150	6	1,362	3,302	631	4,592	14,311
2004	9,599	95	1,564	4,860	822	8,562	17,549
2005	16,596	0	2,505	3,010	546	5,006	17,575
2006	13,348	763	1,662	6,567	1,022	11,468	19,875
2007	9,001	757	1,309	5,215	991	8,434	17,124
2008	9,028	137	1,232	4,259	760	6,469	15,068
2009	10,624	299	987	5,207	973	8,014	18,695
2010	6,808	127	717	2,847	785	4,492	13,364
Average 2001–2010	11,230	218	1,438	4,010	754	6,535	16,155

[a] *Source*: Tiernan 2011. Weir values include estimates.

[b] *Source*: ADF&G, CF Statewide Harvest Receipt (fish ticket) database. Commercial harvest includes only statistical areas 259-22 (Womens Bay).

[c] *Source*: Subsistence harvest records maintained by the CF Westward Region. Subsistence includes harvest from Buskin River and Womens Bay.

[d] *Source*: SWHS database; Jennings et al. 2004, 2006 a-b, 2007, 2009 a-b, 2010 a-b, 2011 a-b.

Exploitation Rate

The estimated annual subsistence exploitation rate of 8.9% was substantially lower than the sport exploitation rate of 30.9%; the commercial fisheries exploitation rate was 1.0%, whereas the total exploitation rate was estimated as 40.8% (Table 3).

Table 3.–Estimated exploitation rates (%) of Buskin River coho salmon subsistence, commercial, and sport fisheries, 2008–2010.

Year		Subsistence Fishery	Sport	CF	Total
2008	Percentage	8.9	30.9	1.0	40.8
	SE	0.39	4.15	0.04	5.78
2009	Percentage	6.1	32.4	1.9	40.4
	SE	0.30	4.48	0.09	6.38
2010	Percentage	7.2	28.7	1.3	37.2
	SE	0.46	6.10	0.08	8.30

Age-Sex-Length

Inriver Run

Age was determined for 211 of 227 coho salmon sampled from the inriver run. Sex was determined for 226 fish (Table 4). There were no significant differences in age or sex composition over the two time strata (18 August–7 September and 8 September–25 September) (age: $\chi^2 = 1.08$, df = 2, $P = 0.58$; sex: $\chi^2 = 0.11$, df = 1, $P = 0.74$; age by sex: $\chi^2 = 3.72$, df = 5, $P = 0.59$). Data from each stratum were subsequently pooled.

Total Run

The age-sex composition of the inriver run was assumed to be representative of the total run (Table 4). Numbers by age of the 2008 coho salmon total run are given in (Table 5). Age-2.1 fish composed 67% of the run, and 30% were age 1.1. There was no significant difference in age composition over sex ($\chi^2 = 0.23$, df = 1, $P = 0.63$). There were more males (56%) than females (44%); the male-to-female ratio was 1.28:1. There was a significant difference in length of males versus females ($Z = 15.9$, $P < 0.05$).

Estimated age composition of the combined subsistence and commercial harvests is given in Appendix C1 and that of the sport harvest is given in Appendix D1; it is noted that these composition estimates are based on the assumption that the age composition of the harvests is identical to that of the inriver run (Table 4).

Table 4.–Estimated age, sex, and mean METF length of the Buskin River coho salmon inriver run, 2008.

	Coho salmon ages					
	1.1	2.0	2.1	3.0	3.1	Total
Females						
Number sampled	25		64		1	99
Percent	11.9		30.5		0.5	43.8
SE percent	2.2		3.2		0.5	3.3
Inriver run	1,075		2,751		43	3,955
SE Inriver run	214		341		43	400
Mean length (mm)	635		637		632	635
SE mean length (mm)	5		5			4
Minimum length (mm)	578		427		632	427
Maximum length (mm)	683		708		632	708
Males						
Number sampled	37	1	78	1	3	127
Percent	17.6	0.5	37.1	0.5	1.4	56.2
SE percent	2.6	0.5	3.3	0.5	0.8	3.3
Inriver run	1,591	43	3,353	43	129	5,073
SE Inriver run	260	43	376	43	74	453
Mean length (mm)	609	321	638	310	638	624
SE mean length (mm)	10		6		26	6
Minimum length (mm)	511	321	500	310	594	310
Maximum length (mm)	731	321	728	310	684	731
All						
Number sampled	63	1	142	1	4	227
Percent	29.9	0.5	67.3	0.5	1.9	100.0
SE percent	3.2	0.5	3.2	0.5	0.9	
Inriver run	2,696	43	6,076	43	171	9,028
SE Inriver run	338	43	503	43	86	608
Mean length (mm)	620	321	638	310	636	629
SE mean length (mm)	6		4		18	4
Minimum length (mm)	511	321	427	310	594	310
Maximum length (mm)	731	321	728	310	684	731

Note: The inriver run was sampled at the weir 18 August–25 September. Totals may not sum because some fish may be sexed but not aged and vice versa.

Table 5.–Estimated age composition with standard errors of Buskin River coho salmon estimated total run, 2008–2010.

Year		Age class 1.1	2.0	2.1	3.0	3.1	Total[a]
2008	Number	4,122	65	9,290	65	262	13,804
	SE	473	66	606	66	131	
2009	Number	2,048	307	13,004	0	717	16,076
	SE	440	177	807	0	268	
2010	Number	1,508	377	7,729	126	189	9,929
	SE	299	153	589	89	109	

Note: Estimates are based on age-class composition of the inriver run at the weir in 2008 and 2010 and a combination of inriver return at weir and sport harvest in 2009.

[a] Total is sum of inriver run at the weir and 80% of SWHS estimate of sport harvests, as well as subsistence and commercial harvests.

YEAR 2009

Total Run, Harvest, and Escapement

The lower weir was installed on 3 August and was tended through 16 September. High water conditions interrupted operation of the weir on 3 occasions: 4–6 August, 28–30 August, and 8–13 September (Table 1). The lake weir was installed on 22 May and remained in operation continuously until 30 September.

The lower weir remained operational for the first 24 hours after it was installed until it was pulled due to high water conditions. The weir was again fish tight on 6 August at 9:30 AM. During the time the lower weir was out, coho salmon counts from the lake weir were substituted for the missing lower weir counts. Between 6 August and 16 September, all species were counted at the lower weir location when possible. On 27 August, a small hole was discovered below 2 panels and 5 coho salmon were estimated to have passed through the weir based on weir crew observations. Another high-water event resulted in the lower weir being inoperable between 2:30 AM on 28 August and 4:10 PM on 30 August. Between 28 and 30 August, an estimated 743 coho salmon entered the system; the estimate was based on the recent 10-year average (1999–2008) daily count for each day. A high water event occurred again, resulting in the lower weir being pulled at 4:30 PM on 8 September and reinstalled 11:00 AM on 13 September. An estimated 1,606 coho salmon entered the system, based on the recent 10-year average escapement for each day. The lower weir was removed for the season due to high water at 7:30 AM on 16 September. The inriver run at the lower weir between 16 September and 30 September (last planned day of operation) was estimated as 5,022 fish, which was the ratio of the count at the lower weir (5,602) to the count at the lake weir (3,958) until 16 September multiplied by the daily counts at the lake weir during the period of extrapolation (3,548; 16–30 September).

The final weir count of coho salmon in the Buskin River was therefore estimated as 10,624 fish, approximately 50% of which were enumerated by 15 September (Appendix A1). A total of 7,506 coho salmon were counted at the lake weir and 3,248 at the lower weir. Approximately 70% of the 2009 final (lower) weir count was estimated (Table 1). Anglers fishing the Buskin River system caught an estimated 8,014 coho salmon and harvested 5,207 (SE 973), expending 18,695 angler-days of effort (Table 2). The reported coho salmon subsistence harvest was 987, and the commercial harvest was 299. The estimated spawning escapement was 9,583 (SE 195) coho salmon (Equation 2). The estimated total run was 16,076 (SE 778) coho salmon (Equation 1).

Exploitation Rate

The estimated annual subsistence exploitation rate of 6.1% was substantially lower than the sport exploitation rate of 32.4%; the commercial fisheries exploitation rate was 1.9%, whereas the total exploitation rate was estimated as 40.4%, similar to that in 2008 (Table 3).

Age-Sex-Length

Inriver Run

Age was determined for 94 of 106 coho salmon sampled from the inriver run at the lower weir (Appendix B1). All fish were sexed. There were no significant differences in age or sex composition over 2 time strata (12 August–31 August and 1 September–7 September) (age: $\chi^2 = 3.25$, df = 2, $P = 0.20$; sex: $\chi^2 = 1.14$, df = 1, $P = 0.29$; age by sex: $\chi^2 = 7.9$, df = 5, $P = 0.16$). Data from each time stratum were pooled.

Sport Harvest

Age was also determined for 63 of 68 coho salmon sampled from the sport fishery during 18–26 September (Appendix B2). All fish were sexed. Samples were collected from fish harvested in the sport fishery only below the lower weir and after 16 September, when the lower weir was removed. There were no significant differences in age or sex composition over time (age: $\chi^2 = 1.59$, df = 2, $P = 0.451$; sex: $\chi^2 = 0.50$, df = 1, $P = 0.478$; age by sex: $\chi^2 = 3.56$, df = 5, $P = 0.62$). Data from the sport harvest sample were pooled.

Total Run

Neither age nor sex composition in the sport fishery differed significantly from that in the inriver run (age: $\chi^2 = 2.82$, df = 2, $P = 0.25$; sex: $\chi^2 = 0.83$, df = 1, $P = 0.36$; age by sex: $\chi^2 = 9.05$, df = 5, $P = 0.11$). Estimates were subsequently pooled to increase precision (Table 6). The pooled estimates were considered representative of the total run. Numbers by age of the 2009 coho salmon total run based on the pooled samples are given in (Table 5).

Age-2.1 fish made up 81% of the pooled data, and 13% were age 1.1 (Table 6). There was no significant difference in age composition over sex (χ^2 = ~0, df = 1, P =1). There were fewer males (49%) than females (51%); the male-to-female ratio was 0.96:1. Male and female lengths did not differ significantly ($Z = -0.087$, $P = 0.93$).

Estimated age composition of the combined subsistence and commercial harvests is given in Appendix C1, and that of the sport harvest is given in Appendix D1. It is noted that these composition estimates are based on the assumption that the age composition of the harvests is identical to that of the inriver run (Table 6).

Table 6.–Estimated age, sex, and mean METF length of the Buskin River coho salmon inriver run based on pooled data from the sport harvest sample, 2009.

		Coho salmon ages					
Sex	Parameter	1.1	2.0	2.1	3.0	3.1	Total
Females							
	Number sampled	11		69		3	89
	Percent	7.0		43.9		1.9	51.1
	SE percent	2.0		4.0		1.1	3.8
	Inriver run	744		4,669		203	5,434
	SE inriver run	223		543		117	566
	Mean length (mm)	584		613		620	603
	SE mean length (mm)	14		6		6	6
	Minimum length (mm)	519		426		609	366
	Maximum length (mm)	658		707		630	707
Males							
	Number sampled	9	3	58		4	85
	Percent	5.7	1.9	36.9		2.5	48.9
	SE percent	1.9	1.1	3.9		1.3	3.8
	Inriver run	609	203	3,925		271	5,190
	SE inriver run	202	117	500		135	554
	Mean length (mm)	582	332	620		669	603
	SE mean length (mm)	22	14	7		18	9
	Minimum length (mm)	491	309	489		636	309
	Maximum length (mm)	658	357	728		715	728
All							
	Number sampled	20	3	127		7	174
	Percent	12.7	1.9	80.9		4.5	100.0
	SE percent	2.7	1.1	3.1		1.7	
	Inriver run	1,353	203	8,594		474	10,624
	SE inriver run	300	117	713		178	778.4
	Mean length (mm)	583	332	616		648	603
	SE mean length (mm)	12	14	4		14	5
	Minimum length (mm)	491	309	426		609	309
	Maximum length (mm)	658	357	728		715	728

Note: The inriver run was sampled at the lower weir 12 August–7 September, and the sport fishery was sampled below the weir 18–26 September; these samples were pooled.

YEAR 2010

Total Run, Harvest, and Escapement

The lower Buskin River weir was installed on 29 July and was tended through 29 September. High water conditions interrupted operation of the weir on one occasion (Table 1). The lake weir was installed on 21 May and remained in operation until 7 October.

The lower weir was fish tight at 2:30 PM on 29 July. The weir was pulled for the season on 29 September at 10:30 AM, and the estimated final escapement was 6,808 coho salmon (of which 3,234 were actually counted) (Appendix A1). From 15 to 17 August, a high-water event required the lower weir to be removed, and 79 coho salmon were estimated for this period based on the recent 10-year average (2000–2009) daily count for those days. A postseason estimate of 3,501 coho salmon was also made as a result of observed significant immigration at the lake weir after 29 September. The estimate was based on the ratio of the total lower weir count (3,307) as of 29 September to the total lake weir count (1,343) as of 1 October multiplied by the daily counts at the lake weir from 30 September through 7 October (1,421).

The estimated inriver run of coho salmon at the lower weir site was 6,808 fish, 50% of which were enumerated by 29 September (Appendix A1). Between 29 July and 7 October, a total of 1,755 coho salmon were actually counted at the lake weir and 3,234 at the lower weir. Approximately 53% of the 2010 reported weir count was estimated (Table 1). Anglers fishing the Buskin River drainage caught an estimated 4,492 and harvested 2,847 (SE 785) coho salmon, expending 13,364 angler-days of effort (Table 2). The reported coho salmon subsistence harvest was 717, and the commercial harvest was 127. The estimated spawning escapement was 6,239 (SE 157) coho salmon (Equation 2). The estimated total run was 9,929 (SE 629) coho salmon (Equation 1).

Exploitation Rate

The estimated annual subsistence fishery exploitation rate of 7.2% was substantially lower than the sport fishery exploitation rate of 28.7%; the commercial fisheries exploitation rate was 1.3%, whereas the total exploitation rate was estimated as 37.2% (Table 3).

Age-Sex-Length

Inriver run

Age was determined for 158 of 201 coho salmon sampled from the inriver run; 201 fish were sexed. Neither age nor sex composition differed significantly over two time strata (19 August–September 9 and 10 September–24 September) (age: $\chi^2 = 3.36$, df = 2, $P = 0.19$; sex: $\chi^2 = 1.89$, df = 1, $P = 0.17$; age by sex: $\chi^2 = 3.74$, df = 5, $P = 0.59$). Data from the two time strata were pooled (Table 7).

Total run

The age-sex composition of the inriver run was assumed to be representative of that of the total run. Estimated numbers by age of the 2010 coho salmon total run are given in (Table 5). Age-2.1 fish composed 77.8% of the inriver run, and 15.2% were age 1.1 (Table 7). There was no significant difference in age composition over sex ($\chi^2 = 0.35$, df = 1, $P = 0.55$). There were more males (56%) than females (44%) and a male-to-female ratio of 1.26:1. Males were significantly smaller than females ($Z = 30.9$, $P < 0.05$). Estimated age composition of the combined subsistence and commercial harvests is given in Appendix C1 and that of the sport harvest is given in Appendix D1; composition estimates are based on the assumption that the age composition of the harvests is identical to that of the inriver run (Table 7).

Table 7.–Estimated age, sex, and mean METF length of Buskin River coho salmon inriver run, 2010.

		Coho salmon ages					
Sex	Parameter	1.1	2.0	2.1	3.0	3.1	Total
Females							
	Number sampled	13		55		2	89
	Percent	8.3		35.3		1.3	44.3
	SE percent	2.2		3.8		0.9	3.5
	Inriver run	567		2,400		87	3,014
	SE inriver run	159		342		62	366
	Mean length (mm)	603		619		618	612
	SE mean length (mm)	12		5		8	5
	Minimum length (mm)	501		492		610	484
	Maximum length (mm)	667		664		625	667
Males							
	Number sampled	11	5	67	2	1	112
	Percent	7.1	3.2	42.9	1.3	0.6	55.7
	SE percent	2.1	1.4	4.0	0.9	0.6	3.5
	Inriver run	480	218	2,924	87	44	3,794
	SE inriver run	146	98	382	62	44	424
	Mean length (mm)	574	320	612	310	682	579
	SE mean length (mm)	23	5	7	6		10
	Minimum length (mm)	470	310	444	304	682	304
	Maximum length (mm)	651	338	711	315	682	720
All							
	Number sampled	24	6	123	2	3	201
	Percent	15.2	3.8	77.8	1.3	1.9	100.0
	SE percent	2.9	1.5	3.3	0.9	1.1	0.0
	Inriver run	1,034	259	5,300	86	129	6,808
	SE inriver run	216	106	539	61	75	628.8
	Mean length (mm)	589	320	615	310	639	594
	SE mean length (mm)	12	5	5	6	22	6
	Minimum length (mm)	470	310	444	304	610	304
	Maximum length (mm)	667	338	711	315	682	720

Note: Inriver run sampled at weir, 19 August through 24 September.

SPAWNER–RECRUIT ANALYSIS

The median of the posterior distribution of S_{MSY} is 7,309 coho salmon (Table 8, Figure 2). The Bayesian analysis suggests that the value of S_{MSY} lies between 5,448 and 13,580 coho salmon with 90% certainty. A plot of the probability that sustainable yield exceeds 90% of the maximum sustainable yield is given in Figure 3. There is probably some positive autocorrelation (ϕ), although the 80% credibility interval for this parameter extends into the negative (Table 8).

The spawner–recruit relationships determined by the median values of $\ln(\alpha)$ and β from the Bayesian analysis and those estimated by a traditional analysis are depicted in Figure 4.

Table 8.–Posterior percentiles for important nodes of the Bayesian analysis.

	Percentile				
Parameter	5	10	median(50)	90	95
$\ln(\alpha)$	0.60	0.71	1.02	1.32	1.42
B	0.00	0.00	0.00	0.00	0.00
σ_{RS}	0.15	0.16	0.22	0.36	0.45
S_{MSY}	5,448	5,789	7,309	10,980	13,580
π_1	0.20	0.20	0.22	0.24	0.25
π_2	0.68	0.69	0.71	0.73	0.74
π_3	0.05	0.06	0.07	0.08	0.08
ϕ	-0.19	-0.06	0.38	0.78	0.86

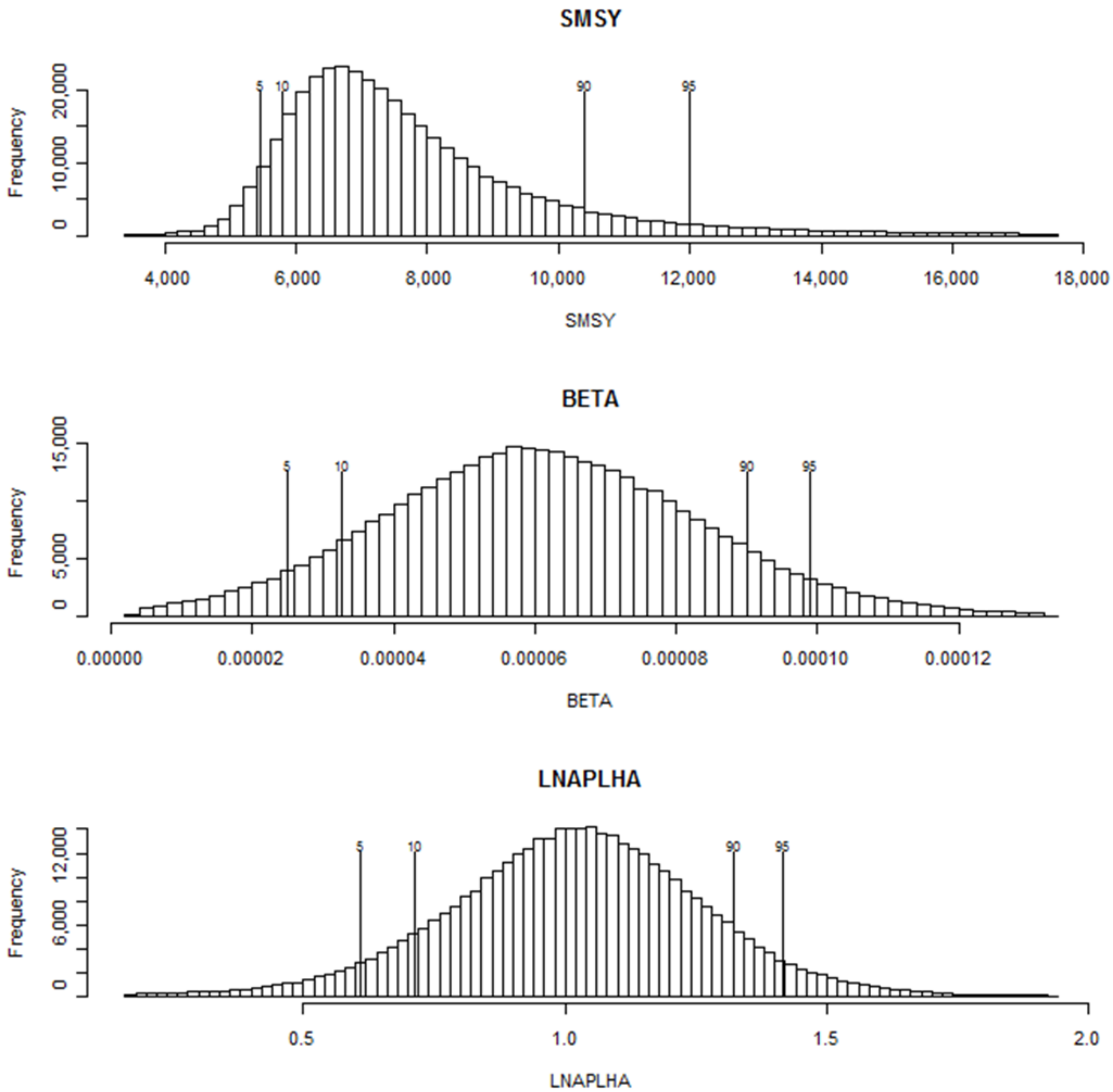

Figure 2.–Posterior distributions of S_{MSY}, β, and $\ln(\alpha)$; vertical lines depict 5th, 10th, 90th, and 95th percentiles of the distributions.

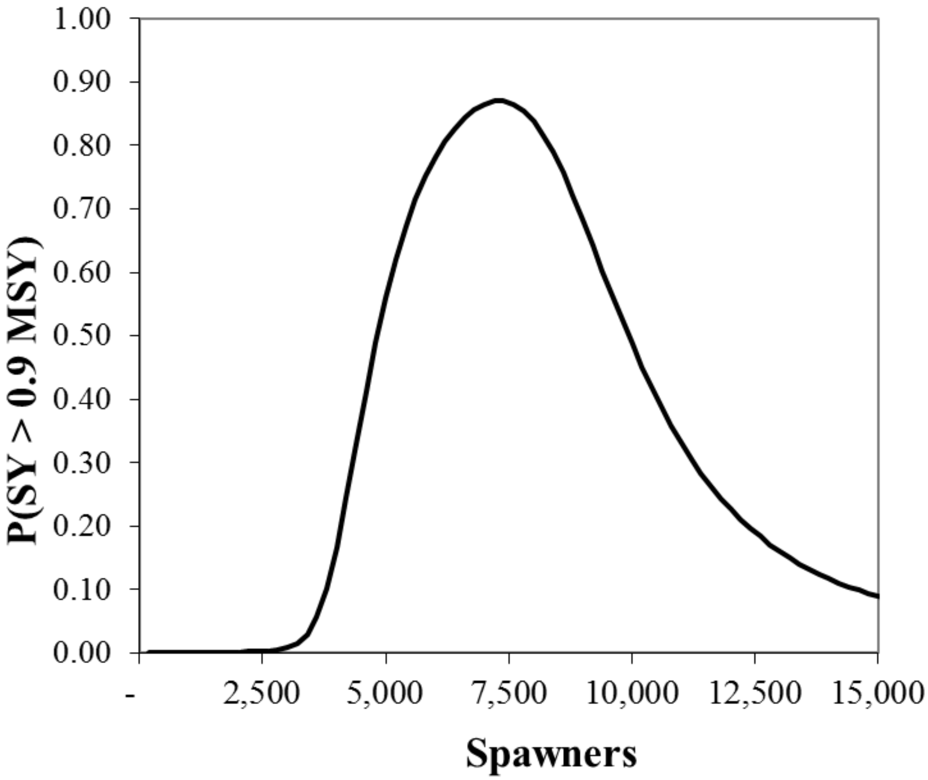

Figure 3.–Probability that sustained yield (SY) is greater than 90% of MSY.

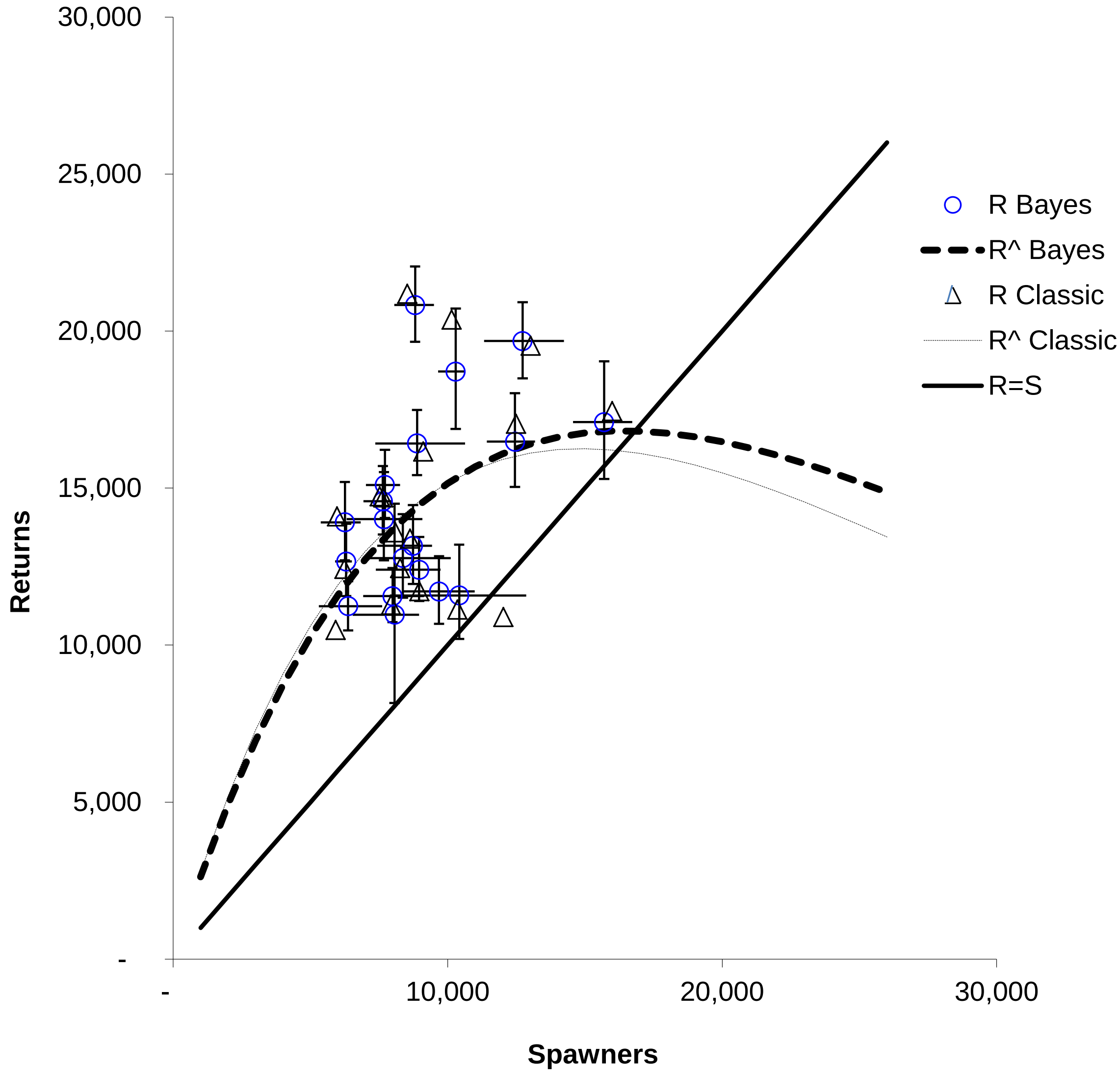

Figure 4.–Spawner–recruit relationships derived from Bayesian analysis and traditional (classic) analysis, and the R = S relationship; error bars are 80% credibility intervals.

DISCUSSION

Collection of age and run data for Buskin River coho salmon from 2008 through 2010 allowed continued construction of a brood table beginning with brood year 1989 (Table 9). Returns are largely complete through brood year 2006 (age-3.1 fish from brood year 2006 will return in 2011; this age class of fish typically represents about 6% of a brood year return). Return per spawner over brood years 1989 through 2006 has averaged 1.64 coho salmon and has ranged from 0.78 to 2.4.

There are a number of sources of bias in the estimates of total run. The first source of bias lies in unreturned subsistence permits. This bias is not thought to be severe; applying the worst-case rate of return of subsistence permits (60%) to each year's harvest shows that at least 92% of the total run is accounted for with the current methods. It is noted also that this adjustment assumes harvest associated with unreturned permits is equal to that of returned permits; however, it is often lower, such that the real bias is probably lower still. A second source of unquantifiable bias is associated with the assumption that 20% of the sport harvest occurs upstream of the weir; this number originated from a creel survey by Murray (1987) and probably fluctuates annually, with a possible (unknown) trend over years. A third source of bias, and possibly the most important, is from the estimation of weir counts for periods when the weir is inoperable. Coho salmon immigration is variable by date both within years and between years. For 2008, immigration during periods of flooding was estimated using the recent 10-year average for the dates in question. Fortunately, the weir was inoperable for only a short period in 2008. In 2009 and 2010, a new method of estimation was used during flood periods, based on the ratio of lower weir to lake weir counts up to the flood stage and on lake weir counts during the flood stage. Although error is probably incurred with this method, it may be small because any spike in immigration that occurs in this system can be detected and reasonably accounted for. The lake weir can also be used to monitor late runs. In 2010, significant immigration occurred after the usual cessation of lower weir activities and was detected by continued operation of the lake weir.

Additionally, errors in estimation of the inriver run and the assumption that the proportion of the sport harvest occurring upstream of the weir is a constant are not accounted for in variance calculations, resulting in an underestimation of the variance of total run, spawning escapement, exploitation rates, and brood year returns involving sampling in 2009.

No change in age-sex composition over time was found in the analysis for either the sport harvest in 2009 or the inriver runs in the years 2008–2010. This finding is fortuitous, given the inability to stratify effectively over time. However, analyses of previous years' data (Schmidt and Evans 2012) show that although there is a general tendency for age-sex composition to remain constant throughout the run, it sometimes does change. For this reason, it is recommended that the current sampling protocol be maintained where fish are sampled throughout the run; such a sample will be more representative of the total run should age-sex composition change through the season.

Because there was no change in age-sex composition over time, length-at-age-sex data can be pooled over 2008–2010. These data show that within males, age-3.1 fish were significantly larger ($Z = 2.4$, $P = 0.008$; one-sided test) than age-2.1 fish (659 and 626 mm, respectively) and age-2.1 fish were significantly larger ($Z = 2.96$, $P = 0.0015$; one-sided test) than age-1.1 fish (625 and 598 mm, respectively). No difference was found in female lengths for age 3.1 versus 2.1 fish ($Z = 0.79$, $P = 0.22$) or 2.1 versus 1.1 fish ($P = 0.07$; $Z = 1.48$) (one sided tests).

Table 9.–Brood table for Buskin River coho salmon, 1989–2008.

	Escapement	Age class										
Brood year	(S)	1.0	1.1	1.2	2.0	2.1	2.2	3.0	3.1	3.2	4.1	Return (R)
1989	8,974	0	2,268	0	213	8,591	0	0	639	0	0	11,711
Proportion		0.00	0.19	0.00	0.02	0.73	0.00	0.00	0.05	0.00	0.00	
Sample year		1991	1992	1993	1992	1993	1994	1993	1994	1995	1995	
1990	5918	0	2,098	38	40	7,972	37	38	259	0	0	10,481
Proportion		0.00	0.20	0.00	0.00	0.76	0.00	0.00	0.02	0.00	0.00	
Sample year		1992	1993	1994	1993	1994	1995	1994	1995	1996	1996	
1991	8,105	0	3,385	0	226	8,829	43	0	1,041	0	68	13,592
Proportion		0.00	0.25	0.00	0.02	0.65	0.00	0.00	0.08	0.00	0.01	
Sample year		1993	1994	1995	1994	1995	1996	1995	1996	1997	1997	
1992	6,240	0	2,734	0	37	8,153	0	0	1,500	0	0	12,424
Proportion		0.00	0.22	0.00	0.00	0.66	0.00	0.00	0.12	0.00	0.00	
Sample year		1994	1995	1996	1995	1996	1997	1996	1997	1998	1998	
1993	5,970	37	2,559	0	0	10,025	55	68	1,260	44	44	14,091
Proportion		0.00	0.18	0.00	0.00	0.71	0.00	0.00	0.09	0.00	0.00	
Sample year		1995	1996	1997	1996	1997	1998	1997	1998	1999	1999	
1994	7,660	0	2,864	0	136	9,037	176	110	2,376	0	0	14,699
Proportion		0.00	0.19	0.00	0.01	0.61	0.01	0.01	0.16	0.00	0.00	
Sample year		1996	1997	1998	1997	1998	1999	1998	1999	2000	2000	
1995	8,268	0	2,300	0	0	9,020	161	44	926	0	0	12,451
Proportion		0.00	0.18	0.00	0.00	0.72	0.01	0.00	0.07	0.00	0.00	
Sample year		1997	1998	1999	1998	1999	2000	1999	2000	2001	2001	
1996	7,943	0	2,288	0	44	8,818	42	40	42	0	0	11,274
Proportion		0.00	0.20	0.00	0.00	0.78	0.00	0.00	0.00	0.00	0.00	
Sample year		1998	1999	2000	1999	2000	2001	2000	2001	2002	2002	

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Brood year	Escapement (S)	1.0	1.1	1.2	2.0	2.1	2.2	3.0	3.1	3.2	4.1	Return (R)
		Age class										
1997	10,353	0	2,174	0	40	8,450	0	42	418	0	0	11,125
Proportion		0.00	0.20	0.00	0.00	0.76	0.00	0.00	0.04	0.00	0.00	
Sample Year		1999	2000	2001	2000	2001	2002	2001	2002	2003	2003	
1998	8,528	0	8034	0	208	11,532	0	46	1,364	0	0	21,184
Proportion		0.00	0.38	0.00	0.01	0.54	0.00	0.00	0.06	0.00	0.00	
Sample Year		2000	2001	2002	2001	2002	2003	2002	2003	2004	2004	
1999	9,110	0	2,139	0	93	11,748	0	88	2,094	0	0	16,162
Proportion		0.00	0.13	0.00	0.01	0.73	0.00	0.01	0.13	0.00	0.00	
Sample Year		2001	2002	2003	2002	2003	2004	2003	2004	2005	2005	
2000	7,530	0	3,652	0	308	9,462	0	0	1,316	0	0	14,737
Proportion		0.00	0.25	0.00	0.02	0.64	0.00	0.00	0.09	0.00	0.00	
Sample Year		2002	2003	2004	2003	2004	2005	2004	2005	2006	2006	
2001	13,028	0	3553	0	0	14,866	0	0	1,112	0	0	19,531
Proportion		0.00	0.18	0.00	0.00	0.76	0.00	0.00	0.06	0.00	0.00	
Sample Year		2003	2004	2005	2004	2005	2006	2005	2006	2007	2007	
2002	10,150	37	5,196	0	66	14,895	0	27	138	0	0	20,360
Proportion		0.00	0.26	0.00	0.00	0.73	0.00	0.00	0.01	0.00	0.00	
Sample Year		2004	2005	2006	2005	2006	2007	2006	2007	2008	2008	
2003	12,490	66	4,938	0	54	11,722	0	0	262	0	0	17,042
Proportion		0.00	0.29	0.00	0.00	0.69	0.00	0.00	0.02	0.00	0.00	
Sample Year		2005	2006	2007	2006	2007	2008	2007	2008	2009	2009	
2004	8,627	0	2,827	0	483	9,290	0	65	717	0	0	13,382
Proportion		0.00	0.21	0.00	0.04	0.69	0.00	0.00	0.05	0.00	0.00	
Sample Year		2006	2007	2008	2007	2008	2009	2008	2009	2010	2010	

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Table 9.–Page 3 of 3.

Brood year	Escapement (S)	Age class 1.0	1.1	1.2	2.0	2.1	2.2	3.0	3.1	3.2	4.1	Return (R)
2005	15,994	69	4,122	0	65	13,004	0	0	189			17,448
Proportion		0.00	0.24	0.00	0.00	0.75	0.00	0.00	0.01	0.00	0.00	
Sample Year		2007	2008	2009	2008	2009	2010	2009	2010	2011	2011	
2006	12,035	0	2,048	0	307	7,729		126	686			10,896
Proportion		0.00	0.19	0.00	0.03	0.71	0.00	0.01	0.06	0.00	0.00	
Sample Year		2008	2009	2010	2009	2010	2011	2010	2011	2012	2012	
2007	7,958	0	1,508		377							1,885
Proportion		0.00	0.80	0.00	0.20	0.00	0.00	0.00	0.00	0.00	0.00	
Sample Year		2009	2010	2011	2010	2011	2012	2011	2012	2013	2013	
2008	8,176	0										0
Proportion		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Sample Year		2010	2011	2012	2011	2012	2013	2012	2013	2014	2014	
Average		0.00	0.22	0.00	0.01	0.70	0.00	0.00	0.06	0.00	0.00	

The total exploitation rate of Buskin River coho salmon was similar over years, ranging from 37% to 41%. Sport exploitation in all three years was 3–5 times higher than that of the subsistence fishery (Table 3).

The spawner–recruit Bayesian analysis gave a lower bound of the 90% credibility interval for S_{MSY} of 5,448 coho salmon. This is higher than the minimum inriver escapement goal currently used (3,200), suggesting a higher minimum inriver escapement goal may be warranted. It is noted that a new inriver goal based on the Bayesian analysis will also include fish that may be harvested in the sport fishery upriver of the weir.

A caveat to the spawner–recruit analysis is that there is a high degree of uncertainty in some of the inriver run estimates and in the proportion of the sport harvest that is taken upstream of the weir. The Bayesian analysis attempted to cater for this uncertainty, but there is still doubt regarding the inputs describing the uncertainty in the model. This concern is mitigated to some extent by our sensitivity analysis whereby we examined the effect of different levels of uncertainty in the weir counts. Even when we set the CVs of the estimated components of the weir count to 100% (vs. 50%), the 90% S_{msy} bounds changed little.

It is recommended that sampling of the Buskin River coho salmon run be continued, allowing an updated spawner–recruit analysis that will inform managers with respect to suitability of the current BEG and whether current exploitation rates are in line with those associated with maximum sustainable yield. Use of the lake weir to augment counts during flood periods and to detect protracted immigration is recommended.

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APPENDIX A: IMMIGRATION OF COHO SALMON THROUGH THE BUSKIN RIVER WEIR, 2001–2010

Appendix A1.–Immigration of coho salmon through the Busken River weir, 2001–2010.

	2001		2002		2003		2004		2005		2006		2007		2008		2009 [a]		2010 [b]	
Date	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%
1 Aug	0	0	1	0	0	0	7	0	1	0	0	0	2	0	1	0	0	0	0	0
2 Aug	0	0	1	0	0	0	9	0	1	0	0	0	2	0	1	0	0	0	0	0
3 Aug	0	0	1	0	0	0	23	0	1	0	0	0	2	0	2	0	2	0	0	0
4 Aug	0	0	1	0	0	0	31	0	1	0	2	0	2	0	3	0	6	0	0	0
5 Aug	0	0	1	0	0	0	34	0	1	0	7	0	2	0	8	0	8	0	0	0
6 Aug	0	0	2	0	0	0	45	0	1	0	9	0	2	0	8	0	8	0	0	0
7 Aug	0	0	3	0	0	0	57	1	1	0	20	0	4	0	8	0	17	0	0	0
8 Aug	0	0	3	0	0	0	75	1	5	0	34	0	4	0	16	0	27	0	5	0
9 Aug	0	0	3	0	2	0	79	1	10	0	61	0	5	0	26	0	33	0	20	0
10 Aug	0	0	3	0	2	0	101	1	24	0	82	1	5	0	34	0	35	0	31	0
11 Aug	0	0	3	0	2	0	139	1	39	0	103	1	7	0	50	1	52	0	40	1
12 Aug	0	0	3	0	4	0	165	2	53	0	121	1	11	0	85	1	70	1	44	1
13 Aug	0	0	9	0	4	0	220	2	63	0	154	1	14	0	103	1	81	1	49	1
14 Aug	0	0	59	1	8	0	282	3	69	0	195	1	29	0	180	2	91	1	60	1
15 Aug	0	0	81	1	27	0	344	4	92	1	208	2	34	0	221	2	94	1	79	1
16 Aug	0	0	84	1	52	0	406	4	127	1	220	2	38	0	362	4	115	1	109	2
17 Aug	14	0	119	1	86	1	467	5	185	1	256	2	42	0	446	5	131	1	139	2
18 Aug	68	1	126	1	133	1	630	7	244	1	327	2	98	1	536	6	160	2	221	3
19 Aug	110	1	178	2	156	1	891	9	315	2	414	3	120	1	595	7	179	2	267	4
20 Aug	131	1	216	2	408	3	1,112	12	360	2	520	4	122	1	677	7	207	2	284	4
21 Aug	366	3	306	3	493	4	1,274	13	448	3	910	7	131	1	765	8	232	2	298	4
22 Aug	509	4	358	3	599	5	1,333	14	539	3	1,059	8	160	2	814	9	251	2	398	6
23 Aug	627	5	429	4	670	5	1,458	15	647	4	1,138	9	232	3	959	11	260	2	419	6
24 Aug	667	5	602	6	769	6	1,683	18	681	4	1,370	10	299	3	1,107	12	267	3	461	7
25 Aug	892	7	688	6	826	6	1,875	20	735	4	1,554	12	346	4	1,185	13	280	3	492	7
26 Aug	935	7	753	7	1,153	9	5,527	58	775	5	1,726	13	415	5	1,304	14	297	3	523	8

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	Year 2001		Year 2002		Year 2003		Year 2004		Year 2005		Year 2006		Year 2007		Year 2008		Year 2009 [a]		Year 2010 [b]	
Date	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%
27 Aug	1,292	10	905	8	1476	11	2,749	29	789	5	2,038	15	701	8	1,380	15	357	3	546	8
28 Aug	1,593	12	1,022	10	1,859	14	3,377	35	803	5	2,318	17	1,250	14	1,466	16	626	6	561	8
29 Aug	1,934	14	1,361	13	2,180	17	3,999	42	823	5	2,639	20	1,450	16	1,486	16	894	8	578	8
30 Aug	2,144	16	1,466	14	2,452	19	4,498	47	834	5	3,907	29	1,700	19	1,519	17	1113	10	584	9
31 Aug	2,311	17	1,579	15	2,791	21	5,250	55	834	5	4,270	32	1,839	20	1,785	20	1253	12	605	9
1 Sep	2,413	18	1,612	15	3,006	23	5,832	61	850	5	4,815	36	2,121	24	2,006	22	1354	13	612	9
2 Sep	2,563	19	1,637	15	3,148	24	6,081	63	866	5	5,302	40	2,205	24	2,494	28	1424	13	619	9
3 Sep	2,651	20	1,651	16	3,243	25	6,545	68	870	5	6,028	45	2,632	29	2,583	29	1678	16	634	9
4 Sep	2,798	21	1,711	16	3,300	25	6,672	70	872	5	6,579	49	3,437	38	2,861	32	1874	18	719	11
5 Sep	2,975	22	1,786	17	3,351	25	6,722	70	873	5	7,166	54	3,670	41	3,138	35	2075	20	922	14
6 Sep	3,065	23	1,853	17	3,408	26	6,793	71	873	5	7,705	58	3,961	44	3,438	38	2317	22	943	14
7 Sep	3,112	23	2,000	19	3,482	26	6,808	71	880	5	8,365	63	4,281	48	3,738	41	2663	25	1,091	16
8 Sep	3,135	23	2,080	20	3,591	27	6,824	71	883	5	8,940	67	4,598	51	4,038	45	3436	32	1,171	17
9 Sep	3,162	23	2,221	21	4,681	36	6,828	71	907	5	9,237	69	4,819	54	4,528	50	3771	35	1,441	21
10 Sep	3,404	25	2,344	22	5,427	41	6,864	72	916	6	9,467	71	4,981	55	5,017	56	4041	38	1,471	22
11 Sep	4,313	32	2,382	22	5,770	44	6,891	72	928	6	9,632	72	5,327	59	5,328	59	4323	41	1,475	22
12 Sep	5,507	41	2,441	23	6,067	46	6,927	72	944	6	9,663	72	5,701	63	5,662	63	4,605	43	1,488	22
13 Sep	6,285	47	2,547	24	6,332	48	6,962	73	964	6	9,697	73	5,856	65	6,127	68	4,777	45	1,492	22
14 Sep	6,714	50	3,565	33	6,553	50	6,972	73	968	6	10,114	76	5,999	67	6,266	69	5,146	48	1,538	23
15 Sep	7,126	53	3,653	34	6,881	52	6,985	73	1,016	6	10,523	79	6,272	70	6,406	71	5,602	53	1,545	23
16 Sep	7,390	55	3,792	36	7,216	55	7,003	73	1,178	7	10,729	80	6,439	72	6,583	73	5,602	53	1,551	23
17 Sep	7,918	59	3,909	37	7,650	58	7,056	74	1,439	9	11,131	83	6,487	72	6,614	73	5,913	56	1,553	23
18 Sep	8,554	63	3,985	37	7,877	60	7,086	74	2,169	13	11,530	86	6,536	73	7,155	79	6,583	62	1,556	23
19 Sep	9,487	70	4,091	38	8,297	63	7,815	81	2,466	15	12,093	91	6,619	74	7,678	85	7,248	68	1,576	23
20 Sep	10,124	75	4,153	39	8,420	64	7,921	83	2,663	16	12,770	96	6,713	75	7,962	88	8,567	81	1,578	23
21 Sep	10,830	80	4,323	41	8,528	65	8,101	84	2,781	17	13,348	100	6,810	76	7,999	89	8,860	83	1,598	23

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Date	Year 2001 N	Year 2001 %	Year 2002 N	Year 2002 %	Year 2003 N	Year 2003 %	Year 2004 N	Year 2004 %	Year 2005 N	Year 2005 %	Year 2006 N	Year 2006 %	Year 2007 N	Year 2007 %	Year 2008 N	Year 2008 %	Year 2009 [a] N	Year 2009 [a] %	Year 2010 [b] N	Year 2010 [b] %
22 Sep	11,313	84	5,912	56	8,343	63	8,253	86	2,906	18			6,911	77	8,087	90	9,390	88	1,901	28
23 Sep	11,808	88	6,640	62	8,448	64	8,421	88	3,161	19			7,448	83	8,312	92	9,715	91	1,946	29
24 Sep	12,308	91	7,528	71	9,595	73	8,542	89	3,371	20			8,171	91	8,398	93	9,810	92	2,819	41
25 Sep	12,854	95	8,859	83	10,836	82	8,733	91	3,475	21			8,292	92	8,699	96	10,244	96	3,064	45
26 Sep	13,156	97	9,834	92	11,512	88	9,290	97	3,559	21			8,366	93	8,834	98	10,304	97	3,174	47
27 Sep	13,308	99	10,293	97	11,878	90	9,359	97	8,168	49			8,444	94	8,939	99	10,502	99	3,260	48
28 Sep	13,392	99	10,516	99	12,440	95	9,492	99	12,909	78			8,752	97	9,003	100	10,573	100	3,301	48
29 Sep	13,494	100	10,616	100	13,150	100	9,555	100	14,515	87			9,000	100	9,028	100	10,624	100	3,307	49
30 Sep			10,649	100			9,599	100	14,910	90			9,001	100			10,624	100	3,309	49
1 Oct									15,275	92									5,794	85
2 Oct									15,411	93									6,028	89
3 Oct									15,622	94									6,237	92
4 Oct									15,796	95									6,537	96
5 Oct																				
6 Oct																				
7 Oct																				
Season total	13,494		10,649		13,150		9,599		16,596		13,348		9,001		9,028		10,624		6,808	
Number estimated	2,911		81		932		233		1,300		3,189		749		1,280		7,376		3,574	
Lower weir in	17 Aug		12 Aug		16 Aug		30 Jul		1 Aug		31 Jul		1 Aug		30 Jul		3 Aug		29 Jul	
Lower weir out	29 Sep		30 Sep		29 Sep		30 Sep		5 Oct		21 Sep		30 Sep		29 Sep		16 Sep		29 Sep	

[a] In 2009, the lower weir was pulled 16 September; the upper lake weir was out 30 September.

[b] In 2010, the lower weir was pulled 29 September; the upper lake weir was out 7 October.

APPENDIX B: SAMPLE AGE COMPOSITION, SEX, AND MEAN LENGTH OF BUSKIN RIVER COHO SALMON INRIVER RETURN AND SPORT HARVEST, 2009

Appendix B1.–Sample age composition, sex, and mean METF length of Buskin River coho salmon sampled from the inriver run at the lower weir, 2009.

		Age class						
Sex	Parameter	1.0	1.1	2.0	2.1	3.0	3.1	Total
Females								
	Number sampled		9		36		1	51
	Percent		9.6		38.3		1.1	48.1
	SE percent		2.9		4.7		1.0	4.9
	Mean length (mm)		575		598		630	583
	SE mean length (mm)		14.4		8.7			8.8
	Minimum length (mm)		519		426		630	366
	Maximum length (mm)		626		691		630	691
Males								
	Number sampled		6	2	36		4	55
	Percent		6.4	2.1	38.3		4.3	51.9
	SE percent		2.4	1.4	4.7		2.0	4.9
	Mean length (mm)		590	319	600		669	590
	SE mean length (mm)		27.9	10.0	8.7		17.5	10.4
	Minimum length (mm)		491	309	489		636	309
	Maximum length (mm)		658	329	689		715	715
All								
	Number sampled		15	2	72		5	106
	Percent		16.0	2.1	76.6		5.3	100.0
	SE percent		3.6	1.4	4.1		2.2	0.0
	Mean length (mm)		581	319	599		661	587
	SE mean length (mm)		13.6	10.0	6.1		15.7	6.9
	Minimum length (mm)		491	309	426		630	309
	Maximum length (mm)		658	329	691		715	715

Note: The inriver run was sampled at the lower weir 12 August–7 September. Data were pooled over the two time strata (12 August–31 August and 1 September–7 September).

Appendix B2.–Age composition, sex, and mean METF length of Buskin River coho salmon sampled from the sport harvest, 2009.

		Age class						
Sex	Parameter	1.0	1.1	2.0	2.1	3.0	3.1	Total
Females								
	Number sampled		2		33		2	38
	Percent		3.2		52.4		3.2	55.9
	SE percent		2.1		6.1		2.1	6.0
	Mean length (mm)		623		629		615	629
	SE mean length (mm)		35.5		5.9		6.0	5.4
	Minimum length (mm)		587		554		609	554
	Maximum length (mm)		658		707		621	707
Males								
	Number sampled		3	1	22			30
	Percent		4.8	1.6	34.9			44.1
	SE percent		2.6	1.5	5.8			6.0
	Mean length (mm)		565	357	654			626
	SE mean length (mm)		39.9		8.3			14.9
	Minimum length (mm)		522	357	574			357
	Maximum length (mm)		645	357	728			728
All								
	Number sampled		5	1	55		2	68
	Percent		7.9	1.6	87.3		3.2	100.0
	SE percent		3.3	1.5	4.0		2.1	0.0
	Mean length (mm)		588	357	639		615	628
	SE mean length (mm)		28.3		5.1		6.0	7.2
	Minimum length (mm)		522	357	554		609	357
	Maximum length (mm)		658	357	728		621	728

Note: The sport fishery was sampled 18 September–26 September.

APPENDIX C: ESTIMATED AGE COMPOSITION OF BUSKIN RIVER COHO SALMON SUBSISTENCE AND COMMERCIAL HARVEST, 2008–2010

Appendix C1.–Estimated age composition of Buskin River coho salmon subsistence and commercial harvest, 2008–2010.

		Age class					
Year	Statistic	1.1	2.0	2.1	3.0	3.1	Total
2008[a]	Estimate	409	6	921	6	26	1,369
	SE	43	6	44	6	13	
2009[b]	Estimate	164	25	1,040	0	57	1,286
	SE	34	14	40	0	21	
2010[a]	Estimate	128	32	657	11	16	844
	SE	24	13	28	8	9	

[a] 2008 and 2010 estimated age composition based on inriver run samples.

[b] 2009 estimated age composition based on pooled sport harvest and inriver run sample.

APPENDIX D: ESTIMATED AGE COMPOSITION OF BUSKIN RIVER COHO SALMON TOTAL SPORT HARVEST, 2008–2010

Appendix D1.–Estimated age composition of Buskin River coho salmon total sport harvest 2008–2010.

		Age class					
Year	Statistic	1.1	2	2.1	3	3.1	Total
2008[a]	Estimate	1,272	20	2,866	20	81	4,259
	SE	210	16	423	16	34	
2009[b]	Estimate	663	99	4,212	0	232	5,207
	SE	148	47	643	0	76	
2010[a]	Estimate	363	54	2,302	0	127	2,846
	SE	99	27	513	0	46	

[a] 2008 and 2010 estimated age composition based on inriver run samples.

[b] 2009 estimated age composition based on pooled sport harvest and inriver run sample.