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Abundance Of Sockeye Salmon In The Alagnak River System Of Bristol Bay Alaska

by

John H. Clark

February 2005

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

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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 Department of Fish and Game	ADF&G
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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ABSTRACT

Review and analysis of available data concerning historic escapement strength of sockeye salmon in the Alagnak River system was undertaken, including: (1) documentation or development of estimates of total escapement for the time series of 1955–2004, (2) analysis of the distribution of those fish among spawning areas within the Alagnak River system, and (3) documentation of historic escapement goals for the stock. Tower counts of escapement strength are provided for the years 1955–1976 and 2002–2004. Aerial survey counts of escapement during the years of 1977–2001 are expanded into total escapement estimates by multiplying annual aerial survey counts by a constant factor of 2.55 (CV = 40%), the average expansion factor observed during nine years in which complete surveys and tower counts were made. A discussion of the bias and precision of the total escapement data set is provided. Since 1954, annual escapement strength for the Alagnak River sockeye salmon stock is estimated to have varied from a low of about 35,000 fish in 1973 to a high of about 5.4 million fish in 2004. Distribution of sockeye salmon among the major spawning sites of the Alagnak River system is documented from aerial surveys conducted in most years from 1944–2004. Recent changes in distribution are tested; distribution of sockeye salmon among spawning sites in 2003 and 2004 was found to be significantly different than historic distributions. In recent years, distribution of the sockeye salmon stock has shifted from the Nonvianuk portion of the drainage to the Kukaklek portion. Since 1962, escapement goals for the stock have ranged from point values of 53,000 fish to 577,000 fish with 185,000 fish being the point value since 1973. Little to no scientific support exists for the various escapement goals listed for this stock over the past 43 years. In prior decades, the Alagnak stock of sockeye salmon was considered a minor stock, few if any directed fishery management actions have been implemented that focused on this stock of sockeye salmon. Since 1999, escapement of sockeye salmon in the Alagnak River has exceeded 1 million fish in 4 of the 6 years with the 2004 escapement being almost 5.4 million. At the current time the Alagnak River sockeye salmon stock has to be considered as an important and major fishery resource of Bristol Bay. The Alaska Department of Fish and Game should: (1) give serious consideration to the escapement needs for Alagnak River system stock of sockeye salmon, (2) give serious consideration to implementing a fishery management regime that takes into account status of the Alagnak River stock of sockeye salmon, and (3) give serious consideration as to how best to sustain the salmon fisheries of Bristol Bay given that the Alagnak stock of sockeye salmon is currently one of the largest runs of fish in the Bristol Bay area.

Key Words: sockeye salmon, *Oncorhynchus nerka*, Alagnak River, Branch River, Bristol Bay, Kulik River, Nanuktuk Creek, Moraine Creek, Battle River, Kukaklek Lake, Nonvianuk Lake, Kulik Lake, Battle Lake, escapement, tower counts, aerial survey, expansion of aerial surveys, spawning distribution, escapement goal

INTRODUCTION

The Alagnak River system (also known as the Branch River) of Bristol Bay Alaska contains four major lakes (Figure 1). Kukaklek and Battle Lakes are drained by the Alagnak River and Nonvianuk and Kulik Lakes are drained by the Nonvianuk River. These two rivers merge to form the main Alagnak River. The system drains westward from the mountainous region bordering Kamishak Bay in Cook Inlet. The Alagnak River system lies south of the Kvichak River system and north of the Naknek River system. The Alagnak River ultimately joins the Kvichak River just downstream from the village of Levelock where the Kvichak River empties into Kvichak Bay on the northwest side of the Alaska Peninsula.

A large escapement of sockeye salmon *Oncorhynchus nerka* into the Alagnak River occurred in 2003 and again in 2004. These high escapements occurred, in part, because ocean harvests have been severely curtailed for several years to protect the co-migrating Kvichak River stock of sockeye salmon. The escapement goal currently listed by the Alaska Department of Fish and Game (ADF&G) for the Alagnak River stock of sockeye salmon is 170,000 to 200,000 fish. Over 3.6 million sockeye salmon were counted past the Alagnak River tower in 2003 and almost 5.4 million were enumerated

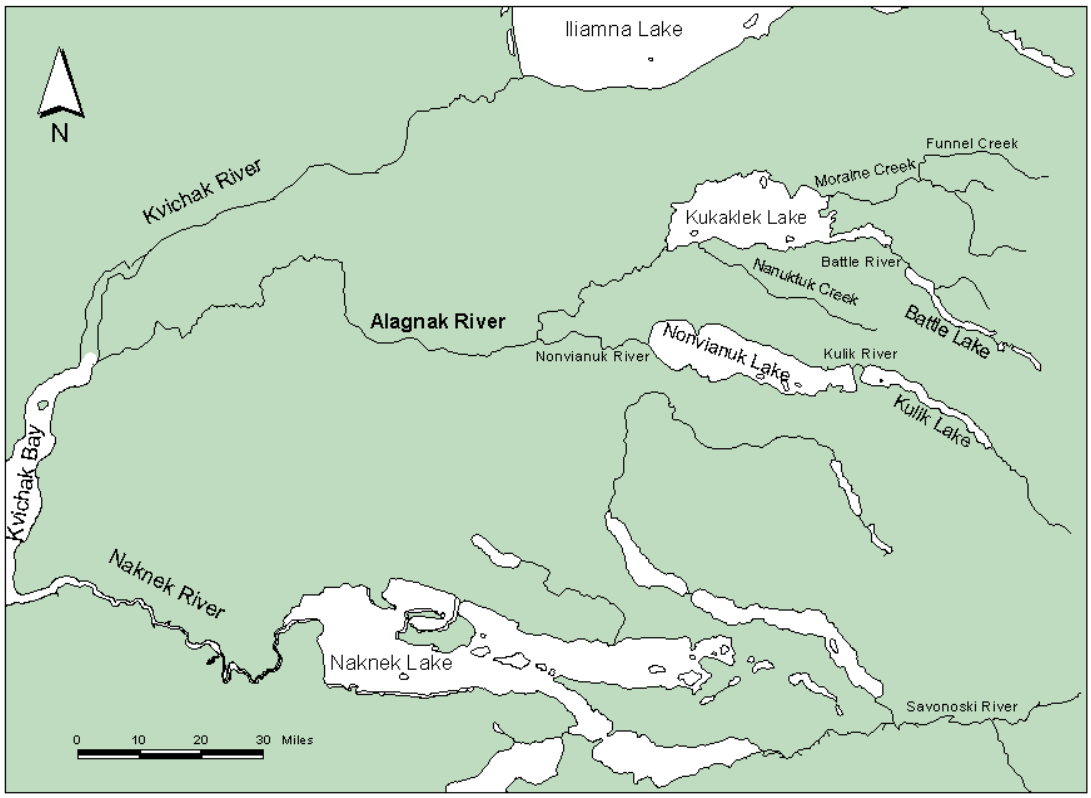

Figure 1.– Map of the Alagnak River Drainage in Bristol Bay.

past the tower in 2004. These large escapements pose important questions for the State's fisheries management program. Questions such as:

- What are the effects of large escapements on the long-term productivity of the Alagnak River stock of sockeye salmon?
- What effect will this have on future harvest opportunities for sport, commercial and subsistence fisheries that harvest this stock?
- Do these massive escapements simply represent huge foregone catches and short-term economic losses or do they offer hope for larger future production?

A critical and objective examination of the effects of the large escapements in the Alagnak River watershed in 2003 and 2004 represents a unique opportunity to learn more about the often talked about phenomenon of over-escapement. Because escapement goals used for fishery management directly affect the economic benefits from the fishery, they are often hotly debated around Alaska, and Bristol Bay is no exception. For example, a recent ADF&G recommendation to increase sockeye salmon escapement goals in some Bristol Bay rivers was met with dissatisfaction from some fishermen, processors and local communities. Many stake holders were not willing to risk their livelihoods today for a potential benefit in 5 or 10 years. This uncertainty continues to cripple efforts to explore the effects of changing escapement goals for some Bristol Bay salmon stocks. The 2003 and 2004 escapements to the Alagnak River have provided an extremely rare opportunity to advance our understanding of the effects of large increases in escapement levels of sockeye salmon and therefore, the attendant short-term and long-term benefits and detriments. The inability of commercial fishermen in Bristol Bay to harvest Alagnak River origin sockeye salmon surplus to the ADF&G escapement goal in 2004 (because of regulations promulgated to limit the catch of Kvichak River origin fish) equated to a reduction in potential harvest that would have been worth in excess of ten million dollars. An important question is whether in the long term,

salmon will increase or decrease as a result of these extraordinarily large escapements. The Office of the Governor provided $70,000 to the ADF&G in July of 2004 to address these questions. Intent of this funded work is to document the impacts of these large escapements in terms of spawning distribution, pre-spawning mortality, egg retention, changes in nutrient and zooplankton levels, mean size of rearing juveniles, and smolt age, size, and relative abundance.

As part of this funded work, an examination and analysis of available data concerning historic escapement strength of sockeye salmon in the Alagnak River system was undertaken. An effort was made to review and analyze: (1) historic documentation of overall escapement strength of sockeye salmon in the Alagnak River system, (2) historic distribution of those fish among spawning areas within the Alagnak River system, and (3) historic escapement goals for the stock. This report is a documentation of those efforts.

ESTIMATED TOTAL ESCAPEMENTS

Historic reports were located and subsequently reviewed. Much of the information was located in the Bristol Bay Annual Management Reports written by ADF&G staff each year since the early 1960s (e.g. ADF&G 1964). ADF&G has summarized aerial survey data in another series of annual reports since the late 1970s (e.g. Randall 1979a).

TOWER COUNTS OF ABUNDANCE

From 1955–1976, the escapement of sockeye salmon in the Alagnak River system was estimated through a tower counting program. This program consisted of having a three-person crew located in a field camp on the lower portion of the Alagnak River enumerate sockeye salmon as they passed upstream on a sub-sampling basis throughout the majority of the immigration. Towers were constructed along each side of the river so that crew members atop the towers could look down and see through the water to visually count fish as they passed upstream along each bank of the river. Each hour, one crew member would ascend the tower and visually count the number of sockeye salmon that swam past the tower in a ten-minute period of time along either the left or right bank of the river. That crew member would then cross the river and within the same hour make a second ten minute count on the other side of the river. The two counts were added and multiplied by six. The crew member would repeat this process each hour over an eight hour period of time. At the end of the eight hour work shift, another crew member would repeat the process and so on. In this fashion, the immigration of sockeye salmon past the tower counting site was estimated throughout the immigration period. Such expanded counts are available on a daily basis and when annually summed across the immigration period, provide an estimate of the total number of sockeye salmon that returned to spawn in the Alagnak River each year from 1955–1976 (Table 1).

For a variety of reasons these stock assessments are estimates of abundance not a census of abundance. However, variances associated with the annual escapement estimates have not been documented. Although not documented, it is believed that the estimates so derived are reasonably precise and relatively unbiased (Seibel 1967). Bias in the form of undercounting likely occurred, at times, due to environmental conditions (water clarity, light conditions, etc.) and due to fish behavior (migration in mid-channel instead of close to shore, etc.).

The tower program was discontinued from 1977–2000. In 2001, the tower counting program was again implemented. The counting site was moved upriver to a site thought more favorable for accurate counting. However, due to operational difficulties, the tower count in 2001 is suspect and the 2001 escapement strength is based upon aerial survey data (Morstad et al 2004). Details concerning how the escapement estimates were derived in 2002–2004 are the same as with the historic counts of 1955–1976. Thus, annual estimates of total escapement in the Alagnak River system for the years 2002–2004 are available; variances for these estimates have not been reported.

Table 1.– Summary of tower counts, aerial surveys counts, and estimates of total escapements of sockeye salmon in the Alagnak River system of Bristol Bay, 1955 to 2004 (references documenting tower counts and aerial surveys counts are provided in parentheses). See Tables 2–4 for details concerning derivation of total estimates of escapement for the years 1977–2001.

Year	Tower Count (Data Source)	Survey Count (Data Source)	Total Escapement Estimate
1955	172,000 (ADF&G 1962)	57,400 (Bill 1977)	172,000
1956	784,000 (ADF&G 1962)	245,000 (Bill 1977)	784,000
1957	126,595 (ADF&G 1962)	85,000 (Bill 1977)	126,595
1958	94,650 (ADF&G 1962)	None	94,650
1959	825,431 (ADF&G 1962)	198,350 (Bill 1977)	825,431
1960	1,240,530 (ADF&G 1962)	None	1,240,530
1961	90,036 (ADF&G 1962)	None	90,036
1962	90,630 (ADF&G 1962)	6,400 (Bill 1977)	90,630
1963	203,304 (ADF&G 1963)	63,125 (Bill 1977)	203,304
1964	248,700 (ADF&G 1964)	None	248,700
1965	175,020 (ADF&G 1965)	None	175,020
1966	174,336 (ADF&G 1966)	110,300 (Bill 1977)	174,020
1967	202,626 (ADF&G 1967)	128,030 (Bill 1977)	202,626
1968	193,872 (ADF&G 1969)	74,350 (Bill 1977)	193,872
1969	182,490 (ADF&G 1971a)	42,066 (Bill 1977)	182,490
1970	177,060 (ADF&G 1971b)	76,900 (Bill 1977)	177,060
1971	187,302 (ADF&G 1972)	None	187,302
1972	151,188 (ADF&G 1973)	None	151,188
1973	35,280 (ADF&G 1974)	None	35,280
1974	214,848 (ADF&G 1976a)	None	214,848
1975	100,480 (ADF&G 1976b)	36,240 (Bill 1977)	100,480
1976	81,822 (ADF&G 1979)	93,640 (Bill 1977)	81,822
1977	None	42,710 (ADF&G 1981a)	109,000
1978	None	229,400 (Randall 1979a)	584,000
1979	None	294,400 (Randall 1979b)	794,000
1980	None	297,900 (Bill 1981)	804,000
1981	None	82,210 (Bill 1983)	222,000
1982	None	239,300 (Bill 1983)	646,000
1983	None	96,220 (Bill 1984)	260,000
1984	None	215,370 (Bill et al. 1985)	581,000
1985	None	118,030 (Bill et al. 1986)	319,000
1986	None	230,180 (Russell et al. 1988a)	621,000
1987	None	154,210 (Russell et al. 1988b)	416,000
1988	None	194,630 (Russell et al. 1989)	525,000
1989	None	196,760 (Russell et al. 1990)	531,000
1990	None	168,760 (Russell et al. 1991)	456,000
1991	None	277,589 (Russell et al. 1992)	749,000
1992	None	224,643 (Russell et al. 1993)	612,000
1993	None	347,975 (Russell et al. 1994)	939,999
1994	None	242,595 (Weiland et al. 1994)	655,000
1995	None	215,713 (Brookover et al. 1996)	582,000
1996	None	306,750 (Regnart et al. 1997)	828,000
1997	None	218,115 (Browning et al. 1998)	589,000
1998	None	252,200 (Weiland et al. 1999)	681,000
1999	None	463,600 (Glick et al. 2000)	1,251,000
2000	None	451,300 (Sands et al. 2001)	1,218,000
2001	None	267,000 (Browning et al. 2002)	721,000
2002	766,962 (Weiland et al. 2003)	282,100 (Sands et al. 2003)	766,962
2003	3,676,146 (ADF&G 2004)	2,110,000 (Higgins et al. 2004)	3,676,146
2004	5,396,592 (this document)	2,356,200 (this document)	5,396,592

AERIAL SURVEYS OF ABUNDANCE

Escapement monitoring in the years 1977–2001 was conducted through an aerial survey program (Table 1). Chartered, fixed-wing, aircraft were used to fly over the Alagnak River system, and the ADF&G staff member aboard visually enumerated the sockeye salmon that were observed at various sites during the survey. ADF&G (1981a) lists only the number of sockeye salmon observed during the 1977 aerial survey; no other documentation of the 1977 survey has been located (dates, counts by spawning site, etc.). In the 24 years of 1978–2001, a single annual survey took place in 4 of the years (17%), two surveys took place in 19 of the years (79%), and three surveys took pace in one of the years (4%). The timing of presence of sockeye salmon at spawning sites in the Alagnak River is later for the rivers that interconnect lakes in the Alagnak River system (Kulik and Battle Rivers) than is the case for streams that are simply tributary to the lakes (Nanuktuk and Moraine Creeks), and that is why in most years, two or more aerial surveys were conducted.

Bill (1977) summarized aerial survey data for sockeye salmon in the Alagnak River system through 1976 and showed that maximum number (peak) of salmon counted during a survey in a year represented from about 20% to 70% of the annual tower count in the years 1966, 1968, 1969, 1970, 1975, and 1976. From this analysis, Bill (1977) suggested that it would be difficult to estimate escapement based upon results of aerial surveys. Nonetheless, the tower project was dropped in 1977, and assessment of the Alagnak River stock simply relied upon aerial survey counts of sockeye salmon. The 1977 Annual Management Report for Bristol Bay listed the escapement of sockeye salmon in the Alagnak River system as 100,000 fish while the peak survey count that year totaled 42,710 (ADF&G 1981a). Thus an expansion factor of about 2.3 was applied to the peak aerial survey in 1977.

Curiously, in each year from 1978–2001, the peak count in each year has been called total escapement. Clearly, as Bill (1977) documented, estimates of escapement based on the assumption that the observed peak aerial survey equals total escapement are seriously biased. Unfortunately, this approach of assuming peak aerial survey counts in the Alagnak River system represent the total escapement and are equivalent to tower counts of escapement has been used in all run reconstructions and all other reports by ADF&G staff when providing statistics for Bristol Bay salmon since 1978. As a result of the continued use of this assumption, the ADF&G has seriously underestimated the escapement of sockeye salmon in the Alagnak River for the years 1978–2001.

The biased data problem does not end simply with underestimation of total escapement of Alagnak River system sockeye salmon. Annual allocations of Bristol Bay sockeye salmon caught in fisheries has been and continues to be dependent upon age specific total escapement estimates. By using biased total escapement estimates, the catch allocations are likewise biased. Hence too many fish caught in the years 1978–2001 have been called Naknek origin, too many fish caught have been called Kvichak origin, and too few fish caught have been called Alagnak origin. In some years these biases would be minor relative to the Kvichak and Naknek stocks, but in other years these biases would not be minor. The bias and effect on total run estimates for the Alagnak stock would always be large when this assumption was used. This bias in turn results in biased brood tables for the Naknek, the Kvichak, and the Alagnak stocks and that bias in turn results in biased estimates of the escapement level that is expected to provide for maximum sustained yield fisheries. Further, the bias in the brood tables directly results in potential bias of forecasts of abundance. As a result, the use of this assumption over a 24 year history has undoubtedly warped a variety of information and statistics that are critically important to current day fishery management in Bristol Bay.

TOTAL ESCAPEMENT BASED UPON EXPANDED AERIAL SURVEYS

Documentation of the counts of sockeye salmon during aerial surveys of the Alagnak River system conducted from 1944–2004 is provided in Appendix 1. There are four major spawning aggregations of sockeye salmon in the Alagnak River system: (1) Kulik Lake and River in the

Nonvianuk portion of the drainage, (2) Nanuktuk Creek, (3) the Moraine Creek drainage comprised of Moraine Creek, Funnel Creek, and Spectacle Creek, and (4) Battle Lake and River. The last three are all within the Kukaklek portion of the drainage. In some of the 61 years from 1944–2004, aerial surveys of the Alagnak River system did not take place. Further, in some of the years when aerial surveys did take place, particularly early in the series, one or more of these four major spawning areas was not surveyed. However, there is a set of 33 years wherein all four major spawning sites were annually surveyed to count sockeye salmon (Table 2). This data set provides an almost continuous set of observations by spawning area for the years 1978–2004.

Available data sets were examined to develop a list of paired annual estimates of tower counts of sockeye salmon and aerial survey counts of sockeye salmon for the Alagnak River system. Sixteen years of such data are available, the earliest year being 1955 and the latest being 2004 (Table 3). These data provide a basis for expanding aerial survey counts into estimates of total escapement. Expansion factors can be calculated by dividing the estimate of total escapement (tower count) by the peak aerial survey count on an annual basis.

Annual estimates of the expansion factor calculated from the full set of data ranged from a low value of 0.97 in 1976 (more fish counted in the aerial survey than past the tower) to a high value of 14.16 in 1962 (tower count was 14-fold the aerial survey count). Using the full data set (n=16), the average expansion factor was 3.27 (CV=93%). A plot of these data is provided in Figure 2. However, included in the full data set of 16 are a number of years wherein all four major spawning sites were not included in the annual aerial survey count, hence, the expansion factor derived would not be applicable to years with observations of surveyed abundance at all four major sites.

Confinement of the data set to the years when all four major spawning sites in the Alagnak River system were surveyed resulted in a reduced data set of 9 observations (Table 3). The annual expansion factors observed for this reduced set of data ranged from a low of 0.97 in 1976 to a high of 4.34 in 1969.

The average expansion factor for this reduced set of data was 2.55 (CV=40%). The nine years of paired data was bootstrapped to evaluate potential bias in using the average value obtained for an estimate of the expansion factor for application to the 1977–2001 aerial survey data (Figure 3). The average bootstrapped expansion factor was 2.54 (90% C.I.=1.95–3.15) indicating that the computed average estimate of 2.55 has little to no statistical bias.

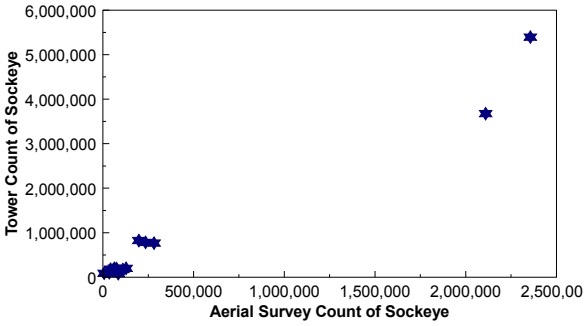

Figure 2.–Plot of aerial survey counts of sockeye salmon versus tower counts made in the same year (all data, n=16).

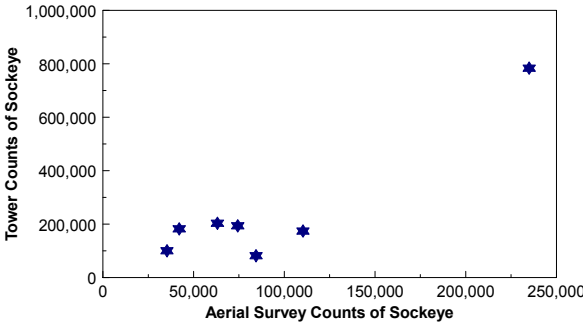

Figure 3.–Plot of aerial survey counts of sockeye salmon versus tower counts made in the same year (n=7); data reduced to years when all four major spawning sites were surveyed and when less than 500,000 total sockeye salmon were counted during aerial survey).

The reason that an expansion factor was being sought was for application to the aerial survey data collected from 1977–2001; in those years, the aerial surveys ranged from a low value of 42,710 sockeye salmon counted in 1977 to a high value of 463,600 sockeye salmon counted in 1999.

Table 2.–Aerial counts of sockeye salmon during years when all four major spawning areas of the Alagnak River system were surveyed. Counts for Kulik = sum of counts for Kulik Lake and River, counts for Battle = sum of counts for Battle Lake and River, and counts for Moraine = sum of counts for Moraine Creek, Funnel Creek, and Spectacle Creek. See Appendix 1 for further details concerning counts by site.

Year	Kulik System	Nanuktuk Creek	Battle System	Moraine System	Total Nonvianuk Drainage	Total Kukaklek Drainage	Total Alagnak Drainage
1956	55,000	15,000	140,000	35,000	55,000	190,000	245,000
1963	22,000	1,700	9,300	24,075	27,450	35,675	63,125
1966	105,700	1,400	2,000	1,200	105,700	4,600	110,300
1968	31,000	2,050	13,000	28,300	31,000	43,350	74,350
1969	13,600	3,160	6,500	18,806	13,600	28,466	42,066
1975	17,625	2,850	10,210	3,450	19,015	17,225	36,240
1976	58,000	400	27,620	5,120	60,500	33,140	93,640
1978	115,300	42,000	14,800	52,100	119,375	110,025	229,400
1979	49,800	58,000	103,600	38,800	53,200	241,000	294,200
1980	121,200	25,500	73,500	68,000	129,700	168,200	297,900
1981	51,160	4,100	18,000	8,400	51,660	30,550	82,210
1982	93,700	36,700	15,700	62,400	111,800	127,500	239,300
1983	20,950	20,600	20,800	31,150	23,020	73,200	96,220
1984	63,400	63,000	36,200	45,100	68,470	146,900	215,370
1985	50,930	9,500	30,630	20,400	56,300	61,730	118,030
1986	31,100	39,100	11,250	107,950	36,455	193,725	230,180
1987	42,440	28,100	44,650	35,500	42,910	111,300	154,210
1988	22,960	46,860	39,480	85,020	23,020	171,610	194,630
1989	76,500	36,500	25,690	56,900	77,630	119,130	196,760
1990	22,750	29,800	14,130	98,200	24,870	143,890	168,760
1991	30,265	45,410	27,970	169,744	32,765	245,824	277,589
1992	35,747	48,840	37,244	102,712	37,047	189,596	226,643
1993	36,950	73,700	38,300	198,275	37,500	310,475	347,975
1994	26,550	57,615	20,370	137,775	26,710	215,885	242,535
1995	35,300	42,488	33,100	103,425	36,350	179,363	215,713
1996	84,400	63,825	33,200	122,625	86,200	220,550	306,750
1997	47,800	27,480	17,950	121,785	49,150	168,965	218,115
1998	14,100	29,900	16,900	191,300	14,100	238,100	252,200
1999	34,000	92,000	60,500	262,000	49,100	414,500	463,600
2000	110,000	82,500	101,900	125,900	110,000	341,300	451,300
2001	85,000	55,800	46,500	79,700	85,000	182,000	267,000
2003	135,000	330,000	232,000	1,323,000	195,000	1,915,000	2,110,000
2004	327,300	699,000	690,300	1,195,000	327,300	2,584,300	2,911,600
Averages	62,652	64,087	61,009	150,276	67,179	280,517	347,664
Medians	47,800	36,700	27,970	68,000	49,150	168,965	226,643
Minimums	13,600	400	2,000	1,200	13,600	4,600	36,240
Maximums	327,300	699,000	690,300	1,323,000	327,300	2,584,300	2,911,600

Table 3.–Total escapement estimates of Alagnak River system sockeye salmon from 1977 to 2001 based upon expansion of aerial surveys.

Year	Tower Count	Aerial Survey Count	Expansion Factor	Date(s) of Aerial Surveys	Survey Coverage	Appropriate to Estimate Average
1955	172,000	57,400	3.00	8/20	Nanuktuk Not Surveyed	No
1956	784,000	235,000	3.34	8/15; 9/1; 9/15	Complete	Yes
1957	126,595	85,000	1.49	9/4	Nanuktuk & Moraine Not Surveyed	No
1959	825,431	198,350	4.16	9/5	Nanuktuk Not Surveyed	No
1962	90,630	6,400	14.16	9/5	Nanuktuk Not Surveyed	No
1963	203,304	63,125	3.22	8/12	Complete	Yes
1966	174,336	110,300	1.58	8/26	Complete	Yes
1967	202,626	128,030	1.58	8/16	Nanuktuk Not Surveyed	No
1968	193,872	74,350	2.61	8/18	Complete	Yes
1969	182,490	42,066	4.34	8/19; 9/3	Complete	Yes
1970	177,060	76,900	2.30	8/26	Nanuktuk & Moraine Not Surveyed	No
1975	100,480	35,325	2.84	8/22; 9/8	Complete	Yes
1976	81,822	84,440	0.97	8/20; 8/30	Complete	Yes
2002	766,962	282,100	2.72	8/22	Nanuktuk Not Surveyed	No
2003	3,676,146	2,110,000	1.74	8/21	Complete	Yes
2004	5,396,592	2,356,200	2.29	7/18 to 9/14	Complete	Yes
					No. of Appropriate Expansions	9
					Expansion Factor Average	2.55
					Standard Deviation	1.03
					Coefficient of Variation	40%

The aerial surveys in 2003 and 2004 were roughly 2.1 million and 2.9 million, respectively, both more than 4-fold the highest count in the years of interest. There was some concern that the 2003 and 2004 data may cause some bias, simply because the counts were so much higher and analyses of these kinds of data with other salmon stocks has demonstrated differential expansion factors as abundance increases. Therefore the data set was examined by eliminating the 2003 and 2004 data points. The average expansion factor for this reduced set of data (n =7 years) was 2.70 with a coefficient of variation of 42%, estimates not statistically different than when the 2003 and 2004 data were included. A plot of these data (n =7) is provided in Figure 4.

Based on the analyses conducted, it was concluded that use of the nine years of paired data to estimate an average expansion factor provided an unbiased estimate of the relationship between these two stock assessment methods. Application of the derived expansion factor of 2.55 to the peak aerial survey counts from 1977–2001 provides a reasonable means of estimating total escapement with available information (Table 4).

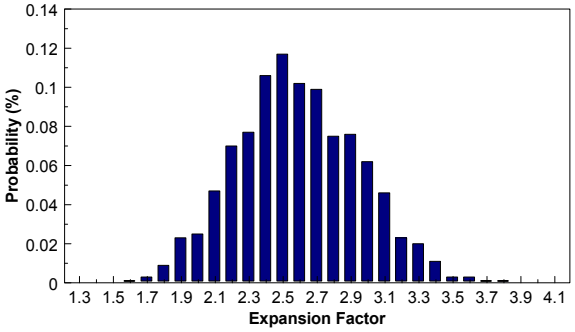

Figure 4.–Probability distribution of the expansion factor statistic derived from bootstrapping; average=2.54, 90% C.I.=1.95–3.15.

Table 4.–Total escapement estimates of Alagnak River system sockeye salmon from 1977 to 2001 based upon expansion of aerial surveys.

Year	Survey Date(s)	Survey Count	Survey Coverage	Expansion Factor Used	Total Escapement Estimate	SE of Total Estimate
1977	Undocumented	42,710	Unknown	2.55	109,000	48,000
1978	8/17 & 8/28	229,400	Complete	2.55	584,000	259,000
1979	8/3 & 8/11	294,200	Complete	2.55	794,000	332,000
1980	8/21 & 8/29	297,900	Complete	2.55	804,000	336,000
1981	8/26	82,210	Complete	2.55	222,000	93,000
1982	8/9 & 8/19	239,300	Complete	2.55	646,000	270,000
1983	8/15 & 8/24	96,220	Complete	2.55	260,000	109,000
1984	8/14 & 8/26	215,370	Complete	2.55	581,000	243,000
1985	8/17 & 8/27	118,030	Complete	2.55	319,000	133,000
1986	8/11	230,180	Complete	2.55	621,000	260,000
1987	8/22	154,210	Complete	2.55	416,000	174,000
1988	8/12 & 9/9	194,630	Complete	2.55	525,000	220,000
1989	8/15 & 8/28	196,760	Complete	2.55	531,000	222,000
1990	8/8 & 8/18	168,760	Complete	2.55	456,000	190,000
1991	8/9 & 8/19	277,589	Complete	2.55	749,000	313,000
1992	8/10 & 8/21	226,643	Complete	2.55	612,000	256,000
1993	8/9 & 8/17	347,975	Complete	2.55	939,999	393,000
1994	8/8 & 8/17	242,535	Complete	2.55	655,000	274,000
1995	8/10 & 8/18	215,713	Complete	2.55	582,000	243,000
1996	8/12 & 8/17	306,750	Complete	2.55	828,000	346,000
1997	8/7 & 8/16	218,115	Complete	2.55	589,000	246,000
1998	8/12 & 8/15	252,200	Complete	2.55	681,000	285,000
1999	8/10 & 8/13	463,600	Complete	2.55	1,251,000	523,000
2000	8/7; 8/15; 9/11	451,300	Complete	2.55	1,218,000	509,000
2001	8/29	267,000	Complete	2.55	721,000	301,000

BIAS AND PRECISION ASSOCIATED WITH TOTAL ESCAPEMENT ESTIMATES BASED UPON EXPANDED AERIAL SURVEYS

The approach of estimating total escapement of sockeye salmon in the Alagnak River system by multiplying peak aerial survey counts by an average expansion factor likely provides unbiased estimates of total escapement. Tower counts of sockeye salmon are believed to be relatively unbiased. Expansion of aerial surveys into total estimates of escapement using the methods employed herein provides a set of estimates that are equivalent, on average, with tower counts. To the extent that the set of tower counts are biased in terms of representing total escapement, the set of expanded aerial surveys are similarly biased. However, the application of the expansion factor neither adds nor subtracts bias from the time series of estimates of total escapement. As a result, Figure 5 provides a reasonable time series trend of total escapement of sockeye salmon in the Alagnak River system of Bristol Bay.

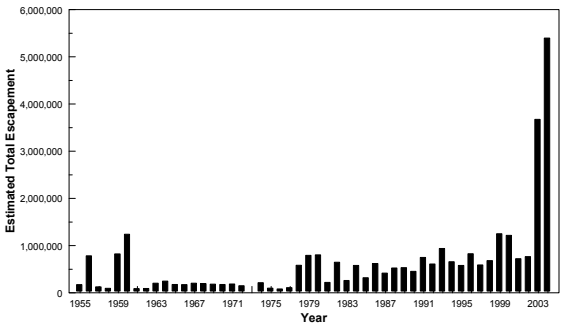

Figure 5.–Estimated total escapement of sockeye salmon in the Alagnak River system, 1955–2004.

On the other hand, escapement estimates that are derived using the methods developed herein for the years 1977–2001 are imprecise. And the level of imprecision is substantially greater than is the case for estimates of total escapement based solely on tower counts. The imprecision is primarily the result of the aerial survey data itself. As can be seen in Table 4, considerable variation is apparent in the years 1978–2001 with regard to the date that the surveys were conducted. For instance, in some years the surveys were flown in early August while in other years, the surveys were flown in late August and early September.

Likewise, inspection of Table 3 reveals that the same is true for the years used to calculate an average expansion factor; in 1963 the survey was flown on August 12th whereas in 1975, the surveys were flown on August 22nd and September 8th. Timing of the surveys alone has the potential to add a lot of imprecision into estimates of total escapement that are based upon annual aerial survey counts multiplied by an average expansion factor. Data collected during aerial surveys conducted in 2004 provide insight into this issue concerning probable measurement errors due simply to timing of surveys. Only in 2004 were more than three surveys flown in any one year; in 2004, a total of seven surveys were flown, the first on July 18th and the last on September 14th (Table 5). As can be seen in Figure 6, counts of sockeye salmon in Nanuktuk Creek varied by threefold during the month of August alone. Counts of sockeye salmon in the Moraine Creek drainage in 2004 varied almost three fold in the month of August (Figure 7). In the Kulik complex (Figure 8) the September counts varied by 3-fold. The August counts in the Battle complex (Figure 9) varied by 2-fold. These data ably demonstrate the levels of measurement error added into estimates of total escapement of Alagnak River system sockeye salmon when those estimates are based on aerial surveys with substantial variation across years in the dates of the surveys themselves.

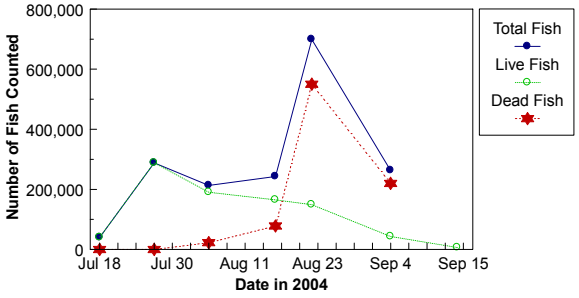

Figure 6.–Abundance of sockeye salmon in Nanuktuk Creek in 2004 based upon aerial surveys.

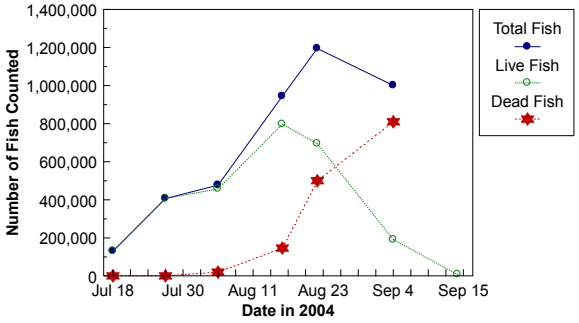

Figure 7.–Abundance of sockeye salmon in the Moraine Creek Drainage in 2004 based upon aerial surveys.

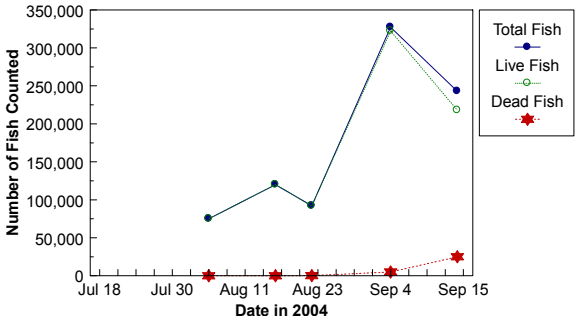

Figure 8.–Abundance of sockeye salmon in the Kulik System in 2004 based upon aerial surveys.

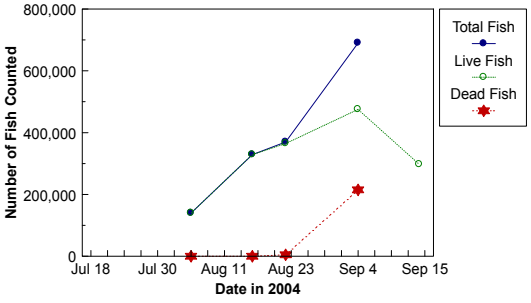

Figure 9.– Abundance of sockeye salmon in the Battle System in 2004 based upon aerial surveys.

Perhaps more on point, the 2004 aerial survey data provide a demonstration that the aerial survey data set from 1977–2001 are likely a very imprecise measurement of annual spawning abundance. The paired data provided in Table 3 ably demonstrates that the 1977–2001 data when used without adjustment as a measurement of total spawning abundance is, on average, substantially biased low. While little can be done to derive a set of precise abundance measurements for the 1977–2001 Alagnak River sockeye salmon escapements, at least the data set can be adjusted to minimize average bias and that is what the estimates listed in Table 4 provide.

DISTRIBUTION OF SOCKEYE SALMON WITHIN THE ALAGNAK RIVER SYSTEM

As noted in the Introduction of this report, a component of the study funded by the Office of the Governor in July 2004 was documentation of the spawning distributions of the large sockeye salmon escapements that occurred in the Alagnak River system in 2003 and 2004. It was felt that comparison of the distribution of these large escapements and their parental distributions to the historic distributions might provide some explanation as to why such high abundance was observed in those two years.

Multiple aerial surveys of the Alagnak River system to count sockeye salmon were flown in 2004; surveys were conducted on seven occasions in 2004, the first taking place on July 18th and the last on September 14th (Table 5). A review of historic surveys was also undertaken and information gleaned was summarized (Table 2 and Appendix 1). Aerial surveys of the four major spawning sites within the Alagnak River system took place each year from 1978–2004 with the exception that in 2001 Nanuktuk Creek was not surveyed. Visual examination of these counts when plotted revealed that abundance of sockeye salmon increased substantially in 2003 and 2004 (Figures 10, 11, 12, and 13). The distribution of sockeye salmon in the Alagnak River system was variable between years with counts in the Kulik system sometimes dominating in the early years of the data set and counts in the Moraine system often dominating in the latter portion of the data set (Figure 14).

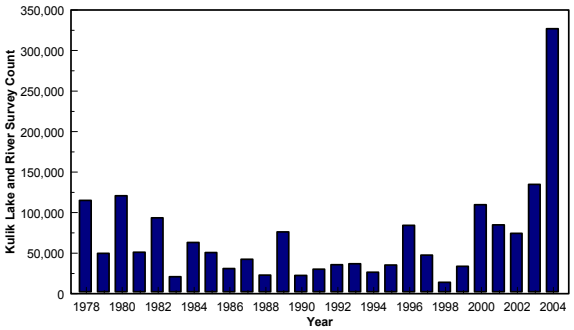

Figure 10.–Counts of sockeye salmon during aerial surveys of Kulik Lake and River, 1978–2004.

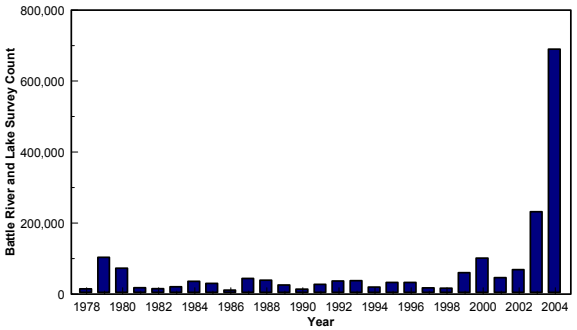

Figure 11.–Counts of sockeye salmon during aerial surveys of Battle Lake and River, 1978–2004.

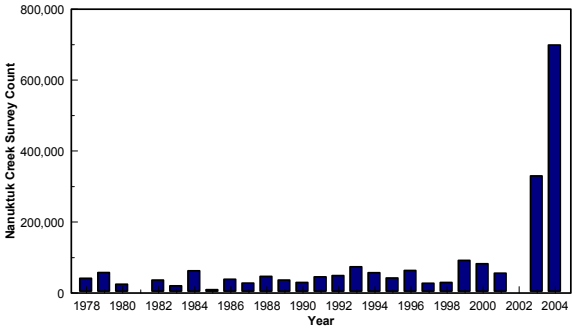

Figure 12.–Counts of sockeye salmon during aerial surveys of Nanuktuk Creek, 1978–2004.

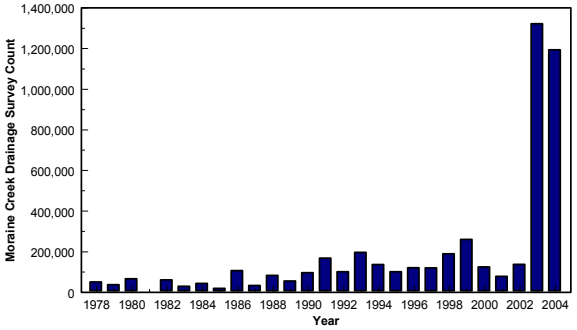

Figure 13.–Counts of sockeye salmon during aerial surveys of the Moraine Creek Drainage, 1978–2004.

Table 5.–Distribution of sockeye salmon based upon aerial surveys in the Alagnak River system, 2004.

Date	Kulik River	Kulik Lake	Nanuktuk Creek	Battle River	Battle Lake	Moraine/Spectacle Creek	Funnel Creek	Alagnak Drainage Total
7/18	No survey	No survey	Live: 40,000 Dead: 0 Sum: 40,000	Live: 0 Dead: 0 Sum: 0	No survey	Live: 120,000 Dead: 0 Sum: 120,000	Live: 10,000 Dead: 0 Sum: 10,000	Sum =170,000
7/27	No survey	No survey	Live: 288,300 Dead: 0 Sum: 288,300	No Survey	No survey	Live: 292,300 Dead: 0 Sum: 292,300	Live: 114,600 Dead: 0 Sum: 114,600	Sum = 695,200
8/5	Live: 73,000 Dead: 0 Sum: 73,000	Live: 2,000 Dead: 0 Sum: 2,000	Live: 190,500 Dead: 22,500 Sum: 213,000	Live: 100,000 Dead: 0 Sum: 100,000	Live: 40,000 Dead: 0 Sum: 40,000	Live: 312,000 Dead: 2,000 Sum: 314,000	Live: 145,200 Dead: 18,000 Sum: 163,200	Sum = 905,200
8/16	Live: 120,000 Dead: 0 Sum: 120,000	No survey	Live: 165,000 Dead: 78,000 Sum: 243,000	Live: 147,000 Dead: 0 Sum: 147,000	Live: 182,000 Dead: 0 Sum: 182,000	Live: 570,000 Dead:4,500 Sum: 574,500	Live: 227,000 Dead: 142,000 Sum: 369,000	Sum =1,635,500
8/22	Live: 92,000 Dead: 200 Sum: 92,200	No survey	Live: 149,000 Dead: 550,000 Sum: 699,000	Live: 365,000 Dead: 5,000 Sum: 370,000	No survey	Live: 640,000 Dead:200,000 Sum: 840,000	Live: 55,000 Dead: 300,000 Sum: 355,000	Sum = 2,356,200 Peak Survey
9/4	Live: 311,000 Dead: 5,000 Sum: 316,000	Live: 11,300 Dead: 0 Sum: 11,300	Live: 43,200 Dead: 220,000 Sum: 263,200	Live: 417,000 Dead: 200,000 Sum: 617,000	Live: 58,300 Dead: 15,000 Sum: 73,300	Live: 184,600 Dead:610,000 Sum: 794,600	Live: 6,000 Dead: 200,000 Sum: 206,000	Sum = 2,281,400
9/14	Live: 210,000 Dead: 25,000 Sum: 235,000	Live: 8,000 Dead: 0 Sum: 8,000	Live: 6,500 Dead: N.A. Sum: N.A.	Live: 284,500 Dead: N.A. Sum: N.A.	Live: 13,000 Dead: N.A. Sum: N.A.	Live: 7,300 Dead: N.A. Sum: N.A.	Live: 450 Dead: N.A. Sum: N.A.	Sum = 554,750
Peak Counts	9/4: 316,000	9/4: 11,300	8/22: 699,000	9/4: 617,000	9/4: 73,300	8/22: 840,000	8/22: 355,000	Sum across locations = 2,911,600

Note: Counts used as peak counts for the Battle River/Battle Lake complex and the Moraine, Spectacle, and Funnel Creek complex are the single day combined peak count; because fish can easily move within these complexes. The single day peak count for the Alagnak system of 2,356,200 on 8/22/04 is 81% of the sum (2,911,600) of the peak counts by individual spawning areas. The Alagnak River tower count in 2004 was 5,396,592 sockeye salmon; the survey expansion factor based on the single day peak count was 2.29 and based on the sum of the individual spawning area peak counts was 1.85. In many prior years there was a single aerial survey of the Alagnak River system to count sockeye salmon.

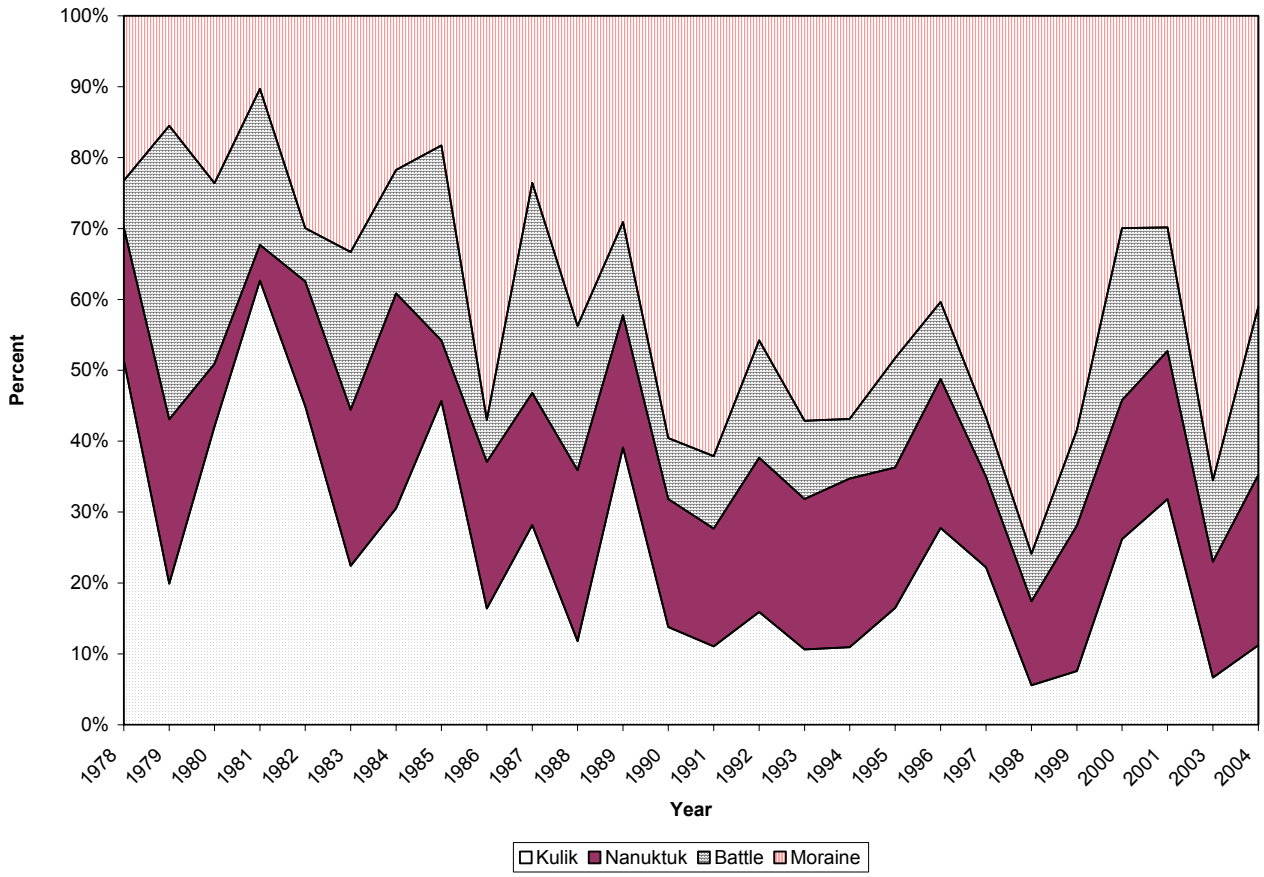

Figure 14.–Annual distribution of sockeye salmon counts in the four major spawning areas of the Alagnak River system, 1978–2004.

The annual geographic distributions of sockeye salmon within the Alagnak River system were statistically evaluated to look for differences between the 2003 and 2004 distributions versus historic distributions. Distributional differences were evaluated as a series of hypotheses tests as follows:

Hypothesis 1: Distribution in 2003 = average distribution in the years prior to 1996.

Hypothesis 2: Distribution in 2004 = average distribution in the years prior to 1996.

Hypothesis 3: Distribution in 2003, 2004 = average distribution in the years prior to 1996.

Hypothesis 4: Average distribution in the years 1997–2000 = average distribution in the years prior to 1997.

The data provided in Table 2 for the years 1978–2004 were used for the hypothesis tests.

Statistical methods that were used for the series of hypotheses tests are described in Appendix 2.

The distributions of sockeye salmon counts in 2003, in 2004 and 2003–2004 were statistically different (rejection of hypothesis 1, 2, and 3) than in earlier years (Table 6). However, the distribution of sockeye salmon counts in 1997–2000, which were the parental years for the 2003–2004 returns, was not statistically different (i.e., failed to reject hypothesis 4) than the distribution of sockeye salmon counts in earlier years (Table 6). These statistical tests demonstrate that changes in the distribution of counts made during aerial surveys of the Alagnak River system took place in 2003 and 2004. Counts increased substantially in the Kukaklek portion of the drainage.

Analysis of the data available indicate that the sockeye salmon escapement levels in 2003 and 2004 in the Nonvianuk portion of the Alagnak River Drainage were higher than normal; roughly two fold higher in 2003 and six fold higher in 2004 than the average escapements

counted in the years 1978–2002 (Figure 10). While these observed escapements were noticeably higher than historic escapements, the increase was substantially less than was the case for major spawning sites in the Kukaklek portion of the drainage. The 2003 observed sockeye salmon escapements in the Kukaklek portion of the system were 6- to 13-fold the averages observed during the years 1978–2002 and in 2004 were 12- to 18-fold the averages observed in the years 1978–2002 (Figures 11, 12, and 13). The mechanism that triggered the larger than observed escapements in the Alagnak River system in 2003 and 2004 was more pronounced in the Kukaklek portion of the drainage than was the case in the Nonvianuk portion of the drainage.

HISTORIC ALAGNAK SOCKEYE SALMON ESCAPEMENT GOALS

ADF&G annual management reports for Bristol Bay were located and subsequently reviewed to document escapement goals that were associated with historic sockeye salmon returns to the Alagnak River system. The earliest reference to an Alagnak River sockeye salmon goal that was located was for 1962 when the point goal listed was 60,000 fish and the escapement goal range listed was 250,000–750,000 fish (ADF&G 1962). A summary of the listed goals with the reference document identifying the escapement goal is provided in Table 7. As can be seen, escapement goals varied substantially from 1962–1972, with point goals varying from a level of 53,000 in 1966 to 577,000 in 1968. The point goal listed in some years was outside of the listed goal range (1962 and 1967).

Scientific analysis providing a basis for these various point goals is noticeably lacking in the ADF&G literature. A conjecture is that the basis for the point goals in the years 1962–1972 was the result of a relatively simple process. For decades, pre-season forecasts of the annual abundance of sockeye salmon runs in Bristol Bay have been developed by ADF&G staff.

From these forecasts, the anticipated harvest rate for the Kvichak River system stock of sockeye salmon is projected, given the escapement goal for that stock. The Alagnak River system stock is harvested in conjunction with the Kvichak stock.

Table 6.–Results of hypothesis tests concerning distribution of sockeye salmon counts in the Alagnak River system.

		Spawner Distribution					
Hypothesis	Years	Nanuktuk	Battle	Moraine	Kulik	Likelihood Ratio	p-value
Historic Data	1978–96	0.20	0.16	0.40	0.24		
Hypothesis 1: Distribution in 2003 = average distribution in prior years (1978–1996)	2003	0.16	0.11	0.65	0.07	48.50	<.001
Hypothesis 2: Distribution in 2004 = average distribution in prior years (1978–1996)	2004	0.24	0.24	0.41	0.11	37.86	<.001
Hypothesis 3: Distribution in 2003–2004 = average distribution in prior years (1978–1996)	2003–04	0.22	0.20	0.49	0.10	13.71	0.003
Hypothesis 4: Distribution in 1997–2000 = average distribution in prior years (1978–1996)	1997–00	0.183	0.160	0.502	0.154	4.83	0.185

Table 7.–Summary of formally listed escapement goals for sockeye salmon in the Alagnak River system of Bristol Bay, 1962 to 2004 and references documenting these goals.

Year	Point Goal	Goal Range	Reference Source
1962	60,000	250,000 to 750,000	ADF&G 1962
1963	500,000	250,000 to 750,000	ADF&G 1963
1964	500,000	250,000 to 750,000	ADF&G 1964
1965	400,000	250,000 to 750,000	ADF&G 1965
1966	53,000	50,000 to 100,000	ADF&G 1966
1967	300,000	800,000 to 1,200,000	ADF&G 1967
1968	577,000	200,000 to 800,000	ADF&G 1969
1969	160,000	120,000 to 200,000	ADF&G 1971a
1970	233,000	190,000 to 250,000	ADF&G 1971b
1971	166,000	122,000 to 212,000	ADF&G 1972
1972	200,000	150,000 to 250,000	ADF&G 1973
1973	185,000	None	ADF&G 1974
1974	185,000	None	ADF&G 1976a
1975	185,000	154,000 to 215,000	ADF&G 1976b
1976	185,000	150,000 to 220,000	ADF&G 1979
1977	185,000	150,000 to 220,000	ADF&G 1981a
1978	185,000	150,000 to 220,000	ADF&G 1981b
1979	185,000	150,000 to 220,000	ADF&G 1982a
1980	185,000	150,000 to 220,000	ADF&G 1981b
1981	185,000	170,000 to 200,000	ADF&G 1982b
1982	185,000	170,000 to 200,000	ADF&G 1983
1983	185,000	170,000 to 200,000	ADF&G 1984
1984	185,000	170,000 to 200,000	ADF&G 1985
1985	185,000	170,000 to 200,000	ADF&G 1986
1986	185,000	170,000 to 200,000	ADF&G 1987
1987	185,000	170,000 to 200,000	ADF&G 1988
1988	185,000	170,000 to 200,000	ADF&G 1989
1989	185,000	170,000 to 200,000	ADF&G 1990
1990	185,000	170,000 to 200,000	ADF&G 1991
1991	185,000	170,000 to 200,000	ADF&G 1992
1992	185,000	170,000 to 200,000	ADF&G 1993
1993	185,000	170,000 to 200,000	ADF&G 1994
1994	185,000	170,000 to 200,000	ADF&G 1995
1995	185,000	170,000 to 200,000	ADF&G 1996
1996	185,000	170,000 to 200,000	ADF&G 1997
1997	185,000	170,000 to 200,000	ADF&G 1998
1998	185,000	170,000 to 200,000	ADF&G 1999
1999	185,000	170,000 to 200,000	ADF&G 2000
2000	185,000	170,000 to 200,000	ADF&G 2001
2001	185,000	170,000 to 200,000	ADF&G 2002
2002	None	170,000 to 200,000	Weiland et al. 2003
2003	None	170,000 to 200,000	ADF&G 2004
2004	None	170,000 to 200,000	ADF&G 2004

Conjecture is that the point goals listed for the Alagnak River stock of sockeye salmon from 1962–1972 were largely the result of the annual multiplication of the forecasted escapement rate for the Kvichak to the total run forecast for the Alagnak. Some of the listed escapement goal range values listed appear to be more or less conjectures on the ADF&G staff's part as the possible production potential from the Alagnak River system, while many of the point goals appear to be more or less what the ADF&G staff felt might be achieved as escapement on an annual basis given that fishing was regulated based upon the Kvichak stock, not the Alagnak stock.

In 1973 the escapement goal listed for the Alagnak River stock was 185,000 sockeye salmon and that value was retained through 2001. The basis of 185,000 sockeye salmon as the escapement goal in 1973 can be easily verified (ADF&G 1974). The preseason forecast in 1973 for the Alagnak River stock of sockeye salmon was 222,000 fish while the forecast for the Kvichak River stock was 2,396,000 fish. The escapement goal for the Kvichak River stock in 1973 was 2,000,000 fish. The goal of 185,000 for the Alagnak River in 1973 was based upon the following simple calculation:

(2,000,000/2,396,000) × 222,000 = 185,000

Thus the basis of the 185,000 escapement goal in 1973 for the Alagnak stock of sockeye salmon was simply predicated upon the dual assumptions that the forecasts for both the Kvichak and Alagnak stocks were accurate and that ADF&G would provide precise management of the Kvichak stock and perfectly achieve the goal for that stock. The listed goal had practically nothing to do with population dynamics nor production potential of the Alagnak stock of sockeye salmon.

The point escapement goal of 185,000 fish for the Alagnak stock was not changed until 2002. In 2002, 2003, and 2004, instead of listing a specific point goal, no point goal was listed for the stock, instead an escapement goal range was listed. In 1973 when the goal of 185,000 was first listed, escapement of sockeye salmon into the Alagnak River system was monitored with a tower based assessment program. As describer earlier in this report, a few years later the assessment effort consisted of aerial surveys. In documents written over the past several years, the goal of 185,000 fish has been called an aerial survey goal, which it was not originally intended to be. When the assessment effort changed to an aerial survey program, the goal should have been adjusted to an equivalent aerial survey, or in other words an aerial survey of about 70,000 fish or a number about 40% of the old tower-based number unless intent was specifically to increase the Alagnak River escapement goal by a factor of about 2.5.

In 1975, an escapement goal range for the Alagnak stock of sockeye salmon was defined as 154,000 to 215,000 fish. The next year it was changed to a range of 150,000 to 220,000 fish, and in 1981 it was defined as 170,000 to 200,000 fish, a value listed each year thereafter through the 2004 fishing season (Table 7).

There is no scientific basis for the current Alagnak River sockeye salmon escapement goal or range (point goal = 185,000 fish & range = 170,000 to 200,000 fish). Few, if any fishery management decisions for the Bristol Bay commercial fishery have been made over the past five decades based upon stock strength of Alagnak River system sockeye salmon. A typical footnote in Bristol Bay Annual Management Reports that accompanies the listed escapement goal for the Alagnak is as follows: "*These systems cannot be managed separately from the major system in the district."* (from ADF&G 1994).

The most recent analysis of escapement goals for the Bristol Bay Area (Fair et al. 2004) recommends that ADF&G set the Alagnak River escapement goal as 100,000 fish minimum and define this goal as a Sustained Escapement Goal (SEG). The last time that an escapement level this low was achieved in the Alagnak River system was in 1976. Four times between 1955 and 1975, escapement levels less than 100,000 fish occurred (Table 1). Fair et al. (2004) justified the recommendation as follows:

"*This stock has SEG quality data and is passively managed and coincidentally harvested. Therefore a risk analysis approach was taken to alert managers to potential changes in*

productivity when the escapement estimate falls below the SEG threshold for 3 consecutive years."

While it is true that the stock has been passively managed, reality is that at current stock abundance levels, the Alagnak River sockeye runs are huge as was very much in evidence in 2003 and 2004. The 2005 forecast for Bristol Bay sockeye salmon predicts a 2005 run of 2.35 million fish to the Kvichak River, a run of 3.76 million to the Naknek River, and a run of 4.93 million for the Alagnak River. Thus, if the 2005 Bristol Bay forecast is accurate, the Alagnak River sockeye salmon run in 2005 will be the major producer of sockeye salmon that contributes to the Naknek-Kvichak fishing district of Bristol Bay.

CHALLENGES FOR THE FUTURE

ADF&G should more carefully consider escapement needs and surplus production potential for the Alagnak River system stock of sockeye salmon. ADF&G should technically evaluate the potenial for implementing a fishery management regime that takes into account status of the Alagnak stock of sockeye salmon. ADF&G should carefully consider how best to sustain the salmon fishery in the Naknek-Kvichak fishing district of Bristol Bay given that the Alagnak stock of sockeye salmon is currently one of the largest runs of fish in Bristol Bay.

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APPENDIX A

Appendix 1.–Distribution of sockeye salmon based upon aerial surveys in the Alagnak River system 1944–2004.

Year	Nonvianuk Lake & Outlet	Kulik River	Kulik Lake	Nonvianuk Drainage Total	Nanuktuk Creek	Battle River	Battle Lake	Spectacle /Moraine Creek	Funnel Creek	Kukaklek Lake & Outlet	Kukaklek Drainage Total	Alagnak Drainage Total
1944		31,000		31,000				3,500			3,500	34,500
1945		22,700		22,700		15,700		21,100			36,800	59,500
1946		36,500		36,500				18,700			18,700	55,200
1947		34,000		34,000		3,900		4,600			8,500	42,500
1948		50,000		50,000		8,600		400			9,000	59,000
1949		700		700				100			100	800
1950		15,000		15,000		3,000		1,700			4,700	19,700
1951												No data
1952												No data
1953												No data
1954		4,800		4,800		1,575		1,200			2,775	7,575
1955		10,000		10,000		42,500		3,400	1,500		47,400	57,400
1956		55,000		55,000	15,000	140,000		35,000			190,000	245,000
1957		65,000		65,000		20,000					20,000	85,000
1958												No data
1959	0	46,100	50	46,150		127,000	0	21,000	4,100	100	152,200	198,350
1960												No data
1961												No data
1962		4,100		4,100		1,700		600			2,300	6,400
1963	5,450	22,000	0	27,450	1,700	8,900	400	24,000	75	600	35,675	63,125
1964												No data
1965												No data
1966	0	105,000	700	105,700	1,400	2,000	0	1,200	0	0	4,600	110,300
1967	1,000	25,000	0	26,000	0	26,000	0	61,000	15,000	30	102,030	128,030
1968	0	31,000	0	31,000	2,050	13,000	0	25,300	3,000	0	43,350	74,350
1969		13,600		13,600	3,160	6,500	0	14,806	4,000	0	28,466	42,066
1970		73,000		73,000		3,900					3,900	76,900

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Appendix 1.– Page 2 of 3.

Year	Nonvianuk Lake & Outlet	Kulik River	Kulik Lake	Nonvianuk Drainage Total	Nanuktuk Creek	Battle River	Battle Lake	Spectacle /Moraine Creek	Funnel Creek	Kukaklek Lake & Outlet	Kukaklek Drainage Total	Alagnak Drainage Total
1971												No data
1972												No data
1973												No data
1974												No data
1975	1,390	17,600	25	19,015	2,850	10,100	110	3,000	450	715	17,225	36,240
1976	2,500	58,000	0	60,500	400	27,500	120	4,320	800	0	33,140	93,640
1977												
1978	4,075	115,100	200	119,375	42,000	14,800	0	35,100	17,000	1,125	110,025	229,400
1979	3,400	49,500	300	53,200	58,000	97,500	6,100	28,300	10,500	40,600	241,000	294,200
1980	8,500	120,000	1,200	129,700	25,500	72,000	1,500	63,000	5,000	1,200	168,200	297,900
1981	500	50,500	660	51,660	4,100	18,000	0	8,100	300	50	30,550	82,210
1982	18,100	93,300	400	111,800	36,700	15,700	0	51,400	11,000	12,700	127,500	239,300
1983	2,070	20,900	50	23,020	20,600	18,900	1,900	26,200	4,950	650	73,200	96,220
1984	5,170	63,300	100	68,470	63,000	35,200	1,000	41,600	3,500	2,600	146,900	215,370
1985	5,370	49,500	1,430	56,300	9,500	29,600	1,030	14,800	5,600	1,200	61,730	118,030
1986	5,355	30,700	400	36,455	39,100	11,150	100	75,950	32,000	35,425	193,725	230,180
1987	470	42,300	140	42,910	28,100	42,700	1,950	31,850	3,650	3,050	111,300	154,210
1988	60	22,960	0	23,020	46,860	39,480	0	80,520	4,500	250	171,610	194,630
1989	1,130	76,000	500	77,630	36,500	25,200	490	41,300	15,600	40	119,130	196,760
1990	2,120	21,650	1,100	24,870	29,800	12,950	1,180	79,100	19,100	1,760	143,890	168,760
1991	2,500	28,665	1,600	32,765	45,410	25,620	2,350	136,166	33,578	1,700	245,824	277,589
1992	1,300	33,847	1,900	37,047	48,840	35,744	1,500	69,568	33,144	800	189,596	226,643
1993	550	35,100	1,850	37,500	73,700	37,100	1,200	144,375	53,900	200	310,475	347,975
1994	160	26,500	50	26,710	57,615	20,300	70	87,480	50,295	125	215,885	242,535
1995	1,050	34,100	1,200	36,350	42,488	31,800	1,300	67,725	35,700	350	179,363	215,713
1996	1,800	82,950	1,450	86,200	63,825	31,500	1,700	97,900	24,725	900	220,550	306,750
1997	1,350	45,150	2,650	49,150	27,480	12,650	5,300	85,445	36,340	1,750	168,965	218,115

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Year	Nonvianuk Lake & Outlet	Kulik River	Kulik Lake	Nonvianuk Drainage Total	Nanuktuk Creek	Battle River	Battle Lake	Spectacle /Moraine Creek	Funnel Creek	Kukaklek Lake & Outlet	Kukaklek Drainage Total	Alagnak Drainage Total
1998	0	14,100	0	14,100	29,900	16,900	0	97,500	93,800	0	238,100	252,200
1999	15,100	32,000	2,000	49,100	92,000	49,000	11,500	152,000	110,000	0	414,500	463,600
2000	0	110,000	0	110,000	82,500	91,500	10,400	74,300	51,600	31,000	341,300	451,300
2001	0	75,000	10,000	85,000	55,800	36,500	10,000	49,700	30,000	0	182,000	267,000
2002	0	65,000	9,500	74,500	0	62,600	6,500	87,300	51,200	0	207,600	282,100
2003	60,000	70,000	65,000	195,000	330,000	112,000	120,000	735,000	588,000	30,000	1,915,000	2,110,000
2004	0	316,000	11,300	327,300	699,000	617,000	73,300	840,000	355,000	0	2,584,300	2,911,600

Appendix 2.–Statistical methods used to detect changes inthe annual distributions of sockeye salmon escapements in the Branch River.

The annual geographic distributions of sockeye salmon within the Alagnak River system were statistically evaluated to look for differences between the 2003 and 2004 distributions versus historic distributions. Distributional differences were evaluated as a series of hypotheses tests as follows:

Hypothesis 1: Distribution in 2003 = average distribution in the years prior to 1996.

Hypothesis 2: Distribution in 2004 = average distribution in the years prior to 1996.

Hypothesis 3: Distribution in 2003, 2004 = average distribution in the years prior to 1996.

Hypothesis 4: Average distribution in the years 1997–2000 = average distribution in the years prior to 1997.

The four hypotheses were tested using the likelihood ratio test (LRT) (Arnold 1990). Using hypothesis number 4 above as an example, the tests were conducted as follows:

Calculate the likelihood ratio statistic:

$$\chi^2 = 2\log\Lambda \text{ with } k\text{-1 degrees of freedom}$$

where k is the number of spawning locations.

$$\Lambda = \frac{L_{Full}}{L_{Reduced}}$$

where

$L_{Reduced}$ = is the likelihood of the reduced model under the null hypothesis, where 1997–2000 has the same distribution as the years prior to 1997.

L_{Full} = is the likelihood of the full model under the alternative hypothesis, where 1997–2000 has a different distribution from the years prior to 1997.

Let

$$L_{Reduced} = L(\mathbf{p}_o \mid \mathbf{x}, \mathbf{n}) = \prod_{j=1}^{s+t}\prod_{i=1}^{k}\left(1/\sqrt{2\pi\sigma^2}\right)\exp\left(\frac{-(x_{ij} - n_j p_{oi})}{2\sigma^2}\right),$$

where

$p_{o\,i}$ = the probability a fish is in location i under the null hypothesis (i = 1,…,k),

$x_{i\,j}$ = the number of fish counted at location i in year j (i = 1,…,k) and (j = 1,…,s + t),

n_j = the total number of fish counted in year j (j = 1,…,s + t),

and

$$L_{Full} = L(\mathbf{p}_R \mid \mathbf{x}_R, \mathbf{n}_R) \cdot L(\mathbf{p}_H \mid \mathbf{x}_H, \mathbf{n}_H)$$

where

$\mathbf{p}_R$ = the probability vector for the years 1997–2000,

$\mathbf{p}_H$ = the probability vector for the years prior to 1997,

$\mathbf{x}_R$ = the matrix of counts in each location for the years 1997–2000,

$\mathbf{x}_H$ = the matrix of counts in each location for the years prior to 1997,

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$\mathbf{n}_R$ = the vector of total counts for the years 1997–2000,
$\mathbf{n}_H$ = the vector of total counts for the years prior to 1997,

$$L(\mathbf{p}_R \mid \mathbf{x}_R, \mathbf{n}_R) = \prod_{j=1}^{s} \prod_{i=1}^{k} \left(1 \Big/ \sqrt{2\pi\sigma^2} \right) \exp\left(\frac{-(x_{Ri,j} - n_{Ri,j} p_{Ri})}{2\sigma^2} \right)$$

where

$p_{Ri,j}$= the probability a fish is in location i under the null hypothesis (i = 1,…,k) for the years 1997–2000,
$x_{Ri,j}$= the number of fish counted at location i in year j (i = 1,…,k) and (j = 1,…,s) for the years 1997–2000,
n_{Ri}= the total number of fish counted in year j (j = 1,…,s) for the years 1997–2000,

$$L(\mathbf{p}_H \mid \mathbf{x}_H, \mathbf{n}_H) = \prod_{j=1}^{t} \prod_{i=1}^{k} \left(1 \Big/ \sqrt{2\pi\sigma^2} \right) \exp\left(\frac{-(x_{Hi,j} - n_{Hi,j} p_{Hi})}{2\sigma^2} \right)$$

where

$p_{H,i}$ = the probability a fish is in location i under the null hypothesis (i = 1,…,k) for the years prior to 1997,
$x_{Hi,j}$= the number of fish counted at location i in year j (i = 1,…,k) and (j = 1,…,s) for the years prior to 1997,
$n_{Hi,j}$ = the total number of fish counted in year j (j = 1,…,s) for the years prior to 1997.

The likelihood ratio statistic was then calculated by using the maximum likelihood estimates for the probabilities ($\boldsymbol{p}$, $\boldsymbol{p}_R$, $\boldsymbol{p}_H$).