Regional Information Report No. 3A10-05

Salmon Age, Sex, and Length Catalog for the Kuskokwim Area, 2009

Final Report for Project 07-303
USFWS Office of Subsistence Management
Fisheries Resource Monitoring Program

by

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Alaska Department of Fish and Game

Division of Commercial Fisheries

Symbols and Abbreviations

The following symbols and abbreviations, and others approved for the Système International d'Unités (SI), are used without definition in the following reports by the Divisions of Sport Fish and of Commercial Fisheries: Fishery Manuscripts, Fishery Data Series Reports, Fishery Management Reports, Special Publications and the Division of Commercial Fisheries Regional Reports. All others, including deviations from definitions listed below, are noted in the text at first mention, as well as in the titles or footnotes of tables, and in figure or figure captions.

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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Sockeye salmon Appendices G and H are available at:
http://www.sf.adfg.state.ak.us/FedAidPDFs/RIR.3A.2010.05Sockeye.pdf

ABSTRACT

The Kuskokwim Area has the largest subsistence Chinook salmon fishery in Alaska, and sustains healthy stocks of sockeye, chum, and coho salmon harvested in local commercial and subsistence fisheries. To support these fisheries, numerous projects have been funded through the U.S. Fish and Wildlife Service, Office of Subsistence Management to monitor Pacific salmon *Oncorhynchus* spp. escapements and subsistence harvest in the region. These projects include the collection of samples that are used to estimate the age, sex, and length (ASL) composition of salmon escapement and subsistence and commercial harvests. *Kuskokwim Salmon Age-Sex-Length Assessment* project (FIS 07-303) provides the support required to process these ASL samples and compile the information into summary tables of use to managers, contributing project leaders, and other interested parties. The annual product of this project is *The Salmon Age-Sex-Length Catalog for the Kuskokwim Area.* This catalog is published in 2 parts, including this narrative, published on the web and in hardcopy, and a series of historical ASL summary tables (Appendices A through H), published only on the web. Both of these products can be found online at: http://www.sf.adfg.state.ak.us/FedAidPDFs/RIR.3A.2010.05Appendices.pdf

Key words: age-sex-length, ASL, Pacific salmon, *Oncorhynchus* spp., Kuskokwim River, age class composition, sex composition, length composition.

INTRODUCTION

The Kuskokwim Area as defined by the Alaska Department of Fish and Game (ADF&G), Division of Commercial Fisheries (CF) encompasses waters from Cape Newenham to the Naskonat Peninsula, including waters around Nunivak and St. Matthew Islands (Figure 1). Primary salmon producing systems include the Kuskokwim, Kanektok, and Goodnews rivers, which drain into Kuskokwim Bay and support runs of Chinook *Oncorhynchus tshawytscha*, sockeye *O. nerka*, chum *O. keta*, pink *O. gorbuscha*, and coho salmon *O. kisutch*. All 5 of these salmon species are harvested in area subsistence, commercial, and sport fisheries, as well as various interception fisheries located outside of the formal management area.

Age, sex, and length (ASL) data are collected and reported annually from subsistence and commercial harvests, escapement, run timing and abundance monitoring projects in the Kuskokwim Area. These data have been collected in the Kuskokwim Area since 1961 (Brannian et al. 2005) and have been cataloged in historical summaries since 1995 (Anderson 1995; Molyneaux and Dubois 1996; Molyneaux and Samuelson 1992). In 2001, subsistence harvest and abundance monitoring projects began as jointly funded and operated by federal, state, and local tribal groups and all collected ASL data from salmon. The United States Fish and Wildlife Service (USFWS) Office of Subsistence Management (OSM) provides assistance by funding the processing of ASL data collected in the Kuskokwim Area.

This narrative functions to provide (1) an overview of research projects that collect data summarized in the Appendices, (2) a description of the methods employed in the collection of these data, and (3) highlights selected results and trends observed in these data throughout the Kuskokwim Area. Historical summary tables are contained within Appendices A through H of this report, accessible online at:

http://www.sf.adfg.state.ak.us/FedAidPDFs/RIR.3A.2010.05Appendices.pdf

This narrative document represents an annual report for USFWS OSM project 07-303.

BACKGROUND

In 2009, a total of 31,434 ASL samples were collected from Chinook, sockeye, chum, and coho salmon captured in Kuskokwim Area subsistence and commercial harvests, and from escapement, run timing, and abundance monitoring projects. The USFWS OSM has 9 existing and proposed projects in the Kuskokwim Area, and all collect salmon ASL data. These projects include: Middle Fork Goodnews and Kanektok (07-305), Kwethluk (07-306), Tuluksak (07-307), George (08-303), Takotna (08-304), and Tatlawiksuk (07-304) river weirs; and inseason ASL collections of subsistence caught Chinook salmon (08-302) and Tuluksak River subsistence Chinook salmon ASL (08-351). Prior to the establishment of these projects, combined ASL sample sizes ranged between 10,000 and 13,000 fish per year. Starting in 2004, the USFWS OSM has provided funding assistance for processing, compiling, and analysis of these additional data through 2 consecutive 3-year grants, projects 04-086 and 07-303.

OBJECTIVES

The objective of the USFWS OSM project 07-303, *Salmon Age-Sex-Length Catalog for the Kuskokwim Area,* is to process, compile and analyze salmon scales, sex and length data collected in Kuskokwim Region fisheries and escapement projects. In 2009, this report consists of datasets from 11 escapement monitoring projects and catch sampling from the Kuskokwim River Chinook salmon subsistence fishery and commercial fisheries in 3 Kuskokwim Area districts.

METHODS

STUDY AREA

The study area for this project includes the entire Kuskokwim Area as described in the Introduction, above (5 AAC 07.100).

Run Assessment

Annual assessments of salmon spawning escapements are monitored in the Kuskokwim Area with weirs, sonar, and aerial surveys (Whitmore et al. 2008; Linderman and Bergstrom 2006). With the exception of aerial surveys, most of these projects collect ASL samples. ASL samples are collected from salmon captured in a variety of ways, including beach seines, live traps, nets, and hook and line. Ground-based projects are typically operated from mid June through mid September to encompass a majority of the Chinook, chum, sockeye, and coho salmon migrations. Ground-based projects have been established throughout the Kuskokwim River drainage (Figure 1) ranging from 216 to 835 river kilometers (rkm) from the river mouth (Table 1).

In 2009, 11 ground-based escapement monitoring projects operated within the Kuskokwim Area. Of those projects, there were 9 weirs, 1 sonar project, and 1 fish wheel tagging project. ASL data collected from these projects are summarized in the Appendices, with few exceptions. Data that are not summarized in the Appendices have been noted in this text.

Escapement Weirs

1) Takotna River weir: location 835 rkm (1995–1999, tower; 2000–present, resistance board weir) (Table 1; Figure 1). ASL data have been collected since 2000, and fish are captured using a trap attached to the weir (Elison et al. 2009b).
2) Tatlawiksuk River weir, location 568 rkm, (1998, fixed panel aluminum weir; 1999–present, resistance board weir) (Table 1; Figure 1; Elison et al. 2009a). ASL data have been collected since 1998, and fish are captured using a trap attached to the weir.

3) Kogrukluk River weir: location 710 rkm, (1969–1978, tower; 1976–1977, weir and tower; 1980–present, fixed picket weir (Table 1; Figure 1; Williams and Shelden 2010). ASL sampling of Chinook salmon began in 1972, using beach seines to capture the fish. ASL collections of sockeye and chum salmon began in 1976, and collection of coho salmon began in 1981. From 1976 to present, fish have been captured using a trap attached to the weir.
4) George River weir: location 453 rkm, (1996–1998, fixed panel aluminum weir; 1999–present, resistance board weir) (Table 1; Figure 1; Stewart et al. 2009). ASL data have been collected since 1996, and fish are captured using a trap attached to the weir.
5) Salmon River weir, location 404 rkm, (2006–present, fixed panel aluminum weir) (Table 1; Figure 1). ASL data were collected from 2006 to 2009, and fish were captured using a trap attached to the weir.
6) Tuluksak River weir: location 248 rkm, operated by the USFWS, (1991–1994, fixed panel aluminum weir; 2001–present, resistance board weir) (Table 1; Figure 1; Miller and Harper 2009b). ASL data have been collected since 2001, and fish are captured using a trap attached to the weir.
7) Kwethluk River weir, location 216 rkm, operated by the USFWS, (1992, fixed panel aluminum weir; 1996–1999, tower; 2000–present, resistance board weir) (Table 1; Figure 1; Miller and Harper 2009a). ASL data have been collected since 2000, and fish are captured using a trap attached to the weir.
8) Kanektok River weir, location 68 rkm from the Kanektok River mouth, which joins the marine waters of Kuskokwim Bay near the community of Quinhagak. 1960–1962, tower; 1984–1986 and 1988, sonar; 1996–1997, tower; 2000–present, resistance board weir (Table 1; Figure 1; Taylor and Clark 2010 a). ASL data have been collected since 2000. Fish are captured using a trap attached to the weir, as well as dip nets; specifically for targeting Chinook salmon.
9) Middle Fork Goodnews River weir, location 10 rkm from the Goodnews River mouth, which joins the marine waters of Goodnews Bay, which drains into the Kuskokwim Bay. 1981–1990, tower; 1991, fixed panel aluminum weir; 1997–present, resistance board weir (Table 1; Figure 1; Taylor and Clark 2010 b). ASL sampling began in 1985 using beach seines to capture the fish. From 1991 to present, fish have been captured using a trap attached to the weir, dip nets specifically for targeting Chinook salmon, and occasionally beach seines.

Escapement Sonar

Aniak River Sonar, location rkm 323, (1980–1995, non-configurable sonar; 1996–2003, user-configurable sonar; 2004–present, Dual-frequency Identification Sonar (DIDSON)) (Table 1; Figure 1; McEwen 2009). ASL data have been collected since 1996 for chum salmon, and fish are captured using beach seines.

Tagging Studies

Kalskag Fish wheels, location rkm 270, (2001-present, fish wheels) (Table 1; Figure 1; Schaberg et al. 2010). ASL data have been collected since 2001, and fish have been captured using fish wheels and drift gillnets. ASL data are paired data to tagged fish, and are not used to determine the composition of the run at that location.

Bethel Test Fishery

Test Fish, location rkm 106, (1984–present, drift gillnets) (Table 1; Figure 1; Bue 2005; Bue and Martz 2006; Molyneaux 1998). ASL data have been collected sporadically for Chinook, chum, sockeye, and coho salmon caught in drift gillnets.

Commercial Fisheries

The Kuskokwim Salmon Management Area is currently divided into 4 commercial fishing districts (5 AAC 07.200; Figure 1). The boundaries of these districts have changed over the years as described in annual management reports (e.g., Burkey et al. 1998; 1999; Ward et al. 2003; Whitmore et al. 2008). District 1 is located in the lower Kuskokwim River and currently extends from Kuskokwim Bay to Bogus Creek, a distance of 203 rkm. District 2 spans a distance of approximately 60 rkm starting in the middle Kuskokwim River, from near Kalskag to Chuathbaluk. District 4 is located in the marine waters of Kuskokwim Bay near the community of Quinhagak and is managed as a terminal fishery supported by the salmon production of the Kanektok River, the principle salmon-producing stream draining into that district. District 5 is located in Goodnews Bay and is managed as a terminal fishery supported by the salmon production of the Goodnews River.

Drift gillnets are currently the principal gear type used in all Kuskokwim Area commercial salmon fisheries (Whitmore et al. 2008). Set gillnets were once common in some locations during the early development of the fisheries, but this practice has largely disappeared (Whitmore et al. 2008). Prior to 1985, commercial fishermen in the Kuskokwim River were unrestricted as to the gillnet mesh size they used during the June Chinook fishery, and many used 8 or 8.5 inch (20 or 22 cm) mesh sizes. Typically, in late June and early July, chum salmon would become the focus of the commercial fishery, at which point, mesh sizes would be restricted to 6 inches (15.2 cm) or smaller.

Since 1985, all Kuskokwim Area commercial fishing districts have been restricted to gillnet mesh sizes of 6 inches (15.2 cm) or smaller (Whitmore et al. 2008). Commercial fishermen in Kuskokwim Bay districts have always been restricted to the smaller mesh sizes. Results from commercial catch sampling described in this catalog are from restricted mesh openings, unless stated otherwise. ASL samples collected from Chinook, chum, sockeye, and coho salmon from Districts 1, 4 and 5 are summarized in Appendices B, D, F, and H.

Subsistence Fisheries

The Kuskokwim Area supports one of the largest subsistence salmon fisheries in the State of Alaska. Subsistence fisheries in this area are prominent and vital elements of the culture and livelihood of many local residents (Coffing 1991[1]; Oswalt 1990). Subsistence harvest occurs

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[1] Coffing, M. *Unpublished*. Kuskokwim area subsistence salmon fishery; prepared for the Alaska Board of Fisheries, Fairbanks, Alaska, December 2, 1997. Alaska Department of Fish and Game, Division of Subsistence, Bethel.

throughout the Kuskokwim Area, but most effort and harvest occurs in the lower 203 rkm of the river, in District 1 (Figure 1). Gear types used by subsistence salmon fisherman include drift gillnets, set gillnets, fish wheels, rod and reel, seines, and spears; however, drift gillnets are consistently the most common gear type used (Coffing *Unpublished*).

Unlike the commercial fishery, there are no restrictions on mesh size for subsistence gillnets, and traditionally fishermen prefer 8.0 to 8.5-inch (20 to 22 cm) mesh sizes when targeting Chinook salmon. Chinook salmon are the only species sampled for ASL information from the subsistence harvest and as of 2004 sampling has been limited to the lower Kuskokwim River (Figure 1).

Pilot projects conducted by ADF&G to collect complete ASL data from subsistence caught Chinook salmon began in 1993, 1994, and 1995 (Molyneaux et al. *In press*), but were discontinued due to a lack of funding. In 2001, this program was re-established and expanded with funding resources provided by the USFWS OSM and cooperation from ADF&G CF and various Tribal organizations (Molyneaux et al. *In press*). Between 2001 and 2003, 3 projects were funded by OSM: FIS 01-023 (Upper River), FIS 01-225 (Middle River), and FIS 01-132 (Lower River). In 2004 the upper and middle river projects were discontinued, leaving only the lower Kuskokwim River subsistence sampling project, which has continued through to the present. In 2008 and 2009, the USFWS initiated a project to collect ASL samples from subsistence caught Chinook salmon on the Tuluksak River, and those data were included in our subsistence ASL totals. Appendix B contains summaries for subsistence Chinook salmon samples collected from 1993 through 1995, but more complete ASL summaries for data collected since 2001.

Sport Fisheries

The numbers of guided sport fishing operations have remained stable in the Kuskokwim Area over recent years, and most effort is focused on the Kanektok, Goodnews, Kisaralik, and Aniak rivers. There is an increasing interest in upper Kuskokwim River tributaries such as the Holitna, George, Oskawalik, and Holokuk rivers, but because of their remote location and increasing fuel costs, guided operations are still minimal (Chythlook 2009). At this time, there are no ADF&G directed, ASL sampling projects for sport caught salmon in the Kuskokwim Area. Collection of ASL information from sport harvest is limited and not reported in the Appendices.

Sampling Strategies

In the Kuskokwim Area, the basic sampling design for ASL is a stratified random sample using 1 of 3 collection methods. The preferred method of sample collection attempts to distribute sampling effort evenly across the salmon run in discreet events with sample sizes sufficient to determine ASL composition in 3 or more snap shots. This method, termed *pulse sampling*, is employed for species and at locations that provide relatively consistent sampling opportunity (e.g. chum and coho salmon at escapement projects). Pulse sampling has proven to be impractical for several Chinook salmon escapements because of issues of relative abundance; consequently, a *daily sampling* method is used. Commercial and subsistence fisheries tend to provide fewer and less consistent opportunities for sample collection. Samples are collected from these fisheries on an opportunistic basis using a *grab sampling* method (Geiger and Wilbur 1990).

Pulse Sampling

The pulse sampling method is essentially a stratified random sampling technique, in which ASL samples are collected periodically over the duration of the migration to account for temporal changes in ASL composition. Ideally, a series of temporally well-distributed pulse samples are collected from each species as the population passes through an access point, such as a weir or test fishery, over time. These samples are used to characterize each escapement or catch.

Each population is sampled a minimum of 3 times during a season, representing the early, middle, and late portions of the run. However, variability exists in salmon run timing between years. Therefore, samples are usually collected in more than 3 pulses within a season to ensure sampling of each portion of the run. The collection of additional pulse samples also improves accuracy and resolution for detecting temporal changes in the ASL composition of the escapement or catch. Well spaced pulse samples have greater power for detecting temporal changes in the ASL composition over other methods, such as random sampling, systematic sampling, or closely spaced grab sampling (Geiger and Wilbur 1990).

The sample size of each pulse is determined following conventions described by Bromaghin (1993). To achieve 95% confidence intervals for an age-sex composition, no wider then ±10% (α=0.05 and d=0.10), we assume 10 age-sex categories for Chinook salmon (n=190), 10 age-sex categories for sockeye salmon (n=190), 8 age-sex categories for chum salmon (n=180), and 6 age-sex categories for coho salmon (n=168). To account for unreadable scales and collection errors we increased sample sizes by 20%, providing a minimum sample goal for each species: 230 Chinook, 230 sockeye, 220 chum, and 200 coho salmon. The need for achieving these sample goals are weighed against the need for collecting each pulse sample over a relatively brief period of time. Consequently, the sample goals serve as guidelines rather than rigid requirements. Sample sizes are usually adequate to meet goals for precision.

Daily Sampling

The daily sampling method is a stratified random sample, in which ASL samples are collected in small numbers on a near daily basis throughout the duration of the migration. Samples are temporally well distributed and sufficient to describe the ASL composition of the annual migration to the desired confidence (95% CI no greater than ±10%). Samples are stratified postseason similar to pulse sampling to account for variations in age-sex structure over time. Sample sizes are generally too small to provide the desired confidence on the stratum level.

Daily sampling is the preferred method for sampling Chinook salmon at escapement projects because of their small run sizes relative to other salmon species. Appropriate sample sizes are determined by following conventions described by Bromaghin (1993) detailed above under Pulse Sampling. Sample sizes vary slightly between projects based on relative abundance of salmon and feasibility of sample collection. At projects where larger samples are realistic, sample sizes are increased to allow the possibility of greater confidence within strata (e.g. Kogrukluk River). At projects with relatively small Chinook salmon populations, the finite population correction is used to determine sample size (e.g. Takotna River, Elison et al. 2009b). Sample sizes for Chinook salmon at each of the Kuskokwim River escapement projects are as follows: Takotna River weir, 169, Tatlawiksuk River weir, 228, Kogrukluk River weir, 499, and George River weir, 348 fish.

Grab Sampling

The grab sample method is essentially a random sampling technique in which ASL samples are collected opportunistically over the duration of the migration to account for temporal changes in ASL composition. The grab sampling method (Geiger and Wilbur 1990) is employed at locations and projects where there is no guarantee that each salmon in the harvest has an equal chance of selection (random sample) or that every i^{th} fish can be sampled (systematic sample). The grab sampling method is used to collect information from Kuskokwim Area commercial salmon and from Kuskokwim River subsistence Chinook salmon harvests where sampling opportunity is often inconsistent.

ASL samples from commercially caught Chinook, chum, sockeye, and coho salmon in the Kuskokwim Area are collected by ADF&G staff. Sampling goals for commercial fisheries are similar to those for escapement projects and follow conventions described by Bromaghin (1993). The sample size goals for each sample by species are: 230 Chinook, 230 sockeye, 220 chum and 200 coho salmon. As with pulse sampling, an effort is made to collect 1 grab sample from each third of the run for each salmon species. Due to the often inconsistent nature of commercial fishing schedules, these grab samples may not be well distributed across the run.

ASL samples from subsistence harvested Chinook salmon in the Kuskokwim Area are most often collected by individuals recruited from various local communities to sample their subsistence catch through time. It is assumed that sampling effort is proportional to subsistence salmon harvest and representative of the overall subsistence harvest. Due to the often inconsistent nature of subsistence fishing schedules, these grab samples may not be well distributed across the run.

Age, Sex, and Length Sampling Procedures

Sampling routine includes the removal of scales from the preferred area of the fish for use in age determination (INPFC 1963). Generally 1 scale is taken from each sockeye and chum salmon, while 3 scales are taken from Chinook and coho salmon to account for regeneration, which interferes with determining freshwater age. At some escapement projects, where scale absorption can be problematic for determining saltwater age, multiple scales are taken from sockeye and chum salmon. All scales are mounted on gum cards. Sex is determined from live salmon (i.e. escapement and run timing projects), by visually examining external morphological features such as development of the kype, roundness of the belly, presence or absence of an ovipositor, and overall size. When sampling dead salmon (i.e. commercial and subsistence harvests), the preferred method for determining sex, is to make a small incision into the abdominal cavity of each fish, to visually inspect for ovaries or testes. Length is measured to the nearest millimeter from mideye to the fork of the tail (MEF). Data are recorded in field notebooks or tally sheets, on computer mark–sense forms, or logged electronically using a hand held data logger. The original scale cards, acetate impressions (see below), and data forms are archived at the ADF&G office in Anchorage.

Please refer to annual project reports for more detailed information on the specific sampling methods and procedures of each Kuskokwim Area project.

Processing and Reporting

Strata Determination

Viewed from a fixed location, such as an escapement-monitoring project or a fishing district, the ASL composition of an upstream-migrating salmon population may change over the course of the season; i.e. differences in migration timing exist within and between Kuskokwim River salmon stocks (Pawluk et al. 2006; Stuby 2007). Quinn (2005) describes an often observed pattern of older or larger fish preceding smaller fish within the migration of particular stocks and across larger mixed stock migrations. Each year, salmon are sampled at fixed locations to estimate ASL compositions of the respective escapement or catch.

The term "stratum" is used here to describe an interval of time during which fish pass a given point such as a weir or sonar project, or are harvested from a given location such as a commercial fishing district. The salmon run is stratified preseason to provide a systematic sampling schedule, and again postseason based on the number and temporal distribution of ASL samples compared with the volume of observed fish passage. Collectively, the strata set for a given species encompasses the entire annual passage or harvest at a given location.

The ASL composition of a stratum is estimated from fish that are sampled at some time within that stratum. The samples may have been taken evenly throughout the stratum, from the midpoint, or weighted towards one end of the time interval. In practice, the sample distribution is driven by fish abundance and the availability of resources to sample the fish. For example, early in the migration, the relative abundance of a given species is low. Although small numbers of fish may be noted daily, densities may be too low to feasibly collect a pulse sample. Therefore, the first stratum of the season may span 10 to 20 days with the representative samples collected only in the last few days of the stratum. For clarity, Appendices A through H list both the sample dates and the stratum dates.

Postseason partitioning allows the distribution of samples to be viewed in context with the overall distribution of the population. Sample sizes often fall short of weekly pulse sampling goals. Thus strata partitioning is subjective in order to allow adequate numbers of samples to be applied to each third of the run.

A well distributed sample of Chinook salmon provided through daily sampling is treated as a single sample or stratum for statistical analysis. However, post season stratification is applied to account for variability in sampling success. Presenting data in this manner also allows researchers to make reasonable comparisons with data from previous years.

In past years, the seasonal ASL composition of harvest or escapement populations was estimated only when the distribution of samples would allow a minimum of 1 stratum for each third of the annual harvest or passage. This "rule of thirds" helped account for seasonal dynamics in the ASL composition of most species. When sample sizes and distribution did not meet the above criteria, sample results were recorded, but no season estimates were presented in the catalog. Due to the smaller run size of Chinook salmon at some Kuskokwim Area escapement projects, technicians were seldom able to collect enough samples to accurately characterize the run based upon the "rule of thirds." Sample collection design and sampling expectations were adjusted to account for these limitations while meeting the objective of providing an estimate of ASL composition.

Age Determination

Age is determined by examining the annuli of scales taken from the preferred area of the fish (INPFC 1963). The scales, which are mounted on gum cards, are impressed in a cellulose acetate using methods described by Clutter and Whitesel (1956). The scale impressions are magnified with a microfiche reader and age is determined through visual identification of annuli. Each salmon species spends varying amounts of time in fresh and salt water before returning to their natal streams to spawn. For example, one sockeye salmon from the Goodnews River might spend 2 years in fresh water before going to sea, and then spend an additional 2 years in salt water before returning to freshwater to spawn; while another fish from the same river might spend 3 and 2 years in each environment respectively. These variations in life history strategies are referred to as “age classes.”

Since 1985, all salmon ages from the Kuskokwim Area have been recorded using European notation. European notation is a 2 digit numbering system referring to the number of freshwater and marine annuli. The first digit represents the freshwater age minus one. The second digit represents the number of annuli formed during marine residency. Total age from brood year is the sum of the 2 ages plus 1. Prior to 1985 Gilbert-Rich notation[2] was commonly used, but in this report and its associated appendices, all ages are reported using European notation, including those determined prior to 1985. Ages are reported on data forms or directly entered into computer ASCII files.

Length information is helpful in determining the age of absorbed or otherwise questionable scales, especially for Chinook salmon which exhibit pronounced length partitioning by age class. When the age of a fish is in question, the technician or biologist reading the scale(s) may use a length range to help decide the proper age of the fish. Length ranges are determined by taking the mean of all fish sampled within that age-class for that specific project, and then selecting a length range of 2 standard deviations above and below the mean. This creates a length range that is 95% accurate for that age-class. If the age of a scale and its corresponding length, fall within the appropriate length range for that age-class, the ager can be confident that they are assigning ages correctly. If the age of the scale and the corresponding length do not fall within the appropriate length range, both are rechecked for correctness.

Data Processing and Summary

ASL data is typically digitized from hand recorded forms or electronic recorders. Most commonly, data is recorded on computer mark-sense forms, which are processed into ASCII files using an optical scanner. Other methods for data recording in the field include portable hand held data recorders (first used in 1998). The data recorder produces an ASCII file that must be parsed to produce a comparable format. The resulting data file is then processed using 1 or more custom programs, depending on the origin of the data. Two types of summary tables are generated: one focusing on age and sex composition of the sample, the other on length statistics by age and sex. The resulting age compositions are applied to the corresponding escapement or catch data to provide an estimate of the total age, sex, and length composition of those populations. Each summary table lists the year, sample dates, the stratum dates, and the number of fish sampled in each stratum. Sample dates are footnoted with pertinent information about the

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[1] In Gilbert-Rich notation 2 digits are listed without a decimal. The first digit represents the total years of life at maturity and the second number, which is usually subscripted, denotes years of fresh water residence, after emerging from the gravel.

data. Fish that are un-aged due to some type of error are not included in ASL summaries. Summary tables are compiled and cataloged in Appendices A through H.

Age-Sex Summaries

Age-sex reports describe the age and sex composition for each temporal stratum as a percentage based on the aged stratum sample. These percentages are used to estimate the number of fish in each age-sex category for the escapement or catch that occurred during the stratum. Season estimates are weighted by the abundance of fish passage or harvest in each temporal stratum. The escapement or harvest numbers listed in the season summaries are the sum of the stratum estimates. The sums are used to calculate the season percentages. Grand total escapement or harvest estimates are the sum of all annual season estimates. The grand total sums are used to derive the grand total percentages.

Length Summaries

Length summaries examine fish length by age-class and sex. Sample dates and stratum dates are identical to the age-sex reports, but sample sizes may differ slightly. The length reports include mean length, standard error, and the range of lengths in each age-sex category. The mean length reported for the season is weighted by fish abundance in each stratum. The weighting is derived by multiplying the mean length of each stratum by the estimated catch or escapement for that stratum. These numbers are summed for all strata in the season then divided by the total estimated catch or escapement for the season. The resulting number is the estimated season mean length for each age-sex category. In Appendices A through H, the mean length reported in the grand total is an average of the annual season mean lengths.

Age, Sex, and Length Database

Historical data from ASL sampling now resides in a database within the AYK salmon database management system (AYK DBMS) (Brannian et al. 2004, 2005). Data are stored as individual fish. At this time, requests for data must be filled by Information Technology (IT) staff. Currently, data retrieval provides only raw data, but IT employees are continuing to develop and improve a web based application that allows the general public to extract ASL data. The AYK DBMS may be accessed using the following link:

http://sf.adfg.state.ak.us/CommFishR3/WebSite/AYKDBMSWebsite/Default.aspx

RESULTS

Tables included in the 2009 Appendices are organized into 4 major sections based on species: Chinook (Appendices A, B), chum (Appendices C, D), coho (Appendices E, F), and sockeye salmon (Appendices G, H):

http://www.sf.adfg.state.ak.us/FedAidPDFs/RIR.3A.2010.05Appendices.pdf

Within each species section, subsections are broken down into project type, (i.e. escapement or harvest). Subsections are then organized by project location, starting with the farthest interior and progressing towards the coast (river mouth), and south along Kuskokwim Bay. Some escapement, test-fish, and subsistence samples are also arranged by gear type such as 8.0-inch drift gillnets or 6.0-inch set gillnets. For each combination of species, project type, and project location, the historical age composition table precedes the historical length table.

Tables presented in Appendices A through H are not exhaustive of all data collected from the Kuskokwim Area. For example, data sets are not included from the South Fork Salmon River (Pitka Fork drainage) where a weir was operated in 1981 and 1982 (Schneiderhan 1982a and 1982b).[3] Some of the data summaries reported in the Appendices are incomplete. Others may periodically be refreshed through new analysis of historical data. Updates to historical tables are done as time and resources allow. Sources for some of the available information include the *Catch and Escapement Statistics Report Series*, annual management reports and annual project reports. Partial summaries of sport caught fish and carcass samples can be found in Marino (1989), Lisac and MacDonald (1995), Dunaway (1997), and MacDonald (1997). These documents are generally limited to individual years and the methods used to expand the ASL information to escapement and catches generally differ from the methods used in this *ASL Progress Report*.

Users of the historical *Catch and Escapement Report Series* (e.g. Andersen 1995; Huttunen 1989) should be cautioned that the season summaries listed in those reports are weighted by the number of fish sampled rather than the escapement or catch in each stratum as is currently done. The latter method, currently in use, is considered an improvement because it may better account for seasonal changes in ASL compositions relative to sampling effort and fish abundance.

DISCUSSION

This section is intended to provide examples of data concerns and common patterns found in salmon age, sex, and length data collected in the Kuskokwim Area. Project leaders are encouraged to use the examples described herein as the basis for expanding ASL discussions in annual reports specific to their projects.

SOURCES OF BIAS

Sampling Design

Salmon populations often demonstrate distinctive and dynamic trends in ASL composition over the course of a single season. It is vital that sampling designs recognize and account for both temporal and spatial variability (Quinn 2005). Sampling effort should be temporally distributed across the migration and results weighted in a manner that accounts for fish abundance.

Resources or sampling conditions sometimes prevent adequate sampling effort. Therefore, the available data should not be used to characterize the entire population unless samples are well distributed and proportional to passage. Some incomplete data sets may not be representative of the overall population, but have been retained within the ASL Catalog in the interest of providing a complete record of all ASL data collected within the Kuskokwim Area. Retaining these data may provide perspectives by which sampling and data analysis procedures may be improved. Incomplete datasets are clearly marked to prevent confusion.

Sampling design has changed historically within the Kuskokwim Area in effort to better capture temporal variability among salmon populations. As these changes occur, data from past years are often reanalyzed through post season stratification, and results sometimes differ between annual reports. Footnotes are used for each data set to indicate where the data came from, how it was collected, and how it is being used.

[3] In the literature the South Fork Salmon River weir is misleadingly referred to as the "Salmon River weir"; in actuality the weir was located on the south fork of the Salmon River.

Carcass Sampling

The use of carcasses for estimating the ASL composition of spawning escapements can be misleading. For example, male Chinook salmon tend to drift downstream after spawning while females tend to remain near their nests, or redds (Kissner and Hubartt 1986). As a result, estimates of ASL composition based on Chinook carcasses collected at weirs tend to be biased towards males (McPherson et al. 1997). Data collected at the Middle Fork Goodnews River weir in 1996 and George River weir in 1997 support this conclusion (Figure 2).

Therefore, it would be reasonable to assume that estimates based on stream bank carcass surveys are biased towards female Chinook salmon. However, Evenson (1991) and Skaugstad (1990) found that when rigorous sampling designs are employed, as in their stream bank surveys of the Chena and Salcha Rivers (Yukon River drainage), the above sex bias did not appear. Either way, collection and interpretation of ASL sample data from Chinook salmon carcasses should be done with caution.

For salmon species other than Chinook, the differential arrival time to spawning grounds that occur between sex and age groups is a potential source of bias in carcass sampling. Temporal dynamics in age composition can be pronounced in sockeye and chum salmon (Quinn 2005). Likewise, changes in sex composition can be pronounced in chum and coho salmon. In general, carcass sampling is not recommended as a means of estimating the ASL composition of escapement populations unless sampling designs can account for the inherent dynamics of populations.

Scale Reader Consistency

There has been concern in recent years about the consistency and accuracy of reading and assigning an age for Chinook salmon scales within the AYK region. Recent studies, anecdotal information, and indigenous knowledge suggest that the proportion of older and larger Chinook salmon may have declined in recent decades in Yukon and Kuskokwim River Chinook salmon populations. Since ADF&G began reading Chinook salmon scales in the 1960s many different readers have interpreted scale growth patterns and assigned ages. Inconsistent age estimation may have led to artificial changes in age composition over time.

DuBois and Liller (2010) conducted a study to investigate whether ADF&G has consistently aged Yukon River Chinook salmon from scales over a 43-year period (1964–2006). Scales from over 7,000 fish were aged by 3 independent readers and compared to ADF&G's ages. In general, the differences in the age estimates between ADF&G and the independent readers were small and likely not biologically significant. However, this study did identify a considerable difference between ADF&G and the independent readers with respect to freshwater age-2 fish and to a lesser extent saltwater age-5 fish. The conclusion of this study was that Yukon River Chinook salmon have been aged consistently (Larry Dubois and Liller 2010). Yukon and Kuskokwim River collaborate closely in reading scales and data processing, and it is reasonable to conclude that Kuskokwim Area Chinook have also been aged consistently.

Scale Absorption

The phenomenon of scale absorption can make reading escapement samples unreliable. The margin of a salmon scale is absorbed by the fish as an energy reserve during the last few weeks of life (Clutter and Whitesel 1956). Absorption is most prominent along the lateral edges of a scale. When viewed to determine age, there may be little or no remnant of the outer annulus on an absorbed scale. The general convention when estimating the age of a salmon from scales is to only use observable annuli, but on occasion, when there is reason to believe a full annulus has been absorbed, the technician or biologist may add an additional year for the missing annulus. Length information can be used to help determine age where reabsorbed scales are apparent, particularly with Chinook salmon.

Scale absorption in Kuskokwim Area salmon is most problematic in fish sampled from the Kogrukluk River, particularly sockeye salmon. The Kogrukluk River is farther interior than most other project where ASL data are collected, and scale absorption generally appears more advanced than elsewhere in the area. Consequently the uncertainty of age estimates is heightened.

A study by Clutter and Whitesel (1956), focusing on British Columbia sockeye salmon, reported that the degree of scale absorption varied between individuals and was most pronounced in males. This also appears to be true of Kogrukluk River sockeye salmon. The degree of scale absorption observed in Kogrukluk River sockeye salmon contributed to a decision in 1995 to discontinue ASL sampling of sockeye salmon at the weir; however, in 2008 ASL sampling was re-introduced to look specifically at fresh water growth. Scale absorption is more moderate elsewhere in the Kuskokwim Area and the confidence of age determination is correspondingly greater.

Length Measurements

Kuskokwim Area ASL sampling protocol requires samplers to record salmon lengths from MEF to the nearest millimeter. This level of precision helps in determining the age of the fish and increases the precision of our season summaries. Historically many types of measuring equipment have been used to collect salmon length data at Kuskokwim Area projects. Commonly used measuring tools include: calipers, meter sticks, clothe measuring tapes, and fish cradles. Each of these measuring tools has its own inherent variability. Straight measuring tools i.e. calipers, meter sticks, and fish cradles provide a rigid length measurement that does not take into account the natural body curvature of a salmon. Straight measuring tools, with the exception of meter sticks, have jaws, sliding rulers, or pointers that can be adjusted to more accurately locate the MEF. Straight measuring tools are at a disadvantage when measuring distorted salmon body shapes (i.e. frozen fish from a processor or tender) because they are not able to bend with the shape of the fish. Flexible measuring devices i.e. clothe measuring tapes can take straight or flexible measurements. If a clothe tape is pulled tight it will take a straight measurement; if kept loose, it will take into account the natural body curvature of a salmon. Clothe tapes can provide better measurements of distorted salmon body shapes. It is important to understand the variability and accuracy between each of these measuring tools, as there are likely to be discrepancies between data sets using different measuring equipment. The types of measuring tools used are not always footnoted.

PATTERNS AND ANALYSIS

Chinook Salmon

Age Composition

Most Chinook salmon return to the Kuskokwim Area in 3 dominate age classes: 1.2, 1.3, or 1.4, and percent compositions of these 3 age-classes vary between escapement projects, commercial and subsistence fisheries. Currently, there are no restrictions on mesh size for subsistence fisherman in the Kuskokwim Area, and subsistence fishermen prefer ≥8-inch mesh sizes to target larger Chinook salmon; however, a variety of mesh sizes are used (Table 3). Age composition of the subsistence fishery using unrestricted mesh gear from 2001 to 2009 was: 8% age-1.2, 40% age-1.3, and 49% age-1.4 (Figure 3). Age composition of Chinook salmon harvested indirectly during the restricted mesh commercial fishery (2001 to 2009) was: 44% age-1.2, 33% age-1.3, and 22% age-1.4, (Figure 4). To best approximate the age composition of returning Chinook salmon to the Kuskokwim Area, both commercial and subsistence ASL data should be combined.

In contrast to the sampling of commercial and subsistence harvests, the methods for sampling Chinook salmon at ground-based escapement projects are believed to provide a random and representative sample of stocks reaching Kuskokwim Area spawning grounds. Methods for capturing fish at escapement projects are not size selective; however, the escapement represents a population that has already undergone selection through the subsistence and commercial fisheries. Therefore, escapement ASL samples may be bias, providing an incorrect representation of overall salmon populations. Escapement samples should be viewed together with samples from the subsistence and commercial fisheries to best approximate the age composition of overall Kuskokwim River salmon runs.

Not all Chinook salmon from a particular spawning year will return in the same season. By observing a relatively high or low abundance of a particular age class within a particular year's migration, it is possible to make limited predictions about the age composition of subsequent returns. For example, a high abundance of age 1.2 (4 year old) Chinook salmon in a given year may indicate a similarly strong return of age 1.3 (5 year old) Chinook the following year (Figure 5).

A review of trends in salmon size throughout the North Pacific by Bigler et al. (1996) reported that the mean age at return for Chinook salmon in the Kuskokwim River decreased significantly ($P < 0.01$) between 1975 and 1993. This study has been criticized because the authors based their conclusion solely on commercial catch data and failed to note that in 1985, the Kuskokwim Area District 1 commercial fishery became restricted to a mesh size of 6 inches or less. Smaller mesh sizes typically capture smaller, younger fish; and the decrease in mean age of return noted by Bigler et al. (1996) may have been an artifact of this gear change. The same study showed no change in the mean age of Yukon River Chinook salmon, and an increase in the mean age of the Kenai River population for the same years. A similar retrospective analysis of Yukon River Chinook salmon by Hyer and Schleusner (2005) was less conclusive with regards to finding basin-wide trends in ASL composition among Yukon River Chinook salmon stocks. The authors noted the relatively short time series of comparable datasets as being the major obstacle to reaching definitive conclusions with respect to age of return. These examples stress the importance of both long-term consistent data collection over several years and good maintenance and dissemination of metadata.

Sex Composition

Female Chinook salmon generally arrive later and are less abundant than males early on in the season as populations return to the Kuskokwim Area. This is most notable at escapement projects e.g. the Takotna River weir (Figure 6). The percent female Chinook salmon also varies between escapement, and commercial harvests with restricted and unrestricted mesh sizes. Prior to the mesh size restrictions of 1985, female Chinook salmon constituted 21% to 52% of the return to Kogrukluk River weir (Appendix A), 28% to 43% of the commercial harvest during restricted mesh openings in Districts 1, and 30% to 43% of the commercial harvest during unrestricted mesh openings in District 1 (Figure 7). Data from the subsistence harvest collected between 2004 and 2008 also tend to show fewer females in the catch even when large mesh gillnets were used (Figure 8, Appendix B).

The sex ratios reported by escapement projects are considered reliable due to advanced development of sexual dimorphism among salmon approaching spawning grounds. At those projects furthest from marine waters, it is often possible to get a rough estimate of sex composition while observing fish passage from the weirs. Visual assessment of sex composition at Takotna and Kogrukluk River weirs has been similar to the percent females estimated by direct examination and handling during ASL sampling (Figures 9 and 10). Deviation between ASL determined and visually determined sex ratios vary somewhat from year to year and are not consistent, thus visual sexing is not a substitute for ASL determined sex ratios (Figure 11). However, the variation is frequently low enough to allow for rough inseason estimates of sex composition based on visual assessment.

Sex ratios determined from the commercial harvest, may not be as reliable due to less pronounced dimorphism early in the migration. Most of the Chinook salmon sampled from commercial catches between 1997 and 1999 were investigated internally to verify the sex (Dubois and Molyneaux 2000). Of those fish that were sex confirmed (*N*=3,704), age-1.2 Chinook salmon were found to be overwhelmingly male (≥98%). However, in samples collected without sex verification, age-1.2 Chinook salmon have been reported as up to 70% female, calling into question the validity of determining sex without internal verification within the commercial fishery. Patterns of sex determination by the two methods remain consistent when considering a larger dataset between 1990 and 2009, and when compared with the Kogrukluk and Tuluksak River weirs (Figure 12); and similar trends were found in age-1.3 Chinook salmon where the occurrence of males was 82% or greater when sex was verified, but as low as 32% in samples without verification (Figure 13).

These suspected errors are not persistent across all years or locations that lack visceral examinations of the fish. For the years examined here, sex ratios reported for the District 1 commercial fishery have been near or within the range found in the verified samples. Escapement samples from Kogrukluk River were also near or within the expected range. Data from Districts 4 and 5, however, show considerable divergence from expected ratios, but not in all years.

The difference between the results from District 1 and those of Districts 4 and 5 may be related to the level of experience and training provided to technicians collecting the samples. Sampling crews in District 1 typically include one or more experienced biologists who closely monitor the sampling routine. Technicians sampling in Districts 4 and 5 have traditionally been more isolated and often have much less experience or training to draw on. From 1997 through the present, all ASL samples collected from fish during the commercial harvest have been internally examined to verify sex; this verification, also helps samplers learn what external features to recognize when visually identifying sex.

In recent years, ADF&G in cooperation with Coastal Villages Seafood have staffed crews in Quinhagak and Platinum dedicated to collecting ASL samples from the District 4 and 5 commercial harvests. These crews are provided with formal training by ADF&G staff prior to deployment and receive additional help from ADF&G biologists as needed throughout the season. These changes to the commercial ASL program have greatly improved the accuracy and reliability of data collected from all commercial fishing districts.

Length Composition

The length frequency distributions of the 3 most predominant Chinook salmon age classes (age-1.2, -1.3, and -1.4) overlap as illustrated in (Figure 14). The most distinctive group is the age-1.2 fish. This age class is comprised mostly of males and the relatively small size of the fish is one of the external morphological characteristics that can help in sex determination. The age-1.3 group contains a few more females, however female lengths tend to be limited to the upper half of the range for that age class (Molyneaux and DuBois 1999); for example, in 1999 District 1 age 1.3 males averaged 675 mm in length while females averaged 801 mm. This same trend is apparent in District 4 where males averaged 694 mm and females averaged 802 mm. The lengths of age-1.4 males and females overlap more broadly.

Sockeye Salmon

Age Composition

Eleven age classes have been reported for sockeye salmon returning to the Kuskokwim Area, and most appear in small numbers. The predominant age class among Area sockeye salmon is age-1.3 (Appendix G and H). The next most common age classes vary depending on location. Among Kuskokwim Bay fisheries and escapements, the second most prevalent age class is age-1.2, while among Kuskokwim River stocks, it is age-2.3. Samples from 1999 show that age-1.3 fish tend to be in greatest proportion early in the season in Kuskokwim Bay and the occurrence of age-1.2 sockeye salmon may increase slightly as the season progresses (Figure 15). Similar patterns are apparent for previous years (Molyneaux and DuBois 1998, 1999).

Sex Composition

The overall annual sex ratio of most Kuskokwim Area sockeye salmon populations is approximately 1 male to 1 female. Commercial fisheries and escapement projects are similar with regard to sex ratio (Figure 16). No clear inseason temporal pattern for the arrival of male and female sockeye salmon is apparent based on Kuskokwim Area sampling data.

Length Composition

The range of lengths found in the various sockeye salmon age classes overlap broadly, however escapement data collected from the Kanektok River in 1997 show the average length for age-1.3 fish to be consistently greater than age-1.2 fish (Figure 17). Furthermore, males tend to average about 20 mm longer than females of the same age class. The average length of age-1.3 sockeye salmon was fairly uniform in the Kanektok River escapement throughout the 1997 season, whereas age-1.2 fish were generally smaller at the start of the season.

A comparison of commercial and escapement ASL data from the Goodnews area shows that age-1.2 and -1.3 female sockeye salmon harvested in the commercial fishery tend to be larger than the same age-sex classes measured at the Middle Fork Goodnews River weir (Figure 18, Appendix G and H). The sockeye salmon harvest for District 5 is estimated to represent 23% of sockeye salmon returning to the Goodnews River drainage (ADF&G 2004). Commercial fisheries in each of the Kuskokwim Area districts are limited to 6-inch or less mesh gillnets.

Chum Salmon

Age Composition

Chum salmon return to the Kuskokwim Area at age-0.2, -0.3, -0.4, and -0.5, with age-0.3 and -0.4 most predominant (Appendix C and D). Older age fish tend to arrive early in the season with younger age fish becoming more dominate as the season progresses. The daily incidence of age-0.2 chum salmon early in the season is near 0%, but may rise to as much as 40% at some escapement projects by the end of August (Figure 19). Conversely, the incidence of 0.4 chum salmon may be as high as 90% early in the season and less than 10% near the end of the season. This pattern is well illustrated at the Tuluksak River weir from 1991 through 1994 (Figure 20) and similar patterns have been reported in streams of the Yukon drainage (Melegari 1996; Tobin and Harper 1995), South Central Alaska (Helle 1979), Southeast Alaska (Clark and Weller 1986), British Columbia (Beacham 1984; Beacham and Starr 1982), and Washington (Salo and Noble 1953). This pattern appears to be common among chum salmon populations. Occasional inconsistencies seen in historical age summaries of the Kuskokwim Area are suspect and should be viewed with some skepticism. Ideally the scales collected from such data sets should be reviewed to confirm the age determinations.

Sex Composition

The overall annual sex ratio of most Kuskokwim Area chum salmon populations approximates 1 male to 1 female. At any given location, males tend to be more predominant early in the season whereas the proportion of females increases as the season progresses. Results from Tuluksak River weir illustrate the point well with the daily percentage of females showing a steady increase as the season progresses from 25% to about 75% in each of 4 consecutive years (Figure 21). Results from commercial samples in 1999 show the same overall trend (Figure 22). These patterns are common in chum salmon populations (Bakkala 1970).

Contrary to traditional in-season patterns, historical data from the Kogrukluk River weir show a decrease in the percentage of female chum salmon between 1981 and 1999; with an extreme low of 4.1% in 1997 (Figure 23). Between 1982 and 2005, the percentage of upriver migrating females was <50% of the total returning chum salmon population. In 2005, there was a record return of chum salmon to the Kogrukluk River, and female chum salmon made up 45.1% of the total run. Since 2005, percentages of female chum salmon have ranged between 34.9 and 45.1%. It is not known what caused the decrease in numbers of female chum salmon between 1982 and 2005. Jasper and Molyneaux (2007) describe some possible causes.

Length Composition

The length frequencies of chum salmon overlap broadly by age and sex groupings, but female chum salmon are generally smaller in length than males of the same age class. Length frequencies for fish sampled at the Kogrukluk River weir between 2002 and 2005 provide a good illustration of this overlap (Figure 24). Kuskokwim Bay and Goodnews River weir chum salmon tend to be larger at age than Kuskokwim River fish. The average length of chum salmon sampled in 1999 from commercial fishing Districts 1, 4 and 5, the Goodnews River weir, and Aniak River sonar, provide a good example of this (Figure 25). Also common among Kuskokwim Area chum salmon stocks is a tendency for the average length of arriving fish to decrease as the migration progresses. This appears true for all age-sex groupings. At Tuluksak River weir, the average decrease in length of age-0.3 and -0.4 chum salmon over the course of the run between years 1991 through 1994 was on the order of 56 mm (Figure 26).

Low sample sizes reduce the statistical significance of trends, so it is important to use only those years that adequate sample sizes are available to properly characterize the run. Years with inadequate samples sizes are footnoted and not included in grand totals (Appendix C and D). For example, when comparing average lengths for male and female chum salmon age-0.3, and -0.4 at Kogrukluk River weir, it is possible to identify an overall decline in length-at-age for both age-sex classes; however, age-0.3 male chum salmon show the clearest trend with the tightest confidence intervals due to an abundance of samples for this age group (Figure 27).

Kuskokwim River chum salmon stocks were among the North Pacific chum salmon stocks reported by Bigler et al. (1996) to have had significant decreases in the average weight-at-age between 1975 to 1993 ($P<0.05$). Again, the authors' conclusion generally relies on commercial catch statistics that, for the Kuskokwim River, contain similar confounding influences to those described above for Chinook salmon, first, the change in fishing practices in 1985 may have influenced chum salmon in a manner similar to that suggested for Chinook salmon, potentially resulting in a reduced average size of chum salmon in the harvest. Second, in the late 1980s, a tendency to extend the commercial fishing season for chum salmon into the second half of July may have resulted in higher proportions of younger age classes and females in the catch for reasons described above. Contrary to the findings of Bigler et al. (1996), chum salmon data from Kogrukluk River escapements and the District 1 commercial harvests both show variable average lengths-at-age over the years, but no strong decreasing trend (Figure 28).

Coho Salmon

Age Composition

Coho salmon return to Kuskokwim Area streams at age-1.1, -2.1 and -3.1. Age-2.1 fish usually account for more than 90% of the return. Age-3.1 fish normally comprise 5% or less of the return. An exception to this trend occurred in 1999 and in 2008, when an atypically high percentage of age-3.1 coho salmon returned to the Kuskokwim River (Appendix E and F).

Sex Composition

Since 1997, sex has been confirmed through internal examination for most coho salmon sampled from commercial harvests. Samples generally exhibited an increasing proportion of females in the catch as the season progressed (Figure 29). This pattern is not always obvious in other databases, possibly due to errors in sexing the fish. Female coho salmon may exhibit some level of kype development, which can confound sexing by external characteristics alone.

Similar to Chinook and chum salmon, coho salmon sex ratios reported by escapement projects are generally believed to be reliable due to advanced development of sexual dimorphism. At those projects furthest from marine waters, it is often possible to get a rough estimate of sex composition while observing fish passage from the weirs. Visual assessment of sex composition at Takotna and Kogrukluk River weirs is similar to the percent female estimated by direct examination and handling during ASL sampling (Figures 30 and 31).

Length Composition

Among coho salmon, no consistent pattern is obvious in the average length-at-age composition. Overall, the mean length of fish does tend to increase as the season progresses, but the pattern is not consistent for all years. There is a tendency for female coho salmon to be larger than males. This pattern was not apparent in the historical database before 1997, calling into question the reliability of sex determination of coho salmon when the sex is not confirmed.

Again, low sample sizes reduce the statistical significance of observed trends. Relative abundance of age-sex classes within the run yield different levels of certainty with respect to trends in length-at-age. When comparing average lengths for different age-sex classes of coho salmon sampled at Kogrukluk River weir, it is difficult to identify any significant trend with regard to size. Sample sizes are typically small in relation to abundance and confidence intervals tend to overlap broadly (Figure 32).

CONCLUSIONS

- The objective for Project 07-303 was fulfilled for 2009. ASL data were compiled across projects that collected samples in the Kuskokwim Area in 2009.
- ASL data can be a helpful tool in identifying important areas of study, however, sample size and statistical significance should always be taken into consideration when making assertions about trends within ASL data.
- The ASL catalog is available electronically from the Division of Commercial Fisheries, Kuskokwim Area web page at:

  http://www.cf.adfg.state.ak.us/region3/pubs/pubshom3.php?a=w

RECOMMENDATIONS

- Continue to stabilize and standardize collection and processing of salmon ASL data to ensure that an adequate time series of data is maintained that will facilitate retrospective analysis.
- Facilitate retrospective data analysis by continuing to report the salmon ASL time series in a manner that allows for broad and easy access to the data sets.
- Continue to process ASL samples in a centralized location with consistent age determination criteria and data processing methods.
- Continue to archive scale cards, paper data collection forms, and electronic data in a centralized location.
- Continue to add historical data summaries to the catalog with the goal of summarizing all data historically collected in the Kuskokwim Area.
- Continue to improve methods for compiling and reporting ASL data, including a reduction in the number and complexity of reports in the online catalog.
- Update figures to include recent year data where fitting, and add illustrations of other data sets.

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Product names used in this report are included for scientific completeness, but do not constitute a product endorsement.

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TABLES AND FIGURES

Table 1.–Distance to selected locations from the mouth of the Kuskokwim River or Bethel.[a]

Location [b]	Distance From River Mouth [c]		Distance from Bethel	
	Kilometer	Miles	Kilometer	Miles
Popokamiut (Downstream boundary District 1)	(3)	(2)	(109)	(68)
Kuskokwim River Mouth [c]	0	0	(106)	(66)
Apokak Slough (Downstream boundary District 1)	5	0	(106)	(66)
Eek River	13	8	(93)	(58)
Eek (community)	46	29	(60)	(37)
Kwegooyuk	22	13	(85)	(53)
Kinak River	32	20	(74)	(46)
Tuntutuliak (community)	45	28	(61)	(38)
Kialik River	50	31	(56)	(35)
Fowler Island	68	42	(39)	(24)
Johnson River	77	48	(29)	(18)
Napakiak (community)	87	54	(19)	(12)
Napaskiak (community)	97	60	(10)	(6)
Oscarville (community)	97	60	(10)	(6)
Bethel (community)	106	66	0	0
Gweek River	135	84	29	18
Kwethluk River	131	82	25	16
Kwethluk (community)	132	82	26	16
Kwethluk River Weir	216	134	109	68
Akiachak (community)	143	89	37	23
Kasigluk River	150	93	43	27
Kisaralik River	151	94	45	28
Akiak (community)	161	100	55	34
Mishevik Slough,	183	114	77	48
Tuluksak River	192	119	85	53
Tuluksak (community)	192	120	86	54
Tuluksak River Weir	248	154	142	88
Nelson Island	190	118	84	52
Bogus Creek (Upstream Boundary District 1)	203	126	97	60
High Bluffs	233	145	127	79
Downstream Boundary District 2	262	163	156	97
Mud Creek Slough	267	166	161	100
Lower Kalskag (community)	259	161	153	95
Kalskag (community)	263	163	157	97
Lower Kalskag Fishwheel (2004)	249	155	143	89
Kalskag Fishwheel (2002, 2003, 2005, and 2006)	270	168	163	102
Birchtree Fishwheel (2001 to 2004)	294	183	187	117

-continued-

Table 1.–Page 2 of 3.

Location [b]	Distance From River Mouth [c]		Distance from Bethel	
	Kilometer	Miles	Kilometer	Miles
Aniak (community)	307	191	201	125
Aniak River	307	191	201	125
Doestock	320	199	214	133
Aniak Sonar Site	323	201	217	135
Buckstock	370	230	264	164
Salmon River	403	250	296	184
Salmon River Weir	404	251	298	185
Kipchuck	407	253	301	187
Chuathbaluk (community)	323	201	217	135
Upstream Boundary District 2	322	200	216	134
Kolmakof River	344	214	238	148
Napaimiut (community)	359	223	253	157
Holokuk River	362	225	256	159
Sue Creek	381	237	275	171
Oskawalik River	398	247	291	181
Crooked Creek (community)	417	259	311	193
Georgetown (community)	446	277	340	211
George River	446	277	340	211
George River Weir	453	281	347	215
Red Devil (community)	472	293	365	227
Sleetmute (community)	488	303	381	237
Holitna River	491	305	385	239
Hoholitna River	538	334	432	268
Chukowan River	709	441	603	375
Kogrukluk River	709	441	603	375
Kogrukluk River Weir	710	441	604	375
Stony River (community)	534	332	428	266
Stony River	536	333	430	267
Lime Village (community)	644	400	538	334
Telaquana River	727	452	621	386
Telaquana Lake (outlet)	772	480	666	414
Necons River	760	472	653	406
Swift River	560	348	454	282
Cheeneetnuk River	587	365	481	299
Gagarayah River	634	394	528	328
Babel River	660	410	554	344
Moose Creek	533	331	426	265

-continued-

Table 1.–Page 3 of 3.

Location [b]	Distance From River Mouth [c]		Distance from Bethel	
	Kilometer	Miles	Kilometer	Miles
Nunsatuk River	620	385	513	319
Selatna River	663	412	557	346
Little Selatna River	669	416	563	350
Black River	679	422	573	356
Katitna River	719	447	613	381
Blackwater River	838	521	732	455
Tatlawiksuk River	563	350	457	284
Tatlawiksuk River Weir	568	353	462	287
Devil's Elbow	599	372	492	306
Vinasale (abandoned community)	665	413	558	347
Takotna River	752	467	645	401
Takotna (community)	832	517	726	451
Takotna River Weir	835	519	729	453
McGrath (community)	753	468	647	402
Middle Fork	806	501	700	435
Big River	827	514	721	448
Pitka Fork	845	525	739	459
Salmon River	880	547	774	481
Windy Fork	901	560	795	494
Medfra (community)	863	536	756	470
South Fork	869	540	763	474
Nikolai (community)	941	585	835	519
East Fork	882	548	776	482
North Fork	884	549	777	483
Swift Fork	1,078	670	972	604
Telida (community)	1,128	701	1,022	635
Highpower Creek	1,151	715	1,044	649
Headwaters South Fork	1,292	803	1,186	737
Headwaters North Fork	1,548	962	1,442	896

[a] Distances are determined using a computer version (Garmin Topo MapSource) of U.S. Geological Survey 1:100,000 scale maps. Routing is as if traveling by boat.

[b] Locations not on the mainstem of the Kuskokwim River are listed as subordinate to the point of departure from the mainstem.

[c] The "mouth" of the Kuskokwim River is defined as the southern most tip of Eek Island (latitude N 60^{o} 05.569, longitude W 162^{o} 19.054), and is one of three points that define the downstream boundry of District 1.

Table 2.–Projects and salmon species for which age sex, and length data are summarized in the 2009 Kuskokwim Area ASL Catalog.

		Salmon Species (ASL Summaries Present = X)			
Project Type	Location	Chinook	Sockeye	Chum	Coho
Escapement	Takotna R.	X	X	X	X
	Tatlawiksuk R.	X	X	X	X
	Kogrukluk R.	X	X	X	X
	George R.	X	X	X	X
	Salmon R.				X
	Kalskag Fishwheels				X
	Aniak R.			X	
	Tulusak R.	X	X	X	X
	Kisaralik R.				
	Kwethluk R.	X	X	X	X
	Kanektok R.	X	X	X	X
	Goodnews R.	X	X	X	X
Commercial	District 1	X	X	X	X
	District 4	X	X	X	X
	District 5	X	X	X	X
Test Fish	Bethel Test Fish				
Subsistence	Kuskokwim R.	X			

Table 3.–Historical mesh size distribution from the Kuskokwim River Subsistence Fishery.

Gear Type	Number of Mesh Sizes Used, By Year								
	2001	2002	2003	2004	2005	2006	2007	2008	2009
Large Mesh Gillnets (≥8-inch mesh)									
8-3/4 inch mesh		1							
8-1/2 inch mesh		3	1			1		1	2
8-1/4 inch mesh		6	6	3	7	5	4	3	4
8-1/8 inch mesh		4	1	1					
8.0 inch mesh		17	25	19	19	16	22	24	26
Subtotal		31 62.0%	33 68.8%	23 82.1%	26 66.7%	22 84.6%	26 63.4%	28 44.4%	32 47.1%
Intermediate Mesh Gillnets (>6-inch but <8-inch mesh)									
7-7/8 inch mesh		1	1		1				1
7-3/4 inch mesh					1		2		
7-5/8 inch mesh						1			
7-1/2 inch mesh		1	2	1	3	2	1	9	8
7-1/4 inch mesh		2				1	2	6	2
7-3/8 inch mesh							1		
7.0 inch mesh		2	1					4	3
Subtotal		6 12.0%	4 8.3%	1 3.6%	5 12.8%	4 15.4%	6 14.6%	19 30.2%	14 20.6%
Small Mesh Gillnets (≤6-inch mesh)									
6-3/4 inch mesh								1	
6-1/2 inch mesh		1		1	2				
6.0 inch mesh		3	3	1	3		4	4	5
5-7/8 inch mesh		1			1		1		5
5-3/4 inch mesh					1		2	1	
5-1/2 inch mesh		2	3	2	1		2	6	9
5-1/4 inch mesh			1						
5-3/8 inch mesh		1						1	
5.0 inch mesh			1					1	2
4-1/2 inch mesh		1							
4.0 inch mesh		4	3					1	1
3-1/2 inch mesh								1	
Subtotal		13 26.0%	11 22.9%	4 14.3%	8 20.5%	0 0.0%	9 22.0%	16 25.4%	22 32.4%
Total		50 100.0%	48 100.0%	28 100.0%	39 100.0%	26 100.0%	41 100.0%	63 100.0%	68 100.0%
Number of Participant Samplers		34	37	21	31	20	25	46	55
Number of Samplers using Multipul Mesh Sizes		16	11	7	8	6	16	17	11

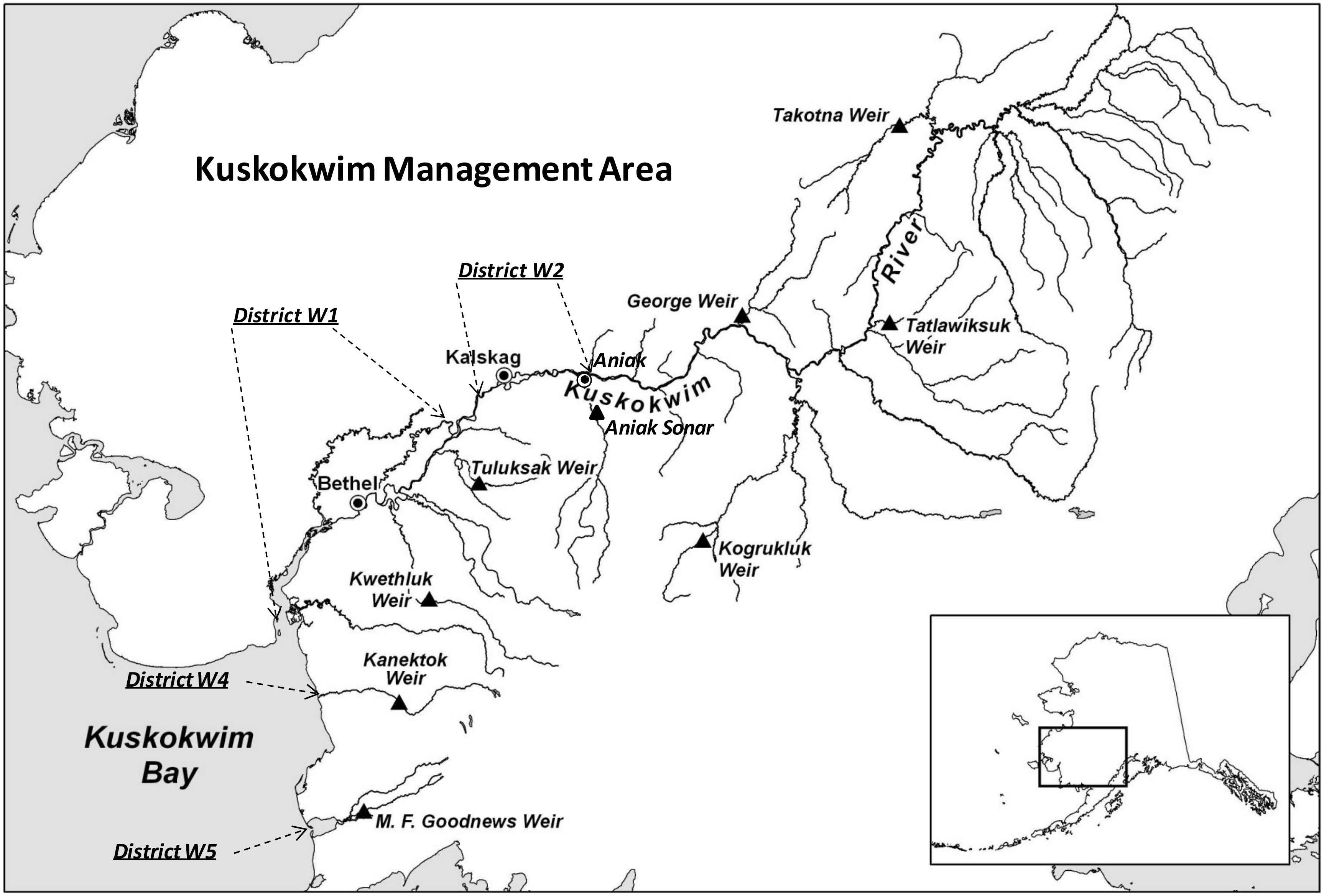

Figure 1.–Kuskokwim Area Map.

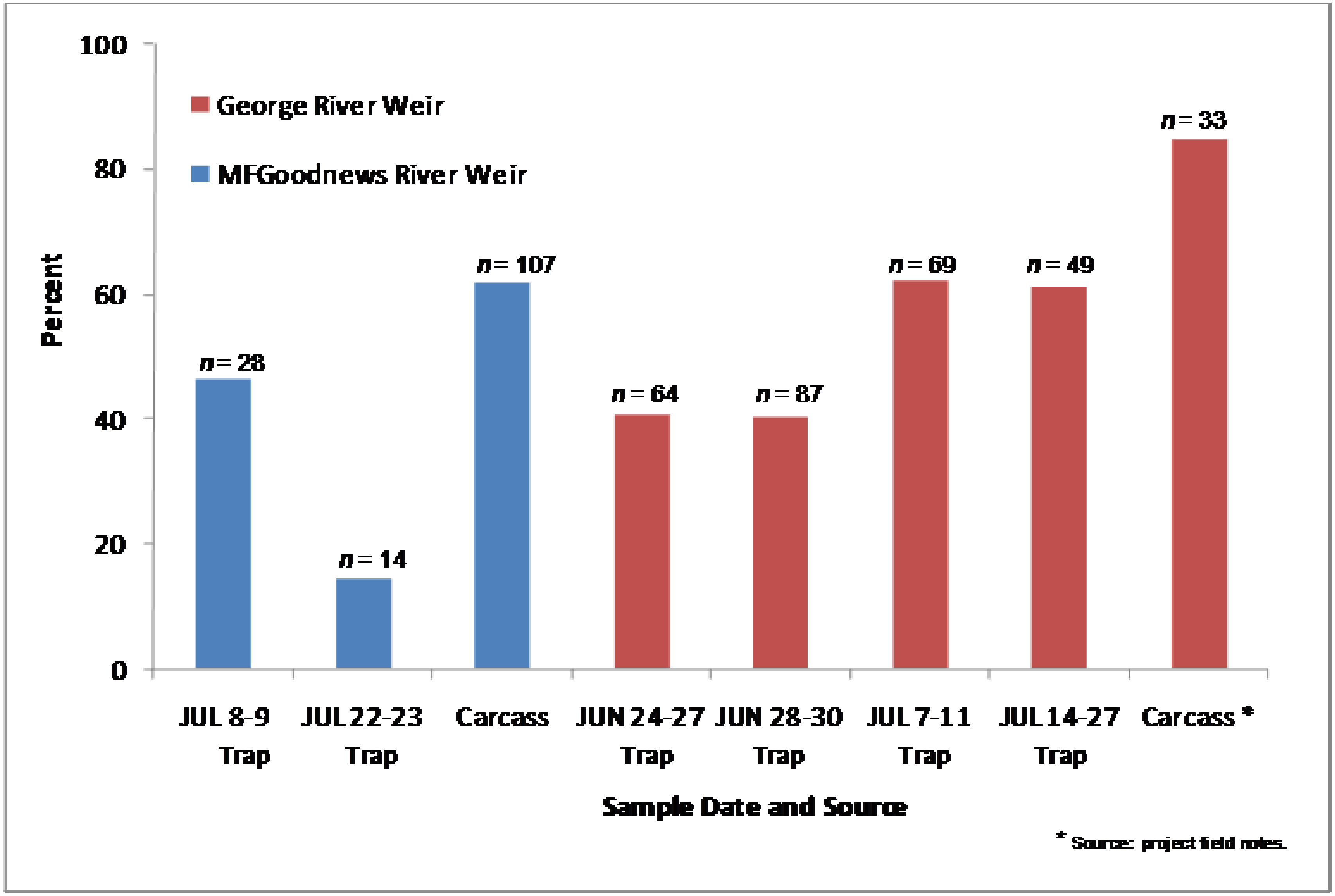

Figure 2.–Percentage of male Chinook salmon in trap and carcass samples from the Middle Fork Goodnews River weir in 1996 and the George River in 1997.

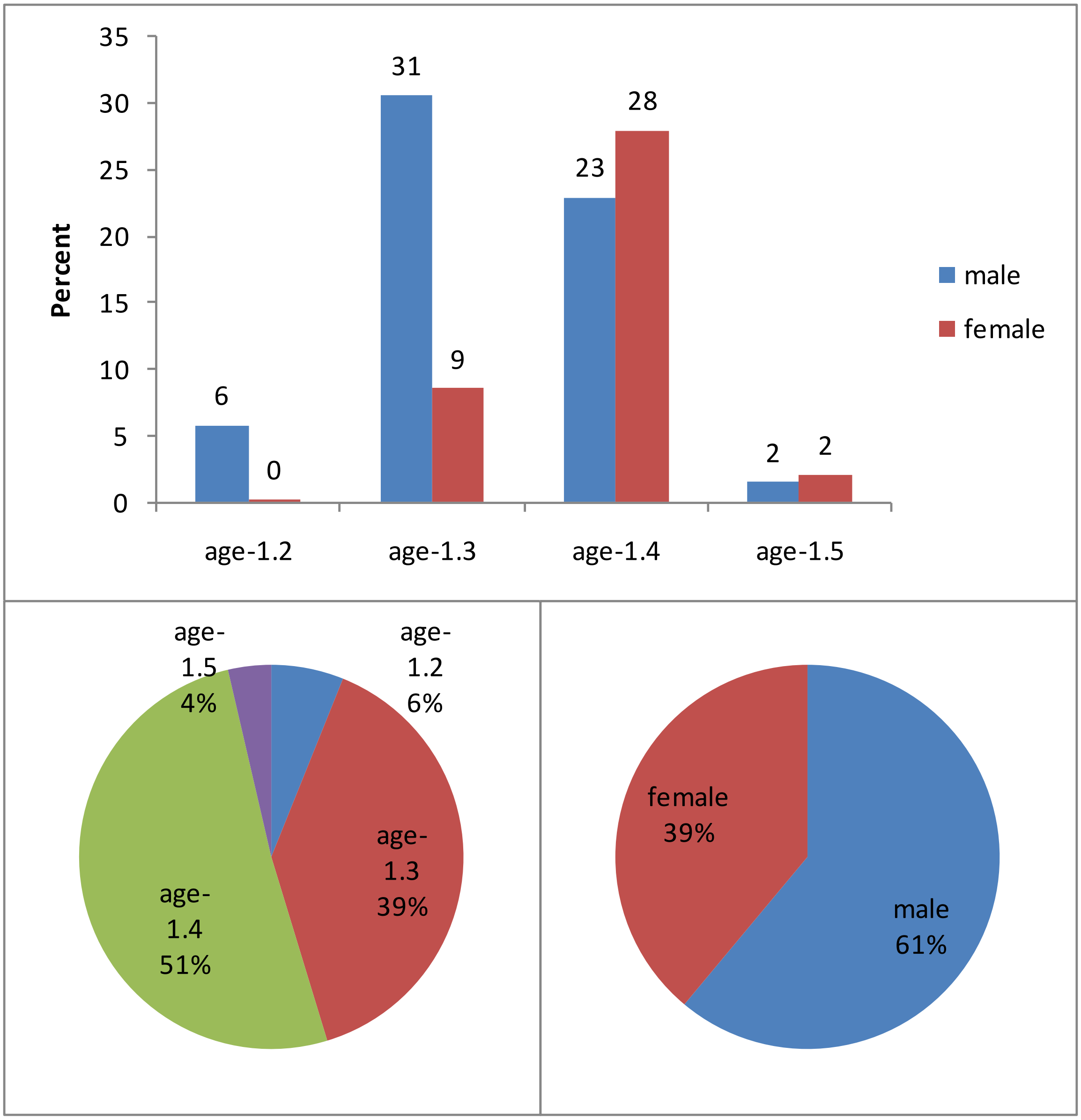

Figure 3.–Average age and sex composition of Subsistence Chinook salmon harvested using Unrestricted mesh gillnets, 2000–2009.

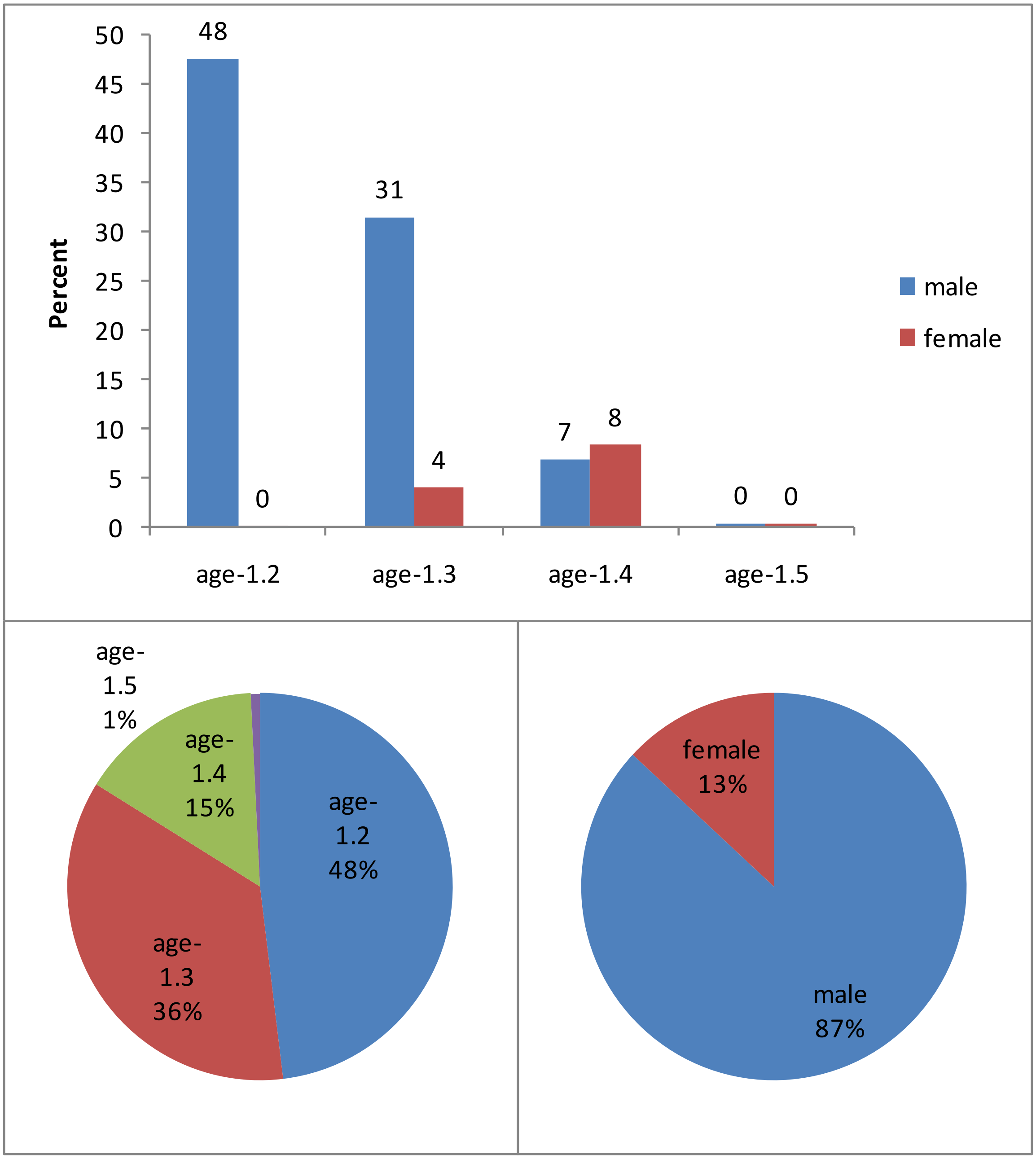

Figure 4.–Average age and sex composition of District W1 Chinook salmon harvested from commercial fishing periods in which gillnet mesh size was restricted to 6 inches or smaller 2000–2009.

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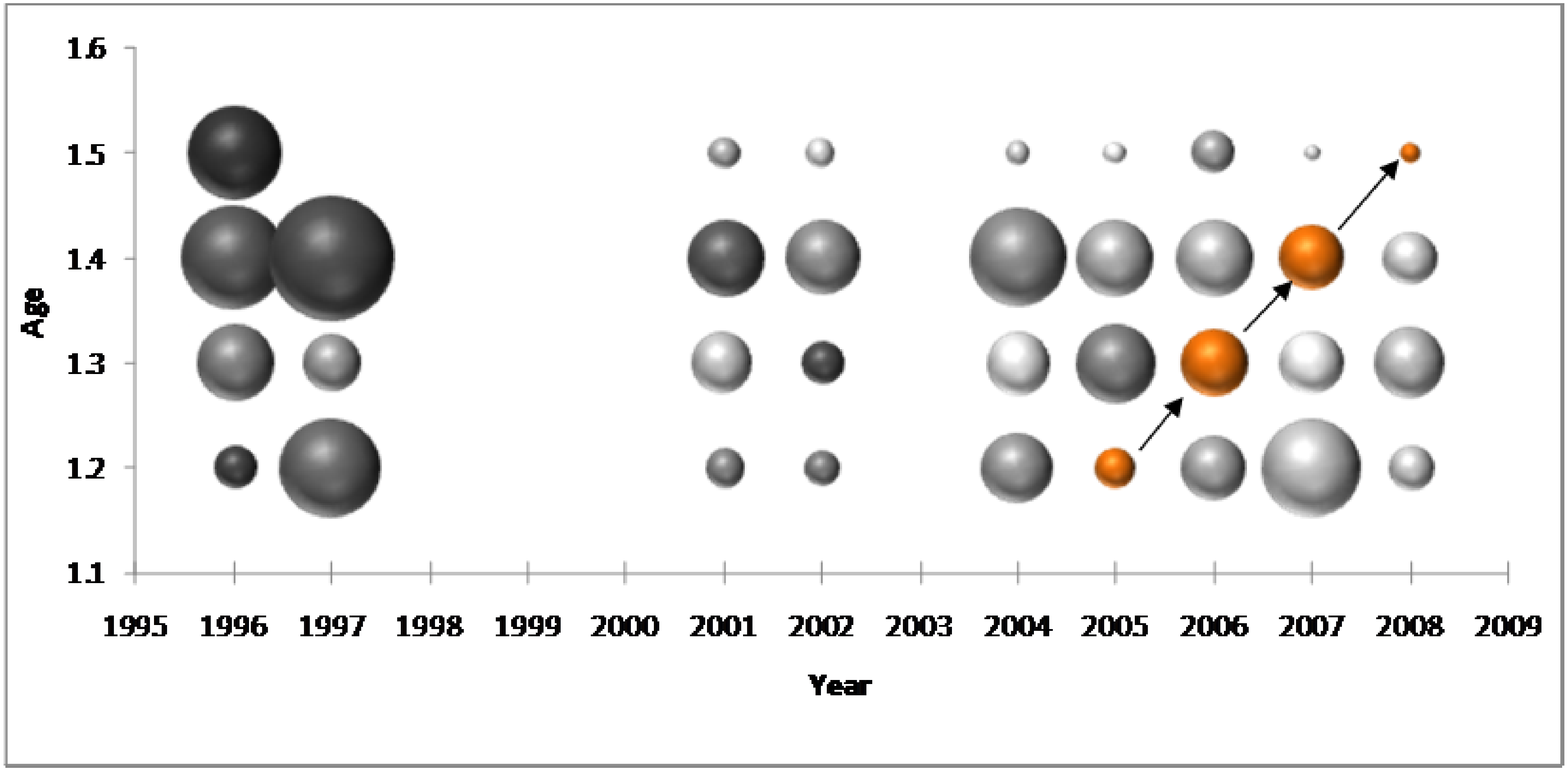


Note: Size of circles represents escapement and arrows illustrate tracking a cohort group. Plots that appear empty (white) correspond to years when greater than 20% of reported escapement was derived from daily passage estimates. Years when sample objectives were not achieved certain no data plots.

Figure 5.–Relative age class abundance of Chinook by return year at George River weir, 2006 to 2008.

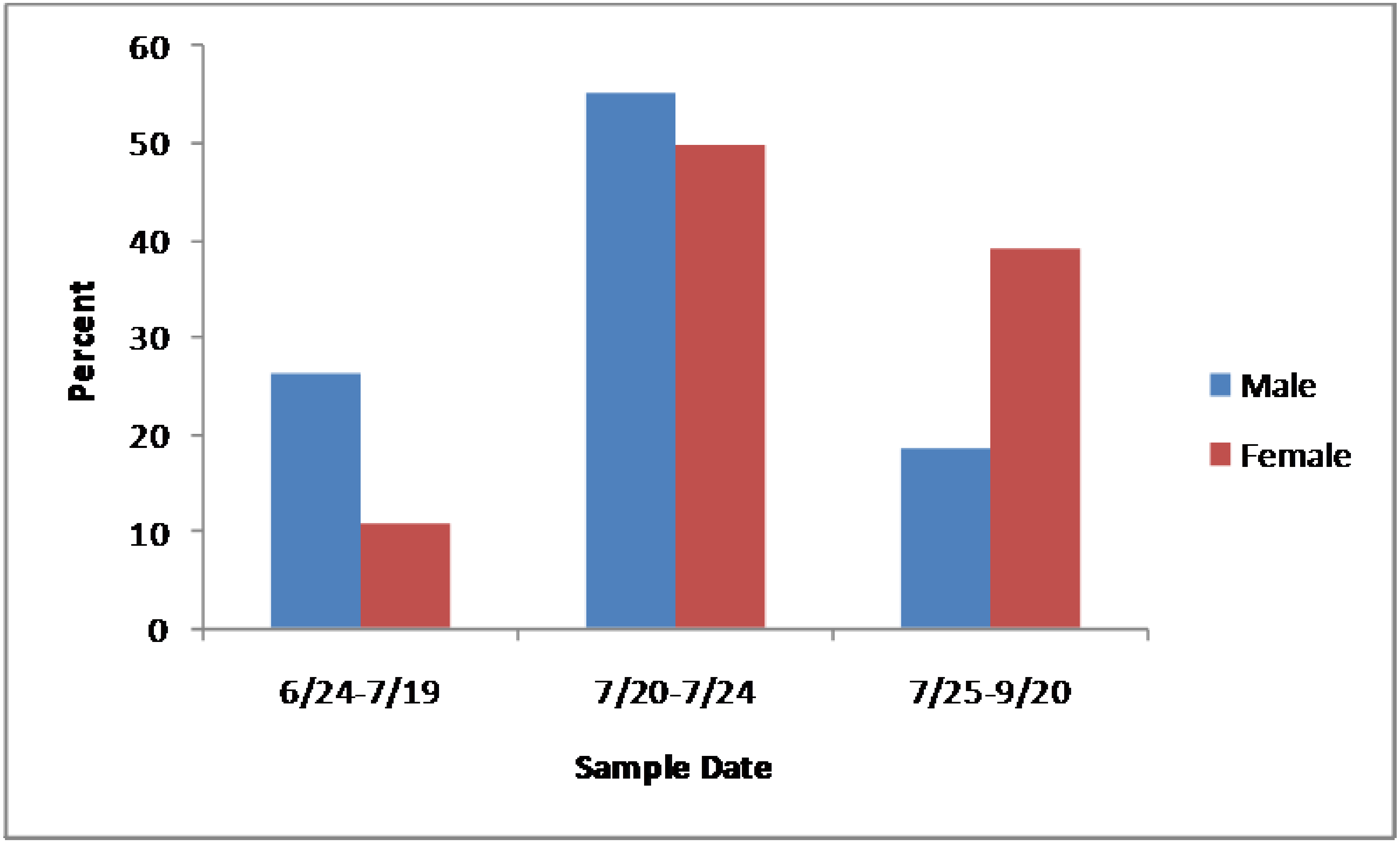


Figure 6.–Percent female Chinook salmon returning to Takotna River weir, 2008.

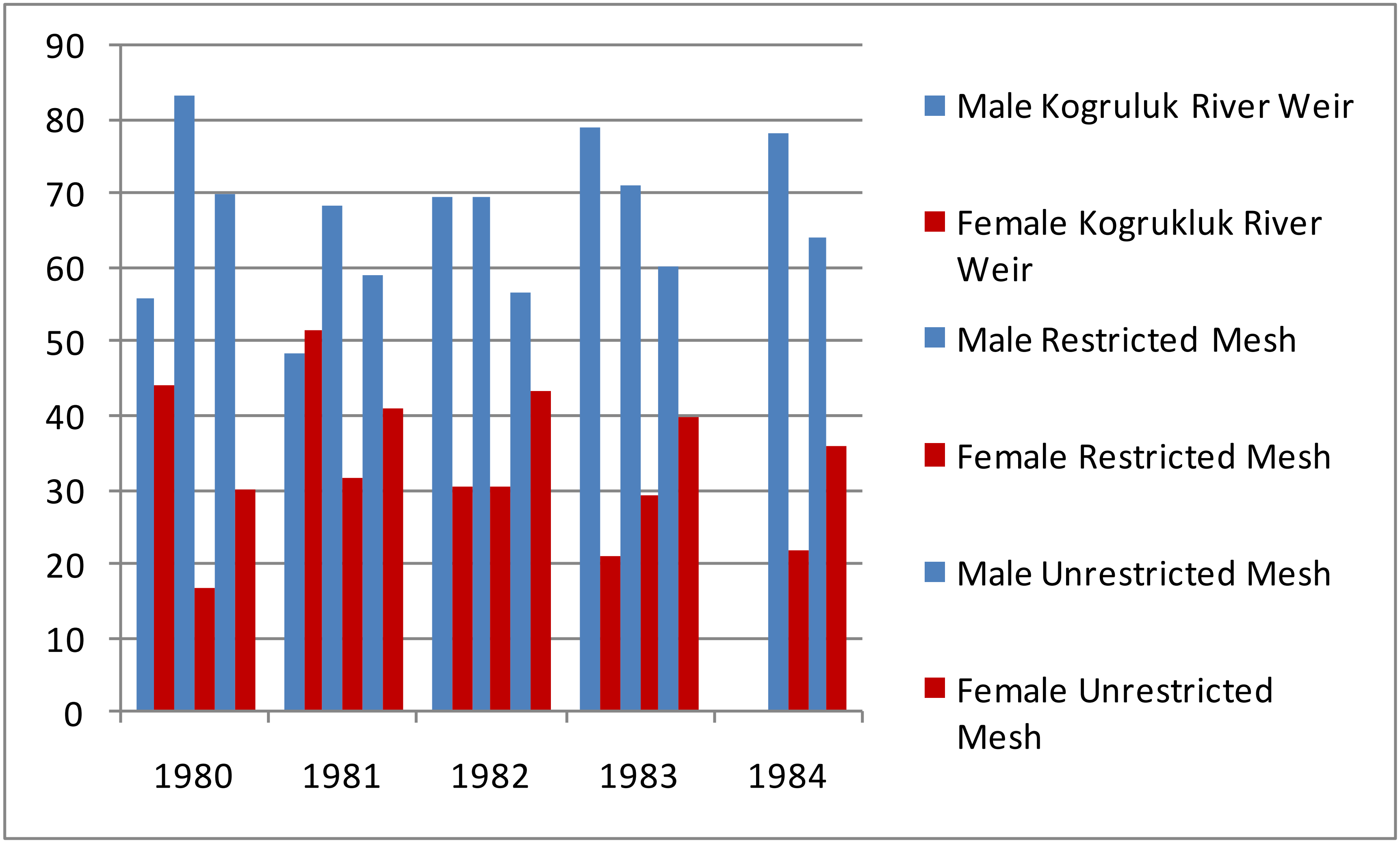


Figure 7.–Percent male and female Chinook salmon at the Kogrukluk Rive weir, and harvested during restricted and unrestricted commercial fishing periods in Kuskokwim Area districts, 1, 4, and 5.

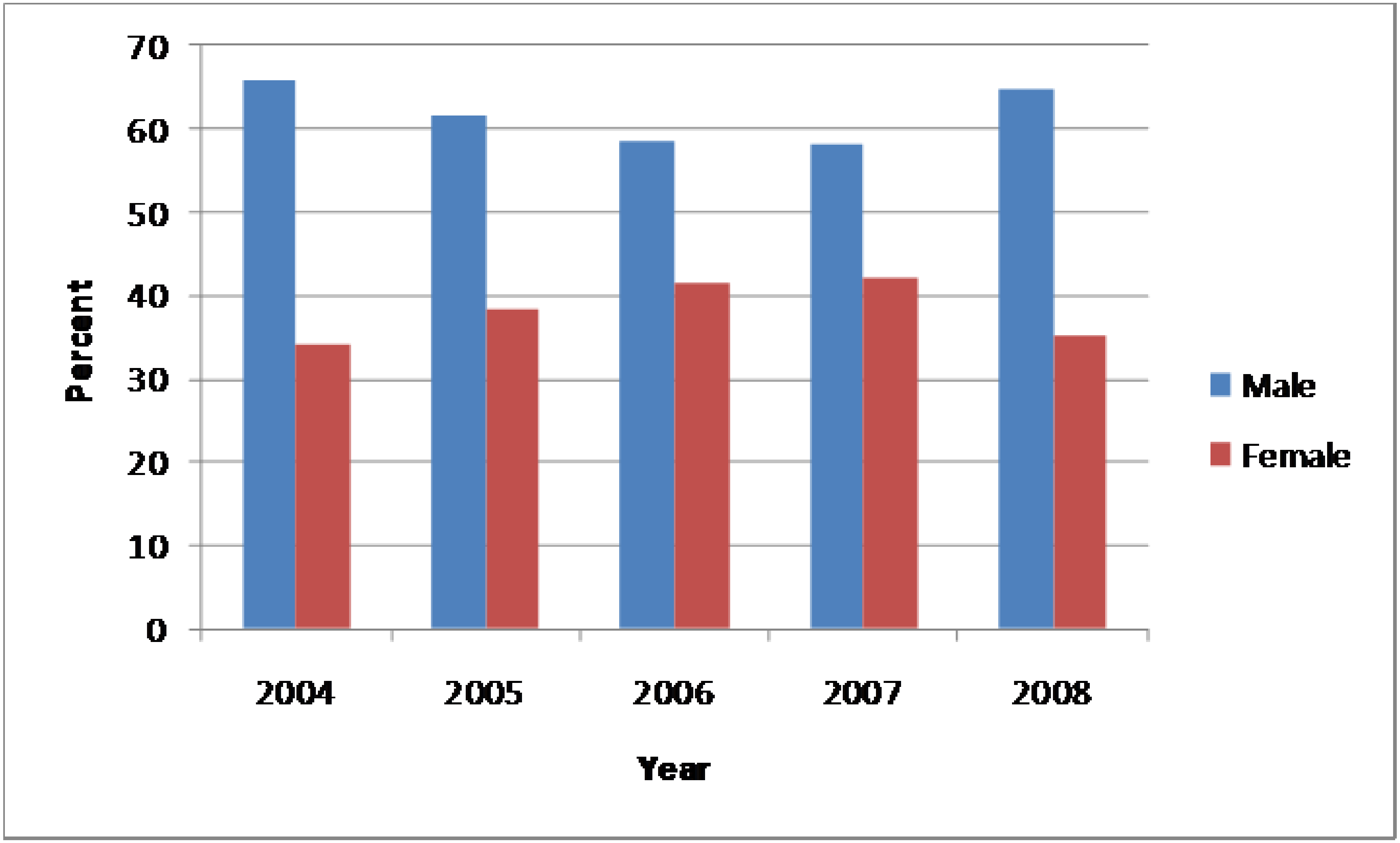


Figure 8.–Percent male and female Chinook salmon caught in 8 inch mesh gillnets between 2004 and 2008 during the subsistence harvest.

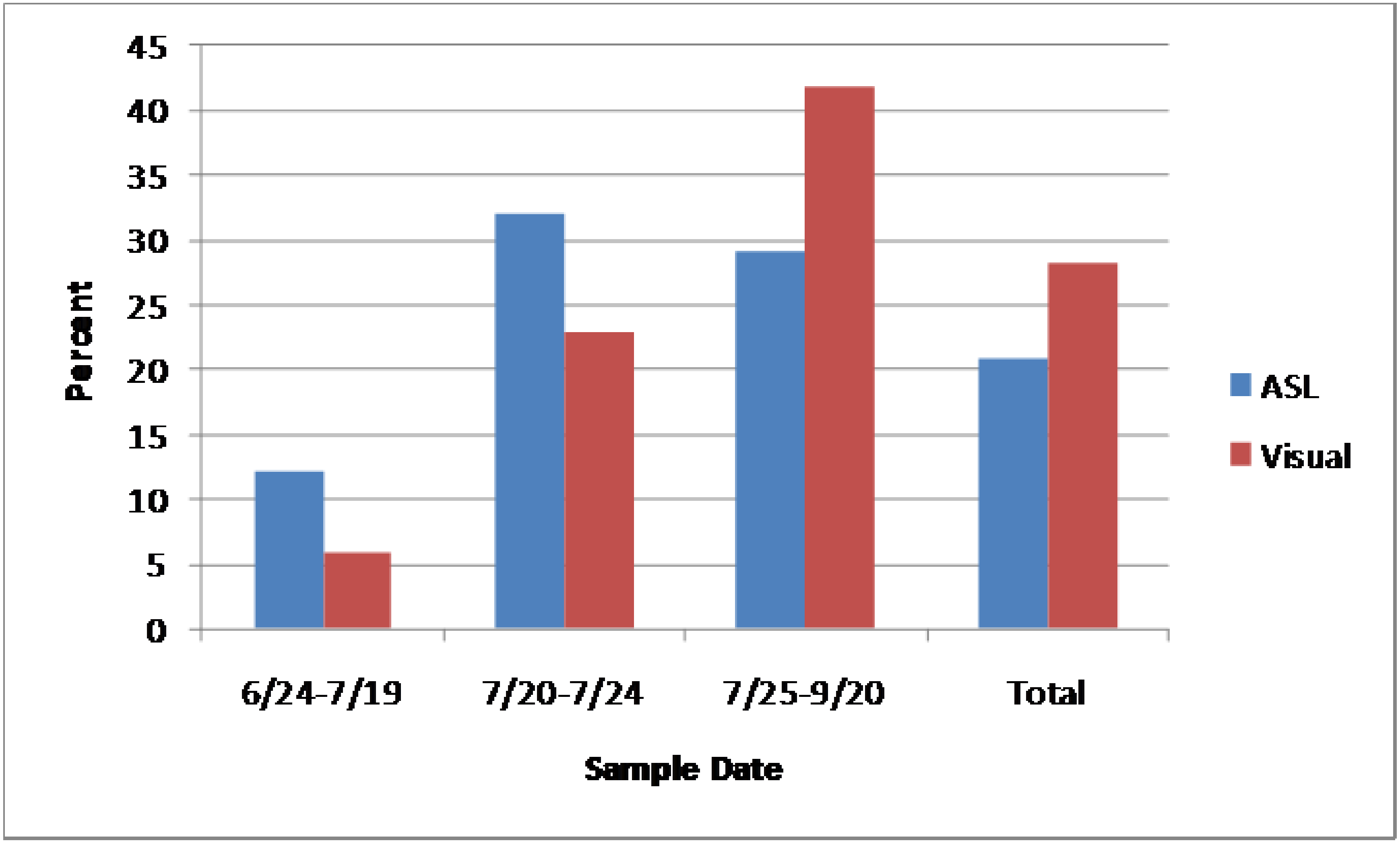


Figure 9.–Comparison of the percentage of female Chinook salmon passing upstream of the Takotna River weir as determined from standard ASL sampling using a fish trap, and from visual inspection of non-ASL sampled fish using standard fish passage procedures, 2008.

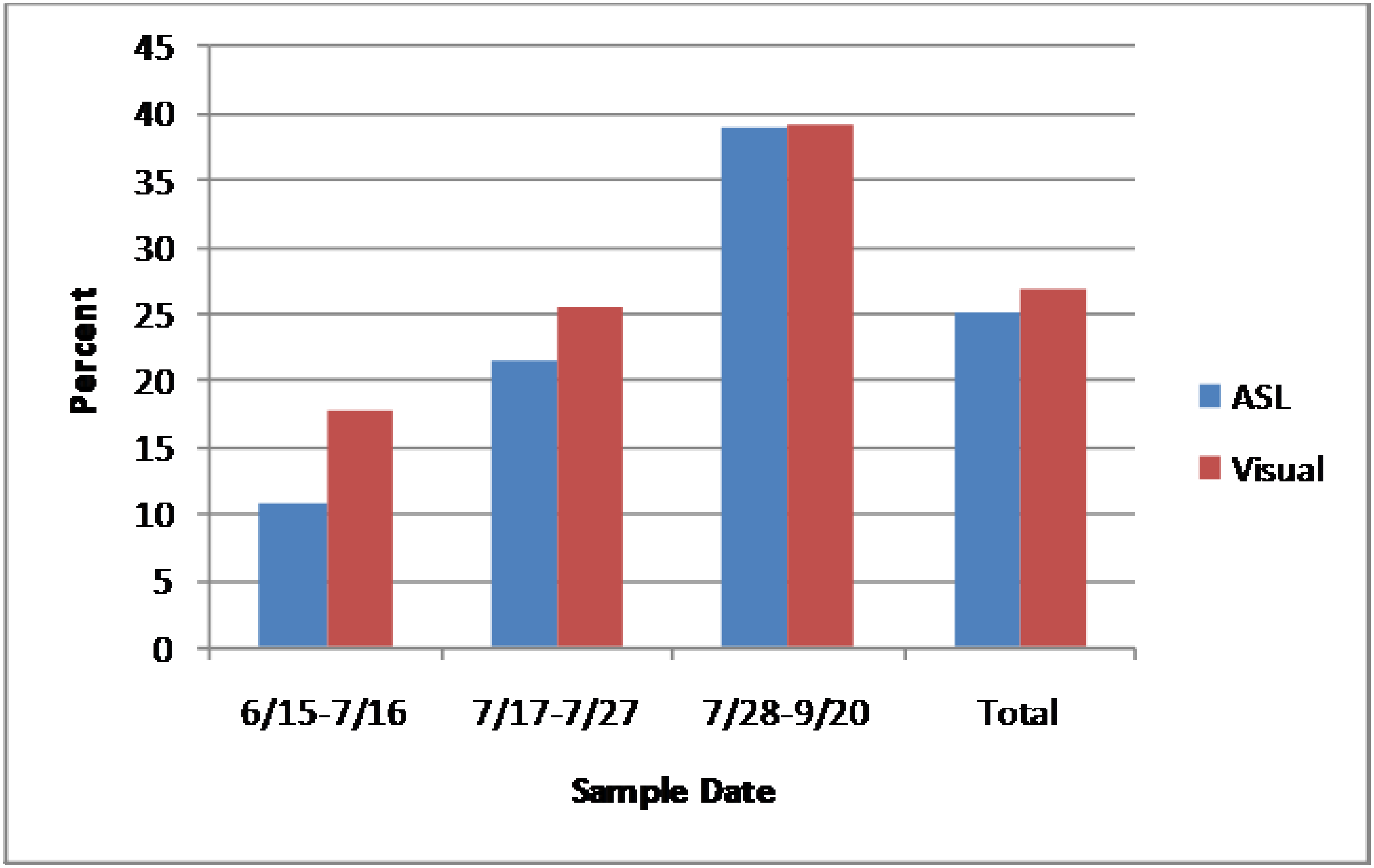
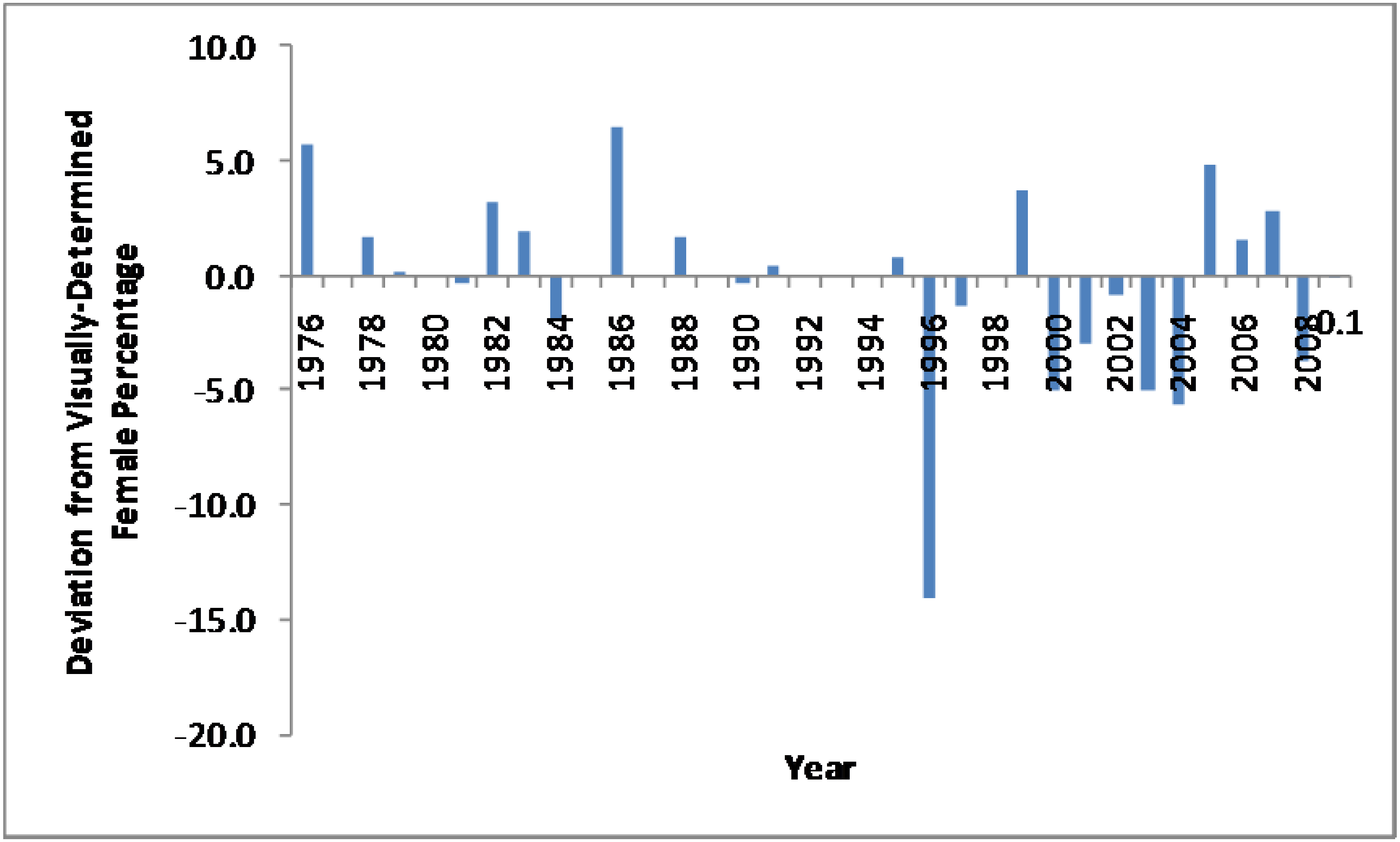
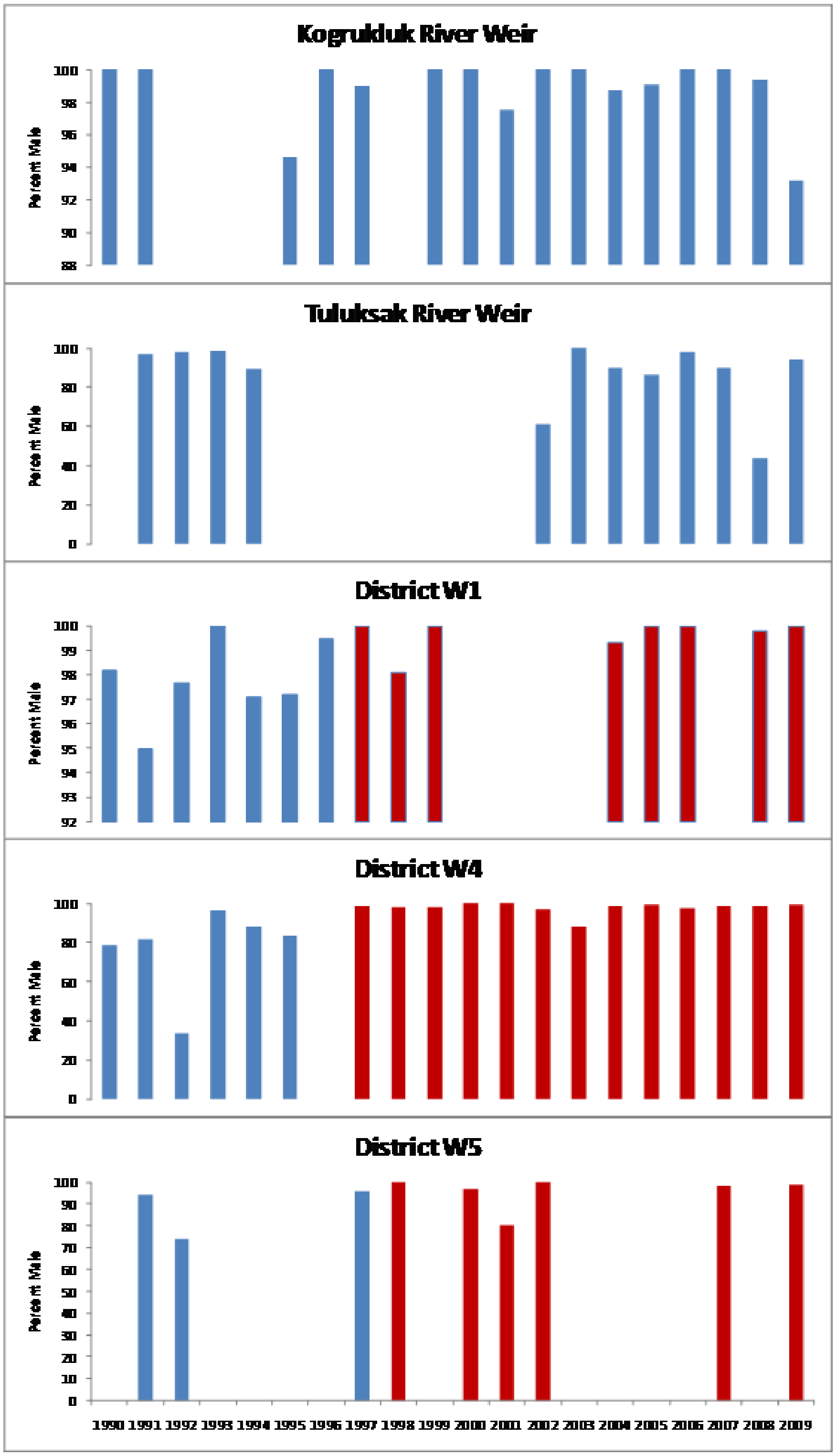


Figure 10.–Comparison of the percentage of female Chinook salmon passing upstream of the Kogrukluk River weir as determined from standard ASL sampling using a fish trap, and from visual inspection of non-ASL sampled fish using standard fish passage procedures, 2008.



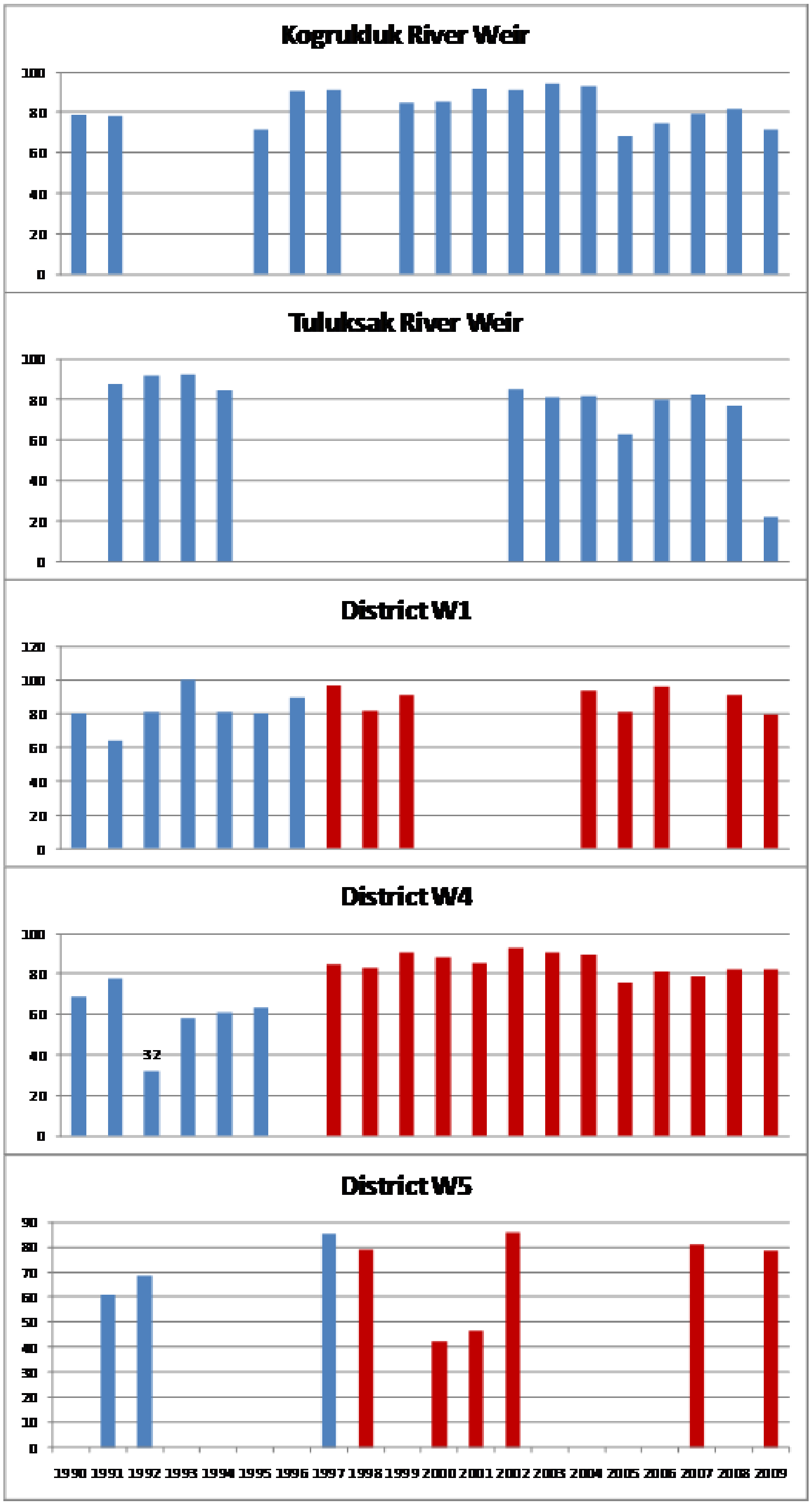
Note: The horizontal line bisecting the plot area at y = 0 represents the visually-determined female percentage during a given year. Columns dropping below the line are instances when the female percentage derived from ASL sampling was less than that of the visual method; columns rising above this line are instances when the female percentage derived from ASL sampling was more than that of the visual method.

Figure 11.–Historic annual deviation of percent females as determined by ASL sampling methods from the percentage determined through standard escapement counts at the Kogrukluk River weir, 2008.



Note: Red bars are sex confirmed fish.

Figure 12.–Percentage of male age-1.2 Chinook salmon documented during ASL sampling at Kogrukluk and Tuluksak River weirs, and commercial fishing districts 1, 4, and 5 (1990–2009).



Note: Red bars are sex confirmed fish.

Figure 13.–Percentage of male age-1.3 Chinook salmon documented during ASL sampling at Kogrukluk and Tuluksak River weirs, and commercial fishing districts 1, 4, and 5 (1990–2009).

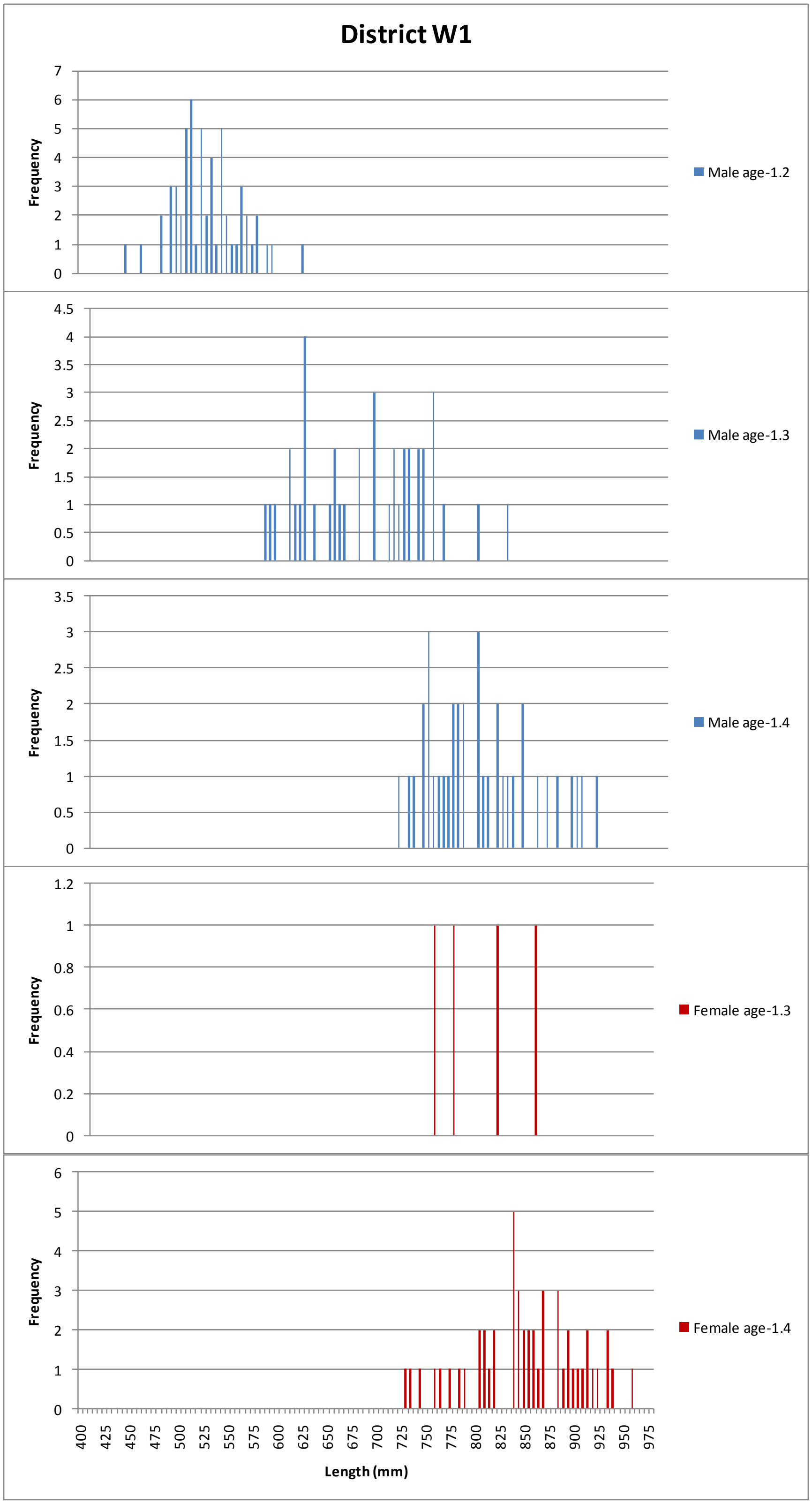


Figure 14.–Length frequency of Chinook salmon by age and sex, harvested in commercial fishing District 1, 1999.

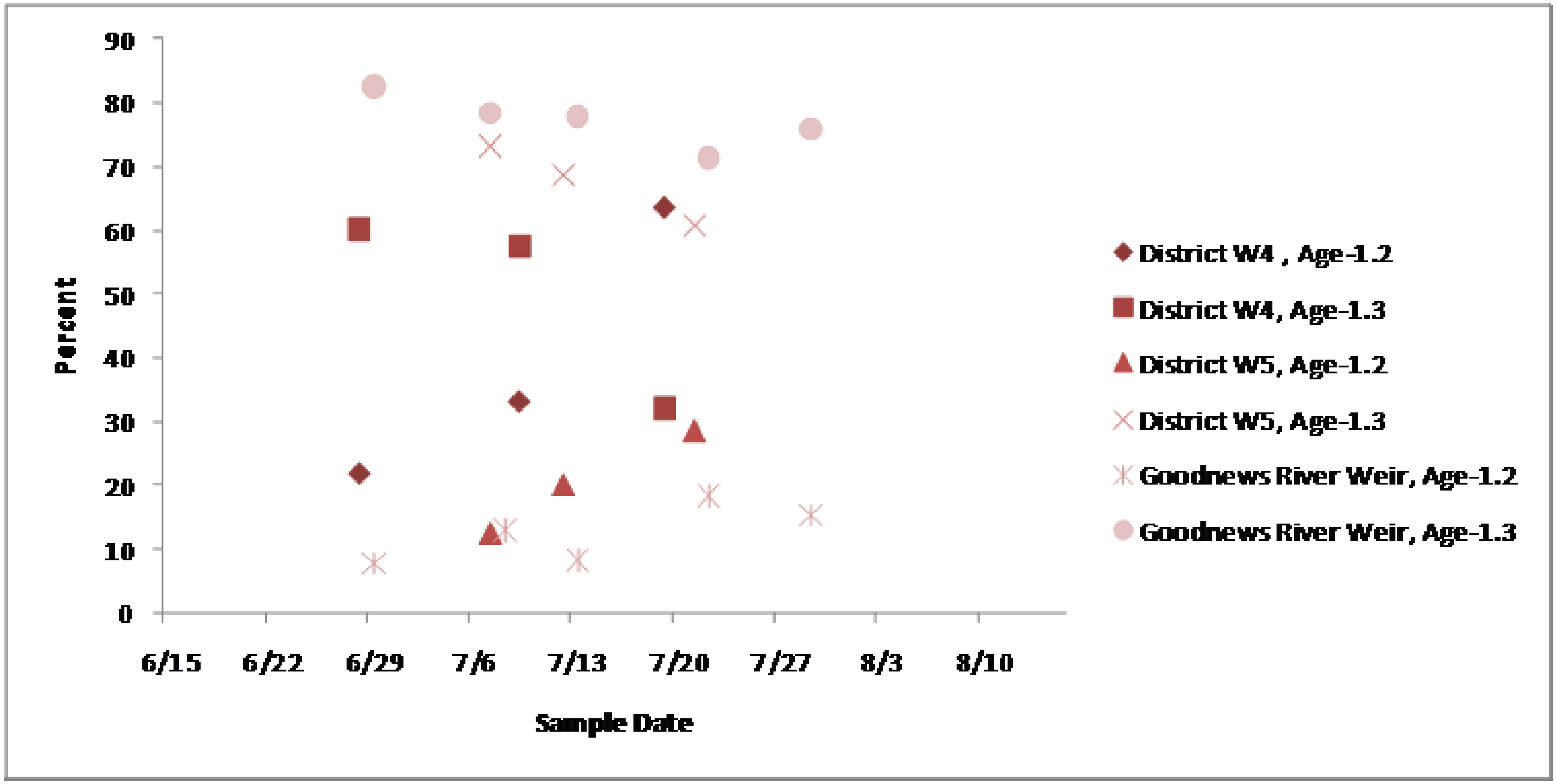


Figure 15.–Annual percentage of age-1.2 and -1.3 sockeye salmon returning to the Goodnews River weir, and harvested in commercial fishing districts 4 and 5, 1999.

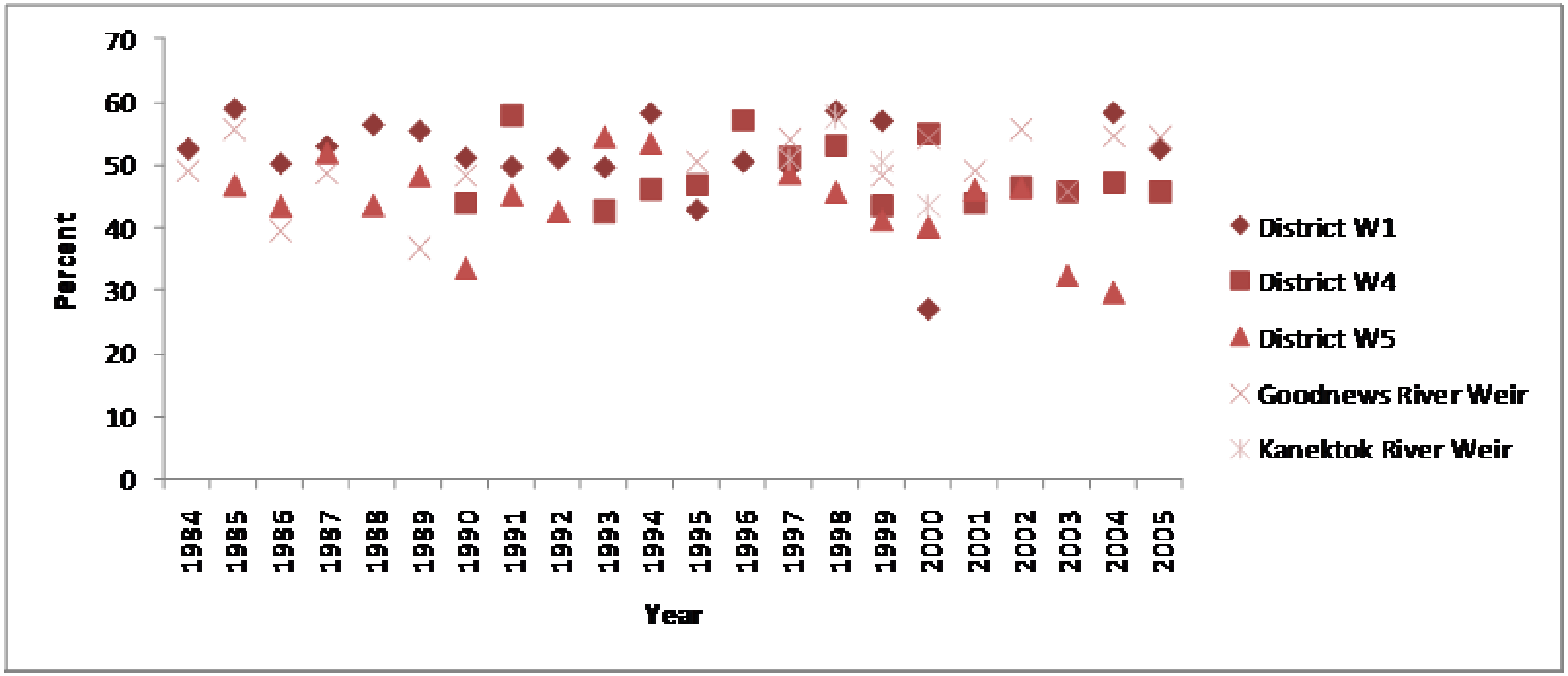


Figure 16.–Historic percentage of female sockeye salmon returning to the Goodnews and Kanektok River weirs, and harvested in commercial fishing.

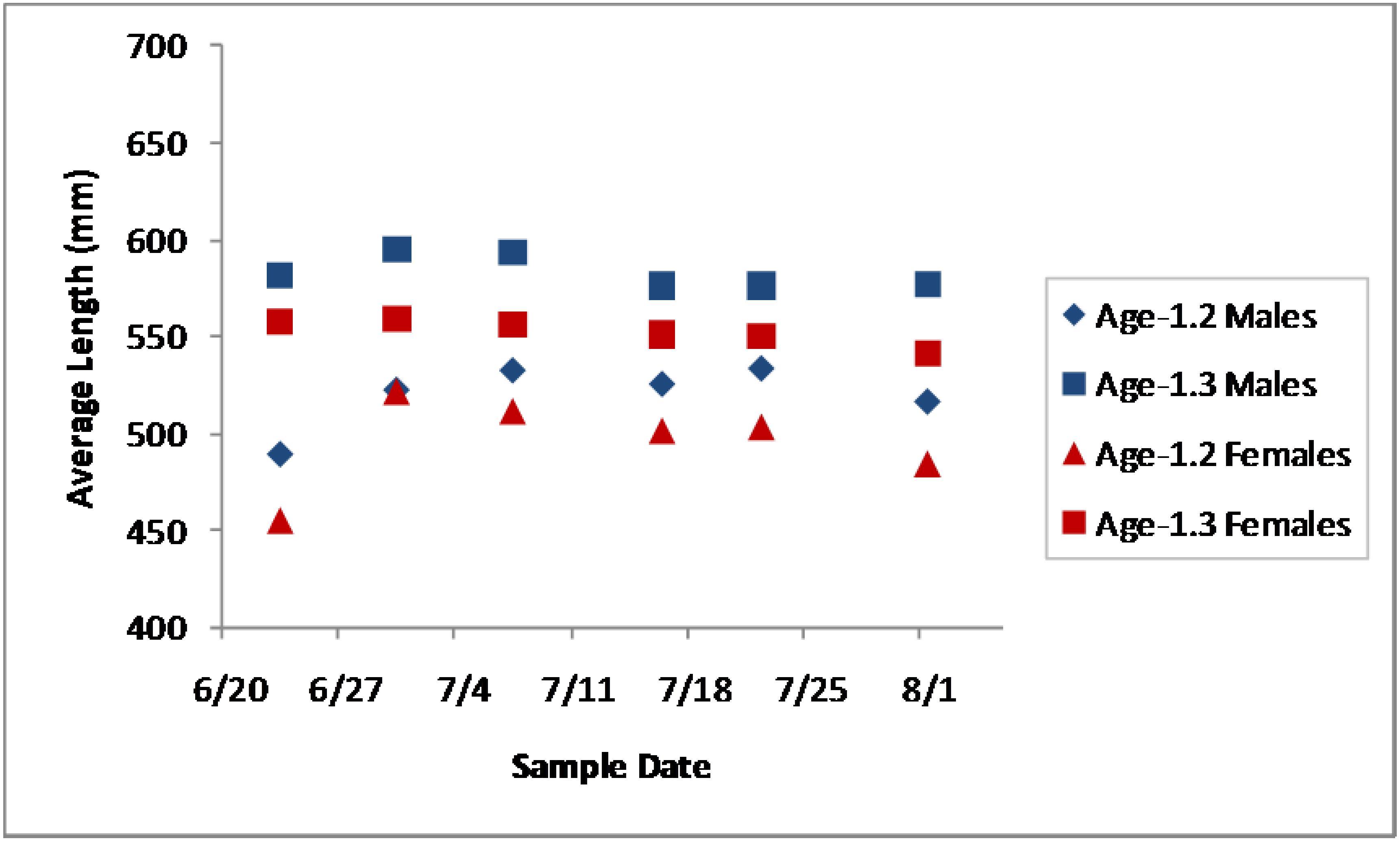


Figure 17.–Average length of male and female sockeye salmon age-1.2 and -1.3, returning to the Kanektok River weir, 1997.

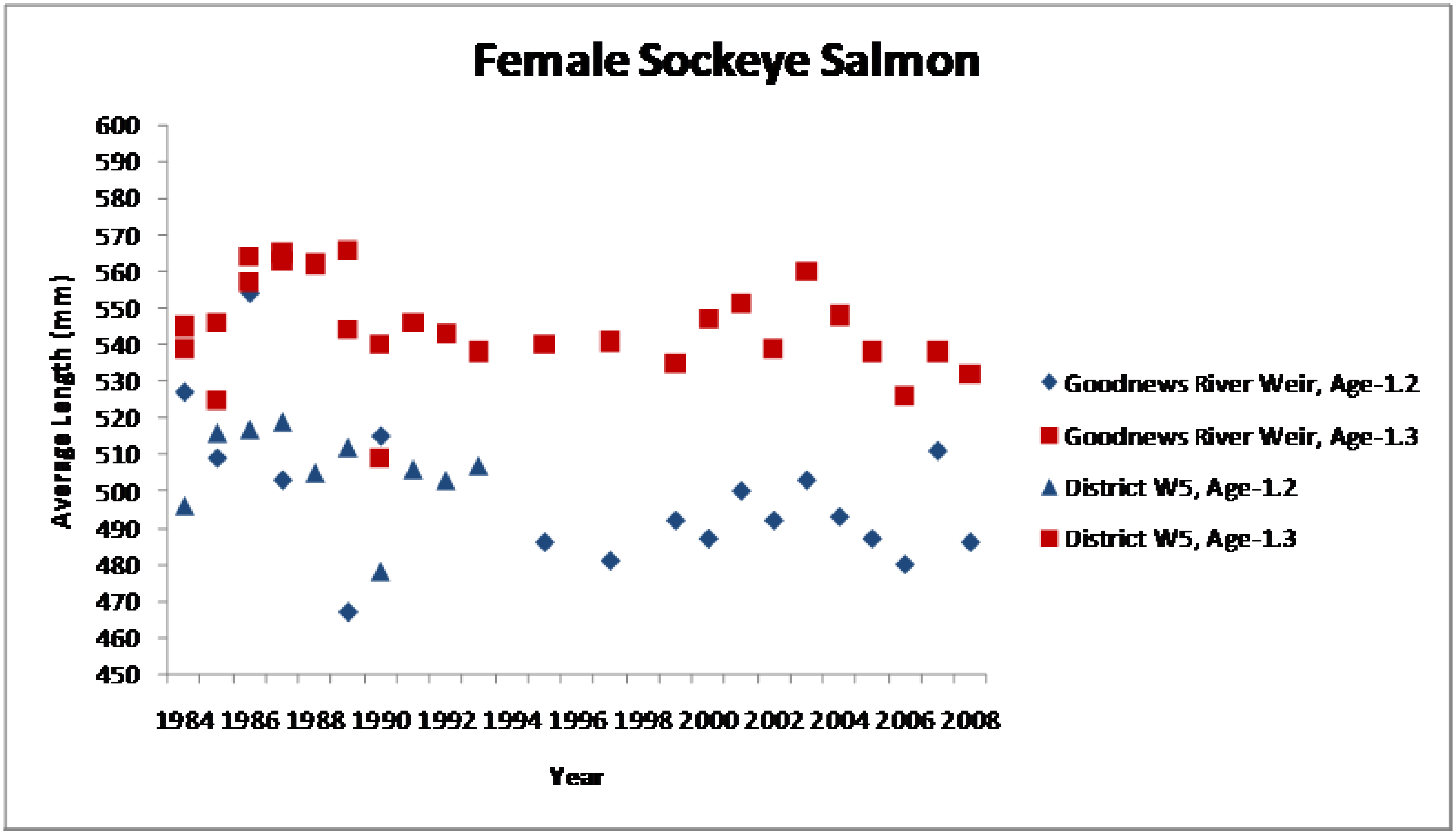


Figure 18.–Historic average length of female sockeye salmon age-1.2 and -1.3 returning to the Goodnews River weir compared with those harvested in commercial fishing District 5.

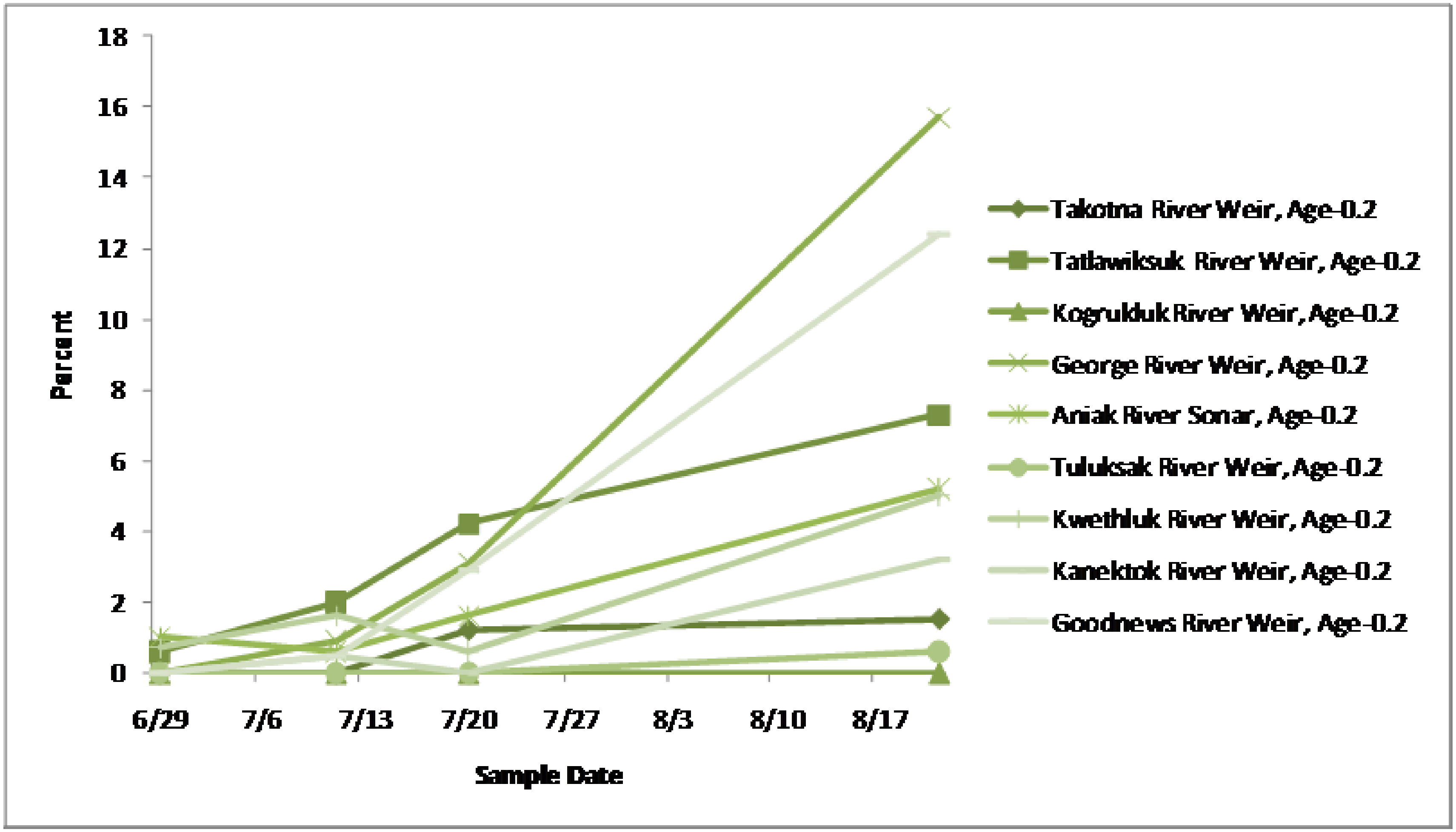


Figure 19.–Percent age-0.2 chum salmon returning to Kuskokwim Area escapement projects, 2002.

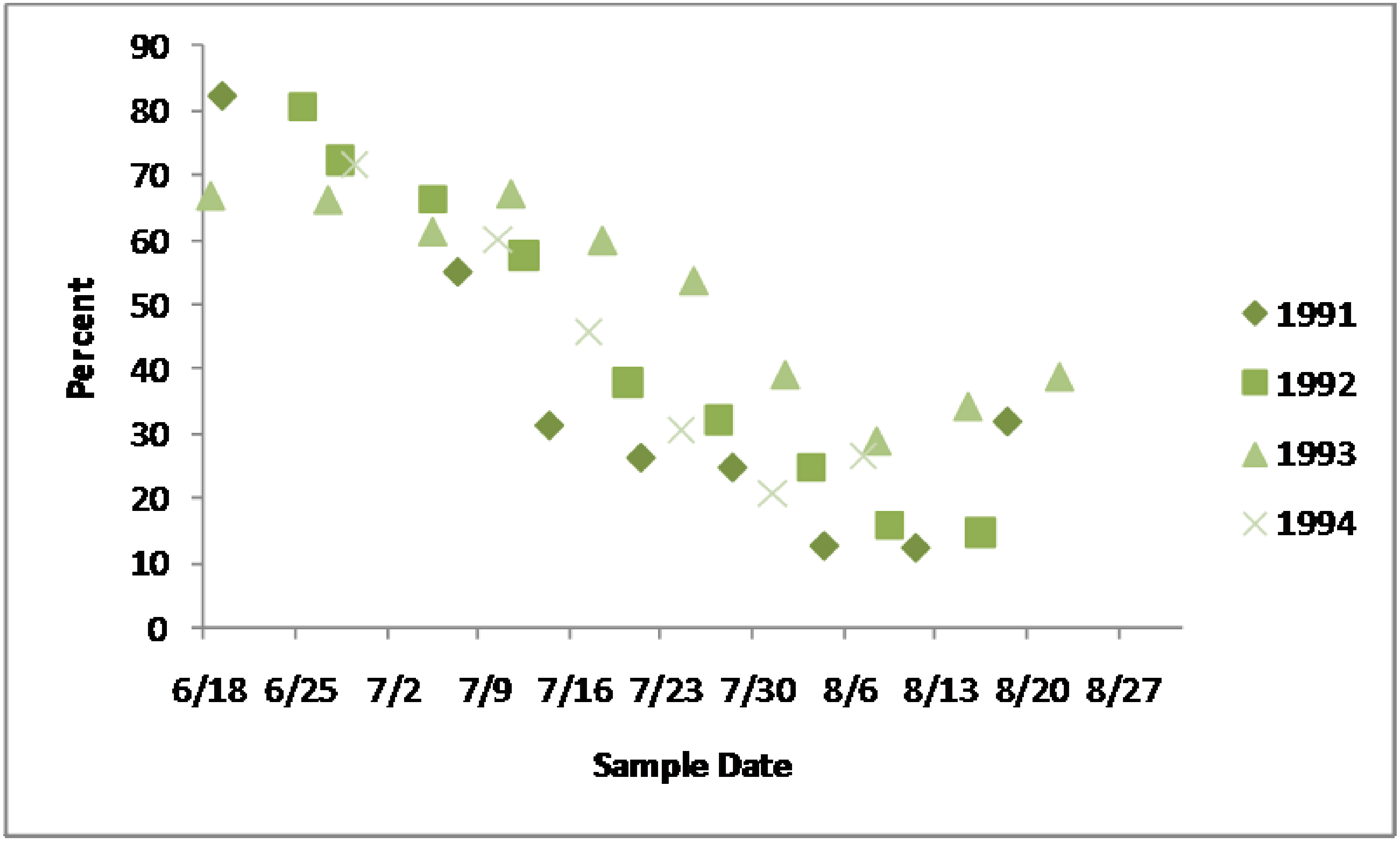


Figure 20.–Percent age-0.4 chum salmon returning to the Tuluksak River weir between 1991 and 1994.

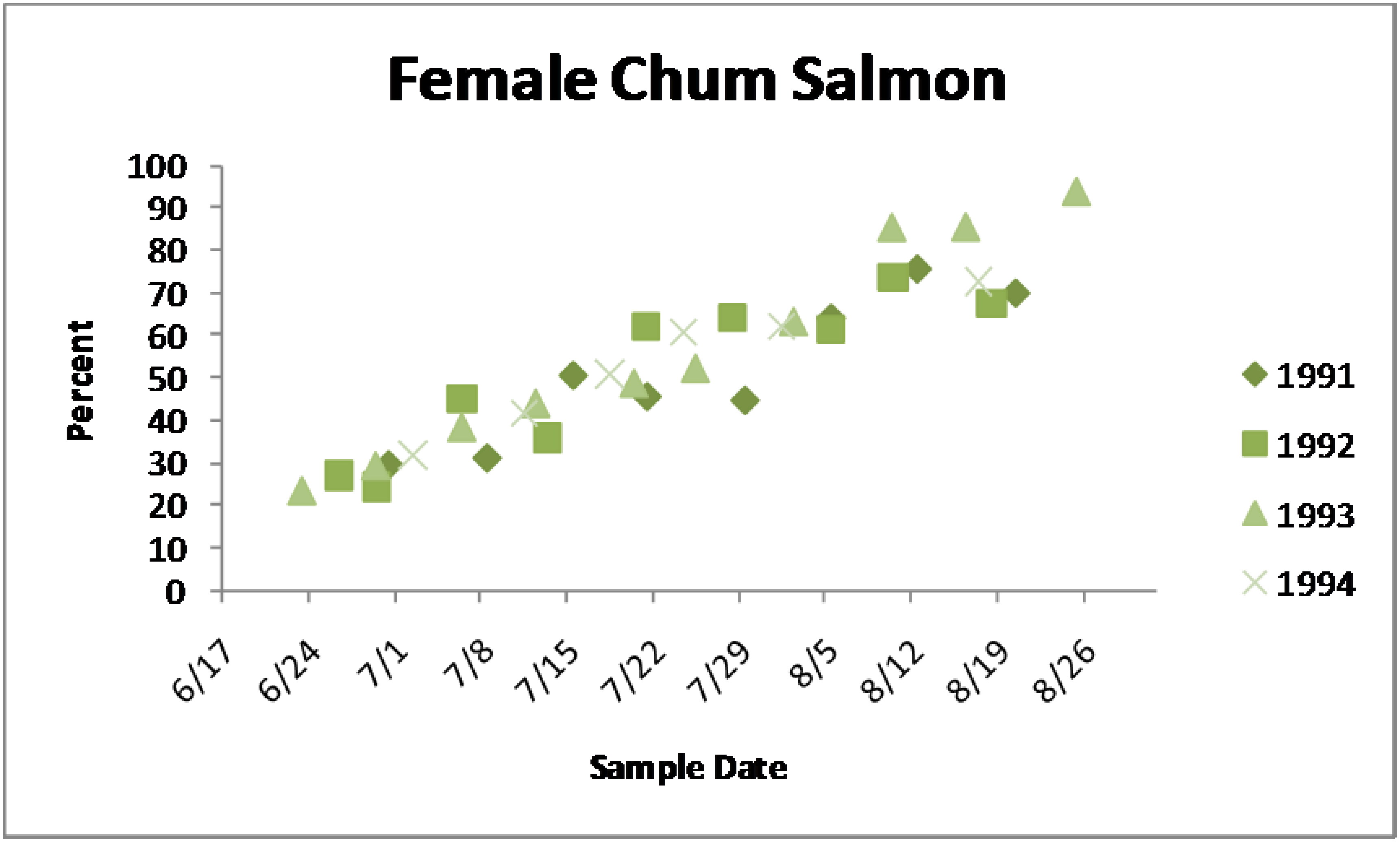


Figure 21.–Percent female chum salmon returning to the Tuluksak River weir between 1991 and 1994.

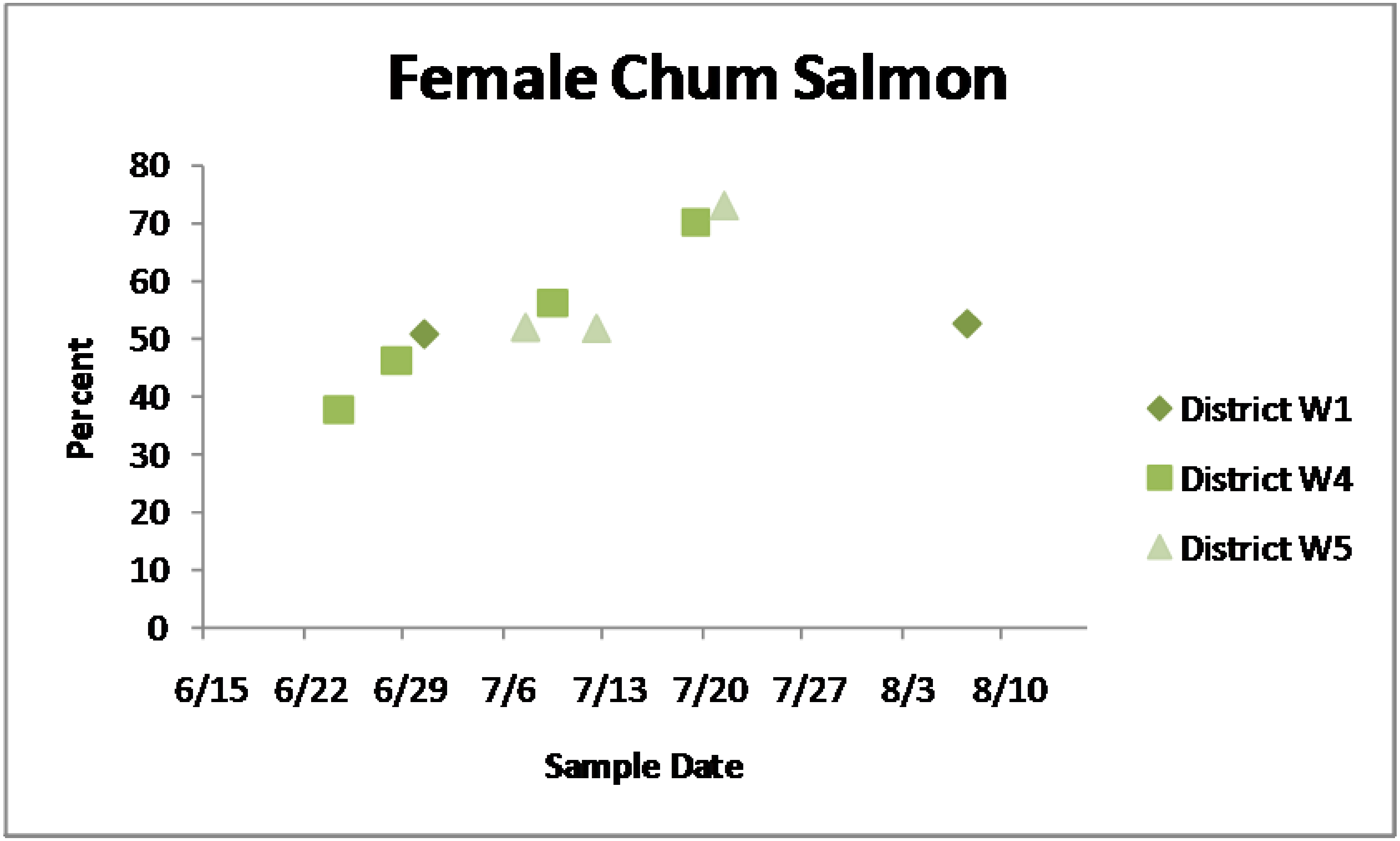


Figure 22.–Percent female chum salmon harvested in commercial fishing districts 1, 4, and 5, 1999.

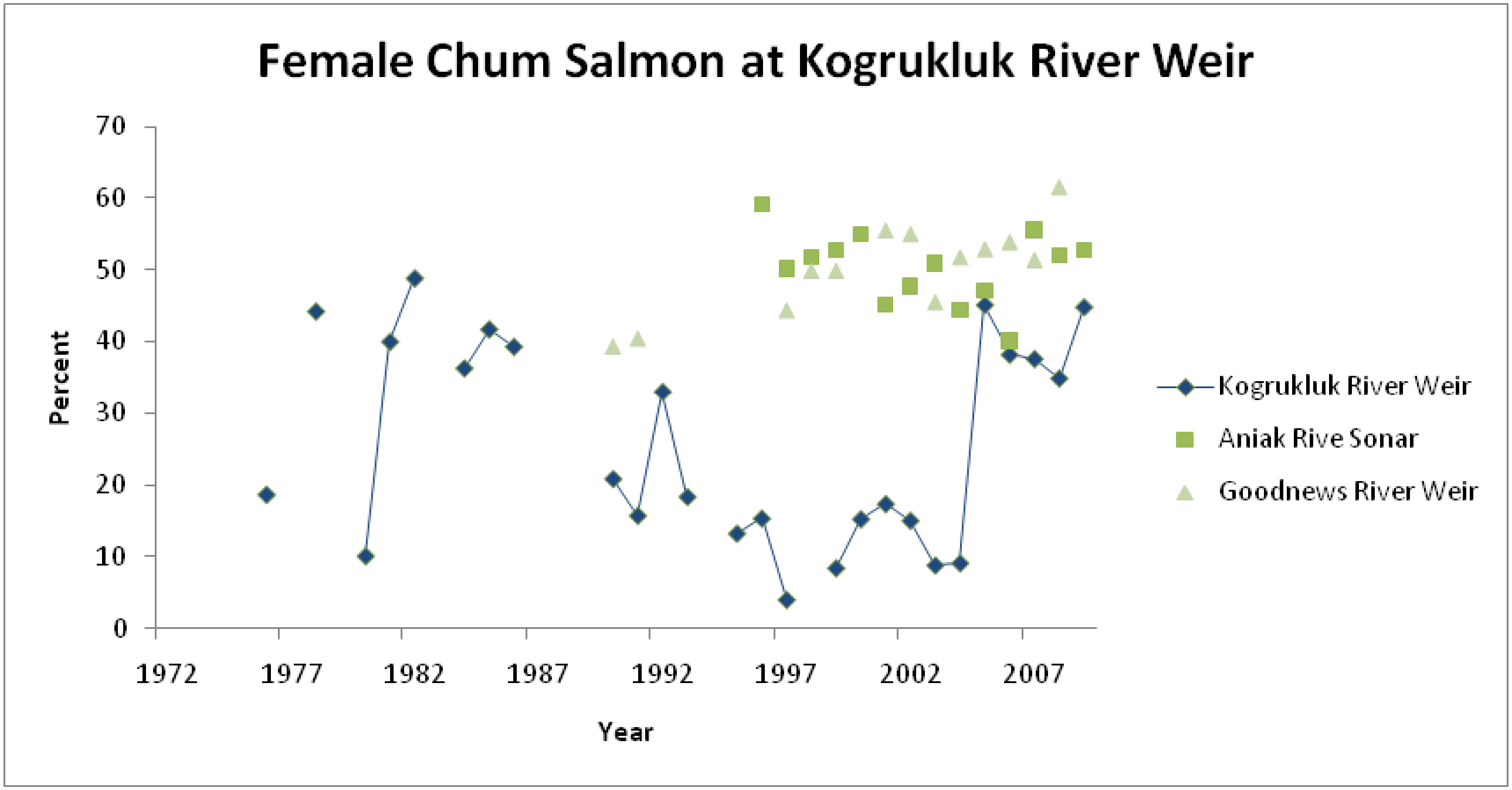


Figure 23.–Percent female chum salmon harvested in commercial fishing districts 1, 4, and 5, 1999.

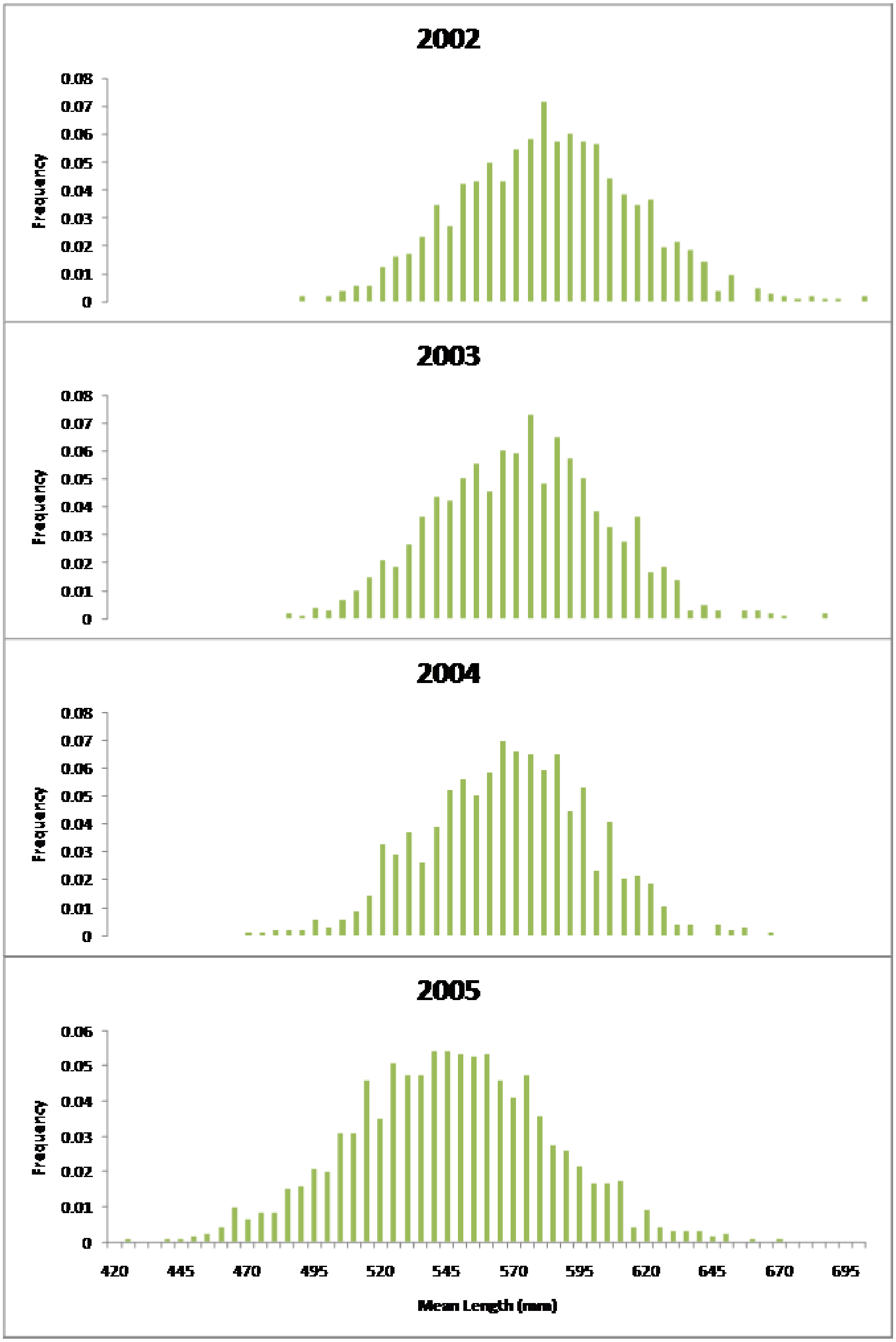


Figure 24.–Length frequency of chum salmon between 2002 and 2005.

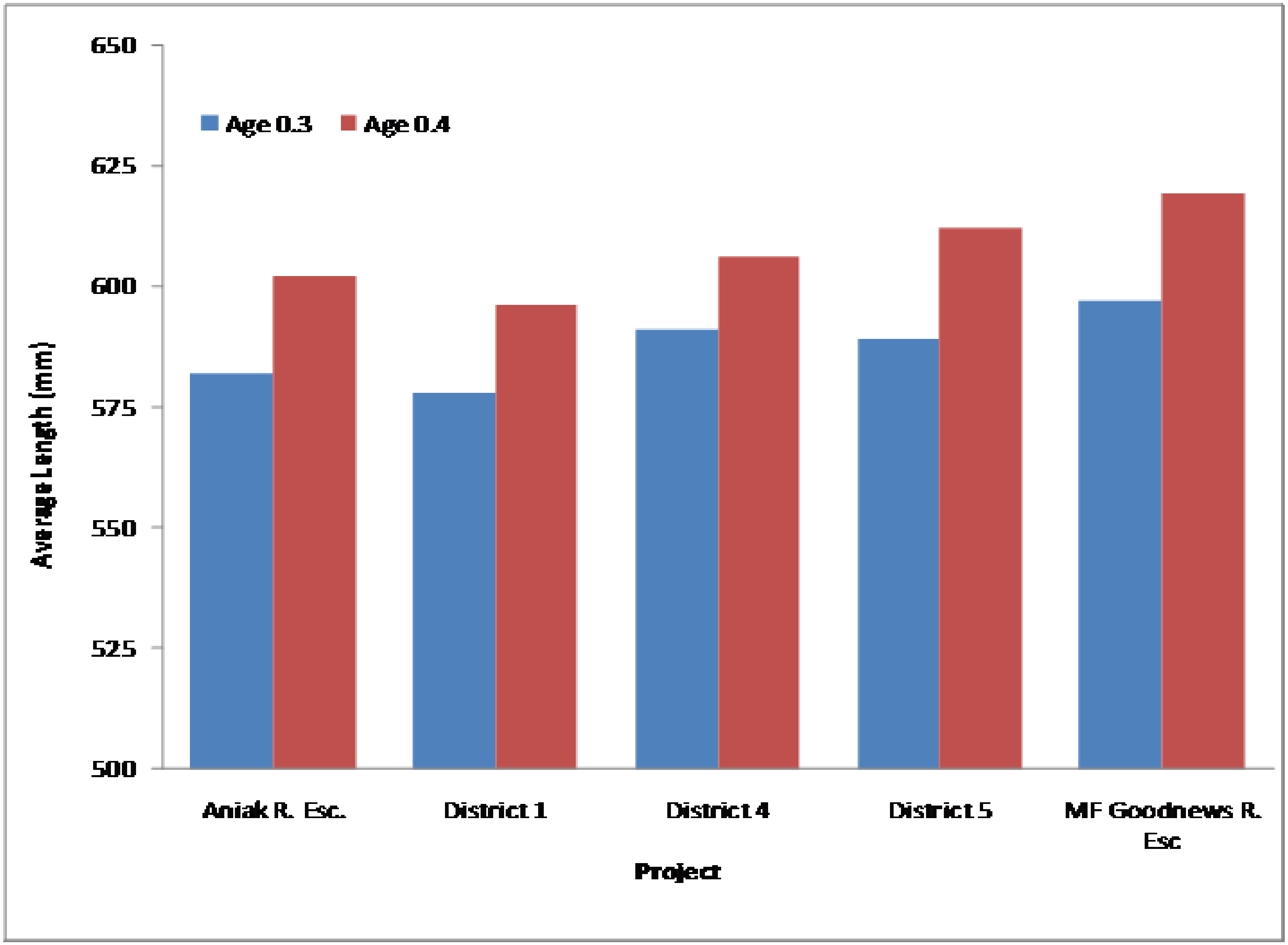


Figure 25.–Average length of male chum salmon from escapement and commercial catches in the Kuskokwim Area, 1999.

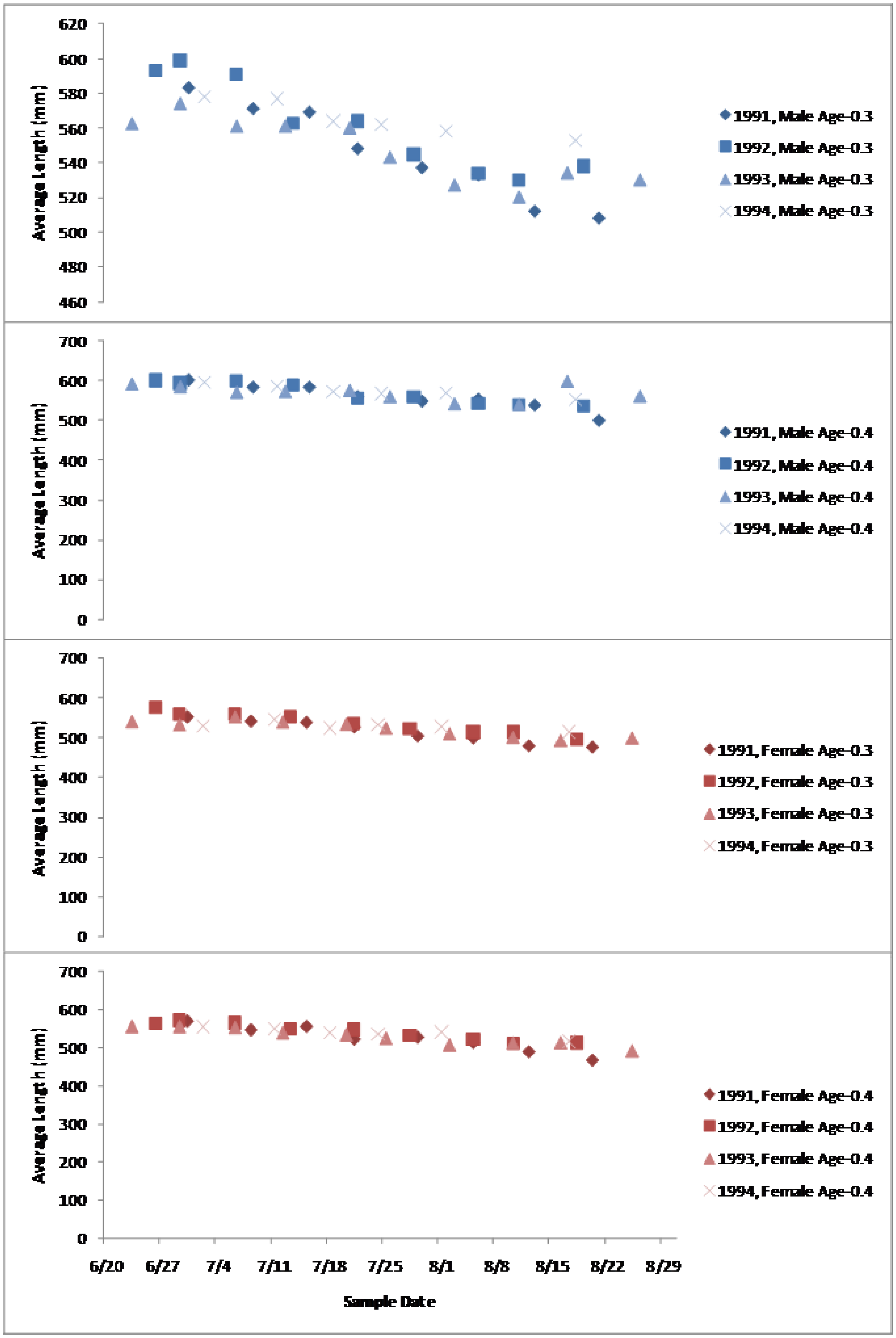


Figure 26.–Annual length at age of male and female chum salmon returning to the Tuluksak River weir, 1991–1994.

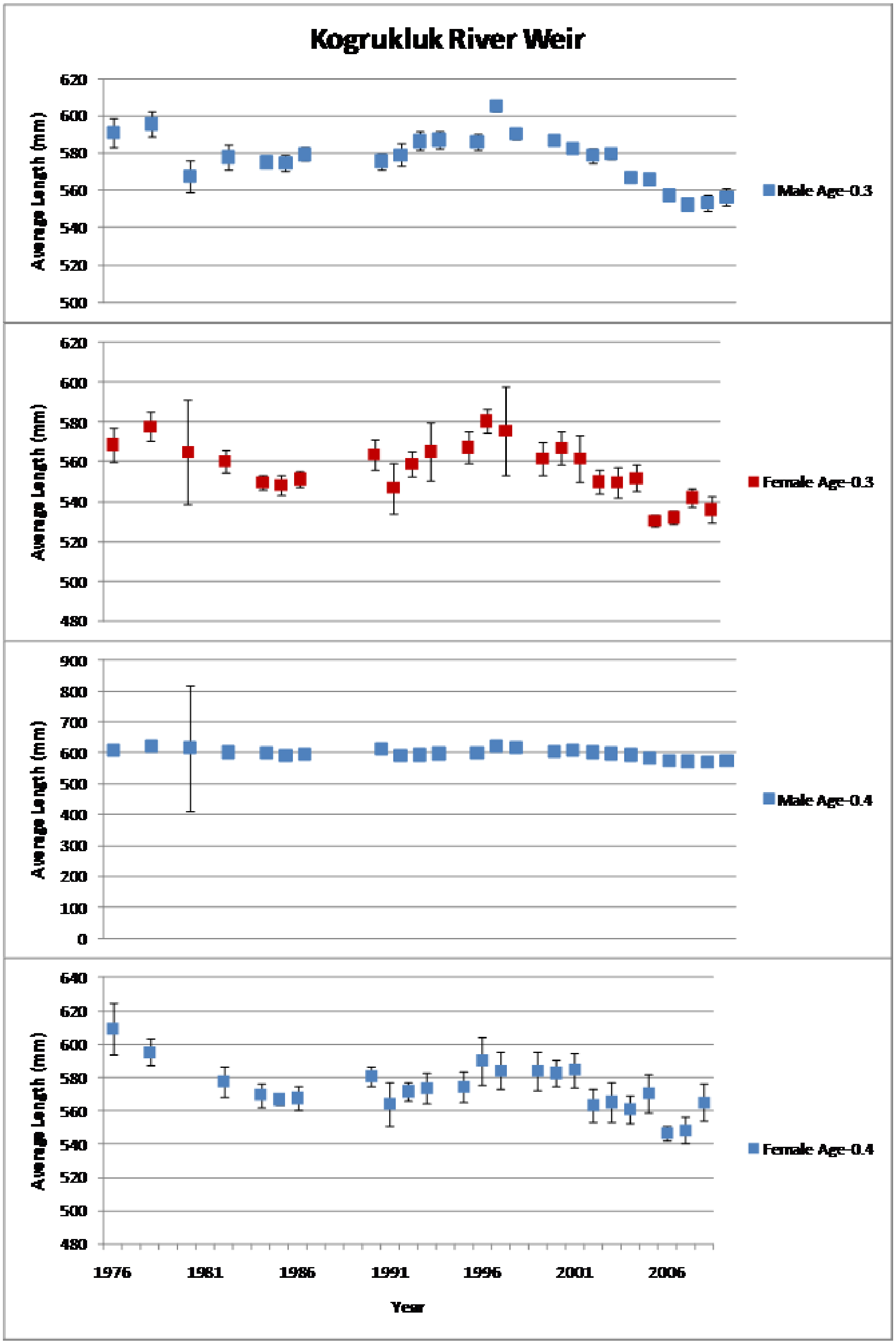


Figure 27.–Historical average annual length for chum salmon with 95% confidence intervals at the Kogrukluk River weir.

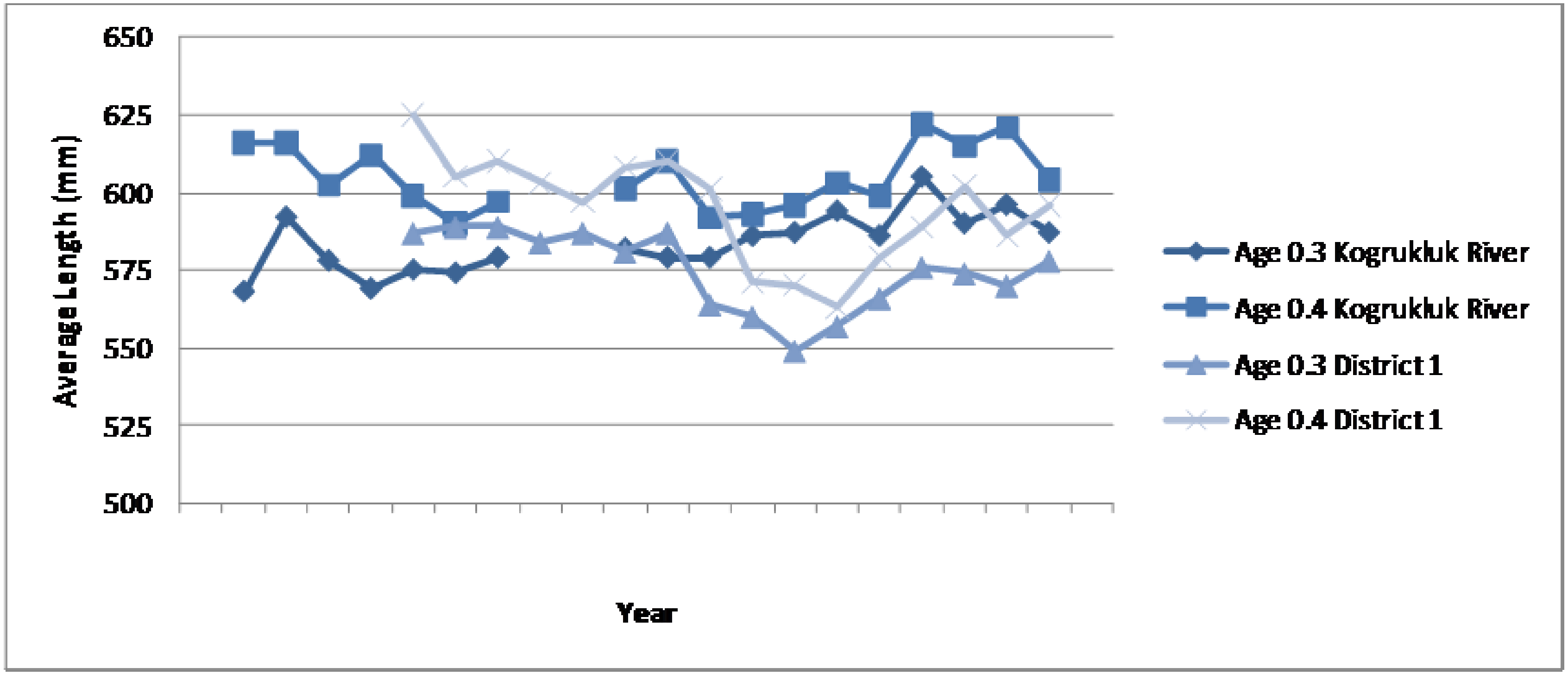


Figure 28.–Historical average length of male chum salmon from the Kogrukluk River escapement and district 1 commercial harvests by age, 1980–1999.

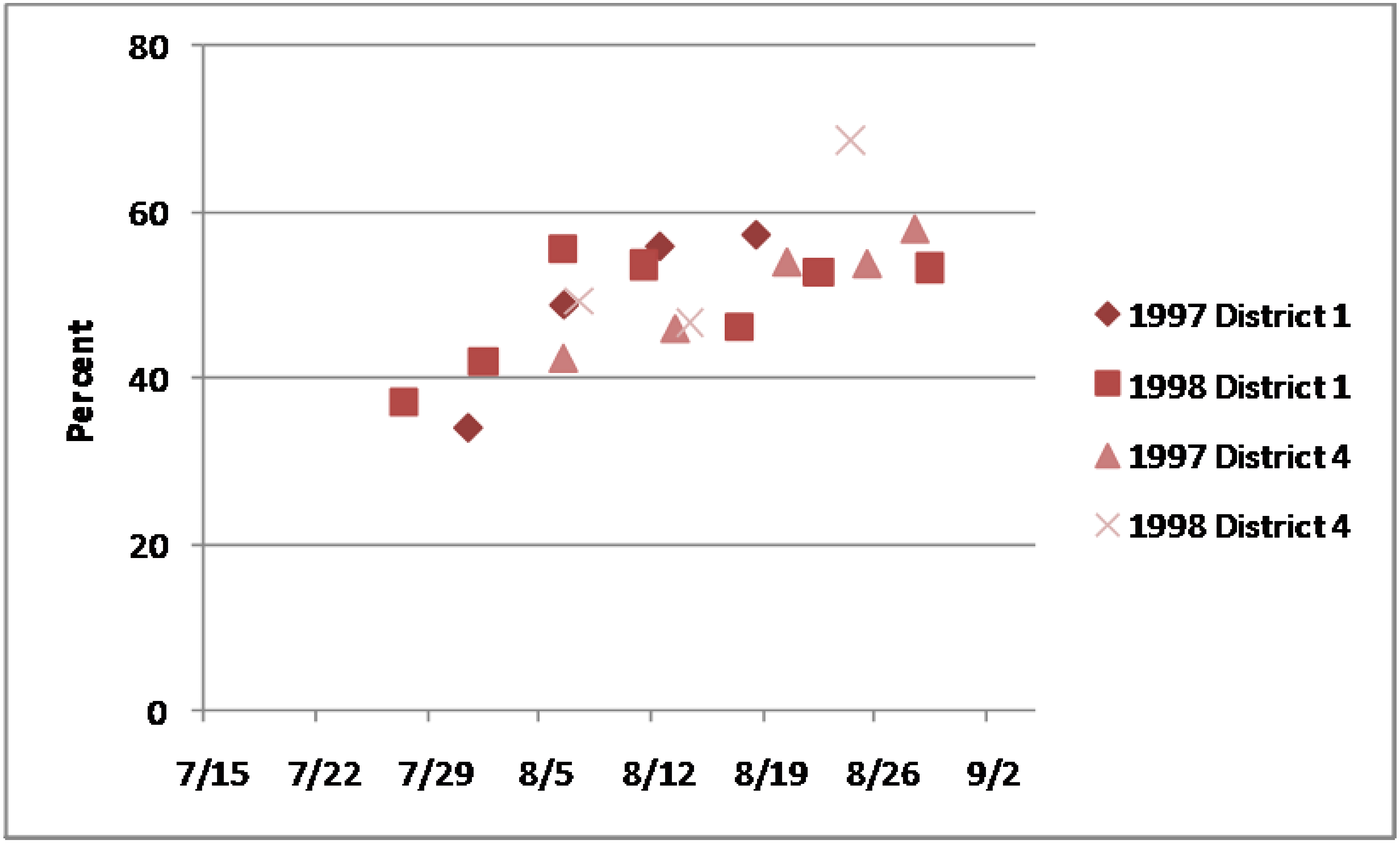


Figure 29.–Percentage of female coho salmon by sample date from commercial fishing districts 1 and 4 in 1997 and 1998.

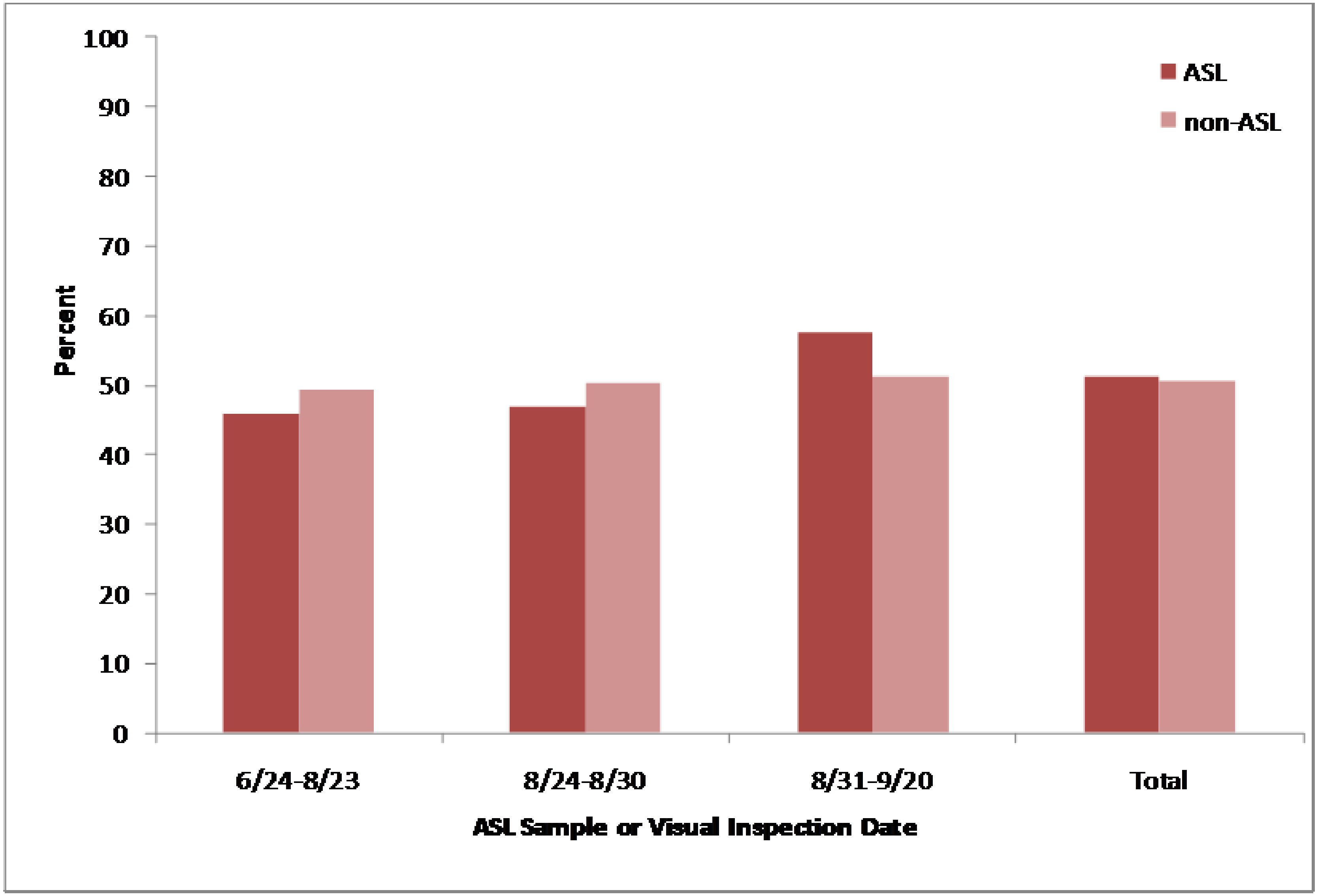


Figure 30.–Comparison of the percentage of female coho salmon passing upstream of the Takotna River weir as determined from standard ASL sampling using a fish trap, and from visual inspection of non-ASL sampled fish using standard fish passage procedures.

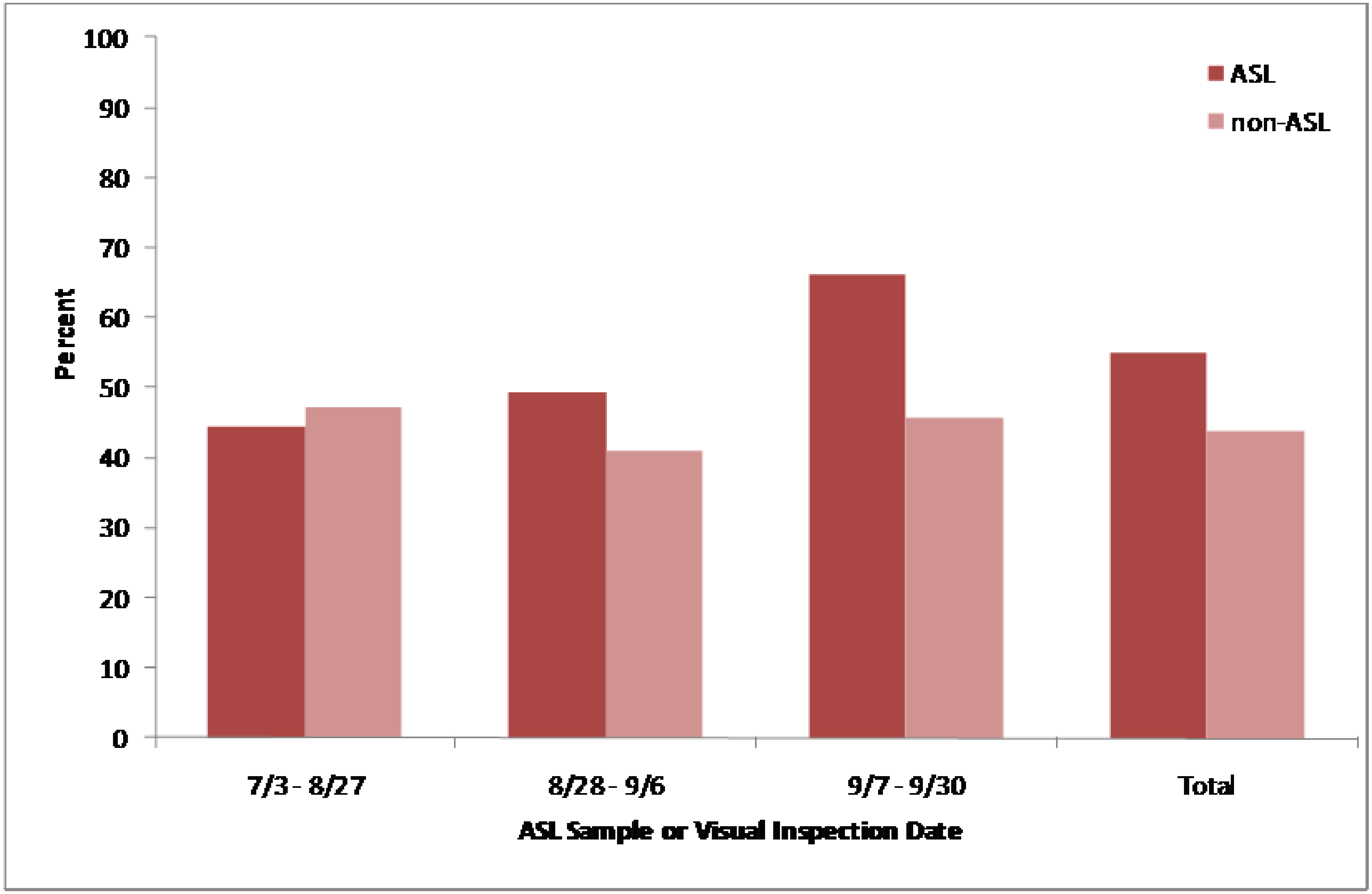


Figure 31.–Comparison of the percentage of female coho salmon passing upstream of the Kogrukluk River weir as determined from standard ASL sampling using a fish trap, and from visual inspection of non-ASL sampled fish using standard ASL sampling procedures, 2008.

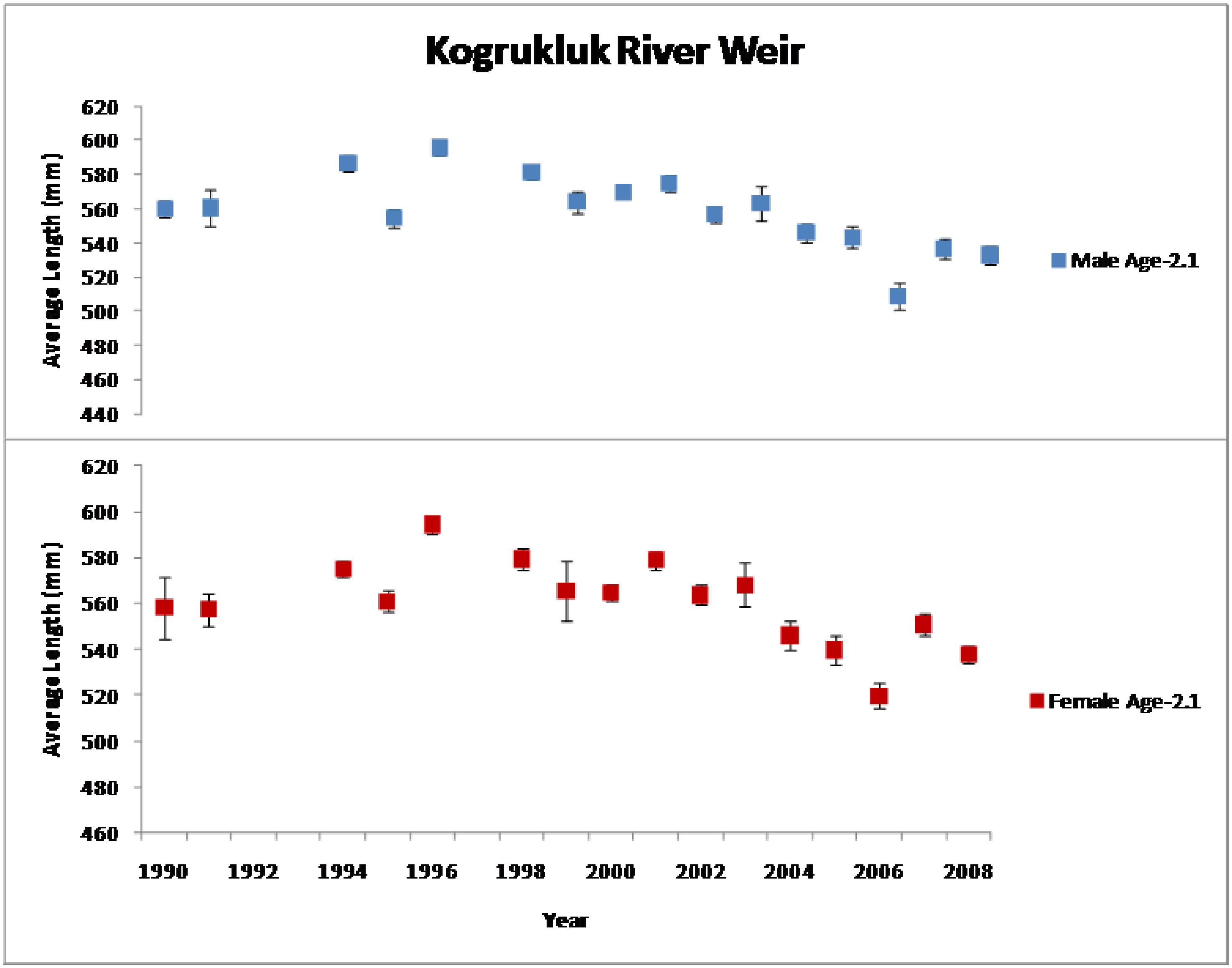


Figure 32.–Historical average annual length for coho salmon with 95% confidence intervals at Kogrukluk River weir.