SALMON AGE, SEX AND LENGTH CATALOG FOR THE KUSKOKWIM AREA, 1999 Progress Report

By

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and

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OEO/ADA STATEMENT

PREFACE

Over the years the Alaska Department of Fish and Game (ADF&G) has invested substantial resources into collecting and processing salmon age, sex and length (ASL) information in the Kuskokwim Area. From 1962 to 1981 results were presented annually in the *ADF&G Salmon Age, Sex, and Size Composition* report series. That series was replaced from 1982 through 1989 with the *Kuskokwim Management Area Salmon Catch and Escapement Statistics* annual report series. ASL information often appears in other documents as well, such as project and annual management reports. In nearly all of these documents only current year data is presented, making inter-annual comparisons cumbersome. As a result, actual use of the ASL database has been limited.

Efforts to compile all historical salmon ASL information into a single report led to the *Salmon Age, Sex and Length Catalog for the Kuskokwim Area, 1995 Progress Report* (Molyneaux and DuBois 1996). That report, and subsequent such reports, have not been exhaustive compilations of all historical ASL data, but they have included summaries that could be compiled given available resources. During the winter of 1999-2000, significant further progress was made compiling historical ASL data, and including newly acquired data for 1999. In fact, the extent of tabular information is now so extensive that there is a need to make it available in electronic format so as to contain this progress report to a manageable size. Tabular data have not yet been posted for electronic data sharing. In the interim, copies may be obtained upon request from the authors, or from the Bethel office of the ADF&G. As resources allow, additional historical information will be processed and added to future *Progress Reports*.

TABLE OF CONTENTS

	Page
LIST OF FIGURES	vii
INTRODUCTION	1
Escapement Monitoring	1
Commercial Fisheries	2
Subsistence Fisheries	4
Sport Fisheries	4
METHODS	5
Sample Collection	6
Sample Size	6
General Sampling Procedures	6
Escapement Sampling	6
Commercial Catch Sampling	7
Subsistence Catch Sampling	7
Data Processing and Reporting	8
Age Determination	8
Computer Processing Format	8
Strata Determination	9
Summary Types	10
Age-Sex Tables	10
Length Tables	10
RESULTS AND DISCUSSION	10
Escapement ASL Summaries	11
Tatlawiksuk River	11
Kogrukluk River	12
George River	12
Aniak River	13
Tuluksak River	13

TABLE OF CONTENTS (continued)

Page

Kwethluk River....14
Kanektok River....14
Middle Fork Goodnews River....15
Commercial Catch ASL Summaries....16
District 1....16
District 2....16
District 4....17
District 5....17
Subsistence Catch ASL Summaries....17
Trends In ASL Composition....18
Sources of Bias....18
Sampling Design....18
Carcass Sampling....18
Scale Absorption....19
Sex Determination....20
Chinook Salmon....20
Age Composition....20
Sex Composition....21
Length Composition....22
Sockeye Salmon....22
Age Composition....22
Length Composition....22
Chum Salmon....23
Age Composition....23
Sex Composition....23
Length Composition....24
Coho Salmon....25

TABLE OF CONTENTS (continued)

Page

Age Composition..25
Sex Composition..25
Length Composition..25

LITERATURE CITED..26

FIGURES..34

LIST OF FIGURES

Figure Page

1. Kuskokwim Area map showing salmon management districts and escapement monitoring projects....34

2. Incidence of male chinook salmon in trap and carcass samples from the Middle Fork Goodnews River weir in 1996 and the George River weir in 1997....35

3. Age and sex composition of District 1 chinook salmon harvested from commercial fishing periods in which gillnet mesh size was restricted to 6 inches or smaller, 1974-1999....36

4. Age and sex composition of District 1 chinook salmon harvested from commercial fishing periods in which gillnet mesh size was unrestricted, 1974-1984....37

5. Historical percentage of age-1.2 chinook salmon reported as males from Kogrukluk River weir and Districts 1, 4 and 5, 1990-1999....38

6. Historical percentage of age-1.3 chinook salmon reported as males from Kogrukluk River weir and Districts 1, 4 and 5, 1990-1999....39

7. Length frequency of District 1 chinook salmon by age and sex, 1999....40

8. Length frequency of District 4 chinook salmon by age and sex, 1999....41

9. Length frequency of District 5 chinook salmon by age and sex, 1999....42

10. Historical trends in the average length of chinook salmon at Kogrukluk River weir, 1984-1999....43

11. Percentage of age-1.2 and -1.3 sockeye salmon by sample date from the Middle Fork Goodnews River weir (MFG) escapement and the District 4 and District 5 commercial catches, 1999....44

12. Average length by sample date for Kanektok River sockeye salmon in 1997....45

13. Percentage of age-0.4 chum salmon by sample date in the Tuluksak River, 1991-1994....46

14. Percentage of age-0.4 chum salmon by sample date from Kuskokwim Area escapements and commercial catches, 1999....47

Figure Page

15. Percentage of female chum salmon by sample date at Tuluksak River weir, 1991-1994 48

16. Percentage of female chum salmon by sample date from Kuskokwim Area escapements and commercial catches. 1999 49

17. Historical percentage of female chum salmon in Kuskokwim Area escapements and commercial catches, 1976-1999 50

18. Historical percentage of female chum salmon by sample date at Kogrukluk River weir, 1980-1999 51

19. Average length of male chum salmon from escapements and commercial catches in the Kuskokwim Area, 1999 52

20. Average length of chum salmon by sample date in the Tuluksak River, 1991-1994 53

21. Historical average length of male chum salmon from Kogrukluk River and District 1 by age, 1980-1999 54

22. Percentage of female coho salmon by sample date from Districts 1 and 4 commercial catches, 1997 and 1998 55

INTRODUCTION

The Kuskokwim Management Area encompasses waters from Cape Newenham to the Naskonat Peninsula, including the waters around Nunivak and St. Matthew Islands (Figure 1). The Kuskokwim, Kanektok, and Goodnews Rivers are the primary salmon producing systems. These rivers drain into Kuskokwim Bay and support runs of chinook *Oncorhynchus tshawytscha*, sockeye *O. nerka*, chum *O. keta*, pink *O. gorbuscha*, and coho salmon *O. keta*. All five of these salmon species are harvested in commercial, subsistence and sport fisheries in the area.

Mature salmon begin to leave marine estuaries and enter freshwater streams of the Kuskokwim Area by late May. Chinook salmon are the first species to arrive, with the bulk of the runs entering freshwater by early July. Small numbers of chinook continue to arrive into August (Molyneaux 1998). Most sockeye salmon arrive between mid-June and late July; however the Kuskokwim River sockeye run is more compressed than the Kuskokwim Bay runs. The majority of Kuskokwim River sockeye enter the lower river by early July. Chum salmon enter freshwater between mid-June and late July. A relatively small but distinct late running population of chum salmon can be found passing through the lower Kuskokwim River by mid-July, however little is known about these late spawning fish. Pink salmon appear in area streams during July and early August and demonstrate strong even-year dominance (Burkey et al. 1997). Coho salmon begin to enter freshwater in late July with the bulk of the entry completed by early September (Molyneaux 1998). Small numbers of coho salmon reportedly continue to enter rivers late into the fall and early winter when the rivers are iced over.

Escapement Monitoring

Annual assessments of salmon spawning escapements are monitored in the Kuskokwim Area by means of weirs, counting towers, a sonar project and aerial surveys (Burkey et al. 1997). The ground based weir, tower and sonar projects typically include some form of ASL sampling program whereby salmon are captured with beach seines, traps or by hook and line for the purpose of collecting ASL data. In some instances carcass sampling may be employed. Streams with the longest histories of ground based escapement monitoring include the Kogrukluk[2] (1969-1999), Aniak (1980-1994, 1996-1999) and Middle Fork Goodnews Rivers (1981-1999, Figure 1). Other streams with less extensive monitoring histories include the South Fork Salmon River of the Pitka Fork drainage (1981-1982), Takotna (1995-1999), Tatlawiksuk (1998-1999), George (1996-1999), Tuluksak (1991-1994), Kwethluk (1992, 1996-1999) and Kanektok Rivers. An overview of these projects was presented to the Alaska Board of Fisheries by Burkey et al. (1997).

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[2] The Kogrukluk River weir has alsobeen referred to as the Ignatti weir and the Holitna River weir.

Most escapement monitoring projects are, or were, operated from mid-June through late July of each year. This timing typically encompasses the bulk of chinook, chum and sockeye runs, but only a fraction of the pink and coho returns. The primary exception is the Kogrukluk River weir, which has been operated through most of the coho season nearly every year since 1981. Pink salmon counts at Kogrukluk River are incomplete because of the wide spacing of the weir pickets (Cappiello and Burkey 1997). Tuluksak and Kwethluk River weirs, which were operated in 1991-1994 and in 1992 respectively, were also maintained through the pink and coho seasons. More recently, the Middle Fork Goodnews River weir project was continued through most of the 1997-1999 pink and coho runs. The George River weir was operated through most of the 1997 and 1999 coho runs. The Tatlawiksuk River weir was operated through most of the 1999 coho run.

A late run of chum salmon occurs in the Kuskokwim River, but they are not incorporated into any escapement monitoring program. Their existence is documented through subsistence reports (Stokes 1983, 1985), personal communications with area residents, aerial surveys, and genetic baseline collections (Seeb et al. 1997). The population is assumed to be relatively small, although it was estimated to comprise about 12% ($\pm$4%) of a random mixed stock commercial catch sample collected at Bethel on July 17, 1996 (Molyneaux and DuBois 1998). These late run chum salmon spawn in September and October rather than July and August as is characteristic of other Kuskokwim Area chum populations. Spawning grounds have only been documented as occurring in a few large upper Kuskokwim basin tributaries such as the Big River, Middle Fork, Pitka Fork and South Fork Kuskokwim Rivers (Figure 1). Visibility in these streams is limited due to suspension of glacial sediments. Chum salmon were found spawning in side channels where visibility was less occluded. The late spawning Kuskokwim chum salmon are genetically distinct from Yukon River fall chums, although their run timing and spawning behavior appear similar. No ASL information is available which is specific to the late run chum salmon of the Kuskokwim River, but they are undoubtedly included in the mixed stock commercial samples from the lower Kuskokwim River.

Commercial Fisheries

Commercial salmon fishing occurred in the Kuskokwim area prior to 1900, but the fish were mostly sold or traded for local consumption (Zagoskin [1847] 1967, Oswalt 1990). Local markets expanded near the turn of the century as salmon were used to feed the growing number of dog teams associated with mining development. The actual magnitude of this harvest is undocumented.

The earliest commercial salmon fishery for export occurred in Kuskokwim Bay in 1913. Kuskokwim River was closed to commercial export of fish until 1935. The river was again closed, or restricted, throughout much of the 1950s due to concerns of over-exploitation voiced by subsistence fishers (Pennoyer et al. 1965). Prior to statehood, harvests were often undocumented, although effort was relatively low until export markets improved in the 1970s (Burkey et al. 1997).

The Kuskokwim Salmon Management Area is currently divided into four commercial fishing districts (Figure 1). The boundaries of these districts have shifted over the years and the changes are described in annual management reports (Burkey et al. 1998). Notwithstanding the boundary changes, District 1 is located in the lower Kuskokwim River and currently extends from Kuskokwim Bay to Bogus Creek, a distance of over 200 km (130 mi). District 2 spans a distance of approximately 100 km (65 mi) in the middle Kuskokwim River, currently extending from near Kalskag to Chuathbaluk. Since 1988, Districts 1 and 2 have been separated by a section of river about 75 km (46 mi) in length, which is closed to commercial fishing. Prior to 1966, all waters above District 2 were referred to as District (or subdistrict) 3. In 1966 District 3 was deleted from the regulations, and since that time, the upper Kuskokwim River has been closed to commercial fishing (Francisco et al. 1995). District 4 is located in the marine waters of Kuskokwim Bay near the community of Quinhagak. The Kanektok River is the principle salmon producing stream for District 4. 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 the principal gear type used in all Kuskokwim Area commercial salmon fisheries, although set gillnets were common in some locations during the early development of the fisheries. Prior to 1985, commercial fishers in the Kuskokwim River were unrestricted as to the mesh size of gillnets used, and many chose 8 or 8.5 inch (20 or 22 cm) mesh sizes during the June chinook fishery (Burkey et al. 1997). Commercial gillnets are currently restricted in all Kuskokwim Area commercial fishing districts to mesh sizes of 6 inches (15.2 cm) or smaller. The maximum allowable gillnet dimensions are 50 fathoms in length and 45 meshes deep. The mesh size restriction has been imposed in the Kuskokwim River since 1985 in an effort to improve declining chinook escapements. Commercial fishers in Kuskokwim Bay districts have been restricted to the smaller mesh sizes since the inception of those fisheries. Results from commercial catch sampling described in this report are from restricted mesh openings unless stated otherwise.

The commercial fisheries in Districts 1 and 2 are currently directed at chum salmon in June and July and coho salmon in August (Burkey et al. 1997). Prior to 1987, the fisheries were directed at chinook salmon in June, but that practice was discontinued because of declining chinook escapements in the mid-1980s. The directed chinook commercial fishery has remained closed in the Kuskokwim River in order to maintain historical levels of subsistence use of the species. Currently, the commercial harvest of chinook and sockeye salmon from the Kuskokwim River is considered incidental to chum salmon.

In contrast, chinook and sockeye salmon are targeted by commercial fishers in District 4 during June and July while coho are the focus in August. Chum catches are considered incidental in District 4. The District 5 commercial fishery is currently directed at sockeye in June and July, and coho salmon in August. Historically, chinook salmon were also targeted in District 5, but declining run size has shifted the management strategy towards a chinook rebuilding plan which prohibits a directed commercial fishery for chinook salmon.

Subsistence Fisheries

The subsistence harvest of fish and wildlife is a prominent and vital element to the way of life of residents in the Kuskokwim Area (Oswalt 1990, Coffing 1991 and 1997). Approximately 1,500 families participate in subsistence salmon fishing (Burkey et al. 1998). Alaska state law mandates that subsistence use of fish populations has priority over other uses (AS 16.05.258). Subsistence fishing occurs throughout the Kuskokwim Area, but the majority of effort takes place in the lower 219 km (136 mi) of the Kuskokwim River (District 1). Traditionally, most subsistence harvest focused on chum salmon for feeding sled dogs that were used for winter transportation. But the subsistence chum harvest has declined as snow machines and airplanes replaced sled dogs as the primary means of winter transportation. The average chum salmon harvest decreased from 200,000 in the 1960s to less than 100,000 in the 1990s (Burkey et al. 1997). Subsistence harvest of chinook salmon, especially large chinook salmon, is used more for human consumption. The average subsistence chinook harvest has increased from about 33,000 in the 1960s to 87,000 in the 1990s (Burkey et al. 1998).

The gear types used by subsistence salmon fishers include drift and set gillnets, fish wheels, rod and reel, seines and spears (Burkey et al. 1997). Drift gillnets are overwhelmingly the most common contemporary gear type in use (Coffing 1997). Unlike commercial fishing, there is no restriction on the mesh size of gillnets used for subsistence fishing. Many fishers choose 8.0 or 8.5 inch (20 or 22 cm) mesh sizes to target larger chinook salmon. The 1994 annual subsistence survey of the Kuskokwim Area included information about the gillnet mesh sizes fishers used to harvest chinook salmon (Francisco et al. 1995). Of 497 respondents, 51 percent reported that they used 8.0 inch mesh or larger, 44 percent used 6.0 inch mesh or smaller, and 5 percent used a mesh size between 6 and 8 inches.[3] These results are comparable to those reported in 1967 where of 588 fishing families surveyed, 517 reported using 'king nets' and 513 reported using 'chum nets' for subsistence fishing (ADF&G 1968).

Sport Fisheries

Sport fishing activity is relatively low in the Kuskokwim Area, although moderate effort does occur in a few specific locations such as the Kanektok, Goodnews, Kisaralik and Aniak Rivers. These streams account for the majority of total angler-days reported for the Kuskokwim Area (Howe et al. 1996). Professional guiding outfits focus mostly on these four river systems, but there is a growing number of guides expanding into other locations such as the Holitna, George, Oskawalik and Holokuk Rivers. There are also a growing number of local area residents using rod and reel gear. While technically regulated as sport fishers, many of these local anglers identify their rod and reel

[3] Francisco et al. (1995) list the total respondents to the gillnet mesh size question as 490 (p 28 and Table 26), however as per discussion with Michael Coffing (ADF&G, Subsistence Division, Bethel), the actual number of respondents is 497. The percentages presented in this report have been corrected accordingly.

catches as part of their subsistence harvest and report it as such (Stokes 1985 and Coffing 1991). In some parts of the Kuskokwim Area the concept of 'sport' or 'recreational' fishing is viewed negatively as wasteful and damaging to the fish (i.e., an important food source). For many the sport fish industry also has a negative association with encroachment by non-locals. These perceptions obscure harvest documentation and the distinction of rod and reel as a sport-fish only gear type (Stokes 1985). This distinction has been divisive and formally called into question at the 1997 Alaska Board of Fisheries meeting. Action was taken on this issue during the March 2000 Board meeting in Anchorage, allowing the use of hook and line gear for subsistence fishing in parts of Western Alaska.

METHODS

As observed from a given location, such as an escapement monitoring project or a fishing district, the ASL composition of a returning salmon population often changes over the course of the season. Each year, salmon are sampled at such locations to estimate the age, sex and length compositions of the respective catches or escapements. Pulse samples of ASL information are collected periodically over the duration of the run to account for the temporal dynamics of populations. Ideally, a series of several well distributed pulse samples are collected for each species and each project or fishery. Each series should include a minimum of three pulse samples representative of the early, middle and late portions of the run. Collecting additional pulse samples allows for greater resolution in detecting temporal changes, and greater reliability in characterizing the true composition of the escapement or catch. For populations whose ASL composition changes over the course of the season, pulse sampling has a greater power of detecting that change than does random sampling, systematic sampling, or two closely spaced "grab" samples (Geiger and Wilbur 1990).

Each pulse sample is assigned to a temporal segment, or strata, of the run which the sample is intended to characterize. The age-sex composition of the sample is then applied to the fish passage, or harvest, that occurs in each stratum. This yields an estimate of the number of fish of each age-sex class in the harvest or escapement for each stratum. The apportioned fish in each stratum are then summed by age and sex to estimate the composition of the population for the entire season. Average fish length for the season is described by age and sex, and derived by weighting the average length in each stratum by the number of fish represented by that stratum. These procedures yield weighted season estimates of the salmon ASL composition for each project or fishery.

Sample Collection

Sample Size

The sample size of each pulse is determined following the convention described by Bromaghin (1993). The goals for each strata by species are: 210 chinook, 210 sockeye, 200 chum and 170 coho salmon. The sample sizes vary between species due to differences in the number of major age-sex groupings that need to be distinguished. These sample sizes were selected so that the 95 percent confidence intervals for simultaneous estimates of age composition proportions would be no wider than 0.10 ($\alpha = 0.05$ and $d = 0.10$). Recommended sample sizes were increased by 8 to 9 percent to account for fish whose age could not be determined due to sampling error or illegible scales. Considering the dynamics of the ASL composition, the need for achieving the sample goals must be 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.

General Sampling Procedures

Sampling routine includes the removal of scales from the preferred area of the fish for use in age determination (INPFC 1963). Generally one scale is taken from each sockeye and chum salmon, however three scales are taken from chinook and coho salmon to account for regeneration of freshwater annuli. At some escapement projects, where absorption is known to occur, multiple scales are taken from chum salmon. All scales are mounted on gum cards. Except where noted, sex is determined by visually examining external morphological characteristics such as development of the kype, roundness of the belly, the presence or absence of an ovipositor, and overall size. Length is measured to the nearest millimeter from mid-eye to the fork of the tail. Data is recorded on computer mark-sense forms or logged electronically on a computerized fish measuring board or hand held data logger. Data from the 1960s and early 1970s was recorded on tally sheets. The original scale cards, acetates and data forms are archived at the ADF&G office in Anchorage.

Escapement Sampling

Escapement ASL samples are collected from salmon passing weirs, counting towers, and a tributary sonar site. The goal is to estimate the seasonal ASL composition of the spawning population of a given tributary. Weir samples are generally obtained from traps built into the weir. Beach seines or gillnets are used at counting tower and sonar sites. The sample sizes and sampling frequency have varied over the years. During some years, a small number of fish were sampled each day, while in other years, a larger daily sample was taken until a pre-determined sample size was achieved for the week. Since 1993, area staff have moved towards the latter method whereby fish are sampled in pulse samples over a short time interval (i.e., one to several days) followed by a number of days without sampling. These pulse samples are taken several times throughout the season to create a series of "snap-shots" of the ASL composition.

Commercial Catch Sampling

Commercial salmon harvest is sampled for ASL data as fishers deliver their catch to floating and shore-based processors located near Bethel, Quinhagak and in Goodnews Bay. The goal is to estimate the season ASL composition of the population of fish harvested in the District 1, 4 and 5 commercial fisheries. Commercial catches are generally sampled after the salmon are off-loaded from the fishing boats. Off-loading crews typically place each salmon in a species-specific tote with no regard to sex, size or stage of maturity. ADF&G's sampling crews sample fish from these totes. In Kuskokwim Bay the crews sometimes obtain samples from the tender hold or individual boats as deliveries are made. In either case, the sample from each day generally includes fish from several boats, but this variable is not monitored and in some instances a sample may come from as few as two or three boats. Samples from Kuskokwim Bay have a greater likelihood of coming from small numbers of deliveries because of the limited resources available for collecting samples. The mesh size used by fishers varies, but it is assumed to be within the legal range of specifications. Time and logistical constraints prohibit interviewing fishers for information regarding mesh size or the exact location at which the fish were caught. Department crews are instructed to sample in a manner which guards against size or sex bias. This usually entails sampling all fish from an individual tote.

Sex was confirmed in most salmon sampled from the commercial fishery starting in 1997. The sex identifications were done by making small incisions into the abdominal cavity of each fish and visually inspecting the gonads to determine the presence of egg skeins or milt sacs. Strata in which the sex of fish was confirmed are identified accordingly.

Subsistence Catch Sampling

Until recent years the chinook harvest of a few subsistence fishers were sampled each year. Most samples were collected from the Bethel area, but in a few instances samples have also been collected from the Aniak area. Prior to 1992, samples were limited to scales removed from fish that were hanging on drying racks. Sex and length could not be determined and details about the harvest method were lacking. In 1992, fish were sampled in the round and included sex and length information. In 1993 through 1995, a small group of subsistence fishers was recruited and trained to collect ASL data from their catches. The fishers collected three scales from each fish, and recorded sex as determined by internal examination of gonads, and length as determined with a meter stick. The fishers also recorded gear type (set net or drift gillnet), mesh size, date of capture and the location of capture. Fishers received monetary compensation for the samples.

The program was discontinued in 1996 due to difficulties in recruiting participants and the time required for training and inseason follow-ups.

Data Processing and Reporting

Age Determination

Age is determined from 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 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. Ages are reported on data forms or directly entered into computer ASCII files. Since 1985, all ages have been recorded using European notation[4]. Prior to 1985, the Gilbert-Rich notation[5] was used. In this report all ages are reported in European notation.

Length information can be somewhat helpful in determining ages of absorbed or otherwise questionable scales, especially with chinook salmon which have more distinctive range of lengths for each age class than other salmon. When aging chinook salmon scales, length at age is compared to historic length at age for that project or district using length summary tables. Ages for which lengths fall outside of the range are noted as questionable. When all chinook salmon have been aged for a particular sample set, a length frequency histogram is compiled. The questionable ages are then reexamined using the corresponding length frequency histogram. Some of the questionable ages are then matched to the expected length at age. Length at age may be useful in resolving questionable ages with chum salmon, but to a much lesser degree than with chinook salmon. Length at age is not generally used when aging sockeye or coho salmon.

Computer Processing Format

Most ASL information from recent years is recorded on computer mark-sense forms that are processed through an OPSCAN machine to produce ASCII computer files. Portable data recorders were first used in the 1998 season and a more bulky fish measuring board has also been used in recent years. The data recorder produces an ASCII file similar to the OPSCAN raw data file. Data from the fish measuring board must be parsed to produce comparable ASCII files. The ASCII files are then processed through a number of programs to produce various summaries.

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[4] In European notation two digits are separated by a decimal and refer to the number of freshwater and marine annuli respectively. The first digit represents the freshwater age minus one. The second digit represents the number of annuli formed during the marine residency. Total age from brood year is the sum of the two ages plus one.

[5] In Gilbert-Rich notation two 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 the years of life after out-migration from freshwater.

One summary focuses on the age and sex composition, another focuses on length statistics by age and sex. Where applicable, the information is applied to escapement and catch data to provide an estimate of the total age, sex and length composition of those populations. A more streamlined computer program was developed in 1997 by biometrics staff that greatly simplifies ASL processing.

Strata Determination

A stratum, as most often used in this report, is a defined time interval during which fish pass a given point such as a weir or tower project, or are harvested from a given location such as District 1. The time interval usually spans approximately 7 days, but the duration may vary from one stratum to the next. For example, the first stratum for chum salmon at a weir project may extend from 18 through 30 June while the second stratum is from 1 to 6 July. The entire season is partitioned into a set of several strata based on the number and temporal distribution of ASL samples. Collectively, the strata set for a given species encompass 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 a stratum. The samples may have been taken evenly throughout the stratum, from the midpoint, or weighted towards one end of the time interval. The sample distribution is driven by fish abundance and the availability of resources to sample the fish. For example, early in the season when fish abundance is low for a given species, a stratum may span ten to twenty days although most of the samples are collected from only the last few days when the crew is able to catch fish for sampling. For this reason, associated tables list both the sample dates and the stratum dates.

Although samples are collected with a strata framework in mind, the final partitioning occurs postseason when the distribution of samples can be viewed in context with the overall distribution of the population. Given that sample sizes often fall short of the goal, the partitioning is subjective. The guiding philosophy is that the information be presented in a manner that allows users of the data to decide whether pooling strata with small sample sizes is warranted given the specific needs.

Generally the season ASL composition for escapement or harvest populations is estimated only when the distribution of samples allow, at a minimum, strata representing each third of the annual passage or harvest. This rule of thirds is necessary due to the seasonal dynamics in the ASL composition of most species. When the rule is not met, the sample results are presented but no season estimates are reported. The rule does not apply to season estimates of commercial harvest when fewer than three commercial fishing periods occurred in a season (e.g., District 1 chum salmon in 1993). The rule of thirds is sometimes applied inconsistently, but this will be corrected in future *ASL Progress Reports*.

Summary Types

Tables associated with this report consist mostly of two types, one that describes escapement or harvest data by age and sex composition, and another that summarizes the length by age and sex. Each table lists the sample dates, the stratum dates and the number of fish sampled in each stratum.

Age/Sex Tables. The age/sex tables describe the age and sex composition for each stratum as a percentage based on the 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 stratum. The escapement or harvest numbers listed in the season summaries are derived as the sum of the stratum estimates, by age/sex category. The sums are in turn used to calculate the season percentages. Grand total escapement or catch estimates are the sum of the season estimates. The grand total sums are then used to derive the grand total percentages.

Length Tables. Data in the length tables is summarized by age class and sex. Sample dates and stratum dates are usually identical to the age/sex tables. The length tables include statistics on 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. The mean length reported in the grand total is the average of the season mean lengths.

RESULTS AND DISCUSSION

As noted in the preface to this report, the extent of tabular information is now so extensive that there is a need to make it available in electronic format so as to contain this progress report to a manageable size. The tabular data that are available will be described in this section, and may be obtained from the authors, or from the Bethel office of the ADF&G. Tables produced to date are arranged by species and include chinook (Tables 1-34), sockeye (Tables 35-48), chum (Tables 49-70) and coho salmon (Tables 71-96). Within each species section the tables are organized by category including escapement, commercial and subsistence. Each of these categories are in turn organized by location. Locations are generally oriented starting with the farthest interior and progressing towards the coast, then south along Kuskokwim Bay. Some escapement and subsistence samples are also arranged by gear type such as 8.0 inch drift gillnets or 6.0 inch set gillnets.

Figures, which are included within this report, are arranged following a similar convention. Graphs related to chinook salmon appear first (Figures 2–10), followed by sockeye (Figures 11-12), chum (Figures 13–21), and coho salmon (Figure 22).

Tables produced to date are not exhaustive of all the 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 1982c and 1982d).[6] Many of the data summaries are also incomplete. As time and resources allow, it is the intention of the authors to continue adding the missing information. 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* 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. The latter method is considered an improvement in that it better accounts for seasonal changes in ASL compositions relative to sampling effort and fish abundance.

Escapement ASL Summaries

Tatlawiksuk River

The Tatlawiksuk River is located at river kilometer (rkm) 616 (river mile, rm, 383) of the Kuskokwim River (Figure 1). A fixed panel aluminum weir was established on the river in 1998 at rkm 4 (rm 2.5). The fixed panel weir, however, was replaced with a resistance board design in 1999 that allowed the operational period to be effectively extended through the coho season. The weir was established and operated as a cooperative project between Kuskokwim Native Association (KNA) and ADF&G. Funding was provided by the Bureau of Indian Affairs (BIA), the National Fish and Wildlife Foundation (NFWF), ADF&G, a grant administered through the Bering Sea Fishermen's Association (BSFA) and the National Oceanic and Atmosphere Administration (NOAA). The operational plan included ASL sampling. Complete summaries

[6] 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.

describe chinook from 1998 through 1999 (Tables 1 and 2), chum from 1998 through 1999 (Tables 49 and 50), and coho salmon for 1999 (Tables 71 and 72).

Kogrukluk River

The Kogrukluk River is located at approximately rkm 200 (rm 122) of the Holitna River, and it is another 540 rkm (336 rm) down the Kuskokwim River to Kuskokwim Bay (Figure 1). Kogrukluk River has the most extensive history of escapement monitoring in the Kuskokwim Area (Cappiello and Burkey 1997). Counting tower projects were operated on the lower Kogrukluk River from 1969 through 1978 (Yanagawa 1972a, 1972b; Kuhlmann 1973, 1974, 1975; Baxter 1976 and 1977). Operational plans began including ASL sampling of chinook salmon in 1972 (Yanagawa 1973). Chum and sockeye salmon were not regularly included in ASL sampling until 1976 when a weir project was initiated (Baxter 1976). Sampling of coho salmon started in 1981 when the operational period of the weir was extended into August and September (Baxter 1982).

Age/sex and length summaries have been produced for Kogrukluk River chinook salmon for the years 1984 through 1999 (Tables 3 and 4). Summaries for chum salmon extend from 1971 though 1999 (Tables 51 and 52), and for coho salmon from 1989 through 1999 (Tables 73 and 74). No ASL information is included for sockeye salmon, however summaries can be found in the annual project reports until 1995 when ASL sampling of this species was discontinued.

George River

The ASL summaries produced for George River are inclusive of all known data sets for the drainage. The George River is located at rkm 497 (rm 309) of the Kuskokwim River (Figure 1). A fixed panel aluminum weir was operated from 1996 through 1998 at rkm 6.4 (rm 4). The fixed weir was operable through the coho run only in 1997. The fixed panel weir was replaced with a resistance board design in 1999 that allowed the operational period to be effectively extended through the coho season. The weir operation is a cooperative project between KNA and ADF&G with much of the funding provided by BIA through a grant administered by BSFA plus additional support from NFWF and NOAA (Molyneaux et al. 1997). The operational plan included ASL sampling in all years. Complete ASL summaries from 1996 through 1999 describe chinook (Tables 5 and 6) and chum salmon (Tables 53 and 54). The samples collected for coho salmon occurred in 1997 and 1999 (Tables 75 and 76). Sockeye salmon were not sampled because of their low abundance.

Aniak River

Summary tables produced to date regarding salmon ASL compositions from the Aniak River are not inclusive of all historical data. Coverage is primarily limited to chum salmon and includes age/sex summaries from 1984, 1985, 1989 and 1994 through 1999 (Table 55); and length summaries from 1995 through 1999 (Table 56). All chum salmon samples were collected with beach seines and were part of the operational plan of the sonar escapement monitoring project. The Aniak River is located at rkm 362 (rm 225) of the Kuskokwim River (Figure 1). The sonar program has been operated at approximately rkm 19 (rm 11.8) since 1980 and ASL sampling has been included in the operations intermittently (Fair 2000). Chum salmon generally dominate over all other species during the sonar operational period, so the passage estimates are not apportioned to species. The escapement estimates described in Table 55, and the average length weighting in Table 56, are based on the unapportioned fish passage estimates.

Drift gillnets were fished in the Aniak River during the 1995 coho season as part of a feasibility study (Knuepfer 1995). Coho salmon were sampled for ASL information and the results are summarized by mesh size in Tables 77 through 82. The gillnet mesh sizes included 2-3/4 inch (7.0 cm), 4 inch (10.2 cm) and 5-3/8 inch (13.7 cm).

Information not yet included in summary tables consist of chum and chinook salmon caught with gillnets deployed in association with the sonar project from 1980 through 1984 (Schneiderhan 1981, 1982a, 1982b, 1984, and 1985). The ASL composition of sport caught chinook, coho and resident species from 1996 are described by Dunaway (1997).

Tuluksak River

The ASL summaries produced for Tuluksak River are inclusive of all known substantive data sets for the drainage. The confluence of the Tuluksak and Kuskokwim Rivers is at rkm 218 (rm 136, Figure 1). The U.S. Fish and Wildlife Service (USFWS) operated a weir at rkm 76 (rm 47.2) from 1991 through 1994 (Harper 1995a, 1995b, 1995c, 1997). Operations included a rigorous salmon ASL sampling program. Complete ASL summaries for all years include chinook (Tables 7 and 8), sockeye (Tables 35 and 36), chum (Tables 57 and 58), and coho salmon (Tables 83 and 84). Sockeye salmon are not abundant in the drainage, consequently their sample sizes are small. A few pink salmon were also sampled, but that information was not included. In all cases, ADF&G staff aged the scales and processed the data.

The chum salmon information from Tuluksak River is of particular interest. The large number of strata in each season, which range from six to ten, allow for detailed and reliable temporal analysis. In addition, the data sets include thorough representation of early and late running fish that tend to illustrate annual extremes in ASL composition often missing from other data sets.

Kwethluk River

Summaries produced for Kwethluk River are also inclusive of all known substantive data sets for the drainage. The confluence of the Kwethluk and Kuskokwim Rivers is at rkm 159 (rm 99, Figure 1). The USFWS operated a weir at rkm 80 (rm 49.7) in 1992 for one year (Harper 1998). Operations included a rigorous salmon ASL sampling program. Complete ASL summaries have been produced for chinook (Tables 9 and 10), sockeye (Tables 37 and 38), chum (Tables 59 and 60), and coho salmon (Tables 85 and 86). The chum salmon data from Kwethluk is of particular interest because it includes nine strata and has a thorough representation of early and late running fish. Again, ADF&G staff aged the scales and processed the ASL data.

A counting tower has been operated on the Kwethluk River from 1996 through 1999 as a cooperative project between the Association of Village Council Presidents (AVCP), ADF&G and USFWS, with much of the funding provided by grant from BIA and administered through BSFA (Cappiello and Sundown 1998). Efforts to collect ASL data in 1996 and 1997 were unsuccessful, so sampling was dropped from the annual operational plan. The tower is scheduled to be replaced with a resistance board weir in 2000.

Kanektok River

The Kanektok River joins the marine waters of Kuskokwim Bay near the community of Quinhagak (Figure 1). Salmon ASL information summaries produced to date for the Kanektok River are not inclusive of all historical data. Most of the summary tables are based on samples collected as part of the 1997 salmon counting tower project operated in the lower river (Menard and Caole 1998). The project was conducted jointly by the Native Village of Kwinhagak (NVK) and ADF&G with much of the funding provided by the BIA, USFWS, and a grant administered through BSFA. The 1997 season included a rigorous ASL sampling schedule with samples being collected by beach seine. Summaries for chinook salmon include the 1997 beach seine catches (Tables 11 and 12), and sport and carcass samples from 1992 through 1996 (Tables 13 and 14) as reported by MacDonald (1997). The carcasses were collected opportunistically from sandbars and may not be representative of the escapement population as will be discussed later. Summaries for sockeye (Tables 39 and 40), chum (Tables 61 and 62), and coho salmon (Tables 87 and 88) are all limited to the 1997 beach seine catches. The tower was operated for a short time during 1998, but few samples were collected due to high water conditions. The tower was not operated during 1999 due to construction of a resistance board weir that is scheduled to begin operation in 2000.

The 1997 ASL samples from the Kanektok River provide an excellent foundation for exploring inseason ASL dynamics. The sockeye and chum summaries are of particular interest. They include six and ten strata, respectively, and are well distributed throughout the runs. Most stratum include large sample sizes, plus the fish were collected just a few miles from the marine environment so absorption of the scale margins was minimal. One cautionary note: the summaries are weighted by the tower counts and the species apportionment of those counts is in question (Menard and Caole 1998).

Historical information not accounted for in summaries produced to date include ASL samples collected during operation of the Kanektok River sonar project which was conducted by ADF&G from 1981 through 1987 (Schultz and Carey 1982, Schultz and Williams 1984). Salmon ASL data were collected as part of the project from 1984 through 1987 (Huttunen 1984, 1985, 1986 and 1988). Most of the samples were taken with beach seines, but carcass samples were collected as well. Additional carcass sampling was done in 1984 as part of a survey trip (Snellgrove and Bue 1984). ADF&G also operated counting towers on the Kanektok River in 1960 through 1962, but no ASL sampling was reported (ADF&G 1960, 1961 and 1962).

Middle Fork Goodnews River

The Middle Fork Goodnews River joins the Goodnews River at about rkm 10 (rm 6.2, Figure 1). The Goodnews River in turn empties into the marine waters of Goodnews Bay. ADF&G has annually operated an escapement monitoring project since 1981 at about rkm 5 (rm 3) of the Middle Fork Goodnews River[7] (Menard 1998). Initially, salmon passage was monitored using a counting tower. Annual operating procedures began to include some form of ASL sampling by 1985. Sampling methods included both carcass sampling and beach seining. Little of this data is included in the summaries produced to date, but results can be found in the annual project reports (Schultz 1985 and 1987; Schultz and Burkey 1989; and Burkey 1989 and 1990).

The tower project was replaced with a fixed panel aluminum weir in 1991 (Menard 1998). The weir included a fish trap for ASL sampling. The operational period of the tower and weir was not inclusive of the pink and coho runs. The fixed panel weir was replaced with a resistance board design in 1997 that allowed the operational period to be effectively extended through the pink and coho seasons.

Information summaries produced to date regarding salmon ASL compositions from the Middle Fork Goodnews River are not inclusive of all historical data, being limited to more recent years. Chinook summaries include age/sex composition from 1990 through 1999 (Table 15), but length summaries are limited to 1995 through 1999 (Table 16). Sockeye summaries are complete and include age/sex and length compositions from 1984 through 1999 (Tables 41 and 42). Chum salmon age/sex summaries include 1990 through 1999 (Table 63), but length summaries are limited to 1995 through 1999 (Table 64). Coho age/sex summaries are limited to 1991, 1995, 1996, 1998 and 1999 (Table 89), and length summaries to 1995, 1996, 1998 and 1999 (Table 90). Also included in the summaries is information from chinook carcass sampling at the weir in 1996 (Tables 17 and 18). As will be discussed later, the carcass data are not representative of the

[7] In the literature the Middle Fork Goodnews River weir /tower are often misleadingly referred to as the "Goodnews River weir/tower"; in actuality the project has always been located on the Middle Fork of the Goodnews River.

escapement population. Overall, the Middle Fork Goodnews River ASL collections tend to have small sample sizes with limited temporal distributions. Data sets have improved in recent years.

Commercial Catch ASL Summaries

The commercial harvest ASL information summaries produced to date for the Kuskokwim Area are not inclusive of all historical data.

District 1

Chinook summaries for District 1 include age/sex compositions from 1974 through 1999 (Table 19), but length summaries are limited to 1990 through 1999 (Table 20). The age/sex summaries for sockeye and coho salmon include 1984 through 1999 (Tables 43 and 91), while the length summaries are limited to 1989 through 1999 for sockeye and 1991 through 1999 for coho salmon (Tables 44 and 92). Chum salmon summaries include age/sex and length compositions from 1984 through 1999 (Tables 65 and 66). Sex was confirmed in all salmon sampled from the District 1 commercial fishery beginning in 1997.

The chinook summaries for 1974 through 1984 include a notation about "unrestricted" and "restricted" mesh sizes. Unrestricted mesh size refers to a commercial fishing period in which fishers were permitted to use gillnets with any mesh size. Typically fishers used larger mesh sizes, such as 8.0 inch (20.3 cm), in order to target large chinook salmon. Samples are assumed to be representative of the overall commercial harvest, but records do not include information as to the actual mesh sizes used to catch the sampled fish. Restricted mesh size refers to a commercial fishing period in which regulations specified that fishers use mesh sizes of 6.0 inches (15.2 cm) or smaller. The most commonly used mesh sizes are between 5.5 and 6.0 inches (14.0 and 15.2 cm).

District 2

Catches from the District 2 commercial fishery are not generally sampled for ASL information. Summaries in the historical *Catch and Escapement Report Series* do list ASL statistics for the district, but the statistics are based on samples collected in District 1 (e.g., Huttunen 1989, Anderson 1995, and Molyneaux and Samuelson 1992). The degree to which District 1 statistics accurately reflect District 2 harvest in not known. The likelihood is diminished due to the differing fishing schedules and the temporal dynamics of salmon ASL compositions.

District 4

Summaries of the age/sex composition of the District 4 commercial harvest of chinook and sockeye salmon are available for 1990 through 1999 (Tables 21 and 45). Length summaries are limited to 1995 through 1999 for chinook and sockeye salmon (Tables 22 and 46). Chum salmon age/sex and length summaries include 1984 through 1999 (Tables 67 and 68). Coho salmon age/sex summaries include 1990 through 1998 (Table 93), whereas length summaries are limited to 1995 through 1998 (Table 94). As with District 1, the sex was confirmed in all salmon sampled from the commercial fishery from 1997 through 1999.

District 5

Age/sex summaries describing the District 5 commercial harvest of chinook and coho salmon are available for 1990 through 1999 (Tables 23 and 95). The age/sex summaries for sockeye salmon include 1985 through 1999 (Table 47). The chum salmon age/sex and length summaries include 1984 through 1999 (Tables 69 and 70). Length summaries are limited to 1995 through 1999 for chinook salmon (Table 24), 1985 through 1999 for sockeye salmon (Table 48), and 1996 through 1999 for coho salmon (Table 96). Most of the fish sampled from District 5 from 1997 through 1999 were internally inspected to confirm sex as noted in the tables.

Subsistence Catch ASL Summaries

Chinook salmon are the only species sampled from the subsistence harvest. Sampling is limited to the Bethel area and Aniak (Figure 1). Results are described by gear type and limited to samples collected between 1993 and 1995 (Tables 25-34), which are the only years when information was reported about gear type. These samples also include the harvest date and sex as determined by internal inspection of the gonads.

Unlike commercial summaries, results of the subsistence samples are not expanded to characterize the entire subsistence harvest. Such efforts are confounded by the varied and sometimes geographically specialized harvest techniques employed by subsistence fishers (Coffing 1997), which include fish wheel, rod and reel, spears, and set and drift gillnets. Gillnets are the most commonly used gear type, but mesh sizes employed vary widely (ADF&G 1968, Francisco et al. 1995). The limited ASL sampling effort precludes any reasonable approximation of the actual ASL composition for subsistence harvests.

Subsistence ASL summaries are described in the historical *Catch and Escapement Report Series* (e.g., Huttunen 1989, Anderson 1995, Molyneaux and Samuelson 1992), but some of the information may be misleading. A method commonly employed in the *Catch and Escapement*

Report Series is to estimate the ASL composition of the subsistence harvest by applying statistics from the commercial catch. The assumption that the selectivity of gear used in the commercial fishery can approximate that of the subsistence fishery is generally incorrect for the reasons described earlier. Most askew are estimates for Kuskokwim River subsistence harvest where fishers employ the widest variety of gear types coupled with distinct geographical differences in preferred gear types (ADF&G 1968, Francisco et al. 1995, Coffing 1997). In Kuskokwim Bay, the application of commercial catch sample data to estimate the ASL composition of the subsistence harvest may have some merit because the gear types are reportedly more alike, but the assumption has not been confirmed.

Trends In ASL Composition

Information in this section is intended to provide a few examples of data concerns and common trends found in salmon ASL information in the Kuskokwim Area. The analysis in this *ASL Progress Report* is not intended to be exhaustive. Project leaders are encouraged to use the examples described herein as the basis for expanding ASL discussions in their annual project reports.

Sources of Bias

Sampling Design. Salmon populations often demonstrate distinctive and dynamic trends in their ASL composition over the course of a single season and it is vital that sampling designs recognize and account for both the temporal and spatial variability (Clutter and Whitesel 1956). Sampling effort should be distributed throughout the run and results weighted in a manner that accounts for fish abundance. Resources or sampling conditions sometimes preclude adequate sampling effort, in which case the available data should not be used to characterize the entire population unless there is clear and justifiable reason to do so. Such incomplete data sets are presented only for the purpose of providing whatever insights may be gleaned from these truncated segments of the populations.

Pulse sampling began to be implemented in the Kuskokwim Area in the early 1990s as a means of accounting for temporal variability in populations. Much of the ASL data reported in the summary tables from years prior to the 1990s has been restratified into a pulse sample format, so results presented here may differ from those reported elsewhere.

Carcass Sampling. The use of carcasses for estimating the ASL composition of spawning escapements can be misleading. Male chinook salmon, for example, tend to drift downstream in a moribund state after spawning while females tend to remain near their 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).

Estimates based on stream bank carcass surveys would tend to be biased towards female chinook salmon. The likelihood of this happening is enhanced by the large size of females, which makes them more visible than smaller males. Evenson (1991) and Skaugstad (1990) found that not to be the case when rigorous sampling designs are employed as was done in their stream bank surveys of the Chena and Salcha Rivers (Yukon River drainage). Not withstanding these findings, collecting and interpreting chinook carcass sample data should be done with caution. Casual or opportunistic sampling is likely especially prone to bias.

For other species, the differential arrival time to spawning grounds that occur between sex and age groups is another potential source of bias in carcass sampling. Temporal dynamics in age composition can be pronounced in sockeye and chum salmon (Figures 11, 13 and 14). Likewise, changes in sex composition can be pronounced in chum and coho salmon (Figures 15, 16 and 22). Other temporal and spatial variations in ASL composition exist in salmon as well. 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 Absorption*.** The phenomenon of scale absorption can make aging of 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 for aging there may be little or no remnant of the outer annulus remaining 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 is used to help decide the correct age, particularly with chinook salmon. The degree of scale absorption observed in the Kuskokwim Area appeared exacerbated in 1997, possibly due to the exceptionally warm water temperatures reported throughout the area. The degree of scale absorption was normal in 1998 and 1999.

Scale absorption in Kuskokwim Area salmon is most problematic in fish sampled from the Kogrukluk River, particularly sockeye salmon. The Kogrukluk River is located approximately 740 rkm (458 rm) from the mouth of the Kuskokwim River (Figure 1), farther than any other project in the drainage where ASL data is collected. Scale absorption generally appears more advanced than elsewhere in the area, consequently the uncertainty of age estimates is heightened.

In their study of British Columbia sockeye salmon, Clutter and Whitesel (1956) reported that the degree of scale absorption varied between individuals and was most pronounced in males. This appears to be true of Kogrukluk River sockeye as well. The degree of scale absorption observed in Kogrukluk River sockeye contributed to the decision in 1995 to discontinue sampling sockeye at that project. Scale absorption is more moderate elsewhere in the Kuskokwim Area and the confidence of age determination is correspondingly greater.

Sex Determination. Secondary sexual characteristics develop and become progressively more obvious in salmon as they near their spawning grounds. Generally an experienced technician at an escapement project can easily and reliably identify the sex of salmon. The task is not as reliable when sampling fish from the commercial harvest. Sexual dimorphism is not always obvious in commercially caught fish and use of characteristics such as kype development are not reliable. Male chinook salmon, for example, may lack a prominent kype while female coho salmon sometimes have pronounced kype development. Both cases are contrary to the common perception that kyped fish are male while unkyped fish are female.

The sex of a salmon can be easily confirmed by an examination of the gonads. However, that requires cutting the fish, and concerns about market quality generally limit the degree to which this can be done. However, beginning in 1997 staff received permission from salmon buyers to make small incisions in fish for sex confirmation during normal ASL sampling. Nearly every fish sampled from the commercial catch was examined in this way. These samples are identified in the appropriate tables with footnotes.

Chinook Salmon

Age Composition. Most chinook salmon return to the Kuskokwim Area at age-1.2, -1.3, or -1.4 (Molyneaux and DuBois 1999). Commercial fishers harvest these three age classes in fairly even proportions when their gillnets are restricted to mesh sizes of six inches or smaller. From 1974 to 1999 the age composition of the District 1 commercial harvest from fishing periods with restricted mesh size averaged 35% age-1.2, 35% age-1.3 and 25% age-1.4 fish (Figure 3). However, for commercial fishing periods with unrestricted gillnet mesh sizes, as was allowed prior to 1985, the age composition was 3% age-1.2, 36% age-1.3 and 56% age-1.4 (Figure 4). During the unrestricted periods fishers often used large mesh sizes such as 8 inch mesh to target the larger chinook salmon. Larger mesh sizes continue to be popular among subsistence fishers.

The age composition of the commercial harvest with restricted mesh size coupled with the subsistence harvest with unrestricted mesh size together probably more closely approximate the true age composition of returning chinook salmon than when both fisheries use unrestricted mesh sizes. Given evidence of the genetic heritability of age at maturity (Hankin et al. 1993), high exploitation rates with large gillnet mesh sizes could exert enough selective pressure on the chinook population to shift it towards smaller, younger fish if continued over many generations. As such, it is in the better interest of conservation to continue to restrict the commercial fishery to smaller mesh sizes.

In their review of trends in salmon size throughout the North Pacific, 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. However, the authors based their conclusion on commercial catch data. The decrease was more likely a result of the 1985 gillnet mesh size restriction described above, than increased salmon abundance at sea as suggested by the authors. Most of the decrease occurred after 1985, which reinforces the alternative explanation. The same study showed no change in the mean age in Yukon River chinook salmon, and an increase in the mean age of the Kenai River population.

Sex Composition. Females are generally less abundant than males in the chinook salmon populations returning to the Kuskokwim Area. Female chinook salmon at Kogrukluk River are estimated to comprise 34 percent of the escapement reported from 1984 to 1999 (Table 3). Information from other streams is less extensive, but the Tuluksak, Kwethluk and Middle Fork Goodnews Rivers averaged 19, 25 and 38 percent females (Tables 7, 9 and 15). Results from the George and Kanektok Rivers show more even ratios with females comprising 53 and 44 percent of the returns (Tables 5 and 11). The female fraction of the commercial harvest in Districts 1, 4 and 5 average 28, 36 and 31 percent (Table 19, 21 and 23; Figure 3) for fishing periods with gillnet mesh size restricted to 6 inches or smaller. For District 1 periods with unrestricted mesh size, the ratio of females increases from 28 to 43 percent (Table 19, Figure 4). Data from subsistence harvests also tend to show fewer numbers of females in the catch even when large mesh gillnets are used (Tables 25 – 34).

The sex ratios reported from escapement projects are generally believed to be reliable due to advanced development of sexual dimorphism. However, the sex ratios reported from the commercial harvest may not be as reliable due to less obvious dimorphism. Most of the chinook salmon sampled from commercial catches from 1997 through 1999 were examined internally to verify sex (Tables 19, 21 and 23). Considering only those fish in which the sex was confirmed ($N = 3{,}704$), age-1.2 chinook salmon were found to be overwhelmingly male; 98 percent or more (Figure 5). In samples collected without sex verification the fraction of age-1.2 chinook reported as male has been as low as 30 percent. Similar trends were found in age-1.3 chinook where the occurrence of males was 82 percent or greater when sex was verified, but as low as 32 percent in samples without verification (Figure 6).

On the encouraging side, these suspected errors are not persistent across all years or locations that lack visceral examinations of the fish. For the years examined, sex ratios reported for the District 1 commercial fishery have been near or within the range found in the verified samples (Figures 5 and 6). 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 are probably due in most part to the level of experience and training provided to the people who were collecting the samples. The sampling crews in District 1 typically includes one or more experienced biologist who closely monitor the sampling routine and periodically examine a small number of fish internally to verify sex. The findings of these occasional dissections are usually shared with others on the crew as a training tool.

Kuskokwim Bay crews sampling in Districts 4 and 5 have traditionally been more isolated and rarely had the benefit of a biologist in attendance. These fisheries are also more remote, crew size is usually smaller, sampling conditions more difficult, and crewmembers often have much less experience or training to draw on. Efforts to resolve some of these problems began in 1997 when much of the sampling responsibility shifted to Bethel where fish are sampled when delivered to local processors. Although logistically challenging, the quality and quantity of the data has improved. Additional training opportunities have been made available by rotating staff between Bethel and Kuskokwim Bay, but there needs to be a more concerted effort to develop the training potential of these rotations.

Length Composition. The length frequency distributions of the three most predominant chinook salmon age classes (age-1.2, -1.3, and -1.4) overlap as illustrated in Figures 7, 8 and 9. 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 the District 1 males averaged 675 mm in length while females averaged 801 mm (Table 20). The same trend occurs in Distinct 4 where males averaged 694 mm and females averaged 802 mm (Table 22), and Distinct 5 where males averaged 701 mm and females averaged 781 mm (Table 24). The lengths of age-1.4 males and females overlap broadly.

Bigler et al. (1996) reported a significant decrease ($P < 0.01$) in the average weight of Kuskokwim River chinook salmon between 1975 and 1993, however this finding is flawed for the same reason described above regarding age composition. The authors relied on commercial catch statistics and did not account for mesh size restrictions imposed beginning in 1985. A review of escapement data from Kogrukluk River shows contrary trends with the average length of age-1.2 and -1.3 males generally increasing between 1984 and 1997, while females did not show a change (Figure 10).

Sockeye Salmon

Age Composition. Eleven age classes have been reported for sockeye salmon returning to the Kuskokwim Area, however the most predominant group is age-1.3. The second most prevalent is age-1.2 in Kuskokwim Bay and age-2.3 in the Kuskokwim River. 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 increased as the season progressed (Figure 11). Similar patterns are apparent in previous years (Molyneaux and DuBois 1999 and 1998).

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 12). Furthermore, males tend to average about 20 mm greater in length 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 season, whereas age-1.2 fish were generally smaller at the start of the season.

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. The older fish tend to arrive earlier in the season with younger fish becoming more prominent as the season progresses. The daily incidence of age-0.4 chum 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 in the historic data for the Tuluksak River (Figure 13) and similar patterns have been reported in streams of the Yukon drainage (Tobin and Harper 1995, Melegari 1996), southcentral Alaska (Helle 1979), southeast Alaska (Clark and Weller 1986), British Columbia (Beacham and Starr 1982; and Beacham 1984), and Washington (Salo and Noble 1953). This pattern appears to be the norm for chum salmon. Occasional inconsistencies seen in historical age summaries of the Kuskokwim Area should be viewed with some skepticism. Ideally the scales collected from such data sets should be reviewed for confirming the age determinations.

Chum salmon abundance in the Kuskokwim Area was low in 1999. The age composition data from escapements and commercial catches showed the characteristic temporal dynamics described above (Figure 14). Relative abundance of age-0.3 and age-0.4 were within the usual range.

Sex Composition. The overall annual sex ratio of most Kuskokwim Area chum salmon populations approximates one male to one 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 percent in each of four consecutive years (Figures 15). Results from both escapement and commercial samples in 1999 show the same overall trend (Figure 16). These patterns are common, if not the standard, in chum salmon populations (Bakkala 1970).

Kogrukluk River, however, is an exception to these norms. The annual percentage of females reported at the weir has always been less than 50 percent (Figure 17). Furthermore the percentage has been on a declining trend since 1981 with a record low in 1997 when females accounted for only four percent of the total escapement (Table 51). That year is also noteworthy in that the weir had the lowest overall passage of chum salmon yet recorded for the project, still the low occurrence of females does not appear to be density dependent.

The temporal trend in female chum salmon occurrence at Kogrukluk River is also often contrary to the norm. In 9 of 12 seasons reported the proportion of females either decrease as the season progresses or shows little change (Figure 18).

The cause of the sex ratio anomaly at Kogrukluk River is unknown. Commercial harvest is a potential factor, however the sex ratio in the commercial fishery is only slightly higher for females than males (Figure 17), and other spawning stocks do not show a female composition on the order of the Kogrukluk River. Furthermore, the lowest proportion of females yet reported from the weir project occurred in 1997 when only one limited commercial fishing period was allowed for chum salmon (Burkey et al. 1997).

Another possible explanation is related to the location of the Kogrukluk River (Figure 1). The stream is found in the headwaters of the Holitna River drainage and there are abundant spawning grounds downstream of the Kogrukluk River, including the main stem of the Holitna River. Schroder (1982) reported that male chum salmon remain sexually active for 10 to 14 days while most females complete their spawning in only 1 or 2 days. If during their prolonged activity, male chum salmon continued to migrate upstream while females remained more stationary, then that would account for the higher proportion of males seen passing Kogrukluk River weir. The fact that the proportion of females rarely increases with the temporal progression of the run further supports this explanation. Although plausible, this hypothesis fails to explain the trend of declining percentages observed over the past seventeen years (Figure 17).

Length Composition. The length frequency of chum salmon overlaps broadly by age and sex groupings, however the average length of females is generally less than males of the same age class. Also, Kuskokwim Bay chum salmon tend to be larger at age than Kuskokwim River fish as illustrated in Figure 19 for 1999. Another common pattern in Kuskokwim Area chum salmon is that as a run progresses the average length of new arrivals tends to decrease for all age-sex groupings. At Tuluksak River the average decrease in length over the course of the run was on the order of 56 mm (Figure 20).

Bigler et al. (1994) have reported significant decreases in the average weight at age for many Alaskan and North Pacific chum salmon populations from 1975 to 1993, including the Kuskokwim River ($P < 0.05$). The authors' conclusion generally relies on commercial catch statistics, which, for the Kuskokwim River, contain some confounding influences. First, prior to 1985 there were no restrictions on the mesh size fishers used and their tendency to use larger mesh sizes for targeting chinook salmon would have also resulted in a higher proportion of larger chum salmon in the catch. Beginning in 1985 the mesh size was restricted to six inches or smaller (Burkey et al. 1998), which would have reduced the average size of chum salmon in the harvest. Second, beginning in the late 1980s there was a growing tendency to extend the commercial fishing season for chum salmon into the second half of July when the average size of chum salmon tends to be smaller due to higher proportions of younger age classes and females in the catch, both of which are smaller in size, and due to the tendency of the average size of all age-sex groups to decrease as the season progresses (Table 65 and 66). Third, as the market value of chum salmon has decreased over the past several years (Burkey et al. 1998), some fishers are beginning to use smaller mesh sizes which tend to be more effective in catching the higher valued sockeye salmon (personal observation). In contrast to the findings of Bigler et al. (1997), 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 decreasing trend (Figure 21).

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 normally compose five percent or less of the return. An exception to this trend occurred in 1999 when an atypically higher percentage of age-3.1 coho returned to the Kuskokwim River. Age-3.1 comprised 13.2% of the harvest in District W1 (Table 91), 12.9% of the return to Tatlawiksuk River (Table 71) and 27.4% of the return to George River (Table 75).

Since 1997 there has been an effort to reduce the number of coho scales collected for age determination to one strata for each quarter or third of the run. Given the overwhelming dominance of age-2.1 fish additional samples were considered unnecessary. Any additional sampling effort for the commercial fisheries is limited to collecting sex and length data.

Sex Composition. Sex was confirmed through internal examination in most coho salmon sampled from the commercial harvest starting in 1997. These samples generally exhibited an increasing proportion of females in the catch as the season progressed (Figure 22). The pattern is not always obvious in other databases, possibly because of errors in sexing the fish. Female coho salmon sometimes have some level of kype development that can confound sexing by external characteristics alone.

Length Composition. No consistent pattern is obvious in the average length composition at age with coho salmon. 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 pattern, however, of female coho salmon tending to be larger than males. The mean lengths of District 1 samples with confirmed sex identification from 1997 and 1998 were pooled over all age classes by year and compared by sex. The mean length of females was found to be significantly greater in both years. In 1997 the mean length was 562 mm for males and 571 mm for females (two-tailed t-test; $P = 0.00069$, df 700). In 1998 the mean length was 567 mm for males and 574 mm for females (two-tailed t-test $P = 0.00026$, df 1154). This pattern is not apparent in the historical database where sex was not confirmed, which adds further question to the reliability of sex determination of coho salmon when the sex is not confirmed.

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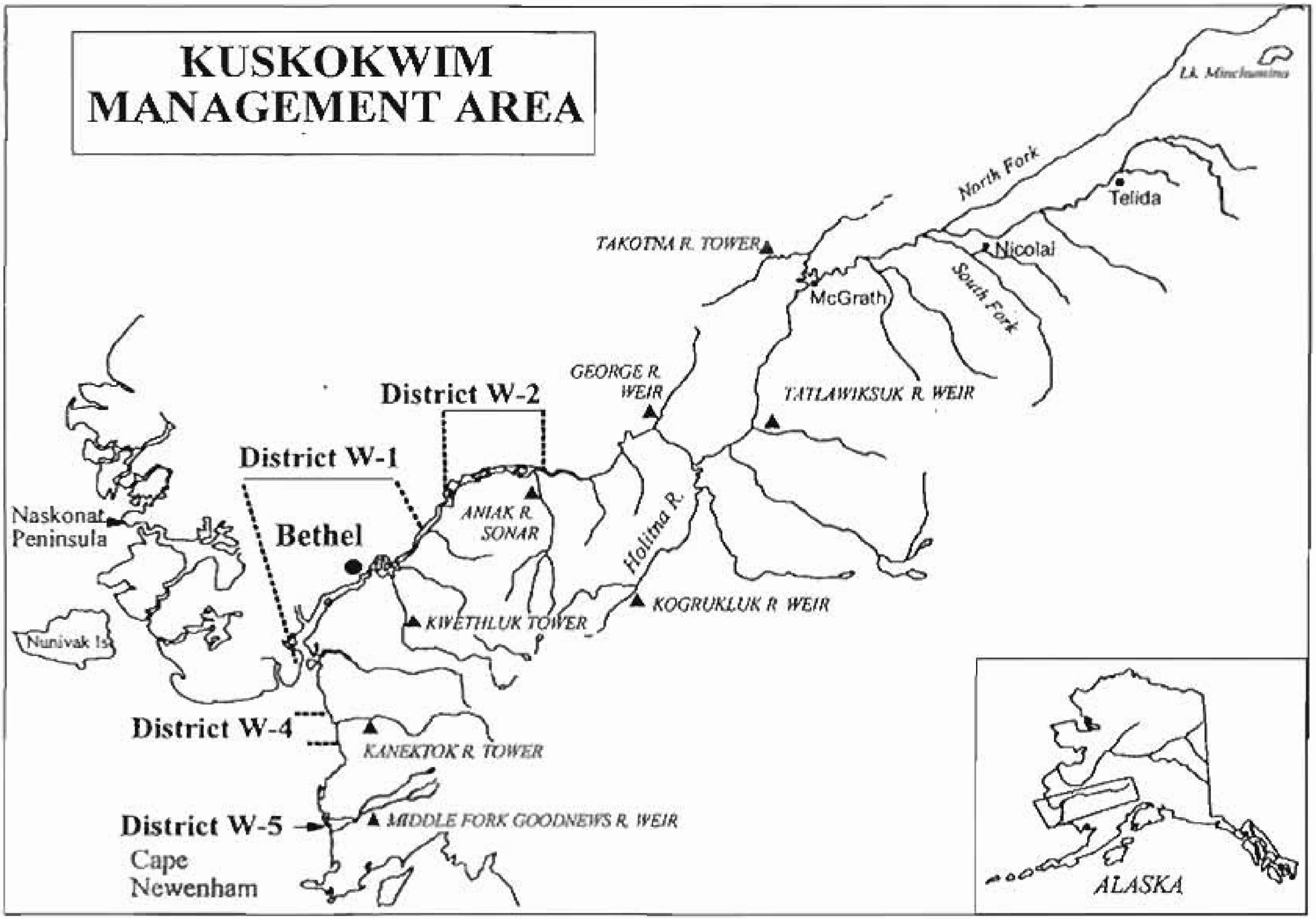

Figure 1. Kuskokwim Area map showing salmon management districts and escapement monitoring projects.

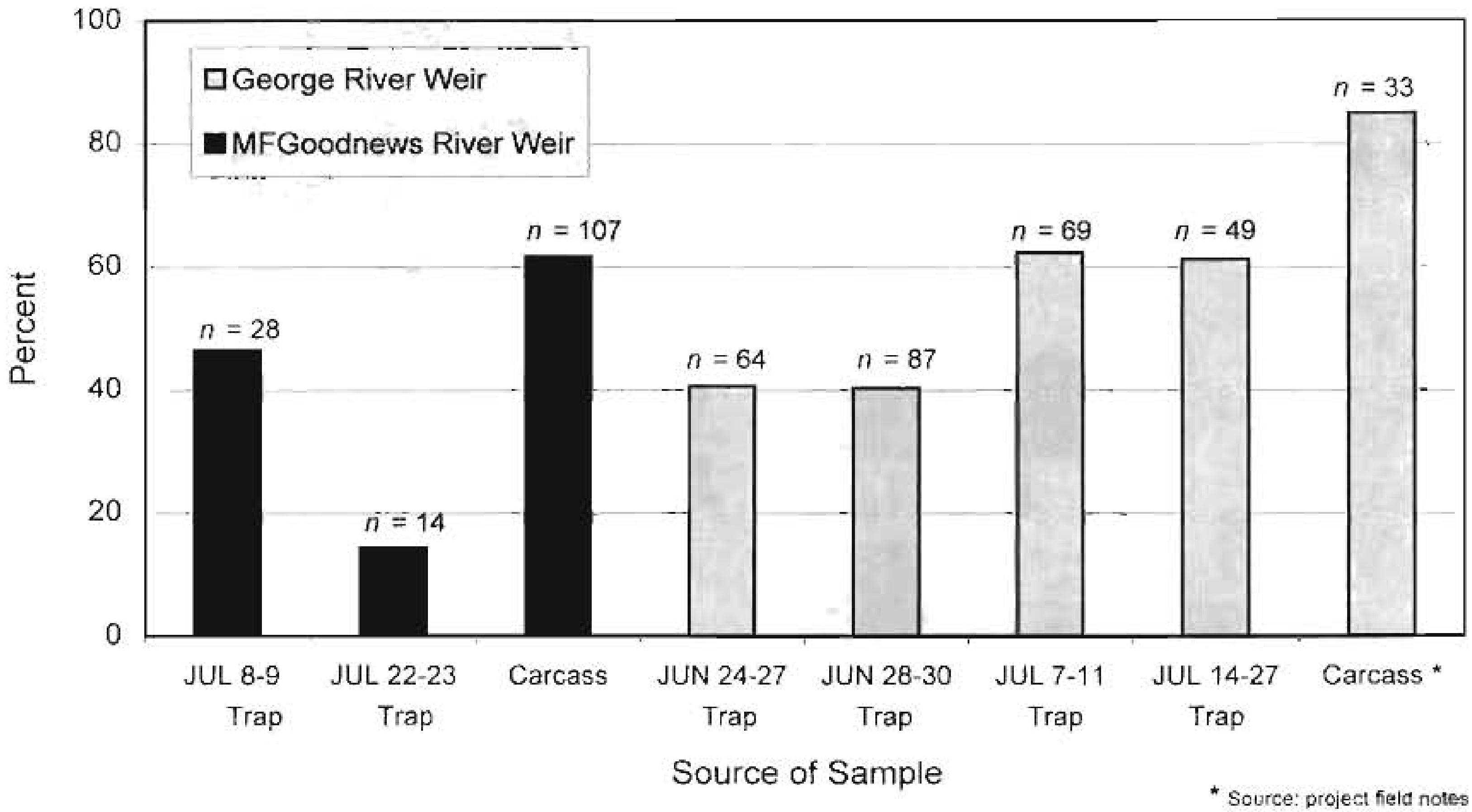

Figure 2. Incidence of male chinook salmon in trap and carcass samples from the Middle Fork Goodnews River weir in 1996 and the George River weir in 1997.

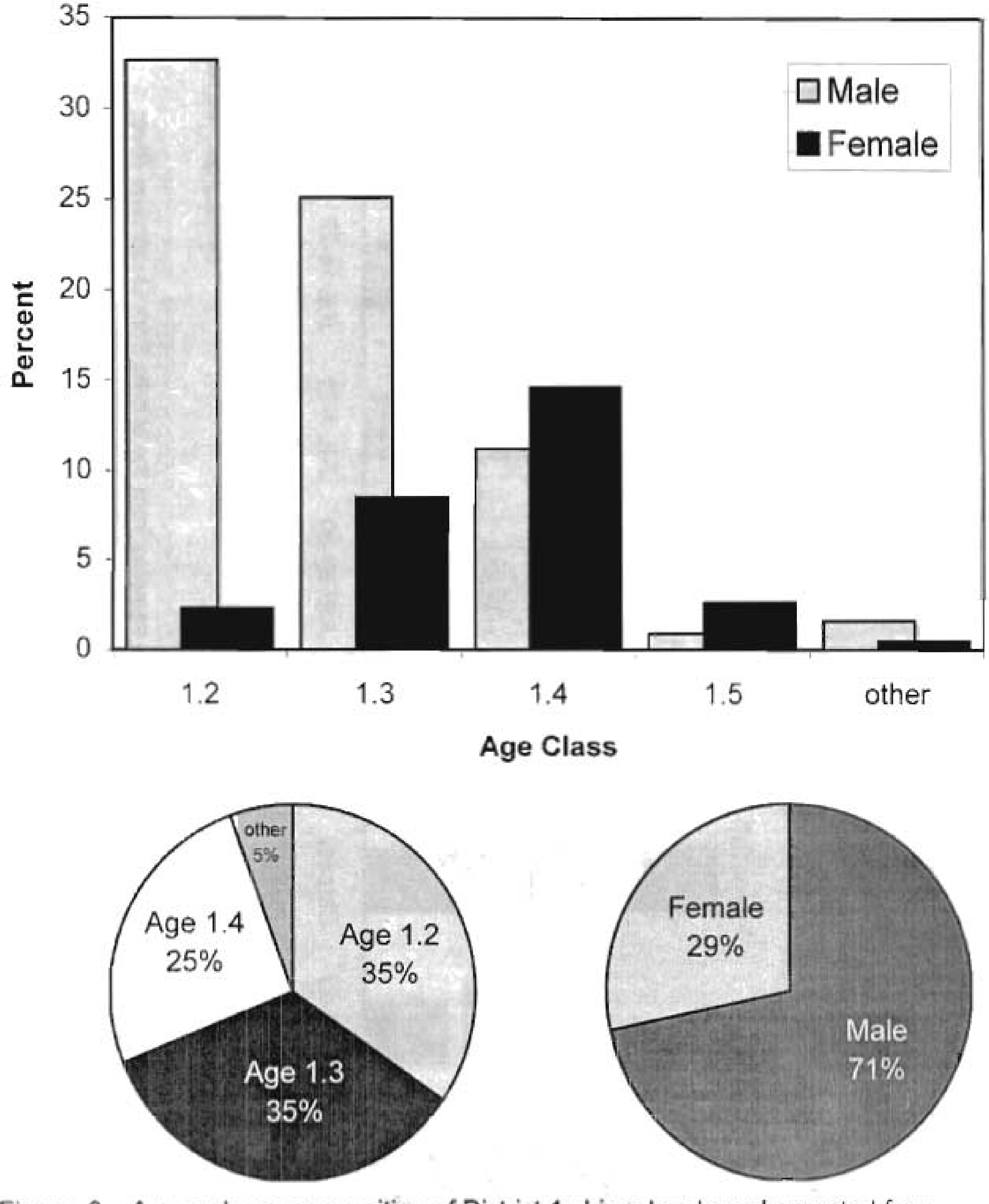

Figure 3. Age and sex composition of District 1 chinook salmon harvested from commercial fishing periods in which gillnet mesh size was restricted to 6 inches or smaller, 1974 - 1999.

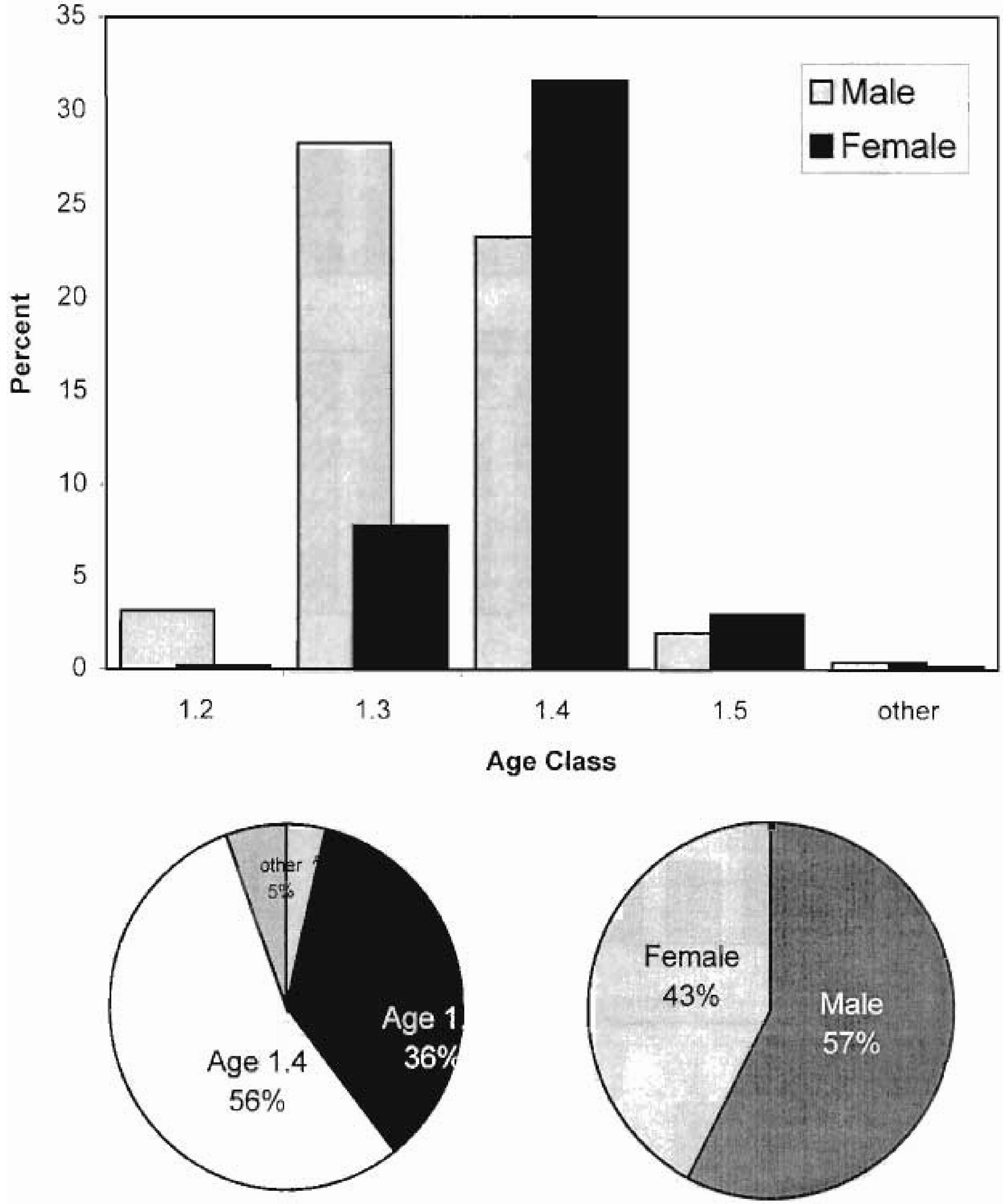

Figure 4. Age and sex composition of District 1 chinook salmon harvested from commercial fishing periods in which gillnet mesh size was unrestricted, 1974 - 1984.

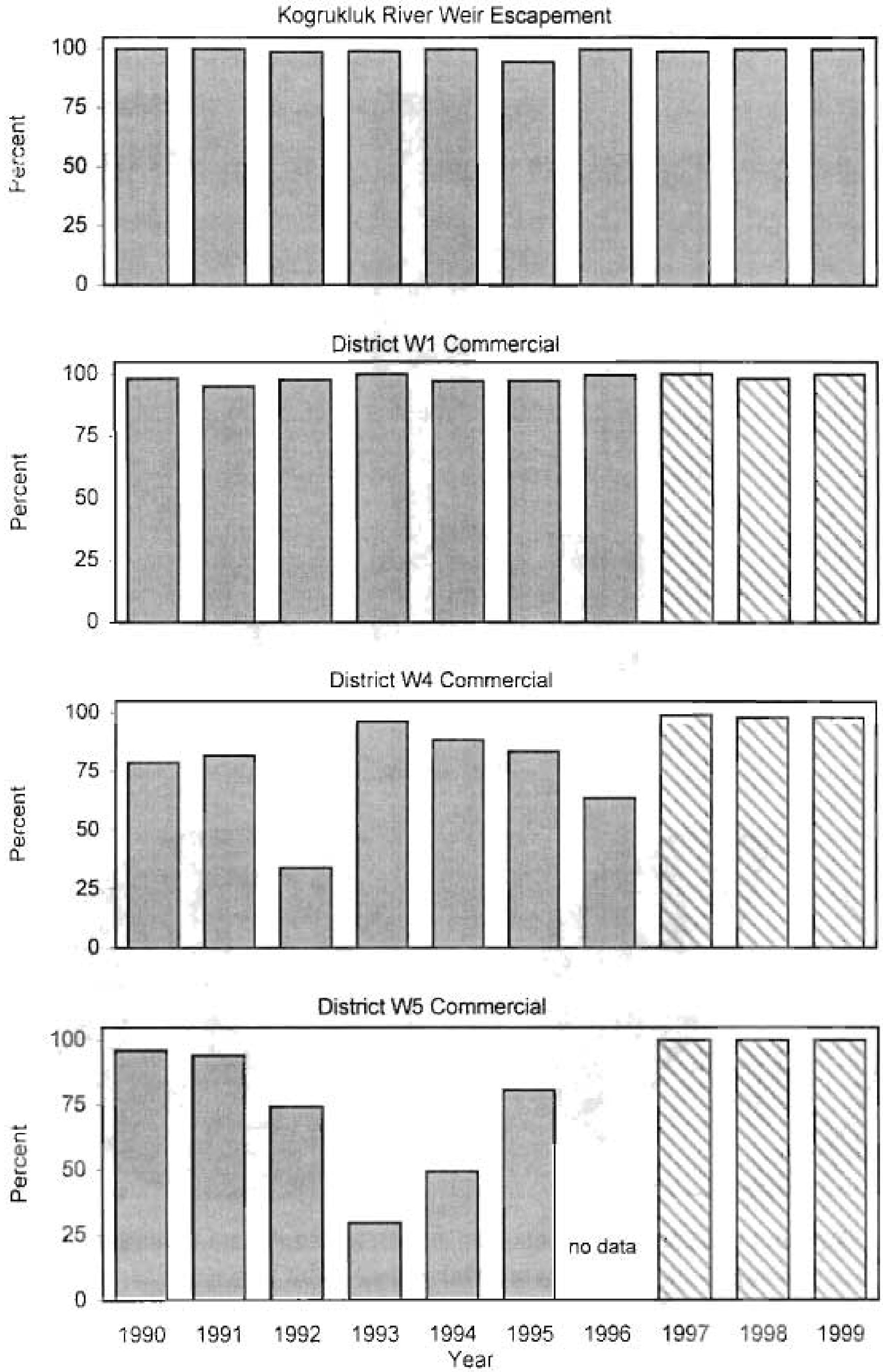

Figure 5. Historical percentage of age-1.2 chinook salmon reported as males from Kogrukluk River weir and Districts 1, 4 and 5, 1990-1999. Hatch-marked bars only include data for fish with confirmed sex identification.

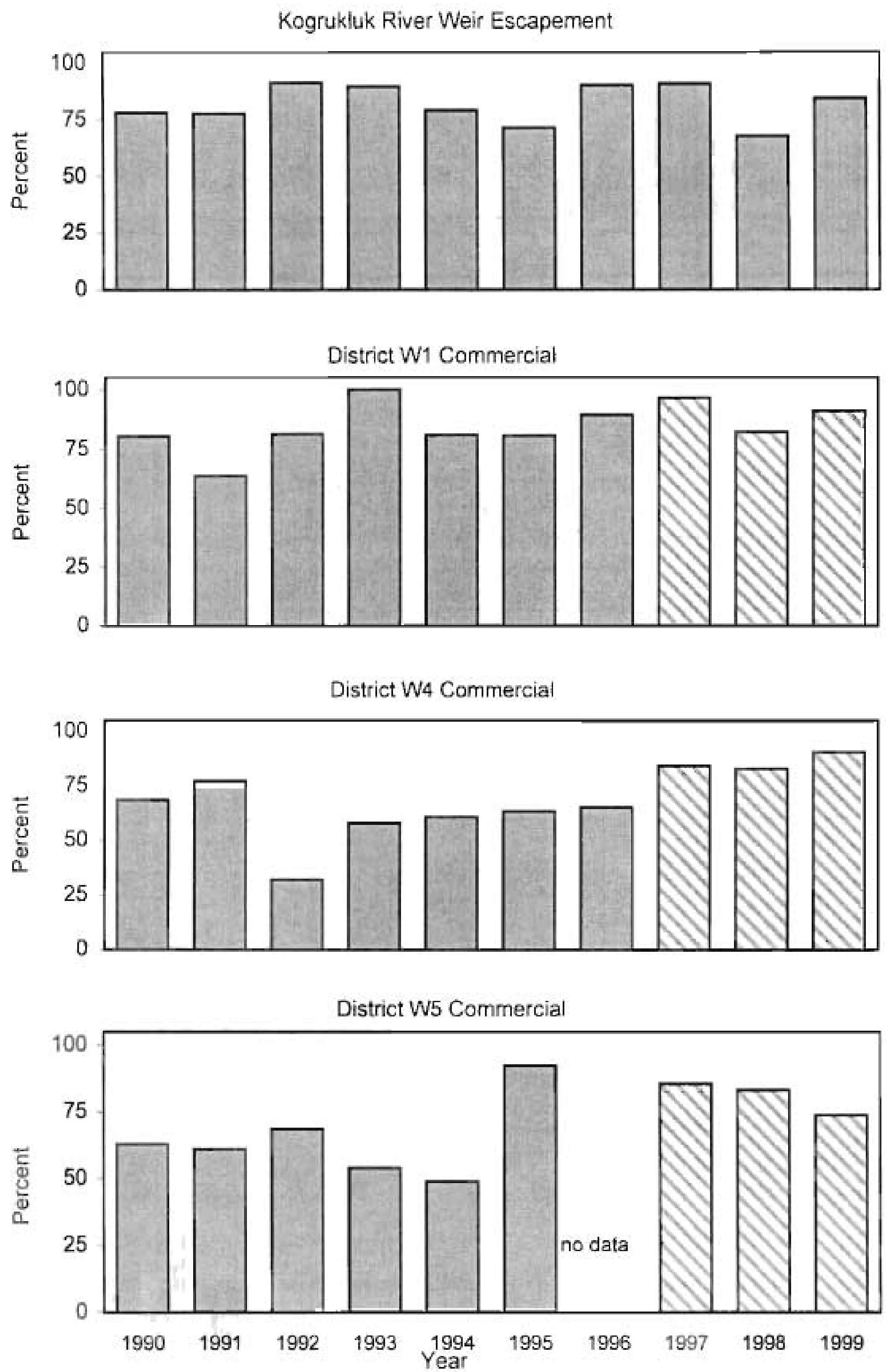

Figure 6. Historical percentage of age-1.3 chinook salmon reported as males from Kogrukluk River weir and Districts 1, 4 and 5, 1990-1999. Hatch-marked bars only include data for fish with confirmed sex identification.

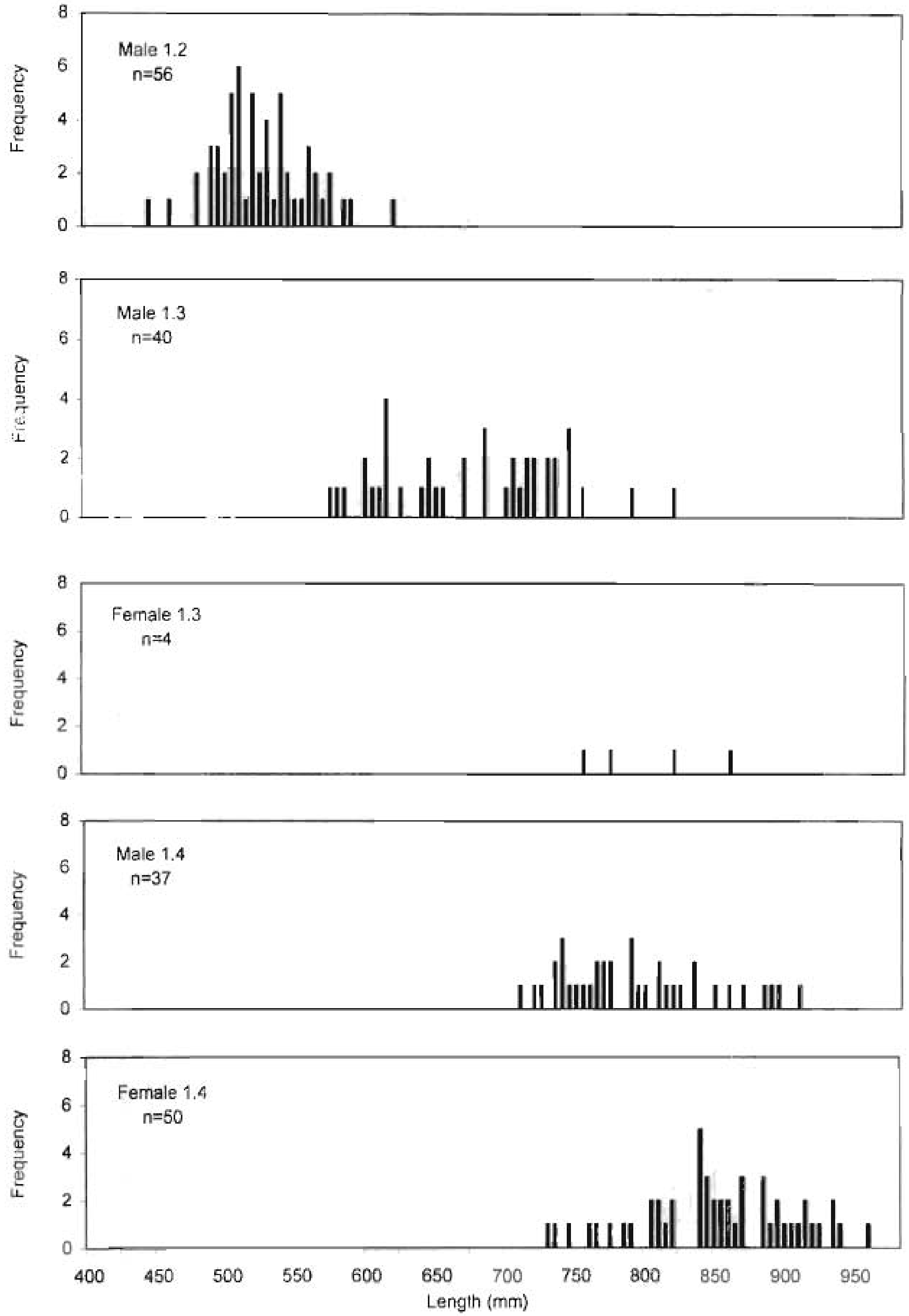

Figure 7. Length frequency of District 1 chinook salmon by age and sex, 1999.

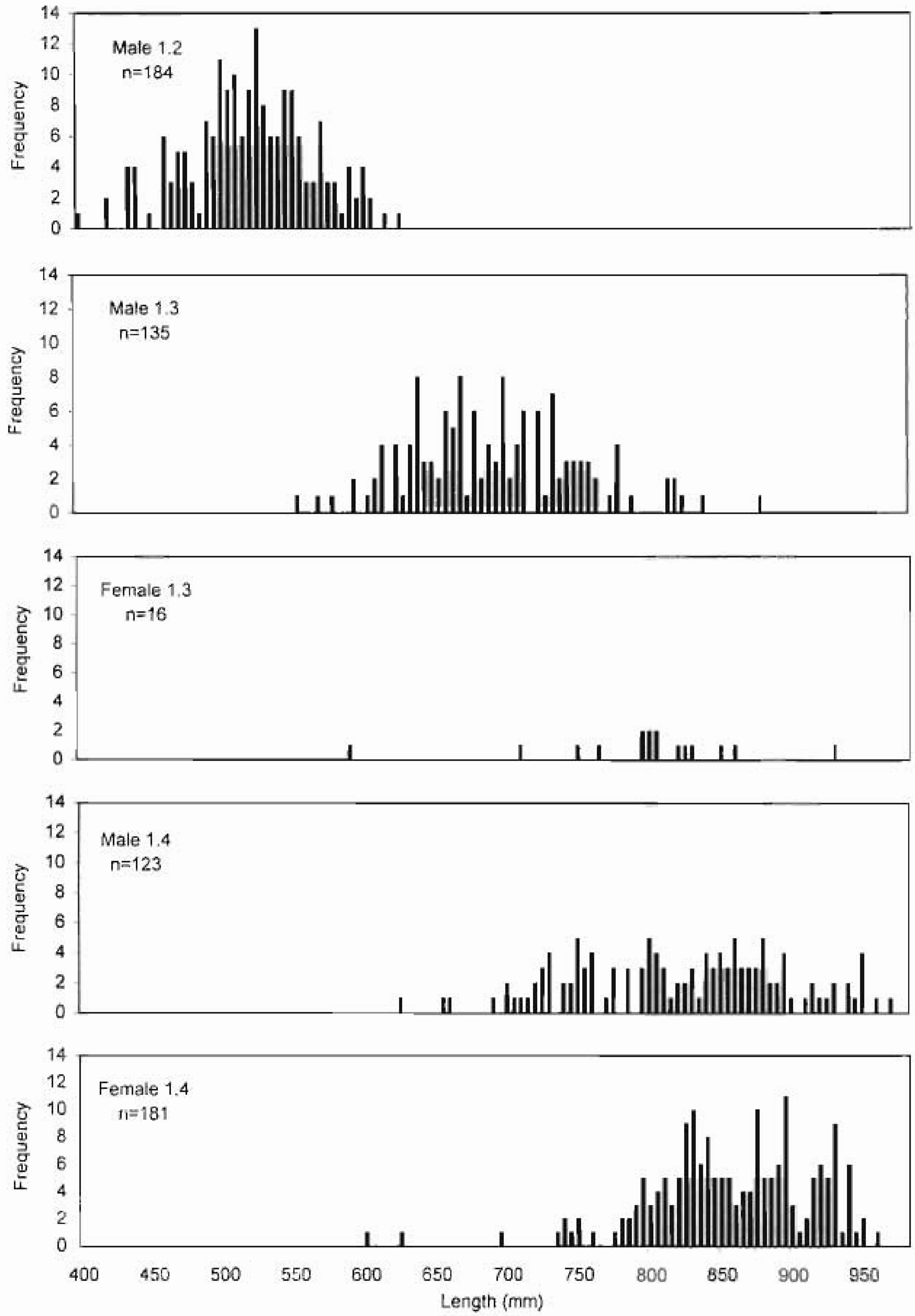

Figure 8. Length frequency of District 4 chinook salmon by age and sex, 1999.

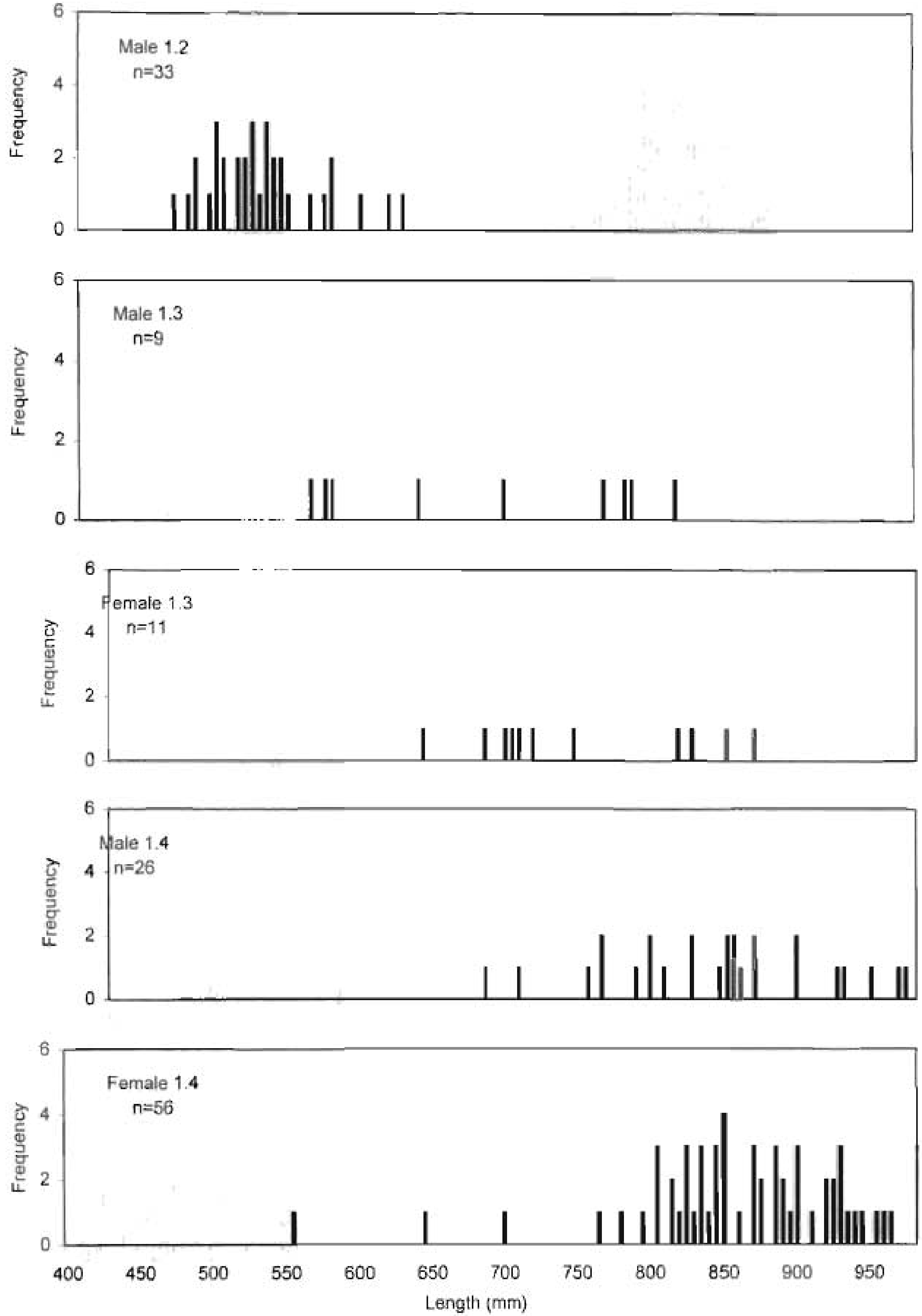

Figure 9. Length frequency of District 5 chinook salmon by age and sex, 1999.

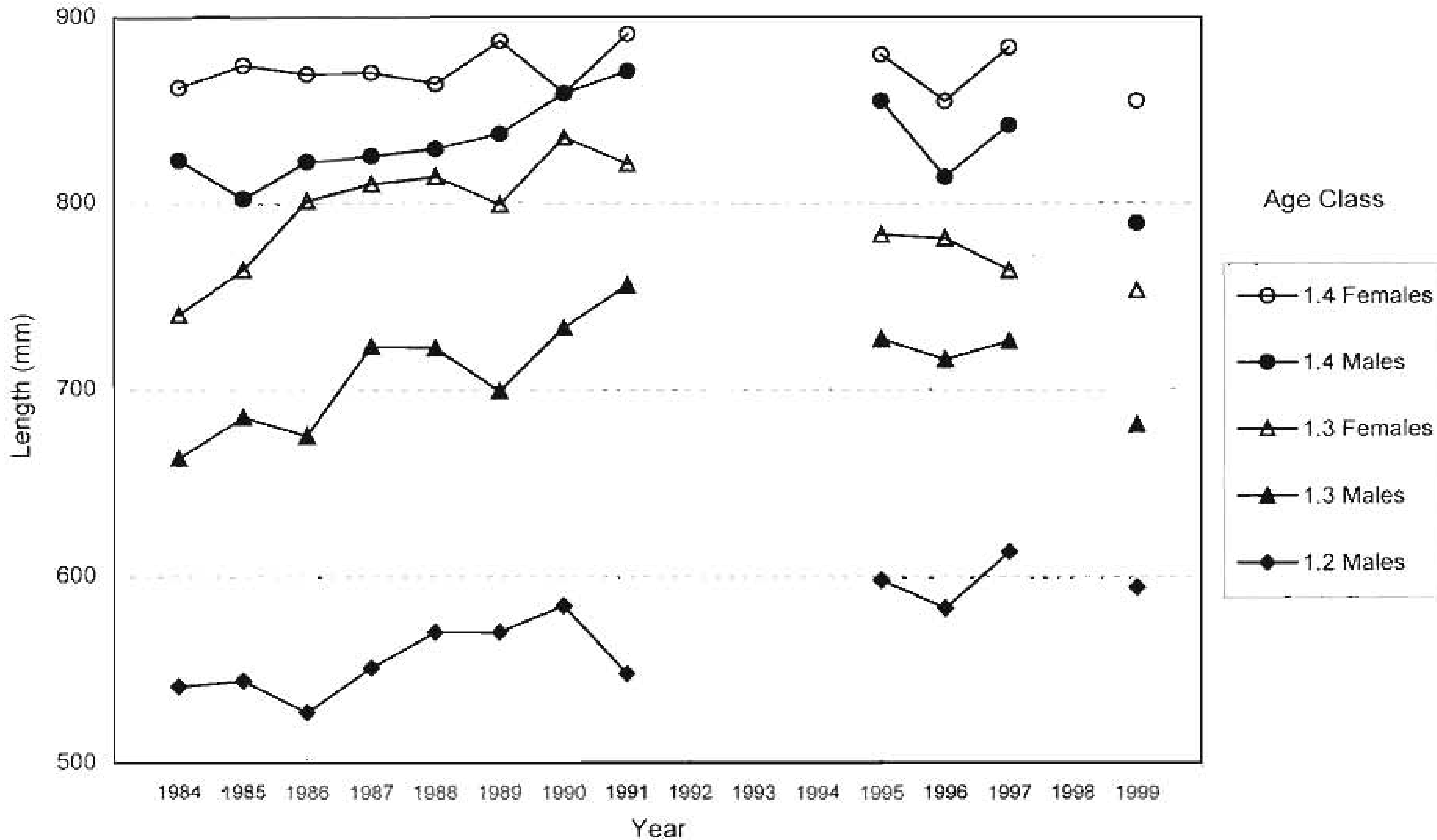

Figure 10. Historical trends in the average length of chinook salmon at Kogrukluk River weir, 1984-1999.

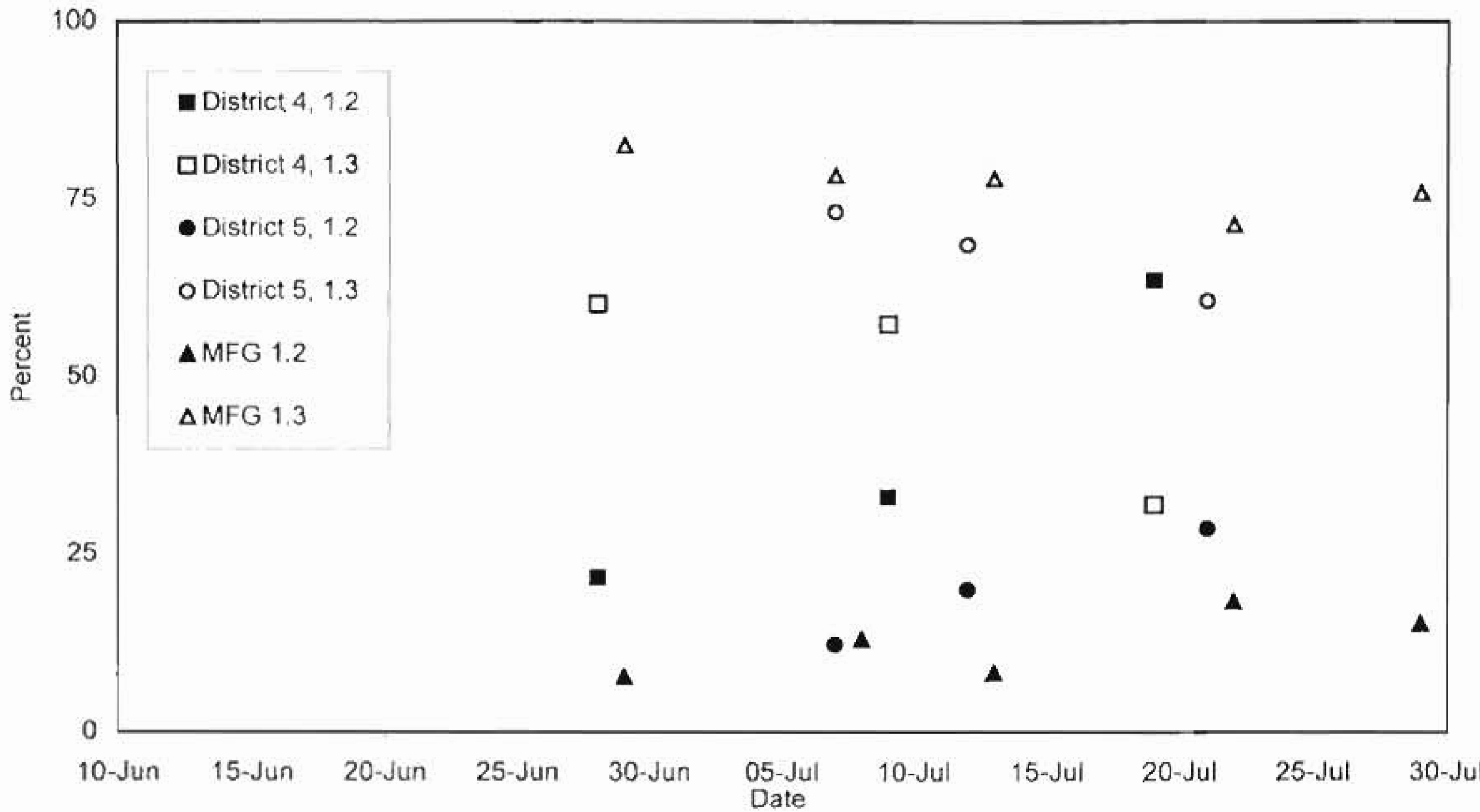

Figure 11. Percentage of age-1.2 and -1.3 sockeye salmon by sample date from the Middle Fork Goodnews River weir (MFG) escapement and the District 4 and District 5 commercial catches, 1999.

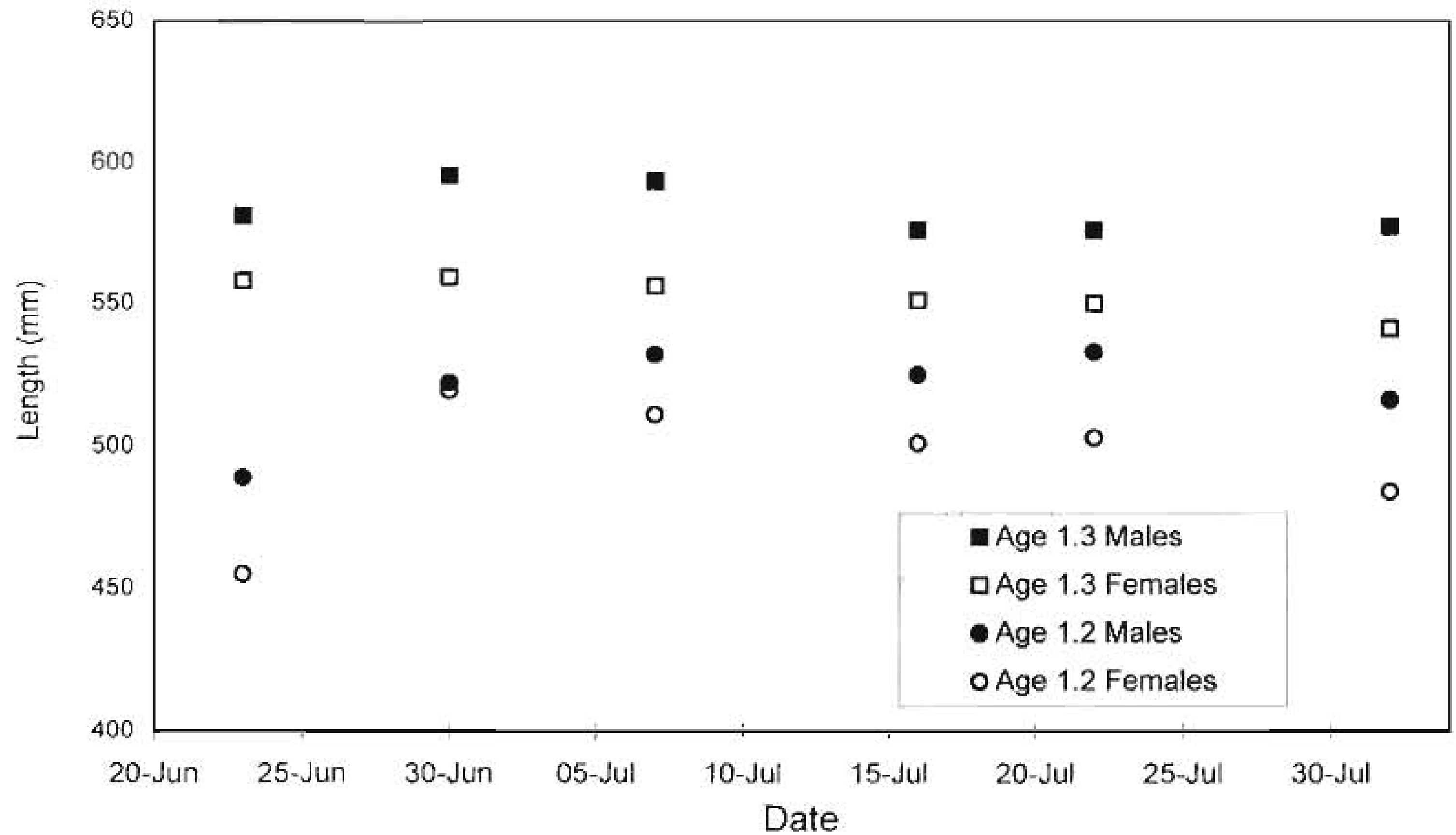

Figure 12. Average length by sample date for Kanektok River sockeye salmon in 1997.

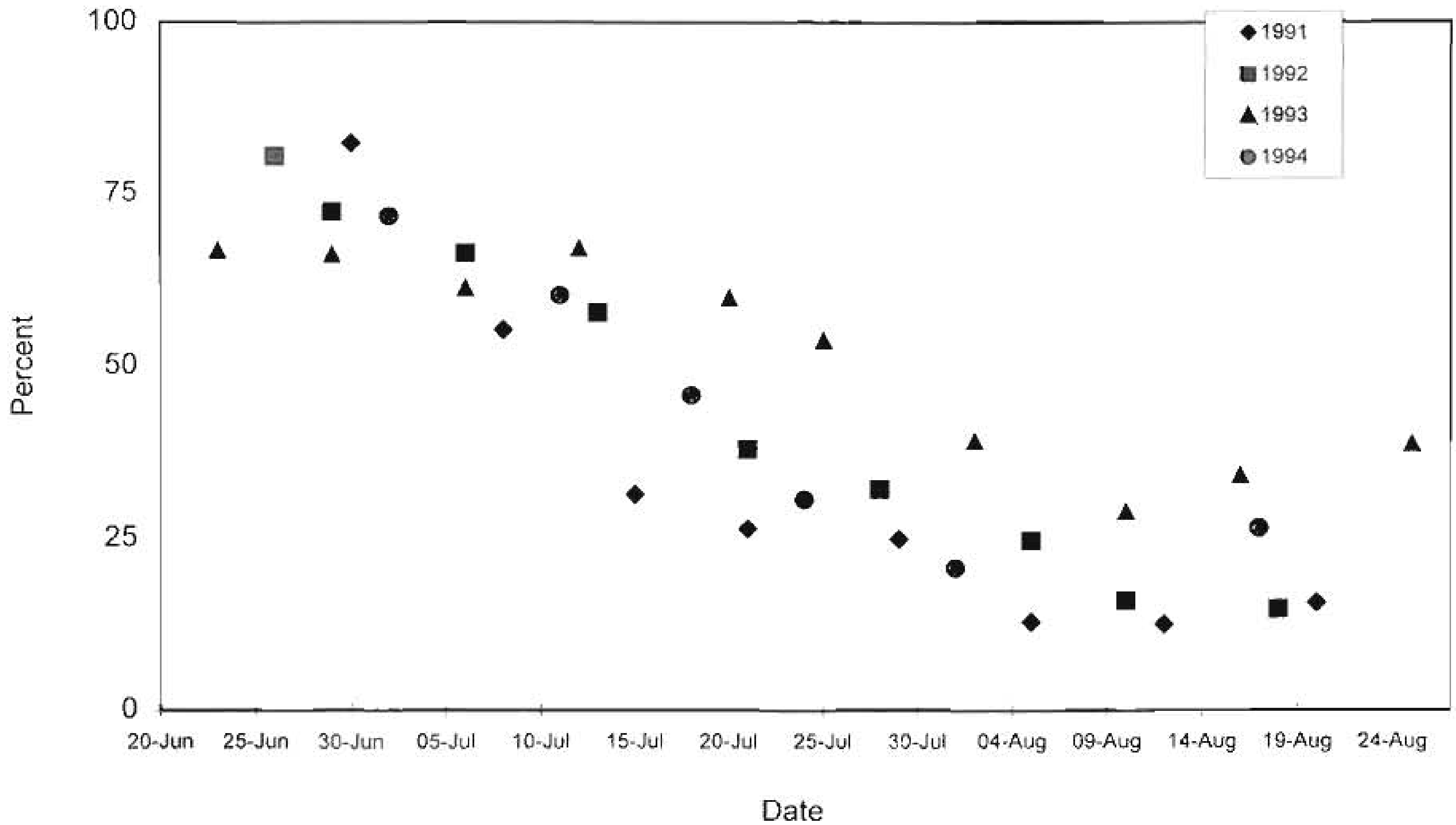

Figure 13. Percentage of age-0.4 chum salmon by sample date in the Tuluksak River , 1991- 1994.

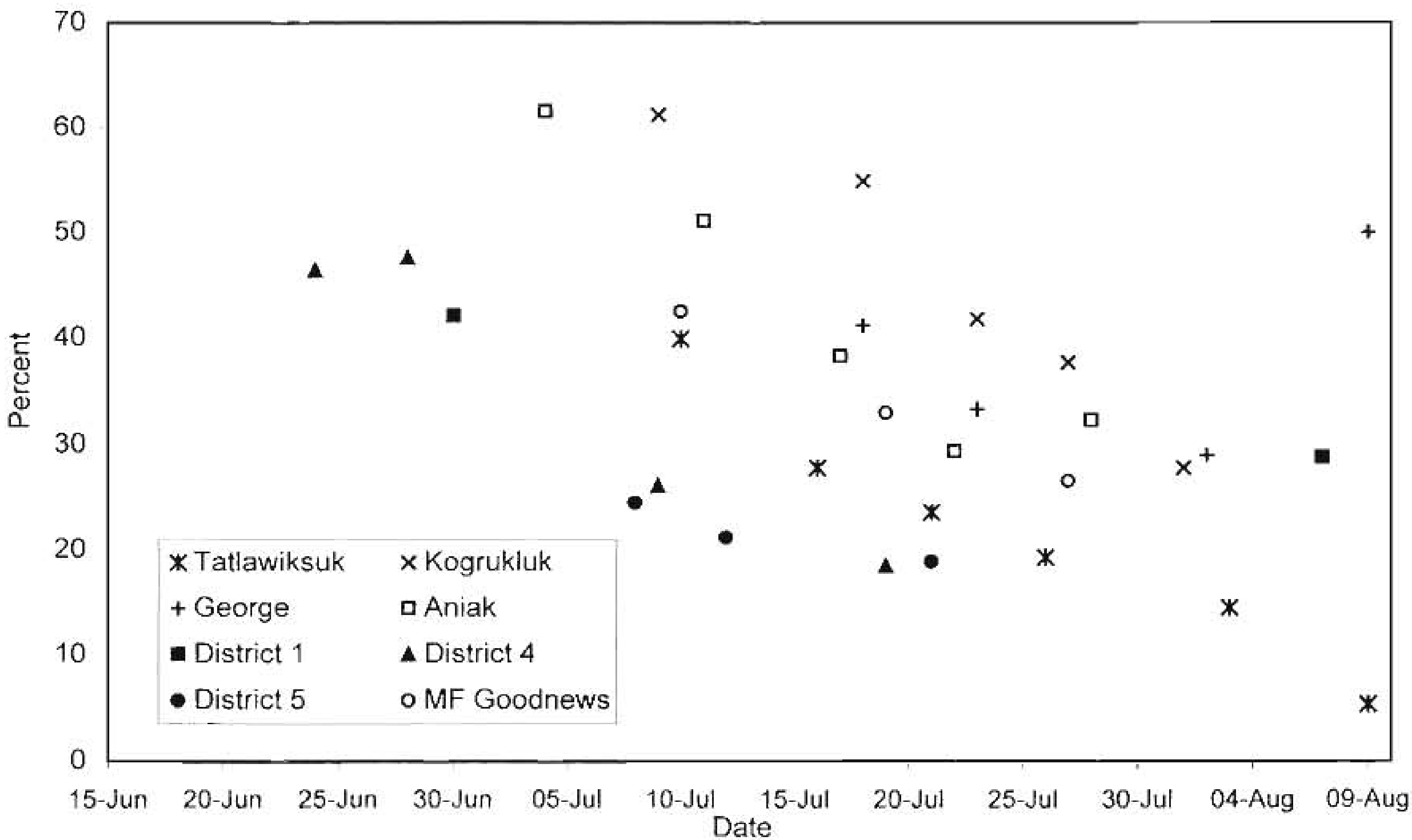

Figure 14. Percentage of age-0.4 chum salmon by sample date from Kuskokwim Area escapements and commercial catches, 1999.

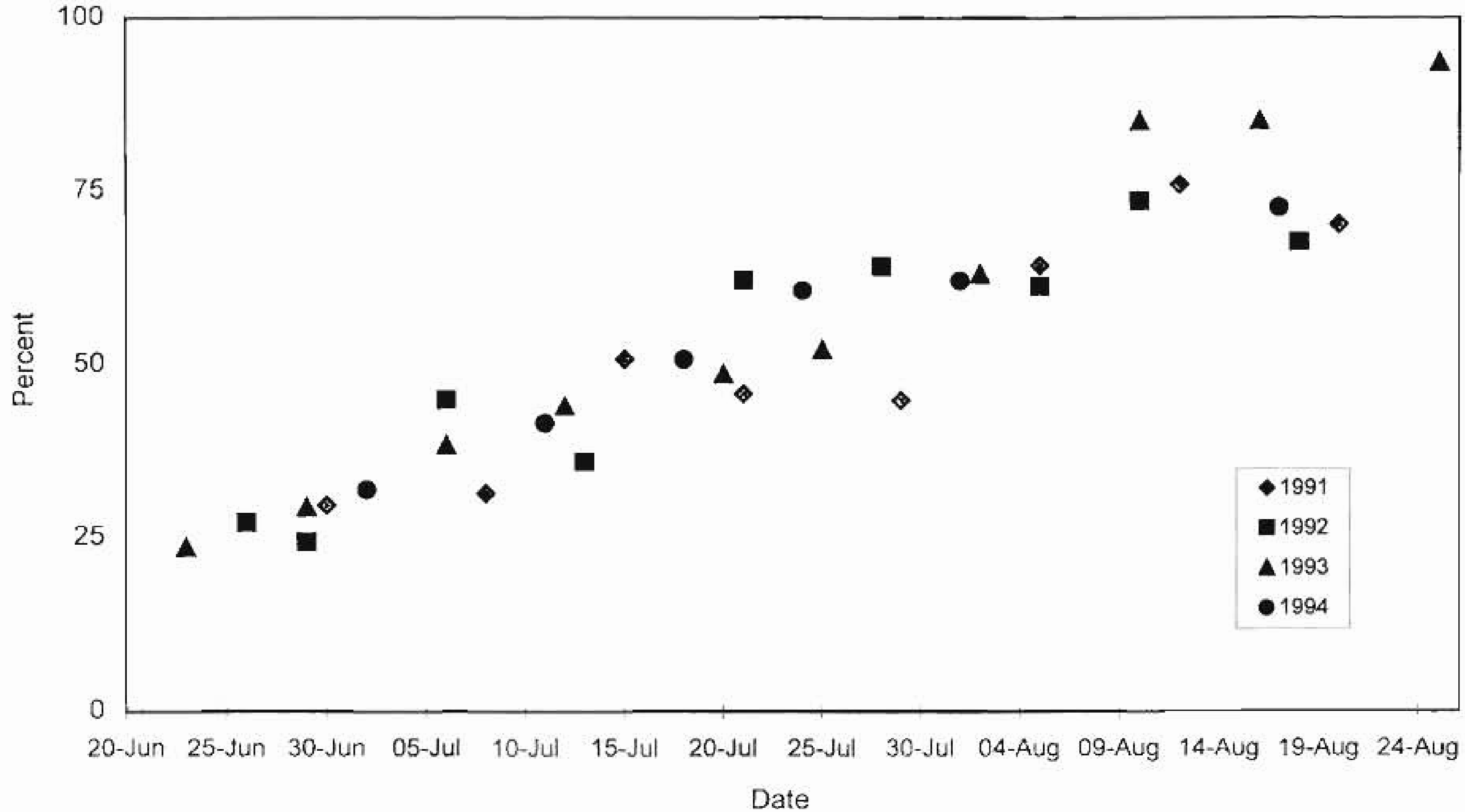

Figure 15. Percentage of female chum salmon by sample date at Tuluksak River weir , 1991- 1994.

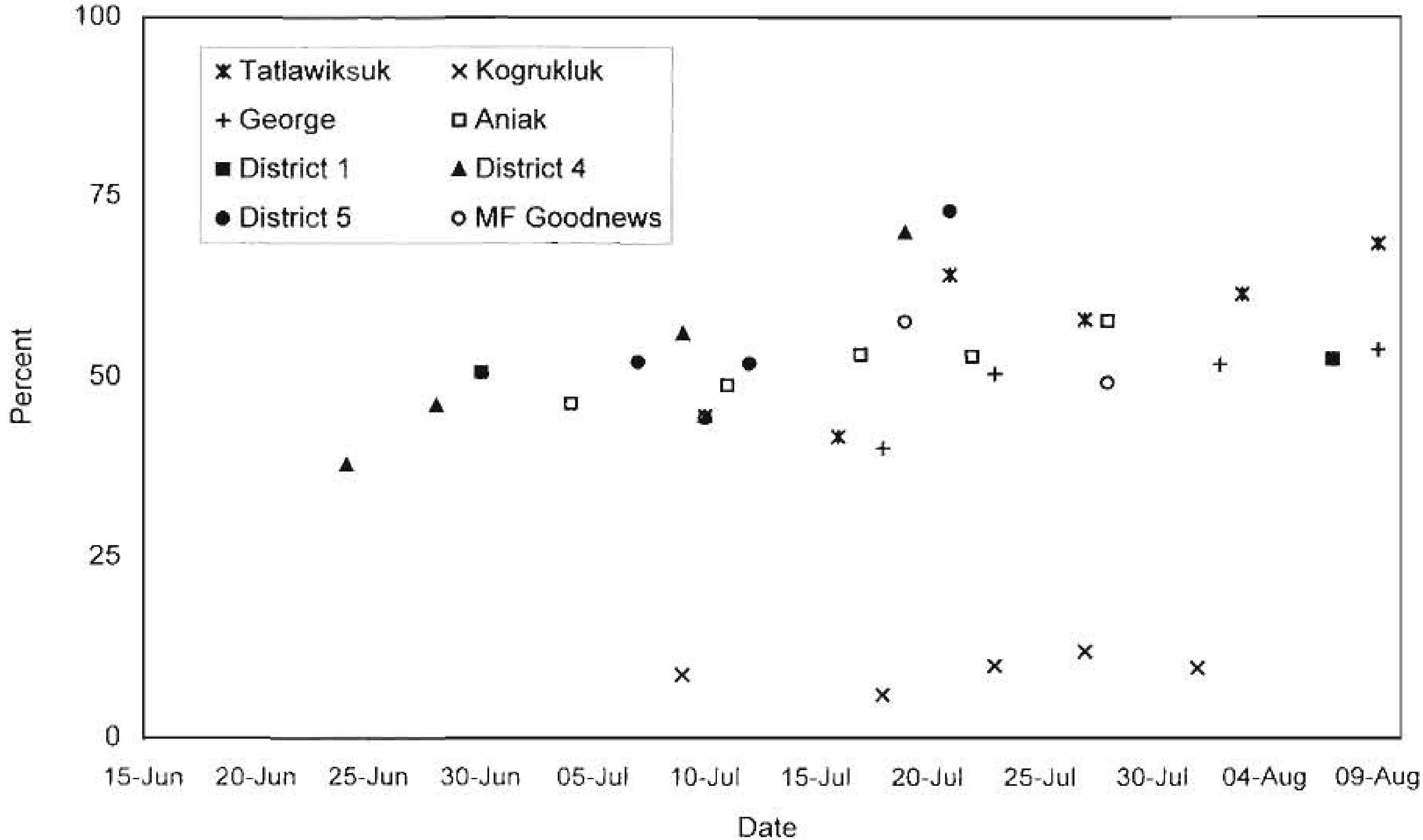

Figure 16. Percentage of female chum salmon by sample date from Kuskokwim Area escapements and commercial catches, 1999.

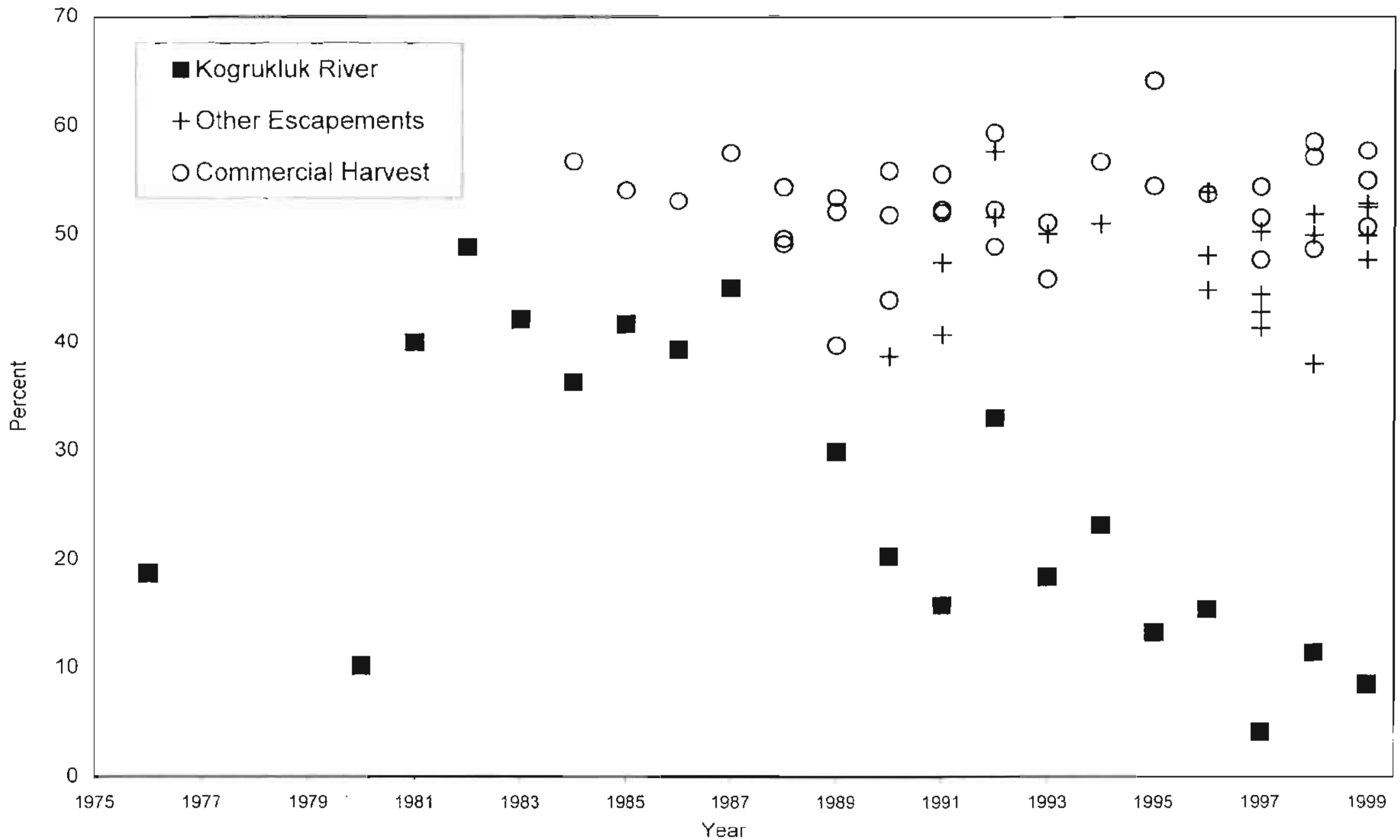

Figure 17. Historical percentage of female chum salmon in Kuskokwim Area escapements and commercial catches, 1976-1999.

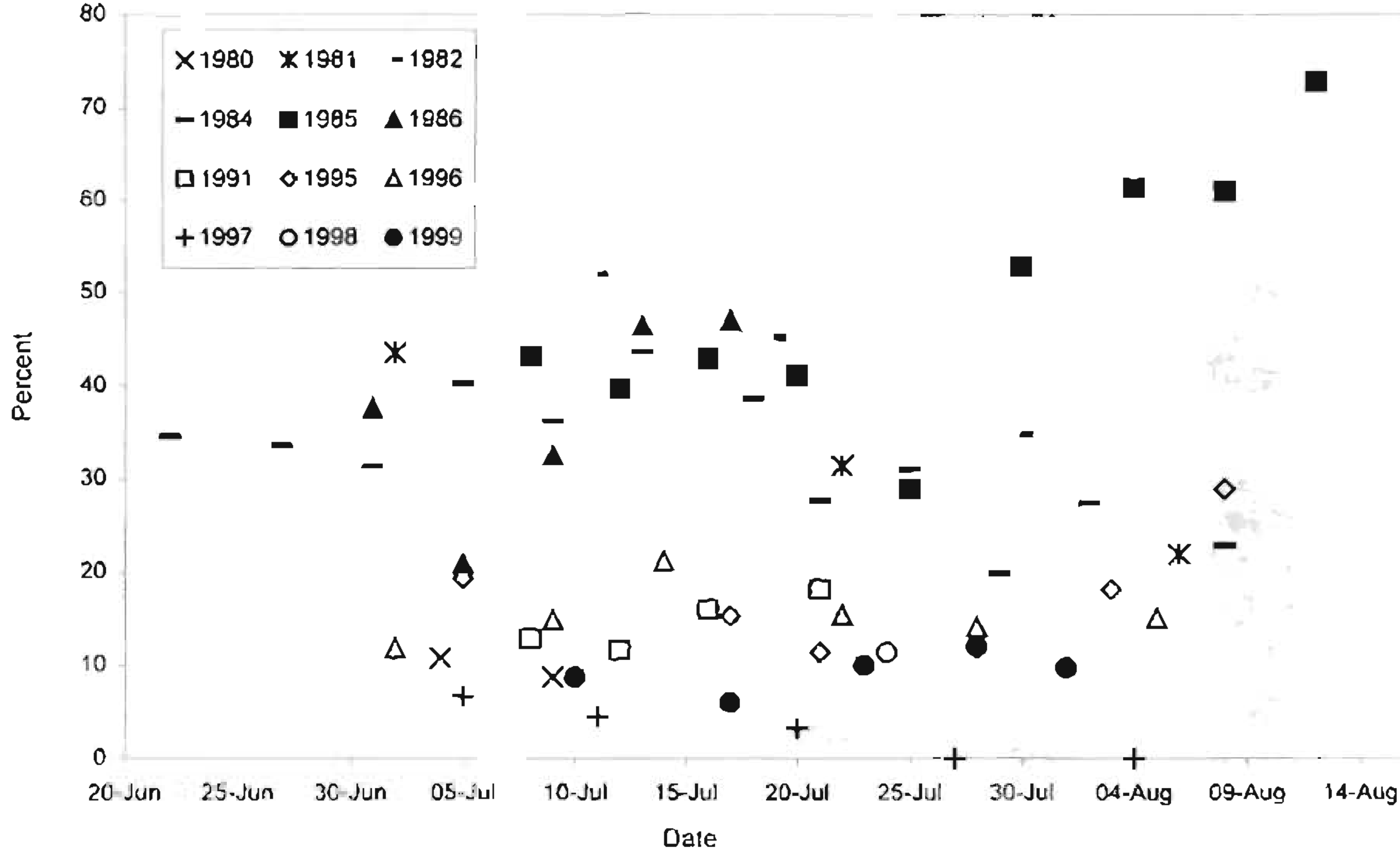

Figure 18. Historical percentage of female chum salmon by sample date at Kogrukluk River weir, 1980-1999.

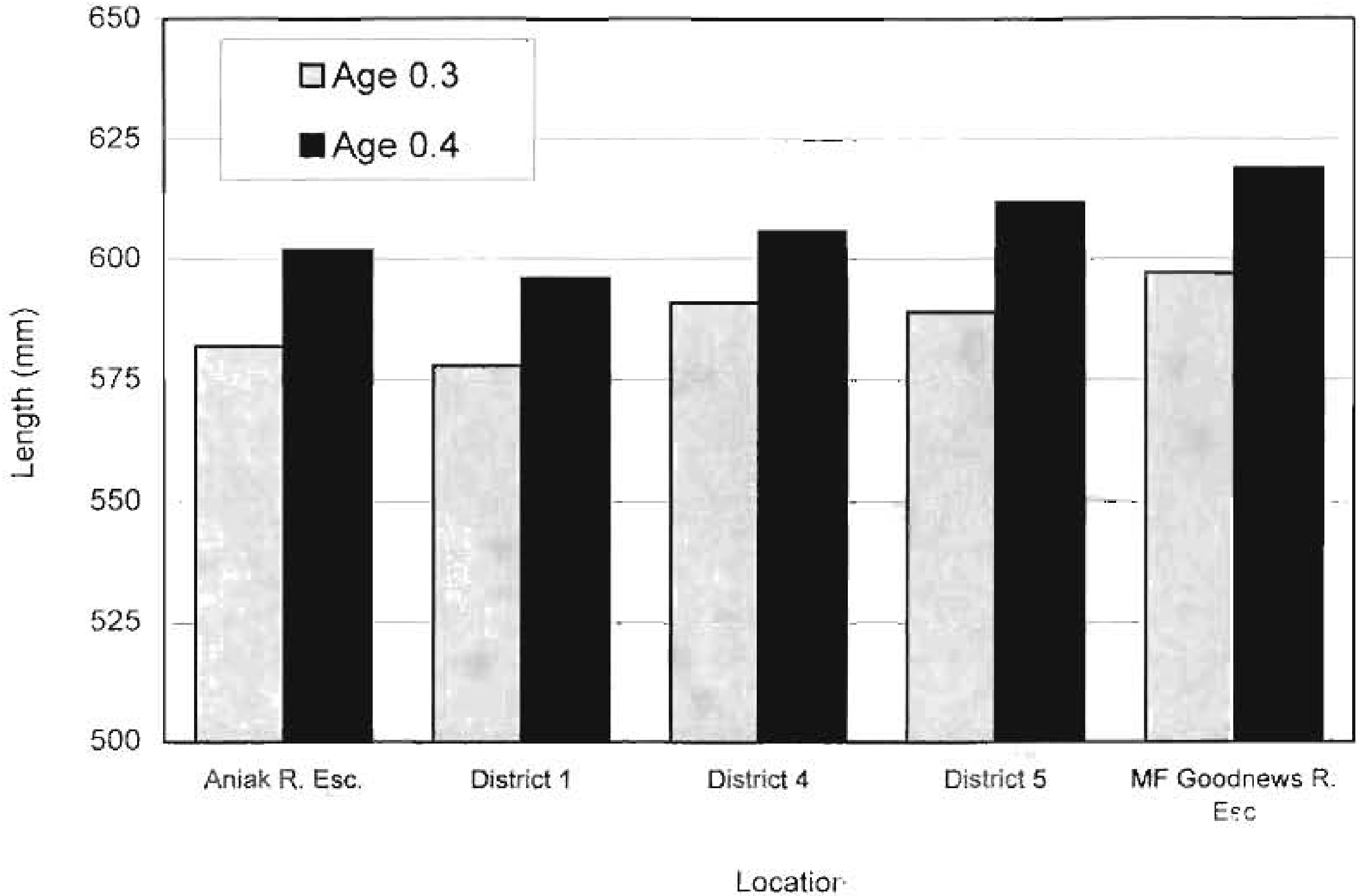

Figure 19. Average length of male chum salmon from escapements and commercial catches in the Kuskokwim Area, 1999.

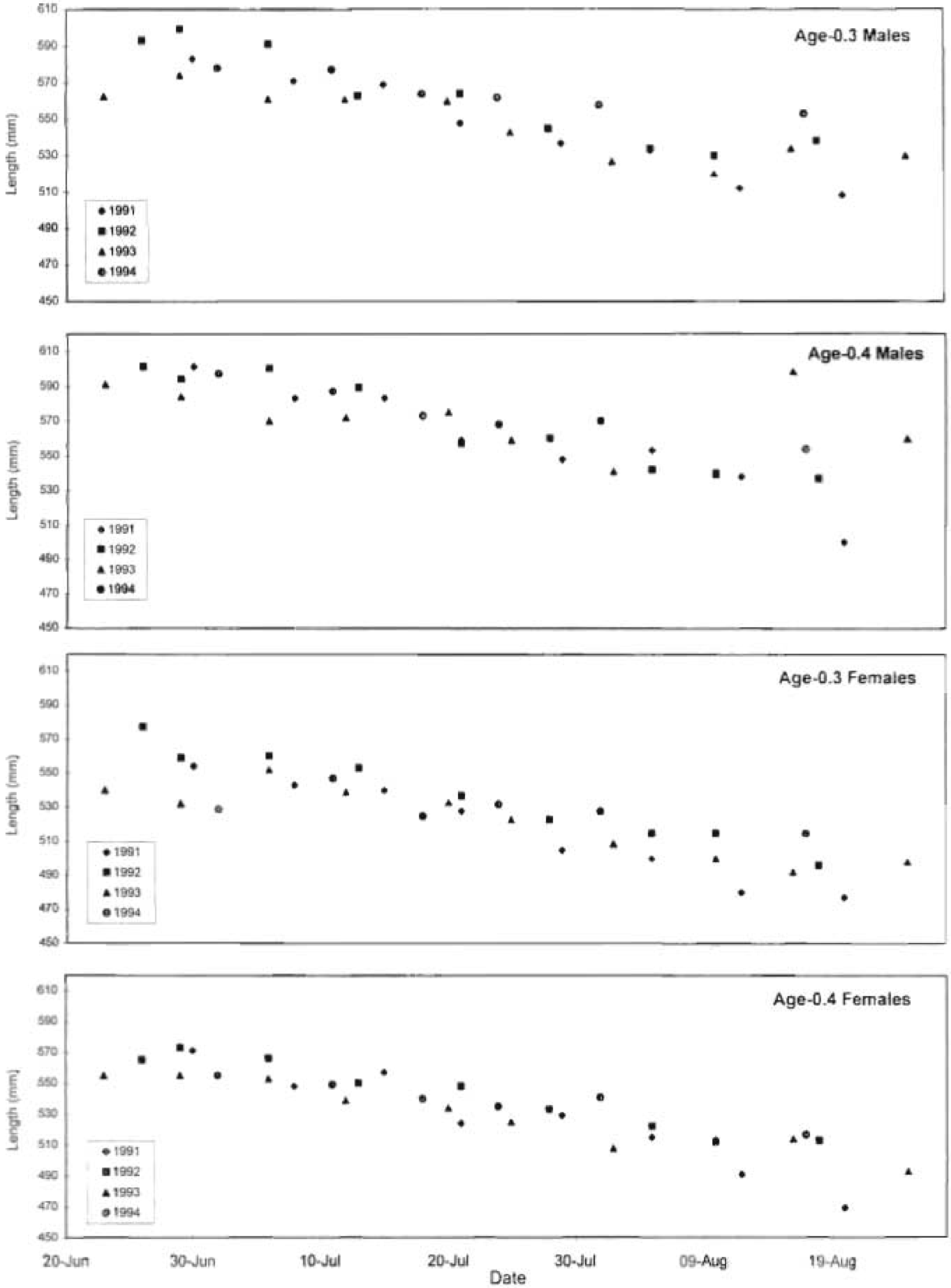

Figure 20. Average length of chum salmon by sample date in the Tuluksak River , 1991 - 1994.

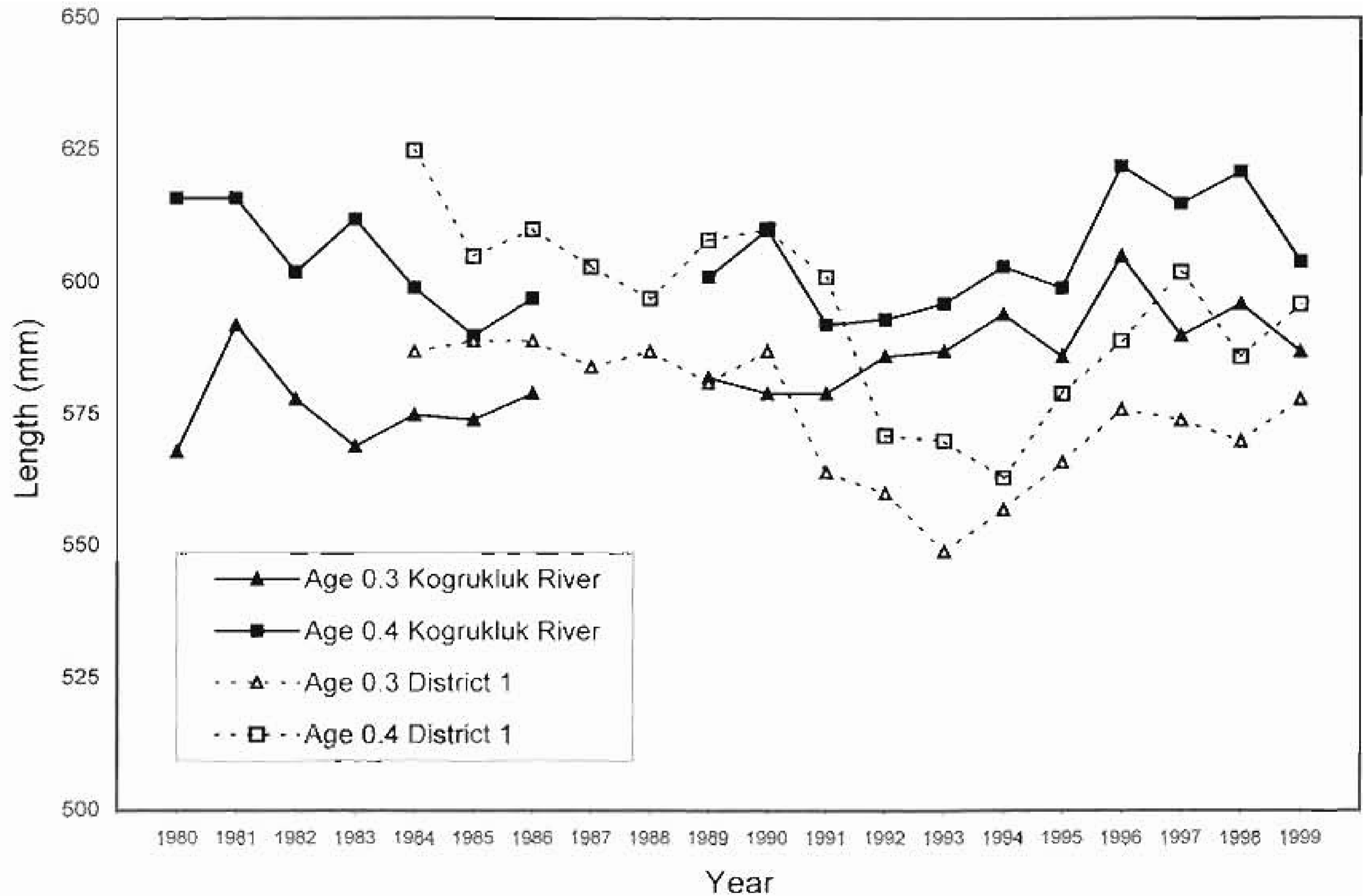

Figure 21. Historical average length of male chum salmon from Kogrukluk River and District 1 by age, 1980-1999.

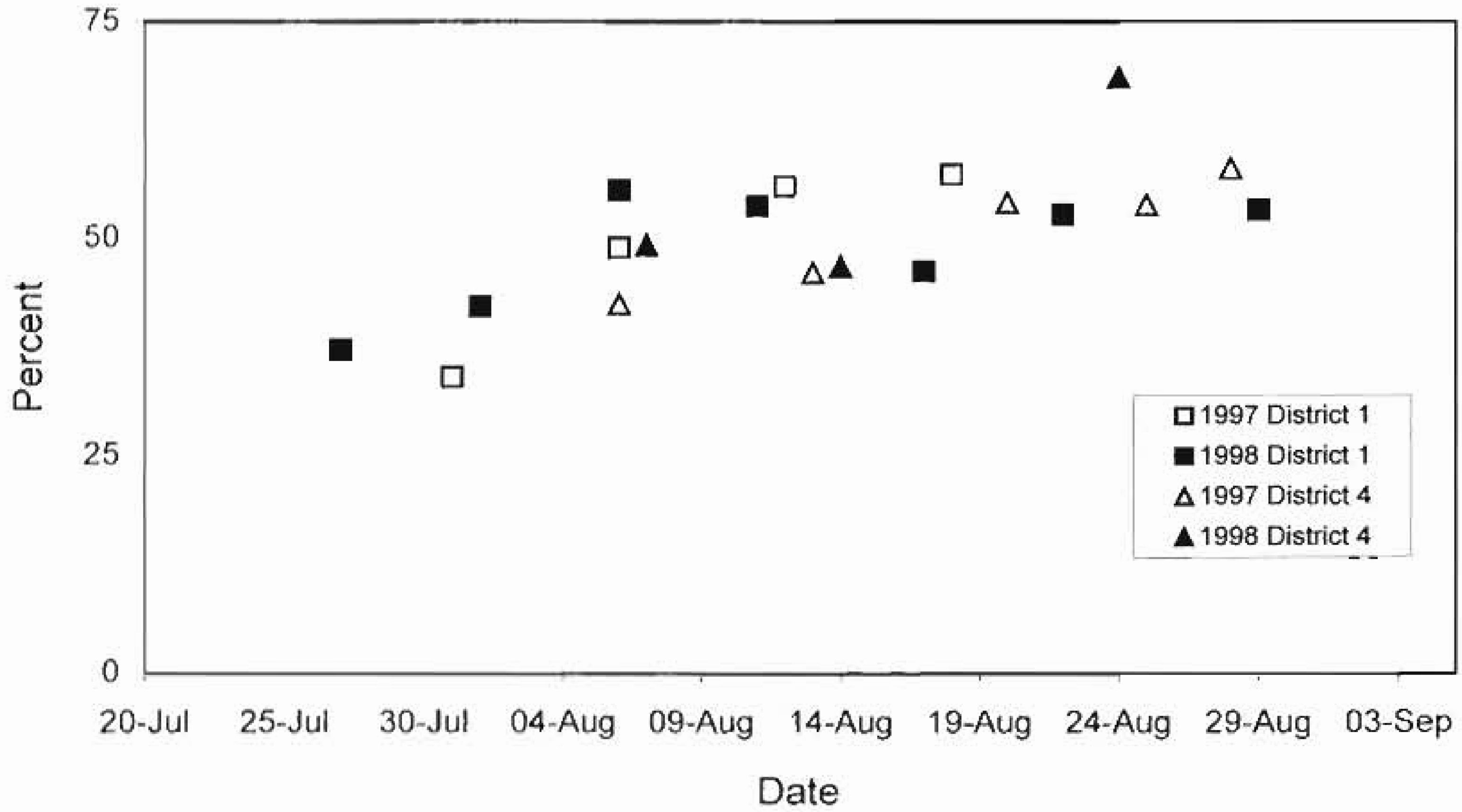

Figure 22. Percentage of female coho salmon by sample date from Districts 1 and 4 commercial catches, 1997 and 1998.