Fishery Data Series No. 10-32

A Mark–Recapture Study of Kuskokwim River Coho, Chum, Sockeye, and Chinook Salmon, 2001–2006

Final Report for Project FIS 04-308
USFWS, Office of Subsistence Management
Fisheries Resource Monitoring Program

by

Kevin L. Schaberg

Zachary W. Liller

and

Douglas B. Molyneaux

May 2010

Alaska Department of Fish and Game **Divisions of Sport Fish and 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, and Special Publications. 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)

Measures (fisheries)

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

Mathematics, statistics

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

FISHERY DATA SERIES NO. 10-32

A MARK–RECAPTURE STUDY OF KUSKOKWIM RIVER COHO, CHUM, SOCKEYE, AND CHINOOK SALMON, 2001–2006

by
Kevin L. Schaberg, Zachary W. Liller, and Douglas B. Molyneaux
Alaska Department of Fish and Game, Division of Commercial Fisheries, Anchorage

Alaska Department of Fish and Game
Division of Sport Fish, Research and Technical Services
333 Raspberry Road, Anchorage, Alaska, 99518-1565

May 2010

This investigation was partially financed by the U.S. Fish and Wildlife Service, Office of Subsistence Management (Project No. FIS 04-308) Fisheries Resource Monitoring Program under agreement number 701814J569.

ADF&G Fishery Data Series was established in 1987 for the publication of Division of Sport Fish technically oriented results for a single project or group of closely related projects, and in 2004 became a joint divisional series with the Division of Commercial Fisheries. Fishery Data Series reports are intended for fishery and other technical professionals and are available through the Alaska State Library and on the Internet: http://www.sf.adfg.state.ak.us/statewide/divreports/html/intersearch.cfm This publication has undergone editorial and peer review.

Kevin L. Schaberg (kevin.schaberg@alaska.gov),
Zachary W. Liller (zachary.liller@alaska.gov),
and
Douglas B. Molyneaux (doug.molyneaux@alaska.gov),
Alaska Department of Fish and Game, Division of Commercial Fisheries,
333 Raspberry Road, Anchorage, Alaska, 99518, USA

This document should be cited as:
Schaberg, K. L., Z. W. Liller, and D. B. Molyneaux. 2010. A mark–recapture study of Kuskokwim River coho, chum, sockeye, and Chinook salmon, 2001–2006. Alaska Department of Fish and Game, Fishery Data Series No. 10-32, Anchorage.

The Alaska Department of Fish and Game (ADF&G) administers all programs and activities free from discrimination based on race, color, national origin, age, sex, religion, marital status, pregnancy, parenthood, or disability. The department administers all programs and activities in compliance with Title VI of the Civil Rights Act of 1964, Section 504 of the Rehabilitation Act of 1973, Title II of the Americans with Disabilities Act (ADA) of 1990, the Age Discrimination Act of 1975, and Title IX of the Education Amendments of 1972.

If you believe you have been discriminated against in any program, activity, or facility please write:
ADF&G ADA Coordinator, P.O. Box 115526, Juneau, AK 99811-5526
U.S. Fish and Wildlife Service, 4401 N. Fairfax Drive, MS 2042, Arlington, VA 22203
Office of Equal Opportunity, U.S. Department of the Interior, 1849 C Street NW MS 5230, Washington DC 20240

The department's ADA Coordinator can be reached via phone at the following numbers:
(VOICE) 907-465-6077, (Statewide Telecommunication Device for the Deaf) 1-800-478-3648,
(Juneau TDD) 907-465-3646, or (FAX) 907-465-6078

For information on alternative formats and questions on this publication, please contact:
ADF&G, Division of Sport Fish, Research and Technical Services, 333 Raspberry Road, Anchorage AK 99518 (907) 267-2375.

TABLE OF CONTENTS

Page

LIST OF TABLES iii

LIST OF FIGURES v

LIST OF APPENDICES vi

ABSTRACT 1

INTRODUCTION 1

OBJECTIVES 2

METHODS 3

Study Design 3

Project Dates 4

Capture Methods 4

- Fish Wheels 4
- Drift Gillnets 5

Tag Deployment 5

Tag Recaptures 6

- Mainstem 6
- Tributaries 6
- Volunteer and Aniak Recaptures 7

Data Entry 7

Data Analysis 8

- Stock-specific Run Timing 8
- Migration Speed 8
- Abundance Estimates 8
- Abundance Estimate Diagnostics 9
  - Assumption 1: Closed Population 10
  - Assumption 2: No Affect of Marking 10
  - Assumption 3: No Tag Loss 10
  - Assumption 4: Equal Probability of Capture, Recapture, or Complete Mixing 11

RESULTS 12

Coho Salmon 12

- Capture and Tag Deployment 12
- Tag Recapture 12
- Stock-specific Run Timing 13
- Stock-specific Migration Speed 14
- Abundance Diagnostics 14
  - Wheel–Weir 14
    - Equal Probability of Tagging 14
    - Complete Mixing 14
  - Wheel–Wheel 15
    - Equal Probability of Tag Recovery 15
    - Complete Mixing 15
- Abundance Estimate 15

Chum Salmon 16

- Capture and Tag Deployment 16
- Tag Recapture 16
- Stock-specific Run Timing 16

TABLE OF CONTENTS (Continued)

Page

Stock-specific Migration Speed 17
Abundance Diagnostics 18
Wheel–weir 18
Equal Probability of Tagging 18
Complete Mixing 18
Wheel–wheel 18
Equal Probability of Tag Recovery 18
Complete Mixing 18
Abundance estimates 18
Sockeye Salmon 19
Capture and Tag Deployment 19
Tag Recapture 19
Stock-specific Run Timing 19
Stock-specific Migration Speed 20
Abundance Diagnostics 20
Wheel–weir 20
Equal Probability of Tagging 20
Complete Mixing 20
Wheel–wheel 21
Equal Probability of Tag Recovery 21
Complete Mixing 21
Abundance estimates 21
Chinook Salmon 21
Tag Deployment 21
Tag Recapture 22
Stock-specific Run Timing 22
Stock-specific Migration Speed 22
DISCUSSION 22
Tag Deployment 22
Tag Recapture 24
Stock-specific Run Timing 26
Stock-specific Migration Speed 27
Abundance Estimation 28
Coho Salmon 28
Chum Salmon 29
Sockeye Salmon 31
ACKNOWLEDGEMENTS 32
REFERENCES CITED 33
TABLES AND FIGURES 37
APPENDIX A 119
APPENDIX B 121
APPENDIX C 131
APPENDIX D 135
APPENDIX E 139

LIST OF TABLES

Table **Page**

1. Project years in which specific objectives were attempted for each target species of Kuskokwim River salmon. 38
2. Operational dates by gear type used in the Kuskokwim River salmon mark–recapture study, 2001–2006. 39
3. Summary of coho salmon captured and anchor-tagged at the Kalskag tagging site, Kuskokwim River 2001–2005. 40
4. Coho salmon tag recovery ratios by recovery site and wheel-weir chi-square analysis of equal probability of capture at the Kalskag tagging site, Kuskokwim River 2001–2005. 41
5. Summary of anchor-tagged coho salmon recovered at recapture projects by gear type used at the Kalskag tagging site, 2001–2005. 43
6. Run timing for coho salmon tagged near Kalskag and recovered in upriver tributaries of the Kuskokwim River, 2001–2005. 45
7. Migration rates for coho salmon tagged near Kalskag and recovered in upriver tributaries of the Kuskokwim River, 2001–2005. 46
8. Wheel-weir chi-square analysis of complete mixing of coho salmon tagged near Kalskag with untagged fish by gear type, Kuskokwim River 2001. 47
9. Wheel-weir chi-square analysis of complete mixing of coho salmon tagged near Kalskag with untagged fish by gear type, Kuskokwim River 2002. 48
10. Wheel-weir chi-square analysis of complete mixing of coho salmon tagged near Kalskag with untagged fish by gear type, Kuskokwim River 2003. 49
11. Wheel-weir chi-square analysis of complete mixing of coho salmon tagged near Kalskag with untagged fish by gear type, Kuskokwim River 2004. 50
12. Wheel-weir chi-square analysis of complete mixing of coho salmon tagged near Kalskag with untagged fish by gear type, Kuskokwim River 2005. 51
13. Wheel-wheel chi-square test of temporally consistent probability of recovering Kalskag tagged coho salmon at Birch Tree Crossing, Kuskokwim River 2001–2004. 52
14. Wheel-wheel chi-square analysis of complete mixing of coho salmon tagged near Kalskag with untagged fish, Kuskokwim River 2001. 53
15. Wheel-wheel chi-square analysis of complete mixing of coho salmon tagged near Kalskag with untagged fish, Kuskokwim River 2002. 54
16. Wheel-wheel chi-square analysis of complete mixing of coho salmon tagged near Kalskag with untagged fish, Kuskokwim River 2003. 55
17. Wheel-wheel chi-square analysis of complete mixing of coho salmon tagged near Kalskag with untagged fish, Kuskokwim River 2004. 56
18. Coho salmon abundance estimates at Kalskag using wheel-wheel and wheel-weir mark-recapture methods, Kuskokwim River 2001–2005. 57
19. Summary of chum salmon captured and anchor-tagged at the Kalskag tagging site, Kuskokwim River 2002-2005. 58
20. Chum salmon tag recovery ratios by recovery site and wheel-weir chi-square analysis of equal probability of capture at the Kalskag tagging site, Kuskokwim River 2002–2005. 59
21. Summary of anchor-tagged chum salmon recovered at recapture projects by gear type used at the Kalskag tagging site, 2002-2005. 61
22. Run timing for chum salmon tagged near Kalskag and recovered in upriver tributaries of the Kuskokwim River, 2002-2005. 63
23. Migration rates for coho salmon tagged near Kalskag and recovered in upriver tributaries of the Kuskokwim River, 2002–2005. 64
24. Wheel-weir chi-square analysis of complete mixing of chum salmon tagged near Kalskag with untagged fish by gear type, Kuskokwim River 2002. 65
25. Wheel-weir chi-square analysis of complete mixing of chum salmon tagged near Kalskag with untagged fish by gear type, Kuskokwim River 2003. 66
26. Wheel-weir chi-square analysis of complete mixing of chum salmon tagged near Kalskag with untagged fish by gear type, Kuskokwim River 2004. 67

LIST OF TABLES (Continued)

Table **Page**

27. Wheel-weir chi-square analysis of complete mixing of chum salmon tagged near Kalskag with untagged fish by gear type, Kuskokwim River 2005. 68
28. Wheel-wheel chi-square test of temporally consistent probability of recovering Kalskag tagged chum salmon at Birch Tree Crossing, Kuskokwim River 2002–2003. 69
29. Wheel-wheel chi-square analysis of complete mixing of chum salmon tagged near Kalskag with untagged fish, Kuskokwim River 2002. 70
30. Wheel-wheel chi-square analysis of complete mixing of chum salmon tagged near Kalskag with untagged fish, Kuskokwim River 2003. 71
31. Summary of sockeye salmon captured and anchor-tagged at the Kalskag tagging site, Kuskokwim River 2002–2006. 72
32. Sockeye salmon tag recovery ratios by recovery site and wheel-weir chi-square analysis of equal probability of capture at the Kalskag tagging site, Kuskokwim River 2001-2005. 73
33. Summary of anchor-tagged sockeye salmon recovered at recapture projects by gear type used at the Kalskag tagging site, 2002–2006. 75
34. Run timing for sockeye salmon tagged near Kalskag and recovered in upriver tributaries of the Kuskokwim River, 2002–2006. 77
35. Migration rates for sockeye salmon tagged near Kalskag and recovered in upriver tributaries of the Kuskokwim River, 2002–2006. 78
36. Wheel-weir chi-square analysis of complete mixing of sockeye salmon tagged near Kalskag with untagged fish by gear type, Kuskokwim River 2002. 79
37. Wheel-weir chi-square analysis of complete mixing of sockeye salmon tagged near Kalskag with untagged fish by gear type, Kuskokwim River 2003. 80
38. Wheel-weir chi-square analysis of complete mixing of sockeye salmon tagged near Kalskag with untagged fish by gear type, Kuskokwim River 2004. 81
39. Wheel-weir chi-square analysis of complete mixing of sockeye salmon tagged near Kalskag with untagged fish by gear type, Kuskokwim River 2005. 82
40. Wheel-weir chi-square analysis of complete mixing of sockeye salmon tagged near Kalskag with untagged fish by gear type, Kuskokwim River 2006. 83
41. Wheel-wheel chi-square test of temporally consistent probability of recovering Kalskag tagged sockeye salmon at Birch Tree Crossing, Kuskokwim River 2001-2004. 84
42. Wheel-wheel chi-square analysis of complete mixing of sockeye salmon tagged near Kalskag with untagged fish, Kuskokwim River 2002. 85
43. Wheel-wheel chi-square analysis of complete mixing of sockeye salmon tagged near Kalskag with untagged fish, Kuskokwim River 2003. 86
44. Sockeye salmon abundance estimates at Kalskag using wheel-wheel and wheel-weir mark-recapture methods, Kuskokwim River 2002–2006. 87
45. Summary of Chinook salmon captured and anchor-tagged at the Kalskag tagging site, Kuskokwim River 2005-2006. 88
46. Chinook salmon tag recovery ratios by recovery site and wheel-weir chi-square analysis of equal probability of capture at the Kalskag tagging site, Kuskokwim River 2005-2006. 89
47. Summary of anchor-tagged Chinook salmon recovered at recapture projects by gear type used at the Kalskag tagging site, 2005–2006. 90
48. Run timing for sockeye salmon tagged near Kalskag and recovered in upriver tributaries of the Kuskokwim River, 2005–2006. 91
49. Migration rates for coho salmon tagged near Kalskag and recovered in upriver tributaries of the Kuskokwim River, 2001–2005. 92

LIST OF FIGURES

Figure **Page**

1. Map of Kuskokwim River Alaska, showing the distribution of commercial harvest areas, population centers, tagging site, and recapture weirs. 93
2. Map of mainstem Kuskokwim River tagging and recovery site locations, 2001–2006. 94
3. Summary of coho salmon captured and anchor-tagged at the Kalskag tagging site, Kuskokwim River 2001–2005. 95
4. Run timing for coho salmon tagged near Kalskag and recaptured in upriver tributaries of the Kuskokwim River, 2001–2005. Vertical lines represent the central 50% with the horizontal line representing the central 80% passage. 96
5. Migration rates for coho salmon tagged near Kalskag and recovered in upriver tributaries of the Kuskokwim River, 2001. Points represent individual tagged fish, where the horizontal line represents the mean migration rate. 97
6. Migration rates for coho salmon tagged near Kalskag and recovered in upriver tributaries of the Kuskokwim River, 2002. Points represent individual tagged fish, where the horizontal line represents the mean migration rate. 98
7. Migration rates for coho salmon tagged near Kalskag and recovered in upriver tributaries of the Kuskokwim River, 2003. Points represent individual tagged fish, where the horizontal line represents the mean migration rate. 99
8. Migration rates for coho salmon tagged near Kalskag and recovered in upriver tributaries of the Kuskokwim River, 2004. Points represent individual tagged fish, where the horizontal line represents the mean migration rate. 100
9. Migration rates for coho salmon tagged near Kalskag and recovered in upriver tributaries of the Kuskokwim River, 2005. Points represent individual tagged fish, where the horizontal line represents the mean migration rate. 101
10. Summary of chum salmon captured and anchor-tagged at the Kalskag tagging site, Kuskokwim River 2002–2005. 102
11. Run timing for chum salmon tagged near Kalskag and recaptured in upriver tributaries of the Kuskokwim River, 2001–2005. Vertical lines represent the central 50% with the horizontal line representing the central 80% passage. 103
12. Migration rates for chum salmon tagged near Kalskag and recovered in upriver tributaries of the Kuskokwim River, 2002. Points represent individual tagged fish, where the horizontal line represents the mean migration rate. 104
13. Migration rates for chum salmon tagged near Kalskag and recovered in upriver tributaries of the Kuskokwim River, 2003. Points represent individual tagged fish, where the horizontal line represents the mean migration rate. 105
14. Migration rates for chum salmon tagged near Kalskag and recovered in upriver tributaries of the Kuskokwim River, 2004. Points represent individual tagged fish, where the horizontal line represents the mean migration rate. 106
15. Migration rates for chum salmon tagged near Kalskag and recovered in upriver tributaries of the Kuskokwim River, 2005. Points represent individual tagged fish, where the horizontal line represents the mean migration rate. 107
16. Summary of sockeye salmon captured and anchor-tagged at the Kalskag tagging site, Kuskokwim River 2002–2006. 108
17. Run timing for sockeye salmon tagged near Kalskag and recaptured in upriver tributaries of the Kuskokwim River, 2002–2006. Vertical lines represent the central 50% with the horizontal line representing the central 80% passage. 109
18. Migration rates for sockeye salmon tagged near Kalskag and recovered in upriver tributaries of the Kuskokwim River, 2002. Points represent individual tagged fish, where the horizontal line represents the mean migration rate. 110
19. Migration rates for sockeye salmon tagged near Kalskag and recovered in upriver tributaries of the Kuskokwim River, 2003. Points represent individual tagged fish, where the horizontal line represents the mean migration rate. 111

LIST OF FIGURES (Continued)

Figures **Page**

20. Migration rates for sockeye salmon tagged near Kalskag and recovered in upriver tributaries of the Kuskokwim River, 2004. Points represent individual tagged fish, where the horizontal line represents the mean migration rate. 112
21. Migration rates for sockeye salmon tagged near Kalskag and recovered in upriver tributaries of the Kuskokwim River, 2005. Points represent individual tagged fish, where the horizontal line represents the mean migration rate. 113
22. Migration rates for sockeye salmon tagged near Kalskag and recovered in upriver tributaries of the Kuskokwim River, 2006. Points represent individual tagged fish, where the horizontal line represents the mean migration rate. 114
23. Summary of Chinook salmon captured and anchor-tagged at the Kalskag tagging site, Kuskokwim River 2005–2006. 115
24. Run timing for Chinook salmon tagged near Kalskag and recaptured in upriver tributaries of the Kuskokwim River, 2005–2006. Vertical lines represent the central 50% with the horizontal line representing the central 80% passage. 116
25. Migration rates for Chinook salmon tagged near Kalskag and recovered in upriver tributaries of the Kuskokwim River, 2005. Points represent individual tagged fish, where the horizontal line represents the mean migration rate. 117
26. Migration rates for Chinook salmon tagged near Kalskag and recovered in upriver tributaries of the Kuskokwim River, 2006. Points represent individual tagged fish, where the horizontal line represents the mean migration rate. 118

LIST OF APPENDICES

Appendix **Page**

A1. Data standardization methods 120
B1. Stratified coho salmon anchor-tag deployment at Kalskag and recovery by deployment week at Birch Tree Crossing, Kuskokwim River 2001. 122
B2. Stratified coho salmon anchor-tag deployment at Kalskag and recovery by deployment week at Birch Tree Crossing, Kuskokwim River 2002. 123
B3. Stratified coho salmon anchor-tag deployment at Kalskag and recovery by deployment week at Birch Tree Crossing, Kuskokwim River 2003. 124
B4. Stratified coho salmon anchor-tag deployment at Kalskag and recovery by deployment week at Birch Tree Crossing, Kuskokwim River 2004. 125
B5. Stratified chum salmon anchor-tag deployment at Kalskag and recovery by deployment week at Birch Tree Crossing, Kuskokwim River 2002. 126
B6. Stratified chum salmon anchor-tag deployment at Kalskag and recovery by deployment week at Birch Tree Crossing, Kuskokwim River 2003. 127
B7. Stratified sockeye salmon anchor-tag deployment at Kalskag and recovery by deployment week at Birch Tree Crossing, Kuskokwim River 2002. 128
B8. Stratified sockeye salmon anchor-tag deployment at Kalskag and recovery by deployment week at Birch Tree Crossing, Kuskokwim River 2003. 129
C1. Exploration of Kuskokwim River coho salmon exploitation, 2001–2005. 132
C2. Exploration of Kuskokwim River chum salmon exploitation, 2002–2005. 133
C3. Exploration of Kuskokwim River sockeye salmon exploitation, 2002–2006. 134
D1. Comparison of coho salmon abundance estimates (95% confidence intervals) at Kaskag, Kuskokwim River 2001–2005. 136
D2. Relationship between mark-recapture coho salmon abundance estimates at Kalskag and escapement index, Kuskokwim River 2001–2005. 137
E1. Comparison of chum salmon abundance estimates at Kalskag with known upriver abundance from independent research, Kuskokwim River 2002–2005. 140

ABSTRACT

The Alaska Department of Fish and Game, Division of Commercial Fisheries conducted a mark–recapture study of coho (2001–2005), chum (2002–2005), sockeye (2002–2006), and Chinook (2005 and 2006) salmon returning to the Kuskokwim River, Alaska. All species were captured and tagged using fish wheels and drift gillnets operated in the lower mainstem Kuskokwim River near the village of Kalskag, river kilometer (rkm) 263. Tagged salmon were recaptured upstream using mainstem fish wheels operated near Birch Tree Crossing (rkm 294) and escapement monitoring weirs located on the Salmon (rkm 404), George (rkm 453), Tatlawiksuk (rkm 568), Kogrukluk (rkm 710) and Takotna (rkm 835) rivers. Run timing past the Kalskag tagging site and migration speed were estimated for all upriver stocks monitored with weirs. Total abundance of coho, chum, and sockeye salmon that reached the Kalskag tagging site was estimated in select years using wheel–wheel and wheel–weir methods (Chinook salmon abundance was not included in this study.) Each salmon species displayed evidence for a stock-specific run timing chronology where fish that traveled further upstream migrated through the lower river earlier in the season. Farther traveling coho and Chinook salmon displayed faster migration speeds compared to individuals traveling to less distant tributaries. Similarly, coho and Chinook salmon that began their upriver migration later in the year traveled faster than earlier migrating individuals. Coho and sockeye salmon abundances were successfully estimated in all years; however, chum salmon abundance estimation was problematic and no reliable estimates were produced.

Key words Kuskokwim River, mark–recapture, fish wheel, coho, chum, sockeye, and Chinook salmon, run timing, migration rate, abundance estimation.

INTRODUCTION

The Kuskokwim River is the second largest river in Alaska, draining an area of about 130,000 km^2 along its 1,498 km course from interior Alaska to the Bering Sea (Figure 1). The drainage produces Chinook (*Oncorhynchus tshawytscha)*, chum (*O. keta)*, sockeye (*O. nerka)*, pink *(O. gorbuscha)*, and coho salmon (*O. kisutch)*, each with numerous stock assemblages and overlapping migratory timings. Salmon spawn and rear throughout the drainage, ranging from the Eek River that joins the Kuskokwim River at river kilometer (rkm) 13, to the uppermost headwaters (Johnson and Daigneault 2008).

Kuskokwim River salmon support subsistence, commercial, and sport fisheries (Whitmore et al. 2008). The subsistence fishery which occurs throughout much of the drainage is one of the largest in the state with approximately 3,500 participating households from 26 communities, and a 10-year average annual harvest of 78,485 Chinook, 60,137 chum, 37,652 sockeye, and 31,546 coho salmon (Whitmore et al. 2008). The commercial salmon fishery occurs primarily in the lower 203 km of the river where approximately 800 permits holders have a 10-year average annual harvest of 8,775 Chinook, 135,026 chum, 28,019 sockeye, and 332,023 coho salmon (Whitmore et al. 2008). Although modest in value compared to other areas of Alaska, the commercial fishery is an important component of the Kuskokwim Area's market economy, income from which supports subsistence harvest activities of local residents (Coffing 1991; Coffing et al. 2001). Sport fishing interest has generally been increasing in recent years, but the 10-year average salmon harvest is only 3,342 fish, with coho salmon accounting for 65% (Whitmore et al. 2008).

Alaska Department of Fish and Game (ADF&G) is responsible for managing the Kuskokwim River salmon fisheries for long-term sustainability. Currently, decisions to open and close fisheries have been based on a gillnet test fishery operated near Bethel (rkm 106), catch trends from commercial and subsistence fisheries, and 7 to 8 tributary escapement monitoring projects. Lacking are estimates of total annual abundance that allow for assessing exploitation rate and productivity, and knowledge about stock-specific dynamics. These information gaps present challenges for ensuring sustainable harvest and decisively identifying periods of conservation

concern. Consequently, fishery managers follow precautionary strategies as per the Alaska Sustainable Salmon Policy (5 AAC 39.222).

Beginning in 1997 salmon appeared to have exceptionally low returns throughout most of Western Alaska (Kruse 1998), resulting in formal disaster declarations. In response, the U.S. Congress appropriated $7 million to develop a disaster research and prevention plan. The resulting Western Alaska Salmon Fisheries Disaster Mitigation Research Plan (WASFDP) recognized the critical need to improve assessment of total annual salmon abundance in the Kuskokwim River and to improve the understanding of stock-specific dynamics (ADF&G 1999).

One of the projects that emerged from WASFDP was this salmon tagging initiative on the Kuskokwim River to identify stock-specific run timing, stock-specific migration speeds, and to estimate total annual abundance through mark–recapture techniques (NOAA Grant Award Number NA96FW0196, Fishery Disaster Relief Program). Starting in 2001, this project initially focused only on coho salmon (Kerkvliet and Hamazaki 2003), but was expanded in 2002 with the aid of matching funds from the State of Alaska (SOA) to also include chum and sockeye salmon (Kerkvliet et al. 2003). Funding from WASFDP phased out in 2003, but the initiative was continued with funding from the Arctic-Yukon-Kuskokwim Sustainable Salmon Initiative (AYK SSI, Project #42443) and by the Federal Office of Subsistence Management (OSM; FIS #03-030; Kerkvliet et al. 2004). Funding from AYK SSI was discontinued in 2004, and a multi-year grant was awarded by OSM (FIS #04-308) to continue the project through 2006, with the inclusion of Chinook salmon.

This document is the final summary report to OSM in completion of FIS #04-308. The goal was to summarize all years of the project; however, not all objectives were exhaustively addressed. Project objectives varied from year to year and were archived in annual reports that were prepared after each field season (Kerkvliet and Hamazaki 2003; Kerkvliet et al. 2003, 2004; Pawluk et al. 2006a; Pawluk et al. 2006b). Major results from each year (i.e. migration characteristics and abundance estimates) with an emphasis on spatial and temporal trends are highlighted here. In addition, the successes and failures of the study are discussed so as to provide context when interpreting the results and provide guidance for future large scale mark–recapture studies.

Changes in funding sources, objectives, staffing, and the evolving understanding of effective tagging methods led to many inconsistencies in data management and analyses associated with this project. Data collected across all project years was standardized to facilitate comparisons. As a result, values presented in this document may not match exactly with their corresponding values published in the individual annual reports. These discrepancies in no way discredit the previous reports; however, the results presented here should be viewed as superseding all previously published results. With this in mind, we encourage the reader to review the associated annual reports (Kerkvliet and Hamazaki 2003; Kerkvliet et al. 2003, 2004; Pawluk et al. 2006a; Pawluk et al. 2006b) for more detailed information.

OBJECTIVES

Cumulative funding over the 6 years (2001–2006) of this project supported part or all of the objectives listed below for each of the 4 targeted species: coho, chum, sockeye, and Chinook salmon. The objectives for each species changed annually due to informational needs and funding availability (Table 1), but in general those objectives were to:

1. Describe stock-specific run timing past the Kalskag tagging site for select spawning aggregates of Kuskokwim River coho, chum, sockeye, and Chinook salmon.
2. Describe stock-specific migration rate for select spawning aggregates of coho, chum, sockeye, and Chinook salmon traveling between the Kalskag tagging site and their respective spawning grounds.
3. Estimate abundance of coho, chum, and sockeye salmon in the Kuskokwim River that reached the Kalskag tagging site.

METHODS

STUDY DESIGN

Mark–recapture methods were used to estimate stock-specific run timing and migration speed for monitored stocks spawning upriver of the village of Kalskag (rkm 263), and estimate total abundance of select salmon species that reached the Kalskag tagging site (Figure 1 and 2). All target species were captured and tagged in the lower mainstem Kuskokwim River using bank-mounted fish wheels and mid-channel drift gillnets. Tagged salmon were recaptured upstream in the mainstem using bank-mounted fish wheels located at Birch Tree Crossing (rkm 287) and escapement monitoring weirs located on the Salmon (Aniak drainage: rkm 404), George (rkm 453), Tatlawiksuk (rkm 568), Kogrukluk (Holitna drainage: rkm 710), and Takotna (rkm 835) rivers (Figure 1 and 2).

This study was designed to allow for 2 distinct opportunities to estimate the abundance of salmon that reached the Kalskag tagging site using mark–recapture methods. The first opportunity used tags deployed at Kalskag and recaptured at Birch Tree Crossing (i.e. wheel–wheel). Wheel–wheel mark–recapture provided the potential for estimating salmon abundance inseason. The second opportunity used tags deployed at Kalskag and recaptured at the upriver tributary escapement monitoring projects (wheel–weir). Wheel–weir methods provided an opportunity to describe run timing past Kalskag and migration speed for each of the monitored upriver stocks. Wheel–weir methods provided postseason abundance estimates only.

The tagging locations near Kalskag were selected because: (1) they were well removed from marine waters, thus salmon were expected to be physiologically more tolerant of capture and tagging stress, (2) they were upstream of commercial fishing and most subsistence fishing, reducing harvest of tagged fish, (3) they were below most salmon spawning streams, and (4) water velocity and channel morphology were known to be adequate for fish wheel and drift gillnet operations.

Recapture locations were considered appropriate for addressing the project objectives because: (1) they could inspect large numbers of salmon for marks, (2) they indexed discrete regions of the middle and upper drainage, and (4) the spatial arrangement provided an opportunity to test mark–recapture assumptions. The Birch Tree Crossing recapture site was selected because it was a suitable location for operating fish wheels and drift gillnets and it was thought to be far enough upriver from the Kalskag tagging site to allow tagged fish to mix completely with untagged fish. The arrangement of recapture gear at Birch Tree Crossing provided an opportunity to test mark–recapture model assumptions. Tributary recapture locations were selected because they capitalized on existing salmon escapement monitoring projects that indexed salmon escapement and age-sex-length (ASL) composition in the lower, middle, and upper portions of the drainage. The spatial arrangement of tributary recapture sites allowed for adequate diagnostics of model

assumptions for abundance estimation, and provided a means of effectively targeting distinct stocks for the purpose of addressing migration characteristics.

PROJECT DATES

The start and end dates of field operations were selected to ensure that sampling occurred throughout the migration of coho, chum, sockeye, and Chinook salmon past the Kalskag tagging site (Table 2). The annual start date was chosen to precede significant passage of chum, sockeye, and Chinook salmon whose run timing precedes that of coho salmon, except 2001 when coho salmon was the only target species. The start date was based on historical daily catch-per-unit-effort (CPUE) data from a commercial salmon test fishery located near Bethel.

The end date for field operations was selected to encompass the majority of the coho salmon migration, while allowing sufficient time for tagged fish to reach upstream recapture sites prior to the end of their operational period. Upriver recapture sites generally ceased operations by September 20. Previous weir reports indicate that only 0.1–0.2% of the coho salmon return passed after that date (Whitmore et al. 2008). Considering ending dates at upriver escapement projects, expected migration rate, and harvest pressures, September 8 was selected as the last day of tag deployment near Kalskag. Coho salmon typically continue their upriver migration into the fall, and perhaps even after the river is frozen (Carlon 2000; Ericksen 1999; Jones III and McPherson 1997; Jones III et al. 2001). Consequently, tagging efforts do not represent the entire coho salmon return. Abundance estimates and migration characteristics of Kuskokwim River coho salmon presented in this report represent those fish vulnerable to harvest.

CAPTURE METHODS

Fish Wheels

Fish wheels were operated near Kalskag from 2001 to 2006 and Birch Tree Crossing from 2001 to 2004. Fish wheels have proven effective for both tagging and recapturing large numbers of adult salmon in large Alaskan rivers (Barrett et. al. 1984a, 1984b; Meehan 1961). The design, number, and location of the fish wheels used changed throughout the duration of this study in order to capitalize on previous years' successes, adjust for sampling inadequacies, and adjust for budgetary constraints (Table 2). Fish wheels were operated 24 hours per day, 7 days per week, except for periods of maintenance, readjustment, or relocation. The fish wheels were staffed for 15 to 16 hours each day by 2-person crews working 7.5 or 8.0 hour shifts. Shift schedules varied across and within years, but always included an early morning/mid afternoon shift and an early evening/late night shift. Each year, as the season progressed and daylight hours shortened, the shift schedule was adjusted. During each shift, fish were tagged from each wheel approximately every 2 hours, depending on catch rates. Between shifts, however, fish were held in flow-through live boxes for periods longer than 2 hours.

During the first year of operations (2001), fish wheels consisted of 2 baskets measuring 2.5x2.5 meters (length x width) constructed of spruce poles. From 2002 to 2006, fish wheels consisted of 3 baskets measuring 2.4x3.0 meters (length x width) constructed of aluminum. In all years, a perforated plywood live box measuring 2.4 x 1.2 x 0.6 meters (length x width x depth) was attached to the offshore side of each wheel and used to hold fish between sampling events. A weir measuring ~5 meters (length) was attached to the inshore side of each fish wheel and extended perpendicular to the bank. Fish wheels were generally positioned so they fished in water depths of 1 to 2 meters, maintained 2 to 4 basket revolutions per minute (rpm), and the

distance between the baskets and substrate was minimized. Fish wheel performance was maintained inseason by adjusting the distance from the shore, the vertical position of the baskets, and location.

Drift Gillnets

Drift gillnetting was conducted near Kalskag from 2001 to 2006 and Birch Tree Crossing from 2002 to 2004. Gillnets were used to tag and capture salmon of each target species that were oriented toward the middle of the river and thus were not susceptible to capture by shore-mounted fish wheels. There were many different fishing locations, mesh sizes, and net lengths used over the duration of the study, which were a function of the target species, catch rates, and river conditions (Table 2). Shorter nets were generally fished when catch rates were high, and longer nets were fished when catches were low. Nets were fished between fish wheel sampling events for a total of 2 hours of actual drift time per day. Drifts were made at established stations located along both banks, offshore from the fish wheels. Stations were selected based on prior success and advice of local fishermen. Nets were deployed from skiffs and drifts lasted approximately 15 minutes per station. At the first sign of fish entanglement, the net was retrieved to reduce stress on the captured fish. Drifts would be repeated at a given station until a total drift time of 15 minutes, or until an 8 hour work day had been achieved.

TAG DEPLOYMENT

All healthy pre-spawn target species caught using fish wheels and drift gillnets near the Kalskag (2001–2006) site were tagged, with the goal of tagging as many fish as possible annually. Tagging consisted of one primary and one secondary mark. The primary mark consisted of a 36 cm spaghetti tag (2001–2004) or an 11 cm T-bar Anchor Tag (2005 and 2006). Each tag had a unique identification number and the phone number of the ADF&G Anchorage office. From 2001 to 2003, tags deployed at Kalskag were of the same color, while from 2004 to 2006 tag colors were used to differentiate gear type and bank of capture (i.e. left and right bank fish wheel and drift gillnets). In 2005, limited availability of tags resulted in the need to tag every other chum and sockeye salmon from 28 July to 4 August; however, because sample sizes remained adequate, the reduction in tag deployment during that time did not affect the study.

Salmon selected for tagging were placed into a padded aluminum cradle that was suspended in a tub filled with fresh circulating river water. Tags were inserted into the back of the fish, on either the left or right side, about 1 cm below the base of the dorsal fin and about 4 fin rays anterior from the posterior end of the dorsal fin. Each fish also received a secondary mark, which consisted of an axillary fin clip, opercula punch, adipose fin clip, or adipose fin punch. Different secondary marks were used in different years, with adipose fin clips being the most common and readily recognizable at recapture sites.

For each tagged fish, detailed information about the capture event was recorded, including: date and time, location, bank, gear type used, handling time, and release time. Biological information about each fish was also recorded, including: sex determined from external characteristics, length measured from mideye to fork of tail (MEF), fish condition (1=good, 2=minor wound, 3=major wound, 4=dead), fish color (1=bright silver, 2=some color, 3=obvious color, 4=spawning colors). Scale samples were collected for age determination following procedures outlined in Molyneaux et al. (2009). Genetic tissue (axillary process) was collected from tagged fish. All non-target species were identified, counted, and released. In addition, tagging crews recorded environmental and fishing condition data daily, including: cloud cover, wind speed and direction,

notes on changes in water level, water temperature, water depth, and fish wheel rpm. Specific types of data collected changed depending on financial constraints or logistical concerns. For example, genetic tissue and scales were not collected in every year. Further, when salmon catches were very high, sex and length data may only have been recorded on a subsample of the catch.

From 2001 to 2003, salmon were also tagged at the Birch Tree Crossing site. However, contrary to previously published annual reports, we chose not to use data from Birch Tree tagged salmon to address the project objectives. Fish tagged at Birch Tree Crossing were not considered in this final analysis because: (1) Birch Tree Crossing did not operate as a tag site in 2004–2006, (2) Birch Tree Crossing and Kalskag tag sites were far enough apart (24 rkm, 1–2 days migration time) to cause concern as to the appropriateness of pooling catch data, (3) sample sizes based on Kalskag recaptures alone were sufficient for addressing the objectives of the study, (4) spatial and temporal trends were not overly sensitive to the removal of Birch Tree tagged fish, (5) using Kalskag tagged fish only made our results more comparable to other related studies of salmon abundance and movement that have used the Kalskag tagging platform as the primary tag deployment site.

TAG RECAPTURES

Tagged fish that were successfully caught at any recapture site were described as "recovered" only if the tag number and date of recovery were recorded and successfully matched with the tag deployment records. Alternatively, tagged fish were described as "observed" when crews were only able to record tag color and date but could not capture the fish, or the reported tag number did not match with the tag deployment records. The sum of recovered and observed tags was described as the total number of tag "recaptures".

Mainstem

Fish wheels and gillnets operated in the mainstem Kuskokwim River at the Birch Tree Crossing site from 2001 to 2004 and served to recapture fish tagged at Kalskag for wheel–wheel estimates. In 2001 and 2004, the focus of the Birch Tree Crossing site was to recapture coho salmon for abundance estimation. In 2002 and 2003, the focus of this site was to recapture chum and sockeye in addition to coho salmon for abundance estimation. Although tagged chum and sockeye salmon were also recaptured at Birch Tree Crossing in 2004 the late start of operations was not sufficient for calculating abundance because much of the run was unmonitored. Tag loss was assessed at the Birch Tree site by examining untagged salmon for secondary marks.

Tributaries

Escapement monitoring projects located on spawning tributaries throughout the drainage recaptured salmon tagged at the Kalskag site for wheel–weir estimates. Of the escapement projects, 2 were located downstream of the tagging site and 4 to 5 were located upstream. The downstream sites were located on the Tuluksak and Kwethluk rivers, and the upstream sites were located on the Salmon (Aniak Drainage), George, Tatlawiksuk, Kogrukluk, and Takotna rivers (Figure 2). Tag recaptures at downstream weirs were not used for estimating abundance or migration characteristics; rather they provided some limited insight into the number of salmon that traveled back downriver after being tagged. The Salmon (operated in 2006 only), George, and Kogrukluk River weirs indexed middle river stocks, while the Tatlawiksuk and Takotna River weirs indexed upper river stocks. Tag loss was assessed at all the weir sites by inspecting

untagged fish for secondary marks during routine ASL sampling. Details of weir operations for the 2006 project year are documented for Kwethluk River by Miller and Harper (2007), Tuluksak River by Plumb et al. (2007), George River by Hildebrand et al. (2007), Kogrukluk River by Liller et al. (2008), Tatlawiksuk River by Costello et al. (2007b), and Takotna River by Costello et al. (2007a).

At each of the weirs, tag recapture was accomplished through the use of a weir mounted fish trap measuring 2.5x1.5 meters (length x width) constructed of tightly spaced aluminum pickets. Traps included an entrance gate, holding box, and exit gate. The trap was incorporated into the weir design such that when both the entrance and exit gates were open, the trap served as the primary passage gate for all salmon. During normal operations, water clarity at the recapture sites was sufficient to allow weir personnel to identify tagged fish as they entered the trap. The entrance and exit gates could be closed quickly to trap tagged fish in the holding box so that tag information could be recorded.

Volunteer and Aniak Recaptures

Local subsistence, commercial, and sport fishermen who caught or found tagged fish were encouraged to report tag information through a lottery reward system advertised in posters, radio announcements, and public meetings. Volunteer tag recoveries provided an opportunity to increase public involvement and interest in the project. Fishermen reported tag information by calling a toll-free phone number printed on each tag or by calling or visiting any ADF&G, Kuskokwim River tribal organization, Kuskokwim Native Association, or U.S. Fish and Wildlife Service office. Contrary to previously published annual reports, the results of the volunteer tag recapture efforts were not presented in this final report, because reported data was often incomplete, overly general, or conflicted with tag deployment records.

The Aniak River sonar crew recaptured tagged salmon opportunistically as part of routine beach seining efforts to collect chum salmon ASL data. From 2002 to 2004 tag recapture efforts ended in late July with the scheduled end of sonar operation. In 2005 and 2006, tag recapture efforts were extended into late September beyond the scheduled end of sonar operations. Contrary to previously published annual reports, the results of the Aniak River sonar tag recapture efforts were not presented in this final report, because of inconsistent recapture effort over time generally resulting in unrepresentative results.

DATA ENTRY

All tagging and capture data collected at the Kalskag and Birch Tree Crossing sites were recorded using Juniper Systems Allegro hand held computers (Allegro). Following each shift, data was downloaded from the Allegro units and imported into a Microsoft Access®[1] database or Microsoft Excel® spreadsheets. Tag recapture data from weir recapture sites was recorded on paper data sheets. Similarly, volunteer recaptures were recorded on paper datasheets at designated reporting locations. Postseason, all fish capture, tag deployment, and tag recapture data was imported into a central Microsoft Access® database. Because of the duration of the project and changes in staffing, data were stored in multiple formats which lead to some database compatibility issues. These problems were identified and data were standardized across all project years (Appendix A1).

[1] Product names used in this publication are included for scientific completeness, but do not constitute product endorsement.

DATA ANALYSIS

Stock-specific Run Timing

Stock-specific run timing past Kalskag was estimated for all monitored upriver stocks (Salmon, George, Tatlawiksuk, Kogrukluk, and Takotna rivers). Estimates were generated by comparing the release dates of Kalskag tagged fish later recovered at upriver recapture sites. Tags recovered from each tributary were pooled and the median, central 50%, central 80% and range of tag dates at Kalskag for each group were portrayed graphically for comparison and trend identification. Variability in stock-specific run timing across project years was investigated by calculating the coefficient of variation (CV) of the median and range of run timing dates for each stock. CVs were compared across all monitored stocks for the purpose of identifying any meaningful trends. A lower CV indicated more stable run timing and a higher CV represented more variable run timing. Julian date was used to calculate summary statistics.

$$CV = \left[\frac{Stdev}{Mean} \right]$$

Migration Speed

Migration speed (rkm/day) for each recovered tagged salmon was calculated as the distance (rkm) between the location of tag deployment (Kalskag) and location of tag recovery, divided by the number days between time of release from the tagging site and recovery. The number of days was calculated as the recapture date minus the release date.

$$\text{Migration Speed} = \frac{[DISTANCE\ \ (rkm)]}{[\#\, days\,]}$$

Migration speed for all recovered tagged fish from each monitored upriver stock (Salmon, George, Tatlawiksuk, Kogrukluk, and Takotna) was pooled and the average and range of the migration speeds were portrayed graphically for comparison and trend identification. Variability in stock-specific migration speed across project years was investigated by calculating the CV of the average migration speed for each stock. CVs were compared across all monitored stocks for the purpose of identifying any meaningful trends. A lower CV indicated more stable migration speed and a higher CV represented more variable migration speed.

Abundance Estimates

Abundance estimates were generated in 2 ways: wheel–wheel and wheel–weir. Wheel–wheel estimates used tags deployed near Kalskag and recaptured upriver at Birch Tree Crossing. Wheel–weir estimates used tags deployed near Kalskag and recaptured upriver at tributary escapement projects. Both the wheel–wheel and wheel–wheel estimates of abundance only represent the total number of fish that reached the Kalskag tagging site. The estimates are inclusive of all salmon that passed upriver of the tagging site (whether they successfully spawned or not) and all salmon that eventually went back downriver after reaching the tagging site.

Wheel–weir abundance estimates were generated using the pooled Chapman modification to the Petersen estimator (Seber 1982), while wheel–wheel abundance estimates were generated using either the pooled Chapman modification to the Petersen estimator, or the Maximum Likelihood (ML) of the Darroch estimator (Darroch 1961; Arnason et. al. 1996; Seber 1982), depending on stratification needs.

The Chapman modified Petersen abundance estimator (Seber 1982) based on pooled tag recaptures, was calculated as:

$$\hat{N}^* = \frac{(C+1)(M+1)}{R+1} - 1 \tag{1}$$

Where:

$\hat{N}^*$ = estimated abundance of salmon in the Kuskokwim River at the Kalskag site,

M = the total number of salmon tagged at the Kalskag site,

C = the total number of salmon examined at all upstream recapture weir projects, and

R = the total number of tagged salmon recaptured at upstream escapement projects.

Maximum Likelihood of the Darroch Estimator (Darroch 1961; Seber 1982) based on temporally stratified tag recoveries, was calculated using Program SPAS (Arnason et al. 1996) as:

$$\hat{N} = \hat{U} + \sum_{i=1}^{s} a_i \tag{2}$$

$$\hat{U} = u' M^{-1} a \ , \tag{3}$$

$$u = \begin{bmatrix} u_1 \\ \vdots \\ u_j \\ \vdots \\ u_t \end{bmatrix} \quad a = \begin{bmatrix} a_1 \\ \vdots \\ a_i \\ \vdots \\ a_s \end{bmatrix} \quad M = \begin{bmatrix} m_{11} & \cdots & m_{1j} & \cdots & m_{1t} \\ \vdots & \ddots & & \iddots & \vdots \\ m_{i1} & & m_{ij} & & m_{it} \\ \vdots & \iddots & & \ddots & \vdots \\ m_{s1} & \cdots & m_{sj} & \cdots & m_{st} \end{bmatrix} \tag{4}$$

Where:

$\hat{N}$ = the estimated abundance of fish in the population at the Kalskag site,

$\hat{U}$ = the estimated abundance of untagged fish in the population at the Kalskag site,

uj = the number of untagged fish in the *j-th* temporal stratum at the Birch Tree Crossing site,

ai = the number of tagged fish released in the *i-th* temporal stratum at the Kalskag site, and

mij = the number of tagged fish released in *i-th* temporal stratum at the Kalskag site and recovered in the *j-th* temporal stratum at the Birch Tree Crossing site.

Abundance Estimate Diagnostics

For the estimates of salmon abundance from mark–recapture methods to be unbiased the following assumptions needed to be met (Seber 1982):

1. The population was closed.
2. Marking did not affect the probability of capture during the second sampling event.
3. Tagged fish did not lose their marks between sampling events.

4. Every fish had an equal probability of being tagged during the first sampling event, or every fish had an equal probability of being recaptured during the second sampling event, or marked fish mixed completely with unmarked fish between sampling events.

Assumption 1: Closed Population

In order for the assumption of population closure to be met, sampling must: (1) occur throughout the entire migration past the Kalskag tagging site for each target species, (2) all salmon that reached the Kalskag site must continue upriver, and (3) the population that passes Kalskag must not experience mortality. Given the study design and salmon biology, the assumption of a closed population was unrealistic. It was recognized that some small proportion of each target species passed the Kalskag tagging site during inoperable periods; although this was primarily a concern for late returning coho salmon. Further, tagged fish were observed backing out of the upriver study area and mortality (i.e. natural and harvest) above the Kalskag tagging site was known to occur. The study design was such that violations of the closed population assumption were minimized; however, the true extent of any imposed bias on abundance estimation was unknown. We did not feel that we could effectively model the proportion of the salmon population that backed out of the study area or the level of upriver mortality. Consequently, we chose to define the abundance estimate as the minimum number of each target salmon species that reached the Kalskag tagging site during the operational period.

Assumption 2: No Affect of Marking

The process of capturing and tagging was assumed to have no effect on the behavior of tagged salmon. Specifically, we assumed that the probability that tagged fish traveled downriver, died, or were harvested after being tagged did not differ from untagged fish. We also assumed that the probability that tagged fish were sampled in the second sample did not differ from untagged fish (i.e. tagged fish were not trap happy or shy). Further, we assumed that capture and tagging did not affect the migration behavior of tagged salmon.

Testing the effects of the capture and tagging process on the behavior of salmon was generally not feasible. Specifically, similarities in the behavior of tagged fish and untagged fish could not be tested. However, from 2001 to 2004, the effects of holding time and live box crowding for fish wheel caught coho, chum, and sockeye salmon were investigated (Kerkvliet and Hamazaki 2003; Kerkvliet et al. 2003; Kerkvliet et al. 2004; Pawluk et al. 2006a; Pawluk et al. 2006b). There was no evidence in any year to suggest that holding time affected recapture probability of any species. There was evidence that as the number of fish in the live box increased, the probability of recapture at Birch Tree Crossing increased for sockeye and chum salmon (Kerkvliet et al. 2004). Consequently, when fish wheel catches were high, sampling occurred more frequently and data collection methods were modified to process fish faster and reduce crowding.

Assumption 3: No Tag Loss

The extent that tag loss affected the estimation of the salmon population that reached Kalskag was evaluated by examining untagged salmon at upstream recapture sites for secondary marks. Evidence of tag loss was considered negligible for each species during each year of the project (Kerkvliet and Hamazaki 2003; Kerkvliet et al. 2003; Kerkvliet et al. 2004; Pawluk et al. 2006a; Pawluk et al. 2006b). In 2001 and 2002, additional fish inspections were conducted to assess

levels of tag loss (Clark and Molyneaux 2003a; Clark and Molyneaux 2003b; Linderman et al. 2003a; Linderman et al. 2003b) which was determined to be minimal.

Assumption 4: Equal Probability of Capture, Recapture, or Complete Mixing

A variety of measures were taken to ensure that target species had a constant non-zero probability of being tagged and recovered, and that tagged fish mixed completely with untagged fish. The study design was such that (1) tagging and recovery efforts occurred throughout most of the migration of target species, (2) tagging and recapture efforts were maintained as consistently as possible throughout the operational period, (3) fish wheels were operated along both banks and gillnets were fished in the middle of the river to ensure all fish and stocks were being targeted regardless of bank orientation, and (4) the distance between the tag site and upriver recapture sites was maximized to allow tagged fish to mix completely with untagged fish. It was anticipated that each gear type and position at Kalskag would have unequal probability of capture for all upriver stocks. However, the combination of all capture gears and positions, working in concert, were believed sufficient to represent upriver stocks.

Chi-square (α=0.05) was used to test to what degree the assumptions of equal capture probability, equal recapture probability, and mixing occurred. Only recapture sites and gear types with expected tag recaptures of 5 or more were included in the chi-square analysis. The results of these tests were examined in conjunction with the raw recapture ratios to determine if an unbiased abundance estimate could be produced, and which estimator (pooled or stratified) was most appropriate. It was important to recognize that failure to pass the chi-square analysis did not necessarily mean that the assumptions were violated, just that they could not be confirmed. If either the assumption of equal capture probability or complete mixing was supported using wheel–weir methods, then the pooled Petersen estimator was considered appropriate (Seber 1982). If both tests failed, the raw recapture ratios were investigated to determine if an estimate should be attempted. In general, if recapture ratios were similar (i.e. within ~1 standard deviation of the mean) and no spatial patterns were identified, a pooled estimate was attempted using wheel–weir data. If either the assumption of equal probability of recapture or complete mixing was supported using wheel–wheel methods, then the pooled Petersen estimator was considered appropriate, otherwise the temporally stratified Darroch estimator (Darroch 1961) was used.

The assumption of equal probability of capture was tested for wheel–weir methods based on tags deployed at Kalskag and recaptured at upriver weirs. Equal probability of capture was tested using chi-square comparing recapture ratios (total recaptured tags to unmarked fish past the weir) among the 4 to 5 upstream weir recapture sites. This analysis tested the null hypothesis that recapture ratios did not differ among monitored stocks. Failure to reject the null hypothesis was used as evidence that upriver stocks were tagged proportionally at the Kalskag tagging site.

The assumption of equal probability of recapture was tested for wheel–wheel methods based on tags deployed at Kalskag and recaptured at Birch Tree Crossing. This assumption was tested using chi-square by comparing the tag recovery ratios over time. The duration of the tagging and recovery efforts were divided into approximate weekly strata and summarized in an s by t matrix, representing the number of fish captured and tagged in the *i-th* tagging stratum and the number of those tagged fish recaptured in the *j-th* recapture stratum; where s is the number of release strata from i=1…s and t is the number of recapture strata from j=1…t (Appendix B1–8). Rows and columns were pooled concurrently so that each stratum had a minimum of 10 recoveries. Adjacent strata with similar recovery ratios were further combined to obtain the most

parsimonious matrix. This analysis tested the null hypothesis that tag recovery did not differ across temporal strata. Failure to reject the null hypothesis was used as evidence that recapture probability was similar throughout the operational period.

The extent that fish tagged from each of the individual gears mixed completely with untagged fish between the tagging site and the Birch Tree Crossing and weir recapture sites was tested using chi-square. Mixing between Kalskag and the upriver weirs was tested by comparing the tag recovery ratios among the upstream weirs by deployment gear type and position at Kalskag (i.e. tag recoveries from the right and left bank fish wheels and mid channel gillnets). This series of 3 separate analyses tested the null hypothesis that recovery ratios by deployment gear did not differ among monitored stocks. Failure to reject the null hypothesis was used as evidence that fish tagged from a given gear at Kalskag mixed completely with untagged fish. The assumption that fish tagged at Kalskag mixed completely with untagged fish was only confirmed if the null hypothesis could not be rejected for all 3 gear types. Complete mixing between Kalskag and Birch Tree Crossing was tested in a similar manner, by comparing recovery ratios for the various capture gears.

RESULTS

COHO SALMON

Capture and Tag Deployment

From 2001 to 2005, total catches of coho salmon at the Kalskag tagging site ranged from 1,363 to 7,148 fish. On average, 95% of the total catch was tagged in each year, with the remaining 5% consisting of unhealthy or previously tagged fish. Tag recaptures at the Kalskag tagging site were relatively low each year ranging from 8 to 121 fish (Table 3). Fish wheel catches accounted for 77–93% of the total catch across all years, with the right bank fish wheel accounting for the majority of the catch in each year. Annually, coho salmon catches were zero near the start of operations suggesting that the early migration past Kalskag was well represented (Figure 3). The first fish captured at Kalskag was in late June or early July in most years, while peak capture typically occurred in middle to late August. Daily catches generally decreased toward the end of operations, although they remained between 30 to 100 fish per day suggesting that the end of the annual migration was not thoroughly represented.

Tag Recapture

From 2001 to 2004, total sample size of coho salmon at the Birch Tree Crossing site ranged from 1,843 to 16,964, with tag recaptures ranging from 13 to 169 fish. From 2001 to 2005, upriver weirs passed between 35,130 and 107,790 coho salmon, with total annual tag recaptures ranging from 102 to 750 fish (Table 4). Most (average: 87%) of the tag recaptures were initially caught and tagged with fish wheels (Table 5). Most (average: 80%) of the recaptured tags were successfully recovered and tag numbers and dates were recorded. Tagged coho salmon were recaptured at all upriver weirs each year. Each year the Kogrukluk River weir recaptured the most tags (range: 51–492) and Takotna River weir recaptured the least (range: 3–38). Annually, tag recapture ratios were low (<0.1%) and similar (i.e. on the same order of magnitude) at all upriver weirs (Table 4). In most years, the Tatlawiksuk and Takotna River weirs displayed lower recapture ratios compared to the George and Kogrukluk River weirs. Tags recaptured at weirs below the tagging site (Kwethluk and Tuluksak Rivers) ranged from 0.1 to 1.3% of the total

deployed tags, representing the minimum proportion of tagged coho salmon that traveled down river after tagging.

Stock-specific Run Timing

Comparisons of the 2001–2005 median passage dates past the Kalskag tagging site for each of the monitored upriver coho salmon stocks suggested a run timing pattern where earlier migrating stocks were bound for more distant headwater reaches of the drainage compared to later migrating stocks (Table 6, Figure 4). Although the pattern was observed in each year of the project there was considerable annual variation. Takotna River, the most upriver monitored stock, had the earliest median run timing in all years in which tags were successfully recovered. George River, the nearest monitored stock upriver of the tagging site, had the latest median run timing in all years of the project. The Tatlawiksuk and Kogrukluk River stocks did not display a consistent temporal pattern. Evidence for a run timing continuum was less apparent as broader time scales, such as the central 50%, 80%, and full range of passage dates, were considered.

The annual variation in stock-specific median passage dates past the Kalskag tagging site was low for each of the monitored upriver stocks. Furthermore, no spatial pattern was observed. The Kogrukluk River coho salmon stock had the most consistent median run timing past Kalskag (CV=1.33%, range 14–22 August) followed by George River (CV=1.60%, range: 21–29 August), Takotna River (CV=2.11%, range: 2–12 August), and Tatlawiksuk River (CV=2.41%, range: 12–25 August).

The total number of days that specific coho salmon stocks were observed migrating past the Kalskag tagging site varied considerably across project years (Table 6). Tatlawiksuk River coho salmon showed the most variable range of migration days past Kalskag (CV=60.03%, range: 4–44 days), followed by George River (CV=32.94%, range: 18–44 days), Takotna River (CV=29.29%, range: 17–37 days), and the Kogrukluk River (CV=21.81%, range: 33–61 days). The Kogrukluk River stock consistently had the most protracted run timing past Kalskag compared to the other monitored upriver stocks (Table 6). In most years, the first coho salmon of known origin past the Kalskag tagging sites was a Kogrukluk River fish. In most years the Takotna River stock displayed the most contracted run timing. The number of days required for more distant stocks (i.e. Kogrukluk and Takotna) to pass the Kalskag tagging site was more consistent compared to less distant stocks (i.e. George and Tatlawiksuk). Distance traveled from the mouth of Kuskokwim River did not yield insight into whether a given stocks run timing would be contracted or protracted.

A comparison of the median recovery and sample dates across project years at each of the weir recovery sites suggests that tagged coho salmon arrive on the spawning grounds later than untagged fish (Table 6). Which may indicate tagging affected the migration of tagged fish. The median recovery date was later than the median sample date for each monitored stock during each year of the project with the exception of George River in 2002 and Takotna River in 2004. The average difference between the median recovery and sample dates was 8, 12, 7, and 6 days for George, Tatlawiksuk, Kogrukluk and Takotna River stocks respectively. The greatest difference was observed in 2001 for each of the recovery sites except Takotna River, which did not recover any tagged fish in that year.

Stock-specific Migration Speed

Comparison of the average migration speed for each of the monitored upriver coho salmon stocks provided some evidence for a continuum where fish migrating farther generally swam faster compared to fish migrating to less distant tributaries (Table 7, Figures 5–9). Although evidence of this continuum was observed in each year of the project, there was considerable annual variation. Tatlawiksuk River (rkm 568) coho salmon did not conform to this pattern in 2004 or 2005 when this stock showed the fastest migration speed of the monitored stocks.

A wide range of migration speeds were observed by tagged coho salmon from 2001 to 2005 and stock-specific ranges overlapped broadly each year (Table 7, Figures 5–9). The Takotna River coho salmon stock had the most consistent migration speed (CV=6.26%, range: 26–30 rkm/day) followed by Kogrukluk River (CV=7.23%, range: 22–27 rkm/day), Tatlawiksuk River (CV = 17.72%, range: 19–29 rkm/day), and George River (CV=23.67%, range: 12–21 rkm/day). Comparisons of the CV of migration speed provided evidence for a continuum where upriver stocks display a more consistent annual migration speed relative to stocks bound for less distant tributaries.

Individual tagged coho salmon bound for upriver tributaries displayed a wide range of migration speeds (range: 7–47 rkm/day) throughout the duration of the study. In each year, the range of observed migration speeds remained relatively constant over the course of the run for each of the monitored stocks. In years when tag recoveries were high for a given stock, there was considerable evidence for a continuum where earlier migrating fish traveled slower than later migrating fish resulting in an increase in stock-specific migration speed as the run progressed (Figures 5–9). This continuum was observed for all monitored coho salmon stocks, although; the Kogrukluk and George River stocks displayed the strongest signature.

Abundance Diagnostics

Wheel–Weir

Equal Probability of Tagging

From 2002 to 2004, the probabilities of tagging upriver coho salmon stocks at Kalskag were not statistically different based on chi-square tests of recapture ratios (Table 4). Conversely, in 2001 and 2005 the probability of tagging upriver coho stocks at Kalskag did differ statistically. However; in both 2001 and 2005, the tag recapture ratios for all monitored stocks were all on the same order of magnitude (within 1 standard deviation of the mean), and showed no obvious spatial trends, suggesting that any associated bias was most likely small. Consequently, we chose to ignore the violation of equal probability of tagging in 2001 and 2005.

Complete Mixing

Coho salmon tagged from each capture gear operated near Kalskag were recovered at most upriver recovery weir sites each year providing empirical evidence that tagged fish mixed with untagged fish (Tables 8–12). The chi-square test of complete mixing of coho salmon tagged from each gear type could not be performed for all gears in most years, because of low sample sizes. However, complete mixing of tagged coho salmon from at least one capture gear type operated at Kalskag was tested in each year. Results of the chi-square tests suggested that complete mixing of coho salmon tagged from the right bank fish wheel occurred in 2005, from the left bank fish wheel in 2002 and 2003, and from the drift gillnets in 2001 and 2002.

Wheel–Wheel

Equal Probability of Tag Recovery

In 2001, the probability that coho salmon tagged near Kalskag were recovered at the Birch Tree Crossing site was not statistically different over time based on chi-square tests of recovery ratios (Table 13). In 2002–2004, however, the probability of recovering tagged fish at Birch Tree Crossing increased as the season progressed.

Complete Mixing

Insight into complete mixing in 2001 was limited due to low sample sizes (Table 14). For 2002–2004 coho salmon tagged from each capture gear operated near Kalskag were recovered with all recapture gears operated near Birch Tree Crossing, providing empirical evidence that tagged fish mixed with untagged fish (Tables 15–17). In most years, tag recoveries at Birch Tree Crossing were low and insufficient for testing complete mixing of fish tagged from each capture gear at Kalskag with untagged fish. However, complete mixing of tagged coho salmon from at least one capture gear type operated at Kalskag was tested in all years except 2001. Results of chi-square tests suggested that complete mixing from the right bank fish wheel occurred in 2003 and 2004 and from the left bank fish wheel in 2003. The extent to which coho salmon tagged from drift gillnets mixed could not be tested in any year due to low sample sizes. Only in 2003 was there evidence that all coho salmon tagged from both fish wheels mixed completely with untagged fish.

Abundance Estimate

For all years, the pooled Petersen model was used to calculate a wheel–weir estimate of coho salmon abundance that reached Kalskag, but details regarding its applicability varied among years. From 2002 to 2004, the critical assumption of equal probability of tagging was met indicating the pooled Petersen model was appropriate and should yield an unbiased abundance estimate. In addition, for 2002–2004, empirical evidence suggested that coho salmon tagged from each gear type mixed with untagged fish; although, this critical assumption could not be confirmed for all gear types each year. In 2001 and 2005, both the tests of equal probability of tagging and complete mixing indicated a potential bias in using the pooled estimator; however, the empirical evidence suggested the bias was likely small and acceptable compared to the alternative of not producing an estimate for those years. The wheel–weir estimates ranged from 440,330 to 1,546,627 coho salmon from 2001 through 2005 (Table 18, Appendix D1).

Unbiased wheel–wheel coho salmon abundance estimates required the use of different modeling techniques across years. In 2001 and 2003, the pooled Petersen model was used to estimate abundance, but details about its applicability varied. In 2001, the critical assumption of equal probability of tag recovery was met and indicated that the pooled model was appropriate and should yield an unbiased abundance estimate. In 2003, the critical assumption that coho salmon tagged from the right and left bank wheels mixed completely with untagged fish was met and also indicated the pooled model was appropriate. In 2003, mixing of gillnet tagged coho salmon could not be tested, but any associated bias was considered acceptable compared to the alternatives of producing a less precise stratified estimate or not producing an estimate for that year. In 2002 and 2004, the temporally stratified Darroch model was used because the critical assumptions for an unbiased estimate from a pooled model were not met. Specifically, the probability of tag recovery at Birch Tree Crossing was not similar over time and the assumption

that tagged fish and untagged fish mixed completely could not be confirmed for all gear types. In 2002 and 2004, the mark–recapture efforts were separated into 3 and 4 temporal strata respectively. Wheel–wheel abundance estimates, using both models, ranged from 170,042 to 675,306 coho salmon (Appendix D1).

CHUM SALMON

Capture and Tag Deployment

From 2002 to 2005, total catches of chum salmon at the Kalskag tagging site ranged from 5,673 to 30,465 fish (Table 19). On average 92% of the total catch was tagged in each year, with the remaining 8% consisting of unhealthy or previously tagged fish. Tag recaptures at the Kalskag tagging site were relatively low each year ranging from 215 to 1,408 fish. Fish wheel catches accounted for 95–99% of the total catch across all years. The right bank wheel accounted for the majority of the catch in all years except 2004. Each year, chum salmon catches were zero or very low near the start of operations suggesting that the early migration past Kalskag was well represented (Figure 10). The first chum salmon captured at Kalskag was in mid June in all years. High daily capture rates typically occurred throughout much of July. Each year, daily catches tapered to only a few fish per day toward the end of operations, suggesting that the end of the migration was well represented.

Tag Recapture

From 2002 to 2004, total sample size of chum salmon at the Birch Tree Crossing site ranged from 18,095 to 19,064, with tag recaptures ranging from 271 to 644 fish (Table 20). From 2002 to 2005, upriver weirs passed between 50,539 and 268,030 chum salmon, with total annual tag recaptures ranging from 69 to 671 fish. Most (average: 98%) of the tag recaptures were initially caught and tagged with fish wheels (Table 21). Most (average: 90%) of the recaptured tags were successfully recovered and tag numbers and dates were recorded. Tagged chum salmon were recaptured at all upstream weirs in each year with the exception of Takotna in 2004. Each year the George River weir recaptured the most tags (range: 59–312) and Takotna River weir recaptured the least (range: 0–6). Annual tag recapture ratios varied considerably between sites (Table 20). Each year tag recapture ratios at upriver weir sites decreased as the distance from the Kalskag tagging site increased. Tags recaptured at weirs below the tagging site (Kwethluk and Tuluksak rivers) ranged from 0.1 and 0.3% of the total deployed tags, representing the minimum proportion of tagged chum salmon that traveled down river after tagging.

Stock-specific Run Timing

Comparisons of the 2002 through 2005 median passage dates past the Kalskag tagging site for each of the monitored upriver chum salmon stocks suggested a run timing pattern where earlier migrating stocks were bound for more distant headwater reaches of the drainage compared to later migrating stocks (Table 22, Figure 11). The median run timing date was earliest for the Takotna River stock and was successively later for the Kogrukluk, Tatlawiksuk, and George River stocks in each year in which tags were successfully recovered and run timing was calculated. The run timing of the Takotna River stock must be taken with caution as annual sample sizes were low. Evidence for a run timing continuum remained apparent as broader time scales, such as the range, central 50%, and 80% were considered (Figure 11).

The annual variation in stock-specific median passage dates past the Kalskag tagging site was low for each of the monitored upriver stocks (Table 22). Furthermore, no spatial pattern was observed. The Tatlawiksuk River chum salmon stock had the most consistent median run timing past Kalskag (CV=1.86%, range: 1–7 July) followed by Kogrukluk River (CV=1.94%, range: 28 June–5 July), and George River (CV=2.22%, range: 9–19 July). Limited tag recoveries from Takotna River precluded meaningful analysis.

The total number of days that specific chum salmon stocks were observed migrating past the Kalskag tagging site varied considerably across project years (Table 22). Kogrukluk River showed the most variable range of migration days past Kalskag (CV=82.25%, range: 7–72 days) followed by Tatlawiksuk River (CV=33.18%, range: 38–72 days) and George River (CV=22.66%, range: 49–84 days). The George River stock generally had the most protracted run timing past Kalskag compared to the other monitored upriver stocks (Table 22). There was some evidence that spatial position was correlated to run timing consistency. The number of days required for a stock to pass the Kalskag tagging site was more consistent for stocks with a shorter distance to travel (i.e. George and Tatlawiksuk) compared to more distant stocks (i.e. Kogrukluk). Distance traveled from the mouth of Kuskokwim River did not yield insight into whether a given stocks run timing would be contracted or protracted. Limited tag recoveries from Takotna River precluded meaningful analysis.

A comparison of the median recovery and sample dates across project years at each of the weir recovery sites provided little insight into the effects of tagging on behavior (Table 22). The median recovery date was consistently later than the median sample date at George River only. There was little difference in the median recovery and sample dates at Tatlawiksuk and Kogrukluk. The average number of days between the median recovery and sample dates was 9, 3, and 1 for George, Tatlawiksuk, and Kogrukluk River stocks respectively. Limited tag recoveries from Takotna River precluded meaningful analysis.

Stock-specific Migration Speed

Chum salmon stocks returning to the 4 monitored upriver tributaries displayed similar annual migration rates, and no spatial pattern was evident (Table 23 and Figures 12–15). The annual variability of the stock-specific average migration speeds was low for each of the monitored upriver stocks. The Tatlawiksuk River chum salmon stock had the most consistent migration speed (CV=2.15%, range: 35–36 rkm/day) followed by Kogrukluk River (CV=6.42%, range: 30–34 rkm/day), and George River (CV=6.63%, range: 27–32 rkm/day). Limited tag recoveries from Takotna River precluded meaningful analysis.

Individual tagged chum salmon bound for upriver tributaries displayed a wide range of migration speeds (range: 11–63 rkm/day) throughout the duration of the study. In each year, the range of observed migration speeds remained relatively constant over the course of the run for each of the monitored stocks. In addition, the migration speed for individual tagged chum salmon was generally consistent throughout the course of the run.

Abundance Diagnostics

Wheel–weir

Equal Probability of Tagging

From 2002 to 2005, the probabilities of tagging upriver chum salmon stocks were statistically different based on chi-square tests of recapture ratios (Table 20). Further, in each year the tag recapture ratios decreased as the distance between the tagging site and recapture site increased.

Complete Mixing

Chum salmon tagged from each capture gear operated near Kalskag were recovered at most upriver recapture sites each year providing empirical evidence that tagged fish mixed with untagged fish (Tables 24–27). For all years, the weir recovery ratios by deployment gear type decreased as the distance from the tagging site to the recovery site increased. The results of chi-square tests indicated that complete mixing of chum salmon tagged from the right bank fish wheel did not occur in any year. Complete mixing of chum salmon tagged from the left bank fish wheel did not occur in 2003 or 2005, and could not be tested in 2002 or 2004 due to low tag recoveries. Complete mixing of chum salmon tagged from gillnets did occur in 2003, but could not be tested in any other year due to low tag recoveries. Never was there evidence that all chum salmon tagged from each gear type mixed completely with untagged fish.

Wheel–wheel

Equal Probability of Tag Recovery

In 2002 and 2003, the probability of recovering tagged chum salmon at Birch Tree Crossing was statistically different over time based on chi-square tests of recovery ratios (Table 28).

Complete Mixing

In 2002 and 2003, chum salmon tagged from each capture gear operated near Kalskag were recovered with most recapture gears operated near Birch Tree Crossing, providing empirical evidence that tagged fish mixed with untagged fish (Tables 29 and 30). In 2002, chum salmon tagged from the left bank fish wheel did mix completely with untagged fish; however, right bank tagged fish did not. Complete mixing from fish wheels could not be confirmed in 2003. Chi-square test of complete mixing of chum salmon tagged using gillnets could not be performed in either year due to low sample sizes.

Abundance estimates

Reliable estimates of the total abundance of chum salmon at Kalskag were not generated using wheel–weir data in 2002–2004 because in each year tag recapture ratios decreased as the distance between the Kalskag tagging site and the upriver recapture sites increased. Wheel–wheel data provided an additional opportunity to estimate the number of chum salmon that reached the Kalskag tagging site. For wheel–wheel estimation, the temporally stratified Darroch model was considered the most appropriate for estimating total abundance of chum salmon in 2002 and 2003 because in both years critical assumptions required for an unbiased pooled estimator were not met. Specifically, the assumptions of complete mixing could not be confirmed and the probability of tag recovery was not constant over time. In 2002 and 2003 the mark–recapture efforts were separated into 6 and 5 temporal strata respectively. Resulting

estimates, however, were known to be biased extremely low; consequently, results are not presented.

SOCKEYE SALMON

Capture and Tag Deployment

From 2002 to 2006, total catches of sockeye salmon at the Kalskag tagging site ranged from 280 to 4,849 fish (Table 31). On average 95% of the total catch was tagged in each year, with the remaining 5% consisting of unhealthy or previously tagged fish. Tag recaptures at the Kalskag tagging site were relatively low each year ranging from 7 to 127 fish. Fish wheel catches accounted for 88–100% of the total catch across all years. The right bank wheel accounted for the majority of the catch in 2004–2006, and the left bank in 2002 and 2003. Each year, sockeye salmon catches were zero or very low near the start of operations suggesting that the early migration past Kalskag was well represented (Figure 16). The first sockeye salmon captured at Kalskag was in early to middle June in all years, while peak capture typically occurred in early July. In all years, daily catches tapered to only a few fish per day toward the end of operations, suggesting that the end of the migration was most likely well represented.

Tag Recapture

From 2002 to 2004, total sample size of sockeye salmon at the Birch Tree Crossing site ranged from 589 to 1,535, with tag recaptures ranging from 4 to 104 (Tables 32). From 2002 to 2006, upriver weirs passed between 3,439 and 64,338 sockeye salmon, with total tag recaptures ranging from 7 to 399. Most (average: 97%) of the tag recaptures at upriver weirs were initially caught and tagged with fish wheels (Table 33). Most (average: 92%) of the recaptured tags were successfully recovered and tag numbers and dates were recorded. With the exception of Kogrukluk River weir, tag recaptures were inconsistent at most upriver weirs. No tagged sockeye salmon were recaptured at George River in 2003, Tatlawiksuk River in 2002 and 2006, and Takotna River in 2002 and 2003. Annual tag recapture ratios varied considerably between sites, often by an order of magnitude or more (Table 33). In addition, when tags were recaptured, the recapture ratio was often higher than expected for weirs that monitored very small numbers of sockeye salmon. Tags recaptured at weirs below the tagging site (Kwethluk and Tuluksak Rivers) ranged from 0.2 to 0.7% of the total deployed tags, representing the known proportion of tagged sockeye salmon that traveled down river after tagging.

Stock-specific Run Timing

Comparisons of the 2002–2006, median passage dates past the Kalskag tagging site for each of the monitored upriver sockeye salmon stocks was generally difficult because of low tag recoveries. However, a general pattern was observed where earlier migrating stocks were bound for more distant headwater reaches of the drainage compared to later migrating stocks (Table 34, Figure 17). The Takotna River stock did not conform to this pattern in any year, although sample sizes were very low. Evidence for a run timing continuum remained apparent as broader time scales, such as the central 50%, 80%, were considered (Figure 17).

George and Kogrukluk rivers were the only sockeye salmon stocks with sufficient tag recoveries in at least half of the project years to meaningfully describe sockeye salmon stock-specific run timing. Tag recoveries from Salmon, Tatlawiksuk, and Takotna were not included in further analyses due to inconsistent and limited tag recoveries over the duration of the project.

The annual variability of the stock-specific median passage dates past the Kalskag tagging site was low for the Kogrukluk and George River sockeye salmon stocks across years in which tag recoveries occurred. The Kogrukluk River stock displayed a more consistent run timing (CV=1.41%, range: 29 June–6 July) than the George River stock (CV=3.49%, range: 24 July–11 August).

The total number of days that specific sockeye salmon stocks were observed migrating past the Kalskag tagging site varied considerably across project years (Table 34). Kogrukluk River fish displayed a more variable range of migration days past Kalskag (CV=50.74%, range: 15–71 days) than George River fish (CV=40.48%, range: 21–54 days).

A comparison of the median recovery and sample dates at the George and Kogrukluk rivers suggests that tagged sockeye salmon arrive on the spawning grounds later than untagged fish, suggesting tagged fish behaved differently than untagged fish (Table 34). The average number of days between the median recovery and sample dates was 3 and 8 for George and Kogrukluk River stocks respectively.

Stock-specific Migration Speed

Individual tagged sockeye salmon displayed a wide range of migration speeds (range: 4–47 rkm/day) throughout the duration of the study (Table 35 and Figures 18–22). In each year, the range of observed migration speeds remained relatively constant over the course of the run for each of the monitored stocks. Salmon River weir was only operated in 2006, but displayed slower migration speeds (mean=8 rkm/day) compared George River (mean=19 rkm/day) and Kogrukluk River (mean=25 rkm/day). Low and inconsistent tag recoveries at most sites confound any observed trends.

The annual variability of the stock-specific average migration speeds was low. The Kogrukluk River sockeye salmon stock displayed a more variable average migration speed (CV=7.91%, range: 22–28 rkm/day) than George River fish (CV=4.17%, range: 19–27 rkm/day). Tag recoveries from Salmon, Tatlawiksuk, and Takotna rivers were not included in the above analysis due to inconsistent and limited tag recoveries over the duration of the project.

Abundance Diagnostics

Wheel–weir

Equal Probability of Tagging

Equal probability of tagging upriver sockeye salmon stocks at the Kalskag tagging site could not be tested from 2002 to 2005 due to low tag recaptures at all recovery sites except Kogrukluk River (Table 32). In 2006, however, the probability of tagging Kogrukluk and Salmon River sockeye salmon was statistically different, based on chi-square test of recapture ratios.

Complete Mixing

Complete mixing of tagged with untagged sockeye salmon could not be tested from 2002 to 2005 due to low tag recoveries at all recovery sites except Kogrukluk River (Tables 36–39). Further, low sample sizes at most recovery sites confounded the empirical evidence related to mixing. In 2006, however, sockeye salmon tagged from the right and left bank fish wheels operated near Kalskag were recovered in sufficient numbers at the Kogrukluk and Salmon River weirs to test for complete mixing of tagged with untagged fish bound for those tributaries (Table 40). The results of the chi-square tests indicated that sockeye salmon tagged from the left bank

fish wheel did mix completely with untagged fish, while fish tagged from the right bank wheel did not.

Wheel–wheel

Equal Probability of Tag Recovery

In 2002, the assumption that the probability of recovering tagged sockeye salmon at Birch Tree Crossing recapture site was constant over time could not be tested due to low tag recoveries (Table 41). In 2003, the probability of recovering tagged sockeye salmon at Birch Tree Crossing increased as the season progressed.

Complete Mixing

In 2002, complete mixing of tagged with untagged sockeye salmon could not be tested due to low tag recoveries by each gear type operated at Birch Tree Crossing (Table 42). Further, low sample sizes and tag recoveries for all recapture gears confounded the empirical evidence related to mixing. In 2003, however, sockeye salmon tagged at each capture gear operated near Kalskag were recovered with most recapture gears operated near Birch Tree Crossing providing empirical evidence that tagged fish mixed with untagged fish (Table 43). In 2003, complete mixing from the left bank fish wheel could not be confirmed, and complete mixing from the right bank fish wheel and gillnets could not be tested.

Abundance estimates

The pooled Petersen model was used for wheel–weir data to estimate total abundance of sockeye salmon at Kalskag from 2002 to 2006, using tag recaptures from the Kogrukluk River only. The wheel–weir abundance estimates ranged from 172,215 to 801,008 fish (Table 44). The pooled model was used for wheel–wheel data to estimate total abundance of sockeye salmon at Kalskag in 2002 and 2003 because in both years tag recoveries at Birch Tree Crossing were low and an appropriate stratification could not be achieved to successfully calculate a temporally stratified Darroch estimate. The wheel–wheel abundance estimates of sockeye salmon were 31,151 in 2002 and 85,887 in 2003 (Table 44). The 95% CIs did not overlap between the wheel–weir and wheel–wheel estimation methods in 2002 or 2003. The wheel–wheel estimates were lower than the wheel–weir estimates in both years.

CHINOOK SALMON

Tag Deployment

In 2005 and 2006, total catches of Chinook salmon at the Kalskag tagging site were 1,191 and 1,304 respectively (Table 45). In both years, 98% of the total catch was tagged, with the remaining 2% consisting of unhealthy Chinook salmon. Recaptures of tagged Chinook salmon at the Kalskag tagging site were low: 11 in 2005 and 4 in 2006. Fish wheel catches accounted for 72% and 73% of the total catch in 2005 and 2006 respectively. The left bank fish wheel accounted for the majority of the catch each year. Annually, Chinook salmon catches were very low near the start of operations suggesting that the early migration past Kalskag was well represented (Figure 23). The first Chinook salmon captured at Kalskag was in early June in both years, while peak capture typically occurred in late June. Daily catches tapered to only a few fish per day toward the end of operations, suggesting that the end of the migration was also well represented.

Tag Recapture

Upriver weirs passed 28,943 and 32,170 Chinook salmon in 2005 and 2006 respectively, with total tag recaptures of 84 and 114 fish (Table 46). In both years, most (75% in 2005 and 62% in 2006) of the tag recaptures at upriver weirs were initially caught and tagged with fish wheels (Table 47). Most (83% in 2005 and 70% in 2006) of the recaptured tags were recovered and tag numbers and dates were recorded. Tagged Chinook salmon were recaptured at all upriver weirs with the exception of Takotna River in 2006. Each year the Kogrukluk River weir recaptured the most tags and Takotna River weir recaptured the least. Annually, tag recapture ratios were on the same order of magnitude at all upriver weir sites (Table 46). Although, chi-square tests indicated that recapture ratios did differ statistically in 2006. Tags recaptured in 2005 and 2006 at weirs below the tagging site (Kwethluk and Tuluksak Rivers) were 0.2–0.3% of the total deployed tags, representing the minimum known proportion of tagged Chinook salmon that traveled down river after tagging.

Stock-specific Run Timing

In 2005 and 2006, comparisons of the median passage dates past the Kalskag tagging site for each of the monitored upriver Chinook salmon stocks showed little to no support for a run timing continuum (Table 48, Figure 24). Median tagging date was about 2 weeks later for each stock in 2006 compared to 2005 (Table 48). Tatlawiksuk River displayed the most contracted run timing in each year followed by Takotna, Salmon, George, and Kogrukluk rivers. In 2005, tagging did not appear to affect arrival time at the upriver weirs. The median tag recovery date was on average within 2 days (+ or -) of the median passage across all sites. In 2006, the median tag recovery date was later than the median sample date at the weir for all stocks except Salmon River.

Stock-specific Migration Speed

A wide range of migration speeds (3.1–44.0 rkm/day) was observed by tagged Chinook salmon in 2005 and 2006, and stock-specific ranges overlapped broadly each year (Table 49 and Figures 25 and 26). Monitored stocks displayed similar migration speeds in both years. Tatlawiksuk Chinook salmon displayed a higher annual variability compared to George and Kogrukluk stocks. In 2006, a comparison of the average migration speed for each of the monitored upriver Chinook salmon stocks showed some pattern for a continuum where fish travelling farther generally migrate faster compared to fish comprising stocks that spawn in less distant tributaries. This pattern was not observed in 2005.

Kogrukluk River Chinook salmon displayed some evidence for a continuum where earlier migrating fish traveled slower than later migrating fish, resulting in an increase stock-specific migration speed as the run progresses (Figures 25 and 26). This was not observed at any other recovery site, although tag recoveries at those sites were generally low.

DISCUSSION

TAG DEPLOYMENT

The location of the Kalskag tagging site (rkm 270) used in 2001–2003, and 2005–2006 was proven effective for capturing and tagging large numbers of Kuskokwim River salmon for mark–recapture studies. This site was characterized as having sufficient water velocities to maintain optimal fish wheel rpms and suitable river bottom contours to maintain efficient fish wheel and

drift gillnet operations. Site suitability resulted in minimal adjustments required to maintain near constant fishing effort during fluctuating water levels. Future mark–recapture studies focused on Kuskokwim River salmon bound for middle and upper river portions of the drainage should strongly consider using this site for tag deployment.

There were 2 main concerns related to the location of the Kalskag tagging site used in 2001–2003, and 2005–2006: (1) disproportionate tagging of Aniak River bound salmon and (2) the inability to sample fish traveling past Kalskag through a side channel in the river. The first concern stemmed from results of a radiotelemetry study conducted by Stuby (2003) that indicated Chinook salmon tagged on the left bank fish wheel had a greater likelihood of entering the Aniak River, suggesting a potential tagging bias. From 2001 to 2005, disproportionate tagging of Aniak River bound salmon could not be formally tested for lack of an established recapture site within that drainage. In 2006, the Salmon River weir was initiated for the primary purpose of investigating tagging bias of Kuskokwim Chinook salmon tagged at the Kalskag site (Stuby 2007). No evidence was found to support a tagging bias associated with Aniak River bound Chinook salmon (Stuby 2007; Bue et al. 2008).

The second concern associated with the Kalskag tagging site was that it was located on the larger of two channels; therefore, the possibility of fish escaping capture by passing through the smaller channel could not be eliminated. It was assumed that all stocks spawning upriver of the Kalskag tagging site passed through both channels of the river in equal proportions, introducing no bias; however, that assumption was not tested. In response to this concern, an alternate tag deployment location downriver near Lower Kalskag (rkm 249) was attempted in 2004. It was hoped that stocks, specifically the Aniak River stock, would be less bank oriented (i.e. more evenly mixed) and thereby reduce the potential for disproportionate tagging. In addition, the location of the Lower Kalskag site was such that the entire river was confined to a single channel, which was expected to improve confidence in the assumption of equal probability of capture and lead to increased catches of target species.

The Lower Kalskag fish wheels, however, experienced multiple operational challenges throughout the 2004 season, which may have resulted in violations of mark–recapture assumptions. The new tagging site proved to have lower overall water velocity, likely due to a greater channel width, which was insufficient to maintain an adequate fish wheel rotation (~2 rpm). Further, the contour of the river bottom was insufficient to allow crews to easily adjust the wheels in place and maintain constant fishing effort as water levels fluctuated; instead, crews were required to relocate the wheels regularly, a time consuming process that likely interfered with fish wheel efficiency. The Lower Kalskag tag site would not be recommended for future mark–recapture studies of Kuskokwim River salmon bound for middle and upper portions of the drainage.

Regardless of tagging site, capture rates for chum, sockeye, and Chinook salmon at the Kalskag sites suggest that the tagging operational period was sufficient to sample these species throughout their migratory period. Consequently, the resulting abundance estimates and migration characteristics represent all phases of the run. However, the extent to which the latter portion of the coho salmon run was represented is unknown. It is widely observed that coho salmon continue their upriver migration in to early winter often after ice has begun to form. Therefore, the resulting coho salmon abundance estimates and migration characteristics most appropriately represent the portions of the run that were exposed to harvest pressures.

Drift gillnets proved to be inefficient for catching, tagging, and releasing large numbers of coho, chum, and sockeye salmon unharmed, but they were effective at targeting Chinook salmon. The stress imposed on entangled salmon required that crews retrieved the nets at the first sign that a salmon was caught, which resulted in low daily catch and tag rates compared to fish wheels. Consequently, tag recaptures of gillnet tagged salmon accounted for a small proportion of the overall tag recoveries for all species except Chinook salmon. Fish wheels alone should provide sufficient numbers of coho and sockeye salmon for Kuskokwim mark–recapture studies, while considerably reducing cost and staff hours. Gillnets were specifically used to target larger Chinook salmon that traveled in deeper faster waters and were not as vulnerable to capture with fish wheels. Based on the relatively high proportion (~20%) of gillnet tagged Chinook salmon recaptured at upriver weirs, gillnets should be incorporated in future Kuskokwim River Chinook salmon mark–recapture studies. A considerable increase in gillnetting effort may be required to address the potential for disproportionate tagging of upriver chum salmon stocks, if upriver stocks are more mid-river oriented. Future mark–recapture studies of Kuskokwim River salmon bound for the upper and middle drainage should weigh the cost and benefits of not operating drift gillnets as a primary capture method.

Although the difficulty in targeting mid-river salmon using drift gillnets introduces the potential for a tagging bias, no such bias was observed. The proportion of tag recoveries at upriver weirs by deployment gear type were very similar to the proportion of tags deployed by gear type. Specifically, the proportion of drift gillnet tagged salmon was similar at all sites, a pattern that suggests mid-river fish were a mixture of lower and upper river stocks. The power to detect this type of bias was small for chum and sockeye salmon due to very low tag deployment from gillnets.

The use of T-bar anchor tags, beginning in 2005, was found to be considerably more efficient compared to the spaghetti tags used in previous years. The sampling time require for applying anchor tags was estimated to be half that required for spaghetti tags. The decrease in tagging time resulted in reduced handling time and stress of targeted species, while allowing crews to better maintain the sampling schedule during periods of high fish wheel catches.

TAG RECAPTURE

The utility of Birch Tree Crossing as a tag recovery site was mixed. Sample sizes and tag recaptures at Birch Tree Crossing were generally sufficient for producing abundance estimates, but the diagnostics of the assumption of complete mixing suggests the proximity to the Kalskag tagging sites (24 rkm) may have been insufficient for tagged fish to fully mix with untagged fish in most years. If salmon stocks did not mix completely with tagged fish by the time they reached the Birch Tree Crossing recovery site, resulting wheel–wheel estimates could be biased low. In addition to issues related to mixing, recapture probability was typically unequal over the course of the run, most likely due to changes in fishing conditions such as water level and clarity. This resulted in the need to use a more complex temporally stratified estimator that resulted in less precise overall estimates. We did not encounter a situation when tag recaptures at Birch Tree Crossing provided an opportunity to estimate abundance when weir recoveries did not; therefore, wheel–wheel simply provided an alternative estimate. Furthermore, recapture operations at Birch Tree Crossing were costly relative to the additional information they provided.

The escapement monitoring weirs operated on the Salmon, George, Tatlawiksuk, Kogrukluk and Takotna rivers, proved to be logistically convenient, cost effective and efficient tag recapture

sites. Weirs provided consistent daily tag recapture effort throughout the course of the salmon run. Weirs generally examined large numbers of salmon for tags and were effective in recapturing sufficient quantities of tagged salmon. However, only the Kogrukluk River weir consistently sampled sufficient numbers of sockeye salmon to be of statistical value, and tag recoveries at Takotna weir were generally low for all but coho salmon. The spatial distribution of upriver weirs was optimal in that they represented discrete spawning aggregates throughout the middle and upper drainage for investigating stock-specific migration characteristics. Further, the spatial array of upriver weirs was adequate for testing the assumptions of an unbiased mark–recapture estimate of abundance, which provided necessary context.

There was some potential for tagged fish to go unnoticed at the upriver weirs. During periods of high salmon passage at the weirs, salmon often pass through the trap in compact groups where the dorsal regions of some fish were obscured. The rate at which tagged fish are not recognized at upriver weirs is unknown; although, unpublished results of radiotelemetry data for Kuskokwim River Chinook, sockeye, coho salmon provide some insight. Radiotagged fish were also tagged with external tags identical to the one used in this study and were recaptured at the same upriver weirs. Most tagged fish identified upstream of the weirs using telemetry were also recognized by the crew; however, in most years, at least a few tagged fish passed upriver of the weirs unnoticed. Wheel–weir estimates are probably biased slightly high as a result of unreported tagged fish at recapture sites. However, the magnitude of this bias was considered acceptable.

Sample sizes and tag recaptures at upriver weirs suggest the current array of salmon escapement monitoring projects may not sufficiently monitor sockeye salmon. Gilk and Molyneaux (*In prep*) used radio tags to identify the distribution of sockeye salmon in the Kuskokwim River from 2005–2007. They identified the Holitna (68%), Stony (19%; specifically Telaquana Lake), and Aniak River (9%) drainages as the three largest sockeye salmon spawning aggregates in the Kuskokwim River. These results provide context for why the Kogrukluk River weir, located in the upper Holitna drainage, accounted for the majority (70–100%) of the sockeye salmon recaptures during this study. The George, Tatlawiksuk, and Takotna River weirs monitor very minor sockeye salmon stocks. Because this study design targeted all stocks equally, it was expected to recapture a few tags from these minor stocks proportional to their annual escapement. However, tag recaptures in these systems were often much higher than expected (e.g. George River in 2002, Tatlawiksuk River in 2004), leading to concern about the representativeness of the data. For example, the Takotna River weir never observes more than 100 sockeye salmon past the weir in a single season. It was most likely random chance that any tags were recaptured at this location and could even have been associated with tagging stress.

In 2006, the addition of the Salmon River weir (Aniak River drainage) provided tag recaptures that represented another large aggregate of the sockeye salmon population in the Kuskokwim River. This weir provided the opportunity to test mark–recapture assumptions for wheel–weir abundance estimation and generate more relevant estimates of stock-specific migration characteristics. Future mark–recapture investigations of sockeye salmon should strongly consider continuation of the Salmon River weir and /or adding a new weir on the Stony River near the outlet of Telaquana Lake.

The results of volunteer and Aniak Sonar tag recapture efforts were not presented in this report, but the utility of these data did warrant comment. The volunteer tag lottery achieved the desired goal of informing and involving local residents in this study. Volunteer tag recaptures successfully provided data related to salmon distribution which were used to update the

anadromous streams catalogue produced by ADF&G Division of Sport Fish. Volunteer and Aniak Sonar tag recaptures also provided additional run timing information for unmonitored stocks. These data were not presented because: (1) they were known to be biased toward the early portions of the salmon run corresponding to the timing of sonar operations and subsistence fishing activities, (2) recapture efforts were sporadic and not consistent across years, (3) stock-specific sample sizes were generally very low, and (4) the location of the volunteer tag recaptures were often vague requiring arbitrary and possibly inappropriate pooling to achieve meaningful sample sizes. Consequently, these data may not have been fully representative of the stocks true run timing past Kalskag. Regardless, volunteer tag recaptures do provide some of the only estimates of run timing for unmonitored stocks. These data can be reviewed in the annual project reports (Kerkvliet and Hamazaki 2003; Kerkvliet et al. 2003, 2004; Pawluk et al. 2006a; Pawluk et al. 2006b).

STOCK-SPECIFIC RUN TIMING

Several assumptions are implicit in our use of recovered tags to describe stock-specific run timings past the Kalskag tagging site and to the relevancy of that knowledge to fishery management in the lower Kuskokwim River. Assumptions were that tagged fish were representative of untagged fish (i.e. behavior was not affected by tagging and mark–recapture efforts were consistent throughout the run). If a chronology in stock-specific run timing exists at Kalskag, it was assumed that the chronology was also maintained in the lower Kuskokwim River for it to be of use to lower river fishery management. It was also assumed that the location and tag number was reported accurately.

We believe that the tagged fish were representative of untagged fish in most years; therefore the annual estimates of stock-specific run timing and all run timing patterns were considered valid. This conclusion was based on a comparison of the median recovery dates of tagged fish versus the median sample date at recapture sites. Differences between these dates may be due to sulking or biased tag deployment and on average rarely exceeded one week. These small differences are consistent with a sulking behavior often identified in mark–recapture studies (e.g. Bernard et al. 1999) and did not affect stock-specific estimates of run timing. Larger discrepancies are most likely due to problems with tagging stocks in proportion to abundance throughout their migration and may not be representative (i.e. all coho salmon in 2001, George River chum salmon in 2004 and 2005, Kogrukluk sockeye salmon in 2004, and George River Chinook salmon in 2006).

When tag recoveries are small, these data are not powerful in describing annual run timing patterns, although their utility can be enhanced by pooling across years. Sockeye salmon tag recoveries were small or non-existent at all sites except Kogrukluk River weir, and the resulting run timings should be viewed with caution. Annual tag recoveries at Takotna River weir were generally low for chum, sockeye, and Chinook salmon, but the repeat pattern among years added confidence to conclusions about patterns. Even with low tag recoveries at some upriver recapture sites all species displayed some evidence for a run timing continuum where stocks traveling farther migrated past Kalskag earlier than less distant stocks. This pattern was observed annually for each species, although chum salmon displayed the clearest signature.

Chum salmon run timing patterns are most likely based on tag recoveries of summer chum salmon and it is unclear whether our results adequately represent Kuskokwim fall chum salmon. Gilk et al. (2005) investigated Kuskokwim River fall chum salmon run timing using genetic mixture analysis. Their results suggest that the relatively few fall chum salmon caught at the

Kalskag fish wheels were from the earlier portion of the run. Through empirical evidence they concluded that Kuskokwim River fall chum salmon spawning appeared to be concentrated in headwater tributaries of the drainage. Their findings were consistent with our run timing results in that upriver chum salmon stocks migrate past Kalskag earlier than lower river stocks. However, migration characteristics for discrete aggregates of fall spawning chum salmon remain unclear.

Sockeye salmon displayed a temporal pattern of stock-specific run timing passed Kalskag where fish traveling further upstream passed earlier in the season. This pattern appears valid even with low tag recoveries. Differentiating stock-specific run timing using mark–recapture has been successfully demonstrated elsewhere on migrating adult sockeye salmon. Consistent differences in timing and migration speed have been observed among distinct sockeye salmon stocks in the Frasier River (Killick 1955). In contrast, such chronological separations have not been as clear in Bristol Bay sockeye salmon runs (Groot and Margolis 1991).

Determining temporal patterns in Chinook salmon, stock-specific run timing past Kalskag was confounded by low tag recoveries at most recapture sites; consequently, the pattern was not readily apparent in 2005 or 2006. Stuby et al. (2007) provided more convincing evidence for this pattern from 2001 to 2006 based on radio tagged Chinook salmon tagged at Kalskag and recovered at the same recapture sites used in this study. The pattern in 2005 and 2006 became even more apparent when data from anchortagged and radiotagged Chinook salmon were combined (Pawluk et al. 2006b). Temporal patterns in stock-specific run timing for Chinook salmon have been demonstrated elsewhere. For example, in the Copper River, individual stocks of Chinook salmon were found to have consistently different mean dates of passage (Savereide 2004). From 1996 to 2001, Keefer et al. (2004) were able to differentiate between 38 spatially separated stocks of Chinook salmon in the Columbia River Basin by median dates of passage using radio tags.

A consistent temporal pattern in coho salmon stock-specific run timing past Kalskag was not apparent. Specifically the Tatlawiksuk and Kogrukluk River stocks did not always follow the expected pattern along the up to down river continuum. It was unlikely that the project study design masked patterns in coho salmon run timing. The recapture weirs did not discontinue sampling until cumulative passage for 3 consecutive days was less than 1% of total passage (D. Molyneaux, Commercial Fisheries Biologist, Alaska Department of Fish and Game, Anchorage; personal communication), which was generally achieved by 20 September. In addition, efforts to sample past 20 September generally did not yield a resurgence of coho salmon.

The number of days that upriver coho and chum salmon stocks were observed passing Kalskag was less variable over the course of this study compared to mid-river stocks. Sample sizes precluded investigating run timing consistency for sockeye and Chinook salmon. Merritt and Roberson (1986) also found earlier migrating sockeye salmon stocks demonstrated a greater consistency of timing among years than later migrating stocks.

STOCK-SPECIFIC MIGRATION SPEED

The primary flaw when calculating stock-specific migration speeds for stocks with wide ranging travel distances is that it assumes fish travel directly from the tagging site to the recapture location, no straying, and no response to handling; but, these assumptions are not biologically valid. The stock-specific run timing results from this study combined with radiotelemetry data from other tagging studies demonstrated that tagged fish displayed a sulking behavior where

upriver migration speed was reduced or even negative for several days following tagging and handling. Although not consistent across all years, stocks, and species, the median date of tag recapture was generally a few days to a week later than the median sample date at upriver recapture sites. Results from radiotagging studies of Kuskokwim River salmon show that following tagging, Chinook, sockeye, and coho salmon often require several days before resuming their upriver migration (e.g. Stuby 2007; Gilk and Molyneaux *In prep*, Schaberg[2]). Consequently, estimates of migration speed are probably biased low. If the duration of sulk-time is relatively consistent across all stocks, the associated bias would decrease as distance from the tagging site increases.

Coho and Chinook salmon displayed evidence for a migration speed continuum where salmon bound for more distant tributaries migrated faster than stocks bound for less distant tributaries. This pattern was relatively consistent for coho salmon throughout the duration of this study. Chinook salmon displayed this pattern clearly in 2006, while results from 2005 were confounded by faster than expected migration speeds of George River fish. Regardless of distance traveled, individual coho and Chinook salmon that passed Kalskag later in the season migrated at a faster speed than those passing earlier in the season. Keefer et al. (2004) also noted that later migrating Chinook salmon displayed faster migration speeds. They suggested that run timing (or migration date) accounted for a large portion of the variation in migration speed, most likely due to the need for arrival at higher elevation spawning grounds at appropriate times and increased reproductive maturation. Another possibility was that the observed migration speed patterns may be a result of milling activity among early arriving fish or stocks, similar to that described by McPherson et al. (1996). If so, it seems the occurrence or duration of milling decreased as the run progressed. No spatial or temporal patterns in chum or sockeye salmon migration speeds were observed in this study.

ABUNDANCE ESTIMATION

Although we calculated abundance estimates for all target species (except Chinook salmon) within each target year using both wheel–wheel and wheel–weir methods, we only presented estimates that we felt were valid. The validity of the abundance estimates were examined by testing mark–recapture assumptions, comparing the estimate with known escapement, and calculating estimates of exploitation rates. Often this process resulted in two different but equally valid estimates (e.g. coho salmon). In these cases, we chose to provide both as a way to highlight the range of potential abundances and the level of uncertainty associated with large-scale mark–recapture studies. All estimates (inclusive of those not presented) and their respective exploitation rates are archived in the Appendices of this document (Appendix C1–C3). It should be noted that the estimates of exploitation were probably biased high because the lower river escapement estimate was incomplete. These data were used for exploratory purposes only and should not be used for formal analyses.

Coho Salmon

Coho salmon abundance was estimated in 2001–2004 using wheel–weir and wheel–wheel methods and in 2005 using wheel–weir methods only. All resulting abundance estimates seemed reasonable. Although, not all mark–recapture assumptions were explicitly met in some years, the

---

[2] Schaberg, K. L. *Unpublished*. Kuskokwim River coho salmon run reconstruction. Located at: Alaska Department of Fish and Game, 333 Raspberry Rd, Anchorage, Alaska.

extent of the bias was perceived small and acceptable. As expected, all estimates were greater than the known upriver escapement as determined by weir counts. The difference between each estimate and the known escapement seemed appropriate to account for coho salmon bound for unmonitored portions of the middle and upper drainage. Furthermore, the resulting estimates of annual exploitation rate seemed reasonable based on the capacity of the coho salmon fishery in those years (Appendix C1).

The investigation of Kuskokwim River coho salmon abundance resulted in different estimates from wheel–weir and wheel–wheel methods in 2001 to 2004 (Appendix D1). In all years, the wheel–wheel estimate was lower than the wheel–weir estimate. It is possible that the distance between the Kalskag tagging site and the Birch Tree Crossing recapture site was insufficient to allow for complete mixing of tagged with untagged coho salmon, which would result in lower estimates of abundance. In 2002 and 2003, the 95% confidence intervals around the two different point estimates overlapped, suggesting both estimates were statistically similar. In 2001 and 2004, the 95% confidence intervals did not overlap. In 2001, both abundance estimates seem reasonable, but the estimated exploitation rate associated with the wheel–wheel estimate was likely high suggesting the wheel–weir abundance estimate may be more appropriate (Appendix C1). In 2004, the difference between the two abundance estimates was considerable but the data alone did not provide a means to resolve which best reflects reality. Each year, Kuskokwim River fisheries managers and researchers used commercial CPUE, Bethel Test Fishery CPUE, various escapement indices, and discussions with local fishermen to determine the relative strength of the coho salmon run. The information from these data sources, in concert, left biologists with the perception that the 2004 coho salmon run was smaller than what was observed in 2003 (D. Molyneaux, Alaska Department of Fish and Game, Anchorage, personal communication). Given the perception of those directly involved with the fishery in 2004, we feel that the wheel–wheel estimate of coho salmon abundance better reflects the relative strength of the run in that year (Appendix D2).

Chum Salmon

Chum salmon analyses were particularly problematic and the potential contributing sources of bias warranted special discussion here. In each year that chum salmon were investigated, tag recapture ratios decreased as the distance to upriver recapture sites increased, a signature that implicated either disproportionate tagging of upriver stocks or delayed mortality. Neither mechanism could be eliminated.

If upriver chum salmon stocks were more oriented toward the middle of the river, they would have had an unequal probability of being captured and tagged since gillnets accounted for a very small number of the total tagged chum salmon at Kalskag (average=202). Tag recoveries by deployment gear at Kalskag do not suggest that disproportionate tagging was the dominant source of bias. This conclusion is based on the observation that (1) the proportion of tag recoveries by deployment gear type was very similar to the proportion of tags deployed by gear type and (2) tag recoveries by all gear types decreased as the distance from the tag site increased. However, the power in determining chum salmon tagging bias was severely low by sample sizes. If disproportionate tagging occurred the abundance estimate could be biased high or low depending on the severity.

Delayed mortality of chum salmon due to handling stress, live box holding time, or live box crowding could explain the observed pattern of decreasing tag recovery ratios at the weirs.

Delayed mortality of salmon has been linked to holding time in fish wheel live boxes (e.g. Bromaghin et al. 2007; Carlon 2000; Burek and Underwood 2002; Underwood et al. 2002) and was a concern throughout this project. The effects of holding time and live box crowding on recapture probability of tagged chum salmon at Birch Tree Crossing and the weirs was examined in 2002 (Kerkvliet et al. 2003). In 2003, the effects of holding conditions were again examined but only the recapture probability at Birch Tree Crossing was considered (Kerkvliet et al. 2004). Recapture probability at the weirs was not affected by holding time in 2002 and Birch Tree recaptures were not affected in either year. However, in 2003, recapture probability increased at Birch Tree as live box crowding at Kalskag increased. The increase in chum salmon recapture probability may have been due to stress causing chum salmon to swim in the slower waters along the banks of the river where they would have been more susceptible to capture with fish wheels. In addition, stressed chum salmon may have had less energy to evade the capture gears at Birch Tree. Live box crowding was specifically an issue during periods of high chum salmon catches. On several occasions it was noted that chum salmon were "overflowing" from the fish wheel live boxes (J. Baumer, Alaska Department of Fish and Game, Anchorage, personal communication). During these instances crews continued to tag all but the most obviously stressed chum salmon. It is reasonable to expect this type of crowding would induce stress and could lead to delayed mortality of chum salmon as they migrated upriver. Most likely delayed mortality was the leading source of chum salmon bias. If that was the case, any resulting wheel–weir abundance estimates would be biased high.

Difficulty in abundance estimation of chum salmon could have been due in small part to differences between Kuskokwim River summer and fall chum salmon life histories. A review of historical data, aerial surveys efforts in 2004, and discussion with local residents led Gilk et al. (2005) to conclude that Kuskokwim River fall and summer chum salmon did not co-occur in the same spawning areas. Fall chum salmon spawning aggregates were primarily confined to the upper portions of the drainage, while summer chum salmon populations occurred primarily in the lower and middle basins. They noted that fall chum salmon were not a large component of the chum salmon sampled by the Kalskag fish wheels in 2004. During their 2004 field season, they did not observe any tagged chum salmon associated with our study during their sampling efforts on the South Fork Kuskokwim River near the village of Nikolai (S. Gilk, Commercial Fisheries Biologist, Alaska Department of Fish and Game, Anchorage; personal communication), although their sample size was low. The spatial distribution of our tag recapture sites was insufficient for testing fall chum salmon tagging biases. However, tagging at Kalskag operated throughout the entire chum salmon migration and would have also represented fall chum salmon. Given our current understanding of Kuskokwim River fall chum salmon (i.e. perceived run timing, distribution, and relative abundance); it is unlikely that differences in chum salmon life histories affected the results of this study.

Biased wheel–weir estimates for chum salmon were calculated using the pooled Petersen estimator for exploratory purposes only. Exploratory abundance estimates ranged from 1.5–11 million chum, which seemed reasonable if not slightly high. As expected, all estimates were greater than the known upriver escapement as determined by weir counts (George, Tatlawiksuk, and Takotna rivers), sonar counts (Aniak River), and additional mark–recapture abundance estimates (Holitna River; Stroka and Brase 2004; Stroka and Reed 2005). The difference between each estimate and the known escapement seemed appropriate to account for the expected large number of chum salmon bound for unmonitored portions of the middle and upper

drainage. Furthermore, the resulting estimates of annual exploitation rate seemed reasonable to low based on the capacity of the chum fisheries in those years (Appendix C2).

Chum salmon wheel–wheel diagnostics suggested the temporally stratified Darroch estimator was the most appropriate model for abundance estimation. The resulting abundance estimates were found to be considerably less than the known upriver escapement as determined by weir counts, sonar counts, and additional mark–recapture abundance estimates (Appendix E1). While the known escapement represented major portions of the known chum salmon distribution in the Kuskokwim River, it was incomplete, suggesting our estimates of total abundance were biased very low.

Sockeye Salmon

The investigation of Kuskokwim sockeye salmon abundance resulted in competing estimates from wheel–weir and wheel–wheel methods in 2002 and 2003. In both years, wheel–wheel estimates were considerably lower than the wheel–weir estimates, which is consistent with other species investigated. It is possible that the distance between the Kalskag tagging site and the Birch Tree Crossing recapture site was insufficient to allow for complete mixing of tagged with untagged sockeye salmon, which would result in low estimates of abundance. The two different point estimates were significantly different from one another in 2002 and 2003. All estimates were greater than the known upriver escapement as determined by weir counts. The difference between each estimate and the known escapement seemed appropriate to account for sockeye salmon bound for unmonitored portions of the middle and upper drainage. However, the estimated exploitation rates associated with the wheel–wheel estimates seemed high given the relatively low commercial and subsistence harvest effort for sockeye salmon (Appendix C3). Alternatively, the estimated exploitation rates associated with the wheel–weir estimates seemed reasonable given the capacity of the fishery in those years. We feel the wheel–weir estimates more appropriately represent sockeye salmon abundance in 2002 and 2003.

In 2004 to 2006, a single wheel–weir abundance estimate was produced for Kuskokwim sockeye salmon. Each annual estimate was greater than the known upriver escapement as determined by weir counts. The difference between each estimate and the known escapement seemed appropriate to account for sockeye salmon bound for unmonitored portions of the middle and upper drainage. The estimated exploitation rates associated with the 2004 to 2006 wheel–weir estimates seemed reasonable given the capacity of the fishery in those years.

Using tag recaptures from George, Tatlawiksuk, and Takotna rivers was deemed inappropriate for estimating sockeye salmon abundance at Kalskag using wheel–weir data. Gilk and Molyneaux (*In prep*) showed that with the exception of the Kogrukluk River all other established salmon escapement monitoring weirs indexed a very small proportion of the Kuskokwim River sockeye salmon population (generally <200 sockeye salmon annually). Further, when tags were recovered from these peripheral sockeye salmon populations, tag recapture ratios were often exceptionally high, suggesting tag recaptures from these sites may not have been representative and thus were not used. Consequently, the wheel–weir estimates are based on Kogrukluk River weir recaptures only.

Low sample sizes combined with low tag recaptures at George, Tatlawiksuk, and Takotna River weirs in 2002–2005 precluded testing mark–recapture assumptions. Therefore, it was not possible to provide the desired context for determining the appropriateness of sockeye salmon abundance estimates determined from Kogrukluk recaptures only. In 2006, sample sizes and tag

recaptures from the Salmon River weir provided the first opportunity to test the mark–recapture assumptions. Test results could not confirm that the critical assumptions of equal probability of capture or complete mixing occurred. Consequently, sockeye salmon abundance estimates based on Kogrukluk recaptures only should be received with caution.

ACKNOWLEDGEMENTS

Many different organizations and individuals were instrumental in the successful completion of this project. Unfortunately it was not feasible to thank all the contributors to this project by name, but we recognize their contribution and thank them for their assistance and guidance. The authors wish to acknowledge the United States Fish and Wildlife Service, Office of Subsistence Management, Orutsararmiut Native Council, ADF&G Sport Fish Division, and Association of Village Council Presidents for their support of this project. Special thanks go to the Kuskokwim Native Association (KNA), as their support and the support of the KNA staff were essential to the project's success. Specifically we would like to acknowledge the KNA Executive Directors, Wayne Morgan and Calvin Simeon; and the KNA fisheries biologists David Cannon and David Orabutt. We would like to acknowledge the role of Carol Kerkviet (2001–2003) and Jason Pawluk (2004–2006) of ADF&G who served as the project leaders for this study. Jayson Baumer and David Folleti of ADF&G served as the project field crew leaders. We would like to thank the many field technicians that worked or volunteered on this project and were so essential to the data collection process. We would like to thank the local Kuskokwim Area residents and fishermen that contributed to this study through the volunteer tag recovery program. Finally, special thanks go out to the businesses and residents of Aniak and Kalskag for their support and guidance regarding this project.

We thank Toshihide Hamazaki of ADF&G for his statistical guidance and review throughout the course of this study. We thank the various ADF&G Commercial Fish Division personnel who provided guidance, comments, and review of the study design and project deliverables. Specifically, we thank Christopher Shelden and Dani Evenson of ADF&G for their review of this document. We also thank Shannon Royse, Region III Publication Technician, for her advice and assistance with formatting and style and for facilitating the review and publication process.

REFERENCES CITED

ADF&G (Alaska Department of Fish and Game). 1999. Research and prevention relative to the 1998 Bristol Bay, Kuskokwim, and Yukon River fishery resource disasters. Alaska Department of Fish and Game, Division of Commercial Fisheries, NOAA (National Oceanic and Atmospheric Administration) Cooperative Agreement NA96W0196, Juneau.

Arnason, A. N., C. W. Kirby, C. J. Schwarz, and J. R. Irvine. 1996. Computer analysis of data from stratified mark–recapture experiments for estimation of salmon escapements and other populations. Canadian Technical Report Fisheries and Aquatic Sciences 2106:37.

Barrett, B. M., F. M. Thompson and S. N. Wick. 1984a. Adult anadromous fish investigations: May-October 1983. Susitna Hydro Aquatic Studies. Report No. 1. Alaska Department of Fish and Game, Anchorage. APA Document # 1450.

Barrett, B. M., F. M. Thompson, and S. N. Wick. 1984b. Adult anadromous fish investigations: May-October 1984. Susitna Hydro Aquatic Studies. Report No. 6. Alaska Department of Fish and Game, Anchorage. APA Document # 2748.

Bernard, D. R., J. J. Hasbrouck, and S. J. Fleischman. 1999. Handling-induced delay and downstream movement of adult Chinook salmon in rivers. Fisheries Research 44:37–46.

Burek, K., and T. J. Underwood. 2002. Morbidity of tagged wild adult fall chum salmon captured by fish wheel in the Yukon River, Alaska. U. S. Fish and Wildlife Service, Alaska Fisheries Technical Report No. 60, Fairbanks.

Bromaghin, J. F., T. J. Underwood, and R. F. Hander. 2007. Residual effects of fish wheel capture and handling of Yukon River fall chum salmon. North American Journal of Fisheries Management 27:860-872.

Bue, B. G., D. B. Molyneaux, and K. L. Schaberg. 2008. Kuskokwim River Chinook salmon run reconstruction. Alaska Department of Fish and Game, Fishery Data Series No. 08-64, Anchorage.

Carlon, J. A. 2000. Assessment of coho salmon from the Kenai River, Alaska, 1997. Alaska Department of Fish and Game, Fishery Data Series No. 00-15, Anchorage. http://www.sf.adfg.state.ak.us/FedAidPDFs/fds00-15.pdf

Clark, K. J., and D. B. Molyneaux. 2003a. Kogrukluk River weir salmon studies, 2002. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 3A03-11. Anchorage. http://www.sf.adfg.state.ak.us/FedAidPDFs/RIR.3A.2003.11.pdf

Clark, K. J., and D. B. Molyneaux. 2003b. Takotna River salmon studies and upper Kuskokwim River aerial surveys, 2002. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 3A03-10. Anchorage. http://www.sf.adfg.state.ak.us/FedAidPDFs/RIR.3A.2003.10.pdf

Coffing, M. 1991. Kwethluk subsistence: contemporary land use patterns, wild resource harvest and use, and the subsistence economy of a lower Kuskokwim River area community. Alaska Department of Fish and Game, Division of Subsistence, Technical Paper No. 157, Juneau. http://www.subsistence.adfg.state.ak.us/TechPap/tp157.pdf

Coffing, M., L. Brown, G. Jennings, and C. Utermohle. 2001. The subsistence harvest and use of wild resources in Akiachak, Alaska, 1998. Alaska Department of Fish and Game, Division of Subsistence, Technical Paper No. 258, Juneau.

Costello, D. J., R. Stewart, D. B. Molyneaux, and D.E. Orabutt. 2007a. Tatlawiksuk river salmon studies, 2006. Alaska Department of Fish Game, Fishery Data Series No. 07-56, Anchorage. http://www.sf.adfg.state.ak.us/FedAidPDFs/fds07-56.pdf

Costello, D. J., D.B. Molyneaux, and C. Goods. 2007b. Takotna River salmon studies, 2006. Alaska Department of Fish and Game, Fishery Data Series No. 07-61, Anchorage. http://www.sf.adfg.state.ak.us/FedAidPDFs/fds07-61.pdf

Darroch, J. N. 1961. Two sample capture-recapture census when tagging and sampling are stratified. Biometrica 48:241-260.

REFERENCES CITED (Continued)

Ericksen, R. P. 1999. Abundance of coho salmon in the Chilkat River in 1998. Alaska Department of Fish and Game, Fishery Data Series No. 99-29, Anchorage. http://www.sf.adfg.state.ak.us/FedAidPDFs/fds99-29.pdf

Gilk, S. E., and D. B. Molyneaux, editors. *In prep*. Kuskokwim River sockeye salmon investigations. Alaska Department of Fish and Game, Divisions of Sport and Commercial Fisheries, Fishery Manuscript, Anchorage.

Gilk, S. E., W. D. Templin, D. B. Molyneaux, T. Hamazaki, and J. A. Pawluk. 2005. Characteristics of fall chum salmon *Oncorhynchus keta* in the Kuskokwim River drainage. Alaska Department of Fish and Game, Fishery Data Series No. 05-56, Anchorage.

Groot, C., and L. Margolis, editors. 1991. Pacific salmon life histories. University of British Columbia Press, Vancouver.

Hildebrand, H. L., R. Stewart, D. J. Costello, and D. B. Molyneaux. 2007. George River salmon studies, 2006. Alaska Department of Fish and Game, Fishery Data Series No. 07-59, Anchorage. http://www.sf.adfg.state.ak.us/FedAidPDFs/fds07-59.pdf

Johnson, J. and M. Daigneault. 2008. Catalog of waters important for spawning, rearing, or migration of anadromous fishes – Western Region, Effective June 2, 2008. Alaska Department of Fish and Game, Special Publication No. 08-08, Anchorage. http://www.sf.adfg.state.ak.us/Static/AWC/PDFs/WST_2008_CATALOG.pdf

Jones III, E. L., and S. A. McPherson. 1997. Relationship between observer counts and abundance of coho salmon in Steep Creek, Northern Southeast Alaska in 1996. Alaska Department of Fish and Game, Fishery Data Series No. 97-25, Anchorage. http://www.sf.adfg.state.ak.us/FedAidPDFs/fds97-25.pdf

Jones III, E. L., J. A. Weller, and A. B. Holm. 2001. Production of coho salmon from the Unuk River, 1999-2000. Alaska Department of Fish and Game, Fishery Data Series No. 01-14, Anchorage. http://www.sf.adfg.state.ak.us/FedAidPDFs/fds01-14.pdf

Keefer, M. L., C. A. Peery, M. A. Jepson, K. R. Tolotti, and T. C. Bjornn. 2004. Stock-specific migration timing of adult spring-summer Chinook salmon in the Columbia River Basin. North American Journal of Fisheries Management 24:1145-1162.

Kerkvliet, C. M., and T. Hamazaki. 2003. A mark–recapture experiment to estimate the total population of Kuskokwim River coho salmon (*Oncorhynchus kisutch*), 2001. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 3A02-15, Anchorage. http://www.sf.adfg.state.ak.us/FedAidpdfs/RIR.3A.2002.15.pdf

Kerkvliet, C. M., T. Hamazaki, K. E. Hyer and D. Cannon. 2003. A mark–recapture experiment to estimate the abundance of Kuskokwim River sockeye, chum and coho salmon, 2002. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 3A03-25, Anchorage. http://www.sf.adfg.state.ak.us/FedAidPDFs/RIR.3A.2003.25.pdf

Kerkvliet, C. M., J. Pawluk, T. Hamazaki, K. E. Hyer and D. Cannon. 2004. A mark–recapture experiment to estimate the abundance of Kuskokwim River sockeye, chum and coho salmon, 2003. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 3A04-14, Anchorage. http://www.sf.adfg.state.ak.us/FedAidpdfs/RIR.3A.2004.14.pdf

Killick, S. 1955. The chronological order of Fraser River sockeye salmon during migration, spawning and death. International Pacific Salmon Fisheries Commission Bulletin 7.

Kruse, G. H. 1998. Salmon run failures in 1997-1998: a link to anomalous ocean conditions? Alaska Fishery Research Bulletin 5 (1):55-63.

Liller, Z. W., D. J. Costello, and D. B. Molyneaux. 2008. Kogrukluk River weir salmon studies, 2006. Alaska Department of Fish and Game, Fishery Data Series No. 08-26, Anchorage. http://www.sf.adfg.state.ak.us/FedAidPDFs/fds08-26.pdf

REFERENCES CITED (Continued)

Linderman, J. C. Jr., D. B. Molyneaux, L. DuBoise and D. J. Cannon. 2003a. George River salmon studies, 1996 to 2002. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 3A03-17. Anchorage. http://www.sf.adfg.state.ak.us/FedAidPDFs/RIR.3A.2003.17.pdf

Linderman, J. C. Jr., D. J. Cannon and D. B. Molyneaux. 2003b. Tatlawiksuk River weir salmon studies, 2002. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 3A03-16. Anchorage. http://www.sf.adfg.state.ak.us/FedAidPDFs/RIR.3A.2003.16.pdf

McEwen, M. S. 2008. Sonar estimation of chum salmon passage in the Aniak River, 2006. Alaska Department of Fish and Game, Fisheries Data Series No. 08-32, Anchorage. http://www.sf.adfg.state.ak.us/FedAidPDFs/fds08-32.pdf

McPherson, S. A., B. J. Glynn, and E. L. Jones III. 1996. A mark–recapture experiment to estimate the escapement of coho salmon in Steep Creek, 1994. Alaska Department of Fish and Game, Fishery Data Series No. 96-31, Anchorage. http://www.sf.adfg.state.ak.us/FedAidPDFs/fds96-31.pdf

Meehan, W. R. 1961. Use of a fish wheel in salmon research and management. Transactions of the American Fisheries Society 90:490-494.

Merritt, M. F., and K. Roberson. 1986. Migratory timing of upper Copper River sockeye salmon stocks and its implications for the regulation of the commercial fishery. North American Journal of Fisheries Management 6:216-225.

Miller, S., and K. C. Harper. 2007. Abundance and run timing of adult Pacific salmon in the Kwethluk River, Yukon Delta National Wildlife Refuge, Alaska, 2006. U.S. Fish and Wildlife Service, Kenai Fish and Wildlife Field Office. Alaska Fisheries Data Series No. 2007-9, Kenai, Alaska.

Molyneaux, D. B., A. R. Brodersen, and Christopher A. Shelden. 2009. Salmon age, sex, and length catalog for the Kuskokwim Area, 2008. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 09-06, Anchorage. http://www.sf.adfg.state.ak.us/FedAidPDFs/rir.3a.2009.06.pdf

Pawluk, J., C.M. Kerkvliet, T. Hamazaki, K.E. Hyer and D. Orabutt. 2006a. A mark–recapture study of Kuskokwim River sockeye, chum and coho salmon, 2004. Alaska Department of Fish and Game, Fishery Data Series No. 06-52, Anchorage. http://www.sf.adfg.state.ak.us/FedAidPDFs/fds06-52.pdf

Pawluk, J., J. Baumer, T. Hamazaki, and D. Orabutt. 2006b. A mark–recapture study of Kuskokwim River sockeye, chum and coho salmon, 2005. Alaska Department of Fish and Game, Fishery Data Series No. 06-54, Anchorage. http://www.sf.adfg.state.ak.us/FedAidPDFs/fds06-52.pdf

Plumb M. P., K. C. Harper, and D. G. Spencer. 2007. Abundance and run timing of adult Pacific salmon in the Kwethluk River, Yukon Delta National Wildlife Refuge, Alaska, 2006. U.S. Fish and Wildlife Service, Kenai Fish and Wildlife Field Office. Alaska Fisheries Data Series No. 2007-4, Kenai, Alaska.

Savereide, J. W. 2004. Inriver abundance, spawning distribution, and run timing of Copper River Chinook salmon in 2003. Alaska Department of Fish and Game, Fishery Data Series No. 04-26, Anchorage. http://www.sf.adfg.state.ak.us/FedAidPDFs/fds04-26.pdf

Seber, G. A. F. 1982. The estimation of animal abundance and related parameters, second edition. Edward Arnold, London.

Stroka, S. M., and A. L. J. Brase. 2004. Assessment of Chinook, chum, and coho salmon escapements in the Holitna River drainage using radiotelemetry, 2001-2003. Final Report for Study 01-141 USFWS Office of Subsistence Management Fishery Information Service Division. Alaska Department of Fish and Game, Fishery Data Series No. 04-07, Anchorage. http://www.sf.adfg.state.ak.us/FedAidPDFs/fds04-07.pdf

Stroka, S. M., and D. J. Reed. 2005. Assessment of Chinook and chum salmon escapements in the Holitna River drainage using radiotelemetry, 2004. Alaska Department of Fish and Game, Fishery Data Series No. 05-49, Anchorage. http://www.sf.adfg.state.ak.us/FedAidPDFs/fds05-49.pdf

Stuby, L. 2003. Inriver abundance of Chinook salmon in the Kuskokwim River, 2002. Alaska Department of Fish and Game, Fishery Data Series No. 03-22, Anchorage. http://www.sf.adfg.state.ak.us/FedAidPDFs/fds03-22.pdf

REFERENCES CITED (Continued)

Stuby, L. 2007. Inriver abundance of Chinook salmon in the Kuskokwim River, 2002-2006. Alaska Department of Fish and Game, Fishery Data Series No. 07-93, Anchorage. http://www.sf.adfg.state.ak.us/FedAidPDFs/fds07-93.pdf

Underwood, T. J., J. F. Bromaghin, and S. P. Klosiewski. 2002. Evidence of handling mortality in fall chum salmon caused by fish wheel capture on the Yukon River, Alaska. U. S. Fish and Wildlife Service, Alaska Fisheries Technical Report No. 59, Fairbanks.

Whitmore, C., M. Martz, J. C. Linderman, R. L. Fisher, and D. G. Bue. 2008. Annual management report for the subsistence and commercial fisheries of the Kuskokwim Area, 2004. Alaska Department of Fish and Game, Fishery Management Report No. 08-25, Anchorage. http://www.sf.adfg.state.ak.us/FedAidPDFs/fmr08-25.pdf

TABLES AND FIGURES

Table 1.–Project years in which specific objectives were attempted for each target species of Kuskokwim River salmon.

	Objective											
	Stock Specific Travel Speed				Stock Specific Run Timing				Abundance Estimate			
Project Year	Coho	Sockeye	Chum	Chinook	Coho	Sockeye	Chum	Chinook	Coho	Sockeye	Chum	Chinook
2001	X				O				X			
2002	X	X	X		X	X	X		X	X	X	
2003	X	X	X		X	X	X		X	X	X	
2004	X	X	X		X	X	X		X	O	O	
2005	X	X	X	X	X	X	X	X	X	O	O	
2006		X		X		X		X		O		

Table 2.–Operational dates by gear type used in the Kuskokwim River salmon mark–recapture study, 2001–2006.

Objective	Location: Site Name	Location: rkm [a]	Gear Type	Description	Year: 2001	2002	2003	2004	2005	2006
Tag Deployment	Kalskag	270	Fish Wheel	Right Bank # 1	7/22–9/8	6/16–9/10t	6/6–9/8	6/7–9/8	6/1–9/9	6/1–9/9
			Gear	Right Bank # 2	NA	NA	NA	NA	6/1–9/9	NA
				Left Bank	7/22–9/8	6/16–9/10	6/6–9/8	6/7–9/8	6/1–9/9	6/1–9/9
			Gillnet	4" Mesh	9/8–9/5 [b]	6/20–9/10 [b]	6/11–9/8 [b]	7/24–9/8 [c]		NA
				6.5" Mesh	8/8–9/5 [b]		NA	NA	NA	NA
				Tangle Net	NA	NA	NA	NA	6/1–9/9 [d]	6/1–9/9 [d]
Tag Recapture	Birch Tree Crossing		Fish Wheel	Right Bank	7/22–9/8	6/8–9/11	6/6–9/10	7/18–9/10	NA	NA
				Left Bank	7/22–9/8	6/8–9/11	6/7–9/10	7/18–9/10	NA	NA
	294		Gillnet	4" Mesh	8/8–9/5 [b]	6/20–6/29; 7/25–9/11 [b]	6/15–7/8; 7/10–15; 7/27–30; 8/15, 18 & 29 [b e]	7/26–9/10 [c]		NA
				6.5" Mesh	8/8–9/5 [b]		NA	NA	NA	NA
				Tangle Net	NA	NA	NA	NA	NA	NA
	Kwethluk River	131	Weir	Floating	8/12–9/13	9/28–9/19	6/20–9/14	6/25–9/10	NA	7/4–9/6
	Tuluksak River	192	Weir	Floating	7/8–8/20; 8/27–9/1 [f]	6/6–9/10	6/16–8/15; 8/19–9/14 [f]	6/20–9/10	6/24–9/9	7/1–8/13; 8/29–9/6 [f]
	Aniak River Sonar	323	Beach Seine	-	NA	6/26–7/31 [g]	6/26–7/31 [g]	6/25–7/31 [g]	6/22–7/31 [g]	6/29–7/31 [g]
	Salmon River	404	Weir	Fixed Panel	NA	NA	NA	NA	NA	6/21–8/8
	George River	453	Weir	Floating	6/25–8/18; 8/27–9/22 [f]	6/21–9/20	7/1 & 2; 7/8–27; 8/4–14; 8/19–9/19 [f]	6/27–9/24	6/15–9/20	5/15–8/17; 8/26–9/20 [f]
	Tatlawiksuk River	568	Weir	Floating	6/20–7/31; 7/4–8/16; 8/27–9/15 [f]	6/17–9/11; 9/20–23 [f]		6/15–9/18	6/12–9/9; 9/20–23	6/15–8/18
	Kogrukluk River	710	Weir	Fixed Panel	7/5–7/19; 7/28–9/25 [f]	6/26–9/24	6/22–7/28; 7/30–8/27; 8/29–9/20 [f]	6/22–9/25	6/22–9/15; 9/20–23 [f]	6/29–8/11; 8/25–9/14 [f]
	Takotna River	835	Weir	Floating	6/23–8/20; 8/23–9/14 [f]	6/23–9/9	7/2–27; 8/1–9/20 [f]	6/23–9/9	6/10–9/20	6/16–8/18; 8/22–9/22 [f]

Note: The Kalskag tagging site was located 270 rkm above the mouth of the Kuskokwim River in all years except 2004, in which it was located at rkm 249.

[a] Distance (rkm) from the mouth of the Kuskokwim River.
[b] Drift gillnets were 45 meshes deep and were either 15 fathoms (27.43 m) or 25 fathoms (45.72 m) in length.
[c] Drift gillnets were 45 meshes deep and were either 5 fathoms (9.14 m) or 10 fathoms (18.28 m) in length.
[d] Tangle nets were made by hanging the gillnets used in 2004 in a 4:1 ratio.
[e] Gillnet operations were sporadic because fish wheel catches were very high.
[f] Weir counts were sporadic due to high water.
[g] Tag recaptures were opportunistic as part of routine weekly chum salmon age-sex-length sampling.

Table 3.–Summary of coho salmon captured and anchor tagged at the Kalskag tagging site, Kuskokwim River 2001–2005.

			Number of Salmon						
			Tagged		Not Tagged		Total Catch		
Year	Tagging Location	Gear Type	n [a]	% [b]	n [a]	% [c]	n [a]	% [d]	Recapture [e]
2001	Right Bank	Fish Wheel	843	65	27	3	870	64	2
	Left Bank	Fish Wheel	204	16	14	6	218	16	3
	Mid-Channel	Drift Gillnet	243	19	32	12	275	20	3
		Total [f]	1,290	95	73	5	1,363	100	8
2002	Right Bank	Fish Wheel	1,583	56	88	5	1,671	56	22
	Left Bank	Fish Wheel	591	21	43	7	634	21	5
	Mid-Channel	Drift Gillnet	630	22	70	10	700	23	8
		Total [f]	2,804	93	201	7	3,005	100	35
2003	Right Bank	Fish Wheel	4,608	68	223	5	4,831	68	70
	Left Bank	Fish Wheel	1,548	23	128	8	1,676	23	39
	Mid-Channel	Drift Gillnet	610	9	31	5	641	9	12
		Total [f]	6,766	95	382	5	7,148	100	121
2004	Right Bank	Fish Wheel	1,377	46	38	3	1,415	47	21
	Left Bank	Fish Wheel	946	32	15	2	961	32	22
	Mid-Channel	Drift Gillnet	641	22	18	3	659	22	3
		Total [f]	2,964	98	71	2	3,035	100	46
2005 [g]	Right Bank # 1	Fish Wheel	3,044	55	141	4	3,185	56	22
	Right Bank # 2	Fish Wheel	892	16	45	5	937	16	23
	Left Bank	Fish Wheel	1,191	22	18	1	1,209	21	40
	Mid-Channel	Drift Gillnet	370	7	7	2	377	7	1
		Total [f]	5,497	96	211	4	5,708	100	86

Note: The Kalskag tagging site was located 270 rkm above the mouth of the Kuskokwim River in all years except 2004, in which it was located at rkm 249.

[a] Number of fish.
[b] Percent of total fish tagged.
[c] Percent of total catch by tagging location.
[d] Percent of total catch.
[e] Recapture of a tagged fish. Not included in total catch.
[f] Percentages relate to total catch.
[g] 2005 was the only year 2 fish wheels were operated on the right bank of the river.

Table 4.–Coho salmon tag recovery ratios by recovery site and wheel–weir chi-square analysis of equal probability of capture at the Kalskag tagging site, Kuskokwim River 2001–2005.

Year	Recovery Location	Distance (rkm) [a]	Sample Size [b]	Total Tagged	Total Untagged	Ratio [c]	Chi-square X^2	df	p-value [d]
2001	BTC Wheels [e]	24	1,843	13	1,830	0.0071			
	George River Weir	183	8,802	26	8,776	0.0030	0.0077		
	Tatlawiksuk River Weir	298	5,669	7	5,662	0.0012	5.4527		
	Kogrukluk River Weir	440	18,308	66	18,242	0.0036	3.1118		
	Takotna River Weir	565	2,351	3	2,348	0.0013	2.1508		
	Upstream Subtotal [f]		35,130	102	35,028	0.0029	10.723	3	0.01332
	Tuluksak River Weir	-134	10,430	5	10,425	0.0005			
	Kwethluk River Weir	-224	19,196	5	19,191	0.0003			
	Downstream Subtotal		29,626	10	29,616	0.0003			
2002	BTC Wheels [e]	24	4,316	46	4,270	0.0108			
	George River Weir	183	6,759	41	6,718	0.0061	0.0093		
	Tatlawiksuk River Weir	298	11,132	56	11,076	0.0051	2.3118		
	Kogrukluk River Weir	440	14,501	108	14,393	0.0075	3.9421		
	Takotna River Weir	565	3,984	19	3,965	0.0048	1.2556		
	Upstream Subtotal [f]		36,376	224	36,152	0.0062	7.5188	3	0.05707
	Tuluksak River Weir	-134	11,487	9	11,478	0.0008			
	Kwethluk River Weir	-224	23,298	7	23,291	0.0003			
	Downstream Subtotal		34,785	16	34,769	0.0005			
2003	BTC Wheels [e]	24	16,964	169	16,795	0.0101			
	George River Weir	183	31,925	220	31,705	0.0069	0.0105		
	Tatlawiksuk River Weir [g]	298	ND	ND	ND	-	-		
	Kogrukluk River Weir	440	68,718	492	68,226	0.0072	0.4872		
	Takotna River Weir	565	7,147	38	7,109	0.0053	3.6429		
	Upstream Subtotal [f]		107,790	750	107,040	0.0070	4.1406	2	0.12615
	Kwethluk River Weir		-224	107,789	58	107,731	0.0005		
	Downstream Subtotal		107,789	58	107,731	0.0005			

-continued-

Table 4.–Page 2 of 2.

Year	Recovery Location	Distance (rkm) [a]	Sample Size [b]	Total Tagged	Total Untagged	Ratio [c]	Chi-square X^2	df	p-value [d]
2004	BTC Wheels [e]	45	10,544	81	10,463	0.0077			
	George River Weir	204	13,248	21	13,227	0.0016	0.6931		
	Tatlawiksuk River Weir	319	16,410	35	16,375	0.0021	0.4686		
	Kogrukluk River Weir	461	26,078	51	26,027	0.0020	0.0424		
	Takotna River Weir	586	3,207	5	3,202	0.0016	0.1967		
	Upstream Subtotal [f]		58,943	112	58,831	0.0019	1.4008	3	0.70536
	Tuluksak River Weir	-113	20,336	2	20,334	0.0001			
	Kwethluk River Weir	-203	64,208	0	64,208	0.0000			
	Downstream Subtotal		84,544	2	84,542	0.0000			
2005	BTC Wheels [e,h]	24	ND	ND	ND	-			
	George River Weir	183	8,197	82	8,115	0.0101	3.1934		
	Tatlawiksuk River Weir	298	6,746	31	6,715	0.0046	10.8781		
	Kogrukluk River Weir	440	23,102	203	22,899	0.0089	0.9069		
	Takotna River Weir	565	2,216	15	2,201	0.0068	0.5733		
	Upstream Subtotal [f]		40,261	331	39,930	0.0083	15.5517	3	0.0014
	Tuluksak River Weir	-134	11,324	6	11,318	0.0005			
	Kwethluk River Weir [i]	-224	ND	ND	ND	-			
	Downstream Subtotal		11,324	6	11,318	0.0005			

Source: Sample size for all escapement weir projects were from the ADF&G CF Kuskokwim Research Master Escapement File, version 2008 (unpublished).

Note: The Kalskag tagging site was located 270 rkm above the mouth of the Kuskokwim River in all years except 2004, in which it was located at rkm 249. BTC stands for Birch Tree Crossing. ND stands for No Data. Dashes represent values that could not be calculated due to data limitations. Chi-square was used to test similarity in recapture ratios of upstream weirs only.

[a] Distance from Kalskag tagging site. Negative numbers indicate a downstream direction.
[b] Number of tagged fish plus untagged fish.
[c] Total number of tag recaptures divided by total number of untagged fish in sample.
[d] p-value criteria is based on an alpha of 0.05.
[e] Located on mainstem Kuskokwim River. Used for wheel-to-wheel estimates.
[f] The upstream subtotal was used for wheel-to-weir abundance estimation. Excludes Birch Tree Crossing.
[g] Tatlawiksuk River weir did not operate in 2003 due to high water damage early season.
[h] Birch Tree Crossing did not operate in 2005.
[i] Kwethluk River weir did not operate in 2005.

Table 5.–Summary of anchortagged coho salmon recovered at recapture projects by gear type used at the Kalskag tagging site, 2001–2005.

			Tagging Source																
			Recovered Tags [ab]								Observed Tags [c]								
			Fish Wheel																
			Right Bank		Left Bank		Drift Gillnet		Total Recovered		Fish Wheel		Drift Gillnet		Unknown		Total Observed		Total Tags [d]
Year	Recovery Location	Distance (rkm) [e]	n [f]	% [g]	n [f]	% [g]	n [f]	% [g]	n [f]	% [h]	n [f]	% [i]	n [f]	% [i]	n [f]	% [i]	n [f]	% [h]	n [f]
2001	BTC Wheels	24	9	69	3	23	1	8	13	100	0	-	0	-	0	-	0	0	13
	George River Weir	183	9	47	2	11	8	42	19	73	7	100	0	0	0	0	7	27	26
	Tatlawiksuk River Weir	298	1	50	0	0	1	50	2	29	5	100	0	0	0	0	5	71	7
	Kogrukluk River Weir	440	42	67	9	14	12	19	63	95	3	100	0	0	0	0	3	5	66
	Takotna River Weir	565	0	-	0	-	0	-	0	0	3	100	0	0	0	0	3	100	3
	Upstream Subtotal		61	63	14	14	22	23	97	84	18	100	0	0	0	0	18	16	115
	Tuluksak River Weir	-134	1	100	0	0	0	0	1	-	4	100	0	0	0	0	4	80	5
	Kwethluk River Weir	-224	0	-	0	-	0	-	0	0	5	100	0	0	0	0	5	100	5
	Downstream Subtotal		1	100	0	0	0	0	1	10	9	100	0	0	0	0	9	90	10
	Total		62	63	14	14	22	22	98	78	27	100	0	0	0	0	27	22	125
2002	BTC Wheels	24	21	46	17	37	8	17	46	100	0	-	0	-	0	-	0	0	46
	George River Weir	183	16	55	5	17	8	28	29	71	7	58	0	0	5	42	12	29	41
	Tatlawiksuk River Weir	298	27	63	4	9	12	28	43	77	12	92	0	0	1	8	13	23	56
	Kogrukluk River Weir	440	62	65	16	17	17	18	95	88	12	92	0	0	1	8	13	12	108
	Takotna River Weir	565	12	63	3	16	4	21	19	100	0	-	0	-	0	-	0	0	19
	Upstream Subtotal		138	59	45	19	49	21	232	86	31	82	0	0	7	18	38	14	270
	Tuluksak River Weir	-134	1	25	1	25	2	50	4	-	5	100	0	0	0	0	5	56	9
	Kwethluk River Weir	-224	0	0	2	100	0	0	2	29	5	100	0	0	0	0	5	71	7
	Downstream Subtotal		1	17	3	50	2	33	6	38	10	100	0	0	0	0	10	63	16
	Total		139	58	48	20	51	21	238	83	41	85	0	0	7	15	48	17	286
2003	BTC Wheels	24	102	63	43	26	18	11	163	96	6	100	0	0	0	0	6	4	169
	George River Weir	183	80	71	28	25	4	4	112	51	107	99	1	1	0	0	108	49	220
	Tatlawiksuk River Weir [j]		ND	-	ND	-	ND	-	ND	-	ND	-	ND	-	ND	-	ND	-	ND
	Kogrukluk River Weir	440	259	79	58	18	9	3	326	66	157	95	9	5	0	0	166	34	492
	Takotna River Weir 298	565	26	76	8	24	0	0	34	89	4	100	0	0	0	0	4	11	38
	Upstream Subtotal		467	74	137	22	31	5	635	69	274	96	10	4	0	0	284	31	919
	Tuluksak River Weir	-134	0	-	0	-	0	-	0	-	26	96	1	4	0	0	27	100	27
	Kwethluk River Weir	-224	10	59	7	41	0	0	17	29	41	100	0	0	0	0	41	71	58
	Downstream Subtotal		10	59	7	41	0	0	17	20	67	99	1	1	0	0	68	80	85
	Total		477	73	144	22	31	5	652	65	341	97	11	3	0	0	352	35	1,004

-continued-

Table 5.–Page 2 of 2.

			Tagging Source																
			Recovered Tags [ab]								Observed Tags [c]								
			Fish Wheel																
			Right Bank		Left Bank		Drift Gillnet		Total Recovered		Fish Wheel		Drift Gillnet		Unknown		Total Observed		Total Tags [d]
Year	Recovery Location	Distance (rkm) [e]	n [f]	% [g]	n [f]	% [g]	n [f]	% [g]	n [f]	% [h]	n [f]	% [i]	n [f]	% [i]	n [f]	% [i]	n [f]	% [h]	n [f]
2004	BTC Wheels	45	32	42	40	52	5	6	77	95	4	100	0	0	0	0	4	5	81
	George River Weir	204	3	60	1	20	1	20	5	24	13	81	3	19	0	0	16	76	21
	Tatlawiksuk River Weir	319	24	73	4	12	5	15	33	94	2	100	0	0	0	0	2	6	35
	Kogrukluk River Weir	461	16	52	5	16	10	32	31	61	9	45	11	55	0	0	20	39	51
	Takotna River Weir	586	5	100	0	0	0	0	5	100	0	-	0	-	0	-	0	0	5
	Upstream Subtotal		80	53	50	33	21	14	151	78	28	67	14	33	0	0	42	22	193
	Tuluksak River Weir	-113	0	0	1	50	1	50	2	100	0	-	0	-	0	-	0	0	2
	Kwethluk River Weir	-203	0	-	0	-	0	-	0	-	0	-	0	-	0	-	0	-	0
	Downstream Subtotal		0	0	1	50	1	50	2	100	0	-	0	-	0	-	0	0	2
	Total		80	52	51	33	22	14	153	78	28	67	14	33	0	0	42	22	195
2005	BTC Wheels [k]	24	ND	-	ND	-	ND	-	ND	-	ND	-	ND	-	ND	-	ND	-	ND
	George River Weir	183	50	66	22	29	4	5	76	93	6	100	0	0	0	0	6	7	82
	Tatlawiksuk River Weir	298	25	83	2	7	3	10	30	97	1	100	0	0	0	0	1	3	31
	Kogrukluk River Weir	440	146	75	39	20	9	5	194	96	9	100	0	0	0	0	9	4	203
	Takotna River Weir	565	11	79	2	14	1	7	14	93	1	100	0	0	0	0	1	7	15
	Upstream Subtotal		232	74	65	21	17	5	314	95	17	100	0	0	0	0	17	5	331
	Tuluksak River Weir	-134	2	67	1	33	0	0	3	50	3	100	0	0	0	0	3	50	6
	Kwethluk River Weir [l]	-224	ND	-	ND	-	ND	-	ND	-	ND	-	ND	-	ND	-	ND	-	ND
	Downstream Subtotal		2	67	1	33	0	0	3	50	3	-	0	-	0	-	3	50	6
	Total		234	74	66	21	17	5	317	94	20	100	0	0	0	0	20	6	337

Note: The Kalskag tagging site was located 270 rkm above the mouth of the Kuskokwim River in all years except 2004, in which it was located at rkm 249. ND stands for No Data. Dashes represent values that could not be calculated due to data limitations.

[a] Tagged fish that were successfully captured, tag number and date were recorded, and tag number was matched with tag deployment data.
[b] Data from recovered tags were used for calculating stock-specific run timing and migration speed.
[c] Tagged fish that were not successfully captured, tag number and date were not recorded, or tag number was not matched with tag deployment data.
[d] Total number of tag recaptures (i.e. recovered plus observed) were used for abundance estimation.
[e] Distance (rkm) from the Kalskag tagging site. Negative numbers indicate a downstream direction.
[f] Number of fish.
[g] Percent of total recovered tags by recapture location.
[h] Percent of total tags by recapture location.
[i] Percent of total observed tags by recapture location.
[j] Tatlawiksuk River weir did not operate in 2003 due to high water damage early season.
[k] Birch Tree Crossing wheels did not operate in 2005.
[l] Kwethluk River weir did not operate in 2004.

Table 6.–Run timing for coho salmon tagged near Kalskag and recovered in upriver tributaries of the Kuskokwim River, 2001–2005.

Year	Recovery Location	Distance (rkm) [a]	Total Recovered Tags	Sample Size	Tagging Date [b] Median	Tagging Date [b] Range	Recovery Date [c] Median	Recovery Date [c] Range	Sample Date [d] Median	Sample Date [d] Range
2001	BTC Wheels [e]	24	13	1,843	12 Aug	2 Aug - 4 Sep	15 Aug	7 Aug - 5 Sep	15 Aug	24 Jul - 10 Sep
	George River Weir	183	19	8,802	28 Aug	8 Aug - 6 Sep	12 Sep	28 Aug - 21 Sep	18 Aug	27 Jul - 22 Sep
	Tatlawiksuk River Weir	298	2	5,669	25 Aug	23 Aug - 27 Aug	7 Sep	2 Sep - 13 Sep	15 Aug	28 Jul - 15 Sep
	Kogrukluk River Weir	440	63	18,308	14 Aug	25 Jul - 6 Sep	9 Sep	18 Aug - 22 Sep	29 Aug	31 Jul - 25 Sep
	Takotna River Weir	565	0	2,351	ND	ND	ND	ND	27 Aug	30 Jul - 14 Sep
2002	BTC Wheels [e]	24	46	4,316	30 Aug	23 Jul - 10 Sep	1 Sep	26 Jul - 12 Sep	18 Aug	13 Jul - 12 Sep
	George River Weir	183	29	6,759	24 Aug	8 Aug - 2 Sep	6 Sep	31 Aug - 10 Sep	6 Sep	28 Jul - 20 Sep
	Tatlawiksuk River Weir	298	43	11,132	20 Aug	20 Jul - 2 Sep	31 Aug	30 Jul - 11 Sep	23 Aug	27 Jul - 22 Sep
	Kogrukluk River Weir	440	95	14,501	22 Aug	8 Jul - 7 Sep	7 Sep	24 Jul - 18 Sep	31 Aug	22 Jul - 24 Sep
	Takotna River Weir	565	19	3,984	11 Aug	28 Jul - 3 Sep	2 Sep	17 Aug - 20 Sep	25 Aug	30 Jul - 20 Sep
2003	BTC Wheels [e]	24	163	16,964	19 Aug	28 Jul - 8 Sep	24 Aug	3 Aug - 8 Sep	20 Aug	23 Jun - 10 Sep
	George River Weir	183	112	31,925	21 Aug	22 Jul - 4 Sep	5 Sep	10 Aug - 14 Sep	28 Aug	18 Jul - 18 Sep
	Tatlawiksuk River Weir [f]		ND	ND	-	-	-	-	-	-
	Kogrukluk River Weir	440	326	68,718	16 Aug	22 Jul - 7 Sep	4 Sep	9 Aug - 19 Sep	1 Sep	20 Jul - 20 Sep
	Takotna River Weir	565	34	7,147	12 Aug	27 Jul - 26 Aug	31 Aug	14 Aug - 13 Sep	27 Aug	26 Jul - 19 Sep
2004	BTC Wheels [e]	298 45	77	10,544	17 Aug	20 Jul - 8 Sep	23 Aug	22 Jul - 10 Sep	14 Aug	18 Jul - 10 Sep
	George River Weir	204	5	13,248	21 Aug	11 Aug - 29 Aug	3 Sep	25 Aug - 5 Sep	1 Sep	21 Jul - 24 Sep
	Tatlawiksuk River Weir	319	33	16,410	12 Aug	28 Jul - 29 Aug	31 Aug	17 Aug - 14 Sep	19 Aug	20 Jul - 18 Sep
	Kogrukluk River Weir	461	31	26,078	16 Aug	3 Aug - 5 Sep	8 Sep	28 Aug - 21 Sep	30 Aug	22 Jul - 25 Sep
	Takotna River Weir	586	5	3,207	2 Aug	24 Jul - 10 Aug	21 Aug	17 Aug - 3 Sep	26 Aug	31 Jul - 16 Sep
2005	BTC Wheels [e, g]	24	ND	ND	-	-	-	-	-	-
	George River Weir	183	76	8,197	29 Aug	4 Aug - 9 Sep	7 Sep	19 Aug - 16 Sep	31 Aug	26 Jul - 20 Sep
	Tatlawiksuk River Weir	298	30	6,746	16 Aug	31 Jul - 8 Sep	30 Aug	15 Aug - 20 Sep	24 Aug	18 Jul - 22 Sep
	Kogrukluk River Weir	440	194	23,102	16 Aug	21 Jul - 9 Sep	8 Sep	21 Aug - 22 Sep	1 Sep	23 Jul - 22 Sep
	Takotna River Weir	565	14	2,216	6 Aug	28 Jul - 28 Aug	3 Sep	22 Aug - 16 Sep	28 Aug	25 Jul - 20 Sep

Note: The Kalskag tagging site was located 270 rkm above the mouth of the Kuskokwim River in all years except 2004, in which it was located at rkm 249. BTC stands for Birch Tree Crossing. ND stands for No Data. Dashes represent values that could not be calculated due to data limitations. Summary based on recovered tags only. Tags observed but not recovered were not included as tagging date was unknown.

[a] Distance from Kalskag tagging site.
[b] Date past the Kalskag tagging site.
[c] Date past the recovery location.
[d] Date of catch at Birch Tree Crossing or observed escapement past weirs. Inclusive of tagged and untagged fish.
[e] Located on the mainstem Kuskokwim River. Dates represent mixed stocks.
[f] Tatlawiksuk River weir did not operate in 2003 due to high water damage early season.
[g] Birch Tree Crossing wheels did not operate in 2005.

Table 7.–Migration rates for coho salmon tagged near Kalskag and recovered in upriver tributaries of the Kuskokwim River, 2001–2005.

Year	Recovery Location	Distance (rkm) [a]	Total Recovered Tags	Migration Time (days) [b]				Migration Rate (rkm/day) [c]			
				Mean	Range		SE	Mean	Range		SE
2001	BTC Wheels [d]	24	13	2	1 -	5	0.42	14	5 -	24	2.33
	George River Weir	183	19	16	7 -	21	0.93	12	9 -	26	1.07
	Tatlawiksuk River Weir	298	2	14	10 -	17	3.50	19	16 -	22	2.85
	Kogrukluk River Weir	440	63	21	12 -	34	0.72	22	13 -	37	0.72
	Takotna River Weir	565	0	-		-	-	-		-	-
2002	BTC Wheels [d]	24	46	3	0 -	19	0.67	16	1 -	24	1.33
	George River Weir	183	29	15	6 -	28	1.08	14	7 -	31	0.99
	Tatlawiksuk River Weir	298	43	14	7 -	23	0.64	22	13 -	34	0.86
	Kogrukluk River Weir	440	95	17	10 -	35	0.44	27	13 -	44	0.61
	Takotna River Weir	565	19	21	15 -	26	0.88	28	22 -	38	1.22
2003	BTC Wheels [d]	24	163	4	0 -	30	0.41	13	1 -	24	0.66
	George River Weir	183	112	14	6 -	26	0.39	14	7 -	31	0.45
	Tatlawiksuk River Weir [e]	298	ND	-		-	-	-		-	-
	Kogrukluk River Weir	440	326	19	11 -	36	0.21	24	12 -	40	0.26
	Takotna River Weir	565	34	19	12 -	27	0.49	30	21 -	47	0.80
2004	BTC Wheels [d]	45	77	5	1 -	25	0.49	14	2 -	45	1.00
	George River Weir	204	5	11	6 -	15	1.61	21	14 -	34	3.64
	Tatlawiksuk River Weir	319	33	19	12 -	37	1.00	26	15 -	37	0.89
	Kogrukluk River Weir	461	31	21	13 -	32	0.87	23	14 -	35	0.97
	Takotna River Weir	586	5	23	19 -	24	0.98	26	24 -	31	1.25
2005	BTC Wheels [d, f]	24	ND	-		-	-	-		-	-
	George River Weir	183	76	11	5 -	24	0.62	20	8 -	37	0.90
	Tatlawiksuk River Weir	298	30	14	7 -	23	0.74	29	13 -	44	1.27
	Kogrukluk River Weir	440	194	20	11 -	42	0.43	24	10 -	40	0.47
	Takotna River Weir	565	14	23	14 -	32	1.46	26	18 -	40	1.71

Note: The Kalskag tagging site was located 270 rkm above the mouth of the Kuskokwim River in all years except 2004, in which it was located at rkm 249. BTC stands for Birch Tree Crossing. ND stands for No Data. Dashes represent values that could not be calculated due to data limitations. Summary based on recovered tags only. Tags observed but not recovered were not included as tagging date was unknown.

[a] Distance from Kalskag tagging site.
[b] Number of days between time of tagging at Kalskag and recovery at recapture location.
[c] Upstream distance traveled per day (rounded to the nearest whole rkm).
[d] Located on the mainstem Kuskokwim River. Data represent mixed stocks.
[e] Tatlawiksuk River weir did not operate in 2003 due to high water damage early season.
[f] Birch Tree Crossing wheels did not operate in 2005.

Table 8.–Wheel–weir chi-square analysis of complete mixing of coho salmon tagged near Kalskag with untagged fish by gear type, Kuskokwim River 2001.

Recapture Location		Kalskag Tagging Gear		
		Right Bank Fish Wheel (n=843)	Left Bank Fish Wheel (n=204)	Drift Gillnets (n=243)
George River Weir				
	Untagged Catch	8,776	8,776	8,776
	Recovered Tags	9	2	8
	Ratio [a]	0.0010	0.0002	0.0009
	Chi-square	1.7630	-	0.3477
Tatlawiksuk River Weir				
	Untagged Catch	5,662	5,662	5,662
	Recovered Tags	1	0	1
	Ratio [a]	0.0002	0.0000	0.0002
	Chi-square	7.1190	-	-
Kogrukluk River Weir				
	Untagged Catch	18,242	18,242	18,242
	Recovered Tags	42	9	12
	Ratio [a]	0.0023	0.0005	0.0007
	Chi-square	5.7853	-	0.1673
Takotna River Weir				
	Untagged Catch	2,348	2,348	2,348
	Recovered Tags	0	0	0
	Ratio [a]	0.0000	0.0000	0.0000
	Chi-square	-	-	-
Total				
	Chi-square	14.6673	-	0.5150
	p-value [b]	0.0007	-	0.4729

Note: The Kalskag tagging site was located 270 rkm above the mouth of the Kuskokwim River. Analysis based on recovered tags only. Tags observed but not recovered were not included as tagging gear type was unknown. Dashes represent values that could not be calculated due to data limitations, generally failure to meet minimum expected tag recoveries (n=5) required for Chi-square analysis.

[a] Recovered tags divided by untagged catch.
[b] p-value criteria is based on an alpha of 0.05.

Table 9.–Wheel–weir chi-square analysis of complete mixing of coho salmon tagged near Kalskag with untagged fish by gear type, Kuskokwim River 2002.

Recapture Location		Kalskag Tagging Gear		
		Right Bank Fish Wheel (n=1,583)	Left Bank Fish Wheel (n=591)	Drift Gillnets (n=630)
George River Weir				
	Untagged Catch	6,718	6,718	6,718
	Recovered Tags	16	5	8
	Ratio [a]	0.0024	0.0007	0.0012
	Chi-square	1.5127	0.0091	0.0099
Tatlawiksuk River Weir				
	Untagged Catch	11,076	11,076	11,076
	Recovered Tags	27	4	12
	Ratio [a]	0.0024	0.0004	0.0011
	Chi-square	2.1775	2.4618	0.0421
Kogrukluk River Weir				
	Untagged Catch	14,393	14,393	14,393
	Recovered Tags	62	16	17
	Ratio [a]	0.0043	0.0011	0.0012
	Chi-square	5.0824	2.0766	0.0125
Takotna River Weir				
	Untagged Catch	3,965	3,965	3,965
	Recovered Tags	12	3	4
	Ratio [a]	0.0030	0.0008	0.0010
	Chi-square	0.0538	-	-
Total				
	Chi-square	8.8264	4.5475	0.0645
	p-value [b]	0.0317	0.1029	0.9683

Note: The Kalskag tagging site was located 270 rkm above the mouth of the Kuskokwim River. Analysis based on recovered tags only. Tags observed but not recovered were not included as tagging gear type was unknown. Dashes represent values that could not be calculated due to data limitations, generally failure to meet minimum expected tag recoveries (*n*=5) required for Chi-square analysis.

[a] Recovered tags divided by untagged catch.
[b] p-value criteria is based on an alpha of 0.05.

Table 10.–Wheel–weir chi-square analysis of complete mixing of coho salmon tagged near Kalskag with untagged fish by gear type, Kuskokwim River 2003.

		Kalskag Tagging Gear		
Recapture Location		Right Bank Fish Wheel (n=4,608)	Left Bank Fish Wheel (n=1,548)	Drift Gillnets (n=610)
George River Weir				
	Untagged Catch	31,705	31,705	31,705
	Recovered Tags	80	28	4
	Ratio [a]	0.0025	0.0009	0.0001
	Chi-square	7.2915	0.0009	-
Tatlawiksuk River Weir [b]				
	Untagged Catch	-	-	-
	Recovered Tags	-	-	-
	Ratio [a]	-	-	-
	Chi-square	-	-	-
Kogrukluk River Weir				
	Untagged Catch	68,226	68,226	68,226
	Recovered Tags	259	58	9
	Ratio [a]	0.0038	0.0009	0.0001
	Chi-square	2.9739	0.0611	-
Takotna River Weir				
	Untagged Catch	7,109	7,109	7,109
	Recovered Tags	26	8	0
	Ratio [a]	0.0037	0.0011	0.0000
	Chi-square	0.1271	0.4939	-
Total				
	Chi-square	10.3926	0.5559	-
	p-value [c]	0.0055	0.7573	-

Note: The Kalskag tagging site was located 270 rkm above the mouth of the Kuskokwim River. Analysis based on recovered tags only. Tags observed but not recovered were not included as tagging gear type was unknown. Dashes represent values that could not be calculated due to data limitations, generally failure to meet minimum expected tag recoveries (*n*=5) required for Chi-square analysis.

[a] Recovered tags divided by untagged catch.
[b] Tatlawiksuk River weir did not operate due to high water early season.
[c] p-value criteria is based on an alpha of 0.05.

Table 11.–Wheel–weir chi-square analysis of complete mixing of coho salmon tagged near Kalskag with untagged fish by gear type, Kuskokwim River 2004.

Recapture Location		Kalskag Tagging Gear		
		Right Bank Fish Wheel (n=1,377)	Left Bank Fish Wheel (n=946)	Drift Gillnets (n=641)
George River Weir				
	Untagged Catch	13,227	13,227	13,227
	Recovered Tags	3	1	1
	Ratio [a]	0.0002	0.0001	0.0001
	Chi-square	7.3144	-	-
Tatlawiksuk River Weir				
	Untagged Catch	16,375	16,375	16,375
	Recovered Tags	24	4	5
	Ratio [a]	0.0015	0.0002	0.0003
	Chi-square	21.6534	-	-
Kogrukluk River Weir				
	Untagged Catch	26,027	26,027	26,027
	Recovered Tags	16	5	10
	Ratio [a]	0.0006	0.0002	0.0004
	Chi-square	3.1189	-	-
Takotna River Weir				
	Untagged Catch	3,202	3,202	3,202
	Recovered Tags	5	0	0
	Ratio [a]	0.0016	0.0000	0.0000
	Chi-square	-	-	-
Total				
	Chi-square	32.0867	-	-
	p-value [b]	<0.0001	-	-

Note: The Kalskag tagging site was located 249 rkm above the mouth of the Kuskokwim River. Analysis based on recovered tags only. Tags observed but not recovered were not included as tagging gear type was unknown. Dashes represent values that could not be calculated due to data limitations, generally failure to meet minimum expected tag recoveries (*n*=5) required for Chi-square analysis.

[a] Recovered tags divided by untagged catch.
[b] p-value criteria is based on an alpha of 0.05.

Table 12.–Wheel–weir chi-square analysis of complete mixing of coho salmon tagged near Kalskag with untagged fish by gear type, Kuskokwim River 2005.

		Kalskag Tagging Gear		
Recapture Location		Right Bank Fish Wheel (n=3,936)	Left Bank Fish Wheel (n=1,191)	Drift Gillnets (n=370)
George River Weir				
	Untagged Catch	8,115	8,115	8,115
	Recovered Tags	50	22	4
	Ratio [a]	0.0062	0.0027	0.0005
	Chi-square	0.1713	5.2546	-
Tatlawiksuk River Weir				
	Untagged Catch	6,715	6,715	6,715
	Recovered Tags	25	2	3
	Ratio [a]	0.0037	0.0003	0.0004
	Chi-square	5.0160	7.5672	-
Kogrukluk River Weir				
	Untagged Catch	22,899	22,899	22,899
	Recovered Tags	146	39	9
	Ratio [a]	0.0064	0.0017	0.0004
	Chi-square	1.2531	0.0152	-
Takotna River Weir				
	Untagged Catch	2,201	2,201	2,201
	Recovered Tags	11	2	1
	Ratio [a]	0.0050	0.0009	0.0005
	Chi-square	0.2488	-	-
Total				
	Chi-square	6.6891	12.8370	-
	p-value [b]	0.0825	0.0016	-

Note: The Kalskag tagging site was located 270 rkm above the mouth of the Kuskokwim River. Analysis based on recovered tags only. Tags observed but not recovered were not included as tagging gear type was unknown. Dashes represent values that could not be calculated due to data limitations, generally failure to meet minimum expected tag recoveries (*n*=5) required for Chi-square analysis.

[a] Recovered tags divided by untagged catch.
[b] p-value criteria is based on an alpha of 0.05.

Table 13.–Wheel–wheel chi-square test of temporally consistent probability of recovering Kalskag tagged coho salmon at Birch Tree Crossing, Kuskokwim River 2001–2004.

					Chi-square		
Year	Sample Period	Untagged Catch	Recovered Tags	Ratio [a]	X^2	df	p-value [b]
2001	24 Jul–20 Aug	1,124	7	0.0062	0.1207		
	21 Aug–11 Sept	706	6	0.0085	0.1917		
	Total	1,830	13	0.0071	0.3124	1	0.5762
2002	28 Jun–18 Aug	2,260	13	0.0058	5.2578		
	19 Aug–2 Sept	1,549	17	0.0110	0.0058		
	3 Sept–12 Sept	461	16	0.0347	23.6917		
	Total	4,270	46	0.0108	28.9553	2	<0.0001
2003	20 Jun–7 Aug	2,931	10	0.0034	11.9209		
	8 Aug–21 Aug	6,810	57	0.0084	1.2406		
	22 Aug–4 Sept	6,283	78	0.0124	4.6933		
	5 Sept–11 Sept	771	18	0.0233	14.4450		
	Total	16,795	163	0.0097	32.2998	3	<0.0001
2004	11 Jul–14 Aug	5,384	21	0.0039	8.7184		
	15 Aug–21 Aug	2,356	13	0.0055	1.0796		
	22 Aug–28 Aug	1,493	25	0.0167	17.5765		
	29 Aug–11 Sept	1,230	18	0.0146	8.7179		
	Total	10,463	77	0.0074	36.0924	3	<0.0001

Note: The Kalskag tagging site was located 270 rkm above the mouth of the Kuskokwim River in all years except 2004, in which it was located at rkm 249. Analysis based on recovered tags only. Tags observed but not recovered were not included as tagging date was unknown.

[a] Recovered tags divided by untagged catch.

[b] p-value criteria is based on an alpha of 0.05.

Table 14.–Wheel–wheel chi-square analysis of complete mixing of coho salmon tagged near Kalskag with untagged fish, Kuskokwim River 2001.

		Kalskag Tagging Gear		
Birch Tree Crossing Recapture Gear		Right Bank Fish Wheel (n=843)	Left Bank Fish Wheel (n=204)	Drift Gillnets (n=243)
Right Bank Fish Wheel				
	Untagged Catch	1,378	1,378	1,378
	Recovered Tags	8	3	0
	Ratio [a]	0.0058	0.0022	0.0000
	Chi-square	-	-	-
Left Bank Fish Wheel				
	Untagged Catch	377	377	377
	Recovered Tags	1	0	1
	Ratio [a]	0.0027	0.0000	0.0027
	Chi-square	-	-	-
Drift Gillnets				
	Untagged Catch	75	75	75
	Recovered Tags	0	0	0
	Ratio [a]	0.0000	0.0000	0.0000
	Chi-square	-	-	-
Total				
	Chi-square	-	-	-
	p-value [b]	-	-	-

Note: The Kalskag tagging site was located 270 rkm above the mouth of the Kuskokwim River. Analysis based on recovered tags only. Tags observed but not recovered were not included as tagging gear type was unknown. Dashes represent values that could not be calculated due to data limitations, generally failure to meet minimum expected tag recoveries (n=5) required for Chi-square analysis.

[a] Recovered tags divided by untagged catch.

[b] p-value criteria is based on an alpha of 0.05.

Table 15.–Wheel–wheel chi-square analysis of complete mixing of coho salmon tagged near Kalskag with untagged fish, Kuskokwim River 2002.

		Kalskag Tagging Gear		
Birch Tree Crossing Recapture Gear		Right Bank Fish Wheel (n=1,583)	Left Bank Fish Wheel (n=591)	Drift Gillnets (n=630)
Right Bank Fish Wheel				
	Untagged Catch	2,066	2,066	2,066
	Recovered Tags	5	5	4
	Ratio [a]	0.0024	0.0024	0.0019
	Chi-square	2.5757	-	-
Left Bank Fish Wheel				
	Untagged Catch	1,204	1,204	1,204
	Recovered Tags	11	7	3
	Ratio [a]	0.0091	0.0058	0.0025
	Chi-square	4.3904	-	-
Drift Gillnets				
	Untagged Catch	1,000	1,000	1,000
	Recovered Tags	5	5	1
	Ratio [a]	0.0050	0.0050	0.0010
	Chi-square	-	-	-
Total				
	Chi-square	6.9661	-	-
	p-value [b]	0.0083	-	-

Note: The Kalskag tagging site was located 270 rkm above the mouth of the Kuskokwim River. Analysis based on recovered tags only. Tags observed but not recovered were not included as tagging gear type was unknown. Dashes represent values that could not be calculated due to data limitations, generally failure to meet minimum expected tag recoveries (n=5) required for Chi-square analysis.

[a] Recovered tags divided by untagged catch.
[b] p-value criteria is based on an alpha of 0.05.

Table 16.–Wheel–wheel chi-square analysis of complete mixing of coho salmon tagged near Kalskag with untagged fish, Kuskokwim River 2003.

		Kalskag Tagging Gear		
Birch Tree Crossing Recapture Gear		Right Bank Fish Wheel (n=4,608)	Left Bank Fish Wheel (n=1,548)	Drift Gillnets (n=610)
Right Bank Fish Wheel				
	Untagged Catch	6,185	6,185	6,185
	Recovered Tags	45	20	6
	Ratio [a]	0.0073	0.0032	0.0010
	Chi-square	1.4618	1.0917	-
Left Bank Fish Wheel				
	Untagged Catch	7,045	7,045	7,045
	Recovered Tags	32	17	2
	Ratio [a]	0.0045	0.0024	0.0003
	Chi-square	2.7067	0.0595	-
Drift Gillnets				
	Untagged Catch	3,565	3,565	3,565
	Recovered Tags	25	6	10
	Ratio [a]	0.0070	0.0017	0.0028
	Chi-square	0.5144	1.0698	-
Total				
	Chi-square	4.6829	2.2210	-
	p-value [b]	0.0962	0.3294	-

Note: The Kalskag tagging site was located 270 rkm above the mouth of the Kuskokwim River. Analysis based on recovered tags only. Tags observed but not recovered were not included as tagging gear type was unknown. Dashes represent values that could not be calculated due to data limitations, generally failure to meet minimum expected tag recoveries (n=5) required for Chi-square analysis.

[a] Recovered tags divided by untagged catch.
[b] p-value criteria is based on an alpha of 0.05.

Table 17.–Wheel–wheel chi-square analysis of complete mixing of coho salmon tagged near Kalskag with untagged fish, Kuskokwim River 2004.

		Kalskag Tagging Gear		
Birch Tree Crossing Recapture Gear		Right Bank Fish Wheel (n=1,377)	Left Bank Fish Wheel (n=946)	Drift Gillnets (n=641)
Right Bank Fish Wheel				
	Untagged Catch	5,629	5,629	5,629
	Recovered Tags	17	11	2
	Ratio [a]	0.0030	0.0020	0.0004
	Chi-square	0.1250	6.3683	-
Left Bank Fish Wheel				
	Untagged Catch	4,095	4,095	4,095
	Recovered Tags	15	29	2
	Ratio [a]	0.0037	0.0071	0.0005
	Chi-square	0.1717	8.7093	-
Drift Gillnets				
	Untagged Catch	739	739	739
	Recovered Tags	0	0	1
	Ratio [a]	0.0000	0.0000	0.0014
	Chi-square	-	-	-
Total				
	Chi-square	0.2967	15.0775	-
	p-value [b]	0.5859	0.0001	-

Note: The Kalskag tagging site was located 249 rkm above the mouth of the Kuskokwim River. Analysis based on recovered tags only. Tags observed but not recovered were not included as tagging gear type was unknown. Dashes represent values that could not be calculated due to data limitations, generally failure to meet minimum expected tag recoveries (n=5) required for Chi-square analysis.

[a] Recovered tags divided by untagged catch.
[b] p-value criteria is based on an alpha of 0.05.

Table 18.–Coho salmon abundance estimates at Kalskag using wheel–wheel and wheel–weir mark–recapture methods, Kuskokwim River 2001–2005.

	Wheel-Wheel Abundance Estimates						Wheel-Weir Abundance Estimates		
	Darroch Estimate			Pooled Petersen			Pooled Petersen		
Year	Point Estimate	Lower 95% CI	Upper 95% CI	Point Estimate	Lower 95% CI	Upper 95% CI	Point Estimate	Lower 95% CI	Upper 95% CI
2001	-	-	-	170,042	79,456	397,288	440,330	333,752	567,380
2002	320,401	200,746	439,953	-	-	-	453,499	380,811	537,244
2003	-	-	-	675,306	546,788	832,070	971,266	848,560	1,105,870
2004	440,588	266,914	614,262	-	-	-	1,546,627	1,214,101	1,986,712
2005	-	-	-	-	-	-	666,747	579,595	785,127

Note: The Kalskag tagging site was located 270 rkm above the mouth of the Kuskokwim River in all years except 2004, in which it was located at rkm 249.

Table 19.–Summary of chum salmon captured and anchor tagged at the Kalskag tagging site, Kuskokwim River 2002–2005.

Year	Tagging Location	Gear Type	Tagged		Not Tagged		Total Catch		Recapture [e]
			n [a]	% [b]	n [a]	% [c]	n [a]	% [d]	
2002	Right Bank	Fish Wheel	4,966	64	409	8	5,375	64	178
	Left Bank	Fish Wheel	2,611	34	275	10	2,886	34	71
	Mid-Channel	Drift Gillnet	155	2	21	12	176	2	1
		Total [f]	7,732	92	705	8	8,437	100	250
2003	Right Bank	Fish Wheel	5,171	62	547	10	5,718	61	209
	Left Bank	Fish Wheel	2,777	33	416	13	3,193	34	141
	Mid-Channel	Drift Gillnet	436	5	13	3	449	5	5
		Total [f]	8,384	90	976	10	9,360	100	355
2004	Right Bank	Fish Wheel	1,982	38	153	7	2,135	38	135
	Left Bank	Fish Wheel	3,287	62	179	5	3,466	61	80
	Mid-Channel	Drift Gillnet	1	0	71	99	72	1	0
		Total [f]	5,270	93	403	7	5,673	100	215
2005 [g]	Right Bank # 1	Fish Wheel	14,383	51	990	6	15,373	50	236
	Right Bank # 2	Fish Wheel	7,231	25	922	11	8,153	27	627
	Left Bank	Fish Wheel	6,339	22	173	3	6,512	21	542
	Mid-Channel	Drift Gillnet	418	1	9	2	427	1	3
		Total [f]	28,371	93	2,094	7	30,465	100	1,408

Note: The Kalskag tagging site was located 270 rkm above the mouth of the Kuskokwim River in all years except 2004, in which it was located at rkm 249.

[a] Number of fish.
[b] Percent of total fish tagged.
[c] Percent of total catch by tagging location.
[d] Percent of total catch.
[e] Recapture of a tagged fish. Not included in total catch.
[f] Percentages relate to total catch.
[g] 2005 was the only year 2 fish wheels were operated on the right bank of the river.

Table 20.–Chum salmon tag recovery ratios by recovery site and wheel–weir chi-square analysis of equal probability of capture at the Kalskag tagging site, Kuskokwim River 2002–2005.

Year	Recovery Location	Distance (rkm) [a]	Sample Size [b]	Total Tagged	Total Untagged	Ratio [c]	Chi Square X^2	df	p-value [d]
2002	BTC Wheels [e]	24	19,064	271	18,793	0.0144			
	George River Weir	183	6,529	65	6,464	0.0101	255.6073		
	Tatlawiksuk River Weir	298	24,539		24,482	0.0023	4.9765		
	Kogrukluk River Weir	440	49,494		49,471	0.0005	45.9226		
	Takotna River Weir	565	4,366	2	4,364	0.0005	4.0934		
	Upstream Subtotal [f]			147	84,781	0.0017	310.5998	3	<0.0001
	Tuluksak River Weir	-134	9,958	12	9,946	0.0012			
	Kwethluk River Weir	-224	34,681	1	34,680	0.0000			
	Downstream Subtotal		44,639	13	44,626	0.0003			
2003	BTC Wheels [e]	24	18,267	332	17,935	0.0185			
	George River Weir	183	25,005	235	24,770	0.0095	65.7003		
	Tatlawiksuk River Weir [g]		ND	ND	ND	-	-		
	Kogrukluk River Weir	440	22,514		22,468	0.0020	50.7517		
	Takotna River Weir	565	3,020	1	3,019	0.0003	14.9941		
	Upstream Subtotal [f]			282	50,257	0.0056	131.4461	2	<0.0001
	Tuluksak River Weir	-134	11,625	8	11,617	0.0007			
	Kwethluk River Weir	-224	41,812	0	41,812	0.0000			
	Downstream Subtotal		53,437	8	53,429	0.0001			
2004	BTC Wheels [e]	45	18,095	644	17,451	0.0369			
	George River Weir	204	13,058	59	12,999	0.0045	123.478		
	Tatlawiksuk River Weir	319	21,245		21,238	0.0003	13.0381		
	Kogrukluk Rivre Weir	461	24,174		24,171	0.0001	22.8666		
	Takotna River Weir	586	1,633	0	1,633	0.0000	-		
	Upstream Subtotal [f]			69	60,041	0.0011	159.3827	2	<0.0001
	Tuluksak River Weir	-113	11,796	15	11,781	0.0013			
	Kwethluk River Weir	-203	37,114	3	37,111	0.0001			
	Downstream Subtotal		48,910	18	48,892	0.0004			
2005	BTC Wheels [eh]	24	ND	ND	ND	-			
	George River Weir	183	14,654	312	14,342	0.0218	2071.3393		
	Tatlawiksuk River Weir	298	55,316		55,145	0.0031	7.6555		
	Kogrukluk River Weir	440	191,588		191,406	0.0010	185.1561		
	Takotna River Weir	565	6,472	6	6,466	0.0009	6.4404		
	Upstream Subtotal [f]			671	267,359	0.0025	2270.5913	3	<0.0001
	Tuluksak River Weir	-134	35,696	49	35,647	0.0014			
	Kwethluk River Weir [i]	-224	ND	ND	ND	-			
	Downstream Subtotal		35,696	49	35,647	0.0014			

-continued-

Table 20.–Page 2 of 2.

Source: Sample size for all escapement weir projects were from the ADF&G CF Kuskokwim Research Master Escapement File, version 2008 (unpublished).

Note: The Kalskag tagging site was located 270 rkm above the mouth of the Kuskokwim River in all years except 2004, in which it was located at rkm 249. BTC stands for Birch Tree Crossing. ND stands for No Data. Dashes represent values that could not be calculated due to data limitations. Chi-square was used to test similarity in recapture ratios of upstream weirs only.

[a] Distance from Kalskag tagging site. Negative numbers indicate a downstream direction.
[b] Number of tagged fish plus untagged fish.
[c] Total number of tag recaptures divided by total number of untagged fish in sample.
[d] p-value criteria is based on an alpha of 0.05.
[e] Located on mainstem Kuskokwim River. Used for wheel-to-wheel estimates.
[f] The upstream subtotal was used for wheel-to-weir abundance estimation. Excludes Birch Tree Crossing.
[g] Tatlawiksuk River weir did not operate in 2003 due to high water damage early season.
[h] Birch Tree Crossing did not operate in 2005.
[i] Kwethluk River weir did not operate in 2005.

Table 21.–Summary of anchor tagged chum salmon recovered at recapture projects by gear type used at the Kalskag tagging site, 2002–2005.

			Tagging Source																
			Recovered Tags [ab]								Observed Tags [c]								
			Fish Wheel																
			Right Bank		Left Bank		Drift Gillnet		Total Recovered		Fish Wheel		Drift Gillnet		Unknown		Total Observed		Total Tags [d]
Year	Recovery Location	Distance (rkm) [e]	n [f]	% [g]	n [f]	% [g]	n [f]	% [g]	n [f]	% [h]	n [f]	% [i]	n [f]	% [i]	n [f]	% [i]	n [f]	% [h]	n [f]
2002	BTC Wheels	24	159	59	111	41	1	0	271	100	0	-	0	-	0	-	0	0	271
	George River Weir	183	39	71	16	29	0	0	55	85	10	100	0	0	0	0	10	15	65
	Tatlawiksuk River Weir	298	43	84	8	16	0	0	51	89	5	83	0	0	1	17	6	11	57
	Kogrukluk River Weir	440	11	69	5	31	0	0	16	70	1	14	0	0	6	86	7	30	23
	Takotna River Weir	565	1	50	0	0	1	50	2	100	0	-	0	-	0	-	0	0	2
	Upstream Subtotal		253	64	140	35	2	1	395	94	16	70	0	0	7	30	23	6	418
	Tuluksak River Weir	-134	3	38	5	63	0	0	8	67	4	100	0	0	0	0	4	33	12
	Kwethluk River Weir	-224	0	-	0	-	0	-	0	0	1	100	0	0	0	0	1	100	1
	Downstream Subtotal		3	38	5	63	0	0	8	62	5	100	0	0	0	0	5	38	13
		Total	256	64	145	36	2	0	403	94	21	75	0	0	7	25	28	6	431
2003	BTC Wheels	24	151	46	173	53	1	0	325	98	4	57	3	43	0	0	7	2	332
	George River Weir	183	98	69	36	25	8	6	142	60	92	99	1	1	0	0	93	40	235
	Tatlawiksuk River Weir [j]	298	ND	-	ND	-	ND	-	ND	-	ND	-	ND	-	ND	-	ND	-	ND
	Kogrukluk River Weir	440	30	88	1	3	3	9	34	74	9	75	3	25	0	0	12	26	46
	Takotna River Weir	565	1	100	0	0	0	0	1	100	0	-	0	-	0	-	0	0	1
	Upstream Subtotal		280	56	210	42	12	2	502	82	105	94	7	6	0	0	112	18	614
	Tuluksak River Weir	-134	4	67	2	33	0	0	6	75	2	100	0	0	0	0	2	25	8
	Kwethluk River Weir	-224	0	-	0	-	0	-	0	-	0	-	0	-	0	-	0	-	0
	Downstream Subtotal		4	67	2	33	0	0	6	75	2	-	0	-	0	-	2	25	8
		Total	284	56	212	42	12	2	508	82	107	94	7	6	0	0	114	18	622

-continued-

Table 21.–Page 2 of 2.

			Tagging Source																
			Recovered Tags [ab]								Observed Tags [c]								
			Fish Wheel						Total								Total		Total
		Distance	Right Bank		Left Bank		Drift Gillnet		Recovered		Fish Wheel		Drift Gillnet		Unknown		Observed		Tags [d]
Year	Recovery Location	(rkm) [e]	n [f]	% [g]	n [f]	% [g]	n [f]	% [g]	n [f]	% [h]	n [f]	% [i]	n [f]	% [i]	n [f]	% [i]	n [f]	% [h]	n [f]
2004	BTC Wheels	45	143	23	485	77	0	0	628	98	16	100	0	0	0	0	16	2	644
	George River Weir	204	35	64	20	36	0	0	55	93	4	100	0	0	0	0	4	7	59
	Tatlawiksuk River Weir	319	6	86	1	14	0	0	7	100	0	-	0	-	0	-	0	-	7
	Kogrukluk River Weir	461	2	100	0	0	0	0	2	67	1	100	0	0	0	0	1	33	3
	Takotna River Weir	586	0	-	0	-	0	-	0	-	0	-	0	-	0	-	0	-	0
	Upstream Subtotal		186	27	506	73	0	0	692	97	21	100	0	0	0	0	21	3	713
	Tuluksak River Weir	-113	2	15	11	85	0	0	13	87	2	100	0	0	0	0	2	13	15
	Kwethluk River Weir	-203	0	0	2	100	0	0	2	-	1	100	0	0	0	0	1	33	3
	Downstream Subtotal		2	13	13	87	0	0	15	83	3	100	0	0	0	0	3	17	18
	Total		188	27	519	73	0	0	707	97	24	100	0	0	0	0	24	3	731
2005	BTC Wheels [k]	24	ND	-	ND	-	ND	-	ND	-	ND	-	ND	-	ND	-	ND	-	ND
	George River Weir	183	199	76	60	23	3	1	262	84	49	98	1	2	0	0	50	16	312
	Tatlawiksuk River Weir	298	130	81	25	16	6	4	161	94	10	100	0	0	0	0	10	6	171
	Kogrukluk River Weir	440	146	85	19	11	7	4	172	95	9	90	1	10	0	0	10	5	182
	Takotna River Weir	565	6	100	0	0	0	0	6	100	0	-	0	-	0	-	0	0	6
	Upstream Subtotal		481	80	104	17	16	3	601	90	68	97	2	3	0	0	70	10	671
	Tuluksak River Weir	-134	22	73	8	27	0	0	30	61	18	95	1	5	0	0	19	39	49
	Kwethluk River Weir [l]	-224	ND	-	ND	-	ND	-	ND	-	ND	-	ND	-	ND	-	ND	-	ND
	Downstream Subtotal		22	73	8	27	0	0	30	61	18	95	1	5	0	0	19	39	49
	Total		503	80	112	18	16	3	631	88	86	97	3	3	0	0	89	12	720

Note: The Kalskag tagging site was located 270 rkm above the mouth of the Kuskokwim River in all years except 2004, in which it was located at rkm 249. BTC stands for Birch Tree Crossing. ND stands for No Data. Dashes represent values that could not be calculated due to data limitations.

[a] Tagged fish that were successfully captured, tag number and date were recorded, and tag number was matched with tag deployment data.
[b] Data from recovered tags were used for calculating stock-specific run timing and migration speed.
[c] Tagged fish that were not successfully captured, tag number and date were not recorded, or tag number was not matched with tag deployment data.
[d] Total number of tag recaptures (i.e. recovered plus observed) were used for abundance estimation.
[e] Distance (rkm) from the Kalskag tagging site. Negative numbers indicate a downstream direction.
[f] Number of fish.
[g] Percent of total recovered tags by recapture location.
[h] Percent of total tags by recapture location.
[i] Percent of total observed tags by recapture location.
[j] Tatlawiksuk River weir did not operate in 2003 due to high water damage early season.
[k] Birch Tree Crossing wheels did not operate in 2005.
[l] Kwethluk River weir did not operate in 2004.

Table 22.–Run timing for chum salmon tagged near Kalskag and recovered in upriver tributaries of the Kuskokwim River, 2002–2005.

Year	Recovery Location	Distance (rkm) [a]	Total Recovered Tags	Sample Size	Tagging Date [b]			Recovery Date [c]			Sample Date [d]		
					Median	Range		Median	Range		Median	Range	
2002	BTC Wheels [e]	24	271	19,064	16 Jul	23 Jun -	21 Aug	17 Jul	24 Jun -	22 Aug	11 Jul	14 Jun -	11 Sep
	George R.	183	55	6,529	09 Jul	23 Jun -	11 Aug	16 Jul	29 Jun -	19 Aug	10 Jul	21 Jun -	12 Sep
	Tatlawiksuk R.	298	51	24,539	07 Jul	23 Jun -	31 Jul	15 Jul	01 Jul -	09 Aug	10 Jul	17 Jun -	12 Sep
	Kogrukluk R.	440	16	49,494	28 Jun	20 Jun -	11 Jul	09 Jul	04 Jul -	24 Jul	11 Jul	26 Jun -	24 Sep
	Takotna R.	565	2	4,366	26 Jun	26 Jun -	27 Jun	12 Jul	11 Jul -	14 Jul	10 Jul	23 Jun -	31 Aug
2003	BTC Wheels [e]	24	325	18,267	20 Jul	25 Jun -	31 Aug	21 Jul	25 Jun -	26 Jul	21 Jul	06 Jun -	10 Sep
	George R.	183	142	25005	16 Jul	29 Jun -	28 Aug	22 Jul	12 Jul -	04 Sep	19 Jul	01 Jul -	13 Sep
	Tatlawiksuk R. [f]	298	ND	ND	-		-	-		-	-		-
	Kogrukluk R.	440	34	22,514	05 Jul	19 Jun -	25 Jul	18 Jul	03 Jul -	10 Aug	18 Jul	21 Jun -	19 Sep
	Takotna R/	565	1	3,020	01 Jul		01 Jul	16 Jul		16 Jul	17 Jul	02 Jul -	09 Sep
2004	BTC Wheels [e]	45	628	18,095	27 Jul	15 Jul -	06 Sep	29 Jul	18 Jul -	08 Sep	25 Jul	18 Jul -	10 Sep
	George R.	204	55	13,058	17 Jul	26 Jun -	30 Aug	24 Jul	04 Jul -	07 Sep	09 Jul	27 Jun -	24 Sep
	Tatlawiksuk R.	319	7	21,245	01 Jul	27 Jun -	07 Sep	10 Jul	05 Jul -	16 Sep	14 Jul	15 Jun -	16 Sep
	Kogrukluk R.	461	2	24,174	30 Jun	27 Jun -	04 Jul	16 Jul	16 Jul -	17 Jul	15 Jul	22 Jun -	23 Sep
	Takotna R.	586	0	1,633	-		-	-		-	10 Jul	23 Jun	04 Sep
2005	BTC Wheels [e, g]	24	ND	ND	-		-	-		-	-		-
	George R.	183	262	14,654	19 Jul	17 Jun -	09 Sep	26 Jul	25 Jun -	16 Sep	14 Jul	15 Jun	20 Sep
	Tatlawiksuk R.	298	161	55,316	07 Jul	19 Jun -	06 Aug	15 Jul	30 Jun -	14 Aug	15 Jul	16 Jun	21 Sep
	Kogrukluk R.	440	172	191,588	05 Jul	19 Jun -	30 Aug	18 Jul	03 Jul -	14 Sep	19 Jul	22 Jun	22 Sep
	Takotna R.	565	6	6,472	03 Jul	20 Jun	08 Jul	18 Jul	05 Jul	22 Jul	16 Jul	16 Jun	16 Sep

Note: The Kalskag tagging site was located 270 rkm above the mouth of the Kuskokwim River in all years except 2004, in which it was located at rkm 249. BTC stands fpr Birch Tree Crossing. ND stands for No Data. Dashes represent values that could not be calculated due to data limitations. Summary based on recovered tags only. Tags observed but not recovered were not included as tagging date was unknown.

[a] Distance from Kalskag tagging site.
[b] Date past the Kalskag tagging site.
[c] Date past the recovery location.
[d] Date of catch at Birch Tree Crossing or observed escapement past weirs. Inclusive of tagged and untagged fish.
[e] Located on the mainstem Kuskokwim River. Dates represent mixed stocks.
[f] Tatlawiksuk River weir did not operate in 2003 due to high water damage early season.
[g] Birch Tree Crossing wheels did not operate in 2005.

Table 23.–Migration rates for coho salmon tagged near Kalskag and recovered in upriver tributaries of the Kuskokwim River, 2002–2005.

Year	Recovery Location	Distance (rkm) [a]	Total Recovered Tags	Migration Time (days) [b] Mean	Range	SE	Migration Rate (rkm/day) [c] Mean	Range	SE
2002	BTC Wheels [d]	24	271	2	0 - 31	0.19	20	1 - 24	0.46
	George R.	183	55	6	4 - 15	0.27	31	12 - 46	0.98
	Tatlawiksuk R.	298	51	8	6 - 11	0.17	36	27 - 50	0.79
	Kogrukluk R.	440	16	13	10 - 17	0.47	34	26 - 44	1.24
	Takotna R.	565	2	16	14 - 18	2.00	36	31 - 40	4.48
2003	BTC Wheels [d]	24	325	2	0 - 23	0.16	19	1 - 24	0.42
	George R.	183	142	7	3 - 17	0.20	27	11 - 61	0.66
	Tatlawiksuk R.[e]	298	ND	-	-	-	-	-	-
	Kogrukluk R.	440	34	15	12 - 20	0.36	30	22 - 37	0.67
	Takotna R.	565	1	15	15	-	38	38	-
2004	BTC Wheels [d]	45	628	2	0 - 35	0.07	24	1 - 45	0.43
	George R.	204	55	7	4 - 14	0.20	30	15 - 51	0.75
	Tatlawiksuk R.	319	7	9	8 - 11	0.42	35	29 - 40	1.56
	Kogrukluk R.	461	2	16	12 - 20	4.00	31	23 - 38	7.68
	Takotna R.	586	0	-	-	-	-	-	-
2005	BTC Wheels [d, f]	24	ND	-	-	-	-	-	-
	George R.	183	262	6	1 - 13	0.10	32	14 - 63	0.46
	Tatlawiksuk R.	298	161	9	6 - 15	0.13	36	20 - 50	0.46
	Kogrukluk R.	440	172	13	7 - 25	0.18	34	18 - 63	0.43
	Takotna R.	565	6	15	13 - 17	0.56	39	33 - 43	4.64

Note: The Kalskag tagging site was located 270 rkm above the mouth of the Kuskokwim River in all years except 2004, in which it was located at rkm 249. BTC stands for Birch Tree Crossing. ND stands for No Data. Dashes represent values that could not be calculated due to data limitations. Summary based on recovered tags only. Tags observed but not recovered were not included as tagging date was unknown.

[a] Distance from Kalskag tagging site.
[b] Number of days between time of tagging at Kalskag and recovery at recapture location.
[c] Upstream distance traveled per day (rounded to the nearest whole rkm).
[d] Located on the mainstem Kuskokwim. Data represent mixed stocks.
[e] Tatlawiksuk River weir did not operate in 2003 due to high water damage early season.
[f] Birch Tree Crossing wheels did not operate in 2005.

Table 24.–Wheel–weir chi-square analysis of complete mixing of chum salmon tagged near Kalskag with untagged fish by gear type, Kuskokwim River 2002.

		Kalskag Tagging Gear		
Recapture Location		Right Bank Fish Wheel (n=4,966)	Left Bank Fish Wheel (n=2,611)	Drift Gillnets (n=155)
George River Weir				
	Untagged Catch	6,464	6,464	6,464
	Recovered Tags	39	16	0
	Ratio [a]	0.0060	0.0025	0.0000
	Chi-square	132.1446	-	-
Tatlawiksuk River Weir				
	Untagged Catch	24,482	24,482	24,482
	Recovered Tags	43	8	0
	Ratio [a]	0.0018	0.0003	0.0000
	Chi-square	7.6057	-	-
Kogrukluk River Weir				
	Untagged Catch	49,471	49,471	49,471
	Recovered Tags	11	5	0
	Ratio [a]	0.0002	0.0001	0.0000
	Chi-square	37.3185	-	-
Takotna River Weir				
	Untagged Catch	4,364	4,364	4,364
	Recovered Tags	1	0	1
	Ratio [a]	0.0002	0.0000	0.0002
	Chi-square	-	-	-
Total				
	Chi-square	177.0687	-	-
	p-value [b]	<0.0001	-	-

Note: The Kalskag tagging site was located 270 rkm above the mouth of the Kuskokwim River. Analysis based on recovered tags only. Tags observed but not recovered were not included as tagging gear type was unknown. Dashes represent values that could not be calculated due to data limitations, generally failure to meet minimum expected tag recoveries (n=5) required for Chi-square analysis.

[a] Recovered tags divided by untagged catch.
[b] p-value criteria is based on an alpha of 0.05.

Table 25.–Wheel–weir chi-square analysis of complete mixing of chum salmon tagged near Kalskag with untagged fish by gear type, Kuskokwim River 2003.

		Kalskag Tagging Gear		
Recapture Location		Right Bank Fish Wheel (n=5,171)	Left Bank Fish Wheel (n=2,777)	Drift Gillnets (n=436)
George River Weir				
	Untagged Catch	24,770	24,770	24,770
	Recovered Tags	98	36	8
	Ratio [a]	0.0040	0.0015	0.0003
	Chi-square	18.5606	14.1797	0.8634
Tatlawiksuk Weir River [b]				
	Untagged Catch	-	-	-
	Recovered Tags	-	-	-
	Ratio [a]	-	-	-
	Chi-square	-	-	-
Kogrukluk River Weir				
	Untagged Catch	22,468	22,468	22,468
	Recovered Tags	30	1	3
	Ratio [a]	0.0013	0.0000	0.0001
	Chi-square	13.2591	15.6546	0.9520
Takotna River Weir				
	Untagged Catch	3,019	3,019	3,019
	Recovered Tags	1	0	0
	Ratio [a]	0.0003	0.0000	0.0000
	Chi-square	5.8763	-	-
Total				
	Chi-square	37.6960	29.8343	1.8154
	p-value [c]	<0.0001	<0.0001	0.1779

Note: The Kalskag tagging site was located 270 rkm above the mouth of the Kuskokwim River. Analysis based on recovered tags only. Tags observed but not recovered were not included as tagging gear type was unknown. Dashes represent values that could not be calculated due to data limitations, generally failure to meet minimum expected tag recoveries (*n*=5) required for Chi-square analysis.

[a] Recovered tags divided by untagged catch.
[b] Tatlawiksuk River weir did not operate due to high water early season.
[c] p-value criteria is based on an alpha of 0.05.

Table 26.–Wheel–weir chi-square analysis of complete mixing of chum salmon tagged near Kalskag with untagged fish by gear type, Kuskokwim River 2004.

		Kalskag Tagging Gear		
Recapture Location		Right Bank Fish Wheel (n=1,982)	Left Bank Fish Wheel (n=3,287)	Drift Gillnets (n=1)
George River Weir				
	Untagged Catch	12,999	12,999	12,999
	Recovered Tags	35	20	0
	Ratio [a]	0.0027	0.0015	0.0000
	Chi-square	67.3943	-	-
Tatlawiksuk River Weir				
	Untagged Catch	21,238	21,238	21,238
	Recovered Tags	6	1	0
	Ratio [a]	0.0003	-	0.0000
	Chi-square	5.9362		-
Kogrukluk River Weir				
	Untagged Catch	24,171	24,171	24,171
	Recovered Tags	2	0	0
	Ratio [a]	0.0001	0.0000	0.0000
	Chi-square	14.0183	-	-
Takotna River Weir				
	Untagged Catch	1,633	1,633	1,633
	Recovered Tags	0	0	0
	Ratio [a]	0.0000	0.0000	0.0000
	Chi-square	-	-	-
Total				
	Chi-square	87.3488	-	-
	p-value [b]	<0.0001	-	-

Note: The Kalskag tagging site was located 249 rkm above the mouth of the Kuskokwim River. Analysis based on recovered tags only. Tags observed but not recovered were not included as tagging gear type was unknown. Dashes represent values that could not be calculated due to data limitations, generally failure to meet minimum expected tag recoveries (*n*=5) required for Chi-square analysis.

[a] Recovered tags divided by untagged catch.
[b] p-value criteria is based on an alpha of 0.05.

Table 27.–Wheel–weir chi-square analysis of complete mixing of chum salmon tagged near Kalskag with untagged fish by gear type, Kuskokwim River 2005.

		Kalskag Tagging Gear		
Recapture Location		Right Bank Fish Wheel (n=21,614)	Left Bank Fish Wheel (n=6,339)	Drift Gillnets (n=418)
George Weir				
	Untagged Catch	14,342	14,342	14,342
	Recovered Tags	199	60	3
	Ratio [a]	0.0139	0.0042	0.0002
	Chi-square	1,146.6721	513.2528	-
Tatlawiksuk Weir				
	Untagged Catch	55,145	55,145	55,145
	Recovered Tags	130	25	6
	Ratio [a]	0.0024	0.0005	0.0001
	Chi-square	9.5331	0.4140	-
Kogrukluk Weir				
	Untagged Catch	191,406	191,406	191,406
	Recovered Tags	146	19	7
	Ratio [a]	0.0008	0.0001	0.0000
	Chi-square	114.1688	43.0274	-
Takotna Weir				
	Untagged Catch	6,466	6,466	6,466
	Recovered Tags	6	0	0
	Ratio [a]	0.0009	0.0000	0.0000
	Chi-square	2.7250	-	-
Total				
	Chi-square	1,273.0989	556.6942	-
	p-value [b]	<0.0001	<0.0001	-

Note: The Kalskag tagging site was located 270 rkm above the mouth of the Kuskokwim River. Analysis based on recovered tags only. Tags observed but not recovered were not included as tagging gear type was unknown. Dashes represent values that could not be calculated due to data limitations, generally failure to meet minimum expected tag recoveries (*n*=5) required for Chi-square analysis.

[a] Recovered tags divided by untagged catch.
[b] p-value criteria is based on an alpha of 0.05.

Table 28.–Wheel–wheel chi-square test of temporally consistent probability of recovering Kalskag tagged chum salmon at Birch Tree Crossing, Kuskokwim River 2002–2003.

					Chi-square		
Year	Sample Period	Untagged Catch	Recovered Tags	Ratio [a]	X^2	df	p-value [b]
2002	14 Jun–7 Jul	6,737	40	0.0059	33.4204		
	8 Jul–14 Jul	4,644	63	0.0136	0.2319		
	15 Jul–21 Jul	3,268	69	0.0211	9.9437		
	22 Jul–28 Jul	2,002	45	0.0225	8.8148		
	29 Jul–4 Aug	1,385	23	0.0166	0.4516		
	5 Aug–11 Sept	757	31	0.0410	35.4973		
	Total	18,793	271		88.3597	5	<0.0001
2003	6 Jun–9 Jul	3,368	22	0.0065	24.7998		
	10 Jul–30 Jul	10,160	240	0.0236	16.5754		
	31 Jul–6 Aug	2,480	26	0.0105	7.8995		
	7 Aug–13 Aug	1,339	19	0.0142	1.1260		
	14 Aug–11 Sept	588	18	0.0306	4.9126		
	Total	17,935	325		55.3134	4	<0.0001

Note: The Kalskag tagging site was located 270 rkm above the mouth of the Kuskokwim River. Analysis based on recovered tags only. Tags observed but not recovered were not included as tagging date was unknown.

[a] Recovered tags divided by untagged catch.
[b] p-value criteria is based on an alpha of 0.05.

Table 29.–Wheel–wheel chi-square analysis of complete mixing of chum salmon tagged near Kalskag with untagged fish, Kuskokwim River 2002.

		Kalskag Tagging Gear		
Birch Tree Crossing Recapture Gear		Right Bank Fish Wheel (n=4,966)	Left Bank Fish Wheel (n=2,611)	Drift Gillnets (n=155)
Right Bank Fish Wheel				
	Untagged Catch	8,609	8,609	8,609
	Recovered Tags	113	61	1
	Ratio [a]	0.0131	0.0071	0.0001
	Chi-square	21.2054	1.8705	-
Left Bank Fish Wheel				
	Untagged Catch	10,062	10,062	10,062
	Recovered Tags	46	50	0
	Ratio [a]	0.0046	0.0050	0.0000
	Chi-square	18.2977	1.6038	-
Drift Gillnets				
	Untagged Catch	122	122	122
	Recovered Tags	0	0	0
	Ratio [a]	0.0000	0.0000	0.0000
	Chi-square	-	-	-
Total				
	Chi-square	39.5031	3.4743	-
	p-value [b]	<0.0001	0.0623	-

Note: The Kalskag tagging site was located 270 rkm above the mouth of the Kuskokwim River. Analysis based on recovered tags only. Tags observed but not recovered were not included as tagging gear type was unknown. Dashes represent values that could not be calculated due to data limitations, generally failure to meet minimum expected tag recoveries (*n*=5) required for Chi-square analysis.

[a] Recovered tags divided by untagged catch.
[b] p-value criteria is based on an alpha of 0.05.

Table 30.–Wheel–wheel chi-square analysis of complete mixing of chum salmon tagged near Kalskag with untagged fish, Kuskokwim River 2003.

		Kalskag Tagging Gear		
Birch Tree Crossing Recapture Gear		Right Bank Fish Wheel (n=5,171)	Left Bank Fish Wheel (n=2,777)	Drift Gillnets (n=436)
Right Bank Fish Wheel				
	Untagged Catch	4,096	4,096	4,096
	Recovered Tags	48	40	0
	Ratio [a]	0.0117	0.0098	0.0000
	Chi-square	5.2349	61.4704	-
Left Bank Fish Wheel				
	Untagged Catch	10,321	10,321	10,321
	Recovered Tags	92	132	0
	Ratio [a]	0.0089	0.0128	0.0000
	Chi-square	0.2972	10.5004	-
Drift Gillnets				
	Untagged Catch	3,518	3,518	3,518
	Recovered Tags	11	1	1
	Ratio [a]	0.0031	0.0003	0.0003
	Chi-square	11.6678	8.6842	-
Total				
	Chi-square	17.1999	80.6550	-
	p-value [b]	0.0002	<0.0001	-

Note: The Kalskag tagging site was located 270 rkm above the mouth of the Kuskokwim River. Analysis based on recovered tags only. Tags observed but not recovered were not included as tagging gear type was unknown. Dashes represent values that could not be calculated due to data limitations, generally failure to meet minimum expected tag recoveries (*n*=5) required for Chi-square analysis.

[a] Recovered tags divided by untagged catch.
[b] p-value criteria is based on an alpha of 0.05.

Table 31.–Summary of sockeye salmon captured and anchor tagged at the Kalskag tagging site, Kuskokwim River 2002–2006.

			Number of Salmon						
			Tagged		Not Tagged		Total Catch		
Year	Tagging Location	Gear Type	n [a]	% [b]	n [a]	% [c]	n [a]	% [d]	Recapture [e]
2002	Right Bank	Fish Wheel	111	42	8	7	119	43	5
	Left Bank	Fish Wheel	146	56	9	6	155	55	1
	Mid-Channel	Drift Gillnet	6	2	0	0	6	2	1
		Total [f]	263	94	17	6	280	100	7
2003	Right Bank	Fish Wheel	569	42	51	8	620	43	4
	Left Bank	Fish Wheel	598	45	56	9	654	45	3
	Mid-Channel	Drift Gillnet	174	13	6	3	180	12	0
		Total [f]	1,341	92	113	8	1,454	100	7
2004	Right Bank	Fish Wheel	1,170	62	40	3	1,210	62	42
	Left Bank	Fish Wheel	705	38	31	4	736	38	25
	Mid-Channel	Drift Gillnet	1	0	3	75	4	0	0
		Total [f]	1,876	96	74	4	1,950	100	67
2005 [g]	Right Bank # 1	Fish Wheel	2,425	53	126	5	2,551	53	39
	Right Bank # 2	Fish Wheel	842	18	88	9	930	19	43
	Left Bank	Fish Wheel	1,234	27	15	1	1,249	26	44
	Mid-Channel	Drift Gillnet	116	3	3	3	119	2	1
		Total [f]	4,617	95	232	5	4,849	100	127
2006	Right Bank	Fish Wheel	2,485	56	34	1	2,519	56	18
	Left Bank	Fish Wheel	1,812	41	23	1	1,835	41	16
	Mid-Channel	Drift Gillnet	102	2	34	25	136	3	2
		Total [f]	4,399	98	91	2	4,490	100	36

Note: The Kalskag tagging site was located 270 rkm above the mouth of the Kuskokwim River in all years except 2004, in which it was located at rkm 249.

[a] Number of fish.
[b] Percent of total fish tagged.
[c] Percent of total catch by tagging location.
[d] Percent of total catch.
[e] Recapture of a tagged fish. Not included in total catch.
[f] Percentages relate to total catch.
[g] 2005 was the only year 2 fish wheels were operated on the right bank of the river.

Table 32.–Sockeye salmon tag recovery ratios by recovery site and wheel–weir chi-square analysis of equal probability of capture at the Kalskag tagging site, Kuskokwim River 2001–2005.

Year	Recovery Location	Distance (rkm) [a]	Sample Size [b]	Total Tagged	Total Untagged	Ratio [c]	Chi Square X^2	df	p-value [d]
2002	BTC Wheels [e]	24	589	4	585	0.0068			
	George R. Weir	183	17	2	15	0.1333	-		
	Tatlawiksuk R. Weir	298	1	0	1	0.0000	-		
	Kogrukluk R. Weir	440	3,913	5	3,908	0.0013	-		
	Takotna R. Weir	565	1	0	1	0.0000	-		
	Upstream Subtotal [f]		3,932	7	3,925	0.0018	-	-	-
	Tuluksak R. Weir	-134	82	0	82	0.0000			
	Kwethluk R. Weir	-224	272	1	271	0.0037			
	Downstream Subtotal		354	1	353	0.0028			
2003	BTC Wheels [e]	24	1,535	23	1,512	0.0152			
	George R. Weir	183	14	0	14	0.0000	-		
	Tatlawiksuk R. Weir	298	ND	ND	-	-	-		
	Kogrukluk R. Weir	440	8,986	54	8,932	0.0060	-		
	Takotna R. Weir	565	4	0	4	0.0000	-		
	Upstream Subtotal [f]		9,004	54	8,950	0.0060	-	-	-
	Tuluksak R. Weir	-134	282	3	279	0.0108			
	Kwethluk R. Weir	-224	2,928	1	2,927	0.0003			
	Downstream Subtotal		3,210	4	3,206	0.0012			
2004	BTC Wheels [e]	45	1,048	104	944	0.1102			
	George R. Weir	204	177	11	166	0.0663	-		
	Tatlawiksuk R. Weir [g]	319	10	3	7	0.4286	-		
	Kogrukluk R. Weir	461	6,767	34	6,733	0.0050	-		
	Takotna R. Weir	586	17	1	16	0.0625	-		
	Upstream Subtotal [f]		6,971	49	6,922	0.0071	-	-	-
	Tuluksak R. Weir	-113	136	2	134	0.0149			
	Kwethluk R. Weir	-203	3,303	6	3,297	0.0018			
	Downstream Subtotal		3,439	8	3,431	0.0023			
2005	BTC Wheels [e, h]	24	ND	ND		-			
	George R. Weir	183	272	13	259	0.0502	-		
	Tatlawiksuk R. Weir	298	74	3	71	0.0423	-		
	Kogrukluk R. Weir	440	37,465	215	37,250	0.0058	-		
	Takotna R. Weir	565	35	2	33	0.0606	-		
	Upstream Subtotal [f]		37,846	233	37,613	0.0062	-	-	-
	Tuluksak R. Weir	-134	642	31	611	0.0507			
	Kwethluk R. Weir [i]	-224	ND	ND		-			
	Downstream Subtotal		642	31	611	0.0507			
2006	BTC Wheels [e, h]	24	ND	ND		-			
	Salmon R. Weir [e]	134	4,327	13	4,314	0.0030	6.9937		
	George R. Weir	183	146	4	142	0.0282	-		
	Tatlawiksuk R. Weir	298	38	0	38	0.0000	-		
	Kogrukluk R. Weir	440	59,773	381	59,392	0.0064	0.5063		
	Takotna R. Weir	565	54	1	53	0.0189	-		
	Upstream Subtotal [f]		64,338	399	63,939	0.0062	7.5	1	0.0062
	Tuluksak R. Weir	-134	920	5	915	0.0055			
	Kwethluk R. Weir	-224	4,066	2	4,064	0.0005			
	Downstream Subtotal		4,986	7	4,979	0.0014			

-continued-

Table 32.–Page 2 of 2.

Source: Sample size for all escapement weir projects were from the ADF&G CF Kuskokwim Research Master Escapement File, version 2008 (unpublished).

Note: The Kalskag tagging site was located 270 rkm above the mouth of the Kuskokwim River in all years except 2004, in which it was located at rkm 249. BTC stands for Birch Tree Crossing. ND stands for No Data. Dashes represent values that could not be calculated due to data limitations. Chi-square was used to test similarity in recapture ratios of upstream weirs only.

[a] Distance from Kalskag tagging site. Negative numbers indicate a downstream direction.
[b] Number of tagged fish plus untagged fish.
[c] Total number of tag recaptures divided by total number of untagged fish in sample.
[d] p-value criteria is based on an alpha of 0.05.
[e] Located on mainstem Kuskokwim River. Used for wheel-to-wheel estimates.
[f] The upstream subtotal was used for wheel-to-weir abundance estimation. Excludes Birch Tree Crossing.
[g] Tatlawiksuk River weir did not operate in 2003 due to high water damage early season.
[h] Birch Tree Crossing did not operate in 2005 or 2006.
[i] Kwethluk River weir did not operate in 2005.

Table 33.–Summary of anchor tagged sockeye salmon recovered at recapture projects by gear type used at the Kalskag tagging site, 2002–2006.

			Tagging Source																
			Recovered Tags [a]								Observed Tags [b]								
			Fish Wheel																
			Right Bank		Left Bank		Drift Gillnet		Total Recovered [c]		Fish Wheel		Drift Gillnet		Unknown		Total Observed		Total Tags [d]
Year	Recovery Location	Distance (rkm) [e]	n	% [f]	n	% [f]	n	% [f]	n	% [g]	n	% [h]	n	% [h]	n	% [h]	n	% [g]	n
2002	BTC Wheels	24	1	25	3	75	0	0	4	100	0	-	0	-	0	-	0	0	4
	George R. Weir	183	1	50	1	50	0	0	2	100	0	-	0	-	0	-	0	0	2
	Tatlawiksuk R. Weir	298	0	-	0	-	0	-	0	-	0	-	0	-	0	-	0	-	0
	Kogrukluk R. Weir	440	2	40	3	60	0	0	5	100	0	-	0	-	0	-	0	0	5
	Takotna R. Weir	565	0	-	0	-	0	-	0	-	0	-	0	-	0	-	0	-	0
	Upstream Subtotal		4	36	7	64	0	0	11	100	0	-	0	-	0	-	0	0	11
	Tuluksak R. Weir	-134	0	-	0	-	0	-	0	-	0	-	0	-	0	-	0	-	0
	Kwethluk R. Weir	-224	0	0	1	100	0	0	1	100	0	-	0	-	0	-	0	0	1
	Downstream Subtotal		0	0	1	100	0	0	1	100	0	-	0	-	0	-	0	0	1
		Total	4	33	8	67	0	0	12	100	0	-	0	-	0	-	0	0	12
2003	BTC Wheels	24	5	22	15	65	3	13	23	100	0	-	0	-	0	-	0	0	23
	George R. Weir	183	0	-	0	-	0	-	0	-	0	-	0	-	0	-	0	-	0
	Tatlawiksuk R. Weir [i]	298	ND	-	ND	-	ND	-	ND	-	ND	-	ND	-	ND	-	ND	-	ND
	Kogrukluk R. Weir	440	23	52	14	32	7	16	44	81	10	-	0	-	0	-	10	19	54
	Takotna R. Weir	565	0	-	0	-	0	-	0	-	0	-	0	-	0	-	0	-	0
	Upstream Subtotal		28	42	29	43	10	15	67	87	10	-	0	-	0	-	10	13	77
	Tuluksak R. Weir	-134	1	33	2	67	0	0	3	100	0	-	0	-	0	-	0	0	3
	Kwethluk R. Weir	-224	0	0	1	100	0	0	1	100	0	-	0	-	0	-	0	0	1
	Downstream Subtotal		1	25	3	75	0	0	4	100	0	-	0	-	0	-	0	0	4
		Total	29	41	32	45	10	14	71	88	10	100	0	0	0	0	10	12	81
2004	BTC Wheels	45	64	63	38	37	0	0	102	98	2	100	0	0	0	0	2	2	104
	George R. Weir	204	10	100	0	0	0	0	10	91	1	100	0	0	0	0	1	9	11
	Tatlawiksuk R. Weir	319	0	0	2	100	0	0	2	67	1	100	0	0	0	0	1	33	3
	Kogrukluk R. Weir	461	24	77	7	23	0	0	31	91	3	100	0	0	0	0	3	9	34
	Takotna R. Weir	586	0	0	1	100	0	0	1	100	0	-	0	-	0	-	0	-	1
	Upstream Subtotal		98	67	48	33	0	0	146	95	7	100	0	0	0	0	7	5	153
	Tuluksak R. Weir	-113	1	50	1	50	0	0	2	100	0	-	0	-	0	-	0	0	2
	Kwethluk R. Weir	-203	3	60	2	40	0	0	5	83	1	100	0	0	0	0	1	17	6
	Downstream Subtotal		4	57	3	43	0	0	7	88	1	100	0	0	0	0	1	13	8
		Total	102	67	51	33	0	0	153	95	8	100	0	0	0	0	8	5	161

-continued-

Table 33.–Page 2 of 2.

			Tagging Source																
			Recovered Tags [a]								Observed Tags [b]								
			Fish Wheel																
			Right Bank		Left Bank		Drift Gillnet		Total Recovered [c]		Fish Wheel		Drift Gillnet		Unknown		Total Observed		Total Tags [d]
Year	Recovery Location	Distance (rkm) [e]	n	% [f]	n	% [f]	n	% [f]	n	% [g]	n	% [h]	n	% [h]	n	% [h]	n	% [g]	n
2005	BTC Wheels [j]	24	ND	-	ND	-	ND	-	ND	-	ND	-	ND	-	ND	-	ND	-	ND
	George R. Weir	183	9	82	2	18	0	0	11	85	2	100	0	0	0	0	2	15	13
	Tatlawiksuk R. Weir	298	2	67	1	33	0	0	3	100	0	-	0	-	0	-	0	0	3
	Kogrukluk R. Weir	440	159	81	34	17	4	2	197	92	17	94	1	6	0	0	18	8	215
	Takotna R. Weir	565	1	50	1	50	0	0	2	100	0	-	0	-	0	-	0	0	2
	Upstream Subtotal		171	80	38	18	4	2	213	91	19	95	1	5	0	0	20	9	233
	Tuluksak R. Weir	-134	19	90	2	10	0	0	21	68	10	100	0	0	0	0	10	32	31
	Kwethluk R. Weir [k]	-224	ND	-	ND	-	ND	-	ND	-	ND		ND	-	ND	-	ND	-	ND
	Downstream Subtotal		19	90	2	10	0	0	21	68	10	100	0	0	0	0	10	32	31
	Total		190	81	40	17	4	2	234	89	29	97	1	3	0	0	30	11	264
2006	BTC Wheels [j]	24	ND	-	ND	-	ND	-	ND	-	ND	-	ND	-	ND	-	ND	-	ND
	Salmon R. Weir [l]	134	4	33	8	67	0	0	12	92	1	100	0	0	0	0	1	8	13
	George R. Weir	183	3	75	1	25	0	0	4	100	0	-	0	-	0	-	0	0	4
	Tatlawiksuk R. Weir	298	0	-	0	-	0	-	0	-	0	-	0	-	0	-	0	-	0
	Kogrukluk R. Weir	440	202	58	146	42	1	0	349	92	24	75	2	6	6	19	32	8	381
	Takotna R. Weir	565	1	100	0	0	0	0	1	100	0	-	0	-	0	-	0	0	1
	Upstream Subtotal		210	57	155	42	1	0	366	92	25	76	2	6	6	18	33	8	399
	Tuluksak R. Weir	-134	0	0	2	100	0	0	2	40	3	100	0	0	0	0	3	60	5
	Kwethluk R. Weir	-224	0	0	1	100	0	0	1	50	1	100	0	0	0	0	1	50	2
	Downstream Subtotal		0	0	3	100	0	0	3	43	4	-	0	-	0	-	4	57	7
	Total		210	57	158	43	1	0	369	91	29	78	2	5	6	16	37	9	406

Note: The Kalskag tagging site was located 270 rkm above the mouth of the Kuskokwim River in all years except 2004, in which it was located at rkm 249. BTC stands for Birch Tree Crossing. ND stands for No Data. Dashes represent values that could not be calculated due to data limitations.

[a] Tagged fish that were successfully captured, tag number and date were recorded, and tag number was matched with tag deployment data.
[b] Tagged fish that were not successfully captured, tag number and date were not recorded, or tag number was not matched with tag deployment data.
[c] Data from recovered tags were used for calculating stock-specific run-timing and travel speed.
[d] Total number of tag recaptures (i.e. recovered plus observed) were used for abundance estimation.
[e] Distance (rkm) from the Kalskag tagging site. Negative numbers indicate a downstream direction.
[f] Percent of total recovered tags by recapture location.
[g] Percent of total tags by recapture location.
[h] Percent of total observed tags by recapture location.
[i] Tatlawiksuk River weir did not operate in 2003 due to high water damage early season.
[j] Birch Tree Crossing wheels did not operate in 2005.
[k] Kwethluk River weir did not operate in 2004.
[l] Salmon River weir (Aniak Drainage) was only operated in 2006 for additional model diagnostics capabilities.

Table 34.–Run timing for sockeye salmon tagged near Kalskag and recovered in upriver tributaries of the Kuskokwim River, 2002–2006.

Year	Recovery Location	Distance (rkm) [a]	Total Recovered Tags	Sample Size	Tagging Date [b]			Recovery Date [c]			Escapement Date [d]		
					Median	Range		Median	Range		Median	Range	
2002	BTC Wheels [e]	24	4	589	5 Aug	1 Jul -	22 Aug	6 Aug	10 Jul -	23 Aug	7 Jul	15 Jun -	7 Sep
	George R.	183	2	17	2 Aug	23 Jul -	13 Aug	10 Aug	31 Jul -	21 Aug	5 Aug	27 Jun -	7 Sep
	Tatlawiksuk R.	298	0	1	-		-	-		-	-		29 Aug
	Kogrukluk R.	440	5	3,913	3 Jul	27 Jun -	12 Jul	20 Jul	11 Jul -	29 Jul	11 Jul	26 Jun -	7 Sep
	Takotna R.	565	0	1	-		-	-		-	-		21 Aug
2003	BTC Wheels [e]	24	23	1,535	11 Jul	21 Jun -	21 Aug	19 Jul	24 Jun -	28 Aug	7 Jul	14 Jun -	3 Sep
	George R.	183	0	14	-		-	-		-	8 Aug	21 Jul -	12 Aug
	Tatlawiksuk R. [f]		ND	ND	-		-	-		-	-		-
	Kogrukluk R.	440	44	8,986	2 Jul	16 Jun -	22 Jul	20 Jul	8 Jul -	6 Aug	16 Jul	27 Jun -	8 Sep
	Takotna R.	565	0	4	-		-	-		-	9 Aug	8 Aug -	9 Sep
2004	BTC Wheels [e] 298	45	102	1,048	30 Jul	9 Jul -	30 Aug	3 Aug	18 Jul -	1 Sep	28 Jul	18 Jul -	10 Sep
	George R.	204	10	177	5 Aug	17 Jul -	16 Aug	12 Aug	25 Jul -	25 Aug	13 Aug	9 Jul -	13 Sep
	Tatlawiksuk R.	319	2	10	21 Jul	16 Jul -	26 Jul	2 Aug	31 Jul -	5 Aug	11 Aug	19 Jul -	18 Sep
	Kogrukluk R.	461	31	6,767	29 Jun	24 Jun -	27 Aug	26 Jul	11 Jul -	9 Sep	12 Jul	27 Jun -	9 Sep
	Takotna R.	586	1	17	22 Jul		22 Jul	16 Aug		16 Aug	17 Aug	31 Jul -	16 Sep
2005	BTC Wheels [e, g]	24	ND	ND	-		-	-		-	-		-
	George R.	183	11	272	11 Aug	6 Jul -	29 Aug	17 Aug	22 Jul -	4 Sep	14 Aug	22 Jun -	19 Sep
	Tatlawiksuk R.	298	3	74	19 Jul	10 Jul -	23 Jul	30 Jul	25 Jul -	3 Aug	30 Jul	13 Jul -	1 Sep
	Kogrukluk R.	440	197	37,465	4 Jul	9 Jun -	19 Aug	21 Jul	5 Jul -	4 Sep	15 Jul	25 Jun -	12 Sep
	Takotna R.	565	2	35	15 Aug	14 Aug -	16 Aug	29 Aug	28 Aug -	31 Aug	17 Aug	17 Jul -	6 Sep
2006	BTC Wheels [e, g]	24	ND	ND	-		-	-		-	-		-
	Salmon R. [h]	134	12	4,327	14 Jul	2 Jul -	28 Jul	4 Aug	19 Jul -	8 Aug	1 Aug	3 Jul -	8 Aug
	George R.	183	4	146	24 Jul	5 Jul -	7 Aug	3 Aug	18 Jul -	14 Aug	5 Aug	9 Jul -	17 Sep
	Tatlawiksuk R.	298	0	38	-		-	-		-	4 Aug	15 Jul -	18 Aug
	Kogrukluk R.	440	349	59,773	6 Jul	21 Jun -	29 Jul	25 Jul	5 Jul -	11 Aug	19 Jul	28 Jun -	14 Sep
	Takotna R.	565	1	54	3 Aug		3 Aug	26 Aug		26 Aug	14 Aug	27 Jul -	19 Sep

Note: The Kalskag tagging site was located 270 rkm above the mouth of the Kuskokwim River in all years except 2004, in which it was located at rkm 249. BTC stands for Birch Tree Crossing. ND stands for No Data. Dashes represent values that could not be calculated due to data limitations. Summary based on recovered tags only. Tags observed but not recovered were not included as tagging date was unknown.

[a] Distance from Kalskag tagging site.
[b] Date past the Kalskag tagging site.
[c] Date past the recovery location.
[d] Date of catch at Birch Tree Crossing or observed escapement past weirs. Inclusive of tagged and untagged fish.
[e] Located on the mainstem Kuskokwim River. Dates represent mixed stocks.
[f] Tatlawiksuk River weir did not operate in 2003 due to high water damage early season.
[g] Birch Tree Crossing wheels did not operate in 2005 or 2006.
[h] Salmon River weir (Aniak Drainage) was only operated in 2006 for additional model diagnostics capabilities.

Table 35.–Migration rates for sockeye salmon tagged near Kalskag and recovered in upriver tributaries of the Kuskokwim River, 2002–2006.

Year	Recovery Location	Distance (rkm) [a]	Total Recovered Tags	Migration Time (days) [b]				Migration Rate (rkm/day) [c]			
				Mean	Range		SE	Mean	Range		SE
2002	BTC Wheels [d]	24	4	3	0	- 9	2.10	19	3	- 24	5.33
	George River	183	2	8	8	- 8	0.00	23	23	- 23	0.00
	Tatlawiksuk River	298	0	-		-	-	-		-	-
	Kogrukluk River	440	5	17	13	- 23	1.91	28	19	- 34	2.82
	Takotna River	565	0	-		-	-	-		-	-
2003	BTC Wheels [d]	24	23	6	1	- 57	2.43	11	0	- 24	1.67
	George River	183	0	-		-	-	-		-	-
	Tatlawiksuk River [e]	298	ND	-		-	-	-		-	-
	Kogrukluk River	440	44	19	13	- 37	0.64	24	12	- 34	0.67
	Takotna River	565	0	-		-	-	-		-	-
2004	BTC Wheels [d]	45	102	3	1	- 22	0.30	21	2	- 45	1.17
	George River	204	10	8	6	- 16	1.02	27	13	- 34	2.28
	Tatlawiksuk River	319	2	13	10	- 15	2.50	27	21	- 32	4.76
	Kogrukluk River	461	31	22	13	- 38	1.15	22	12	- 35	1.05
	Takotna River	586	1	25		25	-	23		23	-
2005	BTC Wheels [d, f]	24	ND	-		-	-	-		-	-
	George River	183	11	8	5	- 16	1.02	25	11	- 37	2.52
	Tatlawiksuk River	298	3	12	11	- 15	1.33	25	20	- 27	3.61
	Kogrukluk River	440	197	18	10	- 38	0.40	26	12	- 44	0.47
	Takotna River	565	2	15	12	- 17	2.50	40	33	- 47	6.92
2006	BTC Wheels [d, f]	24	ND	-		-	-	-		-	-
	Salmon River [g]		12	19	11	- 30	1.75	8	4	- 12	1.86
	George River	183	4	10	7	- 13	1.29	19	14	- 26	2.62
	Tatlawiksuk River	298	0	-		-	-	-		-	-
	Kogrukluk River	440	349	19	10	- 40	0.31	25	11	- 44	0.36
	Takotna River	565	1	23		23	-	25		25	-

Note: The Kalskag tagging site was located 270 rkm above the mouth of the Kuskokwim River in all years except 2004, in which it was located at rkm 249. BTC stands for Birch Tree Crossing. ND stands for No Data. Dashes represent values that could not be calculated due to data limitations. Summary based on recovered tags only. Tags observed but not recovered were not included as tagging date was unknown.

[a] Distance from Kalskag tagging site.
[b] Number of days between time of tagging at Kalskag and recovery at recapture location.
[c] Upstream distance traveled per day (rounded to the nearest whole rkm).
[d] Located on the mainstem Kuskokwim River. Data represent mixed stocks.
[e] Tatlawiksuk River weir did not operate in 2003 due to high water damage early season.
[f] Birch Tree Crossing wheels did not operate in 2005 or 2006.
[g] Salmon River weir (Aniak Drainage) was only operated in 2006 for additional model diagnostics capabilities.

Table 36.–Wheel–weir chi-square analysis of complete mixing of sockeye salmon tagged near Kalskag with untagged fish by gear type, Kuskokwim River 2002.

Recapture Location		Kalskag Tagging Gear		
		Right Bank Fish Wheel (n=111)	Left Bank Fish Wheel (n=146)	Drift Gillnets (n=6)
George River Weir				
	Untagged Catch	15	15	15
	Recovered Tags	1	1	0
	Ratio [a]	0.0667	0.0667	0.0000
	Chi-square	-	-	-
Tatlawiksuk River Weir				
	Untagged Catch	1	1	1
	Recovered Tags	0	0	0
	Ratio [a]	0.0000	0.0000	0.0000
	Chi-square	-	-	-
Kogrukluk River Weir				
	Untagged Catch	3,908	3,908	3,908
	Recovered Tags	2	3	0
	Ratio [a]	0.0005	0.0008	0.0000
	Chi-square	-	-	-
Takotna River Weir				
	Untagged Catch	1	1	1
	Recovered Tags	0	0	0
	Ratio [a]	0.0000	0.0000	0.0000
	Chi-square	-	-	-
Total				
	Chi-square	-	-	-
	p-value [b]	-	-	-

Note: The Kalskag tagging site was located 270 rkm above the mouth of the Kuskokwim River. Analysis based on recovered tags only. Tags observed but not recovered were not included as tagging gear type was unknown. Dashes represent values that could not be calculated due to data limitations, generally failure to meet minimum expected tag recoveries (*n*=5) required for Chi-square analysis.

[a] Recovered tags divided by untagged catch.
[b] p-value criteria is based on an alpha of 0.05.

Table 37.–Wheel–weir chi-square analysis of complete mixing of sockeye salmon tagged near Kalskag with untagged fish by gear type, Kuskokwim River 2003.

Recapture Location		Kalskag Tagging Gear		
		Right Bank Fish Wheel (n = 569)	Left Bank Fish Wheel (n = 598)	Drift Gillnets (n = 174)
George River Weir				
	Untagged Catch	14	14	14
	Recovered Tags	0	0	0
	Ratio [a]	0.0000	0.0000	0.0000
	Chi-square	-	-	-
Tatlawiksuk River Weir [b]				
	Untagged Catch	-	-	-
	Recovered Tags	-	-	-
	Ratio [a]	-	-	-
	Chi-square	-	-	-
Kogrukluk River Weir				
	Untagged Catch	8,932	8,932	8,932
	Recovered Tags	23	14	7
	Ratio [a]	0.0026	0.0016	0.0008
	Chi-square	-	-	-
Takotna River Weir				
	Untagged Catch	4	4	4
	Recovered Tags	0	0	0
	Ratio [a]	0.0000	0.0000	0.0000
	Chi-square	-	-	-
Total				
	Chi-square	-	-	-
	p-value [c]	-	-	-

Note: The Kalskag tagging site was located 270 rkm above the mouth of the Kuskokwim River. Analysis based on recovered tags only. Tags observed but not recovered were not included as tagging gear type was unknown. Dashes represent values that could not be calculated due to data limitations, generally failure to meet minimum expected tag recoveries (*n*=5) required for Chi-square analysis.

[a] Recovered tags divided by untagged catch.
[b] Tatlawiksuk River weir did not operate due to high water early season.
[c] p-value criteria is based on an alpha of 0.05.

Table 38.–Wheel–weir chi-square analysis of complete mixing of sockeye salmon tagged near Kalskag with untagged fish by gear type, Kuskokwim River 2004.

Recapture Location		Kalskag Tagging Gear		
		Right Bank Fish Wheel (n = 1,170)	Left Bank Fish Wheel (n = 705)	Drift Gillnets (n = 1)
George River Weir				
	Untagged Catch	166	166	166
	Recovered Tags	10	0	0
	Ratio [a]	0.0602	0.0000	0.0000
	Chi-square	-	-	-
Tatlawiksuk River Weir				
	Untagged Catch	7	7	7
	Recovered Tags	0	2	0
	Ratio [a]	0.0000	0.2857	0.0000
	Chi-square	-	-	-
Kogrukluk River Weir				
	Untagged Catch	6,733	6,733	6,733
	Recovered Tags	24	7	0
	Ratio [a]	0.0036	0.0010	0.0000
	Chi-square	-	-	-
Takotna River Weir				
	Untagged Catch	16	16	16
	Recovered Tags	0	1	0
	Ratio [a]	0.0000	0.0625	0.0000
	Chi-square	-	-	-
Total				
	Chi-square	-	-	-
	p-value [b]	-	-	-

Note: The Kalskag tagging site was located 249 rkm above the mouth of the Kuskokwim River. Analysis based on recovered tags only. Tags observed but not recovered were not included as tagging gear type was unknown. Dashes represent values that could not be calculated due to data limitations, generally failure to meet minimum expected tag recoveries (*n*=5) required for Chi-square analysis.

[a] Recovered tags divided by untagged catch.
[b] p-value criteria is based on an alpha of 0.05.

Table 39.–Wheel–weir chi-square analysis of complete mixing of sockeye salmon tagged near Kalskag with untagged fish by gear type, Kuskokwim River 2005.

Recapture Location		Kalskag Tagging Gear		
		Right Bank Fish Wheel (n = 3,267)	Left Bank Fish Wheel (n = 1,234)	Drift Gillnets (n = 116)
George River Weir				
	Untagged Catch	259	259	259
	Recovered Tags	9	2	0
	Ratio [a]	0.0347	0.0077	0.0000
	Chi-square	-	-	-
Tatlawiksuk River Weir				
	Untagged Catch	71	71	71
	Recovered Tags	2	1	0
	Ratio [a]	0.0282	0.0141	0.0000
	Chi-square	-	-	-
Kogrukluk River Weir				
	Untagged Catch	37,250	37,250	37,250
	Recovered Tags	159	34	4
	Ratio [a]	0.0043	0.0009	0.0001
	Chi-square	-	-	-
Takotna River Weir				
	Untagged Catch	33	33	33
	Recovered Tags	1	1	0
	Ratio [a]	0.0303	0.0303	0.0000
	Chi-square	-	-	-
Total				
	Chi-square	-	-	-
	p-value [b]	-	-	-

Note: The Kalskag tagging site was located 270 rkm above the mouth of the Kuskokwim River. Analysis based on recovered tags only. Tags observed but not recovered were not included as tagging gear type was unknown. Dashes represent values that could not be calculated due to data limitations, generally failure to meet minimum expected tag recoveries (*n*=5) required for Chi-square analysis.

[a] Recovered tags divided by untagged catch.
[b] p-value criteria is based on an alpha of 0.05.

Table 40.–Wheel–weir chi-square analysis of complete mixing of sockeye salmon tagged near Kalskag with untagged fish by gear type, Kuskokwim River 2006.

Recapture Location		Kalskag Tagging Gear		
		Right Bank Fish Wheel (n = 2,485)	Left Bank Fish Wheel (n = 1,812)	Drift Gillnets (n = 102)
Salmon River Weir				
	Untagged Catch	4,314	4,314	4,314
	Recovered Tags	4	8	0
	Ratio [a]	0.0009	0.0019	0.0000
	Chi-square	7.0902	0.5645	-
George River Weir				
	Untagged Catch	142	142	142
	Recovered Tags	3	1	0
	Ratio [a]	0.0211	0.0070	0.0000
	Chi-square	-	-	-
Tatlawiksuk RiverWeir				
	Untagged Catch	38	38	38
	Recovered Tags	0	0	0
	Ratio [a]	0.0000	0.0000	0.0000
	Chi-square	-	-	-
Kogrukluk River Weir				
	Untagged Catch	59,392	59,392	59,392
	Recovered Tags	202	146	1
	Ratio [a]	0.0034	0.0025	0.0000
	Chi-square	0.5137	0.0410	-
Takotna River Weir				
	Untagged Catch	53	53	53
	Recovered Tags	1	0	0
	Ratio [a]	0.0189	0.0000	0.0000
	Chi-square	-	-	-
Total				
	Chi-square	7.6039	0.6054	-
	p-value [b]	0.0058	0.4365	-

Note: The Kalskag tagging site was located 270 rkm above the mouth of the Kuskokwim River. Analysis based on recovered tags only. Tags observed but not recovered were not included as tagging gear type was unknown. Dashes represent values that could not be calculated due to data limitations, generally failure to meet minimum expected tag recoveries (n=5) required for Chi-square analysis.

[a] Recovered tags divided by untagged catch.
[b] p-value criteria is based on an alpha of 0.05.

Table 41.–Wheel–wheel chi-square test of temporally consistent probability of recovering Kalskag tagged sockeye salmon at Birch Tree Crossing, Kuskokwim River 2001–2004.

					Chi-square		
Year	Sample Period	Untagged Catch	Recovered Tags	Ratio [a]	X^2	df	p-value [b]
2002	15 Jun–14 Jul	475	1	0.0000	-		
	15 Jul–7 Sept	110	3	0.1667	-		
	Total	585	4	0.0068	-	-	-
2003	14 Jun–3 Jul	611	3	0.0049	4.2418		
	4 Jul–13 Jul	409	6	0.0147	0.0078		
	14 Jul–3 Sept	492	14	0.0285	5.5159		
	Total	1512	23	0.0152	9.7655	2	0.0076

Note: The Kalskag tagging site was located 270 rkm above the mouth of the Kuskokwim River. Analysis based on recovered tags only. Tags observed but not recovered were not included as tagging date was unknown.

[a] Recovered tags divided by untagged catch.
[b] p-value criteria is based on an alpha of 0.05.

Table 42.–Wheel–wheel chi-square analysis of complete mixing of sockeye salmon tagged near Kalskag with untagged fish, Kuskokwim River 2002.

		Kalskag Tagging Gear		
Birch Tree Crossing Recapture Gear		Right Bank Fish Wheel (n = 111)	Left Bank Fish Wheel (n = 146)	Drift Gillnets (n = 6)
Right Bank Fish Wheel				
	Untagged Catch	156	156	156
	Recovered Tags	1	1	0
	Ratio [a]	0.0064	0.0064	0.0000
	Chi-square	-	-	-
Left Bank Fish Wheel				
	Untagged Catch	417	417	417
	Recovered Tags	0	2	0
	Ratio [a]	0.0000	0.0048	0.0000
	Chi-square	-	-	-
Drift Gillnets				
	Untagged Catch	12	12	12
	Recovered Tags	0	0	0
	Ratio [a]	0.0000	0.0000	0.0000
	Chi-square	-	-	-
Total				
	Chi-square	-	-	-
	p-value [b]	-	-	-

Note: The Kalskag tagging site was located 270 rkm above the mouth of the Kuskokwim River. Analysis based on recovered tags only. Tags observed but not recovered were not included as tagging gear type was unknown. Dashes represent values that could not be calculated due to data limitations, generally failure to meet minimum expected tag recoveries (n=5) required for chi-square analysis.

[a] Recovered tags divided by untagged catch.
[b] p-value criteria is based on an alpha of 0.05.

Table 43.–Wheel–wheel chi-square analysis of complete mixing of sockeye salmon tagged near Kalskag with untagged fish, Kuskokwim River 2003.

		Kalskag Tagging Gear		
Birch Tree Crossing Recapture Gear		Right Bank Fish Wheel (n = 569)	Left Bank Fish Wheel (n = 598)	Drift Gillnets (n = 174)
Right Bank Fish Wheel				
	Untagged Catch	294	294	294
	Recovered Tags	1	1	0
	Ratio [a]	0.0034	0.0034	0.0000
	Chi-square	-	-	-
Left Bank Fish Wheel				
	Untagged Catch	649	649	649
	Recovered Tags	3	14	0
	Ratio [a]	0.0046	0.0216	0.0000
	Chi-square	-	5.6130	-
Drift Gillnets				
	Untagged Catch	569	569	569
	Recovered Tags	1	0	3
	Ratio [a]	0.0018	0.0000	0.0053
	Chi-square	-	6.5402	-
Total				
	Chi-square	-	12.1532	-
	p-value [b]	-	0.0005	-

Note: The Kalskag tagging site was located 270 rkm above the mouth of the Kuskokwim River. Analysis based on recovered tags only. Tags observed but not recovered were not included as tagging gear type was unknown. Dashes represent values that could not be calculated due to data limitations, generally failure to meet minimum expected tag recoveries (n=5) required for chi-square analysis.

[a] Recovered tags divided by untagged catch.
[b] p-value criteria is based on an alpha of 0.05.

Table 44.–Sockeye salmon abundance estimates at Kalskag using wheel–wheel and wheel–weir mark–recapture methods, Kuskokwim River 2002–2006.

	Wheel-Wheel Abundance Estimates						Wheel–weir Abundance Estimates		
	Darroch Estimate			Pooled Petersen			Pooled Petersen		
Year	Point Estimate	Lower 95% CI	Upper 95% CI	Point Estimate	Lower 95% CI	Upper 95% CI	Point Estimate	Lower 95% CI	Upper 95% CI
2002	-	-	-	31,151	15,575	77,879	172,215	86,107	344,431
2003	-	-	-	85,887	60,626	128,831	219,282	169,866	287,155
2004	-	-	-	-	-	-	362,957	264,656	508,140
2005	-	-	-	-	-	-	801,008	670,773	951,142
2006	-	-	-	-	-	-	688,495	597,816	782,944

Note: The Kalskag tagging site was located 270 rkm above the mouth of the Kuskokwim River in all years except 2004, in which it was located at rkm 249.

Note: Wheel–weir estimates are based on Kogrukluk River weir recaptures only. Model assumptions could not be tested.

Table 45.–Summary of Chinook salmon captured and anchor tagged at the Kalskag tagging site, Kuskokwim River 2005–2006.

			Tagged		Not Tagged		Total Catch		
Year	Tagging Location	Gear Type	n [a]	% [b]	[a]	% [c]	[a]	% [d]	[e]
2005 [f]	Right Bank # 1	Fish Wheel	166	14	6	3	172	14	1
	Right Bank # 2	Fish Wheel	173	15	7	4	180	15	6
	Left Bank	Fish Wheel	497	42	4	1	501	42	2
	Mid-Channel	Drift Gillnet	337	29	1	0	338	28	2
		Total [g]	1,173	98	18	2	1,191	100	11
2006	Right Bank	Fish Wheel	265	21	7	3	272	21	0
	Left Bank	Fish Wheel	653	51	21	3	674	52	3
	Mid-Channel	Drift Gillnet	354	28	4	1	358	27	1
		Total [g]	1,272	98	32	2	1,304	100	4

Note: The Kalskag tagging site was located 270 rkm above the mouth of the Kuskokwim River in all years except 2004, in which it was located at rkm 249.

[a] Number of fish
[b] Percent of total fish tagged
[c] Percent of total catch by tagging location
[d] Percent of total catch
[e] Recapture of a tagged fish. Not included in total catch.
[f] 2005 was the only year 2 fish wheels were operated on the right bank of the river.
[g] Percentages relate to total catch.

Table 46.–Chinook salmon tag recovery ratios by recovery site and wheel–weir chi-square analysis of equal probability of capture at the Kalskag tagging site, Kuskokwim River 2005–2006.

Target Species	Recovery Location	Distance (rkm) [a]	Sample Size [b]	Total Tagged	Total Untagged	Ratio [c]	Chi-square X^2	df	p-value [d]
2005	BTC Wheels [e, f]	24	ND	ND	ND	-			
	George R. Weir	183	3,845	8	3,837	0.0021	0.8622		
	Tatlawiksuk R. Weir	298	2,861	3	2,858	0.0010	3.3505		
	Kogrukluk R. Weir	440	21,731	71	21,660	0.0033	1.1125		
	Takotna R. Weir	565	506	2	504	0.0040	-		
	Upstream Subtotal [g]		28,943	84	28,859	0.0029	5.3252	2	0.0698
	Tuluksak R. Weir	-134	2,653	3	2,650	0.0011			
	Kwethluk R. Weir [h]	-224	ND	ND		-			
	Downstream Subtotal		2,653	3	2,650	0.0011			
2006	BTC Wheels [e, f]	24	ND	ND		-			
	Salmon R. Weir	134	6,393	36	6,357	0.0057	7.3163		
	George R. Weir	183	4,355	11	4,344	0.0025	1.4096		
	Tatlawiksuk R. Weir	298	1,700	3	1,697	0.0018	1.6015		
	Kogrukluk R. Weir	440	19,184	64	19,120	0.0033	0.3832		
	Takotna R. Weir	565	538	0	538	0.0000	-		
	Upstream Subtotal [g]		32,170	114	32,056	0.0036	10.7106	3	0.0134
	Tuluksak R. Weir	-134	993	1	992	0.0010			
	Kwethluk R. Weir	-224	14,124	2	14,122	0.0001			
	Downstream Subtotal		15,117	3	15,114	0.0002			

Source: Sample size for all escapement weir projects were from the ADF&G CF Kuskokwim Research Master Escapement File, version 2008 (unpublished).

Note: The Kalskag tagging site was located 270 rkm above the mouth of the Kuskokwim River. ND stands for No Data. Dashes represent values that could not be calculated due to data limitations. Chi-square was used to test similarity in recapture ratios of upstream weirs only.

[a] Distance from Kalskag tagging site. Negative numbers indicate a downstream direction.
[b] Number of tagged fish plus untagged fish.
[c] Total number of tag recaptures divided by total number of untagged fish in sample.
[d] p-value criteria is based on an alpha of 0.05.
[e] Located on mainstem Kuskokwim river. Used for wheel-to-wheel estimates.
[f] Birch Tree Crossing did not operate in 2005 or 2006.
[g] The upstream subtotal was used for wheel-to-weir abundance estimation. Excludes Birch Tree Crossing.
[h] Kwethluk River weir did not operate in 2005.

Table 47.–Summary of anchor tagged Chinook salmon recovered at recapture projects by gear type used at the Kalskag tagging site, 2005–2006.

			Tagging Source																
			Recovered Tags [a, b]								Observed Tags [c]								
			Fish Wheel																
			Right Bank		Left Bank		Drift Gillnet		Total Recovered		Fish Wheel		Drift Gillnet		Unknown		Total Observed		Total Tags [d]
Year	Recovery Location	Distance (rkm) [e]	n [f]	% [g]	n [f]	% [g]	n [f]	% [g]	n [f]	% [h]	n [f]	% [i]	n [f]	% [i]	n [f]	% [i]	n [f]	% [h]	n [f]
2005	BTC Wheels [j]	24	ND	-	ND	-	ND	-	ND	-	ND	-	ND	-	ND	-	ND	-	ND
	George R. Weir	183	3	60	1	20	1	20	5	63	2	67	0	0	1	33	3	38	8
	Tatlawiksuk R. Weir	298	2	67	1	33	0	0	3	100	0	-	0	-	0	-	0	0	3
	Kogrukluk R. Weir	440	12	19	34	55	16	26	62	87	5	56	0	0	4	44	9	13	71
	Takotna R. Weir	565	1	50	1	50	0	0	2	100	0	-	0	-	0	-	0	-	2
	Upstream Subtotal		18	25	37	51	17	24	72	86	7	58	0	0	5	42	12	14	84
	Tuluksak R. Weir	-134	0	-	0	-	0	-	0	0	3	100	0	0	0	0	3	100	3
	Kwethluk R. Weir [k]	-224	ND	-	ND	-	ND	-	ND	-	ND	-	ND	-	ND	-	ND	-	ND
	Downstream Subtotal		0	-	0	-	0	-	0	0	3	100	0	0	0	0	3	100	3
	Total		18	25	37	51	17	24	72	83	10	67	0	0	5	33	15	17	87
2006	BTC Wheels [j]	24	ND	-	ND	-	ND	-	ND	-	ND	-	ND	-	ND	-	ND	-	ND
	Salmon R. Weir [k]	134	5	16	21	66	6	19	32	89	1	25	0	0	3	75	4	11	36
	George R. Weir	183	4	67	1	17	1	17	6	55	0	0	1	20	4	80	5	45	11
	Tatlawiksuk R. Weir	298	0	0	0	0	3	100	3	100	0	-	0	-	0	-	0	-	3
	Kogrukluk R. Weir	440	9	23	27	68	4	10	40	63	3	13	2	8	19	79	24	38	64
	Takotna R. Weir	565	0	-	0	-	0	-	0	-	0	-	0	-	0	-	0	-	0
	Upstream Subtotal		18	22	49	60	14	17	81	71	4	12	3	9	26	79	33	29	114
	Tuluksak R. Weir	-134	0	-	0	-	0	-	0	-	0	0	0	0	1	100	1	100	1
	Kwethluk R. Weir	-224	1	100	0	0	0	0	1	-	1	100	0	0	0	0	1	50	2
	Downstream Subtotal		1	100	0	0	0	0	1	33	1	50	0	0	1	50	2	67	3
	Total		19	23	49	60	14	17	82	70	5	14	3	9	27	77	35	30	117

Note: The Kalskag tagging site was located 270 rkm above the mouth of the Kuskokwim River. ND stands for No Data. Dashes represent values that could not be calculated due to data limitations.

[a] Tagged fish that were successfully captured, tag number and date were recorded, and tag number was matched with tag deployment data.
[b] Data from recovered tags were used for calculating stock-specific run timing and migration speed.
[c] Tagged fish that were not successfully captured, tag number and date were not recorded, or tag number was not matched with tag deployment data.
[d] Total number of tag recaptures (i.e. recovered plus observed) were used for abundance estimation.
[e] Distance (rkm) from the Kalskag tagging site. Negative numbers indicate a downstream direction.
[f] Number of fish.
[g] Percent of total recovered tags by recapture location.
[h] Percent of total tags by recapture location.
[i] Percent of total observed tags by recapture location.
[j] Birch Tree Crossing wheels did not operate in 2005.
[k] Kwethluk River weir did not operate in 2005.

Table 48.–Run timing for sockeye salmon tagged near Kalskag and recovered in upriver tributaries of the Kuskokwim River, 2005–2006.

Year	Recovery Location	Distance (rkm) [a]	Total Recovered Tags	Sample Size	Tagging Date [b]		Recovery Date [c]		Escapement Date [d]	
					Median	Range	Median	Range	Median	Range
2005	BTC Wheels [e, f]	24	ND	ND	-	-	-	-	-	-
	George R. Weir	183	5	3,845	21 Jun	21 Jun - 23 Aug	3 Jul	29 Jun - 30 Aug	4 Jul	15 Jun - 17 Sep
	Tatlawiksuk R. Weir	298	3	2,861	10 Jun	4 Jun - 13 Jun	3 Jul	27 Jun - 5 Jul	7 Jul	12 Jun - 27 Aug
	Kogrukluk R. Weir	440	62	21,731	19 Jun	6 Jun - 3 Sep	14 Jul	2 Jul - 13 Sep	13 Jul	22 Jun - 15 Sep
	Takotna R. Weir	565	2	506	11 Jun	5 Jun - 18 Jun	12 Jul	8 Jul - 16 Jul	12 Jul	15 Jun - 13 Sep
2006	BTC Wheels [e, f]	24	ND	ND	-	-	-	-	-	-
	Salmon R. Weir	134	32	6,393	26 Jun	18 Jun - 25 Jul	17 Jul	6 Jul - 8 Aug	18 Jul	23 Jun - 8 Aug
	George R. Weir	183	6	4,355	6 Jul	24 Jun - 3 Aug	17 Jul	11 Jul - 10 Aug	7 Jul	16 Jun - 10 Sep
	Tatlawiksuk R. Weir	298	3	1,700	29 Jun	16 Jun - 5 Jul	12 Jul	4 Jul - 15 Jul	10 Jul	25 Jun - 10 Aug
	Kogrukluk R. Weir	440	40	19,184	1 Jul	20 Jun - 14 Aug	22 Jul	8 Jul - 27 Aug	16 Jul	29 Jun - 13 Sep
	Takotna R. Weir	565	0	538	-	-	-	-	18 Jul	20 Jun - 31 Aug

Note: The Kalskag tagging site was located 270 rkm above the mouth of the Kuskokwim River. ND stands for No Data. Dashes represent values that could not be calculated due to data limitations. Summary based on recovered tags only. Tags observed but not recovered were not included as tagging date was unknown.

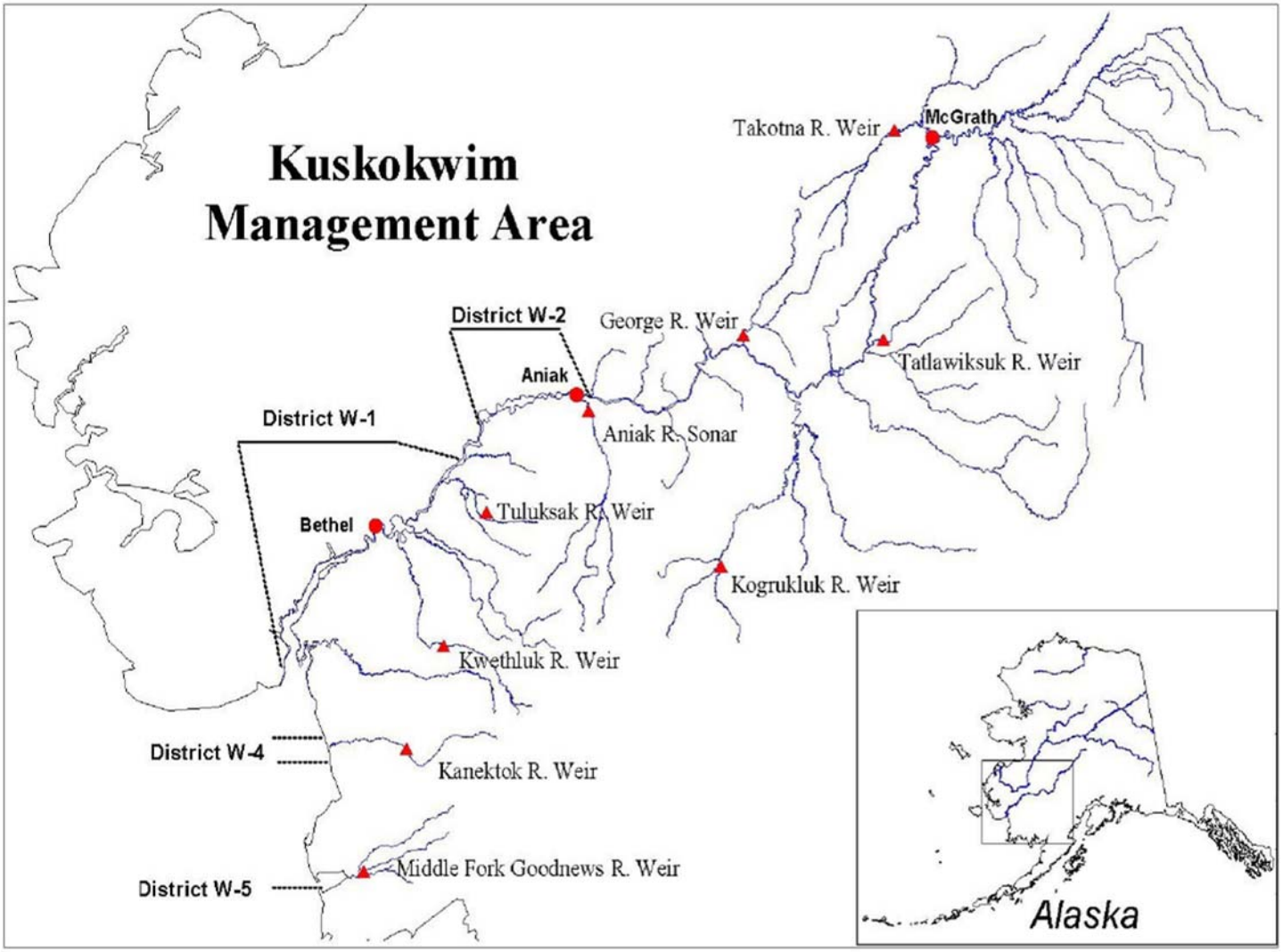
[a] Distance from Kalskag tagging site.
[b] Date past the Kalskag tagging site.
[c] Date past the recovery location.
[d] Date of catch at Birch Tree Crossing or observed escapement past weirs. Inclusive of tagged and untagged fish.
[e] Located on the mainstem Kuskokwim River. Dates represent mixed stocks.
[f] Birch Tree Crossing wheels did not operate in 2005 or 2006.

Table 49.–Migration rates for coho salmon tagged near Kalskag and recovered in upriver tributaries of the Kuskokwim River, 2001–2005.

Year	Recovery Location	Distance (rkm) [a]	Total Recovered Tags	Migration Time (days) [b]				Migration Rate (rkm/day) [c]			
				Mean	Range		SE	Mean	Range		SE
2005	BTC Wheels [d, e]	24	ND	-		-	-	-		-	-
	George River	183	5	8	6	- 12	1.03	23	15	- 31	2.58
	Tatlawiksuk River	298	3	23	17	- 31	4.26	14	10	- 18	2.33
	Kogrukluk River	440	62	23	10	- 43	0.89	21	10	- 44	0.92
	Takotna River	565	2	31	20	- 41	10.50	21	14	- 28	7.23
2006	BTC Wheels [d, e]	24	ND	-		-	-	-		-	-
	Salmon River [f]		32	22	10	- 43	1.28	7	3	- 13	0.39
	George River	183	6	11	7	- 17	1.56	19	11	- 26	2.44
	Tatlawiksuk River	298	3	14	10	- 18	2.33	23	17	- 30	3.82
	Kogrukluk River	440	40	20	12	- 48	1.32	25	9	- 37	1.28
	Takotna River	565	0	-		-	-	-		-	-

Note: The Kalskag tagging site was located 270 rkm above the mouth of the Kuskokwim River. ND stands for No Data. Dashes represent values that could not be calculated due to data limitations. Summary based on recovered tags only. Tags observed but not recovered were not included as tagging date was unknown.

[a] Distance from Kalskag tagging site.
[b] Number of days between time of tagging at Kalskag and recovery at recapture location.
[c] Upstream distance traveled per day (rounded to the nearest whole rkm).
[d] Located on the mainstem Kuskokwim River. Data represent mixed stocks.
[e] Birch Tree Crossing was not operated in 2005 or 2006.
[f] Salmon River weir (Aniak Drainage) was only operated in 2006 for additional model diagnostics capabilities.



Note: Commercial harvest in District W-2 is negligible. Kuskokwim Bay harvest areas and escapement monitoring locations are shown for reference.

Figure 1.–Map of Kuskokwim River Alaska, showing the distribution of commercial harvest areas, population centers, tagging site, and recapture weirs.

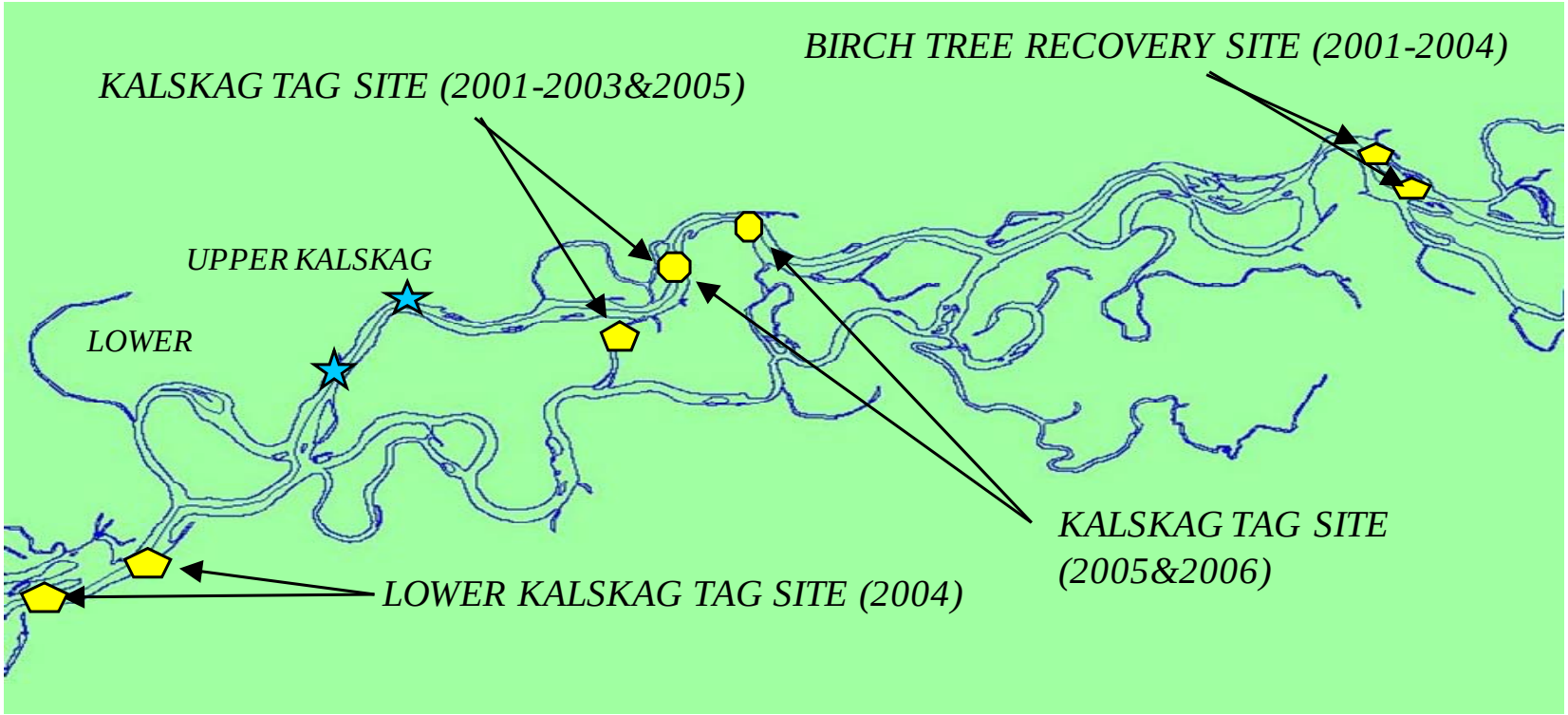
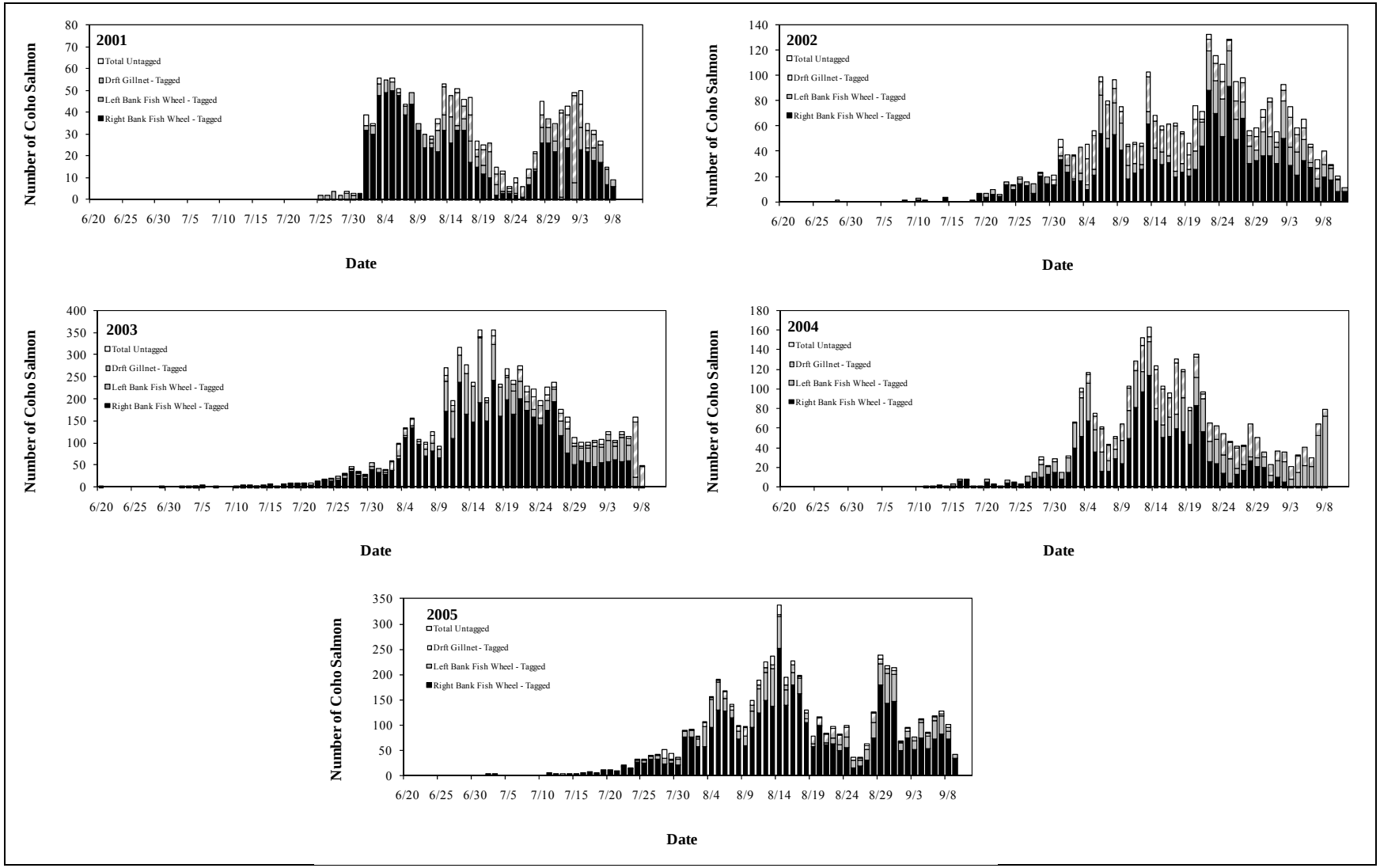
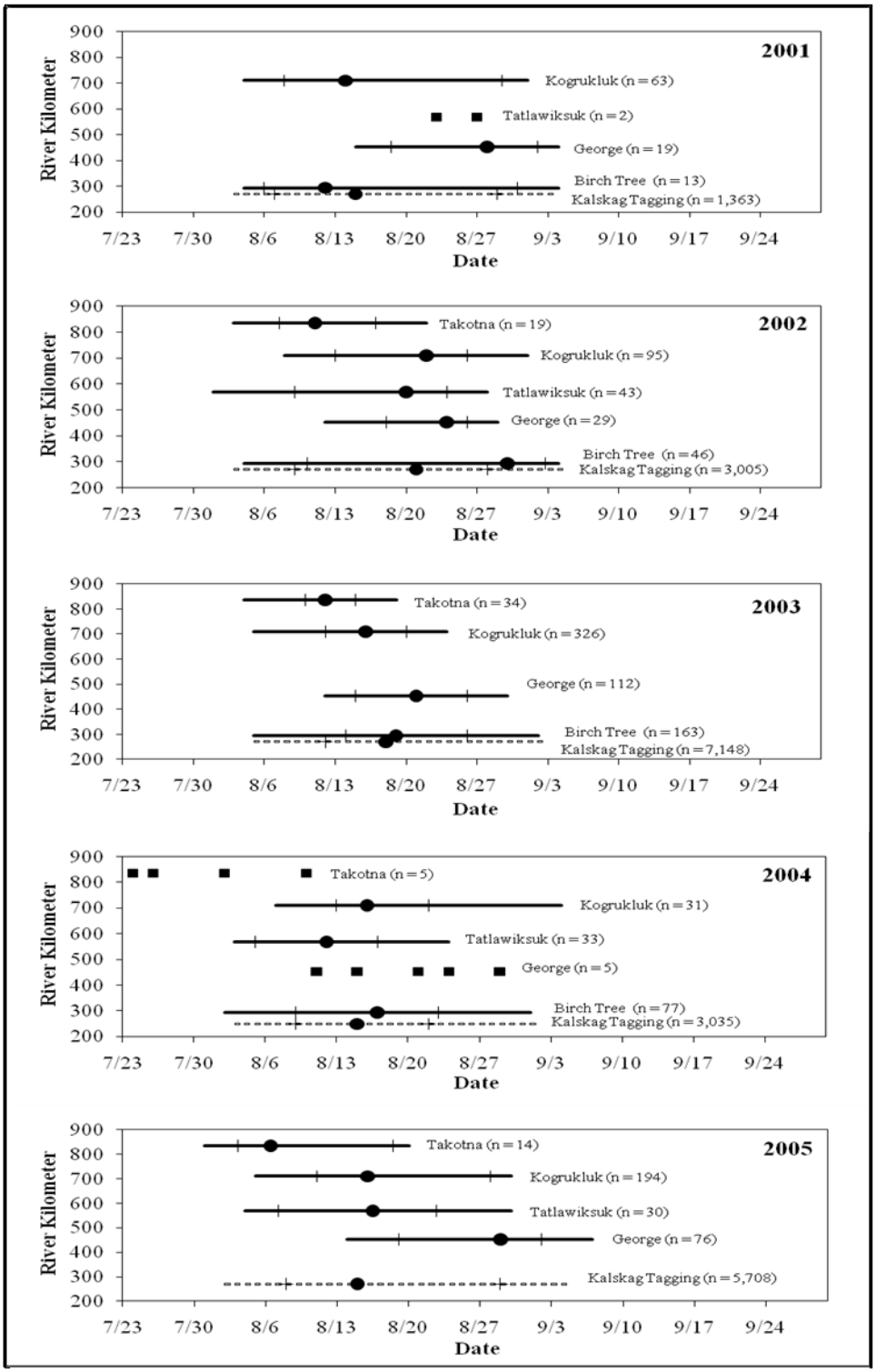


Figure 2.–Map of mainstem Kuskokwim River tagging and recovery site locations, 2001–2006.



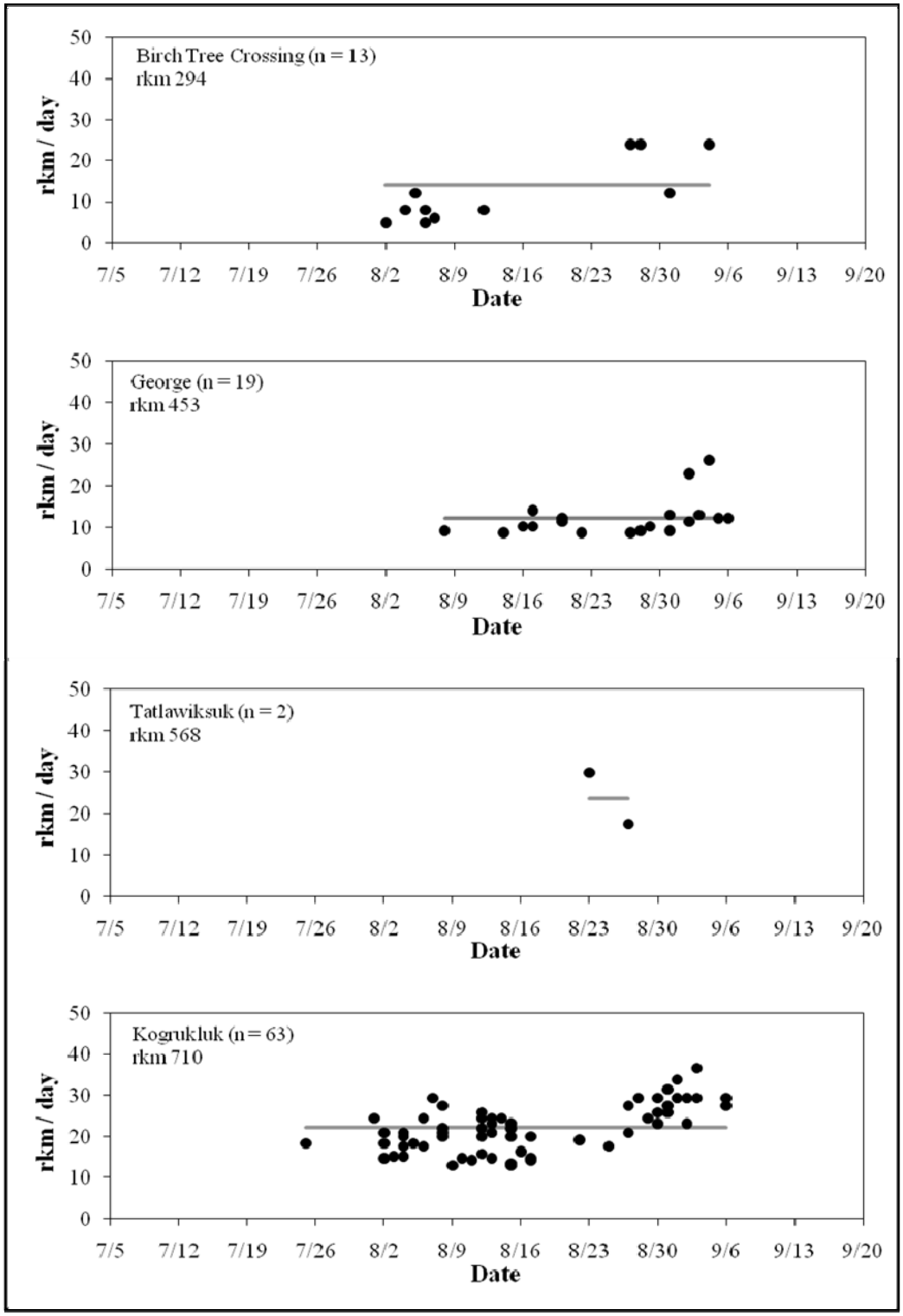
Note: The Kalskag tagging site was located 270 rkm above the mouth of the Kuskokwim River in all years except 2004, in which it was located at rkm 249.

Figure 3.–Summary of coho salmon captured and anchor tagged at the Kalskag tagging site, Kuskokwim River 2001–2005.



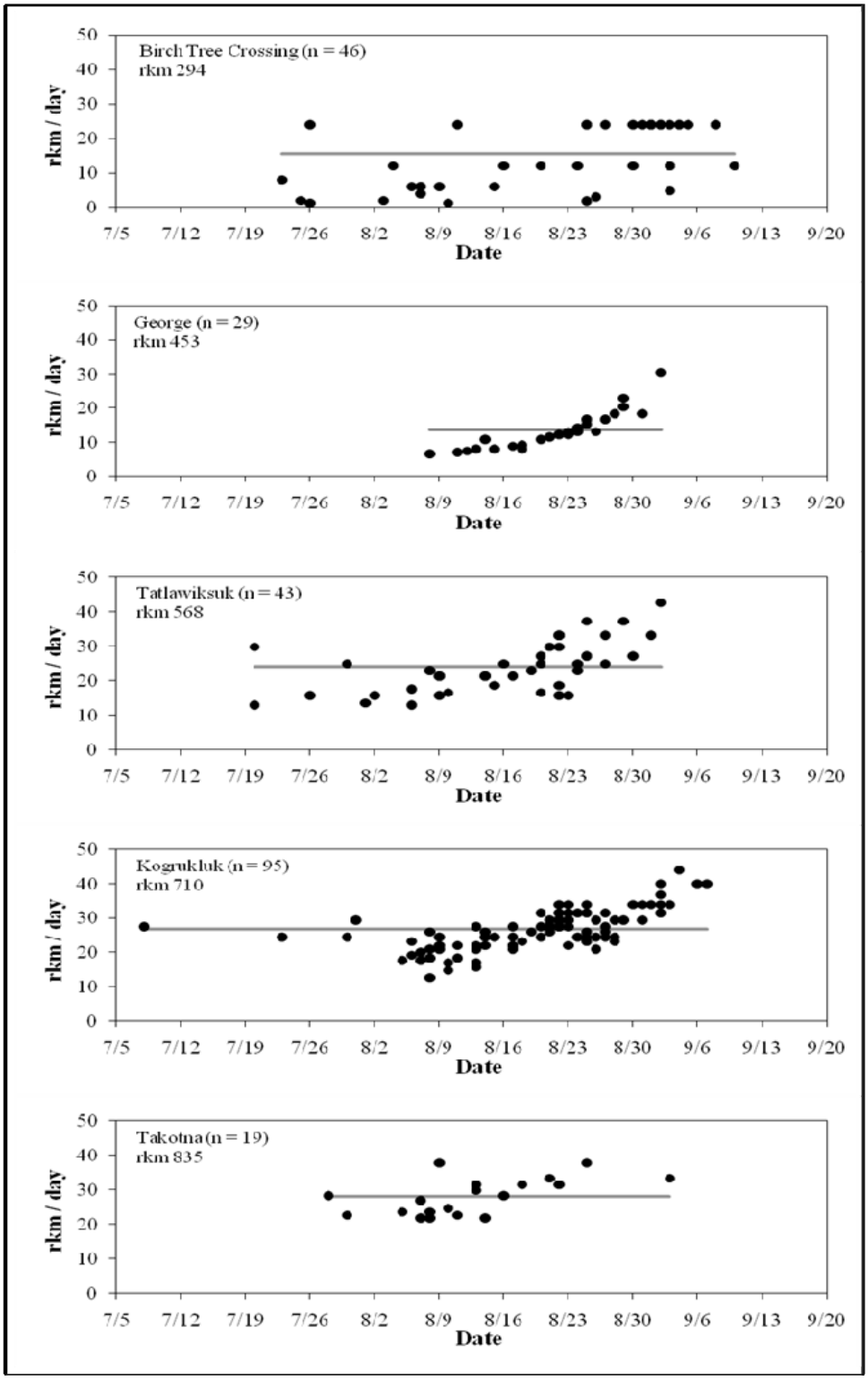
Note: Vertical lines represent the central 50% with the horizontal line representing the central 80% passage. The Kalskag tagging site was located 270 rkm above the mouth of the Kuskokwim River in all years except 2004 in which it was at rkm 249. Tatlawiskuk River weir did not operate in 2003 due to high water early season. Birch Tree Crossing wheels did not operate in 2005.

Figure 4.–Run timing for coho salmon tagged near Kalskag and recaptured in upriver tributaries of the Kuskokwim River, 2001–2005.



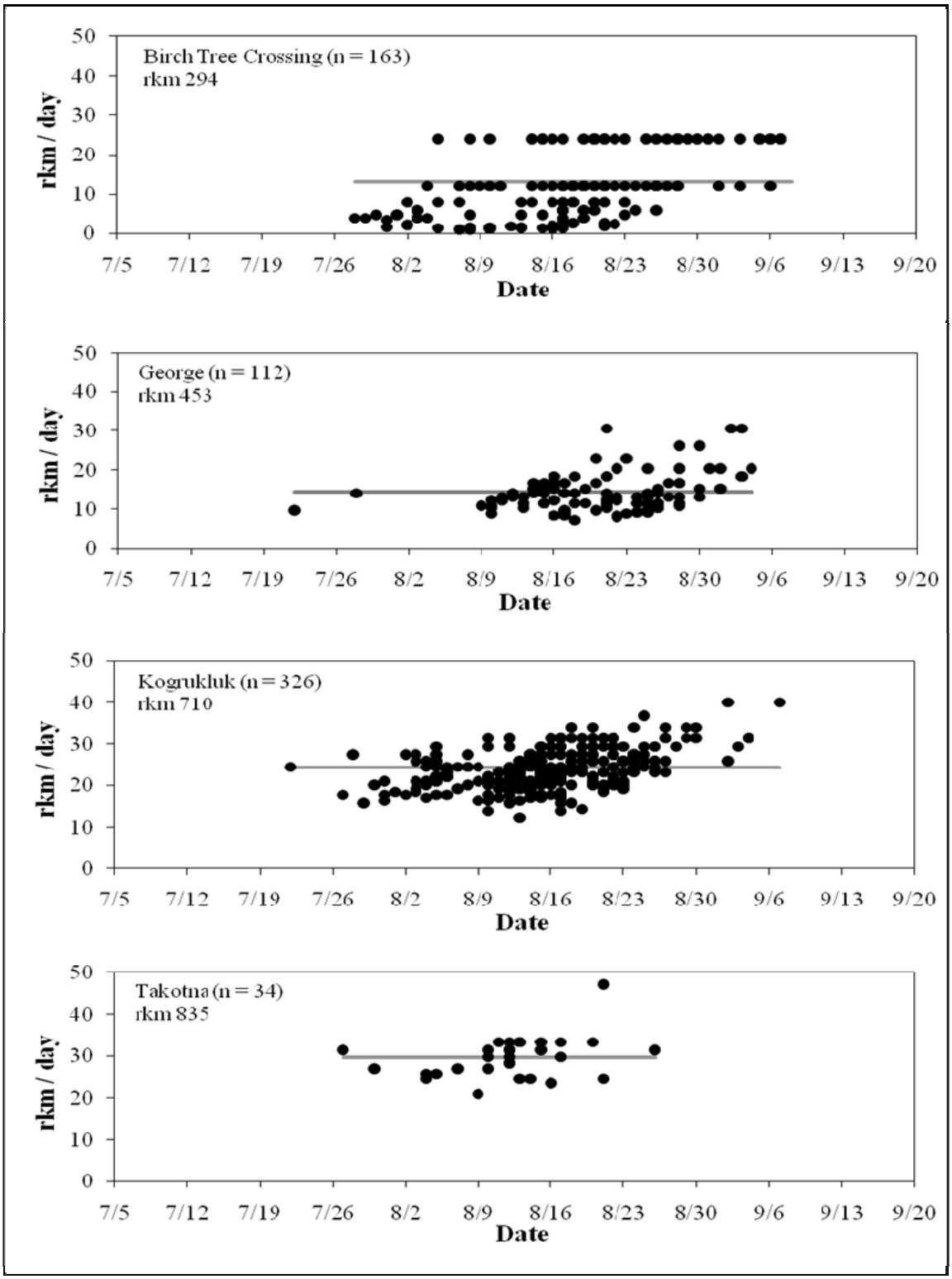
Note: Points represent individual tagged fish, where the horizontal line represents the mean migration rate. The Kalskag tagging site was located 270 rkm above the mouth of the Kuskokwim River. River kilometer (rkm). No tagged coho salmon were recovered at Takotna River weir in 2001.

Figure 5.–Migration rates for coho salmon tagged near Kalskag and recovered in upriver tributaries of the Kuskokwim River, 2001.



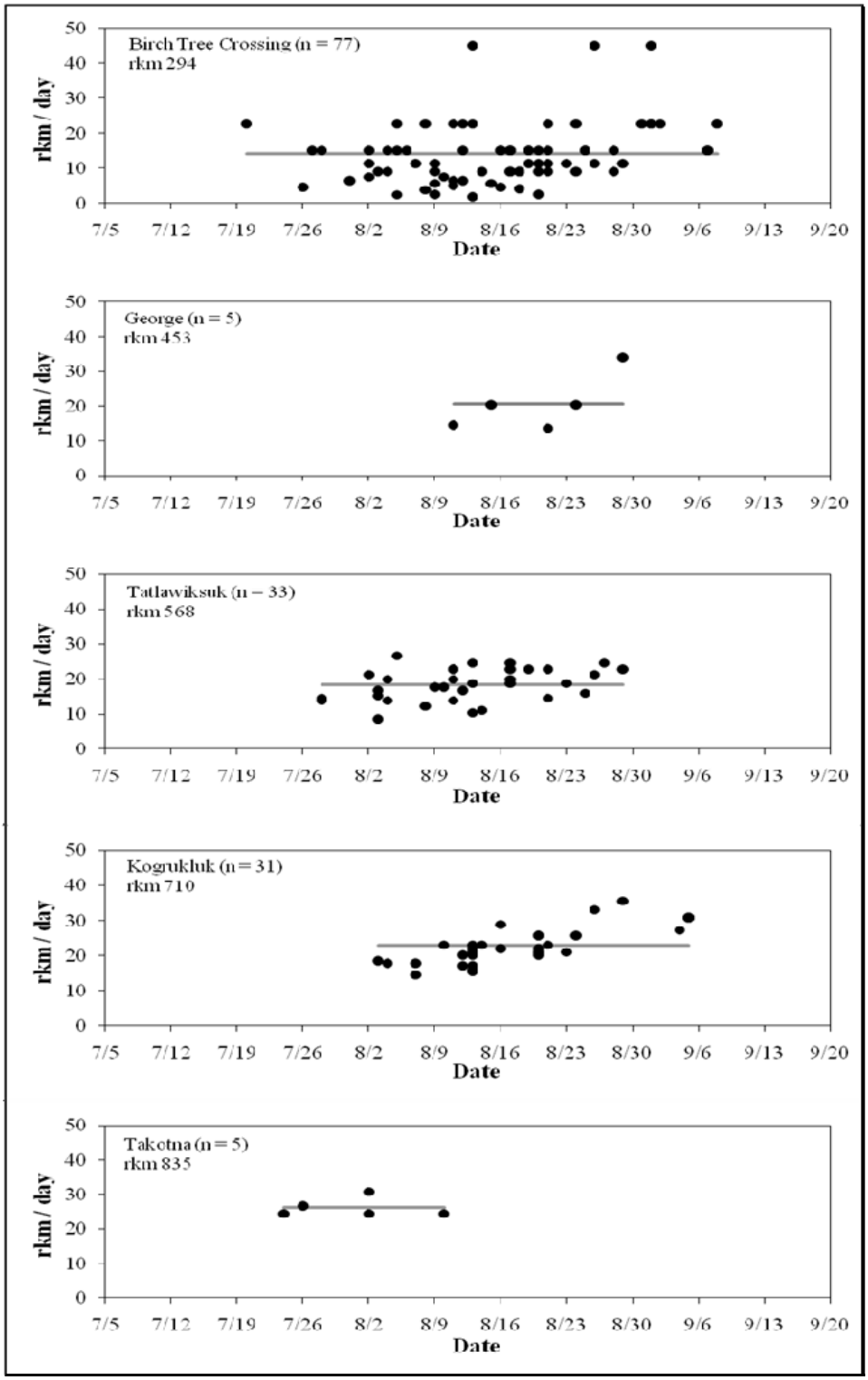
Note: Points represent individual tagged fish, where the horizontal line represents the mean migration rate. The Kalskag tagging site was located 270 rkm above the mouth of the Kuskokwim River. River kilometer (rkm).

Figure 6.–Migration rates for coho salmon tagged near Kalskag and recovered in upriver tributaries of the Kuskokwim River, 2002.



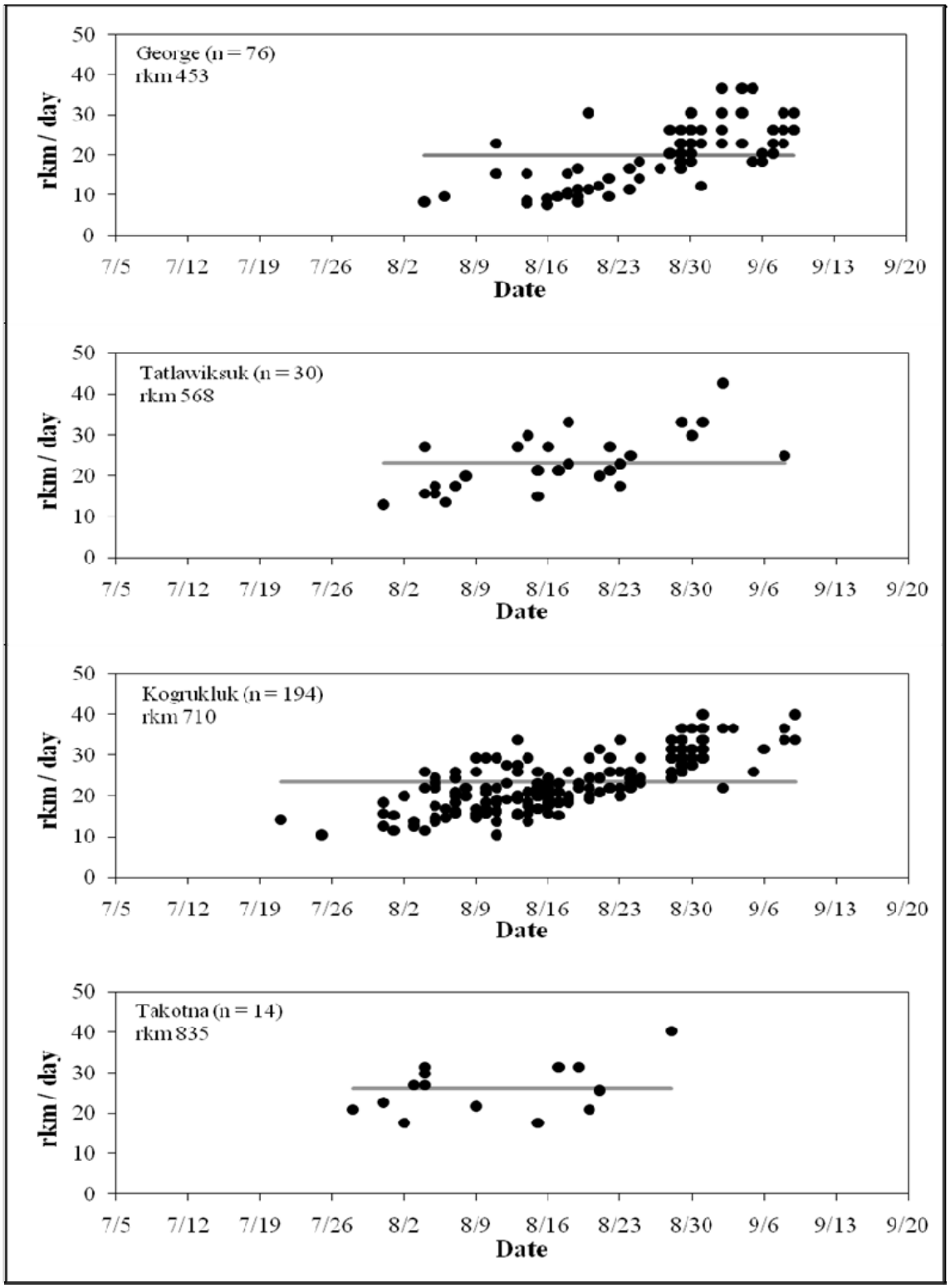
Note: Points represent individual tagged fish, where the horizontal line represents the mean migration rate. The Kalskag tagging site was located 270 rkm above the mouth of the Kuskokwim River. River kilometer (rkm). Tatlawiksuk Weir did not operate in 2003 due to high water early season.

Figure 7.–Migration rates for coho salmon tagged near Kalskag and recovered in upriver tributaries of the Kuskokwim River, 2003.



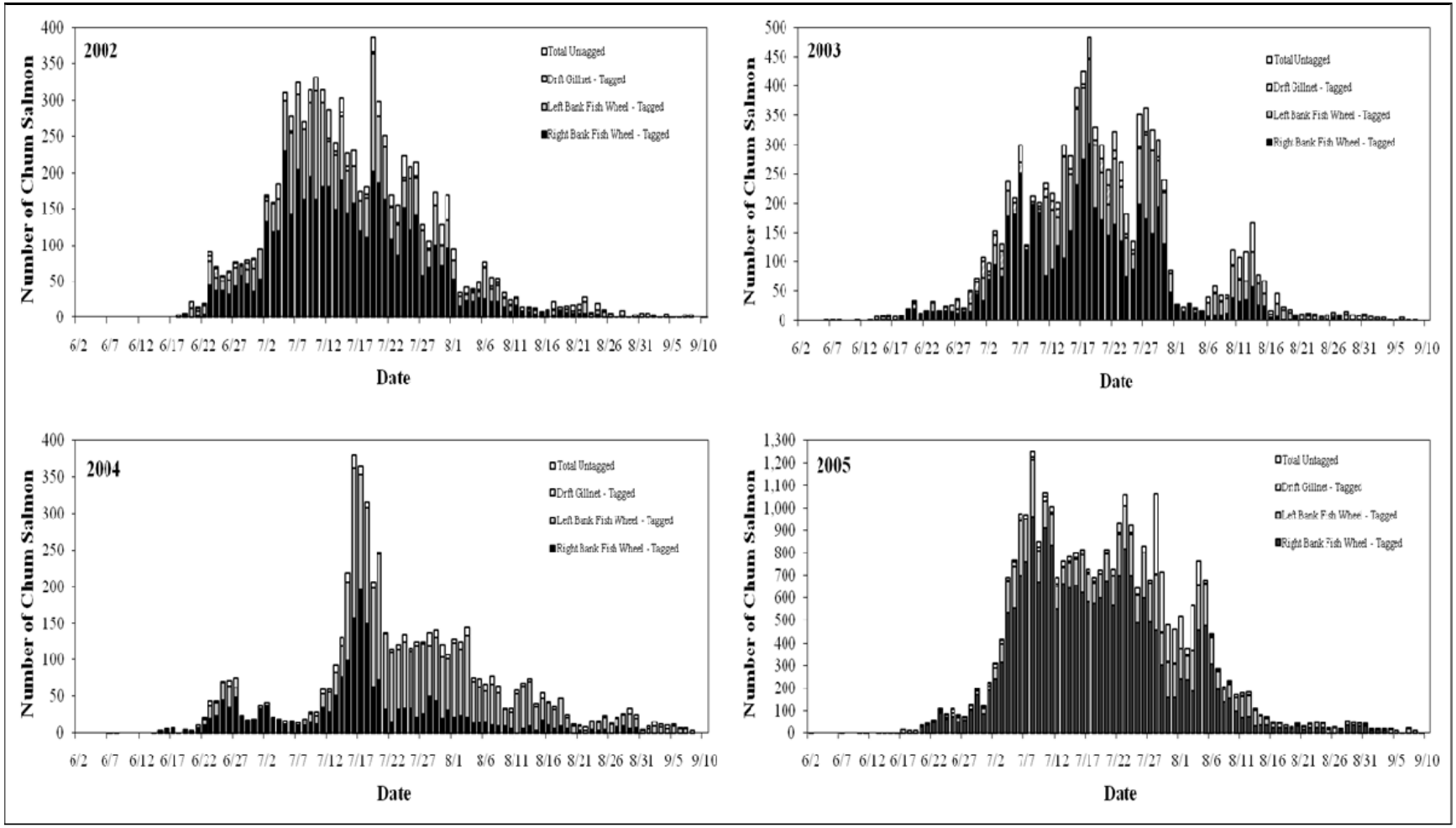
Note: Points represent individual tagged fish, where the horizontal line represents the mean migration rate. The Kalskag tagging site was located 249 rkm above the mouth of the Kuskokwim River. River kilometer (rkm).

Figure 8.–Migration rates for coho salmon tagged near Kalskag and recovered in upriver tributaries of the Kuskokwim River, 2004.



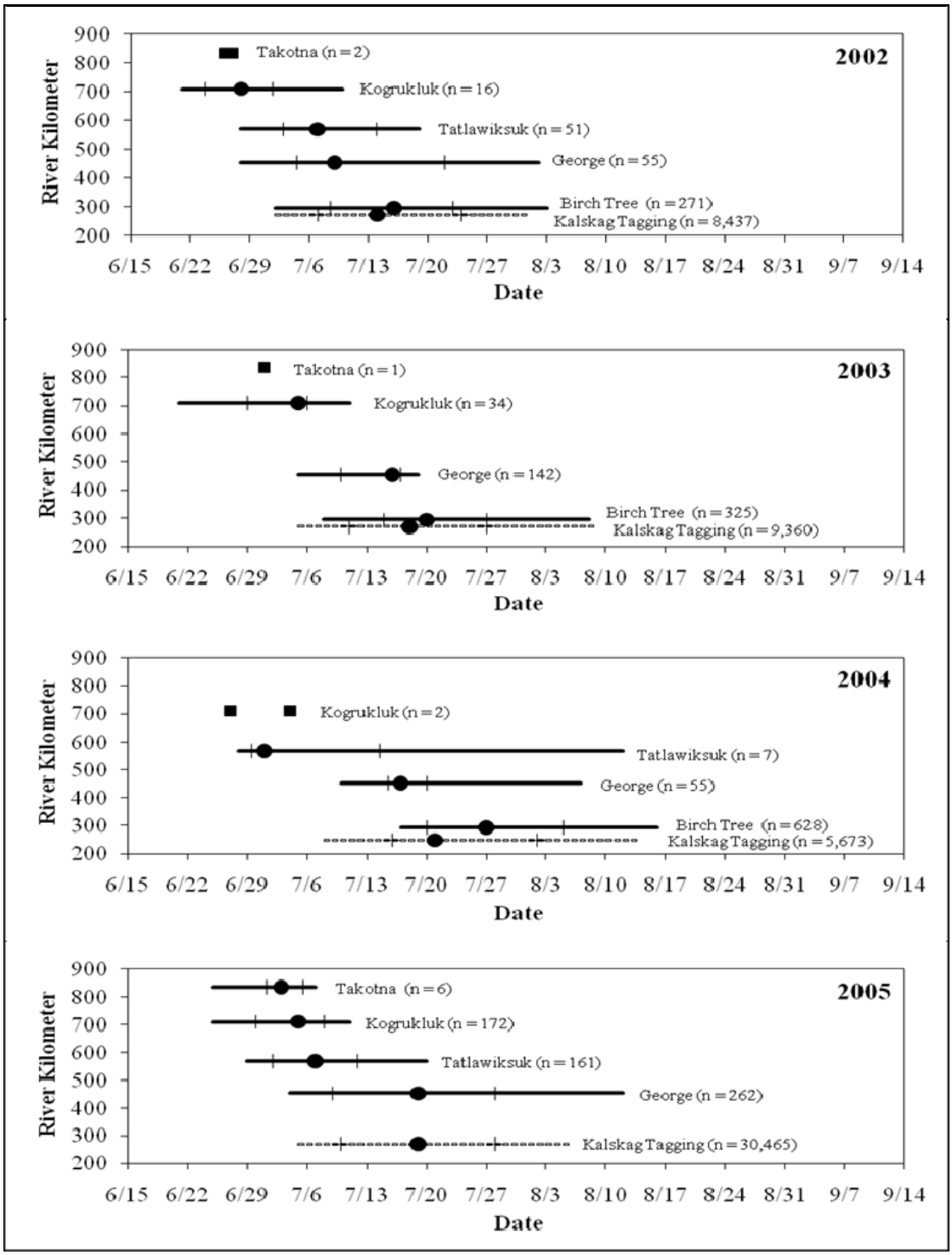
Note: Points represent individual tagged fish, where the horizontal line represents the mean migration rate. The Kalskag tagging site was located 249 rkm above the mouth of the Kuskokwim River. River kilometer (rkm). Birch Tree Crossing Wheels were not operated in 2005.

Figure 9.–Migration rates for coho salmon tagged near Kalskag and recovered in upriver tributaries of the Kuskokwim River, 2005.



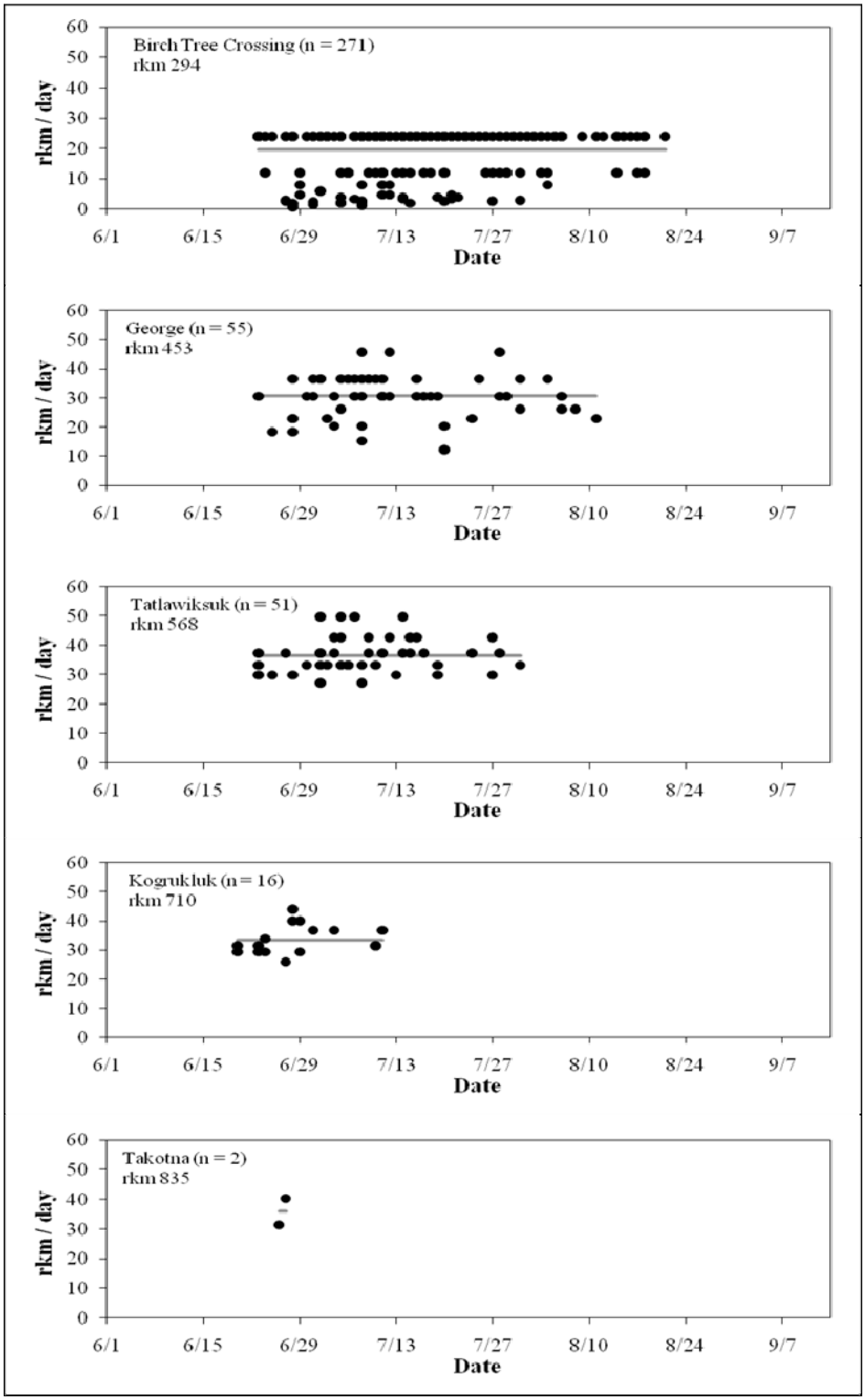
Note: The Kalskag tagging site was located 270 rkm above the mouth of the Kuskokwim River in all years except 2004, in which it was located at rkm 249.

Figure 10.–Summary of chum salmon captured and anchor tagged at the Kalskag tagging site, Kuskokwim River 2002–2005.



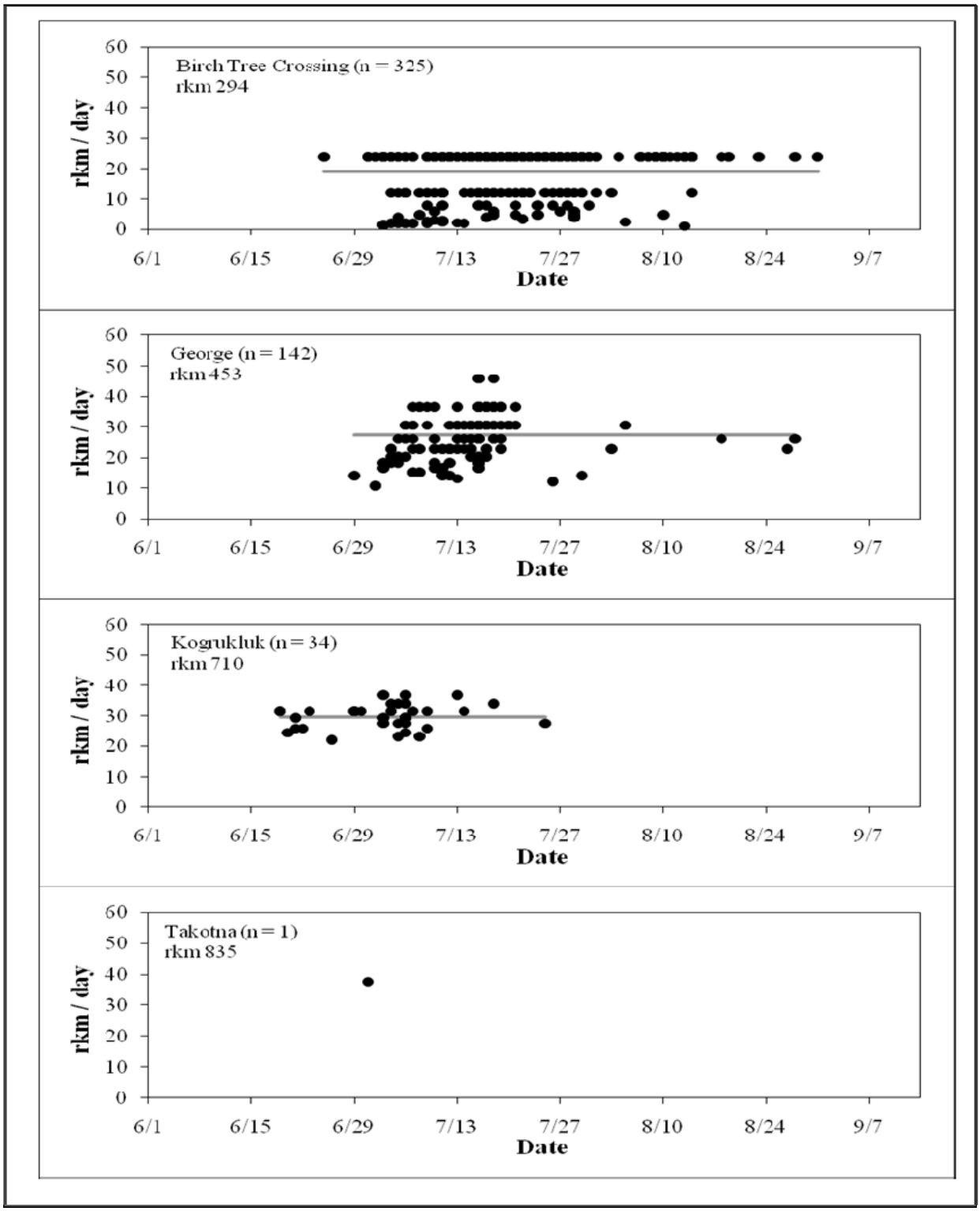
Note: Vertical lines represent the central 50% with the horizontal line representing the central 80% passage. The Kalskag tagging site was located 270 rkm above the mouth of the Kuskokwim River in all years except 2004 in which it was at rkm 249. Tatlawiskuk River weir did not operate in 2003 due to high water early season. Birch Tree Crossing wheels did not operate in 2005. No tagged chum salmon were recovered at Takotna River in 2004.

Figure 11.–Run timing for chum salmon tagged near Kalskag and recaptured in upriver tributaries of the Kuskokwim River, 2001–2005.



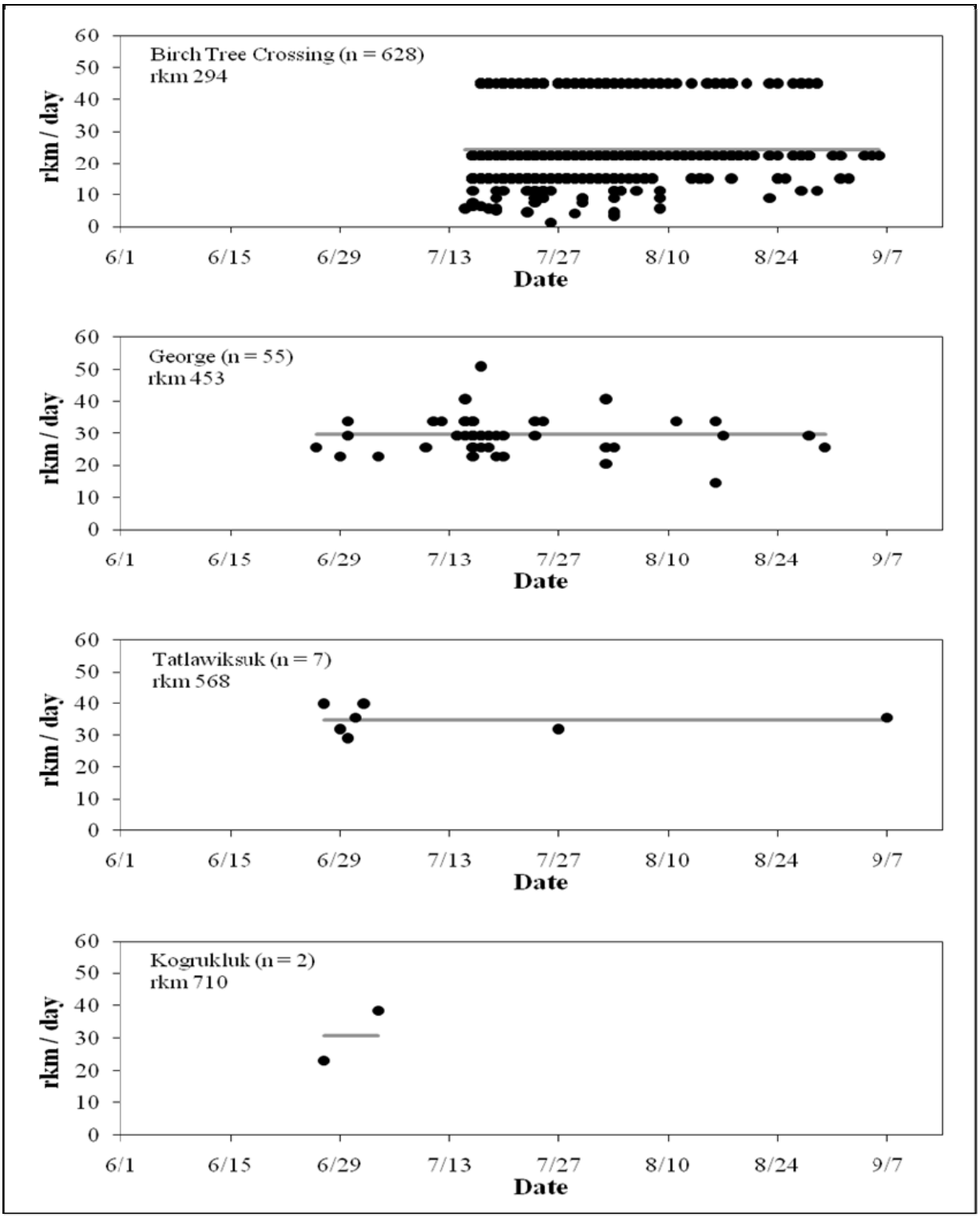
Note: Points represent individual tagged fish, where the horizontal line represents the mean migration rate. The Kalskag tagging site was located 270 rkm above the mouth of the Kuskokwim River. River kilometer (rkm).

Figure 12.–Migration rates for chum salmon tagged near Kalskag and recovered in upriver tributaries of the Kuskokwim River, 2002.



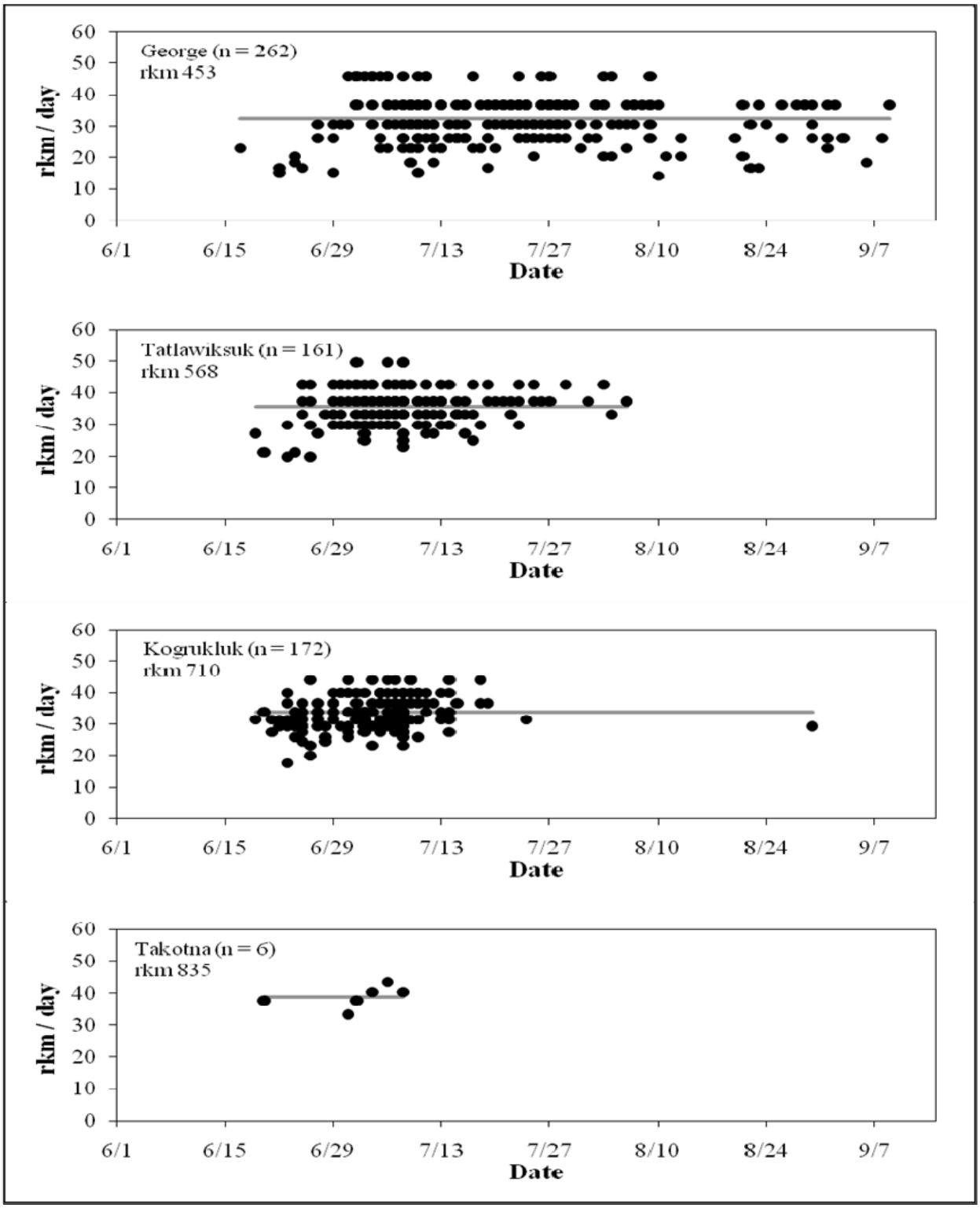
Note: Points represent individual tagged fish, where the horizontal line represents the mean migration rate. The Kalskag tagging site was located 270 rkm above the mouth of the Kuskokwim River. River kilometer (rkm). Tatlawiksuk River weir did not operate in 2003 due to high water early season.

Figure 13.–Migration rates for chum salmon tagged near Kalskag and recovered in upriver tributaries of the Kuskokwim River, 2003.



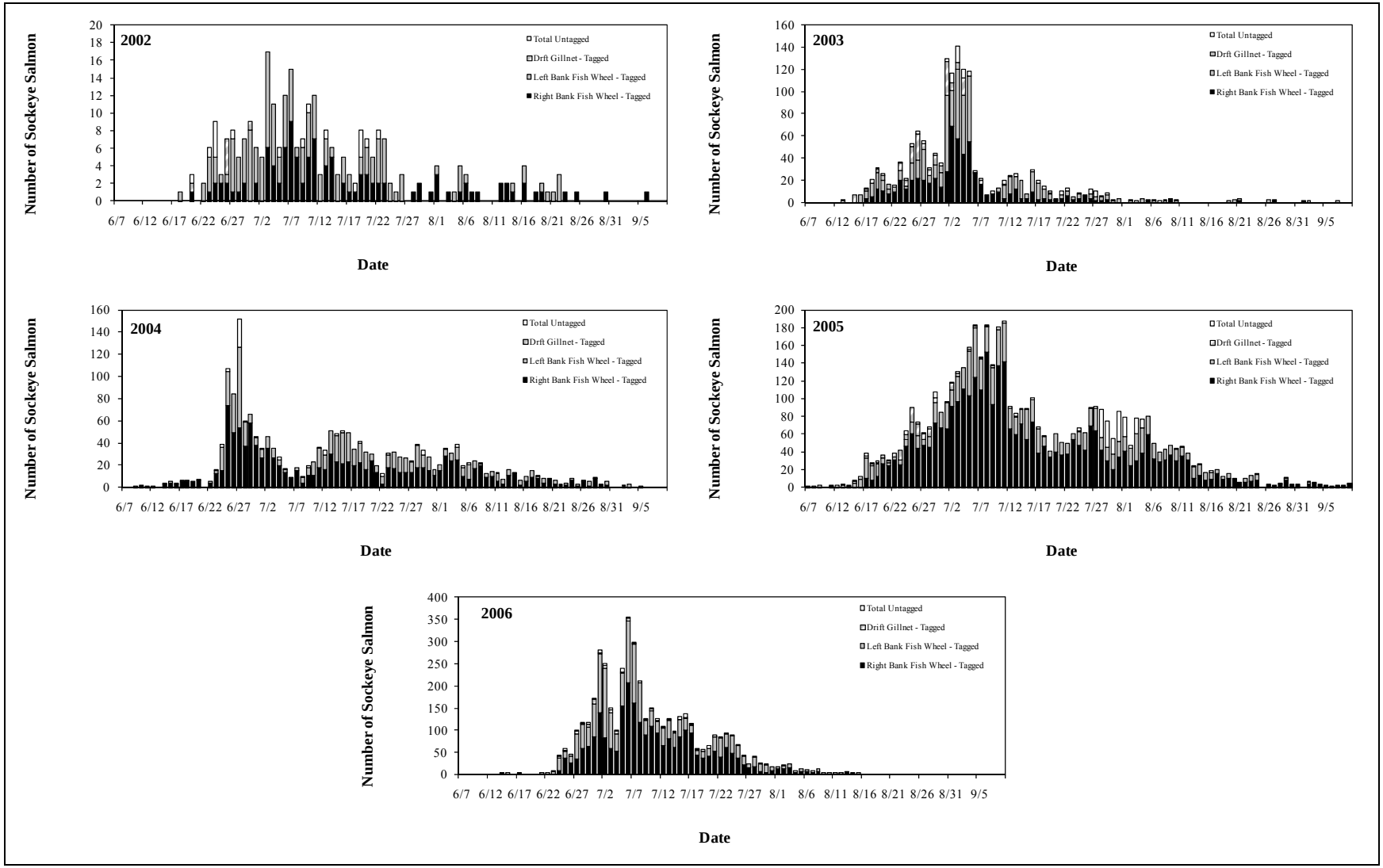
Note: Points represent individual tagged fish, where the horizontal line represents the mean migration rate. The Kalskag tagging site was located 249 rkm above the mouth of the Kuskokwim River. No tagged chum salmon were recovered at Takotna River weir in 2004.

Figure 14.–Migration rates for chum salmon tagged near Kalskag and recovered in upriver tributaries of the Kuskokwim River, 2004.



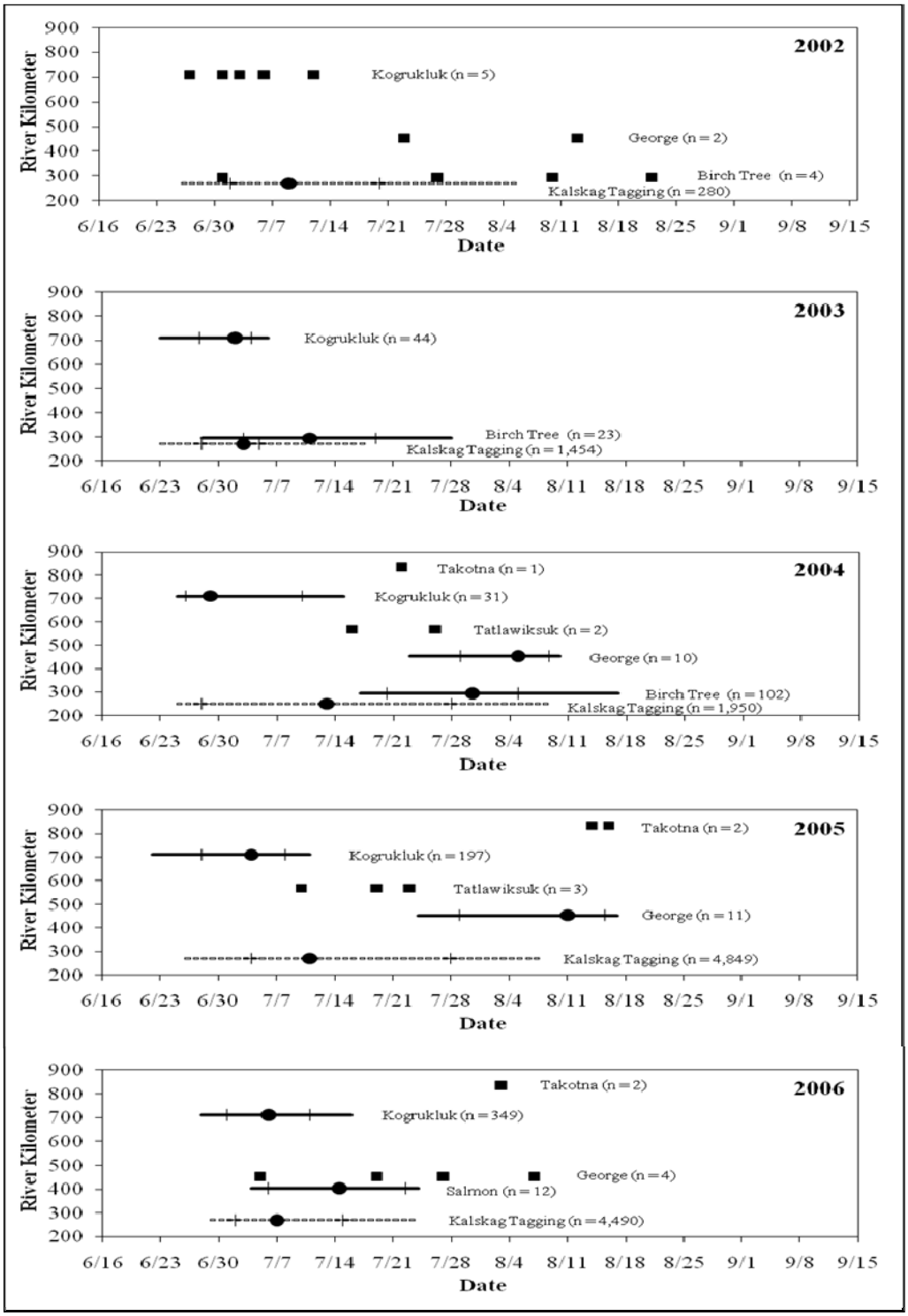
Note: Points represent individual tagged fish, where the horizontal line represents the mean migration rate. The Kalskag tagging site was located 270 rkm above the mouth of the Kuskokwim River. River kilometer (rkm). Birch Tree Crossing Wheels did not operate in 2005.

Figure 15.–Migration rates for chum salmon tagged near Kalskag and recovered in upriver tributaries of the Kuskokwim River, 2005.



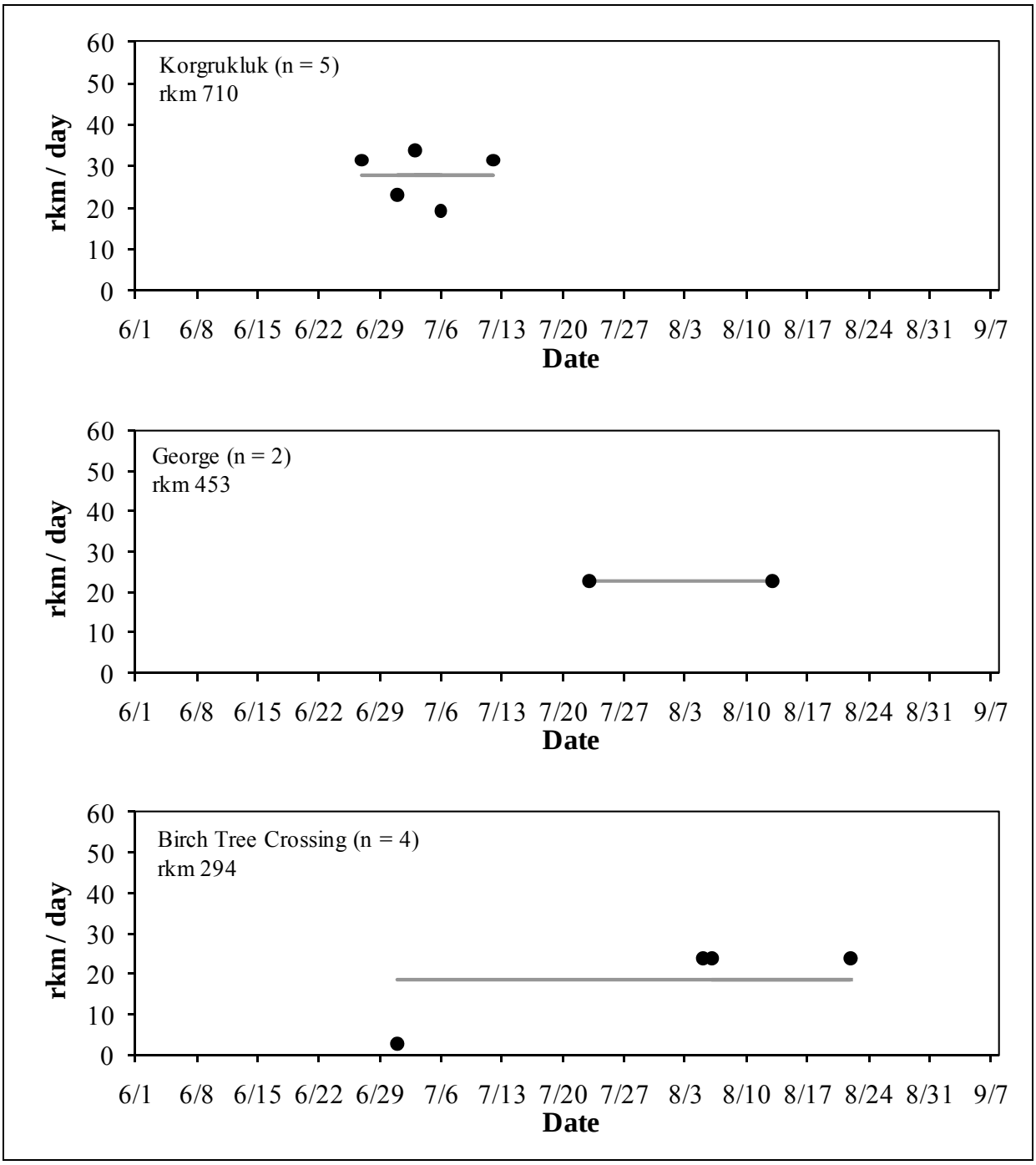
Note: The Kalskag tagging site was located 270 rkm above the mouth of the Kuskokwim River in all years except 2004, in which it was located at rkm 249.

Figure 16.–Summary of sockeye salmon captured and anchor tagged at the Kalskag tagging site, Kuskokwim River 2002–2006.



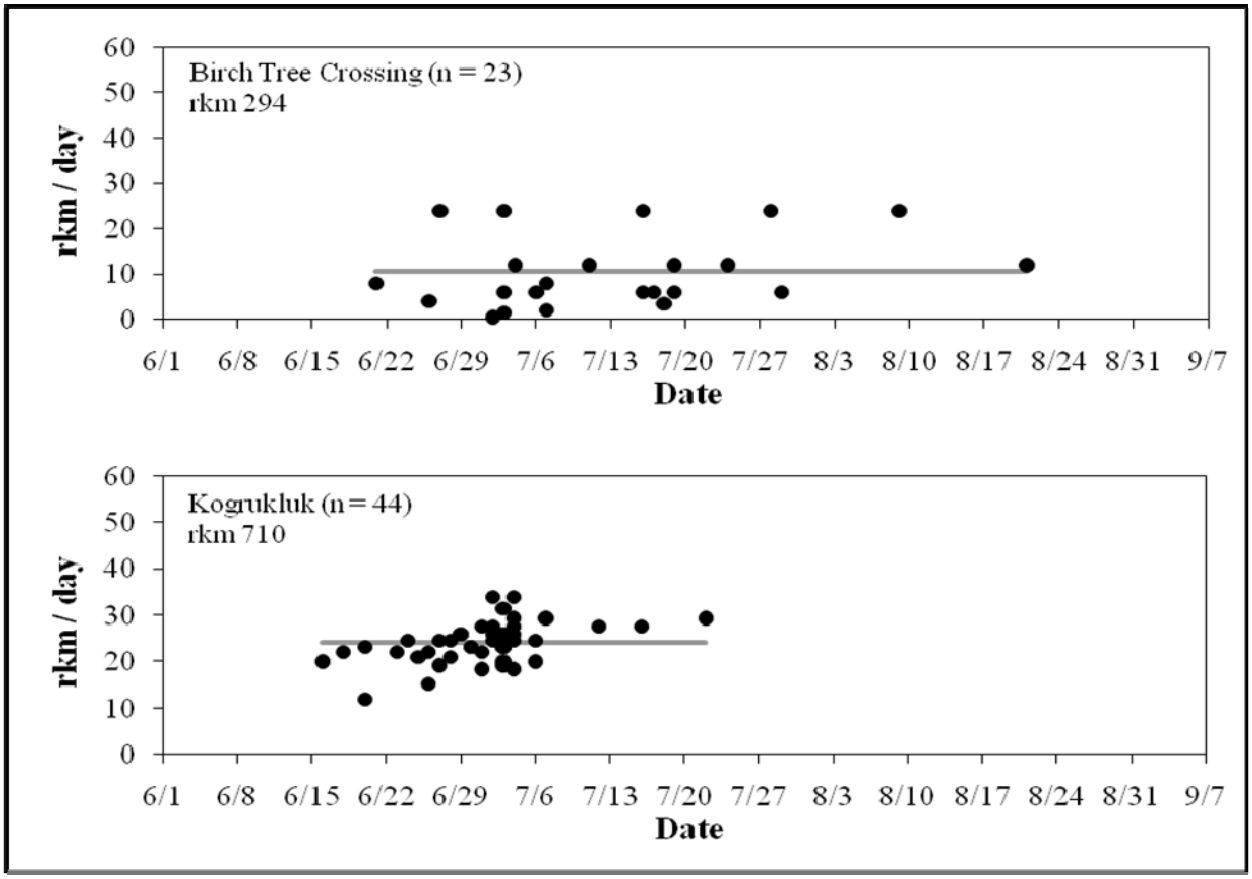
Note: Vertical lines represent the central 50% with the horizontal line representing the central 80% passage. The Kalskag tagging site was located 270 rkm above the mouth of the Kuskokwim River in all years except 2004 in which it was at rkm 249. Tatlawiskuk River weir did not operate in 2003 due to high water early season. Birch Tree Crossing wheels did not operate in 2005 or 2006. No tagged sockeye salmon were recovered at George River in 2003, Tatlawiksuk River in 2002 or 2006, Takotna River in 2002 or 2003.

Figure 17.–Run timing for sockeye salmon tagged near Kalskag and recaptured in upriver tributaries of the Kuskokwim River, 2002–2006.



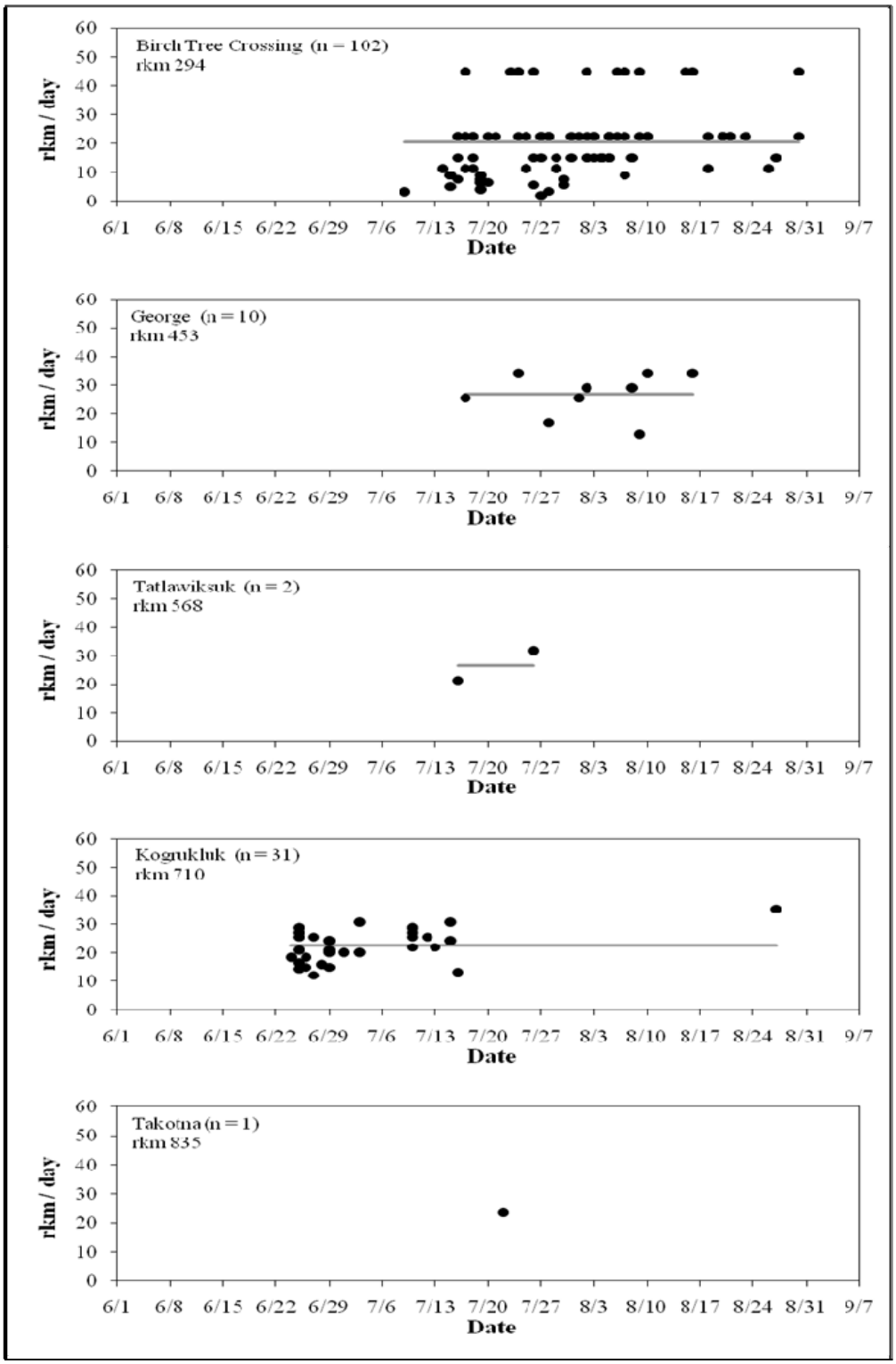
Note: Points represent individual tagged fish, where the horizontal line represents the mean migration rate. The Kalskag tagging site was located 270 rkm above the mouth of the Kuskokwim River. River kilometer (rkm). No tagged sockeye salmon were recovered at Tatlawiksuk or Takotna River weirs in 2003.

Figure 18.–Migration rates for sockeye salmon tagged near Kalskag and recovered in upriver tributaries of the Kuskokwim River, 2002.



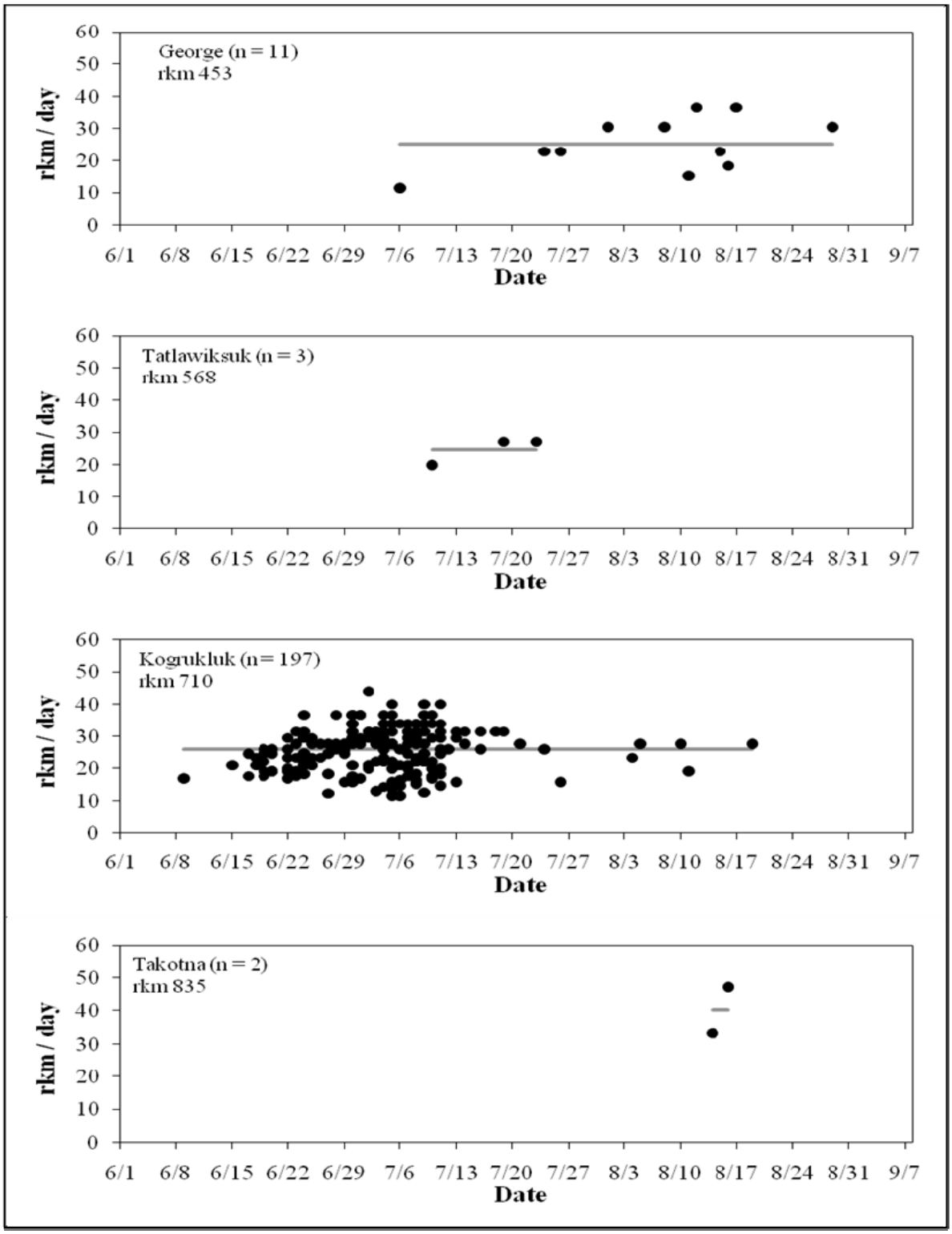
Note: Points represent individual tagged fish, where the horizontal line represents the mean migration rate. The Kalskag tagging site was located 270 rkm above the mouth of the Kuskokwim River. River kilometer (rkm). Tatlawiksuk River weir did not operate in 2003 due to high water early season. No tagged sockeye salmon were recovered at George or Takotna River weirs in 2003.

Figure 19.–Migration rates for sockeye salmon tagged near Kalskag and recovered in upriver tributaries of the Kuskokwim River, 2003.



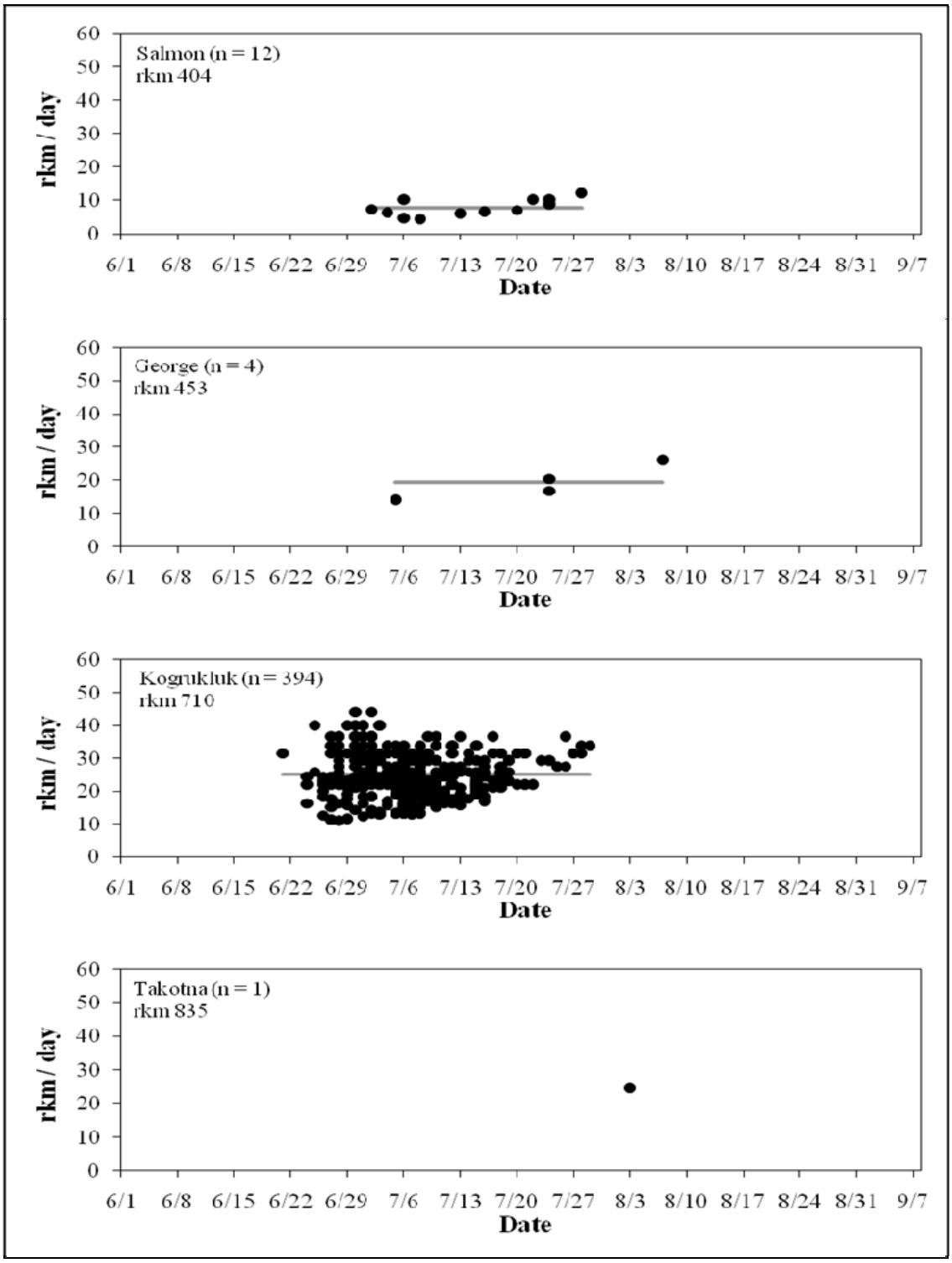
Note: Points represent individual tagged fish, where the horizontal line represents the mean migration rate. The Kalskag tagging site was located 249 rkm above the mouth of the Kuskokwim River. River kilometer (rkm).

Figure 20.–Migration rates for sockeye salmon tagged near Kalskag and recovered in upriver tributaries of the Kuskokwim River, 2004.



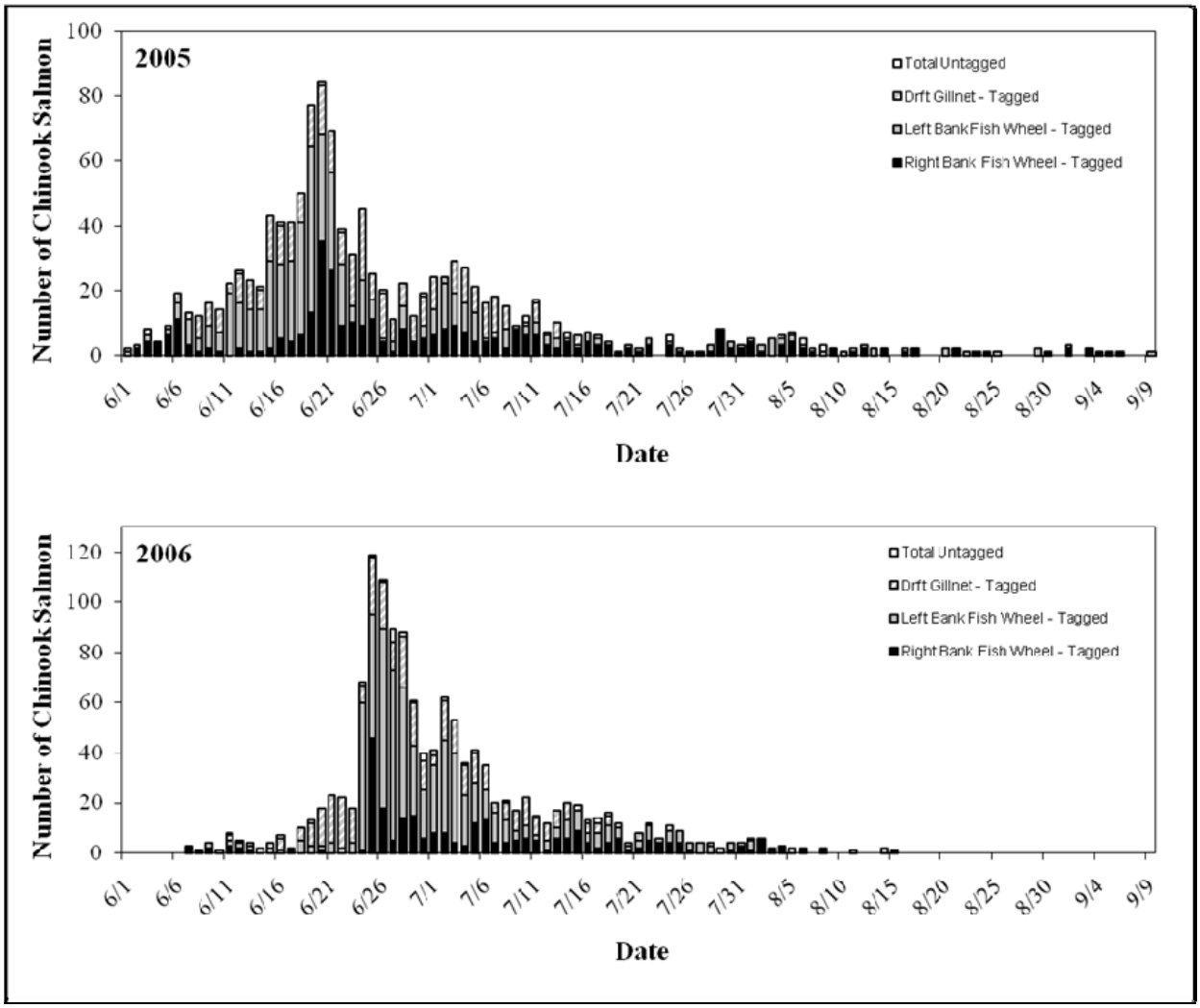
Note: Points represent individual tagged fish, where the horizontal line represents the mean migration rate. The Kalskag tagging site was located 270 rkm above the mouth of the Kuskokwim River. River kilometer (rkm). Birch Tree Crossing wheels did not operate in 2005.

Figure 21.–Migration rates for sockeye salmon tagged near Kalskag and recovered in upriver tributaries of the Kuskokwim River, 2005.



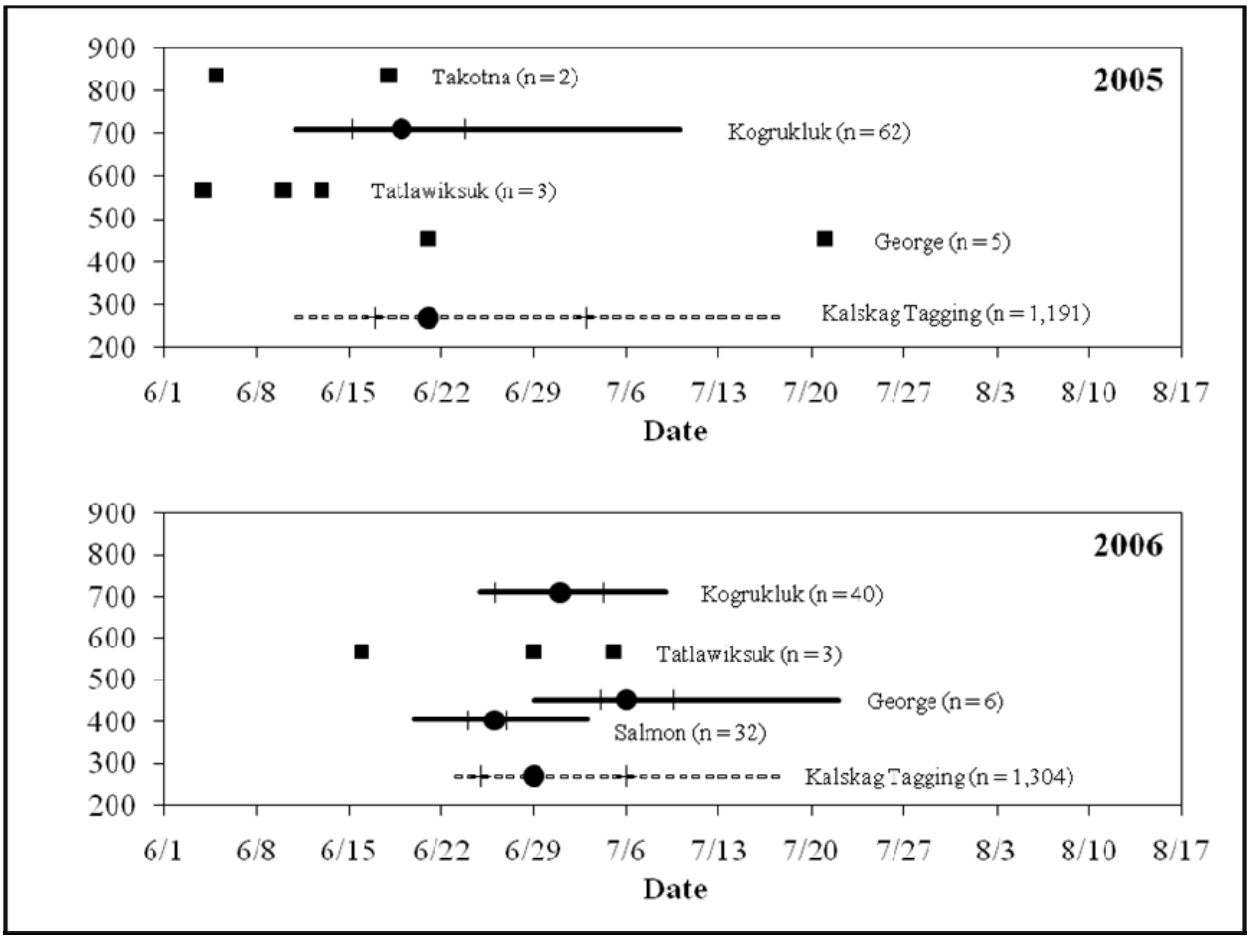
Note: Points represent individual tagged fish, where the horizontal line represents the mean migration rate. The Kalskag tagging site was located 270 rkm above the mouth of the Kuskokwim River. River kilometer (rkm). Birch Tree Crossing wheels did not operate in 2006. Salmon River weir was only operated in 2006. No tagged sockeye salmon were recovered at Tatlawiksuk River in 2006.

Figure 22.–Migration rates for sockeye salmon tagged near Kalskag and recovered in upriver tributaries of the Kuskokwim River, 2006.



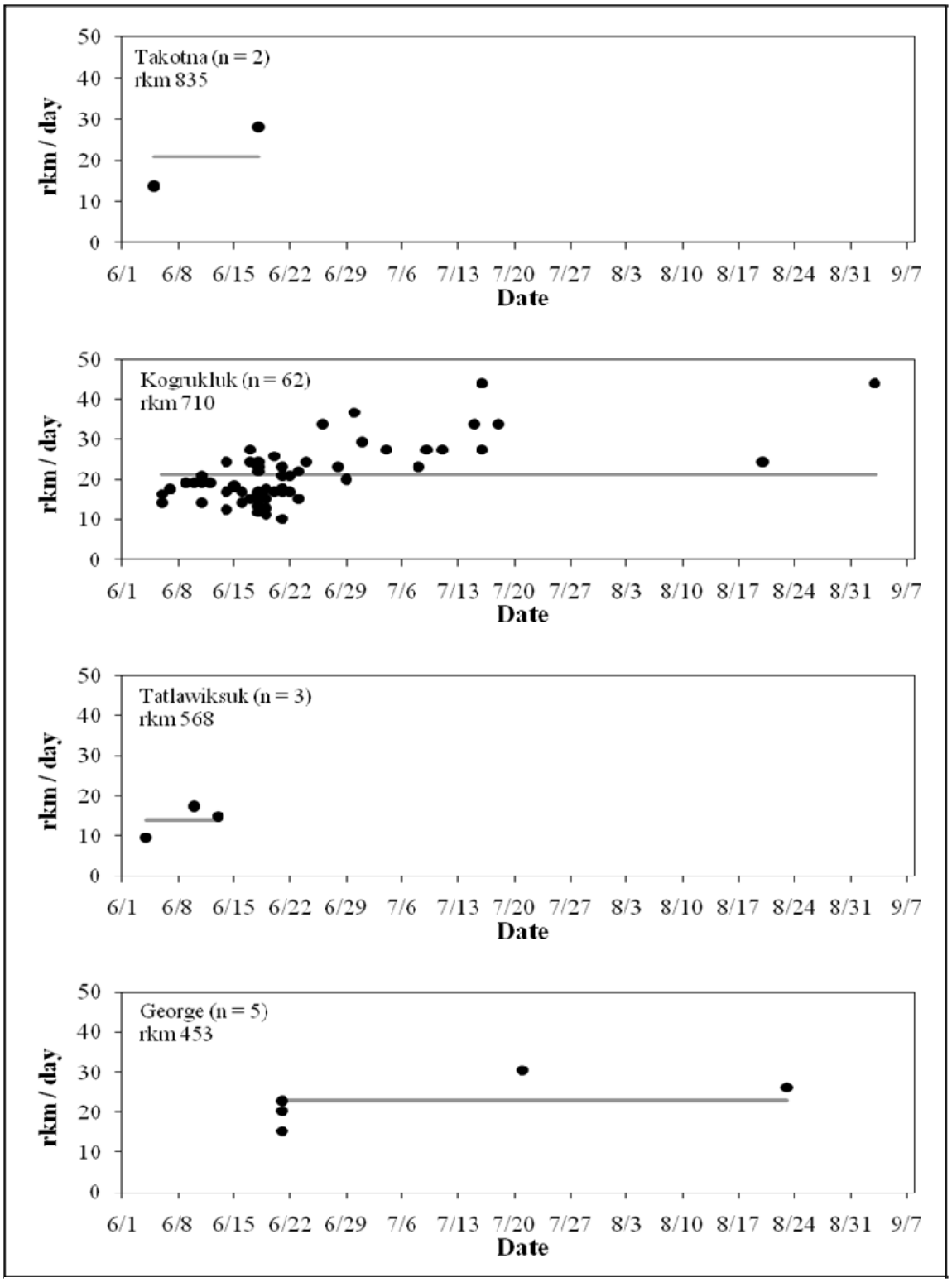
Note: The Kalskag tagging site was located 270 rkm above the mouth of the Kuskokwim River.

Figure 23.–Summary of Chinook salmon captured and anchor tagged at the Kalskag tagging site, Kuskokwim River 2005–2006.



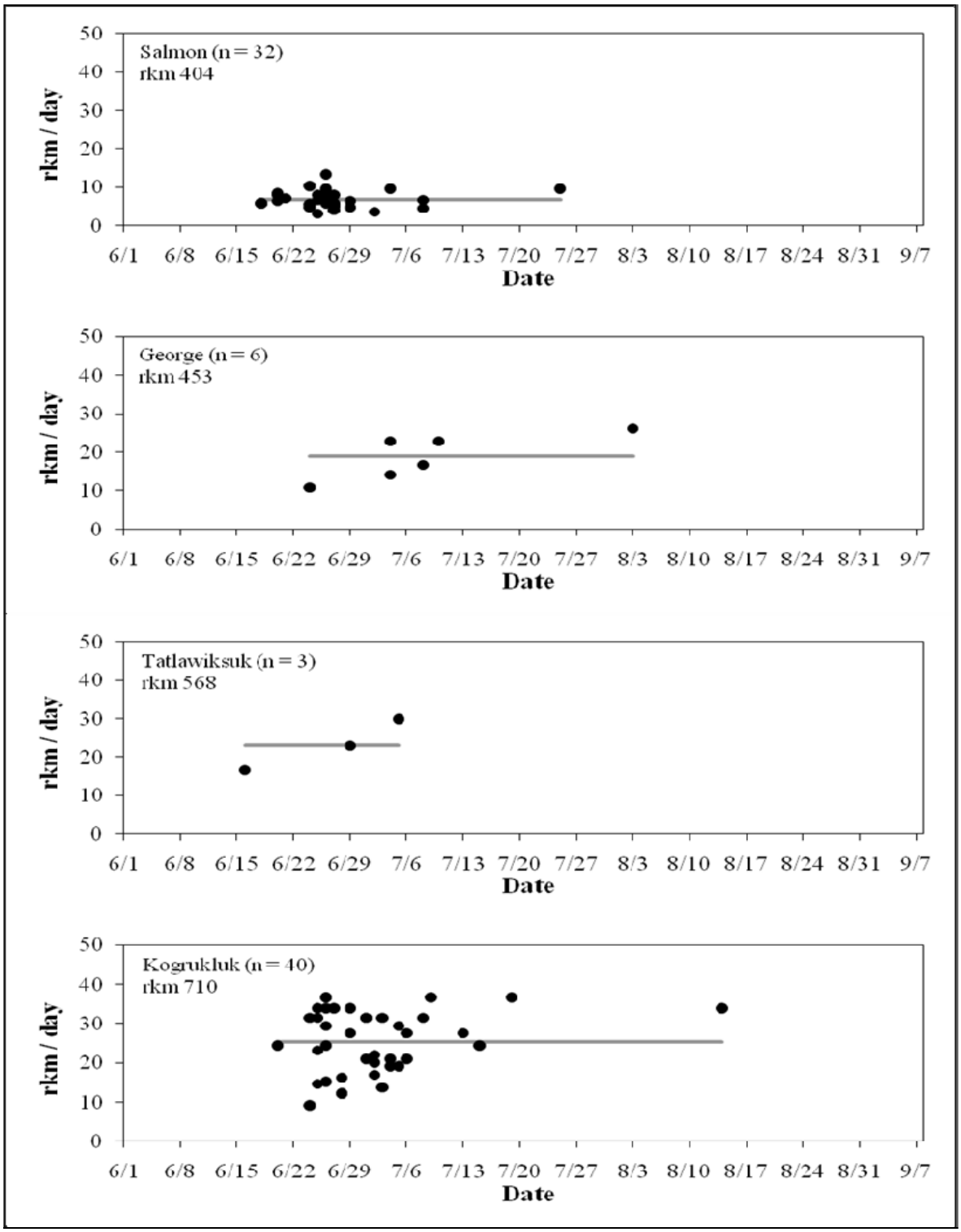
Note: Vertical lines represent the central 50% with the horizontal line representing the central 80% passage. The Kalskag tagging site was located 270 rkm above the mouth of the Kuskokwim River. Birch Tree Crossing wheels did not operate in 2005 or 2006.

Figure 24.–Run timing for Chinook salmon tagged near Kalskag and recaptured in upriver tributaries of the Kuskokwim River, 2005–2006.



Note: Points represent individual tagged fish, where the horizontal line represents the mean migration rate. The Kalskag tagging site was located 270 rkm above the mouth of the Kuskokwim River. River kilometer (rkm). Birch Tree Crossing wheels did not operate in 2005.

Figure 25.–Migration rates for Chinook salmon tagged near Kalskag and recovered in upriver tributaries of the Kuskokwim River, 2005.



Note: Points represent individual tagged fish, where the horizontal line represents the mean migration rate. The Kalskag tagging site was located 270 rkm above the mouth of the Kuskokwim River. River kilometer (rkm). Salmon River weir was only operated in 2006.: Birch Tree Crossing wheels did not operate in 2006. No tagged Chinook salmon were recovered at Takotna River in 2006.

Figure 26.–Migration rates for Chinook salmon tagged near Kalskag and recovered in upriver tributaries of the Kuskokwim River, 2006.

APPENDIX A

Capture and tagging data were examined for accuracy following each data download event. All identified errors were immediately discussed with the sampling crews and resolved inseason. Tag recapture data were screened for accuracy postseason. Five common errors were identified by examining the raw annual tagging and recapture datasets individually and in concert.

(1) Tag numbers recorded incorrectly at either the tag deployment or tag recapture sites prevented matching tag and recapture records required for run timing and migration speed analysis. Consequently, unmatched recaptured tags were described as "observed" and could only be used for limited diagnostics and abundance estimation. This type of error was common during each year of the study but the frequency was generally low compared with the number of correctly recorded tag records.

(2) Duplicate tags (i.e. the same tag number and color) deployed at the tagging sites complicated matching tag deployment and recapture records because of resulting Boolean products. When one or more duplicate tag was recovered that record was matched with all possible tag deployment records sharing the same tag number. It was generally not possible to determine which deployment record was correct. Duplicate tags were deployed in most years (total 2001-2006, n = 246) but most (n = 220, 89%) were deployed in 2002 and represented about 2% of the total tags deployed in that year. Duplicate tagged fish were removed from the dataset and not considered in the analysis.

(3) Duplicate tags recorded at the recovery sites (note: not a function of duplicate tags deployed at tagging site) were addressed on a case by case basis. On occasion, following tag recovery, a tagged fish passed downstream of the recapture weir only to be recovered again at the same location at a later date. Although rare, this type of movement was observed during each year of the project. All such occurrences were identified post season and the first recovery record for that fish was used for analysis. A few records (n = 7) indicated that the same tagged fish was recovered at two different weirs. Although possible, the considerable distance between weir sites made this type of movement unlikely. Rather, the duplicate tag recoveries were most likely a result of the tag number being recorded incorrectly at one of the sites. It was not possible to determine which of the recovery records was correct. Consequently, these tagged fish were removed from the dataset and not considered in the analysis.

(4) Conflicting species assignment at time' of tagging and recapture was detected during the 2002-2006 project years when more than one target species was under investigation. For recovered fish only, when species assignment at time of tagging was inconsistent with any recovery record, that fish was removed from the dataset and not considered in the analysis. Inconsistent species assignment was not common in any year (total occurrences 2002-2006, n = 190).

(5) A few tag recovery records (n = 13) reported recovery dates that preceded the tag deployment date. This type of error was only observed for tag recoveries at the tagging sites. These tagged fish were removed from the dataset and not considered in the analysis.

APPENDIX B

Appendix B1.–Stratified coho salmon anchor tag deployment at Kalskag and recovery by deployment week at Birch Tree Crossing, Kuskokwim River 2001.

Tagging Strata	Total Tagged [a]	7/24–30	8/1–7	8/8–13	8/14–20	8/21–27	8/28–9/4	9/5–11	Total
7/24–31	18	0	0	0	0	0	0	0	0
8/1–7	322	0	3	3	0	0	0	0	6
8/8–13	229	0	0	0	1	0	0	0	1
8/14–20	251	0	0	0	0	0	0	0	0
8/21–27	78	0	0	0	0	0	1	0	1
8/28–9/4	314	0	0	0	0	0	2	3	5
9/5–11	78	0	0	0	0	0	0	0	0
	Total [b]	0	3	3	1	0	3	3	13
	Total Untagged Catch [b]	56	449	354	265	125	386	195	1,830

Note: These data were used as input into SPAS for producing temporally stratified wheel–wheel Darroch abundance estimates. Final input matrix was achieved by pooling rows and columns concurrently so that each stratum had a minimum of 10 recoveries. Adjacent strata with similar recovery ratios were further combined to obtain the most parsimonious matrix. A suitable input matrix was not achieved in 2001. The Kalskag tagging site was located 270 rkm above the mouth of the Kuskokwim River. Birch Tree Crossing was located at rkm 294. Summary based on recovered tags only. Tags observed but not recovered were not included as tagging date was unknown.

[a] At Kalskag tagging site.
[b] At Birch Tree Crossing.

Appendix B2.–Stratified coho salmon anchor tag deployment at Kalskag and recovery by deployment week at Birch Tree Crossing, Kuskokwim River 2002.

		Total Recovered by Tagging Strata [a]										
Tagging Strata	Total Tagged [a]	6/28–7/5	7/6–12	7/13–19	7/20–26	7/27–8/4	8/5–11	8/12–18	8/19–25	8/26–9/2	9/3–12	Total
6/28–7/5	1	0	0	0	0	0	0	0	0	0	0	0
7/6–12	4	0	0	0	0	0	0	0	0	0	0	0
7/13–19	10	0	0	0	0	0	0	0	0	0	0	0
7/20–26	80	0	0	0	1	1	1	1	0	0	0	4
7/27–8/4	265	0	0	0	0	0	1	1	0	0	0	2
8/5–11	474	0	0	0	0	0	3	3	0	1	0	7
8/12–18	439	0	0	0	0	0	0	1	1	0	0	2
8/19–25	629	0	0	0	0	0	0	0	1	3	1	5
8/26–9/2	558	0	0	0	0	0	0	0	0	11	3	14
9/3–12	344	0	0	0	0	0	0	0	0	0	12	12
	Total [b]	0	0	0	1	1	5	6	2	15	16	46
	Total Untagged Catch [b]	0	0	10	62	409	861	918	838	711	461	4,270

Note: These data were used as input into SPAS for producing temporally stratified wheel–wheel Darroch abundance estimates.
Final input matrix was achieved by pooling rows and columns concurrently so that each stratum had a minimum of 10 recoveries. Adjacent strata with similar recovery ratios were further combined to obtain the most parsimonious matrix. The final input matrix was 3x3.

Note: The Kalskag tagging site was located 270 rkm above the mouth of the Kuskokwim River. Birch Tree Crossing was located at rkm 294.

Note: Summary based on recovered tags only. Tags observed but not recovered were not included as tagging date was unknown.

[a] At Kalskag tagging site.
[b] At Birch Tree Crossing.

Appendix B3.–Stratified coho salmon anchor tag deployment at Kalskag and recovery by deployment week at Birch Tree Crossing, Kuskokwim River 2003.

Tagging Strata	Total Tagged [a]	6/20–26	6/27–7/3	7/4–10	7/11–17	7/18–24	7/25–31	8/1–7	8/8–14	8/15–21	8/22–28	8/29–9/4	9/5–11	Total
6/20–26	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6/27–7/3	5	0	0	0	0	0	0	0	0	0	0	0	0	0
7/4–10	7	0	0	0	0	0	0	0	0	0	0	0	0	0
7/11–17	24	0	0	0	0	0	0	0	0	0	0	0	0	0
7/18–24	68	0	0	0	0	0	0	0	0	0	0	0	0	0
7/25–31	243	0	0	0	0	0	0	4	0	1	0	0	0	5
8/1–7	676	0	0	0	0	0	0	6	8	0	1	1	0	16
8/8–14	1,421	0	0	0	0	0	0	0	7	6	3	4	1	21
8/15–21	1,851	0	0	0	0	0	0	0	0	35	20	5	1	61
8/22–28	1,349	0	0	0	0	0	0	0	0	0	21	10	0	31
8/29–9/4	702	0	0	0	0	0	0	0	0	0	0	13	1	14
9/5–11	420	0	0	0	0	0	0	0	0	0	0	0	15	15
	Total [b]	0	0	0	0	0	0	10	15	42	45	33	18	163
	Total Untagged Catch [b]	4	2	3	15	144	729	2,034	2,683	4,127	4,626	1,657	771	16,795

Note: These data were used as input into SPAS for producing temporally stratified wheel–wheel Darroch abundance estimates. Final input matrix was achieved by pooling rows and columns concurrently so that each stratum had a minimum of 10 recoveries. Adjacent strata with similar recovery ratios were further combined to obtain the most parsimonious matrix. Final input matrix was 4x4. Results were not published, rather a pooled estimator was used. The Kalskag tagging site was located 270 rkm above the mouth of the Kuskokwim River. Birch Tree Crossing was located at rkm 294. Summary based on recovered tags only. Tags observed but not recovered were not included as tagging date was unknown.

[a] At Kalskag tagging site.
[b] At Birch Tree Crossing.

Appendix B4.–Stratified coho salmon anchor tag deployment at Kalskag and recovery by deployment week at Birch Tree Crossing, Kuskokwim River 2004.

		Total Recovered by Tagging Strata [a]									
Tagging Strata	Total Tagged [a]	7/11–18	7/19–25	7/26–31	8/1–7	8/8–14	8/15–21	8/22–28	8/29–9/4	9/5–11	Total
7/11–18	24	0	0	0	0	0	0	0	0	0	0
7/19–25	28	0	1	0	0	0	0	0	0	0	1
7/26–31	119	0	0	2	2	0	0	0	0	0	4
8/1–7	481	0	0	0	4	6	0	1	0	0	11
8/8–14	758	0	0	0	0	6	9	1	0	1	17
8/15–21	739	0	0	0	0	0	4	18	1	1	24
8/22–28	370	0	0	0	0	0	0	5	4	0	9
8/29–9/4	232	0	0	0	0	0	0	0	7	0	7
9/5–11	213	0	0	0	0	0	0	0	0	4	4
	Total [b]	0	1	2	6	12	13	25	12	6	77
	Total Untagged Catch [b]	26	390	959	1,908	2,101	2,356	1,493	890	340	10,463

Note: These data were used as input into SPAS for producing temporally stratified wheel–wheel Darroch abundance estimates. Final input matrix was achieved by pooling rows and columns concurrently so that each stratum had a minimum of 10 recoveries. Adjacent strata with similar recovery ratios were further combined to obtain the most parsimonious matrix. The final input matrix was 4x4. The Kalskag tagging site was located 249 rkm above the mouth of the Kuskokwim River. Birch Tree Crossing was located at rkm 294. Summary based on recovered tags only. Tags observed but not recovered were not included as tagging date was unknown.

[a] At Kalskag tagging site.
[b] At Birch Tree Crossing.

Appendix B5.–Stratified chum salmon anchor tag deployment at Kalskag and recovery by deployment week at Birch Tree Crossing, Kuskokwim River 2002.

Tagging Strata	Total Tagged [a]	6/14–23	6/24–30	7/1–7	7/8–14	7/15–21	7/22–28	7/29–8/4	8/5–11	8/12–18	8/19–25	8/26–9/1	9/2–11	Total
6/14–23	146	0	5	0	0	0	0	0	0	0	0	0	0	5
6/24–30	408	0	9	5	1	0	1	0	0	0	0	0	0	16
7/1–7	1,447	0	0	21	9	4	0	0	0	0	0	0	0	34
7/8–14	1,929	0	0	0	53	19	1	0	0	0	0	0	0	73
7/15–21	1,630	0	0	0	0	46	14	1	0	0	0	0	0	61
7/22–28	1,082	0	0	0	0	0	29	4	2	0	0	0	0	35
7/29–8/4	567	0	0	0	0	0	0	18	6	0	0	0	0	24
8/5–11	269	0	0	0	0	0	0	0	9	1	0	0	0	10
8/12–18	70	0	0	0	0	0	0	0	0	7	5	0	0	12
8/19–25	76	0	0	0	0	0	0	0	0	0	1	0	0	1
8/26–9/1	15	0	0	0	0	0	0	0	0	0	0	0	0	0
9/2–11	13	0	0	0	0	0	0	0	0	0	0	0	0	0
	Total [b]	0	14	26	63	69	45	23	17	8	6	0	0	271
	Total Untagged Catch [b]	653	1,898	4,186	4,644	3,268	2,002	1,385	472	157	87	24	17	18,793

Note: These data were used as input into SPAS for producing temporally stratified wheel–wheel Darroch abundance estimates. Final input matrix was achieved by pooling rows and columns concurrently so that each stratum had a minimum of 10 recoveries. Adjacent strata with similar recovery ratios were further combined to obtain the most parsimonious matrix. The final input matrix was 6x6. Results were not supported. The Kalskag tagging site was located 270 rkm above the mouth of the Kuskokwim River. Birch Tree Crossing was located at rkm 294. Summary based on recovered tags only. Tags observed but not recovered were not included as tagging date was unknown.

[a] At Kalskag tagging site.
[b] At Birch Tree Crossing.

Appendix B6.–Stratified chum salmon anchor tag deployment at Kalskag and recovery by deployment week at Birch Tree Crossing, Kuskokwim River 2003.

Tagging Strata	Total Tagged [a]	6/6–11	6/12–18	6/19–25	6/26–7/2	7/3–9	7/10–16	7/17–23	7/24–30	7/31–8/6	8/7–13	8/14–20	8/21–27	8/28–9/10	Total
6/6–11	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6/12–18	28	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6/19–25	144	0	0	1	0	0	0	0	0	0	0	0	0	0	1
6/26–7/2	376	0	0	0	2	1	0	0	0	0	0	0	0	0	3
7/3–9	1,288	0	0	0	0	18	12	12	0	0	0	0	0	0	42
7/10–16	1,721	0	0	0	0	0	37	18	2	0	0	0	0	0	57
7/17–23	2,197	0	0	0	0	0	0	93	17	0	0	0	0	0	110
7/24–30	1,678	0	0	0	0	0	0	0	49	18	0	0	0	0	67
7/31–8/6	219	0	0	0	0	0	0	0	0	8	1	0	0	0	9
8/7–13	466	0	0	0	0	0	0	0	0	0	18	2	0	1	21
8/14–20	184	0	0	0	0	0	0	0	0	0	0	12	0	0	12
8/21–27	46	0	0	0	0	0	0	0	0	0	0	0	1	0	1
8/28–9/10	33	0	0	0	0	0	0	0	0	0	0	0	0	2	2
	Total [b]	0	0	1	2	19	49	123	68	26	19	14	1	3	325
	Total Untagged Catch [b]	3	52	294	877	2,142	2,706	4,525	2,929	2,480	1,339	286	205	97	17,935

Note: These data were used as input into SPAS for producing temporally stratified wheel–wheel Darroch abundance estimates. Final input matrix was achieved by pooling rows and columns concurrently so that each stratum had a minimum of 10 recoveries. Adjacent strata with similar recovery ratios were further combined to obtain the most parsimonious matrix. The final input matrix was 5x5. Results were not supported. The Kalskag tagging site was located 270 rkm above the mouth of the Kuskokwim River. Birch Tree Crossing was located at rkm 294. Summary based on recovered tags only. Tags observed but not recovered were not included as tagging date was unknown.

[a] At Kalskag tagging site.
[b] At Birch Tree Crossing.

Appendix B7.–Stratified sockeye salmon anchor tag deployment at Kalskag and recovery by deployment week at Birch Tree Crossing, Kuskokwim River 2002.

Tagging Strata	Total Tagged [a]	6/28–26	6/27–7/3	7/4–10	7/11–17	7/18–24	7/25–31	8/1–7	8/8–14	8/15–21	8/22–28	8/29–9/4	9/5–11	Total
6/18–26	25	0	0	0	0	0	0	0	0	0	0	0	0	0
6/27–7/3	56	0	0	1	0	0	0	0	0	0	0	0	0	1
7/4–10	65	0	0	0	0	0	0	0	0	0	0	0	0	0
7/11–17	39	0	0	0	0	0	0	0	0	0	0	0	0	0
7/18–24	33	0	0	0	0	0	0	0	0	0	0	0	0	0
7/25–31	8	0	0	0	0	0	0	0	0	0	0	0	0	0
8/1–7	14	0	0	0	0	0	0	2	0	0	0	0	0	2
8/8–14	7	0	0	0	0	0	0	0	0	0	0	0	0	0
8/15–21	9	0	0	0	0	0	0	0	0	0	0	0	0	0
8/22–28	5	0	0	0	0	0	0	0	0	0	1	0	0	1
8/29–9/4	1	0	0	0	0	0	0	0	0	0	0	0	0	0
9/5–11	1	0	0	0	0	0	0	0	0	0	0	0	0	0
	Total [b]		0	1	0	0	0	2	0	0	1	0	0	4
	Total Untagged Catch [b]	66	142	164	141	33	17	9	7	2	0	2	2	585

Note: These data were used as input into SPAS for producing temporally stratified wheel–wheel Darroch abundance estimates. Final input matrix was achieved by pooling rows and columns concurrently so that each stratum had a minimum of 10 recoveries. Adjacent strata with similar recovery ratios were further combined to obtain the most parsimonious matrix. A suitable input matrix was not achieved in 2002. The Kalskag tagging site was located 270 rkm above the mouth of the Kuskokwim River. Birch Tree Crossing was located at rkm 294. Summary based on recovered tags only. Tags observed but not recovered were not included as tagging date was unknown.

[a] At Kalskag tagging site.
[b] At Birch Tree Crossing.

Appendix B8.–Stratified sockeye salmon anchor tag deployment at Kalskag and recovery by deployment week at Birch Tree Crossing, Kuskokwim River 2003.

Tagging Strata	Total Tagged [a]	6/13–20	6/21–27	6/28–7/4	7/5–11	7/12–18	7/19–25	7/26–8/1	8/2–8	8/9–15	8/16–22	8/23–29	8/30–9/7	Total
6/13–20	98	0	0	0	0	0	0	0	0	0	0	0	0	0
6/21–27	247	0	1	2	0	0	0	0	0	0	0	0	0	3
6/28–7/4	576	0	0	1	2	0	1	0	0	0	0	1	0	5
7/5–11	200	0	0	0	2	1	1	0	0	0	0	0	0	4
7/12–18	127	0	0	0	0	1	3	0	0	0	0	0	0	4
7/19–25	43	0	0	0	0	0	2	1	0	0	0	0	0	3
7/26–8/1	25	0	0	0	0	0	0	1	1	0	0	0	0	2
8/2–8	9	0	0	0	0	0	0	0	0	0	0	0	0	0
8/9–15	4	0	0	0	0	0	0	0	0	1	0	0	0	1
8/16–22	5	0	0	0	0	0	0	0	0	0	0	1	0	1
8/23–29	4	0	0	0	0	0	0	0	0	0	0	0	0	0
8/30–9/7	3	0	0	0	0	0	0	0	0	0	0	0	0	0
	Total [b]	0	1	3	4	2	7	2	1	1	0	2	0	23
	Total Untagged Catch [b]	63	226	372	270	251	180	52	32	35	16	13	2	1,512

Note: These data were used as input into SPAS for producing temporally stratified wheel–wheel Darroch abundance estimates. Final input matrix was achieved by pooling rows and columns concurrently so that each stratum had a minimum of 10 recoveries. Adjacent strata with similar recovery ratios were further combined to obtain the most parsimonious matrix. A suitable input matrix was not achieved in 2003. The Kalskag tagging site was located 270 rkm above the mouth of the Kuskokwim River. Birch Tree Crossing was located at rkm 294. Summary based on recovered tags only. Tags observed but not recovered were not included as tagging date was unknown.

[a] At Kalskag tagging site.
[b] At Birch Tree Crossing.

APPENDIX C

Appendix C1.–Exploration of Kuskokwim River coho salmon exploitation, 2001–2005.

Wheel–Wheel [a]					
Year	Abundance [b]	Lower River Escapement [c]	Total Harvest [d]	Total Run [e]	Exploitation Rate [f]
2001	170,042	45,364	225,429	440,835	51.14%
2002	320,401	34,785	123,941	479,127	25.87%
2003	675,306	148,860	324,925	1,149,091	28.28%
2004	440,588	84,552	476,799	1,001,939	47.59%

Wheel–Weir [g]					
Year	Abundance [h]	Lower River Escapement [c]	Total Harvest [d]	Total Run [e]	Exploitation Rate [f]
2001	440,330	45,364	225,429	711,123	31.70%
2002	453,499	34,785	123,941	612,225	20.24%
2003	971,266	148,860	324,925	1,445,051	22.49%
2004	1,546,627	84,552	476,799	2,107,978	22.62%
2005	666,747	11,324	174,970	853,041	20.51%

Note: The Kalskag tagging site was located 270 rkm above the mouth of the Kuskokwim River in all years except 2004, in which it was located at rkm 249.

[a] Anchor tagged near Kalskag and recaptured in the mainstem at Birch Tree Crossing (rkm 294).
[b] Pooled Petersen estimator was used in 2001 and 2003. Temporally stratified Darroch estimator was used in 2002 and 2004.
[c] Sum of escapement past Tuluksak and Kwethluk River weirs (2008 Kuskokwim Area Master Escapement File, *unpublished*). Lower river escapement is incomplete as Kisaralik River and other small drainages are not represented.
[d] Sum of commercial, subsistence, sport, and test fishery harvest (2001–2004 from Whitmore et al. 2008 and 2005 from Jeff Estensen, ADF&G Kuskokwim Area Management Biologist, personal communication).
[e] Sum of mark–recapture abundance estimate, lower river escapement, and total harvest.
[f] Total harvest divided by total run. Exploitation rate is likely high as lower river escapement is incomplete.
[g] Anchor tagged near Kalskag and recaptured at upriver tributary weirs.
[h] Pooled Petersen estimator was used in all years.

Appendix C2.–Exploration of Kuskokwim River chum salmon exploitation, 2002–2005.

Wheel–Wheel [a]					
Year	Abundance [b]	Lower River Escapement [c]	Total Harvest [d]	Total Run [e]	Exploitation Rate [f]
2002	590,192	45,812	81,461	717,465	11.35%
2003	538,306	53,536	47,850	639,692	7.48%

Wheel–Weir [g]					
Year	Abundance [h]	Lower River Escapement [c]	Total Harvest [d]	Total Run [e]	Exploitation Rate [f]
2002	4,437,539	45,812	81,461	4,564,812	1.78%
2003	1,497,447	53,536	47,850	1,598,833	2.99%
2004	4,526,357	50,442	74,670	4,651,469	1.61%
2005	11,316,332	35,696	120,875	11,472,903	1.05%

Note: The Kalskag tagging site was located 270 rkm above the mouth of the Kuskokwim River in all years except 2004, in which it was located at rkm 249.

Note: Chum salmon mark–recapture abundance estimates and subsequent total run and exploitation rates are shown for exploration purposes only, estimates are not supported.

[a] Anchor tagged near Kalskag and recaptured in the mainstem at Birch Tree Crossing (rkm 294).
[b] Temporally stratified Darroch estimator was used in both years.
[c] Sum of escapement past Tuluksak and Kwethluk River weirs (2008 Kuskokwim Area Master Escapement File, *unpublished*). Lower river escapement is incomplete as Kisaralik River and other small drainages are not represented.
[d] Sum of commercial, subsistence, sport, and test-fish harvest (2001–2004 from Whitmore et al. 2008 and 2005 from Jeff Estensen, ADF&G Kuskokwim Area Management Biologist, personal communication).
[e] Sum of mark–recapture abundance estimate, lower river escapement, and total harvest.
[f] Total harvest divided by total run. Exploitation rate is likely high as lower river escapement is incomplete.
[g] Anchor tagged near Kalskag and recaptured at upriver tributary weirs.
[h] Pooled Petersen estimator was used in all years.

Appendix C3.–Exploration of Kuskokwim River sockeye salmon exploitation, 2002–2006.

Wheel–Wheel [a]					
Year	Abundance [b]	Lower River Escapement [c]	Total Harvest [d]	Total Run [e]	Exploitation Rate [f]
2002	31,151	354	29,196	60,701	48.10%
2003	85,887	3,216	35,520	124,623	28.50%

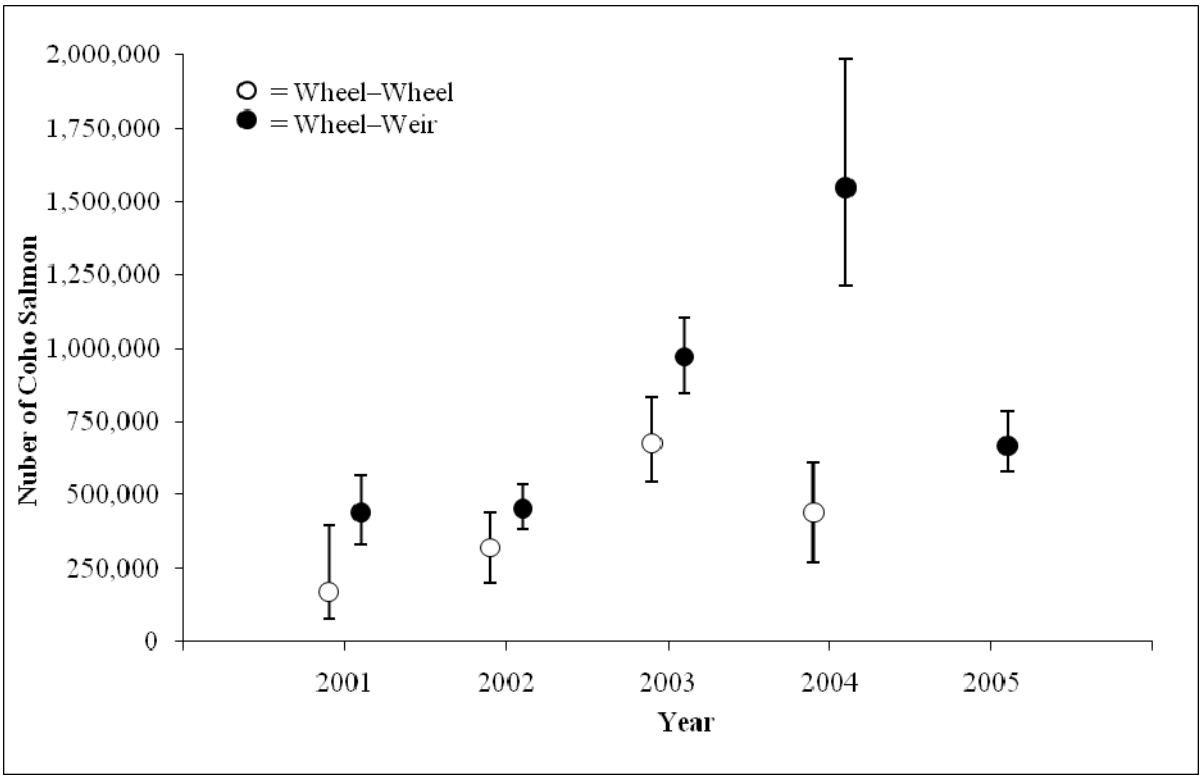
Wheel–Weir [g]					
Year	Abundance [h]	Lower River Escapement [c]	Total Harvest [d]	Total Run [e]	Exploitation Rate [f]
2002	172,215	354	29,196	201,765	14.47%
2003	219,282	3,216	35,520	258,018	13.77%
2004	362,957	3,626	43,323	409,906	10.57%
2005	801,008	642	63,472	865,122	7.34%
2006	688,495	7,717	43,594	739,806	5.89%

Note: The Kalskag tagging site was located 270 rkm above the mouth of the Kuskokwim River in all years except 2004, in which it was located at rkm 249.

[a] Anchor tagged near Kalskag and recaptured in the mainstem at Birch Tree Crossing (rkm 294).
[b] Pooled Petersen estimator was used in 2001 and 2003. Temporally stratified Darroch estimator was used in 2002 and 2004.
[c] Sum of escapement past Tuluksak and Kwethluk River weirs (2008 Kuskokwim Area Master Escapement File, *unpublished*). Lower river escapement is incomplete as Kisaralik River and other small drainages are not represented.
[d] Sum of commercial, subsistence, sport, and test fishery harvest (2001–2004 from Whitmore et al. 2008 and 2005 from Jeff Estensen, ADF&G Kuskokwim Area Management Biologist, personal communication).
[e] Sum of mark–recapture abundance estimate, lower river escapement, and total harvest.
[f] Total harvest divided by total run. Exploitation rate is likely high as lower river escapement is incomplete.
[g] Anchor tagged near Kalskag and recaptured at upriver tributary weirs.
[h] Pooled Petersen estimator was used in all years.

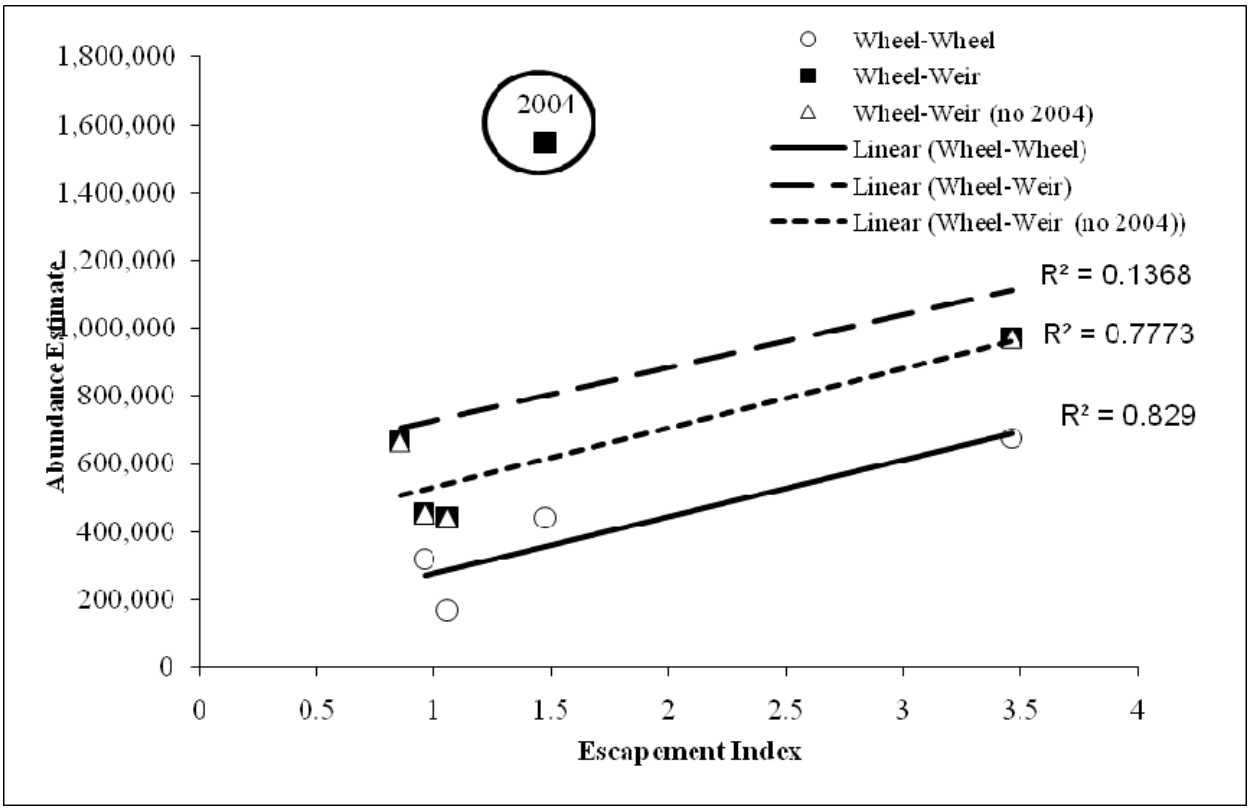
APPENDIX D

Appendix D1.–Comparison of coho salmon abundance estimates (95% confidence intervals) at Kaskag, Kuskokwim River 2001–2005.



Note: The Kalskag tagging site was located 270 rkm above the mouth of the Kuskokwim River in all years except 2004, in which it was located at rkm 249. Wheel–wheel estimates are based on coho salmon anchor tagged near Kalskag and recaptured in the mainstem at Birch Tree Crossing (rkm 294). Wheel–weir estimates are based on coho salmon anchor tagged near Kalskag and recaptured at upriver tributary weirs. The 2004 wheel–wheel estimate is believed to be more appropriate than the wheel–weir estimate.

Appendix D2.–Relationship between mark–recapture coho salmon abundance estimates at Kalskag and escapement index, Kuskokwim River 2001–2005.



Note: The Kalskag tagging site was located 270 rkm above the mouth of the Kuskokwim River in all years except 2004, in which it was located at rkm 249. Wheel–wheel estimates are based on coho salmon anchor tagged near Kalskag and recaptured in the mainstem at Birch Tree Crossing (rkm 294). Wheel–weir estimates are based on coho salmon anchor tagged near Kalskag and recaptured at upriver tributary weirs. The Kuskokwim River escapement index is a composite score calculated as the median of the annual escapement at each weir project standardized by the median escapement for that location.

APPENDIX E

Appendix E1.–Comparison of chum salmon abundance estimates at Kalskag with known upriver abundance from independent research, Kuskokwim River 2002–2005.

Location	Method	Estimate			
		2002	2003	2004	2005
Independent Upriver Abundance Projects					
Aniak River [a]	Sonar (Didson)	472,346	477,544	672,931	1,151,505
George River [b]	Weir	6,529	25,005	13,058	14,654
Holitna River [c]	Mark–Recapture	542,172	ND	996,216	ND
Tatlawiksuk River [bd]	Weir	24,539	ND	21,245	55,316
Takotna River [b]	Weir	4,366	3,020	1,633	6,472
	Subtotal	1,049,952	505,569	1,705,083	1,227,947
Kalskag Mark–Recapture Project					
Kalskag	Wheel–Wheel [e]	590,192	538,306	-	-
	Difference [f]	-459,760	32,737		
Kalskag	Wheel–Weir [g]	4,437,539	1,497,447	4,526,357	11,316,332
	Difference [f]	3,387,587	991,878	2,821,274	10,088,385

[a] Aniak River sonar is located 19 river kilometers upriver from the mouth of the Aniak River (McEwen 2008).
[b] Abundance past all escapement weir projects were from the ADF&G CF Kuskokwim Research Master Escapement File, version 2008 (unpublished).
[c] From Stroka and Reed (2005), estimate inclusive of Kogrukluk River weir passage.
[d] Tatlawiksuk River weir did not operate in 2003 due to high water early season
[e] Wheel–wheel estimates are based on coho salmon anchor tagged near Kalskag and recaptured in the mainstem at Birch Tree Crossing (rkm 294).
[f] Difference between Kalskag mark–recapture abundance estimate and known upriver abundance as determined by independent research. A likely Kalskag estimate would be larger than the upstream subtotal with a difference adequate to account to for unmonitored systems.
[g] Wheel–weir estimates are based on coho salmon anchor tagged near Kalskag and recaptured at upriver tributary weirs.