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Temporal and Spatial Distributions of Kenai River and Susitna River Sockeye Salmon and Coho Salmon in Upper Cook Inlet: Implications for Management

by

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and

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

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Weights and measures (metric)

centimeter	cm
deciliter	dL
gram	g
hectare	ha
kilogram	kg
kilometer	km
liter	L
meter	m
milliliter	mL
millimeter	mm

Weights and measures (English)

cubic feet per second	ft^3/s
foot	ft
gallon	gal
inch	in
mile	mi
nautical mile	nmi
ounce	oz
pound	lb
quart	qt
yard	yd

Time and temperature

day	d
degrees Celsius	°C
degrees Fahrenheit	°F
degrees kelvin	K
hour	h
minute	min
second	s

Physics and chemistry

all atomic symbols	
alternating current	AC
ampere	A
calorie	cal
direct current	DC
hertz	Hz
horsepower	hp
hydrogen ion activity (negative log of)	pH
parts per million	ppm
parts per thousand	ppt, ‰
volts	V
watts	W

General

Alaska Administrative Code	AAC
all commonly accepted abbreviations	e.g., Mr., Mrs., AM, PM, etc.
all commonly accepted professional titles	e.g., Dr., Ph.D., R.N., etc.
at	@
compass directions:	
east	E
north	N
south	S
west	W
copyright	©
corporate suffixes:	
Company	Co.
Corporation	Corp.
Incorporated	Inc.
Limited	Ltd.
District of Columbia	D.C.
et alii (and others)	et al.
et cetera (and so forth)	etc.
exempli gratia (for example)	e.g.
Federal Information Code	FIC
id est (that is)	i.e.
latitude or longitude	lat or long
monetary symbols (U.S.)	$, ¢
months (tables and figures): first three letters	Jan,...,Dec
registered trademark	®
trademark	™
United States (adjective)	U.S.
United States of America (noun)	USA
U.S.C.	United States Code
U.S. state	use two-letter abbreviations (e.g., AK, WA)

Mathematics, statistics

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

FISHERIES DATA SERIES NO. 17-02

TEMPORAL AND SPATIAL DISTRIBUTIONS OF KENAI RIVER AND SUSITNA RIVER SOCKEYE SALMON AND COHO SALMON IN UPPER COOK INLET: IMPLICATIONS FOR MANAGEMENT

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ABSTRACT

This study investigated the temporal and spatial distributions of Kenai and Susitna river sockeye salmon (*Oncorhynchus nerka*) and coho salmon (*O. kisutch*; all stocks combined) in Upper Cook Inlet using southern offshore test fishery (OTF) catch per unit effort (CPUE) and sockeye salmon genetic data from 2006–2012 and 2014 and northern OTF CPUE and genetic data from 2012–2014. Spatial and temporal opportunities to harvest Kenai River sockeye salmon while minimizing harvests of Susitna River sockeye salmon or coho salmon were investigated using CPUE ratios for these stocks. Mean daily ratios of Kenai to Susitna river sockeye salmon CPUEs generally exceeded 10:1 after about July 20. Mean daily ratios of Kenai River sockeye salmon to coho salmon CPUEs generally exceeded 10:1 prior to July 11 along the southern transect and prior to July 18 along the northern transect. These temporal CPUE patterns indicate that in general Kenai River sockeye salmon may be harvested at a higher rate compared to Susitna River sockeye salmon after July 20, but harvest rates on coho salmon will also be higher during this period. Mean CPUE ratios of Kenai to Susitna river sockeye salmon exceeded 10:1 on the eastern end of the northern transect. Mean CPUE ratios of Kenai River sockeye salmon to coho salmon exceeded 10:1 on the eastern end of both transects with the pattern more pronounced along the northern transect. These spatial CPUE patterns indicate that in general Kenai River sockeye salmon may be harvested at a higher rate compared to Susitna River sockeye salmon and coho salmon along the eastern side of Cook Inlet, but harvest rates on Kenai River sockeye salmon would be highest near the center of the inlet. Additional years of sampling will be needed to better estimate stock-specific spatial and temporal distributions and their variability.

Key words: Sockeye salmon, *Oncorhynchus nerka*, coho salmon, *Oncorhynchus kisutch*, Kenai River, Susitna River, Upper Cook Inlet, offshore test fishery (OTF), catch per unit effort (CPUE), genetic, mixed stock analysis

INTRODUCTION

Salmon are commercially harvested in Upper Cook Inlet (UCI) using drift and set gillnets, and these fisheries are managed to achieve salmon escapement goals in several streams flowing into the inlet. Drift gillnet fisheries are conducted only in the Central District; whereas set gillnet fisheries are conducted in both the Central and Northern districts on both the eastern and western shores (Figure 1). During each season, regularly scheduled drift and set gillnet fishery openings have occurred for 12 hours on Mondays and Thursdays beginning at 7:00 a.m. Additional fishing time has been allowed via emergency orders depending on catches, escapements, and the projected run size of sockeye salmon *Oncorhynchus nerka* (Shields and Dupuis 2015).

To achieve escapement goals, drift and set gillnet fisheries have sometimes been restricted to smaller portions of the district to reduce the harvest of specific salmon stocks. These area restrictions have varied throughout each season and across years. Drift gillnet fisheries were sometimes restricted to areas south of the northern or southern tip of Kalgin Island (Figure 2), or to the reduced Kenai or Kasilof corridors along the eastside beaches usually to reduce harvests of Susitna River sockeye salmon and Northern District coho salmon *O. kisutch*. In 2008, the Alaska Board of Fisheries (BOF) declared Susitna River sockeye salmon as a stock of yield concern. In 2011, the BOF created the Expanded Kenai and Kasilof sections (Figure 3) to provide for harvest of Kenai and Kasilof river sockeye salmon while minimizing harvests of Susitna River sockeye salmon and Northern District coho salmon. Descriptions of the management plans governing these fisheries and details of these restrictions for specific years can be found in the UCI Annual Management Reports (Shields and Dupuis 2012, 2013a, 2013b, 2015).

Since 1979, the Alaska Department of Fish and Game (ADF&G) has conducted an offshore test fishery (OTF) project near the southern boundary of the UCI salmon management area (Figure 4). The objective of this project has been to estimate the total run of sockeye salmon returning to UCI before these fish reach commercial harvest areas. Annually since 1992, 6 stations have been fished each day in July along the southern OTF transect running west from Anchor Point. These 6 stations were located near the center of the inlet where the majority of salmon typically migrate as they follow tide rips (Figure 4). Beginning in 2006, tissue samples were collected from sockeye salmon harvested in the southern OTF to estimate stock composition using genetics.

In 2012, a northern OTF project was initiated to investigate the spatial and temporal distributions of sockeye and coho salmon in the Central District drift fishery area. Genetic tissue samples were collected from sockeye (2012) and coho (2013–2014) salmon harvested in this test fishery. In 2012–2013, 7 stations were fished along a transect extending across the northern tip of Kalgin Island (Figure 5). Stations were generally located near tide rips which tend to occur where the bottom slope is relatively steep (Burbank 1977), but stations were also located inside and outside of the Expanded Kenai and Kasilof sections. In 2014, the two stations (6 and 7) located west of Kalgin Island and station 1 located on the east side were dropped due to low catches. Instead two transects were fished, one extending across the northern tip of Kalgin Island (same stations as in 2012–2013) and a second extending across the southern tip of Kalgin Island (Figure 5). This transect design was used to investigate whether the spatial and temporal catch per unit effort (CPUE) patterns observed along the northern Kalgin Island transect were consistent across a broader area of the Central District. As in 2012, stations were generally located near tide rips, and stations along the southern and northern Kalgin Island transects were paired to approximately follow the same bathymetric contour—i.e., stations 5 and 8, 4 and 9, 3 and 10, and 2 and 11 (Figure 5). Stations were also located inside and outside of the Expanded Kenai and Kasilof sections, and the southern Kalgin Island transect was positioned just inside the northern boundary of Drift gillnet Area 1.

In this report, we investigate the temporal and spatial distributions of Kenai and Susitna river sockeye salmon and coho salmon (all Cook Inlet stocks combined) in UCI to investigate spatial and temporal opportunities to harvest Kenai River sockeye salmon while minimizing harvests of Susitna River sockeye salmon or coho salmon. We used (1) southern OTF CPUE and sockeye salmon genetic data from 2006–2012, and 2014, and (2) northern OTF CPUE and sockeye salmon genetic data from 2012–2014 (Shields and Willette 2008, 2009a, 2009b, 2010, 2011; Shields et al. 2013; Dupuis and Willette 2014; Dupuis et al. 2015, 2016). Southern OTF data from 2013 were not included in the analysis due to the large number of stations that were not fished. Although coho salmon genetic data were not available for this analysis, Willette et al. (2003) found that 94% of coho salmon radio tagged (n = 729) along the southern OTF transect were later relocated in Northern District streams primarily the Susitna and Little Susitna rivers (56%). We also calculated the ratio of Kenai to Susitna river sockeye salmon CPUEs and the ratio of Kenai River sockeye salmon to coho salmon CPUEs to identify opportunities to harvest Kenai River sockeye salmon while minimizing harvests of the other stocks.

OBJECTIVES

The objectives of this study were to:

1. Evaluate the temporal and spatial distributions of Kenai and Susitna river sockeye salmon and UCI coho salmon CPUEs along the southern (2006–2012 and 2014) and northern (2012–2014) OTF transects,

2. Evaluate the temporal and spatial distributions of the ratio of Kenai to Susitna river sockeye salmon CPUEs along the southern (2006–2012 and 2014) and northern (2012–2014) OTF transects,

3. Evaluate the temporal and spatial distributions of the ratio of Kenai River sockeye salmon to UCI coho salmon CPUEs along the southern (2006–2012, 2014) and northern (2012–2014) OTF transects,
4. Evaluate the mean daily CPUEs pooled across all years for Kenai and Susitna river sockeye salmon and UCI coho salmon along the southern (2006–2012 and 2014) and northern (2012–2014) OTF transects, and
5. Evaluate the mean total CPUEs pooled across all years for Kenai and Susitna river sockeye salmon and UCI coho salmon by station along the southern (2006–2012 and 2014) and northern (2012–2014) OTF transects.

METHODS

Dupuis et al. (2015) provides a detailed description of the methods used in the UCI offshore test fishery project. Briefly, the number of fish captured at each station *s* on each day *i* was expressed as a CPUE statistic that was standardized to the number of fish caught in 100 fathoms of gear in one hour of fishing time:

$$CPUE_{s,i} = \frac{100\,fm \;\times\; 60\,\text{min} \;\times\; number\ of\ fish}{fm\ of\ gear \;\times\; MFT}\,. \tag{1}$$

Mean fishing time (MFT) was:

$$MFT = (C - B) + \frac{(\text{B} - \text{A}) + (\text{D} - \text{C})}{2}\,, \tag{2}$$

where: A = time net deployment started,

B = time net fully deployed,

C = time net retrieval started, and

D = time net fully retrieved.

Once deployed at a station, drift gillnets were fished 30 minutes before retrieval was started. However, the net was capable of capturing fish prior to being fully deployed and when it was being retrieved. MFT was therefore adjusted by summing the total time it took to set and retrieve the net, then dividing this time in half, and adding it to the time when the entire net was deployed and fished (equation 2).

Daily $CPUE_{s,i}$ data were summed for all *m* stations as follows:

$$CPUE_i = \sum_{s=1}^{m} CPUE_{s,i}\,. \tag{3}$$

The left axillary process was removed from sockeye salmon captured at each station on the southern (station $n \le 50$) and northern (station $n \le 75$) OTF transects for later genetic analysis (Habicht et al. 2007). Barclay et al. (2010a) describe the methods used for genetic sample quality control and data retrieval, and Barclay and Habicht (2012) describe the methods used for genetic mixed stock analysis. Genetic sockeye salmon stock proportions were estimated for temporal strata of various lengths each year to achieve a minimum of approximately 400 tissue samples.

Mean stock-specific (*st*) sockeye salmon catch per unit effort statistics ($CPUE_{st}$) were estimated for each temporal stratum in each year for both the southern and northern OTF transects using a simulation model with 10,000 iterations to estimate the mean and variance of $CPUE_{st}$ for each stratum, i.e.

$$CPUE_{st} = \left[\overline{CPUE_{si}} \cdot (sd_{Cstr} \cdot \varepsilon)\right] \cdot \left[P_{str} + (sd_{Pstr} \cdot \varepsilon)\right] \quad (4)$$

where $\overline{CPUE}_{si}$ was the stratum mean sockeye salmon $CPUE_i$ (Shields and Willette 2008, 2009a, 2009b, 2010, 2011; Shields et al. 2013; Dupuis and Willette 2014; Dupuis et al. 2015, 2016), sd_{Cstr} was the standard deviation of $\overline{CPUE}_{si}$, P_{str} was the genetic stock proportion in stratum *str* (Barclay et al. 2010a, 2010b, 2013, 2014, Dupuis et al. 2016), sd_{Pstr} was the standard deviation of P_{str} and ε were random numbers with normal distributions, a mean of zero and a variance of 1 (RANNOR Function, SAS Institute, Cary, NC). The 90% confidence intervals for the mean $CPUE_{st}$ were approximated using the 5th and 95th percentiles of the distribution of $CPUE_{st}$ estimates. $CPUE_{st}$ were natural logarithm transformed before calculating means and percentiles to normalize their distribution (Quinn and Deriso 1999). Mean $CPUE_{st}$ for Susitna River sockeye salmon were estimated by summing P_{str} and their variances for the Judd, Chelatna, and Larson lake (JCL) and other Susitna and Yentna River (SusYen) reporting groups. Mean coho salmon catch per effort statistics and their 90% confidence intervals were estimated for each stratum after natural logarithm transformation as described in Zar (1984). Linear interpolation was first applied to estimate missing $CPUE_{s,i}$ data within each stratum. Stratum mean $CPUE_i$ was used in this analysis rather than stratum $\sum CPUE_i$ to correct for variable stratum lengths. The ratio of mean Kenai to Susitna river sockeye salmon $CPUE_{st}$ and the ratio of mean Kenai River sockeye salmon $CPUE_{st}$ to mean coho salmon CPUE were calculated for each stratum to investigate temporal opportunities to harvest Kenai River sockeye salmon while minimizing harvests of Susitna River sockeye salmon or coho salmon.

Stock-specific mean run timings (all years combined) were next estimated for both the southern and northern OTF transects using a simulation model with 10,000 iterations to estimate the mean and variance of $CPUE_{st}$ for each day in July after pooling data across all years. Daily stock-specific sockeye salmon catch per unit effort statistics ($CPUE_{st,i}$) were estimated within each stratum:

$$CPUE_{st,i} = CPUE_i \cdot \left[P_{str} + (sd_{Pstr} \cdot \varepsilon)\right], \quad (5)$$

where $CPUE_i$ was the total daily sockeye salmon CPUE for each of the days within temporal stratum *str*. $CPUE_{st,i}$ for Susitna River sockeye salmon were estimated by summing P_{str} and their variances for the JCL and SusYen reporting groups. The 90% confidence intervals for mean $CPUE_{st,i}$ were approximated using the 5th and 95th percentiles of the distribution of $CPUE_{st,i}$ estimates. $CPUE_{st,i}$ were natural logarithm transformed before calculating means and percentiles. The simulation model also calculated the ratio of Kenai to Susitna river sockeye salmon $CPUE_{st,i}$ and the ratio of Kenai River sockeye salmon $CPUE_{st,i}$ to coho salmon $CPUE_i$ in each iteration. Mean daily ratios were then calculated after pooling data across years, and the 90% confidence intervals for the mean ratios were approximated using the 5th and 95th percentiles of their distributions. Mean daily coho salmon $CPUE_i$ were estimated using the simulation model after pooling data across years, and the 90% confidence intervals for the mean $CPUE_i$ were approximated using the 5th and 95th percentiles of their distributions.

Since mean run timing estimated using $CPUE_{st,i}$ could be biased due to the relative magnitude of CPUEs among years, run timing was also estimated by calculating $CPUE_{st,i}$ for each year separately and then dividing by the total annual $CPUE_{st,i}$, i.e.,

$$PCPUE_{st,i} = \frac{CPUE_{st,i}}{\sum_{i=1}^{30} CPUE_{st,i}}, \tag{6}$$

where $PCPUE_{st,i}$ was the estimated mean daily run proportion for a given stock. The mean and variance of the simulated daily $PCPUE_{st,i}$ were then estimated as described above with all years pooled. The mean mid-point of the run for each stock was estimated from the cumulative mean $PCPUE_{st,i}$. The same methods were used to estimate the mean run timing of coho salmon ($PCPUE_i$).

Total stock-specific catch per unit effort statistics ($CPUE_{st,s}$) for each station were used to describe spatial distributions of Kenai and Susitna river sockeye salmon in each year:

$$CPUE_{st,s} = \sum_{i=1}^{30} CPUE_{s,i} \cdot P_s, \tag{7}$$

where P_s was the genetic stock proportion for each station. The 90% credibility intervals on $CPUE_{st,s}$ were estimated by multiplying the genetic stock proportion 90% credibility intervals by the $CPUE_{st,s}$ for each station. Spatial distributions of coho salmon in each year were also described using station total catch per unit effort statistics. Ratios of Kenai to Susitna river sockeye salmon $CPUE_{st,s}$ and Kenai River sockeye salmon $CPUE_{st,s}$ to total coho salmon CPUE were also calculated by station in each year.

Mean stock-specific distributions of Kenai and Susitna river sockeye salmon along the southern and northern OTF transects were also estimated using a simulation model with 10,000 iterations to estimate the mean and variance of $CPUE_{st,s}$ after pooling data across all years. Total stock-specific sockeye salmon catch per unit effort statistics ($CPUE_{st,s}$) were estimated for each station:

$$CPUE_{st,s} = \sum_{i=1}^{30} CPUE_{s,i} \cdot \left[P_s + (sd_s \cdot \varepsilon)\right], \tag{8}$$

where sd_s was the standard deviation of P_s. The 90% confidence intervals for mean $CPUE_{st,s}$ were approximated using the 5th and 95th percentiles of the distribution of $CPUE_{st,s}$ estimates. Only data from stations 1–5 sampled in 2012–2013, as well as data from comparable stations (i.e., stations 5 and 8, 4 and 9, 3 and 10, and 2 and 11) sampled along the upper and lower Kalgin Island transects in 2014 were included in this analysis (Figure 5). $CPUE_{st,s}$ were natural logarithm transformed before calculating means and percentiles. The simulation model also calculated the ratio of total Kenai to Susitna river sockeye salmon $CPUE_{st,s}$ and the ratio of total Kenai River sockeye salmon $CPUE_{st,s}$ to total coho salmon CPUE in each iteration. Mean station ratios were then calculated after pooling data across years and the 90% confidence intervals for the mean ratios were approximated using the 5th and 95th percentiles of their distributions. Mean coho salmon CPUE were estimated after pooling data across years, and the 90% confidence intervals for the mean CPUE were approximated using the 5th and 95th percentiles of their distributions.

RESULTS

SOUTHERN OTF

Across Time

Mean Susitna River sockeye salmon $CPUE_{st}$ along the southern OTF transect peaked between July 5 and 18 in all years except in 2006 and 2012 when it peaked between July 17 and 23 (Figure 6). Mean daily Susitna River sockeye salmon $CPUE_{st,i}$ pooled across all years (Figure 7) and mean daily run proportions ($PCPUE_{st,i}$) peaked between July 10 and 17 (Figure 8). The mean date of the Susitna River sockeye salmon run across the southern transect was July 14 (Figure 9). Mean Kenai River sockeye salmon $CPUE_{st}$ peaked between July 8 and 18 in all years except 2006 and 2012 (Figure 10) when CPUEs peaked between July 24–31 and July 17–19, respectively. Mean daily Kenai River sockeye salmon $CPUE_{st,i}$ pooled across all years (Figure 7) and mean daily run proportions ($PCPUE_{st,i}$) peaked between July 13 and 17 (Figure 8). The mean date of the Kenai River sockeye salmon run was July 17 (Figure 9). Mean coho salmon $CPUE_i$ peaked after July 17 in all years except 2008 and 2010, when it peaked the week prior (Figure 11). Mean daily coho salmon $CPUE_i$ pooled across all years (Figure 7) and mean daily run proportions ($PCPUE_i$) increased steadily throughout July (Figure 8). The mean date of the coho salmon run was July 21 (Figure 9).

The ratios of mean Kenai to Susitna river sockeye salmon $CPUE_{st}$ generally increased after July 10 except in 2014 (Figure 12), and the mean daily ratios pooled across all years increased steadily after July 10 (Figure 7). The ratios of mean Kenai River sockeye salmon $CPUE_{st}$ to mean coho salmon $CPUE_i$ generally decreased throughout July except in 2006 (Figure 13), and the mean daily ratios pooled across all years also decreased throughout July (Figure 7).

Across Stations

Total Susitna River sockeye salmon $CPUE_{st,s}$ were generally highest at stations 6 or 6.5 in 2009-2010 and 2012 (Figure 14), and mean total $CPUE_{st,s}$ pooled across all years were also highest at stations 6 and 6.5 (Figure 15). Total Kenai River sockeye salmon $CPUE_{st,s}$ were generally highest at stations 6 or 6.5 in 2010–2014 (Figure 16), and mean total $CPUE_{st,s}$ pooled across all years were also highest at stations 6 and 6.5 (Figure 15). Total coho salmon CPUE were highest at stations 5, 6 or 6.5 in all years except 2011, when the highest CPUE was at station 7 (Figure 17), and mean total coho salmon CPUE pooled across all years were highest at station 6.5 (Figure 15).

Ratios of total Kenai to Susitna river sockeye salmon $CPUE_{st,s}$ exhibited no consistent pattern along the southern OTF transect (Figures 15 and 18). Ratios of total Kenai River sockeye salmon $CPUE_{st,s}$ to total coho salmon CPUE tended to be higher along the eastern end of the transect (Figure 19), and the mean ratios pooled across all years were highest at stations 4 and 5 (Figure 15).

NORTHERN OTF

Although the northern OTF project sampled two transects in 2014 (Figure 5), it will be referred to as simply the northern OTF transect, because CPUE patterns were similar between the upper and lower Kalgin Island transects.

Across Time

Stratum mean Susitna River sockeye salmon $CPUE_{st}$ peaked between July 14 and 20 along the northern OTF transect in 2012–2014 (Figure 20). Mean daily Susitna River sockeye salmon $CPUE_{st,i}$ pooled across all years (Figure 21) and mean daily run proportions ($PCPUE_{st,i}$) peaked on July 14 (Figure 22). The mean date of the Susitna River sockeye salmon run across the northern transect was July 15 (Figure 23). Stratum mean Kenai River sockeye salmon $CPUE_{st}$ peaked between July 14 and 24 in 2012–2014 (Figure 20). Mean daily Kenai River sockeye salmon $CPUE_{st,i}$ pooled across all years (Figure 21) and mean daily run proportions ($PCPUE_{st,i}$) peaked on July 14 (Figure 22). The mean date of the Kenai River sockeye salmon run was July 16 (Figure 23). Stratum mean coho salmon $CPUE_i$ peaked between July 26–30 in 2012, July 14–15 in 2013 and July 21–24 in 2014 (Figure 20). Mean daily coho salmon $CPUE_i$ pooled across all years (Figure 21) and mean daily run proportions ($PCPUE_i$) generally increased after July 12 (Figure 22). The mean date of the coho salmon run was July 23 (Figure 23).

The ratios of stratum mean Kenai to Susitna river sockeye salmon $CPUE_{st}$ generally increased throughout July (Figure 24), and the mean daily ratios pooled across all years also increased after July 15 (Figure 21). The ratios of stratum mean Kenai River sockeye salmon $CPUE_{st}$ to mean coho salmon $CPUE_i$ decreased throughout July in 2012 and 2014 but not in 2013 (Figure 24), and the mean daily ratios pooled across all years peaked July 13–14 (Figure 21).

Across Stations

Total Susitna River sockeye salmon $CPUE_{st,s}$ were highest at stations 4 in 2012, stations 3–5 in 2013 and stations 3 and 10 and 4 and 9 in 2014 (Figure 25). Mean total Susitna River sockeye salmon $CPUE_{st,s}$ pooled across all years were highest at stations 3–4 (Figure 26). Total Kenai River sockeye salmon $CPUE_{st,s}$ were highest at stations 3–4 in 2012, station 3 in 2013 and stations 3 and 10 and 4 and 9 in 2014 (Figure 25). Mean Kenai River sockeye salmon $CPUE_{st,s}$ pooled across all years were also highest at stations 3–4 (Figure 26). Total coho salmon CPUE were highest at stations 3–4 in 2012, station 5 in 2013 and stations 5 and 8 in 2014 (Figure 25). Mean total coho salmon CPUE pooled across all years were highest at stations 4–5 (Figure 26).

The ratios of total Kenai to Susitna river sockeye salmon $CPUE_{st,s}$ were generally greater on the eastern side of the transect in all years (Figure 27), and the mean ratios pooled across all years were highest at stations 1–2 (Figure 26). The ratios of Kenai River sockeye salmon $CPUE_{st,s}$ to coho salmon CPUE were also highest on the eastern end of the transect in all years (Figure 27), and the mean ratios pooled across all years were highest at stations 1–2 (Figure 26).

DISCUSSION

Although temporal and spatial patterns of CPUE varied considerably among years and variances on mean CPUEs were high, some patterns were consistent between the southern and northern OTF transects. Mean daily $CPUE_{st,i}$ and mean daily run proportions pooled across all years exhibited very similar temporal patterns between the southern and northern OTF transects. Along both transects mean daily Susitna River sockeye salmon $CPUE_{st,i}$ peaked July 10–17, but the run was more compressed along the northern transect (Figures 7 and 21). Mean daily Kenai River sockeye salmon $CPUE_{st,i}$ exhibited a similar pattern with peak CPUEs occurring July 13-17 along both transects, and the run was more compressed along the northern transect. The mean dates of the Susitna and Kenai river sockeye salmon runs also differed by only one day between the two transects (Figures 9 and 23) despite the fact that samples were collected along the southern transect in 6 years (2006–2011) when the northern transect was not sampled. Mean daily coho salmon $CPUE_i$ also exhibited similar temporal patterns between the two transects with an increase in mean $CPUE_i$ after July 12 (Figures 7 and 21), and the mean date of the run differed by only 2 days between the two transects (Figures 9 and 23).

Temporal patterns of mean daily ratios of Kenai to Susitna river sockeye salmon $CPUE_{st,i}$ were similar between the two transects with ratios generally exceeding 10:1 after about July 20 (Figures 7 and 21). Higher Kenai to Susitna river $CPUE_{st,i}$ ratios after July 20 were due to a more prolonged Kenai River run compared to Susitna River. Temporal patterns of mean daily ratios of Kenai River sockeye salmon $CPUE_{st,i}$ to coho salmon $CPUE_i$ differed between the two transects with ratios generally exceeding 10:1 prior to July 11 along the southern transect and prior to July 18 along the northern transect (Figures 7 and 21), but CPUE ratios generally declined below 10:1 along both transects after July 20. These temporal CPUE patterns indicate that in general Kenai River sockeye salmon may be harvested at a higher rate compared to Susitna River sockeye salmon after July 20, but harvest rates on coho salmon will also be higher during this period.

Comparisons of spatial patterns of CPUE between the two transects were less clear in part due to the relatively close spacing of stations along the southern transect. However, mean total Kenai and Susitna river sockeye salmon $CPUE_{st,s}$ were highest near the center of both transects, but mean total coho salmon CPUEs were highest near the center of the southern transect and on the western end of the northern transect (Figures 15 and 26).

Mean ratios of Kenai to Susitna river sockeye salmon $CPUE_{st,s}$ exhibited no clear spatial pattern along the southern transect, but the mean ratio exceeded 10:1 on the eastern end of the northern transect (Figures 15 and 26). Mean ratios of Kenai River sockeye salmon $CPUE_{st,s}$ to coho salmon CPUE exceeded 10:1 on the eastern end of both transects with the pattern more pronounced along the northern transect (Figures 15 and 26). Lower mean ratios of Kenai River sockeye salmon to coho salmon CPUEs along the western end of the northern transect were due to the more westward distribution of coho salmon along this transect. These spatial CPUE patterns indicate that in general Kenai River sockeye salmon may be harvested at a higher rate compared to Susitna River sockeye salmon and coho salmon along the eastern side of Cook Inlet, but harvest rates on Kenai River sockeye salmon would be highest near the center of the inlet.

The temporal and spatial mean CPUE patterns described here would not be expected to be consistent from year to year due to changes in run timings and run-entry patterns of various salmon stocks. However, these results provide a preliminary description of the general spatial and temporal distributions of major sockeye and coho salmon stocks migrating through the Central District. Additional years of sampling will be needed to better estimate stock-specific spatial and temporal distributions and their variability.

ACKNOWLEDGEMENTS

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FIGURES

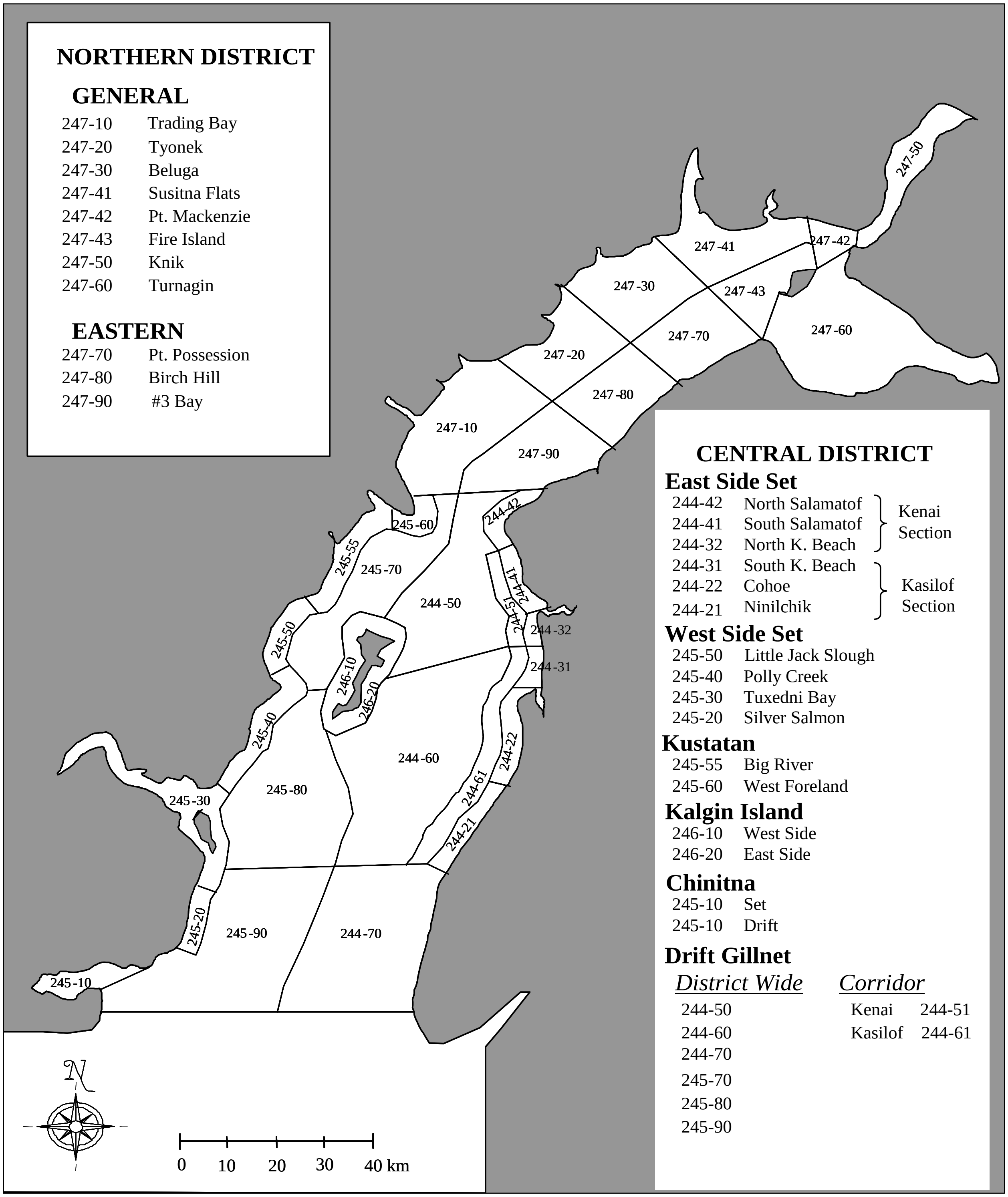

Figure 1.–Fishery districts and subdistricts in the Upper Cook Inlet management area.

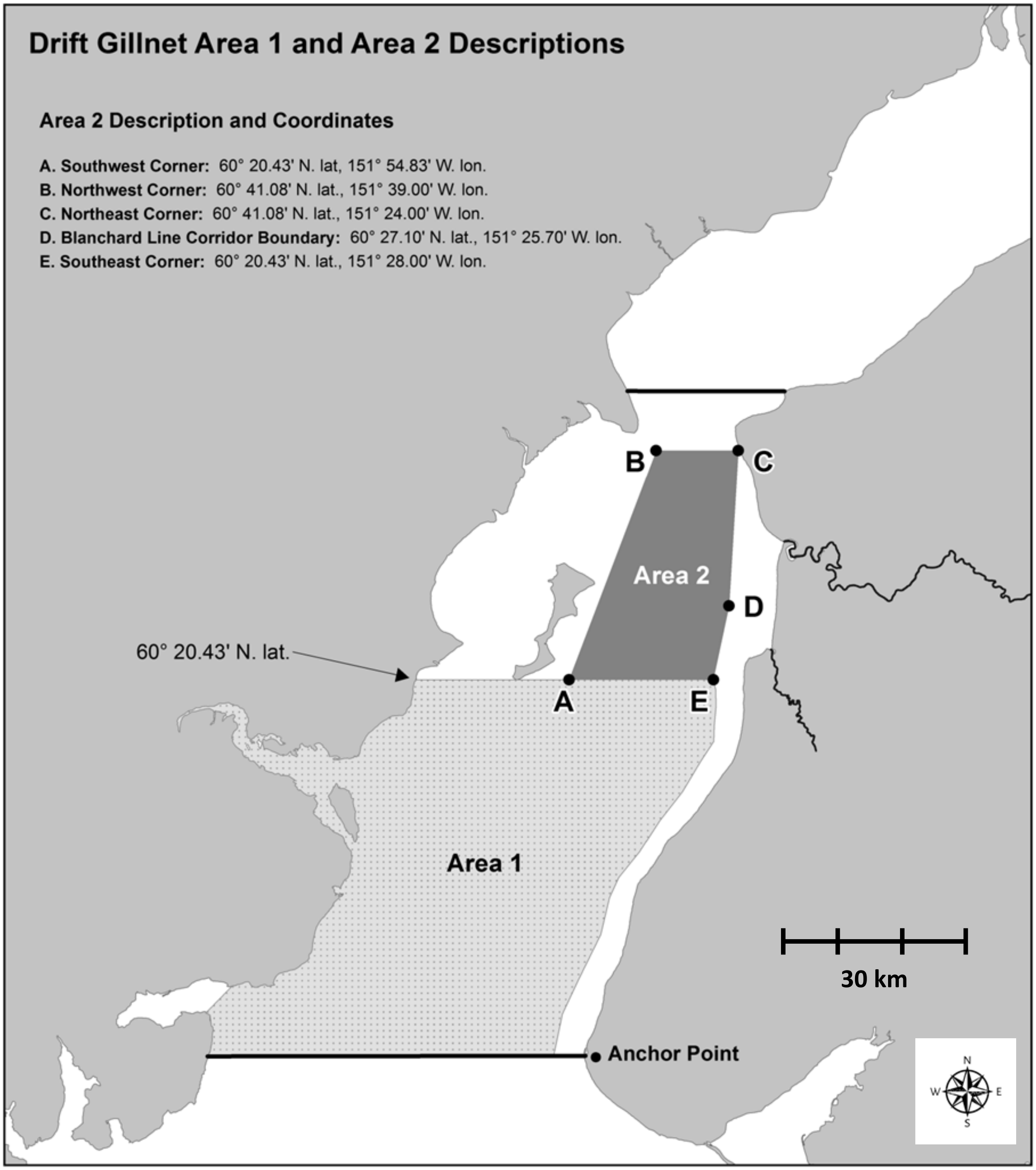

Figure 2.–Boundaries of the drift gillnet fishery management areas 1 and 2.

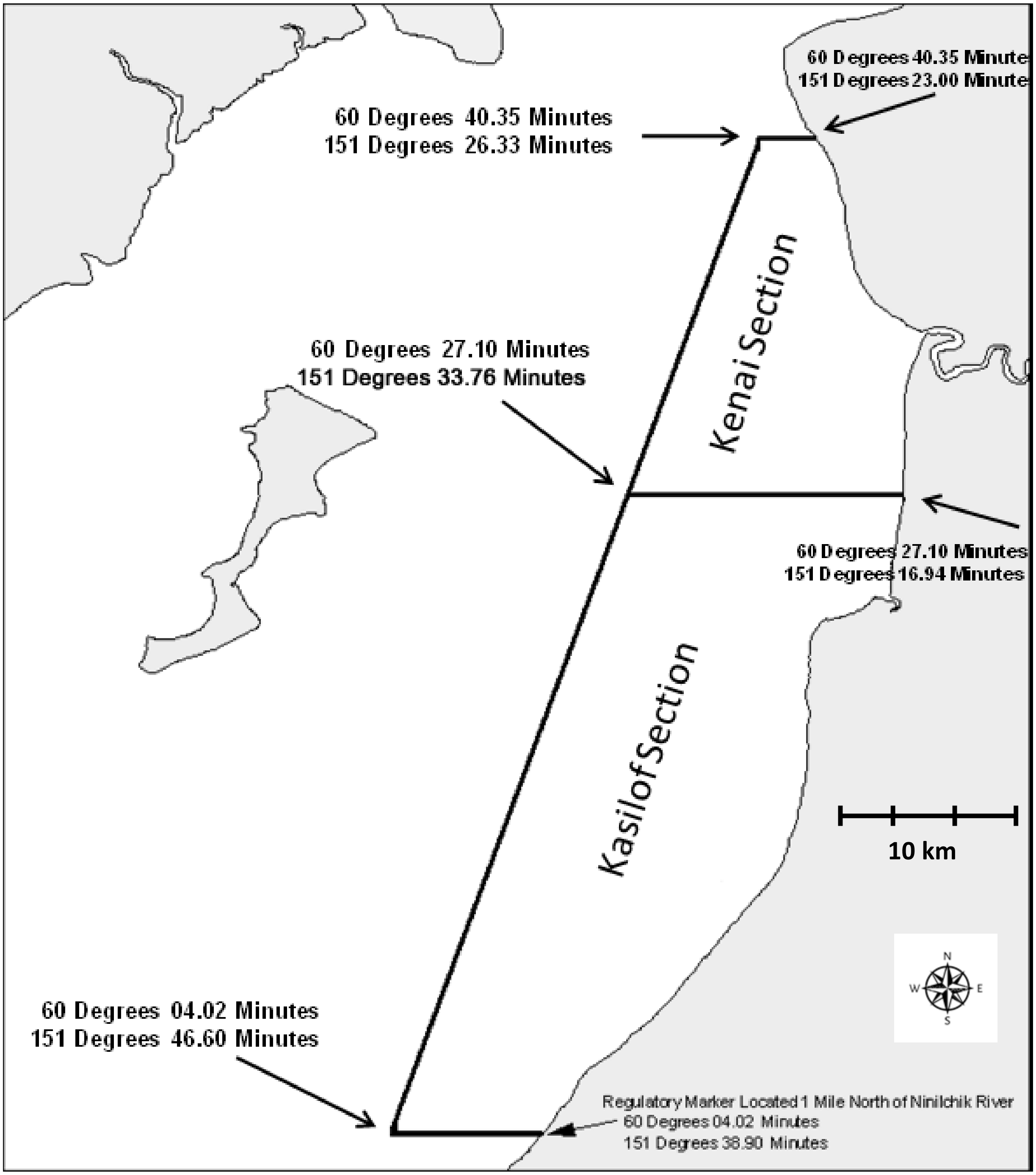

Figure 3.–Boundaries of the drift gillnet fishery expanded Kenai and Kasilof sections.

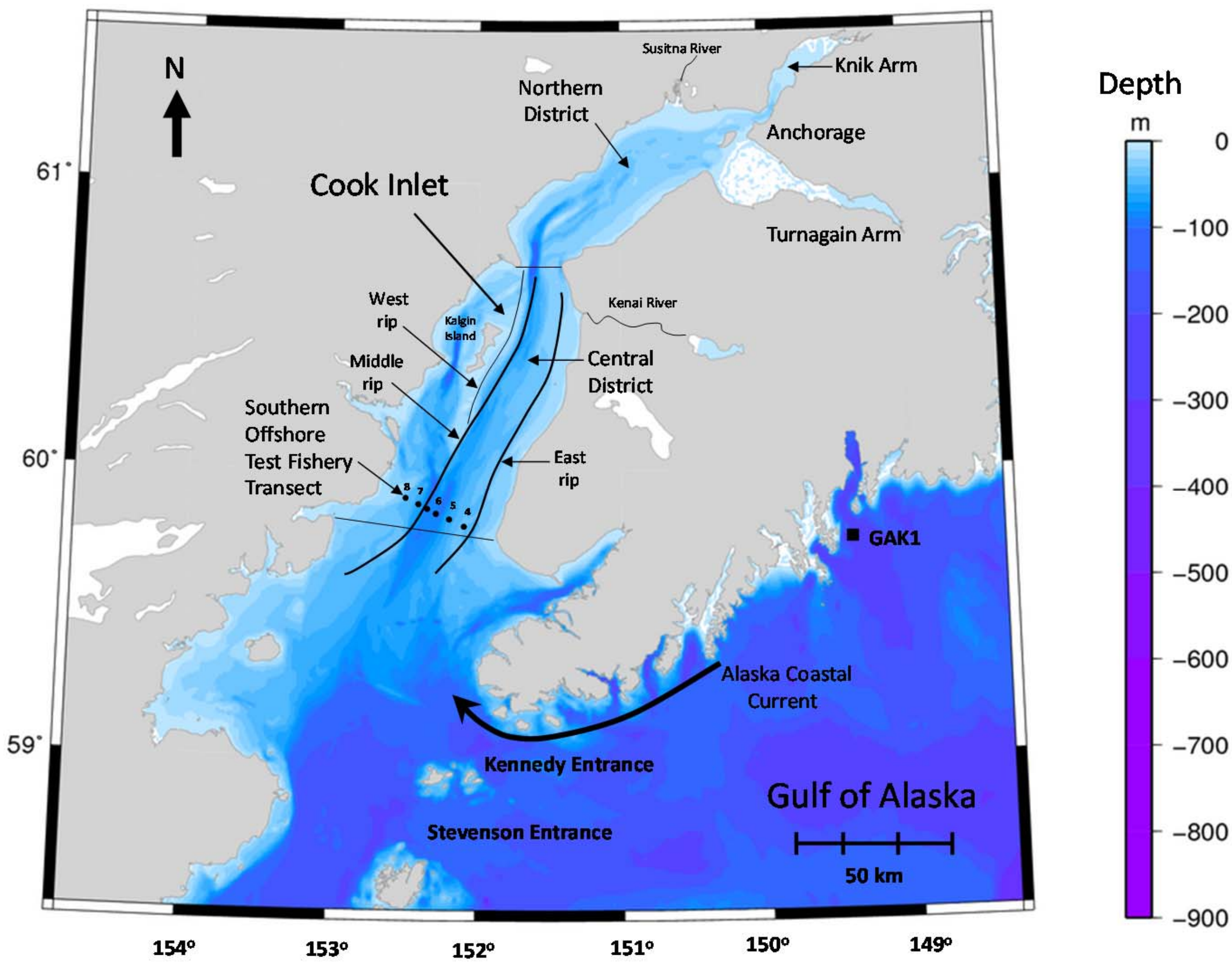

Figure 4.–Bathymetry and major tide rips in Upper Cook Inlet and locations of stations along the southern offshore test fishery transect.

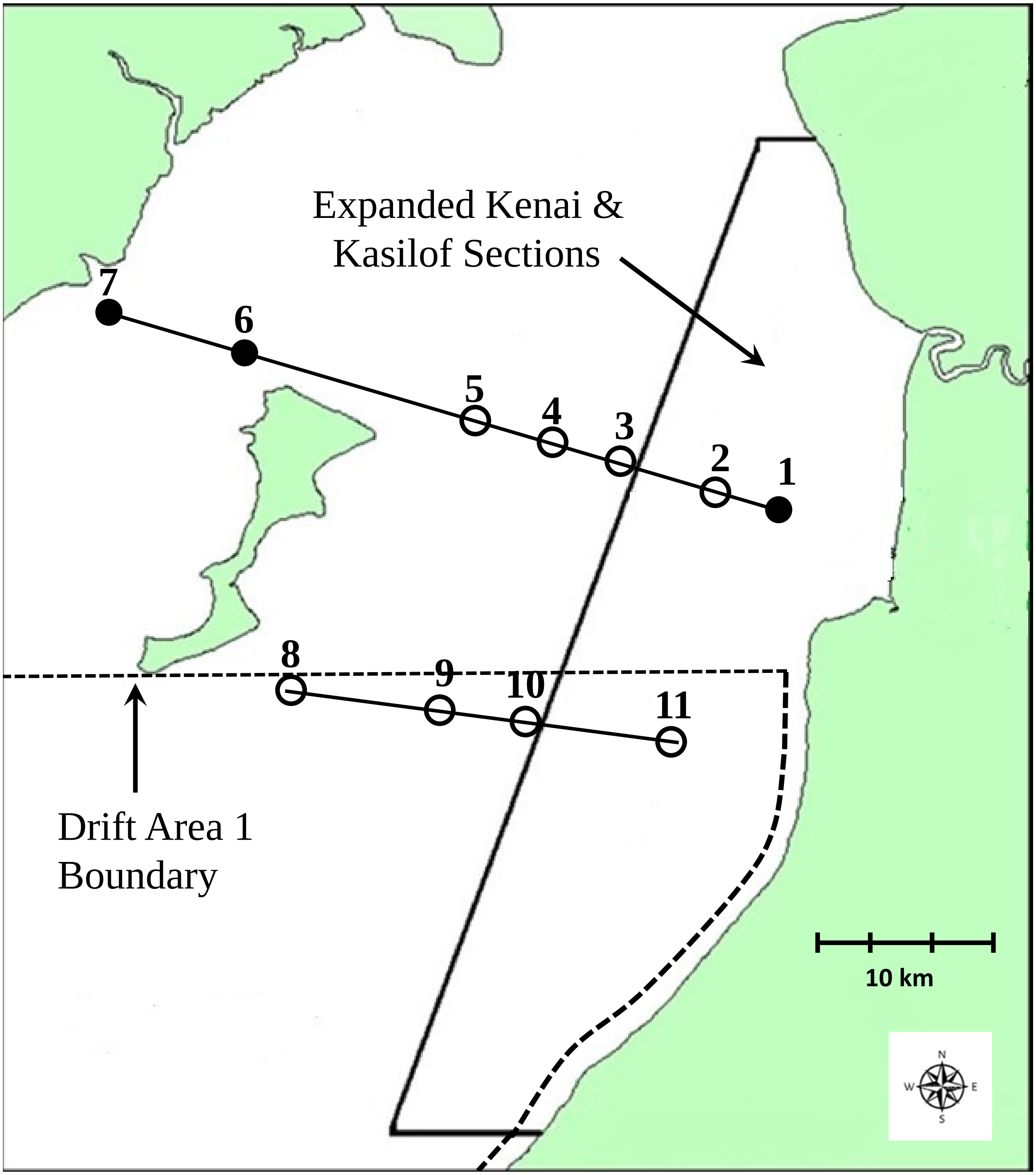

Figure 5.–Locations of stations fished by the northern offshore test fishery vessel and locations of the boundaries of the expanded Kenai and Kasilof sections and drift gillnet area 1.

Note: Stations 1–7 were fished in 2012–2013 and stations 2–5 and 8–11 were fished in 2014 (open circles). The expanded Kenai and Kasilof sections are represented by the solid line and drift gillnet area 1 by the dashed line.

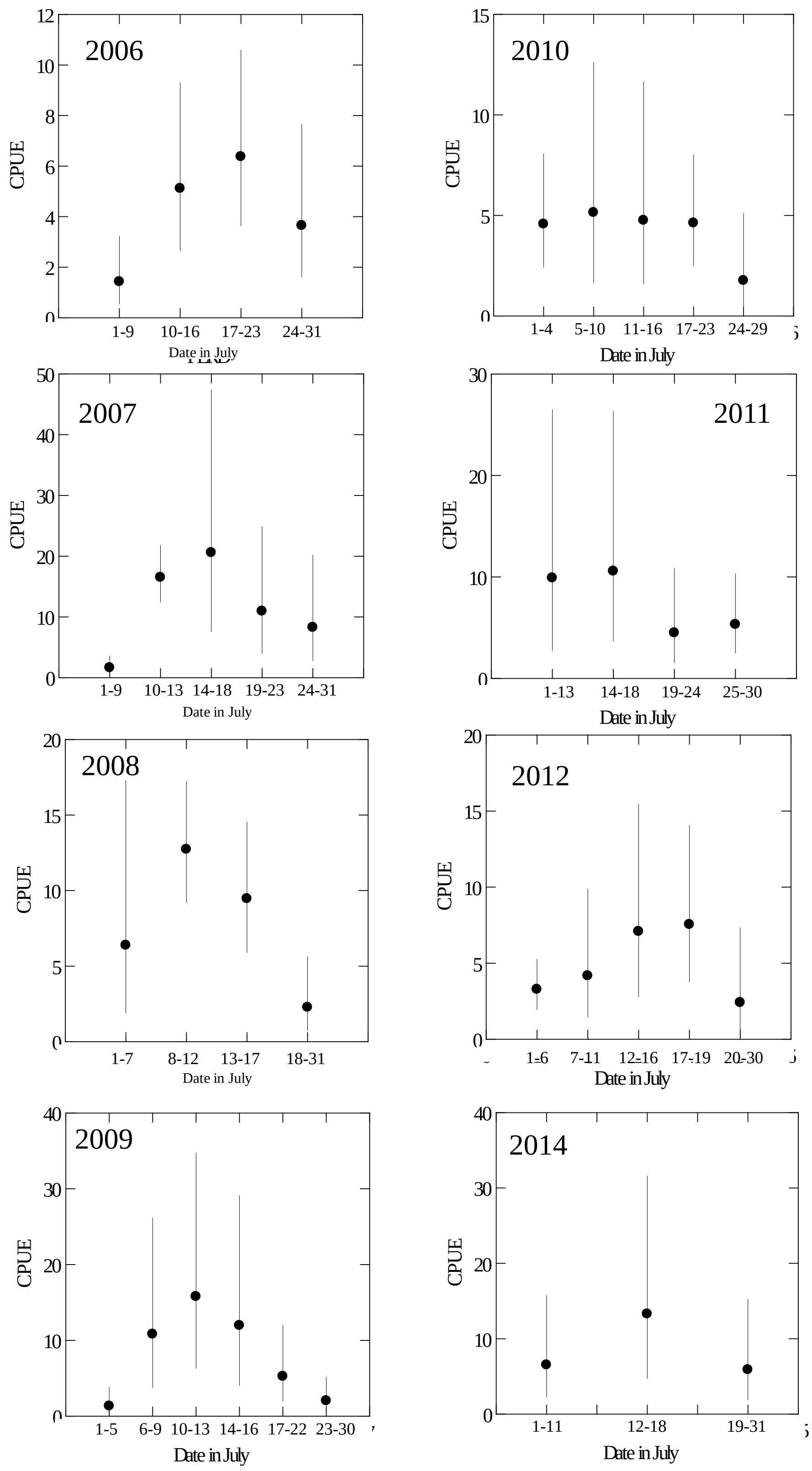

Figure 6.–Mean Susitna River sockeye salmon catch per unit effort ($CPUE_{st}$) by date stratum along the southern OTF transect, 2006–2012 and 2014.

Note: Vertical bars indicate 90% confidence intervals.

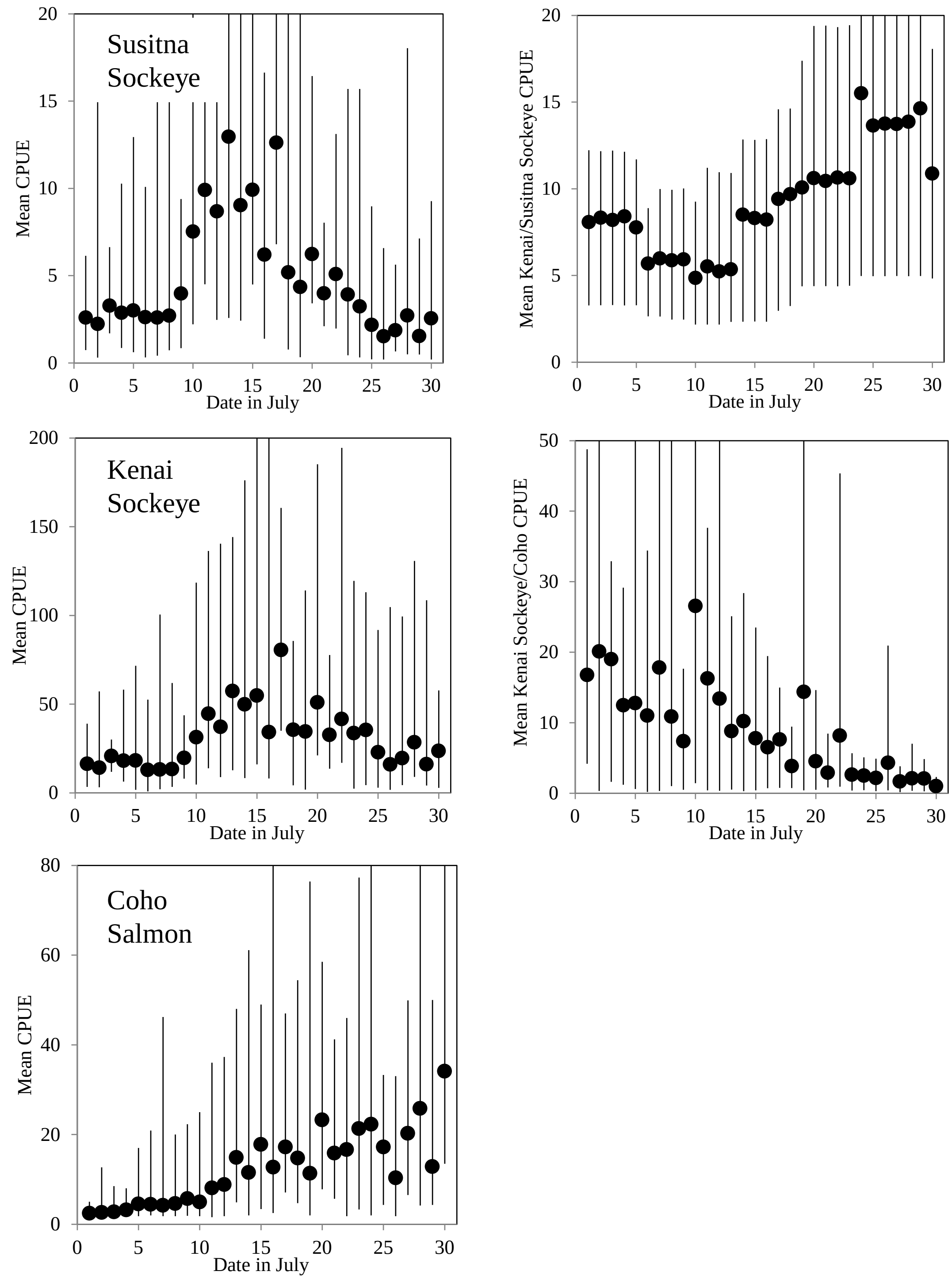

Figure 7.–Mean daily catch per unit effort ($CPUE_{st,i}$) for Kenai and Susitna river sockeye salmon and mean daily coho salmon $CPUE_i$ pooled across all years (2006–2012 and 2014) along the southern OTF transect (left panel).

Note: Mean daily ratios of Kenai to Susitna river sockeye salmon $CPUE_{st,i}$ and mean daily ratios of Kenai River sockeye salmon $CPUE_{st,i}$ to mean daily coho salmon $CPUE_i$ are shown in the right panel. Vertical bars indicate 90% confidence intervals.

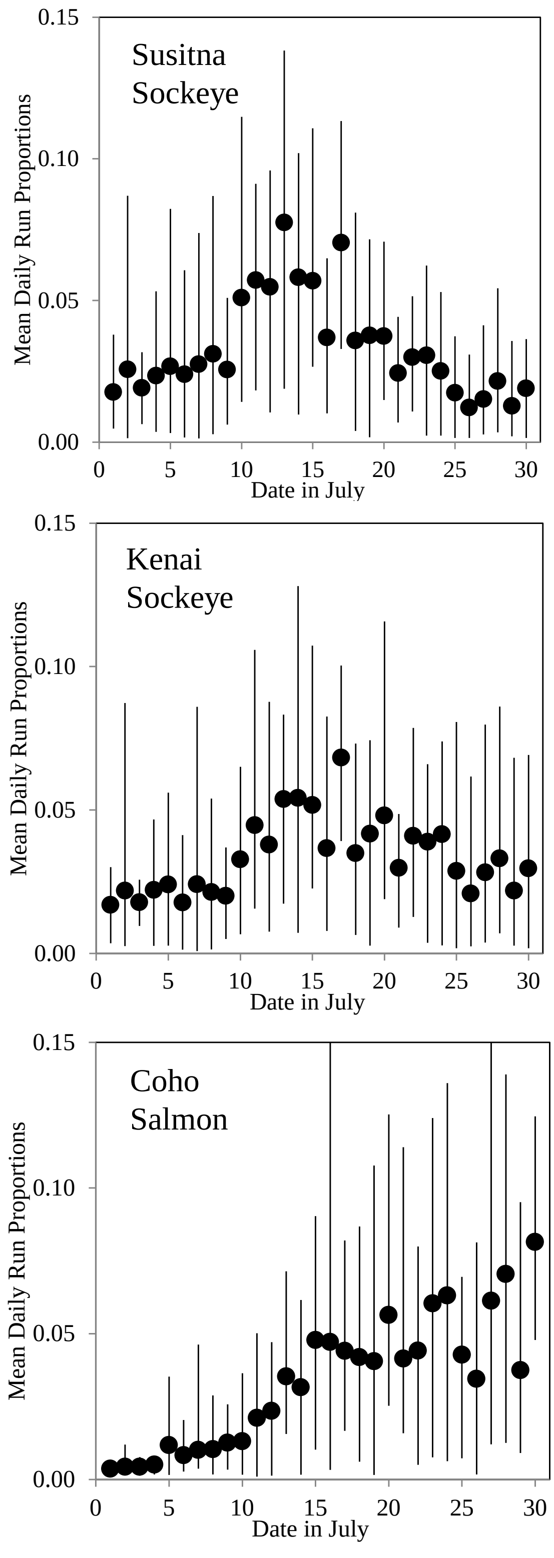

Figure 8.–Mean daily run proportions ($PCPUE_{st,i}$) for Kenai and Susitna river sockeye salmon and coho salmon ($PCPUE_i$) pooled across all years (2006–2012 and 2014) along the southern OTF transect.

Note: Vertical bars indicate 90% confidence intervals.

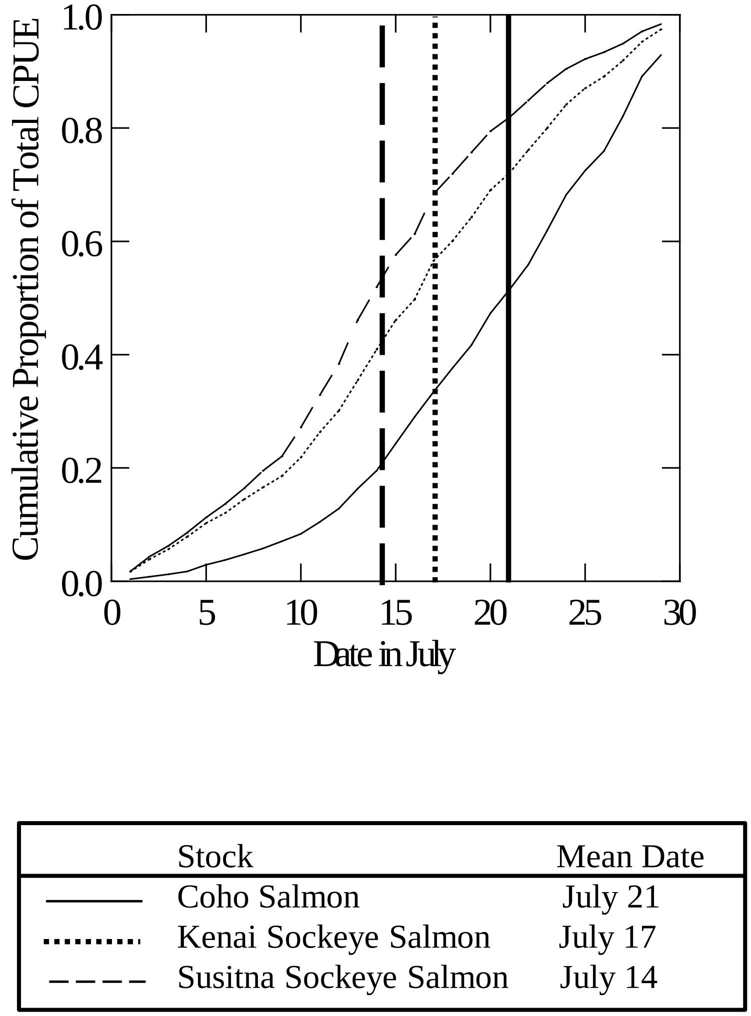

Figure 9.–Mean cumulative proportion of total $PCPUE_{st,i}$ for Kenai and Susitna river sockeye salmon and coho salmon $PCPUE_i$ pooled across all years (2006–2012 and 2014) along the southern OTF transect.

Note: Vertical lines indicate the mean date of the runs for each stock.

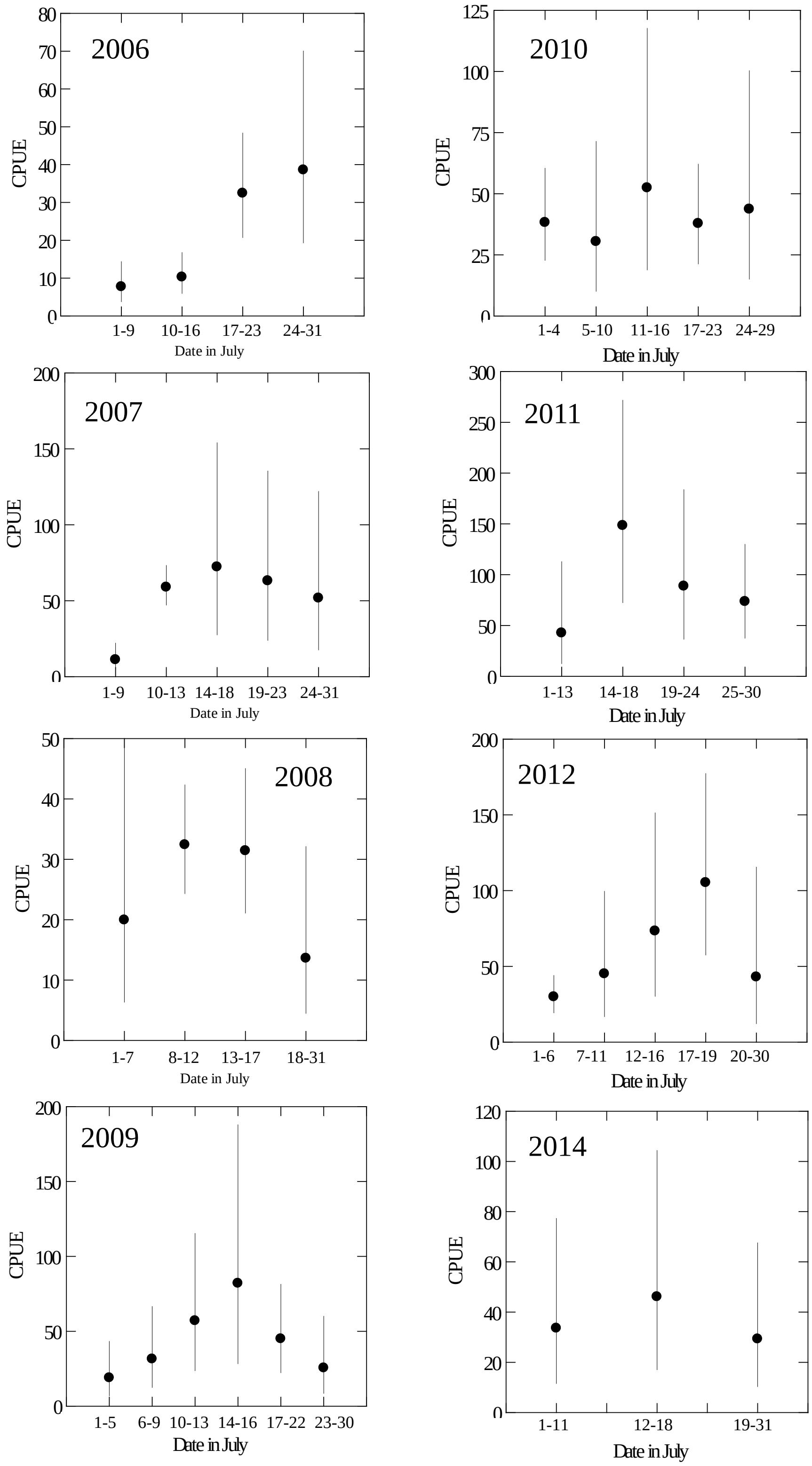

Figure 10.–Mean Kenai River sockeye salmon catch per unit effort ($CPUE_{st}$) by date stratum along the southern OTF transect, 2006–2012 and 2014.

Note: Vertical bars indicate 90% confidence intervals.

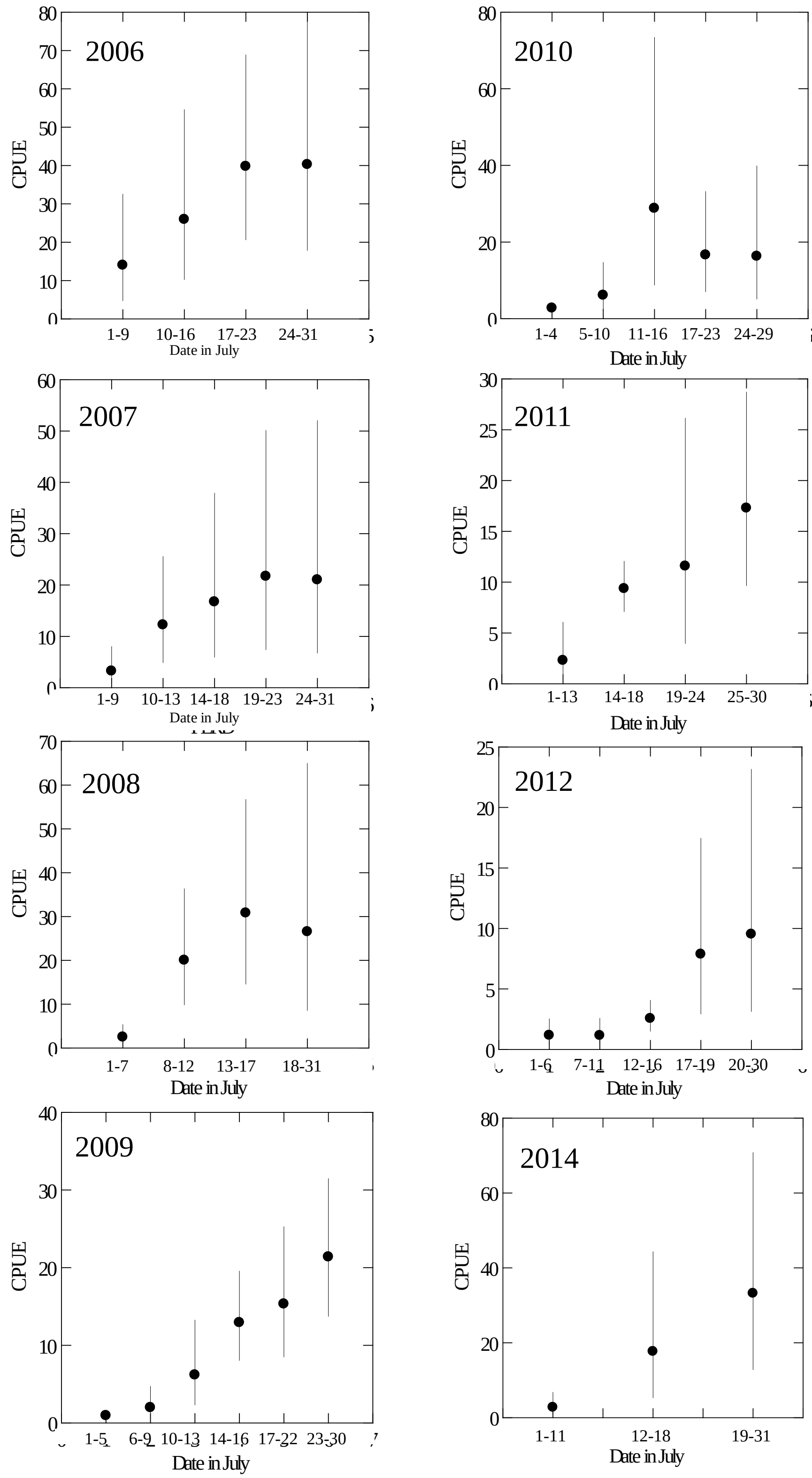

Figure 11.–Mean coho salmon catch per unit effort by date stratum along the southern OTF transect, 2006–2012 and 2014.

Note: Vertical bars indicate 90% confidence intervals.

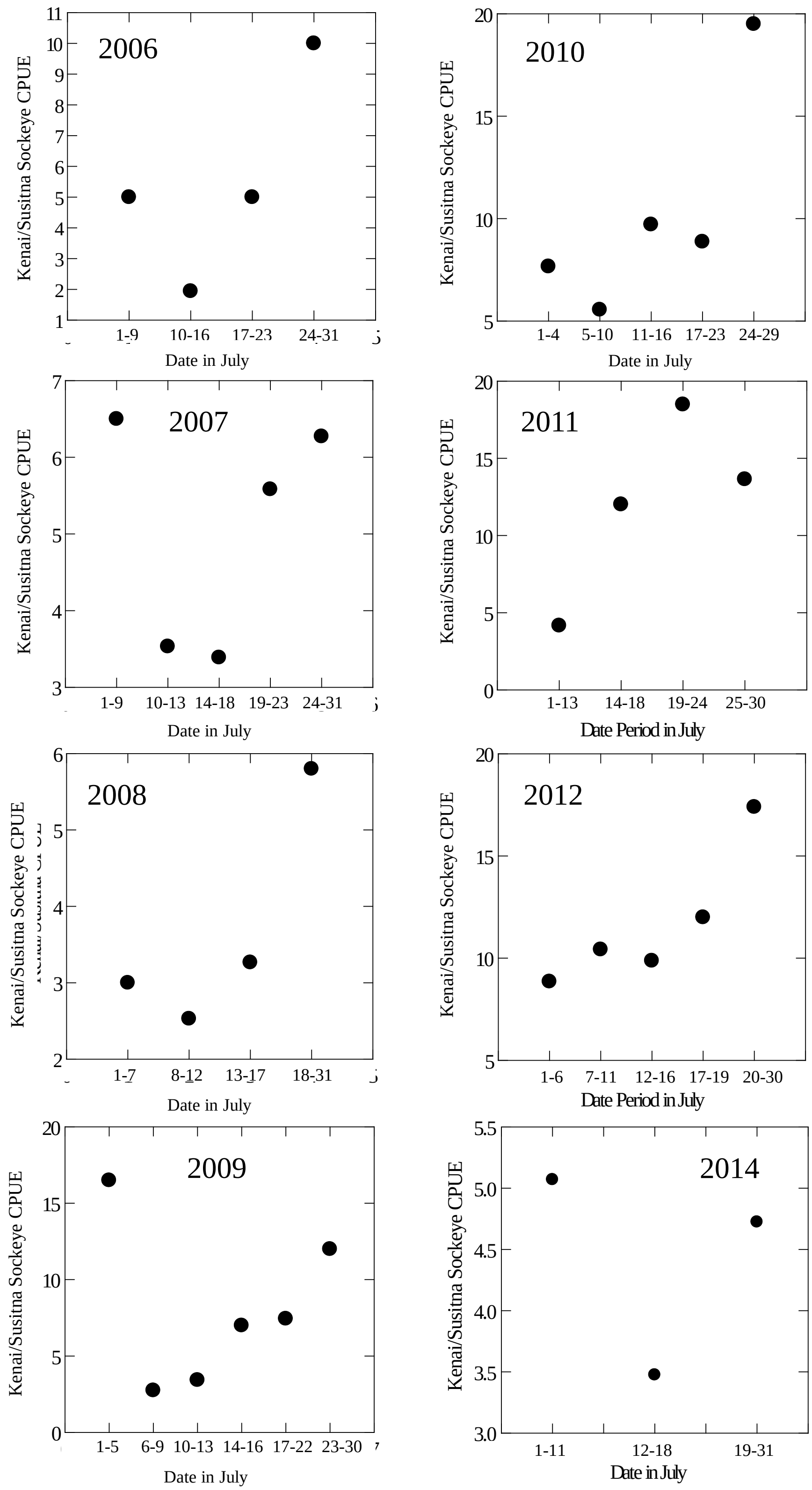

Figure 12.–Ratios of mean Kenai to Susitna river sockeye salmon $CPUE_{st}$ by date stratum along the southern OTF transect, 2006–2012 and 2014.

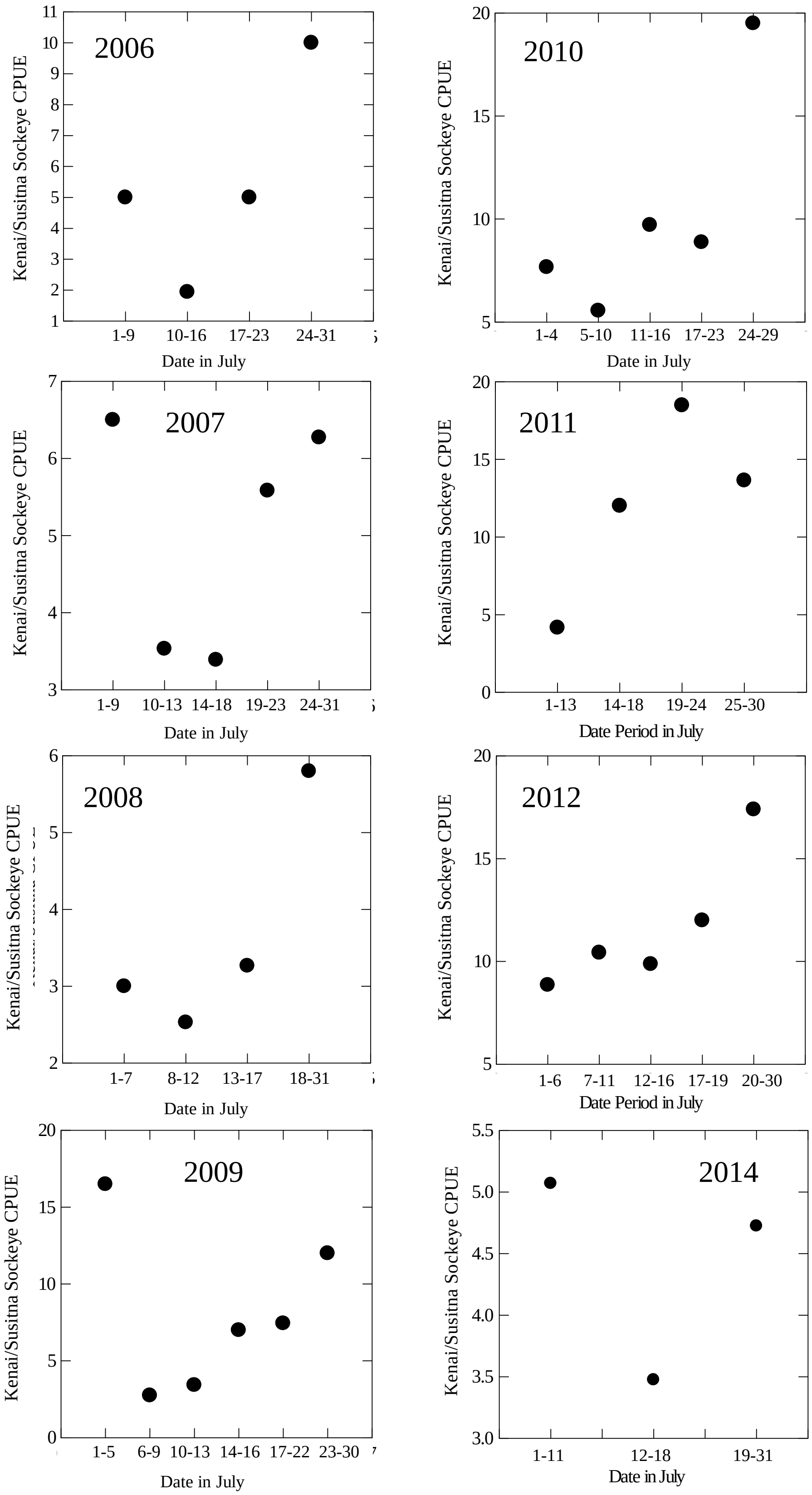

Figure 13.–Ratios of mean Kenai River sockeye salmon $CPUE_{st}$ to mean coho salmon $CPUE_i$ by date stratum along the southern OTF transect, 2006–2012 and 2014.

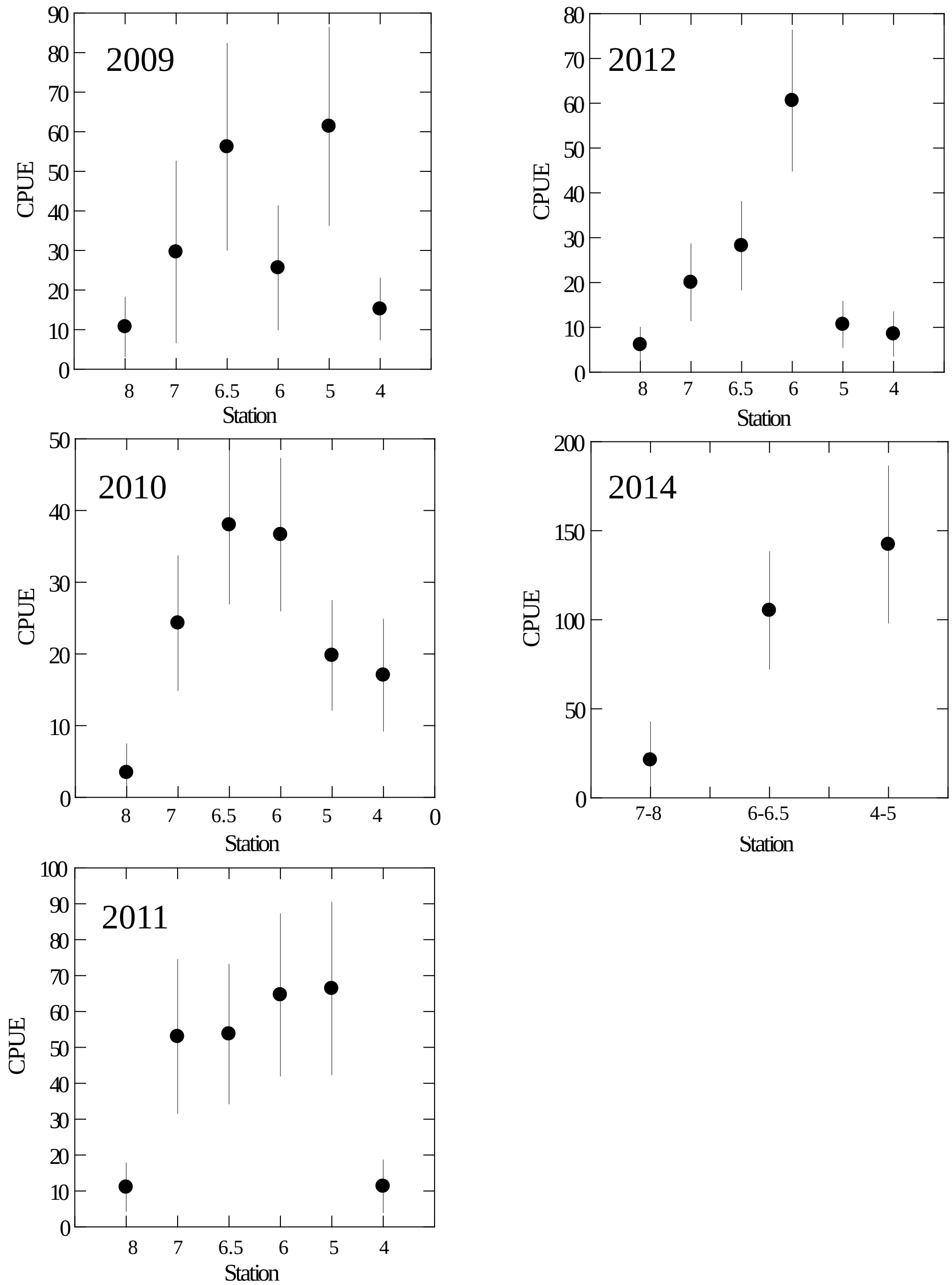

Figure 14.–Total Susitna River sockeye salmon catch per unit effort ($CPUE_{st}$) by station along the southern OTF transect, 2009–2012 and 2014.

Note: In 2014, genetic stock proportions were estimated by pooling adjacent stations. Vertical bars indicate 90% credibility intervals.

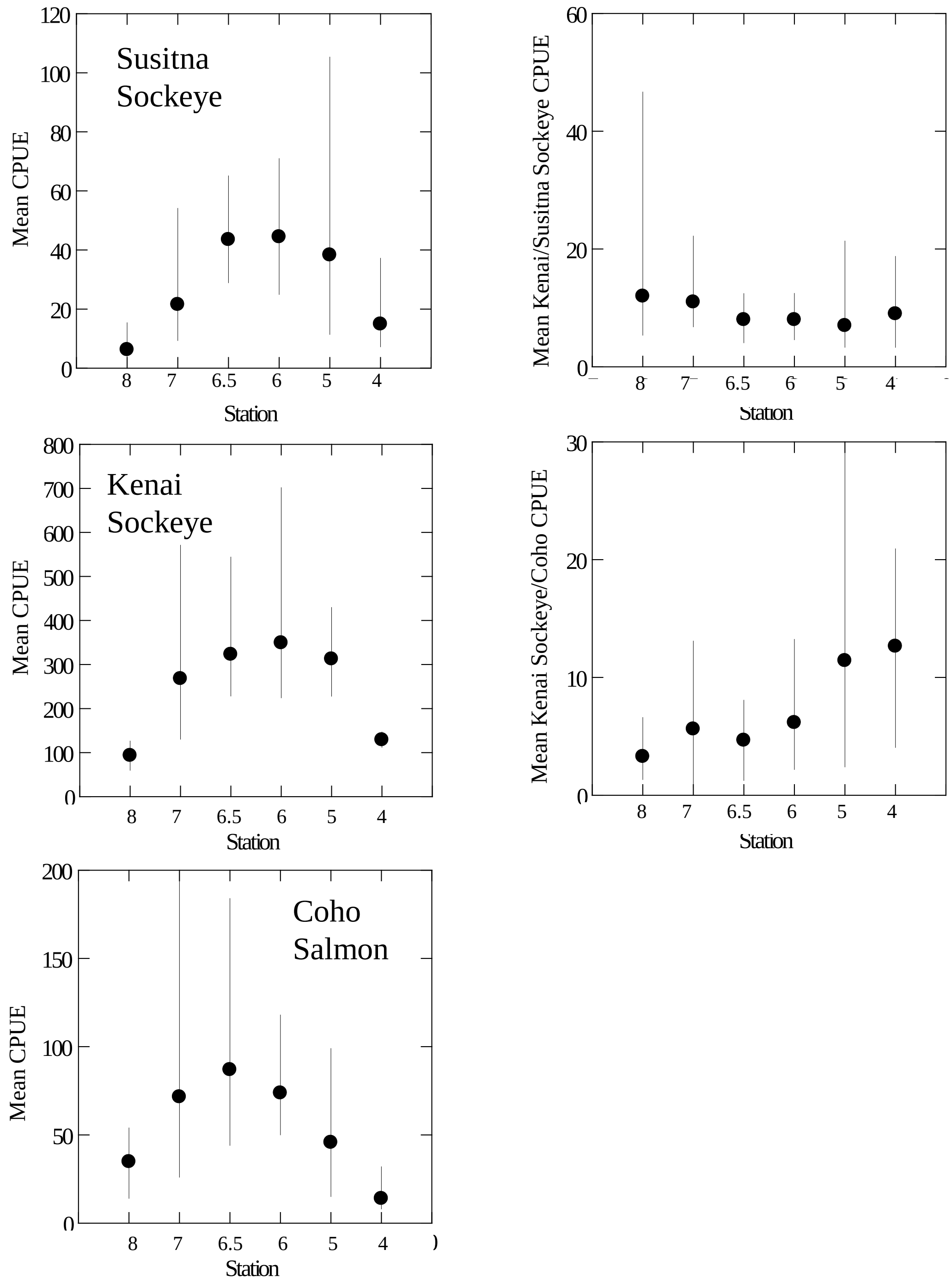

Figure 15.–Mean total Kenai and Susitna river sockeye salmon catch per unit effort ($CPUE_{st,s}$) and mean total coho salmon CPUE pooled across all years (2006–2012, 2014) by station along the southern OTF transect (left panel).

Note: Mean ratios of total Kenai to Susitna river sockeye salmon $CPUE_{st,s}$ and mean ratios of total Kenai River sockeye salmon $CPUE_{st,s}$ to total coho salmon CPUE pooled across all years (2006–2012 and 2014) by station along the southern OTF transect (right panel). Vertical bars indicate 90% confidence intervals.

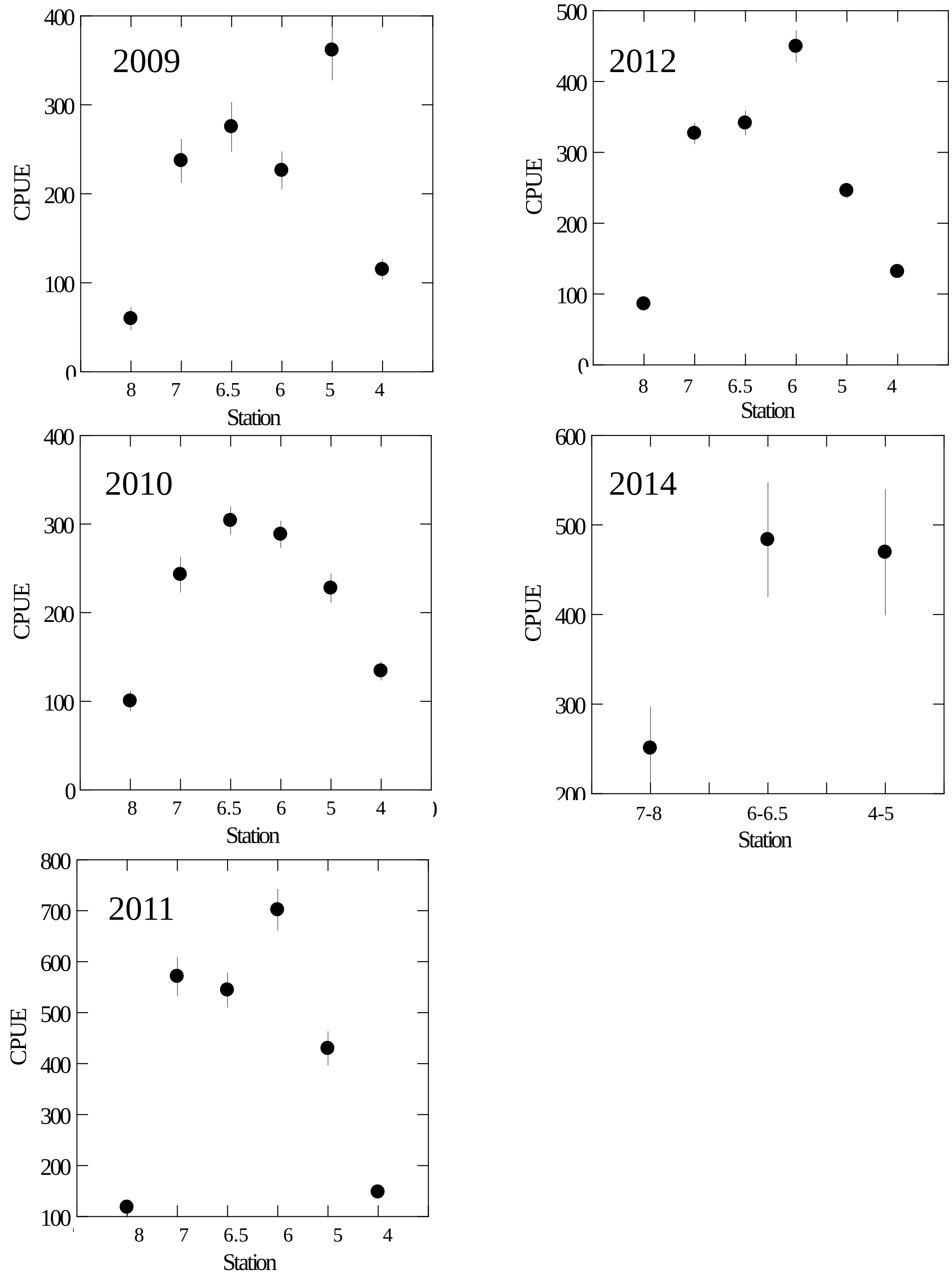

Figure 16.–Total Kenai River sockeye salmon catch per unit effort ($CPUE_{st,s}$) by station along the southern OTF transect, 2009–2012 and 2014.

Note: In 2014, genetic stock proportions were estimated by pooling adjacent stations. Vertical bars indicate 90% credibility intervals.

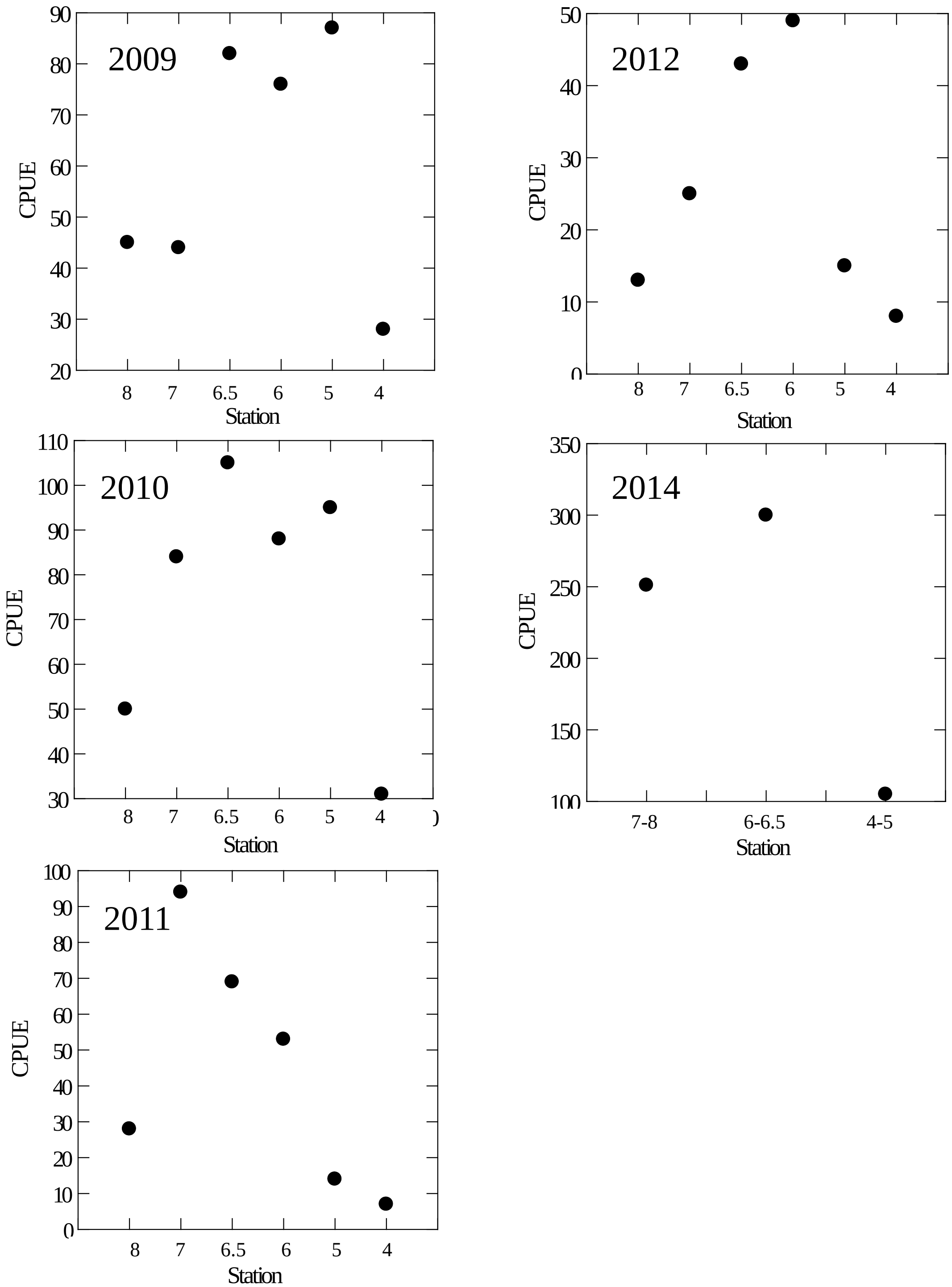

Figure 17.–Total coho salmon catch per unit effort by station along the southern OTF transect, 2009-2012 and 2014.

Note: In 2014, genetic stock proportions were estimated by pooling adjacent stations.

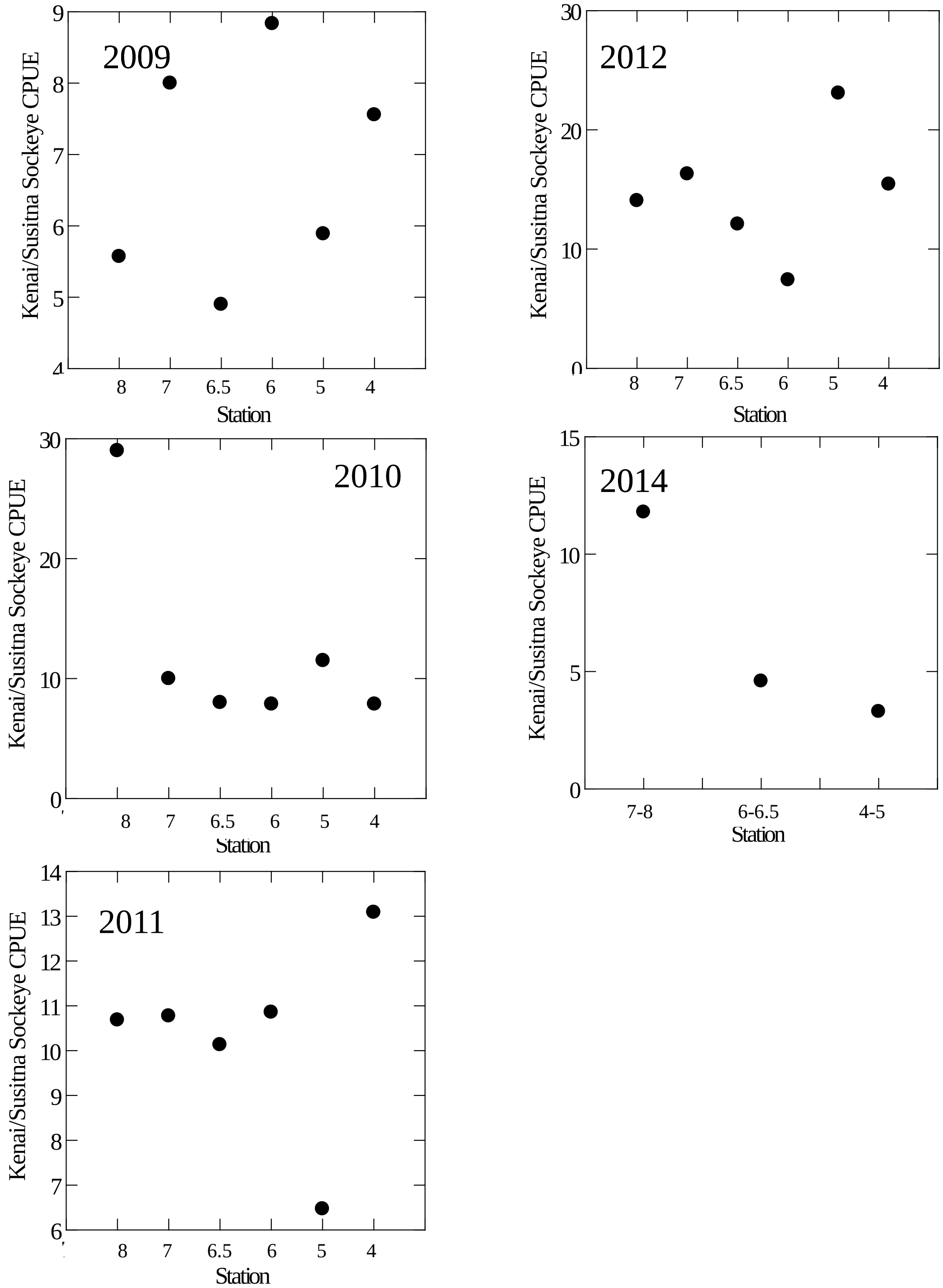

Figure 18.–Ratios of total Kenai to Susitna river sockeye salmon catch per unit effort ($CPUE_{st,s}$) by station along the southern OTF transect, 2006–2012 and 2014.

Note: In 2014, genetic stock proportions were estimated by pooling adjacent stations.

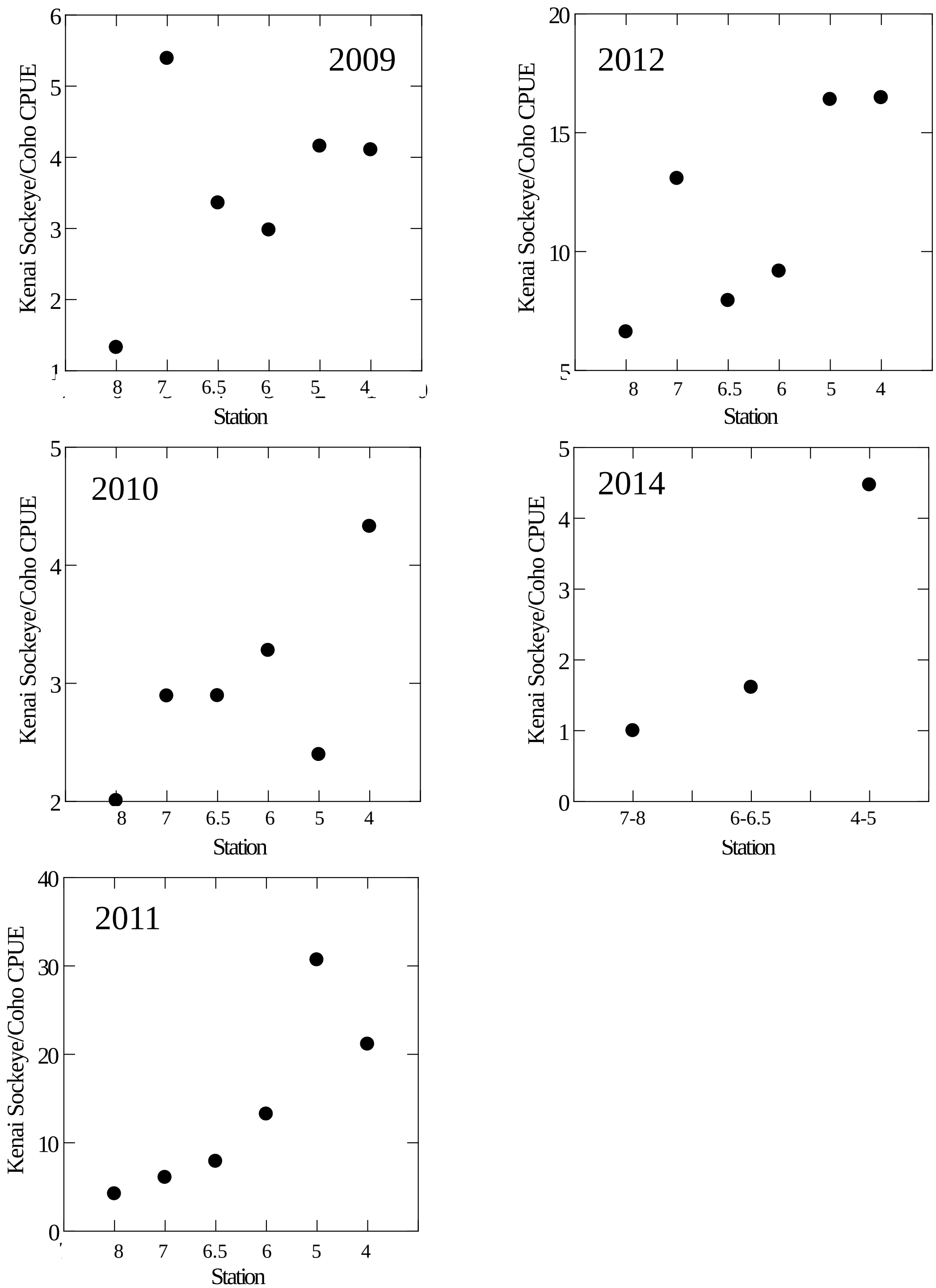

Figure 19.–Ratios of total Kenai River sockeye salmon $CPUE_{st,s}$ to total coho salmon CPUE by station along the southern OTF transect, 2006–2012 and 2014.

Note: In 2014, genetic stock proportions were estimated by pooling adjacent stations.

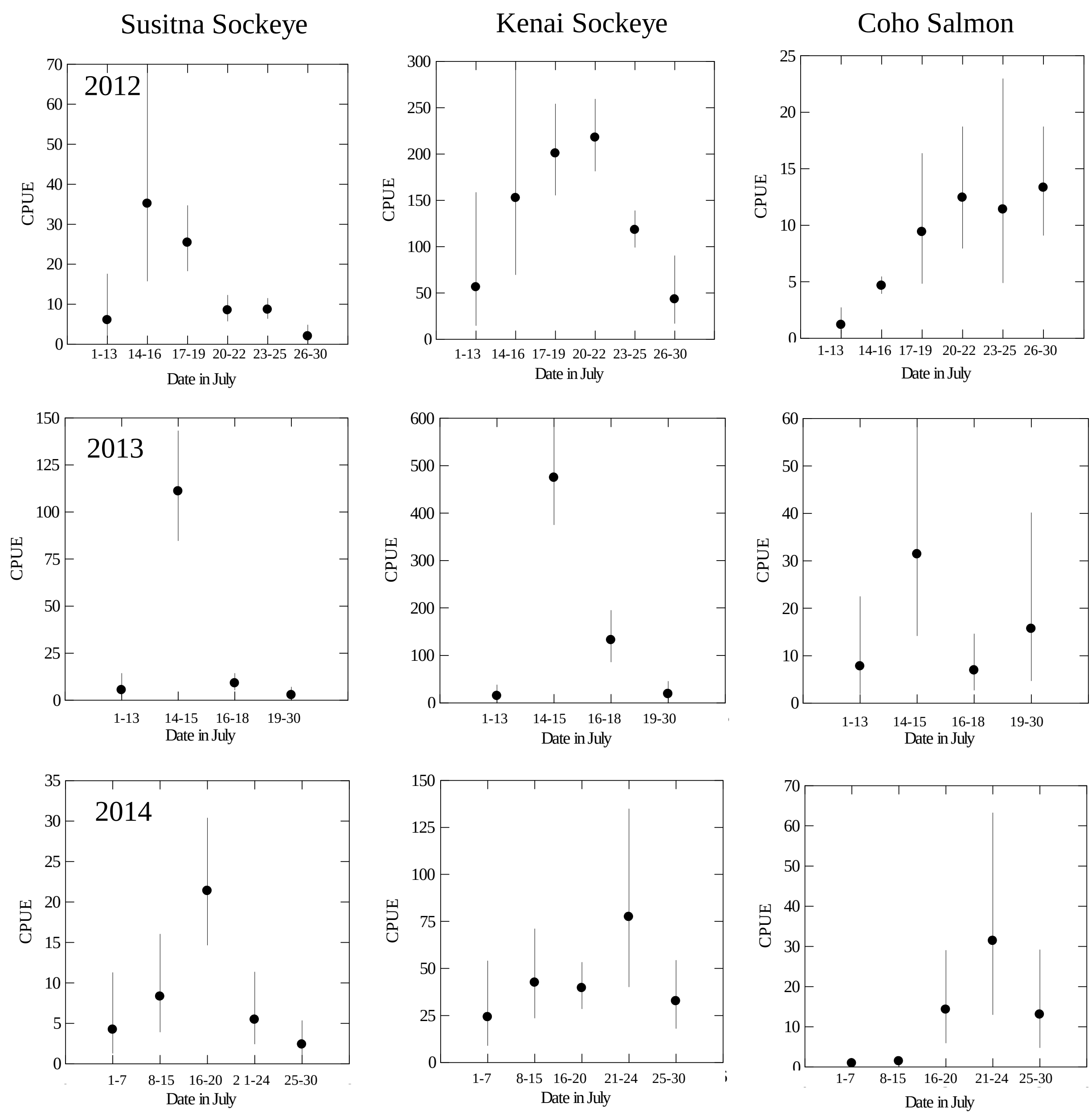

Figure 20.–Mean Kenai and Susitna river sockeye salmon catch per unit effort (*$CPUE_{st}$*) and mean coho salmon CPUE by date stratum along the northern OTF transect, 2012–2014.

Note: Vertical bars indicate 90% confidence intervals.

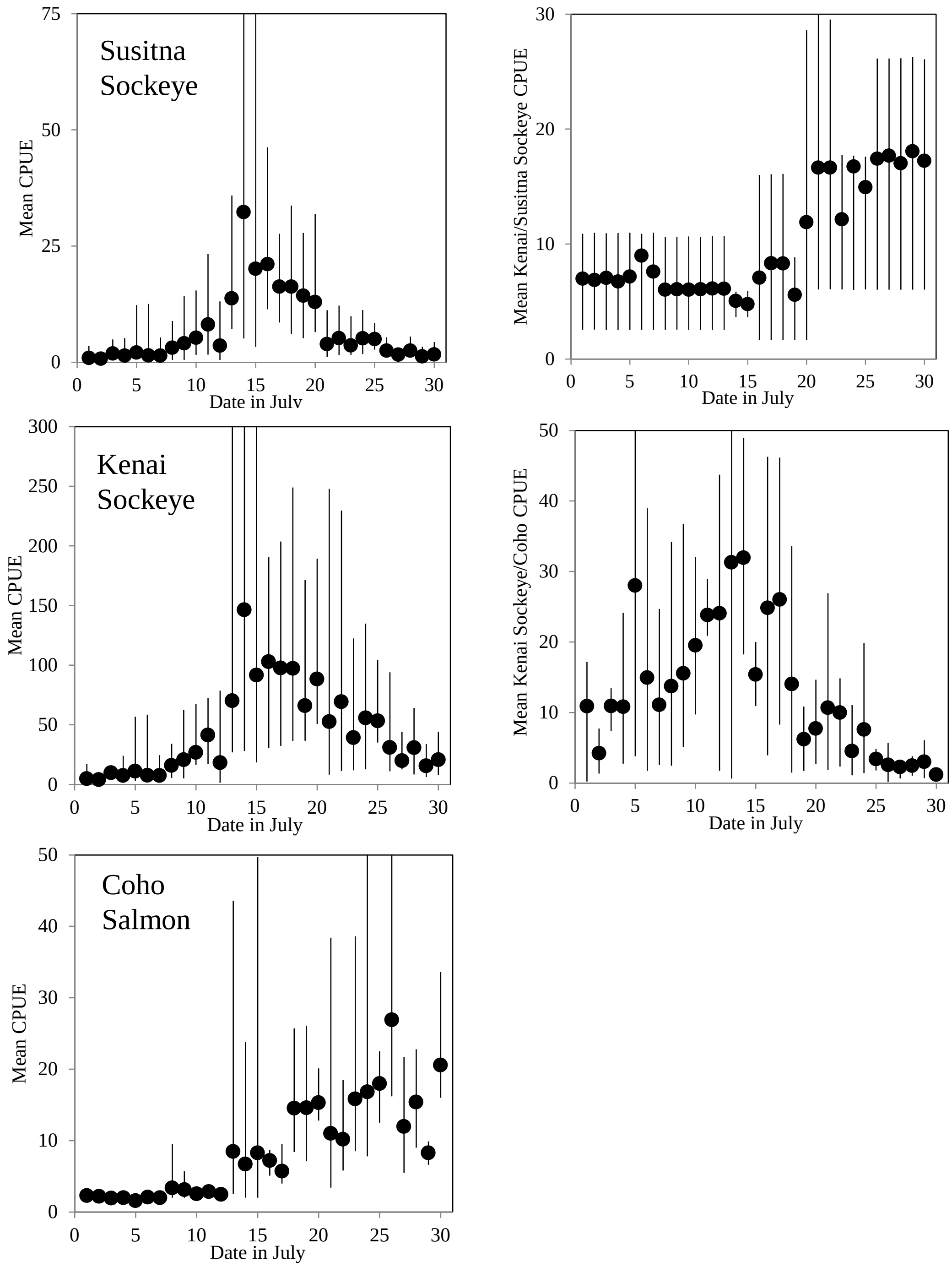

Figure 21.–Mean daily catch per unit effort (*$CPUE_{st,i}$*) for Kenai and Susitna river sockeye salmon and mean daily coho salmon *$CPUE_i$* pooled across all years (2012–2014) along the northern OTF transect (left panel).

Note: Mean daily ratios of Kenai to Susitna river sockeye salmon *$CPUE_{st,i}$* and mean daily ratios of Kenai River sockeye salmon *$CPUE_{st,i}$* to mean daily coho salmon *$CPUE_i$* are shown in the right panel. Vertical bars indicate 90% confidence intervals.

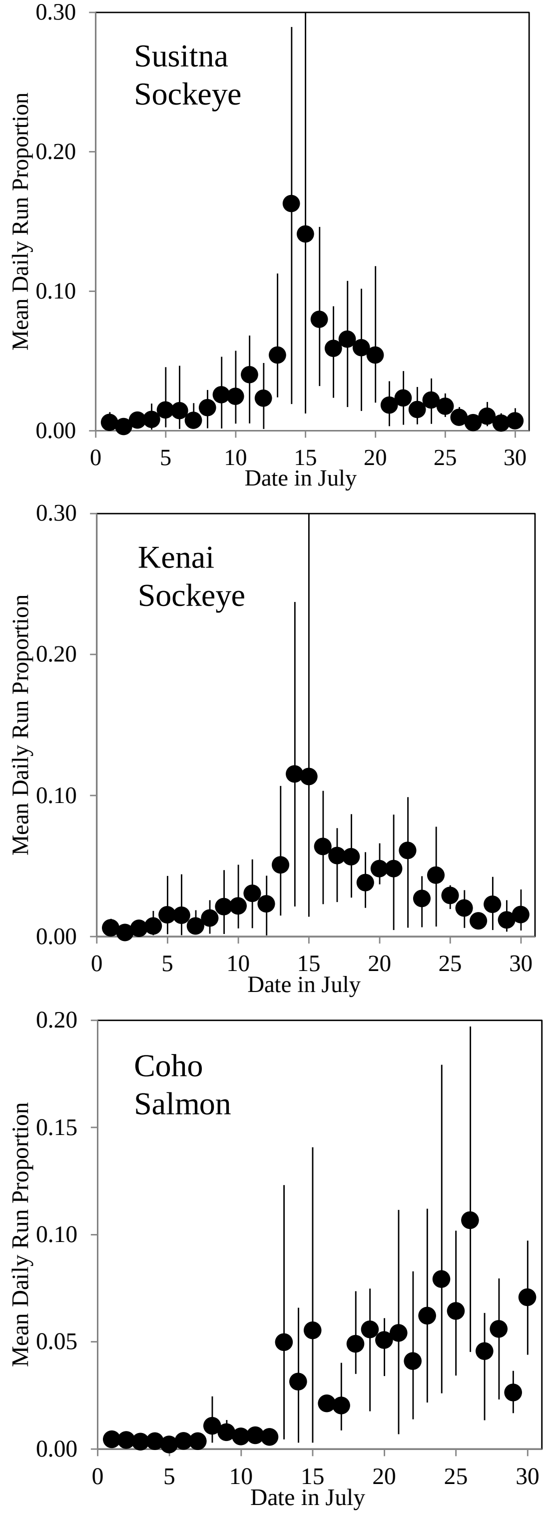

Figure 22.–Mean daily run proportions ($PCPUE_{st,i}$) for Kenai and Susitna river sockeye salmon and mean daily coho salmon run proportions ($PCPUE_i$) pooled across all years (2012–2014) along the northern OTF transect.

Note: Vertical bars indicate 90% confidence intervals.

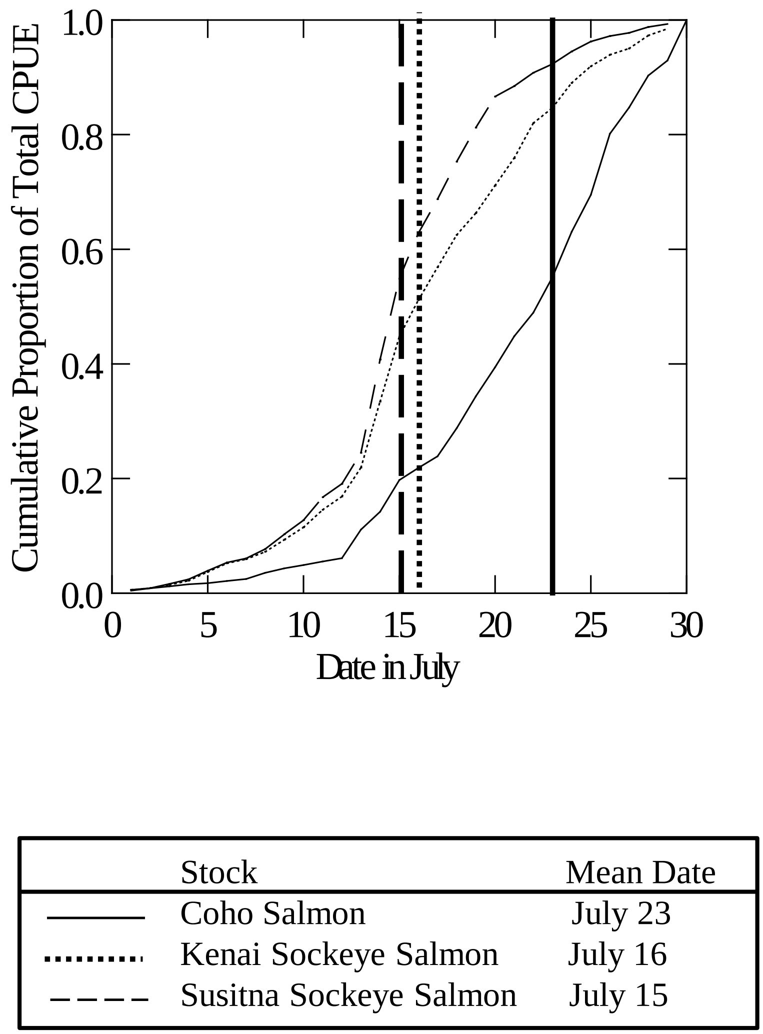

Figure 23.–Mean cumulative proportion of total $PCPUE_{st,i}$ for Kenai and Susitna river sockeye salmon and coho salmon ($PCPUE_i$) pooled across all years (2012–2014) along the northern OTF transect.

Note: Vertical lines indicate the mean dates of the runs for each stock.

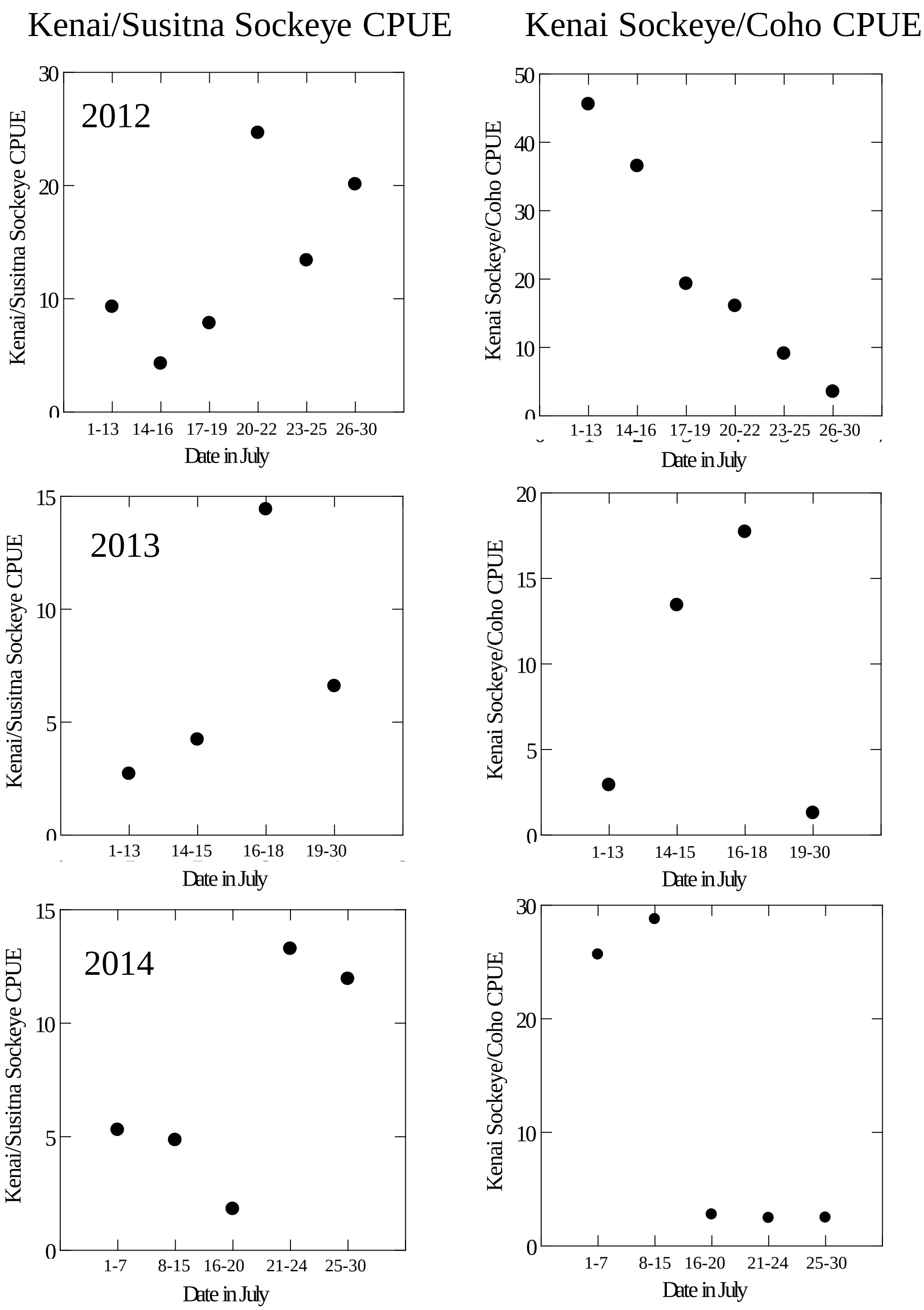

Figure 24.–Ratios of mean Kenai to Susitna river sockeye salmon catch per unit effort ($CPUE_{st}$) by date stratum (left panel), and ratios of mean Kenai River sockeye salmon $CPUE_{st}$ to mean coho salmon $CPUE_i$ by date stratum (right panel) along the northern OTF transect 2012–2014.

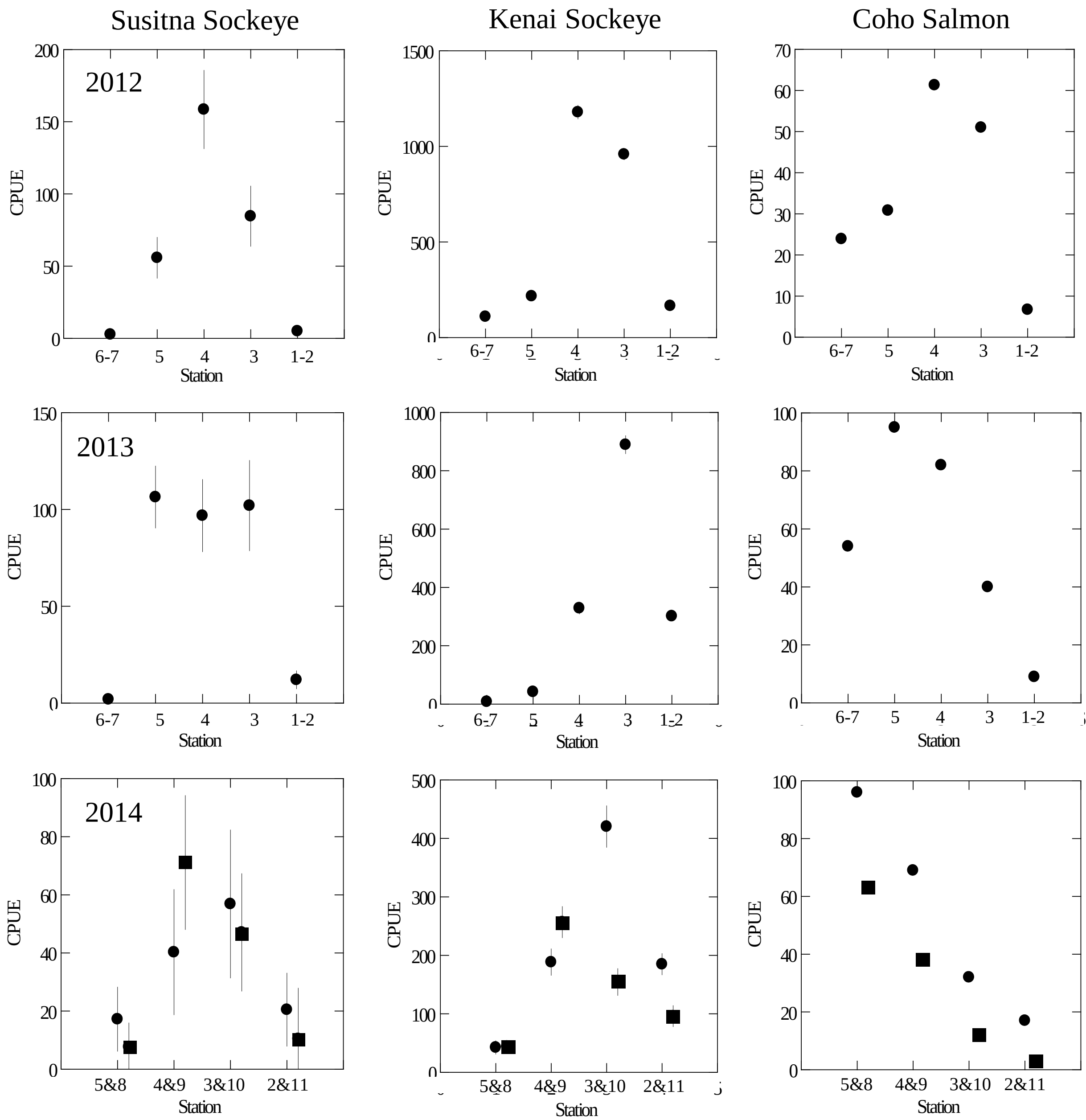

Figure 25.–Total Kenai and Susitna river sockeye salmon catch per unit effort ($CPUE_{st,s}$) and total coho salmon CPUE by station along the northern OTF transect, 2012–2014.

Note: Vertical bars indicate 90% credibility intervals. Total CPUEs are plotted together for paired stations along the upper (solid circles) and lower (solid squares) Kalgin Island transects sampled in 2014.

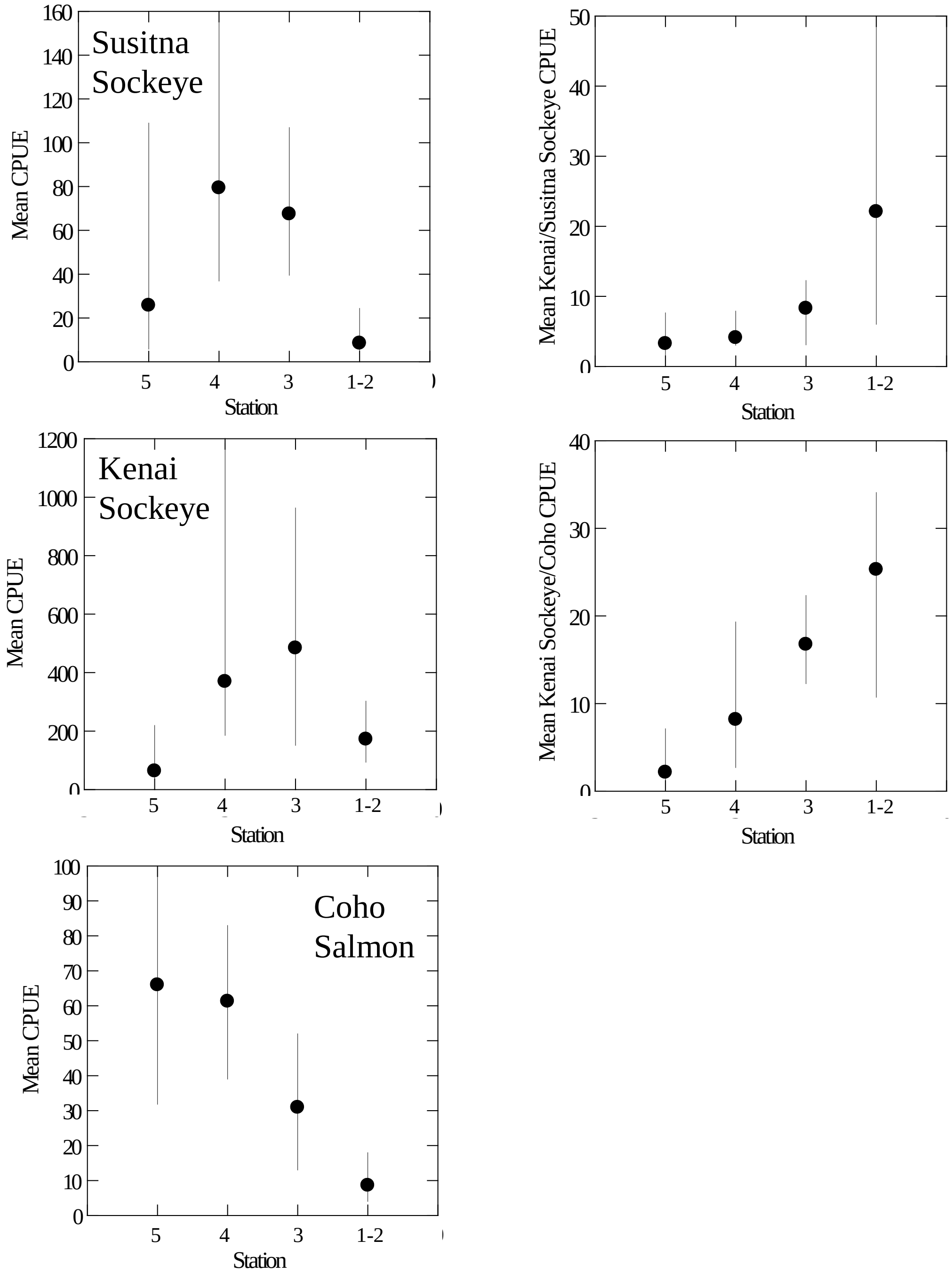

Figure 26.–Mean total Kenai and Susitna river sockeye salmon catch per unit effort ($CPUE_{st,s}$) and mean total coho salmon CPUE pooled across all years (2012–2014) by station along the northern OTF transect (left panel).

Note: Mean ratios of total Kenai to Susitna river sockeye salmon $CPUE_{st,s}$ and mean ratios of total Kenai River sockeye salmon $CPUE_{st,s}$ to total coho salmon CPUE pooled across all years (2012–2014) by station along the northern OTF transect (right panel). Data from comparable stations (i.e., stations 5 and 8, 4 and 9, 3 and 10, and 2 and 11) sampled along the upper and lower Kalgin Island transects in 2014 were pooled in this analysis. Vertical bars indicate 90% confidence intervals.

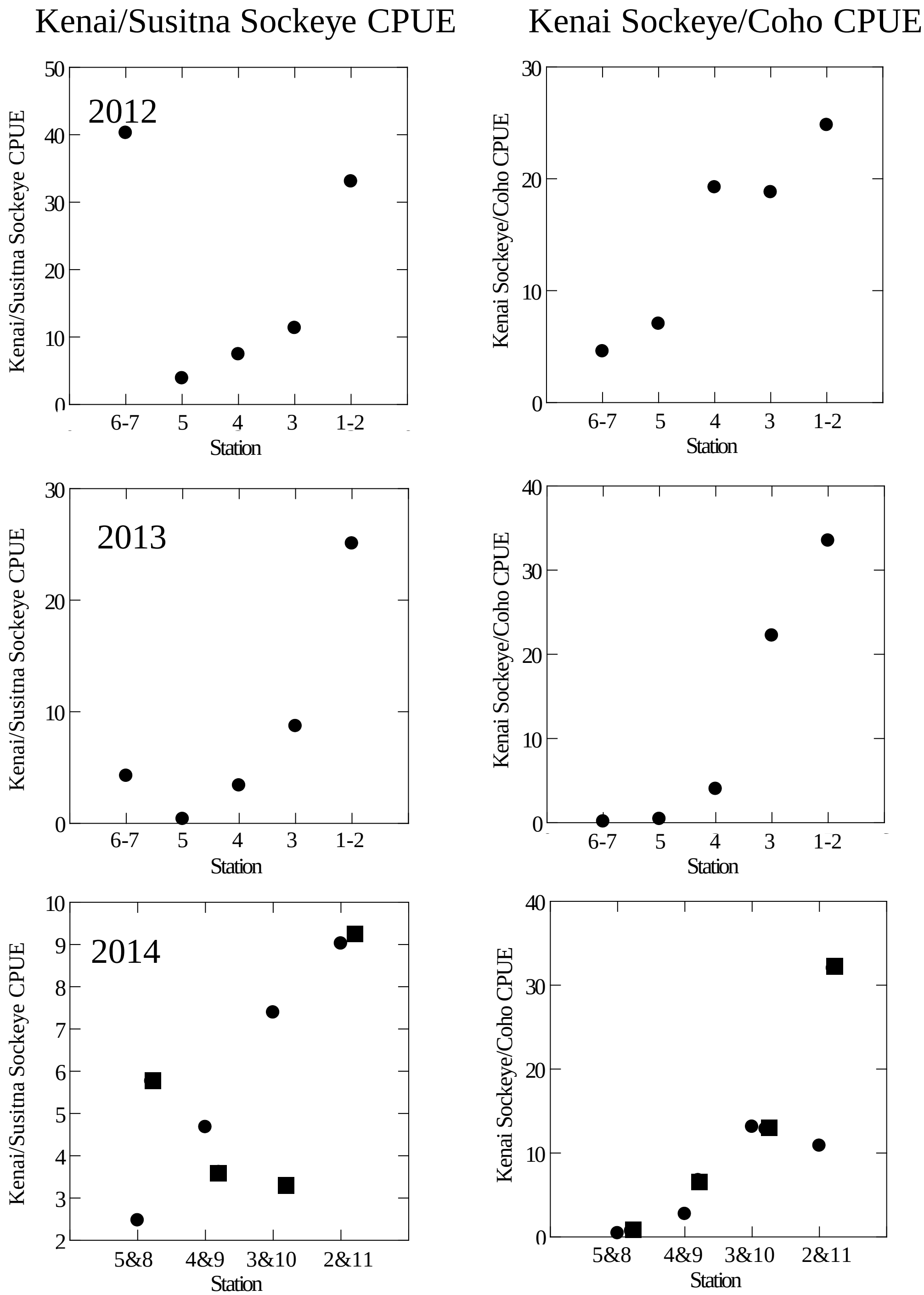

Figure 27.–Ratios of total Kenai to Susitna river sockeye salmon catch per unit effort ($CPUE_{st,s}$) and ratios of total Kenai River sockeye salmon $CPUE_{st,s}$ to total coho salmon CPUE by station along the northern OTF transect, 2012–2014.

Note: Total CPUE ratios were plotted together for paired stations along the upper (solid circles) and lower (solid squares) Kalgin Island transects sampled in 2014.