Fishery Data Series No. 13-41

A Study of Commercial Fishing Gear Selectivity During the 2012/13 Aleutian Islands Golden King Crab Fishery East of 174° W Longitude

by

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September 2013

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

Symbols and Abbreviations

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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

FISHERY DATA SERIES NO. 13-41

A STUDY OF COMMERCIAL FISHING GEAR SELECTIVITY DURING THE 2012/13 ALEUTIAN ISLANDS GOLDEN KING CRAB FISHERY EAST OF 174°W LONGITUDE

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This investigation was partially funded by National Oceanic and Atmospheric Administration (NOAA) Award NA12NMF4370099 ("Bering Sea Crab Research XI"). The views expressed here are those of the authors and do not necessarily reflect the view of NOAA or any of its sub-agencies.

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This document should be cited as:
Vanek, V., D. Pengilly, and M. S. M. Siddeek. 2013. A study of commercial fishing gear selectivity during the 2012/13 Aleutian Islands golden king crab fishery east of 174° W longitude. Alaska Department of Fish and Game, Fishery Data Series No. 13-41, Anchorage.

TABLE OF CONTENTS

Page

LIST OF TABLES

Table **Page**

LIST OF TABLES (Continued)

LIST OF FIGURES

LIST OF FIGURES (Continued)

LIST OF APPENDICES

ABSTRACT

The Alaska Department of Fish and Game (ADF&G) performed a study in cooperation with commercial fishermen to evaluate the use of small-mesh "research pots" to provide data for estimating the contact-selection curve for male golden king crab *Lithodes aequispinus* captured by the pots used in the commercial Aleutian Islands golden king crab fishery. ADF&G conducted the study aboard the *F/V Aleutian No. 1* (a 37.5-m commercial crab-pot fishing vessel) in the Aleutian Islands king crab registration area (Area O) east of 174° W longitude during normal commercial fishing operations of the 2012/13 commercial fishery. Data on the catch and size-sex of golden king crab was obtained from 31 pairs of small-mesh research pots and commercial-fishing pots fished in the same longlined strings. The differences in the catches of legal males were not statistically significant between small-mesh research pots and commercial-fishing pots, but the greater catches by research pots than by commercial-fishing pots were statistically significant for sublegal males <101-mm carapace length (CL), sublegal males 101–120-mm CL, sublegal males >120-mm CL, and females. A logistic function contact-selection curve for male golden king crab by commercial-fishing pots was estimated under the assumptions that the research pots served as control gear that retained males of all sizes captured and that the research pots and commercial-fishing pots had equal relative fishing intensities. The estimated contact-selection curve was comparable to the fishery population-selection curve estimated by a 2013 stock assessment model that relied only on data from the commercial fishery; this study and the 2013 stock assessment model estimated the CL at 50% selectivity to be 1 to 2 mm less than the 136-mm CL size that is used to approximate the minimum legal carapace width for males in the commercial fishery.

Key words: Golden king crab, *Lithodes aequispinus*, Aleutian Islands, fishing gear selectivity

INTRODUCTION

The Aleutian Islands golden king crab fishery is managed under provisions of the Fishery Management Plan for Bering Sea/Aleutian Islands King and Tanner Crab (NPFMC 2011), which establishes a state/federal cooperative management regime that defers crab fishery management to the State of Alaska with federal oversight. The overfishing level, acceptable biological catch, and annual catch limit for Aleutian Islands golden king crab are determined annually through the federal stock assessment process (NPFMC 2012), whereas the harvest levels for each season are determined by the State of Alaska. Under the state/federal cooperative management regime, the State of Alaska must consider the uncertainty in the specification of the federal overfishing level when determining harvest levels and must set the harvest level sufficiently below the federal annual catch limit so that total fishery mortality (the landed catch in the directed fishery and bycatch mortality due to all fisheries) does not exceed the annual catch limit.

The fishery has been prosecuted as a directed fishery since the 1981/82 season and has been open every season since then (Baechler 2012). Harvest peaked during the 1985/86–1989/90 seasons (average season harvest = 11.876-million pounds), but dropped sharply after the 1989/90 season and the average season harvest for the period 1990/91–1995/96 was 6.931-million pounds (Table 1). Actions by the Alaska Board of Fisheries (BOF) in March 1995 restructured the management of the fishery between the 1995/96 and 1996/97 seasons. Prior to the 1996/97 season, the Aleutian Islands were divided into 2 areas for management of king crab fisheries at 171° W longitude: the Dutch Harbor Area (east of 171° W longitude) and the Adak Area (west of 171° W longitude). The BOF's 1995 action combined the Dutch Harbor and Adak Areas into the single Aleutian Islands Registration Area O. Additionally, the BOF directed the Alaska Department of Fish and Game (ADF&G) to manage golden king crab in the areas east and west of 174° W longitude as 2 distinct stocks and stipulated that conservative management plans for the fisheries east and west of 174° W longitude be implemented. Through the 1995/96 season, the former Adak Area was managed under a "size-sex-season" policy with no management towards a specified preseason guideline harvest level (GHL), whereas the former Dutch Harbor

Area was managed on the basis of fishery performance with the historic average landings providing an informal GHL (B. Baechler, ADF&G, Dutch Harbor, July 12, 2012 memorandum). Beginning with the 1996/97 season, a constant-catch harvest strategy was established with a preseason GHL based on historic catches for each of the areas east and west of 174° W longitude: 3.2-million pounds for the area east of 174° W longitude and 2.7-million pounds for the area west of 174° W longitude. The GHL for the area east of 174° W longitude was reduced to 3.0-million pounds for the 1998/99 season and the fishery was managed with a GHL of 3.0-million pounds for the area east of 174° W longitude and 2.7-million pounds for the area west of 174° W longitude during the 1998/99–2004/05 seasons. The average harvest per season for the entire Aleutian Islands Area, east and west of 174° W longitude, for the seasons managed under the GHLs established for 1996/97–2004/05 was 5.687-million pounds. Following implementation of the federal Crab Rationalization Program for Bering Sea and Aleutian Islands in the 2005/06 season, the fishery was managed towards a total allowable catch (TAC), which was specified preseason by ADF&G and distributed to qualifying vessels as fishery quota shares by the National Marine Fisheries Service, rather than towards a GHL. ADF&G continued to manage the fisheries with TACs of 3.0-million pounds for the area east of 174° W longitude and 2.7-million pounds for the area west of 174° W longitude for the 2005/06–2007/08 seasons. In March 2008 the BOF set the TACs for the Aleutian Islands golden king crab fisheries east and west of 174° W longitude into regulation (5 AAC 34.612) until a stock assessment model is established by ADF&G, increasing the TAC for the eastern portion to 3.15-million pounds and for the western portion to 2.835-million pounds. The 2008/09–2011/12 seasons were managed under the TACs established by the BOF in March 2008. The average harvest per season for the entire Aleutian Islands Area, east and west of 174° W longitude, for the rationalized fisheries managed under the TACs established for 2005/06–2011/12 was 5.688-million pounds. In March 2012 the BOF increased the TACs in regulation for the areas east and west of 174° W longitude to 3.31-million pounds and 2.98-million pounds, respectively, until a stock assessment model and state regulatory harvest strategy are established for Aleutian Islands golden king crab and added a provision in the regulation to allow ADF&G to reduce those TACs if necessary to avoid overfishing. The 2012/13 fishery season for Aleutian Islands golden king crab, which is ongoing at the time of writing this report, is the first to be managed under the TACs established in regulation by the BOF in March 2012.

Most of the data available for assessment of trends and levels of Aleutian Islands golden king crab stock are obtained from the fishery through the ADF&G catch-sampling and fishery-observer programs (Baechler 2012; Pengilly 2012; Siddeek et al. 2013a). ADF&G performed pot surveys for golden king crab in the Yunaska-Amukta Island area of the Aleutian Islands (approximately 171° W longitude) in 1991, 1997, 2000, 2003, and 2006 (Watson 2007), but those surveys were too limited in geographic scope and too infrequent to provide a reliable index of abundance for the entire Aleutian Islands Area. Moreover, although that survey was established as a triennial survey in 1997, the increasing costs for vessel charters exceeded available funding to perform the surveys scheduled for 2009 and 2012, resulting in cancellation of the 2009 and 2012 surveys and jeopardizing the ability of ADF&G to perform such surveys in the future. Attempts to develop a stock assessment model for Aleutian Islands golden king crab using fishery data were first presented in 2003 (Siddeek et al. 2005) and have been presented annually for review in the federal stock assessment process during 2008–2012 (Siddeek et al. 2008; Siddeek et al. 2013a). Although the most recent version of the stock assessment model (Siddeek et al. 2013a) shows progress over earlier versions, additional development of the model

is required before it can be used for stock assessment (Report of the North Pacific Fishery Management Council Crab Modeling Workshop, February 26 to March 1, 2013, North Pacific Fishery Management Council, Anchorage, unpublished).

Trends in the fishery-observer, catch-sampling, and harvest data can be affected by changes in fishery practices and participants, as well as by changes in stock abundance and distribution. Two notable trends in fishery data since the establishment of separate management and harvest levels (GHLs or TACs) for the areas east and west of 174° W longitude in the 1996/96 season are an increasing catch per unit effort (CPUE, measured as number of crab per pot lift) of landed legal-size (≥6-in, 152-mm, carapace width) males (Figure 1) and a shift towards larger crab in the size composition of the males in the pot lifts sampled by fishery observers (Figure 2; Pengilly 2012; Siddeek et al. 2013a). The increase in CPUE of landed legal males and in size of captured males is most marked between the last pre-rationalized season (2004/05) and the first rationalized season (2005/06). As a result of the increase in size of captured males, and the accompanying decrease in bycatch of sublegal-size (<6-in, 152-mm, carapace width) males, size frequency distributions in the data collected by fishery observers during the recent rationalized fishery seasons provide little information on the size distribution and relative abundance of sublegal males or on future recruitment to the legal males. Because both trends may be at least partially attributable to changes in fishing practices, particularly those that occurred coincident with rationalization of the fishery, stock assessment modelers for the Aleutian Islands golden king crab stock are currently investigating methods to standardize fishery data in an attempt to separate effects due to fishery participants (the number of vessels fishing, the vessels themselves, and the captains of those vessels) and practices (e.g., fishing gear and soak time) from effects due to changes in stock abundance and recruitment (Siddeek et al. 2012b, 2013b).

The Aleutian Islands golden king crab stock assessment model attempts to model the time series of CPUE in 5-mm carapace length (CL) size groups of male crab >100-mm CL captured by the pots sampled by observers during the fishery (Siddeek et al. 2013a). When examining trends in the size composition of male golden king crab captured by pots sampled by observers during the fishery, 4 sizes (CL) are relevant to management of the fishery and development of the stock assessment model: 101-mm CL (the lower limit of the male size class modeled by the stock assessment model; Siddeek 2013a); 121-mm CL (the lower size limit for mature-size males assumed by the stock assessment model and the lower size limit that ADF&G uses to identify sublegal males that are 1 molt from legal size; Watson et al. 2002; Siddeek et al. 2013a); 136-mm CL (the CL used in the stock assessment model as a proxy for the minimum carapace width for legal size; Siddeek 2013a); and 150-mm CL (the upper CL limit for legal-size males that ADF&G uses to identify recruit-size legal males; B. Baechler, ADF&G, Dutch Harbor, July 12, 2012 memorandum). Table 2 and Figure 3 summarize the size composition data of male golden king crab captured by pots sampled by observers during the 1996/97–2011/12 fishery seasons in the areas east and west of 174° W longitude with the data grouped into the 5 size classes defined by those 4 relevant sizes: <101-mm CL; 101-mm to 120-mm CL; 121-mm to 135-mm CL; 136-mm to 150-mm CL; and >150-mm CL. It is notable that, although only 40% of the male crab in observer pot samples during the 1996/97 season were >135-mm CL, male crab >135-mm CL accounted for 69–86% of the male crab in observer pots samples during the 2005/06–2011/12 seasons, depending on season and area. Moreover, males >150-mm CL have accounted for an increasing portion of the males >135-mm CL in those pot samples, from roughly one-third during the 1996/97–2004/05 seasons to roughly one-half during the 2005/06–2011/12 seasons in the area east of 174° W longitude. Males 121-mm to 135-mm CL, which are considered to be

mature-size and less than 1 molt from legal size, accounted for roughly one-third of the males in observer pot samples during the 1996/97–2004/05 seasons, but accounted for one-fifth or less during the 2005/06–2011/12 seasons. Smaller males (<121-mm CL) accounted for roughly one-fifth of the males in observer pot samples during the 1996/97–2004/05 seasons, but accounted for only one-twentieth during the 2005/06–2011/12 seasons.

Reasons cited for the trend of the increased size of males captured during the fishery since rationalization include the use of increased soak times and of more extensive coverage of escape mesh on pots than is required in regulation (Pengilly 2012; Siddeek et al. 2012b, 2013b). It is also possible that fishery rationalization has afforded the opportunity for the participating vessels to more deliberatively select fishing locations that yield high catches of legal-size crab with low bycatch of sublegal males. It has been unclear, however, what role the following have played in the reduced bycatch of sublegal males since rationalization of the fishery: the size selectivity of the gear as it is presently configured and fished, the locations fished, or actual changes in the relative abundance of sublegal males to legal males in the stock.

ADF&G performed a study in cooperation with a vessel fishing during the 2012/13 Aleutian Islands golden king crab fishery season in the area east of 174° W longitude to gather data for estimating the male size selectivity of the commercial-fishing pots as they are currently configured and fished. Two ADF&G staff were present on board the cooperating commercial fishing vessel for part of the season to obtain data on the number and size distribution of male golden king crab captured by 2 kinds of pots during normal fishing activities: the pots that the vessel used for commercial golden king crab fishing and "research pots" supplied for this study by the Aleutian Islands golden king crab fishery industry. The research pots were comparable to the pots used in ADF&G's Bering Sea and Aleutian Islands king crab surveys and were distinguished from commercial-fishing pots by being fit with small-mesh webbing and by lacking the escape rings and escape mesh that are used in commercial-fishing pots to promote the escape of sublegal males and females. As well as providing data for estimating commercial fishing gear selectivity, this project served as a pilot study for ADF&G to evaluate the merits of possible future efforts to collect priority research data on the Aleutian Islands golden king crab stock from aboard cooperating commercial-fishing vessels fishing research pots.

OBJECTIVES

Objectives of the study of commercial fishing gear selectivity during the 2012/13 Aleutian Islands golden king crab fishery east of 174° W longitude were as follows:

1. Document the catch and size distribution of male golden king crab captured by small-mesh research pots without escape mechanisms in areas normally fished by a vessel commercial fishing in the Aleutian Islands in the area east of 174° W longitude for comparison with the size composition of male golden king crab captured by commercial-fishing pots during the previous rationalized commercial fishery seasons (2005/06–2011/12).
2. Estimate the contact-selection probability curve (Millar and Fryer 1999) for male golden king by pots commercially fished in the Aleutian Islands golden king crab fishery east of 174° W longitude.

3. Document the variety of pots, pot configurations, and pot escape mechanisms in the commercial gear fished by a commercial fishing vessel participating in the 2012/13 Aleutian Islands golden king crab fishery.

METHODS

DEPLOYMENT OF RESEARCH POTS AND CATCH SAMPLING FROM RESEARCH AND PAIRED COMMERCIAL-FISHING POTS DURING COMMERCIAL FISHING

Data collection was performed by 2 ADF&G biologists, Vicki Vanek and Dmitri DelaCruz, aboard a cooperating 37.5-m commercial crab-pot-fishing vessel, the *F/V Aleutian No. 1*, while it fished for golden king crab during the 2012/13 Aleutian Islands Registration Area O golden king crab commercial fishing season in the area east of 174° W longitude.

Research Pots and Their Deployment during Commercial Fishing

Description of research pots. Twenty pots were supplied by the Aleutian Islands golden king crab commercial fishing industry for use in this project. Each of these pots measured 7 ft by 7 ft by 34 in (213 cm by 213 cm by 86 cm; outside dimensions), was webbed with 2.5-in (64-mm) stretched-mesh, and had rigid tunnels with 2 opposing 9-in by 36-in (23-cm by 91-cm; inside dimensions) tunnel-eye openings installed with inward-facing "fingers" ("cod triggers"). These pots were similar in design to those used in the ADF&G Aleutian Islands pot surveys (Watson 2007) and were distinguished from the pots fished during the commercial fishery for golden king crab in the Aleutian Islands by the absence of features that are required by regulation (5 AAC 34.625 (b) (1)) to permit the escape of sublegal golden king crab; i.e., either a minimum of 4 circular rings with minimum inside diameters of 5.5 in (140 mm) installed on a vertical plane or at least one-third of 1 vertical surface composed of not less than 9-in (229-mm) stretched mesh webbing. We will refer to those pots as "research pots" because they do not conform to the lawful gear requirements of 5 AAC 34.625 (b) (1) and could only be transported, set, retrieved, or stored for purposes of conducting this study under the provisions specified in a permit issued by ADF&G to the captains of the *FV Aleutian No. 1*. (Appendix A1). Note that, when installed on a pot, the 2.5-in (64-mm) stretched-mesh webbing used on the research pots opens to squares with a diagonal distance of roughly 45 mm, whereas the 9-in (229-mm) stretched-mesh webbing that satisfies the requirements of 5 AAC 34.625 (b) (1) opens to squares with a diagonal distance of roughly 162 mm.

Deployment of research pots during commercial fishing. The research pots were set and fished during normal commercial fishing operations by the *FV Aleutian No. 1* within the longlined strings of the commercial pots normally fished by that vessel. Prior to setting the research pots, the vessel captain consulted with ADF&G to assure that ADF&G project biologists would be onboard the vessel when those strings of commercial-fishing pots were hauled. Because the research pots were set by the vessel during normal fishing operations, ADF&G did not specify the location, depth, set and haul time and date, or soak time of any of the strings of pots containing a research pot. However, during project planning and performance, ADF&G stressed to the vessel captain that project objectives could not be achieved if the research pots were fished in strings in which the location, depth, set and haul time and date, or soak time did not represent normal fishing activities for the vessel.

One research pot was set in each of 34 longlined strings of commercial pots, 20 that were set between 7 and 22 October 2012 and 14 that were set between 29 October and 5 November 2012. As is typical of the commercial fishery, the vessel fished approximately 30 to 50 pots per longlined string, with 80 fathoms (146 m) of line between pots. The position of each research pot within the string of commercial pots relative to the first pot set in the string was determined prior to setting using a random number table, with the restriction that the pot would not be set in the "anchor pot" position at either end of the string. Research pots were baited by the vessel crew with the same bait and quantity of bait that were applied to the commercial-fishing pots in the strings. The position of the research pot in the string relative to the first pot set in the string (i.e., the anchor pot) and the date and time of setting were recorded.

Selection of Paired Commercial-Fishing Pots and Catch Sampling

Date, time, depth, latitude, and longitude of the research pots at the time they were hauled and the total number of pots (including the 2 anchor pots) set in each string containing a research pot were obtained from the vessel captain. In each string of gear containing a research pot, the next commercial-fishing pot hauled in the string after the research pot was designated as the "paired commercial-fishing pot" for sampling with the research pot in that string. Note that during commercial fishing of longlined pots, the order in which pots within a string are hauled may be the opposite of the order in which they were set. The pairs of research and commercial-fishing pots ("pot pairs") were assigned numbers based on the temporal order in which the research pots were set. Haul date and time and the depth, latitude, and longitude at the time of hauling of each commercial-fishing pot paired with a research pot were obtained from the vessel captain. The position in the string of each commercial-fishing pot paired with a research pot, relative to the first pot set in the string, was also recorded. Additionally, the size (measured in the tunnel-to-tunnel and the door-to-door dimensions) of each commercial-fishing pot paired with a research pot was measured to the nearest 0.5 ft (15 cm), the stretched-mesh size of the escape mesh and inside diameter of escape rings fitted on the pot were measured to the nearest 1 in (25 mm), a description of the position on and coverage of the pot by the escape mesh was recorded, and the number of escape rings and their position on the pot were recorded. Photographs were taken of each commercial-fishing pot paired with a research pot for later reference.

Although 1 research pot was set in 34 strings of pots fished by the vessel, data from only 31 pairs of research and commercial-fishing pots were analyzed because 1 research pot had been inadvertently set in the anchor position of a string and 2 strings containing a research pot were hauled when ADF&G biologists were not onboard the vessel to sample the catch. The 31 pot pairs were hauled and sampled during 2 fishing trips; 14 pairs of pots between 29 October and 6 November 2012 and 17 pairs of pots between 10 and 21 November 2012. Size and sex compositions of the golden king crab catch were determined for each sampled pot. All captured male golden king crab were measured to the mm for CL and assessed for legal size and shell condition. Captured female golden king crab were measured to the mm for CL and assessed for reproductive condition and shell condition. We report on results only for the data collected on CL of males and females and on legal status of males. Carapace length was measured from the posterior margin of the right eye socket to the midpoint of the rear margin of the carapace (Donaldson and Byersdorfer 2005) and the fishery-legal status of males was determined by the carapace width, including spines, relative to the 6.0-in (152-mm) minimum legal size. For purposes of data summarization, we divided males into 4 subclasses: legal; sublegal, >120-mm CL; sublegal, 101-mm to 120-mm CL; and sublegal, <101-mm CL.

A priority was established for obtaining data from male golden king crab over female golden king crab. Female golden king crab in the catch of 4 research pots with high catches of golden king crab were subsampled to avoid impacting progress on catch sampling for the day. In those cases in which subsampling of females occurred, the total catch of females in the pot was counted and a minimum of 50 were randomly sampled, without regard to size or reproductive condition, for recording CL, shell condition, and reproductive condition data (Appendix B1). Due to the subsampling of females that occurred in the 4 research pots, the size frequency distributions that we present for females in all pots sampled and in the research pots are, unlike those presented for females in the commercial-fishing pots and for males in both pot types, estimates and not based on actual counts.

Data collected by fishery observers on the size frequency of males captured during the 1995/96–2011/12 Aleutian Islands golden king crab fishery seasons east of 174° W longitude were obtained from the ADF&G observer database for comparison with the size of males captured during this study.

ESTIMATION OF SIZE SELECTIVITY OF MALE GOLDEN KING CRAB BY COMMERCIAL-FISHING POTS

For the purposes of selectivity analysis we grouped the male size data into 5-mm-CL size classes, with size classes defined by the upper limits being divisible by 5 (e.g., 121–125 mm).

In the context of our study, the "contact-selection curve" (Millar and Fryer 1999) specifies the probability that a crab of size class l is retained by a pot, given that it has entered the pot. We estimated the contact-selection curve for male golden king crab by the commercial-fishing pots sampled in this study, under the assumptions that: 1) the research pots were "control gear" (i.e., all male golden king crab that entered the research pots were retained by the research pots); 2) the relative fishing intensities (Millar and Fryer 1999) of the research pots and the commercial-fishing pots were equal and did not depend on the size of crab; and 3) the contact-selection probability curve, $S(l)$, can be described by a symmetric logistic function; i.e.,

$$S(l) = [e^{(a+bl)}]/[1+e^{(a+bl)}], \quad (1)$$

where a and b are parameters and l is the mid-point of a size class.

Following Millar and Fryer (1999), we estimated the contact-selection curve by conditioning on the total catch by research pots and commercial-fishing pots. Let n_{lR} be the number of male crab in size class l captured by the research pots, n_{lC} be the number of male crab in size class l captured by the commercial-fishing pots, and $y_l = n_{lC}/(n_{lC} + n_{lR})$ be the observed proportion of male crab in length class l that were captured by the commercial-fishing pots out of the total catch by both the research and the commercial-fishing pots of male crab in length class l. Under the 3 assumptions, above, the expected value of the observed proportion, y_l, is

$$E(y_l) = \varphi_l = S(l)/(1 + S(l)). \quad (2)$$

With the observed proportion, y_l, assumed to be drawn from a binomial distribution for each of the $l = 1,\ldots, m$ size classes considered, the log-likelihood of $\varphi_1,\ldots, \varphi_m$ is

$$\sum_{l=1,..,m} [n_{lC} \ln(\varphi_l) + n_{lR} \ln(1-\varphi_l)]. \quad (3)$$

We used the R version of the SELECT program (Millar and Fryer 1999; available at http://www.stat.auckland.ac.nz/~millar/selectware/R/) and the "ttfit" function in the SELECT program to compute the maximum likelihood estimates of the logistic selection curve parameters, a and b, based on equations (1) to (3). Although the "ttfit" function is for fitting a selection curve to data from alternate haul or trouser trawl type experiments, Millar and Fryer (1999) argued that the selection curves for traps and pots are similar to those of towed gear. The SELECT program also computes estimates of the size at 25% selectivity ($l_{25} = [\ln(1/3)-a]/b$), the size at 50% selectivity ($l_{50} = -a/b$), the size at 75% selectivity ($l_{75} = [\ln(3)-a]/b$), and the selection range ($SR = l_{75} - l_{25} = 2\ln(3)/b$).

The 2.5% and 97.5% percentiles of the bootstrap distributions of the statistics (Efron and Tibshirani 1993) were used to provide approximate 95% confidence intervals for the estimated parameters. The bootstrap distributions were generated by estimating the parameters (a and b) and the functions of those parameters (l_{25}, l_{75}, and SR) from the data in each of 1,000 sample replicates of 31 pot pairs, which were produced by resampling with replacement from the sample of 31 pot pairs we obtained for this study.

RESULTS

The 31 pot pairs were fished in the area from 169° 39.77' W longitude (south of Chuginadak I in the Islands of Four Mountains group) west to 171° 52.90' W longitude (the Amukta Pass area; Figure 4, Appendix B1). Soak times ranged from 11 to 31 d (mean = 20 d) and depths fished ranged 120 fathoms (219 m) to 350 fathoms (640 m) with a mean depth of 193.6 fathoms (354 m).

Relative locations of the paired research and commercial-fishing pots within the longlined strings (Appendix B1) are shown graphically in Figure 5. The research pot in a string was closer than the paired commercial-fishing pot to an anchor pot in 16 (52%) cases and was closer to the first pot set in the string in 22 (71%) cases. Depths fished (recorded to the nearest fathom at haul) were identical for the paired research and commercial-fishing pots in 20 (65%) of the strings and the average depth fished for all 31 research pots (193.5 fathoms; 354 m) was nearly identical to the average for all 31 commercial-fishing pots (193.7 fathoms; 354 m). The greatest within-pair discrepancy in the recorded depths fished (19 fathoms; 35 m) occurred at pot pair 32, where the research pot recorded depth was 183 fathoms (335 m) and the commercial-fishing pot's recorded depth was 164 fathoms (300 m).

The sampled commercial-fishing pots ranged in size from 5 ft x 5 ft (1.5 m x 1.5 m) to 6.5 ft x 7 ft (2.0 m x 2.1 m; Table 3). All of the sampled commercial-fishing pots were fit with 9-in (229-mm) stretched-mesh for compliance with 5 AAC 34.625 (b) (1) and exceeded the minimum requirements for coverage of the pots with escape mesh by having either or both of the entire door panel and the tunnel tops and sides fit with escape mesh. Three of the sampled commercial-fishing pots were also fit with 2 or 4 escape rings with inside diameters of 5.5 in (140 mm).

CATCH OF GOLDEN KING CRAB BY POT TYPE

Total catch of golden king crab by the 31 research pots and 31 commercial-fishing pots was 7,909 crab: 5,092 males (2,550 legal-size and 2,542 sublegal-size), 2,810 females (2,053 mature, 750 immature, and 7 of unknown maturity), and 7 of unknown sex (Table 4; Appendix B1). Legal males were captured by both pot types in each of the 31 pot pairs, whereas sublegal males were absent in the commercial-fishing pots of 3 of the pot pairs and females were absent in the

commercial-fishing pots of 3 of the pot pairs and absent in both pot types in 2 of the pot pairs (Appendix B1). Maps of catch by pot type within pot pairs for all sex-size classes (Figure 6), males (Figure 7), legal males (Figure 8), sublegal males (Figure 9) and females (Figure 10) reveal that the most notable spatial trends in catch were the lower catches of sublegal males and, particularly, females at the sampled locations east of 174° 00' W longitude and in the vicinity of the Islands of Four Mountains. The size range of captured males was 56-mm to 190-mm CL (73-mm to 189-mm CL for commercial-fishing pots and 56-mm to 190-mm CL for research pots) and of captured females was 61-mm to 161-mm CL (82-mm to 161-mm CL for commercial-fishing pots and 61-mm to 159-mm CL for research pots; Figure 11).

Catch per unit effort was higher in the research pots than in the commercial-fishing pots for females, legal males, and each of the 3 size classes that we defined for sublegal males (Figure 12). The within-pot-pair differences in CPUE (i.e., the catch in the research pots minus the catch in the paired commercial-fishing pots) were statistically significant ($P<0.05$) for each of the 3 sublegal male sex classes and for females (Table 5).

Although sublegal males were captured by the research pot in all pot pairs fished, their percent of occurrence in both pot types decreased with decreasing size class (Figure 13). In all cases in which only 1 pot within a pot pair captured at least 1 crab of a sex-size class considered here, that pot was a research pot (Table 6). The null hypothesis that commercial-fishing pots and research pots have an equal probability (0.5) of being the only pot within a pot pair to capture at least 1 crab was not rejected by a one-sided binomial test (Cox and Snell 1989) for sublegal males >120 ($P = 0.5^4 = 0.063$), but was rejected for: sublegal males, <101-mm CL ($P = 0.5^{18} < 0.001$); sublegal males, 101-mm to 120-mm CL ($P = 0.5^{13} < 0.001$); and females ($P = 0.5^5 = 0.031$).

There was no decreasing trend in the within-pot-pair CPUE differences with increasing size of the paired commercial-fishing pot. In fact, the within-pot-pair CPUE differences for total golden king crab tended to be greatest in pot pairs with the largest (6.5 ft x 7 ft; 198 cm x 213 cm) commercial-fishing pots and lowest in pot pairs with the smallest (5 ft x 5 ft; 152 cm x 152 cm) commercial-fishing pots (Figure 14). Moreover, although commercial-fishing pots tended to capture less than half of the total golden king crab captured by the 2 pot types within a pair, the proportion captured by the commercial-fishing pot within a pot pair tended to be highest in the pot pairs with the smallest (5 ft x 5 ft; 152 cm x 152 cm) commercial-fishing pots.

The size frequency distribution of males captured by commercial-fishing pots during this study was similar to the male size frequency distributions from the rationalized (i.e., 2005/06–2011/12) commercial seasons and nearly identical to the distribution from the 2011/12 season (Figure 15). The size frequency distribution of males captured in research pots was more similar to the distributions from the pre-rationalized (i.e., 1995/96–2004/05) seasons than to those from the rationalized seasons. However, the size frequency distribution from the research pots was distinguished from the distributions from all the commercial seasons during the 1995/96–2011/12 seasons by having a higher percentage of males <90-mm CL.

ESTIMATION OF SELECTIVITY OF MALE GOLDEN KING CRAB BY COMMERCIAL-FISHING POTS

The size range (56-mm to190-mm CL) of males captured by both pot types provided 27 5-mm-CL size classes to use in fitting the selection curve (Table 7). Estimated parameters of the

contact-selection curve are given in Table 8 with their approximate 95% confidence intervals. The proportion of total catch taken by the commercial fishing estimated by the fit of equation (2) agreed reasonably well with the observed proportions and deviance residuals (Figure 16) showed no systematic pattern except for the size classes for which sample sizes are lowest (i.e., those for sizes <91-mm CL and >175-mm CL).

DISCUSSION

The 31 commercial-fishing pots sampled for this study were fished during normal commercial fishing operations within an area that is regularly fished during the commercial fishery and at depths (average = 194 fathoms, 354 m) and soak times (average = 20 d) that are typical of the commercial fishery in the area east of 174° W longitude. The average depth and soak time of pots fished in the commercial fishery east of 174° W longitude during the 2011/12 fishery season, the most recent season for which data collected by fishery observers are available, were estimated to be 189 fathoms (346 m) and 19 d (Gaeuman 2013). The CPUEs for legal males, sublegal males, and females in the commercial-fishing pots sampled for this study (38, 10, and 9 crab per pot, respectively) were close and comparable to the estimated CPUEs of legal, sublegal, and female golden king crab for the 2011/12 commercial fishery east of 174° W longitude (41, 13, and 10 crab per pot lift, respectively; Gaeuman 2013). Moreover, the size distribution of male golden king crab captured in the sampled commercial-fishing pots was close to those estimated from observer data for the male golden king crab captured during the recent, rationalized (2005/06–2011/12) commercial fisheries in the area east of 174° W longitude. Hence the catch and catch composition of the golden king crab in the 31 commercial-fishing pots sampled for this study can be considered representative of the pots fished during commercial fishery east of 174° under current conditions and fishery practices.

For the purposes of estimating the symmetric logistic contact-selection curve for male golden king crab by commercial-fishing pots, we assumed that the research pots used in this study retained all male golden king crab that entered the pots and that the relative fishing intensities of the research pots and commercial-fishing pots were equal. We did not collect data that could be used to test the assumption that the research pots retained all male golden king crab that entered the pots. However, we note that the 2.5-in (64-mm) stretched-mesh webbing covering the research pots has a diagonal opening of roughly 45 mm when fit on the pot. Hence the webbing used on the research pots was sufficient to retain males at least to the size of the smallest male captured by any of the sampled commercial-fishing pots (73-mm CL). Although we initially had some concern that the research pots, being of larger size (7 ft x 7 ft; 213 cm x 213 cm) than the commercial-fishing pots (5 ft x 5 ft to 6.5 ft x 7 ft; 152 cm x 152 cm to 198 cm x 213 cm), may conferred higher relative fishing intensity, we saw no evidence for that in the comparisons of within-pot-pair catch differences, or comparisons of the within-pot-pair proportions of catch by commercial-fishing-pots by size of commercial-fishing pot. Moreover, the deviance residuals showed no systematic pattern suggesting that the equal-fishing-intensity assumption was violated. Additionally, our estimate of the contact-selection curve rests on the assumption that a male crab of any size was equally likely to enter a research pot as it was to enter a commercial-fishing pot if it were to enter a pot within a pot pair. Although we have no data to test that assumption, from the similarity in the tunnel designs of the research and commercial-fishing pots and the identical manner in which the research and commercial-fishing pots were fished for this study, that assumption seems entirely reasonable.

The results of this study demonstrated that the size distribution of the male golden king crab present on the grounds currently fished by the commercial fishery in the area east of 174° W longitude has a higher representation of sublegal size classes than is indicated by the catch data recorded by fishery observers from commercially-fished pots. The results also provide confirmation that the current practices and configurations of gear used in the commercial fishery are highly effective in reducing the bycatch of sublegal males. Average soak times of the pots fished in the commercial fishery east of 174° W longitude increased from 4.4 d during the pre-rationalized 1996/97–2004/05 fishery seasons to 14.7 d during the rationalized 2005/06–2010/11 fishery seasons (Table 382-2 in ADF&G 2012); the average soak time for the 2011/12 fishery season was 18.5 d (Gaeuman 2013). Increased soak times not only provide for more time for crab of all sizes to enter a pot, but also allow for more time for smaller crab in the pot to exit the pot through the escape mesh or rings (Pengilly and Tracy 1998). Additionally, statements by fishery participants that the pots used in the rationalized fishery are configured to exceed the minimum requirements for escape mesh or escape rings in regulation (Pengilly 2012; Siddeek et al. 2013a) were supported by our documentation of the escape mechanisms in the commercial-fishing pots that were sampled for this study. One intended benefit of the crab rationalization program was a reduction in crab bycatch during the commercial fisheries (NMFS 2004). There are no data comparable to what we presented here for estimating the contact-selection curve for commercial-fishing pots as they were configured and fished during the pre-rationalized fishery seasons. However, the results of this study suggest that the notable features that distinguish the size distribution of males captured during the rationalized seasons from the size distributions during the pre-rationalized seasons (Figures 2 and 3) are largely attributable to reduced retention by commercially-fished pots of the sublegal males and smaller-sized legal males that enter those pots. From the contact-selection curve fit to our data, we estimated that the size at 50% probability of retention for males by the pots fished during the current commercial fishery in the area east of 174° W longitude is approximately 135-mm CL, the same as the CL at recruitment to legal carapace width estimated by Tracy (1998) for Aleutian Islands golden king crab and close to the 136-mm CL that is used as a proxy for minimum legal carapace width in the current stock assessment model (Siddeek et al. 2013a). Furthermore, the probability of retention by pots estimated from the fitted contact-selection curve is only 75% for males at 141-mm CL and does not exceed 99% until sizes >160-mm CL. Estimated probability of retention by pots decreases steeply from 50% for males at 135-mm CL to 25% at 128-mm CL.

Our goal for estimating the contact-selection curve for the fishery east of 174° W longitude was to provide information for further development of a stock assessment model for the Aleutian Islands golden king crab stock (Siddeek et al. 2013a). The stock assessment model also estimates a selection curve, but, rather than estimating the contact-selection curve, the stock assessment model attempts to estimate the "population-selection curve" (Millar and Fryer 1999). In the context of the stock assessment model, the population-selection curve specifies the (relative) probability that a male crab of a given size from the Aleutian Islands golden king crab stock east of 174° W longitude is captured during the fishery. The contact-selection curve estimated from the data collected in this study is compared in Figure 17 with the population-selection curves estimated for the rationalized commercial fishery east of 174° W longitude by the 2 most recent versions of a stock assessment model (Siddeek et al. 2012a, 2013a). The estimates of the size at 50% selectivity are comparable for all the curves shown in Figure 17: 134.5-mm CL from the curve estimated in this study (Table 8), 133.9-mm CL from the curve estimated by Siddeek et al. (2013a), and 135.0-mm CL from the curve estimated Siddeek et al. (2012a). We note in

particular that the contact-selection curve that we estimated coincides closely with the population-selection curve estimated in the most recent stock assessment model for the commercial fishery in the area east of 174° W longitude by Siddeek et al. (2013a). The striking similarity of the population-selection curve estimated by Siddeek et al. (2013a) with the contact-selection curve that we estimated may be due to limitations in the data available for use by the stock assessment model; given the lack of fishery-independent data on the population size distribution, the stock assessment model must rely entirely on fishery data for estimation of the population-selection curve. Fishery-independent data on the male population size distribution is needed to estimate the population-selection curve for the commercial fishery and to determine whether it conforms as closely to our estimated contact-selection curve as does the population-selection curve estimated by Siddeek et al. (2013a). The contact-selection curve that we have estimated can serve as an upper bound for the estimate of the population-selection curve in future development of the stock assessment model until such fishery-independent data become available.

Finally, we note that, although we focused our presentation of results on the catch of male golden king crab, the research pots deployed during our study were also highly effective in capturing female golden king crab. The 31 research pots captured 2,524 females (CPUE = 81 crab per pot lift), whereas the 31 sampled commercial-fishing pots captured only 268 females with a CPUE (9 crab per pot lift) that was comparable to that estimated for the 2011/12 commercial fishery in the area east of 174° W longitude (10 crab per pot lift; Gaeuman 2013). Hence this study also provides evidence for the effectiveness of current fishing practices and gear to reduce bycatch of females, an important consideration given that 71% of the females captured by the research pots in this study were reproductively mature (Table 4). During the 2011/12 season in the area east of 174° W longitude the estimated bycatch of females represented 22% of the catch of legal males, in terms of number of crab captured before discarding (Gaeuman 2013). During the pre-rationalized fishery seasons, however, the female bycatch rate was substantially higher. Prior to the 2001/02 season, the estimated bycatch of females exceeded the catch of legal males (Gaeuman 2013) and as late as the 2004/05 season the estimated bycatch of females was 52% of the retained catch of legal males (Burt and Barnard 2006).

ACKNOWLEDGEMENTS

Partial funding for this project was provided by the Bering Sea Crab Test Fish Project, authorized by the State of Alaska under the Test Fish Program (AS 16.05.050 (15)), and by National Oceanic and Atmospheric Administration (NOAA) Award NA12NMF4370099. The views expressed herein are those of the authors and do not necessarily reflect the views of NOAA or any of its sub-agencies.

The pots that were specially designed and fabricated for this project were provided by the Aleutian Islands King Crab Research Foundation and the Bering Sea Fisheries Research Foundation. We especially thank the captains (Rip Carlton and Rick Alverez) and crew (Sean Doran, Roberto Rizo, Willy Olvalles, James Grigg, Luke Smith, and Ray Moe) of the *F/V Aleutian No. 1* for their most-willing cooperation and assistance, their interest and sharing of knowledge, and their professional seamanship. The research accomplished and the time at sea would not have been as successful without their contributions and adaptations, large and small, and the countless hours of preplanning done by Rip Carlton with the project lead biologist. We thank the Norton Sound Economic Development Corporation for providing the *F/V Aleutian No. 1* as a platform to conduct this study,

and Denby Lloyd (Aleutian Islands King Crab Research Foundation) for facilitating this cooperative project. We also thank Dmitri DelaCruz (ADF&G) for his enormous efforts towards collecting the data presented here while serving as the second research team member at-sea with the project lead biologist, and Susan Strand for her cooperation and assistance while serving as a fishery observer on the *F/V Aleutian No. 1*. Finally, we acknowledge the contributions of the following to this report: reviewers Jie Zheng (ADF&G, Fisheries Scientist), David Barnard (ADF&G, Biometrician), and Heather Fitch (ADF&G, Fishery Biologist); and Katherine Greer (ADF&G, Publications Specialist).

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TABLES AND FIGURES

Table 1.–Harvest history for the Aleutian Islands golden king crab commercial fishery for the combined areas east and west of 174° W longitude from the 1981/82 season through the 2011/12 season (from Pengilly 2012).

Season	GHL/TAC[a] (lb)	Harvest (lb)[b]	Harvest (Number)[b]	Pot lifts	CPUE[c]	Average Weight[d]
1981/82	-	1,319,666	242,407	28,263	8.4	5.4[e]
1982/83	-	9,236,942	1,746,206	179,888	9.4	5.3[e]
1983/84	-	10,495,045	1,964,772	267,519	7.2	5.3[e]
1984/85	-	4,819,347	995,453	90,066	10.7	4.8[f]
1985/86	-	12,734,212	2,811,195	236,281	11.9	4.5[g]
1986/87	-	14,738,744	3,340,627	433,020	7.7	4.4[g]
1987/88	-	9,257,005	2,174,576	306,730	7.1	4.2[g]
1988/89	-	10,627,042	2,488,433	321,927	7.6	4.3[g]
1989/90	-	12,022,052	2,902,913	357,803	8.0	4.1[g]
1990/91	-	6,950,362	1,703,251	214,814	7.7	4.1[g]
1991/92	-	7,702,141	1,847,398	234,857	7.7	4.2[g]
1992/93	-	6,291,197	1,528,328	203,221	7.4	4.1[g]
1993/94	-	5,551,143	1,397,530	234,654	5.8	4.0[g]
1994/95	-	8,128,511	1,924,271	386,593	4.8	4.2[g]
1995/96	-	6,960,406	1,582,333	293,021	5.2	4.4[g]
1996/97	5,900,000	5,815,772	1,334,877	212,727	6.0	4.4[g]
1997/98	5,900,000	5,945,683	1,350,160	193,214	6.8	4.4[g]
1998/99	5,700,000	4,941,893	1,150,029	119,353	9.4	4.3[g]
1999/00	5,700,000	5,838,788	1,385,890	186,169	7.2	4.2[g]
2000/01	5,700,000	6,018,761	1,410,315	172,790	8.0	4.3[g]
2001/02	5,700,000	5,918,706	1,416,768	168,151	8.3	4.2[g]
2002/03	5,700,000	5,462,455	1,308,709	131,021	9.8	4.2[g]
2003/04	5,700,000	5,665,828	1,319,707	125,119	10.3	4.3[g]
2004/05	5,700,000	5,575,051	1,323,001	91,694	14.2	4.2[g]
2005/06	5,700,000	5,520,318	1,263,339	54,685	22.9	4.4[g]
2006/07	5,700,000	5,262,342	1,178,321	53,065	22.0	4.5[g]
2007/08	5,700,000	5,508,100	1,233,848	52,609	23.5	4.5[g]
2008/09	5,985,000	5,680,084	1,254,607	50,666	24.8	4.5[g]
2009/10	5,985,000	5,912,287	1,308,218	52,787	24.8	4.5[g]
2010/11	5,985,000	5,968,849	1,297,229	55,795	23.2	4.6[g]
2011/12	5,985,000	5,964,416	1,284,946	44,241	29.0	4.6[g]

[a] Guideline harvest level (GHL) for the 1996/97–2004/05 seasons and total allowable catch (TAC) for the 2005/06–2011/12 seasons.

[b] Includes deadloss.

[c] Catch (number of crab) per pot lift.

[d] Average weight (pounds) of landed crab, including deadloss.

[e] Managed with 6.5" CW minimum size limit.

[f] Managed with 6.5" CW minimum size limit west of 171° W longitude and 6.0" CW minimum size limit east of 171° W longitude.

[g] Managed with 6.0" CW minimum size limit.

Table 2.–Number (N) of male golden king crab captured by pots sampled by fishery observers and percent in each of 5 size classes defined by carapace length (mm) during the 1996/97–2011/12 commercial Aleutian Islands golden king crab fishery for the areas east and west of 174° W longitude (data from the ADF&G Crab Observer Database, Division of Commercial Fisheries, September 2012).

	East of 174° W longitude						West of 174° W longitude					
		Carapace length class (mm)						Carapace length class (mm)				
Season	N	< 101	101-120	121-135	136-150	>150	N	< 101	101-120	121-135	136-150	>150
1996/97	93,521	9.1%	20.2%	30.8%	27.2%	12.8%	82,826	5.9%	19.7%	34.9%	29.3%	10.3%
1997/98	84,622	8.3%	19.9%	31.9%	28.3%	11.5%	55,861	4.9%	18.3%	31.8%	32.3%	12.6%
1998/99	91,159	8.5%	21.0%	33.4%	26.9%	10.1%	36,488	5.4%	18.2%	33.8%	34.1%	8.5%
1999/00	79,174	6.9%	15.6%	31.8%	32.8%	12.9%	65,203	5.3%	17.9%	33.1%	33.6%	10.2%
2000/01	30,723	7.8%	16.8%	30.3%	32.1%	13.1%	75,313	4.5%	20.0%	34.4%	31.5%	9.6%
2001/02	37,822	5.9%	13.0%	27.3%	38.3%	15.5%	65,651	3.0%	16.2%	35.6%	36.1%	9.2%
2002/03	25,749	4.7%	11.1%	24.9%	40.5%	18.8%	43,114	2.8%	15.9%	35.4%	37.4%	8.5%
2003/04	23,605	3.2%	10.3%	24.9%	40.3%	21.4%	39,056	1.2%	8.7%	33.5%	43.8%	12.8%
2004/05	19,993	2.6%	8.8%	24.0%	41.1%	23.5%	35,539	2.0%	11.3%	35.3%	41.2%	10.2%
2005/06	12,693	1.9%	4.0%	14.7%	44.1%	35.3%	24,186	0.3%	4.8%	24.3%	52.1%	18.6%
2006/07	9,666	2.1%	3.8%	14.9%	41.7%	37.5%	27,095	0.3%	4.4%	20.5%	49.0%	25.8%
2007/08	12,608	0.4%	2.0%	12.2%	42.5%	43.0%	26,796	0.6%	6.3%	23.8%	45.5%	23.7%
2008/09	15,794	0.5%	3.0%	14.5%	42.8%	39.3%	25,253	0.2%	4.8%	21.5%	47.1%	26.3%
2009/10	14,086	0.7%	3.3%	16.4%	43.6%	35.9%	30,141	0.1%	2.7%	16.3%	47.6%	33.3%
2010/11	15,525	1.5%	4.8%	18.0%	41.1%	34.6%	24,881	0.3%	3.4%	18.3%	45.7%	32.4%
2011/12	19,102	0.6%	3.6%	14.4%	44.5%	36.9%	26,105	0.2%	2.9%	17.2%	47.1%	32.7%
Average, 1996/97–2004/05	54,041	6%	15%	29%	34%	16%	55,450	4%	16%	34%	35%	10%
Average, 2005/06–2011/12	14,211	1%	3%	15%	43%	38%	26,351	<0.5%	4%	20%	48%	28%

Table 3.–Outside dimensions of 31 commercial-fishing pots used by the *F/V Aleutian No. 1* during the 2012/13 Aleutian golden king crab fishery in the area east of 174° W longitude that were sampled for the study of commercial-fishing pot selectivity.

Size[a]	Number
5' x 5'	6
5' x 5½'	6
5½' x 6'	5
6' x 6'	2
6' x 6½'	1
6' x 7'	7
6½" x 7'	4

[a] Measured in ft: (tunnel-to-tunnel) x (door-to-door)

Table 4.–Catch of golden king crab by sex and size classes by 31 research (R) pots and 31 commercial-fishing (C) pots fished by the *F/V Aleutian No. 1* during the 2012/13 Aleutian golden king crab fishery in the area east of 174° W longitude that were sampled for the study of commercial-fishing pot selectivity.

		Pot Type		
		C	R	Total
Males		1,477	3,615	5,092
	Legal	1,172	1,378	2,550
	Sublegal	305	2,237	2,542
	<101 mm CL	4	479	483
	101–120 mm CL	25	796	821
	>120 mm CL	276	962	1,238
Females		286	2,524	2,810
	Mature	268	1,785	2,053
	Immature	17	733	750
	Unknown	1	6	7
Unknown sex		0	7	7
Total		1,763	6,146	7,909

Table 5.–Statistics on within-pair differences in catch between the research pot and the commercial-fishing pot (research pot catch minus commercial-fishing pot catch) of golden king crab sex-size classes captured for the study of commercial-fishing pot selectivity by the *F/V Aleutian No. 1* during the 2012/13 Aleutian golden king crab fishery in the area east of 174° W longitude, with results of paired t tests on the mean differences and Wilcoxin signed rank tests on the median differences for sex-size classes.

	Male				
	Sublegal male				
	<101 mm CL	101–120 mm CL	>120 mm CL	Legal	Female
N[a]	20	26	31	31	29
Minimum	1	2	-24	-39	1
Maximum	233	101	81	77	354
SD	52.31	27.25	22.07	26.55	86.53
Median	4.5	20.5	16.0	3.0	47.0
Mean	23.8	29.7	22.1	6.6	77.2
SE	11.70	5.34	3.96	4.77	16.07
P (1-sided t test)[b]	0.028	<0.001	<0.001	0.087	<0.001
P (1-sided Wilcoxin)[c]	<0.001	<0.001	<0.001	0.108	<0.001

[a] N for sex-size class is the number of pot pairs in which >0 crab of the sex-size class were captured.
[b] P-values from t test for H_0: mean difference = 0 versus H_1: mean difference >0.
[c] P-values from Wilcoxin signed rank test for H_0: median difference = 0 versus H_1: median difference >0.

Table 6.– Counts of commercial-fishing (C) pots and research (R) pots with captured golden king crab sex-size classes present (1) or absent (0) in 31 pot pairs fished by the *F/V Aleutian No. 1* during the 2012/13 Aleutian golden king crab fishery in the area east of 174° W longitude for the study of commercial-fishing pot selectivity.

		Count for:				
C pot	R pot	Male, sublegal < 101mm CL	Male, sublegal 101-120 mm CL	Male, sublegal >120 mm CL	Male, legal	Female
0	0	11	5	0	0	2
0	1	18	13	4	0	5
1	0	0	0	0	0	0
1	1	2	13	27	31	24

Table 7.–Number of male golden king crab captured by commercial-fishing (C) pots and research (R) pots fished by the *F/V Aleutian No. 1* during the 2012/13 Aleutian golden king crab fishery in the area east of 174° W longitude, by 5 mm carapace length (CL) size classes.

Size class mid-point	C pots	R pots	Total	C pot pecentage
58	0	3	3	0.0%
63	0	2	2	0.0%
68	0	38	38	0.0%
73	1	55	56	1.8%
78	0	68	68	0.0%
83	2	59	61	3.3%
88	1	54	55	1.8%
93	0	95	95	0.0%
98	0	105	105	0.0%
103	1	146	147	0.7%
108	0	165	165	0.0%
113	6	197	203	3.0%
118	18	288	306	5.9%
123	31	305	336	9.2%
128	69	339	408	16.9%
133	153	326	479	31.9%
138	206	322	528	39.0%
143	237	220	457	51.9%
148	235	231	466	50.4%
153	148	180	328	45.1%
158	111	138	249	44.6%
163	117	99	216	54.2%
168	72	77	149	48.3%
173	40	55	95	42.1%
178	17	30	47	36.2%
183	10	12	22	45.5%
188	2	6	8	25.0%
Total	1,477	3,615	5,092	-

Table 8.–Estimated parameters, with approximate 95% confidence intervals, of the logistic contact-selection curve for male golden king crab in commercial-fishing pots used by the *F/V Aleutian No. 1* during the 2012/13 Aleutian golden king crab fishery in the area east of 174° W longitude.

Parameter	Estimate	95% confidence interval
a	-23.735	(-29.312, -16.915)
b	0.1765	(0.1263, 0.2197)
l_{25} (mm CL)	128.3	(126.0, 129.6)
l_{50} (mm CL)	134.5	(132.8, 137.5)
l_{75} (mm CL)	140.7	(138.0, 145.8)
SR (mm CL)	12.5	(10.0, 17.4)

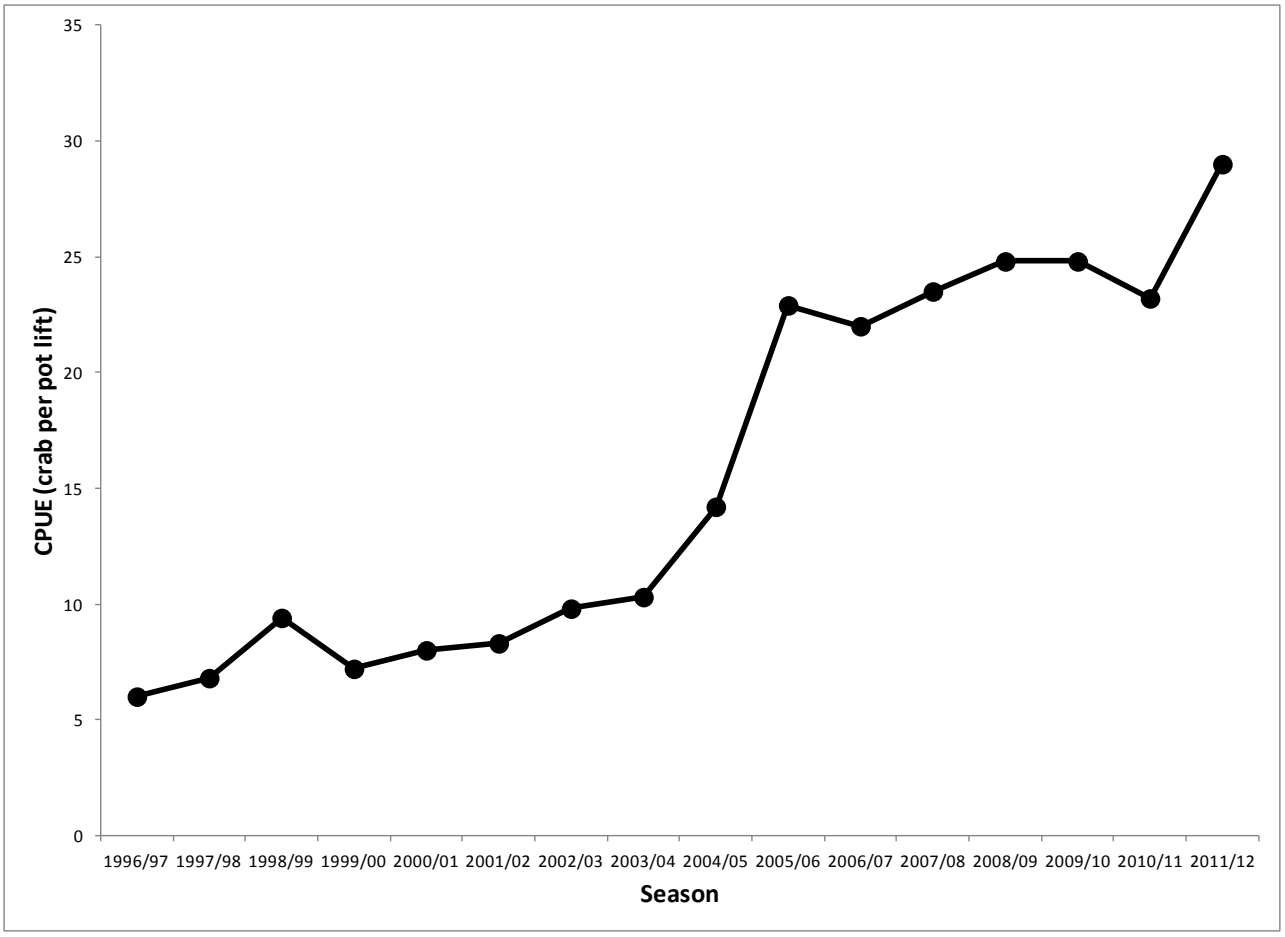

Figure 1.–Catch per pot lift of landed legal males in the Aleutian Islands golden king crab fishery (east and west of 174° W longitude, combined), 1996/97–2011/12.

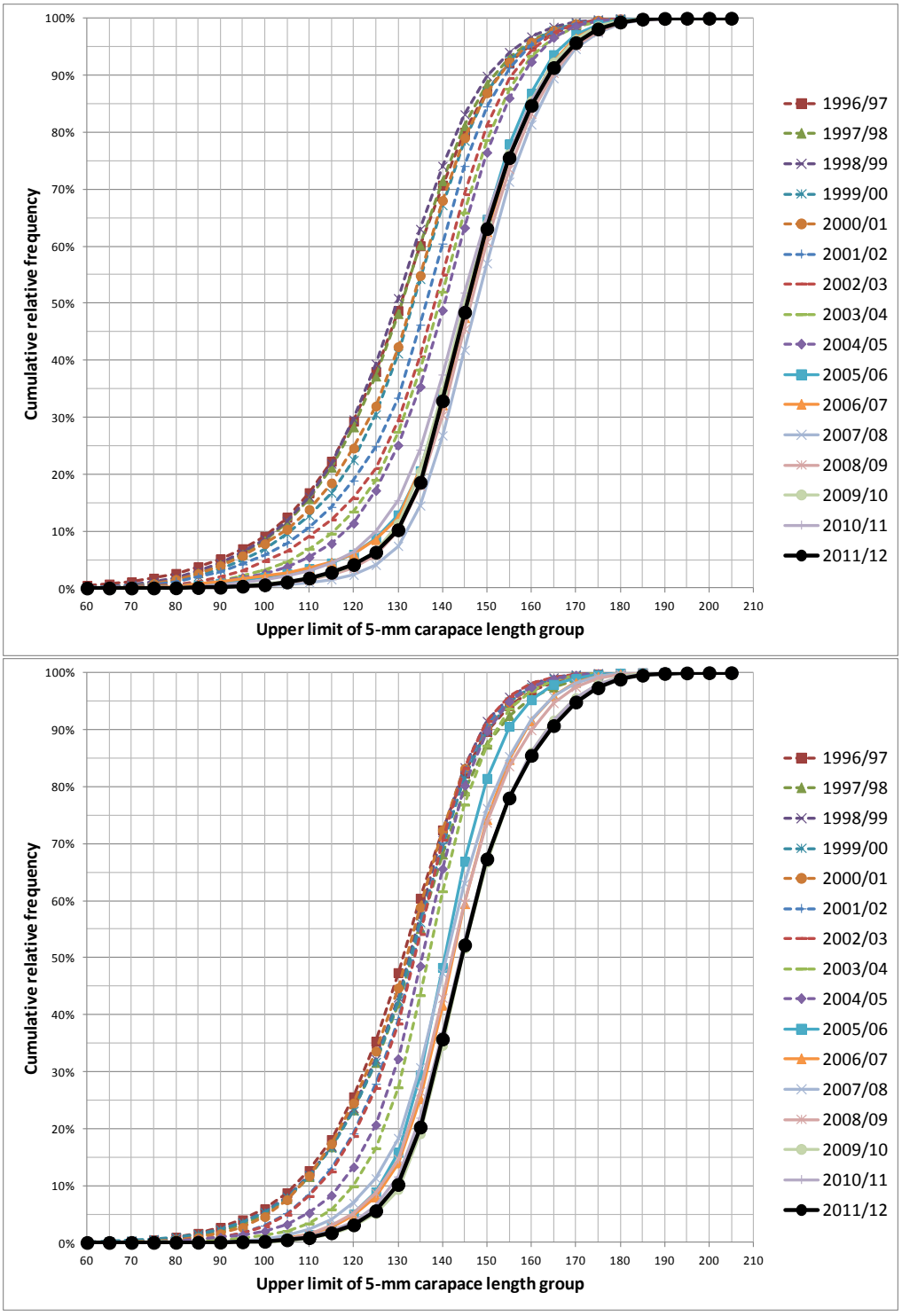

Figure 2.–Cumulative relative size (mm, carapace length) frequency of male golden king crab captured by pots sampled by fishery observers during the 1996/97–20011/12 Aleutian Islands golden king crab fishery, by season, in the areas east (above) and west (below) of 174° W longitude.

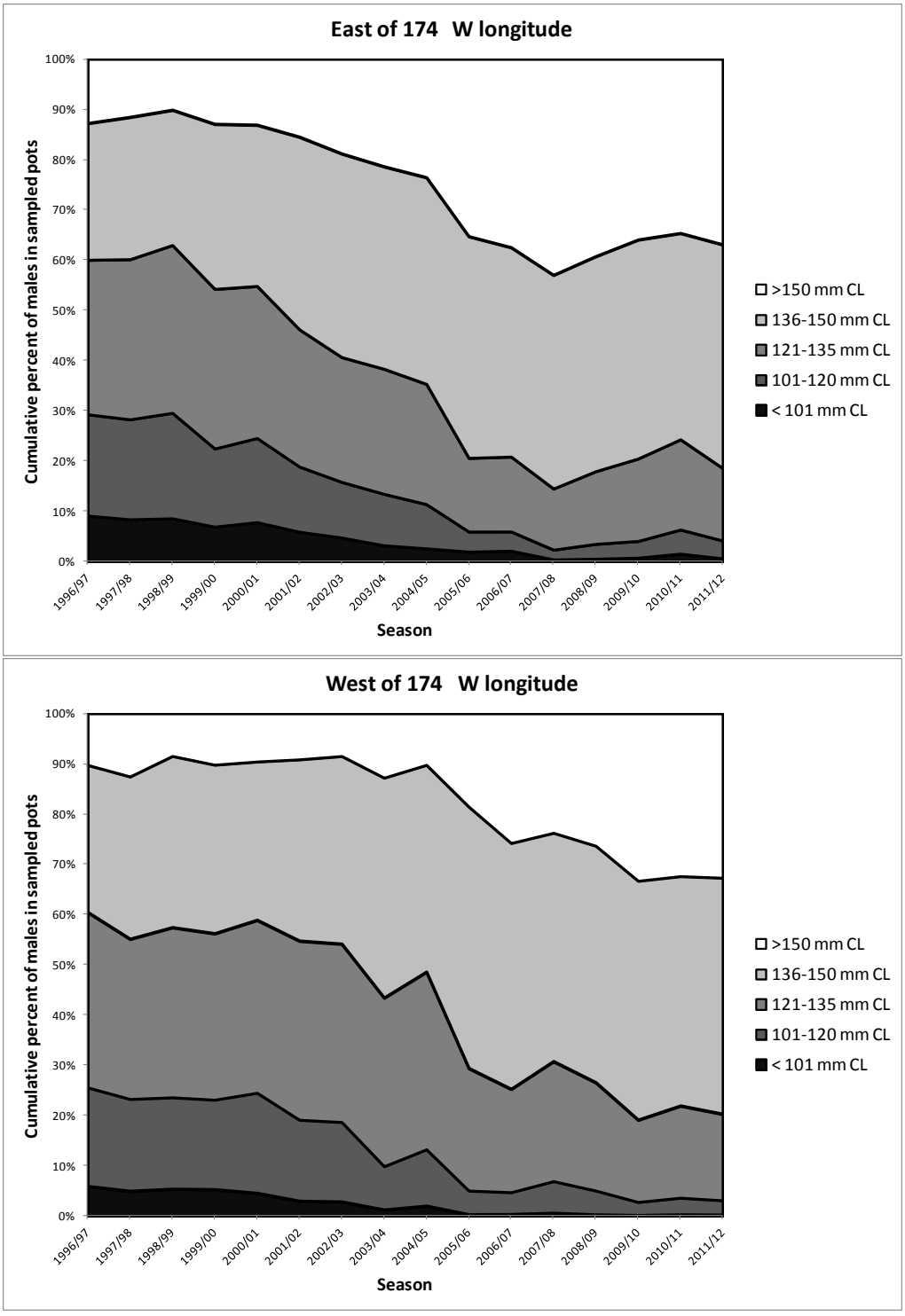

Figure 3.–Percent composition in 5 size classes (mm, carapace length) of male golden king crab captured by pots sampled by fishery observers during the 1996/97 – 20011/12 Aleutian Islands golden king crab fishery, by season, in the areas east (above) and west (below) of 174° W longitude.

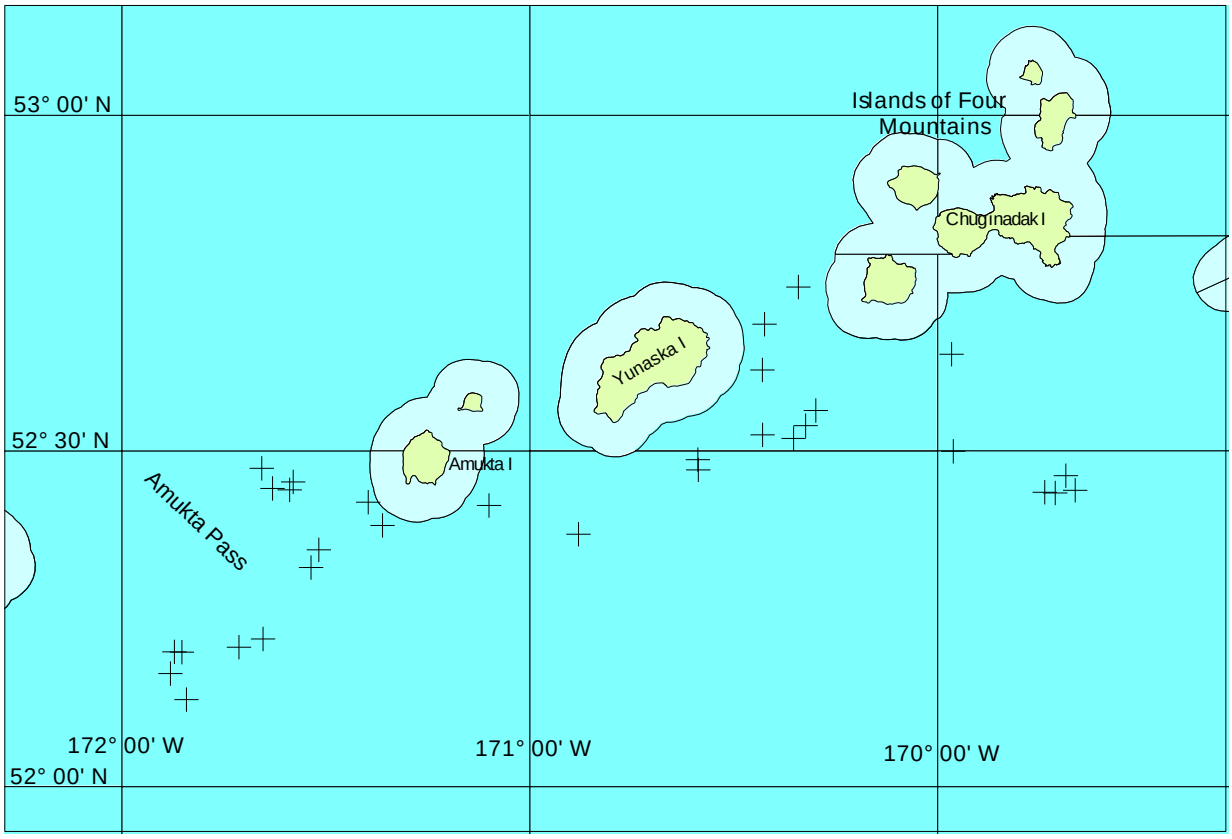

Figure 4.–Locations of 31 pairs of commercial-fishing pots and research pots fished by the *F/V Aleutian No. 1* during the 2012/13 Aleutian golden king crab fishery in the area east of 174° W longitude; locations of pairs are the within-pair haul locations.

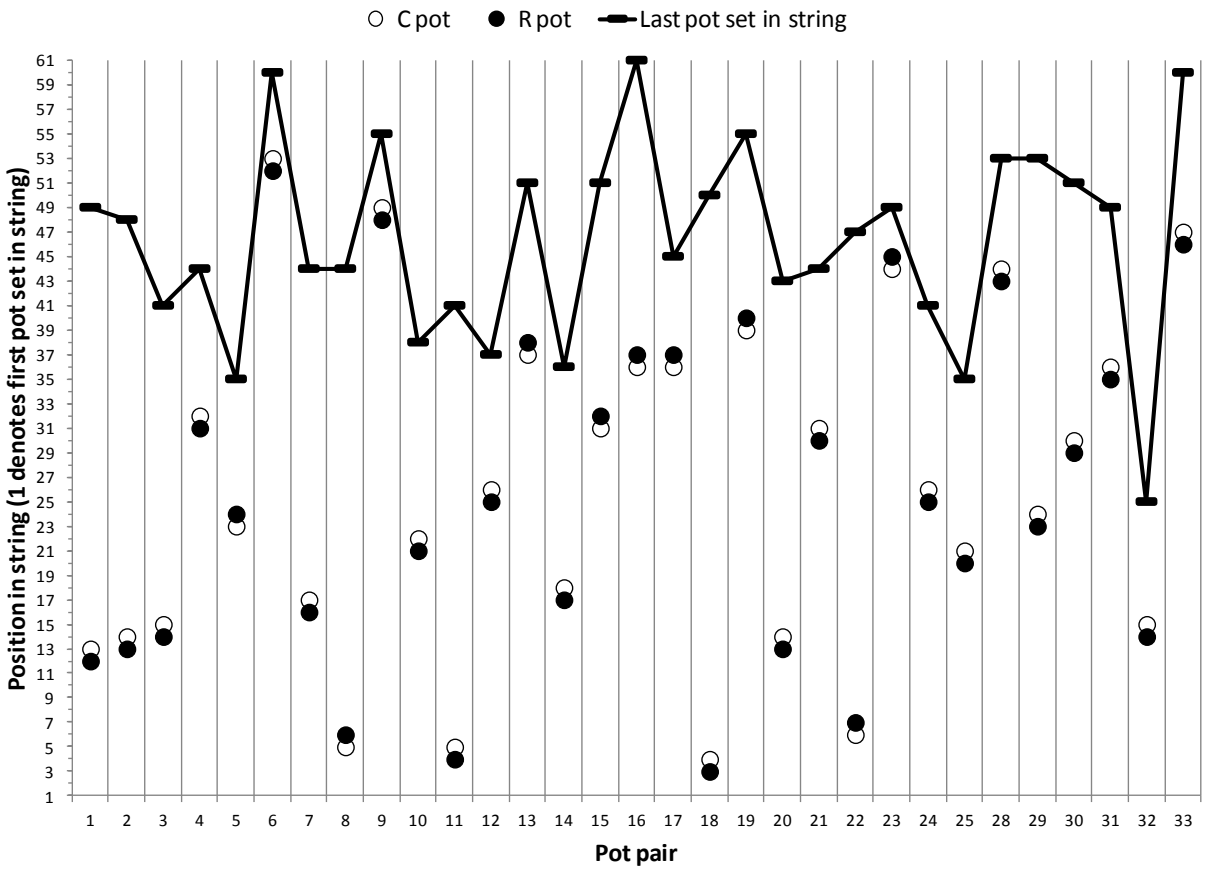

Figure 5.–Within-string relative locations of paired commercial-fishing (C) pots and research (R) pots fished by the *F/V Aleutian No. 1* during the 2012/13 Aleutian golden king crab fishery in the area east of 174° W longitude; locations of pairs are the within-pair haul locations.

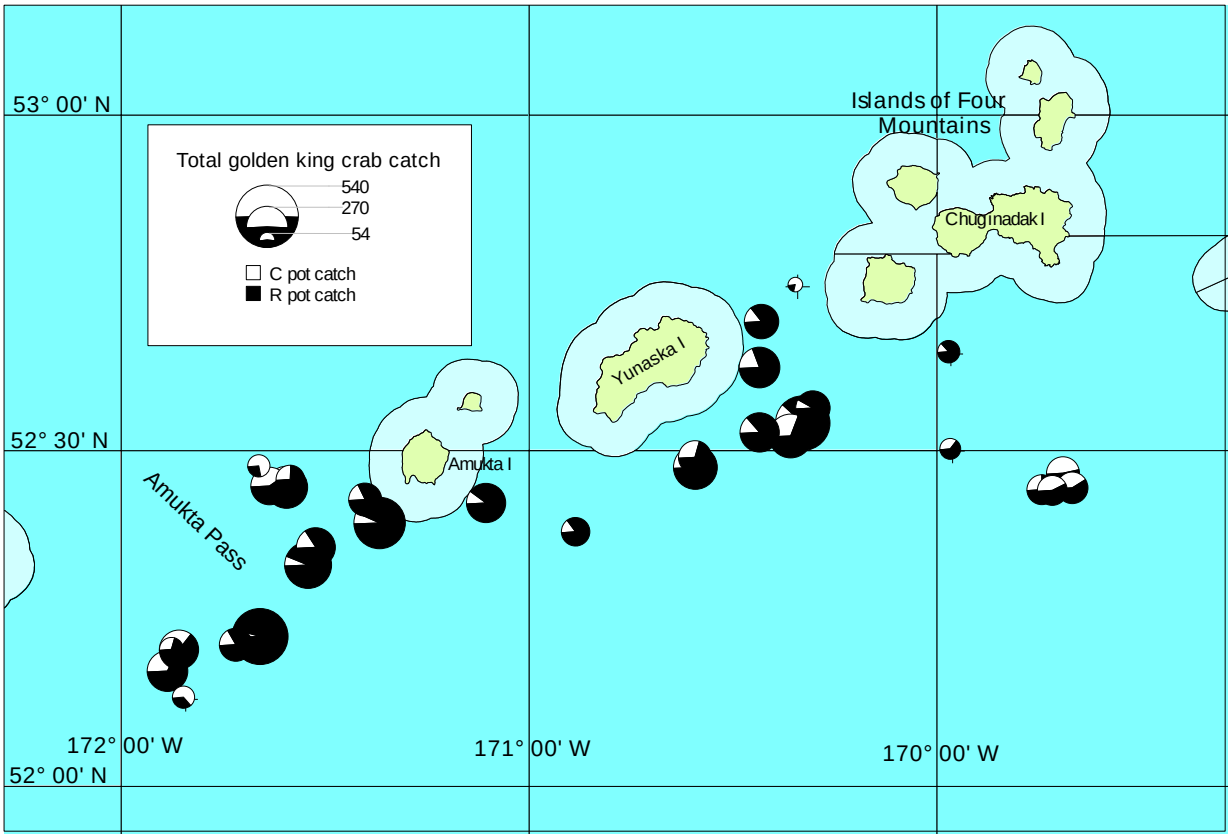

Figure 6.–Total catch of golden king crab in 31 pairs of commercial-fishing (C) pots and research (R) pots fished by the *F/V Aleutian No. 1* during the 2012/13 Aleutian golden king crab fishery in the area east of 174° W longitude, with relative contribution to catch by pot type; locations of pairs are the within-pair haul locations.

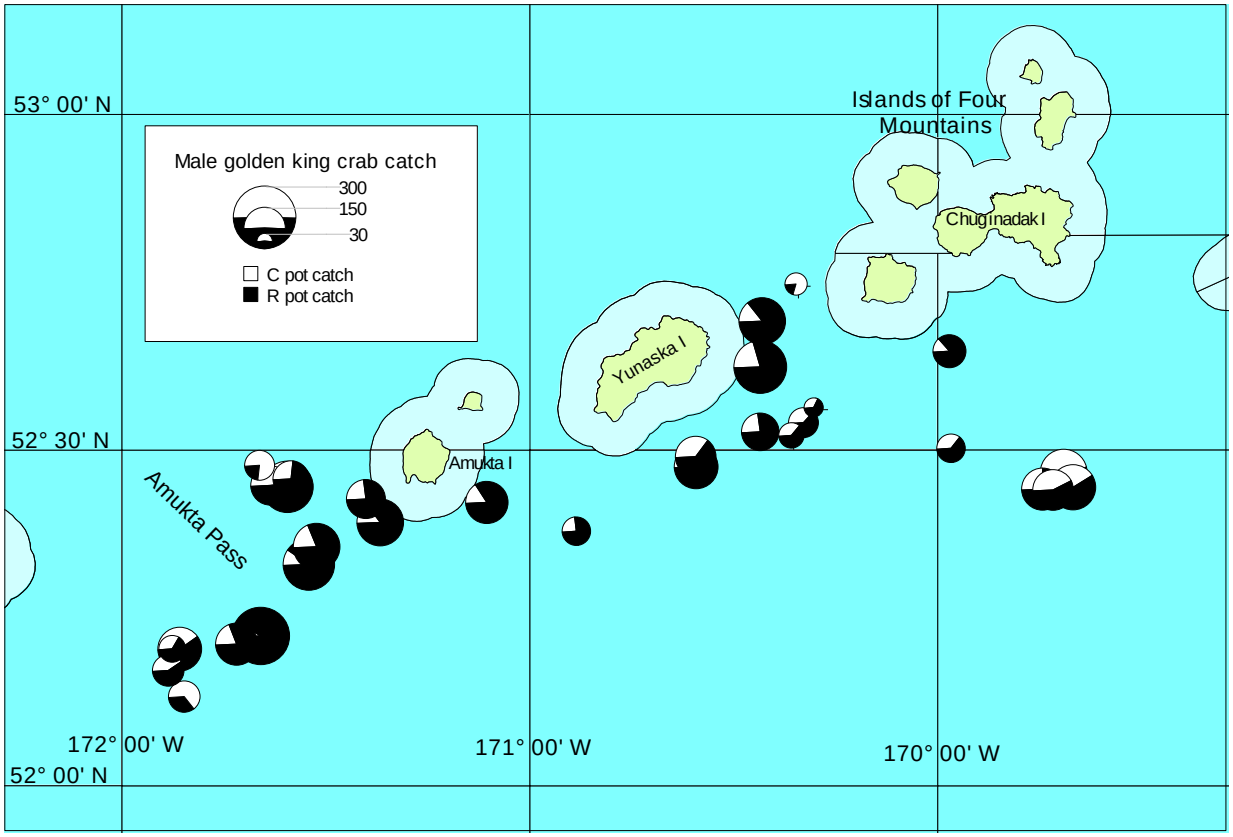

Figure 7.–Catch of male golden king crab in 31 pairs of commercial-fishing (C) pots and research (R) pots fished by the *F/V Aleutian No. 1* during the 2012/13 Aleutian golden king crab fishery in the area east of 174° W longitude, with relative contribution to catch by pot type; locations of pairs are the within-pair haul locations.

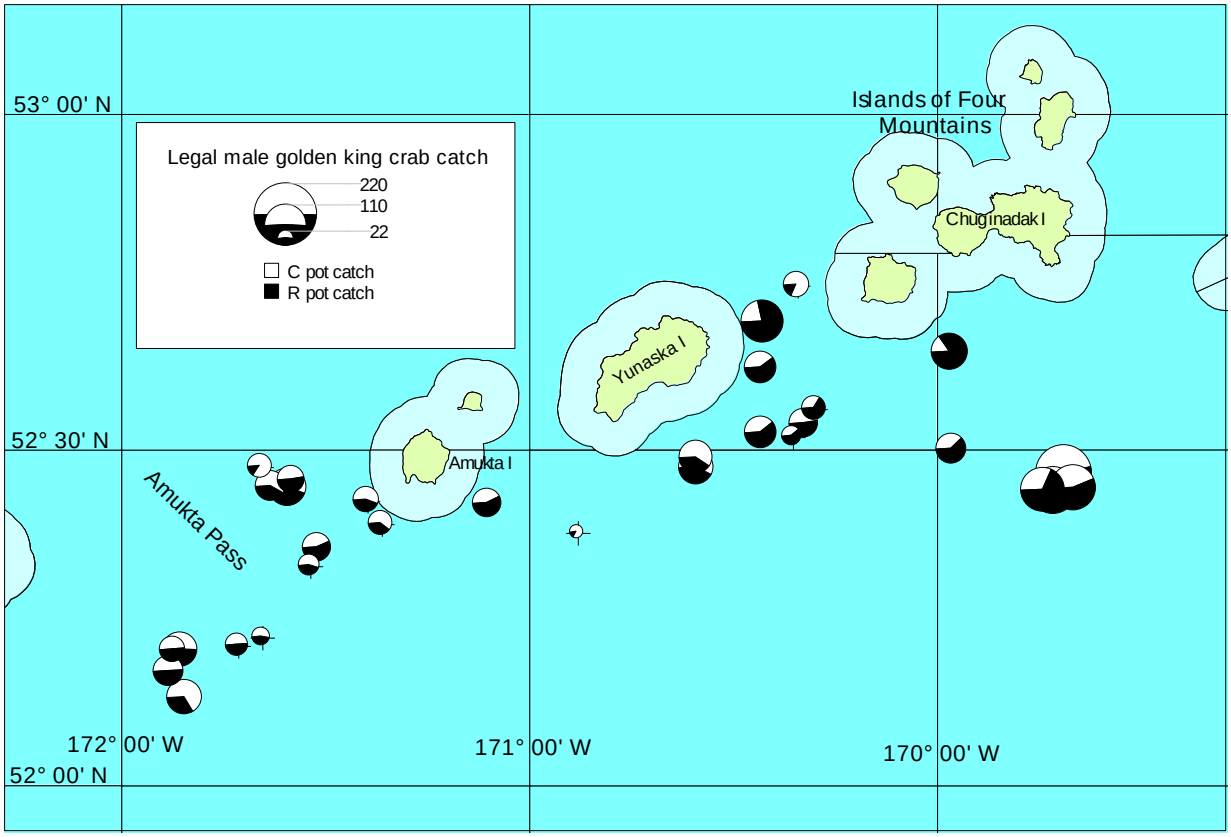

Figure 8.–Catch of legal male golden king crab in 31 pairs of commercial-fishing (C) pots and research (R) pots fished by the *F/V Aleutian No. 1* during the 2012/13 Aleutian golden king crab fishery in the area east of 174° W longitude, with relative contribution to catch by pot type; locations of pairs are the within-pair haul locations.

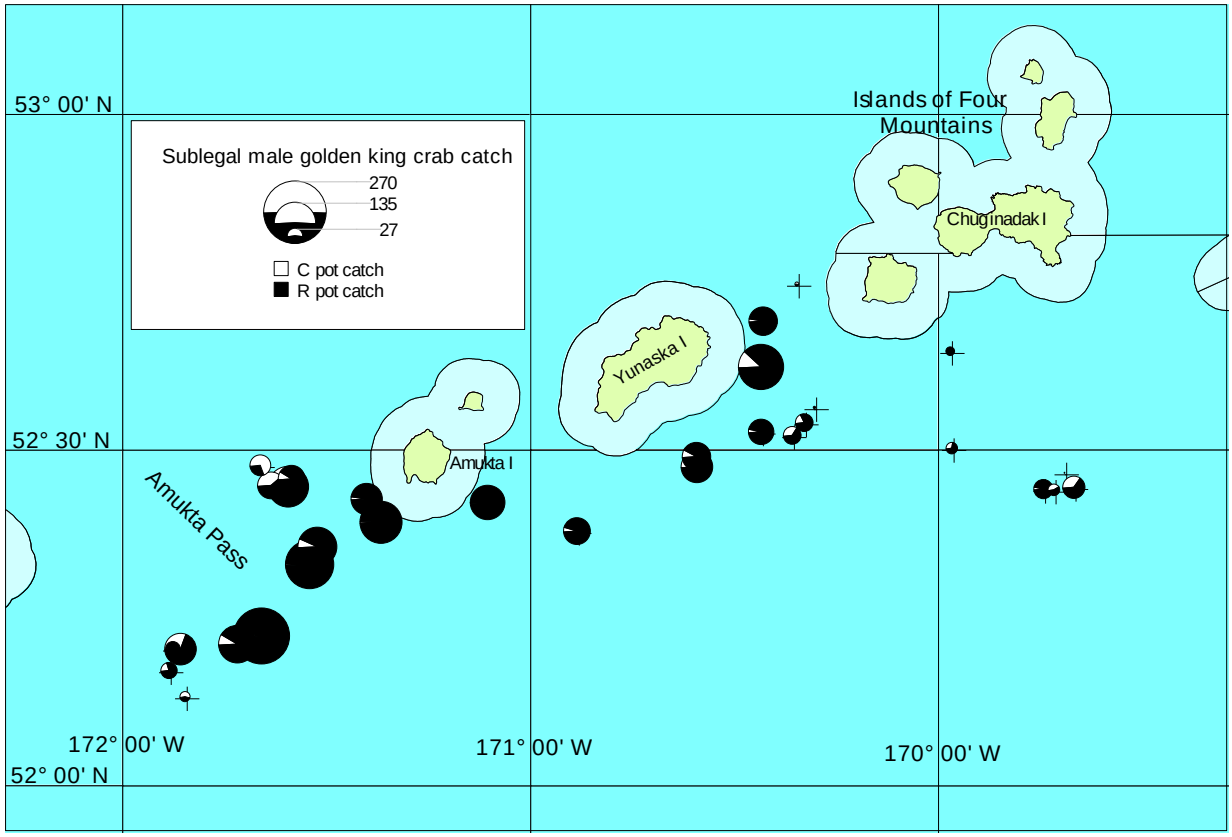

Figure 9.–Catch of sublegal male golden king crab in 31 pairs of commercial-fishing (C) pots and research (R) pots fished by the *F/V Aleutian No. 1* during the 2012/13 Aleutian golden king crab fishery in the area east of 174° W longitude, with relative contribution to catch by pot type; locations of pairs are the within-pair haul locations.

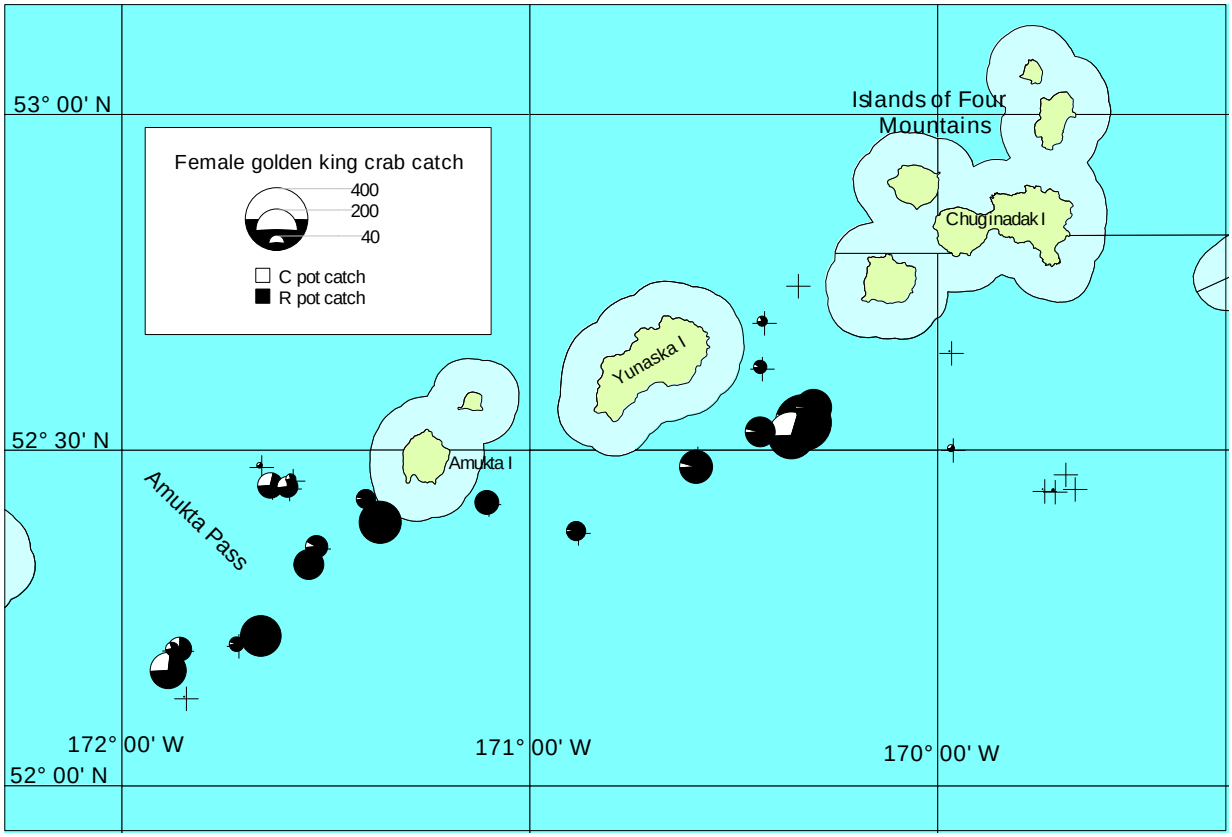

Figure 10.–Catch of sublegal male golden king crab in 31 pairs of commercial-fishing (C) pots and research (R) pots fished by the *F/V Aleutian No. 1* during the 2012/13 Aleutian golden king crab fishery in the area east of 174° W longitude, with relative contribution to catch by pot type; locations of pairs are the within-pair haul locations.

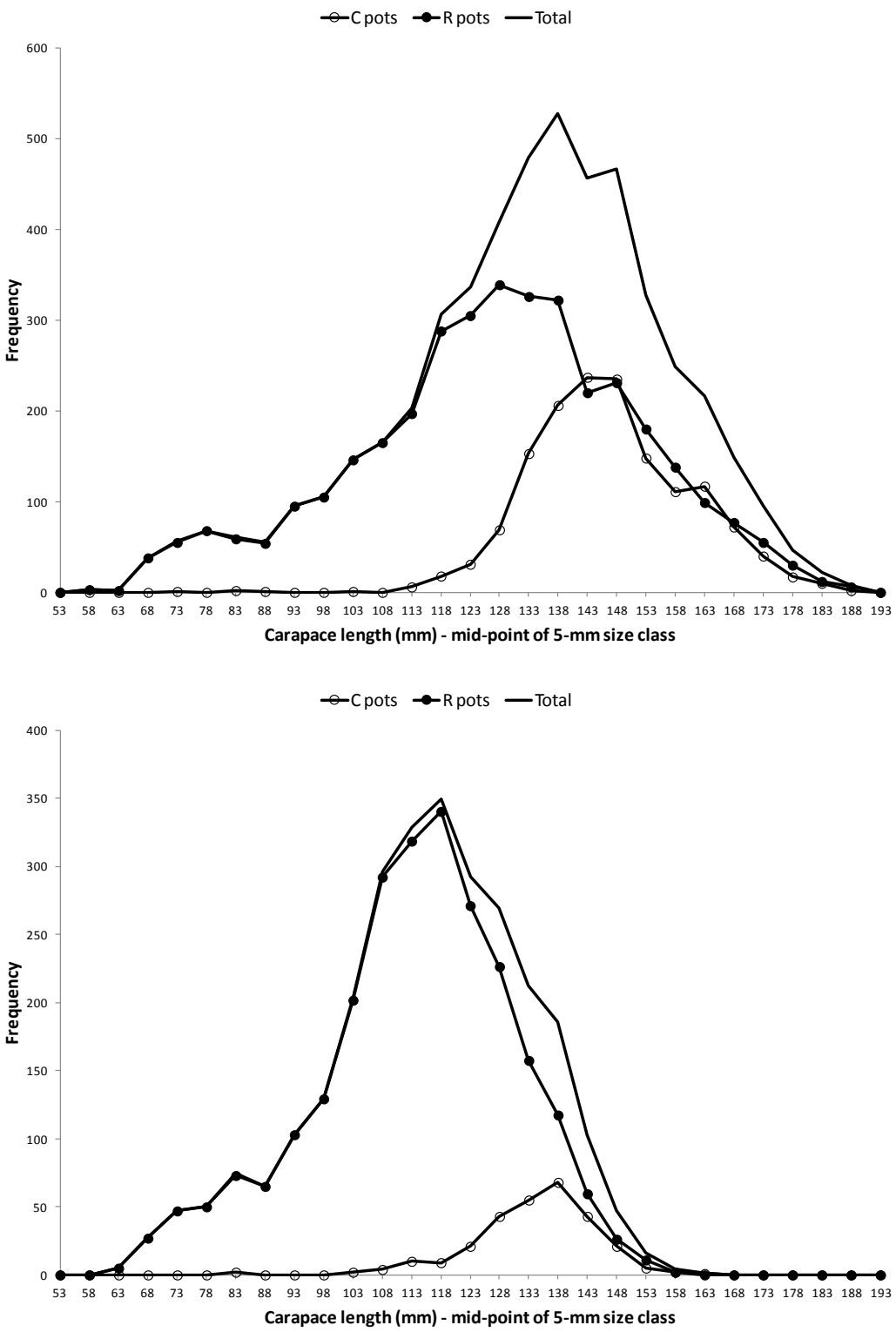

Figure 11.–Size (carapace length, mm) distribution of male (top panel) and female (bottom panel) golden king crab captured, in total and by pot type, in 31 pairs of commercial-fishing (C) pots and research (R) pots fished by the *F/V Aleutian No. 1* during the 2012/13 Aleutian golden king crab fishery in the area east of 174° W longitude.

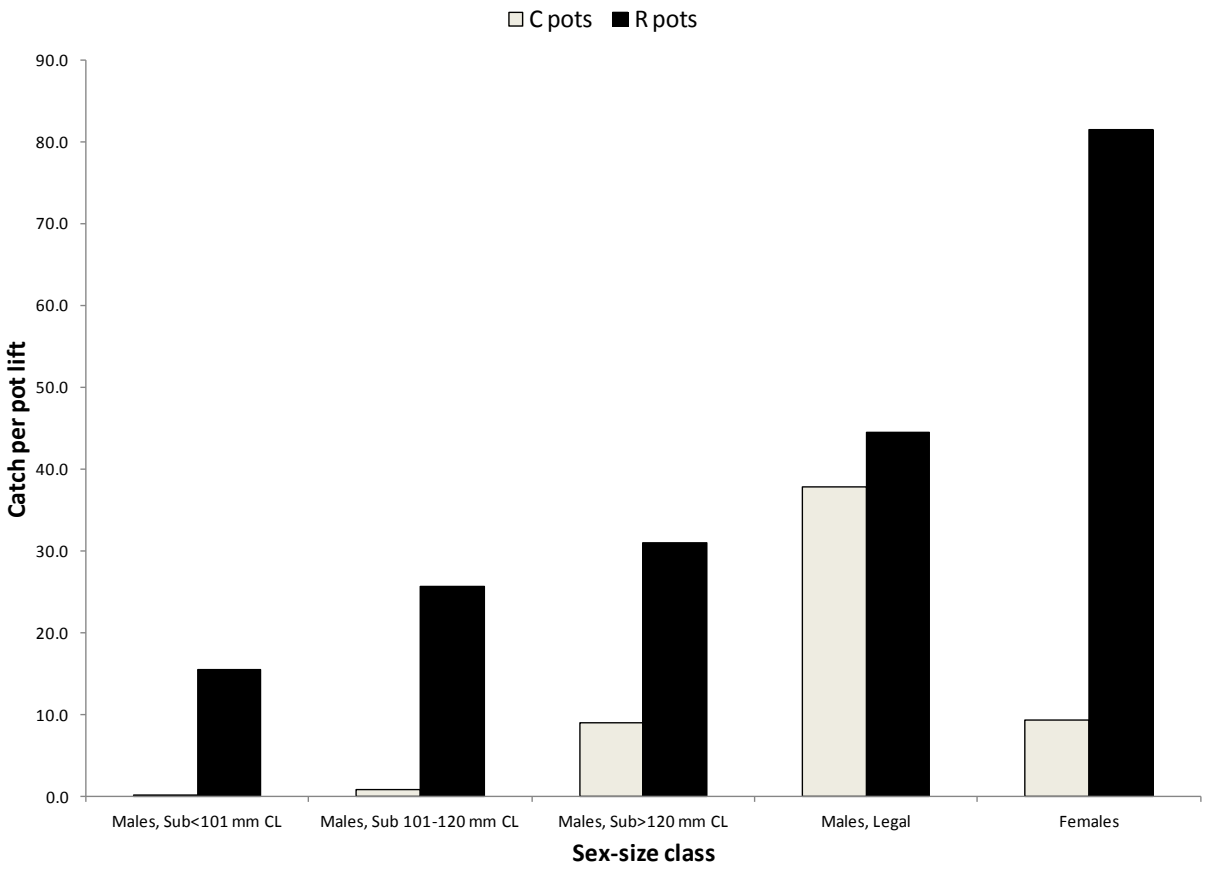

Figure 12.–Catch per pot lift by sex-size class and pot type of golden king crab captured in 31 pairs of commercial-fishing (C) pots and research (R) pots fished by the *F/V Aleutian No. 1* during the 2012/13 Aleutian golden king crab fishery in the area east of 174° W longitude.

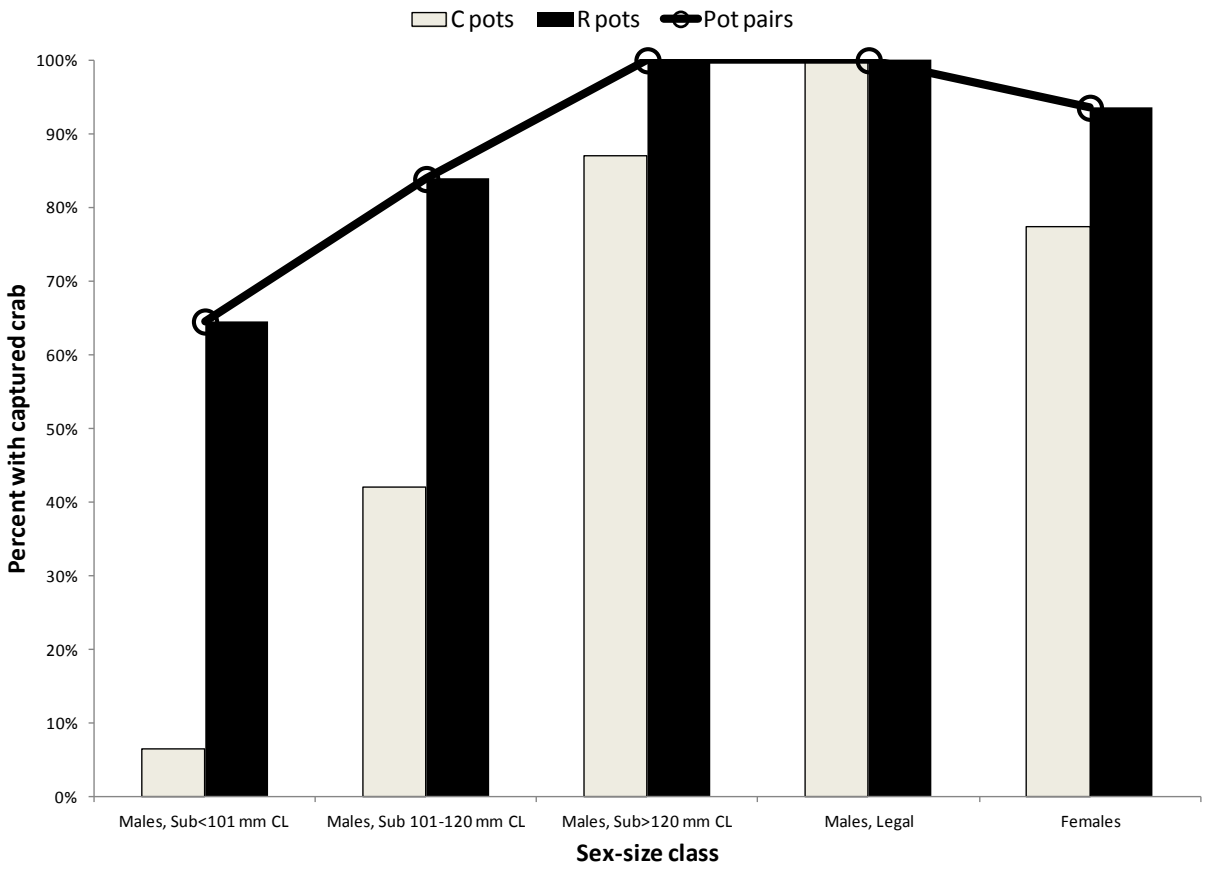

Figure 13.–Percent of pots with non-zero catch of golden king crab by sex-size class and pot type in 31 pairs of commercial-fishing (C) pots and research (R) pots fished by the *F/V Aleutian No. 1* during the 2012/13 Aleutian golden king crab fishery in the area east of 174° W longitude.

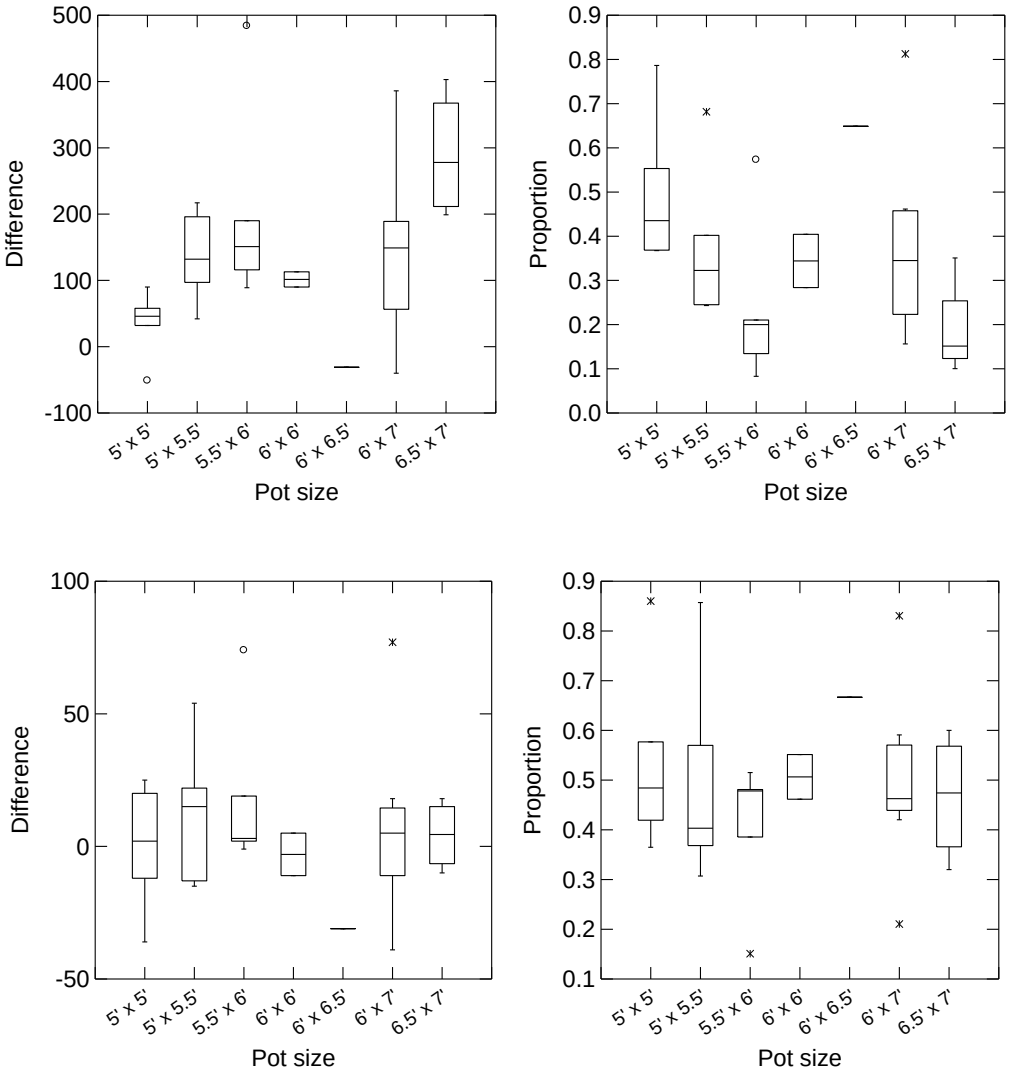

Figure 14.–Box plots of the within-pot-pair differences in catch (research pot catch minus commercial-fishing pot catch; left column of panels) and the within-pot-pair proportions of catch by commercial-fishing-pots (right column of panels) for total golden king crab (top row of panels) and legal male golden king crab (bottom rows of panels) in the 31 pairs of research and commercial-fishing pots, by size of the commercial-fishing pot within the pot pair; pot sizes are the outside dimensions (ft): (tunnel-to-tunnel) x (door-to-door).

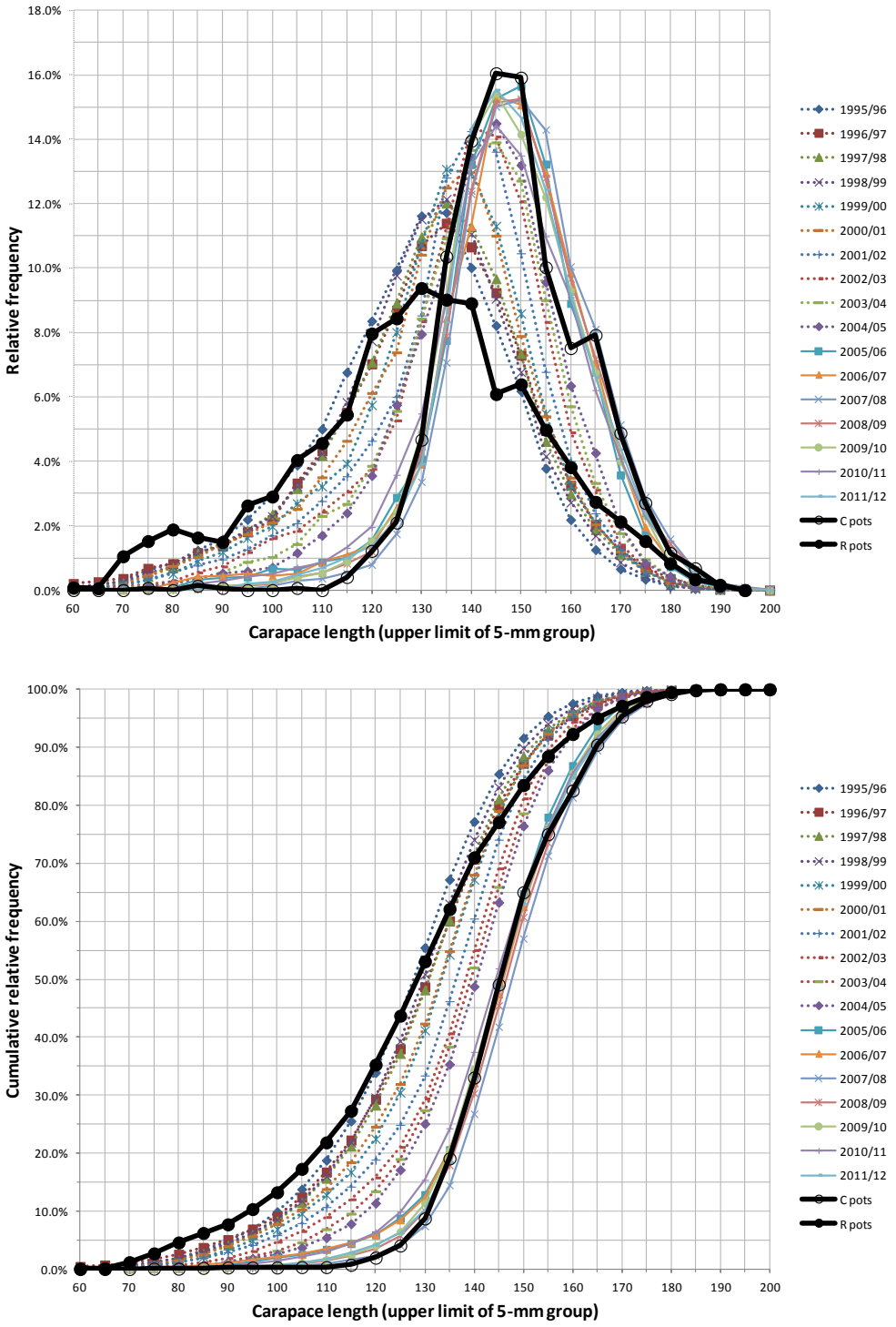

Figure 15.–Relative (top panel) and cumulative (bottom panel) size (carapace length, mm) frequency distributions of male golden king crab by pot type in 31 pairs of commercial-fishing (C) pots and research (R) pots fished by the *F/V Aleutian No. 1* during the 2012/13 Aleutian golden king crab fishery in the area east of 174° W longitude, with comparisons to size frequency distributions from the 1995/96–2011/12 commercial fisheries for the area east of 174° W longitude.

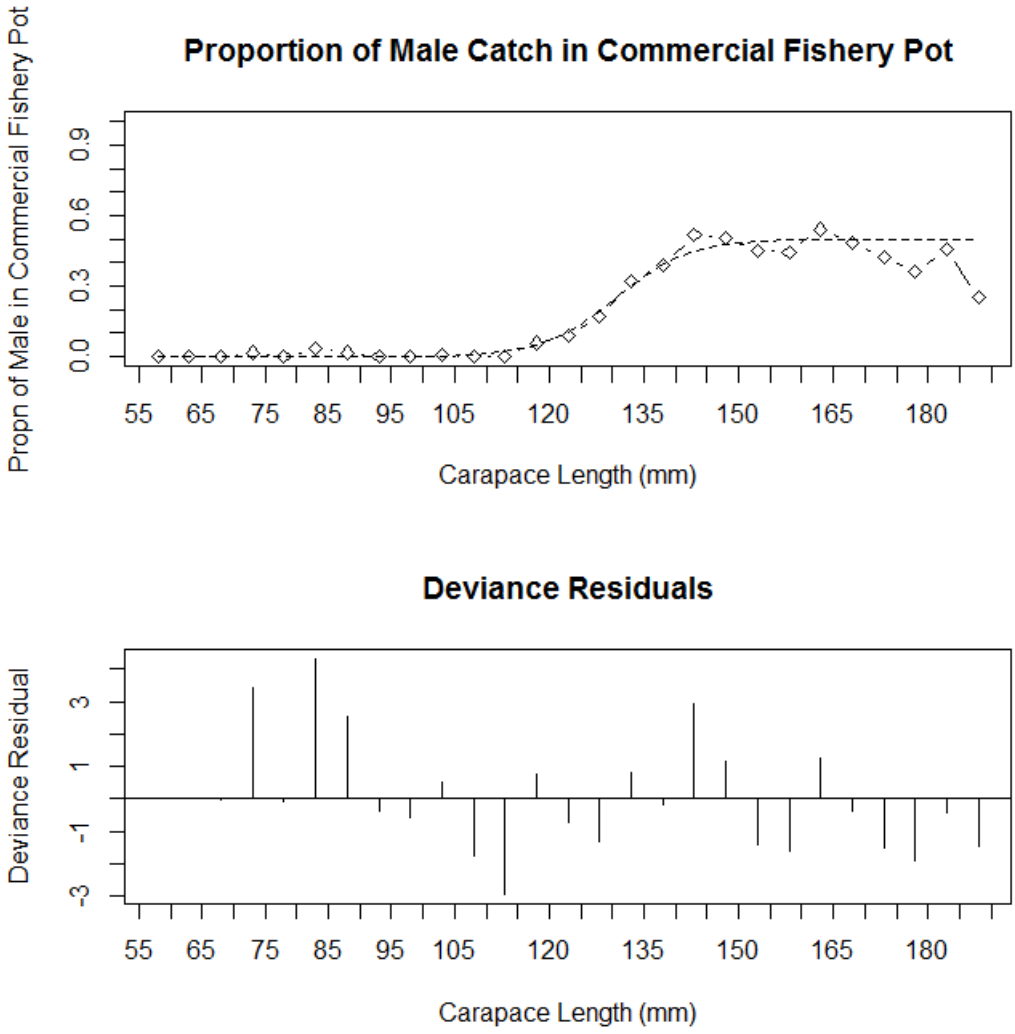

Figure 16.–Fit to the proportion of male golden king crab captured by commercial-fishing pots out of the total male golden king crab captured by 31 pairs of commercial-fishing pots and research pots (top panel), with associated deviance residuals (bottom panel).

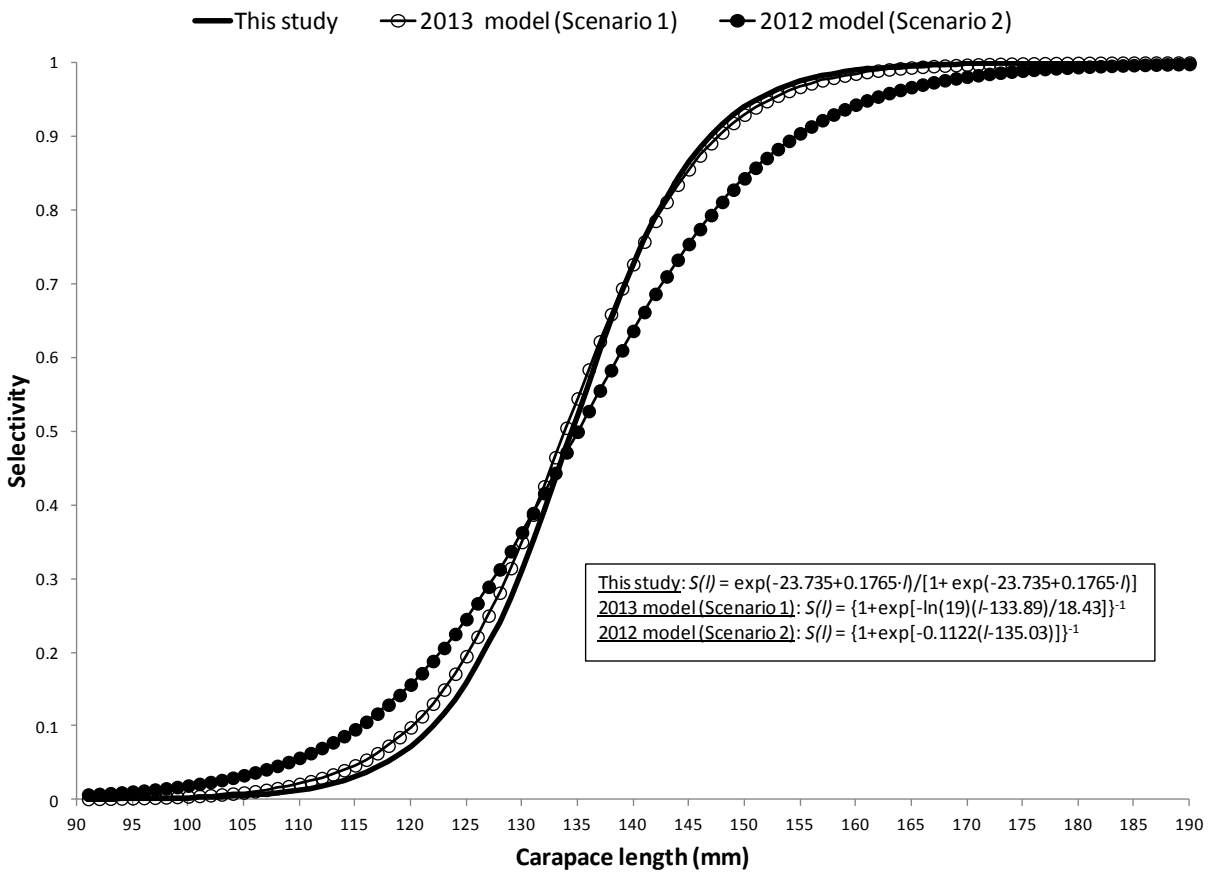

Figure 17.–Contact-selection curve for male golden king crab by commercial-fishing pots estimated in this study compared with population-selection curves for the rationalized (2005/06 and later seasons) commercial fishery for Aleutian Islands golden king crab east of 174° W longitude estimated in stock assessment models by Siddeek et al. (2012a, 2013a).

APPENDIX A. ADF&G PERMIT TO ALLOW THE FISHING VESSEL *ALEUTIAN NO. 1* TO TRANSPORT, SET, RETRIEVE, AND STORE 20 SMALL-MESH POTS DURING THE 2012/13 ALEUTIAN ISLANDS GOLDEN KING CRAB SEASON

Appendix A1.–ADF&G permit to allow the fishing vessel *Aleutian No. 1* to transport, set, retrieve, and store 20 small-mesh pots during the 2012/13 Aleutian Islands golden king crab season.

THE STATE of ALASKA
GOVERNOR SEAN PARNELL

Department of Fish and Game

DIVISION OF COMMERCIAL FISHERIES
Dutch Harbor Office

P.O. Box 920587
Dutch Harbor, AK 99692-0587
Main: 907.581.1239
Fax: 907.581.1572

September 06, 2012

Robert Carlton
61526 Cultus Lake Ct
Bend, OR 97702
(541) 948-1344
rip@bendbroadband.com

Mr. Carlton:

This permit allows the fishing vessel Aleutian No. 1 (ADF&G # 05992) to transport, set, retrieve, and store 20 small-mesh pots for Alaska Department of Fish and Game (ADF&G) for conducting research on fishing gear selectivity during the 2012-13 Aleutian Islands golden king crab season according to the terms below:

1. Permit is valid from September 06, 2012 until vessel has completed commercial fishing operations as defined in 5 AAC 39.675 in the Aleutian Islands golden king crab fishery.
2. Permit is valid only for the fishing vessel Aleutian No. 1, ADF&G #05992. Research pots may not be registered, transported, set, retrieved, or stored by any other vessel under the terms of this permit.
3. Permit is valid only in King Crab Registration Area O (Aleutian Islands).
4. Aleutian No. 1 must be able to accommodate the vessel's observer and up to two ADF&G representatives.
5. Research pots may only be configured according to department specifications, as follows: pot dimensions are 7 feet by 7 feet by 34 inches, tunnel opening is 9 inches by 36 inches, and webbing is 2.5 inches. Pots must have no larger than 30-thread biotwine in accordance with 5 AAC 39.145.
6. ADF&G must have full cooperation from vessel captain and crew regarding research pots and other related data collection activities.
7. Research pots may only be set or retrieved for research purposes as specified by ADF&G, and may not be used to participate in commercial harvest. Crab caught in research pots may not be retained.
8. The 20 research pots will not be included in the number of pots on the vessel registration for the Aleutian Islands golden king crab fishery.
9. Research pot data must not be included in observer, dockside sampling, or fish ticket data. Research pots must be listed separately on the federal Daily Fishing Log and must be clearly marked as research pots.
10. Research pots may be set in fishing strings when the ADF&G representative is not on board; however, research pots may not be baited and doors must be either removed or secured open

-continued-

unless the ADF&G representative is scheduled to be on board the vessel on the following fishing trip. If for any reason research pots are hauled without the ADF&G representative onboard the vessel, those research pots must be rail-dumped.

11. Research pot data must be documented in a pilothouse logbook provided by ADF&G, including research pot activity that occurs without the ADF&G representative on board the vessel.
12. Research pots must be marked in a way to easily differentiate them from legal fishing gear.
13. Research pots may be stored in legal wet storage in accordance with 5 AAC 34.627 until vessel has completed all Aleutian Islands golden king crab fishing operations for the 2012/13 season. At the completion of the Aleutian No. 1's Aleutian Islands golden king crab fishing operations for the 2012/13 season, research pots must be removed from the water and may not be left in wet storage.
14. Permit may be modified or revoked by the department at any time for violation of any permit term.

Heather Fitch
Area Management Biologist

Robert Carlton
F/V Aleutian No. 1

I, the CFEC permit holder, agree to allow the release of confidential harvest information that results from my participation in the Alaska Department of Fish and Game's fishing gear selectivity research obtained under this permit.

I, the CFEC permit holder, agree to allow the release of confidential harvest information that results from my participation in the Alaska Department of Fish and Game's fishing gear selectivity research obtained under this permit.

Signature of Permit Holder

Robert Carlton
Printed Name of Permit Holder

Signature of Alternate Permit Holder

FREDERICK D. ALVAREZ
Printed Name of Alternate Permit Holder

cc:
Alaska Wildlife Troopers, Dutch Harbor, AK
Vicki Vanek, ADF&G, Kodiak, AK
Mary Schwenzfeier, ADF&G, Dutch Harbor, AK

APPENDIX B. GOLDEN KING CRAB CATCH BY SAMPLED POT

Appendix B1.–Fishing dates, locations, and catch of golden king crab by sex and legal status of pots sampled during the ADF&G study of commercial fishing gear selectivity conducted during the 2012/13 Aleutian Islands golden king crab fishery.

			Position	Pots		Soak	North	West	Depth[d]	Males			Unknown
Pair	Type[a]	Date Set	in String[b]	in String[c]	Date Hauled	Days	Latitude[d]	Longitude[d]	(fathoms)	Legal	Sublegal	Females	Sex
1	R	10/7/2012	12	49	10/30/2012	23	52.4743	171.6568	300	7	15	8	0
1	C	10/7/2012	13	49	10/30/2012	23	52.4737	171.6578	300	43	35	3	0
2	R	10/7/2012	13	48	10/30/2012	23	52.3530	171.5178	200	40	133	77[e]	0
2	C	10/7/2012	14	48	10/30/2012	23	52.3525	171.5167	200	29	10	7	0
3	R	10/7/2012	14	41	10/30/2012	23	52.4425	171.5890	302	48	117	60	0
3	C	10/7/2012	15	41	10/30/2012	23	52.4417	171.5890	302	59	35	18	0
4	R	10/9/2012	31	44	10/29/2012	20	52.5370	170.3248	160	36	34	376[f]	0
4	C	10/9/2012	32	44	10/29/2012	20	52.5382	170.3232	160	31	7	22	0
5	R	10/11/2012	24	35	10/31/2012	20	52.4722	170.5863	161	40	84	153[g]	0
5	C	10/11/2012	23	35	10/31/2012	20	52.4715	170.5880	161	53	20	8	0
6	R	10/12/2012	52	60	11/5/2012	24	52.5238	170.4308	162	51	69	137	0
6	C	10/12/2012	53	60	11/5/2012	24	52.5240	170.4283	162	31	3	6	0
7	R	10/12/2012	16	44	11/6/2012	25	52.6882	170.4240	289	105	84	20	0
7	C	10/12/2012	17	44	11/6/2012	25	52.6895	170.4255	289	28	3	4	0
8	R	10/16/2012	6	44	11/1/2012	16	52.4633	169.6860	129	116	2	0	0
8	C	10/16/2012	5	44	11/1/2012	16	52.4630	169.6857	129	98	0	0	0
9	R	10/16/2012	48	55	11/1/2012	16	52.4370	169.7122	135	90	13	3	0
9	C	10/16/2012	49	55	11/1/2012	16	52.4378	169.7118	135	65	8	1	0
10	R	10/17/2012	21	38	11/17/2012	31	52.4195	171.1002	235	40	116	97	0
10	C	10/17/2012	22	38	11/17/2012	31	52.4180	171.1002	234	28	1	0	0
11	R	10/17/2012	4	41	11/17/2012	31	52.3892	171.3625	133	20	167	245	3
11	C	10/17/2012	5	41	11/17/2012	31	52.3890	171.3602	131	30	2	0	0
12	R	10/17/2012	25	37	11/17/2012	31	52.3267	171.5382	211	19	205	133	0
12	C	10/17/2012	26	37	11/17/2012	31	52.3258	171.5347	215	22	2	1	0
13	R	10/17/2012	38	51	11/3/2012	17	52.2070	171.7133	241	24	124	40	0
13	C	10/17/2012	37	51	11/3/2012	17	52.2082	171.7133	241	22	12	3	0
14	R	10/18/2012	17	36	11/4/2012	17	52.1300	171.8428	159	31	8	2	0
14	C	10/18/2012	18	36	11/4/2012	17	52.1290	171.8412	159	62	9	1	0
15	R	10/18/2012	32	51	11/3/2012	15	52.2000	171.8702	206	30	30	31	0
15	C	10/18/2012	31	51	11/3/2012	15	52.2013	171.8727	206	27	1	7	0
16	R	10/19/2012	37	61	10/31/2012	12	52.3767	170.8808	212	3	74	68	0
16	C	10/19/2012	36	61	10/31/2012	12	52.3753	170.8808	212	18	4	3	0
17	R	10/21/2012	37	45	11/10/2012	20	52.6443	169.9650	138	90	13	2	0
17	C	10/21/2012	36	45	11/10/2012	20	52.6438	169.9670	138	16	0	0	0
18	R	10/21/2012	3	50	11/16/2012	26	52.6215	170.4303	171	51	163	33	0
18	C	10/21/2012	4	50	11/16/2012	26	52.6197	170.4293	172	32	22	3	0
19	R	10/22/2012	40	55	11/1/2012	11	52.4990	169.9618	127	47	15	10	0
19	C	10/22/2012	39	55	11/1/2012	11	52.5000	169.9623	127	27	5	4	0
20	R	10/22/2012	13	43	11/11/2012	20	52.7447	170.3427	154	10	2	0	0
20	C	10/22/2012	14	43	11/11/2012	20	52.7435	170.3408	163	49	3	0	0
21	R	10/29/2012	30	44	11/20/2012	22	52.5595	170.2995	165	34	3	182	0
21	C	10/29/2012	31	44	11/20/2012	22	52.5608	170.2982	163	16	0	4	0
22	R	10/30/2012	7	47	11/18/2012	19	52.4238	171.3972	124	27	99	61	1
22	C	10/30/2012	6	47	11/18/2012	19	52.4237	171.3957	120	33	3	3	0
23	R	10/30/2012	45	49	11/18/2012	18	52.4432	171.6302	345	33	51	78	0
23	C	10/30/2012	44	49	11/18/2012	18	52.4450	171.6317	350	45	30	29	0

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Appendix B1.–Page 2 of 2.

Pair	Type[a]	Date Set	Position in String[b]	Pots in String[c]	Date Hauled	Soak Days	North Latitude[d]	West Longitude[d]	Depth[d] (fathoms)	Males		Females	Unknown Sex
										Legal	Sublegal		
24	R	10/30/2012	25	41	11/19/2012	20	52.4545	171.5800	300	35	71	23	3
24	C	10/30/2012	26	41	11/19/2012	20	52.4532	171.5808	300	30	7	5	0
25	R	10/31/2012	20	35	11/21/2012	21	52.4867	170.5885	148	36	78	39	0
25	C	10/31/2012	21	35	11/21/2012	21	52.4872	170.5875	148	52	7	1	0
28	R	11/1/2012	43	53	11/15/2012	14	52.4422	169.6630	144	88	37	1	0
28	C	11/1/2012	44	53	11/15/2012	14	52.4405	169.6628	147	66	18	0	0
29	R	11/1/2012	23	53	11/15/2012	14	52.4383	169.7365	146	97	43	2	0
29	C	11/1/2012	24	53	11/15/2012	14	52.4387	169.7385	160	43	2	0	0
30	R	11/3/2012	29	51	11/19/2012	16	52.2005	171.8525	230	49	72	69	0
30	C	11/3/2012	30	51	11/19/2012	16	52.2000	171.8537	230	48	30	22	0
31	R	11/3/2012	35	49	11/19/2012	16	52.2202	171.6540	236	16	260	233	0
31	C	11/3/2012	36	49	11/19/2012	16	52.2195	171.6542	236	17	7	1	0
32	R	11/4/2012	14	25	11/20/2012	15	52.1687	171.8808	183	41	29	140	0
32	C	11/4/2012	15	25	11/20/2012	15	52.1680	171.8817	164	38	7	49	0
33	R	11/5/2012	46	60	11/21/2012	16	52.5180	170.3540	152	24	26	201[h]	0
33	C	11/5/2012	47	60	11/21/2012	16	52.5193	170.3527	152	14	12	81	0

[a] R for small-mesh "research pot" without escape mechanisms; C for vessel's commercial-fishing pot.

[b] Position of pot in string relative to the first (anchor) pot set in the long-lined string of pots.

[c] Total number of pots in the long-lined string, including the "research pot" and the anchor pots at ends.

[d] Recorded by vessel captain at the time the pot was hauled.

[e] 65 of 77 captured females were sampled for measurements.

[f] 75 of 376 captured females were sampled for measurements.

[g] 50 of 153 captured females were sampled for measurements.

[h] 100 of 201 captured females were sampled for measurements.