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Summary of the 2010/2011 Mandatory Crab Observer Program Database for the Bering Sea/Aleutian Islands Commercial Crab Fisheries

by

William B. Gaeuman

December 2011

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. 11-73

SUMMARY OF THE 2010/2011 MANDATORY CRAB OBSERVER PROGRAM DATABASE FOR THE BERING SEA/ALEUTIAN ISLANDS COMMERICAL CRAB FISHERIES

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TABLE OF CONTENTS

LIST OF TABLES

Table **Page**

LIST OF TABLES (Continued)

LIST OF FIGURES

LIST OF APPENDICES

LIST OF APPENDICES (Continued)

Appendix **Page**

ABSTRACT

Since 1988 Alaska Department of Fish and Game has required varying levels of observer coverage aboard vessels participating in Bering Sea and Aleutian Islands (BSAI) crab fisheries. This report summarizes data collected in the 2010/11 BSAI commercial crab fisheries by crab observers deployed on floating-processor vessels, catcher-processor vessels, and catcher vessels and provides historical data for comparison. Primary data summaries include estimates of catch and catch per unit effort (CPUE) and information about size and shell condition of both discarded and retained crab. Further information about catch rates by soak time and depth, female reproductive condition, sampled pot lift locations, species composition of sampled pot lifts, and total legal tally results is provided in a series of appendices.

Key words: Alaska Department of Fish and Game, Bering Sea, Aleutian Islands, crab observer, golden king crab, red king crab, blue king crab, snow crab, Tanner crab.

INTRODUCTION

Regulations adopted by the Alaska Board of Fisheries (BOF) in 1999 provided the Alaska Department of Fish and Game (ADF&G) with the full authority and responsibility for deploying onboard observers on any vessel participating in the commercial Bering Sea and Aleutian Islands (BSAI) crab fisheries or in any fishery conducted under a commissioner's permit as necessary for fishery management and data-gathering needs. Those regulations required deployment of observers on all vessels that process snow and/or Tanner crabs *Chionoecetes*, red king crab *Paralithodes camtschaticus*, blue king crab *P. platypus*, or golden king crab *Lithodes aequispinus*. Those regulations additionally charged ADF&G with deploying observers as needed on catcher vessels participating in commercial BSAI king and Tanner crab fisheries (excluding those of Norton Sound and St. Lawrence Island Sections). Bowers et al. (2010) provide details on the regulations pertaining to the State of Alaska Shellfish Onboard Observer Program and a history of that program from its inception in 1988.

Along with gear type, location, depth, and soak time of each sampled pot lift, onboard observers collect data describing pot contents, including species composition and the sex and legal status of all commercially important captured crab. For a subset of sampled pot lifts, a range of biological measurements and assessments of all commercially important crab and selected other species of interest is also recorded. Observers also document vessel catch, bycatch, and effort, monitor vessel activities for regulatory compliance, take size-frequency samples, conduct legal tallies, and estimate the average weight of delivered catch. ADF&G Westward Region staff maintain observer-collected information in a database that is used in management and research applications to develop stock-assessment models, to estimate the magnitude and composition of bycatch, to chronicle female reproductive cycles, and to aid in preseason and inseason projections of fishery performance. The database provides a source of information crucial to the comprehensive management of Alaska's BSAI crab stocks.

This report summarizes data collected by onboard observers and dockside samplers during the 2010/11 Bristol Bay red king crab fishery, 2010/11 Bering Sea snow crab fishery, 2010/11 St. Matthew Island blue king crab fishery, 2010 Pribilof Islands golden king crab fishery, and 2010/11 Aleutian Islands golden king crab fisheries east and west of 174° W long (Table 1). For each of these six fisheries, this report gives estimates of catch per unit effort (CPUE), catch, and size-frequency and shell-condition distributions for both discarded and retained crab. Further information about catch rates by soak time and depth, female reproductive condition, location and species composition of sampled pot lifts, and total legal tally sample results is provided in a series of appendices.

METHODS

Methods described in this report correspond only to the data presented and do not describe all observer sampling duties. Comprehensive shellfish observer sampling methods are detailed in the 2010 ADF&G Crab Observer Training and Deployment Manual[1]. In accordance with the provisions of 5 AAC 39.645, observers were deployed on all floating-processor and catcher-processor vessels participating in each fishery, on all catcher vessels prosecuting the St. Matthew Island blue king crab fishery, on randomly selected catcher vessels participating in the Bristol Bay red king crab and Bering Sea snow crab fisheries, and on the single catcher vessel permitted to harvest Pribilof Island golden king crab during 2010. In the Aleutian Islands golden king crab fisheries all catcher vessels were required to carry an observer during harvest of at least 50% of their total harvested weight in each three-month trimester of the nine month season. The number of pot lifts observers were required to sample on each day of fishing activity varied by fishery and vessel type. In general, pot lift sampling goals, as well as observer ability to attain them, depend on a number of variables unique to each fishery and season, including weather, catch rates, assigned research data collection projects, and the order of sampling priorities established by ADF&G. Fishery specific observer deployments and pot lift sampling goals are outlined in Table 1.

TERMS

For the purposes of this report, terms related to the discussion of sampled crabs and observer sampling duties are defined as follows:

Pot lift sample	A randomly selected pot lift from which captured crab of all species are identified and enumerated. For a subset of these pot lifts, measurements and assessments of ancillary characteristics are also recorded for crab of selected species.
Legal tally	Examination of up to 600 crab randomly selected from the retained catch to assure regulatory compliance regarding the retention of crab by species, size, and sex.
Size frequency sample	Biological measurements of up to 100 randomly selected retained crab for the purpose of determining carapace size and shell condition distribution.
Carapace length (CL)	The biological size measurement of all species of king crabs *Lithodes* and *Paralithodes* and hair crab *Erimacrus isenbeckii* taken as the straight-line distance from the posterior margin of the right eye orbit to the medial-posterior carapace margin.
Carapace width (CW)	The biological size measurement of all species of *Chionoecetes* crabs taken as the greatest straight-line distance perpendicular to a line midway between the eyes to the medial-posterior margin, not including the spines (cf. *Legal measurement*, below).

[1] Crab Observer Training and Deployment Manual. September 2010 edition. ADF&G Shellfish Observer Program, Dutch Harbor, unpublished.

Legal measurement	The measurement used to determine if male crabs are at or greater than the minimum legal size for retention: the greatest straight-line distance across the carapace of male crabs, including the spines, perpendicular to a line midway between the eyes to the medial-posterior margin (cf. *Carapace width,* above.
Ovigerous	Bearing a clutch of extruded eggs (pertains only to mature female crabs).
Uneyed eggs	Eggs that are unfertilized or in early developmental stages with no visible eyespots.
Eyed eggs	Eggs in later developmental stages with visible eyespots or prezoeae.
Barren/matted setae	An egg clutch is not present but previous egg brooding is evidenced by dirty pleopodal setae or the presence of attached dead eggs or empty egg cases.
Barren/clean setae	An egg clutch is not present and there is no evidence of previous egg brooding; pleopodal setae are clean, shiny, light in color, and very fine or, rarely, there are no visible setae on the pleopods. Females assigned this code are usually immature.
Shell condition	A description of the appearance of the crab exoskeleton that is determined by examining characteristics that change or show wear with time since the last molt (Donaldson and Byersdorfer 2005; Jadamec et al. 1999). Observers scored the shell condition of sampled crabs as either "soft," "new pliable," "new," "old," or "very old" based on shell hardness and color, the nature and extent of abrasions and wear of the shell surfaces, spines, and dactyls, and the number and type of epibionts on the shell surfaces.
Catch per unit effort (CPUE)	The mean catch for a standard unit of fishing effort. In this report CPUE represents the mean catch in number of crab of a particular species per pot lift.

SAMPLING DUTIES

During the 2010/11 BSAI commercial crab fisheries, observers were deployed on floating-processor vessels, catcher-processor vessels, and catcher vessels. Observers deployed on floating-processors had access only to previously sorted retained catch from delivering catcher vessels, whereas observers placed on catcher-processor and catcher vessels were able to examine the contents of pot lifts prior to sorting by the crew.

Floating-Processor Vessels

Observers deployed on floating-processor vessels primarily monitor deliveries from catcher vessels. Sampling duties during each delivery included obtaining a size-frequency sample, conducting a legal tally, and determining average weight of retained crab.

Catcher-Processor Vessels

Sampling duties for observers deployed on catcher-processor vessels included pot lift sampling, size-frequency sampling, legal-tally sampling, and determination of average weight of retained crab for each day the vessel retained catch. Occasionally, catcher vessels delivered to a catcher-processor vessel. In those situations, the observer sampled the catcher vessel catch as if deployed on a floating processor.

Catcher Vessels

Sampling duties for observers deployed on catcher vessels included pot lift sampling, which was usually the main sampling activity for each day the vessel fished. When the vessel delivered to a processing facility, whether at sea or on shore, the observer obtained a size-frequency sample, conducted a legal tally, and determined average weight of retained crab. If deliveries were made at sea, all sampling was completed by the observer deployed on the catcher vessel.

ESTIMATION OF CPUE AND TOTAL FISHERY CATCH

Estimates of CPUE presented here were generated from observer-collected data using a ratio estimator introduced by Gaeuman (2009). For the purpose of estimation it is assumed that within a fishery observers are assigned to all participating catcher-processor vessels and by simple random sampling to a subset of all participating catcher vessels. It is also assumed that sampled pot lifts are selected by simple random sampling from all pot lifts on each vessel fishing day, independently across days. Under these assumptions it is straightforward to estimate both total catch and the total number of pot lifts for all vessels based on observed vessel days, treating vessel types as strata, vessels as primary sampling units within them, vessel days as strata within vessels, and pot lifts as secondary sampling units within those. The ratio of these estimates of total catch and total number of pot lifts then estimates fishery mean CPUE defined as fishery total catch divided by fishery total effort, i.e. total number of pot lifts. A variance estimator can be developed using standard variance estimators for the component estimators of total catch and total number of pot lifts. Appendix A1 describes both the ratio estimator of CPUE and the derivation of its variance estimator.

Prior to Gaeuman (2009), different estimates of CPUE were calculated depending on the information available and on varying assumptions about the sampling design. The "sample CPUE" reported before 1997 (e.g., Tracy 1995) was calculated as the simple average catch over all sampled pot lifts. Boyle et al. (1997) introduced stratification by day within vessel, and Burt and Barnard (2003) introduced stratification by vessel type into the report series.

By contrast with these design-based estimates of CPUE, actual total fishery (ATF) CPUE as reported in annual management reports for commercial crab fisheries in the BSAI management areas is based on effort and catch information extracted from a combination of fish tickets, daily fishing logs (DFL), and confidential interviews with vessel captains and represents an independent estimate of fishery CPUE[2]. ATF CPUE estimates, however, are available only for retained legal crab. Estimated total catches reported in this document, as opposed to ATF values, were calculated by multiplying CPUE estimates from observer-collected data by corresponding ATF estimates of fishery pot lift totals.

[2] Forrest Bowers, BSAI Area Management Biologist, ADF&G, Dutch Harbor, 2010, personal communication.

Cod Pots

In some crab fisheries regulations allow deployment of a specified number of groundfish-configured pots targeting Pacific cod *Gadus macrocephalus* for use as bait (5 AAC 34.825(k) and 5 AAC 35.525(d)). Though some crab are typically captured in these pots, they generally have a much lower CPUE than pots targeting crab and arguably misrepresent or at least mask a more telling characterization of fishing efficiency in the directed crab pot fishery. ADF&G crab observers are currently instructed not to sample cod pots (2010 Crab Observer Training and Deployment Manual, Unpublished.). Cod pots were deployed during the Bristol Bay red king crab, Bering Sea snow crab, and St. Matthew Island blue king crab 2010/11 fisheries and accounted for 5%, 7% and <1%, respectively, of all pots lifted during observer pot lift sampling days. Consequently, for these fisheries estimators of CPUE can be expected to be biased slightly high relative to ATF CPUE, which does not distinguish between conventional and groundfish-configured pots with respect to fishery effort and CPUE.

RESULTS

BRISTOL BAY RED KING CRAB

The 2010/11 Bristol Bay red king crab season commenced October 15 and closed January 15, with most fishing occurring early in the season. Total allowable catch (TAC) in this fishery was set at 14.839 million pounds, with male crab measuring at least 6.5" carapace width considered legal. Two catcher-processors and 64 catcher vessels took part. Onboard observers sampled 1,891 pot lifts accounting for 1.4% of the ATF reported 131,627 pot lifts (Table 1). Appendix B1 shows locations of sampled pot lifts.

Onboard observers collected CL measurements of 66,625 male red king crab from sampled pot lifts (Figure 1). Average CL was 136.1 mm and 91.7% of the crab were classified as new shell. CL measurements of 6,854 female red king crab from sampled pot lifts averaged 118.5 mm (Figure 2). Approximately 98.4% of the females were new shell. CL measurements were also recorded for 20,138 male red king crab by onboard observers and dockside samplers in size-frequency sampling of retained catch. Average CL was 149.5 mm, and 88.8% of the sampled crab were new shell (Table 2).

Estimated CPUE of legal retained red king crab was 17.2 crab per pot lift (Table 3), as compared to the ATF-reported 18.2. A 95% confidence interval (CI) for this estimate is (15.18, 19.28), from a t-distribution as detailed in Appendix A. Given the ATF reported 131,627 total pot lifts, this yields an estimated total retained catch of 2.26 million crab. Estimated bycatch of discarded sublegal males exceeded legal retained catch at 19.9 crab per pot lift; estimated female bycatch was 3.4 crab per pot lift. CPUE estimates for 2010/11 were generally low by comparison with those from the last few seasons (Figure 3). Some incidental bycatch of discarded Tanner and mostly legal-size male snow crab was also observed in this fishery (Table 3).

Total catches of all animals identified in sampled pot lifts during the 2010/11 Bristol Bay red king crab season are provided in Appendix C1. Additional appendices contain CPUE by soak time (Appendix C2) and depth (Appendix C3) and the reproductive condition of female red king crab from sampled pot lifts (Appendix C4).

Legal tallies conducted on catcher-processor vessels and catcher vessels accounted for 27,664 crab by the end of the 2010/11 season and comprised 0.1% of the fishery-reported harvest

(Appendix D1). Approximately 0.38% of all sampled crab were illegal due to size, sex, or species restrictions.

BERING SEA SNOW CRAB

The 2010/11 Bering Sea snow crab fishery opened October 15 with a TAC of 54.281 million pounds and closed May 15 in the Eastern subdistrict (east of 173° W long) and May 31 in the Western subdistrict (west of 173° W long); however, most of the fishing occurred during January and February. Only male crab measuring at least 3.1" carapace width could be legally retained. Two catcher-processor vessels and 67 catcher vessels participated. Onboard observers sampled 1.5% (2,142) of the ATF reported 147,244 pot lifts (Table 1). Sampled pot lift locations are shown in Appendix B2. Note that although the minimum legal size for snow crab in this fishery is 3.1 inches (~79 mm) CW, processing plants generally do not accept crab smaller than 4 inches CW.

Onboard observers collected CW measurements of 188,357 male snow crab during pot lift sampling (Figure 4). Average CW was 112.8 mm, and 95.6% of the crab were categorized as new shell. Observers also measured CW of 464 female snow crab. Average female snow crab CW was 67.3 mm, with 47.4% of the females judged new shell. CW measurements were additionally recorded on 36,544 male snow crab in size-frequency sampling of retained catch. Average CW was 115.2 mm, and 96.9% of the crab were new shell (Table 4).

Estimated CPUE of legal retained snow crab was 284.5 crab per pot lift (Table 5), with estimated 95% confidence interval (268.55, 300.49). This estimate is significantly higher than the ATF reported CPUE of 256.4 given the assessed statistical precision of the estimate from observer data. The corresponding estimate of total harvest based on the ATF reported pot lift total was 41.89 million crab. Legal retained males accounted for an estimated 88% of all captured snow crab; discarded legal-size male crab smaller than 4 inches (~102 mm) CW made up most of the remainder. While the 2010/11 estimate of legal-retained CPUE is statistically indistinguishable from last year's estimate, bycatch of discarded legal males appears to have decreased to about half of what it was in 2009/10 (Figure 5). As shown in Table 5, observers also documented some bycatch of discarded Tanner crab, mostly sublegal males, along with a smaller number of crab that were judged to be hybrid *Chionoecetes*, including an estimated 70 thousand retained males that were considered to be legally retainable by the criteria of 5 AAC 35.521.

Total catches of all animals identified in sampled pot lifts during the 2010/11 season are provided in Appendix C5. Additional appendices contain sampled pot lift CPUE by soak time (Appendix C6) and depth (Appendix C7) and the reproductive condition of female snow crab in pot lift samples (Appendix C8).

Legal tallies conducted on catcher-processor vessels and catcher-only vessels delivering snow crab to processors totaled 107,328 crab, which accounted for 0.3% of the total reported catch (Appendix D1). Of those, 0.21% were illegal due to size, sex, or species restrictions.

SAINT MATTHEW ISLAND BLUE KING CRAB

The St. Matthew Island blue king crab fishery opened for the second time since 1998 on October 15, 2010 with a TAC of 1.60 million pounds and closed by regulation February 1, 2011. Fishing was mostly completed by December. Legal harvest was limited to male crab measuring at least 5.5" carapace width. All 11 participating catcher vessels were required to carry an observer. Of

the ATF reported 29,346 pot lifts in this fishery, observers sampled 2,419, about 8.2% (Table 1). Locations of sampled pot lifts are mapped in Appendix B3.

Observers took CL measurements from 50,276 male and 10,951 female blue king crab in pot lift sampling. Respective average CL values were 116.3 mm and 89.0 mm. Observers recorded 90.0% of the males and 95.1% of the females as new shell (Figure 6). Size-frequency sampling of 3,487 fishery-retained male blue king crab yielded an average CL of 129.3 mm, with 91.9% of the sampled animals judged new shell (Table 6).

Estimated CPUE of legal retained crab was identical to the ATF reported value of 10.2 crab per pot (Table 7), with approximate 95% confidence interval (10.04, 10.44). Corresponding estimated total harvest, including deadloss, was 299 thousand crab. Though the historical fishery had been considerably more efficient in some years, CPUE of legal retained crab in the past two seasons is in line with fishery performance prior to the 10-year closure (Figure 7). Estimated 2010/11 bycatch of discarded sublegal males slightly exceeded the catch of legal crab, as was true of the 2009/10 season, whereas the estimated female discard bycatch of 5.1 crab per pot was substantially higher than last year's estimate of 1.4 (Gaeuman 2011). In addition, some incidental bycatch of subsequently discarded snow crab occurred in the 2010/11 St. Matthew Island blue king crab fishery, most of it consisting of legal-size males (Table 7).

Total catches of all animals identified in sampled pot lifts during the 2010/11 season are provided in Appendix C9. Additional appendices contain sampled pot lift CPUE by soak time (Appendix C10) and depth (Appendix C11) and the reproductive condition of female blue king crab in pot lift samples (Appendix C12).

Legal tallies conducted on catcher vessels delivering blue king crab to processors totaled 16,047 crab, which accounted for 5.4% of the reported harvest (Appendix D1). Approximately 0.32% of the sampled animals were illegal due to size, sex, or species restrictions.

PRIBILOF ISLANDS GOLDEN KING CRAB

This non-rationalized fishery is currently managed with a guideline harvest level (GHL) of 0.150 million pounds under authority of an ADF&G commissioner's permit valid for a calendar year. Legal harvest is limited to male crab measuring a minimum of 5.5" carapace width, and observer coverage is mandatory. Because a single commercial vessel made landings in 2010, details of all fishing activity and observer sampling efforts are confidential.

ALEUTIAN ISLANDS GOLDEN KING CRAB

In March 1996, the BOF re-designated the Aleutian Islands king crab registration area by combining two existing areas, Dutch Harbor and Adak, and directed ADF&G to manage golden king crab of the Aleutian Islands east and west of 174° W longitude separately as two distinct stocks (Bowers et al. 2010). In 2010/11 both fisheries were open from August 15 to May 15. Legal harvest was restricted to male crab measuring at least 6.5" carapace width.

East of 174° W Longitude

Three catcher vessels participated in the 2010/11 Aleutian Islands golden king crab fishery east of 174° W longitude, where the TAC was set at 3.15 million pounds. Onboard observers sampled 436 pot lifts accounting for 1.7% of the ATF reported 25,851 pot lifts in the fishery (Table 1). Appendix B5 shows sampled pot lift locations.

Average CL of 15,523 male golden king crab measured in pot lift sampling was 144.5 mm, and 96.2% were new shell; average CL of 3,796 measured females was 129.8 mm, and 99.5% were new shell (Figure 9). In size-frequency sampling of 2,353 retained crab, average CL was 151.8 mm, and 96.5% were recorded as new shell (Table 10).

Estimated legal retained, sublegal, and female CPUEs in the 2010/11 eastern Aleutian Islands golden king crab fishery were consistent with estimates from previous years since rationalization (Figure 10). The catch of legal retained males was estimated to be 25.5 crab per pot with 95% confidence interval (23.85, 27.08; Table 11), making it statistically indistinguishable from the ATF reported 26.0. Associated estimated catch was 659 thousand animals. There was no notable bycatch of any other commercially important crab species in this fishery.

Total catches of all animals identified in sampled pot lifts during the 2010/11 eastern Aleutian Islands golden king crab fishery are provided in Appendix C17. Additional appendices contain sampled pot lift CPUE by soak time (Appendix C18) and depth (Appendix C19) and reproductive condition of female golden king crab (Appendix C20) from sampled pot lifts.

Legal tallies conducted throughout the season onboard catcher vessels delivering golden king crab from the eastern Aleutian Islands fishery totaled 6,450 crab. Sampled crab made up approximately 1.0% of the fishery estimated harvest (Appendix D1). Approximately 0.25% of the sampled crab were illegal due to size, sex, or species restrictions

West of 174° W Longitude

A single catcher-processor and 2 catcher vessels participated in the 2010/11 Aleutian Islands golden king crab fishery west of 174° W longitude, where the TAC was set at 2.84 million pounds. ATF reported effort was 29,944 pot lifts, of which observers sampled 867, or 2.9% (Table 1). Locations of sampled pot lifts are shown in Appendix B6.

Onboard observers recorded CL of 24,877 male and 7,516 female golden king crab captured in sampled pot lifts (Figure 11). Male and female CL averages were respectively 145.4 mm and 135.4 mm. New-shell crab made up 97.0% of the males and 98.0% of the females. Average CL of 9,818 male crab measured in size-frequency sampling of retained catch was 152.9 mm, and 97.6% of them were new shell (Table 12).

Estimated legal retained CPUE in this fishery was 21.1 crab per pot (Table 13), with 95% confidence interval (19.79, 22.41). The associated estimate of retained catch is 632 thousand crab. The 2010/11 legal retained CPUE of 21.1, which is close to the ATF-reported value of 20.9, represents a considerable decline from the 2009/10 value of 30.1 (Gaeuman 2011) but is within the range determined by estimates from other years since rationalization (Figure 12). Estimates of discarded male and female golden king crab CPUE in the 2010/11 western fishery are likewise consistent with those from other years since rationalization. Observers in this fishery recorded no noteworthy bycatch of other commercially important crab species.

Appendix C21 lists total catches of all animals observed in sampled pot lifts during the 2010/11 western Aleutian Islands golden king crab fishery. Appendices C22 and C23 give sampled pot lift CPUE by soak time and depth. Appendix C24 characterizes reproductive condition of captured female golden king crab.

Legal tallies conducted onboard catcher and catcher-processor vessels prosecuting the Aleutian Islands golden king crab fishery west of 174° W long totaled 38,009 crab in the 2010/11 season.

Sampled crab made up 6.1% of the ATF-reported harvest (Appendix D1). Approximately 0.63% of all sampled animals were illegal due to size, sex, or species restrictions.

ACCURACY AND PRECISION OF CPUE ESTIMATES

In assessing CPUE estimates for directed catch and bycatch, their precision should be considered. In general, the precision of an estimator is a function of its repeatability or, more formally, its variance. A convenient measure of precision is the coefficient of variation (CV), which is the ratio of the standard deviation to the mean. An estimate of this quantity is provided by the ratio of the standard error (square root of the estimated variance) to the estimate itself. For the observer-based CPUE estimates of legal retained crab from the six fisheries described in this document, these values indicate good levels of precision, ranging from 1.0% for the St. Matthew Island blue king crab fishery (most precise) to 5.6% for the Bristol Bay red king crab fishery (least precise).

A related measure of estimator precision is the confidence interval associated with a suitably chosen level of confidence, frequently 90 or 95%. In addition to standard errors for all CPUE estimates in each directed fishery (Tables 3, 5, 7, 9, 11, 13), this document also reports 95% confidence intervals associated with each estimated CPUE. These confidence intervals are based on a *t*-distribution, as described in more detail in Appendix A1.

Because an estimator may be precise yet still be inaccurate in the sense of assuming a value very far from the target parameter, it is of interest to assess an estimator's accuracy, as well as its precision. Some indication of the accuracy of an estimated CPUE for legal retained crab within a particular fishery may be extracted by directly comparing it to the corresponding ATF reported value. As these two numbers represent essentially independent estimates of fishery CPUE, substantial agreement between the two presumably reflects the fact that neither is wildly inaccurate. On the other hand, a very great disparity between them guarantees at least one estimate is far from the target. For the six fisheries here described, such a comparison yields mixed results (Table 14), with a relative difference ranging from less than 2% in the St. Matthew Island blue king crab and Aleutian Islands golden king crab fisheries to 11% in the Bering Sea snow crab fishery.

In assessing estimates based on observer-sampled pot lifts, the reader should take note of 1) whether the data were gathered by observers deployed on all participating fishing vessels, or on catcher-processor vessels and only a sample of participating catcher-only vessels; and 2) the extent of coverage with respect to the number of days fished by vessels selected for observation, which is of particular concern in the Aleutian Islands golden king crab fisheries. Estimator performance depends both on the proportion of pot lifts sampled and on the extent to which catch rates of sampled pot lifts on observed days aboard observed vessels are "representative" of those of the remaining component of fishery effort. It can at least be hoped that the conscientious application of probability sampling mechanisms in observer deployment and data collection protocols will allow for defensible assessments of estimator precision and greatly reduce the potential for non-ignorable and unquantifiable sampling bias.

ACKNOWLEDGMENTS

Shellfish observers deployed during the 2010/11 BSAI crab fisheries collected the data summarized in this report. Their diligence in collecting biological and fisheries management

information while living and working at sea, often for extended periods and sometimes under extremely challenging conditions, is essential to management of these fisheries.

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TABLES AND FIGURES

Table 1.–BSAI observer fisheries, observer deployment, and observer pot lift sampling effort during 2010/11.

			Catcher-processor vessels		Catcher vessels				
Fishery	Season	TAC[a]	Number[b]	Daily pot lift sampling goal	Number	With onboard observers	Daily pot lift sampling goal	ATF pot lift total[c]	Sampled pot lifts
Bristol Bay red king crab	15Oct–15Jan	14.839	2	4	64	15	7	131,627	1,891
Bering Sea snow crab	15Oct–31May	54.281	2	3	67	25	4	147,244	2,142
Pribilof Islands golden king crab	01Jan–31Dec	0.150[d]	0	NA	1	1	10	–[e]	–[e]
St Matthew Island blue king crab	15Oct–01Feb	1.60	0	7	11	11	10	29,346	2,419
Aleutian Islands golden king crab (east of 174° W)	15Aug–15May	3.15	0	4	3	3	7	25,851	436
Aleutian Islands golden king crab (west of 174° W)	15Aug–15May	2.835	1	4	2	2	7	29,944	867

[a] Total Allowable Catch in millions of pounds.

[b] All catcher-processor vessels are required to carry observers.

[c] Actual Total Fishery reported number of pot lifts.

[d] Guideline Harvest Level (GHL) in millions of pounds.

[e] Confidential.

Table 2.–Carapace length (CL) frequency distribution by shell condition from biological measurements of retained red king crab sampled during the 2010/11 Bristol Bay red king crab fishery.

	Percent			
CL[a] (mm)	New	Old	Very Old	All
81-85	<0.1	0	0	<0.1
86-115	0	0	0	0
116-120	<0.1	0	0	<0.1
121-125	<0.1	0	0	<0.1
126-130	<0.1	<0.1	0	<0.1
131-135	1.5	0.2	0	1.7
136-140	12.0	1.0	<0.1	13.0
141-145	21.7	1.8	<0.1	23.5
146-150	19.9	1.7	<0.1	21.6
151-155	15.4	1.7	<0.1	17.2
156-160	8.9	1.4	<0.1	10.4
161-165	4.9	1.4	<0.1	6.4
166-170	2.6	0.9	<0.1	3.6
171-175	1.3	0.5	<0.1	1.8
176-180	0.4	0.2	<0.1	0.6
181-185	<0.1	<0.1	0	0.1
186-190	<0.1	<0.1	0	<0.1
191-195	0	<0.1	0	<0.1
Total Crab	17,876	2,180	82	20,138
Total Percent	88.8	10.8	0.4	100

[a] Average CL = 149.5 mm.

Table 3.–Estimated CPUE and total catch (thousands of crab) of selected crab species from 1,891 pot lifts sampled by observers deployed during the 2010/11 Bristol Bay red king crab fishery.

Species	CPUE	SE	95% CI	Crab[a]
Red King Crab				
legal retained	17.2	0.96	(15.18, 19.28)	2,260
female	3.4	0.78	(1.50, 5.05)	450
sublegal	19.9	1.32	(17.10, 22.75)	2,620
legal not retained	0.3	0.09	(0.08, 0.46)	40
Tanner Crab				
female	< 0.1	–	–	< 10
sublegal	0.2	0.03	(0.09, 0.22)	30
legal not retained	0.1	0.04	(0.02, 0.21)	10
Snow Crab[b]				
legal not retained	<0.1	–	–	<10

[a] Product of estimated CPUE and ATF reported 131,627 total number of pot lifts.

[b] Observers recorded just 3 sublegal male and no female snow crab in pot lift sampling.

Table 4.–Carapace width (CW) frequency distribution by shell condition from biological measurements of retained snow crab sampled during the 2010/11 Bering Sea snow crab fishery.

	Percent			
CW[a] (mm)	New	Old	Very Old	All
81-85	<0.1	0	0	<0.1
86-90	<0.1	<0.1	0	<0.1
91-95	0.2	<0.1	0	0.2
96-100	1.5	<0.1	<0.1	1.5
101-105	7.5	0.3	<0.1	7.8
106-110	15.4	0.6	<0.1	16
111-115	23.6	0.7	<0.1	24.4
116-120	25.8	0.7	<0.1	26.5
121-125	16.1	0.4	0	16.5
126-130	5.6	0.2	0	5.8
131-135	1.0	<0.1	0	1.1
136-140	0.2	<0.1	0	0.2
141-145	<0.1	0	0	<0.1
Total Crab	35,421	1,104	19	36,544
Total Percent	96.9	3.0	0.1	100

[a] Average CW = 115.2 mm.

Table 5.–Estimated CPUE and total catch (thousands of crab) of selected crab species from 2,142 pot lifts sampled by observers deployed during the 2010/11 Bering Sea snow crab fishery.

Species	CPUE	SE	95% CI	Crab[a]
Snow Crab				
legal retained	284.5	7.74	(268.55, 300.49)	41,890
female	1.0	0.45	(0.02, 1.89)	150
sublegal	0.3	0.06	(0.23, 0.46)	40
legal not retained	37.8	3.81	(31.27, 44.41)	5,570
Tanner Crab				
female	0.3	0.08	(0.16, 0.49)	40
sublegal	25.9	2.44	(10.91, 20.97)	3,810
legal not retained	1.0	0.18	(0.57, 1.33)	150
Hybrid Tanner crab (legally bairdi[b])				
sublegal	0.1	0.10	(0, 0.36)	10
legal not retained	<0.1	–	–	<10
Hybrid Tanner crab (legally *opilio*[c])				
legal retained	0.5	0.39	(0, 1.27)	70
legal not retained	0.6	0.48	(0, 1.61)	90

[a] Product of estimated CPUE and ATF reported 147,244 total number of pot lifts in the Bering Sea snow crab fishery.

[b] Hybrid Tanner crab considered to be *C. bairdi* by the criteria of 5 AAC 35.521; observers recorded no females in pot lift sampling.

[c] Hybrid Tanner crab considered to be *C. opilio* by the criteria of 5 AAC 35.521; observers recorded just 6 females and no sublegal males in pot lift sampling.

Table 6.–Carapace length (CL) frequency distribution by shell condition from biological measurements of retained blue king crab sampled during the 2010/11 St. Matthew Island blue king crab fishery.

	Percent			
CL[a] (mm)	New	Old	Very Old	All
111-115	0.2	0	<0.1	0.3
116-120	7.8	0.7	<0.1	8.6
121-125	22.1	1.9	0.7	24.7
126-130	23	2.0	0.6	25.6
131-135	19.7	1.3	0.2	21.2
136-140	12.4	0.4	<0.1	12.8
141-145	5.0	0.1	<0.1	5.2
146-150	1.3	<0.1	0	1.3
151-155	0.3	0	0	0.3
156-160	<0.1	0	0	<0.1
161-165	<0.1	0	0	<0.1
Total Crab	3,203	225	59	3,487
Total Percent	91.9	6.5	1.7	100

[a] Average CL = 129.3 mm.

Table 7.–Estimated CPUE and total catch (thousands of crab) of selected crab species from 2,419 pot lifts sampled by observers deployed during the 2010/11 St. Matthew Island blue king crab fishery.

Species	CPUE	SE	95% CI	Crab[a]
Blue King Crab				
legal retained	10.2	0.10	(10.04, 10.44)	299
female	5.1	0.23	(4.64, 5.55)	150
sublegal	10.4	0.14	(10.17, 10.71)	305
legal not retained	0.2	0.01	(0.18, 0.22)	6
Snow Crab				
female	<0.1	–	–	<3
sublegal	0.2	0.02	(0.11, 0.19)	6
legal not retained	0.4	0.02	(0.31, 0.39)	10

[a] Product of estimated CPUE and ATF reported 29,346 total number of pot lifts.

Table 8.–Carapace length (CL) distribution by shell condition from biological measurements of retained golden king crab sampled during the 2010 Pribilof Islands golden king crab fishery.

CONFIDENTIAL

Table 9.–Estimated CPUE and total catch (thousands of crab) of selected crab species from 483 pot lifts sampled by observers deployed during the 2010 Pribilof Islands golden king crab fishery.

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Table 10.–Carapace length (CL) distribution by shell condition from biological measurements of retained golden king crab sampled during the 2010/2011 Aleutian Islands golden king crab fishery east of 174° W long.

	Percent			
CL[a] (mm)	New	Old	Very Old	All
96-100	<0.1	0	0	<0.1
101-125	0	0	0	0
126-130	<0.1	0	0	<0.1
131-135	1.8	0	0	1.8
136-140	12.2	<0.1	0	12.3
141-145	18.4	0.3	0	18.7
146-150	18.2	0.4	0	18.6
151-155	14.9	0.5	0	15.4
156-160	11.8	0.8	0	12.7
161-165	7.9	0.4	0	8.2
166-170	6.1	0.5	0	6.6
171-175	2.8	0.3	0	3.1
176-180	1.3	<0.1	0	1.4
181-185	0.6	0.1	0	0.8
186-190	0.3	0	0	0.3
191-195	<0.1	0	0	<0.1
196-200	<0.1	0	0	<0.1
Total Crab	2,271	82	0	2,353
Total Percent	96.5	3.5	0	100

[a] Average CL = 151.8 mm.

Table 11.–Estimated CPUE and total catch (thousands of crab) of golden king crab from 436 pot lifts sampled by observers deployed during the 2010/11 Aleutian Islands golden king crab fishery east of 174° W long.

Species	CPUE	SE	95% CI	Crab[a]
Golden King Crab				
legal retained	25.5	0.82	(23.85, 27.08)	659
female	9.8	0.96	(7.87, 11.63)	250
sublegal	11.0	0.88	(9.31, 12.77)	284
legal not retained	0.8	0.11	(0.59, 1.01)	20

[a] Product of estimated CPUE and ATF reported 25,851 total number of pot lifts.

Table 12.–Carapace length (CL) distribution by shell condition from biological measurements of retained golden king crab sampled during the 2010/11 Aleutian Islands golden king crab fishery west of 174° W long.

	Percent			
CL (mm)	New	Old	Very Old	All
126-130	<0.1	0	0	<0.1
131-135	1.8	0	0	1.8
136-140	10.5	<0.1	0	10.6
141-145	17.7	0.1	0	17.8
146-150	18.3	0.2	0	18.5
151-155	14.1	0.4	0	14.5
156-160	11.8	0.3	0	12.1
161-165	9.4	0.4	0	9.8
166-170	6.3	0.5	0	6.8
171-175	4.2	0.3	<0.1	4.4
176-180	2.1	0.2	<0.1	2.3
181-185	0.9	<0.1	0	1.0
186-190	0.3	<0.1	0	0.3
191-195	<0.1	<0.1	0	0.1
196-200	<0.1	0	0	<0.1
201-205	<0.1	0	0	<0.1
Total Crab	9,578	238	2	9,818
Total Percent	97.6	2.4	0	100

[a] Average CL = 152.9 mm.

Table 13.–Estimated CPUE and total catch (thousands of crab) of golden king crab from 867 pot lifts sampled by observers deployed during the 2010/11 Aleutian Islands golden king crab fishery west of 174° W long.

Species	CPUE	SE	95% CI	Crab[a]
Golden King Crab				
legal retained	21.1	0.67	(19.79, 22.41)	632
female	8.5	0.70	(7.14, 9.88)	250
sublegal	6.7	0.36	(5.98, 7.41)	200
legal not retained	0.8	0.07	(0.68, 0.95)	20

[a] Product of estimated CPUE and ATF reported 29,944 total number of pot lifts.

Table 14.–Comparison of actual total fishery (ATF) and observer data estimates of retained catch CPUE and number (thousands of crab; including deadloss) for 2010/11 BSAI crab fisheries.

	ATF estimates		Observer data estimates		
Fishery	CPUE	Crab	CPUE	Crab	% Difference CPUE[a]
Bristol Bay red king crab	18.2	2,398	17.2	2,260	-5.5
Bering Sea snow crab	256.4	37,758	284.5	41,890	11.0
St. Matthew Island blue king crab	10.2	299	10.2	299	0.0
Pribilof Islands golden king crab	_[b]	_[b]	_[b]	_[b]	_[b]
Eastern Aleutian Islands golden king crab	26.0	671	25.5	659	-1.9
Western Aleutian Islands golden king crab	20.9	626	21.1	632	1.0

[a] $(CPUE_{Obs} - CPUE_{ATF}) / CPUE_{ATF} \times 100$.

[b] Confidential.

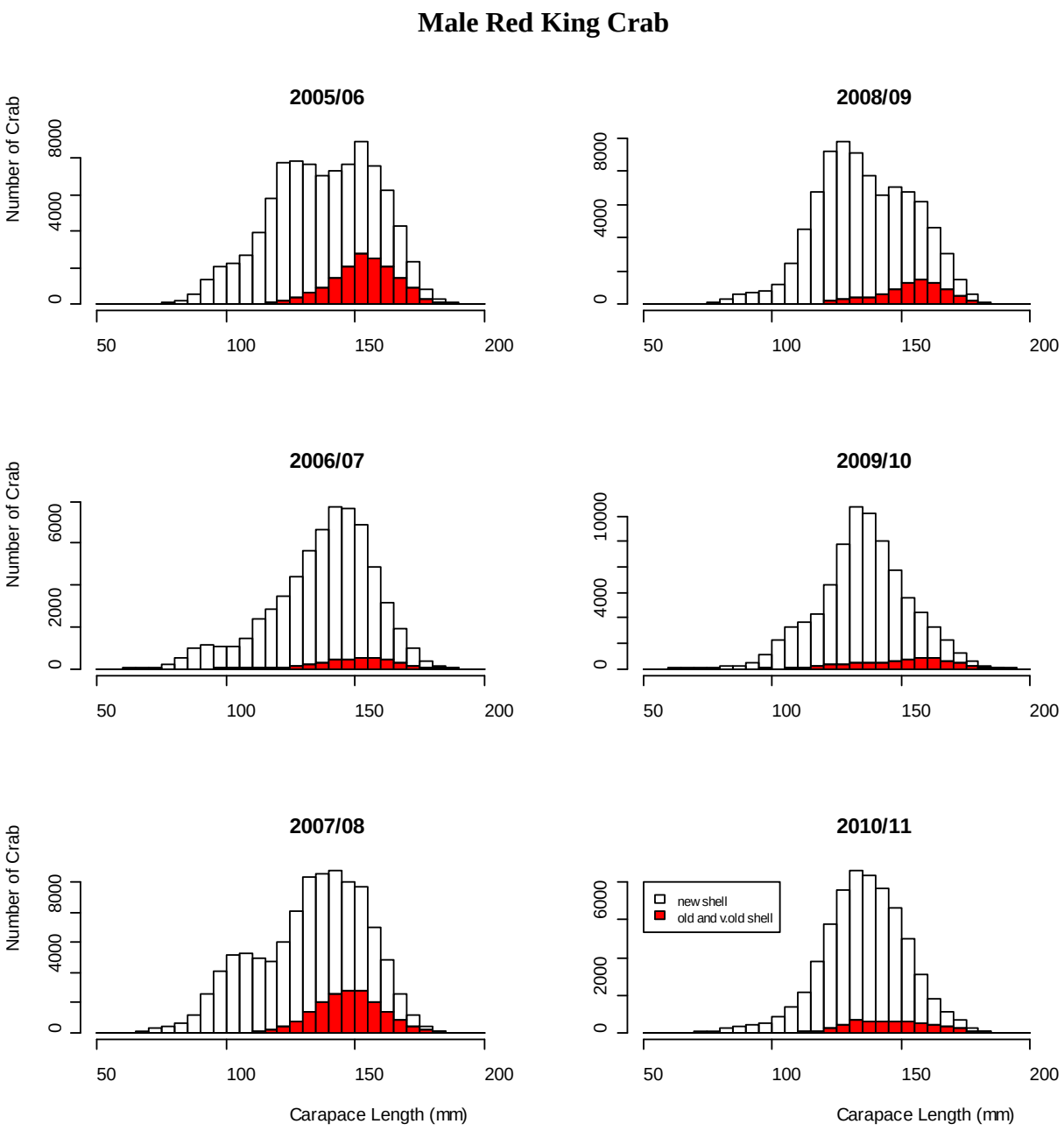


Figure 1.–Carapace length distribution with shell condition for male red king crab from pot lifts sampled during the 2005/06–2010/11 Bristol Bay red king crab fisheries.

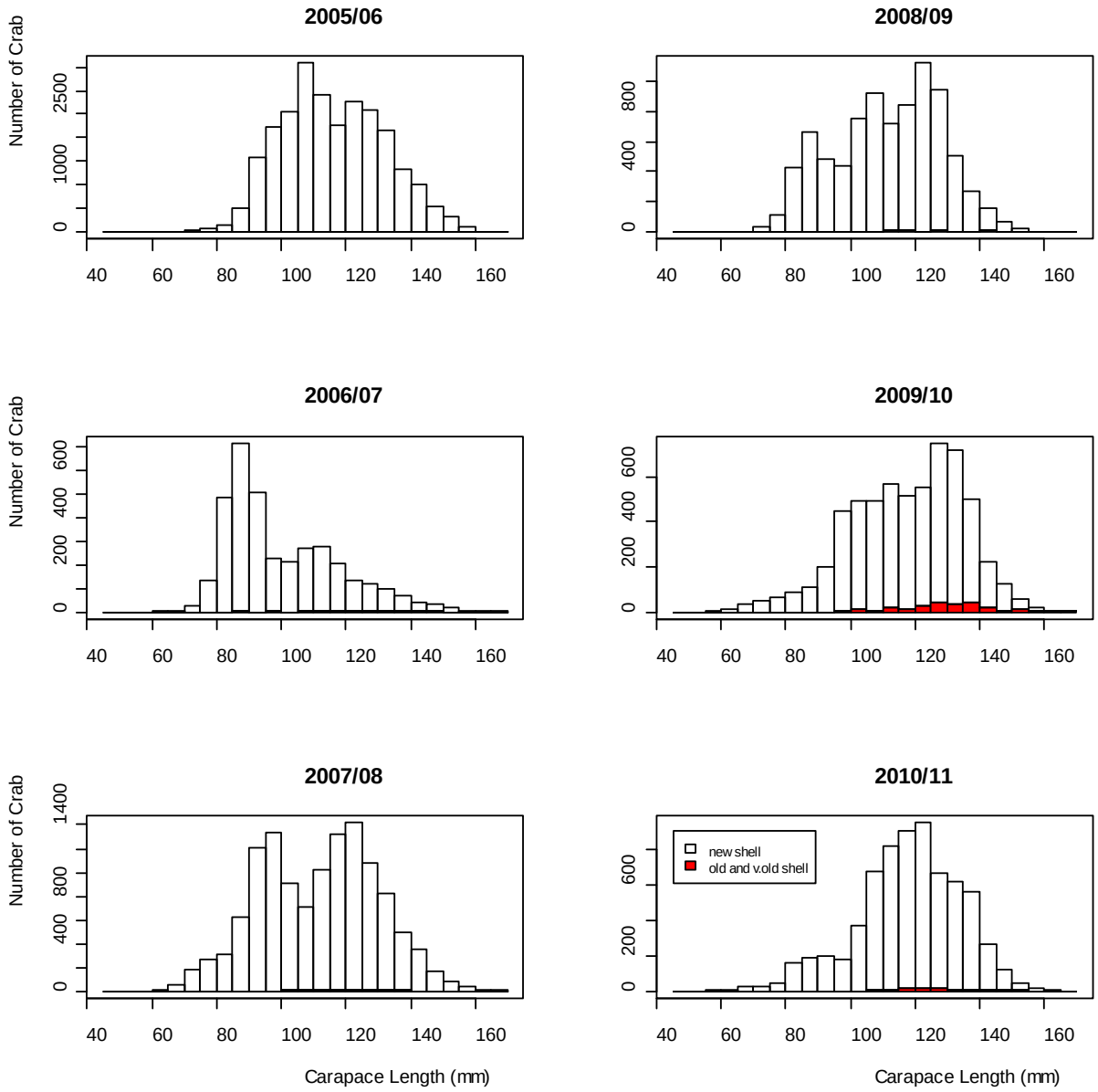


Figure 2.–Carapace length distribution with shell condition for female red king crab from pot lifts sampled during the 2005/06–2010/11 Bristol Bay red king crab fisheries.

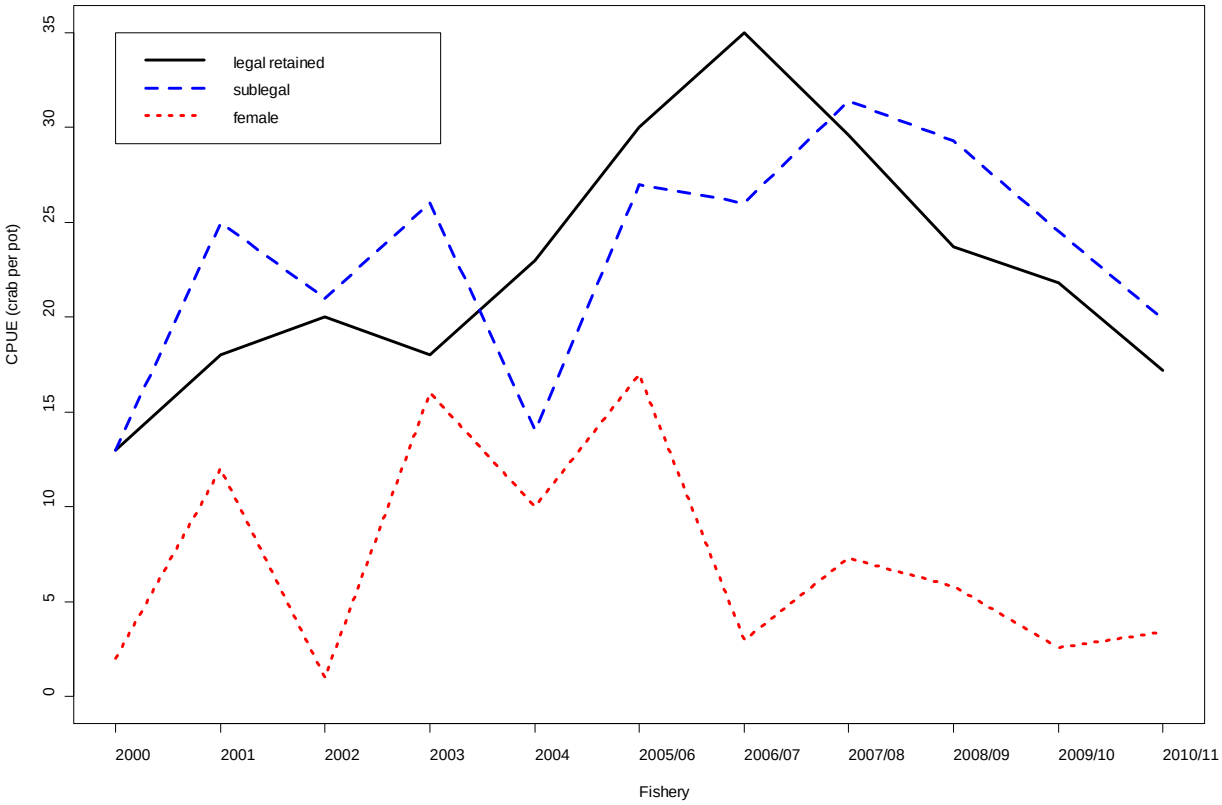


Figure 3.–Estimated red king crab CPUE from pot lifts sampled during the 2000–2010/11 Bristol Bay red king crab fisheries.

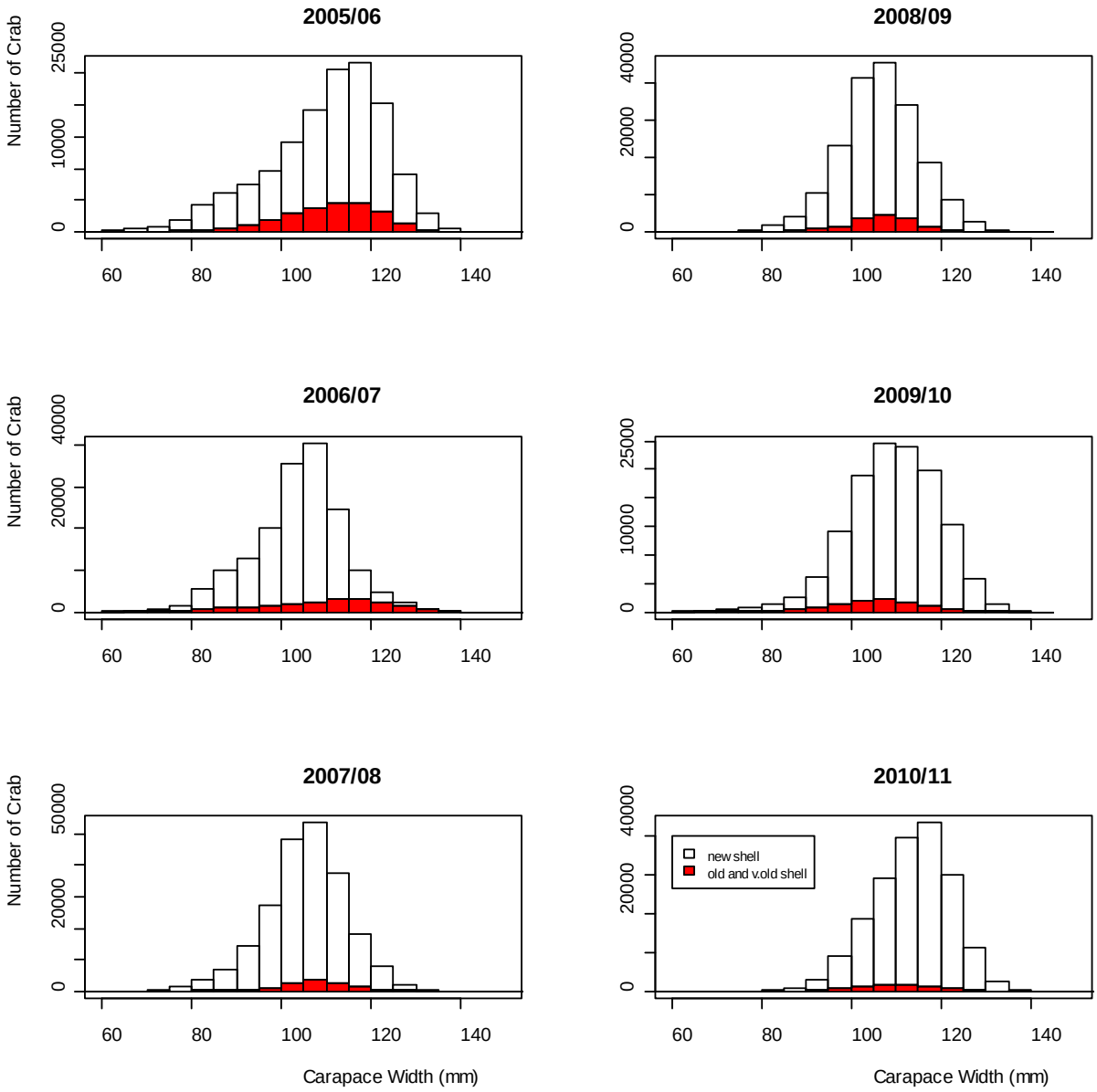


Figure 4.–Carapace width distribution with shell condition for male snow crab from pot lifts sampled during the 2005/06–2010/11 directed Bering Sea snow crab fisheries.

Bering Sea Sow Crab CPUE

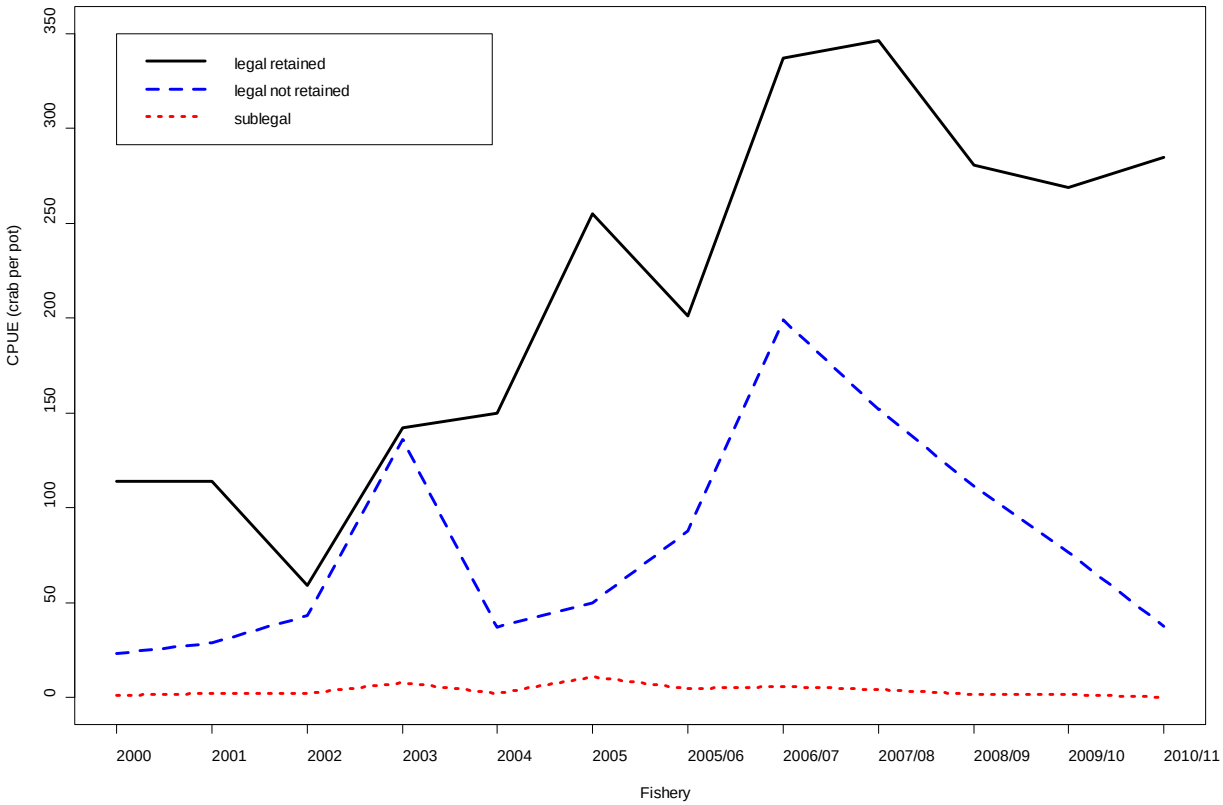


Figure 5.–Estimated snow crab CPUE from pot lifts sampled during the 2000–2010/11 Bering Sea snow crab fisheries.

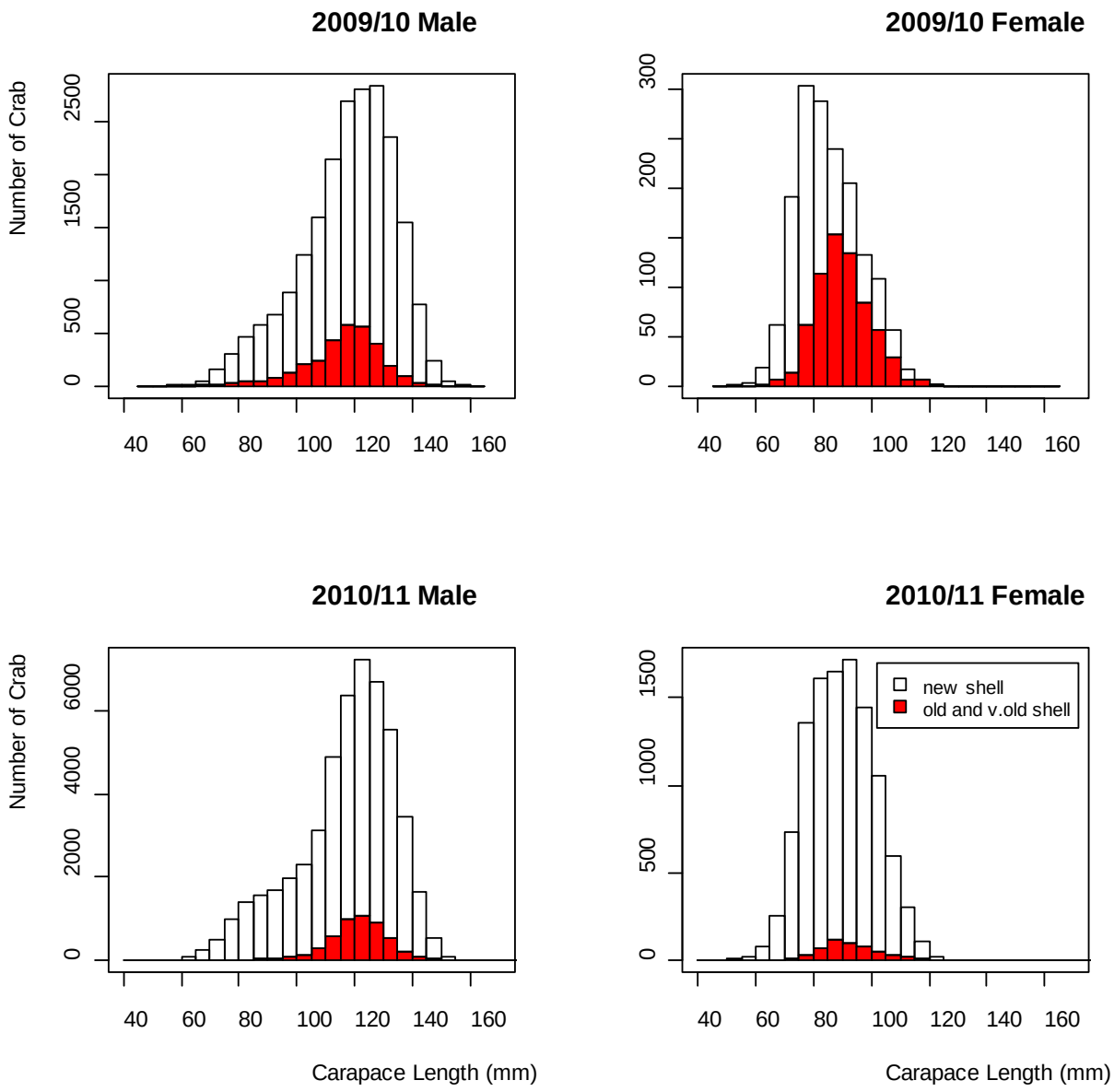
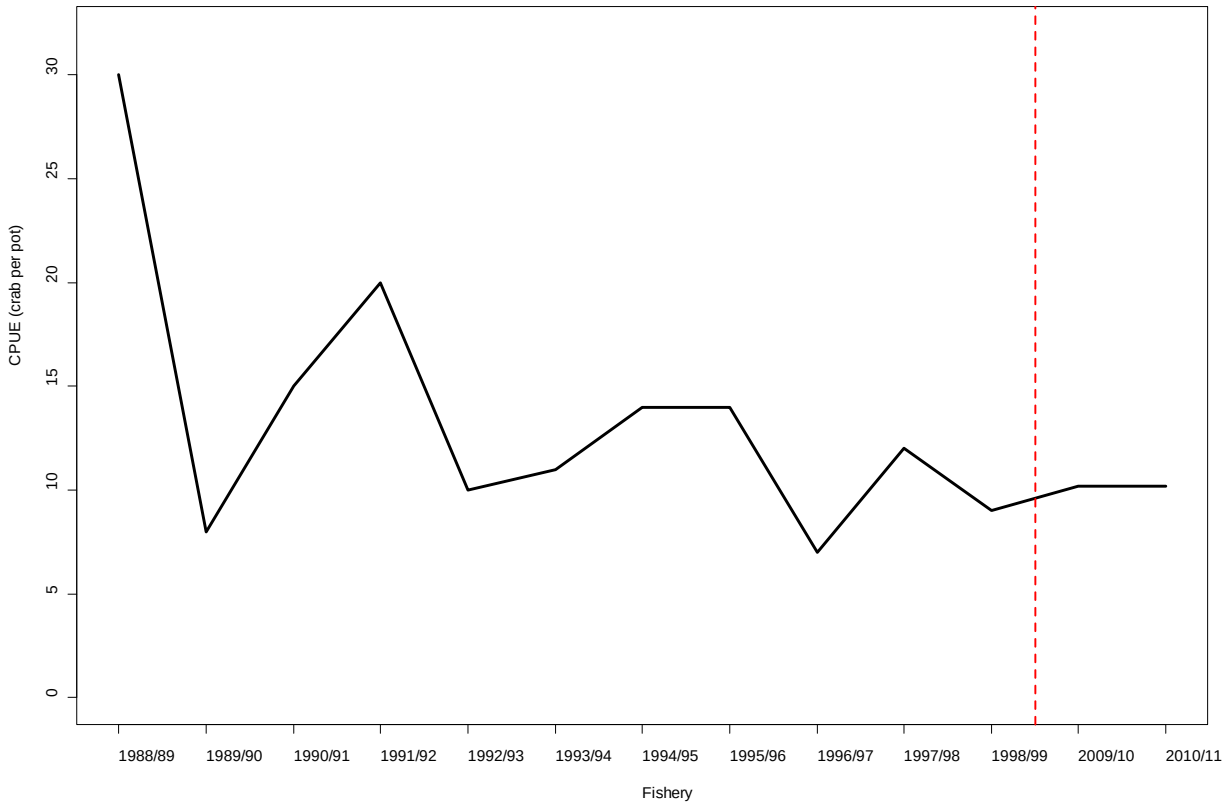


Figure 6.–Carapace length distribution with shell condition for blue king crab from pot lifts sampled during the 2009/10 and 2010/11 St. Matthew Island blue king crab fisheries.



Note: The 2009/10 and 2010/11 numbers are estimates from observer data; earlier numbers are ATF-reported values. The fishery was closed for 10 years after the 1998/99 season.

Figure 7.–Blue king crab legal retained CPUE from the 1988/89–2010/11 St. Matthew Island blue king crab fisheries.

Figure 8.–Carapace length distribution with shell condition for golden king crab from pot lifts sampled during the 2010 Pribilof Islands golden king crab fishery.

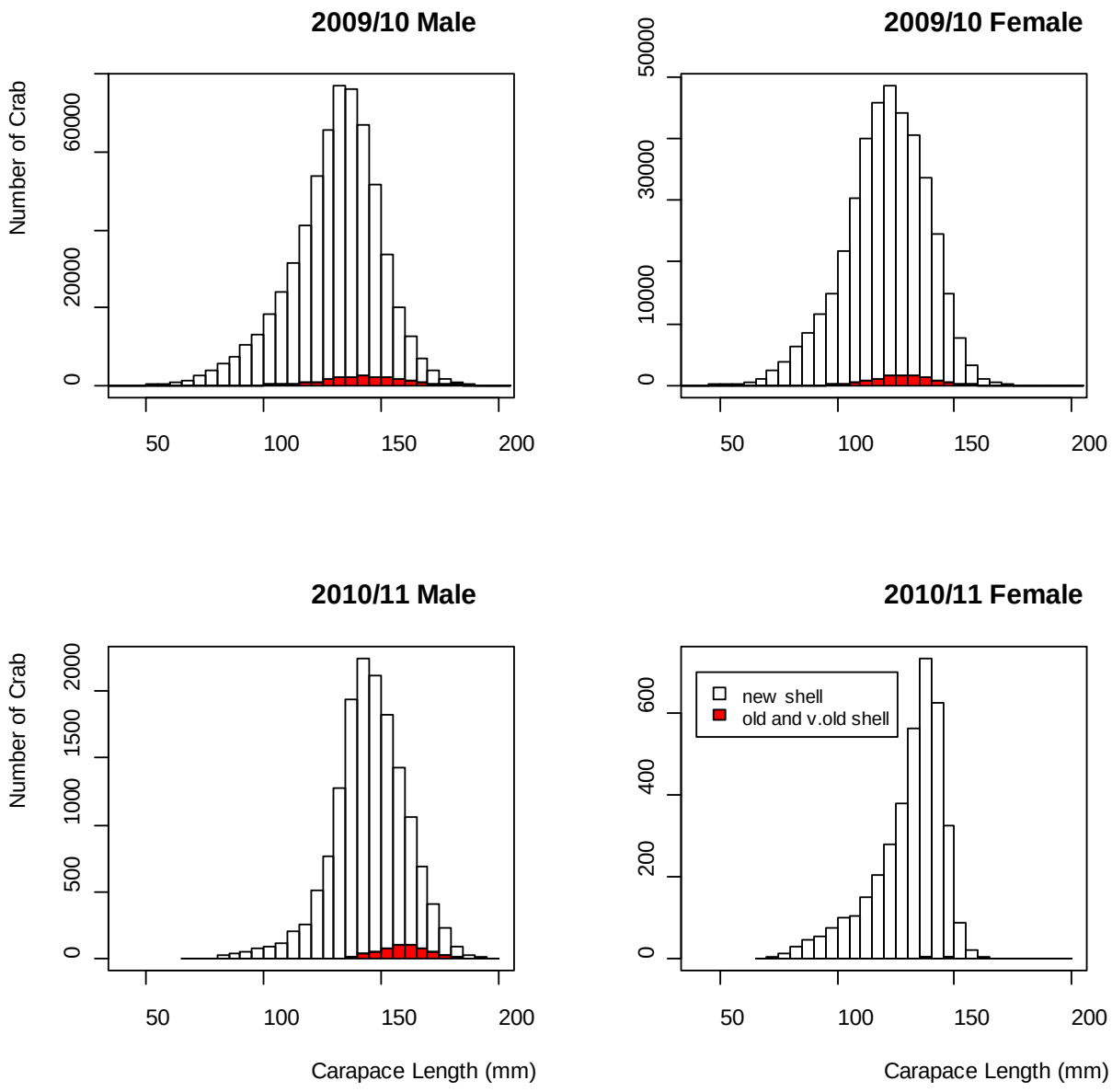


Figure 9.–Carapace length distribution with shell condition for golden king crab from pot lifts sampled during the 2009/10 and 2010/11 Aleutian Islands golden king crab fisheries east of 174° W long.

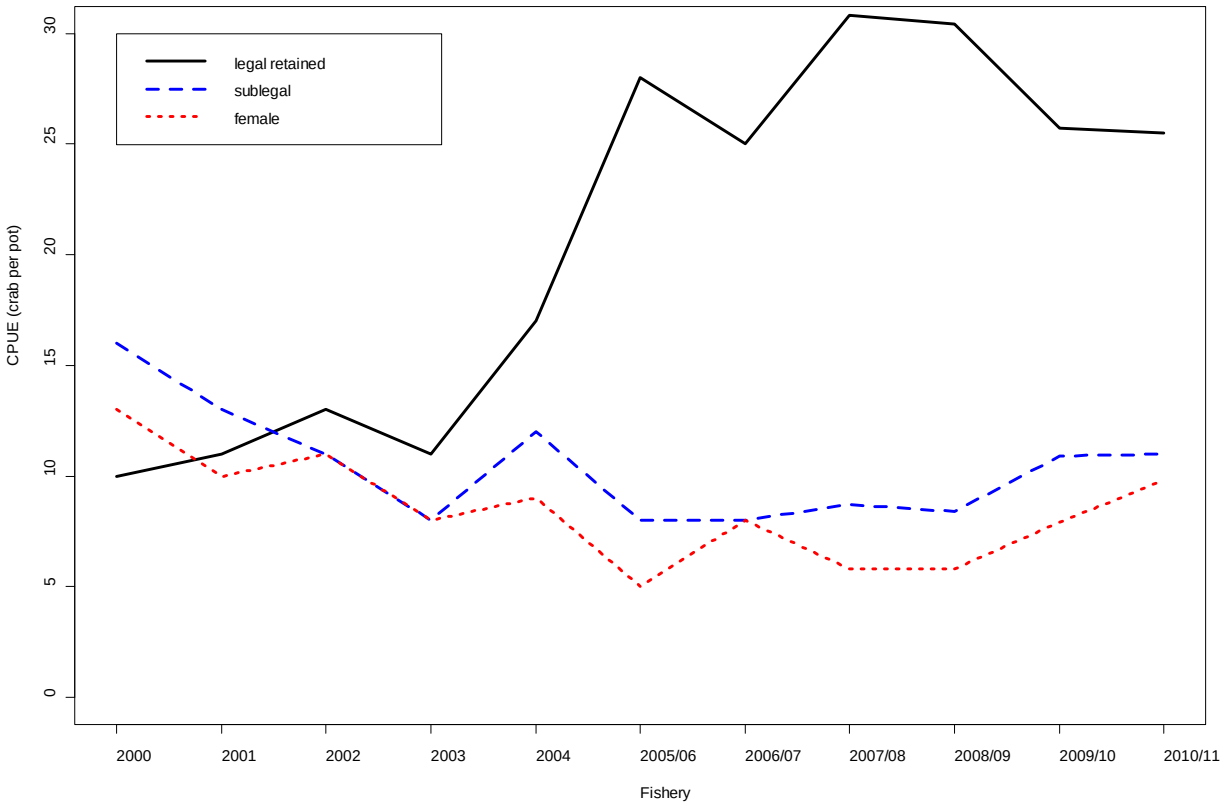


Figure 10.–Estimated golden king crab CPUE from pot lifts sampled during the 2000–2010/11 Aleutian Islands golden king crab fisheries east of 174° W long.

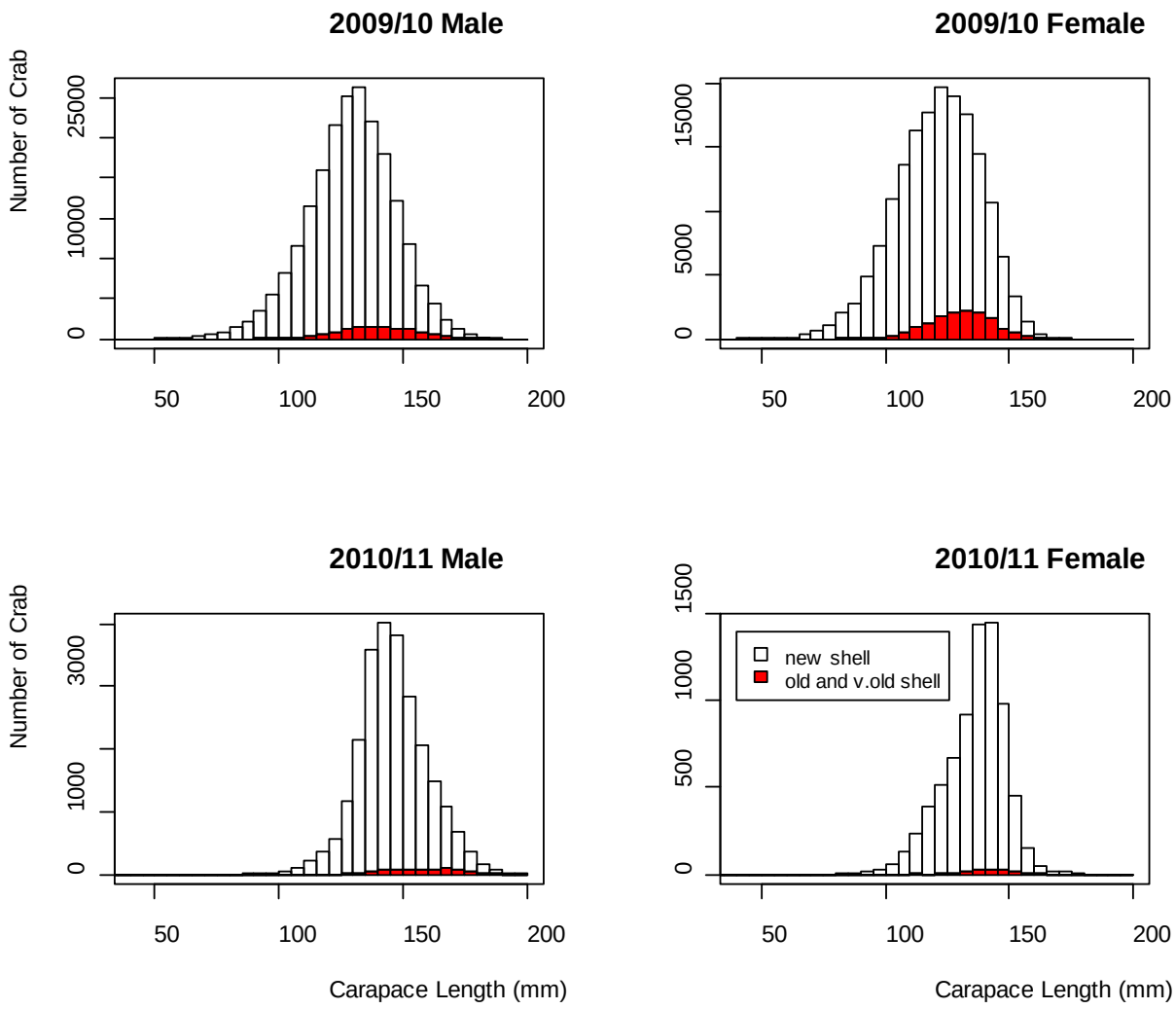


Figure 11.–Carapace length distribution with shell condition for golden king crab from pot lifts sampled during the 2009/10 and 2010/11 Aleutian Islands golden king crab fisheries west of 174° W long.

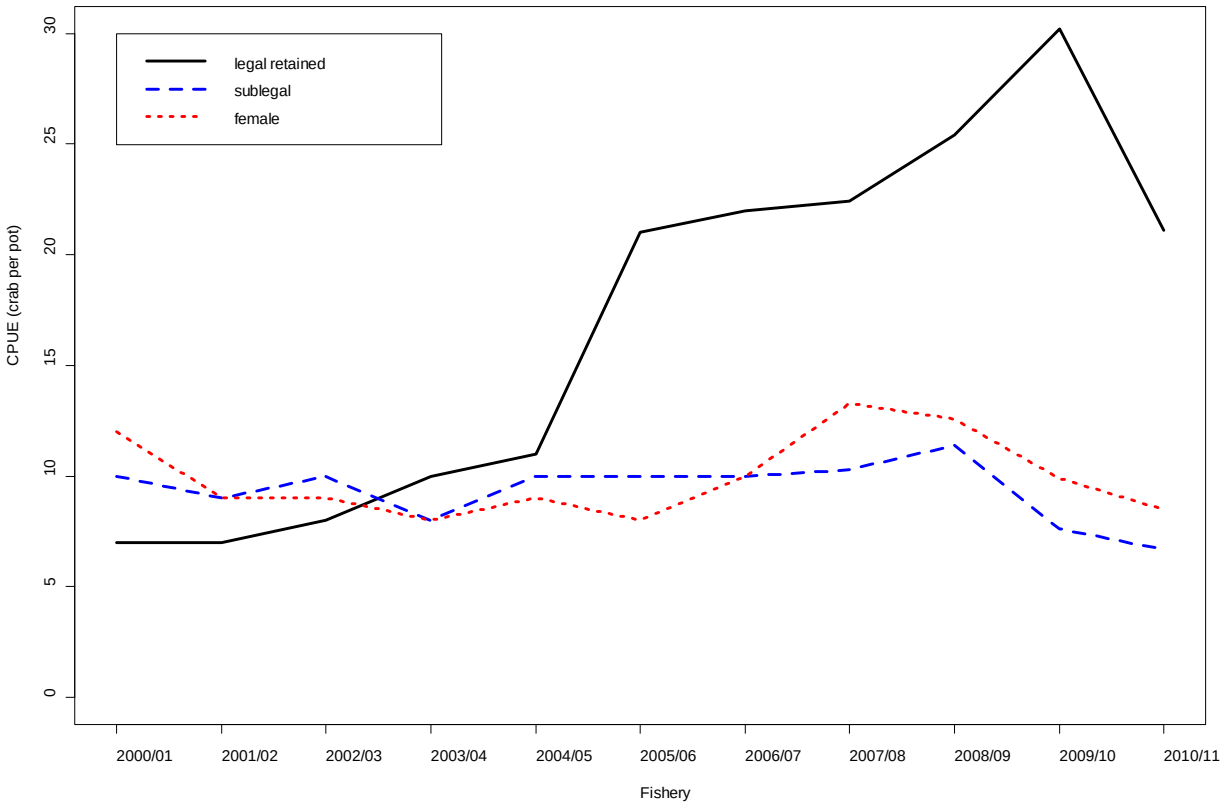


Figure 12.–Estimated golden king crab CPUE from pot lifts sampled during the 2000/01–2010/11 golden king crab fisheries west of 174° W long.

APPENDIX A. ESTIMATION OF CPUE FROM OBSERVER DATA

Under the current sampling design, observed vessels are selected independently within each vessel type, as are randomly sampled pot lifts within each day fished by each observed vessel. We first consider vessels of a single type, e.g. catcher vessels. Let

M = number of vessels of given type (catcher-only or catcher-processor) in fishery

m = number of vessels within given type sampled for observation

D_j = number of days fished by vessel j

N_{jk} = number of pots lifted by vessel j on day k

N_j = total number of pots lifted by vessel j over all D_j days fished

N = total number of pots lifted by all vessels of the given type during fishery

c_{jkl} = number of crab observed on vessel j on day k in sampled pot l

n_{jk} = number of pots sampled on vessel j on day k

$\bar{c}_{jk} = \frac{1}{n_{jk}} \sum_{l}^{n_{jk}} c_{jkl}$

= vessel j sample average number of crab per pot on day k

Further, let τ_j = vessel j total catch over all pots and days fished. We want to estimate overall vessel type CPUE $\mu = \frac{\sum_{j}^{M} \tau_j}{\sum_{j}^{M} N_j}$ (vessel type total catch divided by total number of pot lifts) from the observer data $\{c_{jkl}\}$. Under independent simple random sampling of pots on each day on each vessel and stratifying by day, the usual stratified estimator of τ_j is

$$\hat{\tau}_j = \sum_{k}^{D_j} N_{jk} \bar{c}_{jk} \tag{1}$$

with variance estimator

$$\hat{V}[\hat{\tau}_j] = \sum_{k}^{D_j} N_{jk}^2 \hat{V}ar[\bar{c}_{jk}]$$

$$= \sum_{k}^{D_j} N_{jk}^2 \left(1 - \frac{n_{jk}}{N_{jk}}\right) \frac{1}{n_{jk}} \frac{\sum_{l}^{n_{jk}} (c_{jkl} - \bar{c}_{jk})^2}{n_{jk} - 1} \tag{2}$$

-continued-

by virtue of standard results. See, for example, Cochran (1977). Assuming a simple random sample *S* of *m* out of *M* vessels of the given type, an unbiased estimator of vessel type total catch τ is then simply

$$\hat{\tau} = \frac{M}{m}\sum_{j}^{m}\hat{\tau}_j\,, \tag{3}$$

since conditioning on *S* we have

$$\begin{aligned}
E[\hat{\tau}] &= E[\frac{M}{m}\sum_{j}^{m}\hat{\tau}_j] \\
&= E[E[\frac{M}{m}\sum_{j}^{m}\hat{\tau}_j \mid S]] \\
&= E[\frac{M}{m}\sum_{j}^{m}E[\hat{\tau}_j \mid S]] \\
&= E[\frac{M}{m}\sum_{j}^{m}\tau_j] \\
&= ME[\frac{1}{m}\sum_{j}^{m}\tau_j] \\
&= M\frac{1}{M}\sum_{j}^{M}\tau_j \\
&= \sum_{j}^{M}\tau_j \\
&= \tau\,.
\end{aligned}$$

Its variance, which may also be obtained by conditioning on the initial sample of vessels, is given by $Var[\hat{\tau}] = M^2(1-\frac{m}{M})\frac{1}{m}\frac{\sum_{j}^{M}(\tau_j-\bar{\tau})^2}{M-1} + \frac{M}{m}\sum_{j}^{M}Var[\hat{\tau}_j]$, where $\bar{\tau}$ denotes the mean of the τ_j. An unbiased estimate of this variance is

$$\hat{Var}[\hat{\tau}] = M^2(1-\frac{m}{M})\frac{1}{m}\frac{\sum_{j}^{m}(\hat{\tau}_j-\bar{\hat{\tau}})^2}{m-1} + \frac{M}{m}\sum_{j}^{m}Var[\hat{\tau}_j] \tag{4}$$

with $\bar{\hat{\tau}} = \frac{1}{m}\sum_{j}^{m}\hat{\tau}_j$, the average of the observed vessel estimated total catches (Cochran 1977,

-continued-

Theorem 11.2). Note that if all vessels of the given type are sampled, as is typically true of the catcher/processor fleet, this reduces to $\hat{Var}[\hat{\tau}] = \sum_{j}^{m=M} Var[\hat{\tau}_j]$. On the other hand, since fishery pot lift totals N_j for each observed vessel are in principle known, an unbiased estimate of the vessel type total number of pot lifts is the simple expansion estimator

$$\hat{\lambda} = \frac{M}{m}\sum_{j}^{m} N_j \tag{5}$$

with unbiased variance estimator

$$\hat{Var}[\hat{\lambda}] = M^2(1-\frac{m}{M})\frac{1}{m}\frac{\sum_{j}^{m}(N_j - \overline{N})}{m-1}, \tag{6}$$

where $\overline{N}$ is the N_j sample mean, again in accordance with basic results.

For the combined fishery, given estimates $\hat{\tau}_C$ and $\hat{\tau}_{CP}$ of catcher vessel and catcher-processor vessel total catch, an estimate of overall fishery total catch τ_F is simply their sum

$$\hat{\tau}_F = \hat{\tau}_C + \hat{\tau}_{CP}, \tag{7}$$

and under the assumption that sampling of vessels within each type occurs independently, an estimate of its variance is

$$\hat{Var}[\hat{\tau}_F] = \hat{Var}[\hat{\tau}_C] + \hat{Var}[\hat{\tau}_{CP}]. \tag{8}$$

Both of these estimators inherit unbiasedness from their components. In the same way, an estimate of the overall fishery total number of pot lifts and an estimate of its variance are given by

$$\hat{\lambda}_F = \hat{\lambda}_C + \hat{\lambda}_{CP} \tag{9}$$

and

$$\hat{Var}[\hat{\lambda}_F] = \hat{Var}[\hat{\lambda}_C] + \hat{Var}[\hat{\lambda}_{CP}], \tag{10}$$

likewise unbiased under unbiasedness of the individual vessel type estimators. Overall fishery CPUE can then be estimated using the ratio estimator

$$\hat{\mu} = \frac{\hat{\tau}_F}{\hat{\lambda}_F}. \tag{11}$$

To obtain an approximate variance for (11) we first expand it in a first order Taylor series around

-continued-

$\mu = \frac{\tau_F}{\lambda_F}$ as $\hat{\mu} \cong \mu + \frac{1}{\lambda_F}(\hat{\tau}_F - \tau_F) - \frac{\tau_F}{\lambda_F^2}(\hat{\lambda}_F - \lambda_F)$. Since vessels are selected independently within the two vessel types, taking variances and rearranging things results in

$$\hat{Var}[\hat{\mu}] \cong \frac{M_C^2}{m_C^2} Var[\sum_j^{m_C}(\frac{1}{\lambda_F}\hat{\tau}_j^C - \frac{\tau_F}{\lambda_F^2}N_j^C)] + \frac{M_{CP}^2}{m_{CP}^2} Var[\sum_j^{m_{CP}}(\frac{1}{\lambda_F}\hat{\tau}_j^{CP} - \frac{\tau_F}{\lambda_F^2}N_j^{CP})]. \quad (12)$$

The variances on the right side of (12) can be evaluated by conditioning on the initial simple random sample *S* of vessels within each type. Ignoring for the moment the particular vessel type, this procedure leads to

$$\begin{aligned} Var[\sum_j^m(\frac{1}{\lambda_F}\hat{\tau}_j - \frac{\tau_F}{\lambda_F^2}N_j)] &= Var[E[\sum_j^m(\frac{1}{\lambda_F}\hat{\tau}_j - \frac{\tau_F}{\lambda_F^2}N_j) \mid S]] + E[Var[\sum_j^m(\frac{1}{\lambda_F}\hat{\tau}_j - \frac{\tau_F}{\lambda_F^2}N_j) \mid S]] \\ &= Var[\sum_j^m(\frac{1}{\lambda_F}E[\hat{\tau}_j \mid S] - \frac{\tau_F}{\lambda_F^2}N_j)] + E[\sum_j^m \frac{1}{\lambda_F^2}Var[\hat{\tau}_j \mid S]] \\ &= Var[\sum_j^m(\frac{1}{\lambda_F}\hat{\tau}_j - \frac{\tau_F}{\lambda_F^2}N_j)] + E[\sum_j^m \frac{1}{\lambda_F^2}Var[\hat{\tau}_j] \\ &= m(1-\frac{m}{M})\frac{\sum_j^M (q_j - \bar{q})^2}{M-1} + \frac{m}{M\lambda_F^2}\sum_j^M Var[\hat{\tau}_j], \end{aligned} \quad (13)$$

where $q_j = \frac{1}{\lambda_F}\tau_j - \frac{\tau_F}{\lambda_F^2}N_j$ and $\bar{q} = \frac{1}{M}\sum_j^M q_j$. Appropriate double substitution of (13) into the right side of (12) then gives

$$\begin{aligned} Var[\hat{\mu}] \cong{}& \frac{M_C^2}{m_C}(1-\frac{m_C}{M_C})S_{qC}^2 + \frac{M_C}{m_c\lambda_F^2}\sum_j^{M_C} Var[\hat{\tau}_j^C] \\ &+ \frac{M_{CP}^2}{m_{CP}}(1-\frac{m_{CP}}{M_{CP}})S_{qCP}^2 + \frac{M_{CP}}{m_{CP}\lambda_F^2}\sum_j^{M_{CP}} Var[\hat{\tau}_j^{CP}], \end{aligned} \quad (14)$$

where S_{qC}^2 and S_{qCP}^2 denote the population variances of the quantities q_j^C and q_j^{CP}. Upon replacing these with their sample analogues s_{qC}^2 and s_{qCP}^2 and substituting the estimators determined by (2) for $Var[\hat{\tau}_j^C]$ and $Var[\hat{\tau}_j^{CP}]$ and those in (3) and (5) for τ_F and λ_F, we obtain the variance estimator

$$\hat{Var}[\hat{\mu}] = \frac{M_C^2}{m_C}(1-\frac{m_C}{M_C})s_{qC}^2 + \frac{M_C}{m_c\hat{\lambda}_F^2}\sum_j^{m_C}\hat{Var}[\hat{\tau}_j^C] + \frac{M_{CP}^2}{m_{CP}}(1-\frac{m_{CP}}{M_{CP}})s_{qCP}^2 + \frac{M_{CP}}{m_{CP}\hat{\lambda}_F^2}\sum_j^{m_{CP}} Var[\hat{\tau}_j^{CP}]. \quad (15)$$

-continued-

It should be noted that the overall totals τ_F and λ_F are used in defining the quantities q_j^C and q_j^{CP} and so (3) and (5) are to be used in estimating the latter. With (11) and (15) in hand an approximate $100(1-2\alpha)$ percent confidence interval for overall fishery CPUE μ is

$$\hat{\mu} \pm t_{df,\alpha} \sqrt{\hat{V}ar[\hat{\mu}]}\,, \tag{16}$$

where $t_{df,\alpha}$ denotes the $100(1-\alpha)^{\text{th}}$ percentile of the *t*-distribution on *df* degrees of freedom. In general, we take $df = m_C - 1$, unless all catcher-only vessels are observed, in which case we use the standard normal distribution to determine an appropriate multiplier, i.e. we put $df = \infty$. (Recall that m_C is the number of observed catcher-only vessels in the directed fishery.) Small sample sizes at some levels of the design, underlying skewed pot count distributions, theoretical bias of the ratio estimator, and the use of an approximate variance admittedly give reason for concern about the applicability of standard asymptotic confidence intervals, and future investigation is warranted. Nevertheless, we believe this approach is reasonable and likely conservative rather than otherwise.

As a final note we remark that if the total number of pot lifts λ_F is in fact known, the unbiased estimator

$$\hat{\mu}_u = \frac{\hat{\tau}_F}{\lambda_F} \tag{17}$$

is a natural candidate for estimating fishery CPUE, and an estimate of its variance is easily obtained from (8). However, though ratio estimators such as (11) are in general not design unbiased, in some applications they can perform well in the sense of having smaller mean square error (MSE) than their unbiased counterparts (Lohr 1999, p. 151). For the application at hand we expect vessel catch and vessel pot lift totals to be highly positively correlated and hence that (11) should provide reasonable estimates of the target parameter. Moreover, (11) is robust to undercoverage resulting from failure to sample pots on all days fished by a vessel selected for observation, so long as sampled pots and observed daily pot lift totals are mostly representative of those on unobserved days. The unbiased estimator (17) decidedly lacks this sort of robustness, and we note that significant undercoverage of the type described can occur, especially in the Aleutian Islands golden king crab fishery. It should also be observed that although fishery pot lift totals λ_F, as well as λ_C and λ_{CP}, are routinely extracted from fish ticket data, some uncertainty is associated with these values. More importantly, neither that uncertainty nor its relationship to the observer-collected data is readily quantified, rendering problematic the inferential usefulness of those values in this context.

APPENDIX B. LOCATIONS OF SAMPLED POT LIFTS

Appendix B1.–Locations of pot lifts sampled by observers during the 2010/11 Bristol Bay red king crab fishery.

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Appendix B2.–Locations of pot lifts sampled by observers during the 2010/11 Bering Sea snow crab fishery.

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Appendix B3.–Locations of pot lifts sampled by observers during the 2010/11 St Matthew Island blue king crab fishery.

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Appendix B4.–Locations of pot lifts sampled by observers during the 2010/11 Pribilof Islands golden king crab fishery.

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Appendix B5.–Locations of pot lifts sampled by observers during the 2010/11 Aleutian Islands golden king crab fishery east of 174° W longitude.

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Appendix B6.–Locations of pot lifts sampled by observers during the 2010/11 Aleutian Islands golden king crab fishery west of 174° W longitude.

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APPENDIX C. ADDITIONAL CATCH AND BIOLOGICAL SUMMARIES

Appendix C1.–Total contents of 1,891 pot lifts sampled during the 2010/11 Bristol Bay red king crab fishery.

Commercial Crab Species	Total Catch (number)	Other Species	Total Catch (number)
Red King Crab		arrowtooth flounder	2
legal	31,724	basket star	5
sublegal	34,396	circumboreal toad crab	1
female	6,862	crab unident.	1
Tanner Crab		graceful decorator crab	3
legal	263	great sculpin	205
sublegal	320	hermit crab unident.	24
female	28	Hyas sp.	2
Snow Crab		jellyfish unident.	534
legal	119	limpet unident.	1
sublegal	3	mussel unident.	3
female	0	octopus unident.	2
Blue King Crab		Pacific cod	180
legal	0	Pacific halibut	73
sublegal	0	Pacific lyre crab	4
female	1	rockfish unident.	2
Hair Crab		rock sole unident.	2
legal	115	scale worm unident.	2
sublegal	30	sculpin unident.	225
female	72	sea anemone unident.	9
		sea cucumber unident.	6
		sea urchin unident.	1
		skate unident.	7
		snailfish unident.	2
		snail unident.	240
		sponge unident.	17
		starfish unident.	1,522
		starry flounder	9
		tunicate unident.	40
		walleye pollock	1
		worm unident.	4
		yellowfin sole	739
		yellow Irish lord	7

Appendix C2.–Red king crab per pot by soak time for 1,891 pot lifts sampled during the 2010/11 Bristol Bay red crab fishery.

Soak time[a] (hours)	Percent of sampled pots	Number of crab per pot				
		LRT	LNR	SUB	FEM	Total
0-11	0.3	16.2	0.0	9.2	0.0	25.4
12-23	2.7	15.8	0.0	15.3	1.8	32.9
24-35	9.7	13.6	0.2	13.7	2.9	30.5
36-47	27.9	16.4	0.2	16.4	3.5	36.5
48-59	22.5	15.4	0.3	20.3	4.1	40.0
60-71	11.3	14.5	0.3	19.6	4.9	39.4
72-83	4.8	14.9	0.2	24.8	2.0	41.9
84-95	4.7	18.1	0.3	17.2	1.7	37.4
96-107	4.8	19.9	0.2	18.2	2.8	41.1
108-119	1.7	24.7	0.4	22.9	1.4	49.4
120-131	2.7	26.4	0.3	26.4	2.9	56.0
132-143	2.2	25.0	0.3	25.2	1.0	51.4
144-155	1.7	17.8	0.2	17.5	15.6	51.2
156-167	1.2	16.9	0.2	16.1	3.5	36.7
168-179	0.8	15.9	0.4	17.9	11.2	45.3
180-191	0.2	19.8	0.0	21.5	4.0	45.3
192-203	0.2	29.0	0.0	14.3	7.3	50.7
204-215	0.1	38.5	0.5	21.0	0.0	60.0
216-227	0.4	21.1	0.1	12.1	0.0	33.4
228-239	0.3	16.0	0.0	21.4	0.2	37.6

Note: Observers categorize all sampled crabs as either legal-size retained male (LRT), legal-size non-retained male (LNR), sublegal male (SUB), or female (FEM).

[a] Average soak time was 63 hours.

Appendix C3.–Red king crab per pot by depth for 1,891 pot lifts sampled during the 2010/11 Bristol Bay red king crab fishery.

Depth[a] (fathoms)	Percent of sampled pots	Number of crab per pot				
		LRT	LNR	SUB	FEM	Total
20-24	0.1	26.0	0.5	26.5	0.0	53.0
25-29	11.4	17.5	0.5	28.2	0.6	46.8
30-34	13.7	16.0	0.6	22.3	0.4	39.3
35-39	17.9	18.1	0.1	18.2	4.3	40.8
40-44	25.7	16.5	0.1	14.1	6.1	36.8
45-49	23.4	14.4	0.2	18.8	4.2	37.6
50-54	7.7	18.6	0.1	11.4	2.7	32.8

Note: Observers categorize all sampled crabs as either legal-size retained male (LRT), legal-size non-retained male (LNR), sublegal male (SUB), or female (FEM).

[a] Average depth was 40 fathoms.

Appendix C4.–Reproductive condition (by percent) of female red king crab from pot lifts sampled during the 1996–2010/11 Bristol Bay red king crab fisheries.

		Ovigerous		Barren	
Year	Number of crab	Eyed eggs	Uneyed eggs	Matted setae	Clean setae
1996	11	0	0	0	100
1997	70	65.7	18.6	0	15.7
1998	4,091	45.6	51.8	<0.1	2.6
1999	36	0	86.1	2.8	11.1
2000	1,486	4.0	22.3	0.5	73.2
2001	4,574	66.0	18.7	0.3	15
2002	311	32.1	2.6	0.6	64.6
2003	10,391	9.1	51.5	3.4	35.9
2004	4,111	21.4	48.4	0.6	29.6
2005/06	26,753	41.3	45.0	0.2	13.4
2006/07	3,586	16.5	32.5	1.4	49.5
2007/08	12,451	41.0	41.0	1.7	22.9
2008/09	8,486	50.5	27.8	1.1	20.6
2009/10	6,049	17.2	71.4	1.0	10.2
2010/11	6,840	15.4	76	0.3	8.3

Appendix C5.–Total contents of 2,142 pot lifts sampled during the 2010/11 Bering Sea snow crab fishery.

Commercial Crab Species	Total Catch (number)	Other Species	Total Catch (number)
Snow Crab		arrowtooth flounder	6
legal	681,268	Atka mackerel	1
sublegal	787	basket star	106
female	1,431	bivalve unident.	1
Tanner Crab		brittle star unident.	1
legal	2,180	circumboreal toad crab	3
sublegal	36,762	flatfish unident.	1
female	716	flathead sole	3
Hybrid Tanner Crab (legally *opilio*[a])		giant octopus	16
Legal	2,098	hairy triton (or Oregon triton)	188
Sublegal	0	helmet crab	1
Female	6	hermit crab unident.	28
Hybrid Tanner Crab (legally *bairdi*[b])		jellyfish unident.	63
legal	30	northern rockfish	2
sublegal	293	octopus unident.	6
female	0	Pacific cod	687
Blue King Crab		Pacific halibut	67
legal	0	Pacific lyre crab	16
sublegal	2	prowfish	3
female	0	sculpin unident.	5
Golden King Crab		sea anemone unident.	54
legal	1	sea cucumber unident.	1
sublegal	1	sea urchin unident.	6
female	0	sea whip unident.	1
		skate unident.	4
		snail unident.	9,404
		sponge unident.	1
		starfish unident.	14
		walleye pollock	5
		yellowfin sole	3
		yellow Irish lord	40

[a] Hybrid Tanner crab that are considered to be *C. opilio* by the criteria of 5 AAC 35.521.

[b] Hybrid Tanner crab that are considered to be *C. bairdi* by the criteria of 5 AAC 35.521.

Appendix C6.–Snow crab per pot by soak time for 2,142 pot lifts sampled during the 2010/11 Bering Sea snow crab fishery.

Soak time[a] (hours)	Percent of sampled pots	Number of crab per pot				
		LRT	LNR	SUB	FEM	Total
0-11	0.3	72.7	7.9	0.1	0.0	80.7
12-23	4.1	220.6	31.3	0.3	0.3	252.5
24-35	29.9	263.5	37.5	0.5	1.1	302.8
36-47	25.8	284.2	36.2	0.3	1.1	321.8
48-59	9.4	277.0	28.3	0.1	0.0	305.4
60-71	5.1	286.0	33.5	0.2	0.3	320.0
72-83	3.8	338.1	40.0	0.3	0.0	378.4
84-95	2.4	312.5	35.9	0.2	0.1	348.6
96-107	2.3	282.8	34.8	0.1	0.1	317.8
108-119	1.8	309.8	31.0	0.1	0.0	340.9
120-131	2.6	339.8	41.2	0.4	0.1	381.5
132-143	1.9	312.7	32.0	0.3	0.0	345.1
144-155	2.2	304.1	42.6	0.7	0.1	347.5
156-167	2.4	310.7	38.1	0.5	0.0	349.4
168-179	1.5	333.7	43.3	0.4	0.1	377.4
180-191	1.0	293.4	41.3	0.1	0.0	334.8
192-203	0.8	357.5	67.6	0.2	0.0	425.4
204-215	0.9	330.9	34.5	0.3	0.0	365.7
216-227	0.5	318.4	61.5	0.2	0.0	380.1
228-239	0.2	376.6	50.4	0.6	0.0	427.6
240-251	0.2	322.8	25.2	0.2	0.0	348.2
252-263	0.3	302.3	55.5	0.0	0.0	357.8
> 263	0.5	263.4	26.4	0.4	0.0	290.2

Note: Observers categorize all sampled crabs as either legal-size retained male (LRT), legal-size non-retained male (LNR), sublegal male (SUB), or female (FEM).

[a] Average soak time was 64 hours.

Appendix C7.–Snow crab per pot by depth for 2,419 pot lifts sampled during the 2010/11 Bering Sea snow crab fishery.

Depth[a] (fathoms)	Percent of sampled pots	Number of crab per pot				
		LRT	LNR	SUB	FEM	Total
45-49	<0.1	19.0	5.0	0.0	1.0	25.0
50-54	0.2	16.0	5.3	0.0	0.0	21.3
55-59	2.7	212.9	11.4	0.2	2.4	226.8
60-64	22.7	266.8	41.3	0.3	1.0	309.5
65-69	28.5	268.9	37.8	0.6	1.3	308.5
70-74	32.0	295.4	27.8	0.3	0.1	323.5
75-79	10.9	310.4	44.2	0.3	0.0	354.8
80-84	2.3	357.9	58.6	0.3	0.0	416.8
85-89	0.4	434.3	93.9	0.0	0.0	528.2
90-94	0.3	443.6	100.6	0.1	0.0	544.3
95-99	<0.1	256.0	19.0	0.0	0.0	275.0

Note: Observers categorize all sampled crabs as either legal-size retained male (LRT), legal-size non-retained male (LNR), sublegal male (SUB), or female (FEM).

[a] Average depth was 69 fathoms.

Appendix C8.–Reproductive condition (by percent) of female snow crab from pot lifts sampled during the 1995–2010/11 Bering Sea snow crab fisheries.

		Ovigerous		Barren	
Year	Number of crab	Eyed eggs	Uneyed eggs	Matted setae	Clean setae
1995	423	80.4	12.5	6.1	0.9
1996	136	59.6	3.7	16.2	20.6
1997	789	40.9	0.6	30.4	28.0
1998	90	21.1	8.9	37.8	32.2
1999	99	68.7	5.1	22.2	4.0
2000	6	0	16.7	16.7	66.6
2001	11	18.2	36.4	0	45.4
2002	19	26.3	57.9	10.5	5.3
2003	62	41.9	45.2	9.7	3.2
2004	10	10.0	30.0	0	60.0
2005	9	88.9	11.1	0	0
2005/06	129	6.2	89.2	2.3	2.3
2006/07	57	84.2	14.0	0	1.8
2007/08	365	21.9	71.0	1.6	3.8
2008/09	461	28.4	71.4	0	0.2
2009/10	246	3.3	64.2	8.9	22.8
2010/11	459	3.7	56.0	11.1	29.2

Appendix C9.–Total contents of 2,419 pot lifts sampled during the 2010/11 St. Matthew Island blue king crab fishery.

Commercial Crab Species	Total Catch (number)	Other Species	Total Catch (number)
Blue King Crab		arrowtooth flounder	11
legal	25,147	basket star	149
sublegal	25,221	bigmouth sculpin	28
female	10,965	brittle star unident.	5
Snow Crab		circumboreal toad crab	553
legal	903	flatfish unident.	4
sublegal	368	flathead sole	5
female	107	graceful decorator crab	3
Tanner Crab		great sculpin	166
legal	0	Greenland halibut (or Greenland turbot)	10
sublegal	20	hairy triton (or Oregon triton)	1
female	4	hermit crab unident.	1,085
Red King Crab		Hyas sp.	399
legal	4	invertebrate unident.	1
sublegal	0	jellyfish unident.	31
female	3	mussel unident.	1
***Chionoecetes* unident.**		octopus unident.	3
male	1	Pacific cod	1,054
female	0	Pacific halibut	101
		Pacific lyre crab	111
		Pribilof neptune (or Pribilof whelk)	9
		rock sole unident.	2
		sand dollar unident.	2
		sculpin unident.	219
		sea anemone unident.	2
		skate unident.	24
		snailfish unident.	1
		snail unident.	170
		sponge unident.	10
		starfish unident.	57
		tunicate unident.	2
		walleye pollock	22
		yellowfin sole	141
		yellow Irish lord	95

Appendix C10.–Blue king crab per pot by soak time for 2,419 pot lifts sampled during the 2010/11 St. Matthew Island blue king crab fishery.

Soak time[a] (hours)	Percent of sampled pots	Number of crab per pot				
		LRT	LNR	SUB	FEM	Total
0-11	0.9	5.6	0.2	9.6	18.5	34.0
12-23	26.3	9.6	0.1	10.5	4.7	24.9
24-35	40.9	9.6	0.2	11.2	5.7	26.7
36-47	15.2	11.4	0.2	11.3	2.1	24.9
48-59	2.4	9.5	0.1	8.5	2.5	20.7
60-71	2.6	13.5	0.1	9.6	2.4	25.5
72-83	5.8	12.9	0.3	7.5	2.3	23.0
84-95	3.4	13.1	0.6	7.8	5.3	26.8
96-107	1.0	10.7	0.2	7.4	1.6	20.0
108-119	0.5	12.2	0.1	6.1	8.9	27.3
120-131	0.1	2.5	0.0	2.0	0.0	4.5
132-143	0.1	7.3	0.3	4.0	2.0	13.7
144-155	0.6	5.1	0.2	1.5	0.2	7.0
156-167	0.2	7.2	0.0	3.2	1.6	12.0
168-179	0.1	2.0	0.0	1.3	0.0	3.3

Note: Observers categorize all sampled crabs as either legal-size retained male (LRT), legal-size non-retained male (LNR), sublegal male (SUB), or female (FEM).

[a] Average soak time was 36 hours.

Appendix C11.–Blue king crab per pot by depth for 2,419 pot lifts sampled during the 2010/11 St. Matthew Island blue king crab fishery.

Depth[a] (fathoms)	Percent of sampled pots	Number of crab per pot				
		LRT	LNR	SUB	FEM	Total
10-14	<0.1	1.0	0.0	5.0	0.0	6.0
15-19	0.5	3.3	0.0	4.5	8.5	16.3
20-24	3.5	11.4	0.0	13.6	8.1	33.2
25-29	3.1	8.5	0.1	9.5	22.6	40.7
30-34	8.4	9.7	0.2	14.7	15.4	40.0
35-39	14.8	9.3	0.3	12.5	8.4	30.6
40-44	31.7	9.4	0.2	9.2	2.6	21.3
45-49	35.1	11.8	0.2	9.5	0.5	22.0
50-54	2.6	9.0	0.1	11.2	0.0	20.3
55-59	0.3	2.7	0.0	6.1	0.0	8.9
60-64	0.1	0.0	0.0	0.0	0.0	0.0

Note: Observers categorize all sampled crabs as either legal-size retained male (LRT), legal-size non-retained male (LNR), sublegal male (SUB), or female (FEM).

[a] Average depth was 41 fathoms.

Appendix C12.–Reproductive condition (by percent) of female blue king crab from pot lifts sampled during the 2009/10–2010/11 St. Matthew Island blue king crab fisheries.

		Ovigerous		Barren	
Year	Number of crab	Eyed eggs	Uneyed eggs	Matted setae	Clean setae
2009/10	1,638	1.2	13.2	40.8	44.6
2010/11	10,948	0.6	58.9	15.0	25.6

Appendix C13.–Total contents of 483 pot lifts sampled during the 2010 Pribilof Islands golden king crab fishery.

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Appendix C14.–Golden king crab per pot by soak time for 483 pot lifts sampled during the 2010 Pribilof Islands golden king crab fishery.

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Appendix C15.–Golden king crab per pot by depth for 483 pot lifts sampled during the 2010 Pribilof Islands golden king crab fishery.

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Appendix C16.–Reproductive condition (by percent) of female golden king crab from pot lifts sampled during the 2010 Pribilof Islands golden king crab fishery.

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Appendix C17.–Total pot lift contents for 436 pot lifts sampled during the 2010/11 Aleutian Islands golden king crab fishery east of 174° W long.

Commercial Crab Species	Total Catch (number)	Other Species	Total Catch (number)
Golden King Crab		Anthomastus sp.	2
legal	11,063	arrowtooth flounder	2
sublegal	4,466	Arthrogorgia sp.	7
female	3,798	Atka mackerel	1
Scarlet King Crab		basket star	376
legal	14	bigmouth sculpin	1
sublegal	1	brittle star unident.	61
female	0	Calcigorgia sp.	4
		Caryophyllia sp.	2
		Clavularia sp.	1
		Crypthelia sp.	1
		Cup coral unident.	4
		Cyclohelia sp.	6
		Distichopora sp.	7
		Errinopora sp.	4
		Fanellia sp.	6
		flatfish unident.	3
		graceful decorator crab	1
		Greenland halibut (or Greenland turbot)	1
		hairy triton (or Oregon triton)	6
		jellyfish unident.	1
		Kamchatka coral (or bubblegum coral)	9
		Neptune snail unident.	2
		Pacific cod	1
		Pacific halibut	15
		Plexauridae unident.	3
		Primnoidae Group I	28
		Primnoidae unident.	3
		red-tree coral	1
		rockfish unident.	1
		sculpin unident.	3
		sea urchin unident.	52
		skate unident.	9
		snail unident.	8
		sponge unident.	122
		starfish unident.	58
		Stylaster sp.	53
		tunicate unident.	1

Appendix C18.–Golden king crab per pot by soak time for 436 pot lifts sampled during the 2010/11 Aleutian Islands golden king crab fishery east of 174° W long.

Soak time[a] (days)	Percent of sampled pots	Number of crab per pot				
		LRT	LNR	SUB	FEM	Total
2-4	0.9	11.3	0.3	0.5	1.3	13.3
4-6	11.0	15.7	0.6	4.8	3.4	24.5
6-8	9.9	20.1	0.4	6.7	1.9	29.2
8-10	4.1	23.1	0.8	10.6	9.1	43.6
10-12	6.7	20.4	0.3	13.0	10.7	44.4
12-14	22.9	25.6	0.3	16.9	17.0	59.8
14-16	12.8	28.8	1.2	12.6	12.4	55.0
16-18	6.0	38.2	1.0	7.0	0.8	47.0
18-20	5.5	27.3	0.9	8.6	5.5	42.4
20-22	8.9	24.0	1.8	4.4	2.4	32.7
22-24	5.3	21.7	0.0	7.9	7.7	37.3
24-26	3.2	23.6	0.7	5.7	9.4	39.5
26-28	1.8	50.3	3.5	4.6	10.4	68.8
28-30	0.7	13.7	2.3	1.0	0.0	17.0
38-40	0.2	22.0	0.0	122.0	45.0	189.0

Note: Observers categorize all sampled crabs as either legal-size retained male (LRT), legal-size non-retained male (LNR), sublegal male (SUB), or female (FEM).

[a] Average soak time was 13.9 days.

Appendix C19.–Golden king crab per pot by depth for 436 pot lifts sampled during the 2010/11 Aleutian Islands golden king crab fishery east of 174° W long.

Depth[a] (fathoms)	Percent of sampled pots	Number of crab per pot				
		LRT	LNR	SUB	FEM	Total
60-79	0.5	0.5	1.5	0.0	0.0	2.0
80-99	4.4	21.5	0.4	5.4	1.5	28.8
100-119	9.9	18.0	0.3	5.2	5.1	28.6
120-139	16.5	22.9	0.6	7.7	5.1	36.4
140-159	21.6	27.7	0.9	6.4	5.6	40.6
160-179	10.8	24.4	1.6	10.1	12.9	49.0
180-199	7.6	24.9	0.6	12.0	8.6	46.1
200-219	6.4	26.9	0.7	14.9	15.2	57.7
220-239	6.0	22.0	0.4	14.7	14.5	51.6
240-259	2.5	24.6	0.5	18.0	12.6	55.7
260-279	5.0	25.3	0.6	15.7	14.0	55.7
280-299	3.9	29.5	1.7	13.1	8.8	53.1
300-319	3.7	31.7	0.6	28.0	20.7	80.9
320-339	1.4	26.2	0.5	16.0	6.7	49.3

Note: Observers categorize all sampled crabs as either legal-size retained male (LRT), legal-size non-retained male (LNR), sublegal male (SUB), or female (FEM).

[a] Average depth was 175 fathoms.

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Appendix C20.–Reproductive condition (by percent) of female golden king crab from pot lifts sampled during the 1996/97–2010/11 Aleutian Islands golden king crab fisheries east of 174° W long.

		Ovigerous		Barren	
Year	Number of crab	Eyed eggs	Uneyed eggs	Matted setae	Clean setae
1996/97	59,210	20.8	22.5	18.6	38.1
1997/98	5,383	25.2	19.3	22.1	33.4
1998/99	44,352	18.1	21.0	23.9	37.0
1999/00	36,695	22.1	21.0	23.1	33.8
2000/01	13,615	26.9	18.7	20.1	34.3
2001/02	14,912	20.4	12.5	15.4	51.1
2002/03	9,651	29.6	19.2	18.9	32.3
2003/04	7,990	20.9	33.2	13.6	31.5
2004/05	5,430	24.9	24.7	24.9	25.5
2005/06	1,489	25.8	25.2	18.3	30.7
2006/07	2,328	29.6	35.7	9.1	25.6
2007/08	1,397	18.3	52.5	10.1	19.1
2008/09	2,308	31.3	35.3	17.9	15.5
2009/10	2,604	45.0	26.8	9.4	18.3
2010/11	3,769	40.8	32.3	8.1	18.8

Appendix C21.–Total pot lift contents for 867 pot lifts sampled during the 2010/11 Aleutian Islands golden king crab fishery west of 174° W long.

Commercial Crab Species	Total Catch (number)	Other Species	Total Catch (number)	Other Species	Total Catch (number)
Golden King Crab		Anthomastus sp.	19	mussel unident.	1
legal	19,027	arrowtooth flounder	2	octopus unident.	9
sublegal	5,864	Arthrogorgia sp.	28	Pacific cod	3
female	7,518	Bamboo coral unident.	1	Pacific halibut	1
Scarlet King Crab		basket star	264	Plexauridae unident.	31
legal	3	bigmouth sculpin	1	Primnoidae Group I	166
sublegal	1	bivalve unident.	1	Primnoidae unident.	10
female	0	brittle star unident.	307	Protoptilum sp.	1
Red King Crab		bryozoan unident.	168	red-tree coral	6
legal	1	Calcigorgia sp.	23	rockfish unident.	24
sublegal	1	Caryophyllia sp.	2	scaled crab	1
female	1	Chrysopathes sp.	1	scale worm unident.	4
Hair Crab		Cladopathes sp.	1	sculpin unident.	2
legal	0	Clavularia sp.	15	sea anemone unident.	8
sublegal	1	Coral unident.	5	sea cucumber unident.	4
female	0	Crypthelia sp.	15	sea lily unident.	15
		Cup coral unident.	5	sea pen unident.	3
		Cyclohelia sp.	22	sea raspberry	1
		Distichopora sp.	37	sea spider unident.	14
		Errinopora sp.	5	sea urchin unident.	65
		Fanellia sp.	47	sea whip unident.	2
		Flabellum sp.	1	shrimp unident.	1
		flatfish unident.	3	skate unident.	3
		giant octopus	1	snail unident.	43
		Greenland turbot	2	sponge unident.	369
		grenadier unident.	3	starfish unident.	79
		hairy triton	17	Stylantheca sp.	2
		hydrocoral unident.	1	Stylaster sp.	133
		hydroid unident.	377	tube worm unident.	2
		invertebrate unident.	1	tunicate unident.	75
		jellyfish unident.	1	worm unident.	111
		Kamchatka coral	5	yellow Irish lord	3

Appendix C22.–Golden king crab per pot by soak time for 867 pot lifts sampled during the 2010/11 Aleutian Islands golden king crab fishery west of 174° W long.

Soak Time[a] (days)	Percent of sampled pots	Number of crab per pot				
		LRT	LNR	SUB	FEM	Total
6-8	1.7	7.9	0.1	1.7	0.9	10.7
8-10	2.7	16.1	0.5	15.3	12.4	44.3
10-12	1.3	21.6	0.3	7.9	8.5	38.3
12-14	3.4	17.0	0.6	9.8	12.5	39.9
14-16	3.9	21.2	0.4	9.2	8.1	38.9
16-18	4.9	19.0	1.0	13.0	15.1	48.1
18-20	24.5	15.3	0.7	6.7	9.0	31.6
20-22	17.2	18.7	1.1	7.3	9.3	36.3
22-24	5.4	22.6	1.4	4.9	5.8	34.7
24-26	4.2	25.1	4.5	9.4	3.9	42.9
26-28	7.7	24.4	0.5	3.5	9.1	37.5
28-30	3.7	29.2	0.3	4.4	3.3	37.2
30-32	1.6	23.9	0.6	10.9	3.6	39.0
32-34	2.4	25.2	0.0	3.2	1.6	30.0
34-36	3.4	38.2	0.3	4.8	19.3	62.6
36-38	5.9	34.5	0.5	5.5	6.1	46.6
38-40	4.2	25.2	0.2	2.9	11.1	39.4
40-42	0.6	19.6	0.0	1.2	2.0	22.8
42-44	0.3	14.0	0.0	3.0	15.7	32.7
44-46	0.2	33.0	0.0	1.0	0.0	34.0
46-48	0.3	15.7	0.3	0.0	0.3	16.3
52-56	0.5	16.3	0.3	3.5	2.0	22.0

Note: Observers categorize all sampled crabs as either legal-size retained male (LRT), legal-size non-retained male (LNR), sublegal male (SUB), or female (FEM).

[a] Average soak time was 23.3 days.

Appendix C23.–Golden king crab per pot by depth for 867 pot lifts sampled during the 2010/11 Aleutian Islands golden king crab fishery west of 174° W long.

Depth[a] (fathoms)	Percent of sampled pots	Number of crab per pot				
		LRT	LNR	SUB	FEM	Total
60-79	0.3	41.7	0.0	3.3	1.0	46.0
80-99	2.0	28.1	1.5	2.2	10.6	42.4
100-119	5.9	21.8	0.9	5.0	4.6	32.3
120-139	15.1	24.5	0.7	5.5	5.3	36.0
140-159	15.8	23.9	1.2	7.3	12.0	44.4
160-179	16.3	23.0	0.7	7.3	6.9	38.0
180-199	17.2	19.0	0.5	6.4	6.4	32.3
200-219	11.2	17.2	1.0	7.9	9.2	35.2
220-239	7.7	16.1	0.9	9.4	11.6	38.1
240-259	5.5	16.6	0.7	6.8	16.4	40.6
260-279	1.5	11.5	0.2	1.9	18.9	32.6
280-299	0.8	27.0	1.0	8.1	11.0	47.1
300-319	0.3	24.7	0.7	7.3	4.0	36.7
340-359	0.1	28.0	0.0	5.0	1.0	34.0

Note: Observers categorize all sampled crabs as either legal-size retained male (LRT), legal-size non-retained male (LNR), sublegal male (SUB), or female (FEM).

[a] Average depth was 175 fathoms.

Appendix C24.–Reproductive condition (by percent) of female golden king crab from pot lifts sampled during the 1996/97–2010/11 Aleutian Islands golden king crab fisheries west of 174° W long.

		Ovigerous		Barren	
Year	Number of crab	Eyed eggs	Uneyed eggs	Matted setae	Clean setae
1996/97	67,314	23.6	25.5	21.2	29.6
1997/98	39,343	24.0	26.8	19.8	29.4
1998/99	22,208	23.4	25.9	16.3	34.4
1999/00	45,645	21.3	29.6	19.1	29.9
2000/01	53,716	26.2	28.7	17.1	27.9
2001/02	38,829	26.6	27.8	22.4	23.2
2002/03	22,479	32.8	20.9	11.9	33.9
2003/04	5,946	32.8	26.8	19.2	21.2
2004/05	12,970	26.1	31.7	21.6	20.6
2005/06	5,798	35.2	33.5	21.7	9.6
2006/07	7,136	31.6	36.0	19.3	13.0
2007/08	9,281	43.2	23.9	19.1	13.8
2008/09	7,922	27.5	34.5	15.3	22.7
2009/10	7,155	31.3	30.3	29.1	5.9
2010/11	7,382	31.3	33.4	20.0	15.3

APPENDIX D. RESULTS OF LEGAL TALLY SAMPLES

Appendix D1.–Results of ADF&G legal tally samples from the 2010/11 Bering Sea and Aleutian Islands directed crab fisheries.

Fishery	Sample size	Percent of landed catch[a]	Number of illegal crabs: Male	Female	Non-target species	Total	Percent illegal
Bristol Bay red king crab	27,664	0.12	104	0	0	104	0.38
Bering Sea snow crab	107,328	0.32	0	1	229	230	0.21
St. Matthew Island blue king crab	16,047	5.37	50	1	0	51	0.32
Pribilof Islands golden king crab	_[d]	_[d]	_[d]	_[d]	_[d]	_[d]	_[d]
E. Aleutian Islands golden king crab[b]	6,450	0.96	16	0	0	16	0.25
W. Aleutian Islands golden king crab[c]	38,009	6.07	233	5	0	238	0.63

[a] Based on fishery-reported catch number.

[b] East of 174° W long.

[c] West of 174° W long.

[d] Confidential.