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2019 Southeast Alaska Red King Crab Stock Health Assessment and Management Plan for the 2019/2020 Season

by

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and

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Alaska Department of Fish and Game **Division of 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

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2019 SOUTHEAST ALASKA RED KING CRAB STOCK ASSESSMENT AND MANAGEMENT PLAN FOR THE 2019/2020 SEASON

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ABSTRACT

This report provides an overview of the stock assessment, harvest strategy, and regulations for the 2019/2020 season Southeast red (*Paralithodes* camstchaticus) and blue king crab (*Paralithodes* playpus) commercial and personal use fisheries. The personal use red and blue king crab fishery opened July 1 in Pybus Bay, Seymour Canal, Excursion Inlet, and for non-surveyed areas, while Section 11-A (Juneau Area) opened on August 2 for three and a half days. For the commercial fishery the guideline harvest level is 108,622 lb and is less than the 200,000 lb threshold, therefore the commercial fishery did not open for the 2019/2020 season.

Key words: red king crab, *Paralithodes camtschaticus*, stock assessment, catch per unit effort, CPUE, Southeast

OVERVIEW

The Alaska Department of Fish and Game (ADF&G) annually evaluates stock status and establishes the guideline harvest levels (GHLs) for the Southeast red (RKC) and blue king crab (BKC) fishery using data from fishery independent surveys (pot gear), commercial fishery catch per unit of effort (CPUE), and biological data (length, weight, and shell condition) from the surveys and fishery. The Southeast management area (Registration Area A) consists of all waters defined in 5 AAC 34.100 (Figure 1).

Projected estimates of regional mature male biomass for the 2019/2020 season fall between 1.64 and 1.99 million lb, depending on the expansion factor applied to the non-surveyed areas. However, these values decreased substantially below the baseline level (defined as the average biomass from 1993–2007), suggesting the regional stock remains in a low or depressed state.

The 2019/2020 Southeast commercial RKC fishery season GHL is 108,622 lb and is less than the 200,000 lb minimum threshold [5 AAC 34.113]; therefore, the fishery did not open for the 2019/2020 season. The personal use RKC and BKC fishery opened July 1, 2019 in Pybus Bay, Seymour Canal, Excursion Inlet, and non-surveyed areas with bag and possession limits of one RKC or BKC per person per day. Results from the annual stock assessment survey in the Juneau Area showed overall stock health to be below average, while legal and mature biomass estimates are above long-term averages. The personal use fishery in Section 11-A (Juneau Area) opened for the summer on August 2, 2019 for three and a half days with a seasonal household limit of two legal sized male crab to target 12,583 lb (1,566 crab) and in the winter on January 11th, 2020 for one and a half days with a seasonal household limit of one legal sized male crab to target 2,517 lb (313 crab) (Table 2).

The RKC and BKC commercial fishery and personal use fishery outside of Section 11-A are managed separately and there are no regulatory thresholds or allocations that combine estimated harvest for both user groups. Personal use harvest outside of Section 11-A is not considered when calculating the commercial GHLs for each area to determine whether the total commercial GHL meets the 200,000 lb threshold in regulation for a commercial fishery. A personal use permit was implemented in 2018 for the outside Section 11-A personal use fishery and will provide managers better catch accounting and improve upon future stock assessments and management decisions.

2019 SOUTHEAST RED KING CRAB STOCK ASSESSMENT

SUMMARY OF STOCK STATUS

The Southeast RKC stock assessment regional biomass estimates for the 2019/2020 season range from **1.43–1.73 million lb of legal crab and from 1.64–1.99 million lb of mature crab**, using two expansion factors (Tables 2–4). The legal biomass estimate decreased 1.3% from the previous

year using the 2019 model estimates (Figure 3). The mature biomass estimate decreased 6.0% from the 2019 model estimates.

Survey area biomass is estimated using a 3-stage catch survey analysis model (CSA) and adjusted using the mark-recapture experiments when available (Stratman et al. 2019). Port Frederick and Holkham Bay have not been surveyed since 2015 due to reductions in survey funding and therefore have not been included in determining survey biomass estimates since. The legal crab component is composed of both recruit and post-recruit crab and defined as those greater than 178 mm in carapace width, whereas mature crab are pre-recruit, recruit and post-recruit crab, or those greater than 129 mm in carapace length. Biomass estimates from the survey areas (Table 2, Figure 2) are then expanded based on assumptions of how representative these areas are to the entire population in Southeast.

Both mature and legal survey biomasses have declined an average of 7.0% annually from 2001 to 2013 (Figure 3). Legal and mature biomass had shown region-wide increases for the first time in 2015 since 2008, however this year only three of the seven survey areas had increases in either legal and mature biomass, except for Lynn Sisters, where increases in legal biomass were balanced with decreases in mature biomass (Figures 4–17).

Lynn Sisters was the only area that had an increase in both legal and mature biomass from 2018 (Figure 14); Excursion Inlet, and Juneau both had an increase (less than 10.0 %) in legal biomass but saw a decline in mature biomass from the previous year (Figures 12 and 16).

Compared to historical levels in most areas (with the exception of Juneau and Lynn Sisters), CPUE of juvenile and females size and sex classes are at below average levels, suggesting that either this portion of the population is declining or that the current year's survey did not adequately capture them. The CPUE of some portions of the mature male size and sex classes are still below average for all the survey areas, and three areas (Gambier, Seymour, and Peril) had significantly low values in all mature male CPUEs. Overall, recruitment, in the form of pre-recruit CPUE, is significantly below average levels for five of the seven surveys areas and below average, but not significantly so, in Pybus Bay suggesting that region-wide improvements to mature and legal male biomass are still underway and may take a few more years even with the absence of fishing in most of the survey areas. In the majority of survey areas pre-recruit biomass is still lacking compared to the 1990s and early 2000s and is visualized as the small difference between mature and legal biomass in the area figures (Figures 4–17). A matrix of stock health indicators provides an objective and repeatable evaluation of the survey data; a five-year summary of matrix results is therefore presented here (Table 5). Specific stock health by survey area (Table 6) is discussed below.

ASSESSMENT METHOD UPDATES

The equilibrium exploitation rates were updated for 2018 (Appendix A). In 2017, adjustments to historical (1993–2004) CPUE calculations were performed so that all CPUEs are now calculated using a stratified weighted mean (based on strata area and sample size that were established in 2005). In most cases this reduced the long-term baseline CPUE values for juveniles and females (average values from 1993-2007) used to determine stock health, due to down weighting of rare large catch events. These changes did not substantially change stock health determinations and were considered an improvement to be consistent throughout time. Since 2017 the biomass estimates reflect the current year's model estimates for the entire time series, where previously the legal biomass estimates reported were end-point estimates from the model in each year (Figures 4–17).

MARK-RECAPTURE EXPERIMENT ADJUSTMENTS

All survey areas (Excursion Inlet, Lynn Sisters, Peril Strait, Pybus Bay, Gambier Bay, and Seymour Canal; Figure 2), except Juneau, have a biomass adjustment that is calculated from mark-recapture experiments (Table 1). The Juneau area was too large to effectively conduct a mark-recapture experiment due to not being a closed bay or inlet and requiring multiple vessels increasing costs and logistics. Two of the six survey areas have a single mark-recapture event, while the other four have two events; therefore, the estimate of biomass using this method does not take into account extensive inter-annual variability or variability in population size for all areas and should be applied with caution. The department has completed work on a second mark-recapture estimate for the four larger survey areas, and does not plan at this time, to continue with additional mark-recapture experiments. Mark-recapture attempts in 2013 and 2014 (Lynn Sisters and Excursion Inlet) did not have sufficient sample sizes to produce usable biomass estimates (Robson and Regier 1964). Pybus Bay, Seymour Canal, Excursion Inlet and Gambier Bay were successfully re-sampled in 2014, 2015, 2016, and 2017 respectively. In three of the cases, resampling efforts yielded an adjustment factor similar to the first estimate (Table 1).

Adjustments based on a weighted average of the two sampling events were used to determine the mark-recapture adjustment applied to this year's CSA (Table 1). The biomass estimates presented in this analysis are the 2019 CSA model estimates adjusted by these values.

EXPANSION OPTION FOR NON-SURVEYED AREAS

Regional biomass is estimated from the seven survey areas and extrapolated to the entire region using an expansion factor defined as the proportion of the population that lies within the non-surveyed areas (Tables 2–4, Figure 3). In 2015, the surveyed areas were adjusted since surveys in Port Frederick and Holkham Bay were discontinued due to funding. The removal of Port Fredrick from the survey is accounted for by placing it in the "other areas" designation. A biomass estimate has never been produced for Holkham Bay due to the inconsistency of the data and therefore, it has always been included in the "other areas", thus no changes to the biomass estimation were needed in removing Holkham Bay from the survey.

The expansion factor, or an estimate of the percentage of the population found in the non-surveyed areas using historical harvest data, has not been consistent over time. The expansion factor was reassessed in 2018, with the goal of calculating the expansion factor for two different year ranges and have these presented as options in this report (Tables 2–4). The two ranges chosen represent historical harvests from 1974–1984 (with 47.2% of the harvest coming from the non-surveyed areas), and harvests in a more modern time during the baseline years from 1993–2007 (with 36.1% of the harvest coming from the non-surveyed areas).

Both options involve assumptions about the spatial distribution of the RKC population and the spatial effort of the fleet. The historical harvest time frame was chosen as an option since it includes harvest years before management actions dictated spatial closure or influenced fleet behavior. However, this time frame assumes that the spatial distribution of the RKC in Southeast Alaska has remained consistent over time, specifically since 1974, and with varying population sizes. The baseline time frame (1993–2007) was chosen since it represents both a high and low period in the RKC biomass and is used as a baseline time frame for other metrics in our assessment. However, this time frame is influenced by management actions, such as spatial closures, that greatly influenced the spatial effort of the fleet.

The regional biomass ranges from 1.43–1.73 million lb for legal crab and from 1.64–1.99 million lb for mature crab depending on the expansion factor chosen for non-surveyed areas (Table 2).

HARVEST RATES

Determining an appropriate harvest rate for red king crab in Southeast Alaska has been challenging due to inconsistent recruitment and varying levels of population health. In the past the matrix of stock health and equilibrium exploitation rates have been used (Appendix A). In 2018, the equilibrium exploitation rates, in addition to other harvest options, were recalculated using all available data (1979–2018). The mark-recapture adjusted biomass estimates were used for calculating harvest rate options since increased biomass (based on the adjustments) indicated that historical harvest rates have been lower than previously calculated, assuming reported harvest was accurate. The results of this analysis yielded three options for appropriate harvest rates, each having its own associated risk.

Option 1, using the equilibrium harvest rates, is considered the most **risk neutral option** with an equal probability of the mature male biomass decreasing or increasing in the following year after applying this level of harvest pressure. This option uses a regression model and therefore incorporates both the variability in the harvest rates and their associated change in mature male biomass. In theory, these harvest levels will maintain the equilibrium population size when the population is at equilibrium. For our purposes, equilibrium could be defined as the average baseline population size (Figure 3) or a biomass that is sustainable over time. When the population is below equilibrium, harvesting at these rates will either maintain low population levels or, more likely, cause a decrease in population size. The resulting GHL for option 1 ranges from 104,085 lb to 138,413 lb depending on the expansion factor option used (Table 2).

Option 2, using the average harvest rate for years in which the mature male biomass increased, is considered the **lowest risk option** with a high probability of the mature male biomass increasing in the following year after applying this level of harvest pressure. This option only uses the average of the harvest rates that resulted in population increases, and therefore does not incorporate variability as well as option 1. In theory, these harvest levels will increase the population size regardless of health of the stocks. However, during depressed stock health conditions, where biomass levels are below baseline values, even small harvest levels may still result in a decrease in population size. The resulting GHL for option 2 ranges from 42,436 lb to 56,168 lb depending on the expansion factor option used (Table 3).

Option 3, using an alternative approach to an equilibrium harvest rate, which is the sum of the average harvest rate and the average change in mature male biomass, is considered the **highest risk option**. This option is most appropriate when there is not a significant relationship between the harvest rate and the change in the mature population. In theory this option should have an equal probability of the mature male biomass decreasing or increasing in the following year after applying this level of harvest pressure when the population is at equilibrium levels. However, this option only uses the averages of the harvest rates and the changes in mature male biomass over the entire time range, and therefore does not incorporate variability as well as the model output does in option 1. Similar to option 1 these harvest rates will maintain the equilibrium population size when the population is at equilibrium or baseline levels, but when the population is below equilibrium, harvesting at these rates will either maintain low population levels or, more likely, cause a decrease in population size. The resulting GHL for option 3 ranges from 139,995 lb to 181,189 lb depending on the expansion factor option used (Table 4).

STOCK ASSESSMENT CONCERNS AND RECOMMENDATIONS

Recovery in most of the survey areas, except for the Juneau area, Lynn Sisters and Excursion Inlet, appears to be slow. Most areas, except for Peril Strait, had increasing biomass estimates from 2015–2017, however, in 2018 a decrease in both legal and mature biomass occurred in all survey areas having experienced personal use and commercial harvest in the previous season (2017/2018). The impact of the commercial fishery opening in the 2017/2018 season is confounded by potential increased personal use harvest in the survey areas, but this is hard to quantify since we do not currently have an estimate of personal use harvest in any area except Juneau (Section 11-A), although estimates of personal use harvest are currently being collected with the implementation of the regional king crab personal use harvest permit in 2018. Regional biomass levels have decreased since 2018 and are still below baseline levels (Figure 3). The Juneau Area and Lynn Sisters are the only survey areas where legal and mature biomass are above their baseline levels.

It is unexpected and substantial (probability of 3.0%) that all five areas with harvest in 2017/18 would decline in the subsequent year if the equilibrium harvest rates were appropriate under current conditions. The results suggest that at this time the equilibrium harvest rates are not a risk neutral option but would most likely lead to further population declines. If the goal is to grow populations in the survey areas to average or baseline values, then the only harvest option recommended is option 2 (Table 3).

Slow recovery since 2001, which may be due to poor or inconsistent recruitment, and declines in the survey areas after the last commercial fishery opening (2017/2018 fishing season), suggest that harvesting at the equilibrium harvest levels (those used in the 2017/2018 GHL calculations, option 1 here) from these areas would increase the probability of continued population declines or stunt population growth. Thus, removals at the levels presented in options 1 and 3 (Tables 2 and 4) are not recommended for the upcoming season. Of the three harvest options presented none resulted in a GHL that is above the 200,000 lb threshold required for a fishery opening [5 AAC 34.113].

SURVEY AREA STOCK STATUS AND HARVEST RATE RECOMMENDATION

STOCK STATUS BY SURVEY AREA (TABLE 5, FIGS. 4–17)

Significance in long-term or short-term trends is defined as a p-value <0.05. Long-term trends compare the current year's mean to the long-term baseline value (1993–2007); short-term trends regress the last four years of survey data to determine if a significant increasing or decreasing trend is present. Estimates of legal and mature mark-recapture biomass (adj.legal / adj.mature) for the entire biomass time series for each area were added to the legal biomass graphs, along with their associated long-term baseline (1993–2007; solid black line for legal and grey dotted line for mature) estimates (Figures 4–17). Raw sample sizes for each area are reported in Table 5. Graphs for each area reflect biomass estimates from the 2019 CSA model.

Pybus Bay (below average)

Pybus Bay stock health decreased but remained in below average status. All CPUEs, except for pre-recruits, are significantly below their long-term averages. Pre-recruit CPUE is below its long-term average, but not significantly so. There is a significant short-term decrease in the percentage

of females with poor clutches, which means that the portion of poor clutches is now at a lower health level. Legal biomass decreased 12.0% from the 2018 model and mature biomass decreased 9.0%. Both remain low compared to historical levels in this area. Egg percentage is at a normal level and the percentage of poor clutches is significantly below the baseline value. The mature biomass estimate is 65.3% below the baseline value.

Stock health has declined in Pybus Bay as evident from decreases in CPUE for recruit, post-recruit, and juvenile female class crab. Legal and mature biomass estimates are relatively unchanged from the previous year. While stock health is below average, the Pybus score is at a level that puts it close to a rating of poor. Due to the aforementioned concerns and the low level of the stock biomass in Pybus Bay, no harvestable surplus is recommended for the 2019/2020 season.

Gambier Bay (poor)

Gambier Bay stock health decreased but remained in poor status. All size and sex class CPUEs, except for mature females, are significantly below their long-term averages. In the short-term (last four years), there is a significant decrease in juveniles female, juvenile male, pre-recruit, and post-recruit male CPUE. Juvenile and female portions of this population decreased substantially from the higher levels observed in 2017. The proportion of females with poor clutches is at the long-term baseline of 10.0% and the overall average clutch fullness was lower than typical, although not statistically so. Legal biomass decreased 13.0% and mature biomass decreased 8.0% from the 2018 model estimate. Additionally, the legal and mature biomass estimates are still low compared to historical levels for this area. The mature biomass estimate is 68.8% below the baseline value.

Stock health has declined in Gambier Bay the last two years. While there have been slight improvements in CPUEs across size and sex classes they still remain significantly below their long-term average. Considering these negative trends in Gambier Bay, no harvestable surplus is recommended for the 2019/2020 season.

Seymour Canal (poor)

The overall stock health for Seymour Canal decreased from below average to poor. All size and sex class CPUEs fell significantly below their long-term averages, and no pre-recruit crab were sampled in the survey pots in 2019. There are no significant short-term trends. The juvenile and female portions of this population were under sampled in the 2019 survey (Table 5), and therefore caution should be taken in interpreting any of the indicators of female stock health. The estimate of legal biomass decreased 24.0% and the mature biomass decreased 34.0% from the 2018 model estimates. The mature biomass estimate is 80.1% below the baseline value.

Stock health has declined in Seymour Canal as evident from decreases in CPUEs of all mature male size/sex classes. Given the declines in mature biomass, CPUE reductions for all mature male size/sex classes, and a sharp two-year drop in post-recruit CPUE, no harvestable surplus is recommended for the 2019/2020 season.

Peril Strait (poor)

The Peril Strait stock status remains poor. All recruit classes are significantly below their long-term averages. There are significant short-term decreasing trends in juvenile male, juvenile female, mature female, pre-recruit, and recruit CPUE. Female and juvenile portions of the population are lower than the previous year. The proportion of females with poor clutches was significantly less than 10.0%, and the total egg clutch percentage was at typical levels for this area. The legal

biomass estimate decreased 1.0% from the 2018 model estimate and is the lowest it has been since the survey began. The mature biomass estimate decreased 26.0% from the 2018 model estimate. Reasons for lack of recovery in this area are unclear, but the survey CPUEs do not indicate any consistent signs of improvement. The mature biomass estimate is 89.0% below the baseline value.

Stock health in Peril Strait remains a concern. All size/sex classes are significantly below their long-term averages, and nearly all sex/size classes have significant short-term decreasing trends. Legal and mature biomass estimates have shown no improvement from 2018 and both estimates remain below long-term averages; therefore, no harvestable surplus is recommended for the 2019/2020 season.

Juneau (below average)

The stock status for the Juneau area decreased to below average from moderate in 2018. Juvenile female, juvenile male, pre-recruit, and recruit CPUE fell significantly below the long-term averages, while post-recruit and mature female CPUE were at their long-term average. There is a significant short-term decreasing trend in both pre-recruit and recruit CPUE. Estimates of legal biomass increased 3.5% while mature biomass decreased by 6.0% since 2018 (based on the 2019 model output). When compared to the 2018 model estimate legal biomass increased 1.0%, while mature biomass decreased 12.0%. Indicators of female stock health remain good as indicated by the low proportion of poor clutches and high clutch fullness. Legal biomass is still at its long-term baseline value, but mature biomass fell to 14.0% below the baseline.

Juneau Area stock health was reviewed in July to make recommendations for the personal use fishery in 11-A. Positive trends in stock health are evident. Post-recruit CPUE is above its long-term average. Legal and mature biomass estimates are above long-term averages. However, mature biomass estimates have declined for two consecutive seasons, and pre-recruit and recruit CPUEs are both below long-term averages despite using a reduced harvest rate of 8.0% in 2018. Due to concern with decreasing biomass and portions of the mature size/sex classes, the decision was made in July to set the harvest rate at 7.0% for the 2019/2020 season.

Lynn Sisters (moderate)

Stock health in the Lynn Sister's area increased but remained at a moderate status in 2019. CPUEs for all size and sex classes, with the exception of post-recruit CPUE, are at or above their long-term averages. Post-recruit CPUE is significantly below its long-term average. There are significant increasing short-term trends in pre-recruit and recruit male CPUE. Indicators of female stock health were good, as seen by the low proportion of poor clutches and high clutch fullness. Biomasses increased substantially in this area, with legal biomass increasing 56.0% and mature biomass increasing 85.0% from the 2018 model estimates. Mature biomass is 44.0% above the long-term baseline value.

Positive trends in stock health are evident. Legal and mature biomass estimates are above long-term baselines for the first time in eight years. The majority of size/sex classes are at or above long-term averages. However, there are many indications that stock health remains a concern in Lynn Sisters. While legal and mature biomass increased from last season, a lack of post-recruit biomass suggests that recruitment in the area occurred very recently. After a seven-year closure to all fishing, legal biomass estimates are smaller than seen in all other survey areas with the exception of Peril Strait (Table 1). A permit requirement for personal use fishing outside of Section 11-A was implemented in 2018. The first couple of years of harvest data should better inform on

the potential effort in Lynn Sisters and what level of harvest rates would be appropriate. Given these concerns there is not a harvestable surplus of RKC in the Lynn Sisters area for the 2019/2020 season.

Excursion Inlet (below average)

The stock health of Excursion Inlet decreased but remained at a below average status. CPUEs of juvenile females, juvenile males, mature females, and pre-recruits all fell significantly below their long-term averages. CPUEs of recruit and post-recruit males are at their long-term averages. There are significant short-term decreasing trends in both juvenile male and pre-recruit CPUE. Both the percentage of poor clutches and the average clutch fullness are within normal levels this year. The legal biomass estimate increased 6.0%, while the mature biomass estimate decreased 14.0% from the 2018 model estimates. The mature biomass estimate is 49.1% below the baseline value.

Stock health has declined in Excursion Inlet as evident from negative trends in stock health. Considering these trends in Excursion Inlet, we applied a harvest rate of 6.0% for the 2019/2020 season, which is the updated equilibrium harvest rate and is in line with harvest rates used in other RKC fisheries in Alaska.

Port Frederick (unknown since 2014)

Port Frederick was removed as a survey area in 2015 due to budget constraints and is now considered part of the un-surveyed areas or "other areas" in Tables 2–4. From 1979 to 2004 (the years used by biometrics to expand the survey biomass to the other areas), Port Frederick contributed to 2.4% of the harvest. The previous percent expansion of 65.2% survey areas and 34.8 % other areas was adjusted. Excluding Port Frederick, 62.8% of the harvest is from survey areas and 37.2% from other areas. Adjusting the expansion factor allows for consistency between previous year estimates and the current year, all comparisons regionally were performed with a time series of estimates that were adjusted to not include Port Frederick. For the purposes of assessing the 2019/2020 commercial fishery, Port Frederick is considered part of non-surveyed areas.

Holkham Bay (unknown since 2014)

Holkham Bay was removed as a survey area in 2015 due to budget constraints. The decision to drop Holkham Bay from the survey was based on difficulties in interpreting survey results from this location. Holkham Bay had consistently been surveyed since 2002, however, the data were not always adequate to use in the CSA to produce a biomass estimate; the area was only useful as an index of biomass and the estimates were never included in the region-wide biomass estimate and continues to be part of the non-surveyed areas.

Non-Surveyed Areas

Information used to assess non-surveyed areas for the 2019/2020 commercial fishery recommendation include the current CSA and historical harvest data, by statistical area, from fish tickets. The percentage of historical harvest that occurred within the surveyed areas from the 1974/1975 to 1984/1985 seasons was used to expand the harvestable surplus from the surveyed area to non-surveyed areas. Since 2015, when Port Frederick was removed from the survey, a historical harvest of 52.8% from surveyed areas is used, the remaining 47.2% of harvest is targeted from the non-surveyed areas. Summing up the mature biomass estimates for the surveyed areas, and using this 52.8%/47.2% ratio, yields an adjusted mature biomass estimate of 932,757 lb for

Other Areas. Applying a 10.0% harvest rate (a percentage which is close to the average equilibrium harvest rate for all surveyed areas in combination) to this estimate provides a harvestable surplus of 93,276 lb in the non-surveyed areas.

2019/2020 RKC FISHERY MANAGEMENT ACTIONS

Stock health in both Peril Strait and Gambier Bay has declined from 2018 and both remain categorized as poor. In Peril Strait, all size/sex classes are significantly below their long-term averages and nearly all sex/size classes have significant short-term decreasing trends. In Gambier Bay, all size/sex class CPUEs, with the exception of mature females, are significantly below their long-term averages. Legal and mature biomass estimates have decreased, with a mature biomass estimate that is now 69.0% below the long-term baseline. Both areas will remain closed to fishing.

Stock health in Lynn Sisters has improved, but there are indications that stock health remains a concern. CPUE of post-recruit crab is below long-term averages, suggesting recruitment in the area occurred very recently. The legal biomass estimate is much lower than earlier in the decade when Lynn Sisters was last open. Legal biomass estimates are smaller than seen in all other survey areas with the exception of Peril Strait. A permit requirement for personal use fishing outside of Section 11-A was initiated in 2018. The first couple of years of catch data should better inform the department on the potential effort in Lynn Sisters and what level of harvest rates would be appropriate. Lynn Sisters area will remain closed to fishing.

Stock health in both Pybus Bay and Seymour Canal has declined in 2018. In Pybus Bay, CPUE has decreased for recruit, post-recruit, and juvenile female class crab and the mature biomass estimate is 65.0% below the long-term baseline. In Seymour Canal, CPUEs of all mature male size/sex classes have decreased from 2018. Legal and mature biomass estimates have decreased slightly from the previous year and the mature biomass estimate is 80.0% below the long-term baseline. Pybus Bay and Seymour Canal will be closed to personal use red and blue king crab fishing beginning September 23, 2019.

Stock health in Excursion Inlet has declined, but legal and mature biomass estimates are relatively stable with legal biomass close to its long-term baseline. Excursion Inlet will remain open to fishing.

Non-Surveyed areas have an estimated mature male biomass of 932,757 lb or 47.2% of the regionwide estimate (using historical harvest from the 1974/1975 to 1984/1985 seasons). Stock health in non-surveyed areas may be exhibiting the same trends in stock health seen in surveyed areas, such as decreasing mature and legal male biomass. Geographically, non-surveyed areas encompass a much larger area than surveyed areas and generally see less fishing effort than surveyed areas. Some fishermen have noted good catches of RKC in non-surveyed areas, while others have witnessed declines in areas they fish. The non-surveyed areas, which include Port Frederick and Holkham Bay, can likely withstand a low level of harvest in the near term and will remain open with a minimal bag and possession limit.

Beginning September 23, 2019, all areas open to personal use red and blue king crab fishing outside of Section 11-A will maintain the reduced daily bag and possession limit of one king crab per day as prescribed in regulation [5 AAC 77.664(b)].

FISHERY MANAGEMENT CONCERNS

The RKC and BKC commercial fishery and personal use fishery outside of Juneau (Section 11-A) are managed separately and there are no regulatory thresholds or allocations that combine estimated harvest for both user groups. Personal use harvest outside of Juneau (Section 11-A) is not considered when calculating the commercial GHLs for each area to determine whether the total commercial GHL meets the 200,000 lb threshold in regulation for a commercial fishery [5 AAC 34.113]. The newly implemented permit system for the personal use fishery will provide managers better information on the level of personal use harvest outside of Section 11-A and will improve future CSA estimates and inform potential Alaska Board of Fisheries decisions.

Information is lacking to expand surveyed area biomass out to non-surveyed areas to estimate regionwide RKC biomass. Historical harvest based on fish ticket data is the single information source presently available to make inferences about biomass in the non-surveyed areas. Management actions (e.g. area closures and short seasons) and regulatory changes (e.g. Section 11-A allocation plan) influence the distribution of commercial harvest. The commercial fishery was closed from 1985/1986 to 1992/1993. The 1993/1994 and 1994/1995 seasons featured area closures to protect stocks of concern and the current Section 11-A allocation plan went into effect in 1995/1996. Historical harvest for the period when these management actions were implemented affected spatial distribution of commercial effort. Therefore, the years prior to the 1985/1986 season represent the best historical harvest data by which to calculate regional biomass from survey area data. For the 1974/1975 to 1984/1985 seasons, the average commercial harvest taken from surveyed areas was 52.8% of the total harvest. The surveyed to non-surveyed area was split 52.8% to 47.2%, and that expansion was applied to the sum of the mature biomass estimates. To calculate the commercial GHL this season, management again used an approach first used in 2017, and applied a 10.0% harvest rate to the Other Area adjusted mature biomass estimate, instead of applying the aforementioned 52.8%/47.2% split to the harvestable surplus from the surveyed areas. In future seasons when the 200,000 lb threshold is reached, this approach will likely relieve harvest pressure on surveyed areas and will allow permit holders to fish for RKC in areas that have never been surveyed and currently receive no fishing effort due to the short duration of recent seasons.

REFERENCES CITED

Robson, D. S., and H. A. Regier. 1964. Sample size in Petersen mark-recapture experiments. Transactions of the American Fisheries Society 93(3): 215-226.

Stratman, J., and A. Messmer, K. Wood, T. Bergmann, and K. Palof. 2019. Operational plan: Southeast Alaska red king crab pot survey, 2018–2022. Alaska Department of Fish and Game, Regional Operational Plan ROP.CF.1J.2019.02, Douglas.

TABLES AND FIGURES

Table 1.–Biomass adjustments based on ratio of Chapman mark/recapture estimates to catch-survey analysis (CSA) estimates of legal crab. The ratio of legal to mature crab from the current year was then used to scale the adjustment from biomass of legal crab to biomass of mature crab.

	Mark/Recapture Study (lb)		
Survey area	**CSA**	**M/R**	**Adjustment**
Lynn Sisters [a]	39,886	69,674	1.75
Pybus Bay [b,d]	80,807	236,042	2.92
	17,635	67,220	3.81
	Weighted avg.		3.08
Gambier Bay [b,g]	42,104	180,433	4.29
	25,294	84,394	3.34
	Weighted avg.		3.93
Excursion Inlet [b,f]	20,066	97,232	4.85
	17,184	12,501	0.73
	Weighted avg.		2.95
Seymour Canal [c,e]	6,387	58,002	9.08
	29,062	267,233	9.20
	Weighted avg.		9.17
Peril Strait [c]	19,023	52,377	2.75
Port Frederick [c]	12,523	53,436	4.27

Adjustments were calculated using CSA estimates of the year the Mark / Recapture was done: a = 2009, b = 2010, c = 2011, d = 2014, e = 2015, f = 2016 and g = 2017.

Table 2.–Option 1: risk neutral–model based equilibrium exploitation rates. Summary of 2019 commercial red king crab fishery GHL calculations (lb) for the seven surveyed areas and other areas. Risk neutral option based on 2018 calculated equilibrium exploitation rates (Appendix A). The harvest rate for the non-surveyed areas is a weighted average of the surveyed areas harvest rates (shown below) and the average mature male biomass for each area over the entire time series (1979–2018). Biomass estimates apply the adjustment in Table 1 to the CSA biomass presented here. Biomass of "other areas" was expanded based on the year ranges shown below with two options presented. Personal use catch for "Other Areas" is mean catch estimated from 2008-2012 statewide survey data. Blue king crab (BKC) is estimated as 1.06% of the surveyed areas based on historical catch, and its GHL contribution is an expansion of the surveyed areas GHL using the same percentage.

Survey area	CSA Biomass of legal crab	CSA Biomass of mature crab	Legal biomass	Mature biomass	Equilibrium ER	Total GHL	Personal use catch	2019 Commercial GHL (lb)
Pybus Bay	38,079	47,735	**117,308**	**147,052**	**12%**	17,646	n/a	17,646
Gambier Bay	17,880	20,671	**70,256**	**81,223**	**4%**	3,249	n/a	3,249
Seymour Canal	30,905	30,909	**283,542**	**283,580**	**1%**	2,836	n/a	2,836
Peril Strait	6,467	7,180	**17,805**	**19,768**	**4%**	791	n/a	791
Juneau Area [a]	320,507	359,523	320,507	359,523	**7%**	25,167	15,100	10,067
Lynn Sisters	15,946	36,799	**27,854**	**64,282**	**9%**	5,785	n/a	5,785
Excursion Inlet	23,347	29,871	**68,776**	**87,995**	**6%**	5,280	n/a	5,280
Blue King Crab	4,803	5,646	**9,604**	**11,060**	—	—	—	484
Expansion using baseline years (1993–2007)–36.1% of the population in the NON-survey areas								
Other Areas	255,994	300,939	**511,868**	**589,477**	**10%**	58,948	1,000	57,948
Total	713,927	839,272	**1,427,520**	**1,643,959**	—	—	—	**104,085**
Expansion using historical years (1974–1984)–47.2% of the population in the NON-survey areas								
Other Areas	405,071	476,189	**809,952**	**932,756**	**10%**	93,276	1,000	92,273
Total	863,005	1,014,522	**1,725,605**	**1,987,239**	—	—	—	**138,413**

[a] The Juneau area harvest rate in this option is 17%, but it was open to personal use harvest in summer 2019 at a harvest rate of 7%. "n/a" represents data that is not available or readily estimable from the other bays.

Table 3.–Option 2: lowest risk–high probability of mature male biomass increasing. Summary of 2019 commercial red king crab fishery GHL calculations (lb) for the seven surveyed areas and other areas. Risk adverse option based on 2018 calculated average harvest rates when the mature male biomass was increasing (Appendix A). The exploitation rate for the non-surveyed areas is a weighted average of the surveyed areas harvest rates (shown below) and the average mature male biomass for each area over the entire time series (1979-2018). Biomass estimates apply the adjustment in Table 1 to the CSA biomass presented here. Biomass of "other areas" was expanded based on the year ranges shown below with two options presented. Personal use catch for "Other Areas" is mean catch estimated from 2008-2012 statewide survey data. Blue king crab (BKC) is estimated as 1.06% of the surveyed areas based on historical catch, and its GHL contribution is an expansion of the surveyed areas GHL using the same percentage.

Survey area	Biomass of legal crab	Biomass of mature crab	ADJUSTED legal biomass	ADJUSTED mature biomass	ADJUSTED avg inc ER	Total GHL	Personal use catch	2019 Commercial GHL (lb)
Pybus Bay	38,079	47,735	**117,308**	**147,052**	**2%**	2,941	n/a	2,941
Gambier Bay	17,880	20,671	**70,256**	**81,223**	**2%**	1,624	n/a	1,624
Seymour Canal	30,905	30,909	**283,542**	**283,580**	**0.5%**	1,418	n/a	1,418
Peril Strait	6,467	7,180	**17,805**	**19,768**	**4%**	791	n/a	791
Juneau Area [a]	320,507	359,523	320,507	359,523	**7%**	25,167	15,100	10,067
Lynn Sisters	15,946	36,799	**27,854**	**64,282**	**3%**	1,928	n/a	1,928
Excursion Inlet	23,347	29,871	**68,776**	**87,995**	**1%**	880	n/a	880
Blue King Crab	4,803	5,646	**9,604**	**11,060**	—	—	—	208
Expansion using baseline years (1993–2007)–36.1% of the population in the NON-survey areas								
Other Areas	255,994	300,939	**511,868**	**589,477**	**4%**	23,579	1,000	22,579
Total	713,927	839,272	**1,427,520**	**1,643,959**	—	—	—	**42,436**
Expansion using historic years (1974–1984)–47.2% of the population in the NON-survey areas								
Other Areas	405,071	476,189	**809,952**	**932,756**	**4%**	37,310	1,000	36,310
Total	863,005	1,014,522	**1,725,605**	**1,987,239**	—	—	—	**56,168**

[a] The Juneau area was open to personal use harvest in summer 2019 at a harvest rate of 7%. "n/a" represents data that is not available or readily estimable from the other bays.

Table 4.–Option 3: highest risk option–data based, using a sum of the average harvest rate and average change in mature male biomass. Summary of 2019 commercial red king crab fishery GHL calculations (lb) for the seven surveyed areas and other areas. This exploitation rate option is based on 2018 calculated combination of average harvest rate and average change in mature male biomass for each area (Appendix A). The harvest rate for the non-surveyed areas is a weighted average of the surveyed areas harvest rates (shown below) and the average mature male biomass for each area over the entire time series (1979–2018). Biomass estimates apply the adjustment in Table 1 to the CSA biomass presented here. Biomass of "other areas" was expanded based on the year ranges shown below with two options presented. Personal use catch for "Other Areas" is mean catch estimated from 2008-2012 statewide survey data. Blue king crab (BKC) is estimated as 1.06% of the surveyed areas based on historical catch, and its GHL contribution is an expansion of the surveyed areas GHL using the same percentage.

Survey area	Biomass of legal crab	Biomass of mature crab	ADJUSTED legal biomass	ADJUSTED mature biomass	ADJUSTED avg HR & avg change	Total GHL	Personal use catch	2019 Commercial GHL (lb)
Pybus Bay	38,079	47,735	**117,308**	**147,052**	**18%**	26,469	n/a	26,469
Gambier Bay	17,880	20,671	**70,256**	**81,223**	**5%**	4,061	n/a	4,061
Seymour Canal	30,905	30,909	**283,542**	**283,580**	**4%**	11,343	n/a	11,343
Peril Strait	6,467	7,180	**17,805**	**19,768**	**3%**	593	n/a	593
Juneau Area [a]	320,507	359,523	320,507	359,523	**7%**	25,167	15,100	10,067
Lynn Sisters	15,946	36,799	**27,854**	**64,282**	**10%**	6,428	n/a	6,428
Excursion Inlet	23,347	29,871	**68,776**	**87,995**	**12%**	10,559	n/a	10,559
Blue King Crab	4,803	5,646	**9,604**	**11,060**	–	–	–	737
Expansion using baseline years (1993–2007)–36.1% of the population in the NON-survey areas								
Other Areas	255,994	300,939	**511,868**	**589,477**	**12%**	70,737	1,000	69,737
Total	713,927	839,272	**1,427,520**	**1,643,959**	–	–	–	**139,995**
Expansion using historic years (1974-1984)–47.2% of the population in the NON-survey areas								
Other Areas	405,071	476,189	**809,952**	**932,756**	**12%**	111,931	1,000	100,931
Total	863,005	1,014,522	**1,725,605**	**1,987,239**	–	–	–	**181,189**

[a] The Juneau area harvest rate in this option is 17%, but it was open to personal use harvest in summer 2019 at a harvest rate of 7%. "n/a" represents data that is not available or readily estimable from the other bays.

Table 5.–Total stock health designations and associated scores for 2015–2019 by survey area.

Survey Area	2015	2016	2017	2018	2019
Pybus Bay	Moderate (-1.25)	Below Average (-2.0)	Moderate (0.50)	Below Average (-3.0)	Below Average (-3.75)
Gambier Bay	Below Average (-3.5)	Below Average (-2.0)	Moderate (0.00)	Poor (-5.25)	Poor (-6.00)
Seymour Canal	Poor (-5.0)	Below Average (-3.0)	Moderate (1.25)	Below Average (-3.0)	Poor (-5.0)
Peril Strait	Poor (-5.0)	Poor (-5.5)	Poor (-6.0)	Poor (-5.0)	Poor (-6.25)
Juneau Area	Below Average (-2.5)	Moderate (-1.50)	Above Average (2.5)	Moderate (1.25)	Below Average (-3.50)
Lynn Sisters	Below Average (-4.0)	Poor (-5.0)	Moderate (-1.50)	Moderate (-0.75)	Moderate (0.50)
Excursion Inlet	Poor (-4.75)	Below Average (-4.25)	Moderate (1.00)	Below Average (-2.75)	Below Average (-3.25)
Port Frederick	—	—	—	—	—

Table 6.–Stock health scores and their associated categories used for the previous (2006–2008) and current (since 2008) seasons. Scores are calculated in 0.25 increments.

Score	Previous Categories	Current Categories
-7.00 to -4.50	Poor	Poor
-4.25 to -1.75	Poor	Below Average
-1.50 to 1.50	Moderate	Moderate
1.75 to 4.25	Healthy	Above Average
4.5 to 7.00	Healthy	Healthy

Table 7.–Samples sizes for the 2019 survey by area.

	Pybus Bay	Gambier Bay	Seymour Canal	Peril Strait	Juneau	Lynn Sisters	Excursion Inlet
Pre-recruit	45	27	0	5	243	100	59
Recruit	17	27	9	3	298	37	56
Post-recruit	29	50	35	11	656	19	69
Juvenile male	26	19	0	5	347	176	30
Juvenile female	27	22	0	13	252	233	29
Mature female	122	275	2	47	1162	183	61
Effective No. of Pots	46	52	52	50	215	26	54

Table 8.–Summary of 2019 commercial red king crab fishery GHL calculations (in pounds) and harvest rate recommendations for the 7 surveyed areas and other areas. Adjusted Mature Biomass from the mark-recapture study are shown in bold. Biomass of "Other Areas" was expanded to be 47.2% of the region.

Survey area	CSA Biomass of Legal Crab	CSA Biomass of Mature Crab	Mature biomass	Mature harvest rate	Total GHL	Personal use catch	2018 Commercial GHL
Pybus Bay	38,079	47,735	**147,052**	0.0%	0	0	0
Gambier Bay	17,880	20,671	**81,223**	0.0%	0	0	0
Seymour Canal	30,905	30,909	**283,580**	0.0%	0	0	0
Peril Strait	6,467	7,180	**19,768**	0.0%	0	0	0
Juneau Area	320,507	359,523	359,523	7.0%	25,167	15,100	10,067
Lynn Sisters	15,946	36,799	**64,282**	0.0%	0	0	0
Excursion Inlet	23,347	29,871	**87,995**	6.0%	5,280	0	5,280
Other Areas	405,072	476,191	**932,757**	10.0%	–	–	93,276
Blue King Crab	4,811	5,656	11,079	NA	–	–	0
Total	863,014	1,014,535	1,987,259	5.5%	–	–	108,622

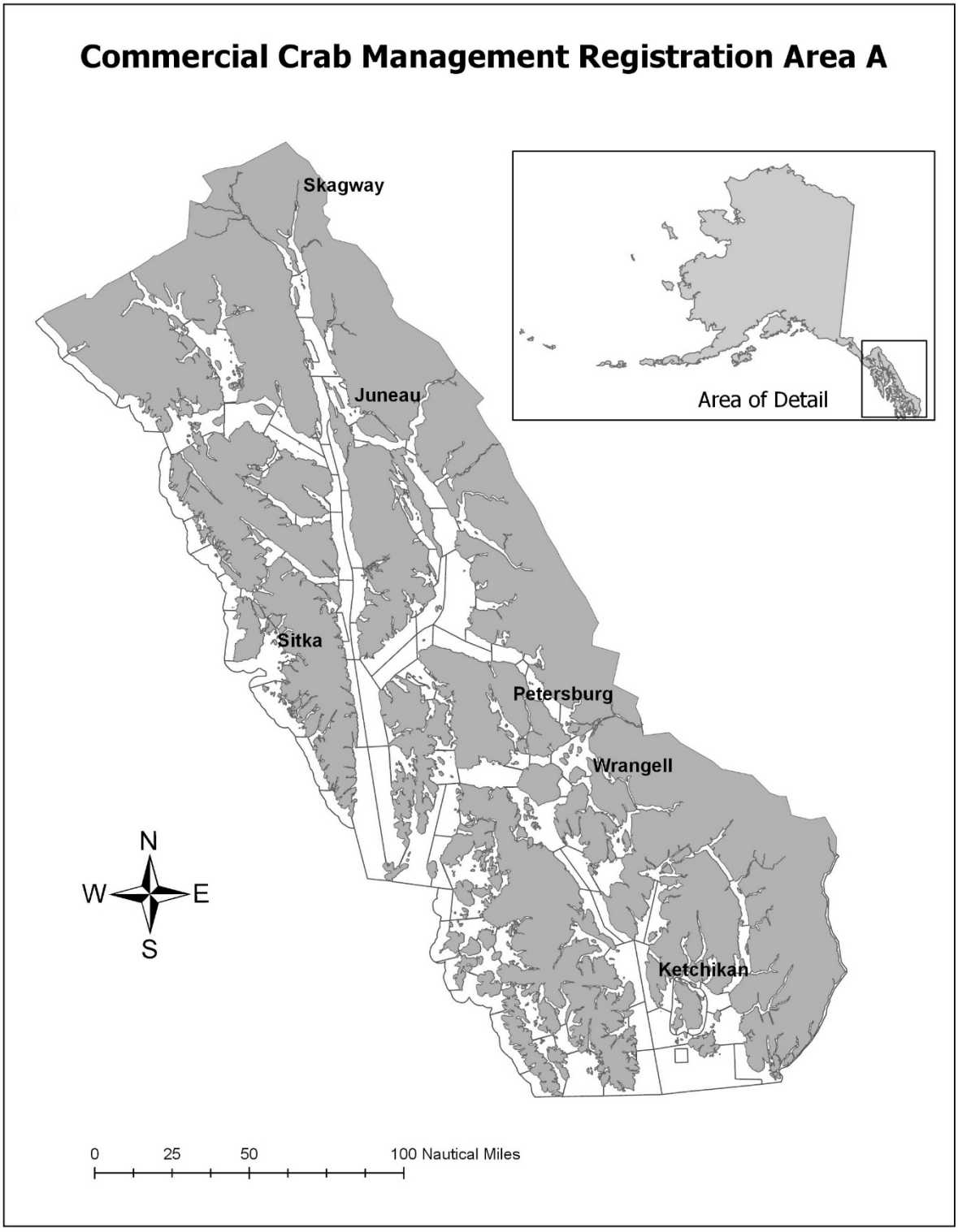

Figure 1.–Map of Registration Area A (Southeast Alaska).

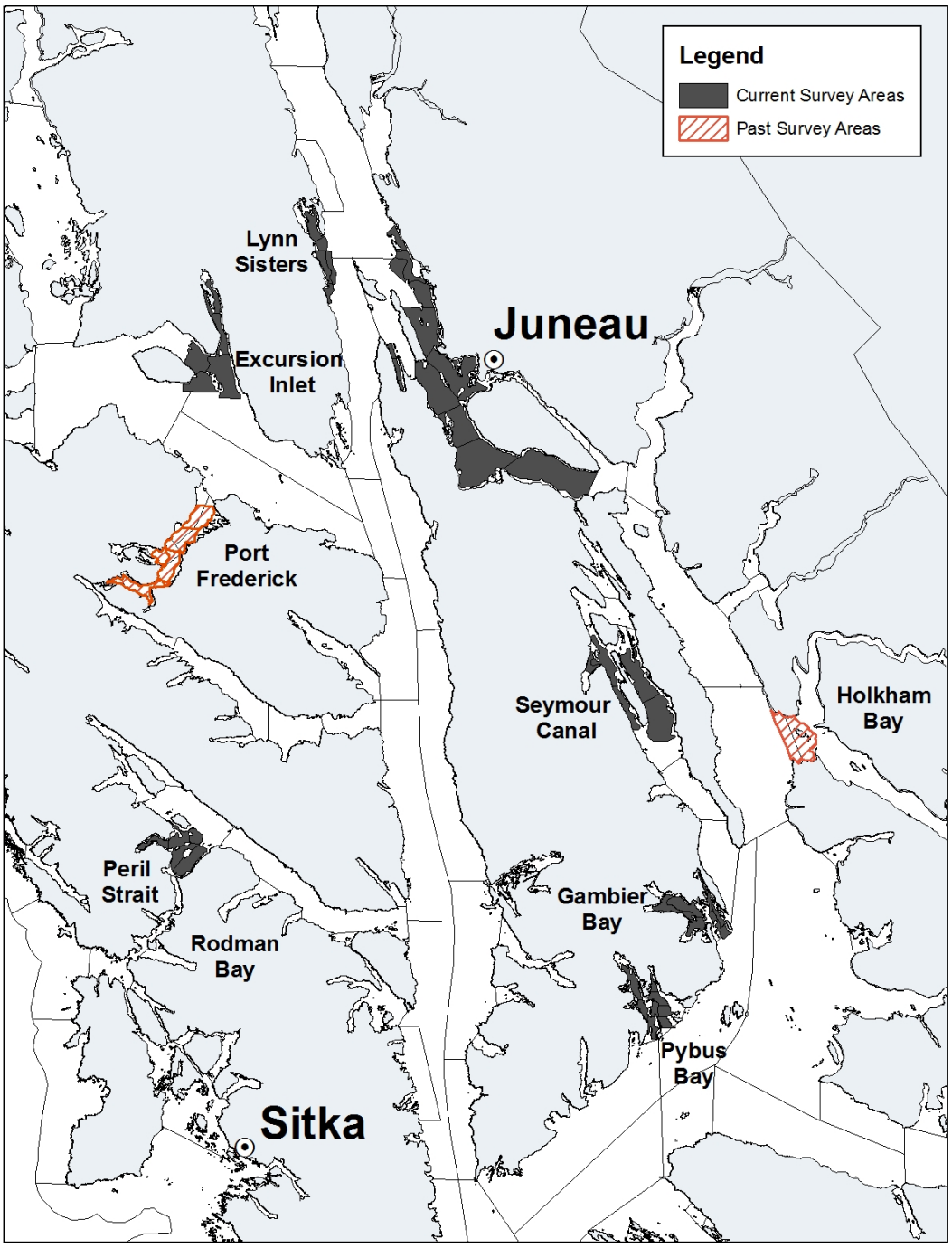

Figure 2.–Map showing 2019 red king crab survey areas in Southeast Alaska. In 2015 Port Frederick and Holkham Bay were removed as survey areas but are shown here for reference.

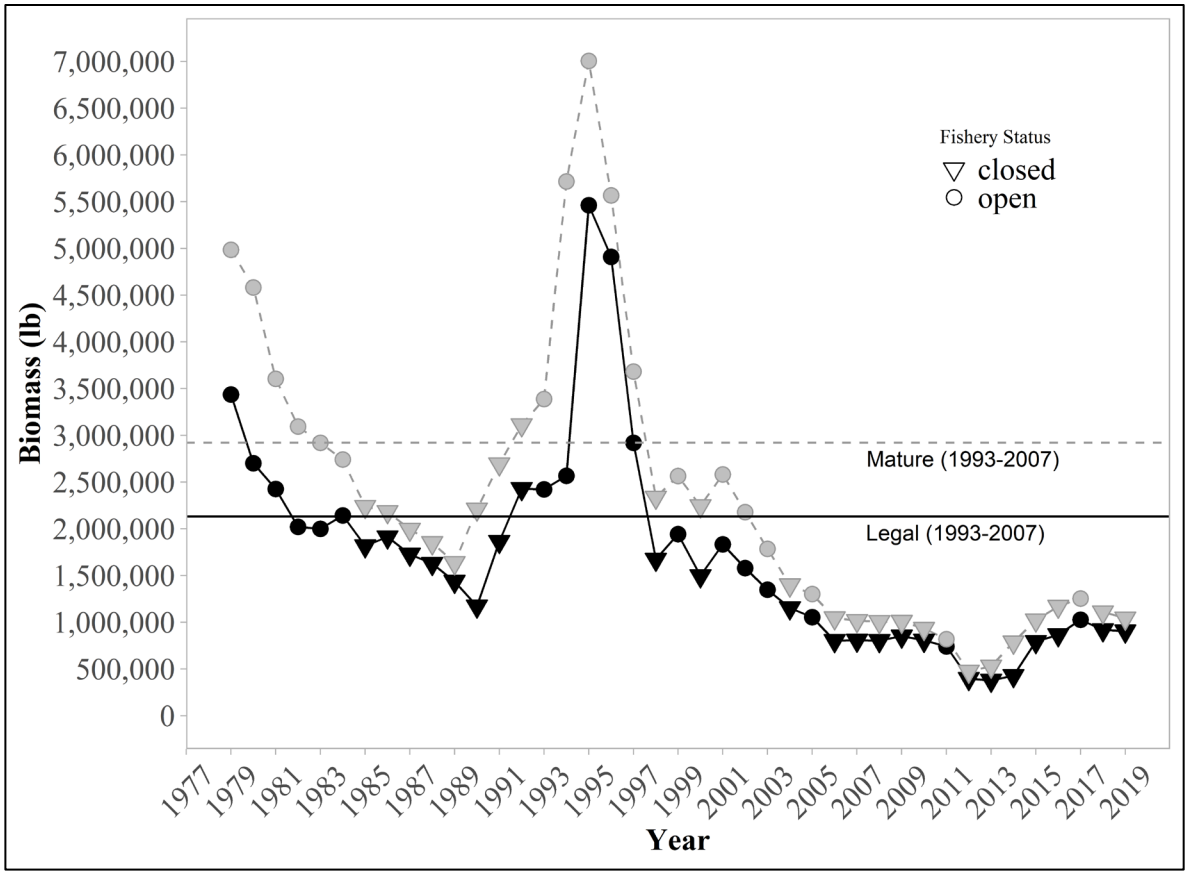

Figure 3.–Total biomass estimates of mature (gray points and line) and legal (black points and line) red king crab for surveyed areas in Southeast Alaska. Estimates based on Catch-Survey Analysis (CSA) methodologies adjusted using mark-recapture study results(Table 1). This does not include Holkham Bay, Port Frederick, or non-surveyed areas. Reference lines represent long-term (1993–2007) average of legal and mature biomass estimates. Triangles represent years without a commercial harvest.

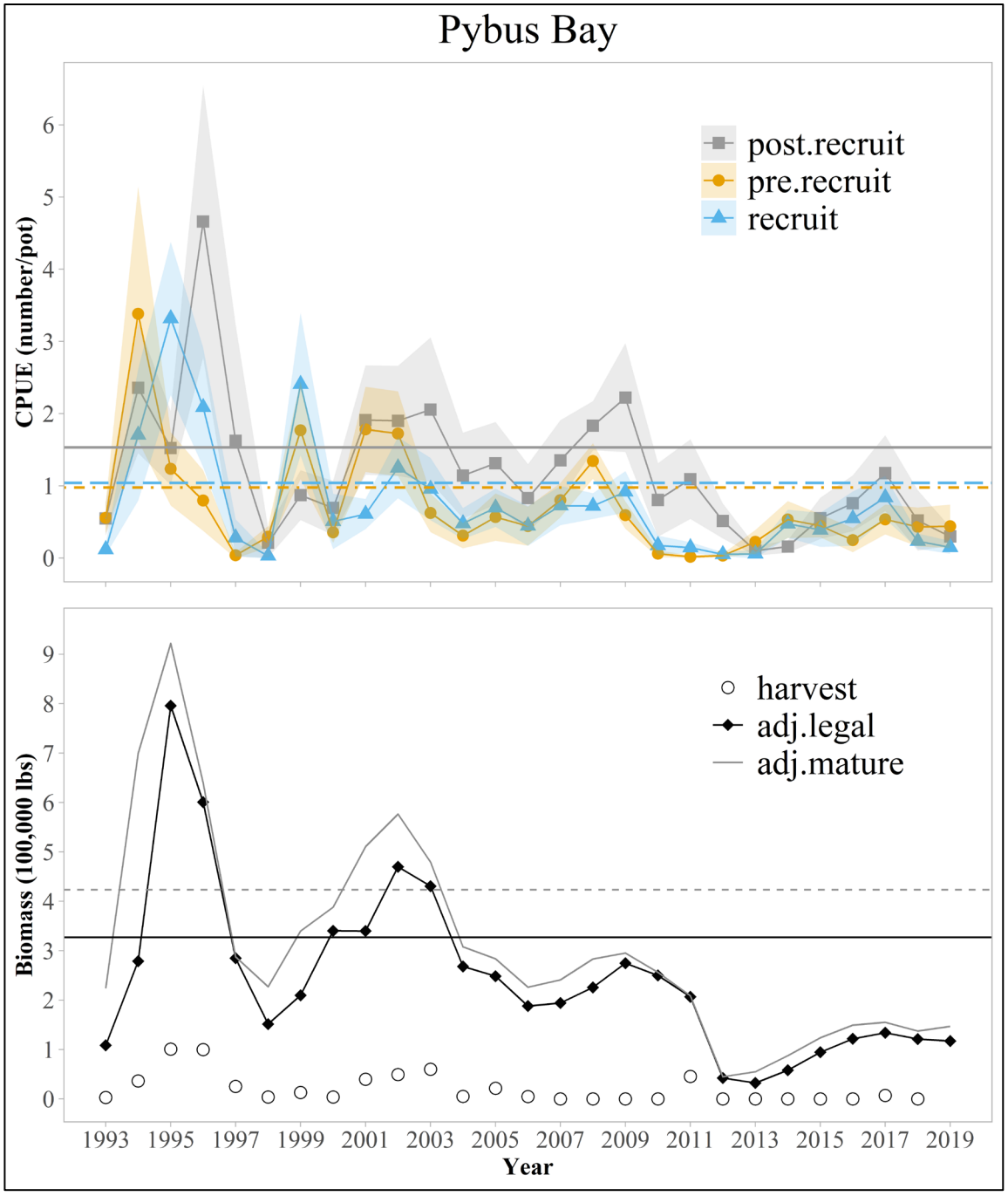

Figure 4.–Pybus Bay CPUEs for male size/sex classes of red king crab, biomass estimates from the current year's CSA model and harvest data. Reference lines represent long-term baselines for each parameter (1993–2007). Gray dotted reference line in the biomass figure represents the long-term baseline for mature biomass, while the solid black refers to the legal biomass. There are no significant short-term trends this year.

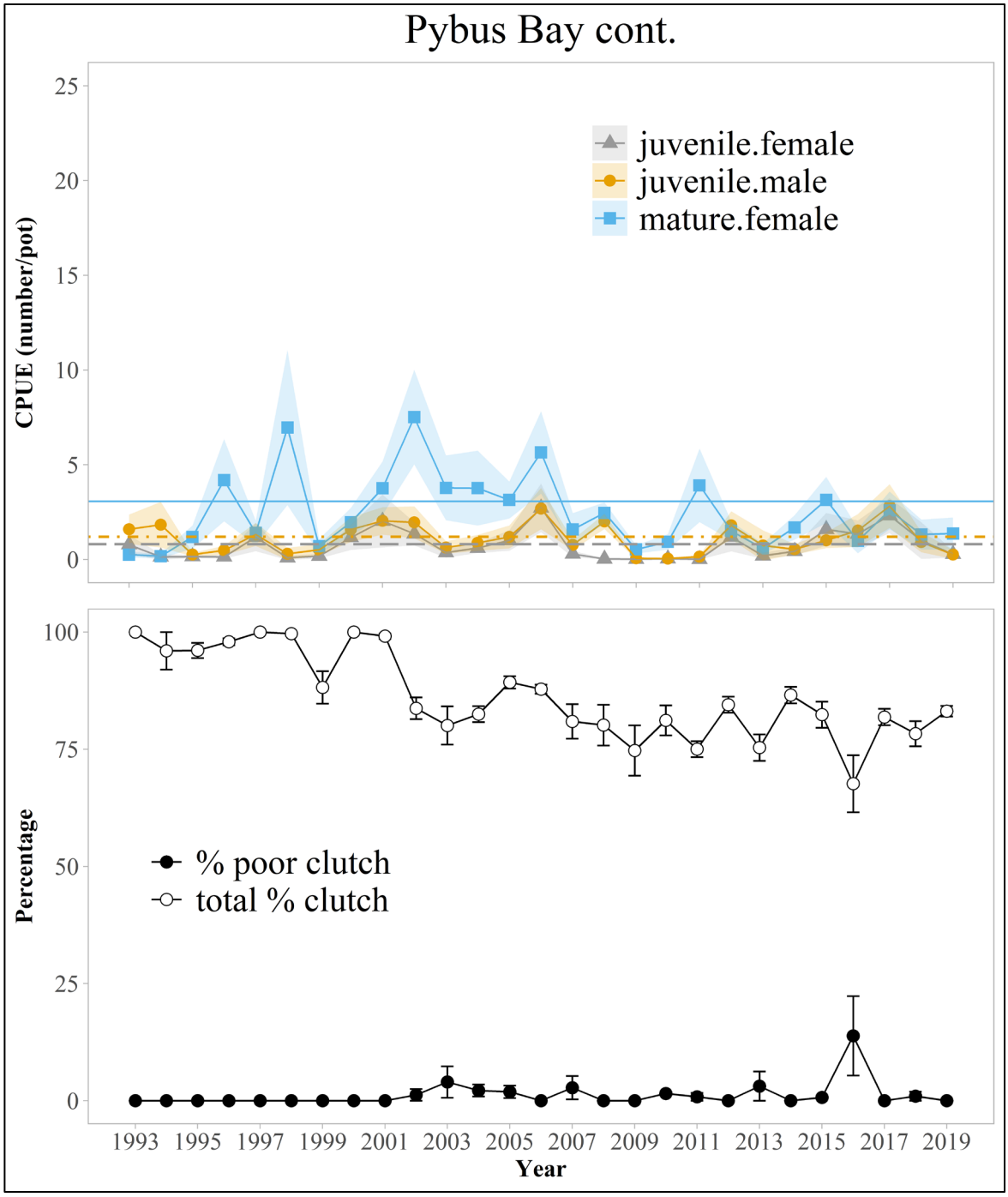

Figure 5.–Pybus Bay CPUEs for female and juvenile male size/sex classes of red king crab, clutch fullness and proportion of poor clutches. Reference lines represent long-term baselines for each parameter (1993–2007). There is a significant short-term increasing trend in the percentage of poor clutches for females this year.

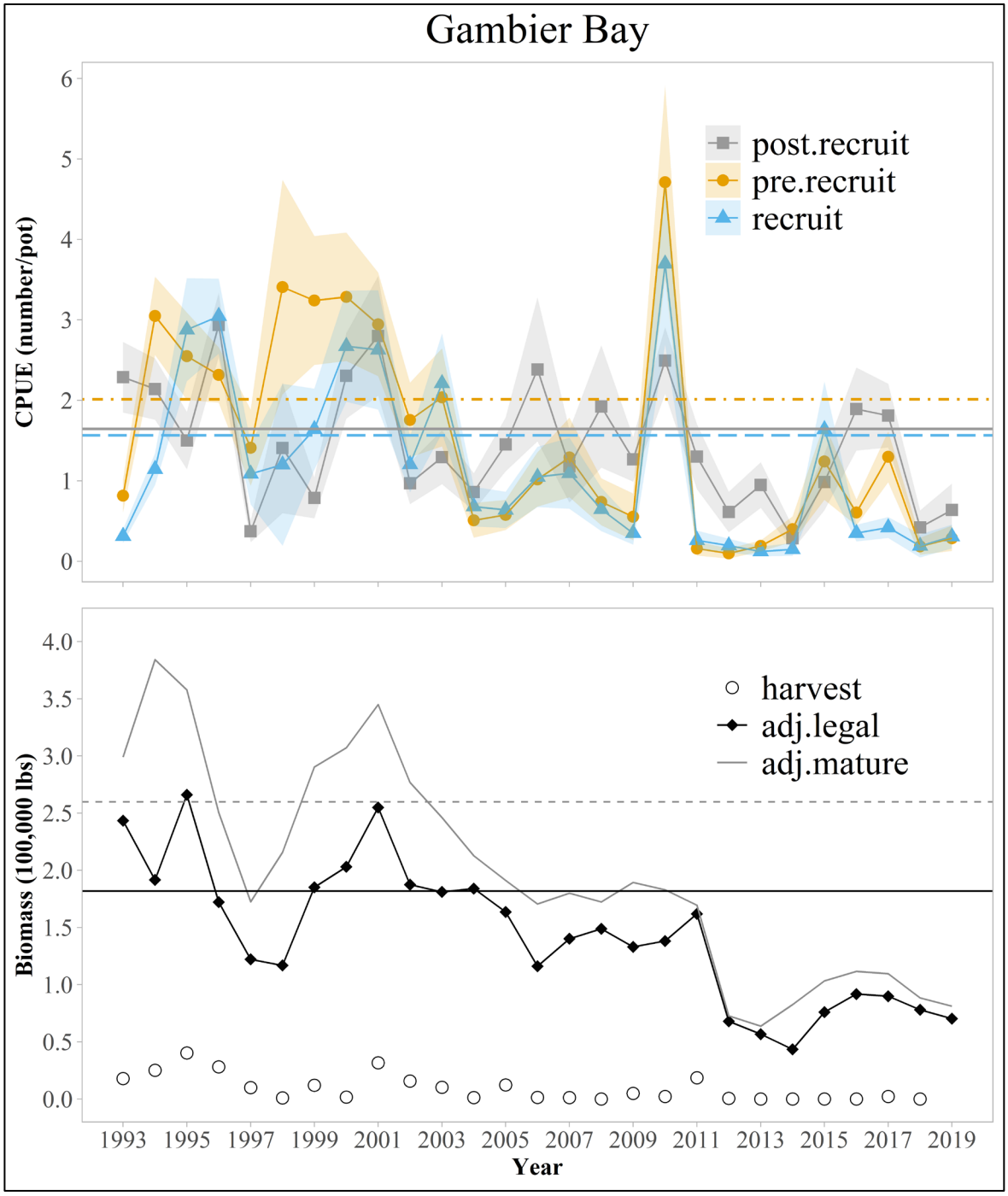

Figure 6.–Gambier Bay CPUEs for male size/sex classes of red king crab, biomass estimates from the current year's CSA model and harvest data. Reference lines represent long-term baselines for each parameter (1993–2007). Gray dotted reference line in the biomass figure represents the long-term baseline for mature biomass, while the solid black refers to the legal biomass. There are significant short-term decreasing trends in pre-recruit and post-recruit male CPUEs.

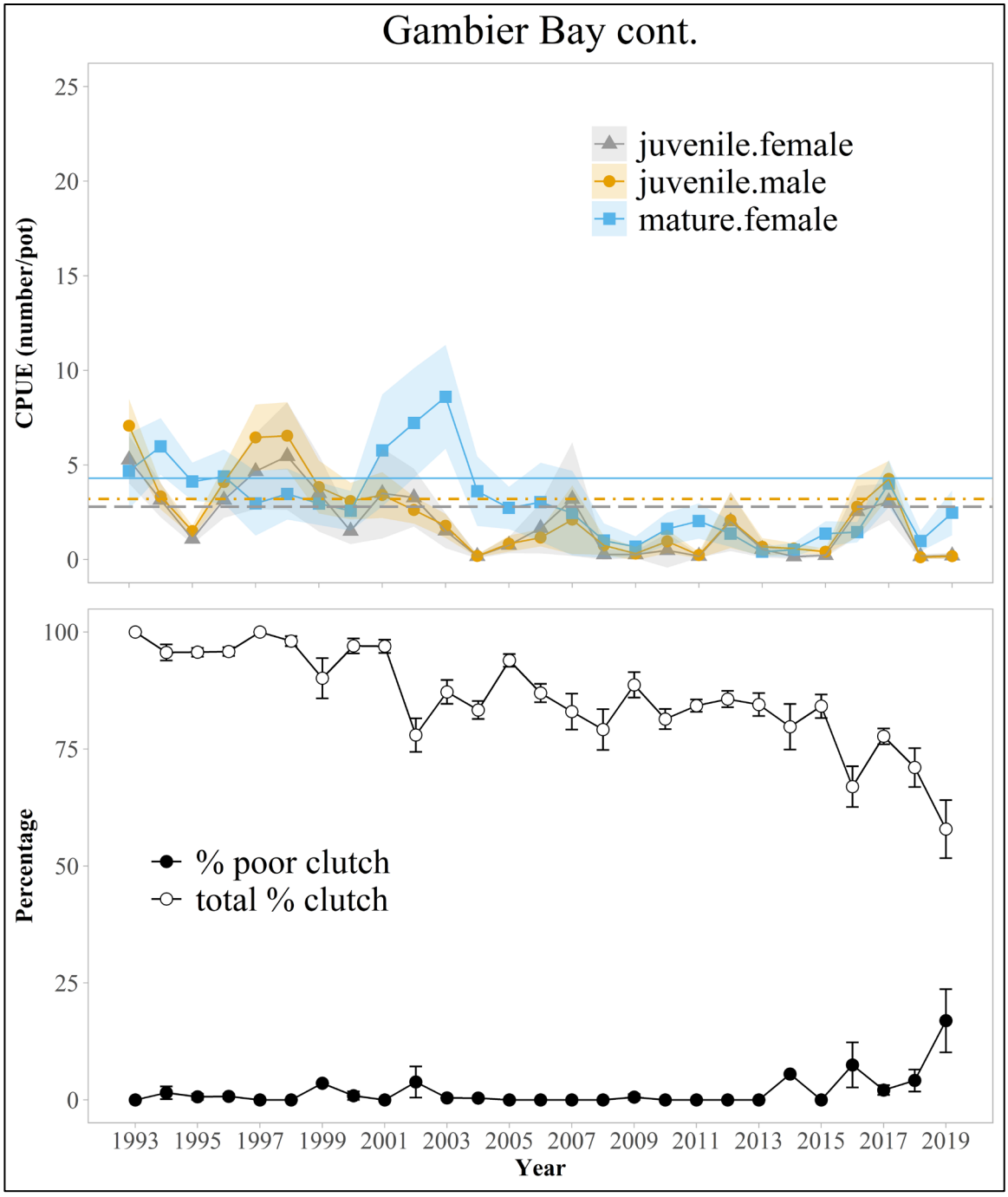

Figure 7.–Gambier Bay CPUEs for female and juvenile male size/sex classes of red king crab, clutch fullness and proportion of poor clutches. Reference lines represent long-term baselines for each parameter (1993–2007). There are significant decreasing short-term trends in juvenile male and female CPUEs.

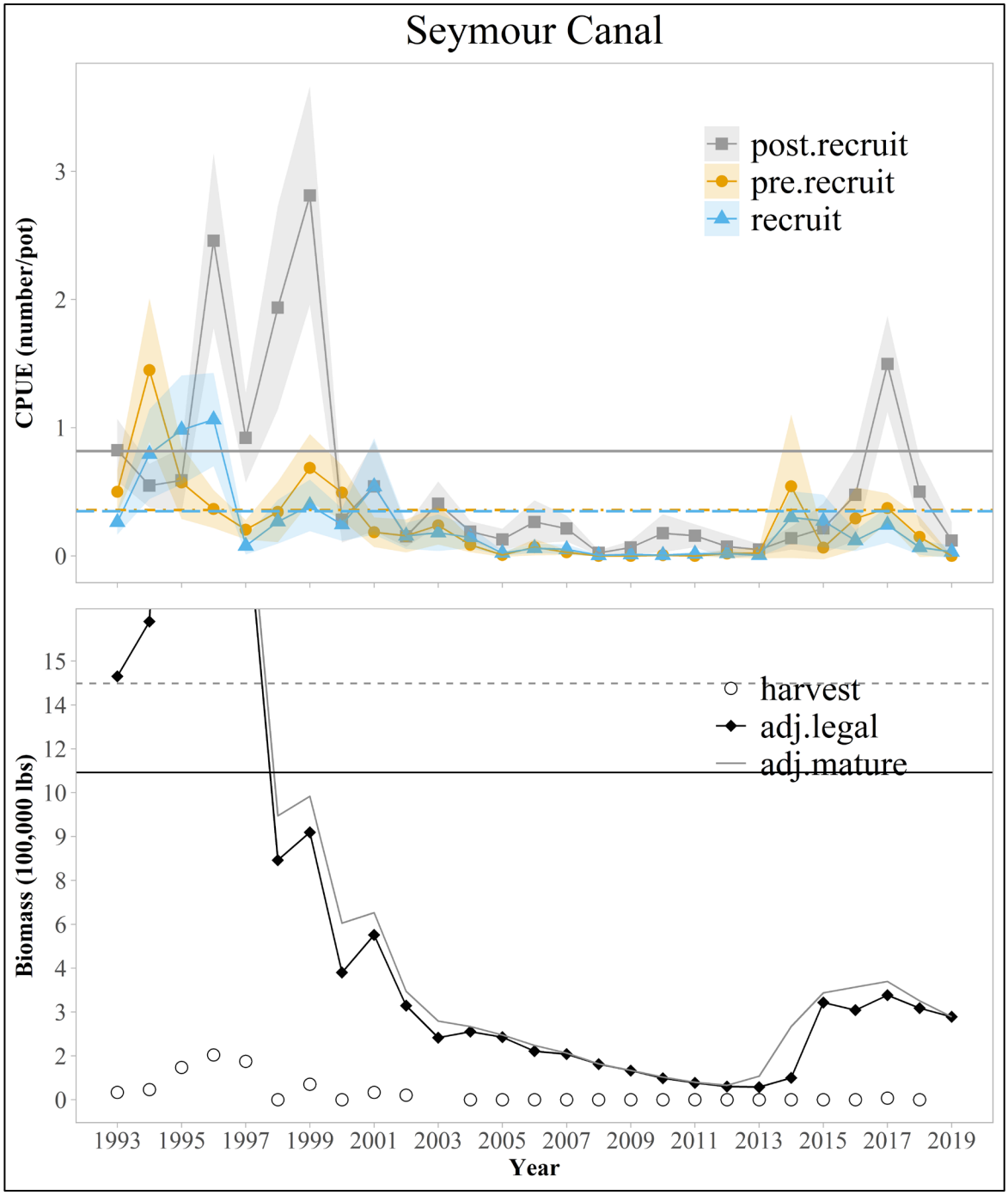

Figure 8.–Seymour Canal CPUEs for male size/sex classes of red king crab, biomass estimates from the current year's CSA model and harvest data. Reference lines represent long-term baselines for each parameter (1993–2007). Gray dotted reference line in the biomass figure represents the long-term baseline for mature biomass, while the solid black refers to the legal biomass. There are no significant short-term trends this year.

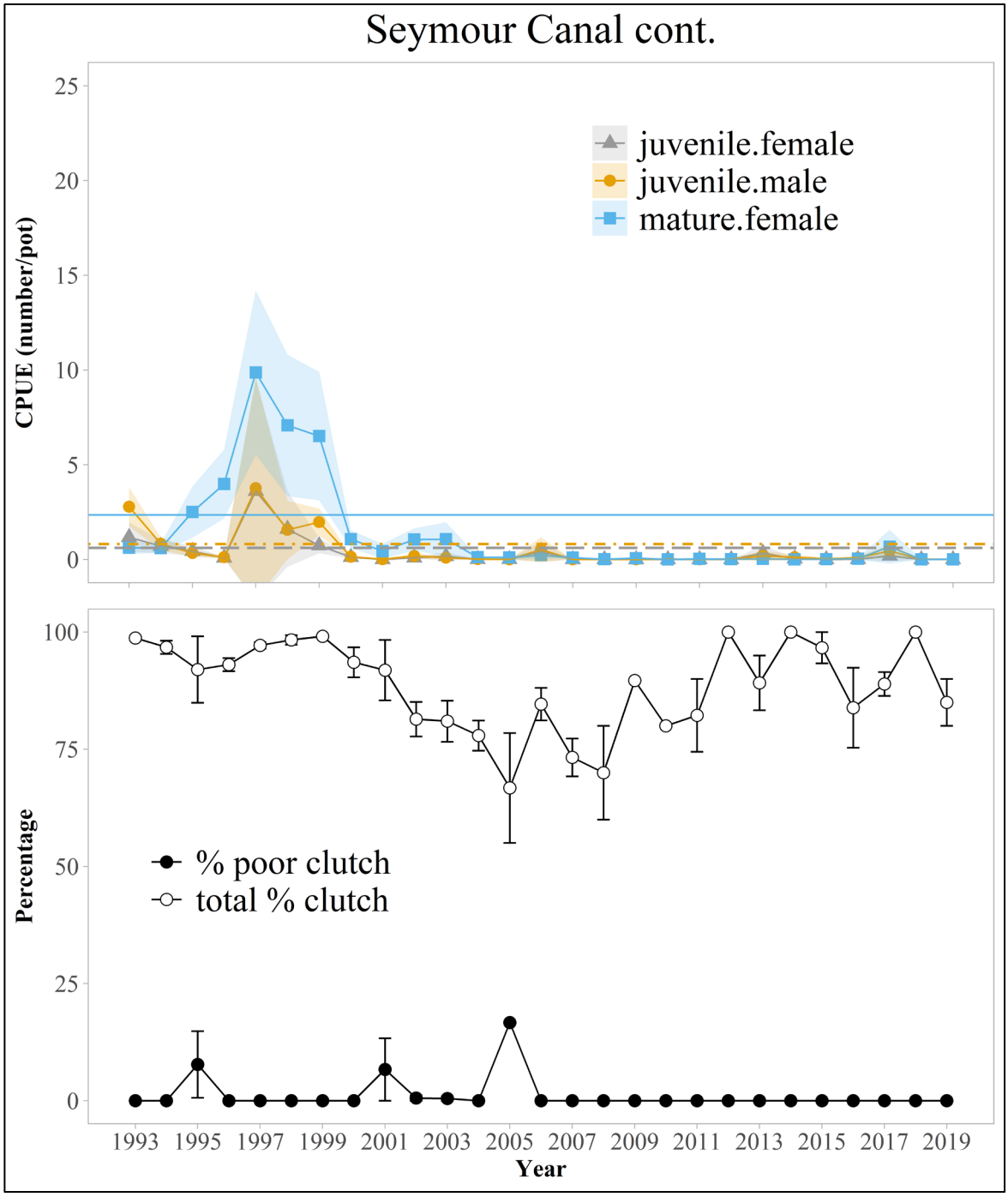

Figure 9.–Seymour Canal CPUEs for female and juvenile male size/sex classes of red king crab, clutch fullness and proportion of poor clutches. Reference lines represent long-term baselines for each parameter (1993–2007). There are no significant short-term trends this year.

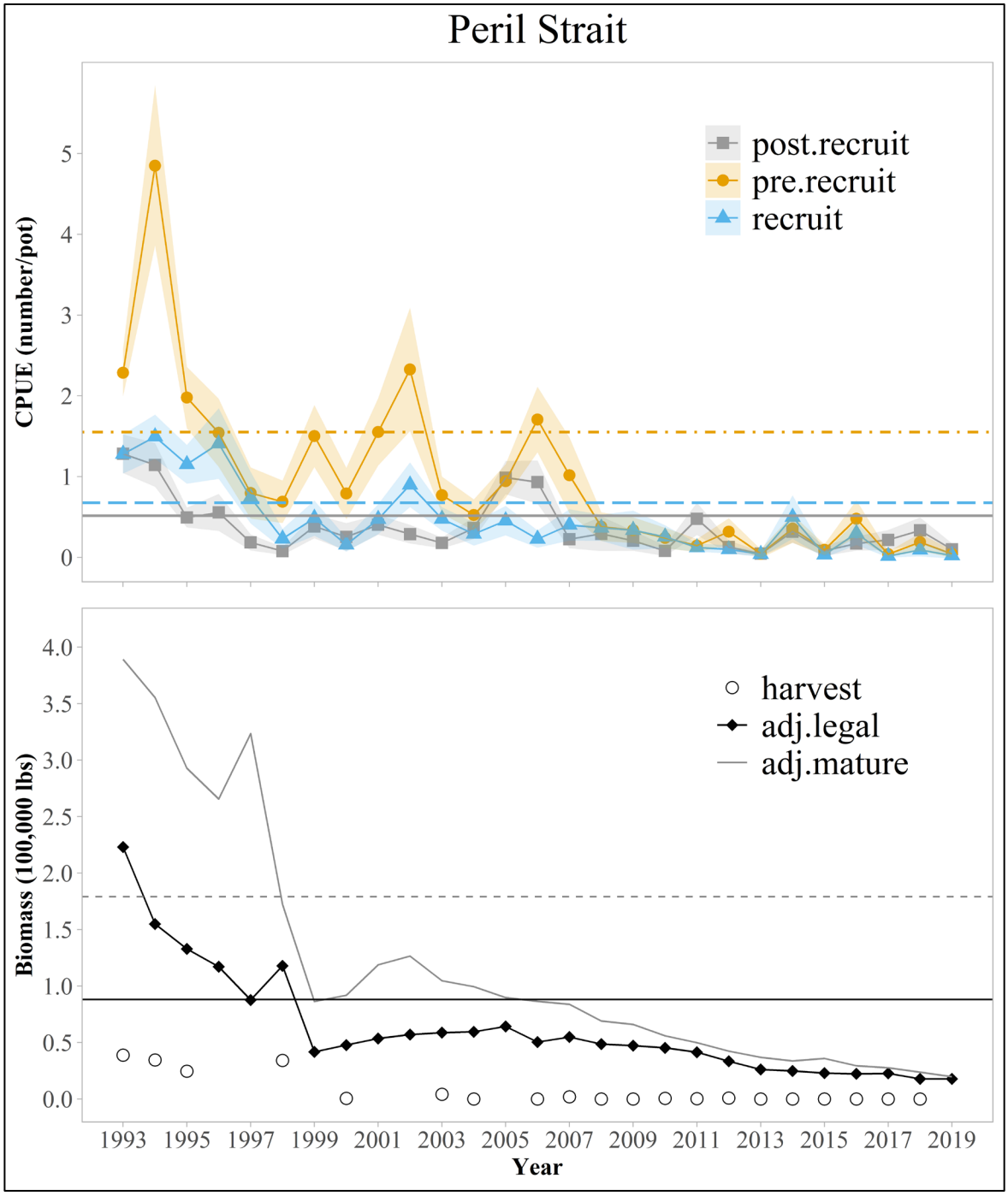

Figure 10.–Peril Strait CPUEs for male size/sex classes of red king crab, biomass estimates from the current year's CSA model and harvest data. Reference lines represent long-term baselines for each parameter (1993–2007). Gray dotted reference line in the biomass figure represents the long-term baseline for mature biomass, while the solid black refers to the legal biomass. There are significant short-term decreasing trends in pre-recruit and recruit CPUEs this year.

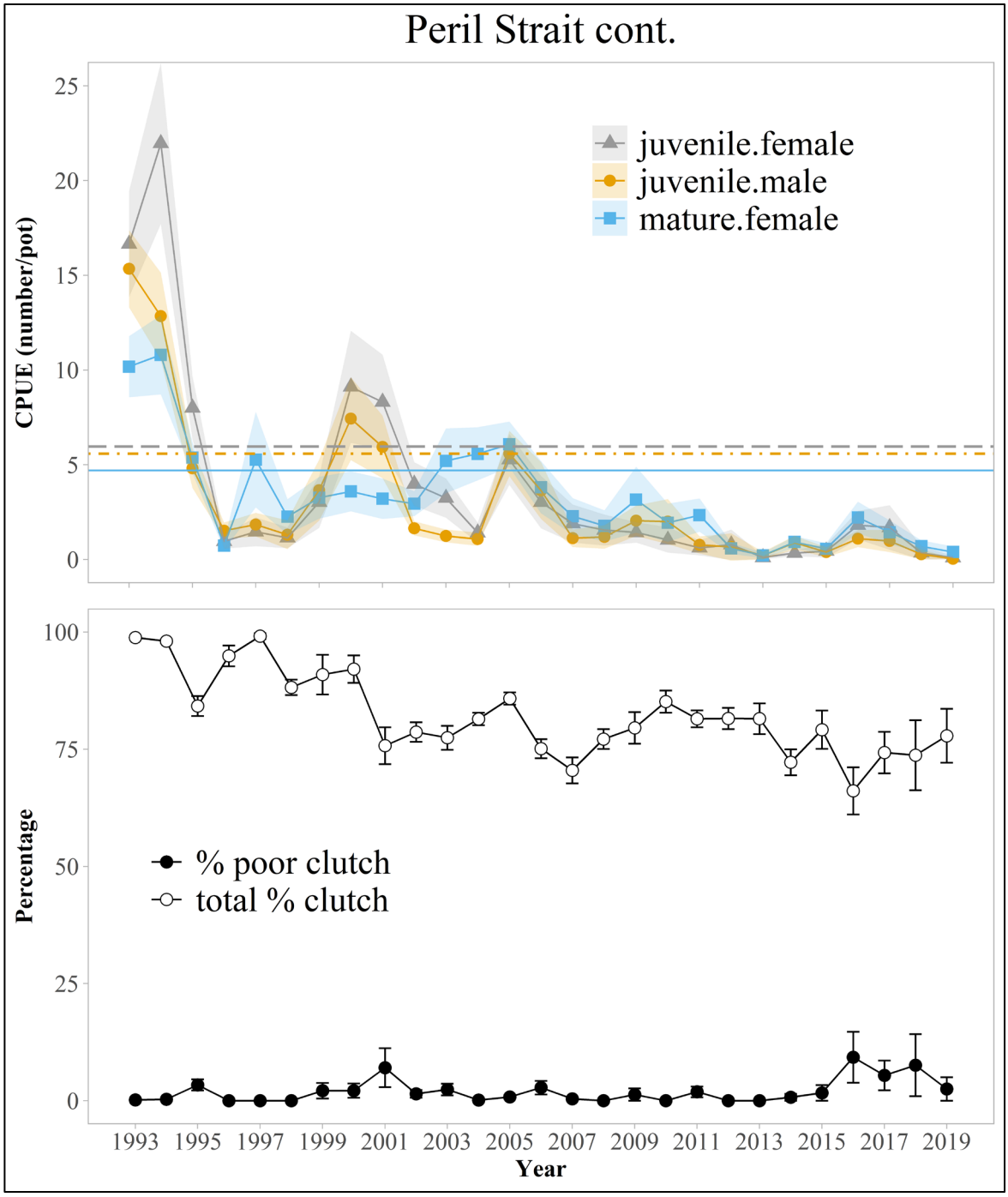

Figure 11.–Peril Strait CPUEs for female and juvenile male size/sex classes of red king crab, clutch fullness and proportion of poor clutches. Reference lines represent long-term baselines for each parameter (1993–2007). There are significant short-term decreasing trends in juvenile male, juvenile female, and mature female CPUEs this year.

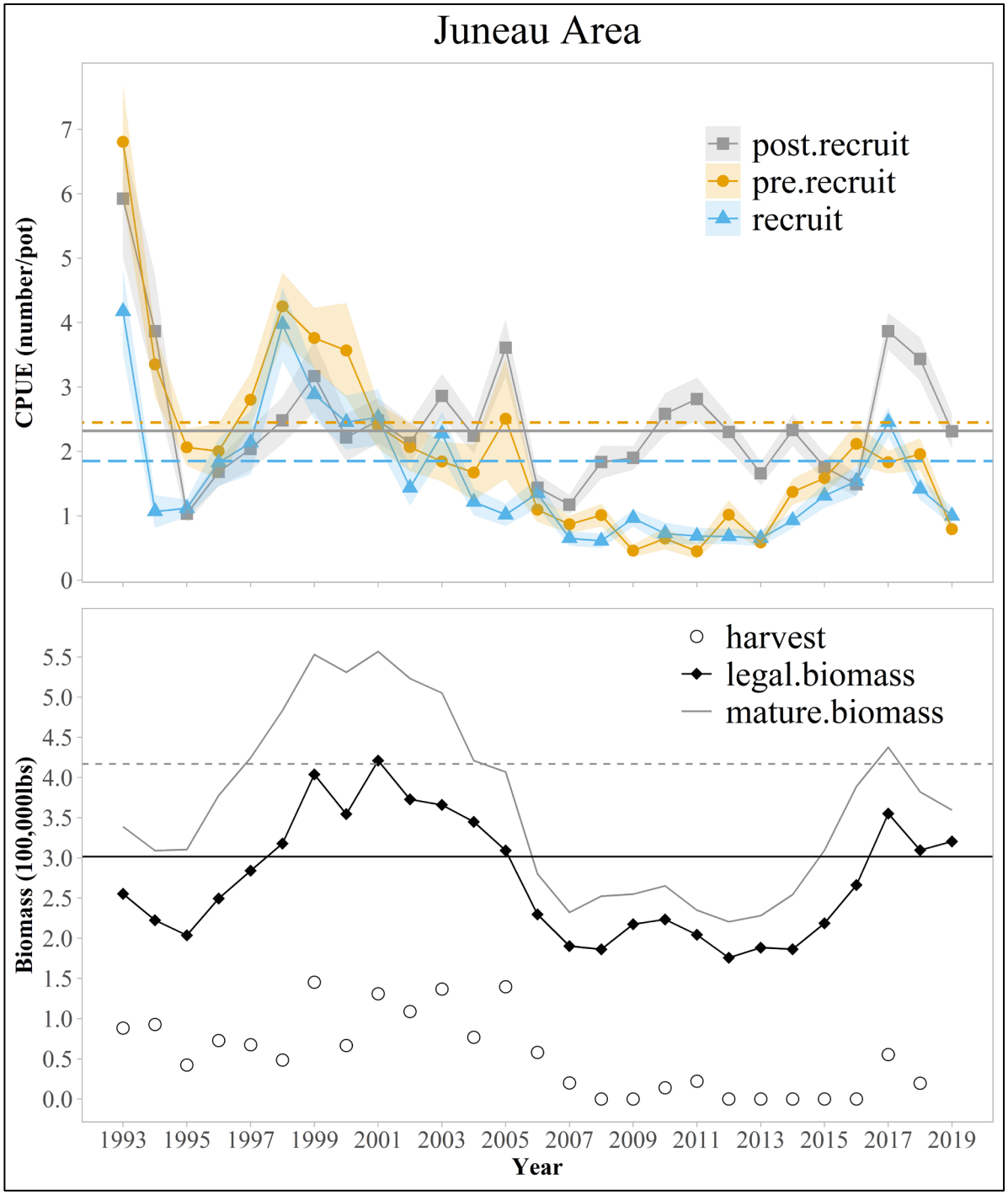

Figure 12.–Juneau area CPUEs for male size/sex classes of red king crab, biomass estimates from the current year's CSA model and harvest data. Reference lines represent long-term baselines for each parameter (1993–2007). Gray dotted reference line in the biomass figure represents the long-term baseline for mature biomass, while the solid black refers to the legal biomass. There are significant short-term decreasing trends in pre-recruit and recruit male CPUEs.

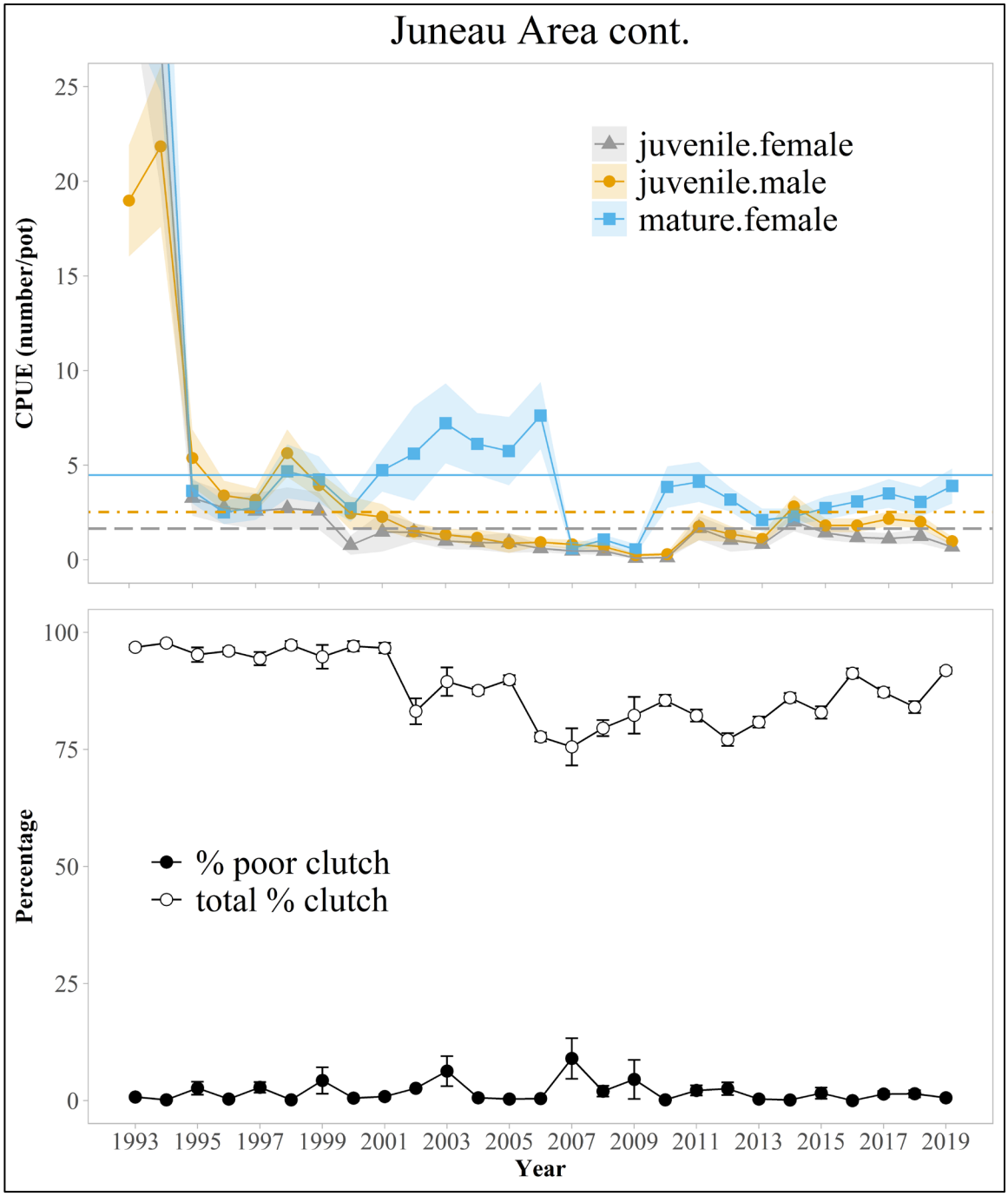

Figure 13.–Juneau area CPUEs for female and juvenile male size/sex classes of red king crab, clutch fullness and proportion of poor clutches. Reference lines represent long-term baselines for each parameter (1993–2007). There are no significant short-term trends for females or juveniles this year.

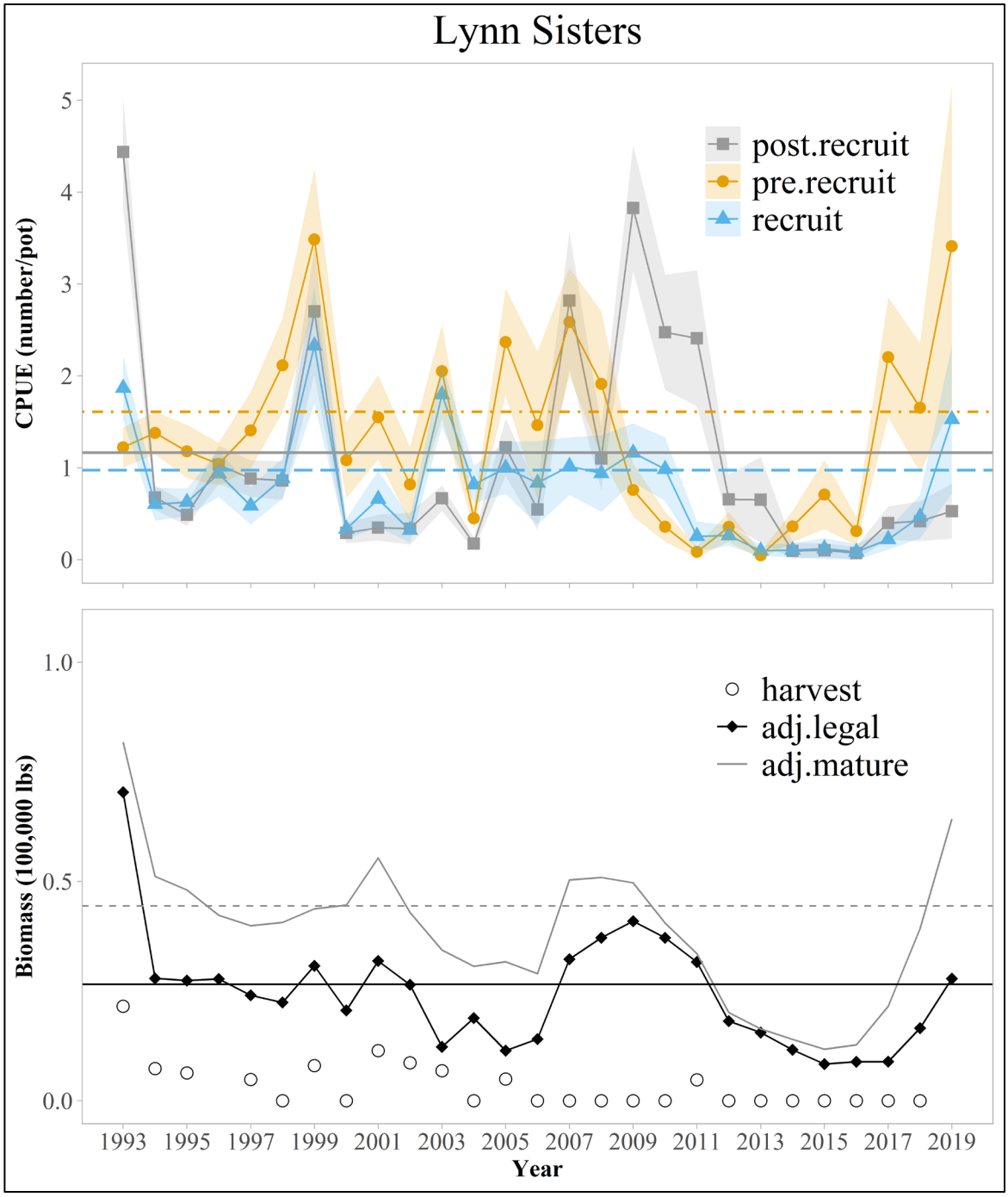

Figure 14.–Lynn Sisters CPUEs for male size/sex classes of red king crab, biomass estimates from the current year's CSA model and harvest data. Reference lines represent long-term baselines for each parameter (1993–2007). Gray dotted reference line in the biomass figure represents the long-term baseline for mature biomass, while the solid black refers to the legal biomass. There are significant short-term increasing trends in pre-recruit and recruit male CPUEs.

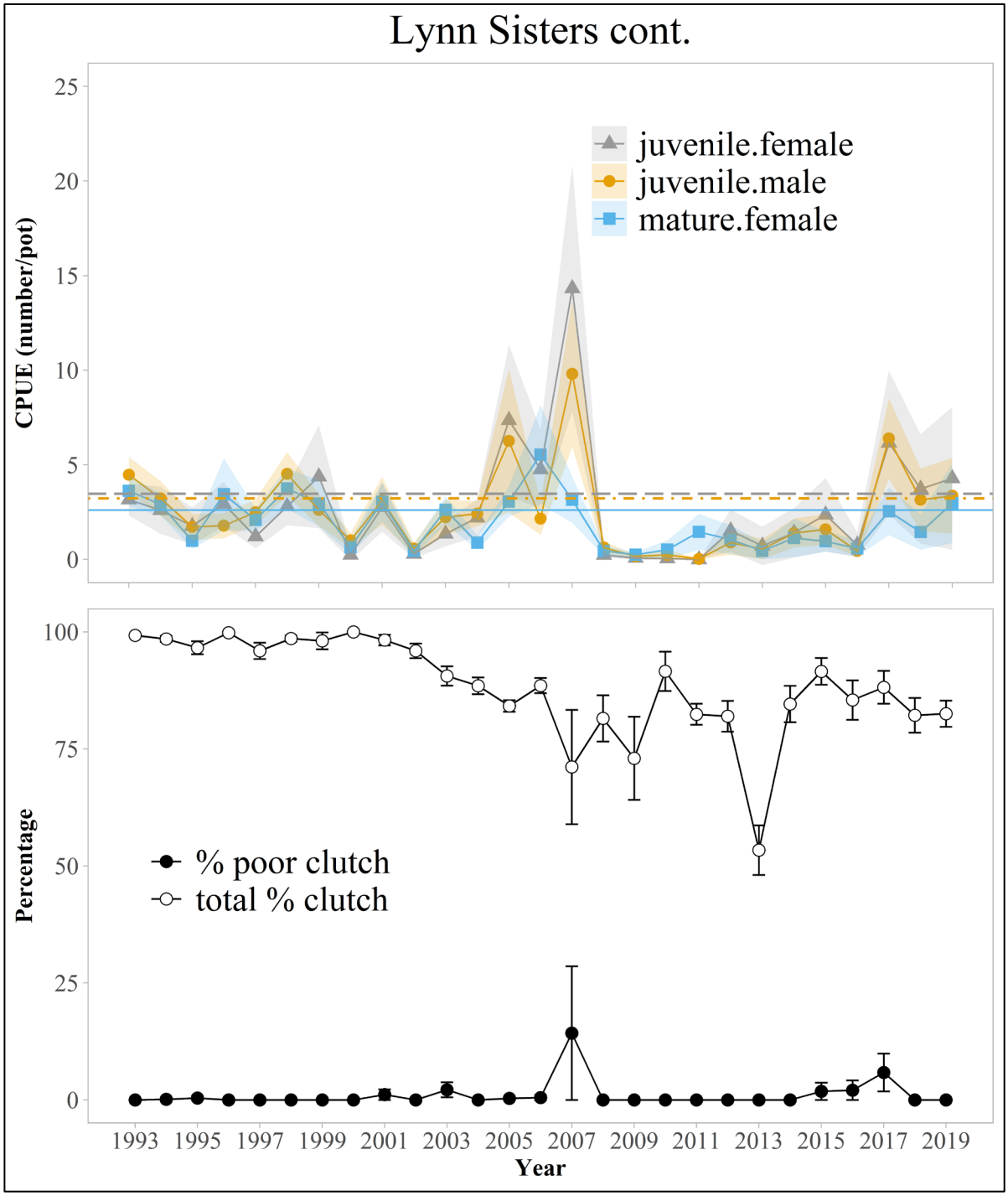

Figure 15.–Lynn Sisters CPUEs for female and juvenile male size/sex classes of red king crab, clutch fullness and proportion of poor clutches. Reference lines represent long-term baselines for each parameter (1993–2007). There are no significant short-term trends this year.

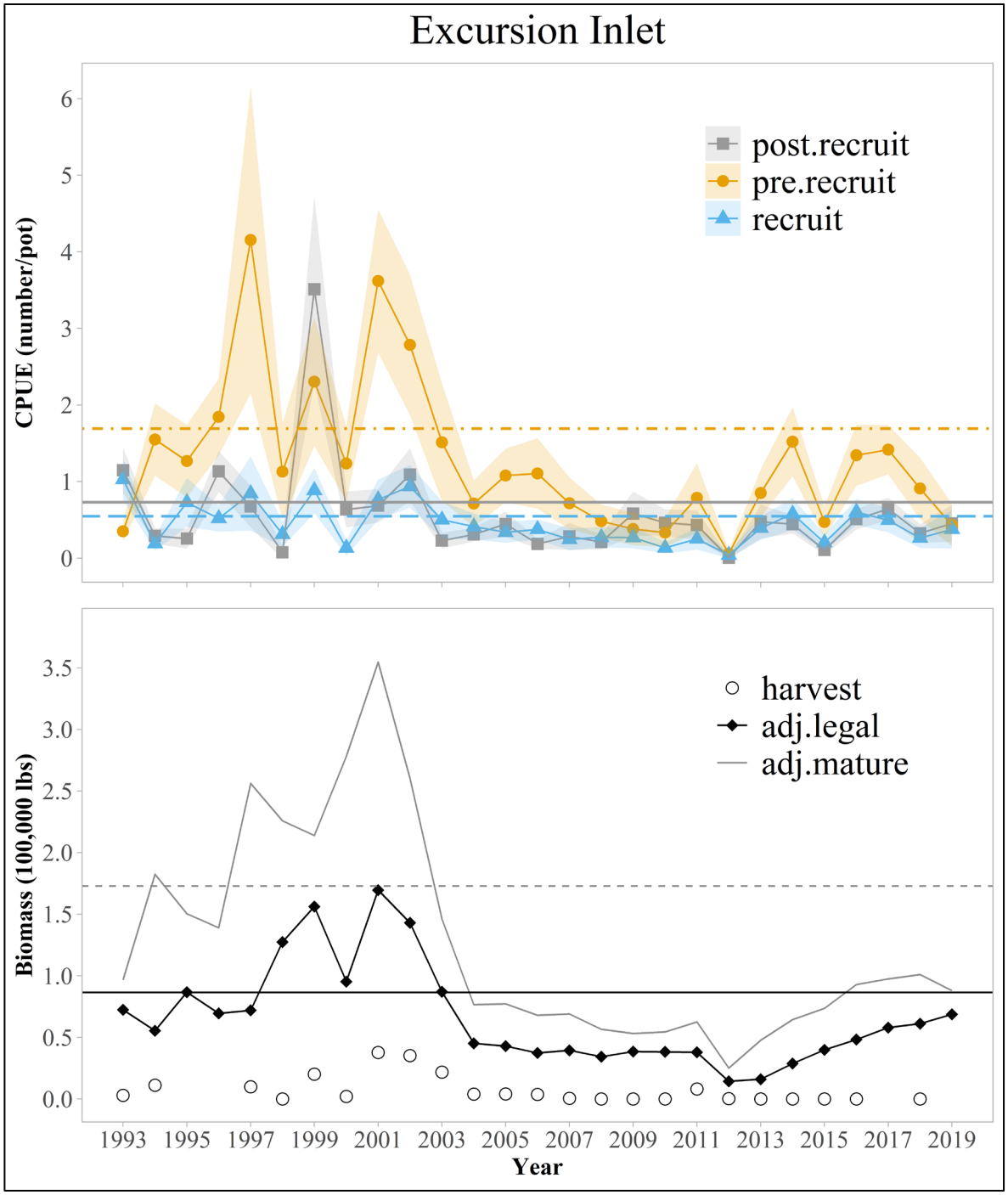

Figure 16.–Excursion Inlet CPUEs for male size/sex classes of red king crab, biomass estimates from the current year's CSA model and harvest data. Reference lines represent long-term baselines for each parameter (1993–2007). Gray dotted reference line in the biomass figure represents the long-term baseline for mature biomass, while the solid black refers to the legal biomass. There is a significant short-term decreasing trend in pre-recruit this year.

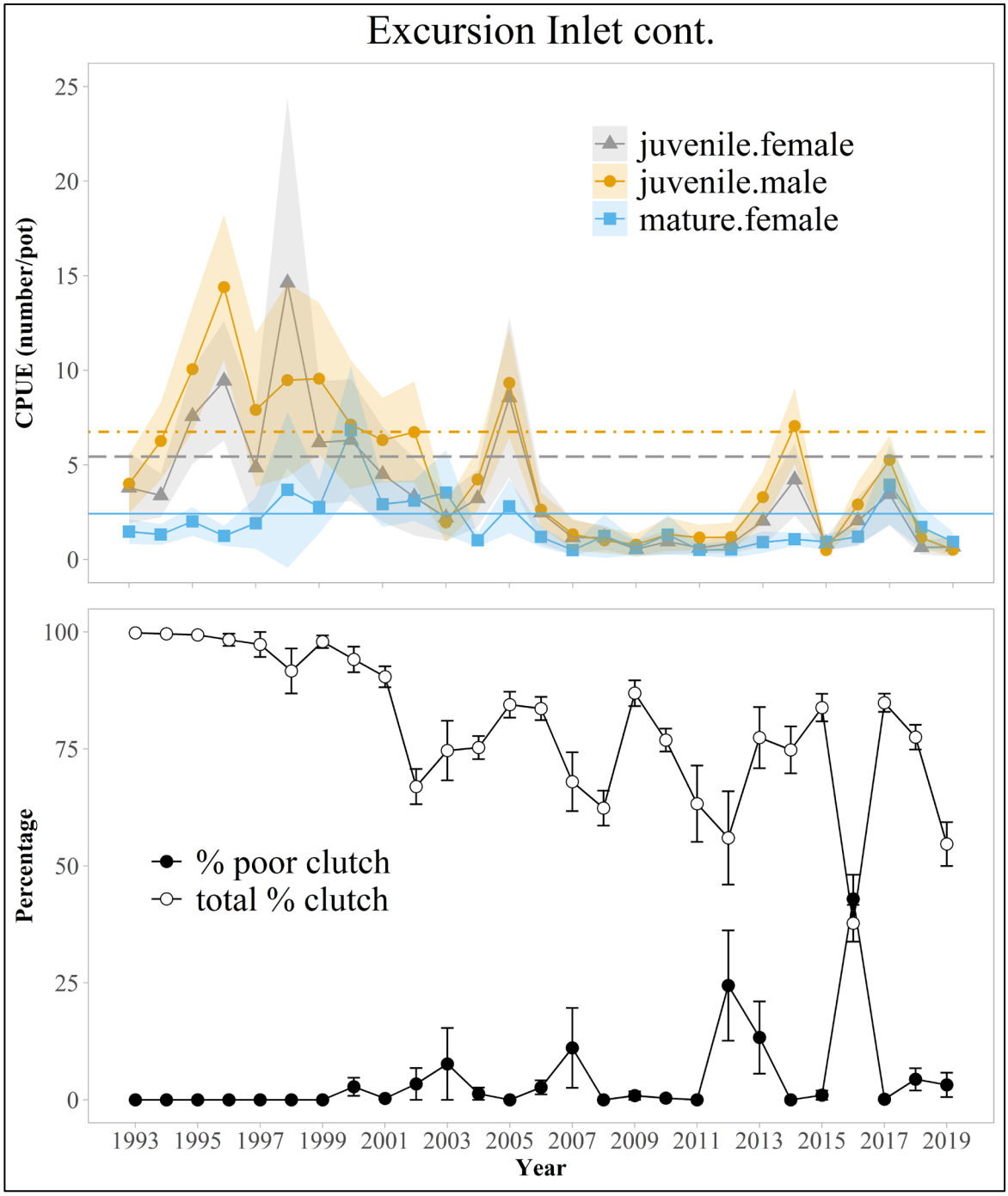

Figure 17.–Excursion Inlet CPUEs for female and juvenile male size/sex classes of red king crab, clutch fullness and proportion of poor clutches. Reference lines represent long-term baselines for each parameter (1993–2007). There are no significant short-term trends in juveniles or females this year.

APPENDIX A: REVIEW OF SOUTHEAST RED KING CRAB EXPLOITATION RATE DETERMINATIONS

INTRODUCTION

Calculating an appropriate exploitation rate for the red king crab fishery in Southeast Alaska is challenging. For many of the survey areas there is not a clear relationship between harvest pressure and population productivity, and furthermore, recruitment, as well as population growth, is highly variable over time. Previous documents have laid out the deficiencies in the Southeast RKC data and have provided some options for determining exploitation rates.

One such option is to calculate equilibrium exploitation rates; in 2011 and 2013, attempts to estimate these were performed using a linear regression of the change in population biomass vs the corresponding observed harvest rate. The results of those analyses were viewed as "equilibrium exploitation rates". Opening the commercial fishery in 2017 for the first time since 2011 prompted the need to revisit this analysis (using all years of the data), and to use this relationship to provide an estimate of the risk associated with alternative exploitation rates. The estimated equilibrium exploitation rates should be considered one tool to determine appropriate exploitation rates for each portion of the population. Other tools, such as the stock health matrix, should also be considered.

METHODS

Approach 1: Empirical method using CSA biomass estimates

An equilibrium exploitation rate is one that would, on average, result in no net change in population size (i.e. the population growth rate would be 0). In order to estimate this rate the observed harvest rate for a given year is related to the change in estimated biomass between that year and the next using a general linear model:

$$HR_{yr} = m(\Delta B_{yr}) + b \qquad \text{(Eq.1)}$$

where

HR_{yr} = the observed harvest rate of a given year,
ΔB_{yr} = the percentage change in mature biomass from that year to the next year,
m and b= the are parameters to be estimated (slope and intercept, respectively).

Harvest rates for each year are calculated by dividing the commercial harvest by the mature biomass estimate for a given year:

$$HR_{yr} = \frac{C_{yr}}{B_{yr}}, \qquad \text{(Eq. 2)}$$

where

C_{yr} = the observed catch (lbs) in a given year,
B_{yr} = the estimated mature biomass (lbs) in that year.

The change in biomass is estimated as:

$$\Delta B_{yr} = \frac{(B_{yr+1} - B_{yr})}{B_{yr}} \qquad \text{(Eq. 3)}$$

The mature male biomass estimates B are from the 2017 CSA analyses (biomass estimates change slightly each year due to the additional data added to the model).

The equilibrium exploitation rates are estimated based on the results of the linear regression analysis. In each area the harvest rate is regressed against the change in mature biomass (using all years that have biomass estimates) to estimate a linear relationship (Eq 1). The equilibrium exploitation rate is estimated from solving for x (harvest rate) where y (change in mature biomass) = 0 in this linear relationship.

Approach 2: Using the average observed harvest rate and the average change in biomass

If there is not a significant relationship between the two variables in the above regression the average harvest rate and the average biomass change over the entire time period were examined. Three possibilities arise: 1) if the average change in biomass is positive (the population is growing), then the average harvest rate may be below an equilibrium level, 2) if the average change in biomass is negative (population decline), then the average harvest rate may be above an equilibrium level, or 3) if the average change in biomass is zero, then the harvest rate is approximately at an equilibrium level. Therefore, the sum of the average harvest rate and the average biomass change can be used to predict an approximate equilibrium exploitation rate for the survey areas that do not have a statistically significant relationship between harvest rate and change in biomass.

$$\overline{HR} and \overline{\Delta B} = \overline{\Delta B} + \overline{HR} \qquad \text{(Eq. 4)}$$

Approach 3: Average harvest rate that has increased the population

An alternative way to examine an appropriate harvest rate for each survey area is to determine the average harvest rate that has produced an increasing population. For this analysis, sustainable is defined as a harvest rate that has resulted in an increase in the population size. Using the figures from approach 1 this is the average harvest rate of those points above the y (change in biomass) = 0 line.

Terms:

Exploitation rate (ER): the percentage of the estimated biomass that is available for future harvest

Harvest rate (HR): the observed fraction of the estimated biomass that was caught in the commercial fishery.

RESULTS

Equilibrium exploitation rate - linear regression approach

Table A1.–Equilibrium exploitation rate using mark-recapture adjusted mature biomass.

Area	Avg HR	Avg population change	p-value	r^2	equilibrium exploitation rate
Pybus Bay	0.061	0.122	0.026	0.127	0.115
Gambier Bay	0.040	0.006	0.008	0.178	0.042
Seymour Canal	0.012	0.023	0.014	0.152	0.014
Peril Strait	0.049	-0.020	0.246	0.036	0.037
Lynn Sisters	0.083	0.014	0.002	0.232	0.091
Excursion Inlet	0.038	0.081	0.015	0.149	0.058
Juneau	0.147	0.027	0.000	0.479	0.172

* Juneau calculations use CSA biomass since there is no mark-recapture adjustment.

Average equilibrium exploitation rate for all areas (unweighted and weighted by average mature biomass over the entire time series) is:

unweighted	weighted
0.076	0.101

Exploitation rate–all approaches

Table A2 summarizes both the equilibrium exploitation rate calculated in approach 1–3. For some areas (Peril, Lynn Sisters, Gambier, and Juneau) the two values for an estimate of equilibrium exploitation rate are the same or very similar (within one percent). For other areas there is a larger difference. Pybus, Seymour, and Excursion have average equilibrium exploitation rates that are approximately double those calculated with approach 1. With these two alternative approaches there is not an easy method to quantify risk of alternative exploitation rates on the population.

Table A2.–Exploitation rates using all three approaches.

Area	Avg HR	Avg population change	Approach 1	Approach 2	Approach 3
Pybus Bay	0.061	0.122	0.115	0.183	0.023
Gambier Bay	0.040	0.006	0.042	0.046	0.023
Seymour Canal	0.012	0.023	0.014	0.035	0.005
Peril Strait	0.049	-0.020	0.037	0.029	0.040
Lynn Sisters	0.083	0.014	0.091	0.098	0.034
Excursion Inlet	0.038	0.081	0.058	0.119	0.013
Juneau	0.147	0.027	0.172	0.174	0.077

* Juneau calculations use CSA biomass since there is no mark-recapture adjustment.

Unweighted average rates for the three approaches above.

Approach 1:	Approach 2:	Approach 3:
0.076	0.098	0.03

Weighted average rates for the three approaches above.

Approach 1:	Approach 2:	Approach 3:
0.101	0.116	0.043

The average exploitation rates for the survey areas are used as a exploitation rate for the non-surveyed areas with the assumption that these areas, on average, behave similarly to the survey areas. The weighted averages would be more appropriate than the unweighted ones, but both are presented here.

Risk assessment

During the discussion of opening the 2017 fishery there was a request to help assess the risk of fishing at a range of harvest rates (instead of just looking at the equilibrium exploitation rate). Assessing risk is complex because the linear relationship examined in approach 1 has substantal variability about it in most areas. However, a rough estimate of risk - in terms of the percentage of mature population decline - can be estimated from these relationships from each area's linear regression model. Three scenarios are presented here:

1) Increase in the mature male biomass(MMB) of 10%.

This is the estimated exploitation rate (ER resulting in a 10% increase in MMB) from approach 1 that may result in a 10% increase in the mature male biomass in the following year under average population conditions.

2) Decline in the mature male biomass of 10%.

This is the estimated exploitation rate (ER resulting in a 10% decrease in MMB) from approach 1 that may result in a 10% decline in the mature male biomass in the following year under average population conditions.

3) Impact of a 20% exploitation rate on the mature male biomass (MMB).

This is the estimated decline in mature male biomass (change in MMB associated with a 20% ER) in the next year that would result from a 20% harvest rate (historically the maximum harvest rate we've imposed on Southeast red crab populations) on mature male biomass under average population conditions.

Table A3.–Assessing risk in equilibrium harvest rates (shown as ratios).

Area	Approach 1	Approach 2	ER results in increase MMB (10%)	ER results in decrease MMB (10%)	Change in MMB from 20% ER
Pybus Bay	0.115	0.183	0.071	0.160	-0.190
Gambier Bay	0.042	0.046	0.018	0.065	-0.676
Seymour Canal	0.014	0.035	0.004	0.025	-1.779
Peril Strait	0.037	0.029	-0.024	0.097	-0.270
Lynn Sisters	0.091	0.098	0.035	0.148	-0.192
Excursion Inlet	0.058	0.119	0.033	0.082	-0.576
Juneau	0.172	0.174	0.079	0.266	-0.030

Figures : Area specific regression relationships

The following figures display the area specific regressions of observed harvest rate and change in mature biomass. Regression lines are shown in blue with their 95% confidence interval shown in gray shading. For all survey areas, except Juneau, the mature biomass used is the adjusted mature biomass using the mark-recapture survey results to adjust the CSA estimates. Three reference points are presented in each figure. The solid black line is the equilibrium exploitation rate from the regression analysis (approach 1). The dashed purple line is the alternative equilibrium exploitation rate calculated using approach 2 above. The dark grey dotted line is the average harvest rate in years with increases in mature biomass (approach 3).

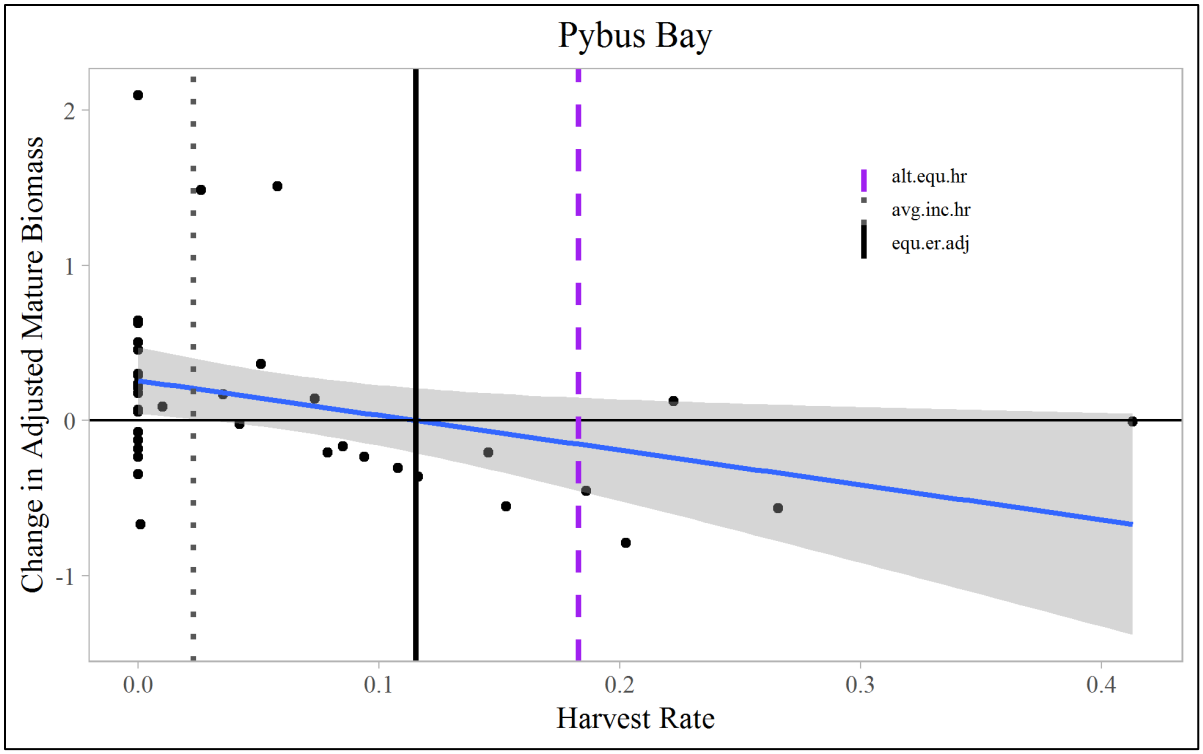

Figure A4.–Regression of observed harvest rates and change in mature male biomass for red king crab in Pybus Bay.

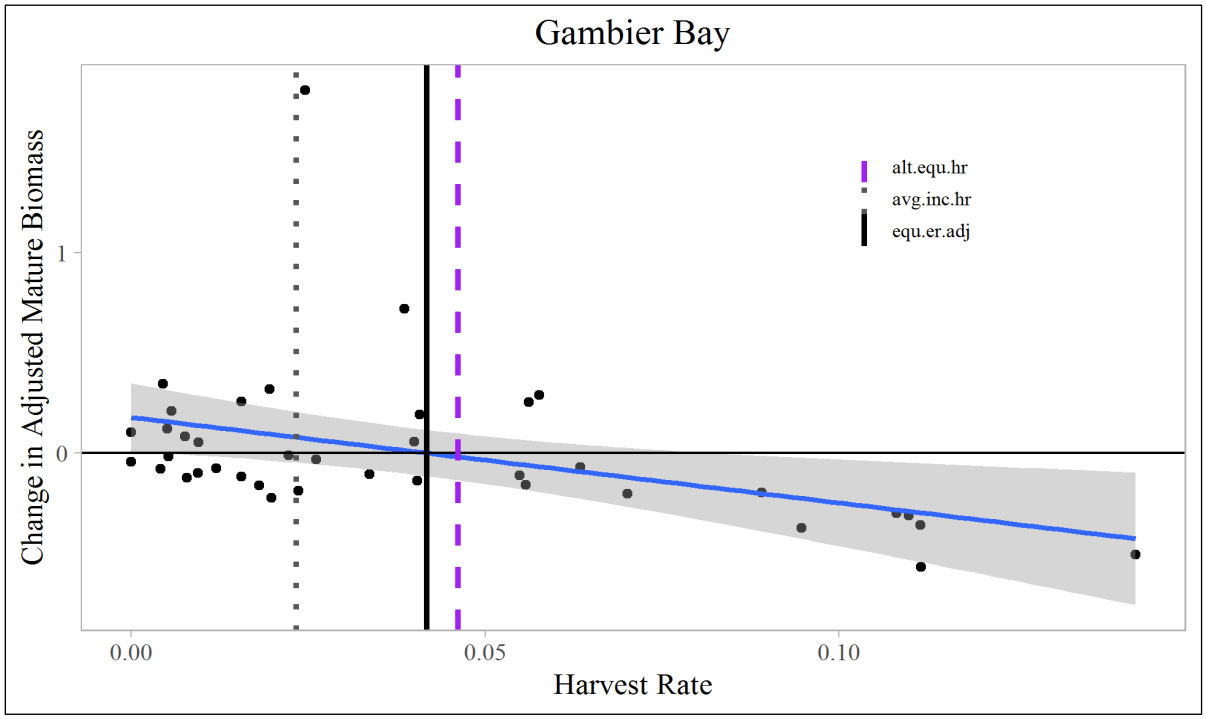

Figure A5.–Regressions of observed harvest rates and change in mature male biomass for red king crab in Gambier Bay.

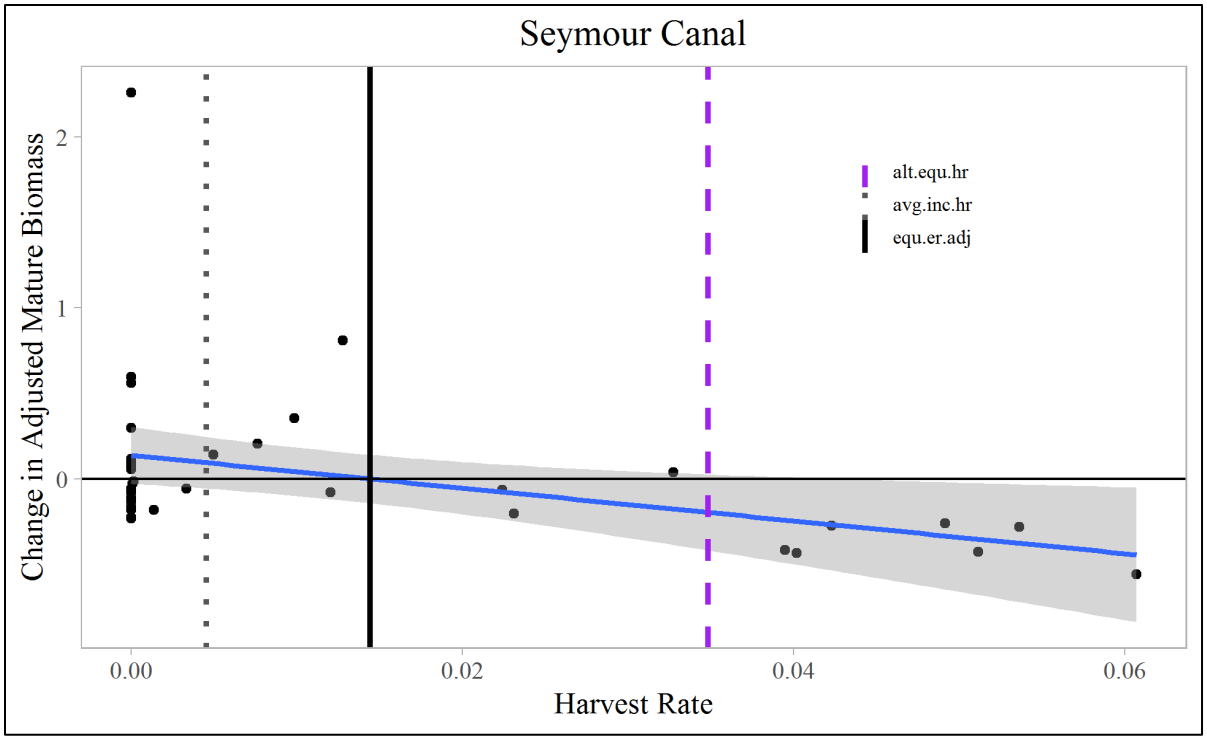

Figure A6.–Regression of observed harvest rates and change in mature male biomass for red king crab in Gambier Bay.

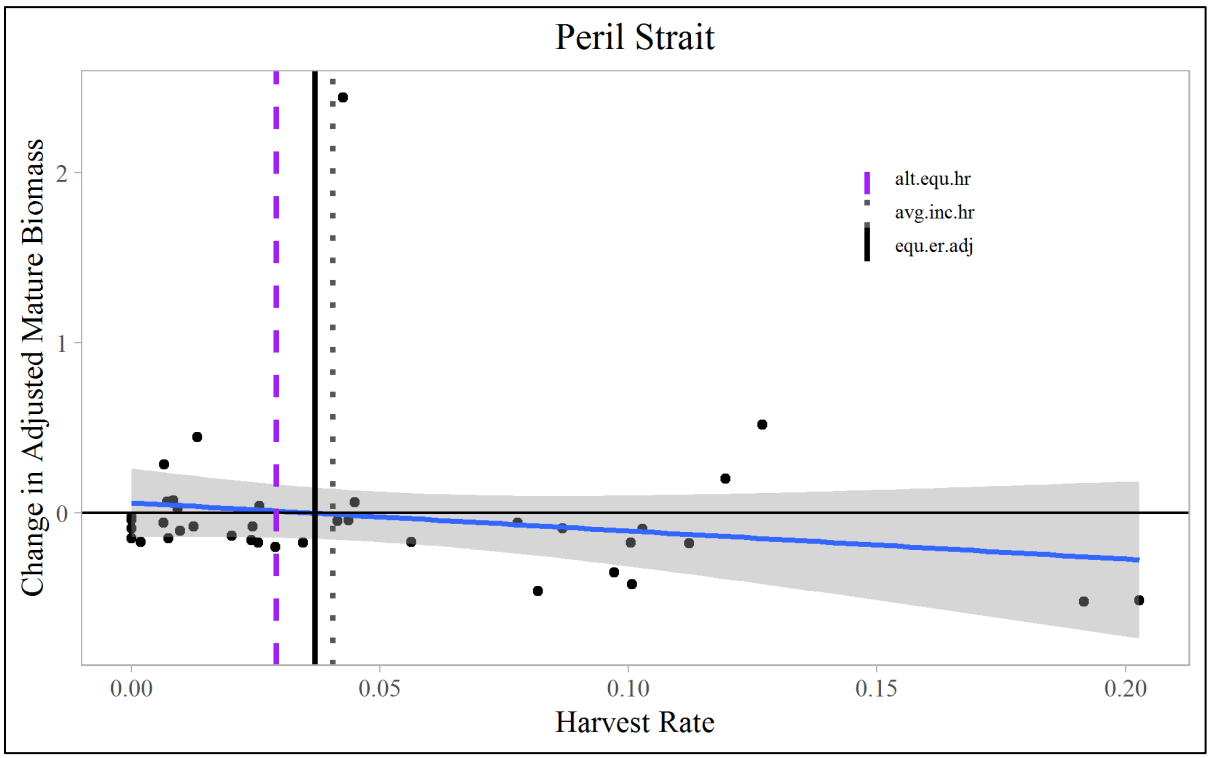

Figure A7.–Regression of observed harvest rates and change in mature male biomass for red king crab in Peril Strait. Regression for Peril Strait is not statistically significant.

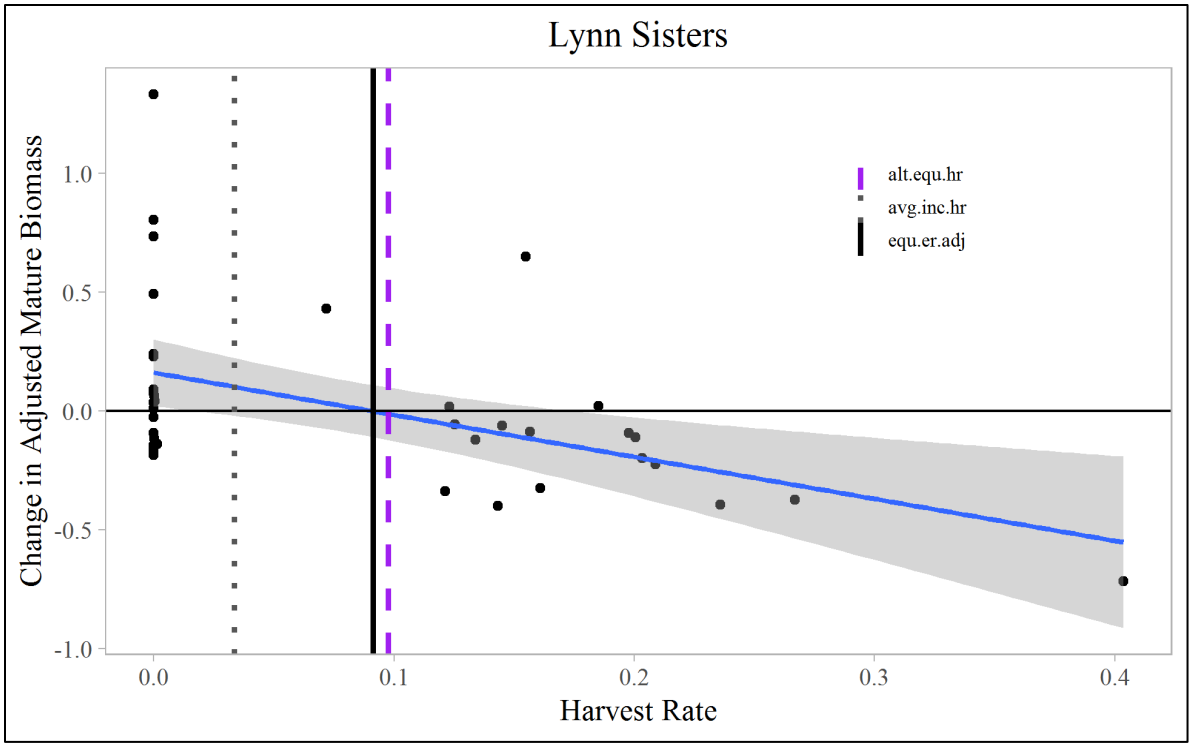

Figure A8.–Regression of observed harvest rates and change in mature male biomass for red king crab in Lynn Sisters.

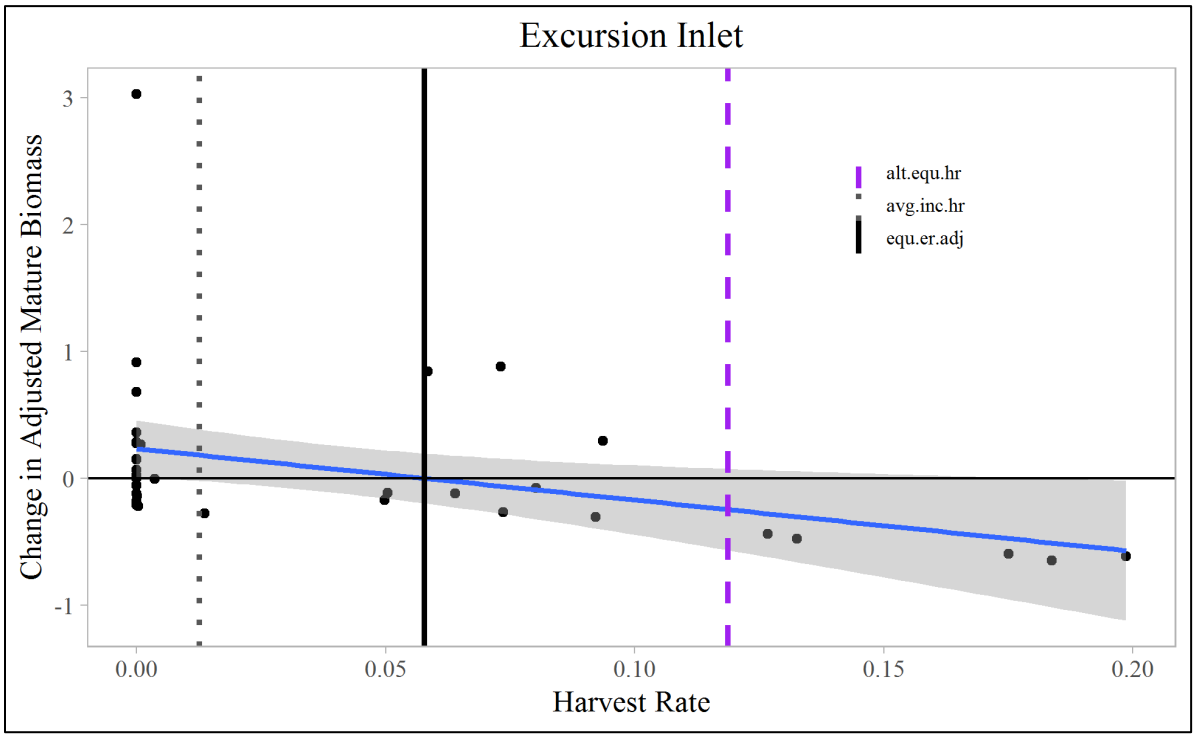

Figure A9.–Regression of observed harvest rates and change in mature male biomass for red king crab in Excursion Inlet.

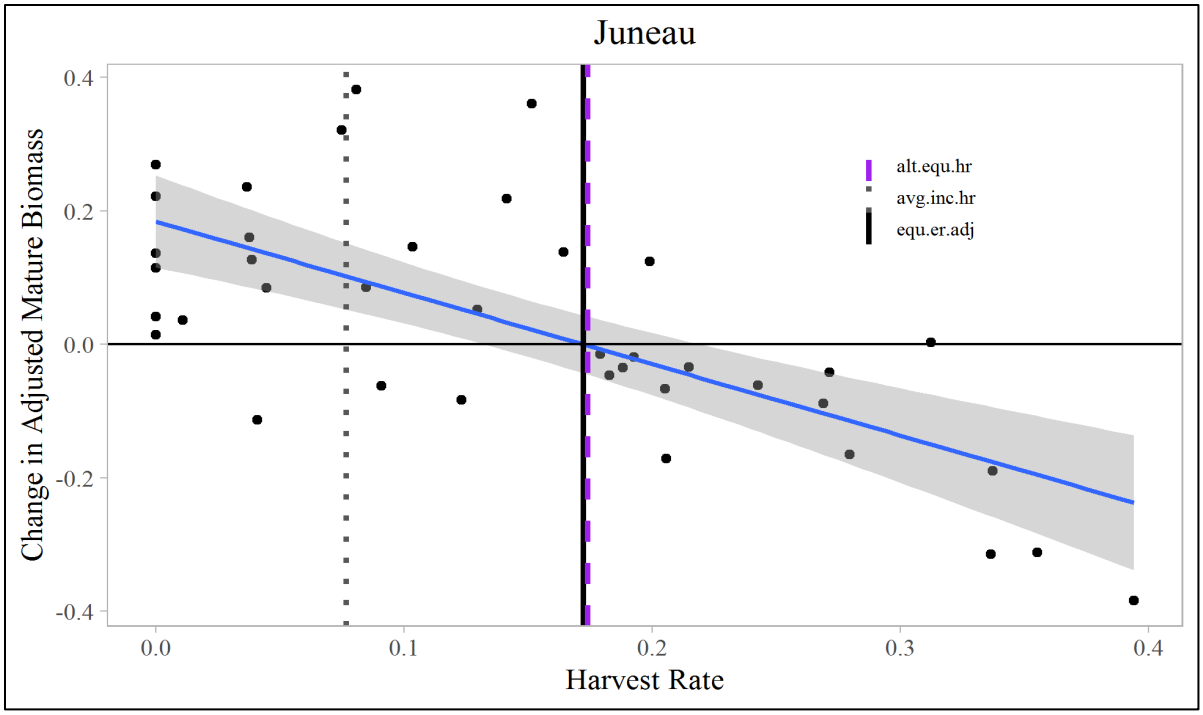

Figure A10.–Regression of observed harvest rates and change in mature male biomass for red king crab in Excursion Inlet.

RECOMMENDATIONS/ FUTURE WORK

For the 2018 stock health assessment for RKC in Southeast the three harvest rate options from Table 2 will be presented. Each of these options has risks and assumptions that need to be considered before they are chosen to calculate a GHL to use in the commercial fishery.

The equilibrium exploitation rate (calculated using approach 1) is considered the most risk neutral option with an equal probability of the mature male biomass decreasing or increasing in the following year after applying this level of harvest pressure. This option uses a regression model and therefore incorporates both the variability in the harvest rates and their associated change in mature male biomass. In theory, these harvest levels will maintain the equilibrium population size when the population is at equilibrium. For our purposes, equilibrium could be defined as the average baseline population size or a biomass that is sustainable over time. When the population is below equilibrium, harvesting at these rates will either maintain low population levels or, more likely, cause a decrease in population size.

The alternative equilibrium exploitation rate (Approach 2) which is the sum of the average harvest rate and the average change in mature male biomass, is considered the riskiest option. In theory this option should have an equal probability of the mature male biomass decreasing or increasing in the following year after applying this level of harvest pressure. However, this option only uses the averages of the harvest rates and the changes in mature male biomass over the entire time range, and therefore does not incorporate variability as well as the model output does in approach 1. Like approach 1 these exploitation rates will maintain the equilibrium population size when the

population is at equilibrium, but when the population is below equilibrium, harvesting at these rates will either maintain low population levels or, more likely, cause a decrease in population size.

The increasing harvest rate (Approach 3) uses the average harvest rate for years in which the mature male biomass increased, is considered the most risk adverse or conservative option with a high probability of the mature male biomass increasing in the following year after applying this level of harvest pressure. This option is just an average of the harvest rates that resulted in population increases, and therefore does not incorporate variability as well as approach 1. In theory, these harvest levels will increase the population size regardless of health of the stocks. However, during depressed stock health conditions even small harvest levels may still results in a decrease in population size.

Exploitation rates calculated from this analysis should be applied after considering the current state of the survey area that is it being applied to. These rates are based on a combination of many population sizes and conditions, and their resulting effect on population growth will be reflected as a combination of the harvest rate and the current health of the population.

Future work on this subject is needed to better understand how each survey area will respond to a range of harvest pressure. Future work may include: development of a method that incorporates mature biomass levels compared to long term averages into equilibrium exploitation rate considerations; development of a Bayesian approach to determining an appropriate exploitation rate; or exploration of time series effect on equilibrium exploitation rate analyses.