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Southeast Alaska Tanner Crab 2006 Stock Assessment and Recommendations for the 2007 Commercial Fishery

by

Chris Siddon,

Julie Bednarski,

and

Gretchen Bishop

March 2009

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)

Measures (fisheries)

fork length	FL
mid eye to fork	MEF
mid eye to tail fork	METF
standard length	SL
total length	TL

Mathematics, statistics

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

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Chris Siddon,
Julie Bednarski,
and
Gretchen Bishop
Alaska Department of Fish and Game, Division of Commercial Fisheries Douglas

Alaska Department of Fish and Game
Division of Sport Fish, Research and Technical Services
333 Raspberry Road, Anchorage, Alaska, 99518-1599

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Chris Siddon,
Julie Bednarski
and
Gretchen Bishop
Alaska Department of Fish and Game, Division of Commercial Fisheries,
802 3rd Street, Douglas, AK 99824 USA

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ABSTRACT

The abundance and stock health of Tanner crab in Southeast Alaska was assessed for the 2007 season. Both fishery-independent and -dependent data were collected; pot surveys were conducted in 13 separate areas and commercial logbooks, together with fish tickets provided estimates of daily catch and pot lifts.

Stock health for each area was determined as "Poor", "Moderate", or "Healthy" through examination of trends in survey clutch fullness and catch rates of various size and sex classes. We estimated the population size prior to the 2006 season using a Leslie depletion estimator, and predicted percent change in the population from 2006 using a Catch-Survey Analysis (CSA). Two management scenarios were examined, using maximum harvest rates of either the mean commercial harvest rate (from depletion estimates), or 50% of the estimated legal crab biomass. Harvest rates were adjusted to 100, 50, or 0% of the maximum for "Healthy", "Moderate", or "Poor" stocks, respectively. Combining the Leslie depletion estimation with the CSA percent change, and average crab weights, the regionwide population was estimated at 1.7 million lbs of legal crab. The harvestable surplus was estimated at 1.0 million lbs using mean commercial harvest rate, or 0.74 million lbs using 50% of legal crab as the maximum harvest rate.

The Southeast Alaska Tanner crab population is at its lowest level in 30 years; continued harvest at the current levels will not likely allow populations to rebound and will increase dependence on a few healthy areas. Four areas—Icy Strait, Thomas Bay, Glacier Bay, and Seymour Canal—produced over 50% of 2006 commercial harvest.

Recommendations to improve the current stock assessment are examined discussed. Most notably these include: post-stratification of RKC survey data for Tanner crab, utilizing the CSA model regionwide (as data allows), and re-examining long-term baselines.

Key words: Tanner crab, *Chionoecetes bairdi*, harvest rate, stock assessment, pot survey, Southeast Alaska, management, Leslie depletion estimator, Catch-survey analysis.

INTRODUCTION

Commercial fishery stock assessments are generally designed to estimate the total population abundance and health of the target species. From this, a surplus biomass available for commercial harvest is estimated that will provide for long-term sustainable use of the resource. To adequately accomplish this goal, unbiased estimates of abundance and stock health are required. These estimates are extremely difficult and costly to obtain, especially for wide-ranging organisms living in relatively inaccessible environments. Due to these difficulties, many logistically simpler methods have been used to obtain information regarding changes in population sizes and health (e.g., Golden King and Dungeness crab assessments in Southeast Alaska). A majority of these methods rely on fishery-dependent data (e.g., fish ticket and logbook), as it is the most easily collected. Due to the nature of commercial fishing, these data have a strong potential to be biased, although due to their large sample sizes they are generally quite precise. In contrast, scientific surveys are designed to provide unbiased estimates, but can have low precision due to relatively small sample sizes. In addition, surveys based on catch rates can often provide only a relative index of abundance and must incorporate fishery data to estimate actual abundance. Thus, many stock assessments, especially in marine systems, combine fishery-dependent and -independent (survey) data to produce the best population estimates from the available data (e.g., Red King crab stock assessment in Southeastern Alaska).

Data collection for the commercial Tanner crab (*Chionoecetes bairdi*) fishery in Southeast Alaska began with fishery-dependent data and has only incorporated fishery-independent data within the last decade. At the onset of the commercial fishery (1968) fish ticket data were collected with the addition of port sampling data in 1970. Additional fishery-dependent data was not collected until the implementation of logbooks during the 1994 season. Logbooks provided more detailed information on harvest and effort than fish tickets, but still have the same potential bias associated with them. The first scientific surveys designed to target Tanner crab in Southeast

Alaska were conducted in 1997. In addition, data on Tanner crab caught as bycatch in the department's Red King Crab Survey (RKCS) began to be used in the late 1990s (J. Clark, pers. comm.). However, with the sharp decline in commercial harvest in the late 1990s there was an increased effort to improve the stock analysis for Tanner crab.

Over the past decade, Tanner crab stock analyses have changed as survey methods changed and the quantity and quality of data have improved (Bednarski et al. *In prep.* a). Prior to 1997, stock assessments were based solely on trends in CPUE and effort data from logbooks and fish ticket data. Analyses were based on simple summary statistics and trends (Clark et al. 2001). From 1997 through 2006, stock health and estimates of relative abundance were examined using data from the Tanner crab survey (TCS) and the RKCS, while commercial logbook data was used to estimate commercial harvest rates and the time required to catch surplus crab. Catch-Survey Analyses (CSA) have been examined as an analysis tool; however the relative short time-series of survey data has hindered its utility in some surveyed areas. The effort to move towards an abundance-based estimate of surplus crab is underway and improvements will continue as the time-series increases.

In this paper we examine the fishery-independent and -dependent data for Tanner crab in southeastern Alaska to provide a biological recommendation regarding the harvestable surplus, while maintaining sufficient population sizes to provide for a long-term sustainable fishery. In addition, we developed an updated method to assess stock health that is objective and repeatable. Specifically, we quantify stock health, and estimate population abundance, harvestable surplus, and number of fishing days for 13 areas throughout Southeast Alaska, which constitute the majority of commercial fishing grounds. These estimates are then expanded to the entire region. To do this, we use survey CPUE, standardized commercial CPUE, Leslie depletion estimation, and CSA modeling (where appropriate) to best predict the changes in Tanner crab abundance for the 2007 fishing season.

METHODS

A combination of fishery-independent (surveys) and fishery-dependent (logbook, fish ticket, port sampling) data was collected to assess the overall stock condition and the relative changes in abundance of Tanner crab. Survey data provides an unbiased assessment of stock health and relative abundance. Logbook data also provides an estimate of population abundance (relative and absolute), and fish ticket and port sampling data provides corroborating evidence and the longest-term dataset to place current data into a historical context. In addition, survey and logbook data are combined into a CSA model, which predicts Tanner crab abundance for the upcoming season and its change from previous years' estimates.

DATA COLLECTION

Survey Data

Surveys are conducted in 13 separate areas throughout southeastern Alaska (Figure **1**). Six areas are surveyed to explicitly target Tanner crab, and 9 areas are designed to target red king crab, but have high levels of Tanner crab bycatch. Two of the areas (Stephens Passage/Juneau and Holkham Bay) are sampled on both surveys and largely overlap. Surveyed areas correspond with commercial fishing grounds that account for over 65% of the total Tanner crab harvest (25-year average). Survey methods for both the TCS and the RKCS are similar. Each area is divided into 1–5 strata based on the density of the target species (e.g., red king crab for the red king crab survey). Surveys are conducted as a random stratified sampling design with the number of pots (the sampling unit) allocated as a function of crab density and strata area. A few changes for both surveys have occurred over time, but there is little evidence that they bias the interpretation of survey results (Bednarski et al. *In prep.* a). Details regarding TCS, RKCS, and pot location generation methods are documented elsewhere (Bednarski et al. *In prep.* b, Clark et al. 2003). Differences between the TCS and RKCS methods include: different sampling dates, and bait. The TCS is conducted in the fall (October), whereas the RKCS is conducted in the summer (June-July). The Tanner crab survey uses an additional ½ of a round pink salmon as hanging bait.

Crab from each pot are counted and classified into size/sex categories by quantifying carapace width, sex, and shell condition (Jadamec et al. 1999). Size classes for males are defined as in Zheng et al. 2006: juveniles (< 109mm CW), prerecruits (109–137mm CW), recruits (newshell crab 138–169mm), and postrecruits (oldshell crab ≥ 138mm CW, and newshell crab ≥ 170CW). Females were separated visually into mature and immature size classes. In addition, a randomly selected subset of crab is weighed, and clutch fullness of all mature females quantified visually.

Fishery Data

In 1994, logbooks became mandatory and together with fish tickets (commercial harvest reports) provide estimates of daily catch and pot lifts for each day in the fishery for each area and each boat fishing (ring net vessels are not included in the logbook program).

Port sampling data provide overall harvest in pounds and the proportion of recruit to postrecruit crab caught in the fishery, and constitute a 37-year time series for the Tanner crab fishery. Similar to the survey data, the proportion of crab in each size category can be used to determine changes in population structure, but any categorization regarding stock health should be made in relation to its absolute magnitude. Although historical data is not an explicit part of the stock assessment, efforts were made to use data to place current data into context.

DATA ANALYSIS

All data were entered and stored in the Integrated Fisheries Database (IFDB), the ADF&G Southeast Region's Oracle-based database. Data analyses were done using JMP 6 (SAS 2005) or Microsoft Excel (CSA modeling).

Stock Health Determination

The overall health of Tanner crab populations for each surveyed area was assessed by comparing the current year's data to long-term and short-term benchmarks. This provides an objective and repeatable method for decision-making. Stock health for each area was determined through an examination of the following response variables: mature female clutch fullness and catch rate (CPUE), juvenile female CPUE, and prerecruit, recruit, and postrecruit male CPUE. These response variables provide a range of indicators of the population over different time scales: from very long (juvenile females; reproductive potential), long (clutch fullness and mature abundance), to short scales (legal males). In assessing stock status, each size/sex class was scored independently and weighted equally. Currently, there is no evidence to support weighting certain response variables more than others. If the current year CPUE (or clutch fullness) was significantly above the long-term average (defined below) it was scored +1, if not different than the long-term average it was scored 0, and if it was significantly lower than the average it was scored -1. Short-term trends (defined below) were scored as +0.25, 0, or -0.25 for significant increase, no change, or significant decrease, respectively. The area score was the sum of the long- and short-term scores for each response variable. Overall scores of less than -1.5 were assessed as "Poor" in stock status, -1.5 to 1.5 as "Moderate", and greater than 1.5 as "Healthy." For areas with both Tanner and red king crab surveys (Juneau and Holkham Bay), the score was determined as the average from each survey (but see Recommendations below).

The long-term benchmarks for the TCS consisted of the overall averages (for each response variable) since the survey began. It should be noted here that due to the relatively short history of this survey, the long-term average only ranges from 6 to10 years. In addition, the commercial harvest has been below its long-term average for the past 6 years, thus the long-term average may be too low of a benchmark and may be biased toward the "Healthy" designation (this should be re-evaluated over the next few years). The long-term benchmark for the RKCS consists of the 10-year average (1993–2002), which corresponds with a commercial harvest that is near the historic average of 1.5 million pounds. Current year's data is then compared to the long-term benchmark (a constant) using individual t-tests for each response variable. The short-term trend for both surveys was calculated as the change over the past 4 years (including the current year) using linear regression weighted by strata area.

Due to the relatively subjective nature of visually determining percent clutch fullness, we used a more robust (but lower resolution) response. Specifically, we quantified the mean proportion of mature females in each pot with clutch fullness of < 25% (i.e., obviously small clutches) weighted by the total number of mature females (in each pot). Due to the timing of the survey relative to Tanner crab life history, low clutch fullness is a rough proxy for fecundity and small clutches are indicative of reduced fecundity, not of recent egg hatching.

Population Estimates and Projections

Due to the relatively short time-series of Tanner crab survey data and the unknown effectiveness of the RKCS in estimating Tanner crab abundance, multiple analyses were used to provide the best interpretation of the available data. Specifically, we examined survey CPUE, standardized commercial CPUE, estimated population size and harvest rates using Leslie depletion estimator, and predicted percent change in the upcoming season's population estimate from the previous year using a CSA.

The majority of fisheries analyses are based on the assumption that the abundance (N) is proportional to catch per unit effort (CPUE):

$$N = \frac{CPUE}{q}, \qquad (1)$$

where CPUE is the total Catch divided by effort (E) and q is the catchability constant. This relationship predicts that a change in CPUE represents a proportional change in abundance. However, this assumes that q is constant even as total effort (E) and population size (N) change. However, catchability may not be constant due to pot competition, gear saturation or the biology or behavior of the target species (Caddy 1977; Brethes et al. 1985; Zhou and Shirley 1997b, 1997a; Zhou and Kruse 1999; Rumble et al. 2007). A more accurate representation of the relationship between N and CPUE is:

$$N = \frac{CPUE}{q(E^{\alpha} N^{\beta})}, \qquad (2)$$

where α and β are parameters to be estimated (Quinn and Deriso 1999). Although these parameters have not been estimated for Tanner crab populations, evidence suggests that there is pot competition and effort is inversely related to CPUE which would mean that $\alpha < 0$. Since alpha is currently unknown, the only way to remove the assumption regarding changes in effort is to hold effort constant. If effort is held relatively constant over all years, then the proportional relationship between CPUE and N is more likely to hold. The effect of N on CPUE cannot be resolved and thus we assume β equals 0.

Survey and Standardized Commercial CPUE

Survey and standardized commercial CPUEs were calculated for all of Southeast Alaska combined and for each surveyed area, and for each year that logbook data has been collected. Each CPUE provides an independent assessment of relative changes in Tanner crab populations.

ADFG survey CPUE for each size/sex class was calculated as a weighted mean based on area size. The CPUE has the same effort each year (n = 20–25 pots/strata) and thus only assumes that $\beta = 0$.

To calculate the standardized commercial CPUE, the total number of pot lifts was kept as close as possible. Identical effort was not possible because logbook data is collected each day. Therefore data was included for the total number of days, which most closely matched the number of pot lifts in the year with the fewest total pot lifts (i.e., effort). From this subset of the logbook data the standardized commercial CPUE is calculated simply as:

$$CPUE_{sc} = \frac{C}{E_s}, \qquad (3)$$

where the catch (C) is the number of crab caught divided by the standardized effort (E_s) . The standardized CPUE was calculated for each area where an ADFG survey (Tanner or RKC) exists.

Commercial and survey CPUE for legal Tanner crab were compared using correlation analyses for each area.

Since the surveys are conducted as a random stratified design, their CPUE is an unbiased estimate. However, the survey sample size is extremely small. In comparison, the pot locations from the commercial data are chosen explicitly by the fishermen to maximize their CPUE and may produce a significant bias. The commercial sample size, however, ranges from hundreds to thousands of pots, which represents a much better sample size. The potential bias of the commercial data would be extremely large if Tanner crab populations were highly aggregative (i.e., hyperstable, $\beta < 0$). Due to these trade-offs there is no way to decide which index is best, so both are used. However, the survey CPUE provides information on the upcoming season, whereas the commercial CPUE can only be used for retrospective analysis.

Leslie Depletion Estimator

The Leslie depletion model (Seber 2002) was used to estimate population size and commercial harvest rates within each subdistrict after completion of the commercial season. The model states that:

$$CPUE(t) = -qK(t) + qN, \qquad (4)$$

where CPUE(t) is the crabs/pot lift, q is the catchability coefficient, N is the total number of legal crab in the population and K(t) is the cumulative commercial catch at time t. CPUE decreases over time as crab are caught and we estimate N at the point where the CPUE is zero (if CPUE is zero then theoretically all of the crab have been caught and K(t) = N). The estimator is well known and widely used with fishery-dependent data (e.g., logbooks). Although this method has its shortcomings, its simplicity and utility continue to make it a useful tool for estimating abundance from CPUE data (e.g., it was used in a re-evaluation of Tanner crab stocks by the Kodiak ADFG regional office). The estimator has four main assumptions:

1. The population is closed (except for fishery removals)
2. All individuals have the same probability of being caught
3. The catchability coefficient is constant (no pot competition, α, $\beta = 0$)
4. All commercially viable areas within a given subdistrict are being fished each year

The first assumption is reasonable as the season has been so short that the probability of migration or natural mortality over this time period is negligible. Also, the probability of prerecruit crabs molting into legal crab during the fishery is remote. The second assumption cannot be evaluated; however there is no evidence that certain legal male crab are caught preferentially. The third assumption may not always hold, as changes in gear density, bait quantity and frequency of pot pulling between the beginning and end of a commercial season, would lead to inseason changes in catchability. However, over the majority of the fishery (of a given year and location) a similar number of pots are lifted each day, making the issue of pot competition (and thus constant catchability within a season) a relatively minor concern. The fourth assumption could significantly underestimate the true population abundance especially in years with very short seasons. However, a preliminary examination of depletion estimators in years with season lengths of 8 days or more suggests that this concern is also minor (ADFG unpublished data).

The depletion estimator analysis was done using linear regression where q is the slope and qN was the y-intercept. Harvest rates are then calculated as (total commercial harvest/estimate of total legal crabs*100). Due to the potential effect of a variable number of pot lifts within a given subdistrict and season, the regression analyses were weighted by pot lifts. Thus, the sampling unit was defined as the CPUE (total crab caught/# of pot lifts) of a fisherman on a given day weighted by the total number of pot lifts of each fisherman.

In addition to individual bay estimates, the regionwide population was estimated through expanding the sum total of the estimates to include all areas in which Tanner crab are harvested. Comparisons of the total harvest from surveyed areas to total harvest in Southeast Alaska showed that 60% of the harvest is taken from surveyed areas (25-year average). Therefore the regionwide population estimate was calculated by scaling the harvest in surveyed areas to 100% (i.e., dividing by 0.60).

Catch-Survey Analysis Model

The CSA model utilizes both survey and commercial harvest data to estimate the total abundance and the percent change (from the previous year) of crab for each area where a survey was conducted. A detailed description of a two-stage CSA model can be found in Collie and Kruse (1998). Our CSA model expands their method to a three-stage (prerecruit, recruit, and postrecruit) model[1]. The CSA model uses commercial harvest to estimate the survey catchability and smoothes out CPUE data due to random yearly variability. Due to the relatively short time periods of the survey data and some seemingly inconsistent results for some survey locations, the CSA model was only used to calculate percent change of Tanner abundance from the previous year. This change was then used in combination with population estimates from the Leslie depletion estimator to predict the current year's abundance. The percent change was also compared with the percent change calculated from the survey CPUE data—either with all bays or only those which had a significant correlation with the commercial CPUE data.

MANAGEMENT SCENARIOS

From the combination of population estimates, stock health determination, and past commercial effort, multiple management scenarios were examined. Harvestable surplus was calculated by adjusting the maximum designated harvest rate by the stock health. Adjusted harvest rates are calculated as 100, 50, or 0% of the maximum harvest rate for "Healthy", "Moderate", or "Poor" stock health, respectively. Maximum designated harvest rates were defined as either the mean commercial harvest rate, or at 50% of legal—the maximum allowable harvest rate on legal size crab currently used in Alaskan Tanner crab fisheries (Hebert et al. 2005). For each harvest rate scenario, the number of fishing days required to catch, but not exceed, the estimated surplus was calculated based on cumulative catch curves of the previous year.

RESULTS

HISTORICAL/REGIONAL OVERVIEW

Catch and effort data collected from fish ticket data show considerable fluctuations since the beginning of the fishery in 1969 (Figure **2**). The number of pot permits ranged from less than 20 to nearly 100, while total harvest in Southeast Alaska ranged from less than 500,000 lbs to peaking at over 3 million lbs in 1982. The long-term average harvest is 1.5 million lbs and the harvest for the past 4 years has been just over half the long-term average. Although effort has decreased substantially over the past decade, the decline in harvest cannot be totally explained by the reduction in effort (Figure **3**).

Regional CPUE from both survey and commercial data show high CPUE in the late 1990s with a dramatic decrease in CPUE through 2003 (Figure **4**). After 2003, the commercial CPUE shows a slight increase in CPUE (from 15 to 17 crab/potlift), while the survey CPUE is relatively stable. Commercial harvest also shows a very similar pattern to both CPUE estimates.

SURVEY AND STANDARDIZED COMMERCIAL CPUE

Survey and commercial CPUE data provide independent assessments of relative Tanner crab abundance for each bay and year. Survey CPUE data show a general decline for Icy Strait, Stephens Passage, Port Camden, Gambier Bay, and Port Frederick over the past decade. Survey CPUE for Thomas Bay showed a general increase over the same time period, with more dramatic increases for Glacier Bay and Seymour Canal over the last 2 years (Figure **5**,Figure **6**). Data from the standardized commercial CPUE show more variable catch rates in general. However,

[1] Personal Communication, Jie Zheng, Alaska Department of Fish and Game, Division of Commercial Fisheries, Juneau, from a study estimating Southeast Alaska Tanner crab abundance using port survey and commercial catch data.

dramatic decreases in CPUE are seen in Holkham Bay, Port Camden, and Gambier Bay. For example, the commercial CPUEs for Holkham Bay and Port Camden were more than 40 legal crab/potlift in the mid to late 1990s and are currently less than 20 legal crab/potlift. Comparisons between survey and commercial CPUE show strong correlations for Icy Strait, Juneau, Gambier Bay, Seymour Canal, Excursion Inlet, and Peril Strait (Table 1).

MODELING

Results from the Leslie depletion modeling estimates 615,000 legal male Tanner crab throughout Southeast Alaska prior to the February 2006 fishery (Table 2). Harvest rates in 2006 ranged from 54–87% and were comparable to the long-term averages (1996–2006; Table 2). Of the six areas surveyed in the TCS, Stephens Passage, Holkham Bay, and Port Camden are at their lowest estimated abundance since 1996. Since Holkham Bay and Port Camden have been closed since 2005 and 2006, respectively, their population estimates were based on the last year commercial fishing occurred. The only bay with an abundance estimate above its 10-year average is Thomas Bay.

Predicted change of Tanner crab populations from 2006 to 2007 were calculated using the CSA model, and directly from survey CPUE data. Changes from the CSA analyses showed decreases of nearly 20% for Icy Strait and Holkham Bay and increases greater than 40% for Glacier Bay and Seymour Canal (Table 1). Changes from survey CPUE data showed more marked changes between years ranging from -25% to 250% (Table 1).

Combining the Leslie depletion estimators of population abundance with the percent change in abundance, and the average crab weights for the upcoming year (2007), we projected the total abundance of legal Tanner crab for each area and regionwide (Table 2). The regionwide abundance was 619,000 crabs with a total weight of 1.7 million lbs. Abundance by area varied considerably, with Icy Strait accounting for 20% of the total abundance, followed by Thomas Bay, Glacier Bay, and Seymour Canal, which each contributed approximately 10%.

STOCK HEALTH

Of the 15 total surveyed areas, 5 were designated “Healthy”, 4 were “Moderate”, and 6 were “Poor” (Table 3). CPUE and clutch fullness varied markedly among size/sex categories, bays, and years (Table 3, Appendix A1 through Appendix A6). Glacier Bay and Seymour Canal showed consistently greater CPUE than their long-term benchmarks and significant increases in CPUE over the past 4 years for mature crab. Conversely, Holkham Bay showed significantly lower CPUE compared with the long-term and a continued decreasing trend over the short-term for many size/sex classes.

MANAGEMENT SCENARIOS

Two different management scenarios were used to estimate the regionwide harvestable surplus; it was estimated at 1 million pounds using mean commercial and 0.74 million pounds using 50% as the maximum harvest rate (Table 4). Under a mean commercial harvest rate scenario, a season length of 7 fishing days for Glacier Bay and Seymour Canal, and 6 days for Pybus Bay would be required to catch the surplus and fishing days were estimated at 3 and 2, respectively for Icy Strait and Thomas Bay—the 2 other “Healthy” areas. All other areas would exceed the harvestable surplus with only 1 day of fishing. Utilizing a maximum harvest rate of 50% reduced the number of fishing days for the “Healthy” areas by 0 to 3 days (Table 4).

DISCUSSION

REGIONWIDE OVERVIEW

Commercial harvest for the past 4 years has been below 0.9 million lbs. This is 59% of the long-term average harvest (1.5 million lbs) and is the lowest harvest in 30 years (Figure 2). Although there has been a significant decrease in commercial effort (Figure 2), this is not sufficient to account for the dramatic decrease in harvest since 1998 (Figure 2, and Figure 3). This observed decline is then due to a decrease in Tanner crab abundance (i.e., natural and/or fishing mortality has exceeded recruitment). The regionwide population estimate for 2007 is 1 to 3% greater than in 2006, which translates into an increase of approximately 5,000 legal crabs or 14,000 lbs (Table 2).

Mean predicted changes in abundance vary from 3 to 41% depending on how they are derived (Table 1). The CSA model uses both survey and commercial fishery data, takes into consideration three (prerecruit, recruit, and postrecruit) size classes of crab, and provides a best fit data over multiple years by smoothing the data. This translates into harvest rates that are estimated using the most data and with the ability to dampen inaccurate estimates due to sampling error. Predicted change using survey data relies on a more limited data set and is more susceptible to over- or under-estimating the change due to sampling error from small sample sizes. For example, large one-year increases in survey CPUE in Glacier Bay and Seymour Canal produced dramatic effects on the regionwide population change (Table 1). Because of this, an additional estimate of population change was calculated using only the areas, which showed a significant correlation between survey and commercial CPUE. If a strong correlation exists, we assume that the survey CPUE, which is inherently unbiased, is also relatively precise. The lack of a strong correlation could arise either due to low precision of the survey CPUE—due to low sample sizes, or due to inaccuracy (i.e., bias) of the commercial CPUE—due to targeting only a small and highly productive portion of the total survey area (i.e., crabs are highly aggregated). However, currently only 6 of 13 areas show a strong correlation between survey and commercial CPUE (Table 1). Due to the large amounts of data, relatively long time series, and thus the ability to dampen sampling error, the estimate of population change from the CSA model is the most appropriate. In addition, the lack of correlations in 7 areas suggests that they would benefit the most from increased sampling and/or restratification.

Although we conducted no detailed analysis of what an appropriate harvest rate is for each area, decreasing abundance estimates in some areas (Table 4), highly variable CPUE (Figure 4, Figure 5, 6), and maximum harvest rates from other regions (Zheng and Kruse 1999a, 1999b) all suggest that harvest rates in Southeast Alaska are too high. Due to the uncertainty of our estimates, setting a maximum harvest rate of 50% of legal is warranted, but may still be too high.

AREA BY AREA OVERVIEW

Although there was little change from 2006 to 2007 in the regionwide population estimate; marked variability among areas and between years is evident (Table 2). Four of the 13 areas surveyed were responsible for over 50% of the commercial harvest in 2006, respectively, they were: Icy Strait: 25%, Thomas Bay: 12%, Glacier Bay: 8%, and Seymour Canal: 8%. The Stephens Passage and Excursion Inlet areas each accounted for approximately 5% of the commercial harvest, while each of the remaining areas were responsible for 1% or less of the total harvest.

Icy Strait is one of the most productive Tanner crab fisheries in Southeast Alaska, yet one of the smallest survey areas and fishing grounds. The projected abundance for 2007 is 20% of total estimated legal Tanner crab in Southeast Alaska. This proportion of crab already accounts for the 18% decrease in abundance compared to the previous year. Although the overall health determination was “healthy”, the CPUEs for all the male size classes except postrecruits were below the long-term benchmark (Table 3). In addition, if short-term trends continue, next year’s stock health determination may be defined as “Moderate”. This small but productive area has become the backbone of the Tanner fishery over the last decade, but evidence suggests that this may not continue without consistently high recruitment levels.

Thomas Bay, the second largest producer in 2006 (Table 2), continues to show strong evidence of a healthy population. Population projections show a stable population and CPUEs for all size/sex classes except small females were greater than their long-term benchmarks (Table 3). However, as mentioned earlier, this benchmark is not necessarily appropriate due to its short time series.

Glacier Bay showed a dramatic increase in CPUE for all size/sex classes in the 2006 survey (Table 3, Appendix A1 and Appendix A2). CPUE in previous years was consistently low and nearly doubled during the 2007 survey. This increase had marked effects on the regionwide projection (Table 1) but due to the partial closure of Glacier Bay and to effort limitations in the portion of the Bay that remains open, the surplus crab are not available to all permit holders for harvest. This combination of factors must be considered when examining Tanner crab population trends at a regional level. For example, the predicted population change (from the CSA model) increased 3% region-wide, however if Glacier Bay is excluded, the predicted population is decreased by 2% (Table 1). Caution must be taken not to let improvements in this stock bias the region-wide analysis of Tanner crab stocks in Southeast Alaska. If Southeast Alaska Tanner crab stocks continue to be managed at a regional level, the increase in abundance in Glacier Bay combined with effort limitations may compensate for declines in the rest of the region, leading to an even greater harvest pressure on those areas. Thus, if the Glacier Bay stock continues to increase, a separate management strategy may be necessary to take advantage of the harvestable surplus.

Seymour Canal showed a similar increase in CPUE to Glacier Bay. After many years of consistently low CPUE (Appendix A3 and Appendix A5) and low commercial effort, CPUE for prerecruits and recruits doubled (Table 3). This increase led to a CSA-predicted increase in legal male crabs of 64% for the 2007 season (Table 1).

Of the remaining areas, Pybus Bay was the only one to be designated as “Healthy” and this was due to high CPUEs of females, juvenile males, and pre- and postrecruits (Table 3). This increase translated into a CSA-predicted increase of 46% in legal male abundance (Table 1).

The areas that were designated as “Moderate” (Lynn Canal, and Peril Strait; Table 3) had predicted population changes of -11% to +2% for legal crab (Table 1).

Port Frederick, Port Camden, Excursion Inlet, Stephens Passage, and Holkham Bay all were designated as “Poor” (Table **3**), and thus should be closed to harvest.

MANAGEMENT SCENARIOS

By assuming that magnitude and distribution of fishing effort for the previous and upcoming season were similar, we were able to predict the number of days in each survey area required to harvest the estimated surplus Tanner crab. With the maximum of the tiered harvest rate set at either mean commercial, or at 50%, seven survey areas would exceed the harvestable surplus if allowed to fish for 1 day and thus no fishing is recommended for these areas (Table 4). Of the remaining areas, only Glacier Bay and Seymour Canal are predicted to have fishing seasons longer than 5 days— which is the previous year’s season length—and only Glacier Bay could sustain a 5-day fishery if a maximum harvest rate set at 50% were used (Table 4). These results show the extreme effectiveness of the commercial Tanner crab fleet and the low population sizes in a majority of Southeast Alaska fishery areas.

CONCLUSIONS AND RECOMMENDATIONS

The Southeast Alaska Tanner crab population is at its lowest level in 30 years with few signs of improvement and many signs of continued declines throughout the region. The ability for 4 healthy areas (out of 13) to continue to provide a long-term sustainable fishery is tenuous with current levels of commercial effort. In addition, with the limited access to fishing in Glacier Bay, the increases seen there are not available to the majority of the commercial fleet. Continued harvest at the current levels will not allow Tanner populations to rebound to earlier levels and will increase the dependence of a sustainable fishery on fewer and fewer healthy areas over time.

Recruitment of Tanner crab is currently difficult to address due to the survey design. Currently, the TCS is designed to target legal male Tanner crab, and the RKCS is designed to target red king crab, not juvenile and female Tanner crab (Appendices 2, 5, 6). This does not allow a reasonable assessment of recruitment pulses of juvenile males, nor how they transition (i.e. survive, grow, and move) to legal Tanner grounds.

As with any stock assessment, continued evaluation of, and improvements to, current methods are required. From this year’s assessment a number of recommendations for subsequent analyses arose. First, a continued effort to incorporate the CSA model as the main tool for stock assessment should be made. Realistically, however, this may be a few more years off as a number of areas are still data limited and model results do not converge. Second, the long-term benchmark for stock health determination for the TCS needs to be re-evaluated. As stated earlier, it is based on all the available data, which correspond to a time period of below average commercial harvest and therefore may be too low. An attempt to estimate a more appropriate benchmark should be attempted and incorporated into the stock health determination. Third, the Tanner crab catch from the RKCS should be examined to create appropriate strata that are based on Tanner crab rather than red king crab. Restratification should increase the precision of our estimates of Tanner abundance using the CSA model. This should be able to be accomplished by post-stratifying Tanner data without changing or influencing the current improvements made to the RKCS design.

In reviewing RKCS data it became apparent that some RKCS areas produce more consistent and accurate results than others. Criteria should be developed to determine which RKCS areas Tanner crab bycatch will be analyzed for stock health and CSA modeling. For some areas, these inconsistent results could be explained if Tanner crab bycatch rate in the RKCS for areas with high red king crab catch rates were an inverse function of red king crab abundance rather than a function of Tanner abundance.

The RKCS and TCS overlap in Holkham Bay and in the Stephens Passage area. A decision should be made as to how the results from these two areas will be incorporated in both the stock health determination and the CSA modeling. Consideration should also be given to reducing the overlap in the respective surveys.

Consideration should be given to refining the protocol for selecting crabs for weighing onboard the RKCS and TCS to assure that a representative sample of weights is obtained. Currently, only male crabs without missing legs are weighed, however a significant proportion of males are missing legs. This results in the average weight measurement being biased slightly high. This current method is calculated as the regressed weight of each carapace width weighted by the number of crab caught at that width (Bednarski et al. *In prep.* b). If the protocol were refined to randomly select crabs for weighing regardless of leg loss, then mean weight could be determined as a function of both carapace width and leg loss, as both are recorded for each crab sampled.

In this report, we provide recommended harvest levels by survey area and for the region as a whole; however, the department has been unable to accurately target a GHL inseason. This is largely because of the intensity of the modern fishery and the small suite of management tools available. Currently the only way to limit the magnitude and distribution of effort is through season length and area closures. Thus, without additional management tools, it is not possible to accurately target even regional GHLs to provide for recovery of the stock. Management tools that might provide some additional ability to target very small, recommended harvest levels would include: tiered pot limits tied to GHLs, hauling hours, or district registration. Alternatively, if effort limits and area closures prove unworkable, a harvest threshold could be put in place to prevent the stock from declining below the level at which regional management by season length alone is effective.

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TABLES AND FIGURES

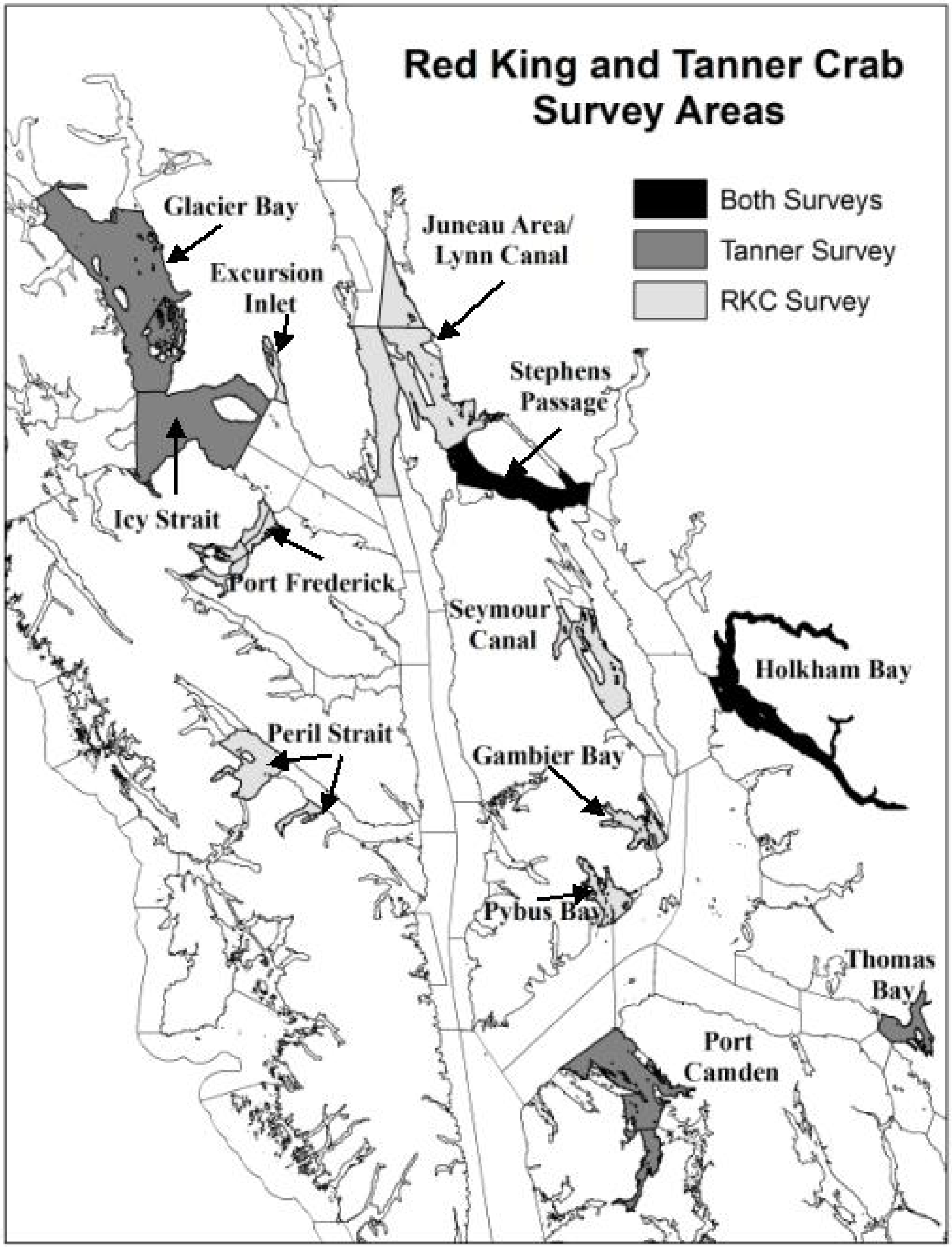


Figure 1.–Red king and Tanner crab survey statistical areas in Southeast Alaska, ADFG Registration Area A.

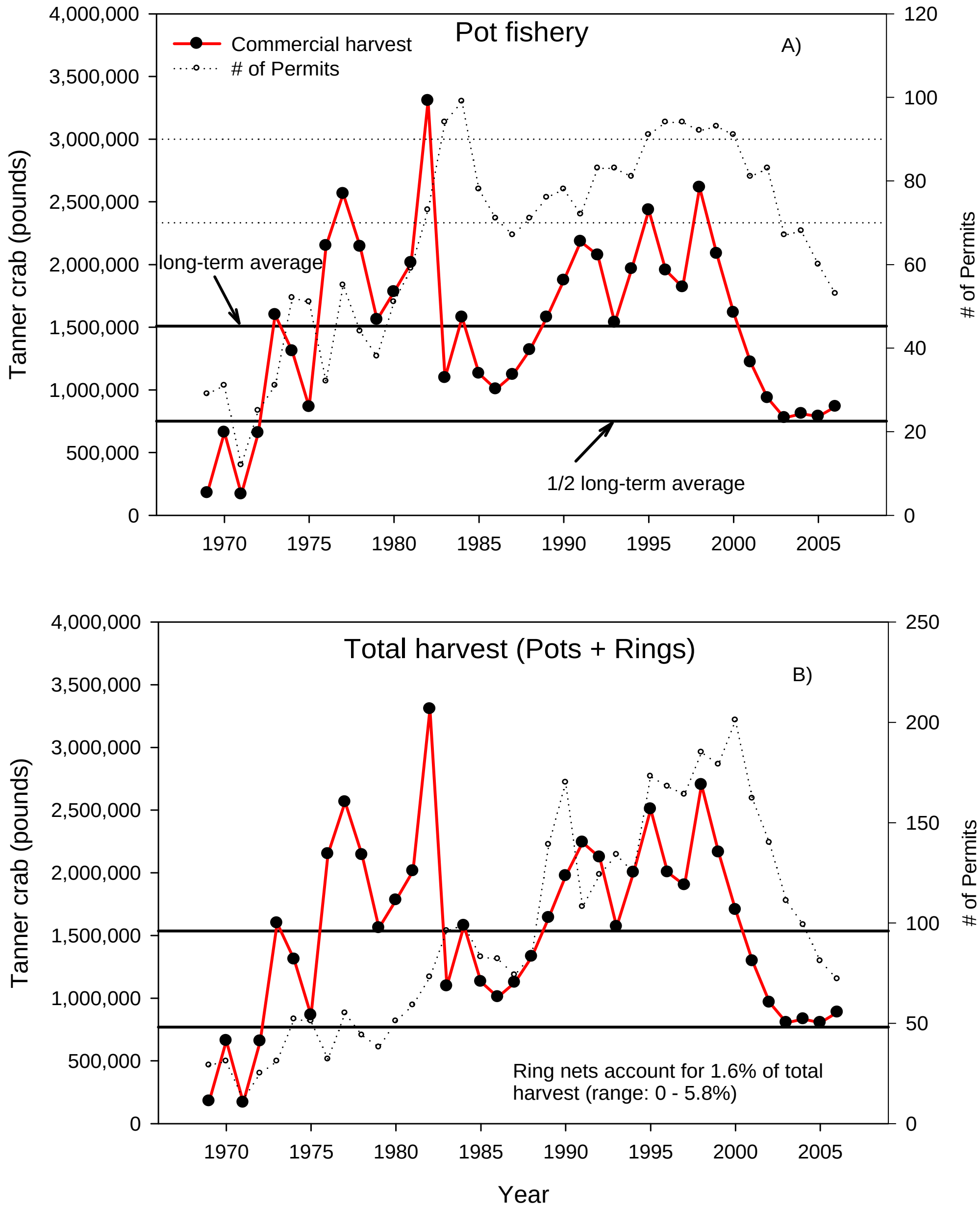


Figure 2.–Commercial harvest of Tanner crab in Southeast Alaska (excluding Yakutat) for A) pot fishery only and B) pot and ring net fisheries combined. Solid black reference lines correspond to the long-term (all years) and ½ of the long-term average, respectively. Dotted lines represent 90 and 70 permits. There is no correlation between catch and number of permits.

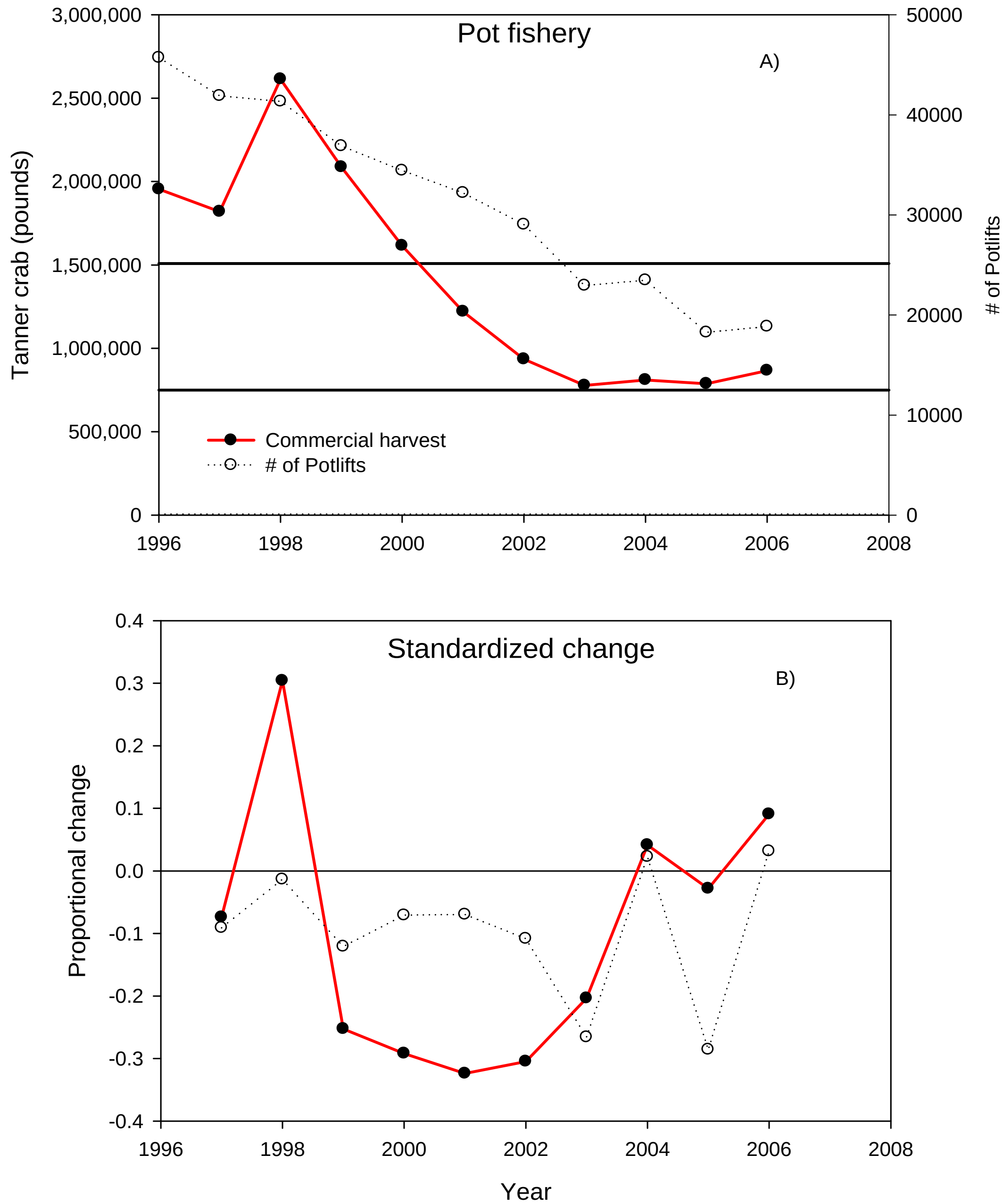


Figure 3.–Total number A) and proportional change B) of Tanner crab commercially harvested (solid line) and total number of pot lifts (dotted line) in Southeast Alaska (excluding Yakutat) between 1996 and 2006. Black reference lines represent the long-term and ½ of the long-term average catch. Proportion change is calculated as (Xt-Xt-1)/Xt-1, where X is either the total catch or number of permits and t is time. There is no correlation between the standardized change of catch and pot lifts ($p = 0.29$).

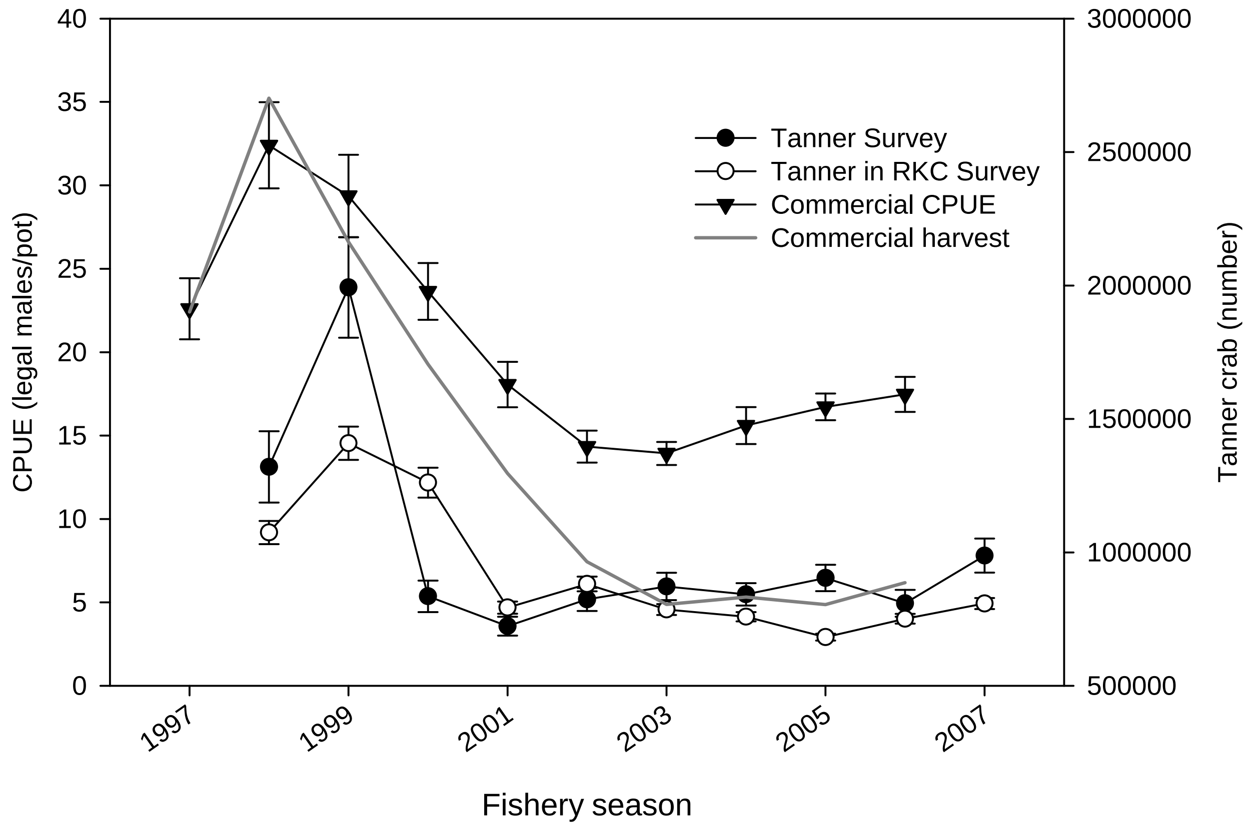


Figure 4.–Mean (±SE) legal male crab CPUE (weighted by location area) for the Tanner crab survey and red king crab locations, standardized commercial CPUE, and commercial catch in Southeast Alaska, 1997–2006.

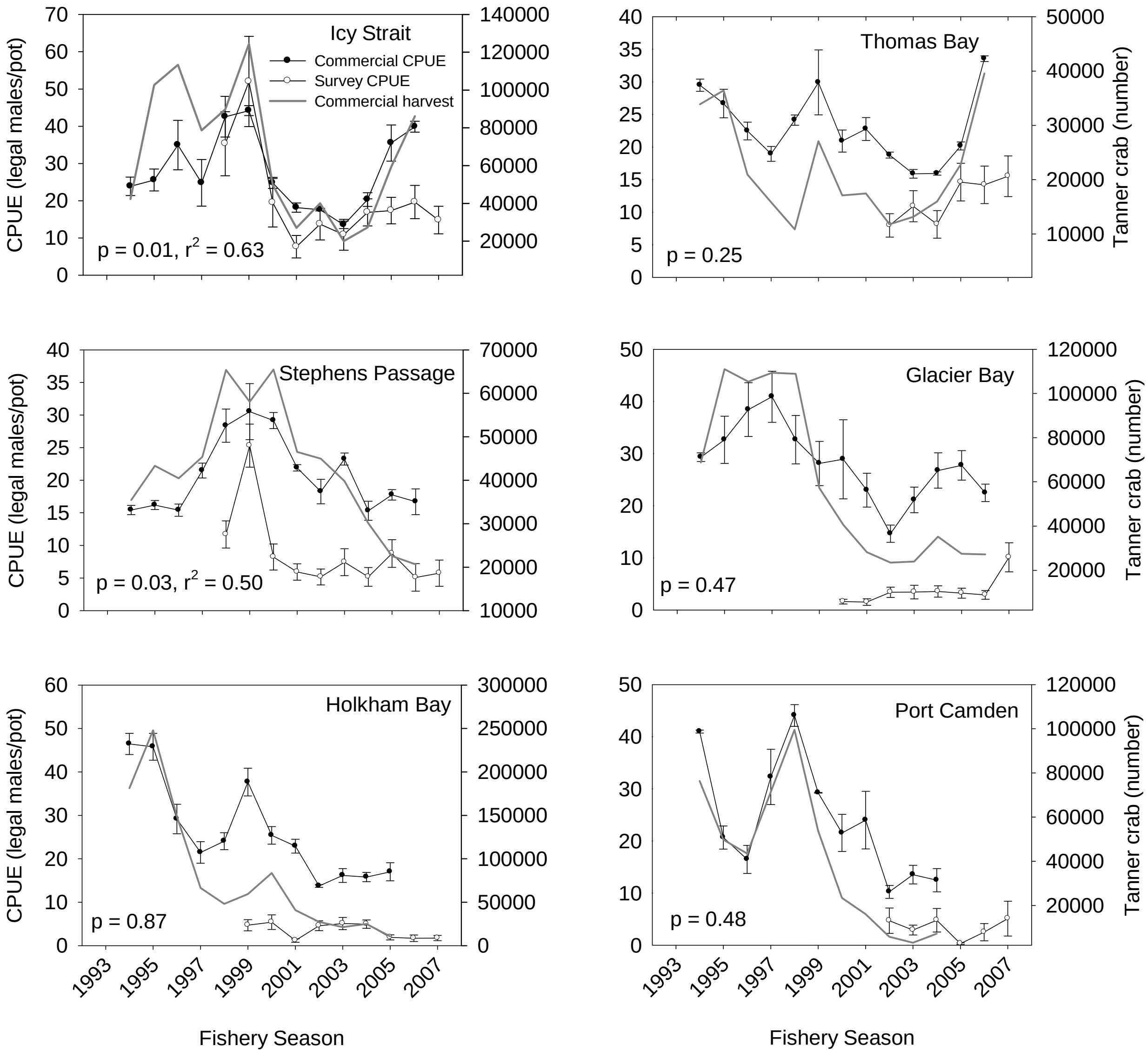


Figure 5.–Mean (±SE) survey CPUE, standardized commercial CPUE, and commercial harvest of legal male Tanner crab in Southeast Alaska. P and r^2 values indicate results of correlation analyses between survey and commercial CPUE data.

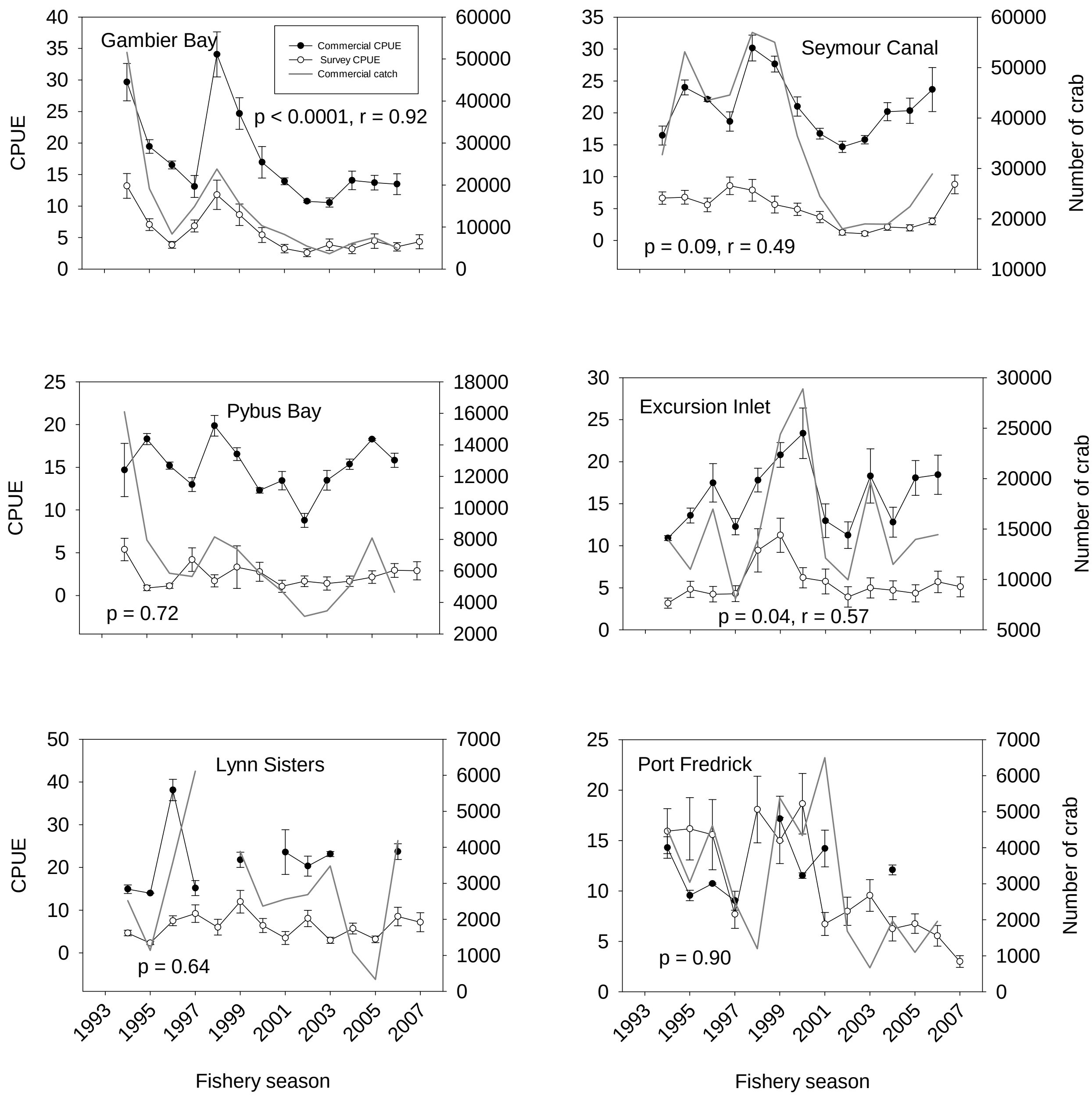


Figure 6.–Mean (±SE) survey CPUE, standardized commercial CPUE, and commercial harvest of legal male Tanner crab in Southeast Alaska. P and r^2 values indicate results of correlation analyses between survey and commercial CPUE data.

Table 1.–Correlation between ADF&G Southeast Alaska Tanner crab surveys and standardized commercial CPUE, and predicted population change for each area using Catch-Survey model, and change in survey CPUE from the previous year (with all areas, or just those with significant correlations). Regionwide change calculated as a weighted mean (weighted by commercial harvest).

	Survey vs. Comm. CPUE		Predicted Population Change		
Survey Area	p-value	Correlation coefficient (r)	CSA	Survey CPUE	Correlated Survey CPUE
TCS					
Icy Strait	0.01	0.79	-0.18	-0.25	-0.25
Stephens Passage	0.03	0.71	-0.11	0.13	0.13
Port Camden	0.48		ND	1.04	
Thomas Bay	0.25		0.02	0.09	
Holkham Bay	0.87		-0.19	0.02	
Glacier Bay	0.47		0.43	2.50	
RKCS					
Gambier Bay	< 0.0001	0.92	-0.08	0.23	0.23
Seymour Canal	0.09	0.49	0.64	1.91	1.91
Pybus Bay	0.72		0.46	-0.02	
Lynn Canal	0.64		-0.11	-0.16	
Excursion Inlet	0.04	0.57	0.00	-0.10	-0.10
Port Frederick	0.9		-0.11	-0.46	
Peril Strait	0.07	0.67	0.02	-0.23	-0.23
Regionwide			0.03	0.41	0.14
w/o Glacier Bay			-0.02	0.14	0.14
w/o Glacier Bay + Seymour			-0.10	-0.07	-0.16

Table 2.–Post- and pre-fishery data and estimates for Southeast Alaska Tanner crab. Commercial harvest based on logbook data. Population estimate and harvest rates estimated from Leslie depletion estimator. The projected abundance was calculated as the product of population change (from CSA) and the population estimate. The projected surplus was projected as the product of the abundance (in lbs) and the mean harvest rate. Average weights for each area determined from survey data.

	Post-fishery 2006				Pre-fishery 2007				
Survey Area	2006 Commercial Harvest (no.)	2006 Population Estimate (no.)	2006 Harvest Rate	Mean H.R. (1996-2006)	Predicted Change from CSA	2007 Population Estimate (no.)	2007 Mean Crab Weight (lbs)	2007 Population Estimate (lbs)	2007 Projected Surplus at Mean H.R.
TCS									
Icy Strait	86,191	142,370	0.61	0.70	-0.18	116,743	2.79	325,714	228,000
Thomas Bay	39,558	54,707	0.72	0.56	0.02	55,801	2.87	160,149	89,684
Stephens Passage	20,630	30,534	0.68	0.61	-0.11	27,175	2.67	72,558	44,260
Glacier Bay	27,215	42,560	0.64	0.77	0.43	60,861	2.54	154,586	119,032
Holkham Bay (2005)	0	16,551	ND	0.62	-0.19	13,406	2.73	36,599	22,692
Port Camden (2004)	0	8,308	ND	0.85	ND	ND	2.73	ND	ND
RKCS									
Gambier Bay	4,973	9,279	0.54	0.65	-0.08	8,537	2.87	24,500	15,925
Seymour Canal	28,886	33,671	0.86	0.66	0.64	55,220	2.73	150,752	99,496
Pybus Bay	4,651	7,898	0.58	0.66	0.46	11,531	2.87	33,094	21,842
Lynn Canal	4,187	5,785	0.72	0.72	-0.11	5,149	2.67	13,747	9,898
Excursion Inlet	14,430	16,532	0.87	0.83	0	16,532	2.79	46,124	38,283
Port Frederick	1,959	ND	ND	ND	-0.11	ND	2.79	ND	ND
Peril Strait	0	ND	ND	ND	0.02	ND	2.67	ND	ND
Total (Survey Areas)	232,680	368,195				370,956		1,017,824	689,111
Other (Non-survey areas)	108,435	246,691				248,540		681,942	461,705
Regional Total	341,115	614,886				619,496		1,699,767	1,150,816
% Caught in surveyed areas	68%								

Table 3.–Matrix of Tanner crab stock health determination for all size/sex classes in each area survey in Southeast Alaska. Bold and bold underlined entries represent positive and negative indicators of stock health, respectively. The long-term benchmark is defined as 1997–2006 for the TCS and 1993–2002 for the RKCS (see Methods for details). Short-term trends are based on individual regression analyses over the past 4 years (including the current year). Total score is the sum of scores (+1,0, -1 for long-term; +.25, 0, -.25 for short-term) for each response variable. Stock health is defined by the total score: < -1.5 = Poor, -1.5 to 1.5 = Moderate, and > 1.5 = Healthy.

Response variables	Icy Strait	Thomas Bay	Stephens Passage/ Juneau[a]	Glacier Bay	Holkham Bay[a]	Port Camden	Gambier Bay	Seymour Canal	Pybus Bay	Lynn Canal	Excursion Inlet[b]	Port Frederick	Peril Strait
Large/Mature Females													
Percent Clutch Fullness < 25% vs. long-term benchmark	**15%**	**22%**	**35%**	**50%**	89%	191%	**0%**	**17%**	**20%**	232%	126%	90%	**35%**
Short-term trend	No Trend	No Trend	No Trend	No Trend	No Trend	No Trend	No Trend	No Trend	No Trend	No Trend	No Trend	No Trend	No Trend
CPUE vs. long-term benchmark	**258%**	159%	**49%**	181%	**39%**	**12%**	**22%**	165%	204%	65%	220%	**63%**	76%
CPUE short-term trend	No Trend	No Trend	No Trend	No Trend	No Trend	No Trend	No Trend	Sig Inc	No Trend	No Trend	No Trend	No Trend	No Trend
Small/Immature Females													
CPUE vs. long-term benchmark	**195%**	**44%**	74%	194%	104%	**0%**	59%	86%	636%	94%	**40%**	94%	91%
CPUE short-term trend	No Trend	No Trend	No Trend	**Sig Inc**	No Trend	No Trend	No Trend	No Trend	**Sig Inc**	No Trend	No Trend	**Sig Inc**	No Trend
Juvenile Males													
CPUE vs. long-term benchmark	**73%**	**170%**	111%	129%	**51%**	**27%**	**45%**	95%	**377%**	86%	**42%**	**243%**	87%
CPUE short-term trend	**Sig. Dec.**	**Sig Inc**	No Trend	No Trend	**Sig. Dec.**	No Trend	No Trend	**Sig. Dec.**	No Trend	No Trend	**Sig. Dec.**	**Sig Inc**	No Trend
Prerecruit Males													
CPUE vs. long-term benchmark	93%	**137%**	65%	148%	**34%**	79%	**52%**	**244%**	**300%**	134%	**181%**	**44%**	95%
CPUE short-term trend	**Sig. Dec.**	No Trend	No Trend	No Trend	**Sig. Dec.**	No Trend	No Trend	**Sig Inc**	**Sig Inc**	No Trend	No Trend	**Sig. Dec**	No Trend
Recruit Males													
CPUE vs. long-term benchmark	**53%**	108%	**58%**	**284%**	**37%**	88%	**56%**	**204%**	88%	109%	**64%**	**20%**	**43%**
CPUE short-term trend	No Trend	No Trend	No Trend	**Sig Inc**	**Sig. Dec.**	No Trend	No Trend	**Sig Inc**	No Trend	No Trend	No Trend	**Sig. Dec.**	No Trend
Postrecruit Males													
CPUE vs. long-term benchmark	**214%**	**174%**	99%	**248%**	84%	198%	87%	90%	177%	145%	156%	**55%**	111%
CPUE short-term trend	**Sig Inc**	**Sig Inc**	No Trend	**Sig Inc**	No Trend	No Trend	No Trend	**Sig Inc**	No Trend	No Trend	**Sig Inc**	No Trend	**Sig Inc**
Total Score	1.75	3.50	-2.00	3.75	-4.75	-3.00	-3.00	3.75	3.50	0.00	-2.00	-3.00	0.25
Stock status	Healthy	Healthy	Poor/Mod	Healthy	Poor/Poor	Poor	Poor	Healthy	Healthy	Moderate	Poor/Mod.	Poor	Moderate

[a] Areas surveyed in both TCS and RKCS. Only TCS results are shown, except for stock status where the TCS result is followed by the averaged result.
[b] Excursion inlet was scored as Poor, but designated Moderate for the management decision (see Discussion for details).

Table 4.–Stock estimates and 2 different management scenarios for estimating commercial Tanner crab season length in Southeast Alaska. The Adjusted Harvest Rate (H.R.) is based on 100, 50, or 0% of either the mean commercial harvest rate for each survey area or of .50 depending upon stock health. The number of fishing days required to catch surplus crab was estimated from the commercial effort in the previous year.

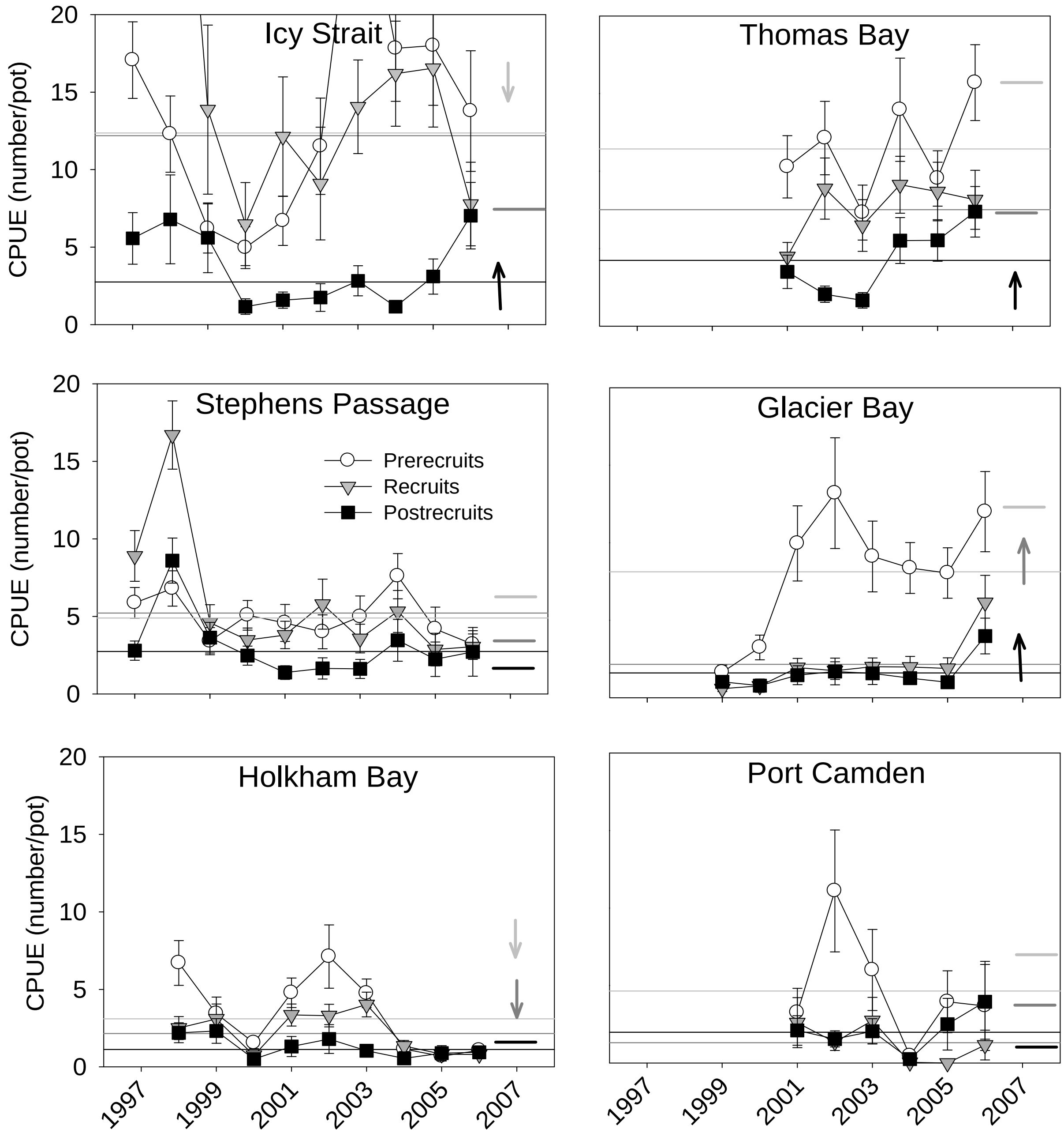
	Stock Estimates			Management scenarios								
				Maximum at mean commercial				Set at .50		Maximum at .50		
Survey Area	Projected Pounds	Projected Surplus at Mean H.R.	Stock Health	Adjusted H.R.	Surplus (no.)	Surplus (lbs)	Fishing Days	Set H.R.	Surplus (lbs)	Adjusted H.R.	Surplus (lbs)	Fishing Days
TCS												
Icy Strait	325,714	228,000	Healthy	0.70	81,720	228,000	3	0.50	162,857	0.50	162,857	1
Stephens Passage	72,558	44,260	Moderate	0.31	8,288	22,130	0	0.50	36,279	0.25	18,139	0
Port Camden	ND	ND	Poor	0.00	0	0	0	0.50	0	0.00	0	0
Thomas Bay	160,149	89,684	Healthy	0.56	31,249	89,684	2	0.50	80,075	0.50	80,075	2
Holkham Bay	36,599	22,692	Poor	0.00	0	0	0	0.50	18,300	0.00	0	0
Glacier Bay	154,586	119,032	Healthy	0.77	46,863	119,032	7	0.50	77,293	0.50	77,293	5
RKCS												
Gambier Bay	24,500	15,925	Poor	0.00	0	0	0	0.50	12,250	0.00	0	0
Seymour Canal	150,752	99,496	Healthy	0.66	36,445	99,496	6	0.50	75,376	0.50	75,376	4
Pybus Bay	33,094	21,842	Healthy	0.66	7,611	21,842	7	0.50	16,547	0.50	16,547	4
Lynn Canal	13,747	9,898	Moderate	0.36	1,854	4,949	0	0.50	6,873	0.25	3,437	0
Excursion Inlet	46,124	38,283	Moderate	0.42	6,861	19,142	0	0.50	23,062	0.25	11,531	0
Port Frederick	ND	ND	Poor	0.00	0	0	0	0.50	0	0.00	0	0
Peril Strait	ND	ND	Moderate	ND	ND	ND	ND	0.50		0.25	ND	ND
Total (Survey Areas)	1,017,824	689,111			220,891	604,274			508,912		445,255	
Other (non-survey	681,942	461,705			147,997	404,864			340,971		298,321	
Regional Total	1,699,767	**1,150,816**			368,887	**1,009,138**			849,883		**743,576**	

Table 5.–Area (km^2) for each Southeast Alaska Tanner crab survey area and strata within an area. Juneau and Holkham Bay from the RKCS were omitted due to the large overlap with TCS areas.

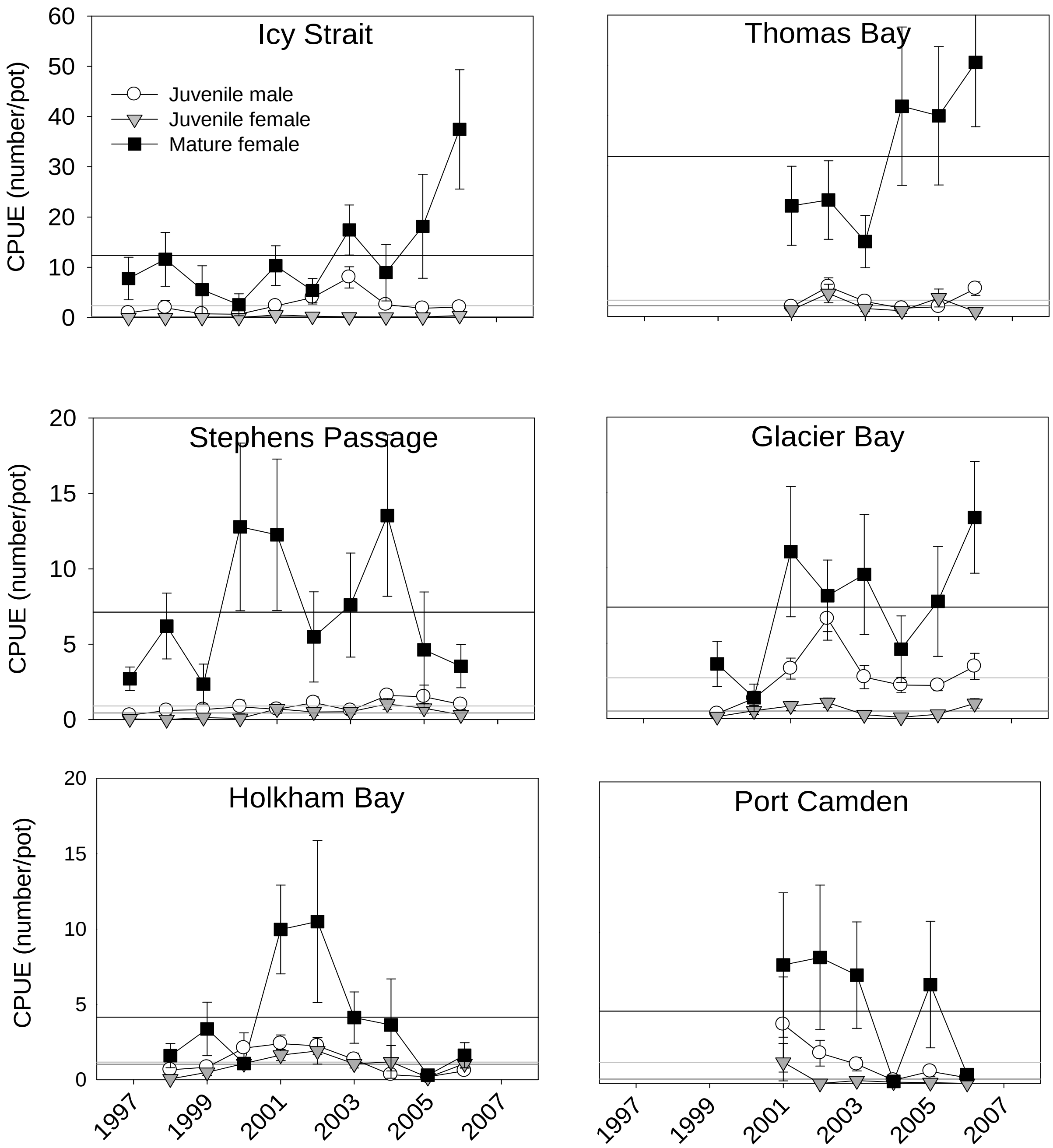
Strata	Tanner Crab Survey (TCS)						Red King Crab Survey (RKCS)							Total
	Icy Strait	Thomas Bay	Stephens Passage	Glacier Bay	Holkham Bay	Port Camden	Gambier Bay	Seymour Canal	Pybus Bay	Lynn Canal	Excursion Inlet	Port Frederick	Peril Strait	
1	36.50	23.39	192.42	133.61	11.48	24.46	10.09	41.64	13.15	8.87	22.29	18.05	12.54	
2				70.30	26.77		9.94	24.32	8.29	6.47	15.73	17.26	9.65	
3					13.17		8.30	14.54	5.92	6.30	16.77	12.17	10.04	
4							7.54	9.68	6.97	5.52	10.52	10.76	6.35	
5							4.50	11.07	4.60	2.57	11.29	8.01	5.44	
Rodman													32.43	
Total Area (km^2)	36.50	23.39	192.42	203.91	51.42	24.46	40.37	101.26	38.93	29.71	76.59	66.26	76.46	961.70
% of Total	4%	2%	20%	21%	5%	3%	4%	11%	4%	3%	8%	7%	8%	100%

APPENDIX A

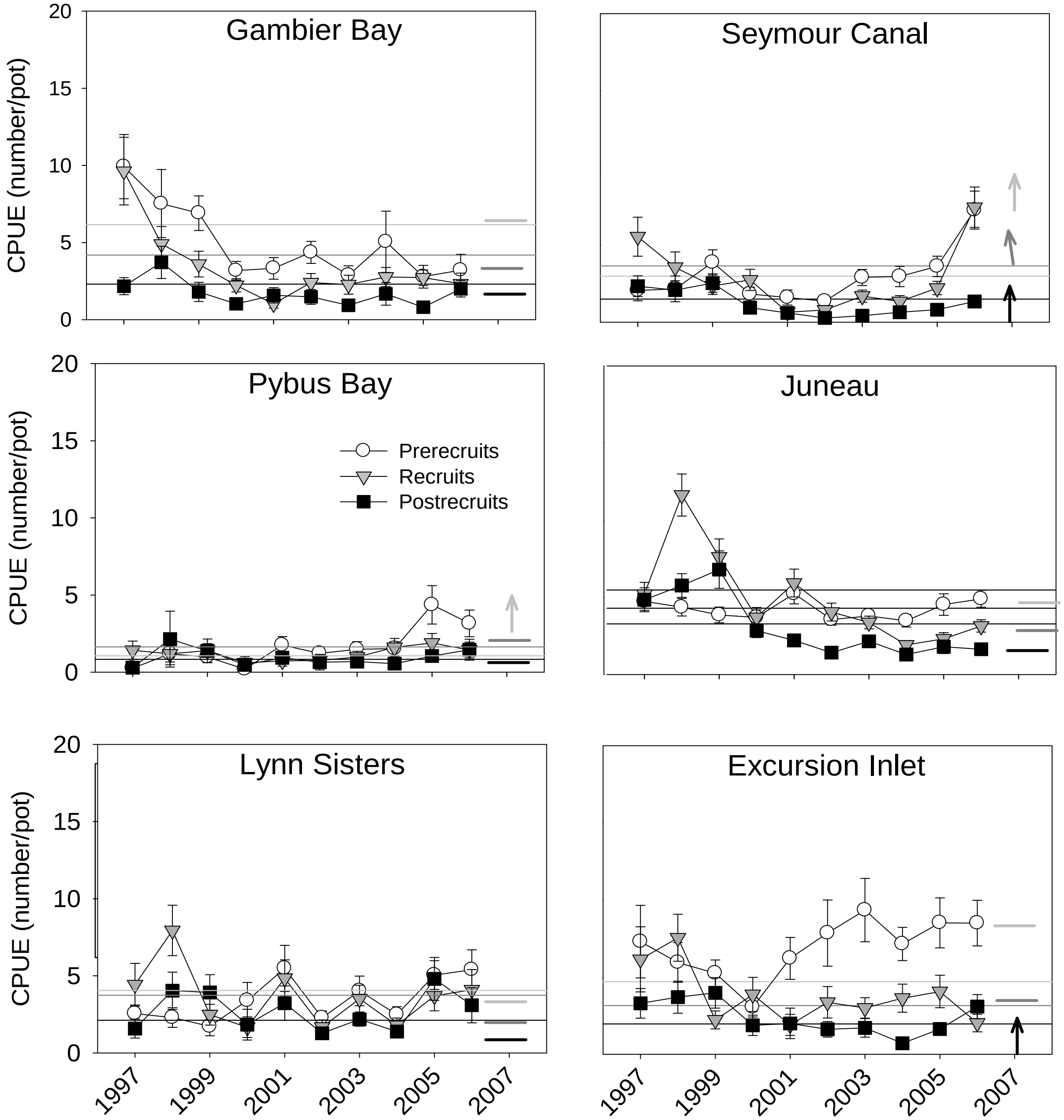
Appendix A1.–Mean (±SE) crab per pot for prerecruit (open circles), recruit (grey triangles), and postrecruit (black squares) Tanner crab at the six Tanner crab survey locations in Southeast Alaska from 1997 to 2006. Symbols on the right side of plots represent a significant increase ($p < 0.05$, up arrow) significant decrease ($p < 0.05$, down arrow), or no significant change ($p > 0.05$, straight line) from linear regression analysis over the last 4 years. Symbol colors represent prerecruit (light grey), recruit (grey), and postrecruit (black) crabs. Light grey, dark grey and black reference lines represent the long-term baselines for prerecruit, recruit, and postrecruit crab, respectively.



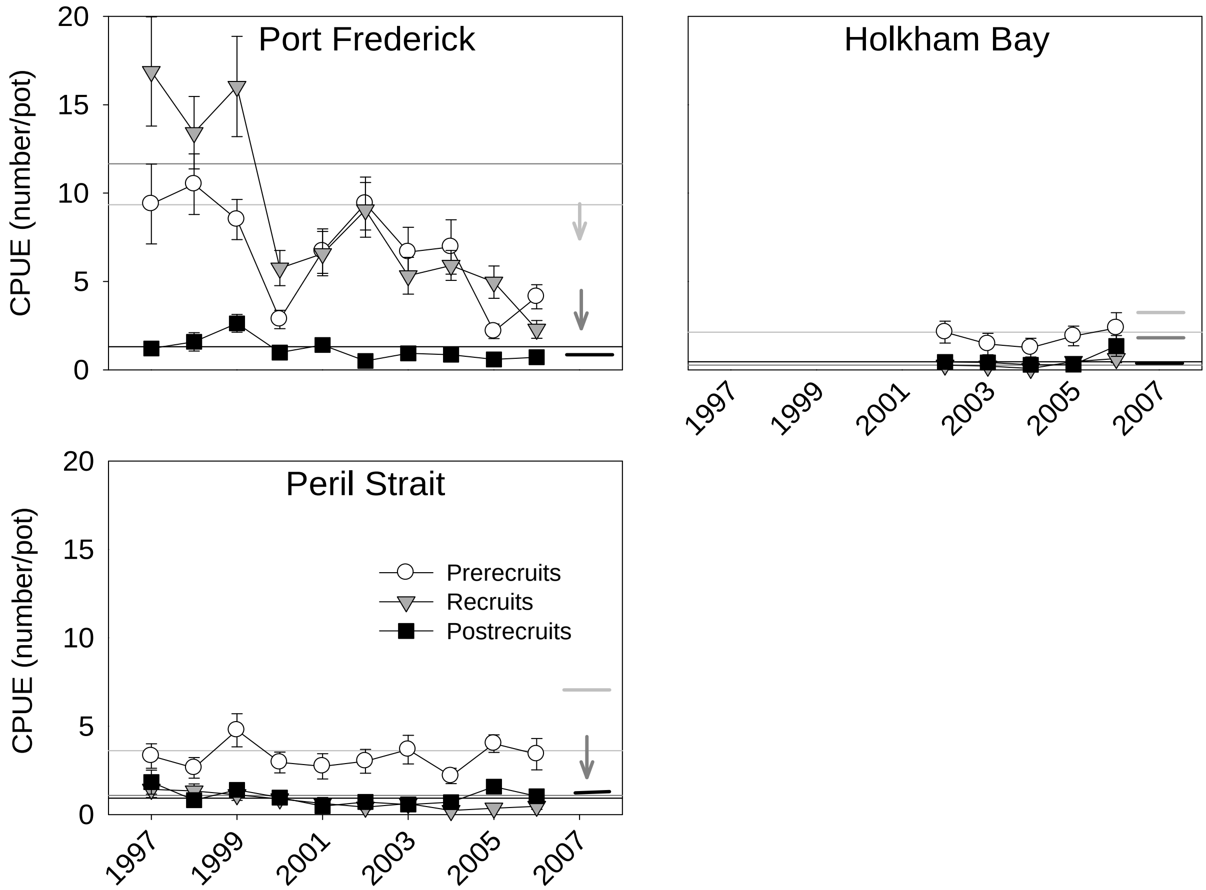
Appendix A2.–Mean (±SE) crab per pot for juvenile male (open circles), juvenile female (grey triangles), and mature female (black squares) Tanner crabs at the six Tanner crab survey locations in Southeast Alaska from 1997 to 2006. Light grey, dark grey and black reference lines represent long-term baselines for juvenile male, juvenile female, and mature female crabs, respectively.



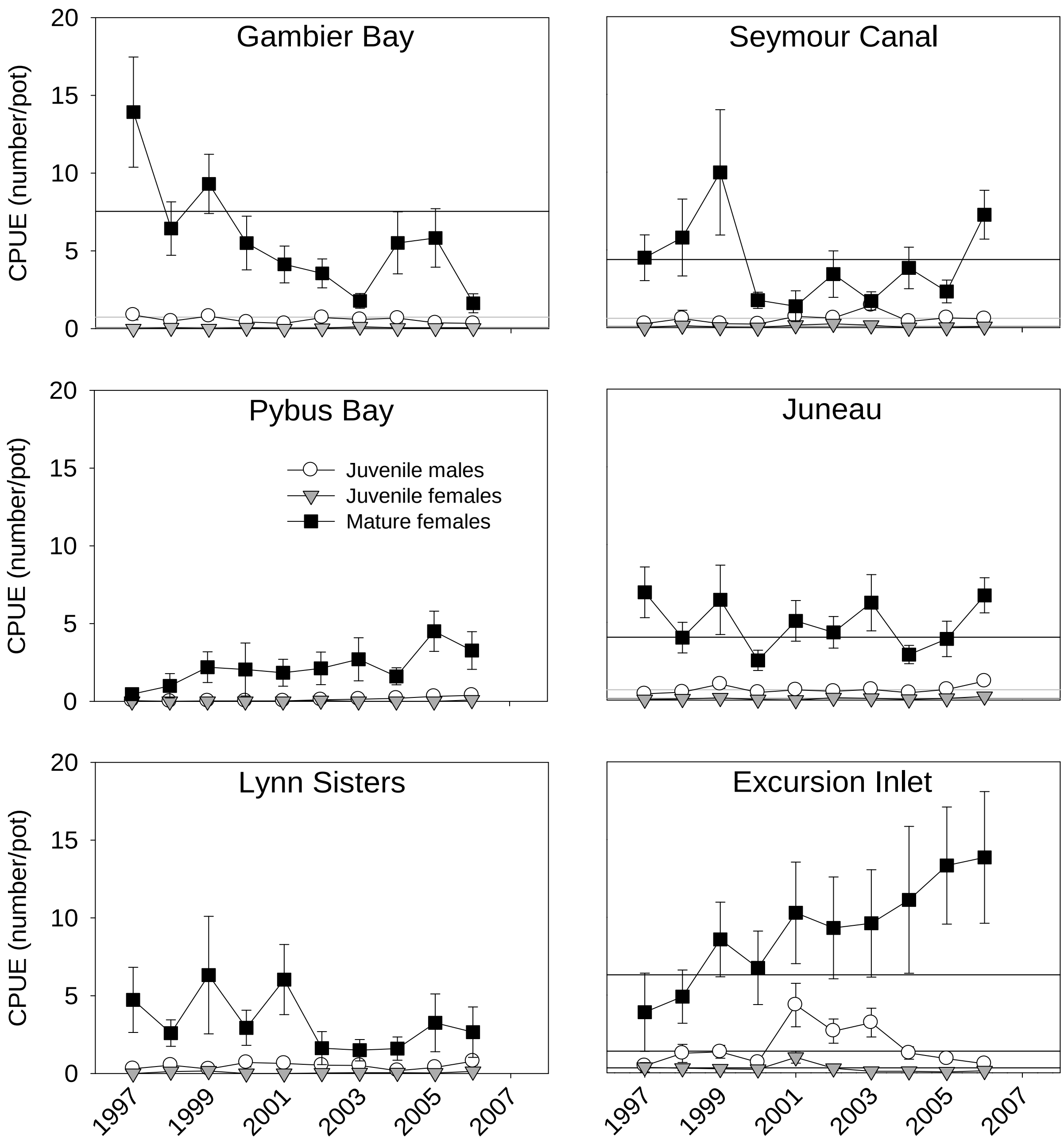
Appendix A3.–Mean (±SE) crab per pot for prerecruit (open circles), recruit (grey triangles), and postrecruit (black squares) Tanner crab at 6 red king crab survey locations in Southeast Alaska from 1997 to 2006. Symbols on the right side of plots represent a significant increase ($p < 0.05$, up arrow) significant decrease ($p < 0.05$, down arrow), or no significant change ($p > 0.05$, straight line) from linear regression analysis over the last 4 years. Symbol colors represent prerecruit (light grey), recruit (grey), and postrecruit (black) crabs. Light grey, dark grey, and black reference lines represent long-term baselines for prerecruits, recruits, and postrecruits, respectively.



Appendix A4.–Mean (±SE) crab per pot for prerecruit (open circles), recruit (grey triangles), and postrecruit (black squares) Tanner crab at 3 red king crab survey locations in Southeast Alaska from 1997 to 2006. Symbols on the right side of plots represent a significant increase ($p < 0.05$, up arrow) significant decrease ($p < 0.05$, down arrow), or no significant change ($p > 0.05$, straight line) from linear regression analysis over the last 4 years. Symbol colors represent prerecruit (light grey), recruit (grey), and postrecruit (black) crabs. Light grey, dark grey, and black reference lines represent long-term baselines for prerecruits, recruits, and postrecruits, respectively.



Appendix A5.–Mean (±SE) crab per pot for juvenile male (open circles), juvenile female (grey triangles), and mature female (black squares) Tanner crab at 6 red king crab survey locations in Southeast Alaska from 1997 to 2006. Symbols on the right side of plots represent a significant increase ($p < 0.05$, up arrow) significant decrease ($p < 0.05$, down arrow), or no significant change ($p > 0.05$, straight line) from linear regression analysis over the last 4 years. Symbol colors represent juvenile male (light grey), juvenile female (grey), and mature female (black) crabs. Light grey, dark grey and black reference lines represent long-term baselines for juvenile males, juvenile females, and mature females, respectively.



Appendix A6.–Mean (±SE) crab per pot for juvenile male (open circles), juvenile female (grey triangles), and mature female (black squares) Tanner crab at 3 red king crab survey locations in Southeast Alaska from 1997 to 2006. Symbols on the right side of plots represent a significant increase ($p < 0.05$, up arrow) significant decrease ($p < 0.05$, down arrow), or no significant change ($p > 0.05$, straight line) from linear regression analysis over the last 4 years. Symbol colors represent juvenile male (light grey), juvenile female (grey), and mature female (black) crabs. Light grey, dark grey and black reference lines represent long-term baselines for juvenile males, juvenile females, and mature females, respectively.