**Regional Information Report No. 1J13-03**

# Southeast Alaska Tanner Crab Survey and Stock Health Prior to the 2011/2012 Season

**by**

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**and**

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**Alaska Department of Fish and Game** **Division of Commercial Fisheries**

## Symbols and Abbreviations

The following symbols and abbreviations, and others approved for the Système International d'Unités (SI), are used without definition in the following reports by the Divisions of Sport Fish and of Commercial Fisheries: Fishery Manuscripts, Fishery Data Series Reports, Fishery Management Reports, Special Publications and the Division of Commercial Fisheries Regional Reports. All others, including deviations from definitions listed below, are noted in the text at first mention, as well as in the titles or footnotes of tables, and in figure or figure captions.

**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, $\chi^2$, 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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# ABSTRACT

Two pot surveys are conducted annually to collect data used to assess the Tanner crab stock in Southeast Alaska. During June/July and October 2011 surveys, 756 eighty-eight-inch diameter conical crab pots were set and soaked for 19.3 h on average in 14 survey areas. For each pot, commercially important crabs were measured for carapace width or length, and shell condition and parasitism determined; reproductive condition was determined for females, and chela height measured for a subsample of male Tanner crabs. Pots were subsampled when very full. Various ancillary data, including bottom temperature and temperature/salinity profiles, was collected as time allowed. Survey CPUE data was modeled using 3-stage catch-survey methods to produce estimates of mature and legal male biomass. Survey CPUE by size and sex class was also compared to long-term average values to determine stock health. Stock health is used to recommend an exploitation rate. Exploitation rates from 0–20% of mature, or a maximum of 40% of legal, were applied to the population estimate by survey area to determine harvestable surplus. Regional mature biomass estimate increased slightly for the 2011/2012 season but only to 41.8% of the long-term average. Estimated harvestable surplus is 0.33 million lb and stock health, based on matrix criteria, is “Poor” or “Below Average” for four areas, “Moderate” for six areas and “Above Average” in four areas. The Tanner crab survey has a 15-year time series, and several survey and assessment improvements remain to be implemented, these include restratification of the Tanner crab survey, logbook verification, developing a method to assess unsurveyed areas, and studies of how interaction between red king crab and Tanner crab may affect catchability. An abundance-based harvest strategy is needed for this fishery. In addition to anthropogenic factors, bitter crab disease and climate change also affect Southeast Alaska Tanner crab populations.



Key words: Tanner crab, *Chionoecetes bairdi*, pot survey, stock assessment, Southeast Alaska


# INTRODUCTION

Two surveys currently provide stock assessment information used to manage the Tanner crab fishery in Southeast Alaska. A fall pot survey targeting Tanner crab (*Chionoecetes bairdi*) (Rathbun 1924) was established in two survey areas in 1997 and has been conducted annually since then. The current survey protocol was not fully developed until 2001 when the last of the six survey areas was added. Tanner crabs are also captured in an annual summer pot survey targeting red king crab. The red king crab survey was established in 1978 and provides information on 10 survey areas (Clark et al. 2003), two of which are also indexed during the Tanner crab survey. Together the two surveys provide information on 14 unique areas throughout Southeast Alaska (Figure 1).

This Tanner and red king crab survey data is used to assess the health of Tanner crab stocks in Southeast Alaska by survey area. The goal of the survey is to produce unbiased estimates of catch per unit effort (CPUE) by recruit class in order to 1) determine stock health by survey area and 2) provide input data for a three-stage catch-survey (C-S) model (Siddon et al. 2009; Zheng et al. 2006). The C-S model is used to estimate mature and legal population sizes while the stock health by survey area is used to determine appropriate mature exploitation rates (ER). This information is used to produce an annual estimate of harvestable surplus for the Southeast Alaska commercial Tanner crab fishery. The estimate of harvestable surplus is a reference level of harvest that would provide for sustainable harvest of stocks and minimize the risk of recruitment failure—as mandated by the Alaska Board of Fisheries’ “Policy on King and Tanner Crab Resource Management” (Hodson 1990), however the current regulatory management plan for the Southeast Alaska Tanner crab fishery does not utilize the annual estimated harvestable surplus, rather it relies on only the annual estimate of mature male biomass and effort information to determine length of the fishing season. Other information currently used in the Tanner crab stock assessment is catch and effort reported on fish tickets.

The long-term goal of the survey is to provide information on the spatial distribution and long-term health of Southeast Tanner crab stocks. Information produced by the survey to achieve these goals includes CPUE, female reproductive status, male length/weight relationship, male chela height/carapace width relationship and visual detection of disease and limb loss.

The objectives of this report are to describe the methods and findings of the 2011 Tanner crab surveys and C-S analyses as they pertain to the 2011 stock status and harvestable surplus determinations.

# METHODS

As Tanner crab survey methods in Southeast Alaska have been described in detail elsewhere (Bednarski et al. 2008), only a brief overview will follow here.

## FIELD

### Sample Design

Pot locations were selected through a stratified random sampling design. The number of pots within each stratum was determined using a Neyman allocation (Cochran 1977). The total number of pots within each survey area was determined based on logistics and the time needed for staff to efficiently sample and set pots. Pot locations for the 2011 Tanner survey are shown below (Figures 2–7). Red king crab survey pot locations for 2011 are reported elsewhere (Bishop et al. 2012).

### Gear Description

Eighty-eight-inch diameter conical crab pots without escape rings were used for the survey in order to catch all size classes of crab. Pots were baited with jar and hanging bait. For jar bait, frozen winter-caught Alaska bait herring, caught the year of the survey, thawed and chopped within 12 hours was used. One half of a pink salmon was used for hanging bait. Chopped herring was loosely filled in two 2-quart bait jars, and the pink salmon was secured to one with a bait hook. Bait jars were suspended at the same height as the top weight ring on opposite sides of the pot.

Temperature sensors, HOBO® TidbiT data loggers[1], were attached to each pot to record bottom temperatures in degrees Celsius at 1-hour intervals.

### Setting and Pulling

Pots were set between 13:00 and 18:00 and pulled between 08:00 and 13:00, allowing a range of 18 to 22 hours for soak times.

### Sampling

Crab from each pot were counted and classified into size/sex categories by quantifying carapace width, sex, and shell condition (Jadamec et al. 1999). Females were sometimes subsampled when there were time constraints.

### Extra Projects

During the Tanner crab survey, an effort was made to accommodate extra projects. Projects were prioritized based upon their relevance to stock assessment and management of commercially

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[1] Product names used in this publication are included for completeness but do not constitute product endorsement.

important crab and shrimp species in Southeast Alaska. The 2011 extra projects are described as follows.

### Tanner Crab Width Spine CW Measurement

For the following areas: Holkham Bay, Seymour Canal, Lynn Sisters, Thomas Bay, Camden Bay, Stephen's Passage, Icy Strait, and Glacier Bay approximately 50 male, shell condition 3 or 4 Tanner crabs were randomly selected and sampled to measure CW with spines in addition to the usual biological CW measurement (Jadamec et al. 1999), which excludes spines.

### Bitter Crab Hemolymph Sampling

In order to check the accuracy of visual determination of bitter crab syndrome (BCS) prevalence, as well as to monitor trends in BCS prevalence, approximately 100 hemolymph samples from randomly selected Tanner crabs were taken from each survey area. Each day crabs were randomly selected from at least five pots regardless of sex, size, and shell condition and hemolymph was extracted using a syringe and preserved in 95% EtOH. PCR assays (Freidman et al. 2005) will be conducted on these samples by the Alaska Fisheries Science Center (AFSC) Pathology Laboratory to determine BCS prevalence.

### Briarosaccus callosus Sampling

Samples of the parasitic barnacle *Briarosaccus callosus* were taken from red and golden king crab whenever present and labeled with date and location and preserved in 95% EtOH for further analysis. These samples were requested by Dr. Henrik Glenner, a crustacean geneticist in Norway.

### Conductivity/Temperature/Depth (CTD)

During 2011 Tanner and red king crab surveys, 18 CTD casts were made throughout Southeast Alaska (Figure 8; Table 1), with three stations being occupied twice. Casts were made using a Seabird 19 plus CTD with conductivity, temperature, and depth sensors; the instrument is calibrated annually. Stations were occupied in transit and the CTD was dropped at a speed of 1 m/s to a maximum depth of 250 m and retrieved. Data was uploaded and archived at the National Oceanic Data Center and can be retrieved online at *http://www.nodc.noaa.gov*.

### Tanner Crab Reproductive Condition

Forty female Tanner crabs each in Thomas Bay and Glacier Bay were collected for reproductive potential studies. Data collected from this study will clarify factors contributing to variability in female reproductive condition and potentially help explain historic differences and/or trends in reproductive condition of female Tanner crab.

### Bitter Crab Survivorship Collections

Through visual examination, 34 BCS-infected and 60 non-infected Tanner crabs were collected in Stephens Passage for a joint laboratory study of BCS survivorship by ADF&G and AFSC Pathology staff. The goal of this study is to determine the temporal lethality of BCS.

### Paralytic Shellfish Poisoning Collections

During leg one of the Tanner crab survey, two legal male Tanner crabs were collected from each survey area to be tested by the Alaska Department of Environmental Conservation to assess the prevalence of Paralytic Shellfish Poisoning (PSP) in Southeast Alaska Tanner crab.

## ANALYSIS

### Stock Health

Stock health is determined by examining crab catch rate (CPUE) by sex and recruit class and female reproductive condition from the survey. The five response variables are: mature female clutch fullness (percent females with clutch fullness less than 25%) and CPUE, and prerecruit, recruit, and postrecruit male CPUE. Short-term (4-yr) and long-term trends in these response variables are evaluated. Short-term trends are evaluated with linear regression, while long-term trends are evaluated by a t-test comparing the current year's mean to an established baseline (determined as the mean of the first 10 years of available data from 1997–2010 for the Tanner crab survey and for 1993–2002 for the red king crab survey). Short-term trends are scored -0.25 for significantly declining, 0.00 for no trend, and +0.25 for significantly increasing while long-term trends are scored -1.00 for significantly below baseline, 0.00 for no difference from baseline, and +1.00 for significantly above baseline. The range of possible scores (-6 to +6) is divided into five ranges, corresponding to stock health categories of "Healthy" (>3.24), "Above Average" (1.25 to 3.24), "Moderate" (-1.25 to 1.24), "Below Average" (-3.25 to -1.26), and "Poor" (<-3.26). Corresponding exploitation rates are 20%, 15%, 10%, 5%, and 0% of mature male crab or a maximum of 40% of legal male crab.

### Exploitation Rate

A fairly simplistic and preliminary analysis was conducted to determine an appropriate regional base ER. The legal and mature ERs for the past 6–10 years were regressed against population change. The ER at which population change was 0 for each surveyed area was designated as that which would maximize sustainable commercial harvest. Finally, the weighted average of survey areas ERs was determined as the regional ER (Appendix A). analysis indicates that the regional ER should not exceed 20% of mature or 40% of legal estimated biomass. Assuming similar growth and stock productivity, this is less conservative than methods used in Kodiak and the Eastern Bering Sea (EBS) where tiered ERs of 0%, 10% or 20% of molting mature males, with a cap of 30% of legal males are used [5 AAC 35.507, 5 AAC 35.508].

### Catch-Survey Modeling

The C-S model utilizes both survey and commercial catch data to estimate the total biomass of crab for each area where a survey was conducted (Collie and Sissenwine 1983). This approach was expanded to three stages (prerecruits, recruits, and postrecruits) (Collie and Kruse 1998) and applied to Tanner crab (Siddon et al. 2009; Zheng et al. 2006). Here we continue the use of the three-stage C-S modeling methods to estimate the biomass of legal (≥138 mm CW) and mature (>109 mm CW) male Tanner crab at the time of the survey. Inputs to this model are commercial harvest, and survey CPUE for prerecruit, recruit, and postrecruit crabs. An instantaneous rate of natural mortality of $M=0.3$, which translates to an annual natural mortality rate of 26% is used. These methods, and the rationale for the assumptions regarding natural mortality and growth, are described in more detail by Zheng et al. (2006).

# RESULTS

A total of 756 useable pot pulls were made over 51 days during the 2011 red king crab and Tanner crab surveys—from 20 to 109 pulls in a survey area (Table 2). The red king crab survey was conducted in three legs. The first leg was conducted from June 21 through 30 and St. James Bay, North Juneau, and Stephens Passage were surveyed; the second leg from July 6 through 15 included Peril Strait, Port Frederick, and Excursion Inlet; and the third leg, from July 19 through 29 included Pybus Bay, Gambier Bay, Seymour Canal, and Holkham Bay. The Tanner crab survey was conducted in two legs, the first leg was conducted from October 3 through 12 and included Thomas Bay, Port Camden, and Holkham Bay; while the second leg was from October 17 through 26 and included Stephens Passage, Icy Strait, and Glacier Bay. During these surveys, soak time averaged 19.3 h, and mean depth 52.9 fathoms (Table 2).

## REGIONAL OVERVIEW

C-S modeling of 2011 fishery and survey data yields a biomass estimate of 3.12 million lb mature or 2.01 million lb legal Tanner crab (Table 3). This is a 9.3% or 0.19 million lb increase from 2010 and is a result of mature male biomass increases for 6 of 14 survey areas, specifically Icy Strait, Glacier Bay, Thomas Bay, Holkham Bay, Pybus Bay, and Peril Strait (Table 3). Notwithstanding these improvements, the regional mature biomass estimate remains near the lowest levels since 1997. Hence, harvest at the maximum exploitation rate would result in a guideline harvest level (GHL) of 0.58 million lb. and using matrix-derived ERs and C-S estimates, of 0.33 million lb for the 2011/2012 fishing season. (Figures 9 and 10, Table 3). Harvest above this level will increase the probability of continued population declines and may produce biomass estimates below the 2.3 million-lb mature male biomass threshold in the near future.

## AREA-SPECIFIC RESULTS

### Tanner Crab Survey Areas

#### Icy Strait, Below Average 5%

The Icy Strait stock health score increased since the 2010 survey. It is currently scored -1.50, up from -3.00 in 2010 (Table 4). This score increase was driven by prerecruit CPUE no longer being below the long-term average and recruit CPUE exhibiting a short-term increase. However large female, recruit, and postrecruit male CPUEs remain below their respective long-term averages. The percentage of females with poor clutch fullness was less than 10%. This area provided 12.0% of the average annual commercial harvest over baseline years, and 6.8% in the 2010/2011 fishery (Figure 11).

#### Glacier Bay, Moderate 10%

The Glacier Bay stock health score improved slightly since the 2010 survey. It is currently scored -1.25, up from -2.00 in 2010 (Table 4). This score increase was driven by CPUE of recruit and postrecruit crab no longer being below the long-term average. CPUE of mature females as well as prerecruit crab remain below the long-term average, while the percentage of females with poor clutch fullness was less than 10%. Short-term trends showed significant declines for prerecruits. This area provided 8.2% of the average annual commercial harvest over baseline years, and 6.9% in the 2010/2011 fishery (Figure 12).

#### Stephens Passage, Below Average 5%

The Stephens Passage stock health score declined slightly since the 2010 survey. It is currently scored -2.25, down from -1.00 in 2010 (Table 4). All CPUE estimates except those of mature females were below the long-term average, and prerecruit CPUE also exhibited significant short-term declines. The percentage of females with poor clutch fullness was less than 10%. There were no other significant short-term trends. This area provided 9.5% of the average annual commercial harvest over baseline years, and 7.7% in the 2010/2011 fishery (Figure 13).

### Thomas Bay, Moderate 10%

The Thomas Bay stock health score improved markedly since the 2010 survey. It is currently scored at 0.75, up from -3.00 in 2010 (Table 4). This score increase was driven by mature female, prerecruit, recruit, and postrecruit male CPUE all being at the long-term average, and the percentage of females with poor clutch fullness being less than 10%. However mature female CPUE exhibited significant short-term declines. Thomas Bay provided 4.8% of the average annual commercial harvest over baseline years, and 5.1% in the 2010/2011 fishery (Figure 14).

### Holkham Bay, Above Average 15%

The Holkham Bay stock health score improved since the 2010 survey. It is currently scored at 2.50, up from 0.25 in 2010 (Table 4). This score increase was driven by CPUE for all size and sex classes being at or above the long-term average and the percentage of females with poor clutch fullness being less than 10% and exhibiting a significant short-term decrease. Recruit CPUE is also exhibiting positive short-term trends. This area provided 7.1% of the average annual commercial harvest over baseline years, and 15.0% in the 2010/2011 fishery (Figure 15).

### Port Camden, Moderate 10%

The Port Camden stock health score improved from the 2010 survey. It is currently scored at 0.00, up from -3.00 in 2010 (Table 4). CPUE of all recruit classes were at the long-term average with no significant short-term trends. The percentage of females with poor clutch fullness did not differ significantly from 10%. This area provided 3.8% of the average annual commercial harvest over baseline years, and 0.0% in the 2010/2011 fishery (Figure 16).

## Red King Crab Survey Areas

### Seymour Canal, Moderate 10%

The Seymour Canal stock score increased slightly since the 2010 survey. It is currently scored -0.25, up from -2.25 in 2010 (Table 5). This score increase was driven by the CPUEs of recruit and postrecruits no longer being significantly below the long-term average. The only short-term trend was a declining prerecruit CPUE, which are now at their long-term average. The percentage of females with poor clutch fullness did not differ significantly from 10%. This area provided 4.8% of the average annual commercial harvest over baseline years, and 6.5% in the 2010/2011 fishery (Figure 17).

### North Juneau, Moderate 10%

The North Juneau stock health score increased slightly since 2010. It is currently scored at 0.25, up from -1.00 in 2010 (Table 5). This score is driven by a below-average CPUE relative to the long-term for recruit males, but prerecruit and postrecruit CPUE do not differ from the long-term average and postrecruit CPUE exhibits a short-term increase. The percentage of females with poor clutch fullness was less than 10%. This area provided 6.3% of the average annual commercial harvest over baseline years, and 3.8% in the 2010/2011 fishery (Figure 18).

### Excursion Inlet, Above Average 15%

The Excursion Inlet stock score showed no change since the 2010 survey, and is currently scored 1.25 (Table 5). This score is the result of the CPUE of all recruit classes being at the long-term average and a short-term increase for postrecruit males. The percentage of females with poor clutch fullness was less than 10%. This area provided 6.3% of the average annual commercial harvest over baseline years, and 6.9% in the 2010/2011 fishery (Figure 19).

**Pybus Bay, Above Average 15%**

The Pybus Bay stock health score increased since the 2010 survey. It is currently scored 3.00, up from -0.50 in 2010 (Table 5). This increase is a result of all male CPUE being above the long-term average, while mature female CPUE is at the long-term average. There are no short-term trends and the percentage of females with poor clutch fullness did not differ significantly from 10%. This area provided 1.2% of the average annual commercial harvest over baseline years, and 3.8% in the 2010/2011 fishery (Figure 20).

**Gambier Bay, Poor 0%**

The Gambier Bay stock health score decreased slightly since the 2010 survey. It is currently scored -3.75, down from -1.00 in 2010 (Table 6). This score is a result of CPUE for all recruit classes being below the long-term average with declining short-term trends for all but postrecruit males. The percentage of females with poor clutch fullness was less than 10%. This area provided 1.8% of the average annual commercial harvest over baseline years, and 1.2% in the 2010/2011 fishery (Figure 21).

**Peril Strait, Above Average 15%**

The Peril Strait stock health score increased slightly since the 2010 survey. It is currently scored 1.75, up from 1.00 in 2010 (Table 6). Prerecruit male CPUE is above the long-term average and recruit and postrecruit CPUEs are at the long-term average; there are significant short-term increases for all mature male recruit classes. The percentage of females with poor clutch fullness did not differ significantly from 10%. This area provided 0.7% of the average annual commercial harvest over baseline years, and 1.2% in the 2010/2011 fishery (Figure 22).

**Lynn Sisters, Moderate 10%**

The Lynn Sisters stock health score increased slightly since the 2010 survey. It is currently scored -0.50, up from -2.00 in 2010 (Table 6). CPUE for all size and sex classes were at the long-term average, although large female and prerecruit CPUE exhibited significant short-term declining trends. The percentage of females with poor clutch fullness did not significantly differ from 10%. This area provided 1.6% of the average annual commercial harvest over baseline years, and 1.2% in the 2010/2011 fishery (Figure 23).

**Port Frederick, Poor 0%**

The Port Frederick stock health score declined markedly since the 2010 survey. It is currently scored -4.00, down from -1.00 in 2010 (Table 6). All recruit classes are below the long-term average, although there were no significant short-term trends. The percentage of females with poor clutch fullness did not significantly differ from 10%. This area provided 0.5% of the average annual commercial harvest over baseline years, and 4.5% in the 2010/2011 fishery (Figure 24).

## EXTRA PROJECTS

There is currently a six (RKC survey) or seven (TC survey) year time series of temperature tidbit data and 2011 is the second year of CTD data collection. The coldest mean bottom temperature was measured in Lynn Sisters at 4.8 °C and the warmest in Port Camden at 8.1 °C. Temperatures in 2011 were fairly average except for Port Camden which was above average (Figures 25 and 26). Although CTD profiles cannot yet be used to detect interannual trends, large differences between locations are evident. The water column was very well stratified during the June/July red king crab survey, with the primary difference between areas being in the depth of the thermo and haloclines, which deepened as time progressed, however; by the time of the October Tanner crab survey, the thermocline had largely degraded, although the halocline remained prominent for some areas (Figures 27, 28, and 29).

Chela height data have been analyzed elsewhere to provide information on size at maturity for Tanner crab in Southeast Alaska (Siddon and Bednarski 2010) although interannual trends have not yet been examined. Likewise, trends in BCS prevalence have been described elsewhere (Bednarski et al. 2010) and will not be updated for 2011.

# DISCUSSION

The 2011/2012 season marks the fifteenth year of the Southeast Alaska Tanner crab stock assessment survey and the fifth for which C-S modeling was conducted to generate biomass estimates. Significant improvements have been made to the methods used to determine the harvestable surplus of Tanner crab over the past three seasons. The C-S model now converges for all survey areas and increased survey effort has resulted in improved model fits. Both of these have allowed a sustainable ER to be determined. Harvestable surplus is now calculated based upon the percent of mature crabs rather than the percent of legal crabs, which has the advantage of adjusting the ER of legal crabs using the abundance of prerecruit crabs, thereby increasing our confidence in stock assessment recommendations.

As with any stock assessment program, opportunities for improvement remain. First, the current Tanner crab survey sample design utilizes random pot placement within strata whose boundaries only roughly describe commercial fishing grounds within each survey area. As a 10 to 15-year time series of survey data now exists, a coarse restratification of survey grounds could be conducted. Besides increasing sample size, restratification has the highest potential to decrease the coefficient of variation of estimated survey CPUE and increase the precision of population estimates. Second, biomass estimates for survey areas from the C-S model are currently expanded to all of Southeast Alaska based upon the proportion of harvest (29%) which occurs in unsurveyed areas. A method of estimating the population size of this area is needed. Methods which employ fishery data such as change-in-ratio (Claytor and Allard 2003), or mark-recapture (Skalski and Robson 1992) should be explored. Thirdly, confidence limits for the C-S model are in the process of being determined and may help us to focus additional survey and analytic efforts on the least precise survey areas. Recent inseason observations obtained from Chad Soiseth, Fisheries Biologist, Glacier Bay National Park (personal communications) suggest that imprecision in at least one survey area, Glacier Bay, may be a result of misreporting location of harvest. The simple, yet time consuming, work of verifying logbook data could improve model estimates. Finally, C-S biomass estimate trends from Tanner crab survey areas track Tanner crab harvest data better than those from RKC survey areas. Considering the fact that strata boundaries within RKC survey areas are tightly defined based upon RKC distribution, this is not surprising, however, for some RKC survey areas, there also appears to be an inverse relationship between

RKC and Tanner crab survey CPUE, which implicates catchability as a factor. This should be further investigated.

Although C-S model results show a slight increase in biomass for several survey areas for the current season, regionwide biomass is currently only 41.8% of the long-term average. For each of the last four commercial fishing seasons, harvest has exceeded the GHL calculated using C-S estimates of mature male biomass and matrix-derived exploitation rates. Consistent recruitment overfishing not only risks stock collapse, but also reduces long-term stock productivity. A meaningful reduction in exploitation rate will be needed to ensure full recovery. In other registration areas in Alaska, reduced exploitation rates have been achieved through establishment of abundance-based harvest strategies. The current harvest strategy for Southeast Alaska Tanner crab was promulgated at the 2009 meeting of the BOF and became effective beginning with the 2009/2010 season. It includes a threshold which is calculated as half the long-term mature male biomass estimated from C-S modeling of survey data. It also includes an algorithm using projected effort and mature male biomass to establish season length. This harvest strategy only significantly constrains harvest pressure when the threshold is not achieved and the season remains closed. However, due to timing of the survey's establishment, the threshold is based upon a time series during which the population experienced a large decline. Development of variable exploitation rates linked to stock size and a biological reference point more representative of stock reproductive potential than mature male biomass should be a high priority.

In addition to anthropogenic factors, physical and biological processes also affect Tanner crab population trends in Southeast Alaska. Bottom temperature information suggests that climate change may be affecting Tanner crab distribution and/or abundance. The mean temperature of 8.1 °C measured at Port Camden approaches the limits of Tanner crab tolerance, suggesting that increases in bottom temperature may be implicated in the decline of the Port Camden Tanner crab stock. Although the upper thermal limit of Tanner crabs has yet to be described, both Somerton (1981) and Nielsen et al. (2007) found effects of temperature on Tanner crab distribution. Somerton in the EBS, where he postulated that temperature not only influenced the distribution of Tanner crab but might also be responsible for much of the regional variability in size. Nielsen et al. (2007) in Glacier Bay found Tanner crabs distributed in waters 4–8 °C, suggesting that 8 °C is an upper temperature limit to Tanner crab distribution. Further evidence of temperature regulating distribution is indicated in that mean pot depth was, in all cases, at or below the depth of the seasonal thermo and haloclines in CTD profiles. If mean pot depth can be inferred to be a rough proxy for mean crab depth, this may be because summer water temperature above the thermocline forms a barrier to crab depth distribution. This is consistent with the above-mentioned findings (Nielsen et al. 2007; Somerton 1981).

A thorough review of BCS prevalence in Southeast Alaska Tanner crab was recently published (Bednarski et al. 2010). While interannual trends were identified within only a few survey areas, the Southeast Alaska distribution of BCS has increased over the past 20 years and may be contributing to stock declines in some areas. As BCS is thought to be 100% fatal to Tanner crabs (Meyers et al. 1987), its prevalence may need to be considered in estimating natural mortality.

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## TABLES AND FIGURES

Table 1.–Latitude and longitude of oceanographic stations where CTD drops are conducted during annual shellfish surveys in Southeast Alaska. Stations 3, 6, 8, 10, 12, 13, 18, 21, and 25 were sampled during the 2011 Tanner crab survey and Stations 2 through 11 during the 2011 red king crab survey.

| Station no. | Station name | Decimal degrees Latitude | Decimal degrees Longitude |
|---|---|---|---|
| 1 | Lynn Sisters | 58.34504 | -135.09472 |
| 2 | Poundstone Reef | 58.33415 | -135.01425 |
| 3 | Scull Island | 58.12432 | -134.35402 |
| 4 | Peril Strait | 57.34296 | -135.30175 |
| 5 | Port Frederick | 58.05745 | -135.31514 |
| 6 | Icy Strait | 58.13470 | -135.23392 |
| 7 | Excursion Inlet | 58.23021 | -135.25955 |
| 8 | Five Fingers | 57.24821 | -133.46168 |
| 9 | Pybus Bay | 57.17193 | -134.02926 |
| 10 | Gambier Bay | 57.28348 | -133.58998 |
| 11 | Seymour Canal | 57.47281 | -134.04936 |
| 12 | Endicott Arm | 57.43343 | -133.30916 |
| 13 | Port Snettisham | 57.57224 | -133.57854 |
| 14 | Cordova Bay | 55.01726 | -132.38238 |
| 15 | Clarence Strait | 55.28312 | -132.01446 |
| 16 | Ernest Sound | 55.50478 | -132.12752 |
| 17 | Stikine Strait | 56.42844 | -132.58716 |
| 18 | Thomas Bay | 57.02204 | -132.50305 |
| 19 | Chatham Strait | 57.58943 | -134.76149 |
| 20 | Tenakee Inlet | 57.75844 | -135.14554 |
| 21 | Glacier Bay | 58.37468 | -136.04897 |
| 22 | Back Behm | 55.89867 | -131.13050 |
| 23 | West Behm | 55.57767 | -131.79930 |
| 24 | George & Carroll | 55.30817 | -131.49920 |
| 25 | Port Camden | 56.80408 | -133.91487 |

Table 2.–Overview of useable effort by survey area during the 2011 red king crab (RKCS) and Tanner crab surveys (TCS) in Southeast Alaska. Additional pot pulls that were made in two new strata in the Port Camden survey area are not reported here.

| Survey area | Project | No. Pots | Mean depth (fa) | SE depth | Mean soak (h) | SE soak |
|---|---|---|---|---|---|---|
| Icy Strait | TCS | 44 | 52.5 | 2.5 | 19.6 | 0.1 |
| Glacier Bay | TCS | 62 | 96.0 | 5.9 | 19.1 | 0.1 |
| Stephens Passage | TCS/ RKCS | 109 | 36.1 | 1.6 | 19.1 | 0.1 |
| Thomas Bay | TCS | 42 | 44.5 | 2.7 | 19.5 | 0.2 |
| Holkham Bay | TCS/ RKCS | 77 | 110.5 | 5.8 | 19.1 | 0.1 |
| Port Camden | TCS | 20 | 37.3 | 1.8 | 20.0 | 0.1 |
| | | | | | | |
| Seymour Canal | RKCS | 66 | 42.1 | 2.6 | 19.2 | 0.1 |
| North Juneau | RKCS | 88 | 48.3 | 1.7 | 19.3 | 0.1 |
| Excursion Inlet | RKCS | 46 | 61.2 | 2.8 | 19.4 | 0.1 |
| Pybus Bay | RKCS | 44 | 42.7 | 1.8 | 19.6 | 0.1 |
| Gambier Bay | RKCS | 48 | 39.1 | 3.2 | 19.2 | 0.1 |
| Peril Strait | RKCS | 43 | 39.0 | 1.0 | 19.5 | 0.1 |
| Lynn Sisters | RKCS | 22 | 42.7 | 5.2 | 18.8 | 0.2 |
| Port Frederick | RKCS | 45 | 48.3 | 3.5 | 18.7 | 0.1 |
| TOTAL | | **756** | **52.9** | | **19.3** | |

Table 3.–Results of catch-survey modeling estimation of legal and mature Southeast Alaska Tanner crab biomass and GHL calculations using exploitation rates based upon stock health for each of 14 surveyed areas and other areas for the 2011/2012 fishing season. See Tables 4 and 5 below for a more detailed look at the basis of stock health determinations. The expansion factor of 71% (29% for non-surveyed areas) for the total legal and mature crab biomass was based on the percent of commercial harvest taken from 1980–2000 in surveyed areas. The 1993–2002 mean harvest is used as the historical baseline.

| | **2010** | **2011** | | | | | | **1993–2002** | |
|---|---|---|---|---|---|---|---|---|---|
| **Survey area** | **Mature biomass** | **Legal biomass** | **Mature biomass** | **Stock health** | **Mature exploitation rate** | **Legal exploitation rate** | **Total GHL** | **Mean harvest** | **Mean mature biomass** |
| TCS | | | | | | | | | |
| Icy Strait | 76,538 | 80,039 | 171,469 | Below Average | 5% | 11% | 8,573 | 185,166 | 740,664 |
| Glacier Bay | 346,303 | 227,644 | 452,488 | Moderate | 10% | 20% | 45,249 | 255,482 | 1,021,928 |
| Stephens Passage | 259,463 | 173,108 | 218,939 | Below Average | 5% | 6% | 10,947 | 144,241 | 576,964 |
| Thomas Bay | 110,673 | 93,531 | 161,099 | Moderate | 10% | 17% | 16,110 | 59,356 | 237,424 |
| Holkham Bay | 133,162 | 134,856 | 208,265 | Above Average | 15% | 23% | 31,240 | 245,541 | 982,164 |
| Port Camden | 107,273 | 13,212 | 34,972 | Moderate | 10% | 26% | 3,497 | 39,239 | 156,956 |
| RKCS | | | | | | | | | |
| Seymour Canal | 276,646 | 183,962 | 249,924 | Moderate | 10% | 14% | 24,992 | 115,719 | 462,876 |
| North Juneau | 177,326 | 134,772 | 156,580 | Moderate | 10% | 12% | 15,658 | 83,188 | 332,752 |
| Excursion Inlet | 258,409 | 167,244 | 240,803 | Above Average | 15% | 22% | 36,120 | 79,705 | 318,820 |
| Pybus Bay | 128,025 | 114,162 | 150,178 | Above Average | 15% | 20% | 22,527 | 23,783 | 95,132 |
| Gambier Bay | 51,555 | 23,545 | 28,147 | Poor | 0% | 0% | 0 | 53,615 | 214,460 |
| Peril Strait | 69,479 | 43,751 | 96,952 | Above Average | 15% | 33% | 14,543 | 16,184 | 64,736 |
| Lynn Sisters | 30,325 | 26,976 | 32,577 | Moderate | 10% | 12% | 3,258 | 9,400 | 37,600 |
| Port Frederick | 14,412 | 9,192 | 11,120 | Poor | 0% | 0% | 0 | 13,920 | 55,680 |
| Other Areas | 838,772 | 582,449 | 904,111 | | | | 90,134 | 541,009 | 2,164,036 |
| Total | 2,892,318 | 2,008,444 | 3,117,625 | | | | 327,766 | 1,865,548 | 7,462,192 |

Table 4.–Matrix of stock health determination for all size/sex classes of Tanner crab from the 2011 Tanner crab surveys in Southeast Alaska. The long-term average is defined as the first 10 years of available data from 1997–2011. Short-term trends are based on individual regression analyses over the past 4 years (including the current year). Short-term trends are scored -0.25 for significantly declining, 0.00 for no trend, and +0.25 for significantly increasing while long-term trends are scored -1.00 for significantly below baseline, 0.00 for no difference from baseline, and +1.00 for significantly above baseline.

| | **Icy Strait** | | **Glacier Bay** | | **Stephens Passage** | | **Thomas Bay** | | **Holkham Bay** | | **Port Camden** | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Parameter** | **% of Baseline** | **Score** | **% of Baseline** | **Score** | **% of Baseline** | **Score** | **% of Baseline** | **Score** | **% of Baseline** | **Score** | **% of Baseline** | **Score** |
| Large/mature females | | | | | | | | | | | | |
| Percent clutch fullness < 25% | | | | | | | | | | | | |
| vs. long-term average | -72% | 1 | -70% | 1 | -59% | 1 | -80% | 1 | -83% | 1 | -100% | 0 |
| short term trend | | 0.25 | | 0 | | 0 | | 0 | | 0.25 | | 0 |
| CPUE vs. long-term average | -45% | -1 | -52% | -1 | -34% | 0 | -15% | 0 | 96% | 0 | 62% | 0 |
| CPUE short-term trend | | 0 | | 0 | | 0 | | -0.25 | | 0 | | 0 |
| Prerecruit males | | | | | | | | | | | | |
| CPUE vs. long-term average | -5% | 0 | -47% | -1 | -41% | -1 | 1% | 0 | 30% | 0 | 75% | 0 |
| CPUE short-term trend | | 0 | | -0.25 | | -0.25 | | 0 | | 0 | | 0 |
| Recruit males | | | | | | | | | | | | |
| CPUE vs. long-term average | -46% | -1 | -6% | 0 | -54% | -1 | 26% | 0 | 94% | 1 | -100% | 0 |
| CPUE short-term trend | | 0.25 | | 0 | | 0 | | 0 | | 0.25 | | 0 |
| Postrecruit males | | | | | | | | | | | | |
| CPUE vs. long-term average | -83% | -1 | 14% | 0 | -30% | -1 | 8% | 0 | 47% | 0 | 125% | 0 |
| CPUE short-term trend | | 0 | | 0 | | 0 | | 0 | | 0 | | 0 |
| 2010 Total score | -3.00 | | -2.00 | | -1.00 | | -3.00 | | 0.25 | | -3.00 | |
| 2010 Stock health | Below Average | | Below Average | | Moderate | | Below Average | | Moderate | | Below Average | |
| 2010 Mature exploitation rate | 5% | | 5% | | 10% | | 5% | | 10% | | 0% | |
| 2011 Total score | -1.50 | | -1.25 | | -2.25 | | 0.75 | | 2.50 | | 0.00 | |
| 2011 Stock health | Below Average | | Moderate | | Below Average | | Moderate | | Above Average | | Moderate | |
| 2011 Mature exploitation rate | 5% | | 10% | | 5% | | 10% | | 15% | | 10% | |

Table 5.–Matrix of stock health determination for all size/sex classes of Tanner crab in Southeast Alaska for four 2011 red king crab survey areas. The long-term average is defined from 1993–2002. Short-term trends are based on individual regression analyses over the past 4 years (including the current year). Short-term trends are scored -0.25 for significantly declining, 0.00 for no trend, and +0.25 for significantly increasing while long-term trends are scored -1.00 for significantly below baseline, 0.00 for no difference from baseline, and +1.00 for significantly above baseline.

| | **Seymour Canal** | | **North Juneau** | | **Excursion Inlet** | | **Pybus Bay** | |
|---|---|---|---|---|---|---|---|---|
| **Parameter** | **% of Baseline** | **Score** | **% of Baseline** | **Score** | **% of Baseline** | **Score** | **% of Baseline** | **Score** |
| Large/mature females | | | | | | | | |
| Percent clutch fullness < 25% | | | | | | | | |
| vs. long-term average | -39% | 0 | -90% | 1 | -68% | 1 | -44% | 0 |
| short term trend | | 0 | | 0 | | 0 | | 0 |
| CPUE vs. long-term average | -11% | 0 | 11% | 0 | 43% | 0 | 311% | 0 |
| CPUE vs. short-term trend | | 0 | | 0 | | 0 | | 0 |
| Prerecruit males | | | | | | | | |
| CPUE vs. long-term average | -6% | 0 | -8% | 0 | -6% | 0 | 233% | 1 |
| CPUE short-term trend | | -0.25 | | 0 | | 0 | | 0 |
| Recruit males | | | | | | | | |
| CPUE vs. long-term average | -33% | 0 | -30% | -1 | 13% | 0 | 186% | 1 |
| CPUE short-term trend | | 0 | | 0 | | 0 | | 0 |
| Postrecruit males | | | | | | | | |
| CPUE vs. long-term average | -31% | 0 | 7% | 0 | 14% | 0 | 136% | 1 |
| CPUE short-term trend | | 0 | | 0.25 | | 0.25 | | 0 |
| 2010 Total score | -2.25 | | -1.00 | | 1.25 | | -0.50 | |
| 2010 Stock health | Below Average | | Moderate | | Above Average | | Moderate | |
| 2010 Mature exploitation rate | 5% | | 10% | | 15% | | 10% | |
| 2011 Total score | -0.25 | | 0.25 | | 1.25 | | 3.00 | |
| 2011 Stock health | Moderate | | Moderate | | Above Average | | Above Average | |
| 2011 Mature exploitation rate | 10% | | 10% | | 15% | | 15% | |

-continued-

Table 6.–Matrix of stock health determination for all size/sex classes of Tanner crab in Southeast Alaska for four 2011 red king crab survey areas. The long-term average is defined from 1993–2002. Short-term trends are based on individual regression analyses over the past 4 years (including the current year). Short-term trends are scored -0.25 for significantly declining, 0.00 for no trend, and +0.25 for significantly increasing while long-term trends are scored -1.00 for significantly below baseline, 0.00 for no difference from baseline, and +1.00 for significantly above baseline.

| | **Gambier Bay** | | **Peril Strait** | | **Lynn Sisters** | | **Port Frederick** | |
|---|---|---|---|---|---|---|---|---|
| **Parameter** | **% of Baseline** | **Score** | **% of Baseline** | **Score** | **% of Baseline** | **Score** | **% of Baseline** | **Score** |
| Large/mature females | | | | | | | | |
| Percent clutch fullness < 25% | | | | | | | | |
| vs. long-term average | -79 | 1 | -10 | 0 | -37 | 0 | 21 | 0 |
| short term trend | | 0 | | 0 | | 0 | | 0 |
| CPUE vs. long-term average | -91 | -1 | 124 | 0 | -57 | 0 | -56 | -1 |
| CPUE vs. short-term trend | | -0.25 | | 0 | | -0.25 | | 0 |
| Prerecruit males | | | | | | | | |
| CPUE vs. long-term average | -86 | -1 | 63 | 1 | -13 | 0 | -64 | -1 |
| CPUE short-term trend | | -0.25 | | 0.25 | | -0.25 | | 0 |
| Recruit males | | | | | | | | |
| CPUE vs. long-term average | -89 | -1 | 49 | 0 | -22 | 0 | -45 | -1 |
| CPUE short-term trend | | -0.25 | | 0.25 | | 0 | | 0 |
| Postrecruit males | | | | | | | | |
| CPUE vs. long-term average | -61 | -1 | 89 | 0 | 70 | 0 | -30 | -1 |
| CPUE short-term trend | | 0 | | 0.25 | | 0 | | 0 |
| 2010 Total score | -1.00 | | 1.00 | | -2.00 | | -1.00 | |
| 2010 Stock health | Moderate | | Moderate | | Below Average | | Moderate | |
| 2010 Mature exploitation rate | 10% | | 10% | | 5% | | 10% | |
| 2011 Total score | -3.75 | | 1.75 | | -0.50 | | -4.00 | |
| 2011 Stock health | Poor | | Above Average | | Moderate | | Poor | |
| 2011 Mature exploitation rate | 0% | | 15% | | 10% | | 0% | |

Table 7.–Stock health scores for the Southeast Alaska Tanner crab fishery, by survey area 2007–2011.

| | Year | | | | |
|---|---|---|---|---|---|
| **Survey area** | **2007** | **2008** | **2009** | **2010** | **2011** |
| Icy Strait | -4.50 | -5.00 | -2.75 | -3.00 | -1.50 |
| Glacier Bay | 0.25 | 1.00 | -3.00 | -2.00 | -1.25 |
| Stephens Passage | -1.00 | -1.00 | -1.00 | -1.00 | -2.25 |
| Thomas Bay | -1.00 | 0.75 | -2.50 | -3.00 | 0.75 |
| Holkham Bay | -2.25 | -0.50 | -0.75 | 0.25 | 2.50 |
| Port Camden | -4.25 | -2.00 | -3.00 | -3.00 | 0.00 |
| Seymour Canal | 2.00 | -1.00 | -0.75 | -2.25 | -0.25 |
| North Juneau | -4.25 | -0.75 | -1.75 | -1.00 | 0.25 |
| Excursion Inlet | -1.25 | -1.25 | -0.25 | 1.25 | 1.25 |
| Pybus Bay | 3.25 | 1.00 | 1.00 | -0.50 | 3.00 |
| Gambier Bay | -3.00 | -0.75 | -1.75 | -1.00 | -3.75 |
| Peril Strait | 2.50 | -2.25 | -1.25 | 1.00 | 1.75 |
| Lynn Sisters | -0.75 | 0.25 | -2.00 | -2.00 | -0.50 |
| Port Frederick | -0.75 | -2.50 | 0.25 | -1.00 | -4.00 |

Table 8.–Legal biomass estimate, calculated GHL, and harvest in pounds, and matrix-derived and achieved annual legal exploitation rates for 2006/2007–2011/2012 Southeast Alaska commercial Tanner crab seasons.

| **Parameter** | **2007/08** | **2008/09** | **2009/10** | **2010/11** | **2011/12** |
|---|---|---|---|---|---|
| Legal biomass estimate | 3,013,246 | 2,791,159 | 2,419,124 | 1,818,781 | 2,008,444 |
| Recommended GHL | 497,897 | 421,248 | 279,845 | 238,720 | 327,766 |
| Harvest | 605,062 | 599,722 | 961,681 | 891,344 | 1,109,784 |
| Matrix-derived exploitation rate | 16.5% | 15.1% | 11.6% | 13.1% | 16.3% |
| Achieved exploitation rate | 20.1% | 21.5% | 39.8% | 49.0% | 55.3% |

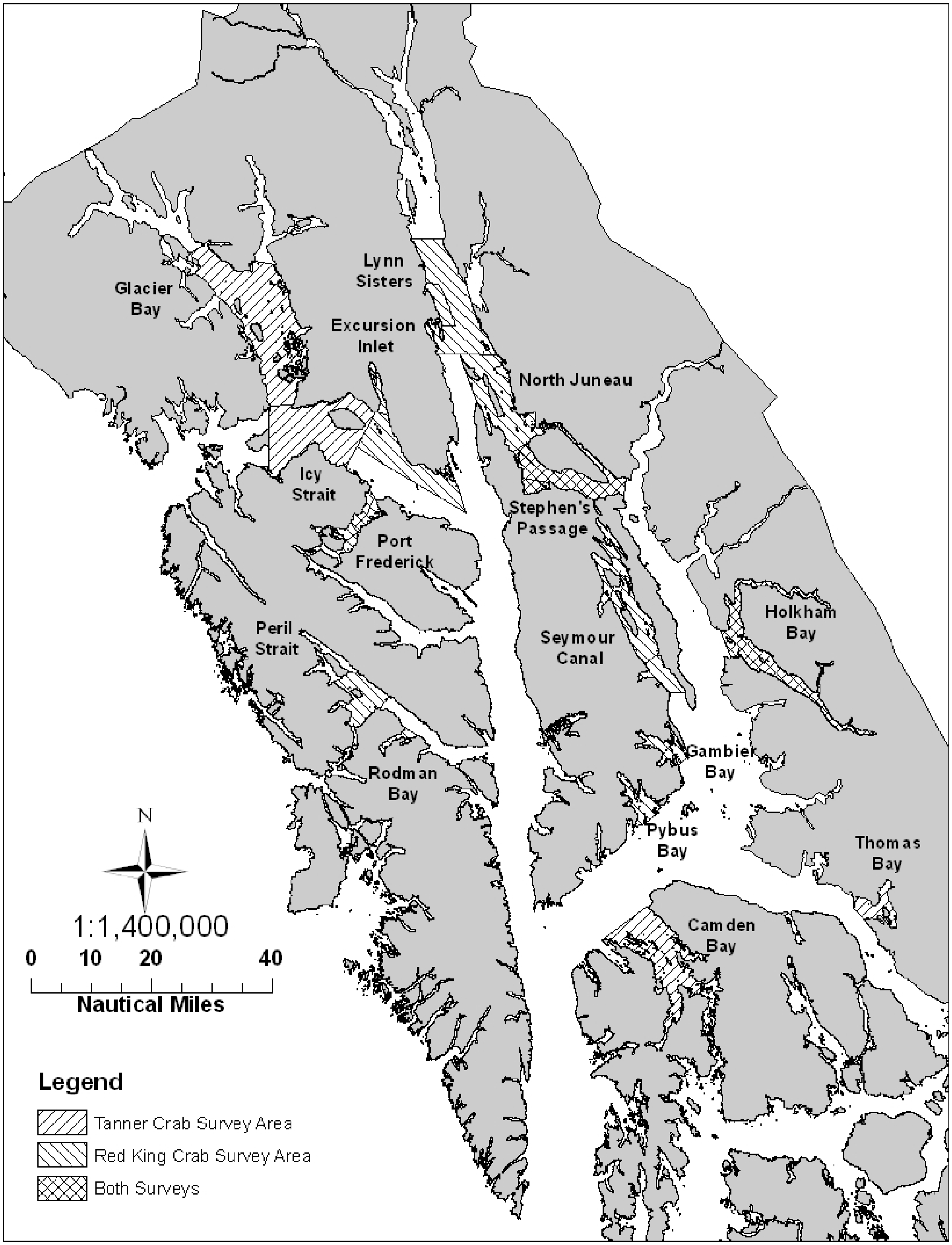


Figure 1.–Tanner and red king crab survey areas in Southeast Alaska.

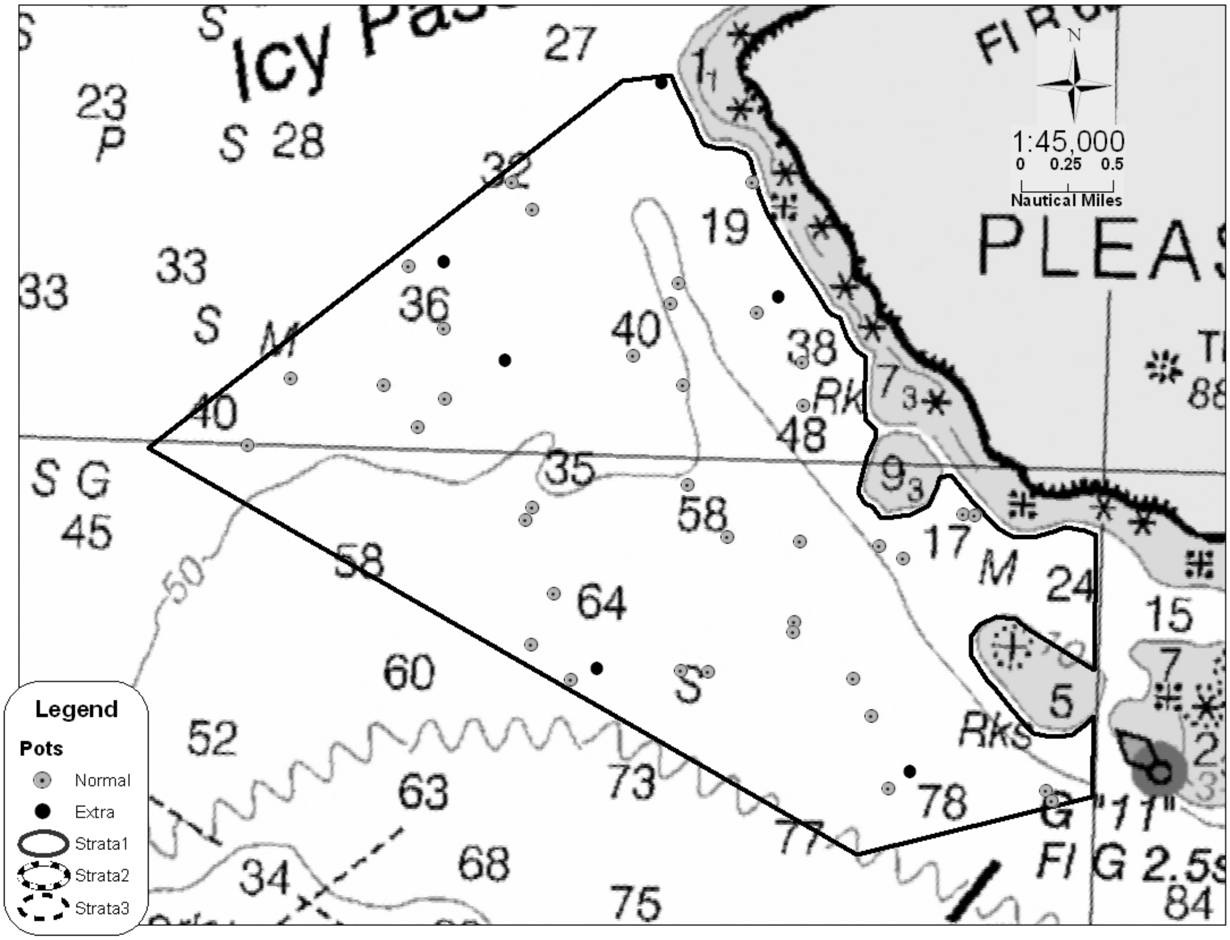


Figure 2.–Tanner crab survey pot locations in Icy Strait, Southeast Alaska, 2011.

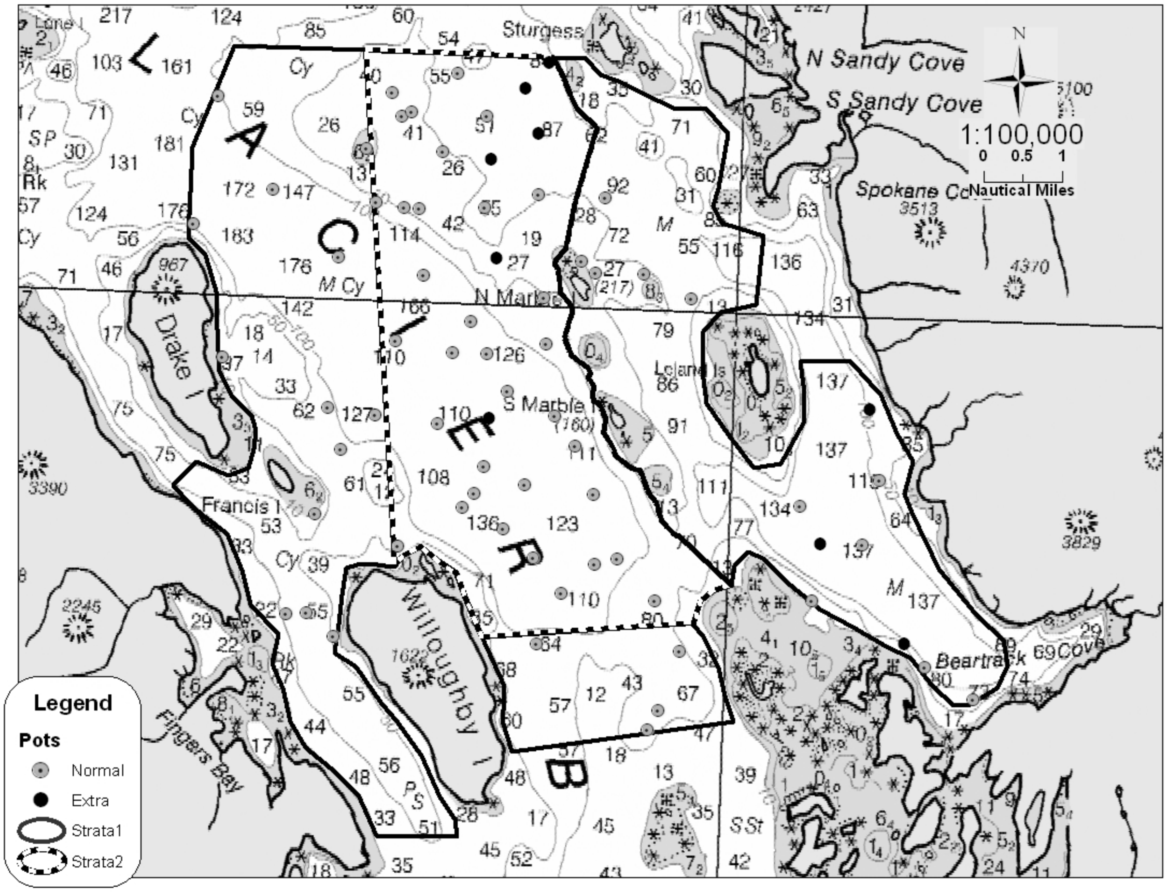


Figure 3.–Tanner crab survey pot locations in Glacier Bay, Southeast Alaska, 2011.

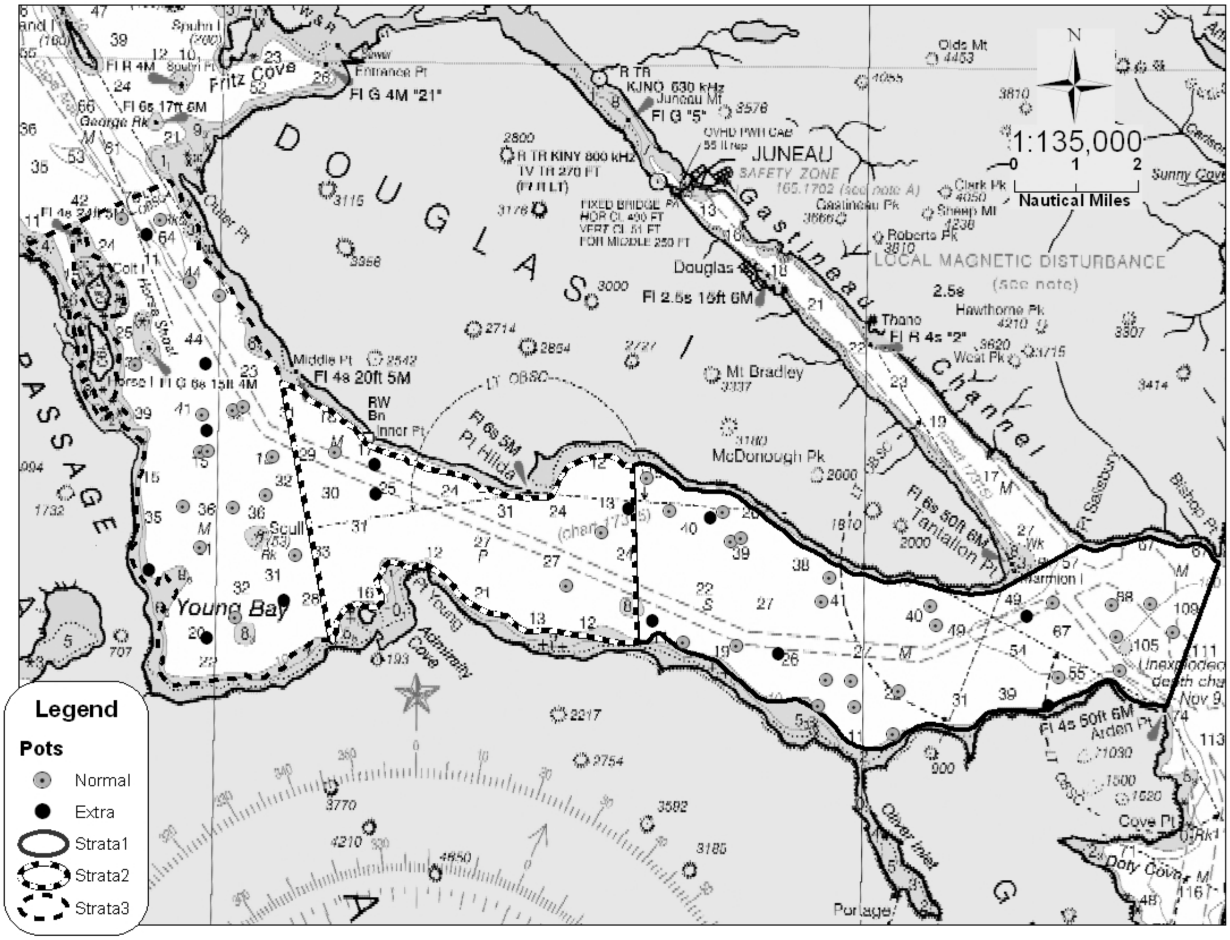


Figure 4.–Tanner crab survey pot locations in Stephens Passage, Southeast Alaska, 2011.

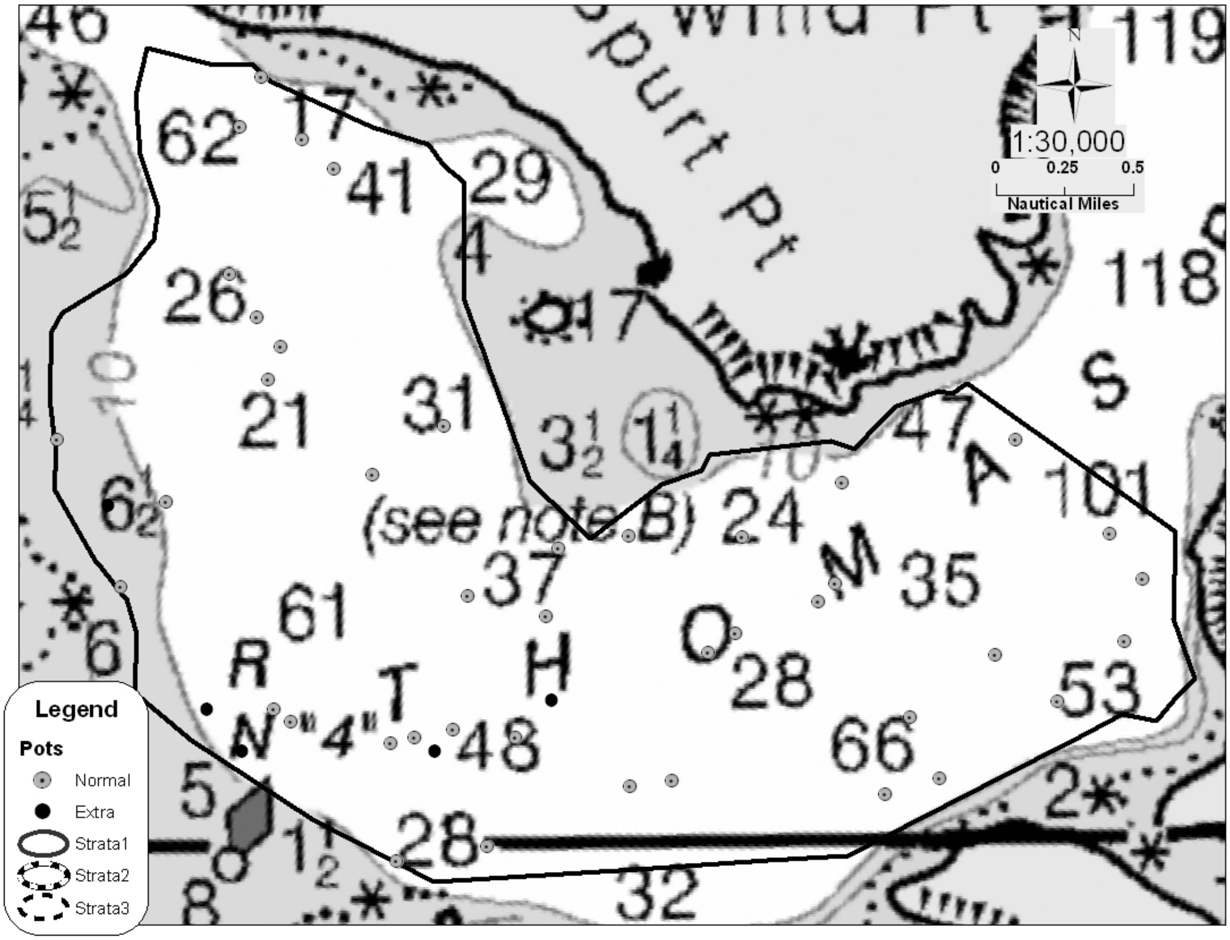


Figure 5.–Tanner crab survey pot locations in Thomas Bay, Southeast Alaska, 2011.

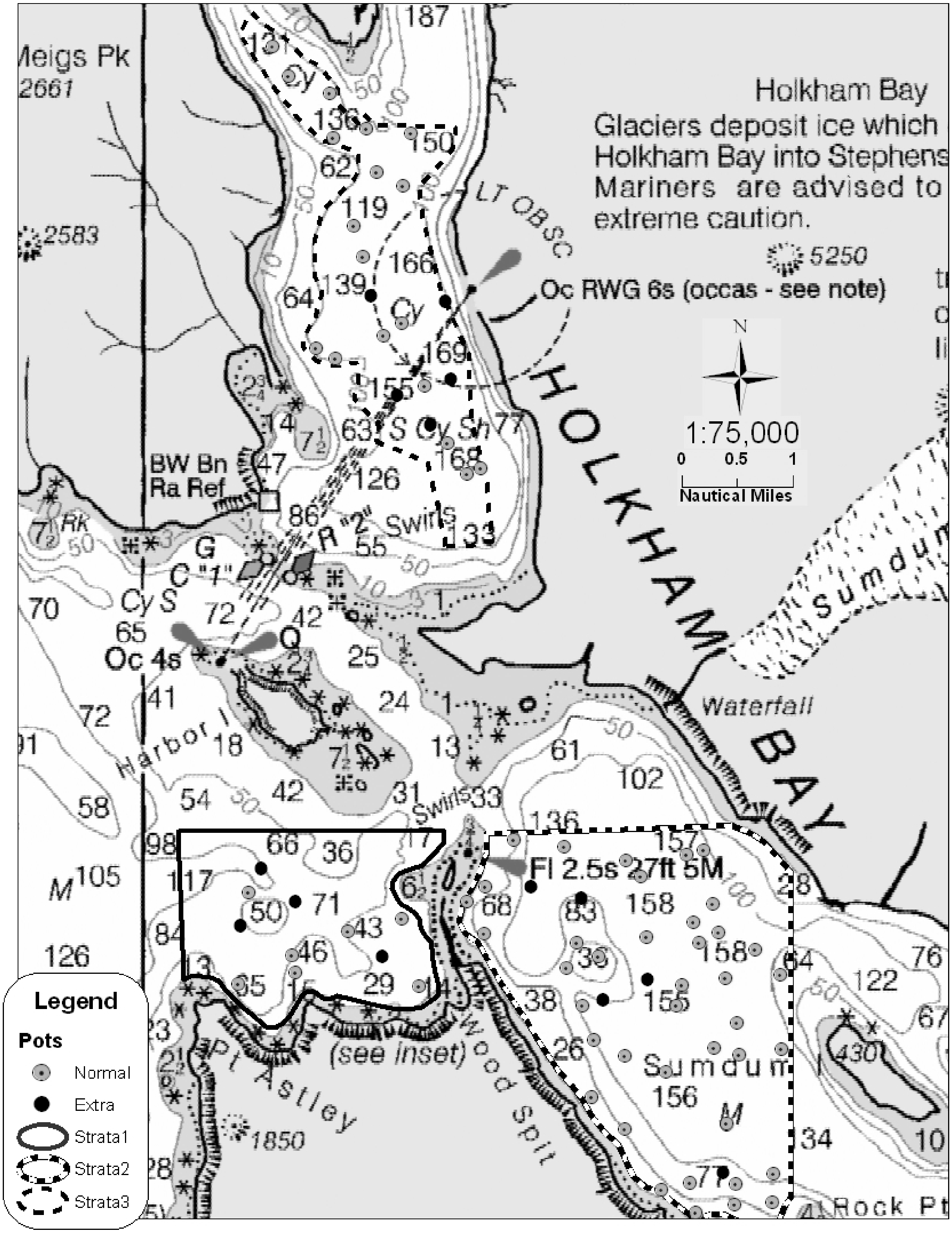


Figure 6.–Tanner crab survey pot locations in Holkham Bay, Southeast Alaska, 2011.

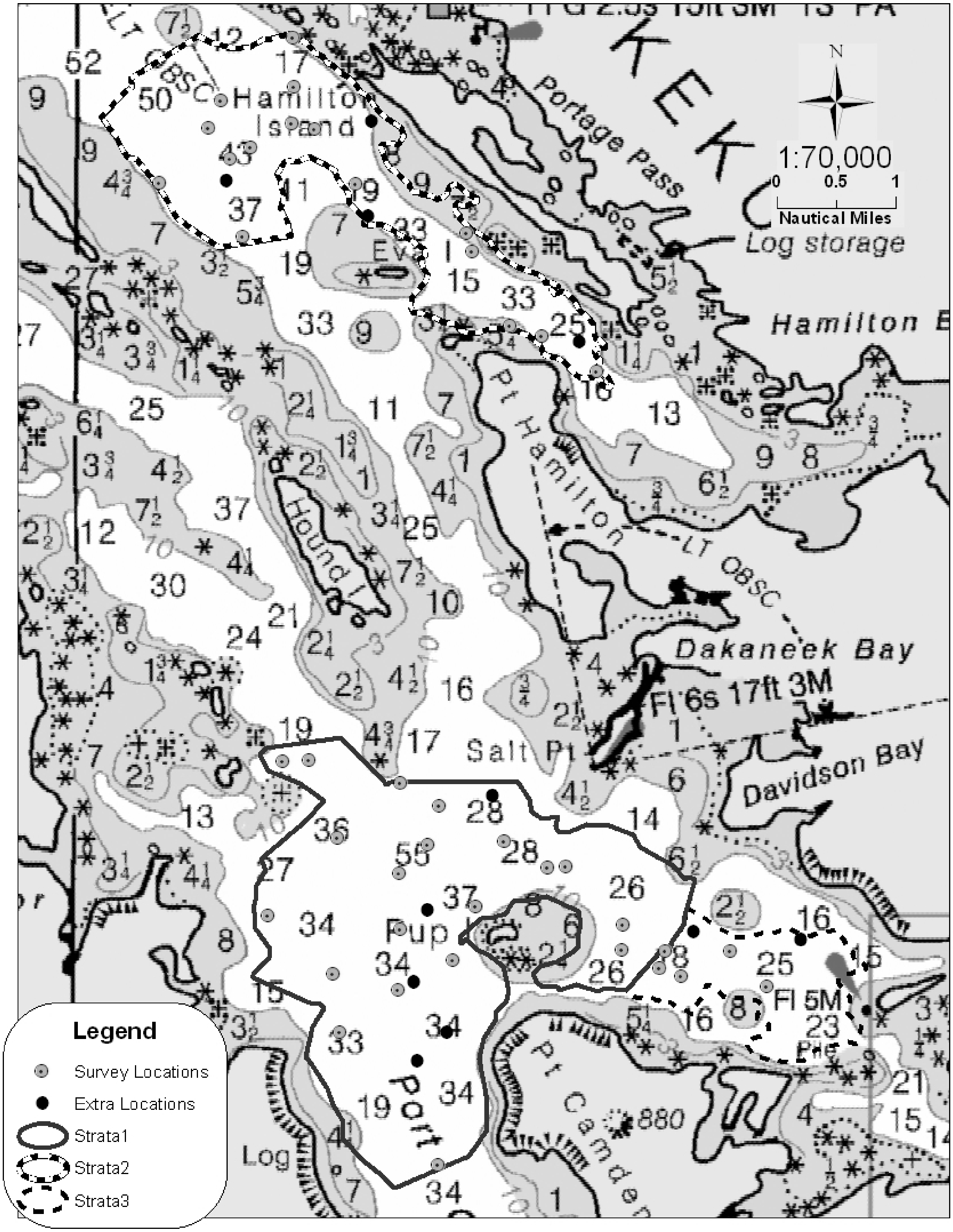


Figure 7.–Tanner crab survey pot locations in Port Camden, Southeast Alaska, 2011.

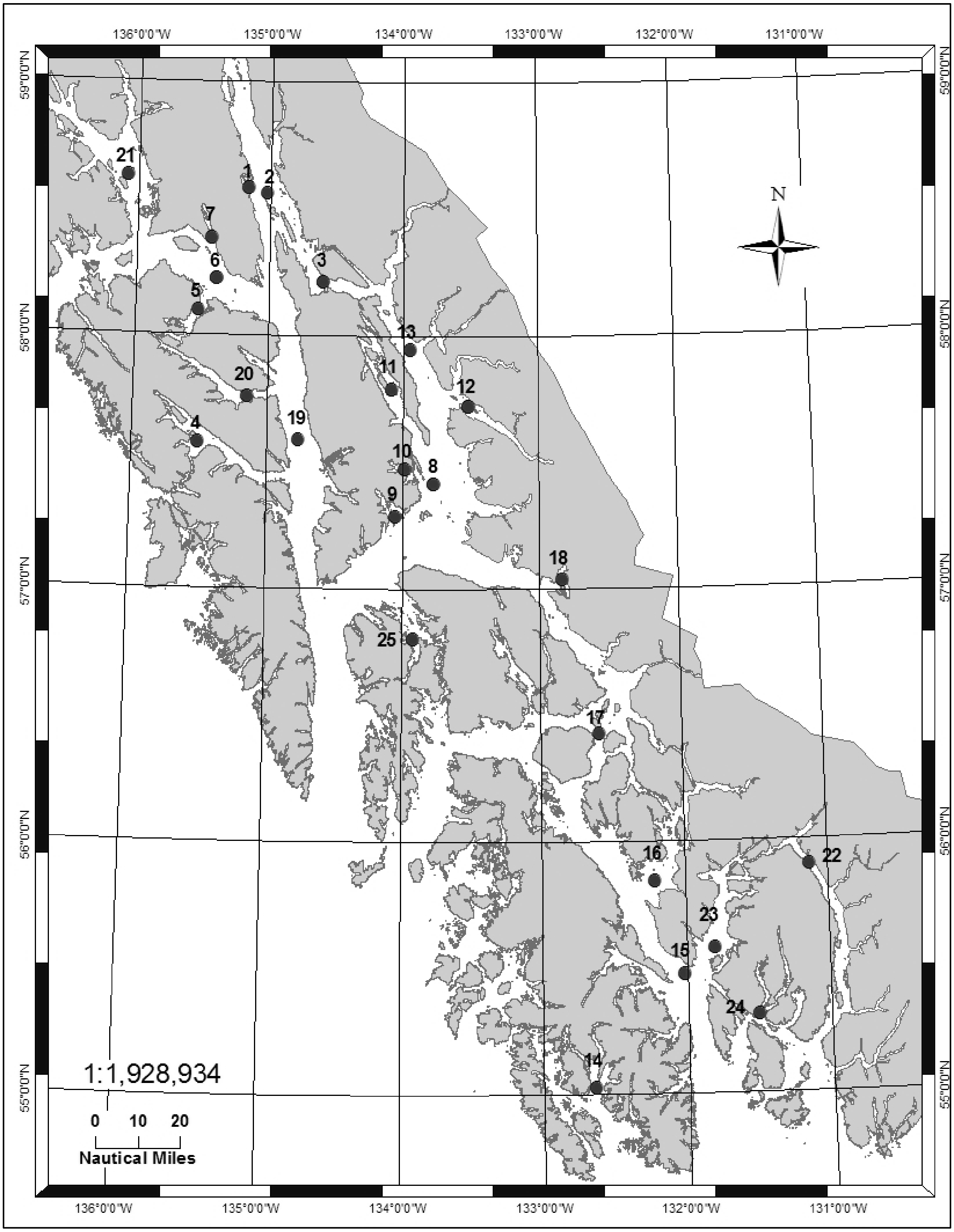


Figure 8.–CTD stations sampled during the 2011 shellfish surveys in Southeast Alaska. Stations 3, 6, 8, 12, 13, 18, 21, and 25 were sampled during the 2011 Tanner crab survey and Stations 2–11 during the 2011 red king crab survey.

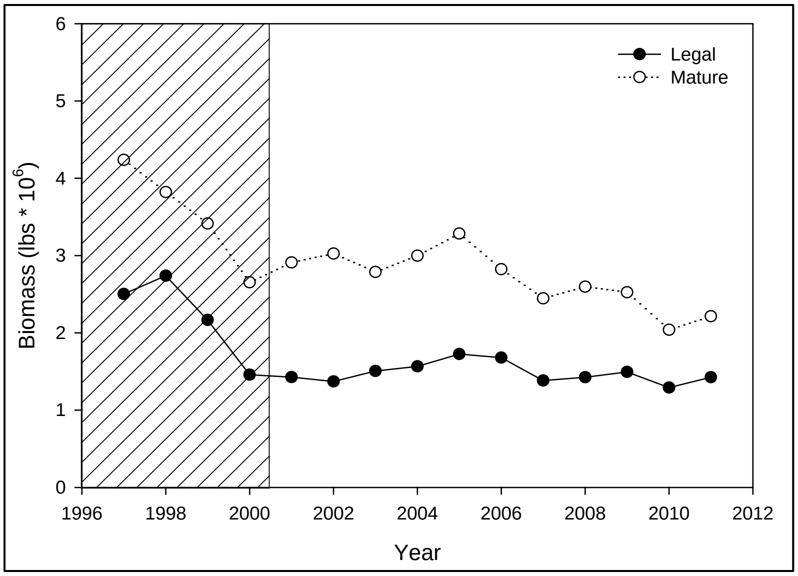


Figure 9.–Trends in mature and legal Tanner crab biomass in surveyed areas estimated by catch-survey modeling of pot survey data for Southeast Alaska during 1997–2011 surveys. Hatched area is where biomass of areas not surveyed (Port Camden, Thomas Bay, Glacier Bay) are estimated by their minimum biomass of all subsequent years.

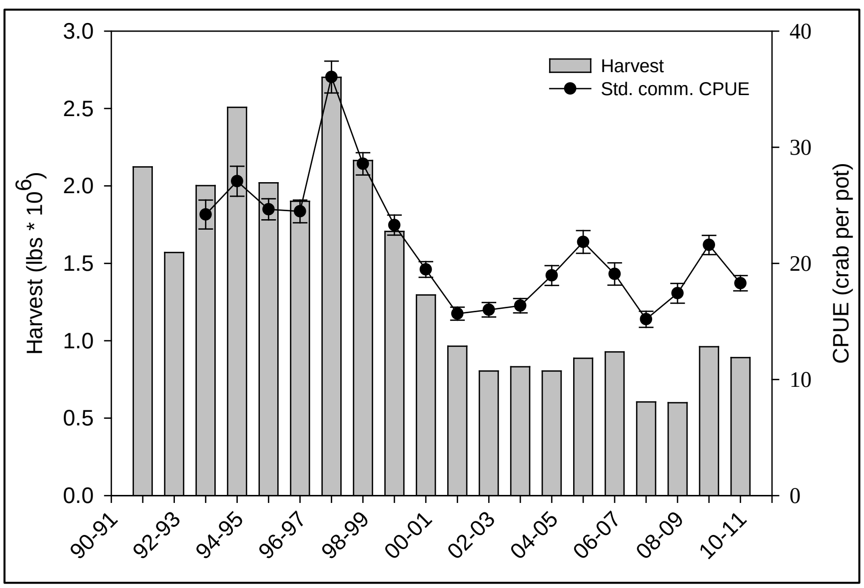


Figure 10.–Southeast Alaska commercial Tanner crab harvest and standardized commercial catch per unit effort (CPUE) for 1991/1992 through 2009/2010 seasons. CPUE was calculated using logbook data, which began during the 1993/1994 season. Standardize CPUE was calculated by using a similar number of potlifts for each year, based on the year (2008/2009) with the fewest number of potlifts (12,521).

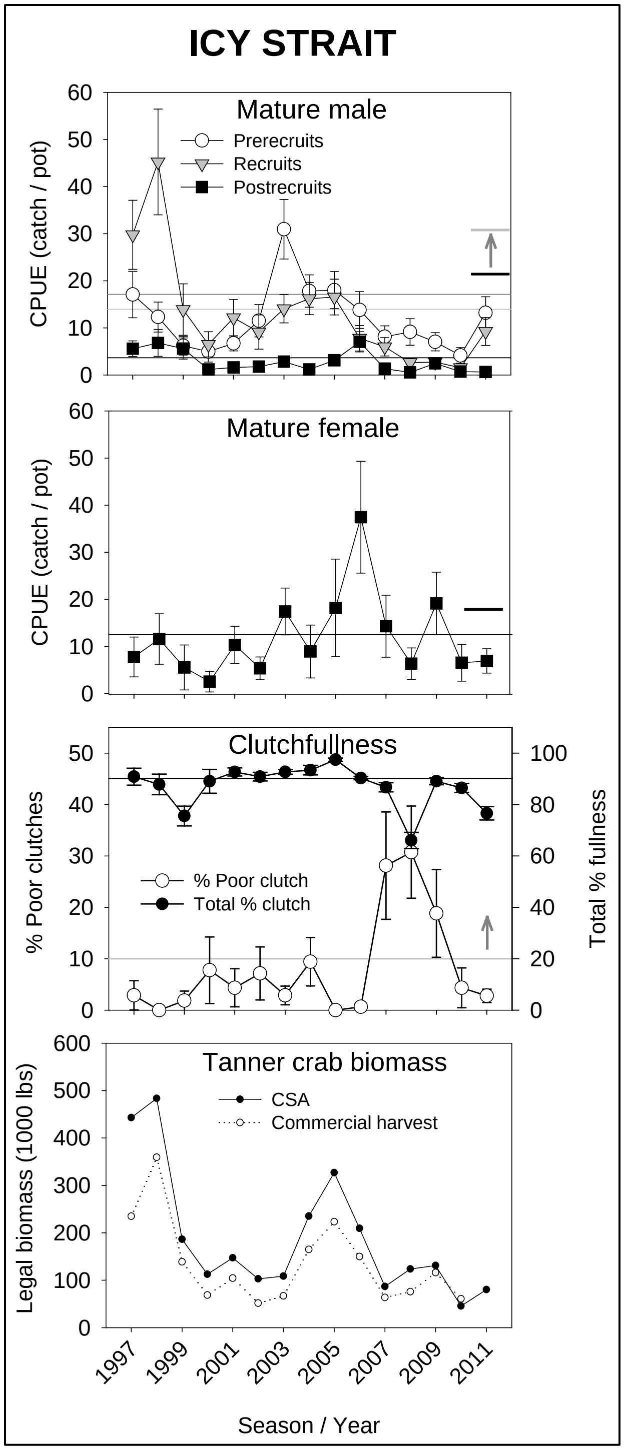


Figure 11.–Tanner crab CPUE for all size/sex classes, clutch fullness, proportion of poor clutches, legal biomass estimates from catch survey analysis (CSA), and harvest data in Icy Strait, Southeast Alaska, 2011. Symbols on the right side of plots represent a significant increase ($p < 0.05$, up arrow) 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. Reference lines represent long-term average (benchmark) (1997–2006).

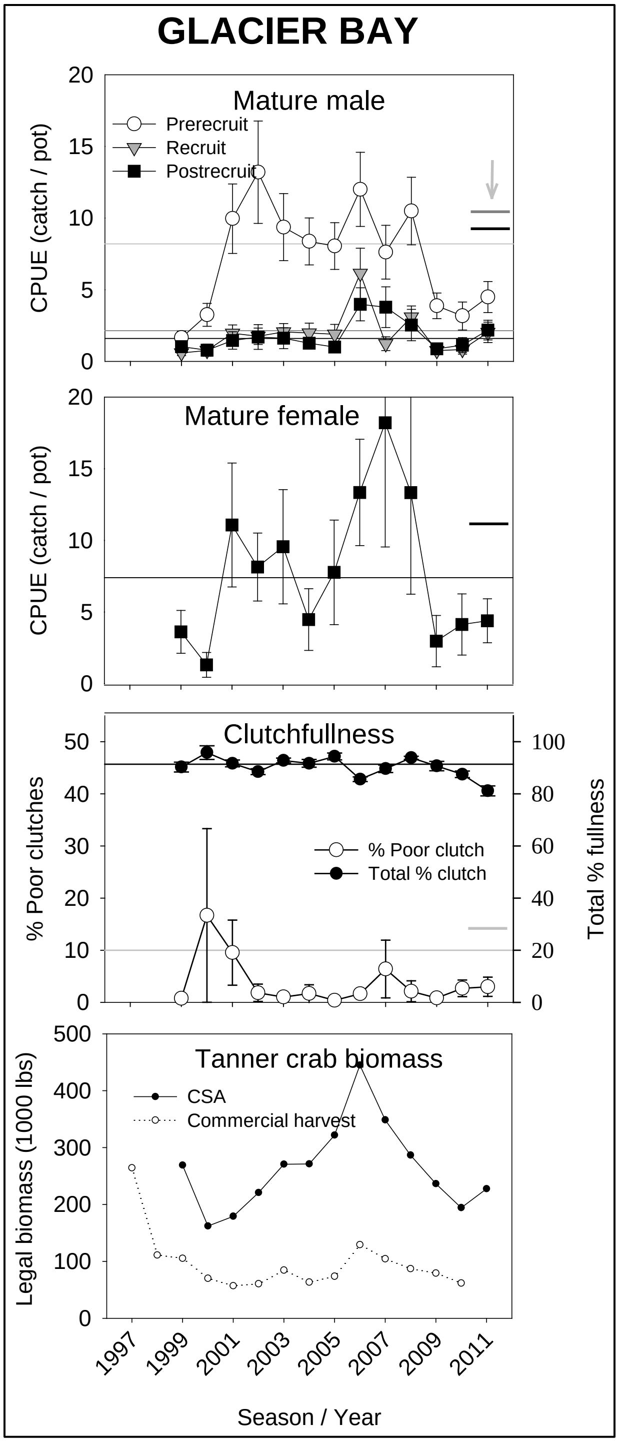


Figure 12.–Tanner crab CPUE for all size/sex classes, clutch fullness, proportion of poor clutches, legal biomass estimates from catch survey analysis (CSA), and harvest data in Glacier Bay, Southeast Alaska, 2011. Symbols on the right side of plots represent a significant increase ($p < 0.05$, up arrow) 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. Reference lines represent long-term average (benchmark) (1999–2008).

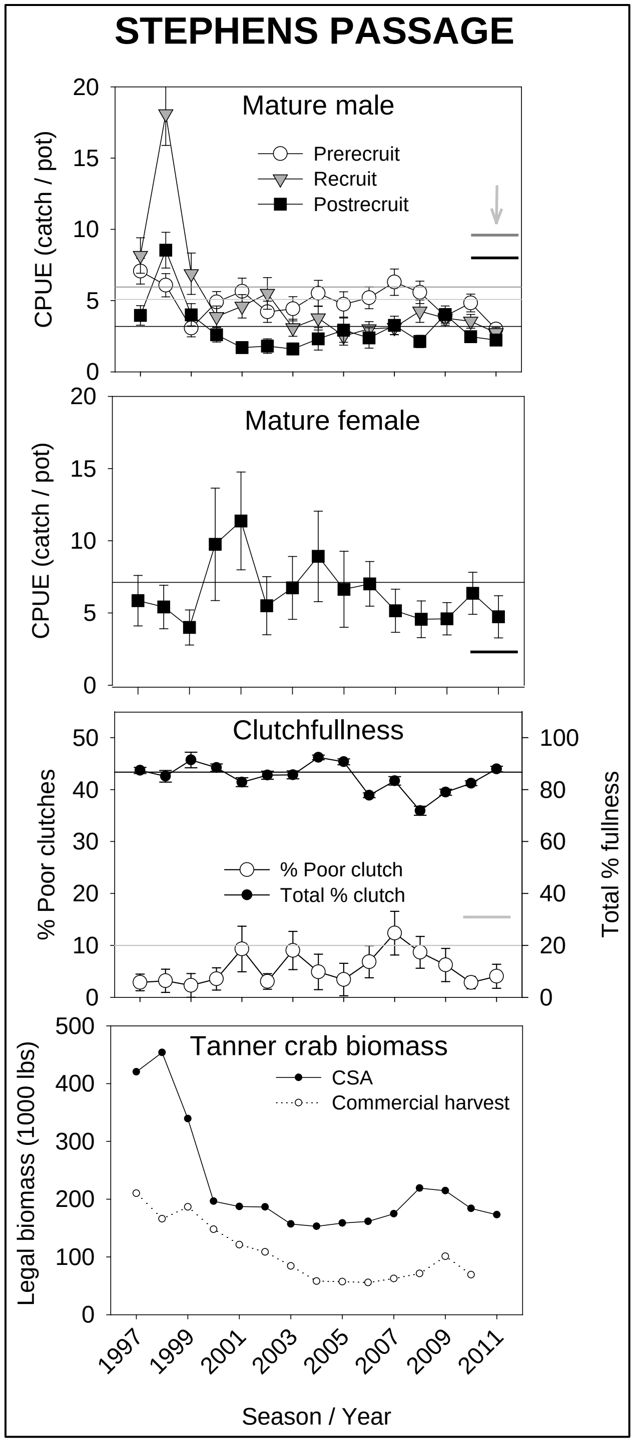


Figure 13.–Tanner crab CPUE for all size/sex classes, clutch fullness, proportion of poor clutches, legal biomass estimates from catch survey analysis (CSA), and harvest data in Stephens Passage, Southeast Alaska, 2011. Symbols on the right side of plots represent a significant increase ($p < 0.05$, 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. Reference lines represent long-term average (benchmark) (1997–2006).

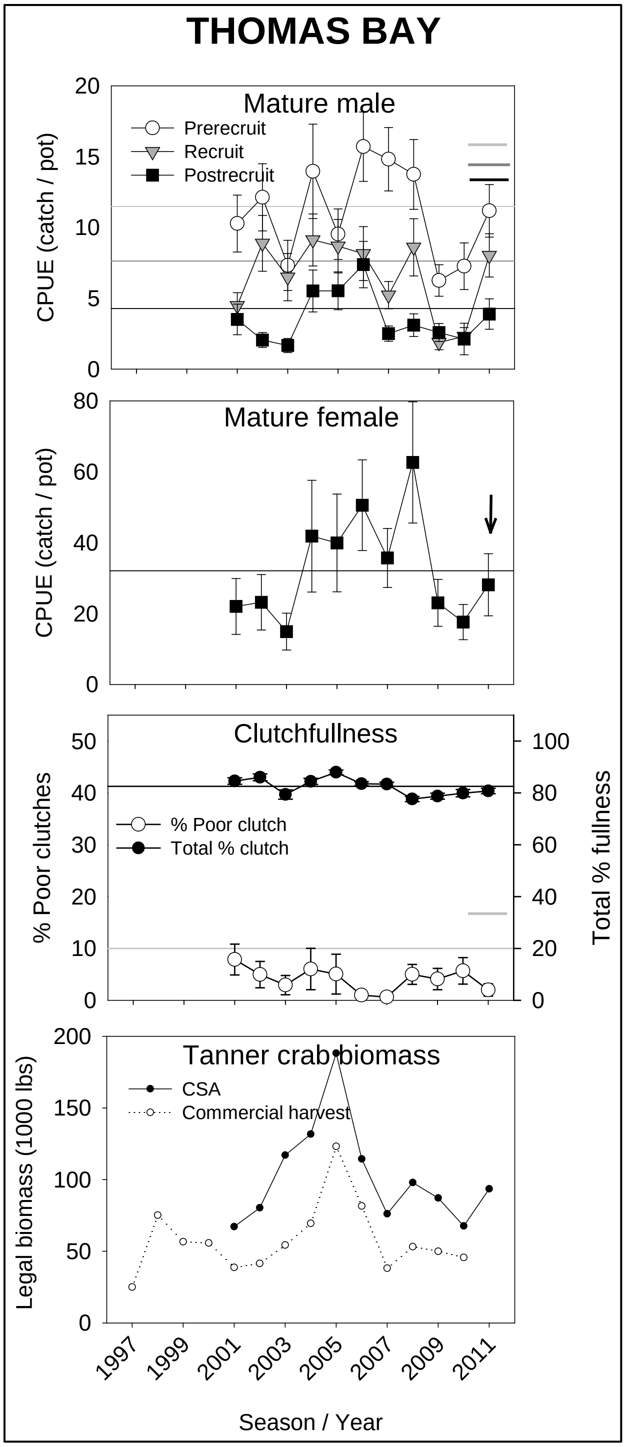


Figure 14.–Tanner crab CPUE for all size/sex classes, clutch fullness, proportion of poor clutches, legal biomass estimates from catch survey analysis (CSA), and harvest data in Thomas Bay, Southeast Alaska, 2011. Symbols on the right side of plots represent a significant increase ($p < 0.05$, up arrow) 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. Reference lines represent long-term average (benchmark) (2001–2010).

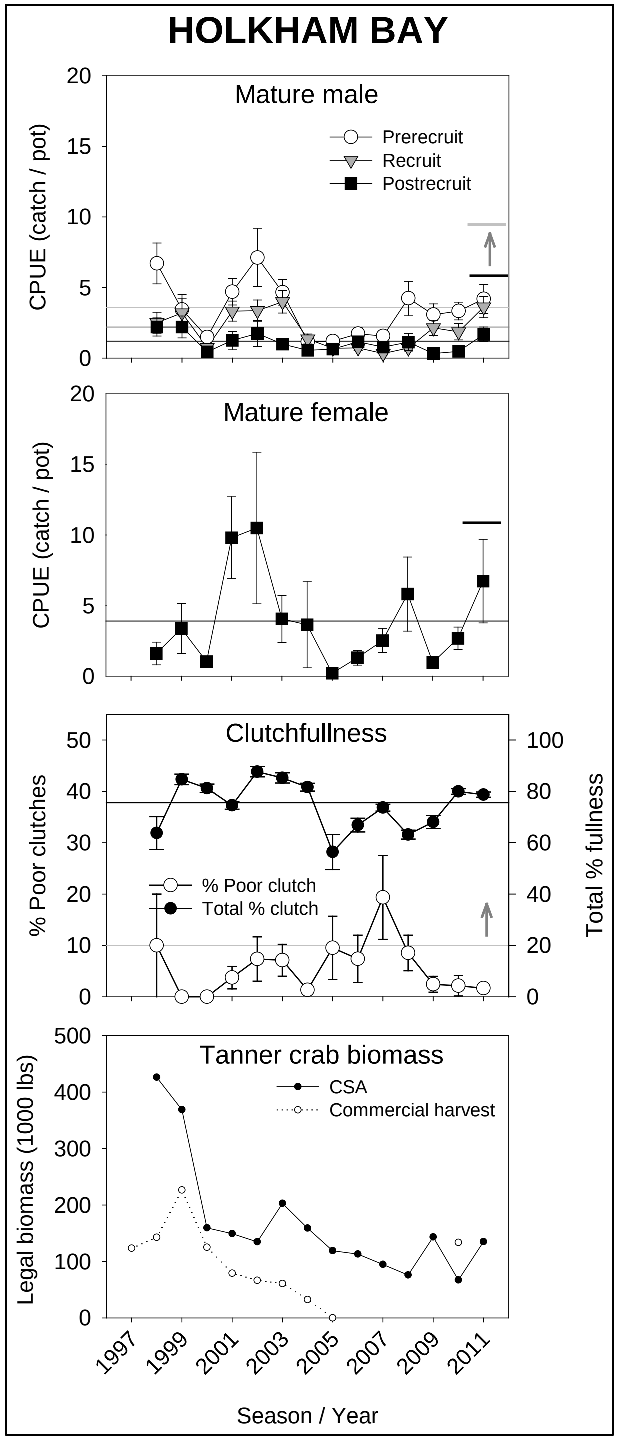


Figure 15.–Tanner crab CPUE for all size/sex classes, clutch fullness, proportion of poor clutches, legal biomass estimates from catch survey analysis (CSA), and harvest data in Holkham Bay, Southeast Alaska, 2011. Symbols on the right side of plots represent a significant increase ($p < 0.05$, up arrow) 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. Reference lines represent long-term average (benchmark) (1998–2007).

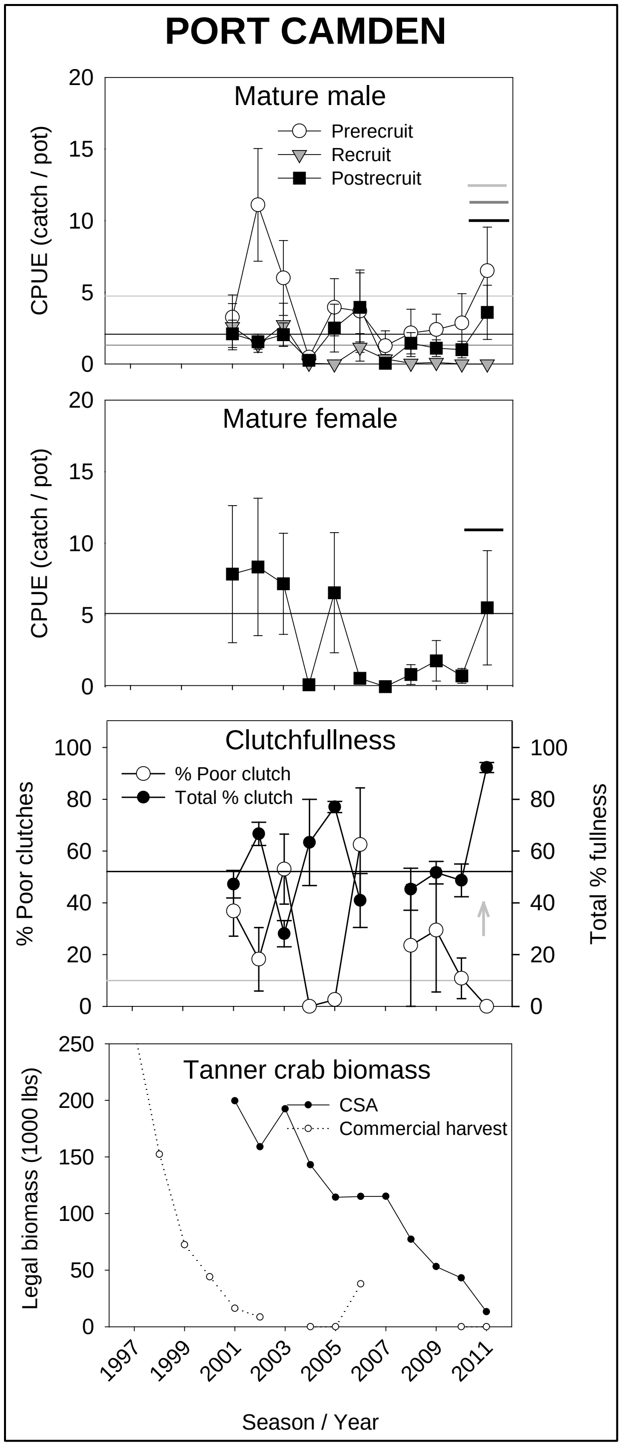


Figure 16.–Tanner crab CPUE for all size/sex classes, clutch fullness, proportion of poor clutches, legal biomass estimates from catch survey analysis (CSA), and harvest data in Port Camden, Southeast Alaska, 2011. Symbols on the right side of plots represent a significant increase ($p < 0.05$, up arrow) 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. Reference lines represent long-term average (benchmark) (2001–2010).

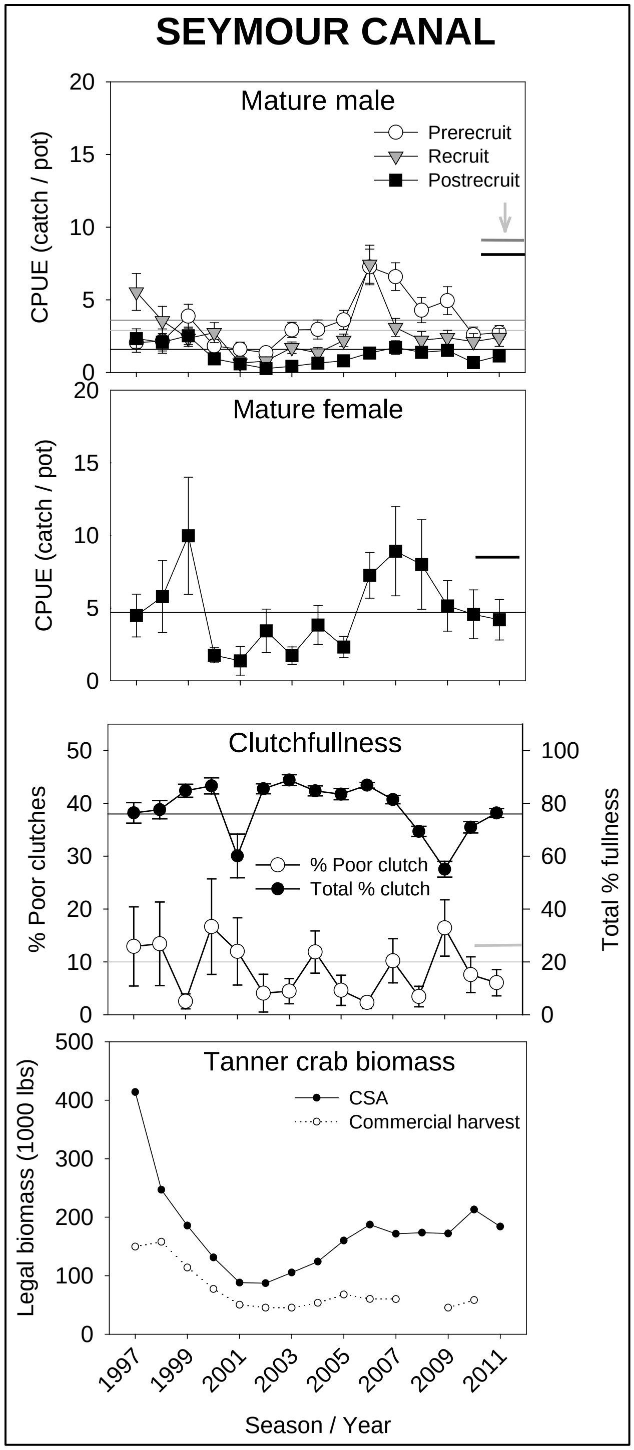


Figure 17.–Tanner crab CPUE for all size/sex classes, clutch fullness, proportion of poor clutches, legal biomass estimates from catch survey analysis (CSA), and harvest data in Seymour Canal, Southeast Alaska, 2011. Symbols on the right side of plots represent a significant increase ($p < 0.05$, up 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. Reference lines represent long-term average (benchmark) (1993–2002).

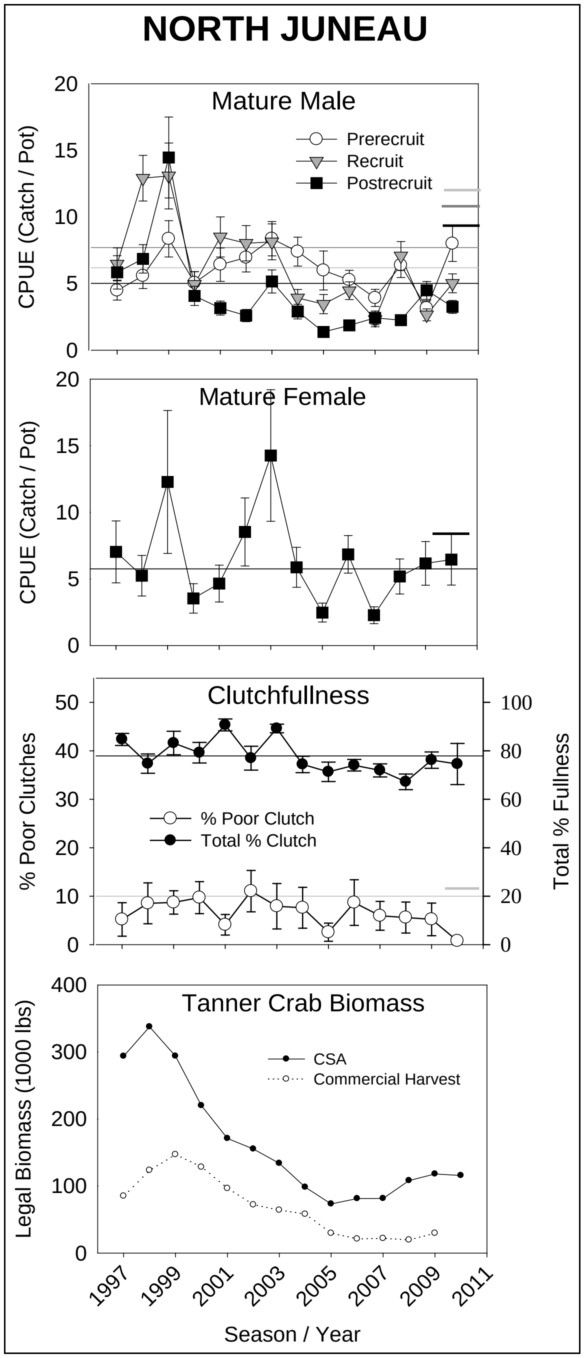


Figure 18.–Tanner crab CPUE for all size/sex classes, clutch fullness, proportion of poor clutches, legal biomass estimates from catch survey analysis (CSA), and harvest data in North Juneau, Southeast Alaska, 2011. Symbols on the right side of plots represent a significant increase ($p < 0.05$, up arrow) 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. Reference lines represent long-term average (benchmark) (1993–2002).

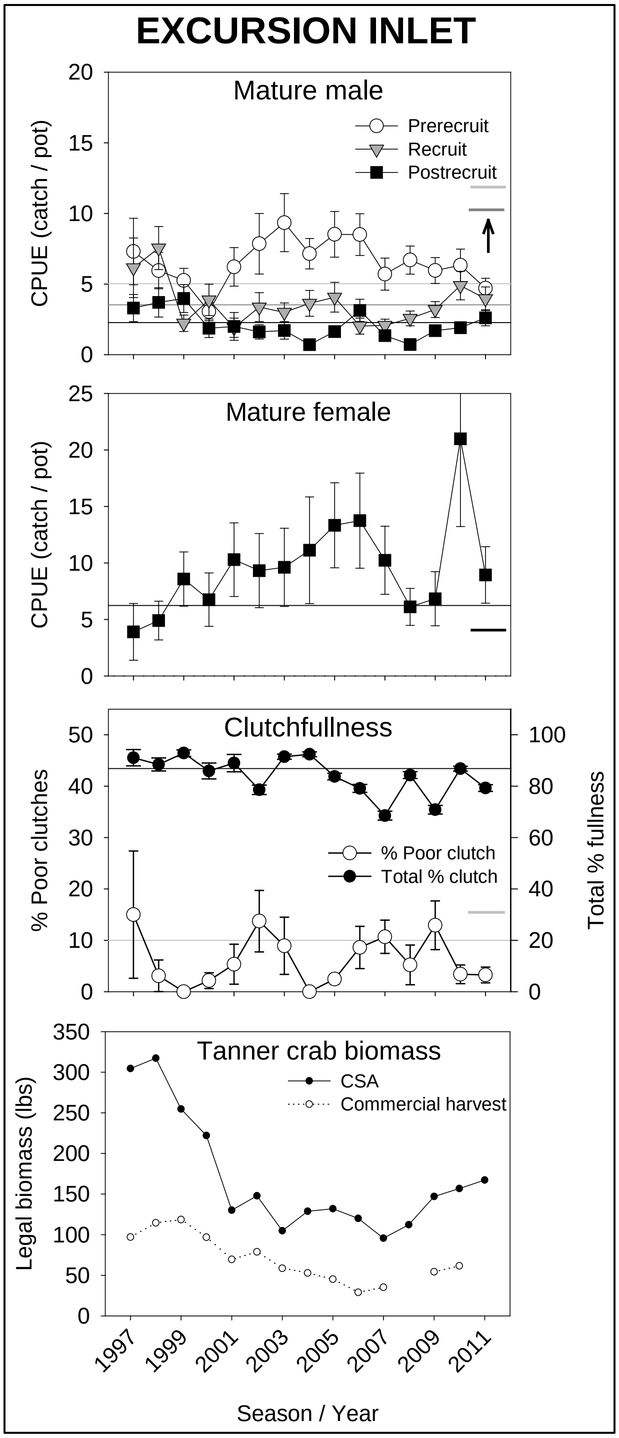


Figure 19.–Tanner crab CPUE for all size/sex classes, clutch fullness, proportion of poor clutches, legal biomass estimates from catch survey analysis (CSA), and harvest data in Excursion Inlet, Southeast Alaska, 2011. Symbols on the right side of plots represent a significant increase ($p < 0.05$, up 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. Reference lines represent long-term average (benchmark) (1993–2002).

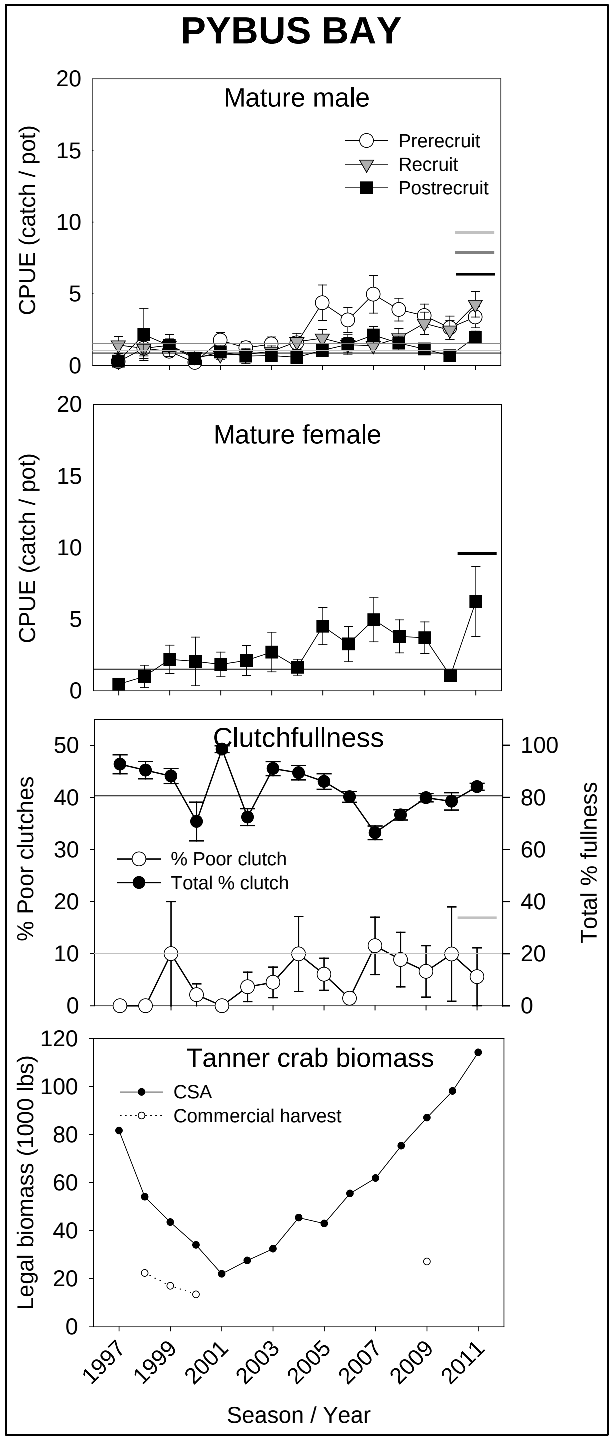


Figure 20.–Tanner crab CPUE for all size/sex classes, clutch fullness, proportion of poor clutches, legal biomass estimates from catch survey analysis (CSA), and harvest data in Pybus Bay, Southeast Alaska, 2011. Symbols on the right side of plots represent a significant increase ($p < 0.05$, up arrow) 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. Reference lines represent long-term average (benchmark) (1993–2002).

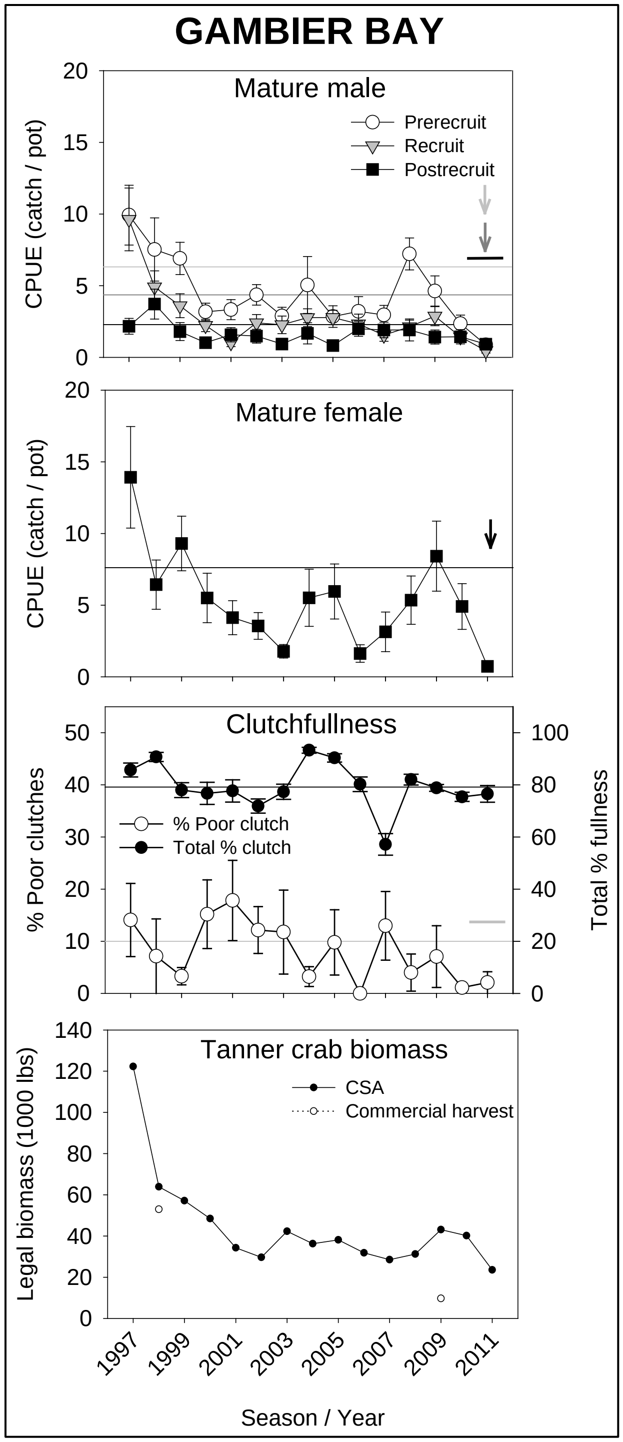


Figure 21.–Tanner crab CPUE for all size/sex classes, clutch fullness, proportion of poor clutches, legal biomass estimates from catch survey analysis (CSA), and harvest data in Gambier Bay, Southeast Alaska, 2011. Symbols on the right side of plots represent a significant increase ($p < 0.05$, up arrow) 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. Reference lines represent long-term average (benchmark) (1993–2002).

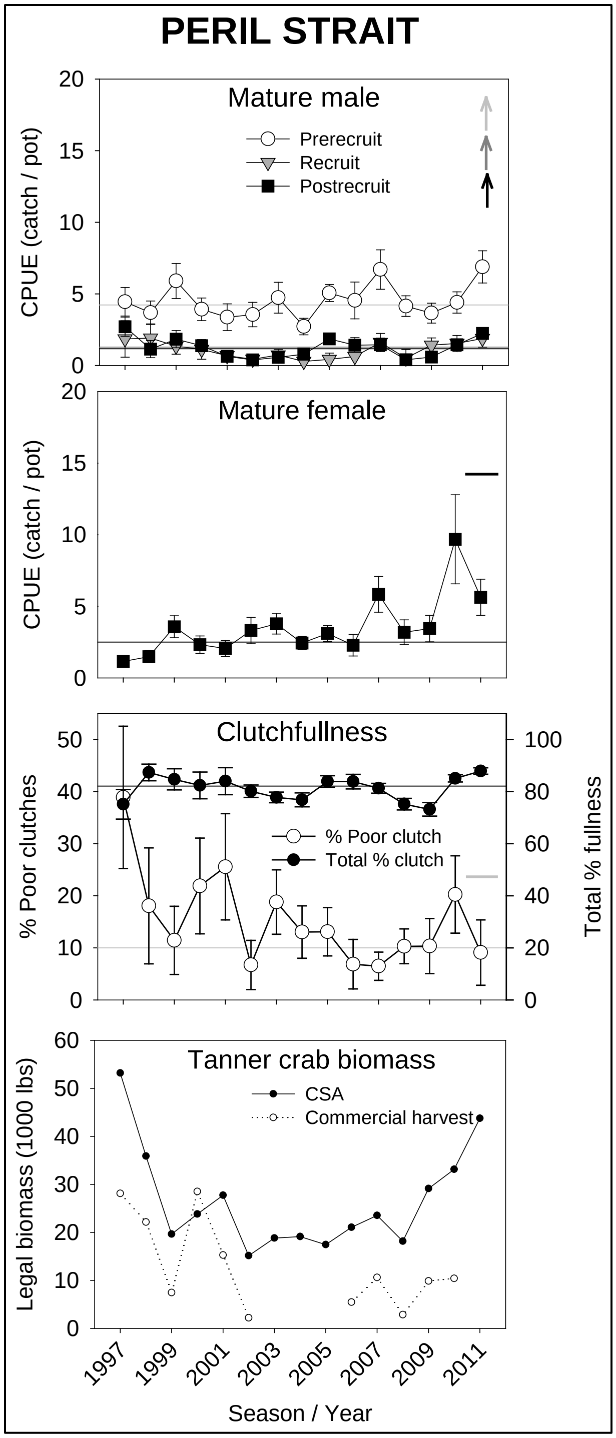


Figure 22.–Tanner crab CPUE for all size/sex classes, clutch fullness, proportion of poor clutches, legal biomass estimates from catch survey analysis (CSA), and harvest data in Peril Strait, Southeast Alaska, 2011. Symbols on the right side of plots represent a significant increase ($p < 0.05$, up arrow) 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. Reference lines represent long-term average (benchmark) (1993–2002).

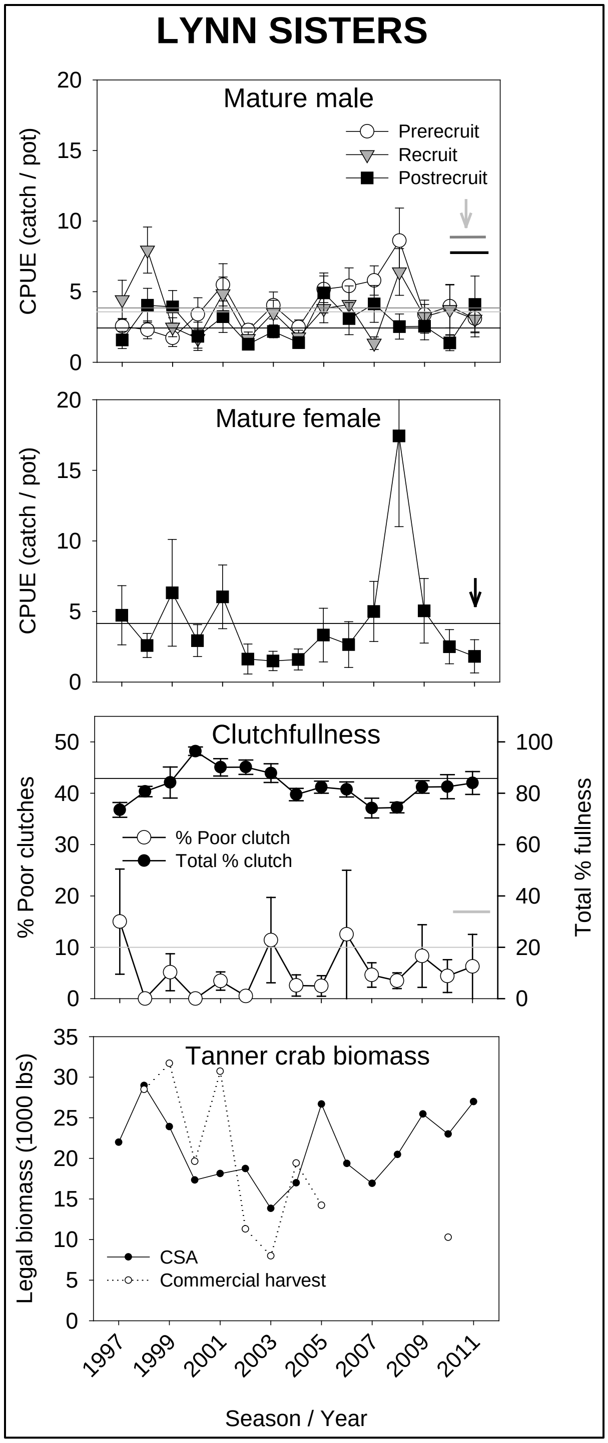


Figure 23.–Tanner crab CPUE for all size/sex classes, clutch fullness, proportion of poor clutches, legal biomass estimates from catch survey analysis (CSA), and harvest data in Lynn Sisters, Southeast Alaska, 2011. Symbols on the right side of plots represent a significant increase ($p < 0.05$, up arrow) 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. Reference lines represent long-term average (benchmark) (1993–2002).

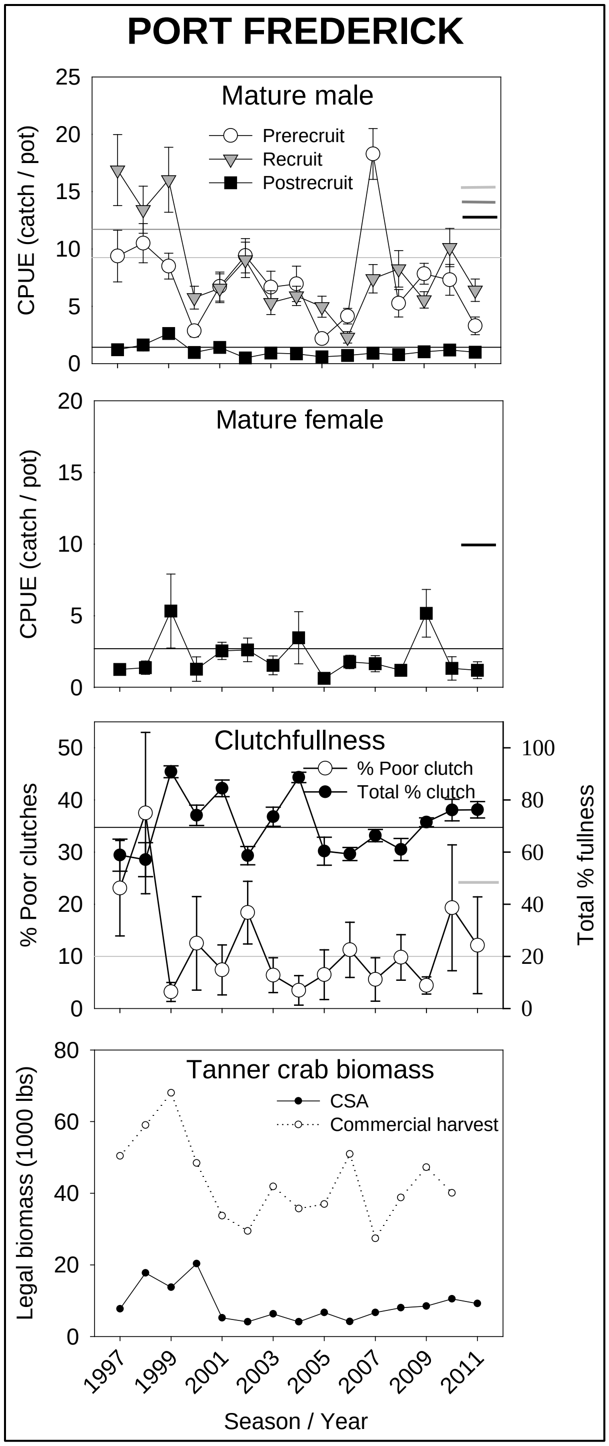


Figure 24.–Tanner crab CPUE for all size/sex classes, clutch fullness, proportion of poor clutches, legal biomass estimates from catch survey analysis (CSA), and harvest data in Port Frederick, Southeast Alaska, 2011. Symbols on the right side of plots represent a significant increase ($p < 0.05$, up 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. Reference lines represent long-term average (benchmark) (1993–2002).

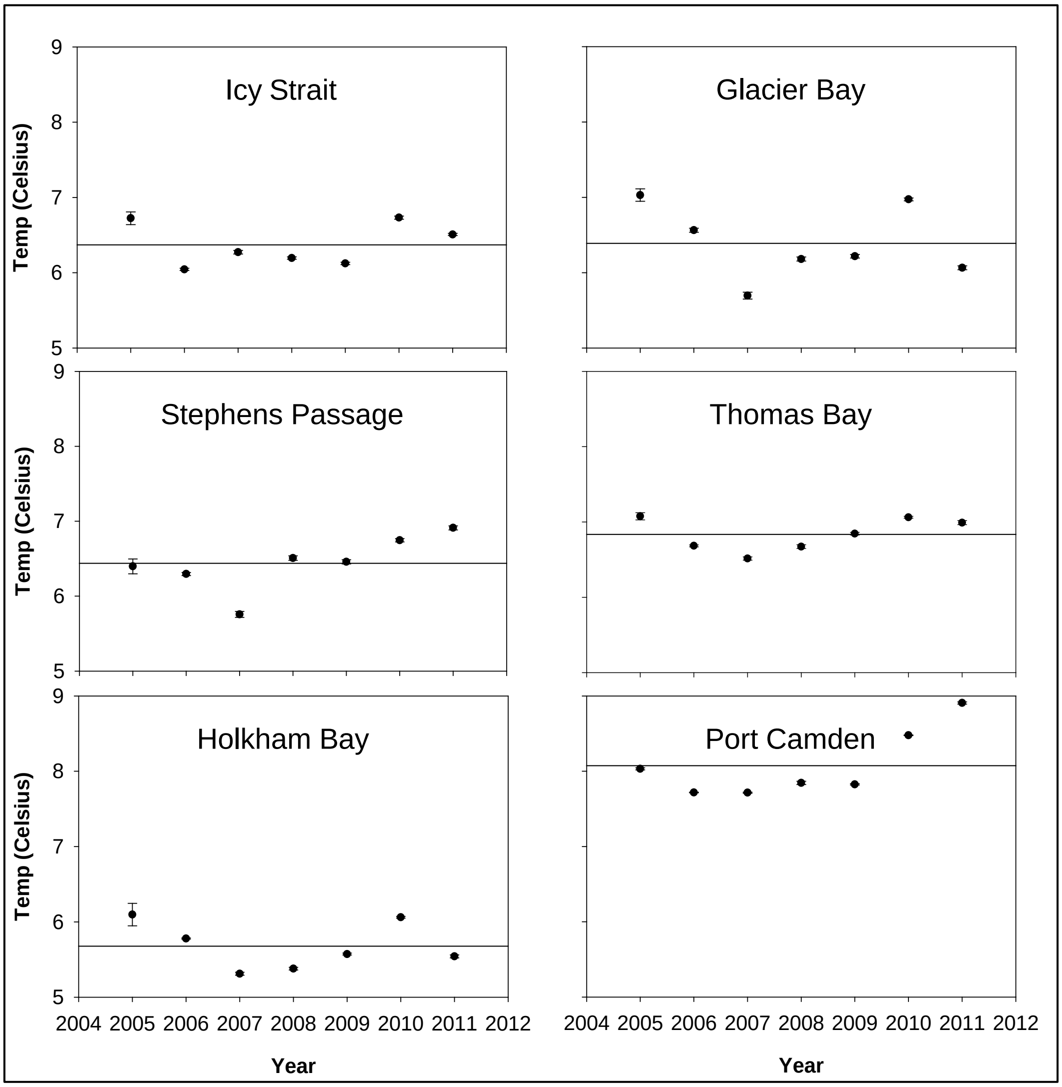


Figure 25.–Mean bottom temperature from 2005–2011 for each area surveyed during October Tanner crab surveys. Line represents mean of all years shown.

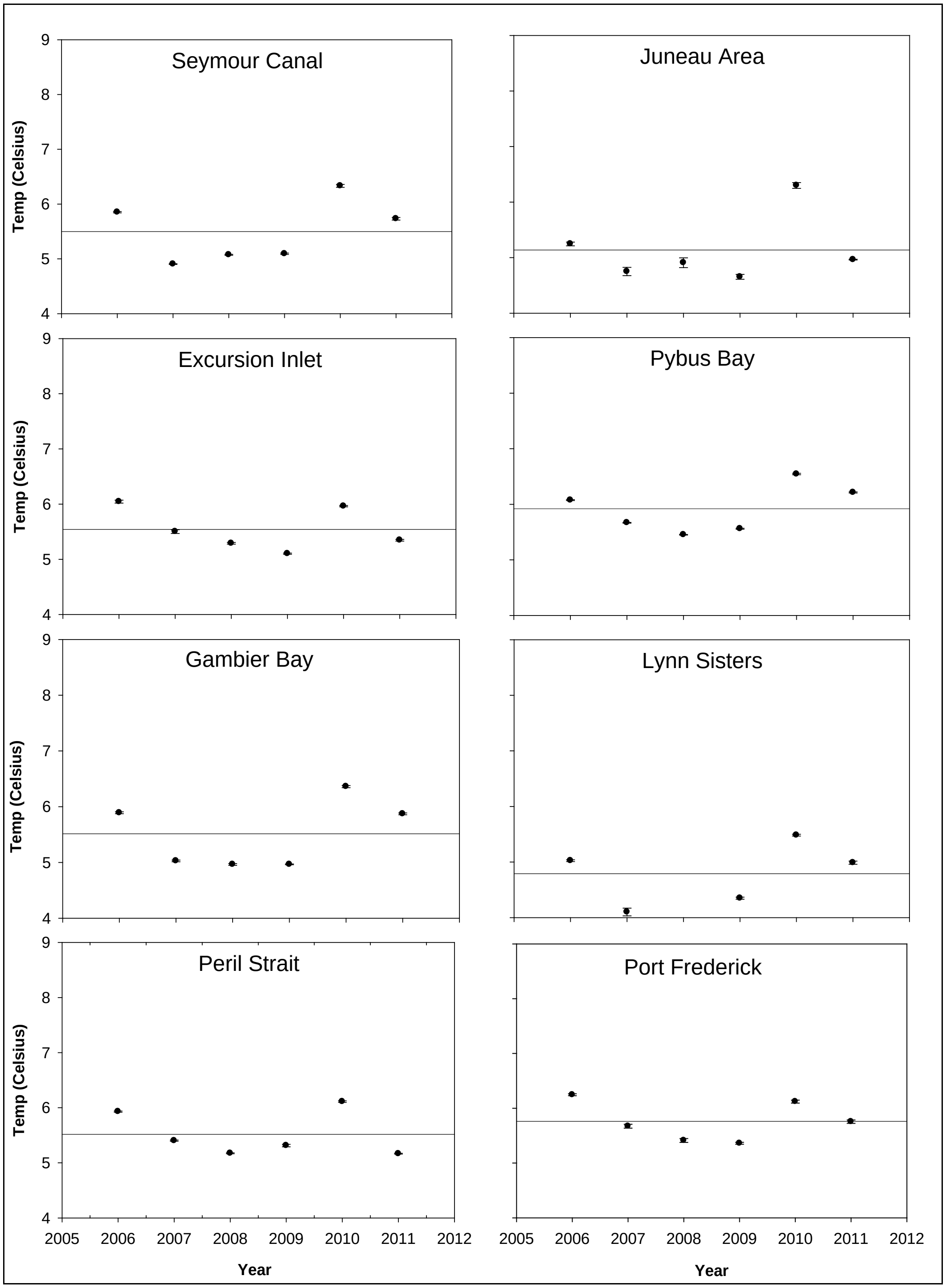


Figure 26.–Mean bottom temperature from 2006–2011 for each area surveyed during June and July red king crab surveys. Line represents mean of all years shown.

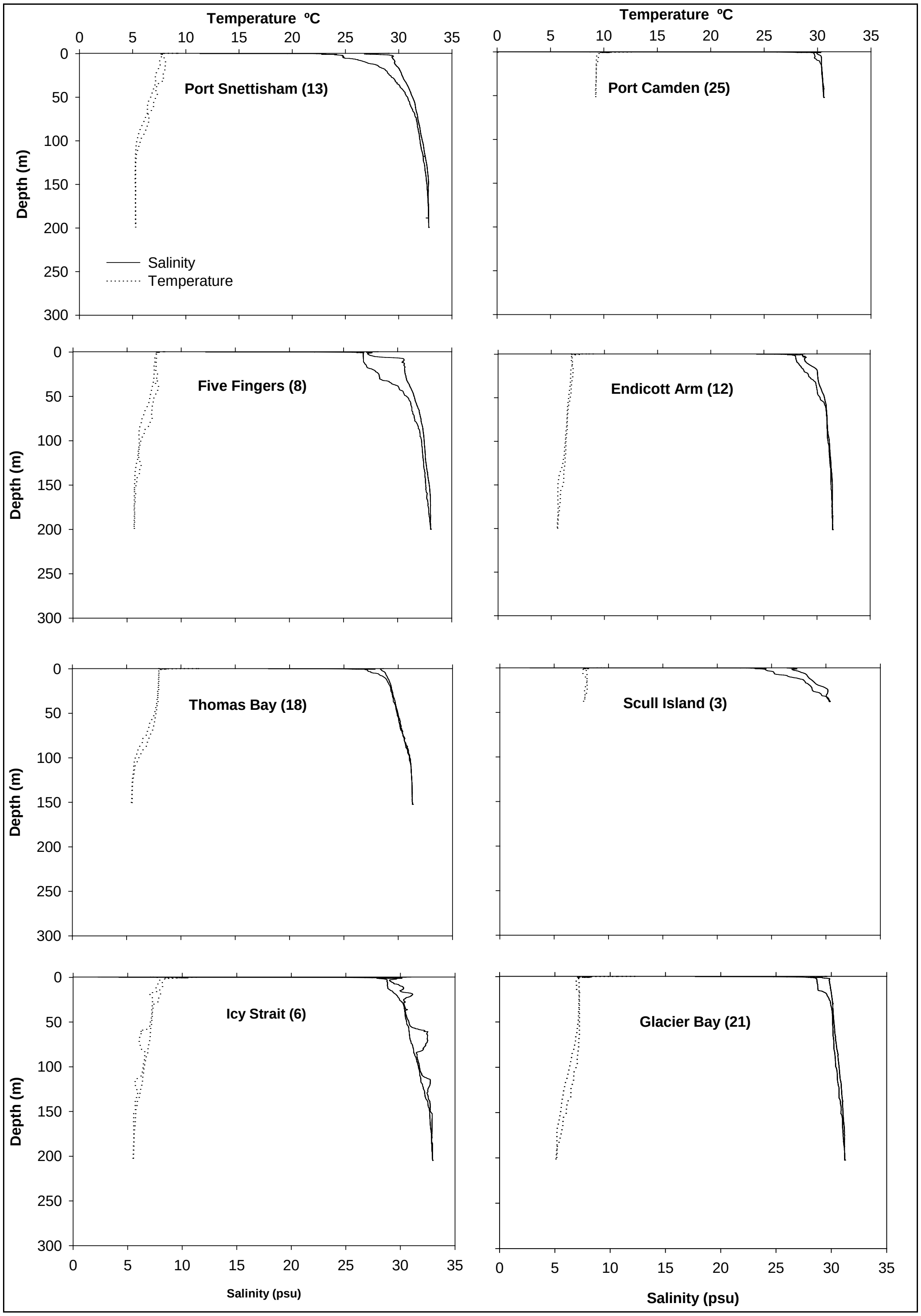


Figure 27.–Temperature profiles taken by CTD during the 2011 October Tanner crab survey at eight oceanographic stations.

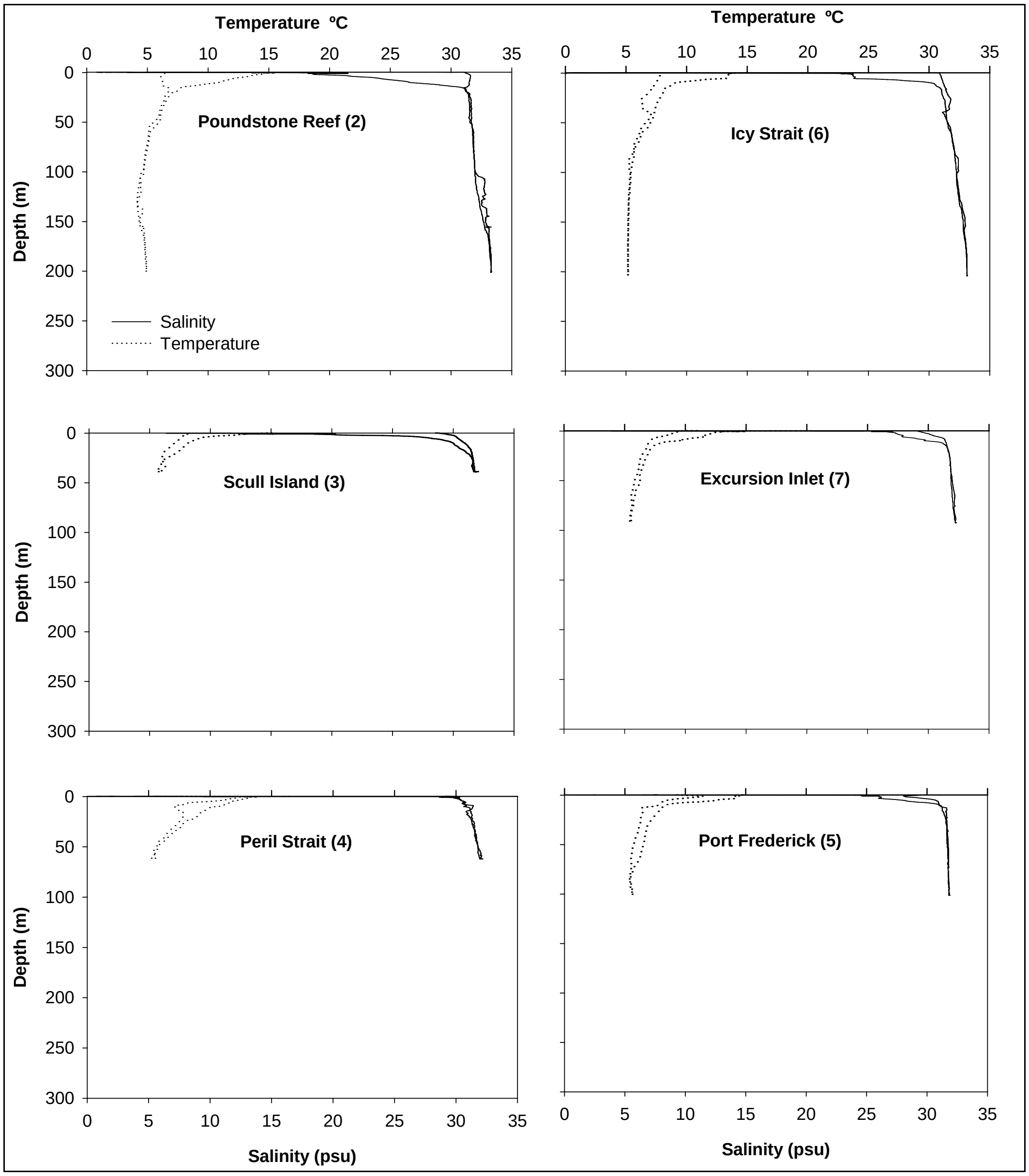


Figure 28.–Temperature profiles taken by CTD during the 2011 June/July red king crab survey for 6 of 10 oceanographic stations.

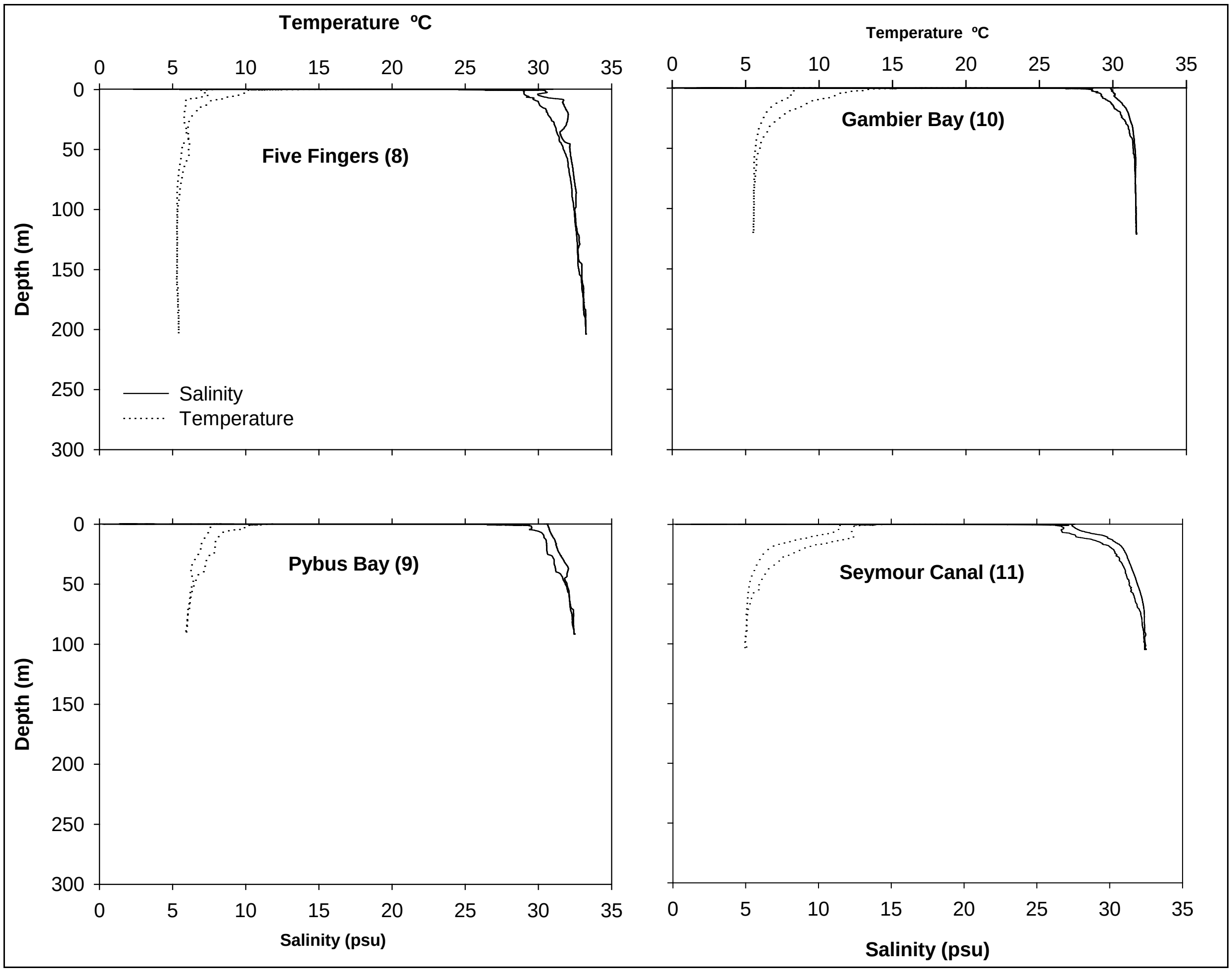


Figure 29.–Temperature profiles taken by CTD during the 2011 June/July red king crab survey for 4 of 10 oceanographic stations.

# APPENDICES

To estimate an appropriate exploitation rate (ER) where the crab biomass does not change in the following year (i.e., where population growth rate is zero), the ER of a given year was correlated with the change in estimated biomass between that year and the next using the general linear model:

$$HR_{yr} = m(\Delta B_{yr+1}) + b \,,$$

where $HR_{yr}$ is the ER of a given year, $\Delta B_{yr+1}$ is the change in biomass in the next year, and $m$ and $b$ are parameters to be estimated (slope and intercept, respectively).

ERs for each year were estimated by dividing the commercial harvest by the biomass estimate for a given year:

$$HR_{yr} = \frac{Comm.Catch_{yr}}{Biomass_{yr}} \,.$$

The change in biomass was estimated as:

$$\Delta B_{yr+1} = \frac{(B_{yr+1} - B_{yr})}{B_{yr}} \,.$$

The biomass estimates (*B*) were from the 2007 CSA analyses (biomass estimates change slightly each year due to the additional data added to the model).

The proposed ERs were estimated based on the results of the correlation analyses. If there was a significant relationship between the previous year ER and the current year biomass estimate, then the proposed ER was simply calculated by setting the change in biomass to zero and solving for the corresponding ER. If, however no relationship exists between the two variables, the average ER and the average biomass change was examined. Three possibilities arise: 1) if the average change in biomass is positive (the population is growing), then the average ER is too low, 2) if the average change in biomass is negative (population decline) the average ER is too high, or 3) the average change in biomass is zero, then the ER is correct. Therefore to predict an appropriate ER for those surveyed areas that do not have a strong relationship between ER and change in biomass, the sum of the average ER and the average biomass change is used.

Results from these analyses showed that ER and change in biomass were strongly correlated for 5 (out of 14) surveyed areas for mature Tanner crab and 3 surveyed areas for legal Tanner crab. Proposed maximum mature ERs ranged from 3% in Peril Strait to 34% in Icy Strait with and overall average of 19%. The regionwide proposed mature ER is 20%, calculated as a weighted average with each surveyed area weighted by its average commercial harvest from 1997–2006. The proposed maximum legal ER ranged from less than 0% to 69% with an average of 32%. The regionwide proposed legal ER is 38% (based on the weighted average).

Appendix B.–Documentation of time series used for baseline. Baselines in the Tanner crab survey are defined as the mean values from the first ten years that data is available (used for stock health determination). The baselines in the red king crab survey are defined as the mean values for the years 1993–2002. Thomas Bay and Port Camden baselines were completed in 2011.

| Project | Survey area | Baseline years |
|---|---|---|
| Tanner crab survey | Icy Strait | 1997–2006 |
| | Glacier Bay | 1999–2008 |
| | Stephens Passage | 1997–2006 |
| | Thomas Bay | 2001–2010 |
| | Holkham Bay | 1998–2007 |
| | Port Camden | 2001–2010 |
| Red king crab survey | Seymour Canal | 1993–2002 |
| | North Juneau | 1993–2002 |
| | Excursion Inlet | 1993–2002 |
| | Pybus Bay | 1993–2002 |
| | Gambier Bay | 1993–2002 |
| | Peril Strait | 1993–2002 |
| | Lynn Sisters | 1993–2002 |
| | Port Frederick | 1993–2002 |